Watershed health

July 2018

Vermilion River Watershed Monitoring and Assessment Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

Authors

MPCA Vermilion River Watershed Report Team: Karsten Klimek, Scott Niemela, Pam Anderson, Nathan Sather, Jesse Anderson, Amy Mustonen, Jeff Jasperson, Michael Bourdaghs, Bruce Monson, Shawn Nelson, Sophia Vaughan, Stacia Grayson, Dave Christopherson, James Jahnz, Tom Schaub

Contributors/acknowledgements

Citizen Stream Monitoring Program Volunteers
Minnesota Department of Natural Resources
Minnesota Department of Health
Minnesota Department of Agriculture
Sportsmen's Club of Lake Vermilion

Project dollars provided by the Clean Water Fund (from the Clean Water, Land and Legacy Amendment).

The MPCA is reducing printing and mailing costs by using the Internet to distribute reports and information to wider audience. Visit our website for more information.

MPCA reports are printed on 100% post-consumer recycled content paper manufactured without chlorine or chlorine derivatives.

Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 |

651-296-6300 | 800-657-3864 | Or use your preferred relay service. | Info.pca@state.mn.us

This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

Document number: wq-ws3-09030002b

Contents

Figures

Tables

List of acronyms

CI Confidence Interval

Chl-a chlorophyll-a

CLMP Citizen Lake Monitoring Program

CSAH County State Aid Highway

CSMP Citizen Stream Monitoring Program

CWA Clean Water Act

CWLA Clean Water Legacy Act

DNR Minnesota Department of Natural Resources

EQuIS Environmental Quality Information System

EX Exceeds Criteria (Bacteria)

EXP Exceeds Criteria, Potential Impairment

EXS Exceeds Criteria, Potential Severe Impairment

FS Full Support

FWMC Flow Weighted Mean Concentration

HUC Hydrologic Unit Code

IBI Index of Biotic Integrity

IWM Intensive Watershed Monitoring

LRVW Limited Resource Value Water

MDH Minnesota Department of Health

MPCA Minnesota Pollution Control Agency

MSHA Minnesota Stream Habitat Assessment

MTS Meets the Standard

Nitrate-N Nitrate Plus Nitrite Nitrogen

NHD National Hydrologic Dataset

NH3 Ammonia

OP Orthophosphate

PCB Poly Chlorinated Biphenyls

PWI Protected Waters Inventory

RNR River Nutrient Region

SWAG Surface Water Assessment Grant

SWCD Soil and Water Conservation District

SWUD State Water Use Database

TALU Tiered Aquatic Life Uses

TKN Total Kjeldahl Nitrogen

TMDL Total Maximum Daily Load

TP Total Phosphorous

TSS Total Suspended Solids

USGS United States Geological Survey

WID Waterbody Identification Number

WPLMN Watershed Pollutant Load Monitoring Network

Executive summary

In 2015, the Minnesota Pollution Control Agency (MPCA) conducted Intensive Watershed Monitoring (IWM) within the Vermilion River Watershed. The primary goal of IWM is to describe the condition of rivers, streams and lakes within each of Minnesota's 80 major watersheds using a comprehensive suite of indicators. IWM is a comprehensive monitoring program that includes monitoring for biology and chemistry. The data was used to assess surface waters for its ability to support uses such as aquatic life (biology) and aquatic recreation (swimming etc.). Near the outlet of the watershed, an analysis of mercury within fish tissue was also conducted which served as a basis for assessing aquatic consumption (how much mercury is in the fish). Additionally, data was also collected and used to compute pollutant loads with the Watershed Pollutant Load Monitoring Network (WPLMN). MPCA staff, Surface Water Assessment Grant (SWAG) recipients, and citizen volunteers completed work related to the IWM effort.

Twenty-one (95%) streams fully supported aquatic life. Only one stream, a tributary to the Sand River, did not support aquatic life based on the fish community. All of the nine streams assessed for aquatic recreation were supporting.

Assessment results for the Vermilion River Watershed indicate that the fish and macroinvertebrate (aquatic insect) communities are in good condition. Although some human development and impact has occurred within the watershed, it is relatively untouched compared to other watersheds in Minnesota. Wetland influence (which can cause naturally low dissolved oxygen and pH) is apparent in some streams. Beaver impoundments also plausibly serve as barriers to fish passage in many streams.

A total of 20 lakes within the watershed had sufficient data collected to assess for aquatic recreation. Of those assessed, 95% fully support aquatic recreation, and therefore met the water quality standards in Minnesota's Northern Lakes and Forests ecoregion. Echo and Myrtle Lakes did not meet standards protective of aquatic recreation, with nuisance algal blooms occurring during summer months. The impairment in Echo Lake was due to natural conditions, as the lakeshore is predominately undeveloped and the watershed is dominated by forest and wetlands. Most lakes in the Vermilion River Watershed are high quality, reflective of the public forests and wetlands that abound in much of the watershed. Lake Vermilion has been intensively monitored by the MPCA and citizen volunteers for decades. It meets standards for total phosphorus (TP), chlorophyll-a (Chl-a), and Secchi transparency. In the Vermilion River Watershed, the highest quality, most at-risk lakes include the Eagles Nest Chain. Pelican Lake at Orr, Minnesota is also a strong candidate for protection, as it is close to the impairment threshold, and is one of the most developed lakes in the watershed.

Introduction

Water is one of Minnesota's most abundant and precious resources. The Minnesota Pollution Control Agency (MPCA) is charged under both federal and state law with the responsibility of protecting the water quality of Minnesota's water resources. MPCA's water management efforts are tied to the 1972 Federal Clean Water Act (CWA), which requires states to adopt water quality standards to protect their water resources and the designated uses of those waters, such as for drinking water, recreation, fish consumption and aquatic life. States are required to provide a summary of the status of their surface waters and develop a list of water bodies that do not meet established standards. Such waters are referred to as "impaired waters" and the state must make appropriate plans to restore these waters, including the development of total maximum daily loads (TMDLs). A TMDL is a comprehensive study determining the assimilative capacity of a waterbody, identifying all pollution sources causing or contributing to impairment, and an estimation of the reductions needed to restore a waterbody so that it can once again support its designated use.

The MPCA currently conducts a variety of surface water monitoring activities that support our overall mission of helping Minnesotans protect the environment. To successfully prevent and address problems, decision makers need good information regarding the status of the resources, potential and actual threats, options for addressing the threats and data on the effectiveness of management actions. The MPCA's monitoring efforts are focused on providing that critical information. Overall, the MPCA is striving to provide information to assess, and ultimately, to restore or protect the integrity of Minnesota's waters.

The passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and the initial resources for state and local governments to accelerate efforts to monitor, assess, restore and protect surface waters. This work is implemented on an on-going basis with funding from the Clean Water Fund created by the passage of the Clean Water Land, and Legacy Amendment to the state constitution. To facilitate the best use of agency and local resources, the MPCA has developed a watershed monitoring strategy, which uses an effective and efficient integration of agency and local water monitoring programs to assess the condition of Minnesota's surface waters, and to allow for coordinated development and implementation of water quality restoration and improvement projects.

The strategy behind the watershed monitoring approach is to intensively monitor streams and lakes within a major watershed to determine the overall health of water resources, identify impaired waters, and to identify waters in need of additional protection. The benefit of the approach is the opportunity to begin to address most, if not all, impairments through a coordinated TMDL process at the watershed scale, rather than the reach-by-reach and parameter-by-parameter approach often historically employed. The watershed approach will more effectively address multiple impairments resulting from the cumulative effects of point and non-point sources of pollution and further the CWA goal of protecting and restoring the quality of Minnesota's water resources.

This watershed-wide monitoring approach was implemented in the Vermilion River Watershed beginning in the summer of 2015. This report provides a summary of all water quality assessment results in the Vermilion River Watershed and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring and monitoring conducted by local government units.

The watershed monitoring approach

The watershed approach is a 10-year rotation for monitoring and assessing waters of the state on the level of Minnesota's 80 major watersheds. The major benefit of this approach is the integration of monitoring resources to provide a more complete and systematic assessment of water quality at a geographic scale useful for the development and implementation of effective TMDLs, project planning, effectiveness monitoring and protection strategies. The following paragraphs provide details on each of the four principal monitoring components of the watershed approach. For additional information see: Watershed Approach to Condition Monitoring and Assessment (MPCA 2008) (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

Watershed pollutant load monitoring

The Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term statewide river monitoring network initiated in 2007 and designed to obtain pollutant load information from 199 river monitoring sites throughout Minnesota. Monitoring sites span three ranges of scale:

Basin – major river main stem sites along the Mississippi, Minnesota, Rainy, Red, Des Moines, Cedar and St. Croix rivers

Major Watershed – tributaries draining to major rivers with an average drainage area of 1,350 square miles (8-digit HUC scale)

Subwatershed – major branches or nodes within major watersheds with average drainage areas of approximately 300-500 square miles

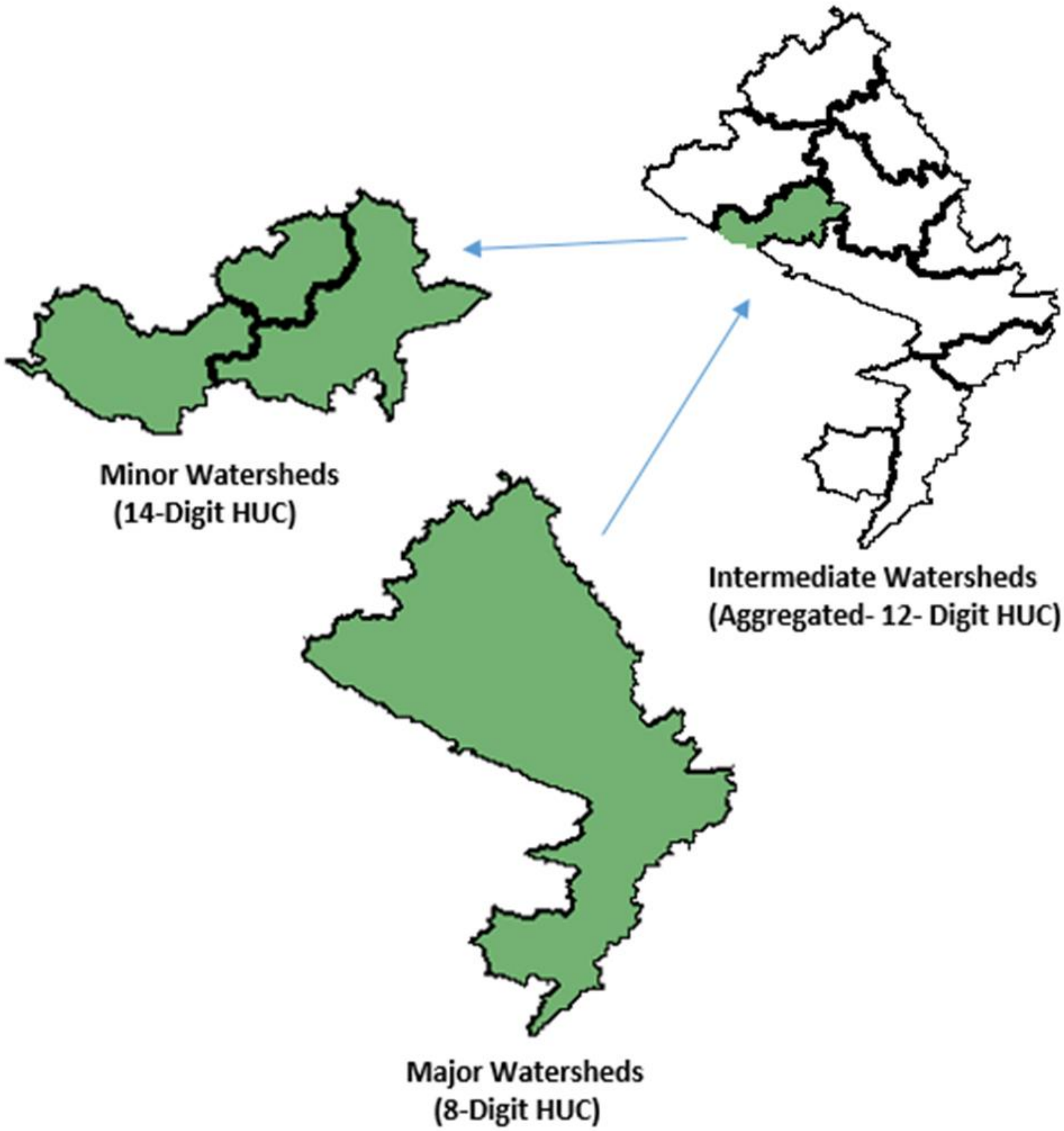
The program utilizes state and federal agencies, universities, local partners, and MPCA staff to collect water quality and flow data to calculate nitrogen, phosphorus, and sediment pollutant loads.

Intensive watershed monitoring

The intensive watershed monitoring strategy utilizes a nested watershed design allowing the sampling of streams within watersheds from a coarse to a fine scale (Figure 1). Each watershed scale is defined by a hydrologic unit code (HUC). These HUCs define watershed boundaries for water bodies within a similar geographic and hydrologic extent. The foundation of this approach is the 80 major watersheds (8-HUC) within Minnesota. Using this approach, many of the smaller headwaters and tributaries to the main stem river are sampled in a systematic way so that a more holistic assessment of the watershed can be conducted and problem areas identified without monitoring every stream reach. Each major watershed is the focus of attention for at least one year within the 10-year cycle.

River/stream sites are selected near the outlet of each of three watershed scales, 8-HUC, aggregated 12-HUC and 14-HUC (Figure 1). Within each scale, different water uses are assessed based on the opportunity for that use (i.e., fishing, swimming, supporting aquatic life such as fish and insects). The major river watershed is represented by the 8-HUC scale. The outlet of the major 8-HUC watershed (green triangle in Figure 2) is sampled for biology (fish and macroinvertebrates), water chemistry and fish contaminants to allow for the assessment of aquatic life, aquatic recreation and aquatic consumption use support. The aggregated 12-HUC is the next smaller subwatershed scale, which generally consists of major tributary streams with drainage areas ranging from 75 to 150 mi^2. Each aggregated 12-HUC outlet (green dots in Figure 2) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use support. Within each aggregated 12-HUC, smaller watersheds (14 HUCs, typically 10-20 mi^2), are sampled at each outlet that flows into the major aggregated 12-HUC tributaries. Each of these minor subwatershed outlets is sampled for biology to assess aquatic life use support (red dots in Figure 2).

Figure 1. The intensive watershed monitoring design.

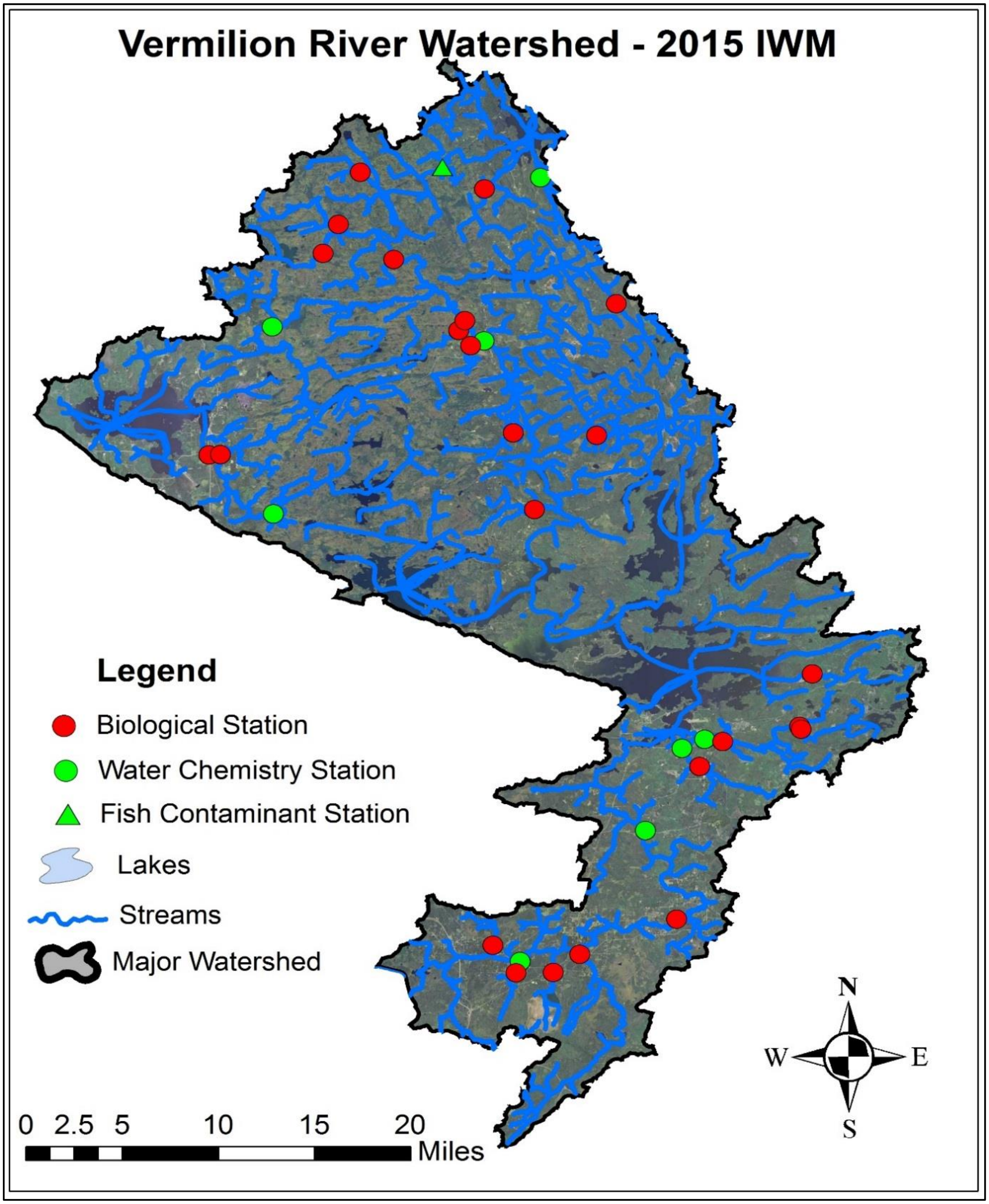


Lake monitoring

Lakes most heavily used for recreation (all those greater than 500 acres and at least 25% of lakes 100-499 acres) are monitored for water chemistry to determine if recreational uses, such as swimming and wading, are being supported and where applicable, where fish community health can be determined. Lakes are prioritized by size, accessibility (can the public access the lakes), and presence of recreational use.

Specific locations for sites sampled as part of the intensive monitoring effort in the Vermilion River Watershed are shown in Figure 2 and are listed in Appendices 2.1 and 2.2.

Figure 2. Intensive watershed monitoring sites for streams in the Vermilion River Watershed.

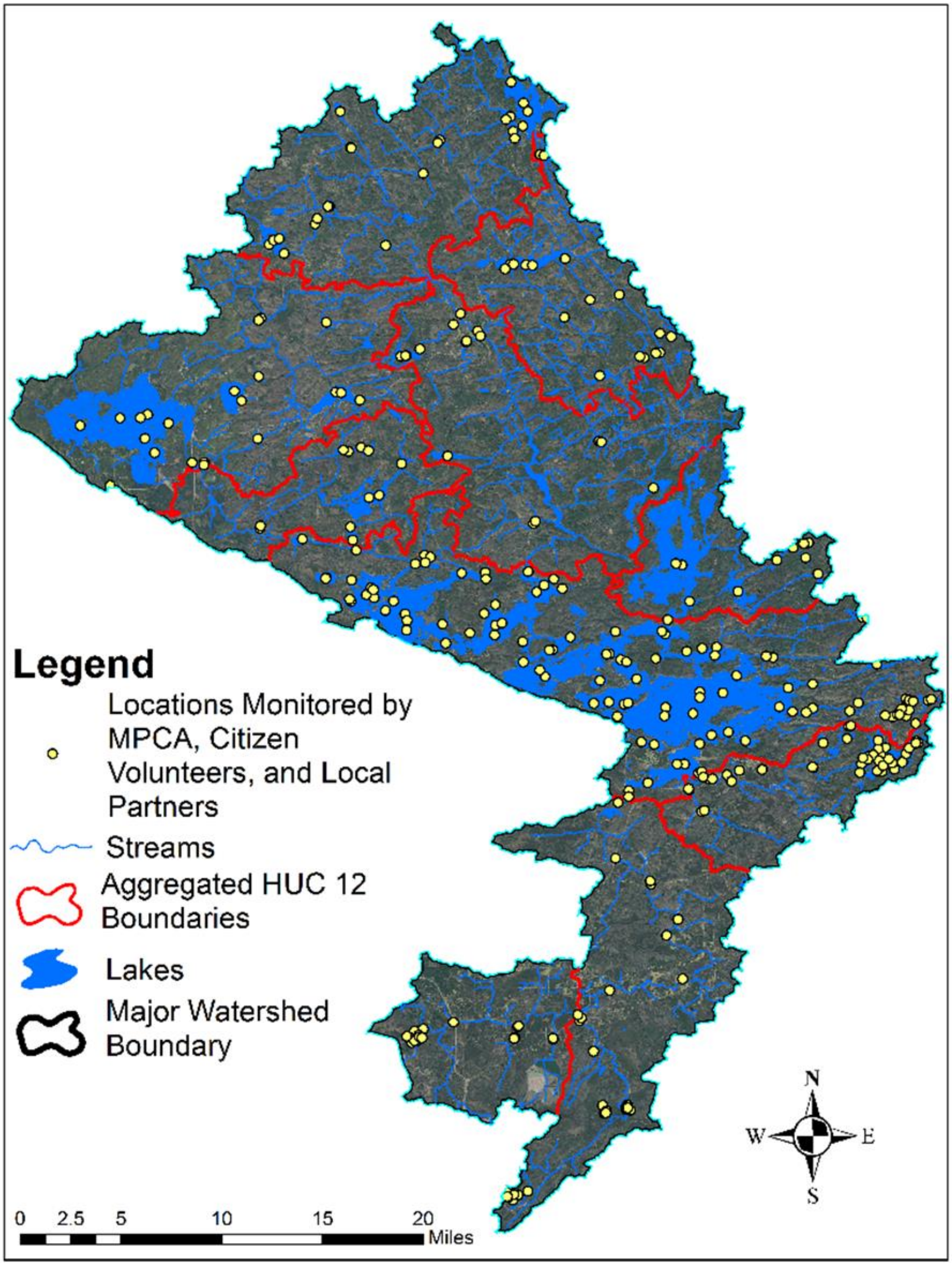


Citizen and local monitoring

Citizen and local monitoring is an important component of the watershed approach. The MPCA and its local partners jointly select the stream sites and lakes to be included in the intensive watershed monitoring process. Funding passes from MPCA through Surface Water Assessment Grants (SWAGs) to local groups such as counties, soil and water conservation districts (SWCDs), watershed districts, nonprofits and educational institutions to support lake and stream water chemistry monitoring. Local partners use the same monitoring protocols as the MPCA, and all monitoring data from SWAG projects are combined with the MPCA's to assess the condition of Minnesota lakes and streams. Preplanning and coordination of sampling with local citizens and governments helps focus monitoring where it will be most effective for assessment and observing long-term trends. This allows citizens/governments the ability to see how their efforts are used to inform water quality decisions and track how management efforts affect change. Many SWAG grantees invite citizen participation in their monitoring projects and their combined participation greatly expand our overall capacity to conduct sampling.

The MPCA also coordinates two programs aimed at encouraging long term citizen surface water monitoring: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Like the permanent load monitoring network, having citizen volunteers monitor a given lake or stream site monthly and from year to year can provide the long-term picture 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. Figure 3 provides an illustration of the locations where citizen-monitoring data were used for assessment in the Vermilion River Watershed.

Figure 3. Monitoring locations of local groups, citizens and the MPCA lake monitoring staff in the Vermilion River Watershed.



Assessment methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters that are determined to be supporting or non-supporting of their designated uses as evaluated by the comparison of monitoring data to criteria specified by Minnesota Water Quality Standards (Minn. R. Ch. 7050 2008; https://www.revisor.leg.state.mn.us/rules/?id=7050). The assessment and listing process involves dozens of MPCA staff, other state agencies and local partners. The goal of this effort is to use the best data and best science available to assess the condition of Minnesota's water resources. For a thorough review of the assessment, methodologies see: Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA 2018). https://www.pca.state.mn.us/sites/default/files/wq-iw1-04j.pdf.

Water quality standards

Water quality standards are the fundamental benchmarks by which the quality of surface waters are measured and used to determine impairment. These standards can be numeric or narrative in nature and define the concentrations or conditions of surface waters that allow them to meet their designated beneficial uses, such as for fishing (aquatic life), swimming (aquatic recreation) or human consumption (aquatic consumption). All surface waters in Minnesota, including lakes, rivers, streams and wetlands are protected for aquatic life and recreation where these uses are attainable. Numeric water quality standards represent concentrations of specific pollutants in water that protect a specific designated use. Narrative standards are statements of conditions in and on the water, such as biological condition, that protect their designated uses.

Protection of aquatic recreation means the maintenance of conditions safe and suitable for swimming and other forms of water recreation. In streams, aquatic recreation is assessed by measuring the concentration of *E. coli* bacteria in the water. To determine if a lake supports aquatic recreational activities its trophic status is evaluated, using total phosphorus, Secchi depth and Chl-a as indicators. Lakes that are enriched with nutrients and have abundant algal growth are eutrophic and do not support aquatic recreation.

Protection of consumption means protecting citizens who eat fish from Minnesota waters or receive their drinking water from waterbodies protected for this beneficial use. The concentrations of mercury and polychlorinated biphenyls (PCBs) in fish tissue are used to evaluate whether or not fish are safe to eat in a lake or stream and to issue recommendations regarding the frequency that fish from a particular waterbody can be safely consumed. For lakes, rivers and streams that are protected as a source of drinking water the MPCA primarily measures the concentration of nitrate in the water column to assess this designated use.

Protection of aquatic life means the maintenance of a healthy aquatic community, including fish, invertebrates and plants. Biological monitoring, the sampling of aquatic organisms, is a direct means to assess aquatic life use support, as the aquatic community tends to integrate the effects of all pollutants and stressors over time. To effectively use biological indicators, the MPCA employs the Index of Biotic Integrity (IBI). This index is a scientifically validated combination of measurements of the biological community (called metrics). An IBI is comprised of multiple metrics that measure different aspects of aquatic communities (e.g., dominance by pollution tolerant species, loss of habitat specialists). Metric scores are summed together and the resulting index score characterizes the biological integrity or "health" of a site. The MPCA has developed stream IBIs for (fish and macroinvertebrates) since these communities can respond differently to various types of pollution. The MPCA also uses a lake fish IBI developed by the Minnesota Department of Natural Resources (DNR) to determine if lakes are meeting aquatic life use. Because the lakes, rivers, and streams in Minnesota are physically, chemically, and biologically diverse, IBI's are developed separately for different stream classes and lake class groups to account for this natural variation. Further interpretation of biological community data is provided by an assessment threshold or biocriteria against which an IBI score can be compared within a given stream class. In general, an IBI score above this threshold is indicative of aquatic life use support, while a score below this threshold is indicative of non-support. Additionally, chemical parameters are measured and assessed against numeric standards developed to be protective of aquatic life. For streams, these include pH, dissolved oxygen, un-ionized ammonia nitrogen, chloride, total suspended solids, pesticides, and river eutrophication. For lakes, pesticides and chlorides contribute to the overall aquatic life use assessment.

Protection for aquatic life uses in streams and rivers are divided into three tiers: Exceptional, General, and Modified. Exceptional Use waters support fish and macroinvertebrate communities that have minimal changes in structure and function from the natural condition. General Use waters harbor "good" assemblages of fish and macroinvertebrates that can be characterized as having an overall balanced distribution of the assemblages and with the ecosystem functions largely maintained through redundant attributes. Modified Use waters have been extensively altered through legacy physical modifications, which limit the ability of the biological communities to attain the General Use. Currently the Modified Use is only applied to streams with channels that have been directly altered by humans (e.g., maintained for drainage, riprapped). These tiered uses are determined before assessment based on the attainment of the applicable biological criteria and/or an assessment of the habitat. For additional information, see: http://www.pca.state.mn.us/index.php/water/water-permits-and-rules/water-rulemaking/tiered-aquatic-life-use-talu-framework.html).

Table 1. Proposed tiered aquatic life use standards.

Proposed tiered aquatic life use	Acronym	Proposed use class code	Description
Warm water General	WWg	2Bg	Warm water Stream protected for aquatic life and recreation, capable of supporting and maintaining a balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the General Use biological criteria.
Warm water Modified	WWm	2Bm	Warm water Stream protected for aquatic life and recreation, physically altered watercourses (e.g., channelized streams) capable of supporting and maintaining a balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the Modified Use biological criteria, but are incapable of meeting the General Use biological criteria as determined by a Use Attainability Analysis
Warm water Exceptional	WWe	2Be	Warm water Stream protected for aquatic life and recreation, capable of supporting and maintaining an exceptional and balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the Exceptional Use biological criteria.
Coldwater General	CWg	2Ag	Coldwater Stream protected for aquatic life and recreation, capable of supporting and maintaining a balanced, integrated, adaptive community of cold-water aquatic organisms that meet or exceed the General Use biological criteria.
Coldwater Exceptional	CWe	2Ae	Coldwater Stream protected for aquatic life and recreation, capable of supporting and maintaining an exceptional and balanced, integrated, adaptive community of cold-water aquatic organisms that meet or exceed the Exceptional Use biological criteria.

A small percentage of stream miles in the state (~1% of 92,000 miles) have been individually evaluated and re-classified as a Class 7 Limited Resource Value Water (LRVW). These streams have previously demonstrated that the existing and potential aquatic community is severely limited and cannot achieve aquatic life standards either by: a) natural conditions as exhibited by poor water quality characteristics, lack of habitat or lack of water; b) the quality of the resource has been significantly altered by human activity and the effect is essentially irreversible; or c) there are limited recreational opportunities (such as fishing, swimming, wading or boating) in and on the water resource. While not being protective of aquatic life, LRVWs are still protected for industrial, agricultural, navigation and other uses. Class 7 waters are also protected for aesthetic qualities (e.g., odor), secondary body contact, and groundwater for use as a potable water supply. To protect these uses, Class 7 waters have standards for bacteria, pH, dissolved oxygen and toxic pollutants.

Assessment units

Assessments of use support in Minnesota are made for individual waterbodies. The waterbody unit used for river systems, lakes and wetlands is called the "assessment unit". A stream or river assessment unit usually extends from one significant tributary stream to another or from the headwaters to the first tributary. A stream "reach" may be further divided into two or more assessment reaches when there is a change in use classification (as defined in Minn. R., Ch. 7050) or when there is a significant morphological feature, such as a dam or lake, within the reach. Therefore, a stream or river is often segmented into multiple assessment units that are variable in length. The MPCA is using the 1:24,000 scale high resolution National Hydrologic Dataset (NHD) to define and index stream, lake and wetland assessment units. Each river or stream reach is identified by a unique waterbody identifier (known as its WID), comprised of the USGS eight-digit hydrologic unit code (8-HUC) plus a three-character code that is unique within each HUC. Lake and wetland identifiers are assigned by the DNR. The Protected Waters Inventory (PWI) provides the identification numbers for lake, reservoirs and wetlands. These identification numbers serve as the WID and are composed of an eight-digit number indicating county, lake and bay for each basin.

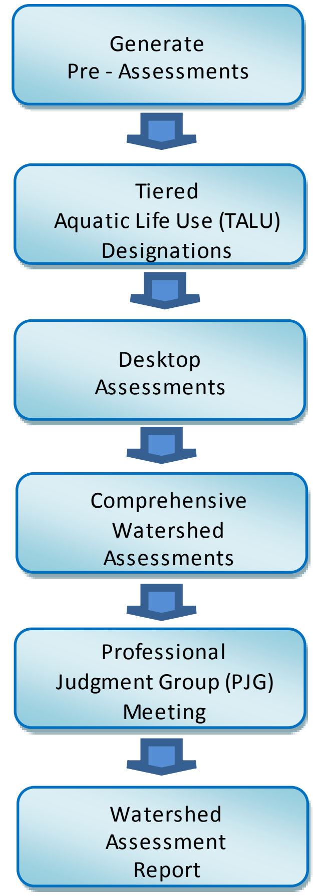
It is for these specific stream reaches or lakes that the data are evaluated for potential use impairment. Therefore, any assessment of use support would be limited to the individual assessment unit. The major exception to this is the listing of rivers for contaminants in fish tissue (aquatic consumption). Over the course of time it takes fish, particularly game fish, to grow to "catchable" size and accumulate unacceptable levels of pollutants, there is a good chance they have traveled a considerable distance. The impaired reach is defined by the location of significant barriers to fish movement such as dams upstream and downstream of the sampled reach and thus often includes several assessment units.

Determining use attainment

For beneficial uses related to human health, such as drinking water or aquatic recreation, the relationship is well understood and thus the assessment process is a relatively simple comparison of monitoring data to numeric standards. In contrast, assessing whether a waterbody supports a healthy aquatic community is not as straightforward and often requires multiple lines of evidence to make use attainment decisions with a high degree of certainty. Incorporating a multiple lines of evidence approach into MPCA's assessment process has been evolving over the past few years. The current process used to assess the aquatic life use of rivers and streams is outlined below and in Figure 4.

The first step in the aquatic life assessment process is largely an automated process performed by logic programmed into a database application where all data from the 10 year assessment window is gathered; the results are referred to as 'Pre-Assessments'. Data filtered into the "Pre-Assessment" process is then reviewed to insure that data is valid and appropriate for assessment purposes. Tiered use designations are determined before data is assessed based on the attainment of the applicable biological criteria and/or an assessment of the habitat. Stream reaches are assigned the highest aquatic life use attained by both biological assemblages on or after November 28, 1975. Streams that do not attain the Exceptional or General Use for both assemblages undergo a Use Attainability Analysis (UAA) to determine if a lower use is appropriate. A Modified Use can be proposed if the UAA demonstrates that the General Use is not attainable as a result of legal human activities (e.g., drainage maintenance, channel stabilization) which are limiting the biological assemblages through altered habitat. Decisions to propose a new use are made through UAA workgroups, which include watershed project managers and biology leads. The final approval to change a designated use is through formal rulemaking.

Figure 4. Flowchart of aquatic life use assessment



The next step in the aquatic life assessment process is a comparison of the monitoring data to water quality standards. Pre-assessments are then reviewed by either a biologist or water quality professional, depending on whether the parameter is biological or chemical in nature. These reviews are conducted at the workstation of each reviewer (i.e., desktop) using computer applications to analyze the data for potential temporal or spatial trends as well as gain a better understanding of any extenuating circumstances that should be considered (e.g., flow, time/date of data collection, or habitat).

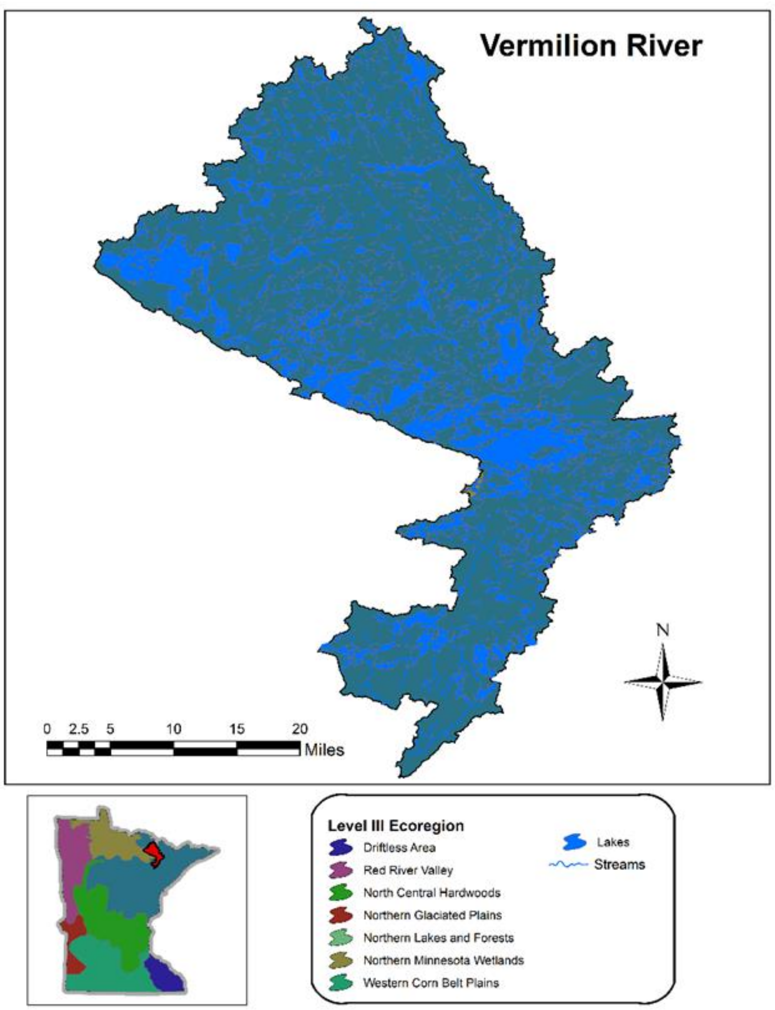
The next step in the process is a Comprehensive Watershed Assessment meeting where reviewers convene to discuss the results of their desktop assessments for each individual waterbody. Implementing a comprehensive approach to water quality assessment requires a means of organizing and evaluating information to formulate a conclusion utilizing multiple lines of evidence. Occasionally, the evidence stemming from individual parameters are not in agreement and would result in discrepant assessments if the parameters were evaluated independently. However, the overall assessment considers each piece of evidence to make a use attainment determination based on the preponderance of information available. See the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List* (MPCA 2016) https://www.pca.state.mn.us/sites/default/files/wq-iw1-04j.pdf for guidelines and factors considered when making such determinations.

The last step in the assessment process is the Professional Judgment Group meeting. At this meeting, results are shared and discussed with entities outside of the MPCA that may have been involved in data collection or that might be responsible for local watershed reports and project planning. Information obtained during this meeting may be used to revise previous use attainment decisions (e.g., sampling events that may have been uncharacteristic due to annual climate or flow variation, local factors such as impoundments that do not represent the majority of conditions on the WID). Waterbodies that do not meet standards and therefore do not attain one or more of their designated uses are considered impaired waters and are placed on the draft 303(d) Impaired Waters List. Assessment results are also included in watershed monitoring and assessment reports.

Watershed overview

The Vermilion River Watershed is located in the Rainy River Basin of northeast Minnesota. The watershed drains an area of roughly 1,035 square miles (662,427 acres) of land in St. Louis County within the Northern Lakes and Forests ecoregion (NRCS, 2007). It contains 565 lakes greater than 10 acres in size. The major river, the Vermilion River, originates at the outlet of Lake Vermilion located in the south central portion of the watershed. The headwaters include Armstrong Lake and Armstrong River, east of Lake Vermilion. Eagles Nest Lakes 1, 2, 3 and 4 are located south of Armstrong Lake. These lakes form the headwaters of the East Two Rivers that drains into Pike Bay of Lake Vermilion. The Pike River, which originates between the towns of Gilbert and Virginia, flows north approximately 26 miles into Pike Bay of Lake Vermilion. From Lake Vermilion, the Vermilion River flows north through a remote region of Minnesota, approximately 42 miles to Crane Lake near Voyageurs National Park. Major lakes north of Lake Vermilion include Elbow, Pelican, Moose, Myrtle, Elephant, and Echo; major stream tributaries to the Vermilion north of Vermilion Lake include the Pelican and Echo Rivers. The watershed also includes portions of the Boundary Waters Canoe Area Wilderness around Trout Lake. Lake Vermilion is a highly valued resource. It is one of the most popular and developed lakes in the watershed. However, the majority of the Vermilion River Watershed is rather undeveloped compared to other watersheds in Minnesota. As a result, recreational tourism is the major economic driver, with some forest industry, mining, and a small amount of farming also occurring.

Figure 5. The Vermilion River Watershed within the Northern Lakes and Forests ecoregion of Northeast Minnesota.

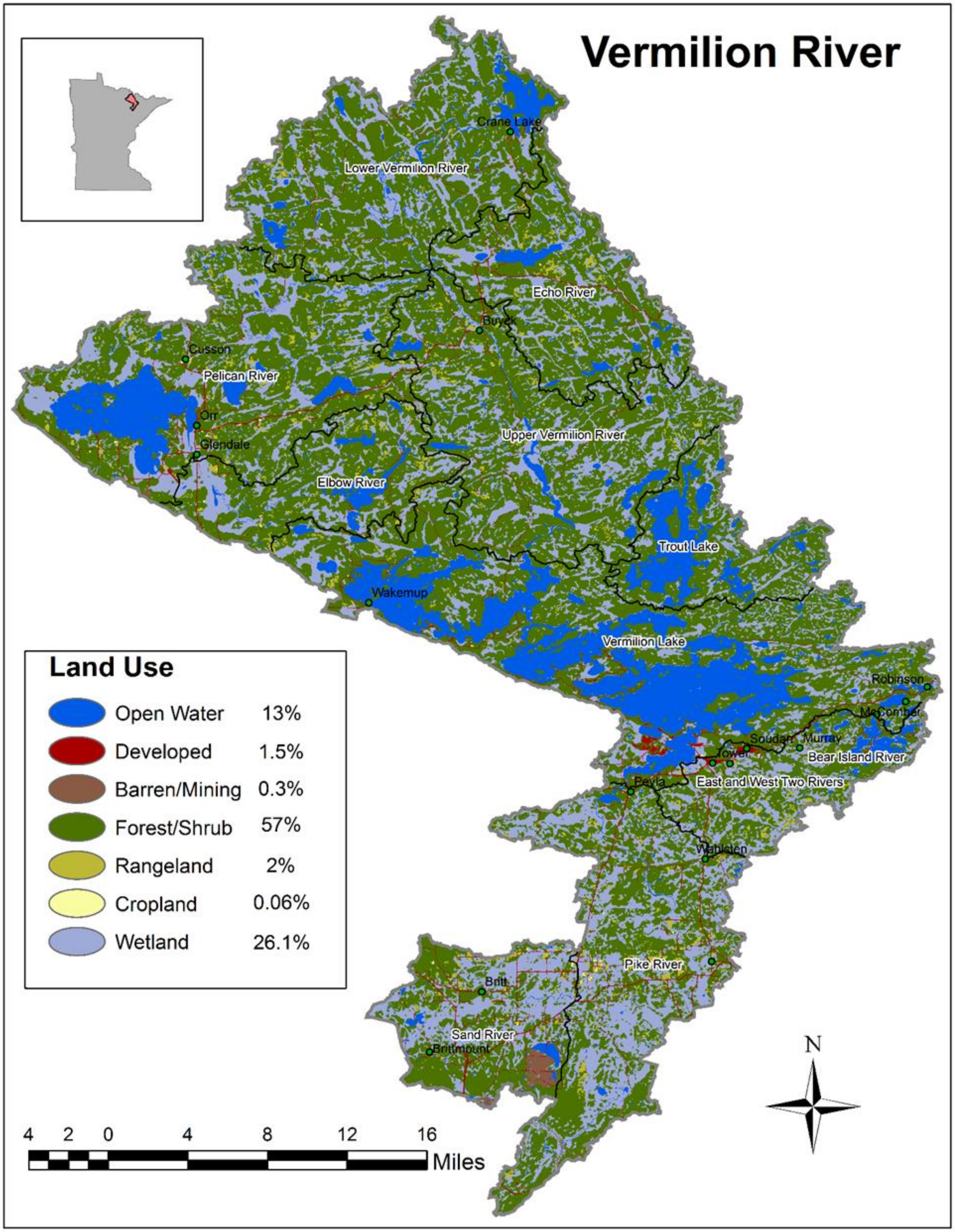


Land use summary

Compared to other watersheds in Minnesota, the Vermilion River appears relatively un-impacted. Land use is dominated by variants of natural cover, with a majority (approximately 68%) being forested. Wetland and or shrub lands comprise approximately 17% of the area with open water accounting for roughly 13% of the watershed. The watershed has 100's of lakes but a large percentage of the open water is attributed to Lake Vermilion, a large lake located in the south-central portion of the watershed. Land use associated with agriculture is extremely low in the Vermilion River Watershed, accounting for only 0.1% of its area. Residential and or commercial lands account for only 1% of the watershed, as no large cities exist. The most populated towns are Tower with 496 residents and Orr with 282 residents. The overall watershed population is 14,423 (roughly 14 people per square mile). Roughly, 60% of land within the Vermilion River Watershed is under State and or Federal ownership (approximately 30% each). A very small amount of land is owned by the County (approximately 0.3 %) and just under 40% is privately held (NRCS, 20007).

Development pressure remains moderate, with lands frequently being parceled out for timber production or recreational uses. Increased shoreline and woodland development has been observed over recent years surrounding several area lakes, especially Vermilion, the Eagles Nest Chain, and Pelican.

Figure 6. Land use in the Vermilion River Watershed.



Surface water hydrology

The Vermilion River Watershed includes 10 intermediate (aggregate 12-digit HUC) sized watersheds and 68 minor (14-digit HUC) sized watersheds. Major streams within the system include the Vermilion River, Pike River, Sand River, Echo River, East Two, and West Two River. Major lakes include Vermilion, Pelican, Trout, and the Eagles Nest lakes. The water of Vermilion River flows from an elevation of 1,369 feet above sea level at Lake Vermilion to an elevation of 1,135 feet above sea level at Crane Lake, with an average elevation in the watershed of 1,310 feet. A unique trait of the Vermilion River Watershed compared to most others of Minnesota is that the primary direction of water flow is to the North instead of South. This is due to the fact that this watershed exists north of the Laurentian Divide, a continental divide of North America that separates river systems that flow northwards to the Arctic Ocean and Hudson Bay, from those that flow southwards to the Atlantic Ocean, Caribbean Sea and Gulf of Mexico.

Compared to other watersheds in Minnesota, the Vermilion River Watershed has a relatively small percentage of altered/channelized streams (Figure 7 and Figure 8). Typically, areas of the state with higher agricultural land use have a higher percentage of altered streams. Fortunately, for the Vermilion River Watershed, aside from minimal channelization where, for example, streams meet roads, ditching is a relatively rare occurrence.

Figure 7. Map of percent modified streams by major watershed (8-HUC).

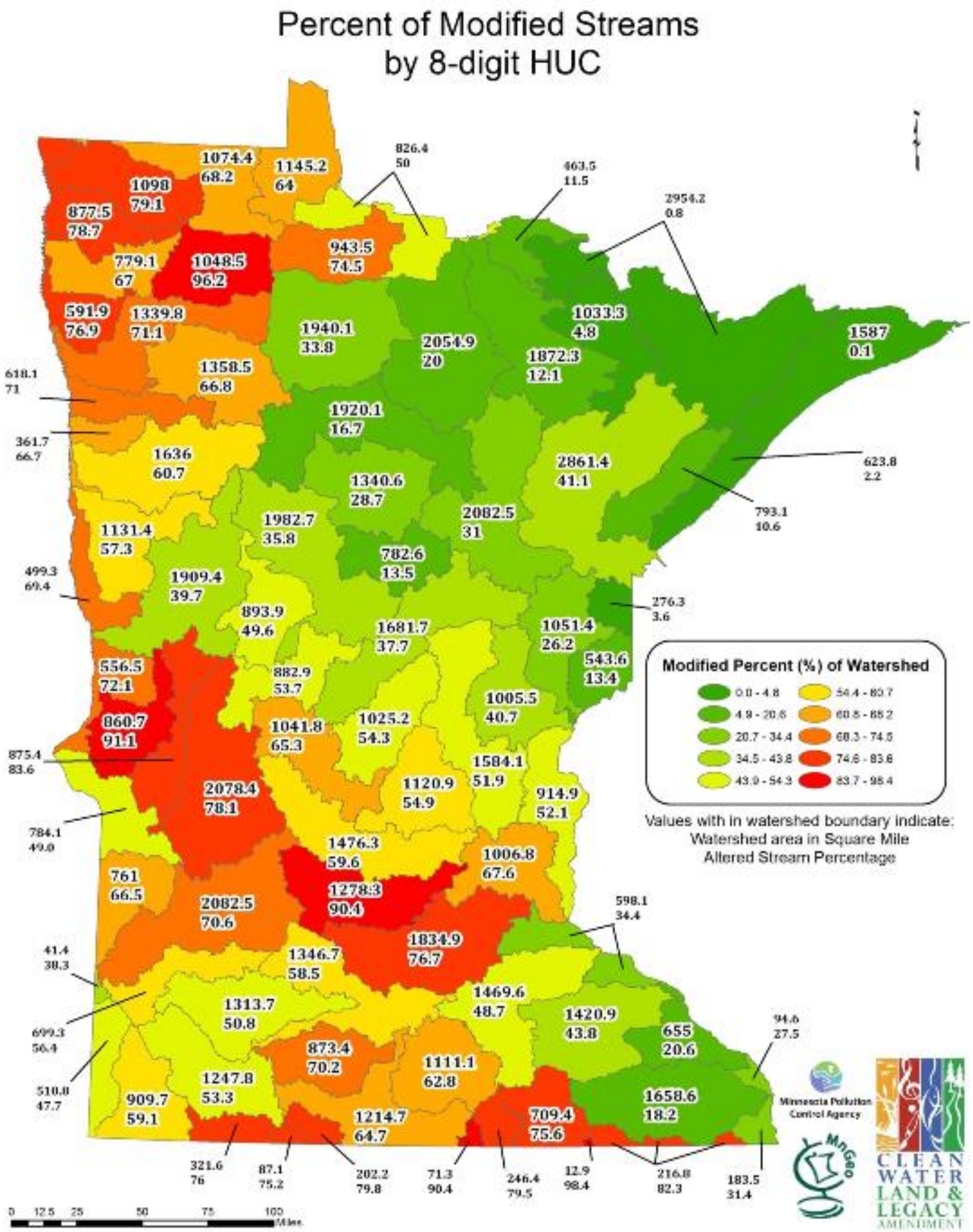
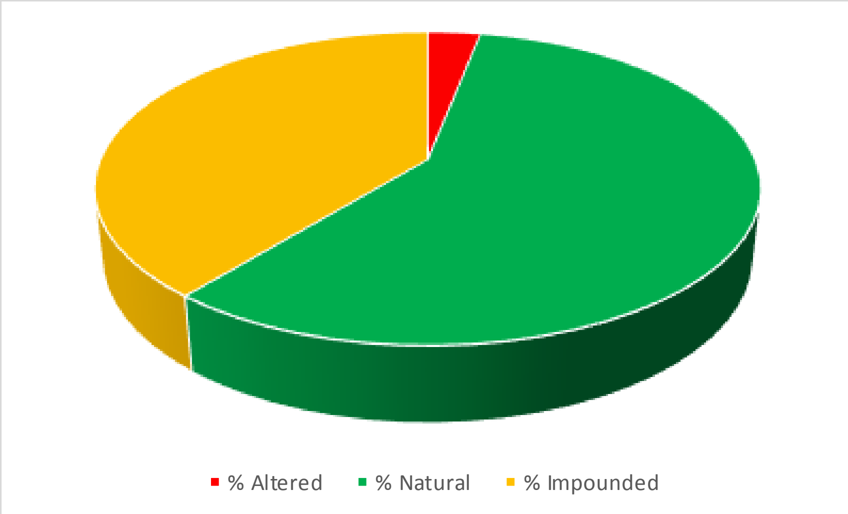


Figure 8. Comparison of natural to altered streams in the Vermilion River Watershed (percentages derived from the Statewide Altered Water Course project).

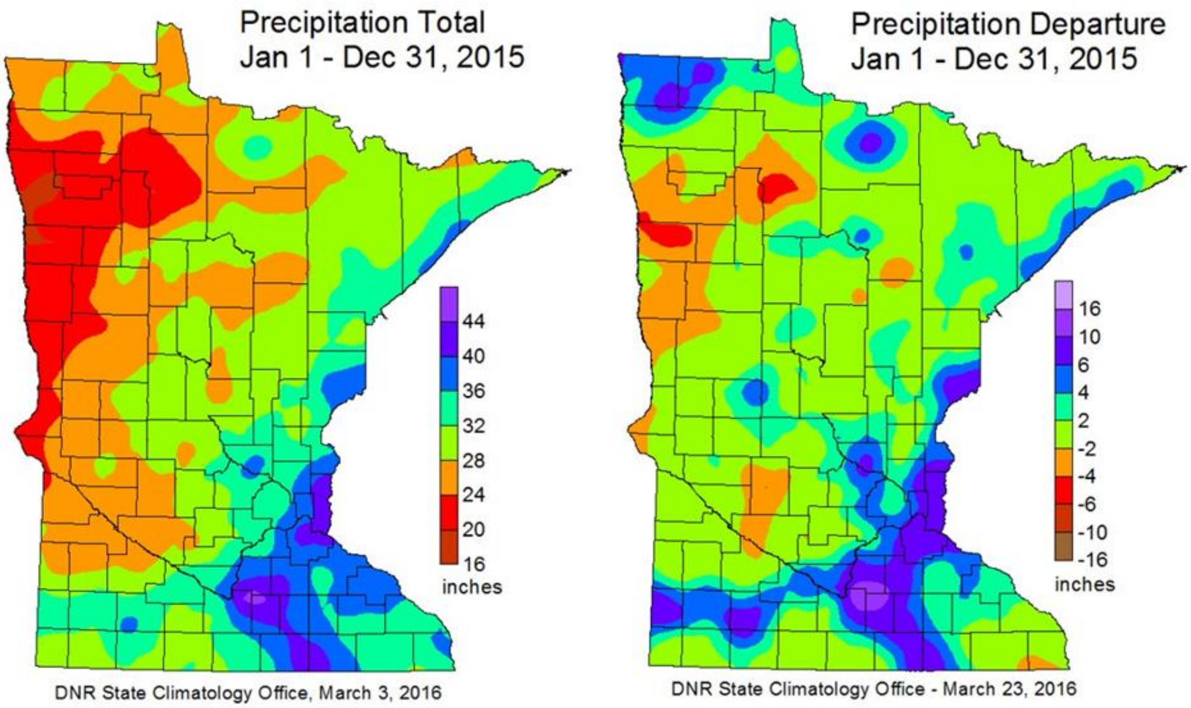


Climate and precipitation

Minnesota has a continental climate, marked by warm summers and cold winters. The mean annual temperature for Minnesota is 4.6˚C (NOAA, 2016); the mean summer (June-August) temperature for the Vermilion River Watershed is 16.9˚C and the mean winter (December-February) temperature is -12.8˚ C (DNR: Minnesota State Climatology Office, 2017).

Precipitation is an important source of water input to a watershed. Figure 9 displays two representations of precipitation for calendar year 2015. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the eastern portion of the state. According to this figure, the Vermilion Watershed area received 24 to 28 inches of precipitation in 2015. The display on the right shows the amount that precipitation levels departed from normal. The watershed area experienced precipitation of 2 inches below normal in 2015.

Figure 9. Statewide precipitation total (left) and precipitation departure (right) during 2015 (Source: DNR State Climatology Office, 2016).



The Vermilion River Watershed is located in the Northeast precipitation region. Figure 10 and Figure 11 display the areal average representation of precipitation in Northeast Minnesota for 20 and 100 years, respectively. An areal average is a spatial average of all the precipitation data collected within a certain area presented as a single dataset. Though rainfall can vary in intensity and time of year, rainfall totals in the Northeast region display no significant trend over the last 20 years. However, precipitation in this region exhibits a significant rising trend over the past 100 years ($p<0.001$). This is a strong trend and matches similar trends throughout Minnesota.

Figure 10. Precipitation trends in Northeast Minnesota (1996-2015) with five-year running average (Source: WRCC, 2017).

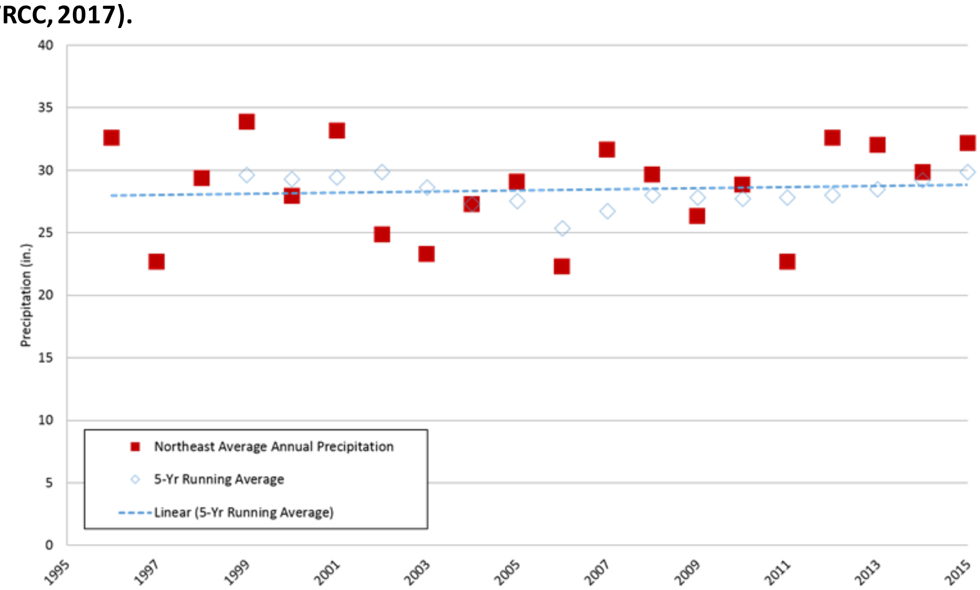
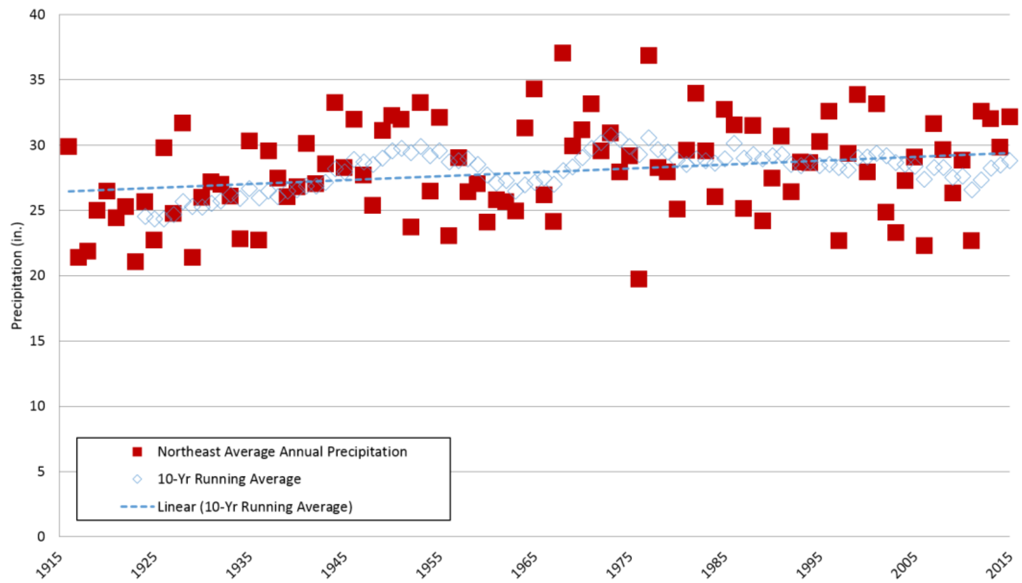


Figure 11. Precipitation trends in Northwest Minnesota (1916-2015) with 10-year running average (Source: WRCC, 2017).



Hydrogeology and groundwater quality and quantity

Hydrogeology

Hydrogeology is the study of the interaction, distribution and movement of groundwater through the rocks and soil of the earth. The geology of a region strongly influences the quantity of groundwater available, the quality of the water, the sensitivity of the water to pollution, and how quickly the water will be able to recharge and replenish the source aquifer. This branch of geology is important to understand as it indicates how to manage groundwater withdrawal and land use and can determine if mitigation is necessary.

Surficial and bedrock geology

Surficial geology is identified as the earth material located below the topsoil and overlying the bedrock. Glacial sediment is limited in much of the Vermilion River Watershed due to the majority of the watershed with bedrock exposed at the surface. The depth to bedrock ranges from surface level to over 250 feet below deposits of the various ice lobes that reached this watershed during the last glacial period, as well as during previous glaciations in the last 2.58 million years. The deposits at the surface are associated with two ice lobes, the Des Moines and Rainy lobes, and post-glacial alterations to that sediment, including soil formation and peat accumulation. The geomorphology includes lake modified till, end and ground moraines, mine pits and dumps, peat, outwash and alluvium (Figure 12) (Hobbs & Goebel, 1982). The glacial sediment consists of sand and gravel stream sediment with a predominantly sandy texture.

Bedrock is the main mass of rocks that form the earth, located underneath the surficial geology and can only be seen in much of the watershed where weathering has exposed the bedrock. Precambrian bedrock lies under the extent of the Vermilion River Watershed, displaying evidence of volcanic activity. The main terrane groups include Quetico and the Wawa Subprovinces (Jirsa et al., 2011). The rock types that are found in the uppermost bedrock include basalt, gneiss, granite, greywacke, iron formations, mafic metavolcanic rock, monzonite, and paragneiss (Figure 13) (Morey & Meints, 2000).

Figure 12. Quaternary geology within the Vermilion River Watershed (GIS Source: Hobbs & Goebel, 1982; Morey & Meints, 2000).

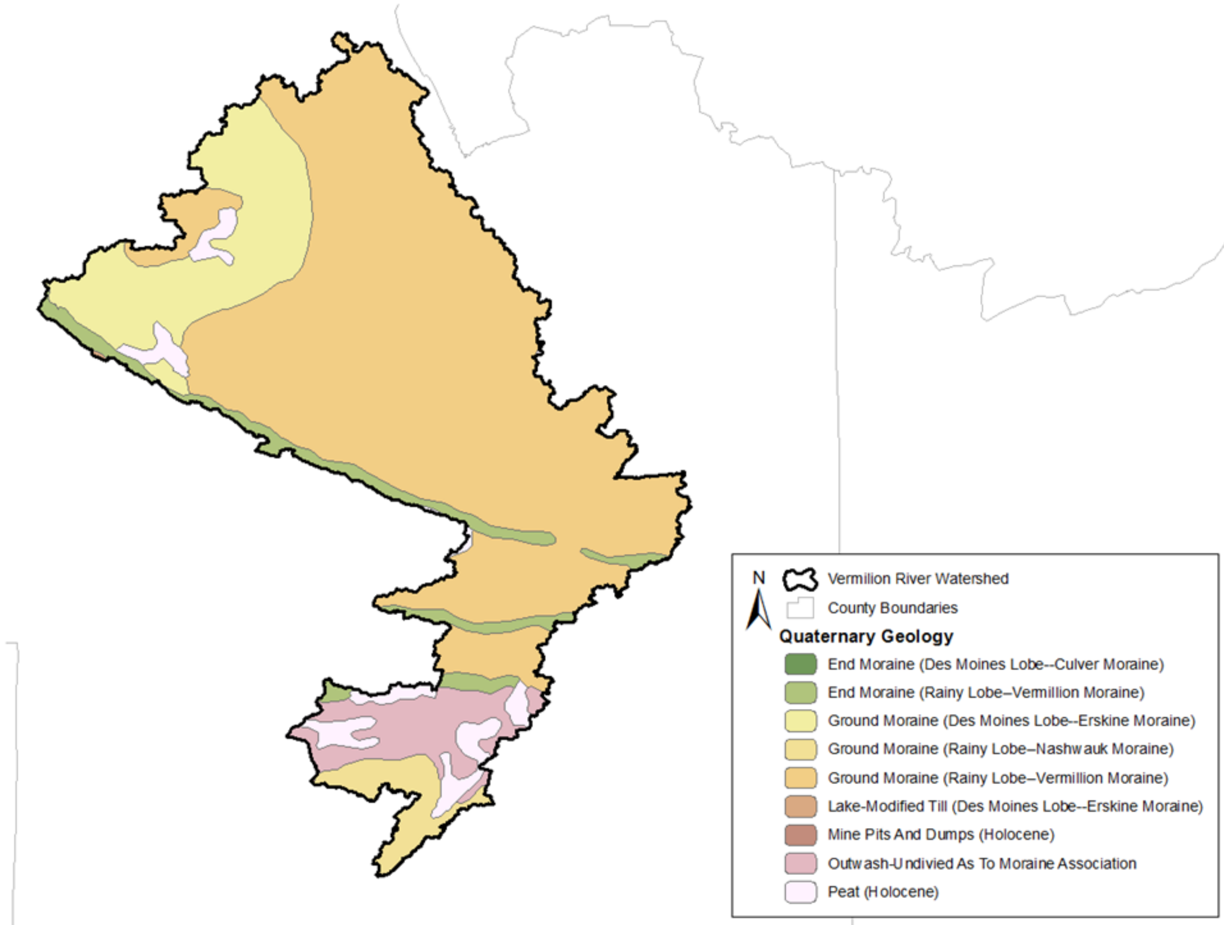
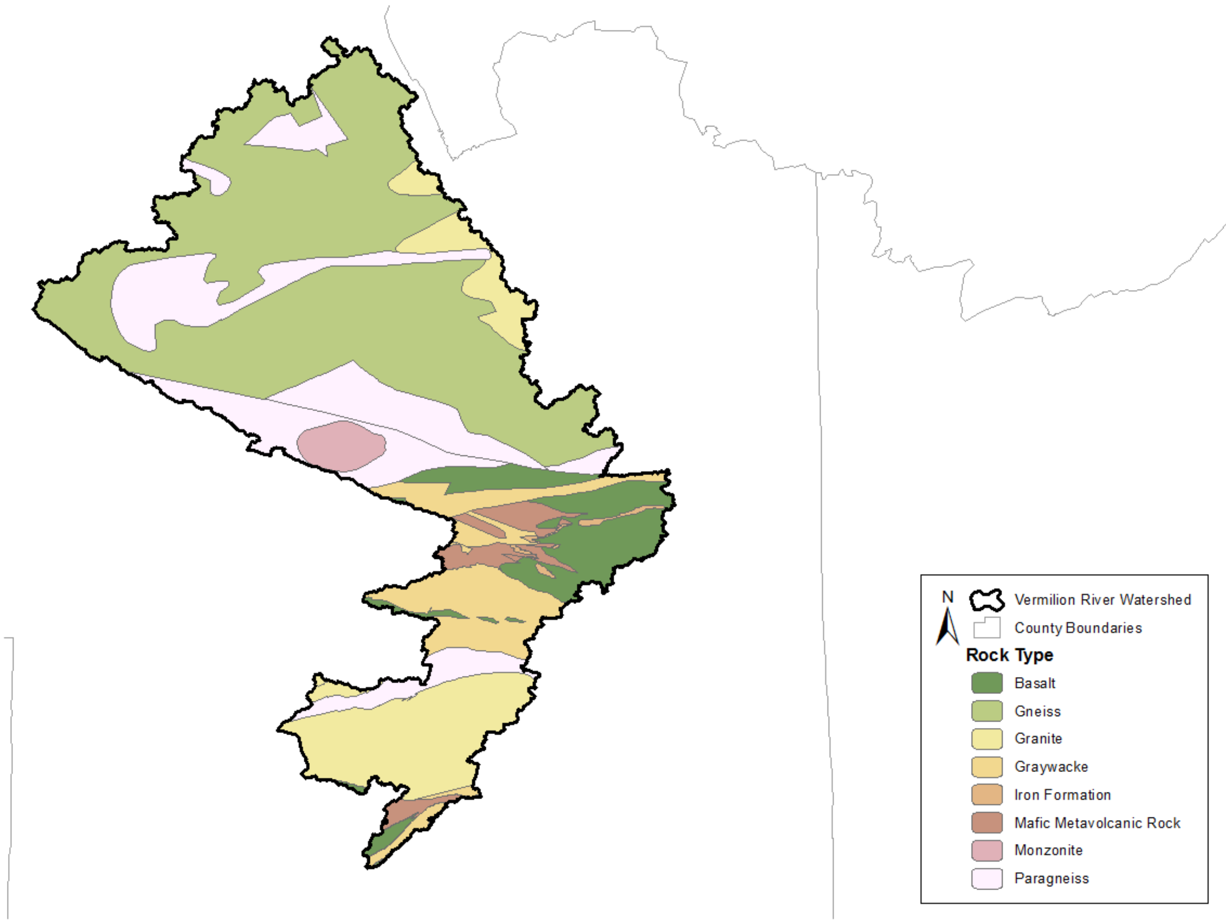


Figure 13. Bedrock geology rock types within the Vermilion River Watershed (GIS Source: Hobbs & Goebel, 1982; Morey & Meints, 2000).



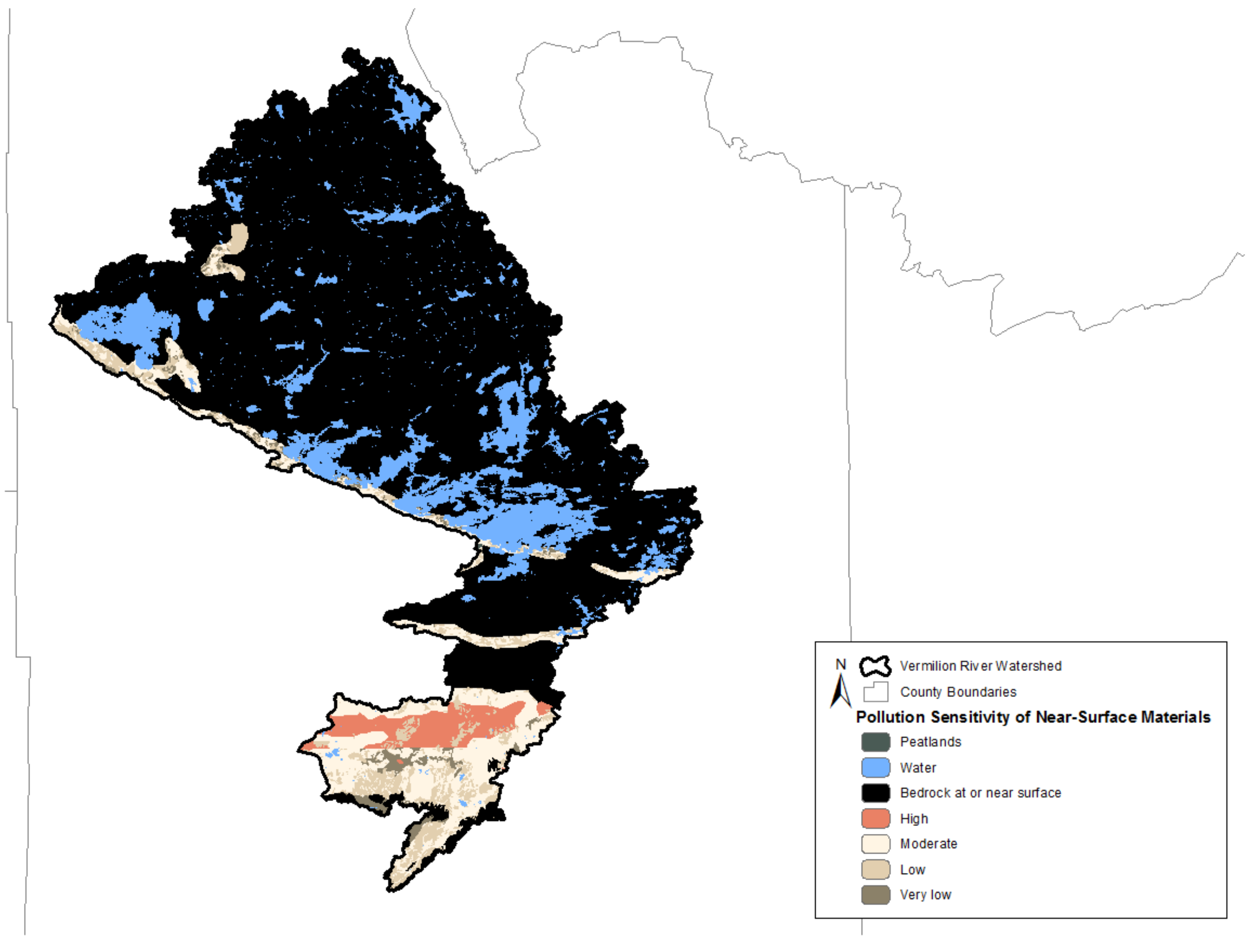
Aquifers

Groundwater aquifers are layers of water-bearing units that readily transmit water to wells and springs (USGS, 2016). As precipitation hits the surface, it infiltrates through the soil zone and into the void spaces within the geologic materials underneath the surface, saturating the material and becoming groundwater (Zhang, 1998). The water table is the uppermost portion of the saturated zone, where the pore-water pressure is equal to local atmospheric pressure. The geologic material determines the permeability and availability of water within the aquifer. Minnesota's groundwater system is comprised of three types of aquifers: 1) igneous and metamorphic bedrock aquifers, 2) sedimentary rock aquifers, and 3) glacial sand and gravel aquifers (MPCA, 2005). The Vermilion River Watershed is located within the Arrowhead Groundwater Province with exposed fractured igneous and metamorphic bedrock aquifers lying deep beneath thin clayey and sandy unconsolidated sediments (DNR, 2001; DNR, 2017a). The general availability of groundwater for this watershed can be categorized as limited in the surficial sands, buried sands and bedrock (DNR, 2017a). Faults and fractures within the Precambrian rocks serve as local sources of groundwater for this area (DNR, 2001) and are primarily withdrawn from the Giants Range Granite Undivided aquifer (PAGR).

Groundwater pollution sensitivity

Since bedrock aquifers are typically covered with thick till, they would normally be better protected from contaminant releases at the land surface. It is also less likely that withdrawals from these wells would have a direct and significant impact on local surface water bodies. In contrast, surficial aquifers are typically more likely to 1) be vulnerable to contamination, 2) have direct hydrologic connections to local surface water, and 3) influence the quality and quantity of local surface water. The DNR is working on a hydrogeological atlas focused on the pollution sensitivity of the bedrock surface. It is being produced county-by-county, and is awaiting completion for St. Louis County within the Vermilion River Watershed. Until the hydrogeological atlas is finished, a 2016 statewide evaluation of pollution sensitivity of near-surface materials completed by the DNR is utilized to estimate pollution vulnerability up to ten feet from the land surface. This display is not intended to be used on a local scale, but as a coarse-scale planning tool. According to this data, the Vermilion River Watershed is estimated to primarily consist of bedrock at or near the surface with low to moderate with some high pollution sensitivity areas in the southern area of the watershed, most likely due to the presence of sand and gravel Quaternary geology (Figure 14) (DNR, 2016).

Figure 14. Pollution sensitivity of near-surface materials for the Vermilion River Watershed (GIS Source: DNR, 2016).



Groundwater potential recharge

Groundwater recharge is one of the most important parameters in the calculation of water budgets, which are used in general hydrologic assessments, aquifer recharge studies, groundwater models, and water quality protection. Recharge is a highly variable parameter, both spatially and temporally, making accurate estimates at a regional scale difficult to produce. The MPCA contracted the US Geological Survey to develop a statewide estimate of recharge using the SWB – Soil-Water-Balance Code. The result is a gridded data structure of spatially distributed recharge estimates that can be easily integrated into regional groundwater studies. The full report of the project as well as the gridded data files are available at: https://gisdata.mn.gov/dataset/geos-gw-recharge-1996-2010-mean.

Recharge of these aquifers is important and limited to areas located at topographic highs, those with surficial sand and gravel deposits, and those along the bedrock-surficial deposit interface (Figure 15). Typically, recharge rates in unconfined aquifers are estimated at 20 to 25% of precipitation received, but can be less than 10% of precipitation where glacial clays or till are present (USGS, 2007). For the Vermilion River Watershed, the average annual potential recharge rate to surficial materials ranges from 0.70 to 14.25 inches per year, with an average of 5.70 inches per year (Figure 16). The statewide average potential recharge is estimated to be four inches per year with 85% of all recharge ranging from three to eight inches per year. When compared to the statewide average potential recharge, the Vermilion River Watershed receives slightly higher average potential recharge.

Figure 15. Average annual potential recharge rate to surficial materials in Vermilion River Watershed (1996-2010) (GIS Source: USGS, 2015).

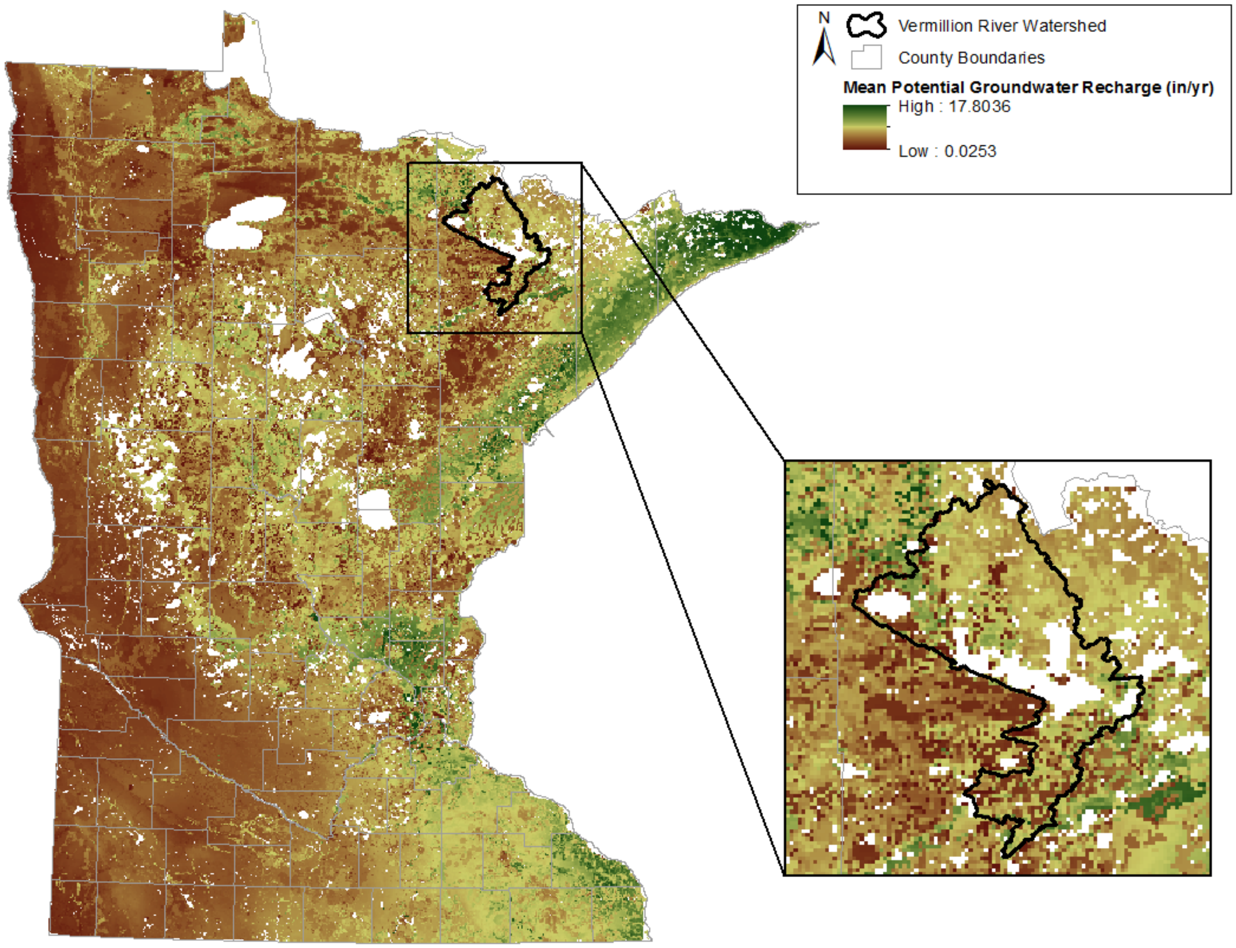
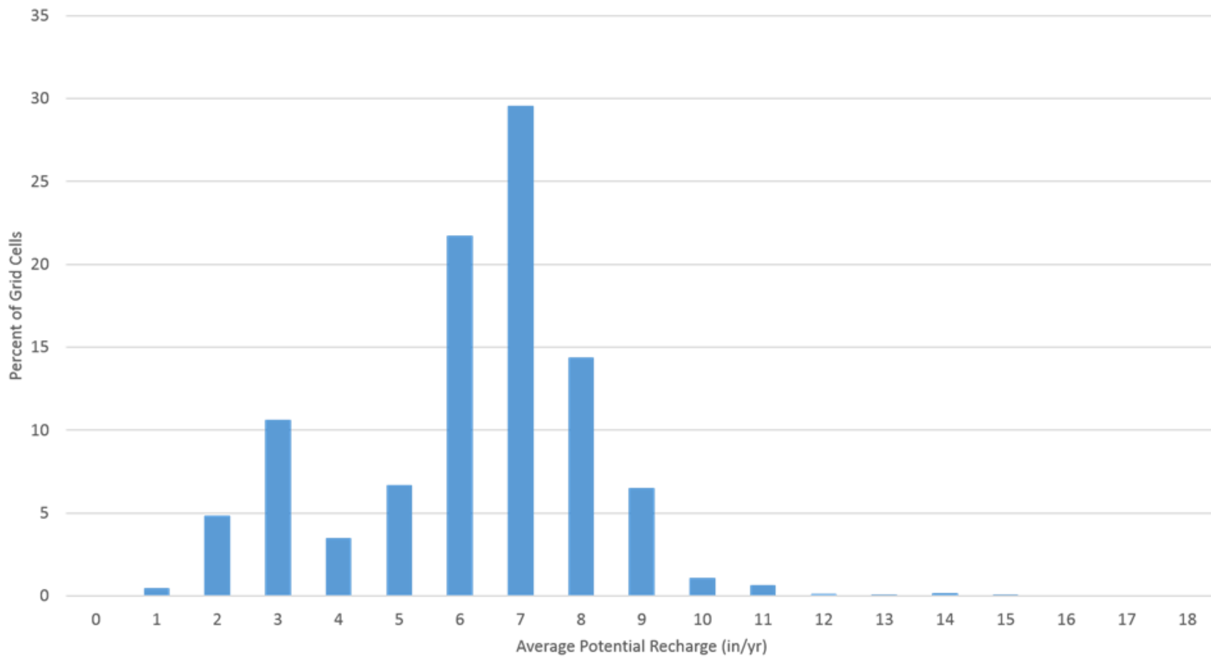


Figure 16. Average annual potential recharge rate percent of grid cells in the Vermilion River Watershed (1996-2010).

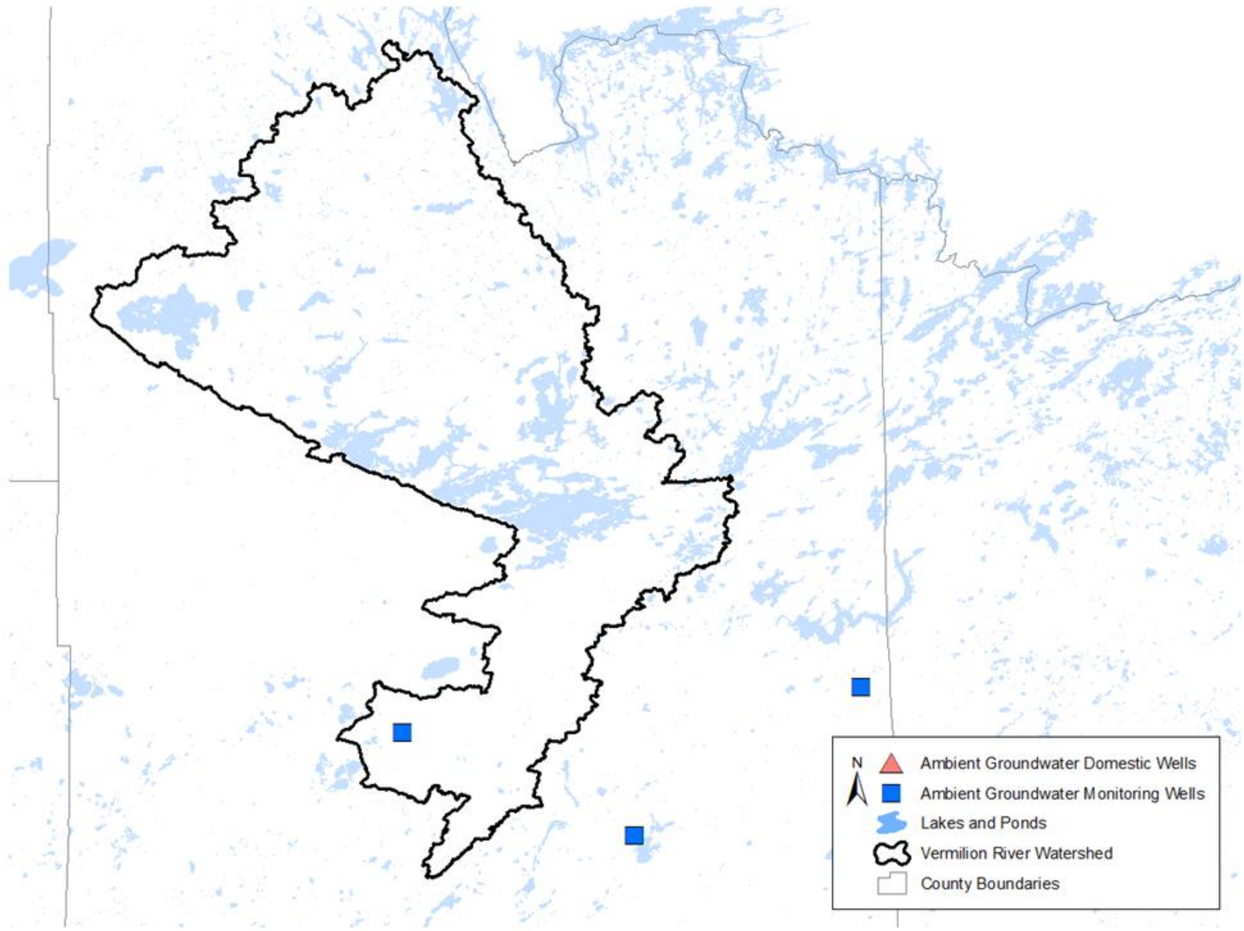


Groundwater quality

Approximately 75% of Minnesota's population receives their drinking water from groundwater, undoubtedly indicating that clean groundwater is essential to the health of its residents. The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of chemicals including nutrients, metals, and volatile organic compounds. These ambient groundwater wells represent a mix of deeper domestic wells and shallow monitoring wells. The shallow wells interact with surface waters and exhibit impacts from human activities more rapidly. Available data from federal, state and local partners are used to supplement reviews of groundwater quality in the region.

There is currently one MPCA Ambient Groundwater Monitoring well within the Vermilion River Watershed (Figure 17). Data collection for the network ranges from 2004 to 2016; however, the well within this watershed was only sampled in 2015 and 2016. Therefore, due to the limited amount of data available, data analysis was not conducted on this well within the Vermilion River Watershed.

Figure 17. MPCA ambient groundwater monitoring well locations within the Vermilion River Watershed

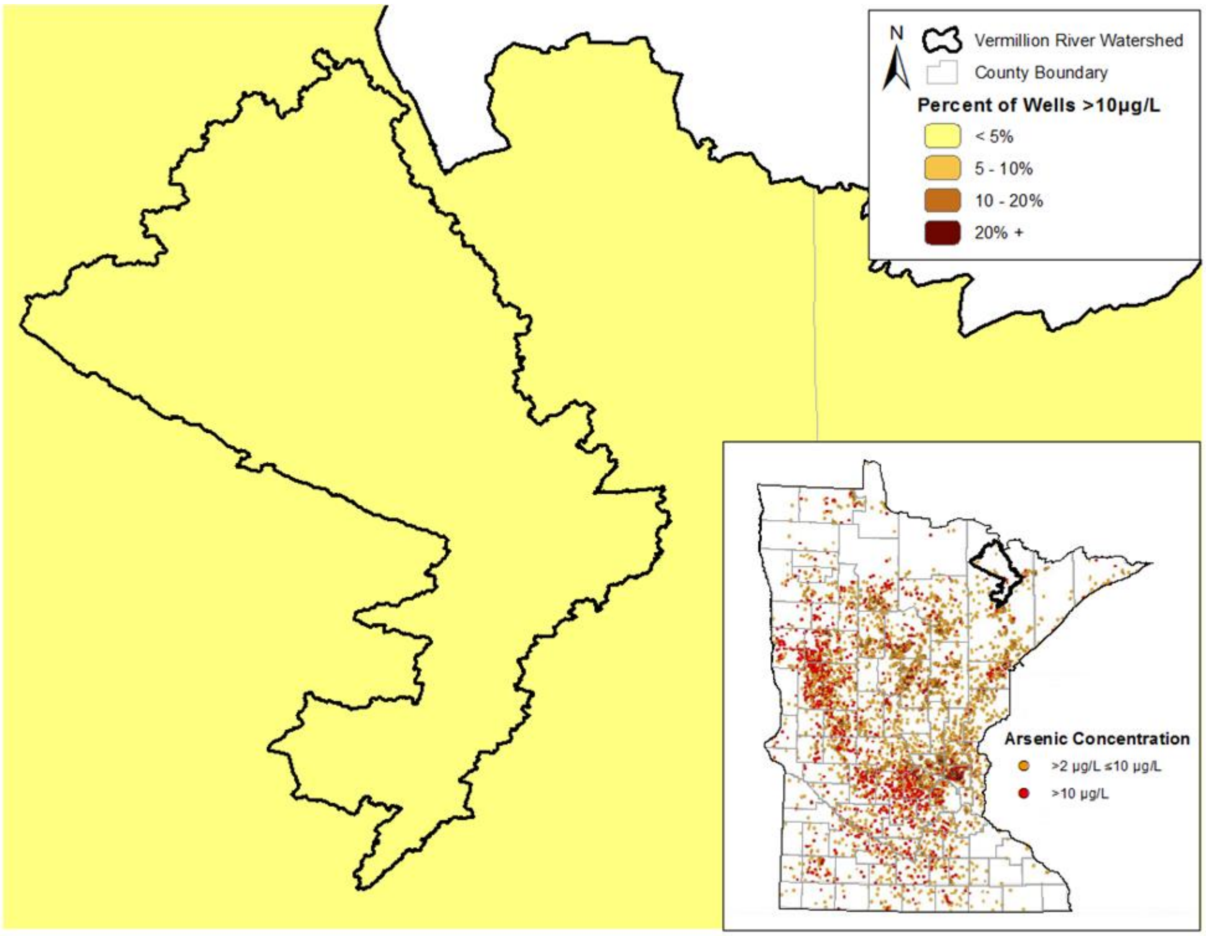


Regional groundwater quality

From 1992 to 1996, the MPCA conducted baseline water quality sampling and analysis of Minnesota's principal aquifers. The Vermilion River Watershed lies entirely within the Northeast Region. The groundwater quality in this region is considered good when compared to other areas with similar aquifers. However, there are some exceedances of drinking water criteria for arsenic, beryllium, boron, manganese and selenium (MPCA, 1999). Concentrations of chemicals within the Precambrian aquifers were comparable to similar aquifers throughout the state and concentrations of major cations and anions were lower in the surficial and buried drift aquifers when compared to similar aquifers statewide (MPCA, 1999). Many of the exceedances identified were attributed to geology, but some trace inorganic chemicals may be of concern locally. Volatile organic compounds were also detected in this region, with the most common detections associated with well disinfection, atmospheric deposition and fuel oils (MPCA, 1999).

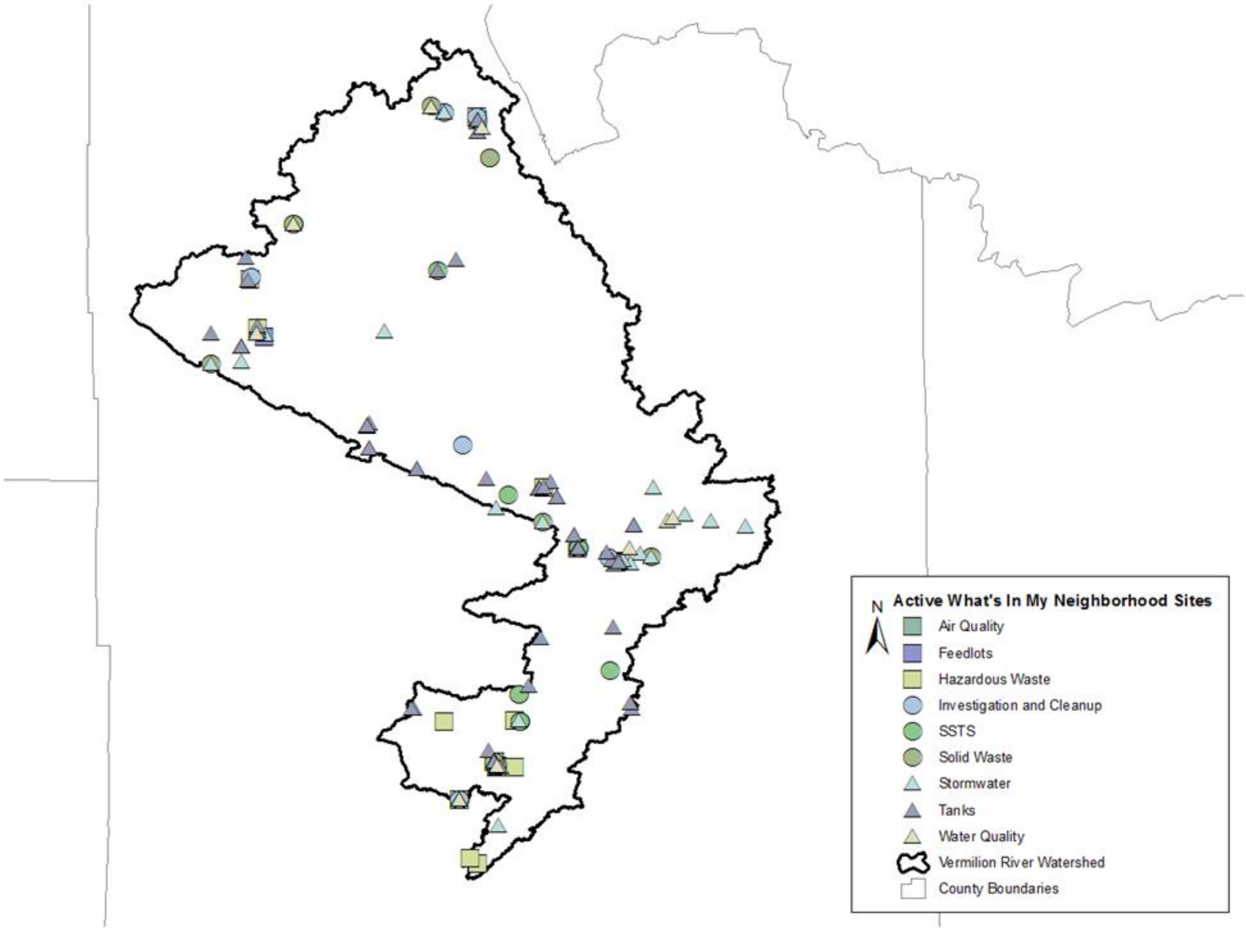
Another source of information on groundwater quality comes from the Minnesota Department of Health (MDH). Mandatory testing for arsenic, a naturally occurring but potentially harmful contaminant for humans, of all newly constructed wells. This testing identified that 10.7% of all wells installed from 2008 to 2015 have arsenic levels above the maximum contaminant level (MCL) for drinking water of 10 micrograms per liter (ug/L) (MDH, 2016a). In the Vermilion River Watershed, the majority of new wells are within the water quality standards for arsenic levels, but there are some exceedances to the MCL. When observing concentrations of arsenic by percentage of wells that exceed the MCL of 10 ug/L per county, the watershed lies within St. Louis County, with less than 5% exceedances (3.7%) (MDH, 2016b) (Figure 18). It is important to reiterate that the percentages of arsenic concentration exceedances are per county, not specifically for Vermilion River Watershed. For more information on arsenic in private wells, please refer to the MDH's website: https://apps.health.state.mn.us/mndata/arsenic_wells.

Figure 18. Percent wells with arsenic occurrence greater than the MCL for the Vermilion River Watershed (2008-2015) (Source: MDH, 2016b).



A statewide dataset of potentially contaminated sites and facilities with environmental permits and registrations is available at the MPCA's website, through a web-based application called, "What's In My Neighborhood" (WIMN). This MPCA resource provides the public with a method to access a wide variety of environmental information about communities across the state. The data is divided into two groups. The first is potentially contaminated sites, and includes contaminated properties, formerly contaminated sites, and those that are being investigated for suspicion of being contaminated. The second category is made up of businesses that have applied for and received different types of environmental permits and registrations from the MPCA. An example of an environmental permit would be for a business acquiring a permit for a storm water or wastewater discharge, requiring it to operate within limits established by the MPCA. In the Vermilion River Watershed, there are currently 202 active sites identified by WIMN: 84 tanks (aboveground and belowground), 35 stormwater (construction and industrial stormwater), 27 subsurface sewage treatment systems (SSTS), 23 hazardous waste sites, 12 investigation and cleanup sites, 9 solid waste sites, 9 water quality sites (wastewater), 2 air quality sites, and 1 feedlot (Figure 19Figure 19). For more information regarding WIMN, refer to the MPCA webpage at http://www.pca.state.mn.us/index.php/data/wimn-whats-in-my-neighborhood/whats-in-my-neighborhood.html.

Figure 19. Active "What's In My Neighborhood" site programs and locations for the Vermilion River Watershed (Source: MPCA, 2017).



Groundwater quantity

The DNR permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons per day or one million gallons per year. Permit holders are required to track water use and report back to the DNR annually. The changes in withdrawal volume detailed in this groundwater report are a representation of water use and demand in the watershed and are taken into consideration when the DNR issues permits for water withdrawals. Other factors not discussed in this report but considered when issuing permits include: interactions between individual withdrawal locations, cumulative effects of withdrawals from individual aquifers, and potential interactions between aquifers. This holistic approach to water allocations is necessary to ensure the sustainability of Minnesota's groundwater resources.

The three largest permitted consumers of water in the state are (in order) power generation, public water supply (municipal), and irrigation (DNR, 2017b). According to the most recent DNR Permitting and Reporting System (MPARS), in 2015 the withdrawals within the Vermilion River Watershed were primarily utilized for industrial processing (54.9%), such as sand and gravel washing. The remaining withdrawals include: water supply (24.3%), water level maintenance (17.6%), and special categories including aquaculture, construction non-dewatering, and pollution containment (3.1%). From 1996 to 2015, withdrawals associated with industrial and special categories have increased significantly ($p<0.001$), while non-crop irrigation has decreased statistically over this time period ($p<0.001$). Water level maintenance displayed no indication of increasing or decreasing trends.

Figure 20 displays total high capacity withdrawal locations within the watershed with active permit status in 2015. During 1996 to 2015, groundwater withdrawals within the Vermilion River Watershed exhibit a significant decreasing withdrawal trend ($p<0.001$) (Figure 21), while surface water withdrawals exhibit an increasing trend ($p<0.05$) (Figure 22).

Figure 20. Locations of active status permitted high capacity withdrawals in 2015 within the Vermilion River Watershed.

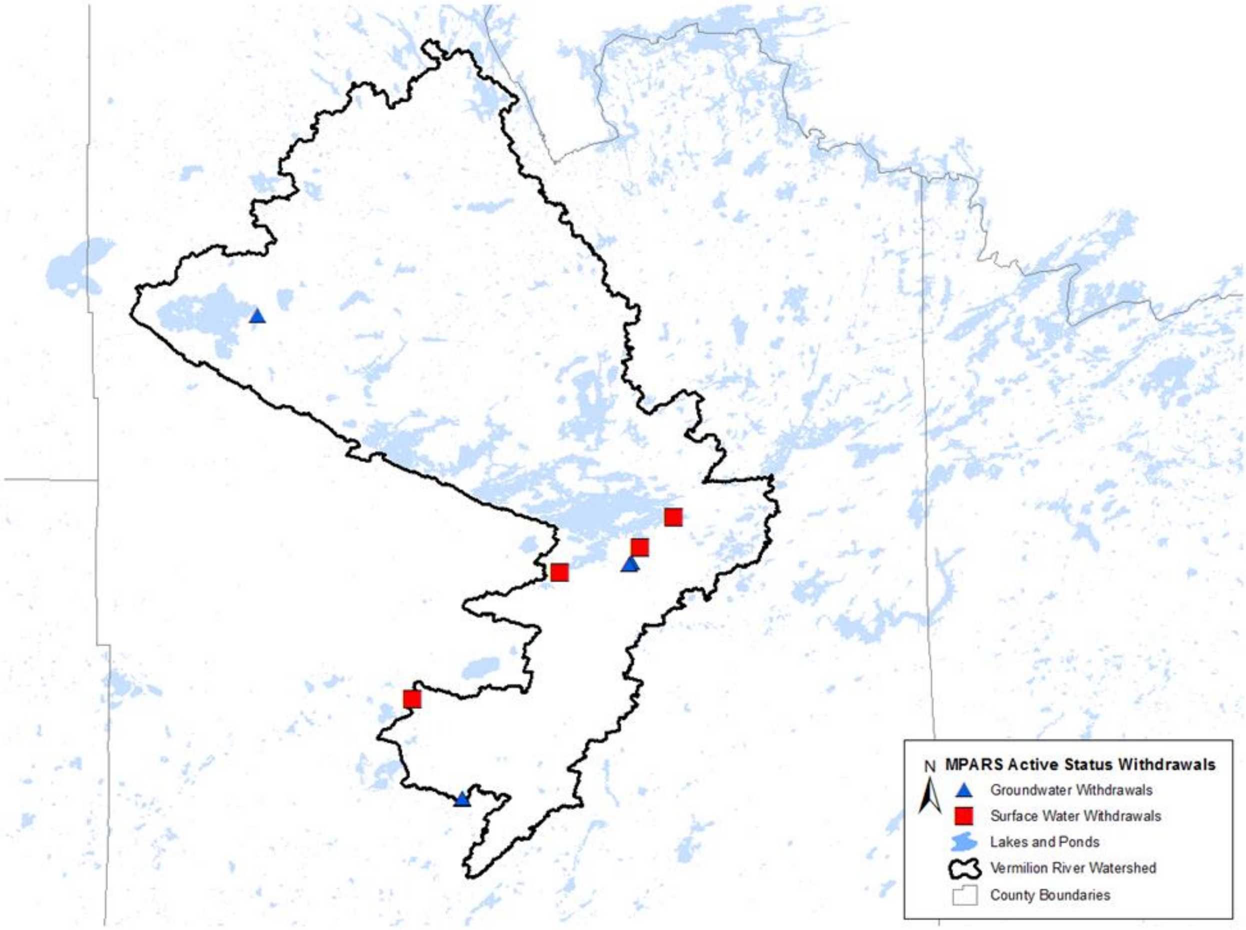


Figure 21. Total annual groundwater withdrawals in the Vermilion River Watershed (1996-2015).

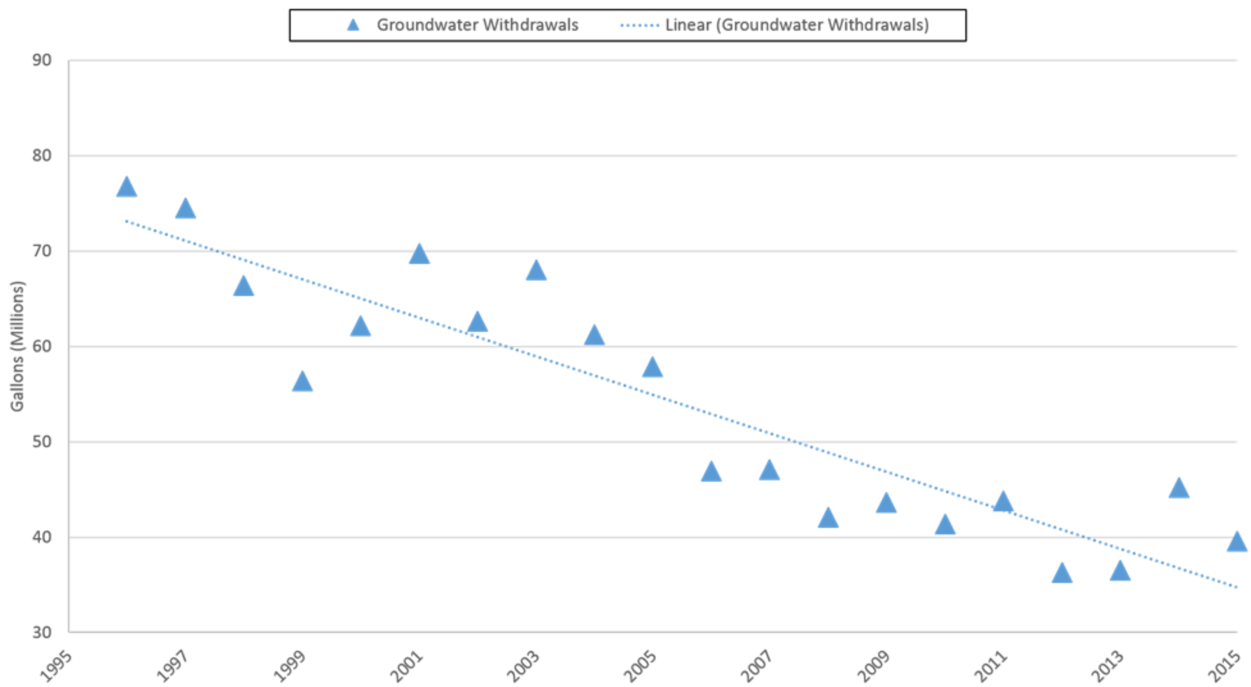
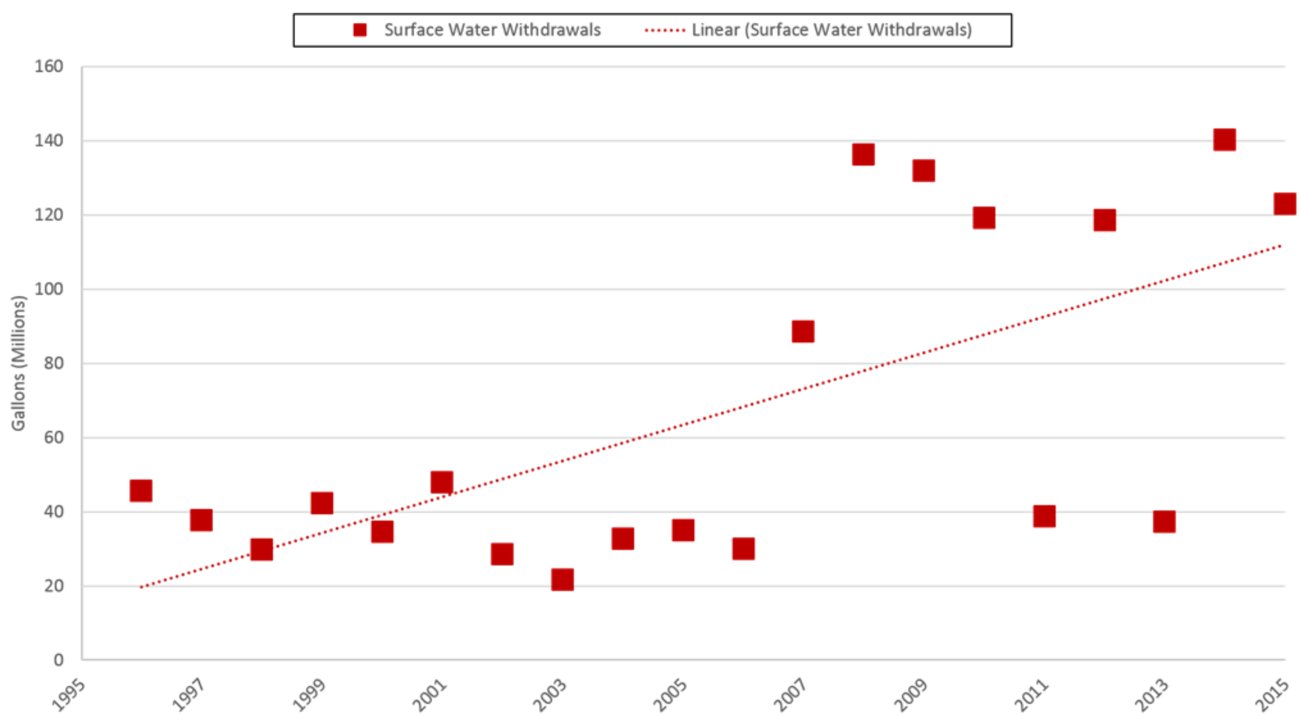


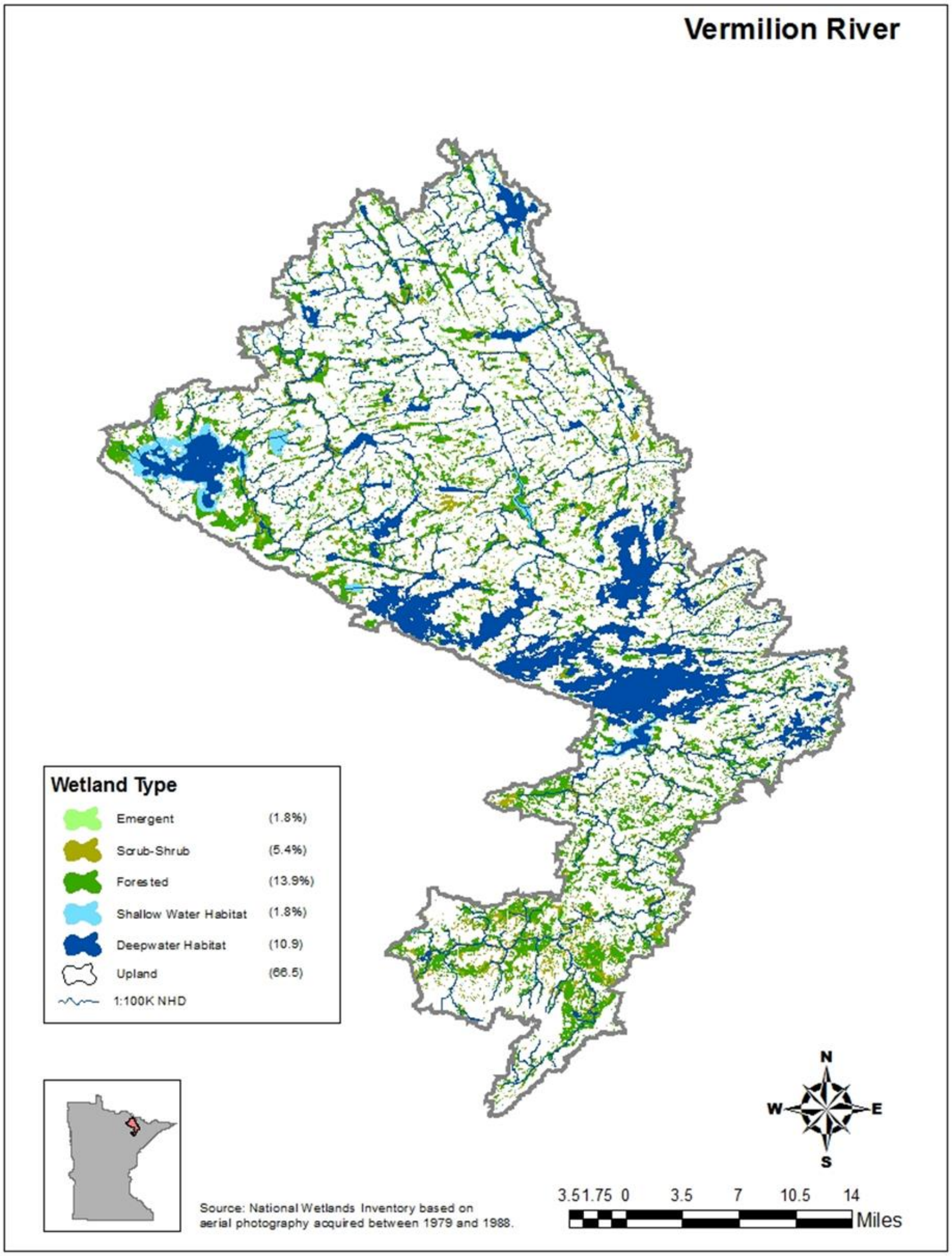
Figure 22. Total annual surface water withdrawals in the Vermilion River Watershed (1996-2015).



Wetlands

Wetlands are common in the Vermillion River Watershed. National Wetlands Inventory (NWI) data estimate the watershed contains 149,766 acres of wetlands— approximately 23% of the watershed area (Figure 23). This is slightly greater than the statewide wetland coverage rate of 19% (Kloiber and Norris 2013). Forested wetlands are the predominant type and include coniferous swamps and bogs (dominated by black spruce, tamarack, and/or white cedar) and hardwood (black ash) swamps.

Figure 23. Wetlands and surface water in the Vermillion River Watershed. Watershed coverage by general wetland type is provided in the legend.



Glacial scouring and moraines from multiple glacial advances have helped form the topographic relief found in the Vermilion River Watershed today (MNGS 1997). Numerous small to moderately sized wetlands have formed in the depressions and swales left behind. Due to the relatively cool-wet climate of the region, the majority of these wetlands are peat forming swamps and bogs—where organic soils have developed due to saturated conditions. As peat has low hydrologic conductivity, excess precipitation can slowly runoff the wetland surface via saturation-overland flow (Acreman and Holden 2013). These peat-forming wetlands serve as the source waters and/or significantly contribute water for many of the streams in the watershed. Saturation-overland flow waters from wetlands typically are high in dissolved organic material (e.g., staining), low in dissolved oxygen, and may have low pH. In addition, beaver activity is high in the watershed and numerous beaver ponds and meadows (grass and sedge dominated wetlands that form when dams fail and ponds partially drain) occur along small streams throughout the watershed. Wetland drainage is minimal in the watershed, as development pressure is low and a significant portion is in the protected Boundary Waters Canoe Area Wilderness. The most notable source of wetland loss is due to construction of mine tailings ponds on the southern margin of the watershed. Finally, it should be noted that wild rice has been documented in many lakes throughout the watershed and the Pike and Vermilion Rivers, and may also be present in an unknown number of wetlands and low gradient streams.

Watershed-wide data collection methodology

Lake water sampling

MPCA staff sampled the larger lakes in the Vermilion River Watershed in 2015 and 2016, for the purpose of enhancing the dataset for assessment of aquatic recreation. The waters sampled during the survey included Vermilion, Elbow, Pelican, Myrtle and Crane lakes.

Local partners with the North St. Louis and Koochiching County SWCDs, and the University of Minnesota's Natural Resource Research Institute (NRRI), monitored 10 other lakes in the watershed, through grant agreements with the MPCA. These lakes included several in more remote portions of the watershed such as Winchester, Ban, Astrid and Trout lakes.

There are currently 22 volunteers enrolled in the MPCA's Citizen Lake Monitoring Program conducting monitoring on 11 lakes within the watershed.

Sampling methods are similar among monitoring groups and are described in the document entitled "MPCA Standard Operating Procedure for Lake Water Quality" found at http://www.pca.state.mn.us/publications/wq-s1-16.pdf. The lake recreation use assessment requires eight observations/samples within a 10-year period (June to September) for phosphorus, Chl-a, and Secchi depth.

No lakes were monitored for fish community health in the Vermilion River Watershed. The DNR is in the process of developing biological health metrics for Canadian Shield lakes within the Lake Superior and Rainy River drainage basins.

Stream water sampling

Nine water chemistry stations were sampled from May through September in 2015, and again June through August of 2016 to provide sufficient water chemistry data to assess aquatic life and recreation. Water chemistry stations were placed at the outlet of each aggregated 12 HUC subwatershed that was greater than 40 square miles in area (green circles/triangles in (Figure 2). A contract was awarded to the North St. Louis County SWCD to conduct this monitoring. (See Appendix 2.1 for locations of stream water chemistry monitoring sites. See Appendix 1 for definitions of stream chemistry analytes monitored in this study).

Two streams in the watershed were monitored by volunteers through the MPCA's Citizen Stream Monitoring Program, Wolf Creek near Lake Vermilion, and the Pelican River.

Stream flow methodology

MPCA and DNR joint stream water quantity and quality monitoring data for dozens of sites across the state on major rivers, at the mouths of most of the state's major watersheds, and at the mouths of some aggregated 12-HUC subwatersheds are available at the DNR/MPCA Cooperative Stream Gaging webpage at: http://www.dnr.state.mn.us/waters/csg/index.html.

Stream biological sampling

The biological monitoring component of the intensive watershed monitoring in the Vermilion River Watershed was completed during the summer of 2015. A total of 29 sites were newly established across the watershed and sampled. These sites were located near the outlets of most minor HUC-14 watersheds. In addition, four existing biological monitoring stations within the watershed were revisited in 2015. These monitoring stations were initially established as part of a random Rainy River Basin wide survey in 2005. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2017 assessment was collected in 2015. A total of 21 reaches were sampled for biology in the Vermilion River Watershed. Waterbody assessments to determine aquatic life use support were conducted for all of the reaches. Biological information that was not used in the assessment process will be crucial to the stressor identification process and will also be used as a basis for long-term trend results in subsequent reporting cycles.

To measure the health of aquatic life at each biological monitoring station, indices of biological integrity (IBIs), specifically Fish and Invert IBIs, were calculated based on monitoring data collected for each of these communities. A fish and macroinvertebrate classification framework was developed to account for natural variation in community structure which is attributed to geographic region, watershed drainage area, water temperature and stream gradient. As a result, Minnesota's streams and rivers were divided into seven distinct warm water classes and two cold-water classes, with each class having its own unique Fish IBI and Invert IBI. Each IBI class uses a unique suite of metrics, scoring functions, impairment thresholds, and confidence intervals (CIs) (For IBI classes, thresholds and CIs, see Appendix 3.1). IBI scores higher than the impairment threshold and upper CI indicate that the stream reach supports aquatic life. Contrarily, scores below the impairment threshold and lower CI indicate that the stream reach does not support aquatic life. When an IBI score falls within the upper and lower confidence limits additional information may be considered when making the impairment decision such as the consideration of potential local and watershed stressors and additional monitoring information (e.g., water chemistry, physical habitat, observations of local land use activities). For IBI results for each individual biological monitoring station, see Appendices 4.1 and 4.2.

Fish contaminants

Minnesota Department of Natural Resource (DNR) fisheries staff collect most of the fish for the Fish Contaminant Monitoring Program. In addition, MPCA's biomonitoring staff collect up to five piscivorous (top predator) fish and five forage fish near the HUC8 pour point, as part of the Intensive Watershed Monitoring. All fish collected by the MPCA are analyzed for mercury and the two largest individual fish of each species are analyzed for polychlorinated biphenyls (PCBs).

Captured fish were wrapped in aluminum foil and frozen until they were thawed, scaled (or skinned), filleted, and ground to a homogenized tissue sample. Homogenized fillets were placed in 60 mL glass jars with Teflon™ lids and frozen until thawed for lab analysis. The Minnesota Department of Agriculture Laboratory analyzed the samples for mercury and PCBs. If fish were tested for perfluorochemicals (PFCs), whole fish were shipped to AXYS Analytical Laboratory, which analyzed the homogenized fish fillets for 13 PFCs. Of the measured PFCs, only perfluorooctane sulfonate (PFOS) is reported because it bioaccumulates in fish to levels that are potentially toxic and a reference dose has been developed.

From the fish contaminant analyses, MPCA determines which waters exceed impairment thresholds. The Impaired Waters List is prepared by the MPCA and submitted every even year to the U.S. EPA. MPCA has included waters impaired for contaminants in fish on the Impaired Waters List since 1998. Impairment assessment for PCBs (and PFOS when tested) in fish tissue is based on the fish consumption advisories prepared by the MDH. If the consumption advice is to restrict consumption of a particular fish species to less than a meal per week the MPCA considers the lake or river impaired. The threshold concentration for impairment (consumption advice of one meal per month) is an average fillet concentration of 0.22 mg/kg for PCBs (and 0.200 mg/kg for PFOS).

Monitoring of fish contaminants in the 1970s and 1980s showed high concentrations of PCBs were primarily a concern downstream of large urban areas in large rivers, such as the Mississippi River, and in Lake Superior. Therefore, PCBs are now tested where high concentrations in fish were measured in the past and the major watersheds are screened for PCBs in the watershed monitoring collections.

Before 2006, mercury in fish tissue was assessed for water quality impairment based on MDH's fish consumption advisory, the same as PCBs. With the adoption of a water quality standard for mercury in edible fish tissue, a waterbody has been classified as impaired for mercury in fish tissue if 10% of the fish samples (measured as the 90^{th} percentile) exceed 0.2 mg/kg of mercury. At least five fish samples of the same species are required to make this assessment and only the last 10 years of data are used for the assessment. MPCA's Impaired Waters List includes waterways that were assessed as impaired prior to 2006 as well as more recent impairments.

Pollutant load monitoring

Intensive water quality sampling occurs at all WPLMN sites. Thirty-five samples per year are allocated for basin and major watershed sites and 25 samples per season (ice out through October 31) for subwatershed sites. Because concentrations typically rise with streamflow for many of the monitored pollutants, and because of the added influence elevated flows have on pollutant load estimates, sampling frequency is greatest during periods of moderate to high flow. All major snowmelt and rainfall events are sampled. Low flow periods are also sampled although sampling frequency is reduced, as pollutant concentrations are generally more stable when compared to periods of elevated flow.

Water sample results and daily average flow data are coupled in the $FLUX_{32}$ pollutant load model to estimate the transport (load) of nutrients and other water quality constituents past a sampling station over a given period of time. Loads and flow weighted mean concentrations (FWMCs) are calculated for total suspended solids (TSS), total phosphorus (TP), dissolved orthophosphate, nitrate plus nitrite nitrogen (NO_3+NO_2-N), and total Kjeldahl nitrogen (TKN).

More information can be found at the WPLMN website.

Groundwater monitoring

The MPCA maintains an Ambient Groundwater Monitoring Network that monitors the aquifers that are most likely to be polluted with non-agricultural chemicals. This network primarily targets the shallow aquifers that underlie the urban parts of the state, due to the higher tendency of vulnerability to pollution. The MPCA's Ambient Groundwater Monitoring Network as of 2018, when this report was produced, consisted of approximately 270 wells that are primarily located in the sand and gravel and Prairie du Chien- Jordan aquifers.

Some wells in the MPCA's network are used to discern the effect of urban land use on groundwater quality and comprise an early warning network. Most wells in this early warning network contain water that was recently recharged into the groundwater, some even less than one year old. The wells in the early warning network are distributed among several different settings to determine the effect land use has on groundwater quality. These assessed land use settings are: 1) sewered residential, 2) residential areas that use subsurface sewage treatment systems (SSTS) for wastewater disposal, and 3) commercial or industrial, and 4) undeveloped. The data collected from the wells in the undeveloped areas provide a baseline to assess the extent of any pollution from all other land use settings.

Water samples from the MPCA's Ambient Groundwater Monitoring Network wells generally are collected annually by MPCA staff. This sampling frequency provides sufficient information to determine trends in groundwater quality. The water samples are analyzed to determine the concentrations of over 100 chemicals, including nitrate, chloride, and VOCs.

Information on groundwater monitoring methodology is taken from Kroening and Ferrey's report: The Condition of Minnesota's Groundwater, 2007-2011 (2013). To download ambient groundwater monitoring data, please refer to: https://www.pca.state.mn.us/data/groundwater-data.

Wetland monitoring

The MPCA is actively developing methods and building capacity to conduct wetland quality monitoring and assessment. Our primary approach is biological monitoring—where changes in biological communities may be indicating a response to human-caused impacts. The MPCA has developed IBIs to monitor the macroinvertebrate condition of depressional wetlands that have open water and the Floristic Quality Assessment (FQA) to assess vegetation condition in all of Minnesota's wetland types. For more information about the wetland monitoring (including technical background reports and sampling procedures), please visit the MPCA Wetland monitoring and assessment webpage.

The MPCA currently does not monitor wetlands systematically by watershed. Alternatively, the overall status and trends of wetland quality in the state and by major ecoregion is being tracked through probabilistic monitoring. Probabilistic monitoring refers to the process of randomly selecting sites to monitor; from which, an unbiased estimate of the resource can be made. Regional probabilistic survey results can provide a reasonable approximation of the current wetland quality in the watershed.

As few open water depressional wetlands exist in the watershed, the focus will be on vegetation quality results of all wetland types.

Individual aggregated 12-HUC subwatershed results

Aggregated 12-HUC subwatersheds

Assessment results for aquatic life and recreation use are presented for each Aggregated HUC-12 subwatershed within the Vermilion River. The primary objective is to portray all the full support and impairment listings within an aggregated 12-HUC subwatershed resulting from the complex and multi-step assessment and listing process. This scale provides a robust assessment of water quality condition at a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The graphics presented for each of the aggregated HUC-12 subwatersheds contain the assessment results from the 2017 Assessment Cycle as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2015 intensive watershed monitoring effort, but also considers available data from the last ten years.

The proceeding pages provide an account of each aggregated HUC-12 subwatershed. Each account includes a brief description of the aggregated HUC-12 subwatershed and summary tables of the results for each of the following: a) stream aquatic life and aquatic recreation assessments, and b) lake aquatic life and recreation assessments. Following the tables is a narrative summary of the assessment results and pertinent water quality projects completed or planned for the aggregated HUC-12 subwatershed. A brief description of each of the summary tables is provided below.

Stream assessments

A table is provided in each section summarizing aquatic life and aquatic recreation assessments of all assessable stream reaches within the aggregated HUC-12 subwatershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2012 assessment process (2014 U.S. Environmental Protection Agency [EPA] reporting cycle); however, impairments from previous assessment cycles are also included and are distinguished from new impairments via cell shading (see footnote section of each table). These tables also denote the results of comparing each individual aquatic life and aquatic recreation indicator to their respective criteria (i.e., standards); determinations made during the desktop phase of the assessment process (see Figure 4). Assessment of aquatic life is derived from the analysis of biological (fish and invert IBIs), dissolved oxygen, total suspended solids, chloride, pH, total phosphorus, Chl-a, biochemical oxygen demand and un-ionized ammonia (NH_3) data, while the assessment of aquatic recreation in streams is based solely on bacteria (*Escherichia coli*) data. Included in each table is the specific aquatic life use classification for each stream reach: cold-water community (2A); cool or warm water community (2B); or indigenous aquatic community (2C). Where applicable and sufficient data exists, assessments of other designated uses (e.g., class 7, drinking water, aquatic consumption) are discussed in the summary section of each aggregated HUC-12 subwatershed as well as in the Watershed-wide results and discussion section.

Lake assessments

A summary of lake water quality is provided in the aggregated HUC-12 subwatershed sections where available data exists. This includes aquatic recreation (phosphorus, Chl-a, and Secchi) and aquatic life, where available (chloride). Similar to streams, parameter level and over all use decisions are included in the table.

Sand River Aggregated 12-HUC HUC 0903000201-03

In the southwestern corner, the Sand River Subwatershed is the most upstream contributor of the Vermilion River Watershed. Draining an area of approximately 62 miles, it is entirely within St. Louis County. The primary reach within this contributing system is the Sand River, which begins at Sandy Lake in the far western portion of this watershed and flows east approximately 12 miles prior to its confluence with the Pike River. Tributaries to the Sand River within this area include Britt Creek, Wouri Creek, and a few other unnamed reaches, all of which being under seven miles long and having relatively small drainage areas.

Table 2. Aquatic life and recreation assessments on stream reaches: Sand River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name,* *Reach Description*	**Biological Station ID**	**Reach Length (miles)**	**Use Class**	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides ***	Eutrophication	**Aquatic Life**	**Aquatic Rec. (Bacteria)**
09030002-645 **Trib. to Sand River** **Headwaters to Sand R**	15RN021	3.97	WWg	EXS	MTS	EX	IF	IF	-	IF	IF	-	-	IMP	NA
09030002-501 **Sand River** **Headwaters (Sandy Lk 69-0730-00) to Pike R**	05RN078	11.84	WWg	MTS	-	IF	IF	MTS	-	MTS	MTS	-	IF	SUP	SUP
09030002-572 **Wouri Creek** **Unnamed Cr to Sand R**	15RN024	3.12	WWg	MTS	-	IF	IF	IF	-	IF	IF	-	-	SUP	NA

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 3. Lake assessments: Sand River Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi trend	Aquatic life indicators: Fish IBI	Aquatic life indicators: Chloride	Aquatic life indicators: Pesticides ***	Aquatic recreation indicators: Total phosphorus	Aquatic recreation indicators: Chlorophyll-a	Aquatic recreation indicators: Secchi	Aquatic life use	Aquatic recreation use
Little Sandy	69-0729-00	85	3	Shallow Lakes	NLF	--	NA	NA	NA	IF	IF	NA	NA	IF
Sandy	69-0730-00	119	3	Shallow Lakes	NLF	--	NA	NA	NA	IF	IF	NA	NA	IF

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: -- = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

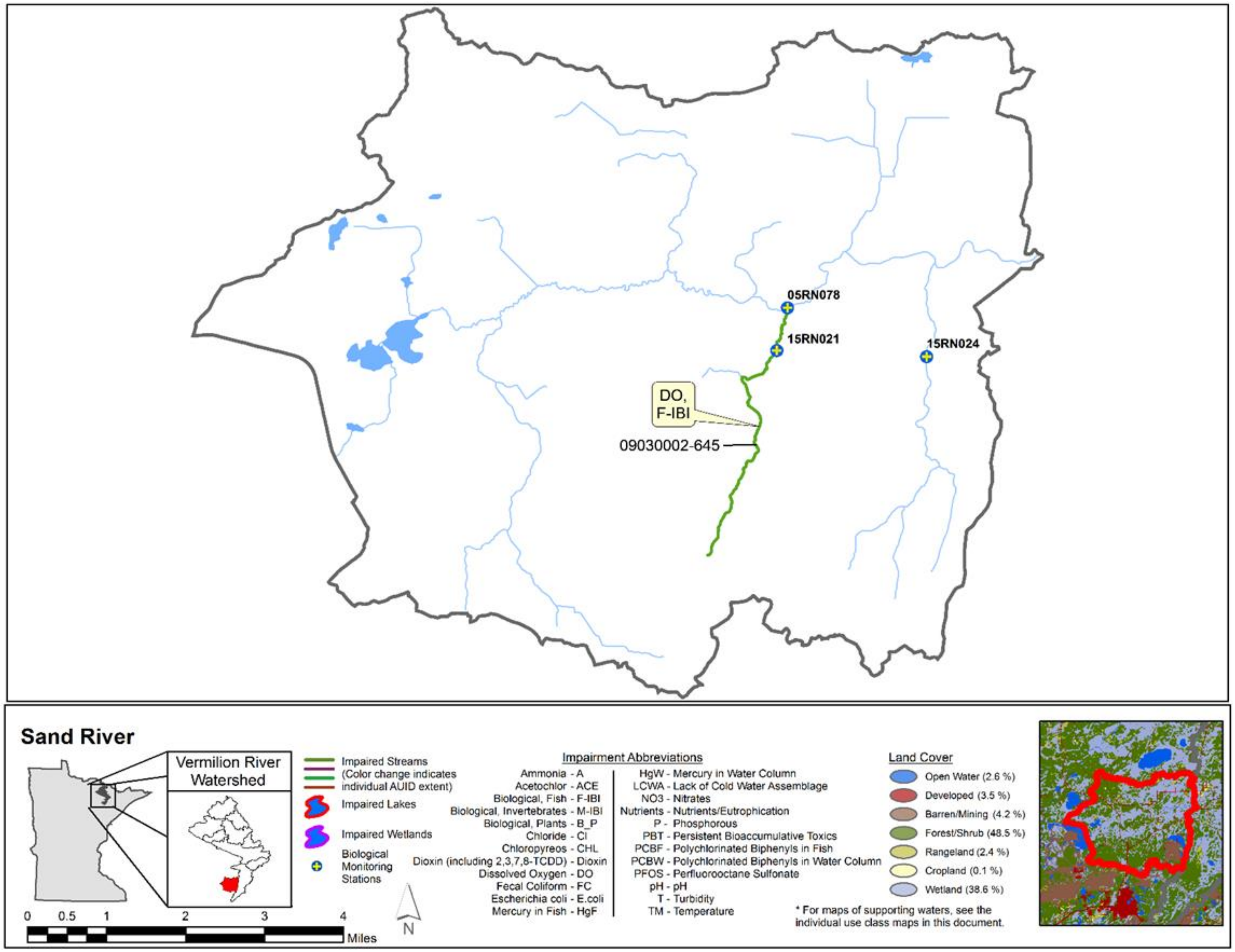
Summary

Three reaches in this watershed were assessed for aquatic life (Tributary to Sand River, Sand River, and Wouri Creek). Fish communities were surveyed on all reaches but macroinvertebrates were only collected at the biological monitoring station on the tributary to Sand River. The tributary to Sand River did not support aquatic life based on poor FIBI results. The fish community was comprised of two species (central mudminnow and white sucker) and was largely dominated by central mudminnow. Both of these species are tolerant to stressful conditions such as low dissolved oxygen and high sediment, with central mudminnow being considered very tolerant. The macroinvertebrate community had good taxa diversity and indicated support for aquatic life. Habitat conditions based on Minnesota Stream Habitat Assessment (MSHA) scores were good and similar between stations.

The stream monitoring site for this watershed was located at the County Road 303 (Rice River Road) bridge, about four river miles upstream of the confluence with the Pike River. The Sand River originates in a taconite tailings basin and flows east through a low-gradient landscape dominated by wetlands. As such, water quality conditions at this location were reflective of these characteristics. TP concentrations were at typical levels (~ 30 µg/L), and dissolved oxygen was occasionally below the standard, particular during mid-summer low flow conditions. Chloride concentrations met standards protective of aquatic life, but were elevated compared to other sites in the Vermilion River Watershed; potential sources of chloride include road salt application from the Highway 53 corridor, or the large taconite tailings basin in the headwaters. Overall, the *E. coli* bacteria data indicated full support for aquatic recreation. One sample taken during high flows had very high bacteria concentrations (> 2,419 colonies/ 100 mL) but all other samples from 2015-2016 were well below the standard of 1,260 colonies / 100 mL.

There are two very shallow lakes in the headwaters of this watershed, Sandy and Little Sandy. DNR, as part of their Shallow Lake Program occasionally samples both, but there was not sufficient data to assess for aquatic recreation. The available data indicated that these lakes had low levels of TP and Chl-a, and naturally low Secchi transparency.

Figure 24. Currently listed impaired waters by parameter and land use characteristics in the Sand River Aggregated 12-HUC.



Pike River Aggregated 12-HUC

HUC 0903000201-01

The Pike River Subwatershed is located in the southern portion of the Vermilion Watershed and is located entirely within St. Louis County. Draining an area of approximately 123 square miles, it is one of the largest contributing subwatersheds to the Vermilion River system. It includes the Pike River, its primary reach, from its headwaters to the Pike's confluence with Lake Vermilion, an approximate distance of 47 river miles. As the Pike River winds north, the Sand River adjoins it approximately half way up the subwatershed from the west. No lakes were monitored within this subwatershed.

Table 4. Aquatic life and recreation assessments on stream reaches: Pike River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name, Reach Description*	Biological Station ID	Reach Length (miles)	Use Class	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides***	Eutrophication	**Aquatic Life**	**Aquatic Rec. (Bacteria)**
09030002-502 Pike River Headwaters to Sand R	15RN022	18.6	WWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
09030002-503 Pike River Sand R to Vermilion Lk	05RN077 15EM037 15RN001	27.93	WWg	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	-	MTS	SUP	SUP

Abbreviations for Indicator Evaluations: -- = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria)
Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, FS = Full Support
Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use.

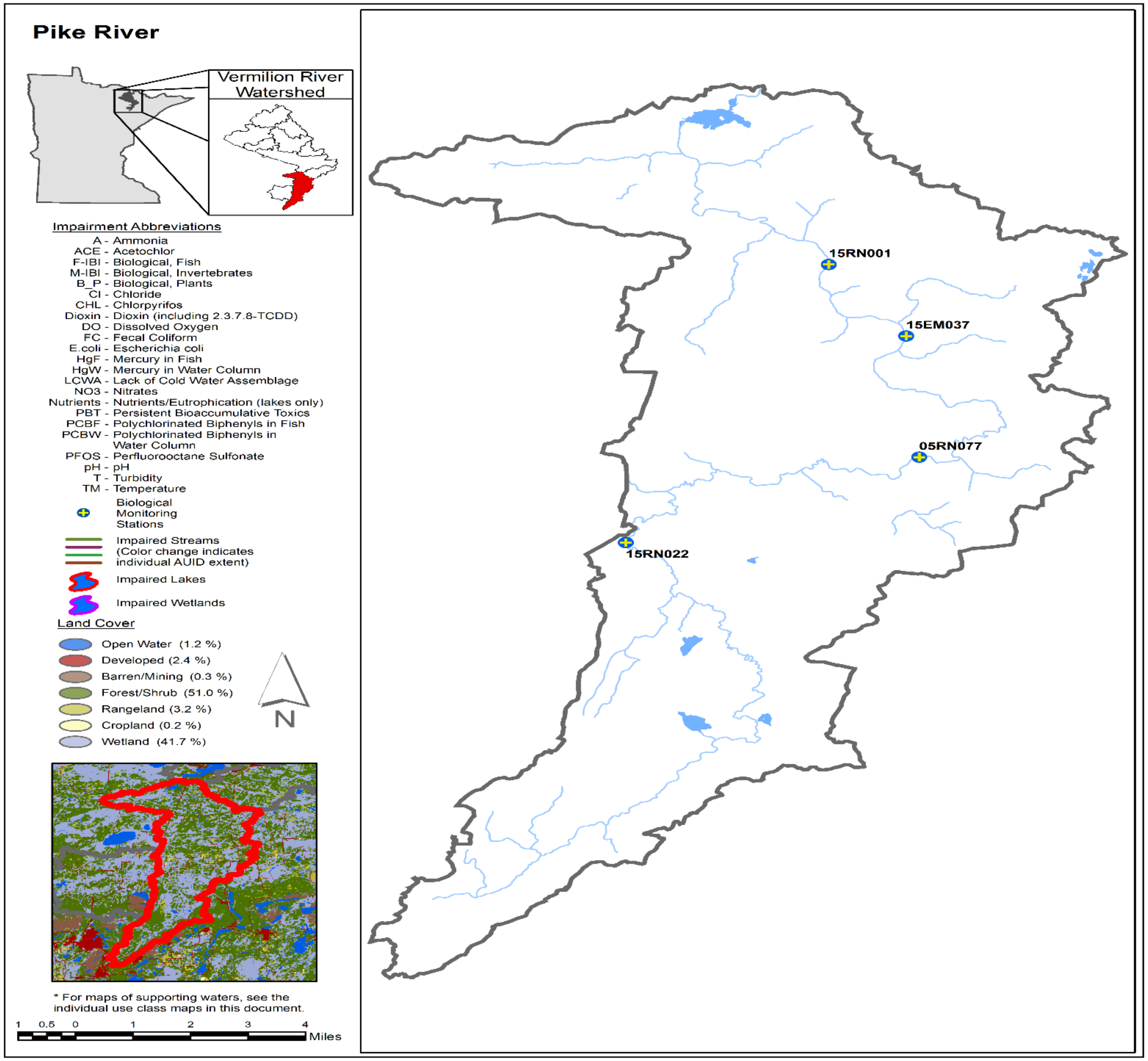
Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: -- = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Summary

The Pike River Subwatershed is dominated by forests and wetlands with little human disturbance. Two segments of the Pike River were sampled and assessed for aquatic life. Fish and macroinvertebrate communities were typical of healthy low gradient stream conditions, and indicated support for aquatic life. Habitat conditions were very good and fairly consistent between stations as indicated by Minnesota Stream Habitat Assessment (MSHA) scores.

The Pike River is the principal tributary to Lake Vermilion. Over much of its length, the river is surrounded by extensive riparian wetlands. The stream monitoring site was located on Saint Louis County Road 26, about six miles upstream of Lake Vermilion. Conventional chemistry parameters at this location indicate good water quality reflective of the wetland dominated landscape. Sediment and nutrient concentrations met standards, although TP levels were nearing the standard. DO flux was minimal, typical of low gradient wetland streams. *E. coli* bacteria concentrations in the Pike River were consistently low and indicated full support for aquatic recreation.

Figure 25. Currently listed impaired waters by parameter and land use characteristics in the Pike River Aggregated 12-HUC.



East and West Two Rivers Aggregated 12-HUC — HUC 0903000202-03

The East and West Two Rivers Subwatershed is located in the south-central portion of the Vermilion River Watershed. Draining an area of approximately 52 square miles, it is one of the smaller contributing subwatersheds of the Vermilion River. Entirely within St. Louis County, the East and West Two Rivers are the major reaches within this system. The East Two River originates from Eagles Nest Lake in the eastern portion of the drainage and flows west approximately 13 miles before entering into Pike Bay, which is the southern-most bay of Lake Vermilion near Tower, Minnesota. Similarly, the West Two River originates in the South-central portion of the drainage and flows to the Northwest approximately nine miles before also entering Pike Bay. Both the East and West Two River are support coldwater species (such as trout) for some if not all of their stream length, and were historically managed for such species. The outlet portion of the East Two River just upstream of Pike Bay, has recently been heavily modified. The outlet near Tower has been dredged, as part of the "Tower Harbor Project". The project was/is intended to bring tourism and recreational interest to the area through the construction of a Marina on the outlet of the East Two River.

Table 5. Aquatic life and recreation assessments on stream reaches: East and West Two Rivers Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name,* *Reach Description*	Biological Station ID	Reach Length (miles)	Use Class	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides***	Eutrophication	**Aquatic Life**	**Aquatic Rec. (Bacteria)**
09030002-509 **West Two River** **Headwaters to T61 R15W S6, north line**	15RN026 15RN002	8.34	CWg	MTS	MTS	IF	IF	MTS	MTS	IF	MTS	-	MTS	SUP	SUP
09030002-647 **East Two River** **Headwaters (Eagles Nest Lk 2 69-0285-02) to Unnamed Cr**	15RN028	9.03	CWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
09030002-648 **East Two River** **Unnamed Cr to T62 R15W S32, west line**	15RN029	3.24	WWg	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	-	IF	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated us e; = insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water

*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 6. Lake assessments: East and West Two Rivers Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi trend	Aquatic life indicators:			Aquatic recreation indicators:			Aquatic life use	Aquatic recreation use
							Fish IBI	Chloride	Pesticides ***	Total phosphorus	Chlorophyll-a	Secchi		
Eagles Nest #4	69-0218-00	175	49	Deep Lake	NLF	I	NA	NA	NA	IF	IF	MTS	NA	IF
Eagles Nest #1	69-0285-01	318	76	Deep Lake	NLF	I	NA	NA	NA	MTS	MTS	MTS	NA	FS
Eagles Nest #2	69-0285-02	398	39	Deep Lake	NLF	D	NA	NA	NA	MTS	MTS	MTS	NA	FS
Eagles Nest #3	69-0285-03	1018	49	Deep Lake	NLF	NT	NA	NA	NA	MTS	MTS	MTS	NA	FS

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, **--** = not enough data
Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2018 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Summary

Similar to its upstream counterparts, the East and West Two Rivers Subwatershed is dominated by forest and wetlands with minimal disturbance. Three reaches were assessed for aquatic life; one reach on the West Two River, and the other two on the East Two River. All of the reaches fully support aquatic life. Water chemistry sampling was conducted at two locations; on the East Two River near the city of Tower and West Two River just upstream of MN Highway 169. Both streams flow into Pike Bay of Lake Vermilion, and principally drain low gradient wetland landscapes with little disturbance.

The most downstream reach of the East Two River will be reclassified from coldwater to warmwater. A distinct shift in fish and macroinvertebrate community composition occurred between the upstream and downstream biological monitoring stations on this reach. Coldwater taxa such as burbot and mottled sculpin were present at the furthest upstream station, whereas there were no coldwater taxa in the downstream reach. The species present in the downstream reach were more indicative of low gradient/wetland influenced streams. Water chemistry data collected at this downstream reach also support the proposed use class change from coldwater to warm water. Low DO concentrations suggest that the stream is strongly influenced by wetlands. Although DO flux was low, indicating low productivity, dissolved oxygen concentrations were often (68% of the observations) below the 5 mg/L warm water standard for warmwater streams. *E. coli* bacteria concentrations in the E. Two River were consistently low and indicated full support for aquatic recreation.

In the West Two River, TP and DO flux (i.e. sonde deployment) met standards. There were 54 DO observations. A high percentage of the DO samples (85%) did not attain the 7 mg/L cold-water standard. MPCA assessment staff reviewed the DO datasets within the context of high biological integrity scores and attributed the low DO concentrations to upstream wetland influence rather than anthropogenic (human) influence. Suspended sediment and Secchi tube datasets suggested high water clarity in the West Two River. *E. coli* bacteria concentrations were consistently low and indicated full support for aquatic recreation.

The Eagles Nest chain of lakes comprise the headwaters of the East Two River. Three of these lakes have assessment level data; Eagles Nest Four currently does not have a public access and was not assessed. Water quality is excellent in the Eagles Nest chain of lakes. Eagles Nest 1-3 fully support aquatic recreation. They had very low TP and Chl-a concentrations and very clear water- near oligotrophic conditions. Average Secchi transparency in the lakes ranged from 6.1 m (20 feet) on Eagles Nest #1 to 4.2 m (13.7 feet) on Eagles nest #3 (Figure 26). Volunteer lake transparency monitoring allows analysis of water clarity trends on the lakes. Transparency from 1990-2016 improved slightly (~ 0.5 feet per decade) in lakes #1 and #4 and declined slightly in #2 (~ 1.5 feet per decade). No trend was detected in #3. Trends in these lakes are sensitive to annual change, and results have fluctuated among lakes (increase, stable, decrease) in recent years.

Figure 26. Water quality summary for assessed lakes in the East Two River Watershed.

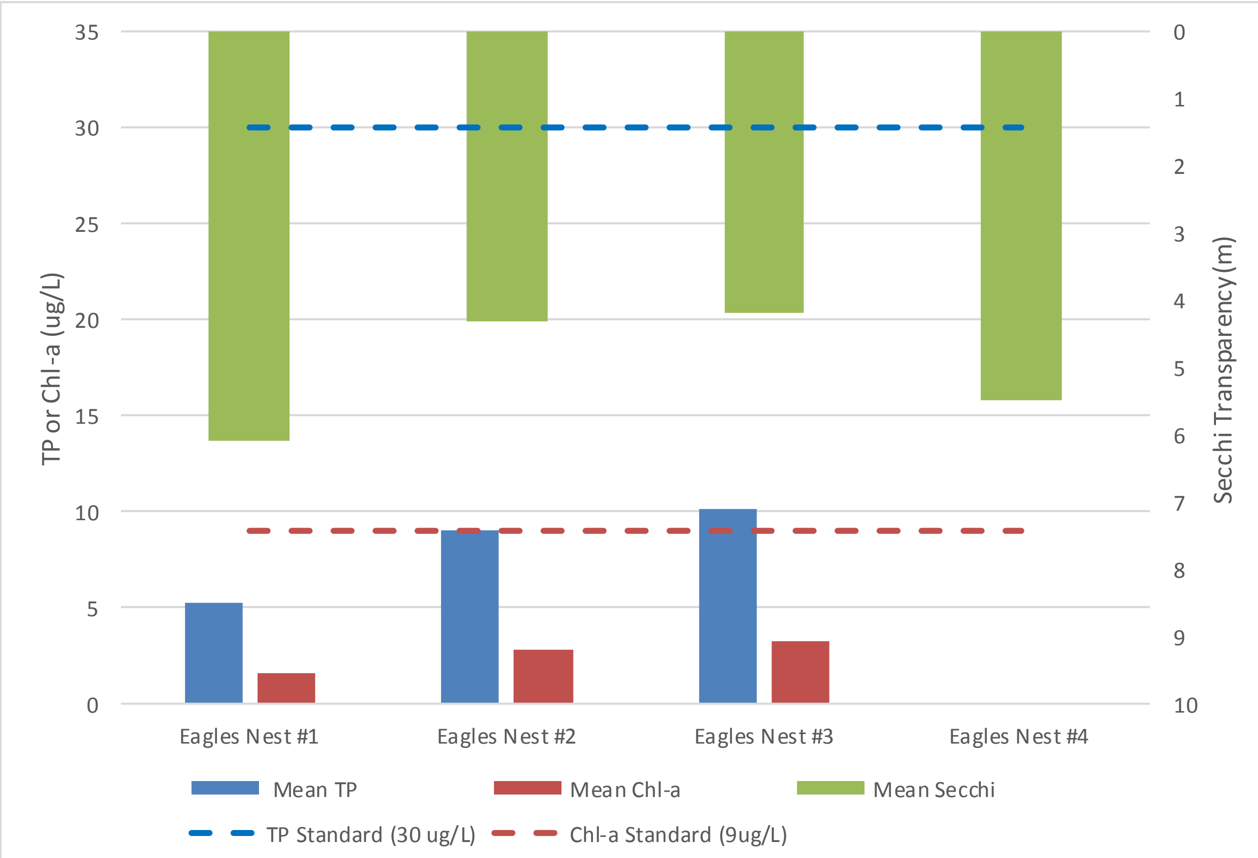
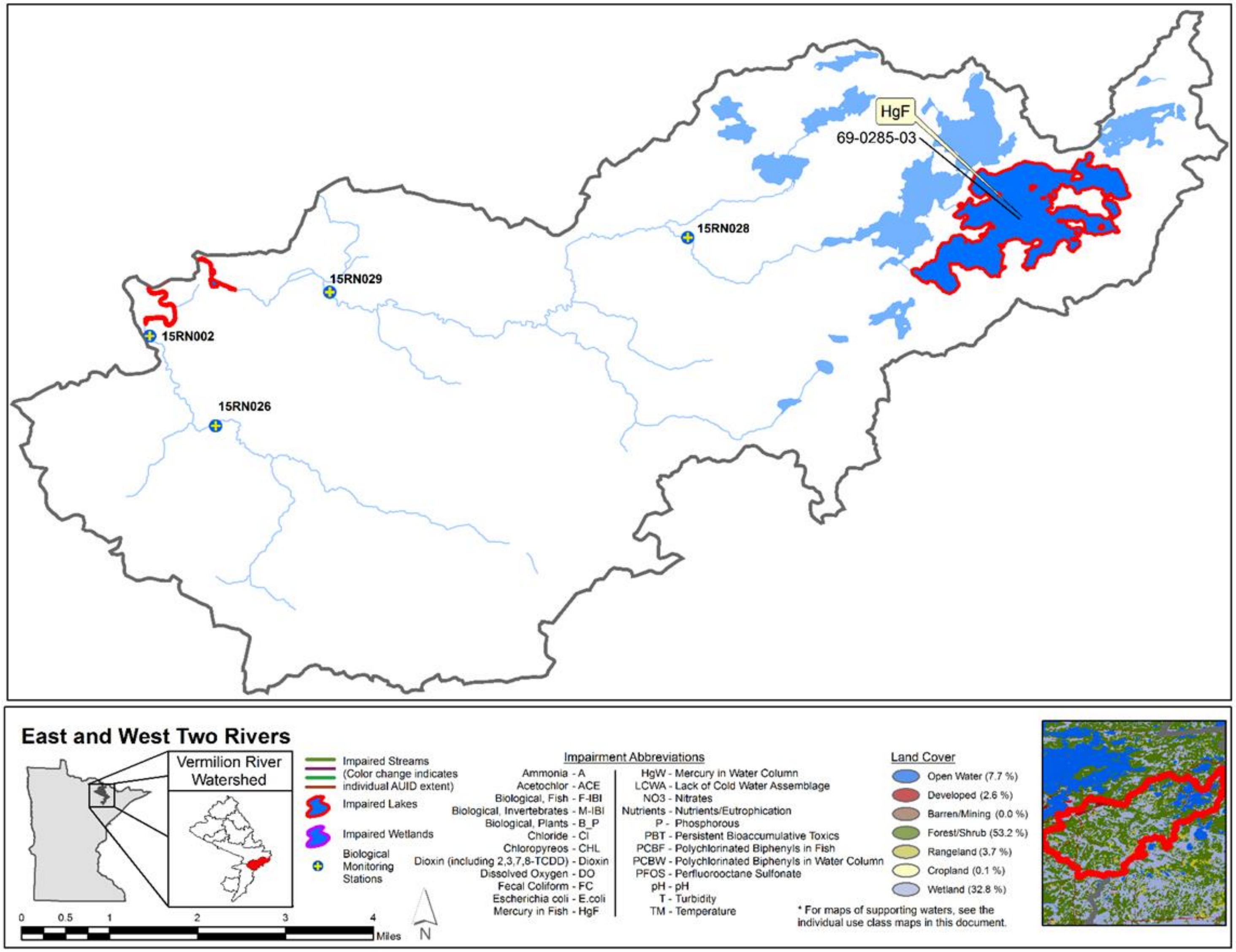


Figure 27. Currently listed impaired waters by parameter and land use characteristics in the East and West Two Rivers Aggregated 12 -HUC.



Vermilion Lake Aggregated 12-HUC

HUC 0903000202-01

The Lake Vermilion Subwatershed is in the heart of the Vermilion River drainage. Covering an area of roughly 200 square miles, it is also the largest subwatershed in the Vermilion River major watershed. The Vermilion River Subwatershed is unique in that aside from a few tributaries, which come into Lake Vermilion from the East, the watershed is dominated by Lake Vermilion. Lake Vermilion, which covers an area of roughly 62 square miles, consists of more than 25% of the total subwatershed area. It includes numerous islands (more than 300) and bays, with vegetative cover along its rocky shorelines, providing exceptional fishing for a variety of species such as walleye, smallmouth/largemouth bass, bluegill, crappie, northern pike, and muskellunge. Its shorelines are surrounded by forests of aspen, pine, and birch. Parts of its northern shore and islands are within the Superior National Forest, and an entry point to the Boundary Waters Canoe Area Wilderness also exists in this area. Many resorts line Lake Vermilions' shoreline, serving as a significant economic driver to the area. The Ojibwe originally called the lake Onamuni "Nee-Man-Nee", which means "Lake of the sunset glow". A few small tributaries which are all under five miles in length flow into the lake from its east side including Bear Creek, Rice Creek, Mud Creek, and the Armstrong River. The Armstrong River is one of the largest of these at just under six miles long. It originates from Armstrong Lake (roughly 380 acres) to the east of Lake Vermilion. Aside from some development around Armstrong Lake, the riparian areas surrounding these tributaries to Lake Vermilion have minimal human impact.

Table 7. Aquatic life and recreation assessments on stream reaches: Vermilion Lake Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name,* *Reach Description*	Biological Station ID	Reach Length (miles)	Use Class	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides ***	Eutrophication	Aquatic Life	Aquatic Rec. (Bacteria)
09030002-505 **Armstrong River** **Headwaters (Armstrong Lk 69-0278-00) to Vermilion Lk**	15RN009	5.79	WWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	IF	SUP	NA

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information

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

Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water

*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 8. Lake assessments: Vermilion Lake Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators:			Aquatic recreation indicators:			Aquatic life use	Aquatic recreation use
							Fish IBI	Chloride	Pesticides ***	Total phosphorus	Chlorophyll-a	Secchi		
West Robinson	69-0217-00	116	8	Shallow Lake	NLF	--	NA	NA	NA	MTS	MTS	MTS	NA	FS
Mud	69-0275-00	153	30	Deep Lake	NLF	--	NA	NA	NA	IF	IF	IF	NA	IF
Clear	69-0277-00	105	24	Deep Lake	NLF	NT	NA	NA	NA	IF	IF	MTS	NA	IF
Armstrong	69-0278-00	373	34	Deep Lake	NLF	NT	NA	NA	NA	MTS	MTS	MTS	NA	FS
Little Armstrong	69-0279-00	65	26	Deep Lake	NLF	NT	NA	NA	NA	IF	IF	MTS	NA	IF
East Vermilion	69-0378-01	25,622	75	Deep Lake	NLF	I	NA	NA	NA	MTS	MTS	MTS	NA	FS
West Vermilion	69-0378-02	11,330	57	Deep Lake	NLF	I	NA	NA	NA	MTS	MTS	MTS	NA	FS
Pike Bay	69-0378-03	2,054	10	Deep Lake	NLF	--	NA	NA	NA	MTS	MTS	IF	NA	FS
Black	69-0740-00	117	8	Shallow Lake	NLF	--	NA	NA	NA	IF	IF	IF	NA	IF
Sunset	69-0764-00	301	5.5	Shallow Lake	NLF	--	NA	NA	NA	IF	IF	IF	NA	IF

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains

Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, -- = not enough data

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

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

Key for Cell Shading: ☐ = existing impairment, listed prior to 2016 reporting cycle; ☐ = new impairment; ☐ = full support of designated use ; ☐ = insufficient information.

Summary

Because of the large lake dominance within the Vermilion Lake Subwatershed, only one biological monitoring reach was sampled on the Armstrong River. The Armstrong River had excellent channel development and very good fish and macroinvertebrate communities, indicating support for aquatic life.

This subwatershed is dominated by lakes and did not have a stream water quality site. Three lakes in the watershed had assessment level data, West Robinson, Armstrong, and Vermilion – which is divided into three basins (East, West, and Pike Bay). All three water bodies fully supported aquatic recreation. West Robinson and Armstrong flow into Armstrong Bay of Lake Vermilion. Armstrong Lake is much deeper than West Robinson, and therefore is lower in productivity, and much clearer; Secchi averaged 5.9 meters (19 feet; Figure 28). Lake Vermilion has a very robust water quality monitoring dataset. Water quality data has been collected by the Vermilion Lake Association and MPCA in 2000, 2008, and 2015. In all three basins, TP and Chl-a concentrations met standards. Lake Vermilion TP and Chl-a summer averages from 2000, 2008, and 2015 are shown in Table 9. Overall, most of Lake Vermilion is consistently mesotrophic in condition, with moderate levels of TP and Chl-a. TP concentrations were lowest in 2015, likely because that year was much drier than average, with lake levels and inflows significantly below normal. TP concentrations were higher, and Chl-a lower, in Pike Bay due to the influence of the Pike River. Secchi transparency is naturally low in Pike Bay due to tannin staining. On average, TP concentrations were very similar in West and East Vermilion; Chl-a was slightly higher in the West Basin, but not statistically different. Overall, Secchi transparency is about 1 meter greater in the West Basin, likely, because this part of the lake has a small watershed, and is not influenced by the Pike River.

A long-term record of Secchi depth on Lake Vermilion (1976-2017) indicates improvement in lake clarity over time. This valuable dataset is a testament to citizen engagement, especially the membership of the Lake Vermilion Association (formally the Lake Vermilion Sportsman's Club). In the East basin, Secchi has increased by 0.1 to 0.6 feet per decade; the West basin has increased by about 0.5 feet per decade. Secchi depth has been relatively stable since the late 1980s; the overall improvement in water clarity is predominately attributed to improvements in Tower's wastewater treatment facility, which occurred in the late 1970's. Due to the high amount of recreational use and lakeshore development on Lake Vermilion, and the recent introduction of aquatic invasive species in the lake, continued citizen Secchi monitoring is strongly encouraged.

Table 9. Lake Vermilion Basins Summer Mean Water Quality Data. MPCA and Vermilion Lake Association Data.

Parameter	West Vermilion Wakemup Bay			East Vermilion Big Bay			Pike Bay		
	2000	2008	2015	2000	2008	2015	2000	2008	2015
Total Phosphorus (ug/L)	24.5	21.5	11	23	22.2	10.5	30.5	29.1	16.5
Chlorophyll-a (ug/L)	8.9	4.7	9.8	5.6	6.2	7.7	10.8	3.4	3.7
Secchi Transparency (m)	2.9	2.8	3.2	2.4	2.1	2.7	0.9	1.1	1.3

Figure 28. Water quality summary of assessed lakes in the Vermilion Lake Watershed.

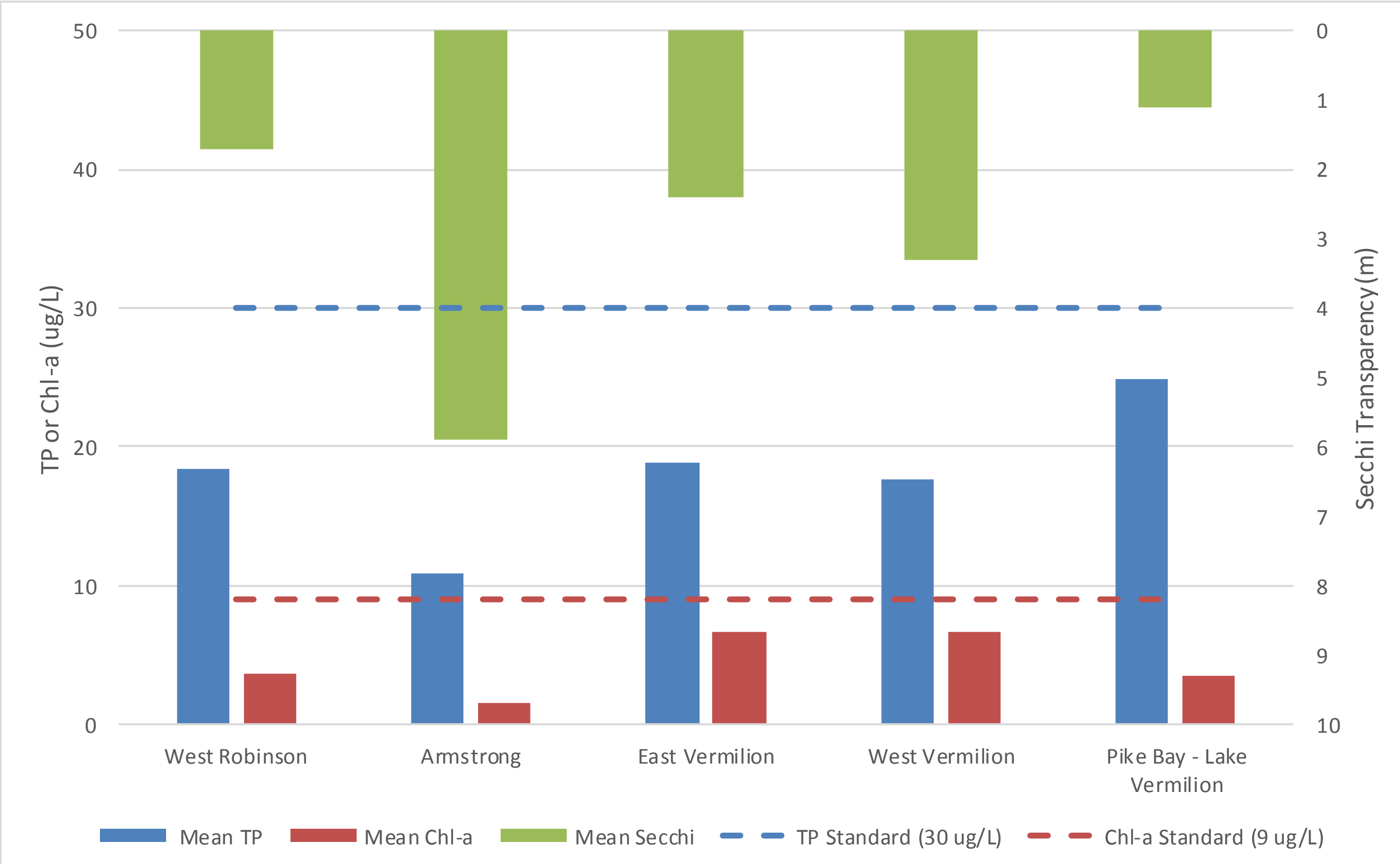
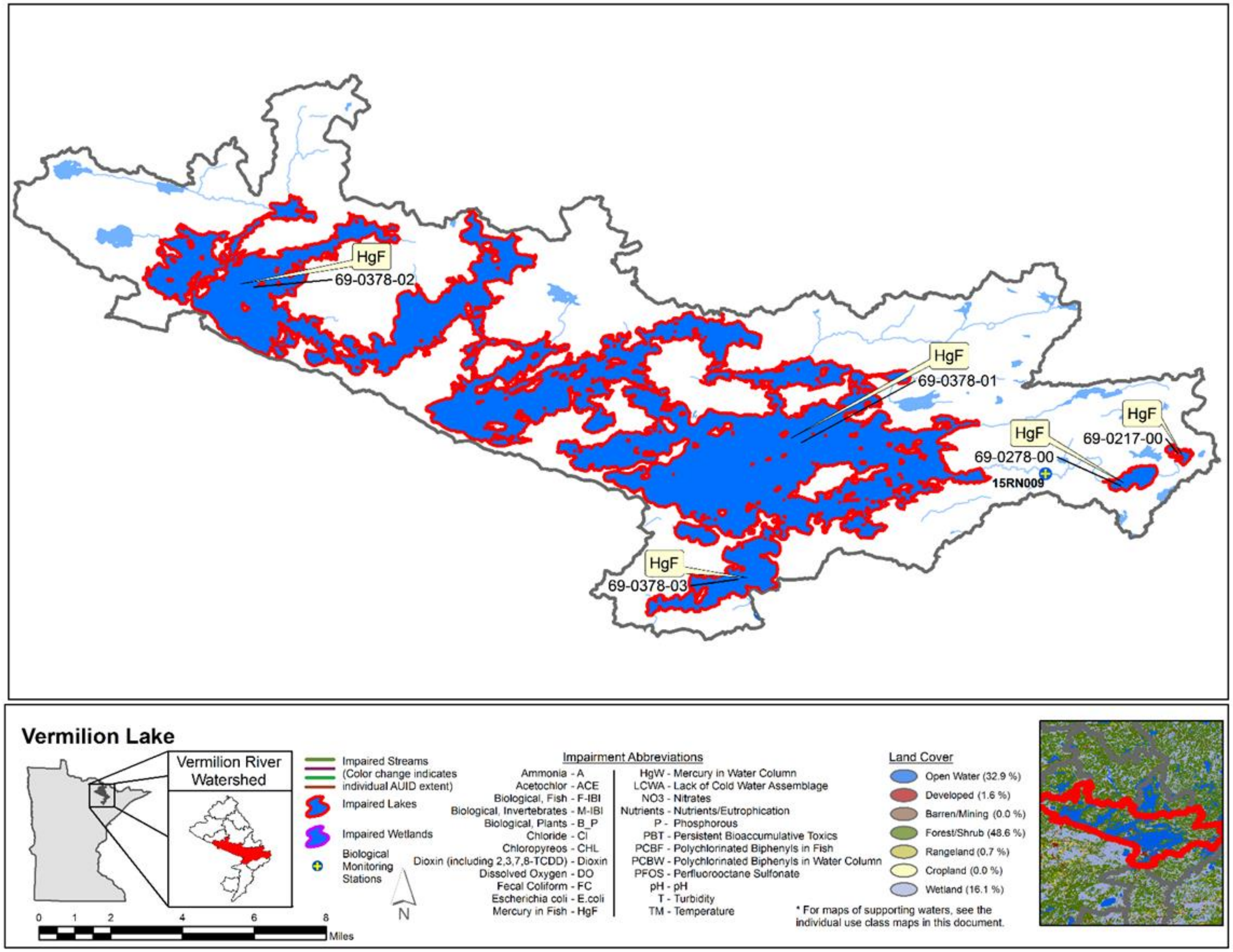


Figure 29. Currently listed impaired waters by parameter and land use characteristics in the Vermilion Lake Aggregated 12-HUC.



Trout Lake Aggregated 12-HUC

HUC 0903000202-02

The Trout Lake Subwatershed is located in the East-Central portion of the Vermilion River Drainage. Consisting of an area approximately 50 square miles in size, it is one of the smallest contributing subwatersheds to the Vermilion River system. The subwatershed is lake dominated with Trout Lake being the largest at just over 11.5 square miles in area. Several smaller lakes are also present such as Little Trout, Pine, Glenmore, and Buck. Stream reaches within this subwatershed are negligible. Those that do exist are very small and connect the smaller lakes to each other and ultimately Trout Lake. Eventually the water from Trout Lake enters Lake Vermilion via Bystrom Bay. No biological monitoring stations were established because of the lake influence and lack of significant stream resources.

Table 10. Lake assessments: Trout Lake Aggregated 12-HUC.

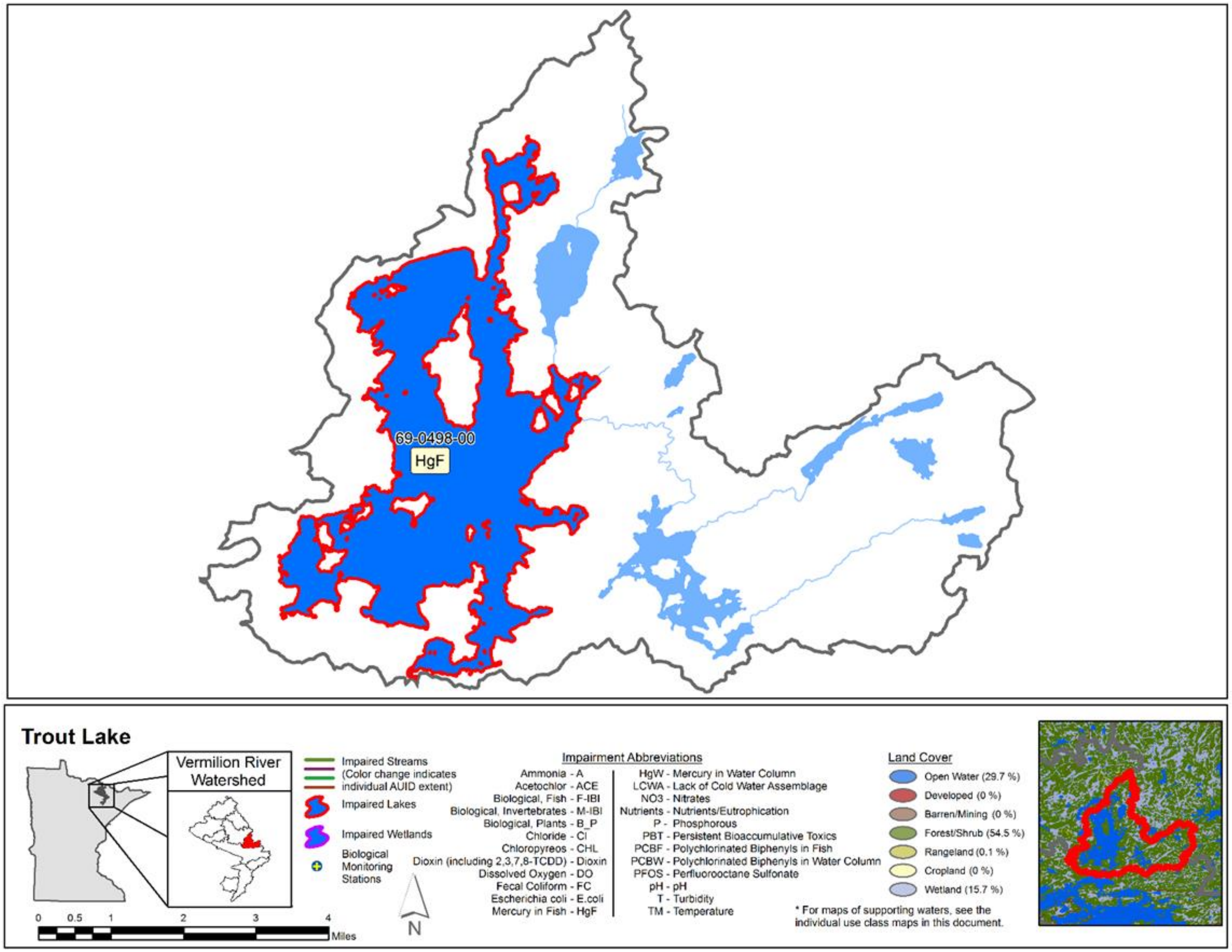
Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators: Fish IBI	Aquatic life indicators: Chloride	Aquatic life indicators: Pesticides ***	Aquatic recreation indicators: Total phosphorus	Aquatic recreation indicators: Chlorophyll-a	Aquatic recreation indicators: Secchi	Aquatic life use	Aquatic recreation use
Trout	69-0498-00	7374.9	98	Deep Lake; Lake Trout	NLF	--	NA	NA	NA	MTS	MTS	MTS	NA	FS

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Summary

This lake-dominated watershed within the Boundary Waters Canoe Area did not include a stream monitoring site. Trout Lake is the only lake with assessment level data. It was monitored by the University of Minnesota's NRRI in 2015-2016. As expected, water quality was excellent in Trout Lake indicating oligotrophic conditions. TP, Chl-a, and Secchi transparency attained the more stringent standards protective of the lake's lake trout population. Secchi transparency averaged 5.3 m (17.3 feet). Water quality conditions in 2015-2016 did not significantly change from the MPCA's initial water quality sampling of the lake in 2006. It is estimated that Trout Lake contributes 1.3% of the P load to Lake Vermilion (MPCA, 2009 Lake Vermilion water quality assessment report).

Figure 30. Currently listed impaired waters by parameter and land use characteristics in the Trout Lake Aggregated 12-HUC.



Upper Vermilion River Aggregated 12-HUC HUC 0903000205-02

The Upper Vermilion Subwatershed is located in the north-central portion of the Vermilion River System. This watershed is primarily a flow-through subwatershed of the Vermilion River that extends from the outlet of Lake Vermilion to the Pelican Rivers confluence with the Vermilion River. Draining an area of roughly 130 square miles, it is one of the larger subwatersheds of the Vermilion River. The Vermilion River flows north through this subwatershed receiving flow from several streams along the way including Two Mile Creek, Hilda Creek, Eight Mile Creek, and several unnamed tributaries. The length of these contributing streams vary from just a couple miles long to under 20 miles. Minimal human impacts occur within this subwatershed as less than 1% is developed.

Table 11. Aquatic life and recreation assessments on stream reaches: Upper Vermilion Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name, Reach Description*	Biological Station ID	Reach Length (miles)	Use Class	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides ***	Eutrophication	**Aquatic Life**	**Aquatic Rec. (Bacteria)**
09030002-610 **Two Mile Creek** **Unnamed Cr to Vermilion R**	15RN010	4.27	WWg	MTS	-	IF	IF	IF	-	IF	IF	-	IF	SUP	NA
09030002-528 **Hilda Creek** **Headwaters (Oriniak Lk 69-0587-00) to Vermilion R**	15RN012	16.05	WWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	IF	SUP	NA
09030002-529 **Vermilion River** **Hilda Cr to Pelican R**	15RN005 05RN021	13.81	WWg	MTS	-	IF	MTS	MTS	MTS	MTS	MTS	-	MTS	SUP	SUP
09030002-644 **Trib. to Vermilion River** **Headwaters to Vermilion R**	15RN014	7.92	WWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	IF	SUP	NA
09030002-646 **Trib. to Vermilion River** **Unnamed lk (69-1056-00) to Vermillion R**	15RN025	1.89	WWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	IF	SUP	NA

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 12. Lake assessments: Upper Vermilion River Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators: Fish IBI	Aquatic life indicators: Chloride	Aquatic life indicators: Pesticides ***	Aquatic recreation indicators: Total Phosphorus	Aquatic recreation indicators: Chlorophyll-a	Aquatic recreation indicators: Secchi	Aquatic life use	Aquatic recreation Use
Winchester	69-0690-00	318.3	50	Deep Lake	NLF	--	NA	NA	NA	MTS	MTS	MTS	NA	FS
Kjostad	69-0748-00	442.5	58	Deep Lake	NLF	--	NA	NA	NA	MTS	MTS	MTS	NA	FS

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: -- = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2014 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.

Summary

Extensive forests and wetlands characterize the Upper Vermilion Subwatershed. Five warmwater stream reaches were assessed for aquatic life. Fish and macroinvertebrates communities were in good condition, indicating support for aquatic life for all of the assessed reaches.

The stream monitoring site for this watershed was located on the Vermilion River at the County Road 24 bridge at the community of Buyck. This location is also periodically sampled for the MPCA's Watershed Pollutant Load Monitoring Network during conditions when deep snow restricts road access to the Lower Vermilion site near the Crane Lake confluence. The robust water quality data at Buyck indicates high water quality and full support for aquatic life. TP and sediment levels were consistently low and met standards. Dissolved oxygen levels also regularly met the 5 mg/L standard; there were no exceedances in 59 samples collected over several seasons and years. Bacteria concentrations in the Upper Vermilion River were consistently low and indicated full support for aquatic recreation.

Two lakes in this watershed had assessment-level datasets, Winchester and Kjostad lakes. Both lakes are surrounded by public forest, and have a small amount of development (seasonal cabins). Winchester and Kjostad lakes fully supporting aquatic recreation; TP, Chl-a, and Secchi datasets clearly met standards (Figure 31). Both of the lakes are close to oligotrophic. Winchester is classified as a cool / warm water lake, although the DNR has recently stocked it with Lake Trout. Low nutrients levels and abundant dissolved oxygen concentrations in samples collected in 2015-2016 appear to support the suitability of this lake for Lake Trout.

Figure 31. Water quality summary of assessed lakes in the Vermilion Lake watershed

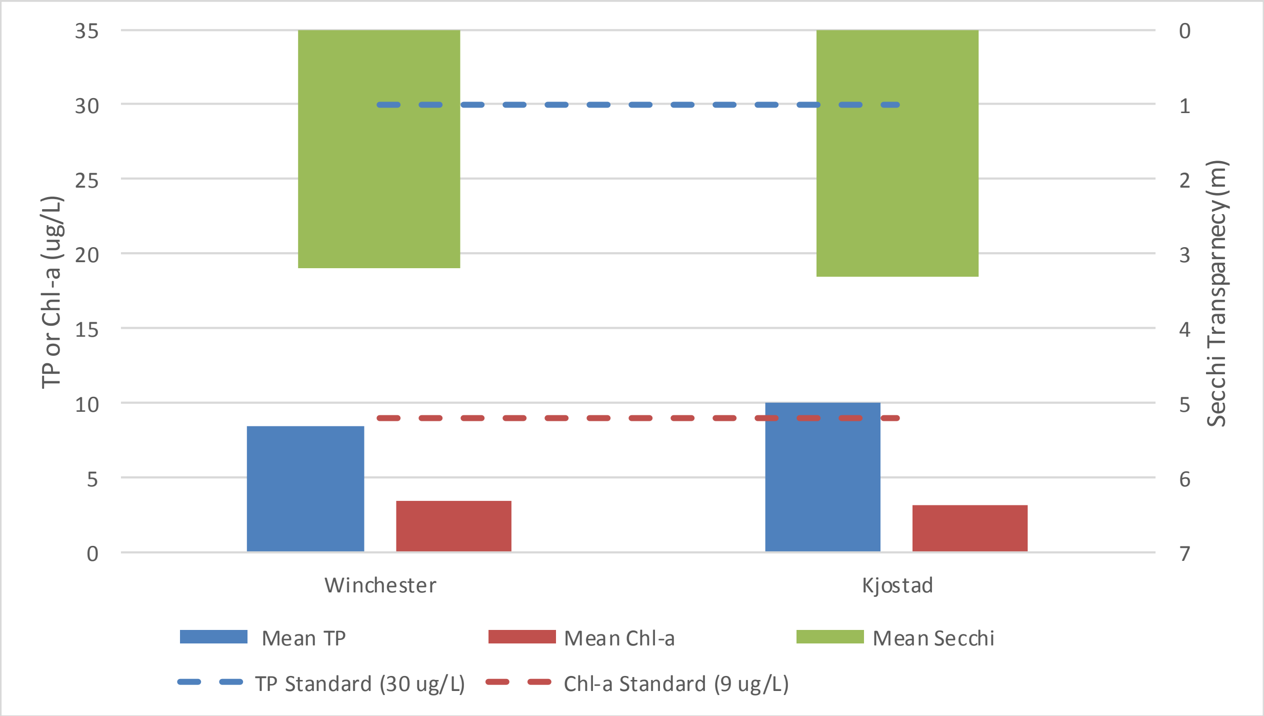
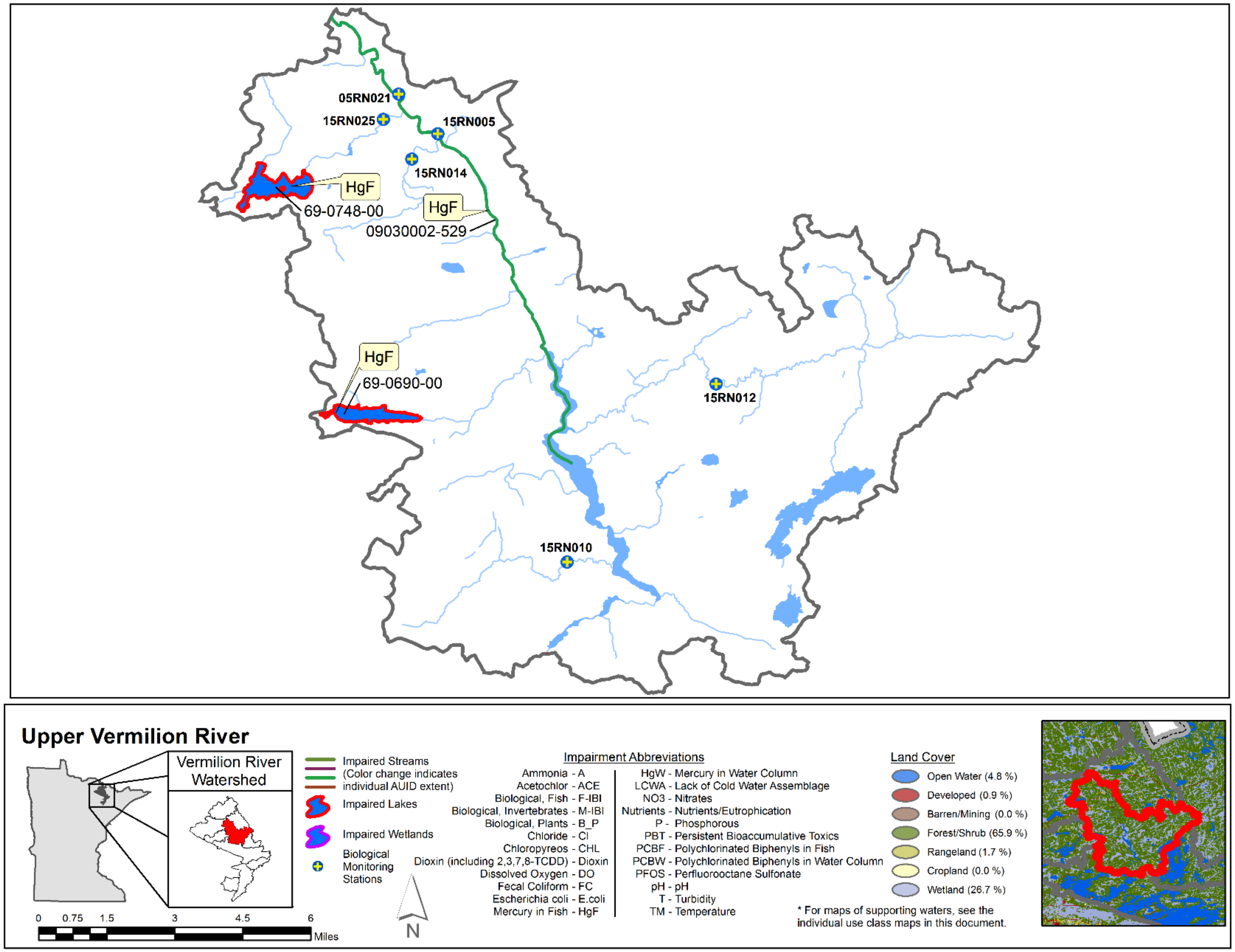


Figure 32. Currently listed impaired waters by parameter and land use characteristics in the Upper Vermilion Aggregated 12-HUC.



Elbow River Aggregated 12-HUC HUC 0903000203-02

The Elbow River Subwatershed is a small subwatershed (58 square miles) in the northwest-central portion of the Vermilion River system. This subwatershed is unique for the Vermilion River Watershed in that unlike others, the Elbow River (its primary reach) does not flow directly into the Vermilion main-stem, but rather into the Pelican River Subwatershed. The Elbow River originates from Elbow Lake, a 1,600-acre basin located in the eastern portion of the subwatershed. From Elbow Lake, the Elbow River flows approximately 12 miles to the west and then northwest before flowing into the Pelican River. There are very few tributaries to the Elbow River, aside from one, which connects Ban Lake to the Elbow River. The Elbow River drains a remote section of the Kabetogama State Forest, and is principally composed of public forest and wetlands.

Table 13. Aquatic life and recreation assessments on stream reaches: Elbow River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name, Reach Description*	Biological Station ID	Reach Length (miles)	Use Class	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides ***	Eutrophication	**Aquatic Life**	**Aquatic Rec. (Bacteria)**
09030002-604 Elbow River Unnamed Cr to Rice Lk	15RN004	4.66	WWg	MTS	MTS	IF	IF	IF	MTS	IF	MTS	-	IF	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 14. Lake assessments: Elbow River Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators:			Aquatic recreation indicators:			Aquatic life use	Aquatic recreation use
							Fish IBI	Chloride	Pesticides ***	Total phosphorus	Chlorophyll-a	Secchi		
Susan	69-0741-00	277	10	Shallow Lake	NLF	--	NA	NA	NA	IF	MTS	IF	NA	FS
Ban	69-0742-00	388	15	Shallow Lake	NLF	NT	NA	NA	NA	MTS	MTS	MTS	NA	FS
Elbow	69-0744-00	1,677	60	Deep Lake	NLF	--	NA	NA	NA	MTS	MTS	IF	NA	FS

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2014 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.

Summary

Fish and macroinvertebrate communities in this subwatershed are in good condition and indicate support for aquatic life. Habitat and water quality at this location was also excellent. Phosphorus concentrations were relatively low, and dissolved oxygen concentrations were consistently above the 5 mg/L standard. Minor exceedances of the pH standard were common. Low pH has been documented in many other low gradient wetland streams in the vicinity. pH levels can become low when wetland material decomposes, producing weak acids. Bacteria concentrations in the Elbow River were consistently low and indicated full support for aquatic recreation.

The three largest lakes in the watershed, Susan, Ban, and Elbow were assessed for aquatic recreation. All three lakes are bog-stained with naturally low Secchi transparency. As a result, the assessments focused on phosphorus and algae concentrations (Figure 33). Elbow Lake, the deepest of the three lakes had excellent water quality, with low phosphorus and algae. Susan and Ban lakes are shallow. These lakes are more productive, as shallow lakes cannot trap phosphorus at depth. All of the lakes currently support swimming and wading activities.

Figure 33. Water quality summary of assessed lakes in the Elbow River watershed

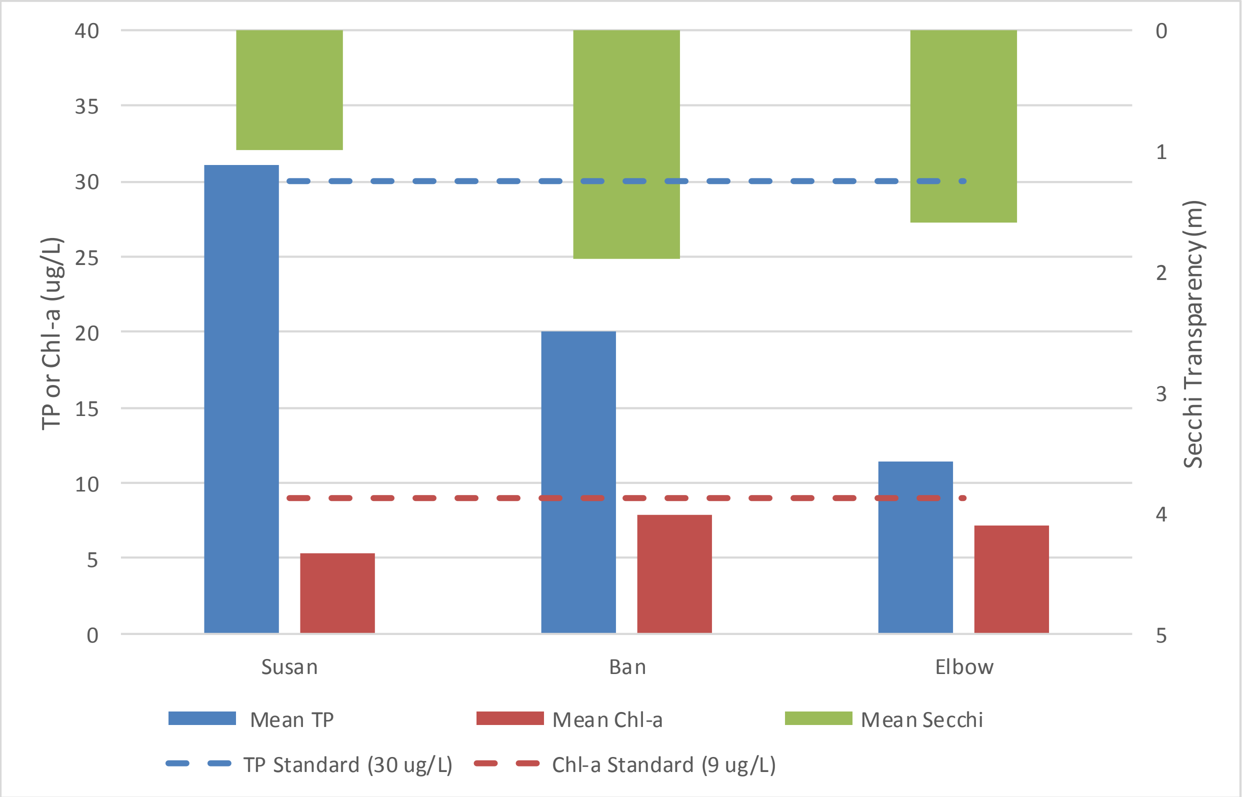
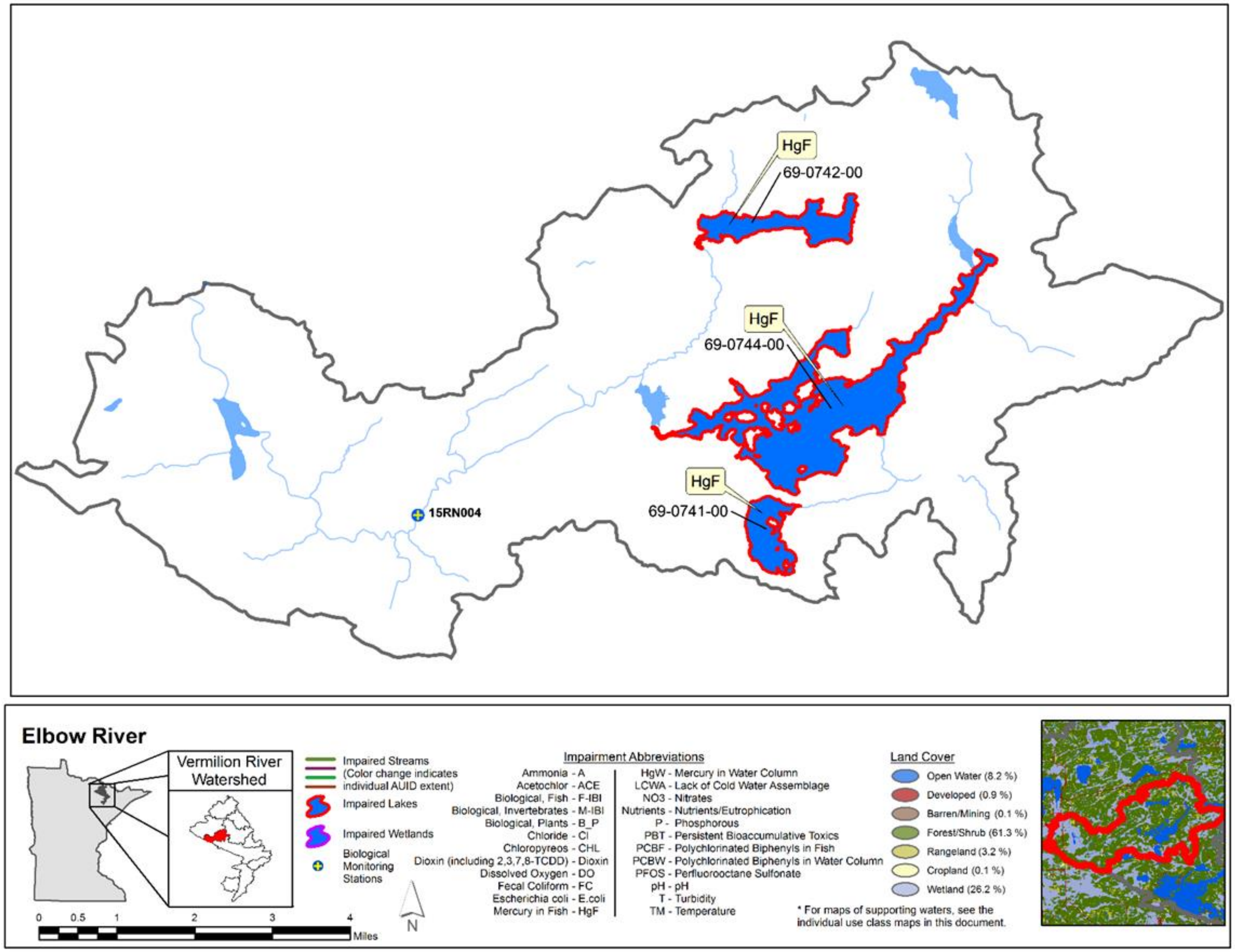


Figure 34. Currently listed impaired waters by parameter and land use characteristics in the Elbow River Aggregated 12-HUC.



Pelican River Aggregated 12-HUC HUC 0903000203-01

The Pelican River Subwatershed is in the far northwestern corner of the Vermilion River system. Draining an area of roughly 152 square miles, it is the second largest flow contributor to the Vermilion River Watershed. The Pelican River originates from Pelican Lake (11,500 acres) on the western side of the subwatershed. The largest town is Orr (Population 303), which is on the east side of the lake. From its origin at the outlet of Pelican Lake, the Pelican River flows approximately 37 miles to the northeast before reaching the Vermilion River. It receives flow from the Elbow River approximately 2 miles from the Pelican Lake outlet. Further downstream, Cusson and Clear Creek also contribute water to the Pelican River, although these two tributaries are much smaller in size (roughly 5 miles in length). Most of the watershed is remote and composed of public forest and wetlands, with riparian wetlands adjacent to the stream channel.

Table 15. Aquatic life and recreation assessments on stream reaches: Pelican River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name, Reach Description*	**Biological Station ID**	**Reach Length (miles)**	**Use Class**	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides***	Eutrophication	**Aquatic Life**	**Aquatic Rec. (Bacteria)**
09030002-530 **Pelican River** **Pelican Lk to Vermilion R**	15RN023 15RN006	37.11	WWg	EXP	-	IF	IF	MTS	MTS	IF	MTS	-	MTS	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 16. Lake assessments: Pelican River Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators:			Aquatic Recreation Indicators:			Aquatic life use	Aquatic recreation use
							Fish IBI	Chloride	Pesticides ***	Total phosphorus	Chlorophyll-a	Secchi		
Myrtle	69-0749-00	876	20	Shallow Lake	NLF	--	NA	NA	NA	EX	EX	IF	NA	NS
Bell	69-0805-00	108	7	Shallow Lake	NLF	--	NA	NA	NA	IF	IF	IF	NA	IF
Moose	69-0806-00	922	8.5	Shallow Lake	NLF	--	NA	NA	NA	IF	IF	IF	NA	IF
Pelican	69-0841-00	11,466	38	Deep Lake	NLF	NT	NA	NA	NA	MTS	EX	MTS	NA	FS

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Summary

Two biological monitoring stations and one chemistry station were sampled on one reach. Macroinvertebrates were not sampled because the stream was not wadeable. The biological and chemistry data suggest that this reach of the Pelican River supports aquatic life but it is heavily influenced by natural wetland conditions. Fish communities were primarily composed of tolerant wetland indicative taxa (e.g. yellow perch and golden shiner). DO concentrations were naturally low; approximately 44% of DO samples were below the 5 mg/L standard, although there were no severe exceedances (< 2 mg/L). The DNR has reported occasional fish kills in the watershed, especially during winter low flows, and corroborated the MPCA's finding of naturally low levels of dissolved oxygen in the river system. TP concentrations averaged 33 µg/L, a similar value to other wetland-dominated watersheds, and comparable to levels observed in Pelican Lake. Lastly, pH levels at this location were occasionally below the 6.5 standard, these exceedances were minor and have been documented in many other forested landscapes throughout northeast Minnesota. Bacteria concentrations in the Pelican River were consistently low and indicated full support for aquatic recreation.

Pelican Lake, at the City of Orr, is the largest lake in the watershed; much of the lake is shallow and suitable for aquatic plant growth. The lake is a very popular fishing destination, and home to several resorts. Overall, Pelican Lake fully supports aquatic recreation (Figure 35). However, occasional algal blooms (> 20 µg/L) do occur on the lake.

Figure 35. Water quality summary of assessed lakes in the Pelican River watershed

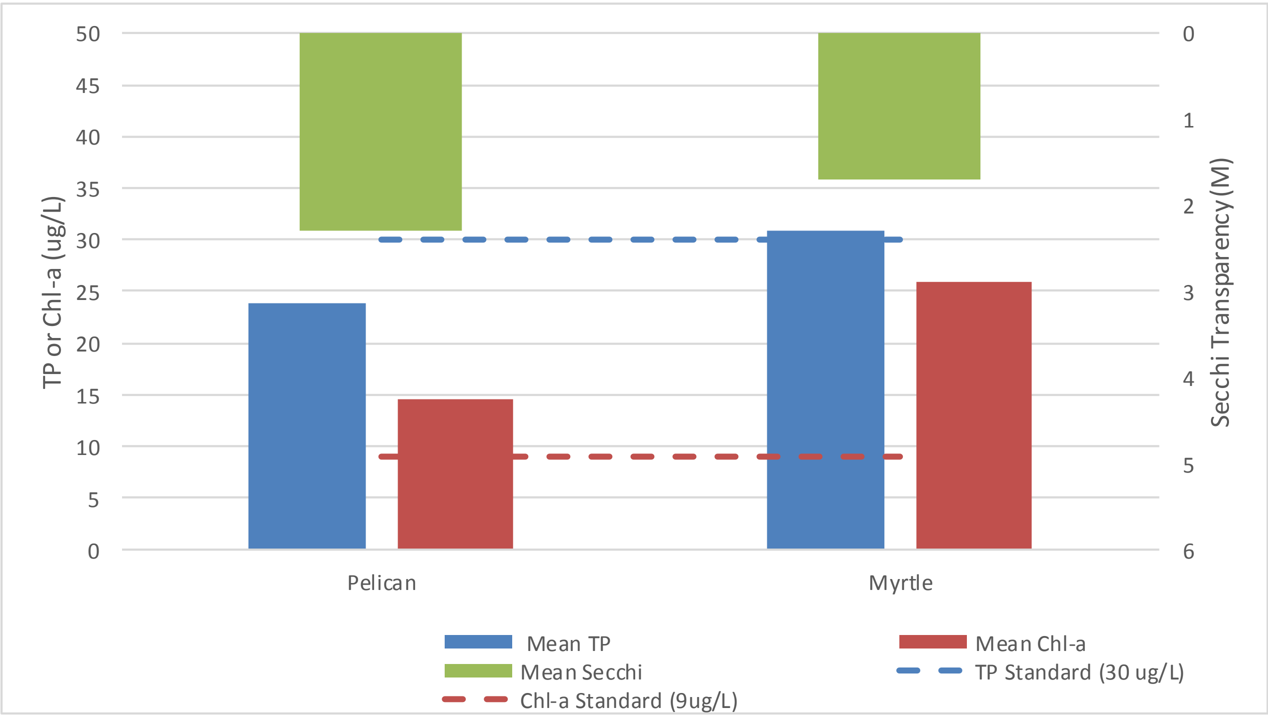
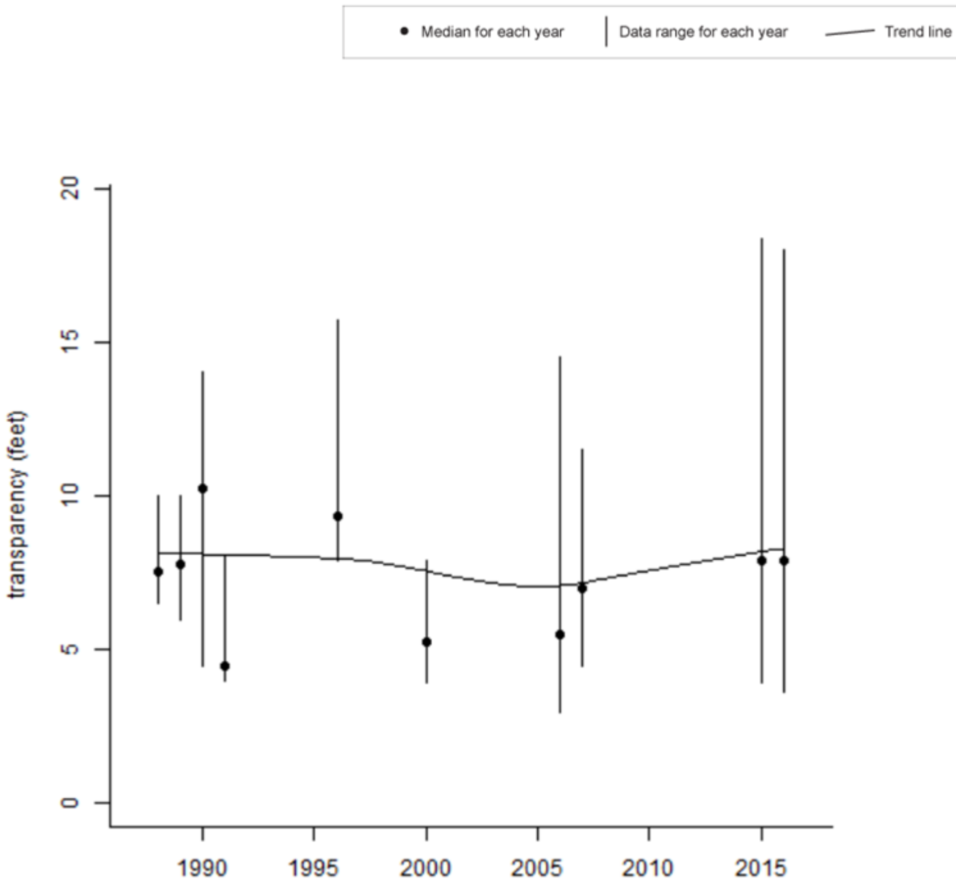


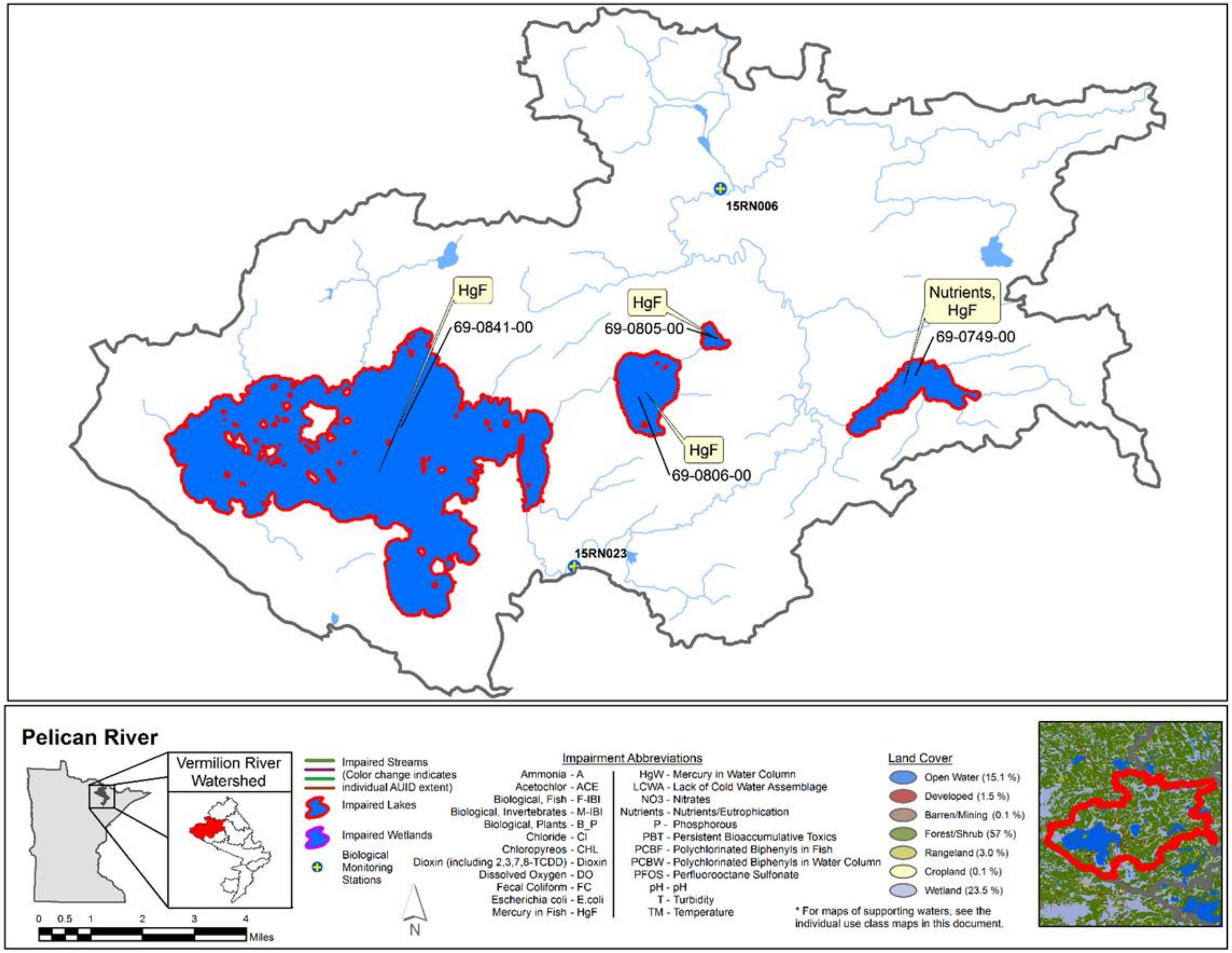
Figure 36. Secchi transparency trends in Pelican Lake (69-0841).



Myrtle Lake is a shallow lake with poor water quality. The south shore of the lake is moderately developed, including one resort; the north shore is largely undeveloped and managed by Superior National Forest. Myrtle was assessed as not supporting for aquatic recreation; average Chl-a concentration (26 µg/L) ranks as the highest of all 106 St. Louis County lakes with assessment-level data collected over the last decade. Algal blooms were observed in Myrtle Lake, and reduced clarity impacted recreation use (Figure 37).

Figure 37. Nuisance algal bloom on Myrtle Lake, June 2015 (MPCA photo).

Figure 38. Currently listed impaired waters by parameter and land use characteristics in the Pelican River Aggregated 12-HUC.



Echo River Aggregated 12-HUC HUC 0903000204-01

The Echo River Subwatershed is located in the far northeastern corner of the Vermilion River System. Draining an area of roughly 80 square miles, it is an intermediately sized contributor to the Vermilion River Watershed. The Echo River originates from Echo Lake, a 1,100-acre basin. Echo Lake is fed by a few small streams, including Picket Creek, which receives water from numerous smaller tributaries such as Brendvold, Finstad, Hanson, and Lost Jack creeks prior to entering Echo Lake. Further to the East, Camp 97 Creek also feeds Echo Lake from the south. At the outlet of Echo Lake on its far east side, the Echo River only flows a short distance to the northeast before the Hunting Shack River flows into it from the south. The Hunting Shack River is the only major tributary to the Echo River on its northern route to Crane Lake and is nearly the same size as the Echo River (approximately 9 miles). The Echo River watershed drains a remote and undeveloped part of Superior National Forest south of Crane Lake and adjacent to the Boundary Waters Canoe Area Wilderness.

Table 17. Aquatic life and recreation assessments on stream reaches: Echo River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name,* *Reach Description*	Biological Station ID	Reach Length (miles)	Use Class	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides***	Eutrophication	**Aquatic Life**	**Aquatic Rec. (Bacteria)**
09030002-583 **Hunting Shack River** **Headwaters (Pauline Lk 69-0588-00) to Unnamed Cr**	15RN015	4.36	WWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	IF	SUP	NA
09030002-532 **Echo River** **Echo Lk to Crane Lk**	15RN007	9.84	WWg	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	-	MTS	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 18. Lake assessments: Echo River Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators: Fish IBI	Aquatic life indicators: Chloride	Aquatic life indicators: Pesticides ***	Aquatic recreation indicators: Total phosphorus	Aquatic recreation indicators: Chlorophyll-a	Aquatic recreation indicators: Secchi	Aquatic life use	Aquatic recreation use
Astrid	69-0589-00	116.3	30	Deep Lake	NLF	--	NA	NA	NA	MTS	MTS	MTS	NA	FS
Maude	69-0590-00	91.6	26	Deep Lake	NLF	--	NA	NA	NA				NA	IF
Echo	69-0615-00	1,124.8	10	Shallow Lake	NLF	NT	NA	NA	NA	EX	EX	IF	NA	NS

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Summary

Two reaches were sampled for biology within the Echo River Subwatershed. Fish and macroinvertebrate communities supported aquatic life. The Echo River in particular, had a very high quality fish community with several sensitive and or late maturing species such as smallmouth bass, burbot, and rock bass. Lithophilic spawning species (require coarse substrate to spawn) like longnose dace, walleye, and log perch were also sampled. The fish IBI score was well above the threshold for Exceptional Use. However, the Macroinvertebrate IBI score did not meet the Exceptional Use threshold so the reach will remain designated as General Use. Water quality in this subwatershed was good, with low nutrient, sediment, and bacteria levels.

Astrid and Echo lakes were assessed for aquatic recreation. Astrid Lake, part of a remote chain of lakes south of the Echo Trail (Co. Rd. 116), is undeveloped except for two rustic campsites. Astrid Lake fully supported aquatic recreation with low algae levels and high clarity. Echo Lake is a Sentinel Lake, and is routinely monitored by the MPCA and DNR as part of a long-term effort to assess environmental variables that affect lake chemistry and biology. Echo Lake was chosen to represent a shallow, nutrient-rich lake on the Canadian Shield. A detailed report on the lake can be found here:

https://www.pca.state.mn.us/sites/default/files/wq-2slice69-0615.pdf. The most recent water quality monitoring data further support Echo Lake's high productivity (Figure 39). The high productivity is likely due to the lake's shallow basin and large wetland-dominated watershed. There is very low anthropogenic (human) land-use in the vicinity.

Figure 39. Water quality summary of assessed lakes in the Echo River Watershed.

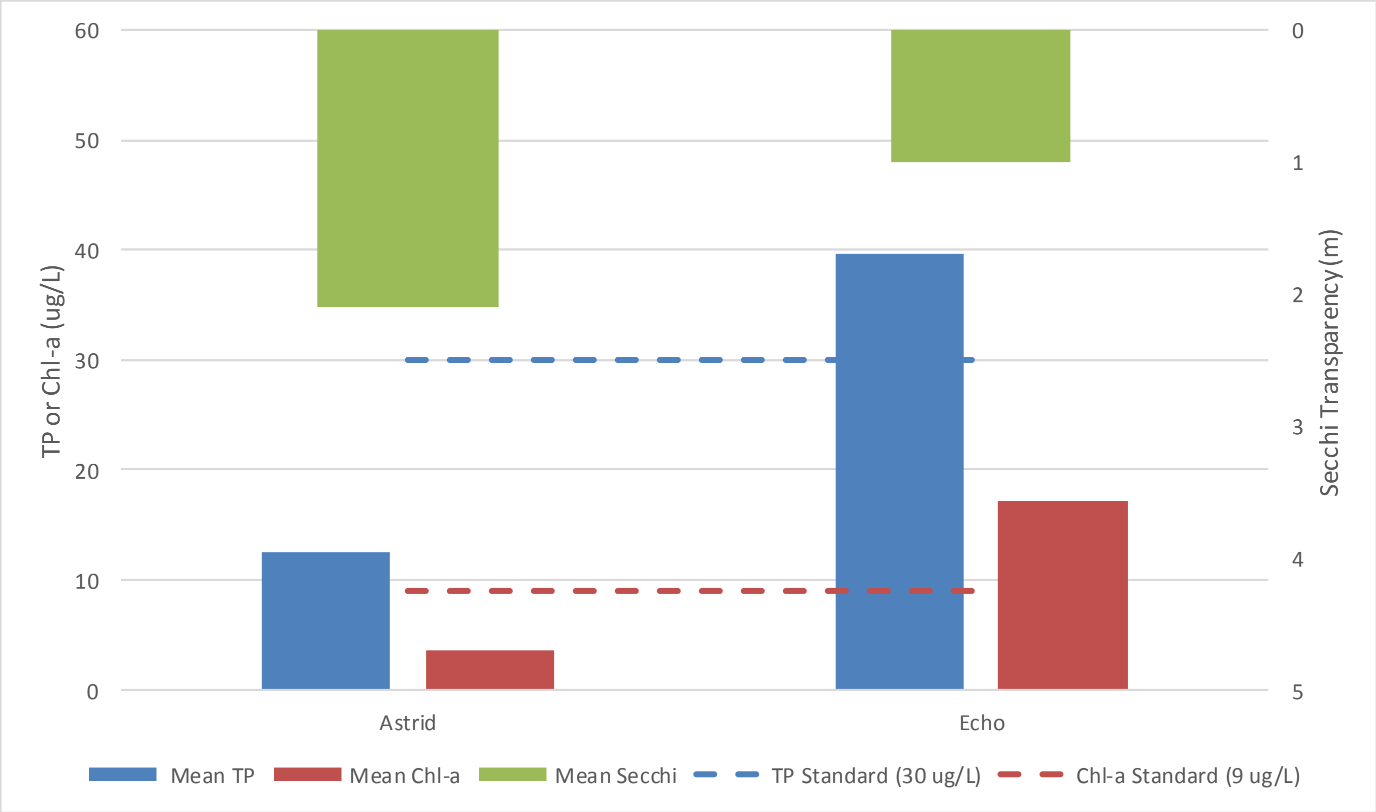
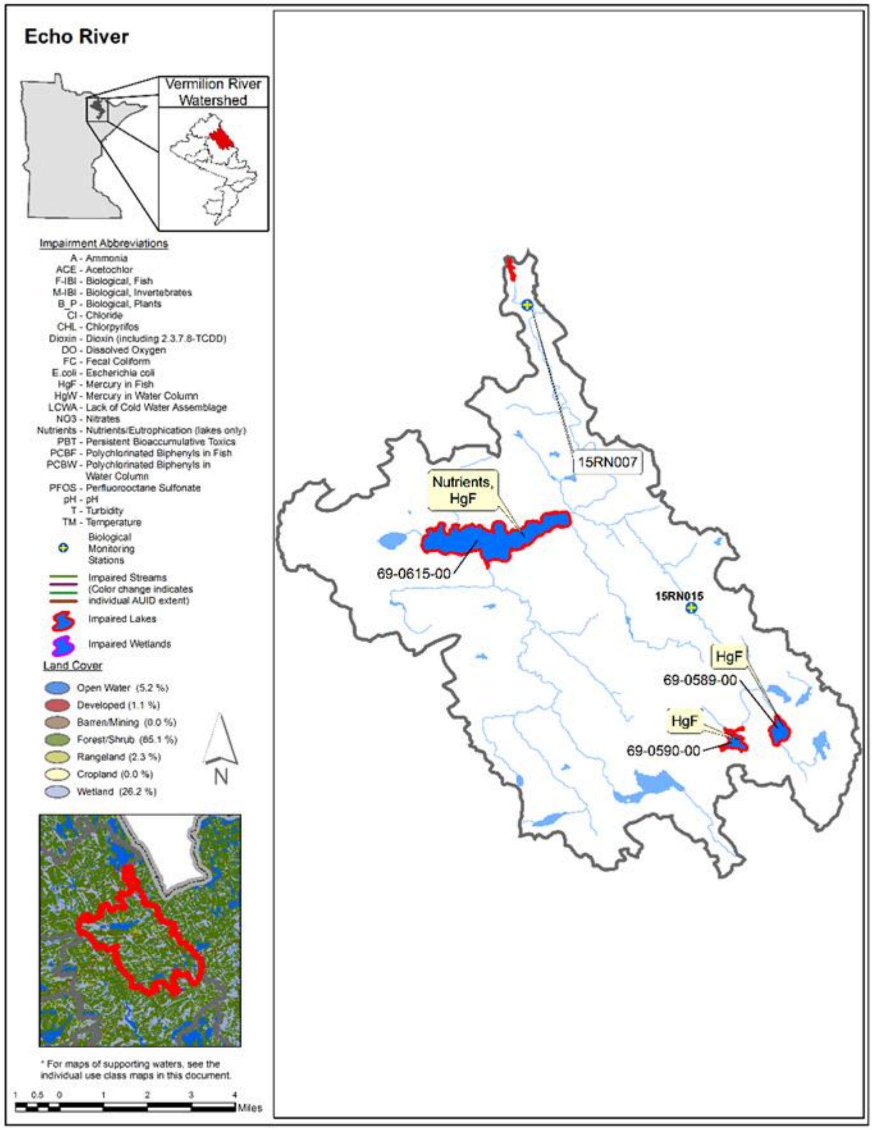


Figure 40. Currently listed impaired waters by parameter and land use characteristics in the Echo River Aggregated 12-HUC.



Lower Vermilion River Aggregated 12-HUC HUC 0903000205-01

The Lower Vermilion Subwatershed serves as the outlet of the watershed. Its drainage area spans from the Pelican River's confluence to Crane Lake. The last 21 miles of the Pelican River flow through this subwatershed before it enters Crane Lake. Covering an area of roughly 125 square miles, it is one of the larger contributing subwatersheds to the Vermilion River system.

Table 19. Aquatic life and recreation assessments on stream reaches: Lower Vermilion River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name,* *Reach Description*	Biological Station ID	Reach Length (miles)	Use Class	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides ***	Eutrophication	Aquatic Life	Aquatic Rec. (Bacteria)
09030002-531 **Vermilion River** **Pelican R to Crane Lk**	14RN152 05RN090	21.24	WWg	MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS	-	MTS	SUP	SUP
09030002-593 **Bug Creek** **Unnamed Cr to Elephant Cr**	15RN018	1.94	WWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	IF	SUP	NA
09030002-565 **Flap Creek** **Unnamed Cr to Marion Cr**	15RN020	1.81	WWg	MTS	MTS	IF	IF	IF	-	IF	IF	-	IF	SUP	NA

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 20. Lake assessments: Lower Vermilion River Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators:			Aquatic recreation indicators:			Aquatic life use	Aquatic recreation use
							Fish IBI	Chloride	Pesticides ***	Total phosphorus	Chlorophyll-a	Secchi		
Crane	69-0616-00	3047	80	Deep Lake	NLF	NT	NA	NA	NA	MTS	MTS	IF	NA	FS
Marion	69-0755-00	184	13	Shallow Lake	NLF	--	NA	NA	NA	IF	MTS	MTS	NA	FS
Elephant	69-0810-00	717	30	Deep Lake	NLF	NT	NA	NA	NA	MTS	IF	MTS	NA	FS

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EX** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Summary

The Lower Vermilion is the furthest downstream subwatershed of the Vermilion River system. Three streams were assessed for aquatic life based on fish and macroinvertebrates; all streams fully support aquatic life. Very little human disturbance and good habitat likely contribute to healthy aquatic communities in this subwatershed.

The stream monitoring site for this watershed was located at Superior National Forest Road 491, about three river miles upstream of Crane Lake. This location is routinely sampled as an MPCA load monitoring station. The robust dataset here indicates a high water quality, reflective of the region's public forests, wetlands, and upstream lakes. This reach of river met eutrophication standards- TP, Chl-a, and dissolved oxygen flux are all within acceptable levels. Also, sediment levels were consistently low; and pH samples routinely met standards. Bacteria concentrations in the Lower Vermilion River were low and indicated full support for aquatic recreation.

Three lakes in the watershed were assessed for aquatic recreation – Crane, Marion, and Elephant. Crane Lake is the pour point of the Vermilion River. This lake is on the edge of Voyageurs National Park; a large portion of the south shore is developed. Crane Lake has a robust water quality dataset, as the lake is routinely monitored by Voyageurs National Park personnel, and was also sampled by the MPCA in 2015-2016. TP and Chl-a concentrations were at expected levels, indicated mesotrophic conditions, and attainment of water quality standards. Secchi transparency averaged 1.8 meters, naturally low because of bog staining from the Vermilion River.

Marion Lake is a shallow, undeveloped lake in a remote part of the watershed. TP concentrations were very close to the 30 µg/L standard, while Chl-a and Secchi datasets met standards. Overall, the lake was assessed fully supported aquatic recreation. Elephant Lake is also a Sentinel Lake. Elephant was chosen to represent a lake of moderate depth and productivity in the Canadian Shield region. The lake has been routinely monitored from 2008-2011 and 2015-2016. Water quality has been fairly consistent over time, with the exception of 2015, which had lower than average P concentrations (the summer of 2015 was abnormally dry). Overall, Elephant Lake fully supported aquatic recreation. Occasionally, there are mild algae blooms on the lake; samples taken during mid-summer drove up the long-term mean value to slightly above the Chl-a standard (Figure 41). The detailed Elephant Sentinel Lake report can be found here: https://www.pca.state.mn.us/sites/default/files/wq-2slice69-0810.pdf.

Figure 41. Water quality summary of assessed lakes in the Lower Vermilion watershed.

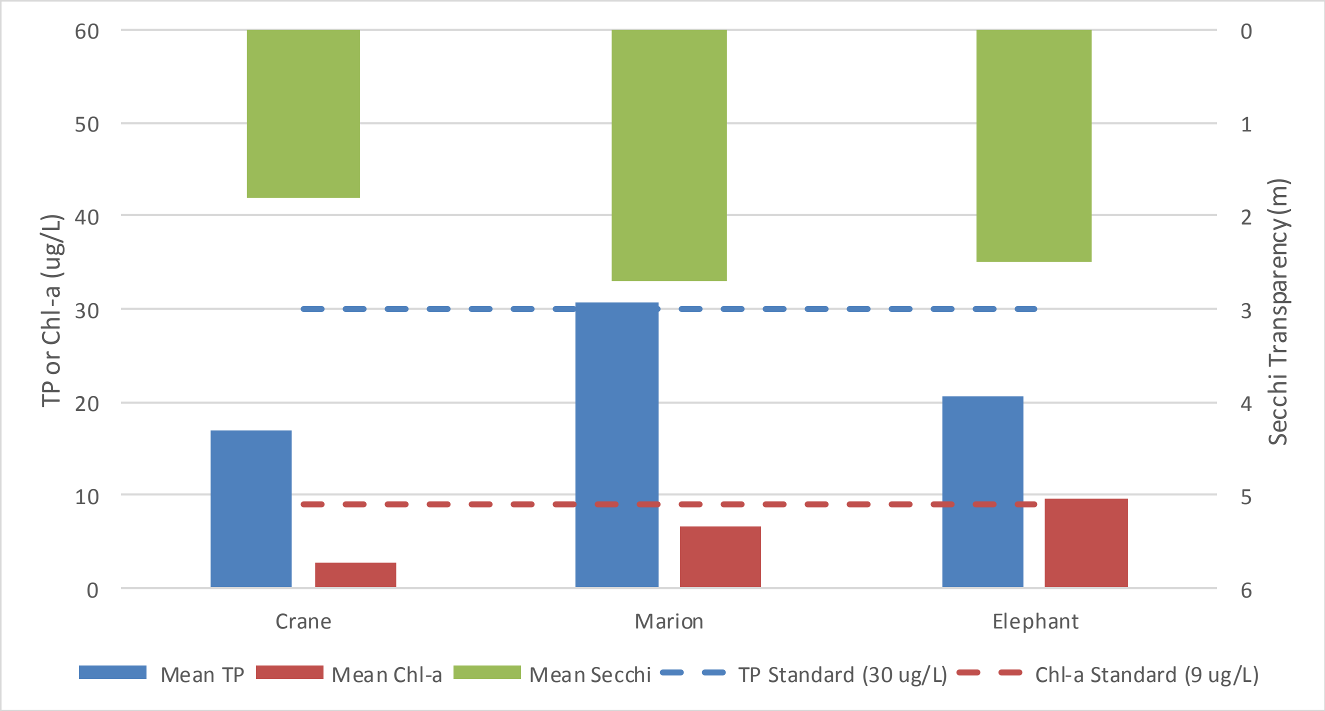
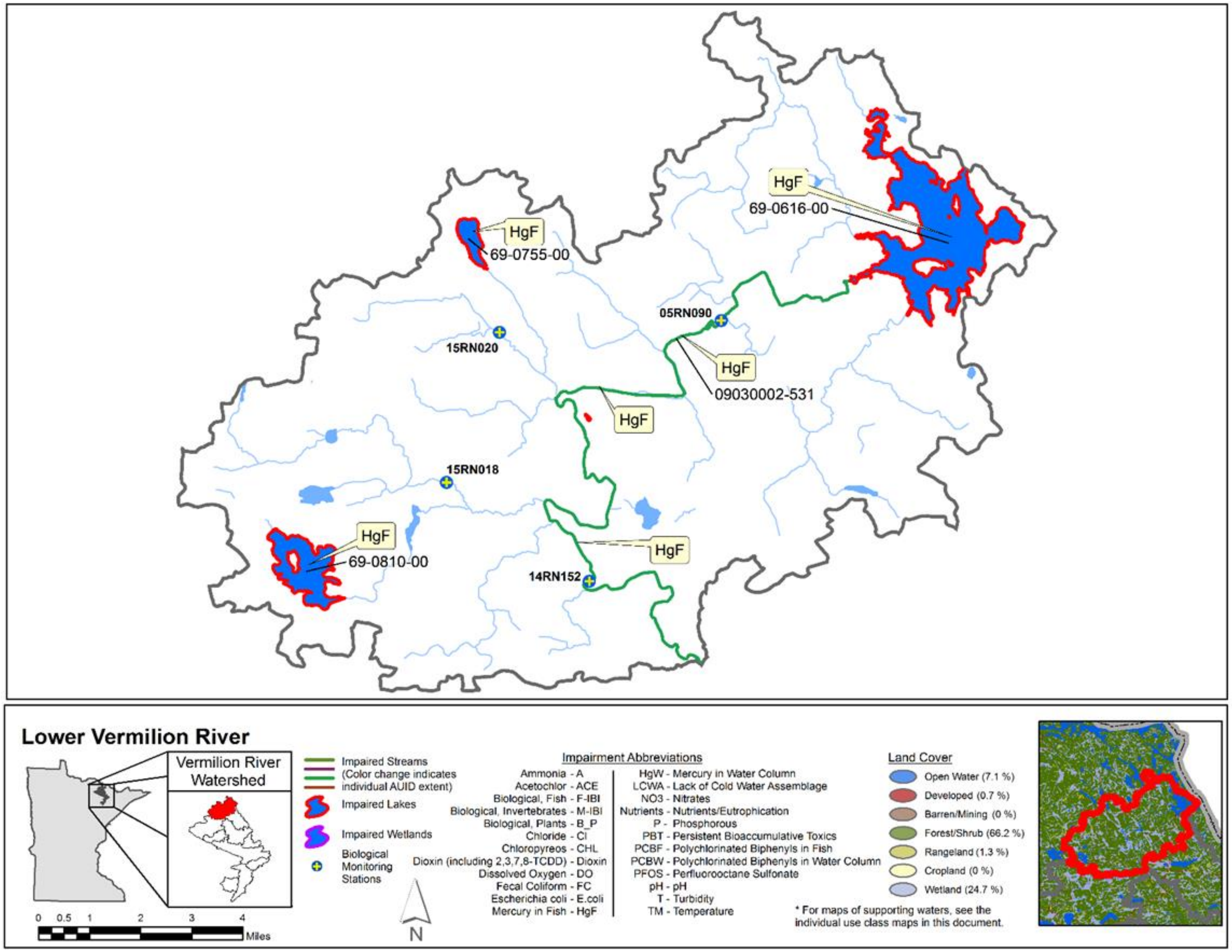


Figure 42. Currently listed impaired waters by parameter and land use characteristics in the Lower Vermilion Aggregated 12-HUC.



Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed unit of the Vermilion River, grouped by sample type. Summaries are provided for lakes, streams, and rivers in the watershed for the following: aquatic life and recreation uses, aquatic consumption results, load monitoring data results, transparency trends, and remote sensed lake transparency. Waters identified as priorities for protection or restoration work were also identified. Additionally, groundwater and wetland monitoring results are included where applicable.

Following the results are a series of graphics that provide an overall summary of assessment results by designated use, impaired waters, and fully supporting waters within the entire Vermilion River Watershed.

Stream water quality

Twenty-one of the 196 stream reaches were assessed (Table 21). Of the assessed streams, 20 streams fully supported aquatic life and all 9 streams fully supported aquatic recreation. No reaches were classified as limited resource waters.

Throughout the watershed, one reach did not support aquatic life.

Table 21. Assessment summary for stream water quality in the Vermilion River Watershed.

				Supporting		Non-supporting			
Watershed	**Area (acres)**	**# Total WIDs**	**# Assessed WIDs**	**# Aquatic life**	**# Aquatic recreation**	**# Aquatic life**	**# Aquatic recreation**	**Insufficient data**	**# Delistings**
Vermilion River **HUC 8**	**661,299**	**196**	**21**	**20**	**9**	**1**	**0**	**0**	**0**
Sand River	39,936	15	3	2	1	1	0	0	0
Pike River	78,720	10	2	2	1	0	0	0	0
East and West Two River	33,024	24	3	3	2	0	0	0	0
Lake Vermilion	128,281	39	1	1	0	0	0	0	0
Trout Lake	32,499	8	0	0	0	0	0	0	0
Upper Vermilion	83,534	22	5	5	1	0	0	0	0
Elbow River	37,149	7	1	1	1	0	0	0	0
Pelican River	97,140	21	1	1	1	0	0	0	0
Echo River	50,650	24	2	2	1	0	0	0	0
Lower Vermilion	80,311	26	3	3	1	0	0	0	0

Fish contaminant results

Mercury and polychlorinated biphenyls (PCBs) were analyzed in fish tissue samples collected from the Vermilion River in 2015 by the MPCA biomonitoring staff. Samples had previously been collected by DNR fisheries staff in 1994. Thirty-five lakes in the watershed have been tested for mercury and PCBs in fish. In addition, two lakes—Armstrong (69-0278) and Vermilion (69-0378)—were tested for perfluorochemicals.

Vermilion River is on the 2018 Impaired Waters Inventory (IWI) for mercury in fish tissue; the three listed WIDs for the river extend from Lake Vermilion to Crane Lake. PCBs were tested in a composite sample of three walleye in 1994 and the result was less than the 0.01 mg/kg reporting limit (Table 22). PCBs were again tested in two individual shorthead redhorse in 2015 and the results were less than the 0.025 mg/kg reporting limit.

Thirty-one of the 35 tested lakes are on the IWI for mercury in fish tissue, identified with an asterisk (*) in Table 22. Thirteen of the lakes with mercury impairments qualified for inclusion in the Minnesota Statewide Mercury TMDL. Many of the lakes were tested for PCBs; most results were below the reporting limit. The highest PCB concentration was 0.041 mg/kg in a Lake Trout from Trout Lake (69-0498) in 1992. The results for perfluorooctane sulfonate (PFOS) in Armstrong and Vermilion lakes were below the reporting limit.

Table 22. Fish contaminants: summary of fish length, mercury, PCBs, and PFOS by waterway-species-year.

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
VERMILION R.** (09030002-527, 09030002-529, 09030002-531)	UPSTREAM OF FR 491, 2.5 MI W OF CRANE LAKE	Shorthead redhorse	2015	FILSK	5	5	16.98	16.3	18.3	0.690	0.526	0.908	2	0.025	0.025	Y				
		Smallmouth bass	2015	FILSK	4	4	14	10.6	18.1	0.791	0.534	1.101								
	VERMILLION DAM TO CRANE LAKE	Northern pike	1994	FILSK	4	1	20.3	20.3	20.3	0.400	0.400	0.400								
		Walleye	1994	FILSK	15	4	18.45	13.7	23	0.568	0.260	0.760	1	0.01	0.01	Y				
		White sucker	1994	FILSK	4	1	19.8	19.8	19.8	0.370	0.370	0.370								
		Yellow perch	1994	FILSK	4	1	10.4	10.4	10.4	0.200	0.200	0.200								
69021700	WEST ROBINSON*	Northern pike	2004	FILSK	5	5	27.7	16.6	33.0	0.246	0.091	0.401								
69021800	EAGLES NEST #4*	Black crappie	2008	FILSK	7	2	12.0	11.1	12.9	0.070	0.042	0.098								
		Northern pike	1984	FILSK	5	1	16.6	16.6	16.6	0.130	0.130	0.130								
		Smallmouth bass	2008	FILSK	5	5	15.5	10.7	16.9	0.301	0.251	0.394								
		Walleye	1984	FILSK	5	2	16.0	14.8	17.2	0.245	0.180	0.310								
69027800	ARMSTRONG*	Bluegill sunfish	1997	FILSK	10	1	6.8	6.8	6.8	0.110	0.110	0.110								
			2007	FILSK	10	1	7.3	7.3	7.3	0.025	0.025	0.025					1	0.98	0.98	Y
			2012	FILSK	5	1	7.2	7.2	7.2	0.033	0.033	0.033								
		Black crappie	2007	FILSK	4	1	7.5	7.5	7.5	0.029	0.029	0.029								
		Largemouth bass	2007	FILSK	2	2	11.4	9.8	12.9	0.095	0.078	0.112								
		Northern pike	1997	FILSK	10	10	21.8	17.6	27.6	0.260	0.170	0.320	2	0.01	0.01	Y				
		Smallmouth bass	2007	FILSK	5	5	14.0	10.9	16.1	0.250	0.185	0.340								
		Walleye	1997	FILSK	10	10	20.6	18.0	28.5	0.447	0.300	0.820	2	0.01	0.01	Y				
			2012	FILSK	6	6	19.2	17.8	21.9	0.342	0.214	0.550								
		White sucker	1997	FILSK	6	1	19.3	19.3	19.3	0.066	0.066	0.066	1	0.01	0.01	Y				
			2012	FILSK	3	1	17.0	17.0	17.0	0.073	0.073	0.073								
69028501	EAGLES NEST #1	Largemouth bass	2008	FILSK	7	7	12.3	11.5	14.3	0.125	0.087	0.204								
		Northern pike	1984	FILSK	12	3	22.7	18.3	28.6	0.167	0.060	0.330								
		Walleye	1984	FILSK	9	2	19.2	17.0	21.4	0.180	0.090	0.270								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
69028502	EAGLES NEST #2	Northern pike	1984	FILSK	4	1	27.8	27.8	27.8	0.120	0.120	0.120								
		Walleye	1984	FILSK	3	1	13.6	13.6	13.6	0.100	0.100	0.100								
69028503	EAGLES NEST #3*	Bluegill sunfish	1990	FILSK	10	1	6.2	6.2	6.2	0.058	0.058	0.058	1	0.01	0.01	Y				
		Northern pike	1984	FILSK	7	2	19.6	18.2	21.0	0.255	0.190	0.320								
			1990	FILSK	9	2	19.8	17.5	22.0	0.365	0.350	0.380	2	0.01	0.01	Y				
		Smallmouth bass	1990	FILSK	3	1	14.0	14.0	14.0	0.250	0.250	0.250	1	0.01	0.01	Y				
		Walleye	1984	FILSK	13	3	17.4	14.3	20.9	0.483	0.180	0.670								
			1990	FILSK	3	1	14.5	14.5	14.5	0.260	0.260	0.260	1	0.01	0.01	Y				
		White sucker	1990	FILSK	12	3	17.3	14.2	20.2	0.113	0.020	0.200	3	0.013	0.014					
69037800	VERMILION*	Bluegill sunfish	1997	FILSK	20	2	7.1	6.6	7.6	0.120	0.059	0.180								
			2002	FILSK	8	1	7.5	7.5	7.5	0.086	0.086	0.086								
			2010	FILSK	5	5	5.7	5.3	6.3								5	4.948	5.03	Y
		Black crappie	2002	FILSK	8	1	10.1	10.1	10.1	0.063	0.063	0.063								
			2012	FILSK	8	2	9.3	7.7	10.9	0.076	0.055	0.097								
		Cisco (Lake herring)	1997	FILSK	16	2	13.3	13.2	13.3	0.092	0.083	0.100	2	0.01	0.01	Y				
		Northern pike	1977	PLUG	22	22	23.8	17.6	33.0	0.211	0.100	0.470								
			1982	FILSK	38	6	22.1	16.9	26.7	0.268	0.200	0.410								
			1995	FILSK	15	15	22.7	12.8	36.3	0.312	0.069	0.766								
			2009	FILSK	6	6	23.8	22.7	25.5	0.331	0.138	0.474								
		Walleye	1977	PLUG	30	30	16.0	12.4	23.0	0.198	0.090	0.730								
			1982	FILSK	39	6	16.7	12.7	20.2	0.310	0.200	0.420								
			1990	FILSK	23	4	19.0	11.0	25.1	0.245	0.120	0.360	4	0.01	0.01	Y				
			1995	FILSK	10	10	16.1	8.2	23.6	0.264	0.062	0.621								
			1997	FILSK	19	19	15.1	11.9	22.0	0.162	0.080	0.340	4	0.01	0.01	Y				
			2002	FILSK	5	5	18.2	15.9	21.0	0.225	0.185	0.288								
			2006	FILSK	22	22	15.3	11.0	24.1	0.135	0.071	0.279								
			2009	FILSK	5	5	17.9	16.4	19.0	0.234	0.166	0.279								
			2010	FILSK	5	5	14.5	12.2	18.1								5	4.928	4.98	Y
			2012	FILSK	6	6	15.3	12.2	17.8	0.220	0.142	0.293								
		White sucker	1990	FILSK	13	2	15.6	13.6	17.5	0.027	0.020	0.033	2	0.01	0.01	Y				
			2002	FILSK	4	1	18.8	18.8	18.8	0.066	0.066	0.066								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
		Yellow perch	2006	WHORG	10	3	5.7	5.3	6.2	0.038	0.034	0.043								
69044600	BASS*	Bluegill sunfish	2014	FILSK	10	1	6.9	6.9	6.9	0.050	0.050	0.050								
		Northern pike	2014	FILET	8	8	28.1	25.0	39.8	0.239	0.112	0.612								
69045500	LITTLE TROUT*	Bluegill sunfish	2013	FILSK	10	2	9.8	9.4	10.1	0.099	0.098	0.099								
		Cisco (Lake herring)	1992	FILSK	8	1	12.8	12.8	12.8	0.050	0.050	0.050	1	0.021	0.021					
		Northern pike	1992	FILSK	11	3	22.4	19.3	25.3	0.173	0.140	0.200	1	0.01	0.01	Y				
			2013	FILSK	6	6	22.7	20.1	27.0	0.272	0.181	0.410								
		Walleye	1992	FILSK	16	2	14.5	13.2	15.8	0.185	0.160	0.210	1	0.01	0.01	Y				
			2013	FILSK	6	6	18.0	14.7	23.7	0.411	0.277	0.734								
		White sucker	1992	FILSK	8	1	18.9	18.9	18.9	0.040	0.040	0.040								
		Yellow perch	1992	WHORG	8	1	7.5	7.5	7.5	0.010	0.010	0.010								
69045700	NIGH**	Northern pike	2000	FILSK	10	10	18.5	17.0	19.7	0.637	0.470	0.970								
		Walleye	2000	FILSK	6	6	18.3	14.8	20.8	1.070	0.680	1.250								
		White sucker	2000	FILSK	4	1	18.4	18.4	18.4	0.480	0.480	0.480								
69045900	CRELLIN**	Yellow perch	1994	FILSK	10	2	11.5	10.9	12.1	0.935	0.870	1.000								
69049800	TROUT*	Cisco (Lake herring)	1992	FILSK	8	1	11.6	11.6	11.6	0.066	0.066	0.066								
		Lake trout	1977	PLUG	15	15	19.2	15.0	24.8	0.286	0.110	0.500								
			1982	FILSK	14	3	17.4	11.9	22.5	0.270	0.140	0.390								
			1992	FILSK	4	3	22.6	18.0	27.1	0.217	0.090	0.330	2	0.036	0.041					
		Northern pike	1977	PLUG	5	5	25.6	20.0	30.0	0.582	0.250	0.980								
			1992	FILSK	9	3	27.0	22.8	32.9	0.307	0.150	0.550	1	0.01	0.01	Y				
			1996	FILSK	10	10	23.6	11.5	33.8	0.336	0.120	0.609								
			2002	FILSK	24	24	20.0	13.5	27.1	0.339	0.130	0.710								
			2008	FILSK	7	7	26.4	21.0	39.6	0.525	0.247	1.378								
		Rock bass	1992	FILSK	10	1	6.5	6.5	6.5	0.160	0.160	0.160								
		Smallmouth bass	1977	PLUG	5	5	13.7	11.3	14.8	0.360	0.280	0.420								
		Walleye	1977	PLUG	25	25	16.6	14.0	21.4	0.400	0.200	0.950								
			1982	FILSK	20	3	18.1	12.6	24.6	0.343	0.190	0.630								
			1992	FILSK	18	3	17.3	13.1	22.5	0.297	0.140	0.540	1	0.034	0.034					
		Yellow perch	2002	WHORG	10	1	6.1	6.1	6.1	0.116	0.116	0.116								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
			2008	WHORG	5	1	5.6	5.6	5.6	0.104	0.104	0.104								
69058000	PIKE RIVER FLOWAGE**	Northern pike	1994	FILSK	5	2	21.8	18.3	25.3	1.380	0.710	2.050	1	0.01	0.01	Y				
			2004	FILSK	16	16	21.7	13.3	29.9	0.623	0.324	1.079								
		White sucker	1994	FILSK	6	1	16.6	16.6	16.6	0.680	0.680	0.680								
		Yellow perch	1994	FILSK	4	1	9.0	9.0	9.0	0.400	0.400	0.400								
			2004	WHORG	10	2	5.4	5.3	5.5	0.104	0.101	0.107								
69058200	WOLF*	Bluegill sunfish	2016	FILSK	10	1	7.9	7.9	7.9	0.173	0.173	0.173								
		Northern pike	1996	FILSK	3	3	22.8	18.8	26.2	0.230	0.140	0.350	1	0.01	0.01	Y				
		Walleye	1996	FILSK	10	3	15.2	12.8	17.9	0.167	0.110	0.250								
			2016	FILSK	8	8	19.6	16.4	23.6	0.676	0.364	1.080								
		White sucker	1996	FILSK	8	1	17.5	17.5	17.5	0.120	0.120	0.120								
			2016	FILSK	5	1	18.8	18.8	18.8	0.090	0.090	0.090								
		Yellow perch	1996	FILSK	10	1	9.2	9.2	9.2	0.120	0.120	0.120								
69058700	ORINIACK*	Northern pike	2003	FILSK	8	8	21.9	16.4	33.9	0.435	0.130	0.869								
		Walleye	2003	FILSK	8	8	16.9	12.3	24.6	0.280	0.140	0.621								
		White sucker	2003	FILSK	8	1	15.0	15.0	15.0	0.053	0.053	0.053								
		Yellow perch	2003	FILSK	10	1	6.1	6.1	6.1	0.059	0.059	0.059								
69058800	PAULINE**	Northern pike	1992	FILSK	6	2	20.0	17.6	22.3	0.815	0.650	0.980	1	0.01	0.01	Y				
		Walleye	1992	FILSK	5	1	16.4	16.4	16.4	0.510	0.510	0.510	1	0.01	0.01	Y				
69058900	ASTRID**	Northern pike	1994	FILSK	8	2	19.1	17.9	20.2	0.900	0.870	0.930								
			2000	FILSK	6	6	20.5	17.5	22.6	1.015	0.810	1.280								
			2006	FILSK	5	5	19.8	15.5	26.7	1.142	0.455	1.811								
			2016	FILSK	12	12	17.4	13.6	23.0	0.757	0.535	1.206								
		Walleye	1994	FILSK	4	2	16.7	14.7	18.6	0.695	0.590	0.800	1	0.01	0.01	Y				
			2000	FILSK	7	7	15.8	12.0	21.3	0.641	0.470	0.980								
			2006	FILSK	6	6	17.2	14.6	19.6	0.847	0.609	1.345								
		White sucker	1994	FILSK	7	1	18.1	18.1	18.1	0.400	0.400	0.400								
			2000	FILSK	3	1	17.4	17.4	17.4	0.300	0.300	0.300								
69059000	MAUDE**	Northern pike	1993	FILSK	16	2	19.9	18.4	21.4	0.560	0.450	0.670	1	0.01	0.01	Y				
			2007	FILSK	6	6	21.7	18.1	27.4	0.676	0.330	0.888								
			2014	FILSK	3	3	20.6	19.4	21.9	1.091	0.991	1.228								
		Walleye	1993	FILSK	13	2	14.1	10.9	17.3	0.375	0.270	0.480								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
			2014	FILSK	4	4	16.5	14.9	18.4	0.700	0.557	1.009								
		White sucker	1993	FILSK	3	1	17.9	17.9	17.9	0.210	0.210	0.210								
		Yellow perch	2007	FILSK	7	1	10.2	10.2	10.2	0.367	0.367	0.367								
				WHORG	4	1	5.8	5.8	5.8	0.193	0.193	0.193								
69059100	PICKET*	Northern pike	2001	FILSK	4	4	23.4	18.2	29.4	0.199	0.118	0.360	1	0.01	0.01	Y				
		Walleye	2001	FILSK	10	10	16.4	13.1	20.5	0.190	0.101	0.329								
		Yellow perch	2001	FILSK	6	1	8.4	8.4	8.4	0.089	0.089	0.089								
69061500	ECHO**	Black crappie	1991	FILSK	18	1	13.4	13.4	13.4	0.170	0.170	0.170								
		Largemouth bass	2008	FILSK	6	6	11.9	10.4	13.1	0.289	0.191	0.491								
		Northern pike	1983	FILSK	1	1	22.0	22.0	22.0	0.480	0.480	0.480								
			1991	FILSK	15	3	22.4	18.0	27.4	0.507	0.400	0.590	2	0.01	0.01	Y				
			1996	FILSK	10	10	21.7	14.3	29.3	0.238	0.110	0.476								
			2001	FILSK	19	19	21.0	14.1	29.8	0.248	0.114	0.385								
			2006	FILSK	15	15	22.8	17.4	27.1	0.296	0.192	0.415								
			2014	FILSK	15	15	20.0	14.8	26.5	0.282	0.168	0.435								
		Smallmouth bass	2008	FILSK	6	6	16.1	12.7	19.3	0.350	0.234	0.466								
		Walleye	1983	FILSK	7	2	20.2	17.8	22.6	0.700	0.630	0.770								
			1991	FILSK	17	3	16.9	13.4	20.8	0.720	0.280	1.100	2	0.014	0.018					
			1996	FILSK	5	5	16.9	9.3	25.9	0.342	0.074	0.801								
		White sucker	1991	FILSK	17	3	17.6	14.2	20.5	0.220	0.110	0.340	1	0.01	0.01	Y				
		Yellow perch	1991	FILSK	8	1	8.6	8.6	8.6	0.130	0.130	0.130								
			2001	WHORG	10	2	5.7	5.5	5.9	0.039	0.039	0.039								
			2006	WHORG	10	3	6.8	6.1	7.5	0.058	0.053	0.063								
69061600	CRANE**	Black crappie	1991	FILSK	8	1	11.9	11.9	11.9	0.630	0.630	0.630								
			2002	FILSK	8	1	9.1	9.1	9.1	0.460	0.460	0.460								
		Cisco (Lake herring)	1991	FILSK	8	2	13.8	12.4	15.2	0.425	0.410	0.440								
			1999	FILSK	11	4	13.8	10.6	17.1	0.403	0.310	0.580	1	0.013	0.013					
		Northern pike	1976	PLUG	23	23	24.5	18.9	37.2	1.175	0.550	2.940								
			1982	FILSK	13	4	24.8	18.3	32.0	0.830	0.660	0.900								
			1991	FILSK	19	4	25.2	17.4	32.8	0.975	0.520	1.600	3	0.01	0.01	Y				
			1995	FILSK	10	10	23.7	17.7	35.0	0.876	0.327	2.038								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
			1996	FILSK	10	10	26.1	19.5	35.9	0.828	0.397	1.846								
			2002	FILSK	16	16	22.7	17.9	34.0	1.139	0.662	1.670								
			2006	FILSK	8	8	22.1	17.3	26.6	1.016	0.629	1.859								
			2011	FILSK	11	11	22.0	19.1	27.8	0.980	0.450	1.856								
		Sauger	1991	FILSK	7	1	11.2	11.2	11.2	1.400	1.400	1.400								
			2002	FILSK	5	5	11.8	10.0	13.2	1.167	0.788	2.010								
		Smallmouth bass	1991	FILSK	4	1	11.6	11.6	11.6	0.620	0.620	0.620								
		Sucker, unknown species	1979	WHORG	3	1	16.7	16.7	16.7	0.140	0.140	0.140								
		Walleye	1976	PLUG	53	53	13.1	10.1	19.6	0.815	0.350	1.530								
			1979	WHORG	5	1	14.1	14.1	14.1	0.990	0.990	0.990								
			1982	FILSK	18	3	16.8	12.2	21.0	1.147	0.860	1.300								
			1991	FILSK	23	23	16.8	9.2	27.8	1.292	0.370	2.900								
				FLDP	23	23	16.8	9.2	27.8	1.144	0.290	2.700								
			1996	FILSK	5	5	18.1	10.0	28.0	1.083	0.463	2.498								
			1999	FILSK	15	15	18.2	12.7	24.0	1.026	0.620	1.600								
		White sucker	1979	WHORG	7	1	17.3	17.3	17.3	0.190	0.190	0.190								
			1991	FILSK	11	3	16.3	12.9	20.3	0.277	0.120	0.390								
		Yellow perch	1991	WHORG	15	1	6.3	6.3	6.3	0.260	0.260	0.260								
			1999	FILSK	10	1	8.4	8.4	8.4	0.500	0.500	0.500								
			2002	WHORG	10	1	5.9	5.9	5.9	0.288	0.288	0.288								
			2006	WHORG	10	3	6.2	5.7	6.6	0.204	0.198	0.215								
69067900	KABUSTASA*	Northern pike	1999	FILSK	8	8	21.3	18.9	23.5	0.230	0.160	0.300	1	0.01	0.01	Y				
		Yellow perch	1999	FILSK	9	1	8.9	8.9	8.9	0.070	0.070	0.070								
69069000	WINCHESTER*	Bluegill sunfish	1994	FILSK	8	1	7.4	7.4	7.4	0.190	0.190	0.190								
			2001	FILSK	10	1	8.1	8.1	8.1	0.160	0.160	0.160								
		Lake trout	2009	FILSK	6	6	16.4	13.6	18.7	0.394	0.202	0.671								
		Smallmouth bass	2001	FILSK	3	3	8.8	8.1	9.8	0.392	0.342	0.479								
		White sucker	1994	FILSK	1	1	19.4	19.4	19.4	0.150	0.150	0.150								
69072900	LITTLE SANDY	Northern pike	1987	FILSK	14	4	25.6	16.4	34.7	0.855	0.630	1.130	1	0.05	0.05	Y				
69074100	SUSAN*	Black crappie	1996	FILSK	10	1	8.9	8.9	8.9	0.130	0.130	0.130								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
		Walleye	1996	FILSK	18	5	16.6	12.4	21.1	0.374	0.170	0.670	1	0.01	0.01	Y				
69074200	BAN**	Bluegill sunfish	2012	FILSK	10	2	8.0	7.2	8.8	0.279	0.261	0.297								
		Black crappie	1993	FILSK	8	1	9.8	9.8	9.8	0.270	0.270	0.270								
			2000	FILSK	10	1	10.0	10.0	10.0	0.180	0.180	0.180								
		Northern pike	1993	FILSK	12	4	22.1	17.3	26.8	0.328	0.190	0.420	1	0.01	0.01	Y				
			2000	FILSK	7	7	23.3	18.9	27.9	0.463	0.220	0.600								
			2012	FILSK	6	6	20.8	16.2	29.7	0.707	0.439	1.589								
		Smallmouth bass	1993	FILSK	7	2	13.1	11.5	14.6	0.455	0.330	0.580	1	0.01	0.01	Y				
		Walleye	2000	FILSK	5	5	20.0	16.9	22.4	0.660	0.410	0.790								
		White sucker	2000	FILSK	5	1	19.8	19.8	19.8	0.150	0.150	0.150								
			2012	FILSK	2	1	15.9	15.9	15.9	0.110	0.110	0.110								
69074400	ELBOW**	Northern pike	1983	FILSK	11	4	24.6	18.1	31.9	0.425	0.310	0.540								
			1995	FILSK	4	4	21.9	19.2	29.0	0.460	0.317	0.692								
			2003	FILSK	11	11	22.3	14.1	33.0	0.557	0.174	1.463								
			2008	FILSK	6	6	24.0	17.0	29.0	0.746	0.595	0.893								
			2013	FILSK	4	4	22.3	19.1	24.9	0.528	0.485	0.600								
		Walleye	1983	FILSK	3	1	19.3	19.3	19.3	0.400	0.400	0.400								
			1992	FILSK	16	3	16.8	12.8	20.2	0.510	0.250	0.700	1	0.019	0.019					
			1995	FILSK	11	11	16.5	14.0	23.6	0.436	0.237	1.102								
		White sucker	1992	FILSK	8	1	17.4	17.4	17.4	0.220	0.220	0.220	1	0.01	0.01	Y				
		Yellow perch	1992	WHORG	6	1	6.7	6.7	6.7	0.110	0.110	0.110								
			2003	WHORG	10	3	7.6	6.9	8.2	0.197	0.190	0.203								
			2008	WHORG	10	2	6.0	5.7	6.2	0.087	0.081	0.093								
69074700	CLEAR	Northern pike	2008	FILSK	1	1	20.2	20.2	20.2	0.281	0.281	0.281								
		Yellow perch	2008	WHORG	6	2	5.9	5.5	6.3	0.092	0.087	0.096								
69074800	KJOSTAD**	Black crappie	1994	FILSK	7	1	11.5	11.5	11.5	0.200	0.200	0.200								
		Cisco (Lake herring)	1994	FILSK	8	1	15.6	15.6	15.6	0.280	0.280	0.280	1	0.01	0.01	Y				
		Northern pike	1982	FILSK	10	4	25.9	18.7	33.7	0.935	0.410	1.200								
			1988	FILSK	1	1	34.3	34.3	34.3	1.000	1.000	1.000	1	0.01	0.01	Y				
			1996	FILSK	10	10	20.5	15.6	27.6	0.497	0.270	0.921								
			2002	FILSK	6	6	22.6	16.7	26.3	0.631	0.456	0.813								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
			2007	FILSK	7	7	22.1	15.3	28.1	0.660	0.406	1.128								
			2012	FILSK	12	12	23.2	19.1	27.1	0.835	0.579	1.556								
		Walleye	1982	FILSK	8	2	16.4	13.0	19.8	0.720	0.570	0.870								
			1988	FILSK	10	10	17.7	13.2	27.0	0.797	0.480	1.700	1	0.01	0.01	Y				
			1994	FILSK	5	1	10.2	10.2	10.2	0.150	0.150	0.150								
			1997	FILSK	10	10	16.4	13.0	21.1	0.524	0.320	1.050	2	0.01	0.01	Y				
				WHORG	9	9	16.8	13.8	21.1	0.452	0.290	0.890								
				WHORG	1	1	13.0	13.0	13.0	0.310	0.310	0.310								
		Yellow perch	1997	WHORG	2	2	8.7	8.4	8.9	0.215	0.180	0.250								
			2002	WHORG	10	2	5.9	5.7	6.0	0.201	0.177	0.224								
			2007	WHORG	10	2	6.6	6.2	7.0	0.198	0.165	0.231								
69074900	MYRTLE*	Black crappie	1994	FILSK	8	1	9.5	9.5	9.5	0.140	0.140	0.140								
			2007	FILSK	9	1	7.3	7.3	7.3	0.081	0.081	0.081								
		Northern pike	1984	FILSK	14	3	22.7	17.0	27.4	0.323	0.200	0.410								
			1994	FILSK	18	4	24.0	19.0	28.9	0.263	0.180	0.350	1	0.01	0.01	Y				
			2007	FILSK	6	6	24.2	21.5	28.5	0.334	0.311	0.367								
		Walleye	1984	FILSK	5	2	17.6	16.0	19.2	0.410	0.410	0.410								
		White sucker	1994	FILSK	8	1	18.6	18.6	18.6	0.150	0.150	0.150								
69075500	MARION*	Bluegill sunfish	1995	FILSK	10	1	7.8	7.8	7.8	0.056	0.056	0.056								
			2012	FILSK	5	1	7.3	7.3	7.3	0.110	0.110	0.110								
		Northern pike	2012	FILSK	6	6	20.8	18.1	25.8	0.584	0.339	0.722								
		Walleye	1995	FILSK	17	3	18.1	14.6	21.4	0.417	0.210	0.560	1	0.01	0.01	Y				
69080500	BELL**	Northern pike	2006	FILSK	5	5	23.9	20.6	26.7	0.588	0.455	0.789								
		Yellow perch	2006	WHORG	6	5	7.7	5.8	9.6	0.111	0.078	0.198								
69080600	MOOSE**	Black bullhead	1993	FILET	8	1	9.7	9.7	9.7	0.150	0.150	0.150								
		Black crappie	1993	FILSK	8	1	10.3	10.3	10.3	0.230	0.230	0.230								
		Northern pike	1983	FILSK	16	4	24.5	17.9	31.0	0.423	0.140	0.730								
			1993	FILSK	22	5	22.3	16.4	28.3	0.366	0.170	0.490	1	0.01	0.01	Y				
			1996	FILSK	10	10	22.0	18.6	26.2	0.448	0.301	0.686								
			2000	FILSK	24	24	22.5	15.4	31.2	0.359	0.130	0.950								
			2007	FILSK	19	19	24.2	14.0	29.8	0.403	0.043	0.553								
			2013	FILSK	12	12	21.0	16.3	29.4	0.443	0.272	0.669								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
		Walleye	1983	FILSK	10	2	15.7	14.1	17.3	0.245	0.210	0.280								
			1993	FILSK	10	2	16.4	12.8	20.0	0.330	0.050	0.610	1	0.01	0.01					
		Yellow perch	2000	WHORG	9	9	7.8	5.0	9.8	0.110	0.030	0.190								
			2007	WHORG	10	2	6.6	5.9	7.2	0.067	0.064	0.069								
69081000	ELEPHANT*	Black crappie	1991	FILSK	10	1	11.1	11.1	11.1	0.140	0.140	0.140								
			2001	FILSK	10	1	9.7	9.7	9.7	0.102	0.102	0.102								
			2009	FILSK	8	2	9.2	8.8	9.5	0.087	0.079	0.094								
		Northern pike	1991	FILSK	6	3	26.9	22.3	32.9	0.427	0.310	0.520	3	0.01	0.01	Y				
			2014	FILSK	8	8	25.1	21.0	28.5	0.337	0.305	0.419								
		Smallmouth bass	1991	FILSK	9	2	13.0	10.0	16.0	0.265	0.180	0.350	1	0.01	0.01	Y				
		Walleye	1991	FILSK	25	4	20.6	13.0	29.5	0.555	0.200	1.200	3	0.013	0.02					
			2001	FILSK	8	8	17.2	12.5	22.1	0.240	0.117	0.470								
			2009	FILSK	7	7	13.8	12.2	17.4	0.199	0.152	0.292								
			2014	FILSK	3	3	20.3	19.5	21.8	0.539	0.505	0.572								
		White sucker	1991	FILSK	18	3	16.8	11.3	20.9	0.100	0.051	0.160	1	0.01	0.01	Y				
			2001	FILSK	4	1	20.1	20.1	20.1	0.111	0.111	0.111								
		Yellow perch	1991	FILSK	10	1	9.5	9.5	9.5	0.056	0.056	0.056								
69084100	PELICAN*	Bluegill sunfish	1992	FILSK	10	1	7.7	7.7	7.7	0.200	0.200	0.200								
		Black bullhead	1992	FILET	6	1	10.5	10.5	10.5	0.160	0.160	0.160	1	0.01	0.01	Y				
		Largemouth bass	1992	FILSK	8	2	14.8	13.0	16.6	0.355	0.290	0.420								
		Northern pike	1977	FILSK	32	14	25.0	15.8	34.3	0.757	0.140	1.400								
				PLUG	24	24	20.8	10.8	28.2	0.278	0.130	0.690								
			1982	FILSK	15	4	25.0	18.6	33.2	0.460	0.280	0.630								
			1992	FILSK	32	5	22.3	13.8	30.9	0.450	0.210	0.940	1	0.01	0.01	Y				
			1995	FILSK	10	10	25.7	18.4	34.8	0.500	0.244	0.877								
			2001	FILSK	24	24	20.8	13.9	30.0	0.329	0.161	0.961								
			2007	FILSK	24	24	23.4	16.3	31.2	0.401	0.181	0.830								
			2012	FILSK	12	12	20.8	17.4	31.4	0.336	0.210	0.766								
		Smallmouth bass	1977	PLUG	5	5	14.2	13.1	15.4	0.220	0.130	0.360								
		Walleye	1977	FILSK	23	9	20.5	13.0	27.0	1.048	0.210	1.700								

WID / RIVER	Waterway / Location	Species	Year	Anat-omy[1]	Total Fish	Number Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)			
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max	< RL
				PLUG	6	6	17.7	9.5	25.9	0.402	0.100	0.870								
			1992	FILSK	8	2	21.0	18.9	23.1	0.540	0.460	0.620	1	0.016	0.016					
			1995	FILSK	4	4	19.3	18.2	19.9	0.470	0.284	0.838								
		Yellow perch	2001	WHORG	10	3	7.0	5.9	7.9	0.124	0.095	0.156								
			2007	WHORG	10	2	5.8	5.5	6.0	0.049	0.040	0.058								

*** Impaired for mercury in fish tissue as of 2016 Draft Impaired Waters List; categorized as EPA Class 4a for waters covered by the Statewide Mercury TMDL.**

**** Impaired for mercury in fish tissue as of 2014 Draft Impaired Waters List; categorized as EPA Class 5 for waters needing a TMDL.**

1 Anatomy codes: FILSK – edible fillet, skin-on; FILET—edible fillet, skin-off; BIOPSY or PLUG—dorsal muscle piece, without skin; WHORG—whole organism; NOHV-organism without head or viscera; PLUSK-dorsal muscle with skin;

Pollutant load monitoring

The WPLMN has two sites within the Vermilion River Watershed as shown in Table 26.

Table 23. WPLMN stream monitoring sites for the Vermilion River watershed.

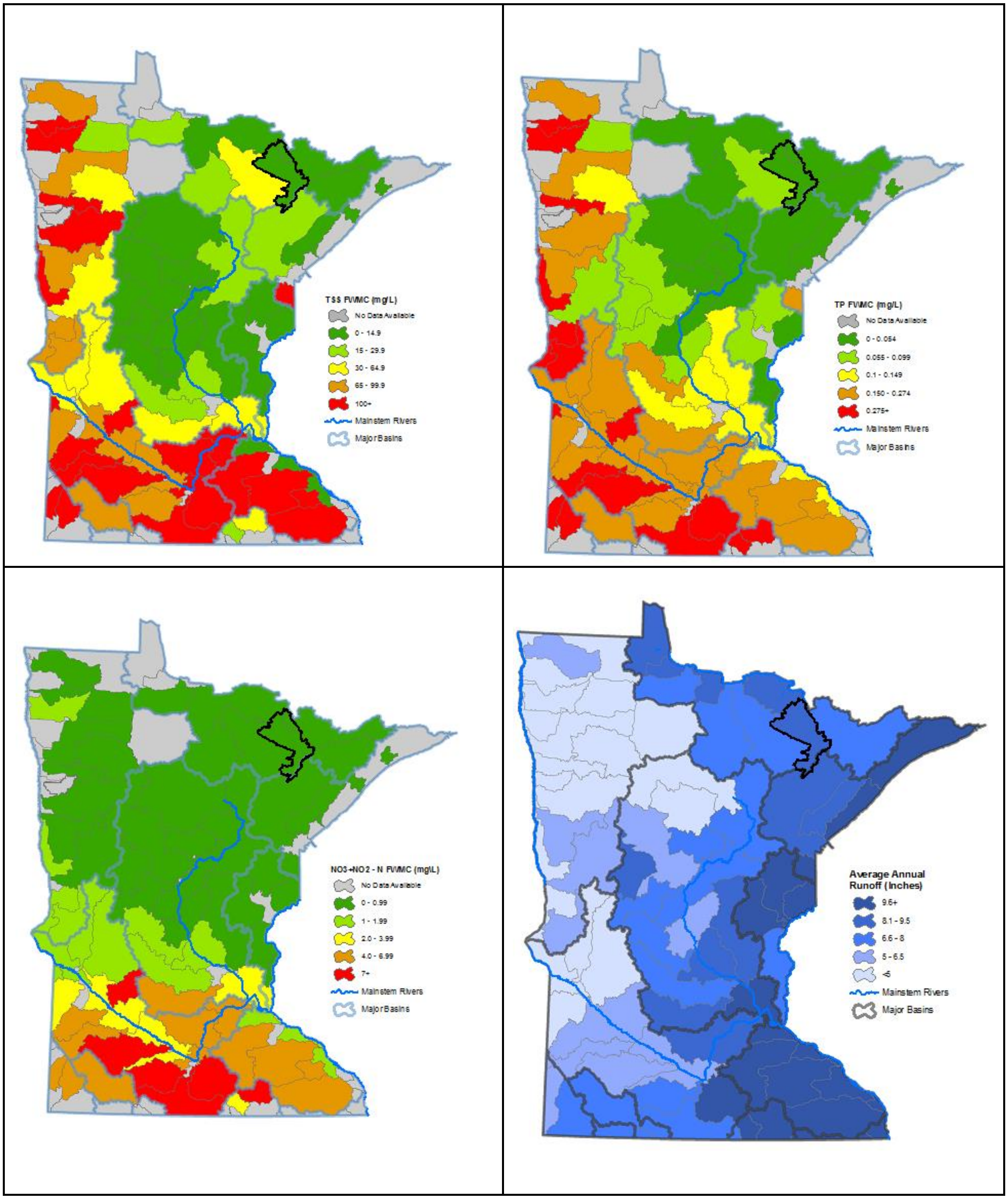
Site Type	Stream Name	USGS ID	DNR/MPCA ID	EQuIS ID
Major Watershed	Vermilion River near Crane Lake	05129115	E73002001	S005-088
Subwatershed	Vermilion River near Buyck, CSAH 24	NA	H73017001	S006-505

Average annual FWMCs of TSS, TP, and NO_3+NO_2-N for major watershed stations statewide are presented below (Figure 43), with the Vermilion River Watershed highlighted. Water runoff, a significant factor in pollutant loading, is also shown. Water runoff is the portion of annual precipitation that makes it to a river or stream; thus it can be expressed in inches.

As a rule, elevated levels of TSS and NO_3+NO_2-N are regarded as "non-point" source derived pollutants originating from many small diffuse sources such as urban or agricultural runoff. Excess TP can be attributed to both non-point as well as point sources such as industrial or wastewater treatment plants. Major "non-point" sources of phosphorus include dissolved phosphorus from fertilizers and phosphorus adsorbed to and transported with sediment during runoff.

Excessive TSS, TP, and NO_3+NO_2-N in surface waters impacts fish and other aquatic life, as well as fishing, swimming and other recreational uses. High levels of NO_3+NO_2-N is a concern for drinking water.

Figure 43. 2007-2015 average annual TSS, TP, and NO3-NO2-N flow weighted mean concentrations, and runoff by major watershed.



When compared with other major watersheds throughout the state, Figure 43 shows the average annual TSS, TP, and NO_3+NO_2-N FWMCs for the Vermilion River Watershed to be some of the lowest in the state and several times lower than watersheds in southern and western Minnesota.

Nitrate plus nitrite nitrogen (NO_3+NO_2-N) levels measured from the Vermilion River were low from a statewide perspective and when compared to other watershed outlet sites in the Rainy River Basin. Flow weighted mean NO_3+NO_2-N concentrations between 2009 through 2015 were at or less than 0.08 mg/L for all years. The mean concentration of the 127 samples collected over the monitoring period was 0.048 mg/L.

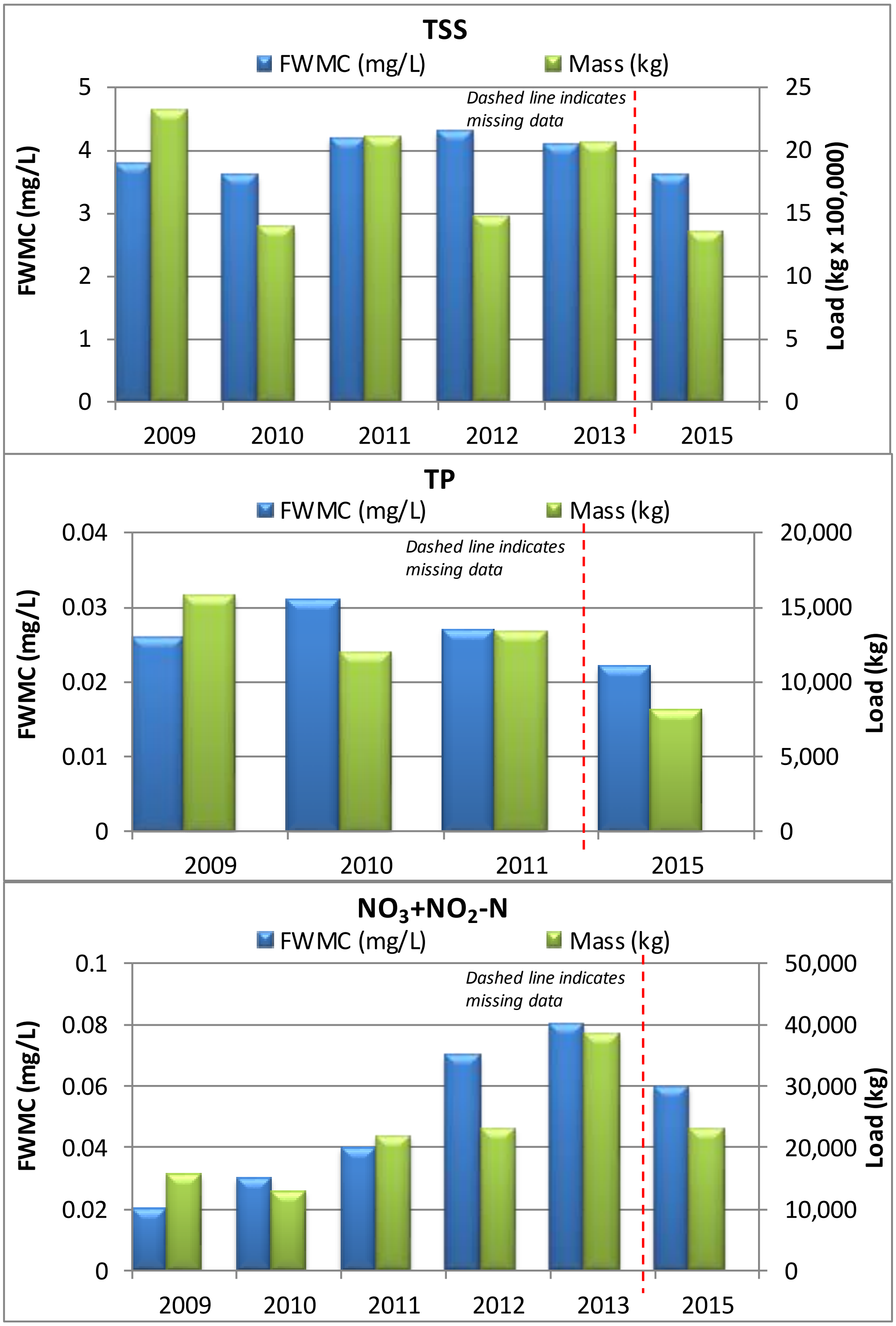
Total suspended solids levels measured from the Vermilion River were also very low when compared to other Minnesota streams of this order. Annual flow weighted mean TSS concentrations ranged from 3.6 to 4.3 mg/L over the 2009 through 2015 monitoring period. The mean concentration of the 158 samples collected over this interval was 4 mg/L with only two of these samples exceeding the TSS water quality standard of 15 mg/L for the Northern River Nutrient Region.

Like the other parameters, total phosphorus concentrations measured from the Vermilion River over the seven year monitoring period were low. Total phosphorus flow weighted mean concentrations ranged from 0.022 to 0.031 mg/L, with only 3% of the 112 samples collected during the summer months exceeding the water quality TP standard of 0.05 mg/L for the Northern River Nutrient Region.

More information, including results for subwatershed stations, can be found at the WPLMN website.

Substantial year-to-year variability in water quality occurs for most rivers and streams, including the Vermilion River. Results for individual years are shown in the charts (Figure 44) below.

Figure 44. TSS, TP, and NO3+NO2-N Flow Weighted Mean Concentrations and Loads for the Vermilion River near Crane Lake, Minnesota.



Groundwater monitoring

Stream flow

Stream flow data from the United States Geological Survey's real-time streamflow gaging stations for the Vermilion River was analyzed for annual mean discharge and summer monthly mean discharge (July and August). Figure 45 is a display of the annual mean discharge for the Vermilion River near Crane Lake, Minnesota from water years 1996 to 2015. The data shows that although streamflow appears to be decreasing over time, there is no statistically significant trend. Figure 46 displays July and August mean flows for the same time frame, for the same waterbody. Graphically, the data appears to be increasing in July and decreasing in August, but neither at a statistically significant rate. By way of comparison at a state level, summer month flows have declined at a statistically significant rate at a majority of streams selected randomly for a study of statewide trends (Streitz, 2011). For additional streamflow data throughout Minnesota, please visit the USGS website: http://waterdata.usgs.gov/mn/nwis/rt.

Figure 45. Annual mean streamflow for Vermilion River near Crane Lake, Minnesota (1996-2015) (Source: USGS, 2017).

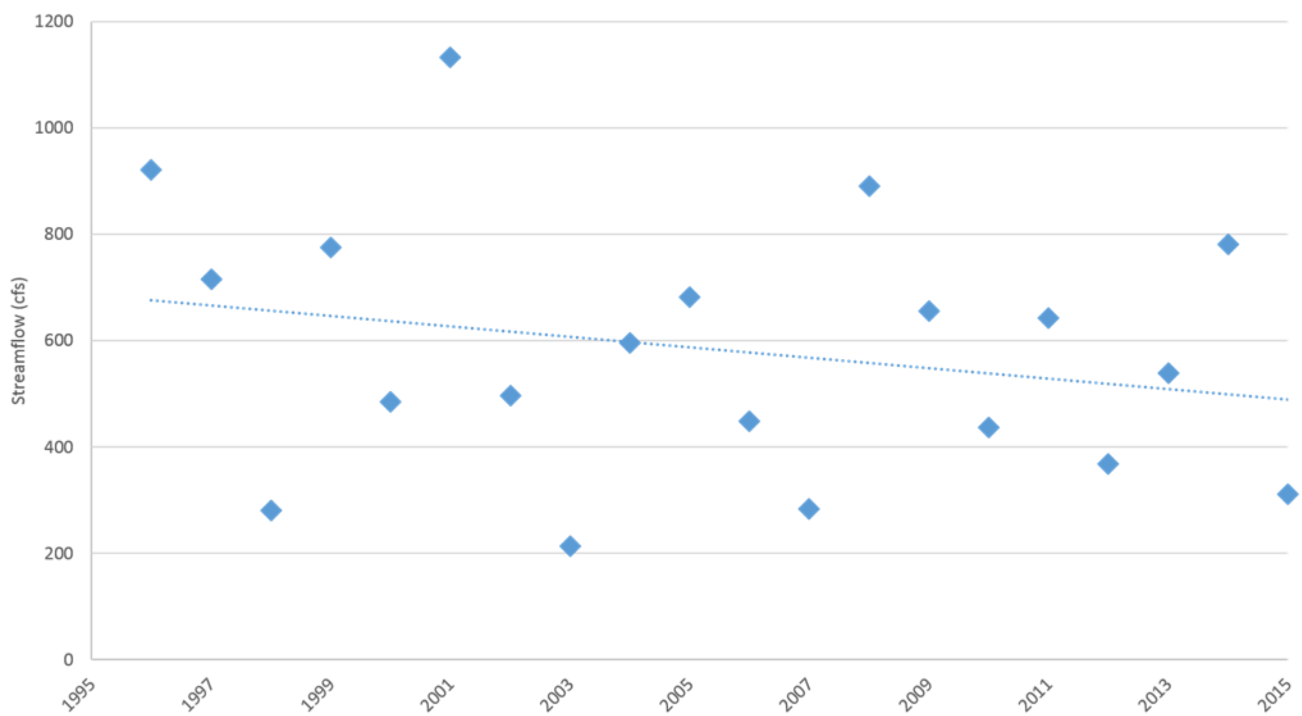
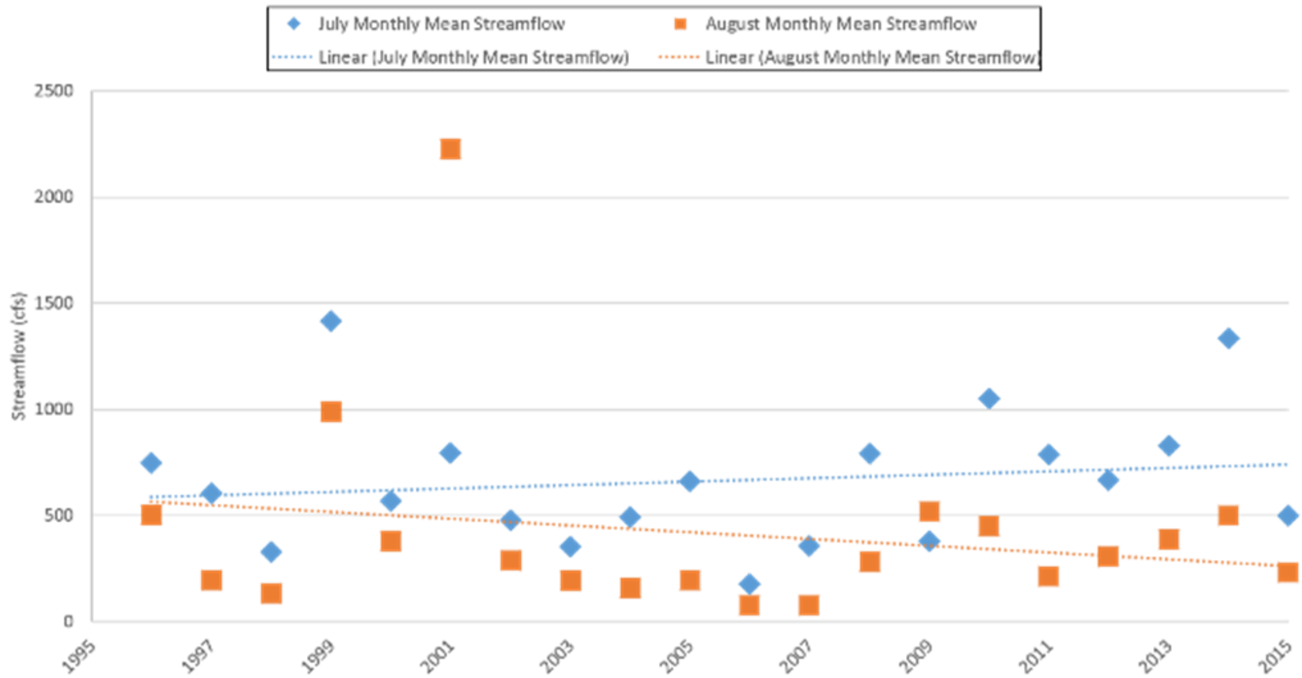


Figure 46. Monthly mean streamflow for Vermilion River near Crane Lake, Minnesota (1996-2015) (Source: USGS, 2017).



Wetland condition

Wetland vegetation quality is generally high in Minnesota (MPCA 2015). This is driven by the large share of wetlands located in Minnesota's northern forest ecoregion where development and resulting wetland quality impacts are much less widespread compared to the rest of the state. Wetlands that are in exceptional or good condition have had few (if any) measurable changes in their expected native species composition or abundance distribution. Wetland vegetation quality is largely degraded outside of northern Minnesota, where non-native plant species (most notably Reed canary grass and Narrow leaf or Hybrid cattail) have replaced native wetland plant communities over the majority of the remaining wetlands (MPCA 2015).

As the entire Vermilion River Watershed lies within Minnesota's Northern Forest ecoregion, wetland vegetation quality in the watershed is expected to be high overall. An estimated 84% of the wetlands in the ecoregion are in good-exceptional vegetation condition (MPCA 2015). Wetland quality impacts in the watershed are likely localized. Primary impacts to wetland vegetation quality include hydrology alterations associated with road building and mining, and logging impacts in coniferous swamps.

Figure 47. Stream Tiered Aquatic Life Use designations in the Vermilion River Watershed.

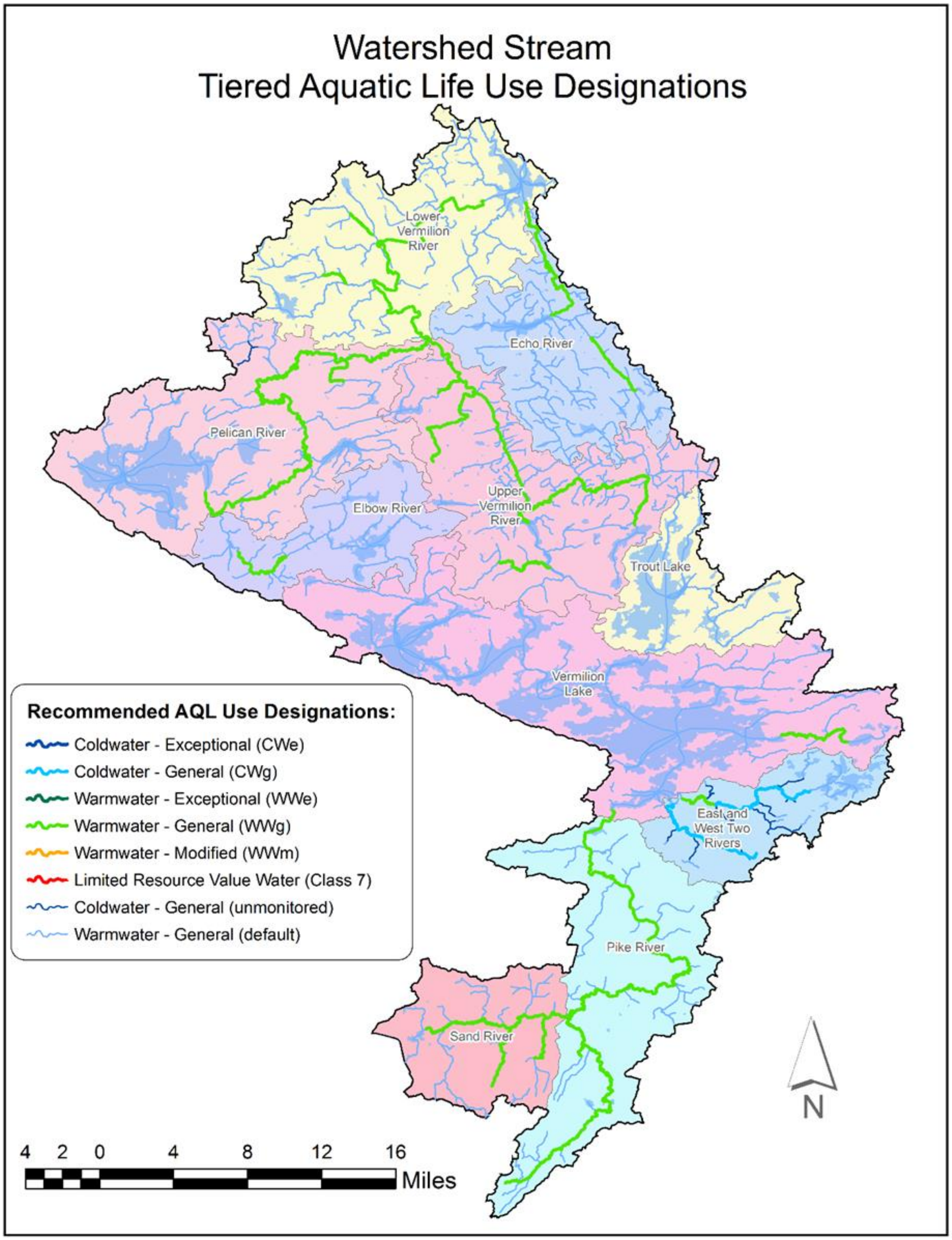


Figure 48. Fully supporting waters by designated use in the Vermilion River Watershed.

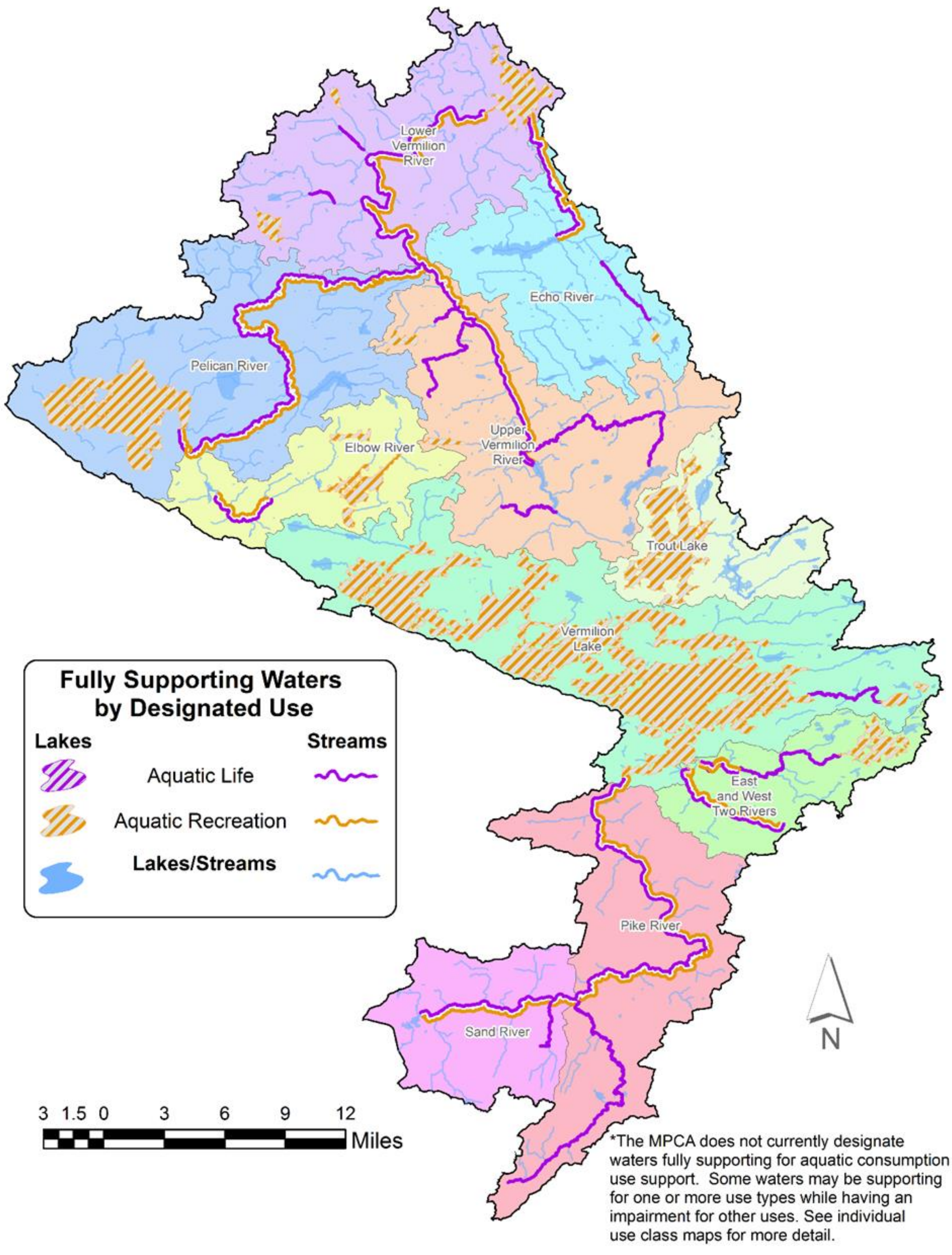


Figure 49. Impaired waters by designated use in the Vermilion River Watershed. Map depicts results of AY2017 assessment cycle only.

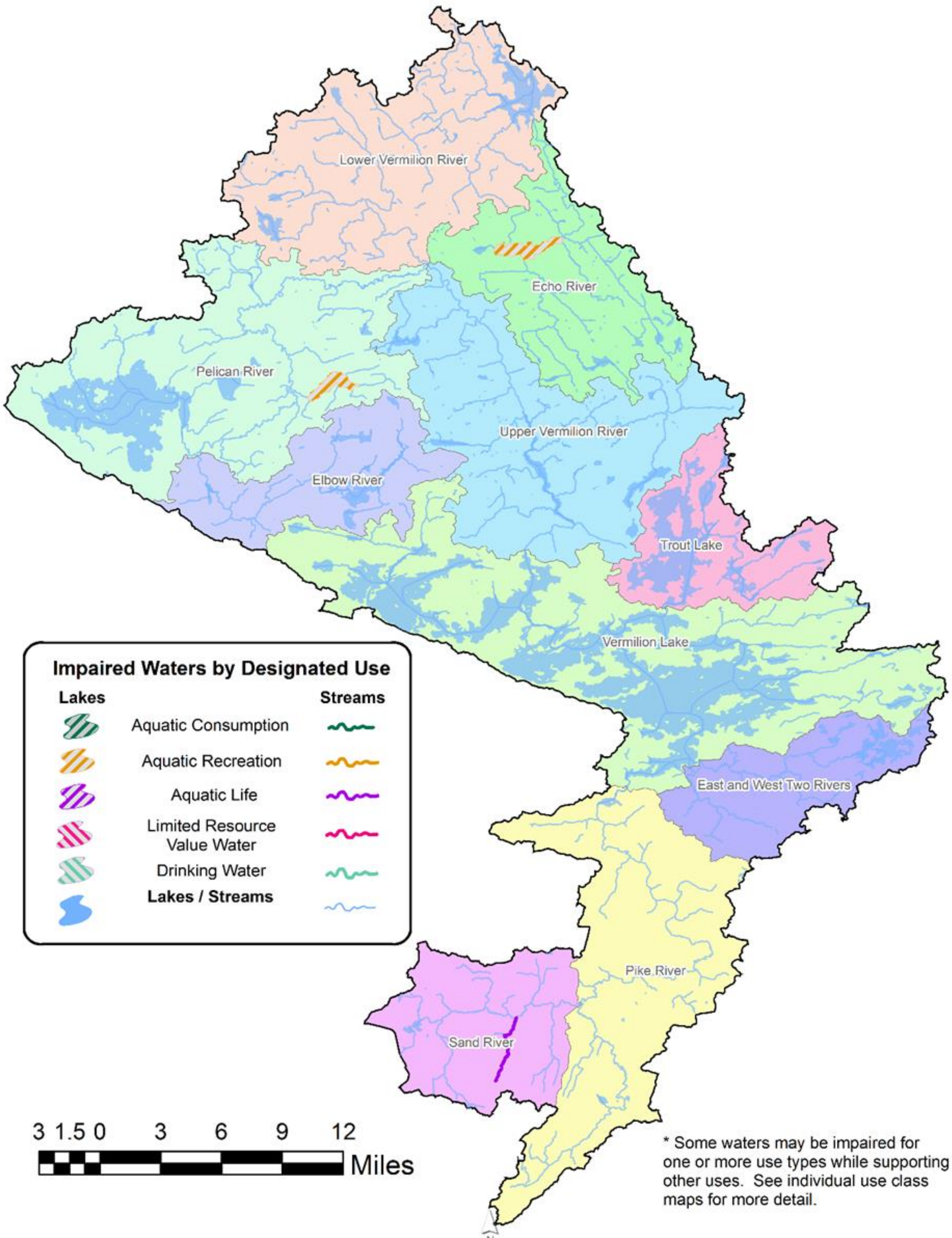


Figure 50. Aquatic consumption use support in the Vermilion River Watershed.

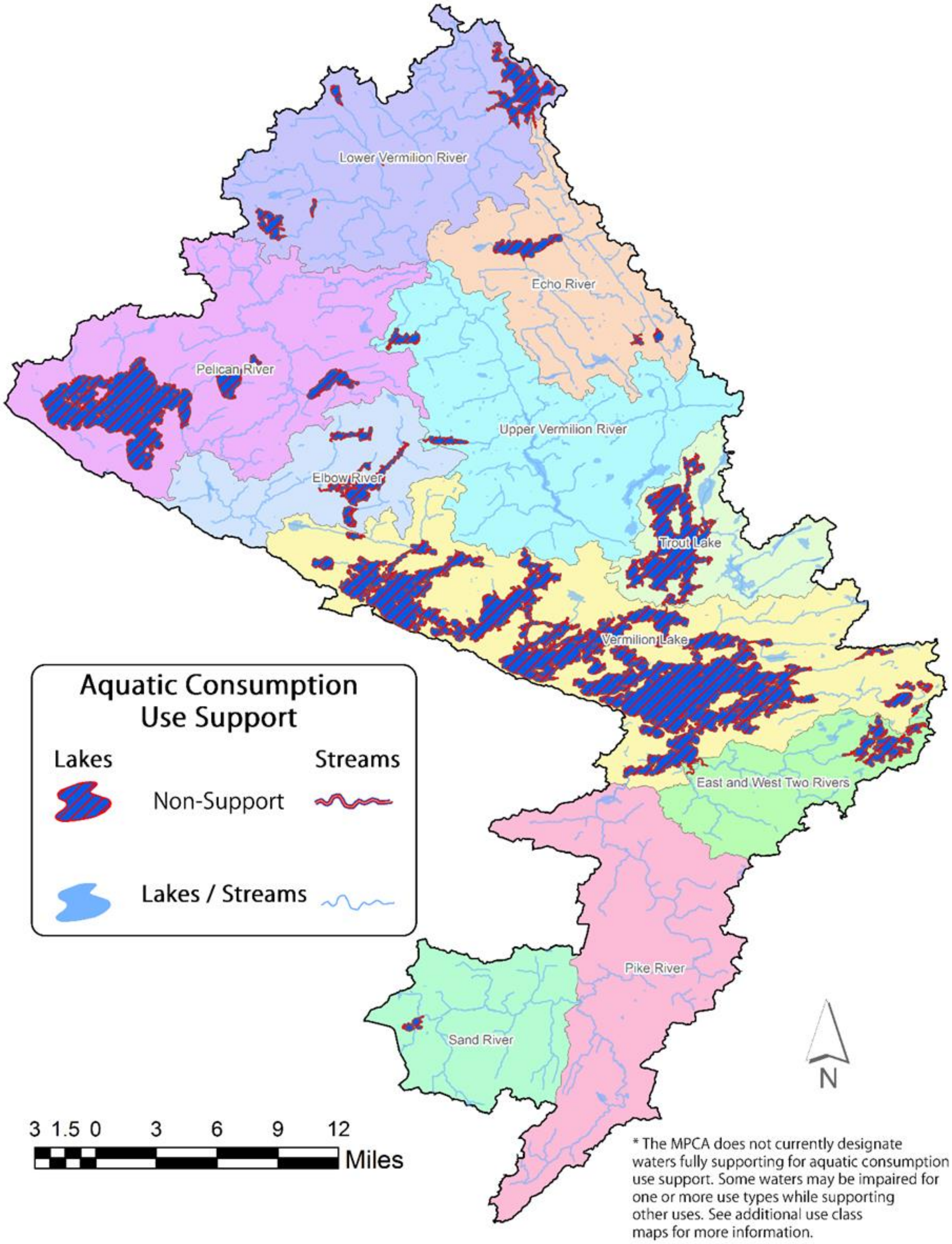


Figure 51. Aquatic life use support in the Vermilion River Watershed.

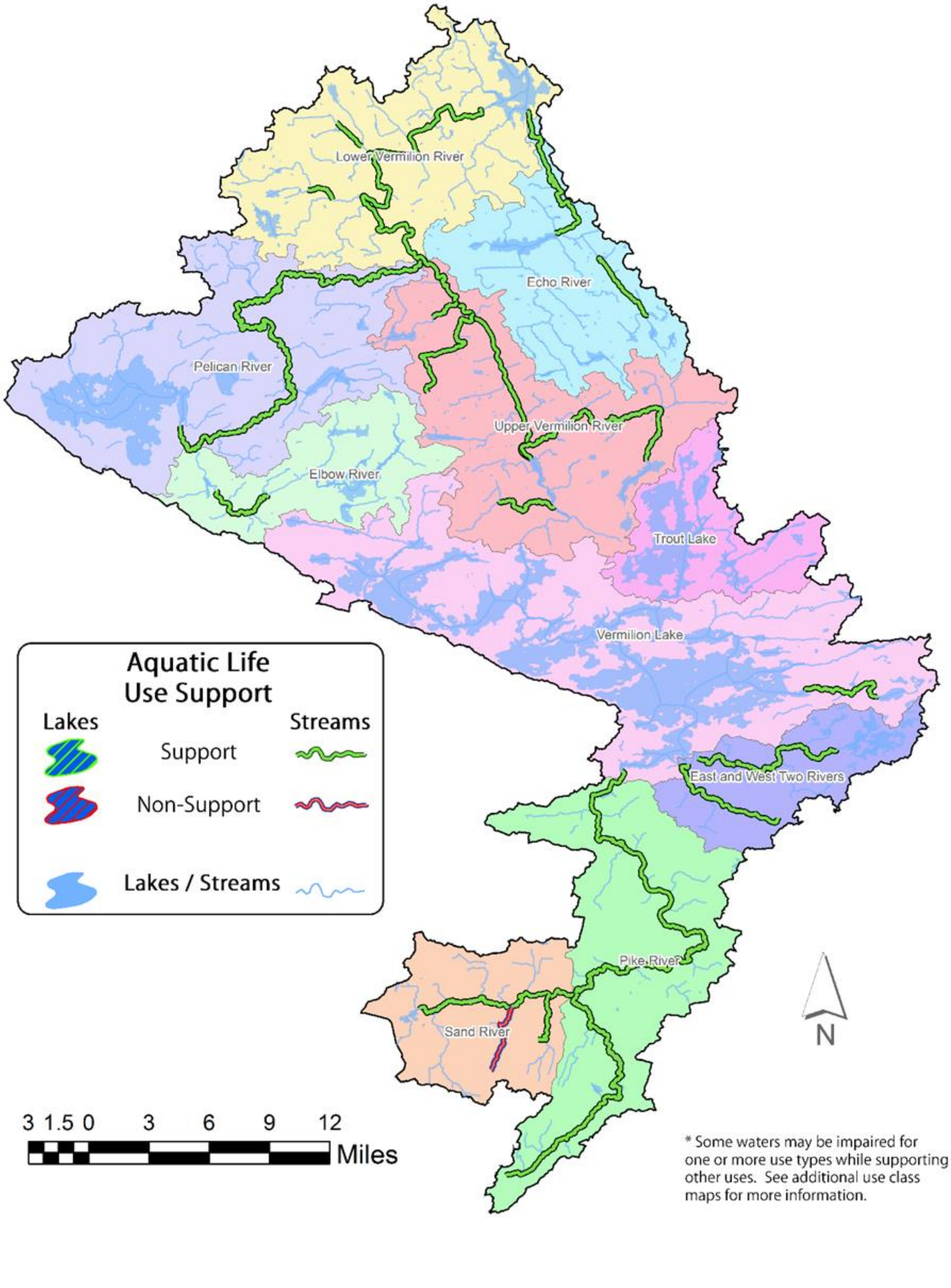
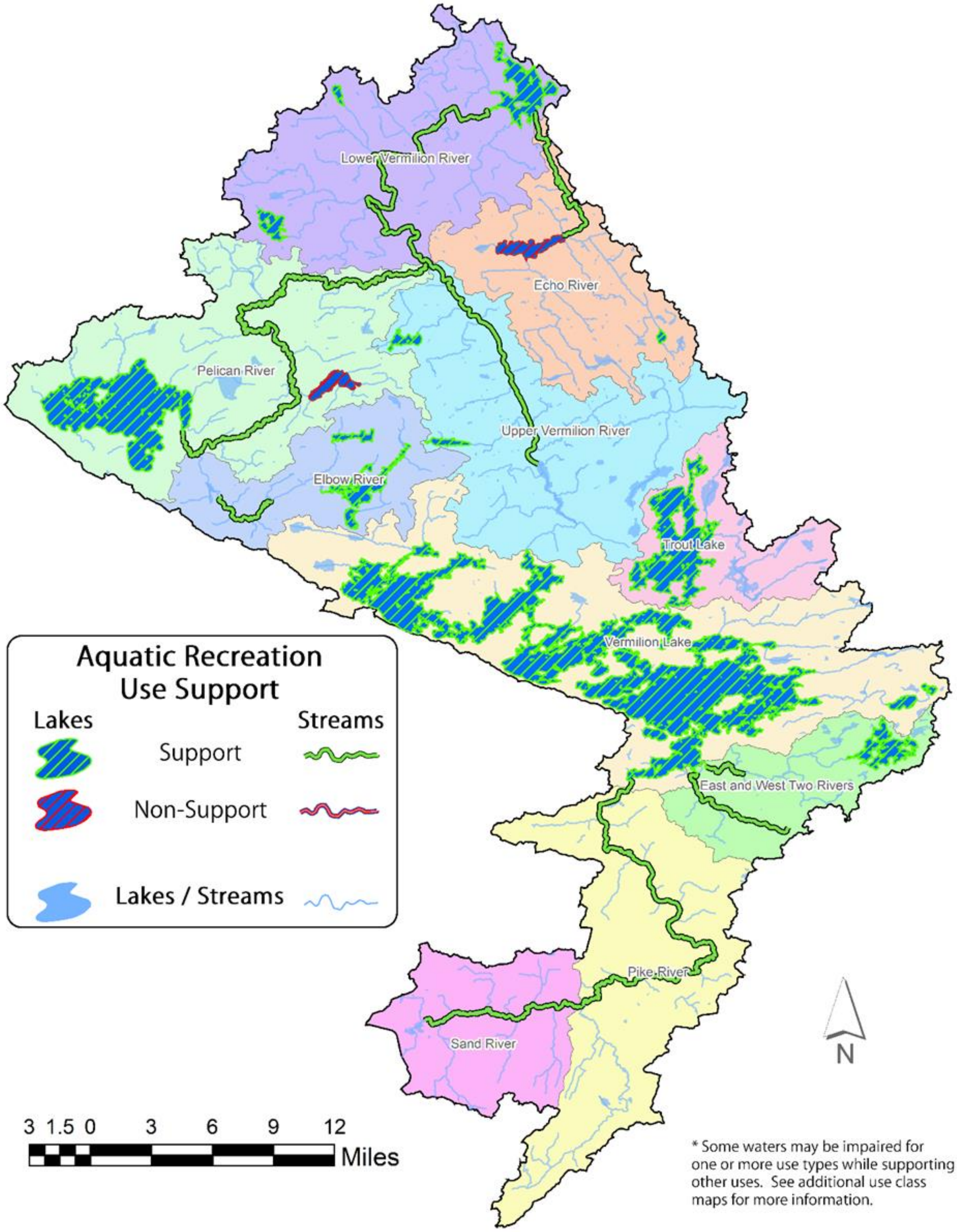


Figure 52. Aquatic recreation use support in the Vermilion River Watershed.



Transparency trends for the Vermilion River Watershed

MPCA completes annual trend analysis on lakes and streams across the state based on long-term transparency measurements. The data collection for this work relies heavily on volunteers across the state and also incorporates any agency and partner data submitted to EQuIS.

The trends are calculated using a Seasonal Kendall statistical test for waters with a minimum of eight years of transparency data; Secchi disk measurements in lakes and Secchi tube measurements in streams.

There are two citizen stream monitoring volunteers in the Vermilion River Watershed; there are insufficient data at these locations to determine long-term trends in stream transparency. Long-term trends in Secchi transparency vary among the lakes. A total of 14 lakes had sufficient data to determine temporal trends. Four lakes have increasing trends, while one lake had declining trends – Eagles Nest #2.

Table 24. Water Clarity Trends.

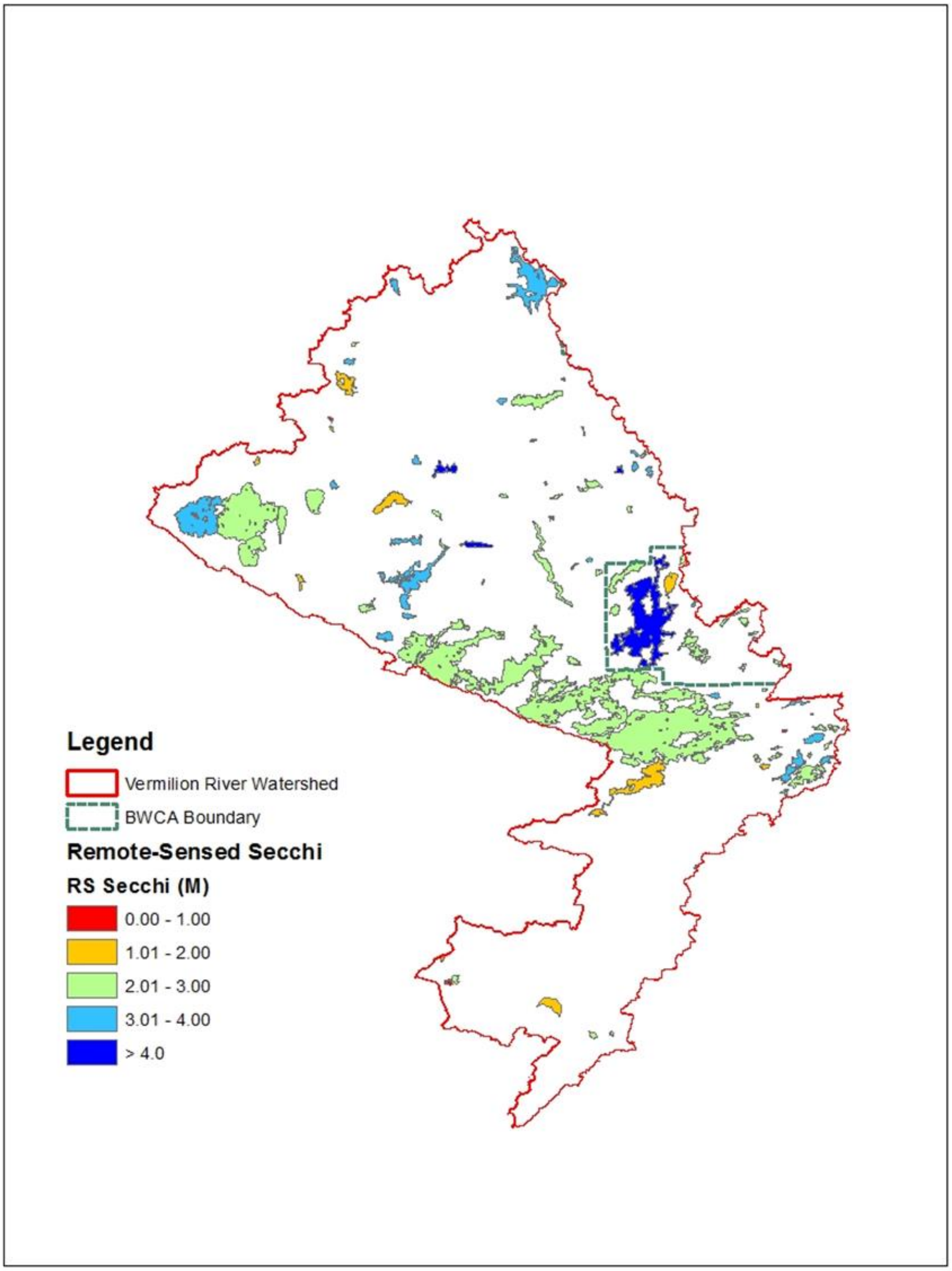
Vermilion River Watershed HUC 09030002	Streams	Lakes
Number of sites w/increasing trend	0	4
Number of sites w/decreasing trend	0	1
Number of sites w/no trend	2	9

In June 2014, the MPCA published its final trend analysis of river monitoring data located statewide based on the historical Milestones Network. The network is a collection of 80 monitoring locations on rivers and streams across the state with good, long-term water quality data. The period of record is generally more than 30 years, through 2010, with monitoring at some sites going back to the 1950s. While the network of sites is not necessarily representative of Minnesota's rivers and streams as a whole, they do provide a valuable and widespread historical record for many of the state's waters. Starting in 2017, the MPCA will be switching to the Pollutant Load Monitoring Network for long-term trend analysis on rivers and streams. Data from this program has much more robust sampling and will cover over 100 sites across the state.

Remote sensing for lakes in the Vermilion River Watershed

The University of Minnesota has developed methods to use satellite imagery to estimate Secchi transparency. Remotely sensed Secchi varied from ~ 1 to greater than 4 meters (Figure 53), and compared favorably to monitored transparency in most lakes. Remotely sensed transparency was lowest in the shallow lakes (such as Myrtle and Pike Bay of Lake Vermilion) and was highest in deep, less-productive undeveloped lakes (such as Trout and Winchester).

Figure 53. Remotely sensed Secchi transparency on lakes in the Vermilion River Watershed.



Priority waters for protection and restoration in the Vermilion River Watershed

The MPCA and DNR have been developing methods to help identify waters that are high priority for protection and restoration activities. Protecting lakes and streams from degradation requires consideration of how human activities impact the lands draining to the water. In addition, helping to determine the risk for degradation allows for prioritization to occur; so limited resources can be directed to waters that would benefit most from implementation efforts.

The results of the analysis are provided to watershed project teams for use during WRAPS and One Watershed One Plan or other local water plan development. The results of the analysis are considered a preliminary sorting of possible protection priorities and should be followed by a discussion and evaluation with other resource agencies, project partners and stakeholders. Other factors that are typically considered during the protection prioritization process include: whether a water has an active lake or river association, is publically accessible, presence of wild rice, presence of invasive, rare or endangered species, as well as land use information and/or threats from proposed development. Opportunities to gain or enhance multiple natural resource benefits ("benefit stacking") is another consideration during the final protection analysis. At present, the prioritization methodology has been developed for lakes based on recreation use and is summarized below (MPCA 2017). Stream Protection and Prioritization method development is nearing completion. Waterbodies identified during the assessment process as vulnerable to impairment are also included in the summary below.

The results for selected indicators and the risk priority ranking for each lake are shown in Appendix 6.

Although all streams deserve protection, special consideration should be given to streams which have statistically indicated a risk of being degraded based on their current habitat and biological characteristics, or where watershed risk has been rated as highly susceptible to disturbance. Within the Vermilion River Watershed, five streams have been identified with these characteristics. They include: Bug Creek, Hilda Creek, Huntingshack River, Echo River, and Flap Creek. Every effort should be made to protect and preserve the biological integrity of these waters for years to come.

The DNR and MPCA have developed criteria for protection of high-quality unimpaired lakes at the greatest risk of water quality decline. The methods estimate a probability of loss of transparency due to an increase in phosphorus reaching the lake. Each lake with sufficient data has a unique phosphorus load reduction target or goal; identified as the 25th percentile of monitored summer-mean concentration (this value is different, and more stringent, than the lake's applicable phosphorus standard). These data are compared to the percentage of the lake-shed with disturbed land-use. In the Vermilion River Watershed, disturbed land-use is very low (maximum of 3% on three lakes) and most often urbanization – lakeshore development and road density. The highest quality, most at-risk lakes include the Eagles Nest Chain (Appendix 6). Pelican Lake at Orr, Minnesota would also be a strong candidate for protection, because it is close to both recreational use impairment and its lake specific phosphorus target, and is one of the most developed lakes in the watershed.

Summaries and recommendations

As a whole, the Vermilion River Watershed is relatively undisturbed compared to other watersheds in Minnesota. Protected lands in the watershed include a portion within the Boundary Waters Canoe Area Wilderness (BWCA). The watershed is highly valued as a recreational resource and is one of the few areas remaining in the state where citizens can go to experience a truly wild and natural environment. The biological and chemical monitoring conducted during the 2015-2016 intensive Watershed Monitoring effort support the fact that water resources in the Vermilion River Watershed are in excellent condition including most of its lakes, the Vermilion River main-stem and most of its upstream tributaries.

The Vermilion River Watershed is home to a number of large, relatively pristine lakes. Pelican Lake, Crane Lake, Lake Vermilion, and the Eagles Nest Chain of Lakes all provide a wealth of recreation opportunities for residents and visitors to the area. The watershed is also home to two Sentinel Lakes, providing high resolution monitoring to help track changes due to a warming climate; Elephant and Echo lakes.

Efforts should be made to minimize significant land use changes in this watershed to ensure the quality and integrity of the water resources for years to come. In areas of higher development pressure, such as Pelican Lake, it will be important for best management practices to be in place to mitigate nutrient inputs and protect water quality.

Groundwater quality and quantity

Although groundwater is not considered a resource concern in the Vermilion River Watershed, groundwater protection should be considered for both for quantity and quality. Quantity is based on the amount of water withdrawn versus the amount of water being recharged to the aquifer. Groundwater availability is limited in this area, despite high recharge rates, due to the abundance of bedrock that can make drilling and extraction difficult. Groundwater withdrawals in the watershed have decreased significantly from 1996 to 2015 ($p<0.001$), while surface water withdrawals are increasing ($p<0.05$).

There is also a limited amount of groundwater quality data available specifically for the Vermilion River Watershed. Baseline water quality data indicated that the Northwest region has groundwater quality that is considered good when compared to areas with similar aquifers, despite some exceedances to drinking water criteria. MDH determined that this area also had some exceedances of arsenic's MCL. Arsenic is primarily naturally occurring and can be linked to presence of a clay layer and low dissolved oxygen levels, often associated with the Des Moines glacial lobe till, which is abundant in this region. Furthermore, the pollution sensitivity of near-surface materials throughout the watershed should be considered. The majority of the watershed has bedrock at the near surface and lacks deep layers of surficial material to protect groundwater from possible risk of contamination, while the lower portion of the watershed has low to high pollution sensitivity. Additionally, it is estimated that the development pressure is moderate throughout the watershed where land is converted from occasional lands to timberland or recreation (USDA NRCS). As population increases in this area, development and deforestation may also increase, and while it may appear that this watershed does not exhibit a great risk at this time, it is important to continue to monitor potentially harmful sites in order to inhibit possible water pollution.

Additional and continued monitoring will increase the understanding of the health of the watershed and its groundwater resources and aid in identifying the extent of the issues present and risk associated. Increased localized monitoring efforts will help accurately define the risks and extent of any issues within the watershed. Adoption of best management practices will benefit both surface and groundwater.

Literature cited

Acreman, M., and J. Holden. 2013. How wetlands affect floods. Wetlands 33:773-786.

Hobbs, H.C. and Goebel, J. E. (1982), Geologic Map of Minnesota, Quaternary Geology, S-01. Minnesota Geological Survey. Using: *ArcGIS* [GIS software]. Version 10.3.1. Redlands, CA: Environmental Systems Research Institute. Retrieved from https://conservancy.umn.edu/handle/11299/60085

Jirsa, M.A., Boerboom, T. J., Chandler, V.W., Mossler, J. H., Runkel, A. C. and Setterholm, D. R. (2011), Geologic Map of Minnesota, Bedrock Geology, S-21. Minnesota Geological Survey. Using: *ArcGIS* [GIS software]. Version 10.3.1. Redlands, CA: Environmental Systems Research Institute. Retrieved from https://conservancy.umn.edu/handle/11299/101466

Kloiber, S.M. and D.J. Norris. 2013. Status and trends of wetlands in Minnesota: wetland quantity trends from 2006 to 2011. Minnesota Department of Natural Resources. St. Paul, MN. http://files.dnr.state.mn.us/eco/wetlands/wstmp_trend_report_2006-2011.pdf

Kroening, S. and Ferrey, M. (2013), The Condition of Minnesota's Groundwater, 2007-2011. Document number: wq-am1-06. Retrieved from https://www.pca.state.mn.us/sites/default/files/wq-am1-06.pdf

Minnesota Department of Health (2016a), Arsenic in Private Wells: Facts & Figures. Retrieved from https://apps.health.state.mn.us/mndata/arsenic_wells

Minnesota Department of Health (2016b), Private Wells - Arsenic. Retrieved from https://apps.health.state.mn.us/mndata/webmap/wells.html

Minnesota Department of Natural Resources (2001), Figure1. Minnesota Ground Water Provinces. Retrieved from http://files.dnr.state.mn.us/natural_resources/water/groundwater/provinces/gwprov.pdf

Minnesota Department of Natural Resources (2016), Pollution Sensitivity of Near-Surface Materials. County Geologic Atlas Program. Using: *ArcGIS* [GIS software]. Version 10.3.1. Redlands, CA: Environmental Systems Research Institute. Retrieved from https://gisdata.mn.gov/dataset/geos-hydrogeology-atlas-hg02

Minnesota Department of Natural Resources (2017a), Groundwater Provinces. Retrieved from http://dnr.state.mn.us/groundwater/provinces/index.html

Minnesota Department of Natural Resources (2017b), Water use- Water Appropriations Permit Program. Retrieved from http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

Minnesota Department of Natural Resources: State Climatology Office (2016), Annual Precipitation Maps. Retrieved from http://www.dnr.state.mn.us/climate/historical/annual_precipitation_maps.html

Minnesota Department of Natural Resources: State Climatology Office (2017), Climate. Retrieved from http://www.dnr.state.mn.us/faq/mnfacts/climate.html

Minnesota Geological Survey (MNGS). 1997. Minnesota at a Glance—Quaternary Glacial Geology. Minnesota Geological Survey, University of Minnesota, St. Paul, MN. http://conservancy.umn.edu/handle/59427

Minnesota Pollution Control Agency (1999), Baseline Water Quality of Minnesota's Principal Aquifers: Region 1, Northeast Minnesota.

Minnesota Pollution Control Agency (2005), Minnesota's Ground Water [PowerPoint slides]. Retrieved from https://www.pca.state.mn.us/sites/default/files/pp-mngroundwater.pdf

Minnesota Pollution Control Agency (2017), What's In My Neighborhood. Retrieved from https://www.pca.state.mn.us/data/whats-my-neighborhood

Minnesota Pollution Control Agency (MPCA). 2007b. Minnesota Statewide Mercury Total Maximum Daily Load. Minnesota Pollution Control Agency, St. Paul, Minnesota.

Minnesota Pollution Control Agency (MPCA). 2008a. Watershed Approach to Condition Monitoring and Assessment. Appendix 5.2 *in* Biennial Report of the Clean Water Council. Minnesota Pollution Control Agency, St. Paul, Minnesota.

Minnesota Pollution Control Agency (MPCA). 2010a. Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity). http://www.pca.state.mn.us/index.php/view-document.html?gid=14922.

Minnesota Pollution Control Agency (MPCA). 2015. Status and Trends of Wetlands Minnesota: Vegetation Quality Baseline. Wq-bwm-1-09. Minnesota Pollution Control Agency, St. Paul, MN. https://www.pca.state.mn.us/sites/default/files/wq-bwm1-09.pdf

Minnesota Pollution Control Agency (MPCA). Guidance Manual for Assessing the Quality of Minnesota Surface Water for the Determination of Impairment: 305(b) Report and 303(d) List. Environmental Outcomes Division, Minnesota Pollution Control Agency, St. Paul, Minnesota.

Minnesota Pollution Control Agency (MPCA). 2010d. Minnesota Milestone River Monitoring Report. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/streams-and-rivers/minnesota-milestone-river-monitoring-program.html.

Minnesota Pollution Control Agency (MPCA). 2010e. Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria. http://www.pca.state.mn.us/index.php/view-document.html?gid=6072.

Minnesota Pollution Control Agency (MPCA). 2017. Incorporating Lake Protection Strategies into WRAPS Reports.

Minnesota Rules Chapter 7050. 2008. Standards for the Protection of the Quality and Purity of the Waters of the State. Revisor of Statutes and Minnesota Pollution Control Agency, St. Paul, Minnesota.

Morey, G.B., and Meints, J. (2000), Geologic Map of Minnesota, Bedrock Geology, S-20. Minnesota Geological Survey. Using: *ArcGIS* [GIS software]. Version 10.3.1. Redlands, CA: Environmental Systems Research Institute. Retrieved from https://mrdata.usgs.gov/geology/state/state.php?state=MN

National Oceanic and Atmospheric Administration: National Centers for Environmental Information (NOAA) (2016), Climate at a Glance: Time Series. Retrieved from http://www.ncdc.noaa.gov/cag/time-series/us/21/0/tavg/12/12/1895-2015?base_prd=true&firstbaseyear=1895&lastbaseyear=2000

National Resource Conservation Service (NRCS). 2007. Rapid Watershed Assessment: Vermilion (MN/IA) HUC: 09030002. NRCS. USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021816.pdf

Streitz, A. (2011), Minnesota Pollution Control Agency. Retrieved from http://www.mgwa.org/newsletter/mgwa2011-4.pdf

United States Department of Agriculture, Natural Resources Conservation Service (No Date), Rapid Watershed Assessment: Vermilion (MN) HUC: 903002. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021816.pdf

United States Geological Survey (2007), Ground Water Recharge in Minnesota. Retrieved from http://pubs.usgs.gov/fs/2007/3002/pdf/FS2007-3002_web.pdf

United States Geological Survey (2015), Mean Annual Potential Groundwater Recharge Rates from 1996-2010 for Minnesota. Methodology documented in Smith, E.A. and Westernbroek, S.M., 2015 Potential groundwater recharge for the state of Minnesota using the Soil-Water-Balance model, 1996-2010: U.S. Geological Survey Investigations Report 2015-5038. Using: *ArcGIS* [GIS software]. Version 10.3.1. Redlands, CA: Environmental Systems Research Institute. Retrieved from https://conservancy.umn.edu/handle/11299/60085

United States Geological Survey (2016), Aquifers and Groundwater. Retrieved from http://water.usgs.gov/edu/earthgwaquifer.html

United States Geological Survey (2017), USGS 05129115 Vermilion River near Crane Lake, MN. Retrieved from https://waterdata.usgs.gov/mn/nwis/inventory/?site_no=05129115

Western Regional Climate Center (WRCC) (2017), U.S.A. Divisional Climate Data. Retrieved from http://www.wrcc.dri.edu/spi/divplot1map.html

Zhang, H. (1998), Geologic Atlas of Stearns County, Minnesota: Hydrogeology of the Quaternary Water Table System. County Atlas Series, Atlas C-10, part B, Plate 8 of 10, Hydrogeology of the Quaternary Water-table System.

Appendix 1. Water chemistry definitions

Dissolved oxygen (DO) - Oxygen dissolved in water required by aquatic life for metabolism. Dissolved oxygen enters into water from the atmosphere by diffusion and from algae and aquatic plants when they photosynthesize. Dissolved oxygen is removed from the water when organisms metabolize or breathe. Low DO often occurs when organic matter or nutrient inputs are high, and light inputs are low.

Escherichia coli (*E. coli*) - A type of fecal coliform bacteria that comes from human and animal waste. *E. coli* levels aid in the determination of whether or not fresh water is safe for recreation. Disease-causing bacteria, viruses and protozoans may be present in water that has elevated levels of *E. coli*.

Nitrate plus Nitrite – Nitrogen - Nitrate and nitrite-nitrogen are inorganic forms of nitrogen present within the environment that are formed through the oxidation of ammonia-nitrogen by nitrifying bacteria (nitrification). Ammonia-nitrogen is found in fertilizers, septic systems and animal waste. Once converted from ammonia-nitrogen to nitrate and nitrite-nitrogen, these species can stimulate excessive levels of algae in streams. Because nitrate and nitrite-nitrogen are water soluble, transport to surface waters is enhanced through agricultural drainage. The ability of nitrite-nitrogen to be readily converted to nitrate-nitrogen is the basis for the combined laboratory analysis of nitrate plus nitrite-nitrogen (nitrate-N), with nitrite-nitrogen typically making up a small proportion of the combined total concentration. These and other forms of nitrogen exist naturally in aquatic environments; however, concentrations can vary drastically depending on season, biological activity, and anthropogenic inputs.

Orthophosphate - Orthophosphate (OP) is a water-soluble form of phosphorus that is readily available to algae (bioavailable). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from wastewater treatment plants, noncompliant septic systems and fertilizers in urban and agricultural runoff.

pH - A measure of the level of acidity in water. Rainfall is naturally acidic, but fossil fuel combustion has made rain more acid. The acidity of rainfall is often reduced by other elements in the soil. As such, water running into streams is often neutralized to a level acceptable for most aquatic life. Only when neutralizing elements in soils are depleted, or if rain enters streams directly, does stream acidity increase.

Total Kjeldahl nitrogen (TKN) - The combination of organically bound nitrogen and ammonia in wastewater. TKN is usually much higher in untreated waste samples then in effluent samples.

Total phosphorus (TP) - Nitrogen (N), phosphorus (P) and potassium (K) are essential macronutrients and are required for growth by all animals and plants. Increasing the amount of phosphorus entering the system therefore increases the growth of aquatic plants and other organisms. Excessive levels of Phosphorous over stimulate aquatic growth and resulting in the progressive deterioration of water quality from overstimulation of nutrients, called eutrophication. Elevated levels of phosphorus can result in: increased algae growth, reduced water clarity, reduced oxygen in the water, fish kills, altered fisheries and toxins from cyanobacteria (blue green algae) which can affect human and animal health.

Total suspended solids (TSS) – TSS and turbidity are highly correlated. Turbidity is a measure of the lack of transparency or "cloudiness" of water due to the presence of suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter and plankton or other microscopic organisms. The greater the level of TSS, the murkier the water appears and the higher the measured turbidity.

Higher turbidity results in less light penetration, which may harm beneficial aquatic species and may favor undesirable algae species. An overabundance of algae can lead to increases in turbidity, further compounding the problem.

Unionized ammonia (NH3) - Ammonia is present in aquatic systems mainly as the dissociated ion $NH4^{+}$, which is rapidly taken up by phytoplankton and other aquatic plants for growth. Ammonia is an excretory product of aquatic animals. As it comes in contact with water, ammonia dissociates into $NH4^{+}$ ions and ^{-}OH ions (ammonium hydroxide). If pH levels increase, the ammonium hydroxide becomes toxic to both plants and animals.

Appendix 2.1. Intensive watershed monitoring water chemistry stations in the Vermilion Watershed

EQuIS ID	Biological station ID	WID	Waterbody name	Location	Aggregated 12-digit HUC
S013-257	15RN001	09030002-503	Pike River	At CSAH 26 (Wahlsten Rd), 3 mi. W of Wahlsten.	Pike River
S013-258	15RN002	09030002-509	West Two River	At West Two Rd, 1 mi. W of Tower.	East and West Two Rivers
	15RN003	09030002-504	East Two River	At Pine Street, in Tower.	East and West Two Rivers
S013-262	15RN007	09030002-532	Echo River	At CR 424 (Nelson Rd), 1 mi. SE of Crane Lake.	Echo River
S013-261	15RN006	09030002-530	Pelican River	At Forest Rd 609, 5 mi. NE of Cusson.	Pelican River
S010-248	05RN090	09030002-570	Vermilion River	US of FR 491, 2.5 mi W of Crane Lake.	Vermilion River 8 digit HUC
S010-236	05RN078	09030002-503	Sand River	At Rice River Road, 2 mi. East of Britt.	Sand River
S013-260	15RN005	09030002-529	Vermilion River	At CSAH 24, in Buyck.	Upper Vermilion River
S013-259	15RN004	09030002-604	Elbow River	At CR 905, 3 mi. NE of Gheen.	Elbow River

Appendix 2.2. Intensive watershed monitoring biological monitoring stations in the Vermilion River Watershed

WID	Biological station ID	Waterbody name	Biological station location	County	Aggregated 12-digit HUC
09030002-509	15RN002	West Two River	Upstream of West Two Rd, 1 mi. W of Tower	Saint Louis	East and West Two Rivers
09030002-509	15RN026	West Two River	Downstream of Rivers Rd, 1.5 mi. S of Tower	Saint Louis	East and West Two Rivers
09030002-647	15RN028	East Two River	Downstream of unnamed road, just SE of Murray	Saint Louis	East and West Two Rivers
09030002-532	15RN007	Echo River	Upstream of CR 424 (Nelson Rd), 1 mi. SE of Crane Lake	Saint Louis	Echo River
09030002-583	15RN015	Hunting Shack River	Downstream of FR 199 (NE off Echo TR), 7.5 mi. E of Buyck	Saint Louis	Echo River
09030002-604	15RN004	Elbow River	Upstream of CR 905, 3 mi. NE of Gheen	Saint Louis	Elbow River
09030002-531	14RN152	Vermilion River	Downstream of FR 601, 5.5 mi. NW of Buyck	Saint Louis	Lower Vermilion River
09030002-531	05RN090	Vermilion River	Upstream of FR 491, 4 mi. W of Crane Lake	Saint Louis	Lower Vermilion River
09030002-565	15RN020	Flap Creek	Upstream of FR 203, 7.5 mi. W of Crane Lake	Saint Louis	Lower Vermilion River
09030002-593	15RN018	Bug Creek	Downstream of FR 203, 10 mi. SW of Crane Lake	Saint Louis	Lower Vermilion River
09030002-530	15RN006	Pelican River	Downstream of FR 609, 5 mi. NE of Cusson	Saint Louis	Pelican River
09030002-530	15RN023	Pelican River	Upstream of Johnson Rd, 1 mi. SE of Orr	Saint Louis	Pelican River
09030002-502	15RN022	Pike River	Upstream of CSAH 21, 4 mi. E of Britt	Saint Louis	Pike River
09030002-503	05RN077	Pike River	Downstream of CR 373, 8.5 mi. N of Biwabik	Saint Louis	Pike River
09030002-503	15RN001	Pike River	Upstream of CSAH 26 (Wahlsten Rd), 3 mi. W of Wahlsten	Saint Louis	Pike River
09030002-645	15RN021	Trib. to Sand River	Downstream of CR 307 (Wuori Rd), 2 mi. SE of Britt	Saint Louis	Sand River
09030002-501	05RN078	Sand River	Upstream of CR 303, 7 mi. NE of Virginia	Saint Louis	Sand River
09030002-572	15RN024	Wouri Creek	Upstream of CR 368 (Stockland Rd), 3 mi. E of Britt	Saint Louis	Sand River

WID	Biological station ID	Waterbody name	Biological station location	County	Aggregated 12-digit HUC
09030002-646	15RN025	Trib. to Vermilion River.	Upstream of River Rd, 1.5 mi. W of Buyck	Saint Louis	Upper Vermilion River
09030002-529	05RN021	Vermilion River	Downstream of CR 24, 13.5 mi. NE of Cusson	Saint Louis	Upper Vermilion River
09030002-529	15RN005	Vermilion River	Downstream of CR 24, in Buyck	Saint Louis	Upper Vermilion River
09030002-644	15RN014	Trib. to Vermilion River	Upstream of CSAH 23, 0.5 mi. W of Buyck	Saint Louis	Upper Vermilion River
09030002-610	15RN010	Twomile Creek	Downstream of CR 422, 9 mi. S of Buyck	Saint Louis	Upper Vermilion River
09030002-528	15RN012	Hilda Creek	Upstream of FR 200, 19 mi. E of Orr	Saint Louis	Upper Vermilion River
09030002-505	15RN009	Armstrong River	Downstream of unnamed road, 5.5 mi. NE of Tower	Saint Louis	Vermilion Lake

Appendix 3.1. Minnesota statewide IBI thresholds and confidence limits

Class #	Class name	Use class	Exceptional use threshold	General use threshold	Modified use threshold	Confidence limit
Fish						
1	Southern Rivers	2B, 2C	71	49	NA	±11
2	Southern Streams	2B, 2C	66	50	35	±9
3	Southern Headwaters	2B, 2C	74	55	33	±7
10	Southern Coldwater	2A	82	50	NA	±9
4	Northern Rivers	2B, 2C	67	38	NA	±9
5	Northern Streams	2B, 2C	61	47	35	±9
6	Northern Headwaters	2B, 2C	68	42	23	±16
7	Low Gradient	2B, 2C	70	42	15	±10
11	Northern Coldwater	2A	60	35	NA	±10
Invertebrates						
1	Northern Forest Rivers	2B, 2C	77	49	NA	±10.8
2	Prairie Forest Rivers	2B, 2C	63	31	NA	±10.8
3	Northern Forest Streams RR	2B, 2C	82	53	NA	±12.6
4	Northern Forest Streams GP	2B, 2C	76	51	37	±13.6
5	Southern Streams RR	2B, 2C	62	37	24	±12.6
6	Southern Forest Streams GP	2B, 2C	66	43	30	±13.6
7	Prairie Streams GP	2B, 2C	69	41	22	±13.6
8	Northern Coldwater	2A	52	32	NA	±12.4
9	Southern Coldwater	2A	72	43	NA	±13.8

Appendix 3.2. Biological monitoring results – fish IBI (assessable reaches)

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi²	Fish class	Threshold	FIBI	Visit date
HUC 12: 0903000201-03 (Sand River)							
09030002-501	05RN078	Sand River	32.27	7	42	56.87	21-Jul-15
09030002-572	15RN024	Wouri Creek	6.48	7	42	59.26	07-Jul-15
09030002-645	15RN021	Unnamed creek	10.39	7	42	0.00	07-Jul-15
HUC 12: 0903000201-01 (Pike River)							
09030002-502	15RN022	Pike River	38.53	6	42	48.60	29-Jun-15
09030002-503	05RN077	Pike River	114.39	5	47	70.44	23-Jul-15
09030002-503	15EM037	Pike River	138.96	5	47	51.20	30-Jun-15
09030002-503	15RN001	Pike River	150.77	5	47	58.78	21-Jul-15
09030002-503	15RN001	Pike River	150.77	5	47	70.71	01-Jul-15
HUC 12: 0903000202-03 (East and West Two Rivers)							
09030002-509	15RN026	West Two River	14.06	11	35	37.10	08-Jul-15
09030002-509	15RN002	West Two River	17.92	11	35	50.18	07-Jul-15
09030002-647	15RN028	East Two River	10.48	11	35	63.09	08-Jul-15
09030002-647	15RN028	East Two River	10.48	11	35	70.54	23-Jun-15
09030002-648	15RN029	East Two River	29.00	7	42	69.05	20-Sep-16
HUC 12: 0903000202-01 (Vermilion Lake)							
09030002-505	15RN009	Armstrong River	12.33	6	42	59.27	24-Jun-15
HUC 12: 09030002-02 (Trout Lake)							
No assessable fish data							

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi^2	Fish class	Threshold	FIBI	Visit date
HUC 12: 0903000205-02 (Upper Vermilion)							
09030002-528	15RN012	Hilda Creek	29.34	7	42	72.48	22-Jul-15
09030002-529	15RN005	Vermilion River	607.27	4	38	59.79	15-Jul-15
09030002-529	05RN021	Vermilion River	615.97	4	38	63.14	15-Jul-15
09030002-610	15RN010	Twomile Creek	12.02	7	42	41.65	30-Jun-15
09030002-644	15RN014	Unnamed creek	9.46	6	42	54.63	21-Jul-15
09030002-646	15RN025	Unnamed creek	6.31	6	42	37.50	07-Jul-15
HUC 12: 0903000203-02 (Elbow River)							
09030002-604	15RN004	Elbow River	41.53	6	42	46.90	30-Jul-15
HUC 12: 0903000203-01 (Pelican River)							
09030002-530	15RN023	Pelican River	127.74	5	47	43.98	09-Jul-15
09030002-530	15RN006	Pelican River	176.69	5	47	42.73	16-Jul-15
HUC 12: 0903000204-01 (Echo River)							
09030002-532	15RN007	Echo River	78.35	5	47	86.36	22-Jul-15
09030002-583	15RN015	Hunting Shack River	14.07	6	42	59.93	29-Jul-15
HUC 12: 0903000205-01 (Lower Vermilion)							
09030002-531	14RN152	Vermilion River	837.69	4	38	54.84	04-Sep-14
09030002-531	14RN152	Vermilion River	837.69	4	38	62.36	15-Jul-15
09030002-531	05RN090	Vermilion River	906.98	4	38	43.77	16-Jul-15
09030002-565	15RN020	Flap Creek	6.72	7	42	64.84	07-Jul-15
09030002-593	15RN018	Bug Creek	9.89	7	42	75.81	30-Jun-15

Appendix 3.3. Biological monitoring results-macroinvertebrate IBI (assessable reaches)

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi^2	Invert class	Threshold	MIBI	Visit date
HUC 12: 0903000201-03 (Sand River)							
09030002-645	15RN021	Unnamed creek	10.39	4	51	70.89	20-Sep-16
09030002-645	15RN021	Unnamed creek	10.39	4	51	41.46	20-Aug-15
HUC 12: 0903000201-01 (Pike River)							
09030002-502	15RN022	Pike River	38.53	3	53	61.10	20-Aug-15
09030002-503	05RN077	Pike River	114.39	3	53	62.00	18-Aug-15
HUC 12: 0903000202-03 (East and West Two Rivers)							
09030002-648	15RN029	East Two River	29.00	4	51	91.94	14-Sep-16
09030002-509	15RN002	West Two River	17.92	8	32	40.86	17-Aug-15
09030002-647	15RN028	East Two River	10.48	8	32	39.38	18-Aug-15
HUC 12: 0903000202-01 (Vermilion Lake)							
09030002-505	15RN009	Armstrong River	12.33	3	53	64.46	27-Aug-15
HUC 12: 09030002-02 (Trout Lake)							
No assessable macroinvertebrate data							
HUC 12: 0903000205-02 (Upper Vermilion)							
09030002-646	15RN025	Unnamed creek	6.31	3	53	76.10	19-Aug-15
09030002-528	15RN012	Hilda Creek	29.34	3	53	54.20	19-Aug-15
09030002-644	15RN014	Unnamed creek	9.46	4	51	68.21	19-Aug-15
HUC 12: 0903000203-02 (Elbow River)							
09030002-604	15RN004	Elbow River	41.53	3	53	59.00	29-Jul-15
HUC 12: 0903000203-01 (Pelican River)							
No assessable macroinvertebrate data							
HUC 12: 0903000204-01 (Echo River)							
09030002-532	15RN007	Echo River	78.35	3	53	69.34	19-Aug-15
09030002-583	15RN015	Hunting Shack River	14.07	3	53	49.00	29-Jul-15
09030002-583	15RN015	Hunting Shack River	14.07	3	53	70.46	20-Sep-16

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi^2	Invert class	Threshold	MIBI	Visit date
HUC 12: 0903000205-01 (Lower Vermilion)							
09030002-531	14RN152	Vermilion River	837.69	1	49	52.50	04-Sep-14
09030002-565	15RN020	Flap Creek	6.72	4	51	63.11	19-Aug-15
09030002-593	15RN018	Bug Creek	9.89	4	51	52.68	19-Aug-15

Appendix 4.1. Fish species found during biological monitoring surveys

Common name	Quantity of stations where present	Quantity of individuals collected
black bullhead	6	58
black crappie	5	53
blackchin shiner	3	13
blacknose dace	6	76
blacknose shiner	4	10
bluegill	3	38
brassy minnow	2	12
brook stickleback	7	188
burbot	15	152
central mudminnow	20	523
common shiner	12	195
creek chub	9	53
fathead minnow	4	13
finescale dace	5	56
golden shiner	15	270
hybrid sunfish	1	1
Iowa darter	5	14
johnny darter	10	116
lamprey ammocoete	1	1
largemouth bass	7	16
logperch	1	1
longnose dace	6	51
mottled sculpin	3	10
northern pike	19	74
northern redbelly dace	8	150
pearl dace	10	256
pumpkinseed	1	3
rock bass	11	116
shorthead redhorse	1	22
smallmouth bass	7	149
spottail shiner	5	72
tadpole madtom	7	31
walleye	7	58
white sucker	23	417
yellow perch	12	340

Appendix 4.2. Macroinvertebrate species found during biological monitoring surveys

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Amphipoda		
Crangonyx	2	5
Hyalella	12	301
Amphipoda	1	6
Basommatophora		
Ferrissia	11	62
Lymnaeidae	5	8
Pseudosuccinea columella	1	1
Bulimnaea megasoma	1	1
Physidae	3	14
Physella	4	47
Planorbidae	6	62
Gyraulus	8	162
Helisoma anceps	4	41
Planorbella	1	1
Coleoptera		
Dytiscidae	6	21
Laccophilus	1	1
Liodessus	2	16
Neoporus	2	3
Stenelmis	9	63
Dubiraphia	7	21
Optioservus	3	22
Macronychus glabratus	3	23
Gyrinidae	1	2
Gyrinus	4	12
Haliplus	7	24
Peltodytes	1	1
Hydraena	5	12
Hydrophilidae	1	1
Anacaena	2	8
Helophorus	1	3
Decapoda		
Orconectes	7	7
Diptera		
Bezzia/Palpomyia	1	4
Ceratopogonidae	4	4
Atrichopogon	2	16
Dasyhelea	1	2
Ceratopogoninae	7	18
Chironomini	1	1

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Chironomus	1	7
Cryptochironomus	2	8
Cryptotendipes	1	1
Dicrotendipes	4	10
Endochironomus	1	5
Glyptotendipes	3	14
Lauterborniella agrayloides	2	3
Microtendipes	10	88
Parachironomus	2	3
Paratendipes	1	2
Phaenopsectra	5	6
Polypedilum	17	155
Stenochironomus	9	19
Tribelos	5	21
Xenochironomus xenolabis	1	1
Culicidae	1	1
Anopheles	2	2
Dixidae	1	1
Dixella	2	3
Roederiodes	1	3
Empididae	1	2
Hemerodromia	9	50
Ephydridae	1	6
Orthocladiinae	3	7
Brillia	1	2
Cardiocladius	1	1
Corynoneura	2	2
Cricotopus	12	55
Eukiefferiella	3	12
Heterotrissocladius	1	1
Hydrobaenus	3	54
Nanocladius	4	30
Orthocladius	6	26
Parakiefferiella	2	3
Parametriocnemus	5	62
Paraphaenocladius	1	1
Psectrocladius	2	2
Rheocricotopus	4	11
Synorthocladius	1	1
Thienemanniella	2	4
Tvetenia	6	53
Xylotopus par	1	2
Orthocladius (Symposiocladius)	1	1
Pseudochironomus	1	1

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Simulium	12	285
Tabanidae	2	4
Thienemannimyia Gr.	16	185
Tanypodinae	4	6
Clinotanypus	1	1
Ablabesmyia	9	34
Conchapelopia	1	1
Labrundinia	1	1
Larsia	1	1
Pentaneura	1	3
Thienemannimyia	2	2
Zavrelimyia	4	15
Procladius	4	15
Tipula	3	4
Antocha	1	2
Pilaria	1	1
Erioptera	1	1
Dicranota	1	1
Neostempellina reissi	2	3
Tanytarsini	6	9
Micropsectra	11	105
Paratanytarsus	7	25
Rheotanytarsus	13	199
Stempellinella	6	29
Tanytarsus	16	74
Ephemeroptera		
Baetisca	2	3
Labiobaetis propinquus	5	31
Baetidae	1	1
Baetis	3	7
Baetis brunneicolor	3	5
Baetis flavistriga	3	6
Callibaetis	1	2
Acerpenna pygmaea	4	31
Procloeon	6	42
Acerpenna	8	27
Acentrella turbida	1	1
Caenis diminuta	7	179
Sparbarus maculatus	1	1
Caenis	1	3
Caenis hilaris	1	6
Ephemerellidae	3	13
Ephemerella	2	39
Eurylophella	12	265

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Eurylophella temporalis	1	29
Heptageniidae	3	18
Stenacron	5	12
Maccaffertium	11	124
Maccaffertium modestum	1	2
Leptophlebiidae	12	123
Paraleptophlebia	1	5
Siphloplecton	1	1
Haplotaxida		
Enchytraeus	4	4
Mesenchytraeus	1	1
Nais	6	12
Tubificinae	4	13
Limnodrilus	1	1
Aulodrilus	1	1
Naididae	2	4
Dero	2	2
Hemiptera		
Belostoma flumineum	5	19
Corixidae	6	23
Sigara	4	14
Trichocorixa	1	1
Gerridae	1	1
Limnoporus	1	4
Mesovelia	1	1
Notonectidae	1	1
Notonecta	4	4
Neoplea striola	3	10
Veliidae	1	1
Rhagovelia	1	2
Microvelia	1	1
Lepidoptera		
Crambidae	2	3
Parapoynx	2	5
Lumbriculida		
Lumbriculus	1	1
Lumbriculidae	3	5
Megaloptera		
Nigronia	4	12
Neotaenioglossa		
Hydrobiidae	7	240
Neuroptera		
Sisyra	1	2
Odonata		

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Aeshnidae	2	3
Aeshna	4	19
Boyeria	3	4
Boyeria vinosa	3	9
Anisoptera	1	1
Calopterygidae	3	18
Hetaerina	1	1
Calopteryx	10	27
Calopteryx aequabilis	2	4
Epitheca canis	1	1
Neurocordulia yamaskanensis	1	1
Corduliidae	9	16
Coenagrionidae	9	59
Cordulegaster	1	1
Gomphidae	2	2
Hagenius brevistylus	1	1
Ophiogomphus rupinsulensis	1	1
Libellulidae	1	4
Macromia illinoiensis	1	1
Plecoptera		
Perlodidae	1	1
Isoperla	1	3
Perlidae	1	5
Acroneuria	2	3
Acroneuria lycorias	3	9
Acroneuria abnormis	1	2
Paragnetina media	5	21
Micrasema	1	1
Micrasema rusticum	2	27
Phylocentropus	1	2
Glossosomatidae	1	3
Glossosoma	1	1
Helicopsyche borealis	2	17
Hydropsyche placoda	1	13
Hydropsychidae	3	22
Diplectrona modesta	1	1
Cheumatopsyche	9	67
Hydropsyche	4	119
Hydropsyche betteni	6	66
Ceratopsyche	3	93
Ceratopsyche sparna	3	22
Hydroptilidae	1	4
Hydroptila	1	2
Oxyethira	8	35

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Lepidostoma	2	7
Oecetis furva	2	5
Oecetis testacea	7	29
Leptoceridae	2	5
Triaenodes	7	27
Mystacides	1	5
Oecetis	2	2
Oecetis avara	2	11
Nectopsyche	1	10
Nectopsyche diarina	1	9
Ceraclea	8	20
Glyphopsyche irrorata	1	1
Limnephilidae	11	54
Pycnopsyche	1	25
Nemotaulius hostilis	3	7
Molanna	2	12
Chimarra	18	324
Phryganeidae	4	13
Ptilostomis	9	89
Phryganea	2	2
Polycentropodidae	6	57
Polycentropus	4	15
Neureclipsis	1	10
Nyctiophylax	1	3
Psychomyia flavida	2	13
Lype diversa	1	1
Unclassified		
Nemata	1	1
Acari	11	74
Hirudinea	9	93
Veneroida		
Pisidiidae	14	82

Appendix 5. Minnesota Stream Habitat Assessment results

Habitat information documented during each fish-sampling visit is provided. This table convey the results of the Minnesota Stream Habitat Assessment (MSHA) survey, which evaluates the section of stream sampled for biology and can provide an indication of potential stressors (e.g., siltation, eutrophication) impacting fish and macroinvertebrate communities. The MSHA score is comprised of five scoring categories including adjacent land use, riparian zone, substrate, fish cover and channel morphology, which are summed for a total possible score of 100 points. Scores for each category, a summation of the total MSHA score, and a narrative habitat condition rating are provided in the tables for each biological monitoring station. Where multiple visits occur at the same station, the scores from each visit have been averaged. The final row in each table displays average MSHA scores and a rating for the aggregated HUC-12 subwatershed.

# Visits	Biological station ID	Reach name	Land use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish cover (0-17)	Channel morph. (0-36)	MSHA score (0-100)	MSHA rating
Habitat Results: *Sand River*									
3	15RN021	Trib. to Sand River	5	10.5	12.6667	13	14	55.1	Fair
1	15RN024	Wouri Creek	5	10.5	12.8	14	16	58.3	Fair
1	05RN078	Sand River	5	10	10	12	15	52	Fair
Average Habitat Results:			5	10.3	11.8	13	15	55.1	Fair
Habitat Results: *Pike River Aggregated*									
2	15RN001	Pike River	5	10.7	18	12	16.5	62.2	Fair
2	15RN022	Pike River	5	11	20.9	15	17	68.9	Good
1	15EM037	Pike River	5	11	11	12	17	56	Fair
2	05RN077	Pike River	5	10.5	17.8	11	17.5	61.8	Fair
Average Habitat Results:			5	10.9	16.7	13	16.8	62.4	Fair
Habitat Results: *East and West Two River*									
3	15RN028	East Two River	5	12.8333	16.06667	13.66	23.6	71.2	Good
1	15RN026	West Two River	5	11.5	19.2	12	18	65.7	Fair
2	15RN002	West Two River	5	12.7	22.3	12.5	29	81.5	Good
2	15RN029	East Two River	5	11	14.15	15	19.5	64.6	Fair
Average Habitat Results:			5	12.4	17.9	13.3	22.5	70.8	Good
Habitat Results: Lake Vermilion									
2	15RN009	Armstrong River	5	13.2	22.2	9	23	72.4	Good
Average Habitat Results:			5	13.2	22.2	9	23	72.4	Good
Habitat Results: Trout Lake									
	No MSHA data								
Habitat Results: Upper Vermilion									
2	15RN012	Hilda Creek	5	10.5	11.0	14	20	60.5	Fair
1	15RN005	Vermilion River	4.5	13.5	21	15	25	79	Good

# Visits	Biological station ID	Reach name	Land use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish cover (0-17)	Channel morph. (0-36)	MSHA score (0-100)	MSHA rating
1	05RN021	Vermilion River	5	13.5	22.9	16	27	84.4	Good
1	15RN010	Twomile Creek	5	10	8	7	13	43	Poor
2	15RN014	Trib. to Vermilion	5	10.5	13.8	14.5	14.5	58.3	Fair
2	15RN025	Trib. to Vermillion	5	12.5	16.5	15	22	71	Good
Average Habitat Results:			4.8	11.9	15.8	13	20.2	66.1	Good

# Visits	Biological station ID	Reach name	Land use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish cover (0-17)	Channel morph. (0-36)	MSHA score (0-100)	MSHA rating
Habitat Results: Elbow River									
1	15RN004	Elbow River	5	12	21.2	12	21	71.2	Good
Average Habitat Results:			5	12	21.2	12	21	71.2	Good
Habitat Results: Pelican River									
1	15RN023	Pelican River	5	10	13.6	14	16	58.6	Fair
1	15RN006	Pelican River	5	11	20	15	14	65	Fair
Average Habitat Results:			5	10.5	16.8	14.5	15	61.8	Fair
Habitat Results: Echo River									
3	15RN015	Hunting Shack	5	12.6667	21.5667	11.66	19.3	70.2	Good
2	15RN007	Echo River	5	11	19.7	12.5	22.5	70.7	Good
Average Habitat Results:			5	11.8	20.7	12.1	20.9	70.5	Good
Habitat Results: Lower Vermilion									
3	14RN152	Vermilion River	5	12.3333	15.7333	15	19.3	67.4	Good
1	05RN090	Vermilion River	5	14	23.8	15	24	81.8	Good
2	15RN018	Bug Creek	5	10.5	11	14.5	15	56	Fair
2	15RN020	Flap Creek	5	11	5	13	11.5	45.5	Fair
Average Habitat Results:			5	13.2	19.8	14.3	17.5	62.7	Fair

Qualitative habitat ratings

= Good: MSHA score above the median of the least-disturbed sites (MSHA>66)

= Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45 < MSHA < 66)

= Poor: MSHA score below the median of the most-disturbed sites (MSHA<45)

Appendix 6. Lake protection and prioritization results

Lake ID	Lake Name	Mean TP	Trend	% Disturbed Land Use	5% load reduction goal	Priority
69061500	Echo	36.1	No Evidence of Trend	1%	236	NA, natural background
69084100	Pelican	31.0	No Evidence of Trend	2%	408	Highest
69021800	Eagles Nest No. Four	10.4	Decreasing Trend	2%	4	Higher
69028501	Eagles Nest #1	9.2	No Evidence of Trend	2%	15	Higher
69028502	Eagles Nest #2	12.0	No Evidence of Trend	2%	18	Higher
69028503	Eagles Nest #3	15.3	No Evidence of Trend	2%	29	Higher
69074100	Susan	33.0	Insufficient Data	2%	16	Higher
69074400	Elbow	10.8	Insufficient Data	1%	58	Higher
69074900	Myrtle	18.8	Insufficient Data	3%	38	Impaired; Higher
69021700	West Robinson	19.7	Insufficient Data	3%	7	High
69027800	Armstrong	26.7	No Evidence of Trend	3%	32	High
69037800	Vermilion	27.0	Increasing Trend	2%	2759	High
69038100	Buck	28.0	Insufficient Data	0%	19	High
69045700	Nigh	57.0	Insufficient Data	2%	14	High
69049800	Trout	11.5	Insufficient Data	0%	180	High
69058800	Pauline	50.0	Insufficient Data	2%	17	High
69058900	Astrid	14.3	Insufficient Data	0%	9	High
69059000	Maude	78.0	Insufficient Data	1%	32	High
69061600	Crane	22.5	Insufficient Data	2%	2619	High

Lake ID	Lake Name	Mean TP	Trend	% Disturbed Land Use	5% load reduction goal	Priority
69069000	Winchester	7.5	Insufficient Data	0%	6	High
69072900	Little Sandy	20.0	Insufficient Data	2%	13	High
69073000	Sandy	17.0	Insufficient Data	2%	15	High
69074000	Black	78.0	Insufficient Data	1%	57	High
69074200	Ban	22.8	Increasing Trend	0%	20	High
69074800	Kjostad	9.8	Insufficient Data	0%	6	High
69075500	Marion	29.0	Insufficient Data	0%	9	High
69076400	Sunset	24.0	Insufficient Data	0%	15	High
69081000	Elephant	17.6	No Evidence of Trend	0%	25	High