Watershed health

July 2018

Roseau River Watershed Monitoring and Assessment Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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List of acronyms

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

EPA U.S. Environmental Protection Agency

EQuIS Environmental Quality Information System

EXP Exceeds Criteria, Potential Impairment

EXS Exceeds Criteria, Potential Severe Impairment

FWMC Flow Weighted Mean Concentration

HUC Hydrologic Unit Code

IBI Index of Biotic Integrity

IWM Intensive watershed monitoring

LRVW Limited Resource Value Water

MDA Minnesota Department of Agriculture

MDH Minnesota Department of Health

MINLEAP Minnesota Lake Eutrophication Analysis Procedure

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

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

UAA Use Attainability Analysis

USGS United States Geological Survey

WMA Wildlife Management Area

WID Waterbody Identification Number

WPLMN Watershed Pollutant Load Monitoring Network

Executive summary

In 2015 and 2016, the Minnesota Pollution Control Agency (MPCA) and local partners conducted intensive watershed monitoring (IWM) of surface waters in the Roseau River Watershed of Northwest Minnesota. One lake and 14 streams were monitored, and the resulting water chemistry and biological data was used to assess the quality and use support of these waters.

Water quality varied from good to poor throughout the watershed. In general, the Roseau River and most tributaries are in good condition, as is Hayes Lake (the watershed's only lake). Several high-quality streams occur in the upper portion of the watershed, where forested areas within Hayes Lake State Park and Beltrami Island State Forest provide benefits to water quality and aquatic habitat. Wetlands in this upper portion of the watershed are also in good condition. However, land use, altered hydrology, and other stressors have impacted the water quality and biological integrity of some streams. Approximately 30% of the monitored streams were not meeting standards for aquatic life or recreation. Wetlands in the agricultural portions of the watershed are generally in poor-to-fair condition.

Some water quality impairments may be related to flood damage reduction efforts (e.g., channel modification, stream diversion) while others may reflect contemporary land use practices such as row crop agriculture and unrestricted livestock access to streams. Some streams may also be suffering legacy effects related to long-ago efforts to improve land for agricultural uses (e.g., wetland drainage). Formal diagnosis of potential stressors will follow the monitoring and assessment component of IWM. At the same time, some water quality improvements are evident, most notably a reduction in total suspended solids (TSS) on lower reaches of the Roseau River.

The aquatic resources of the Roseau River Watershed provide a wide range of benefits and uses. The rivers, streams, lakes, wetlands, and groundwater provide habitat for aquatic life, recreational opportunities and water for irrigation, as well as consumption by wildlife, livestock, and people. Restoration and protection strategies should be developed to both improve the condition of degraded resources and ensure that unimpaired waters remain in good condition.

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 water resources and 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 reductions needed to restore a waterbody so that it can once again support designated uses.

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 resources, potential and actual threats, options for addressing threats, and data regarding 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 and protect the integrity of Minnesota's waters.

The passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and 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 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 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, and to identify both impaired waters and waters in need of additional protection. A benefit of this 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 employed in the past. The watershed approach will more effectively address multiple impairments resulting from 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 Roseau River Watershed beginning in the summer of 2015. This report provides a summary of all water quality assessment results in the Roseau 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 in each of Minnesota's 80 major watersheds. The major benefit of this approach is integration of monitoring resources to provide a more complete and systematic assessment of water quality at a geographic scale useful for 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 spatial scales:

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 IWM strategy utilizes a nested watershed design; streams are monitored from a coarse to a fine scale, and each watershed scale is defined by a hydrologic unit code (HUC). HUCs define watershed boundaries for water bodies within a similar geographic and hydrologic extent. The foundation of this approach are the 80 major watersheds (HUC-8s) within Minnesota's borders. Using this approach, headwaters and tributaries to main stem rivers are sampled in a systematic way so that a comprehensive watershed assessment 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, HUC-8, aggregated 12-digit HUC and HUC-14 (Figure 1). At each scale, different water uses are assessed based on opportunities for particular uses (e.g., fishing, swimming, supporting aquatic life such as fish and insects). The major river watershed is represented by the HUC-8 scale. The outlet of the major watershed is sampled for biological indicators (fish and macroinvertebrates), water chemistry and fish contaminants to allow for assessment of aquatic life, aquatic recreation and aquatic consumption use support. The aggregated 12-digit HUC is a finer-scale subwatershed which generally consists of major tributary streams with drainage areas ranging from 75 to 150 mi^2. Each aggregated 12-digist HUC outlet (green dots in Figure 2) is sampled for biological indicators and water chemistry for assessment of aquatic life and aquatic recreation use support. Within each aggregated 12-digit HUC, "minor watersheds" (HUC-14s, typically 10-20 mi^2), are sampled at each outlet that flows into major tributaries.

Each of these minor watershed outlets is sampled for biological indicators to assess aquatic life use support (red dots in Figure 2).

Figure 1. The Intensive Watershed Monitoring Design.

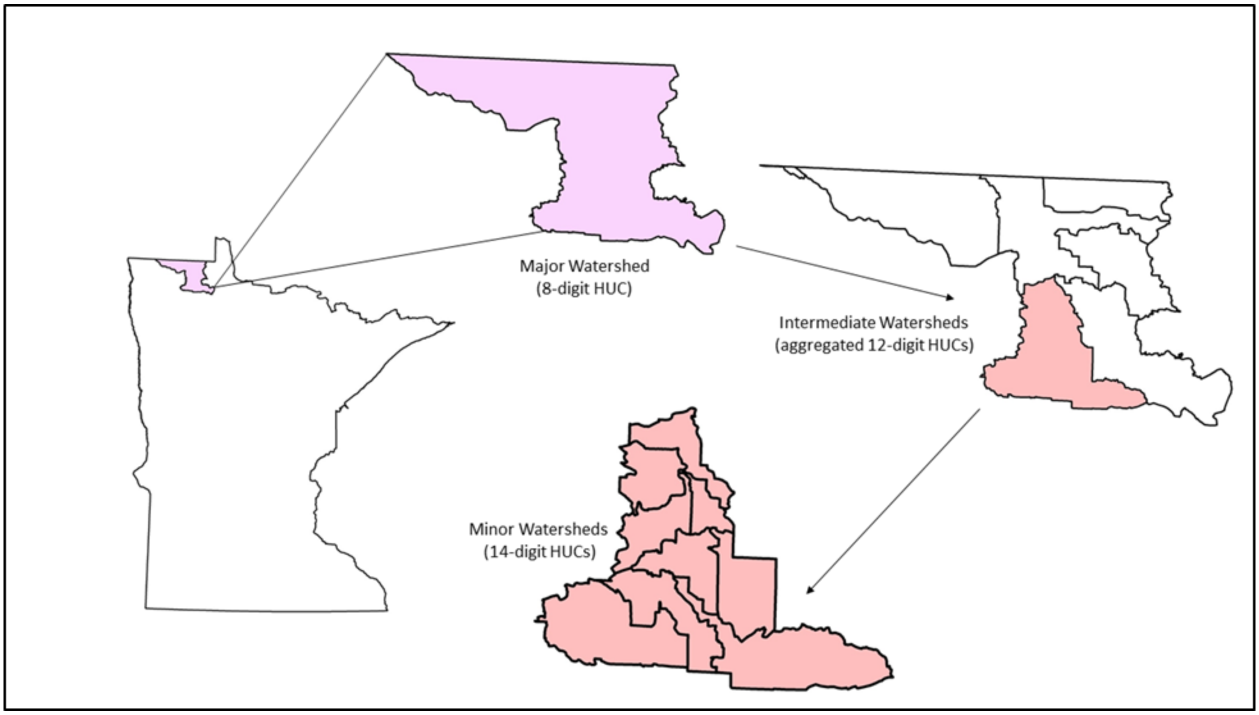
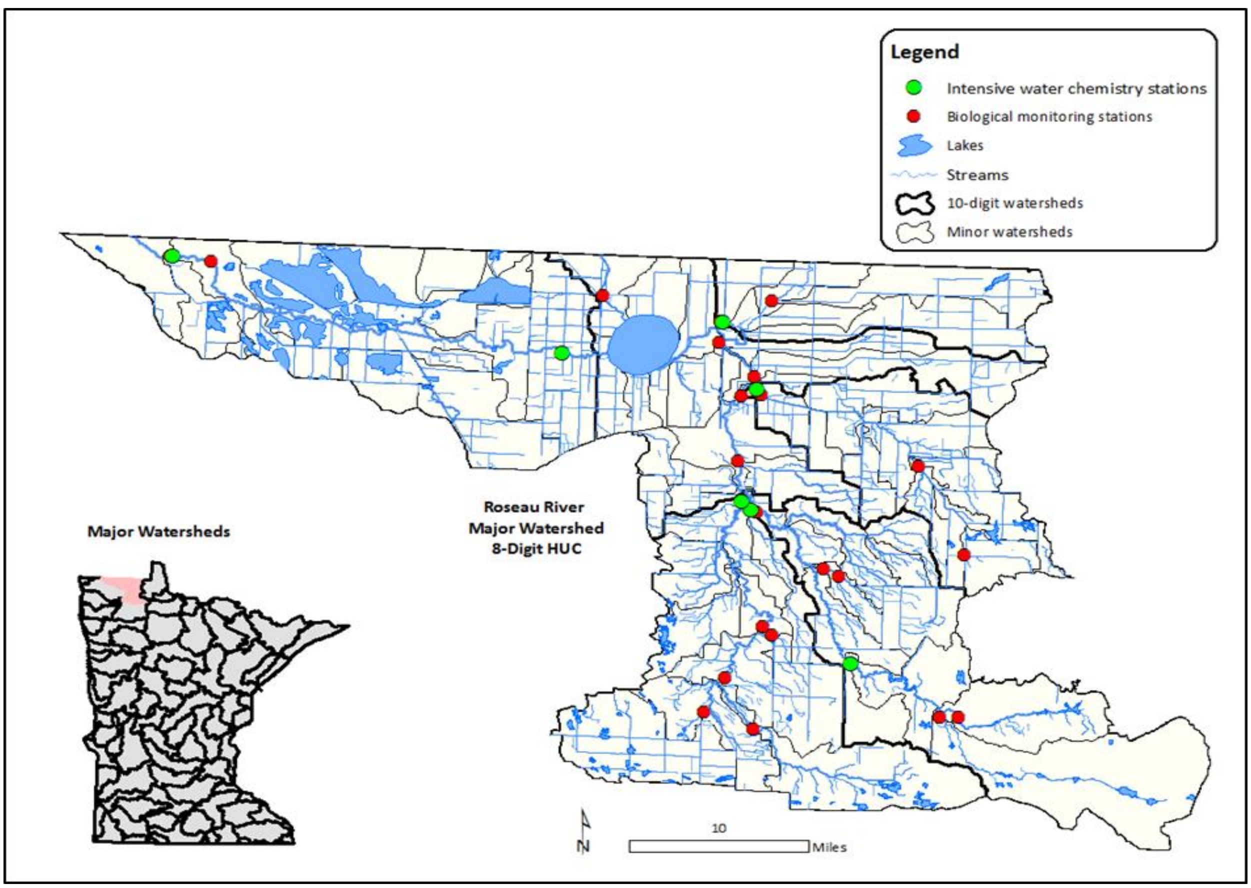


Figure 2. Intensive Watershed Monitoring sites for streams in the Roseau River Watershed.



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 to determine if recreational uses (such as swimming and wading) are being supported and, where applicable, fish community health can be determined. Lakes are prioritized by size, degree of public access, and presence of recreational use.

Citizen and local monitoring

Citizen and local monitoring is an important component of the watershed approach. The MPCA and local partners jointly select stream sites and lakes to be included in the IWM process. Funding for monitoring efforts 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. Local partners use the same monitoring protocols as the MPCA, and 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 observation of long-term trends. This allows citizens/governments to see how their efforts inform water quality decisions and track how management efforts effect change. Many SWAG grantees invite citizen participation in their monitoring projects and this combined participation greatly expands the overall monitoring capacity.

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 a long-term dataset needed to evaluate current status and trends. Citizen monitoring is especially effective in helping to track water quality changes that occur in the years between intensive monitoring years. As of this report's development, there are no citizen monitoring locations in the Roseau River Watershed; however, ongoing monitoring efforts should attempt to establish collaborative relationships with citizens and local partners.

Assessment methodology

The CWA requires states to report every two years on the condition of waters of the state. 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 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 fundamental benchmarks by which the quality of surface waters are measured and impairment status is determined. 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 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 chlorophyll-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 water body 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 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 and the resulting index score characterizes the biological integrity or health of a site. The MPCA has developed distinct stream IBIs for fish and macroinvertebrates since these communities can respond differently to various types of pollution. The MPCA also uses a lake fish community IBI developed by the Minnesota Department of Natural Resources (DNR) to determine if lakes are meeting aquatic life use. Because lakes, rivers, and streams in Minnesota are physically, chemically, and biologically diverse, IBIs are developed separately for different stream classes and lake class groups to account for natural variation. Further interpretation of biological community data is provided by an assessment threshold ("biocriteria") against which an IBI score can be compared. 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. Chemical parameters are also 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 an overall aquatic life use assessment.

Protection for aquatic life uses in streams and rivers are divided into three tiers: Exceptional, General, and Modified (Table 1). Exceptional Use waters support fish and macroinvertebrate communities that have minimal changes in structure and function from natural condition. General Use waters harbor "good" assemblages of fish and macroinvertebrates that have an overall balanced distribution of taxa and with ecosystem functions largely maintained through redundant attributes. Modified Use waters have been extensively altered through legacy physical modifications, which limit the ability of biological communities to attain the General Use. The Modified Use is only applied to streams with channels that have been directly altered by humans (e.g., maintained for drainage, rip-rapped). Tiered uses are determined before assessment based on attainment of applicable biological criteria and an assessment of habitat conditions. 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 Minnesota's streams (approximately 1% of 92,000 miles) have been individually evaluated and re-classified as Class 7 Limited Resource Value Waters (LRVWs). 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 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 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. In this manner, a stream or river is often segmented into multiple assessment units' 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 a United States Geological Survey (USGS) eight-digit hydrologic unit code (HUC-8) plus a three-character code that is unique within each major watershed. Lake and wetland identifiers are assigned by the DNR. The Protected Waters Inventory provides 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 assessment units that data are evaluated for potential use impairment, and assessment of use support is limited to each individual assessment unit. The major exception to this approach 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. For aquatic consumption assessments, impaired reaches are defined by the location of significant barriers to fish movement (such as dams) and may span multiple "standard" assessment units.

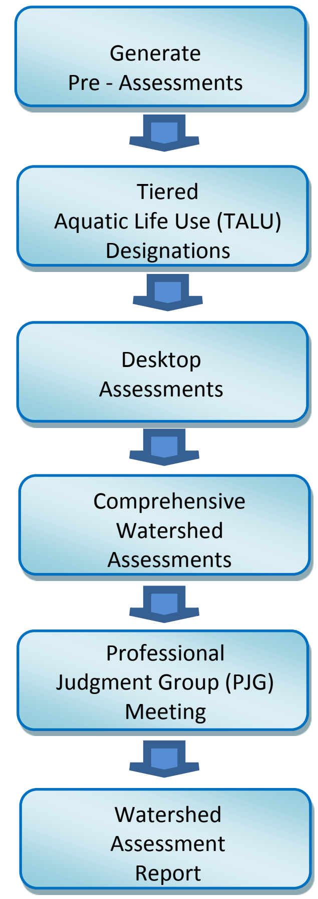
Determining use attainment

For beneficial uses related to human health, such as drinking water or aquatic recreation, the relationship is well understood and thus the assessment process 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. An approach that incorporates multiple lines of evidence into the assessment process has evolved 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 3.

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 reviewed to ensure that data are valid and appropriate for assessment purposes. Tiered use designations are determined before data is assessed based on attainment of applicable biological criteria and habitat conditions. 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 General Use is not attainable as a result of legal human activities (e.g., drainage maintenance, channel stabilization) which limiting biological assemblages through altered habitat. Decisions to propose a new use are made through UAA workgroups, which include watershed project managers and biologists. The final approval to change a designated use occurs through formal rulemaking.

The next step in the aquatic life assessment process is comparison of monitoring data to water quality standards. Pre-assessments are reviewed by either a biologist or water quality professional, depending on whether the parameter is biological or chemical in nature. Reviews are conducted at the workstation of each reviewer (i.e., desktop) using computer applications to analyze 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).

Figure 3. Flowchart of aquatic life use assessment process.



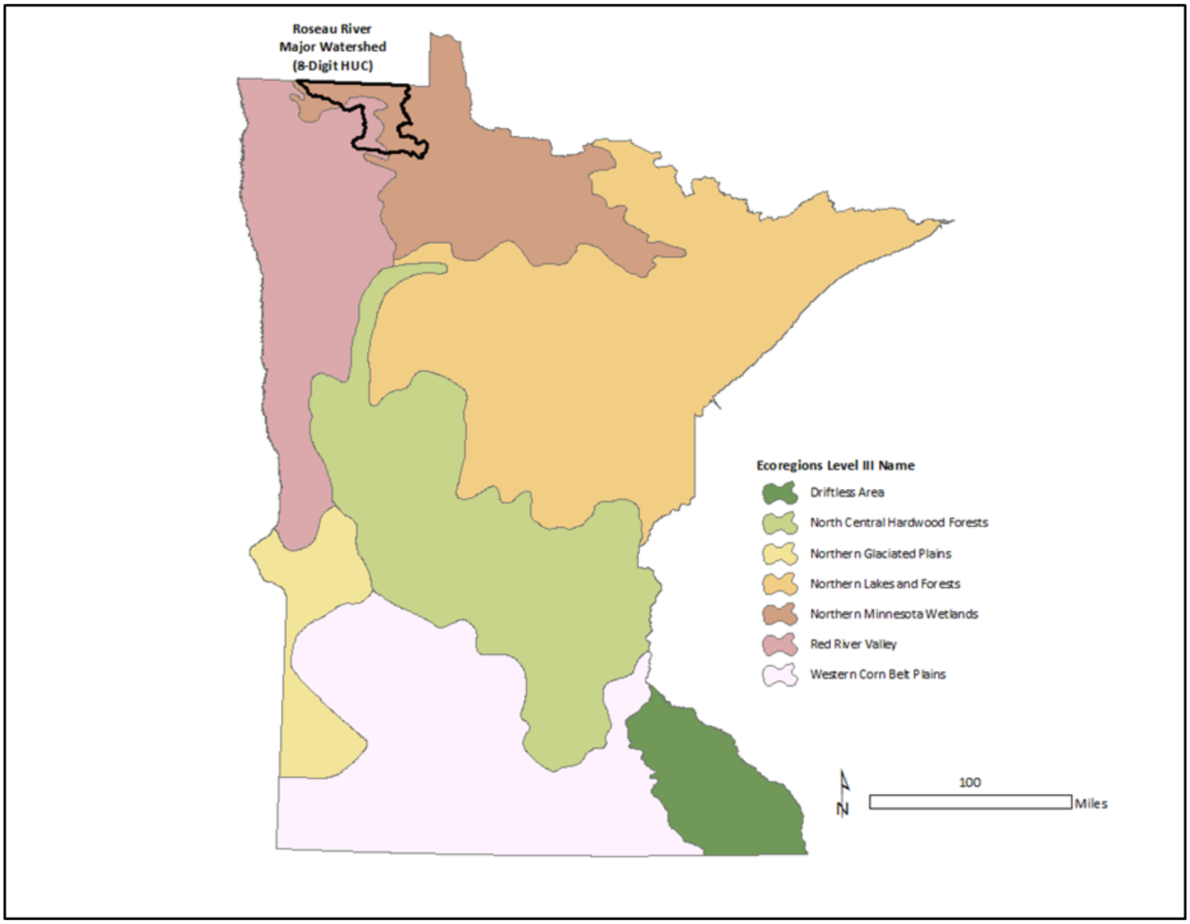
The next step is a Comprehensive Watershed Assessment meeting where reviewers convene to discuss results of their desktop assessments for each individual waterbody. Implementing a comprehensive approach to water quality assessment requires a means of organizing and evaluating information to formulate 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 2018) 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 placed on the draft 303(d) Impaired Waters List. Assessment results are also included in watershed monitoring and assessment reports.

Watershed overview

The Roseau River Watershed drains approximately 1,100 square miles of Roseau and Kittson counties in Northwestern Minnesota. The watershed lies on a low-gradient landscape, most of which is the former bed of Glacial Lake Agassiz, which occupied the region between 8,500 and 12,560 years ago. The highest elevations are in the southeast corner of the watershed, where sand and gravel ridges mark former beaches of the glacial lake. The surficial geology of the watershed is comprised entirely of glacial lake sediments interspersed with peat deposits, reflecting the landscape's Pleistocene setting beneath an inland sea. Most of the watershed lies within the Northern Minnesota Wetlands ecoregion, with a smaller proportion lying in the Red River Valley Ecoregion (Figure 4).

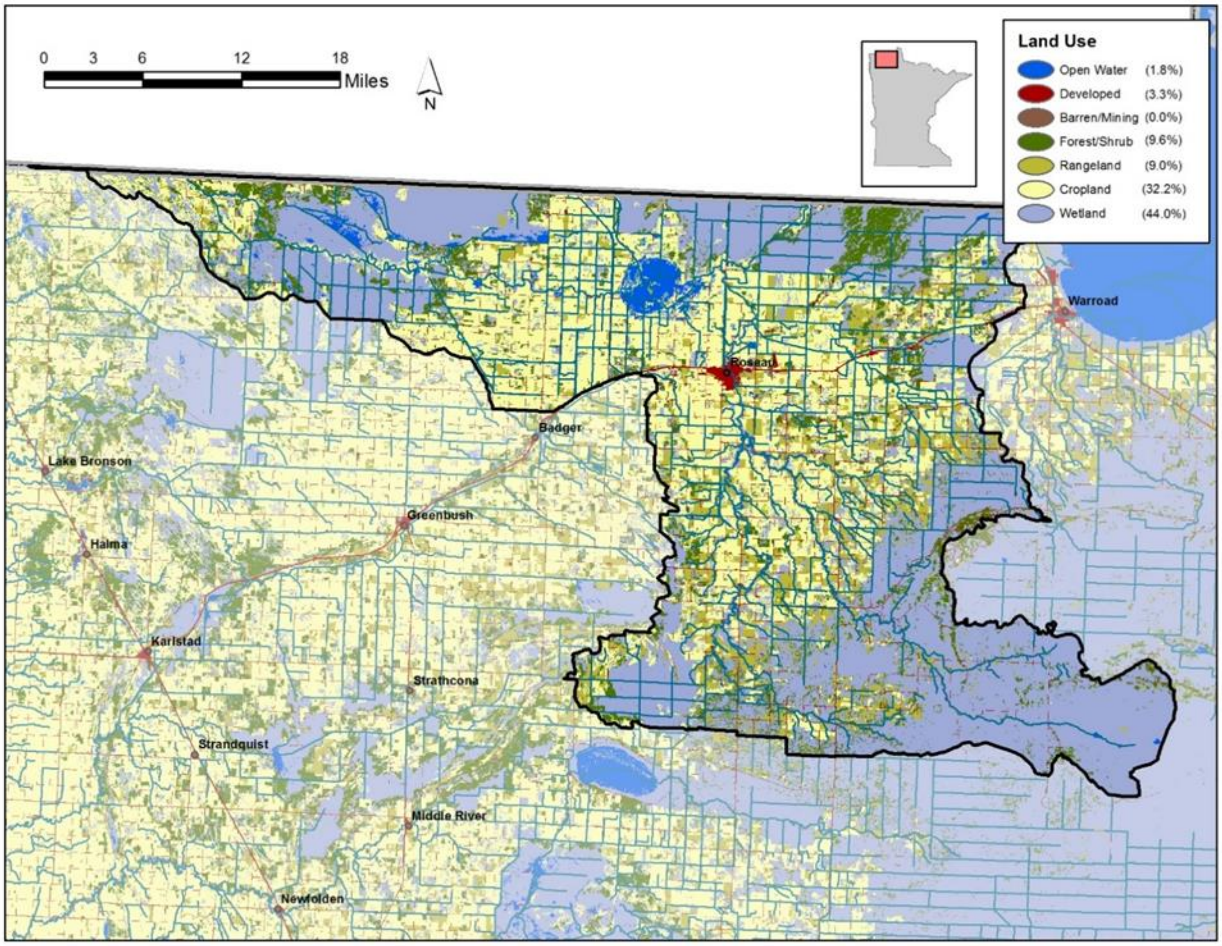
Figure 4. The Roseau River Watershed within the Northern Minnesota Wetlands and Red River Valley ecoregions of Northwest Minnesota.



Land use summary

Wetlands are the most abundant cover type in the Roseau River Watershed, comprising 44% of the land area. Pasture and cropland together make up another 40%, concentrated in the central portion of the watershed. Forest covers approximately 10% of the watershed, mostly in the north- and southeast corners. Development is present at very low levels (3.3% of the watershed), mainly around the City of Roseau (population 2,633) (Figure 5).

Figure 5. Land use in the Roseau River Watershed.



Surface water hydrology

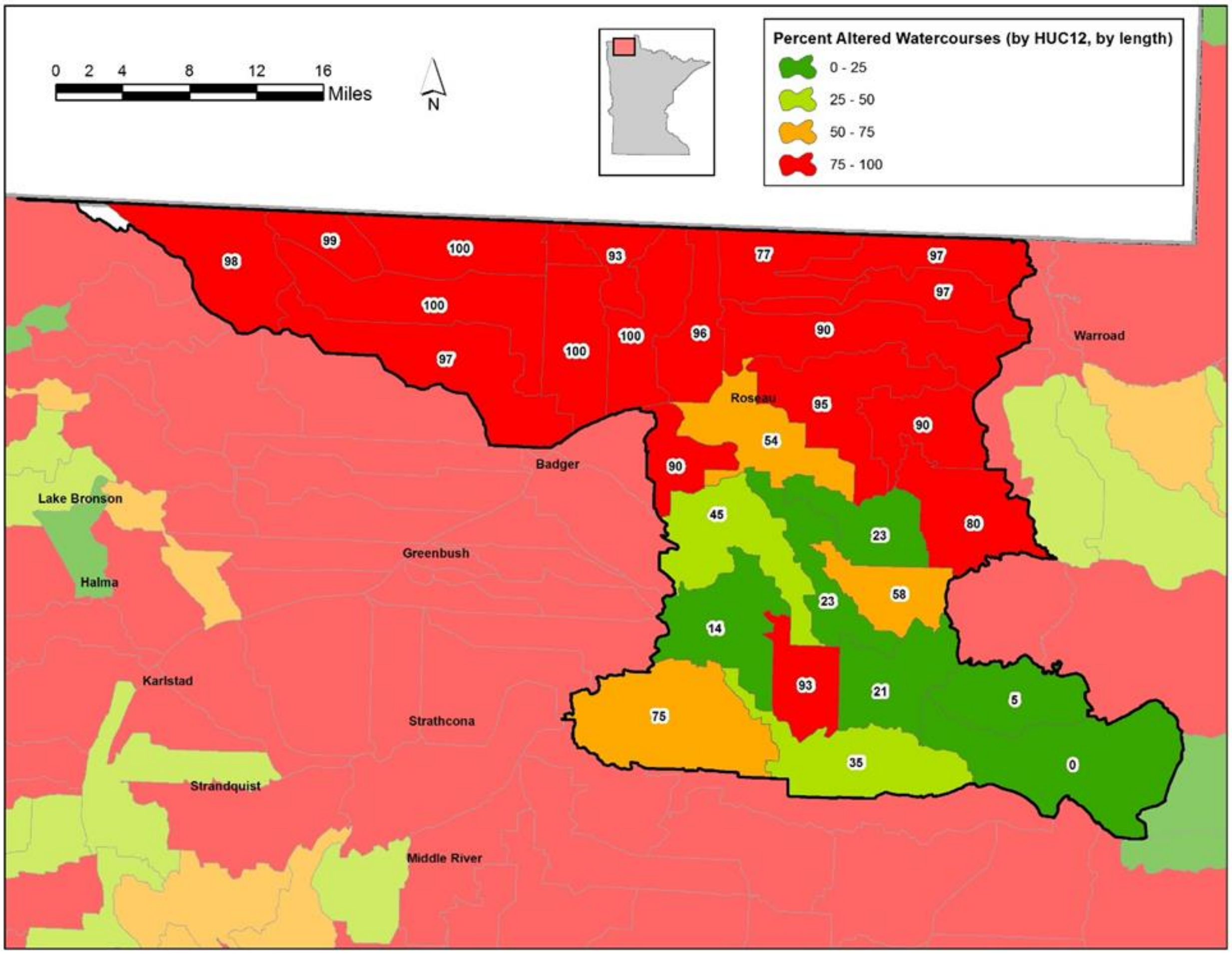
The Roseau River is the main watercourse, flowing generally southeast to northwest. The river crosses the Canadian border in Kittson County near the community of Caribou, after which it flows northwest through Manitoba towards its confluence with the Red River of the North.

The Roseau River has two branches, which are nearly equal in size where they come together at the community of Malung. After the confluence, the river flows north through the city of Roseau, then bends west as it picks up Sprague Creek, a major tributary flowing south from Canada. The river then passes through the drained bed of Roseau Lake. The river exits the Roseau Lake Basin near the community of Ross, then flows west/northwest through an enormous wetland complex adjacent to the Canadian border. Exiting the wetlands, the river flows northwest for approximately five miles to the border. Besides Sprague Creek, other significant tributaries include Hay Creek, Mickinock Creek, Paulson Creek, and Pine Creek.

Wetlands are abundant, particularly in the lower portion of the watershed, where what was once known as the “Big Roseau Swamp” covered vast areas. The “Big Swamp” has been extensively ditched, diked, drained, and impounded, but 77,000 acres of wetlands still exist within the Roseau River Wildlife Management Area. Extensive wetlands are also found in the headwaters of most drainages, particularly along the eastern and southern edges of the watershed. No natural lakes exist within the watershed, but a portion of the upper Roseau River has been impounded to form Hayes Lake. Roseau Lake was a shallow, permanent body of water before it was drained in the early 20th Century. The basin still fills with water at certain times of the year.

Surface drainage is common in the watershed. More than 50 miles of the mainstem Roseau River have been dredged and diked, and diversion channels have been constructed to route high flows around the City of Roseau. Stream channelization is more prevalent in the lower portions of the watershed, but some catchments in the upper watershed have also been heavily altered (e.g., Paulson Creek). In total, 886 miles of streams and rivers in the Roseau River Watershed have been ditched, 73% of all watercourses in the watershed (Figure 6).

Figure 6. Altered watercourses in the Roseau River Watershed, summarized as a percentage of all watercourses, by HUC-12.

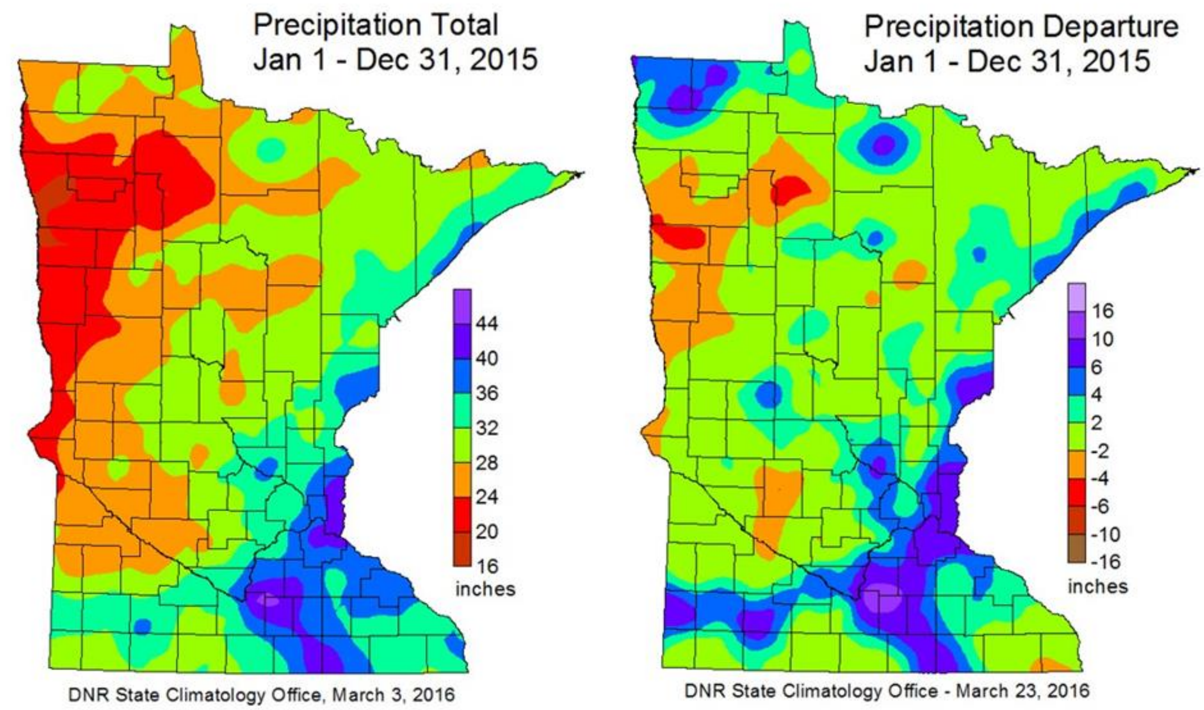


Climate and precipitation

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 Roseau River Watershed is 17.8˚C and the mean winter (December-February) temperature is -13.9˚ C (DNR 2017).

Precipitation is an important source of water input to a watershed. Figure 7 depicts precipitation for calendar year 2015. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the southeastern portion of the state. The Roseau River 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 experienced precipitation that ranged from 2 inches below normal to 6 inches above normal in 2015.

Figure 7. Statewide precipitation total (left) and precipitation departure (right) during 2015 (Source: DNR 2016a).



The Roseau River Watershed is located in the northwest precipitation region. Figure 8 and Figure 9 display the areal average representation of precipitation in Northwest 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 this region display no significant trend over the last 20 years. However, precipitation in Northwest Minnesota 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 8. Precipitation trends in Northwest Minnesota (1996-2015) with five-year running average (Source: WRCC 2017).

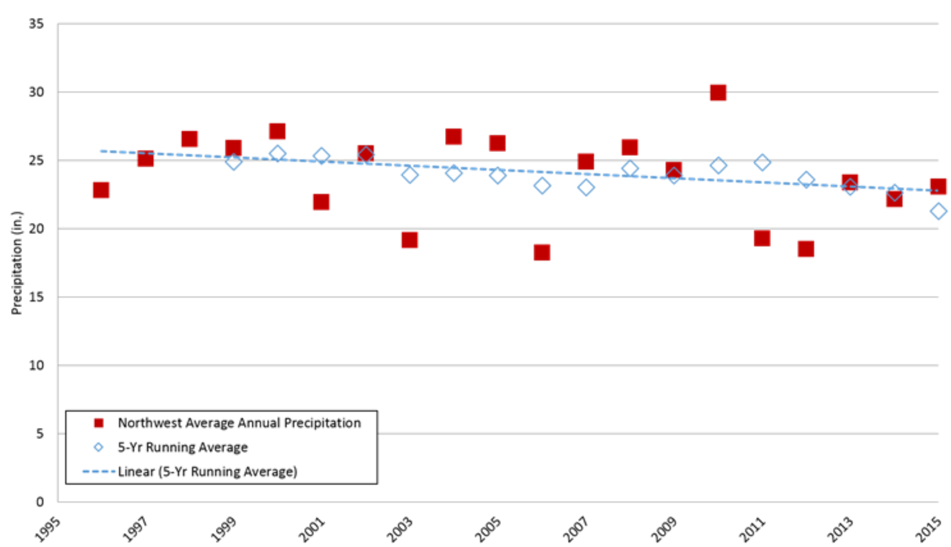
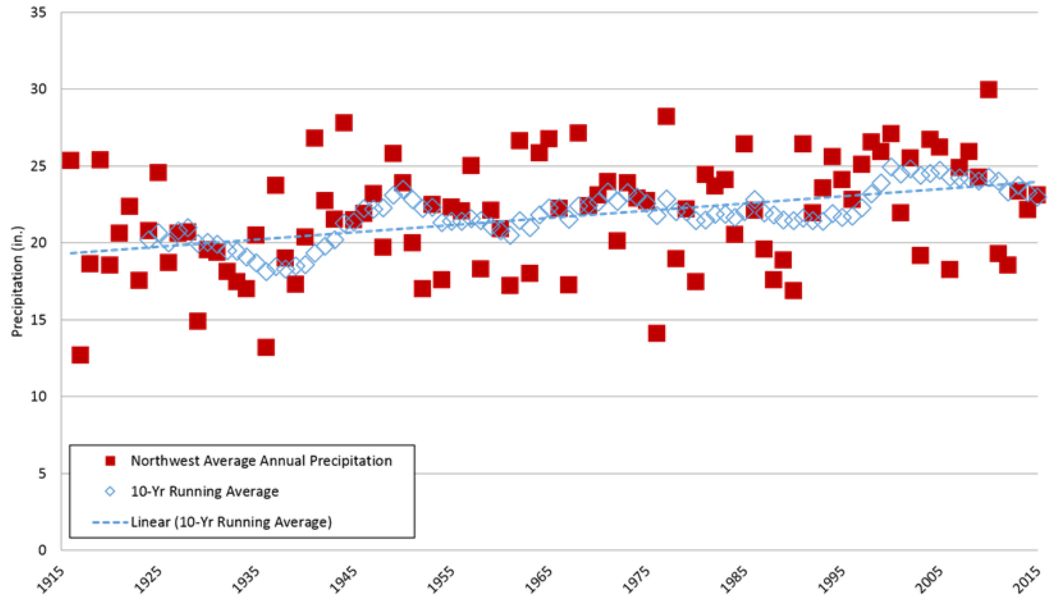


Figure 9. Precipitation trends in Northwest Minnesota (1915-2015) with 10-year running average (Source: WRCC 2017).



Hydrogeology and groundwater quality

Hydrogeology

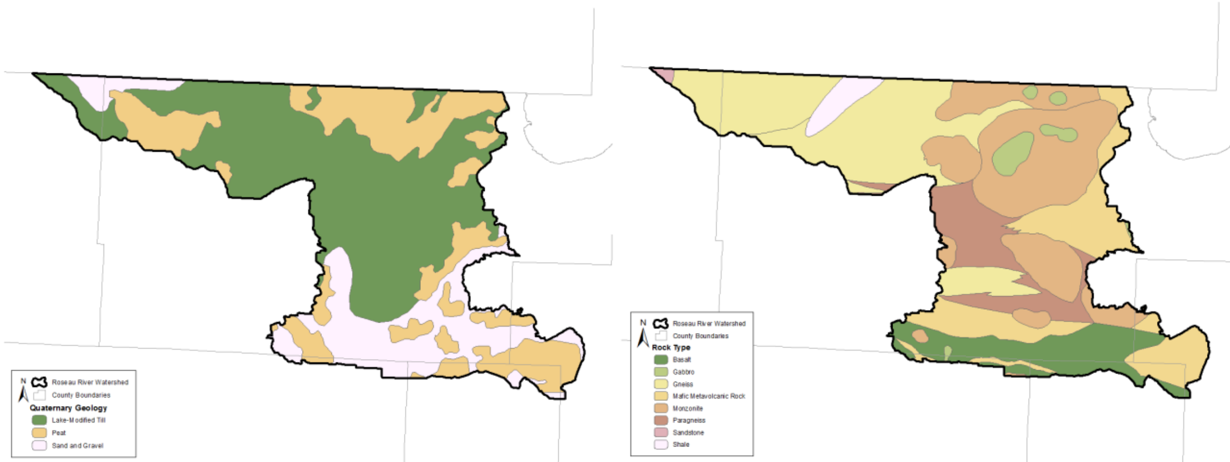
Hydrogeology is the study of the interaction, distribution and movement of groundwater through rocks and soil of the earth. The geology of a region strongly influences the quantity of groundwater available, the quality of the water, the sensitivity of the water to pollution, and how quickly water will be able to recharge and replenish the source aquifer. This branch of geology is important for management of land use and groundwater withdrawal, 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 at the surface throughout the Roseau River Watershed and is the parent material for the soils that have developed since glaciation. The depth to bedrock ranges from 103 feet to 371 feet and is buried by 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 the Des Moines lobe, and post-glacial alterations to that sediment, including soil formation and peat accumulation. The geomorphology includes glacial lake sediment (sand and gravel), lake modified till (Des Moines Lobe-Erskine Moraine), and peat (Holocene) (Figure 10, *left*) (Hobbs & Goebel 1982). The glacial sediment is primarily silty calcareous till with a predominantly clayey texture.

Bedrock is the main mass of rocks that form the Earth, located underneath the surficial geology and can be seen in only a few places where weathering has exposed the bedrock. Precambrian bedrock lies under the extent of the Roseau River Watershed, displaying evidence of volcanic activity. The main terrane group is the Wabigoon Subprovince, as well as foliated to gneissic bedrock (Jirsa et al 2011). Mafic plug-like intrusions are also scattered throughout the watershed. Within the watershed, there is also an area of Cretaceous undifferentiated bedrock overlying the Precambrian bedrock consisting of conglomerate, sandstone, mudstone and shale. The rock types that are found in the uppermost bedrock include basalt, gabbro, gneiss, mafic metavolcanic rock, mozonite, paragneiss, sandstone, and shale (Figure 10, *right*) (Morey & Meints 2000).

Figure 10. Quaternary geology (left) and bedrock geology rock types (right) within the Roseau River Watershed.



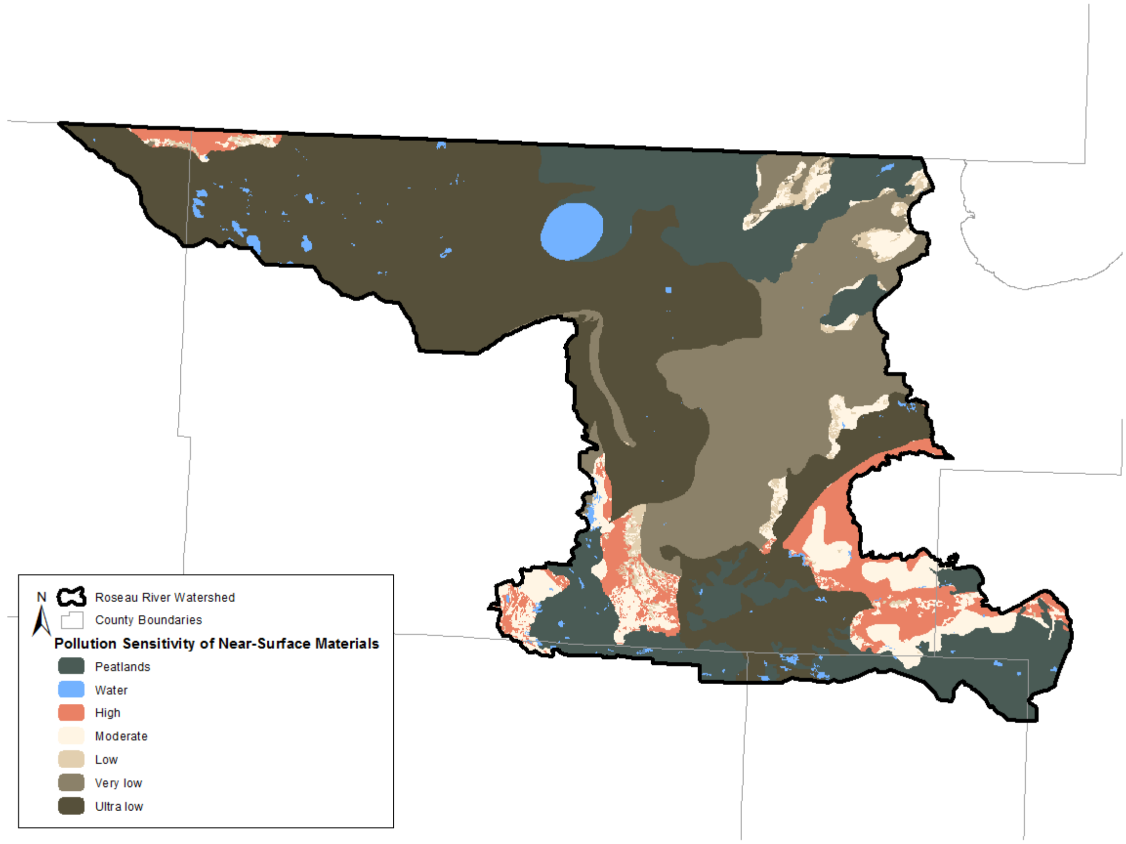
Aquifers

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 Roseau River Watershed is located within the Western Groundwater Province with fractured igneous and metamorphic bedrock aquifers lying deep beneath clayey unconsolidated sediments (DNR 2001, DNR 2018a). The fractured bedrock, although deep beneath the glacial sediments, is used locally as an aquifer (DNR 2018a). The Roseau River Watershed's quaternary geology is predominately made up of silty glacial sediments and sand and gravel aquifers with the Quaternary Buried Artesian Aquifer and the Quaternary Water Table Aquifer) as the primary sources for groundwater withdrawals. The general availability of groundwater for this region can be categorized as moderate in the surficial sands, limited in the buried sands, and limited in the bedrock (DNR 2018a)

Groundwater pollution sensitivity

Since bedrock aquifers are typically covered with thick till, they are normally better protected from contaminant releases at the land surface. It is also less likely that withdrawals from these wells 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 awaiting completion for those counties within the Roseau 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 10 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 Roseau River Watershed is estimated to have primarily ultra-low to low with some high pollution sensitivity areas scattered throughout the watershed, correlating to the presence of sand and gravel Quaternary geology (Figure 11) (DNR 2016b).

Figure 11. Pollution Sensitivity of Near-Surface Materials for Roseau 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 United States 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 12). 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 Roseau River Watershed, the average annual potential recharge rate to surficial materials ranges from 0.23 to 11.90 inches per year, with an average of 4.34 inches per year (Figure 13). The statewide average potential recharge is estimated to be4 inches per year with 85% of all recharge ranging from 3 to 8 inches per year. When compared to the statewide average potential recharge, the Roseau River Watershed receives approximately the same average potential recharge.

Figure 12. Average annual potential recharge rate to surficial materials in Roseau River Watershed (1996-2010) (GIS Source: USGS 2015).

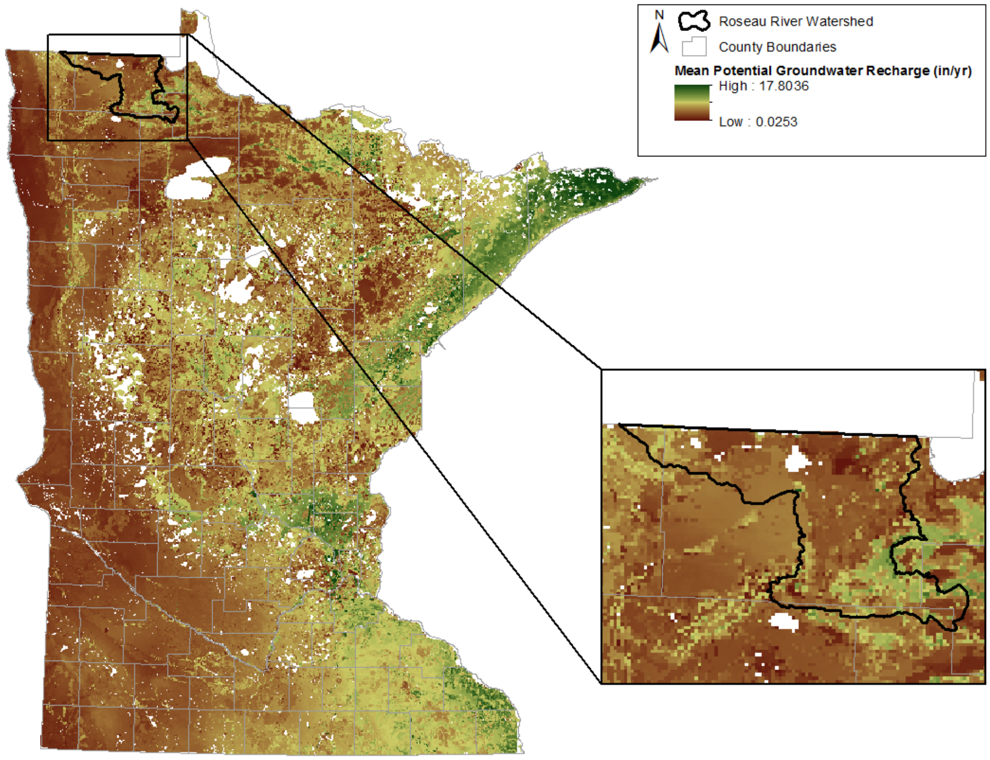
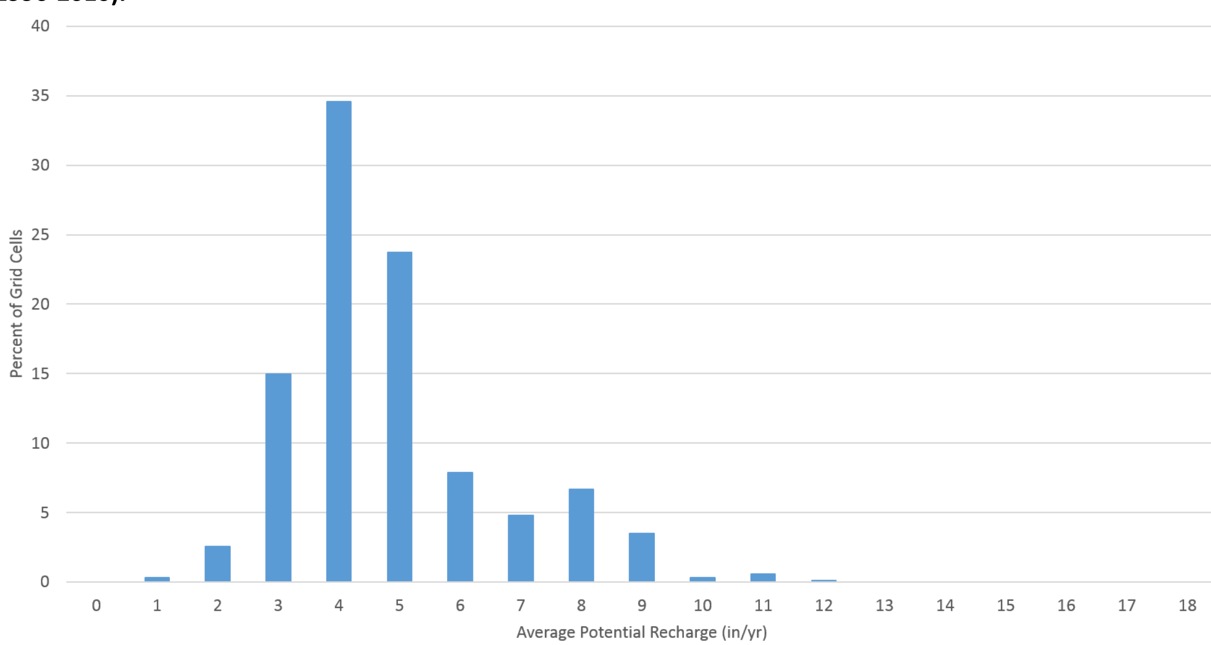


Figure 13. Average annual potential recharge rate percent of grid cells in the Roseau River Watershed (1996-2010).



Groundwater quality

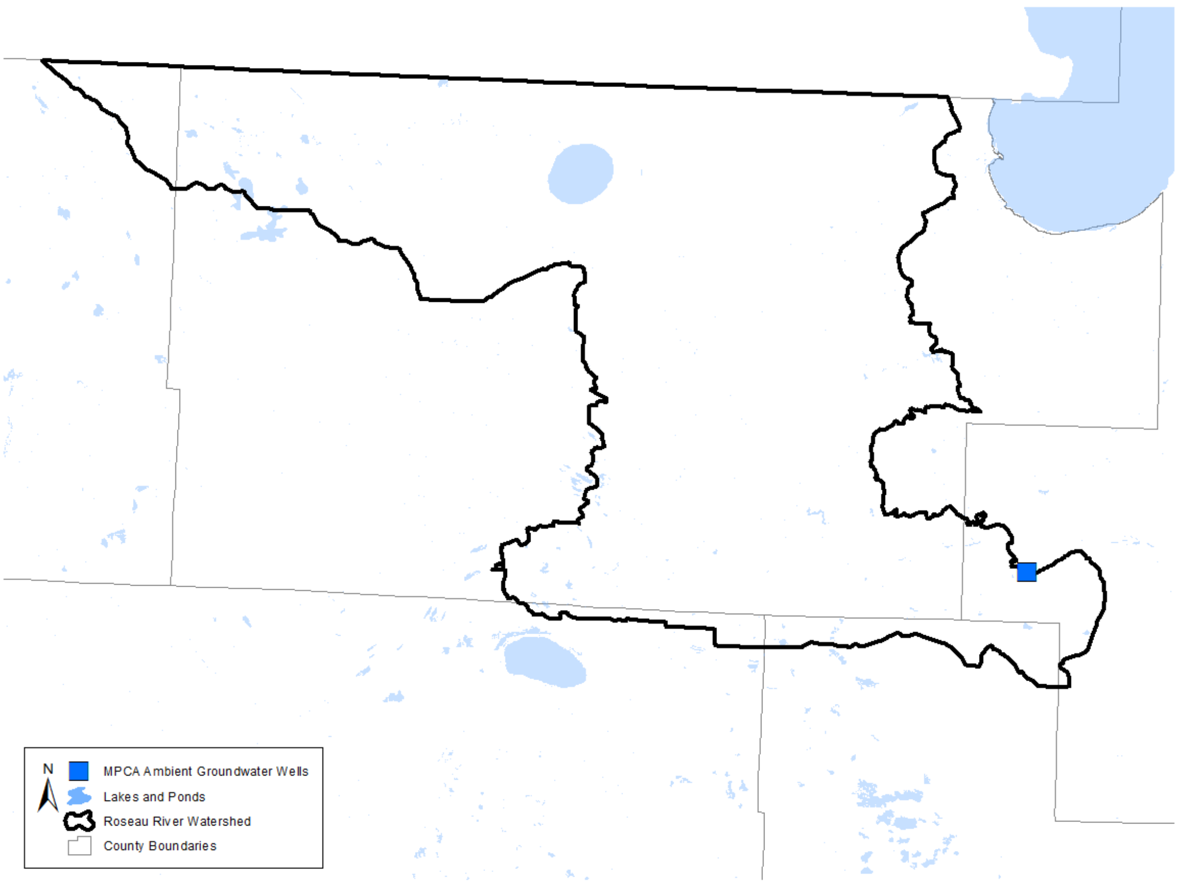
Approximately 75% of Minnesota's population receives their drinking water from groundwater, undoubtedly indicating that clean groundwater is essential to the health of its residents. The MPCA's

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 on the border of the Roseau River Watershed (Figure 14). Data collection for the network ranges from 2004 to 2016; however, the well within this watershed was added in 2012 and is missing data from 2014. Initial data analysis of this well was limited due to a lack of available data.

The monitoring well is located in an undeveloped area. There was 100% detection with the following analytes: barium, calcium, inorganic nitrogen (nitrate and nitrite), magnesium, phosphorus, potassium and strontium. There was an 80% detection frequency for sodium and 60% for sulfate. There were also one detection flag for chloromethane and copper (20% detection frequency). All detections were below drinking water maximum contaminant levels (MCLs) and there is no cause for concern at this time.

Figure 14. MPCA ambient groundwater monitoring well locations within the Roseau River Watershed.

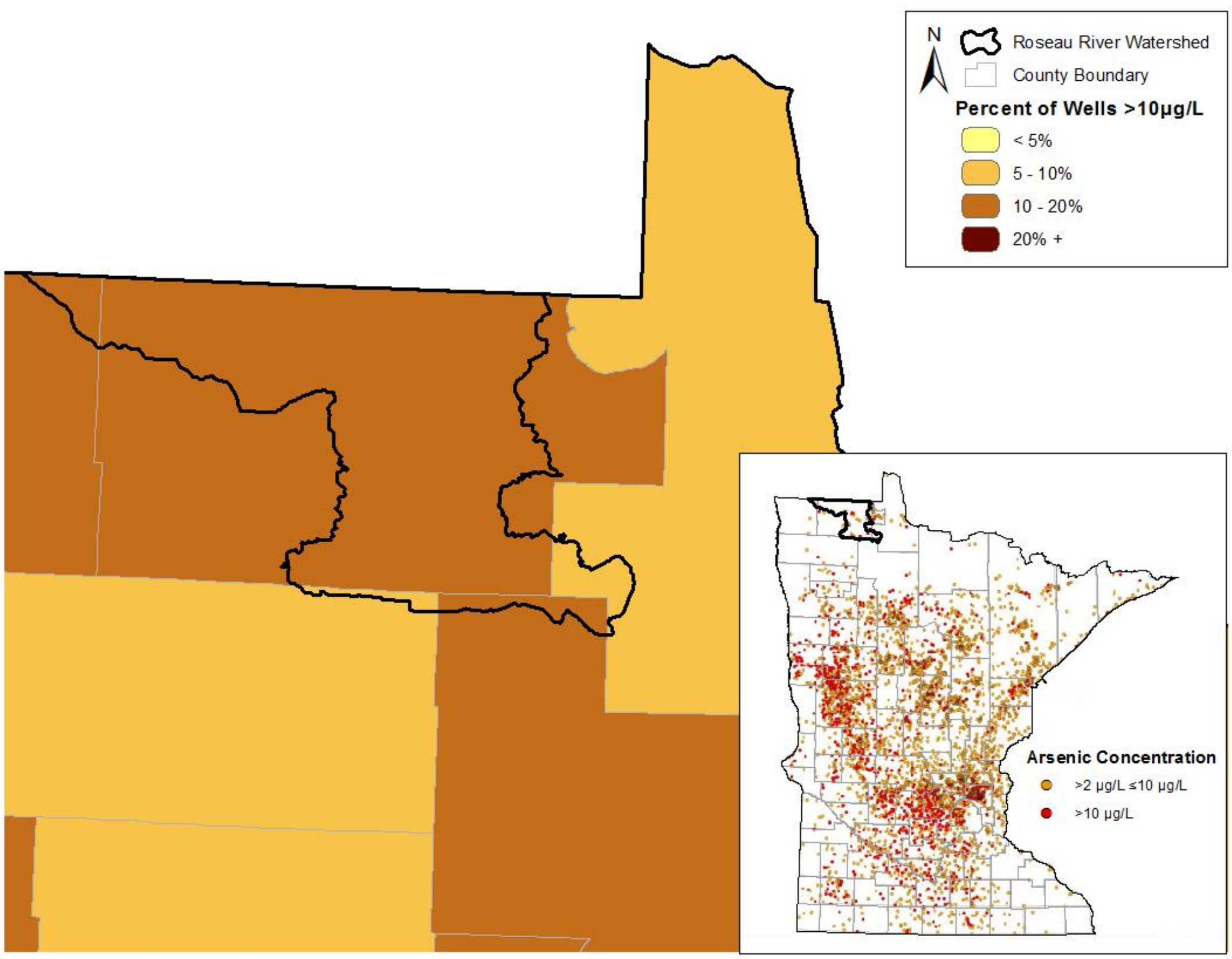


Regional groundwater quality

From 1992 to 1996, the MPCA conducted baseline water quality sampling and analysis of Minnesota's principal aquifers. The Roseau River Watershed lies entirely within the northwest region, which was identified as having higher concentrations of chemicals in the sand and gravel aquifers and Cretaceous aquifers when compared to other areas with similar aquifers. The greatest indicator of poor water quality in this region was the presence of Cretaceous bedrock followed by location. The number of exceedances of drinking criteria for arsenic, barium, boron, manganese, molybdenum, nitrate and selenium ranged from one to twelve, depending on the aquifer (MPCA 1999). Volatile organic compounds were also detected with chloroform as the most commonly detected compound, which is correlated with well disinfection (MPCA 1999).

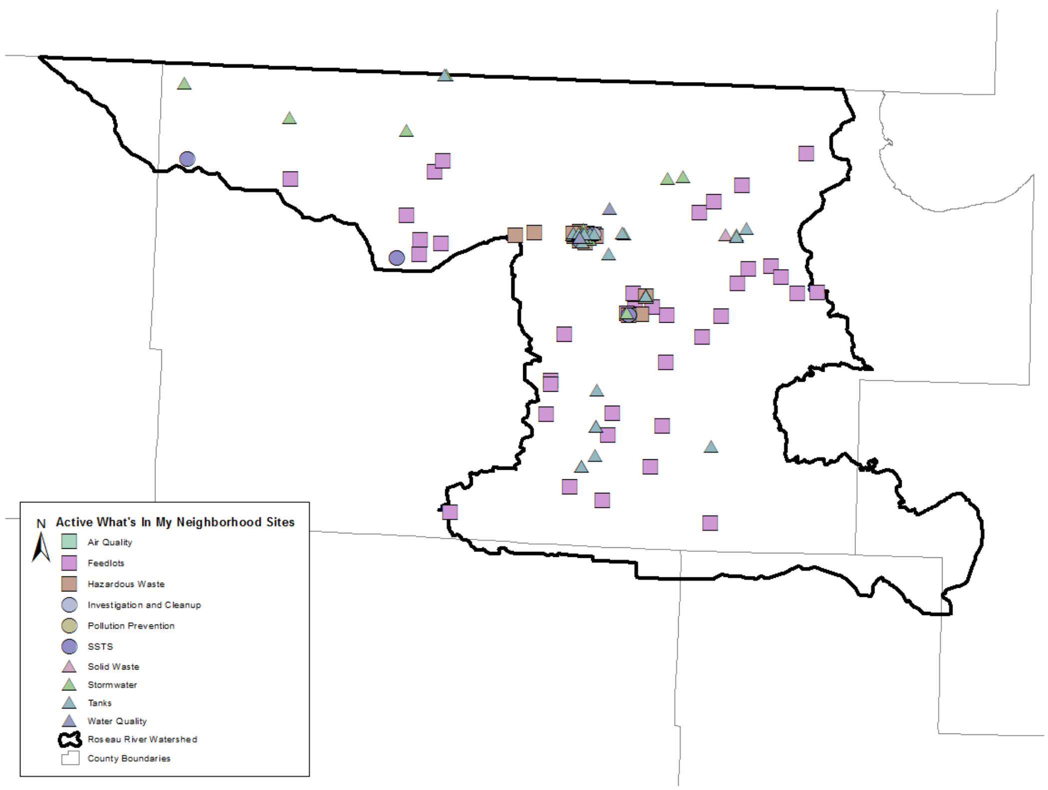
Another source of information on groundwater quality comes from the Minnesota Department of Health (MDH). Mandatory testing for arsenic, a naturally occurring but potentially harmful contaminant for humans, of all newly constructed wells has found that 10.7% of all wells installed from 2008 to 2015 have arsenic levels above the MCL for drinking water of 10 micrograms per liter (MDH 2016a). In the Roseau River Watershed, the majority of new wells are within the water quality standards for arsenic levels, but there are exceedances to the MCL. When observing concentrations of arsenic by percentage of wells that exceed the MCL of 10 micrograms/liter per county, the watershed lies within counties that range from 9.0 to 15.2% exceedances. By county, the percentages of wells identified with concentrations exceeding the MCL are as follows: Roseau (15.2%), Beltrami (10.2%), Kittson (14.3%), Lake of the Woods (9.5%), and Marshall (9.0%) (MDH 2016b) (Figure 15). It is important to reiterate that the percentages of arsenic concentration exceedances are per county, not specifically for Roseau 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 15. Percent wells with arsenic occurrence greater than the MCL for the Roseau 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 Roseau River Watershed, there are currently 140 active sites identified by WIMN: 39 feedlots sites, 32 tanks (aboveground and underground), 26 hazardous waste sites, 24 stormwater sites (construction and industrial stormwater), 8 subsurface sewage treatment systems (SSTS), 3 investigation and cleanup sites, 3 water quality sites (wastewater), 2 air quality sites, 2 solid waste sites, and 1 pollution prevention site (Figure 16). For more information regarding "What's in My Neighborhood", 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 16. Active "What's In My Neighborhood" site programs and locations for the Roseau River Watershed (Source: MPCA 2018).



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 (municipals), and irrigation (DNR 2018b). According to the most recent DNR Permitting and Reporting System (MPARS), in 2015 the high capacity permitted withdrawals within the Roseau River Watershed were primarily utilized for water level maintenance (89.1%) and for water supply (10.9%). The water level maintenance draws water solely from surface water sources while water supply draws from only groundwater sources.

Figure 17 displays total high capacity withdrawal locations within the watershed with active permit status in 2015. During 1996 to 2015, groundwater withdrawals within the Roseau River Watershed exhibit a significant decreasing withdrawal trend ($p<0.001$), while surface water withdrawals exhibit a statistically significant increasing trend ($p<0.001$) (Figure 18). However, surface water withdrawals began reporting in 2010 and when analyzed for trends from 2010 to 2015, there is no significance.

Figure 17. Locations of active status permitted high capacity withdrawals in 2015 within the Roseau River Watershed.

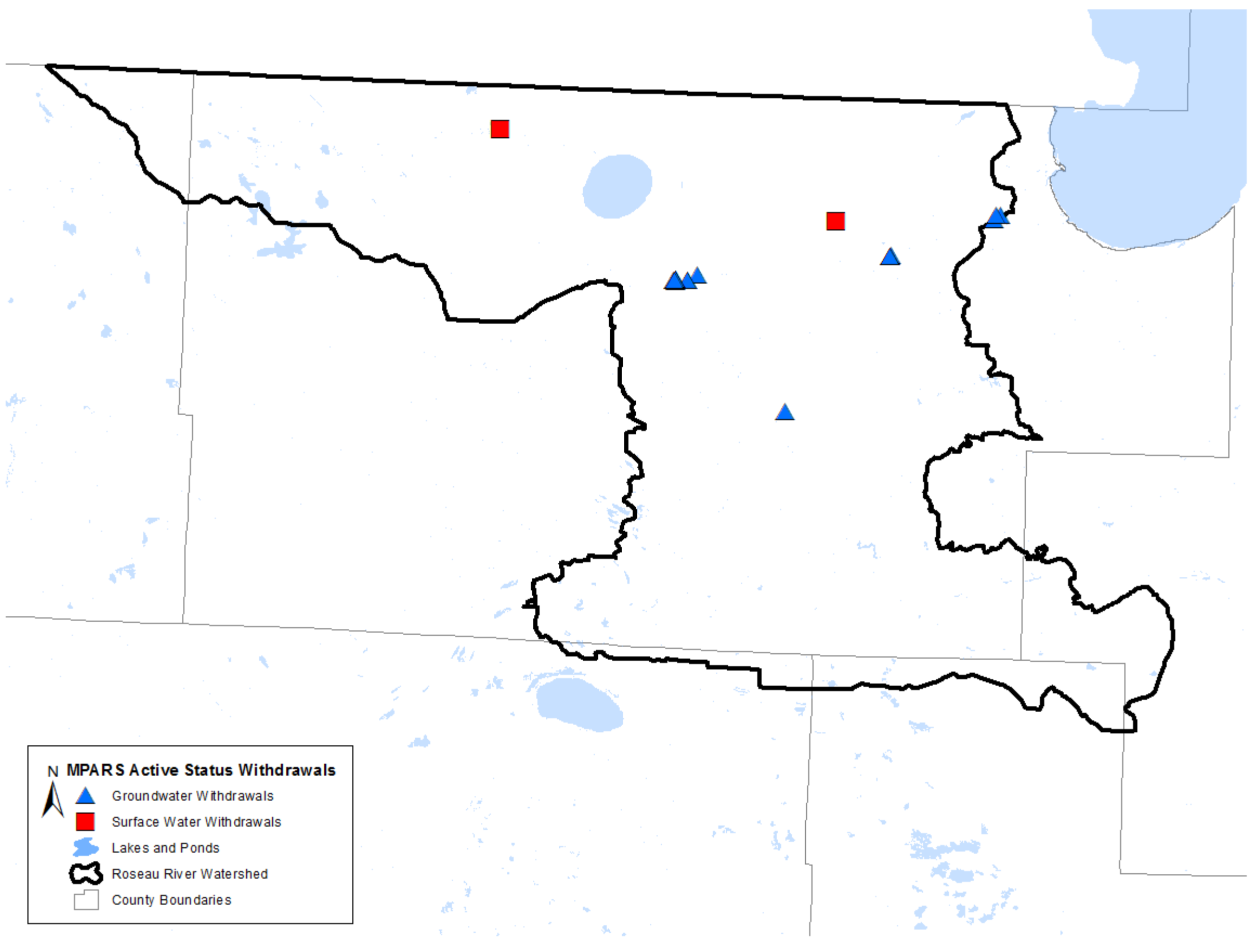
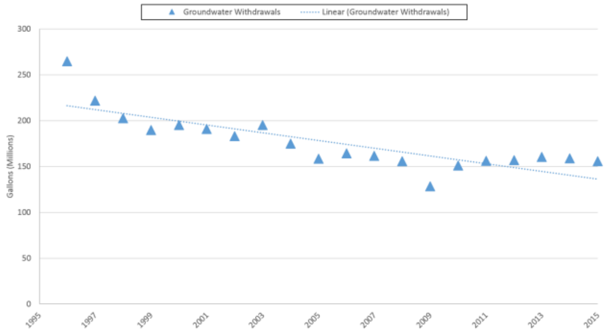
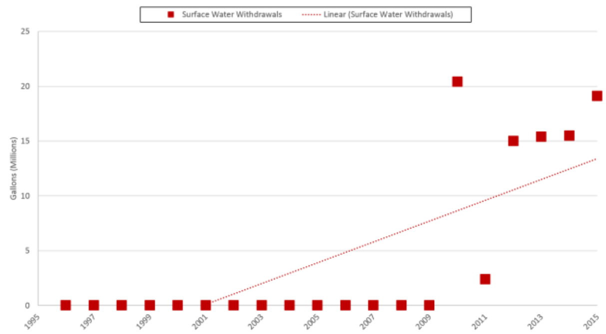


Figure 18. Total annual groundwater (left) and surface water (right) withdrawals in the Roseau River Watershed (1996-2015).

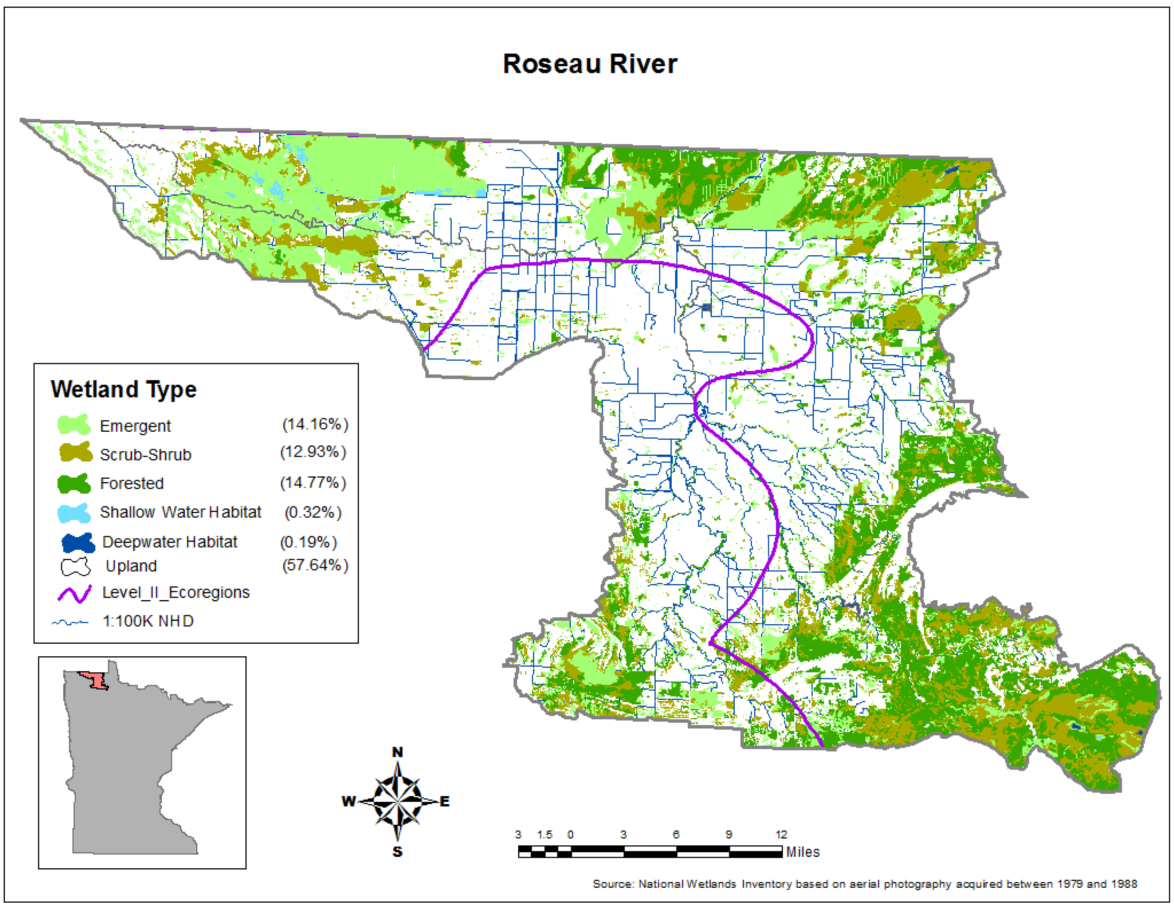




Wetlands

Not counting open water portions of lakes and rivers, the Roseau River Watershed has approximately 288,745 acres of wetland, which is equivalent to 42.5% of the watershed area. Forested wetlands are the most common wetland class in this watershed comprising 14.8% of the total wetland area followed closely by emergent wetlands that make up 14.2% of the watershed (Figure 19). Scrub-shrub wetlands are the third most common wetland class comprising (12.9%). Deep water and shallow water habitats combined make up a small (0.51%) proportion of the Roseau River Watershed. These estimates and distribution observations were derived from the original Minnesota National Wetland Inventory (NWI) based primarily on 1982-1983 high altitude spring leaf-off CIR imagery https://lta.cr.usgs.gov/NHAP.

Figure 19. Wetlands and surface water in the Roseau River Watershed. Wetland data are from the original Minnesota National Wetlands Inventory.



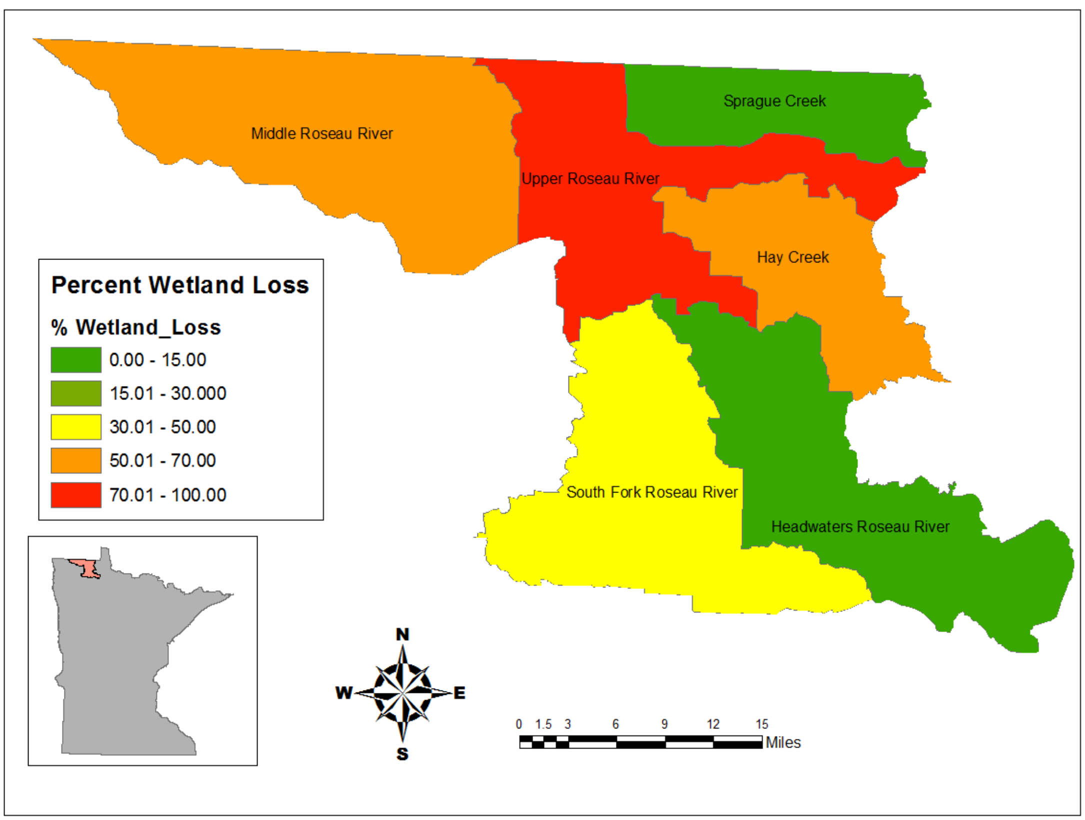
The Roseau River Watershed surface geology is dominated by glacial lake sediment, lake modified till and deep peat. Lake modified till occurs in most of the central region of the watershed and was derived from the Des Moines glacial lobe as part of the Erskine Moraine complex. Wetland formation was common due to extensive shallow to exposed bedrock features in this region, and derived from the extensive ground moraine derived till that resulted in frequent shallow depressions from the most recent glacial ice sheet. The Roseau River Watershed occurs within two, highly contrasting level II ecoregions; the Mixed Wood Shield to the north and east part of the watershed and the Temperate Prairies in the central west region.

Wetland extent varied greatly in the Roseau River Watershed both currently and historically. Historic wetland extent as determined by soil drainage class polygons, classified as "Poorly Drained" or "Very Poorly Drained" and the current wetland extent estimates are derived from the original Minnesota National Wetland Inventory (NWI).

At the HUC-10 subwatershed scale, the Headwaters Roseau River Subwatershed currently supports the highest proportion of wetlands (12%), and the Hay Creek Subwatershed supports the smallest amount (3.4%). There are noteworthy spatial differences in historic wetland extent compared to current wetland extent (Figure 20). For example, the Upper Roseau River Subwatershed had lost an estimated 71% of its historic wetlands by the early 1980s, while the Sprague Creek and Roseau River Headwaters Subwatersheds had lost only 14.2% and 6.4%, respectively. Portions of the drainage network used to convert these wetland resources are clearly visible on hydrographic maps (Figure 19).

The National Wetland Inventory is being updated and the Roseau River Watershed is included in the Northwest Minnesota NWI update phase, which is expected to be completed by the summer 2018. Once completed, more current estimates of wetland conversion rates will be possible.

Figure 20. Loss of historic wetlands in the Roseau River Watershed.



Watershed-wide data collection methodology

Lake water sampling

Hayes Lake was sampled in 2015 and 2016 for total phosphorus, chlorophyll-a, and Secchi transparency by Roseau Soil and Water Conservation District (SWCD). 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, chlorophyll-a and Secchi transparency.

Stream water sampling

Seven water chemistry stations were sampled May through September of 2015, and again June through August of 2016, to provide sufficient water chemistry data to assess aquatic life and recreation uses. Following the IWM design, water chemistry stations were placed at the outlet of each subwatershed that was >40 square miles in area (green circles in Figure 2**Error! Reference source not found.**). A SWAG was awarded to the Roseau Soil and Water Conservation District (SWCD) to conduct this water quality monitoring. (See Appendix B for locations of stream water chemistry monitoring sites. See Appendix A for definitions of stream chemistry analytes monitored in this study).

Stream flow methodology

MPCA and the DNR jointly collect stream water quantity and quality 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 subwatersheds; these data 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 Roseau River Watershed IWM was completed during the summers of 2015 and 2016. Fish and macroinvertebrates were sampled at 23 stations across 13 different WIDs, all of which were assessed for aquatic life use support. 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.

For each biological sample, an IBI score was calculated to represent the quality of the observed assemblage. IBI scores higher than the impairment threshold and upper confidence limit indicate that the stream reach supports aquatic life. In a similar fashion, scores below the impairment threshold and lower confidence limit indicate that the stream reach does not support aquatic life. When an IBI score falls within the upper and lower confidence intervals additional information may be considered when making a use support decision, such as the presence (or absence) of potential 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 Appendix E and Appendix F.

Fish contaminants

The 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 major watershed pour point as part of IWM. All fish collected by 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-milliliter (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 prepared and 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 has a reference dose.

MPCA determines which waters exceed impairment thresholds based on the fish contaminant analysis. The MPCA prepares and submits the Impaired Waters List to the U.S. Environmental Protection Agency (EPA) every even-numbered year. 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 Minnesota Department of Health (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 milligrams per kilogram (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 also 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, similar to PCBs. With the adoption of a water quality standard for mercury in edible fish tissue, a waterbody is 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 ten 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: https://www.pca.state.mn.us/water/watershed-pollutant-load-monitoring-network.

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. As of 2018 (when this report was produced), the MPCA's Ambient Groundwater Monitoring Network consisted of approximately 250 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, 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 volatile organic compounds (VOCs).

Information on groundwater monitoring methodology is taken from Kroening and Ferrey (2013). To download ambient groundwater monitoring data: 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. The MPCA's 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: https://www.pca.state.mn.us/water/wetland-monitoring-and-assessment.

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

Individual HUC-10 subwatershed results

HUC-10 subwatersheds

Assessment results for aquatic life and recreation use are presented for each HUC-10 subwatershed within the Roseau River HUC-8. The primary objective is to portray all fully supporting and impaired waterbodies resulting from the assessment and listing process. This scale provides a robust assessment of water quality condition at a practical size for development, management, and implementation of effective TMDLs and protection strategies. The graphics presented for each subwatershed contain 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 2015-2016 IWM effort, but also considers available data from the last ten years.

The proceeding pages provide an account of each HUC-10 subwatershed. Each account includes a brief description of the subwatershed and summary tables for: a) stream aquatic life and aquatic recreation assessments, and b) lake aquatic life and recreation assessments. A narrative summary of assessment results and pertinent water quality projects completed or planned for the subwatershed is also included. A brief description of each summary table 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 each subwatershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect results of the 2017 assessment process (2018 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 include results of comparing each individual aquatic life and aquatic recreation indicator to their respective criteria (i.e., standards); these determinations are made during the desktop phase of the assessment process (see Figure 3). Assessment of aquatic life is derived from analysis of biological indicators (fish and macroinvertebrate IBIs), dissolved oxygen, total suspended solids, chloride, pH, total phosphorus, chlorophyll-a, biochemical oxygen demand and un-ionized ammonia (NH_3) data, while 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 subwatershed as well as in the watershed-wide results and discussion section.

Lake assessments

A summary of lake water quality is provided for subwatersheds with available data. This includes aquatic recreation indicators (phosphorus, chlorophyll-a, and Secchi transparency) and aquatic life indicators (chloride and fish IBI). Parameter-level and overall use decisions are included in the table.

Headwaters Roseau River Subwatershed HUC 0902031401

The Headwaters Roseau River Subwatershed drains 212 square miles to the south and east of the city of Roseau. More than 60% of the subwatershed lies within Beltrami Island State Forest; overall, land use is dominated by forest and wetland cover types. However, most of the undeveloped land is located in the upper portion of the subwatershed and land cover transitions abruptly to cropland and pasture in the lower third of the subwatershed. Population density is generally low (less than five people per square mile) and concentrated near the unincorporated community of Malung. The Roseau River is the primary watercourse, flowing 60 miles northwest towards its confluence with the South Fork Roseau River. Tributaries include Hansen Creek, Bear Creek, and Severson Creek (also known as County Ditch 23). Hayes Lake, an impoundment of the Roseau River, is located near the headwaters of Roseau River, within Hayes Lake State Park.

Summary

Water quality is generally good in the Headwaters Roseau River Subwatershed (Table 2). The mainstem of the Roseau River was monitored in several locations and met all water quality standards. Longnose Dace, a stream fish that requires high-quality habitat and cool water temperatures, was found in the Roseau River near the community of Malung – this was the only record of Longnose Dace in the entire Roseau River Watershed and may represent an isolated population of the species. In the upper portion of the subwatershed, Hayes Lake was found to have low concentrations of phosphorus and algae, providing excellent opportunities for swimming, fishing, and non-motorized boating (Table 3).

Aquatic life is impaired on two reaches of Severson Creek (County Ditch 23), where low macroinvertebrate IBI scores indicate potential problems with water quality and/or habitat conditions. Severson Creek drains an agricultural landscape, which includes a high proportion of channelized streams. Biological indicators suggest that conditions have degraded since the stream was first monitored in 2005.

Table 2. Aquatic life and recreation assessments on stream reaches: Headwaters Roseau River Subwatershed.

WID ***Reach name,*** *Reach description*	**Biological Station ID**	**Reach length (miles)**	**Use class***	**Aquatic life indicators:**										**Aquatic life**	**Aquatic rec. (Bacteria)**
				Fish IBI	**Invert IBI**	**Dissolved oxygen**	**TSS**	**Secchi Tube**	**Chloride**	**pH**	**Ammonia -NH_3**	**Pesticides *****	**Eutrophication**		
09020314-504 ***Roseau River*** *Headwaters to S Fk Roseau R*	15RD005 15RD006 15RD033	61	WWg	MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS		MTS	FS	FS
09020314-517 ***Hansen Creek*** *Unnamed lk (68-0083-00) to Roseau R*	05RD083	6	WWg	MTS	MTS	IF	IF	IF		IF	IF		IF	FS	
09020314-541 ***Severson Creek/County Ditch 23*** *Severson Cr to Unnamed cr*	15RD016	1	WWg	MTS	EXP	IF	IF	IF		IF	IF		IF	NS	
09020314-516 ***Severson Creek (County Ditch 23)*** *Unnamed cr to Roseau R*	05RD085	2	WWg	MTS	EXS	IF	IF	IF		IF	IF		IF	NS	

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: Headwaters Roseau River Subwatershed.

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		
Hayes Lake	68-0004-00	194	27	Deep Water	NMW	NT	--	--	--	MTS	MTS	MTS	--	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

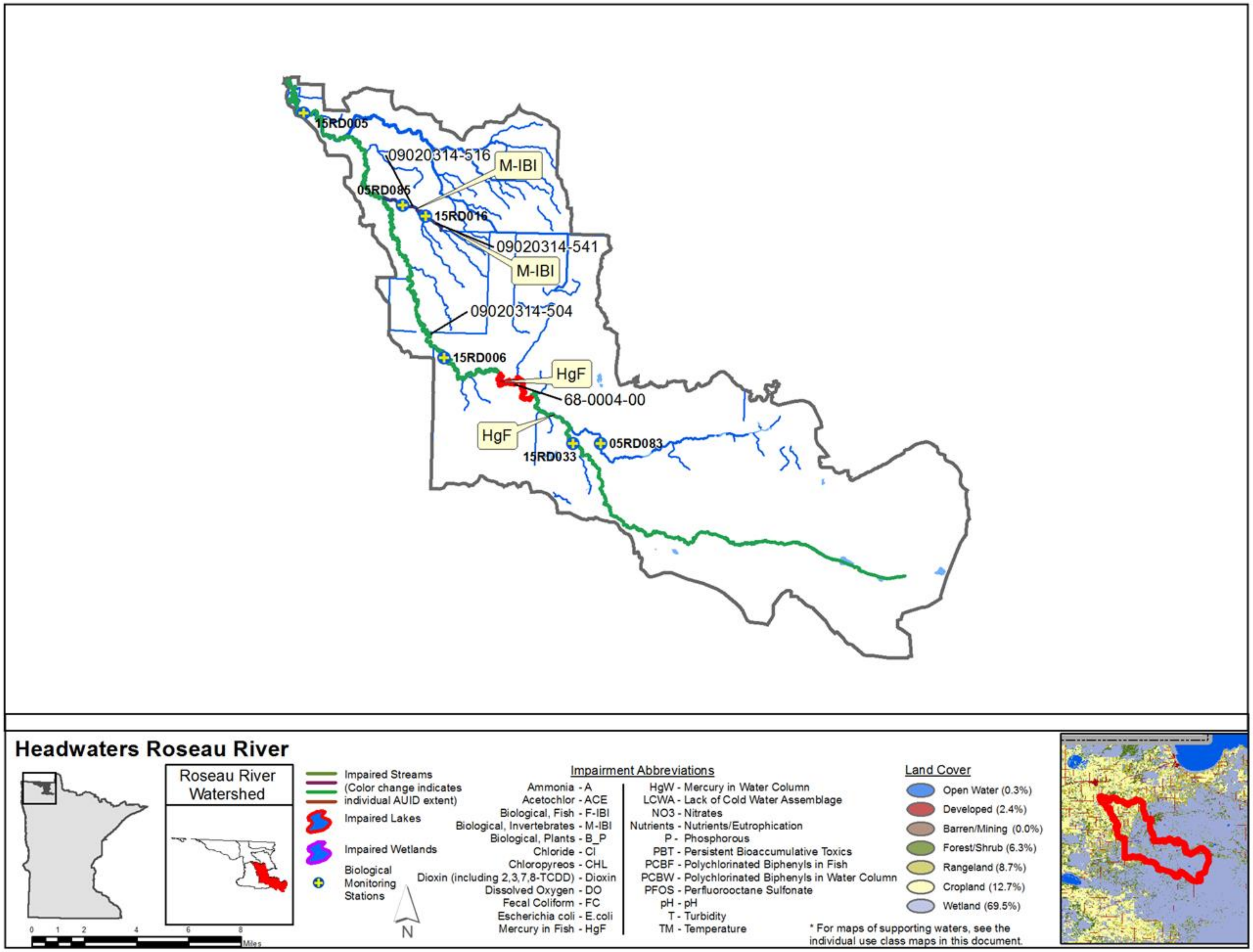
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, **--** = not enough data

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 2016 reporting cycle; = new impairment; = full support of designated use; = ins ufficient information.

Figure 21. Currently listed impaired waters by parameter and land use characteristics in the Headwaters Roseau River Subwatershed.



South Fork Roseau River Subwatershed HUC 0902031402

The South Fork Roseau River Subwatershed drains 214 square miles to the south of the city of Roseau. Approximately half of the subwatershed is covered by forest and wetlands, and half is used for pasture and cropland. Most of the natural land cover is concentrated in the upper portion of the subwatershed, while agricultural land uses dominate the lower portion. Population density is generally low (approximately ten people per square mile), although a few small communities are found in the subwatershed. The South Fork Roseau River is the primary watercourse, flowing 50 miles north towards its confluence with the Roseau River at the community of Malung. Tributaries include Mickinock Creek and Paulson Creek.

Summary

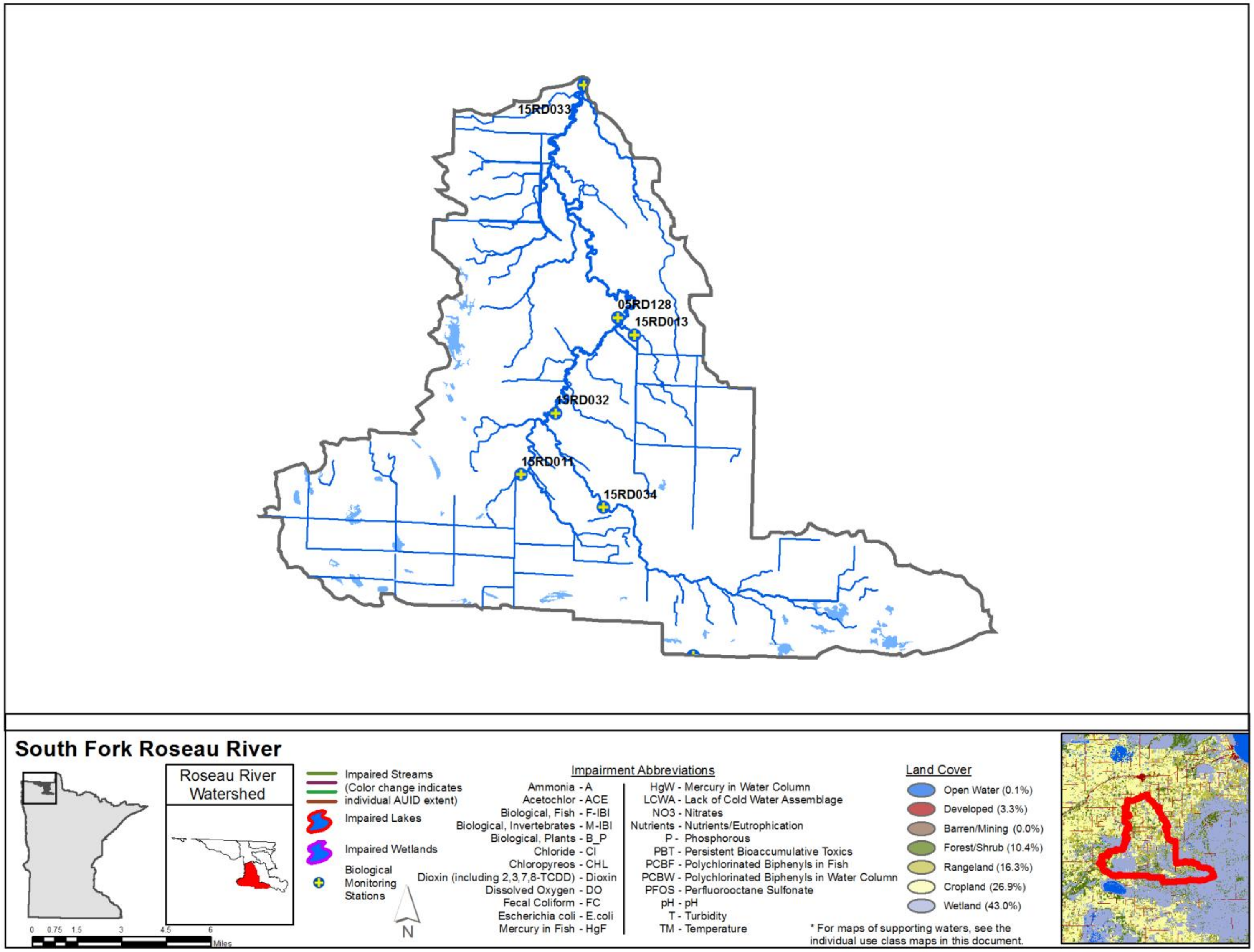
Water quality is generally good in the South Fork Roseau River Subwatershed; no aquatic life or aquatic recreation impairments were identified (Table 4Table 4). The South Fork Roseau River was monitored in several locations and met water quality standards for aquatic life and aquatic recreation, although phosphorus levels were somewhat elevated. Larvae of the pollution-intolerant insect *Synorthocladius* were found at two different locations on the South Fork Roseau River; this insect has been found at only one other location in the entire Minnesota portion of the Red River Basin (Otter Tail River near Detroit Lakes); its presence in the South Fork Roseau River indicates excellent water quality. Mickinock and Paulson Creeks drain mixed landscapes of forest, wetland, and agricultural land uses. Both streams were found to support aquatic life based on fish and macroinvertebrate IBI scores.

Table 4. Aquatic life and recreation assessments on stream reaches: South Fork Roseau River Subwatershed.

WID *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)
09020314-503 ***Roseau River, South Fork*** *Headwaters to Roseau R*	05RD128 15RD003 15RD032 15RD034	50	WWg	MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS		IF	FS	FS
09020314-521 ***Unnamed ditch (Judicial Ditch 63)*** *Unnamed ditch to Mickinock Cr*	none	2	WWg			IF	MTS	MTS		MTS			MTS	IF	
09020314-522 ***Mickinock Creek*** *Unnamed ditch to Unnamed cr*	15RD011	1	WWg	MTS	MTS	IF	IF	IF		IF	IF		IF	FS	
09020314-540 ***Paulson Creek*** *Unnamed ditch to S Fk Roseau R*	15RD013	1	WWg	MTS	MTS	IF	IF	IF		IF	IF		IF	FS	

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.

Figure 22. Currently listed impaired waters by parameter and land use characteristics in the South Fork Roseau River Subwatershed.



Hay Creek Subwatershed HUC 0902031403

The Hay Creek Subwatershed drains 116 square miles to the south and east of the city of Roseau. Agricultural land uses make up slightly more than 50% of the subwatershed, mostly row crop with a smaller proportion of pastureland. Approximately 40% of the subwatershed is covered by forest and wetlands, mostly in the headwaters of the subwatershed where 20 square miles lies within Beltrami Island State Forest. Population density is generally low (approximately one person per square mile), mostly concentrated in the outskirts of Roseau and a handful of small communities found east of Roseau along Highway 11. Stream channelization is widespread, particularly in the lower portion of the subwatershed.

Hay Creek is the primary watercourse, flowing 17 miles northwest towards its confluence with the Roseau River. Nearly the entire length of Hay Creek has been channelized, and as the creek approaches the Roseau, a high-water diversion channel routes high flows across the subwatershed boundary into a storage reservoir. The headwater source of Hay Creek is Bemis Hill Creek (also known as County Ditch 9), a ditch that is also a designated trout stream.

Summary

Hay Creek was monitored in several locations, and multiple water quality impairments were identified (Table 5). Aquatic life is impaired based on low fish and macroinvertebrate IBI scores, as well as high concentrations of suspended sediment. IBI scores have declined since the stream was first monitored in 2005. Aquatic recreation is impaired by high levels of bacteria, although these conditions appear to be restricted to the northern portion of the stream. Local partners will be working with landowners to correct the bacteria issue. In the headwaters of Hay Creek, County Ditch 9 (Bemis Hill Creek) is a unique resource for this part of the state. Stocked with Brook Trout, its cold waters also support sensitive aquatic insects like the stonefly *Amphinemura*, which is extremely rare in Northwestern Minnesota.

Table 5. Aquatic life and recreation assessments on stream reaches: Hay Creek Subwatershed.

WID *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)
09020314-505 ***Hay Creek*** *Headwaters to Roseau R*	05RD043 05RD084	17	WWg	EXP	EXS	IF	EX	EX	MTS	MTS	MTS		IF	NS	NS
09020314-512 ***County Ditch 9*** *T161 R37W S29, south line to Hay Cr*	15RD017	3	CWg	MTS	MTS		IF	IF					IF	FS	

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

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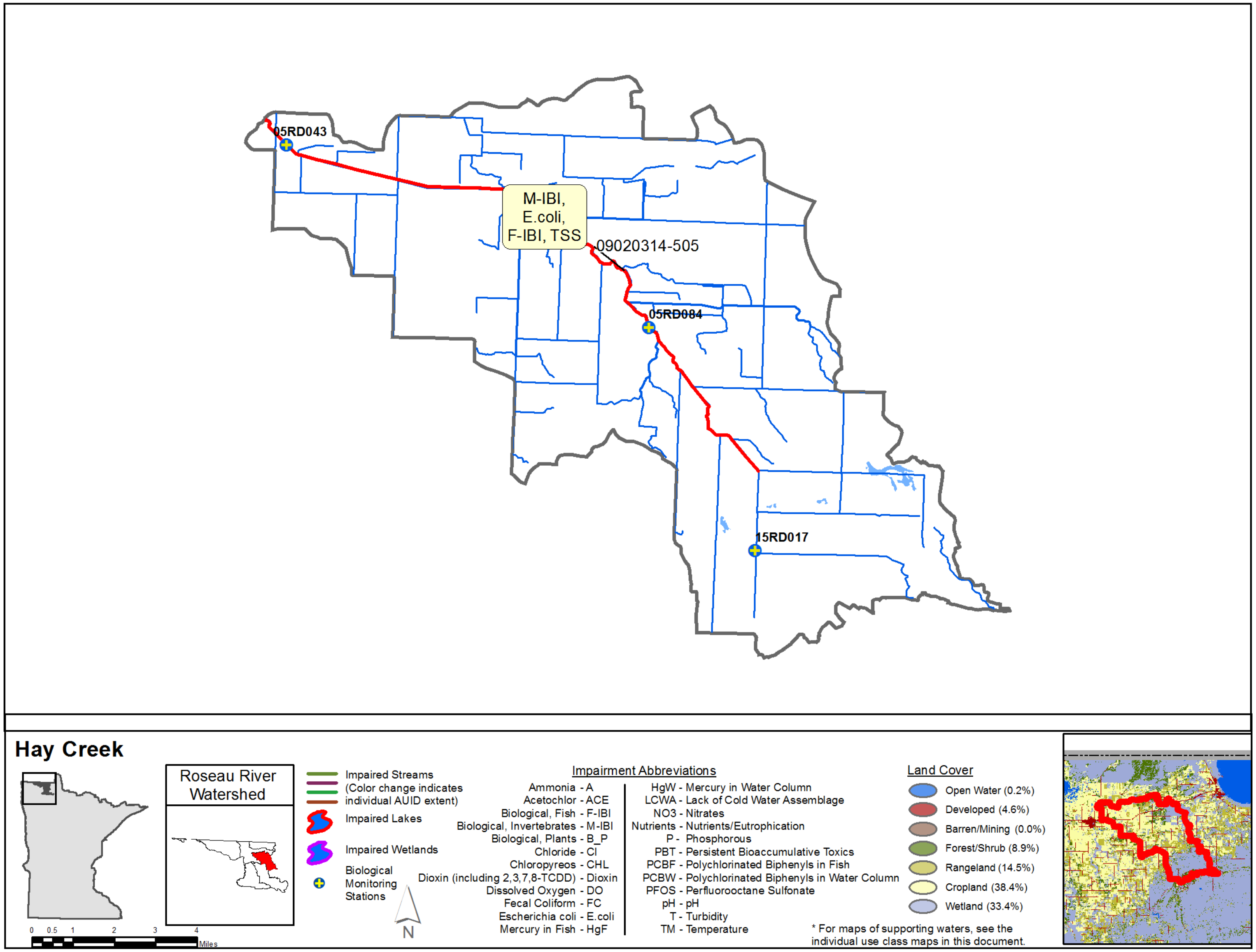
Key for Cell Shading: existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

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.

Figure 23. Currently listed impaired waters by parameter and land use characteristics in the Hay Creek Subwatershed.



Sprague Creek Subwatershed HUC 0902031404

The Sprague Creek Subwatershed drains 286 square miles northeast of the City of Roseau. Approximately 70% of Sprague Creek's catchment lies in Canada; only 87 square miles lie south of the U.S./Canada border. The U.S. portion of the HUC-10 is mostly within the boundaries of Lost River State Forest; land use is dominated by forest and wetland, with a relatively small proportion of agricultural land uses. Population density is low (approximately five people per square mile), concentrated along the far eastern edge of the subwatershed, where small ditches drain the outskirts of the City of Warroad. There are no lakes in the subwatershed.

Sprague Creek is the primary watercourse, flowing nine miles south from the Canadian border towards its confluence with the Roseau River north of the City of Roseau, and was the only stream monitored in the subwatershed. Although most of the subwatershed's wetlands are crossed by drainage ditches, Sprague Creek's channel remains largely unmodified.

Summary

Water quality appears to be fairly good in Sprague Creek; no new impairments were identified and IBI scores indicate support for aquatic life (Table 6). An existing aquatic life impairment for turbidity will be re-evaluated once sufficient data has been collected; a limited dataset suggests that current conditions may meet the TSS standard. Some high phosphorus concentrations have been observed in recent years, but average concentrations are well below the water quality standard. It should be noted that, while most of Sprague Creek's catchment is densely forested, a narrow band of cropland surrounds the stream in many places, particularly near the Canadian border.

Table 6. Aquatic life and recreation assessments on stream reaches: Hay Creek Subwatershed.

WID ***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)
09020314-508 ***Sprague Creek*** *MN/Canada border to Roseau R*	15RD004 15RD024	9	WWg	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS		IF	FS	FS

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

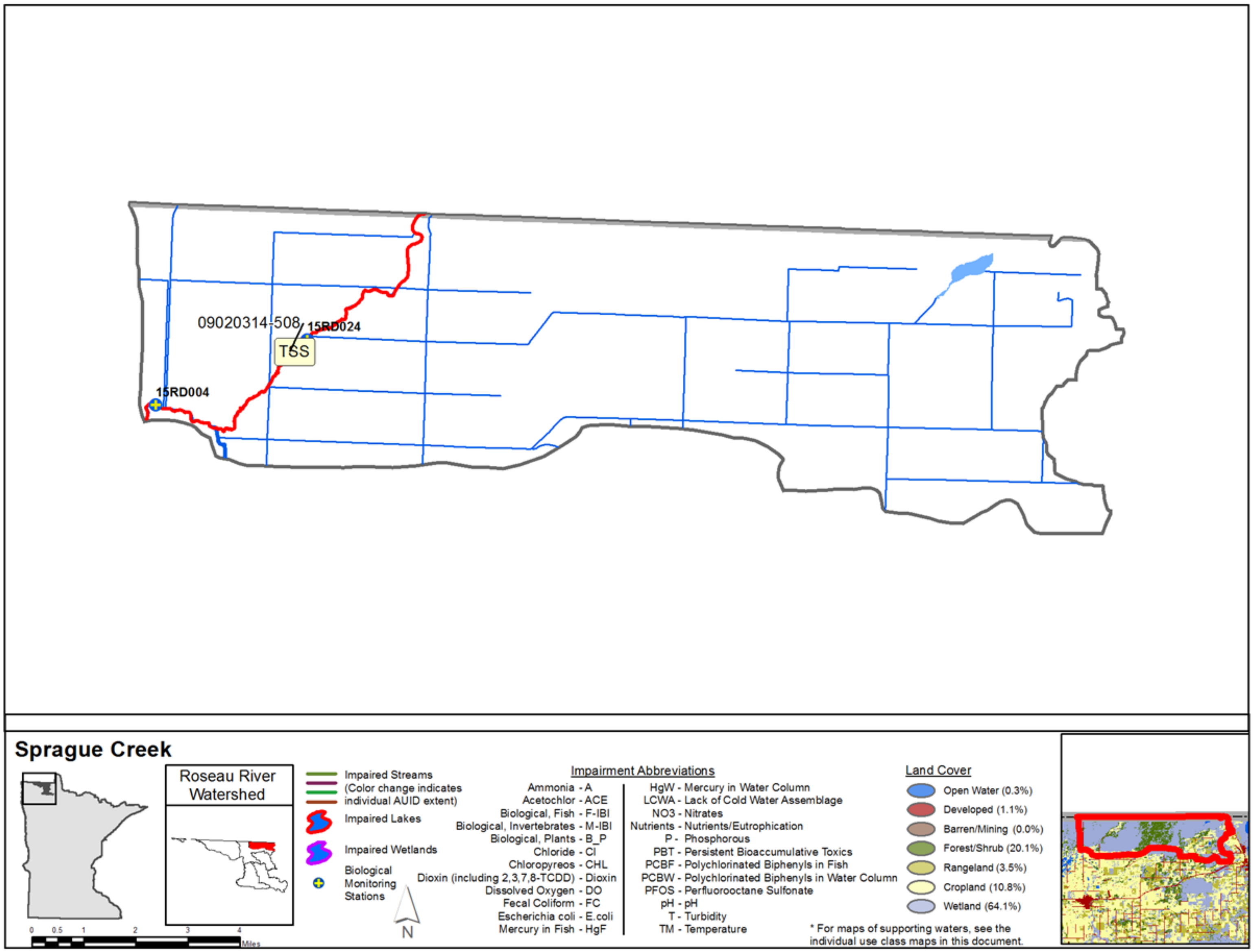
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)

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.

Figure 24. Currently listed impaired waters by parameter and land use characteristics in the Sprague Creek Subwatershed.



Upper Roseau River Subwatershed HUC 0902031405

The Upper Roseau River Subwatershed includes 183 square miles surrounding the city of Roseau. The HUC-10 is the most developed in the Roseau River Watershed, and population density is high for this region of the state (approximately 30 people per square mile). The subwatershed also has the highest proportion (60%) of agricultural land use in the Roseau River Watershed. The Roseau River is the major watercourse. It flows north though the city of Roseau, then angles northwest and west through the drained bed of Roseau Lake, a distance of 23 miles from its confluence with the South Fork Roseau River to the western boundary of the HUC-10 at Ross. Along the way, most of the Roseau River's major tributaries enter the river, including the South Fork Roseau River, Hay Creek, Sprague Creek, and Pine Creek. Downstream of the Hay Creek confluence, the Roseau River has been dredged for nearly the entire remaining distance to the Canadian border; this work was first undertaken in the early 20th Century. A recently constructed diversion channel (Roseau East Diversion) routes high flows around the city of Roseau, and a portion of the river upstream of the city is partially impounded by the remains of a dam.

Summary

The Roseau River was monitored at multiple locations within the Upper Roseau River HUC-10 (Table 7). Fish and macroinvertebrate IBI scores indicate that the reach between the South Fork and Hay Creek (AUID 502) is in good condition. The reach of the Roseau River between Hay Creek and the community of Ross (WID 501) also appears to be in good condition, and will be discussed in more detail as part of the following subwatershed summary (see Middle Roseau River, 0902031406).

Pine Creek flows six miles from the Canadian border to the Roseau River, entering the river within the drained bed of Roseau Lake. Aquatic life is impaired in Pine Creek based on low fish IBI scores. Pine Creek originally drained more than 85 square miles, most of which lay on the Canadian side of the border. In the 1950s, a flood-control diversion channel was constructed on the Canadian side, which routes most of Pine Creek's flow southwest to large ponds on the U.S. side (in the Roseau River Wildlife Management Area). At the point of diversion, Pine Creek drains approximately 50 square miles. As a result of the diversion, the downstream portion of Pine Creek receives much less flow than it did historically, and has likely suffered associated impacts to water quality and aquatic habitat.

Table 7. Aquatic life and recreation assessments on stream reaches: Upper Roseau River Subwatershed.

WID *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)
09020314-502 ***Roseau River*** *S Fk Roseau R to Hay Cr*	15RD008 15RD027	9	WWg	MTS	MTS	IF	IF	IF		IF	IF		IF	FS	
09020314-542 ***Pine Creek*** *Unnamed cr to Roseau R*	15RD029	6	WWg	EXS	MTS	IF	IF	IF		IF	IF		MTS	NS	FS

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
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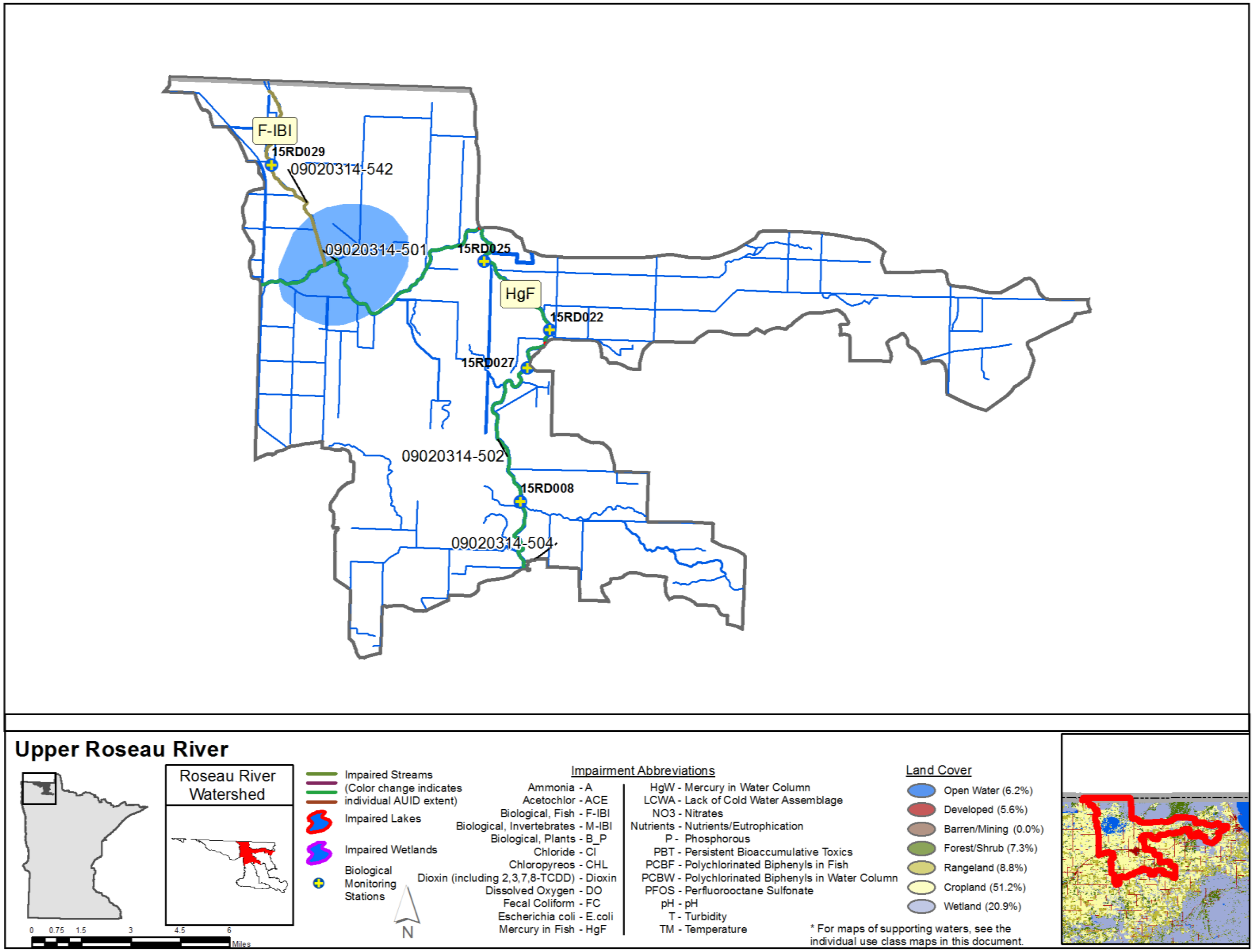
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Figure 25. Currently listed impaired waters by parameter and land use characteristics in the Upper Roseau River Subwatershed.



Middle Roseau River Subwatershed HUC 0902031406

The Middle Roseau River Subwatershed drains 250 square miles. The Roseau River is the major watercourse, flowing 50 miles from the community of Ross to the Canadian border. An enormous wetland complex (the “Big Swamp”) dominates the center of the HUC-10, comprising approximately 40% of the subwatershed. Most of the Big Swamp lies within the boundaries of the Roseau River Wildlife Management Area (WMA). An extensive network of ditches crosses the WMA, draining into the Roseau River, but few other natural streams are found in this subwatershed. On the eastern and western sides of the WMA, land use is dominated by cropland and pasture. A few small communities are found in the subwatershed, but population density is low (less than people per square mile).

Summary

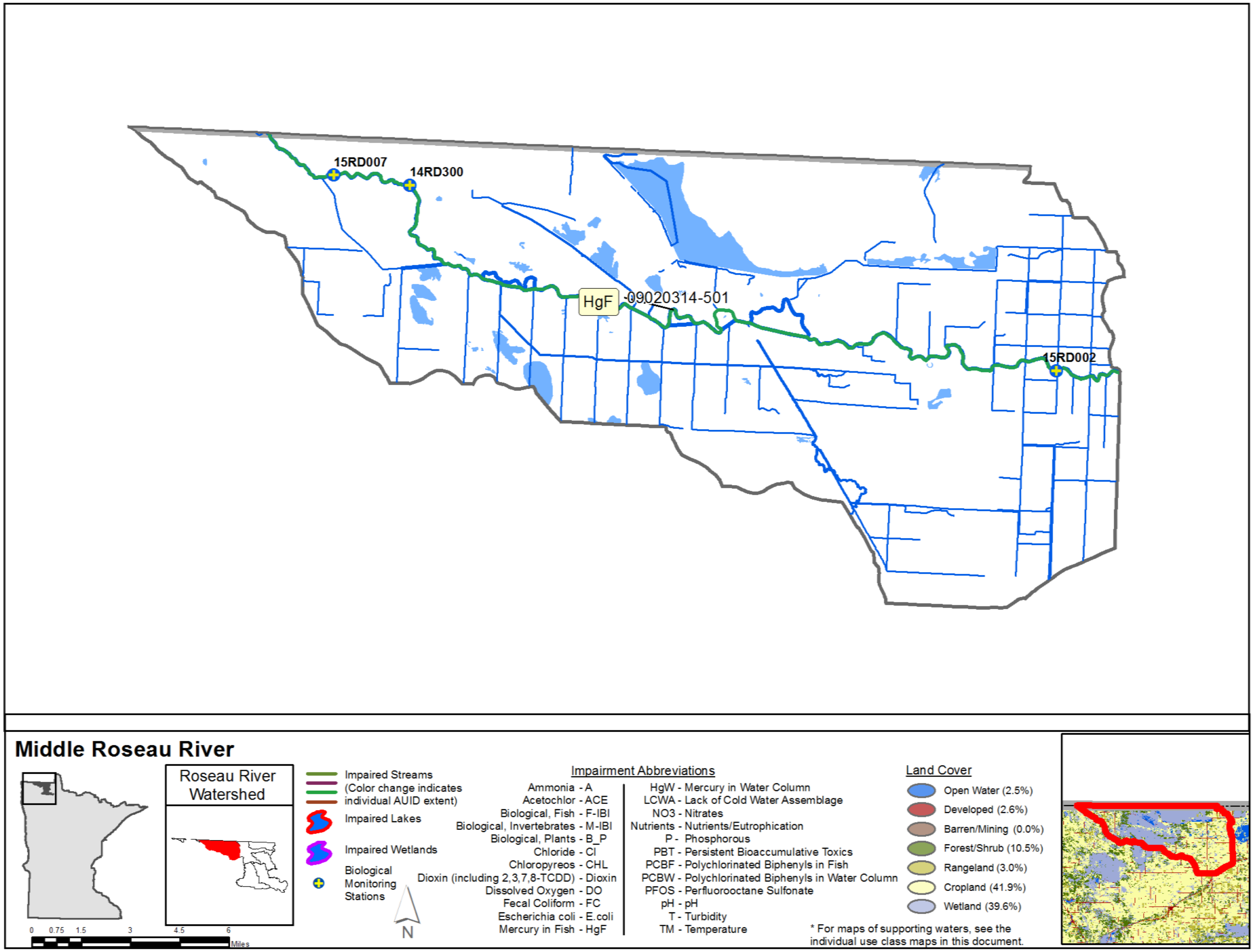
The Roseau River was monitored at multiple locations within the Middle Roseau River Subwatershed (Table 8). Most aquatic life indicators suggest good water quality, and no impairments were identified. Phosphorus levels are high, but chlorophyll-a levels are very low, indicating that elevated phosphorus is not resulting in increased algal growth. Existing impairments for low dissolved oxygen and high levels of turbidity were removed. In the case of dissolved oxygen, the existing impairment was corrected by acknowledging the influence of the massive wetland complex immediately adjacent to the Roseau River. In the case of turbidity, conditions have improved since the early 2000s.

Table 8. Aquatic life and recreation assessments on stream reaches: Middle Roseau River Subwatershed.

WID *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)
09020314-501 ***Roseau River*** *Hay Cr to MN/Canada border*	14RD300 15RD002 15RD007 15RD022 15RD025	50	WWg	MTS	MTS	MTS	MTS	MTS	MTS	MTS	MTS		IF	FS	FS

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.

Figure 26. Currently listed impaired waters by parameter and land use characteristics in the Middle Roseau River Subwatershed



Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed unit of the Roseau River Watershed, grouped by sample type. Summaries are provided for lakes, streams, and rivers in the watershed for the following: aquatic life and aquatic recreation uses, aquatic consumption results, load monitoring data results, and transparency trends. 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 Roseau River Watershed.

Stream water quality

Fourteen of the 35 stream WIDs were assessed (Table 9). Of the 14 assessed streams, nine fully supported aquatic life and five streams fully supported aquatic recreation. Four streams did not support aquatic life and/or recreation. Of those, four did not support aquatic life and one did not support aquatic recreation.

Lake water quality

Hayes Lake is the only lake in the watershed. It met standards for aquatic recreation (Table 10). The lake has a large watershed, which consists of 90% wetlands.

Fish contaminant results

Mercury and PCBs were analyzed in fish tissue samples collected from the Roseau River in 2015 by MPCA biomonitoring staff. Samples had previously been collected by DNR fisheries staff in 1992. The only lake sampled for fish contaminants in the watershed was Hayes Lake; samples were collected in 1993 and 2014.

The Roseau River is on the 2018 Impaired Waters Inventory (IWI) for mercury in fish tissue; the three listed WIDs for the river extend from headwaters to the Canada border. All species collected in 2015 were tested for PCBs and all were determined to contain less than the reporting limit, except for a common carp collected in 1992, which was only slightly above the 0.025 mg/kg reporting limit (Table 11).

Hayes Lake is on the IWI but qualified for inclusion in the Minnesota Statewide Mercury TMDL. Fish from Hayes Lake tested for PCBs were below the reporting limit.

Table 9. Assessment summary for stream water quality in the Roseau River Watershed.

				Supporting		Non-supporting			
Watershed	Area (acres)	# Total WIDs	# Assessed WIDs	# Aquatic life	# Aquatic recreation	# Aquatic life	# Aquatic recreation	Insufficient data	# Delistings
09020314 **HUC-8**	**679,641**	**35**	**14**	**9**	**5**	**4**	**1**	**1**	**0**
0902031401	136,144	6	4	2	1	2	0	0	0
0902031402	136,927	14	4	3	1	0	0	1	0
0902031403	74,331	5	2	1	0	1	1	0	0
0902031404	55,790	2	1	1	1	0	0	0	0
0902031405	117,122	5	2	1	1	1	0	0	0
0902031406	159,328	3	1	1	1	0	0	0	2

Table 10. Assessment summary for lake water chemistry in the Roseau River Watershed.

			Supporting		Non-supporting			
Watershed	Area (acres)	Lakes >10 acres	# Aquatic life	# Aquatic recreation	# Aquatic life	# Aquatic recreation	Insufficient data	# Delistings
09020314 **HUC-8**	**679,641**	**1**	**N/A**	**1**	**0**	**0**	**0**	**0**
0902031401	136,144	1	N/A	1	0	0	0	0

Table 11. Fish contaminants: summary of fish length, mercury, PCBs, and PFOS by waterway-species-year

					Total	Number	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)			
WID / RIVER	Waterway / Location	Species	Year	Anatomy[1]	Fish	Samples	Mean	Min	Max	Mean	Min	Max	N	Mean	Max	<RL
ROSEAU R.** (09020314-501, 09020314-504, 09020314-502)	DOWNSTREAM OF CR53 AT CARIBOU	Channel catfish	2015	FILET	1	1	23.4	23.4	23.4	0.675	0.675	0.675	1	0.025	0.025	Y
		Northern pike	2015	FILSK	7	7	19.9	17.5	23.1	0.296	0.175	0.407	5	0.025	0.025	Y
		Walleye	2015	FILSK	1	1	19.4	19.4	19.4	0.962	0.962	0.962	1	0.025	0.025	Y
		White sucker	2015	FILSK	1	1	18.0	18.0	18.0	0.519	0.519	0.519	1	0.025	0.025	Y
	RM 126-128, 7 MI NW OF ROSEAU PUB. ACC.	Common carp	1992	FILSK	8	2	19.4	18.2	20.7	0.285	0.180	0.390	1	0.028	0.028	
		Walleye	1992	FILSK	5	2	14.2	9.5	18.9	0.420	0.250	0.590	1	0.01	0.01	Y
68000400	HAYES*	Bluegill sunfish	2014	FILSK	10	1	8.7	8.7	8.7	0.112	0.112	0.112				
		Black crappie	1993	FILSK	11	1	6.8	6.8	6.8	0.160	0.160	0.160				
		Northern pike	1993	FILSK	16	4	23.5	18.4	28.4	0.255	0.190	0.300	1	0.01	0.01	Y
			2014	FILSK	8	8	25.9	20.6	35.0	0.289	0.208	0.540				
		White sucker	1993	FILSK	5	1	18.7	18.7	18.7	0.290	0.290	0.290	1	0.01	0.01	Y
			2014	FILSK	3	1	20.4	20.4	20.4	0.177	0.177	0.177				

* 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

Pollutant load monitoring

The WPLMN has one site within the Roseau River watershed as shown in Table 12. Due to access issues, samples are not collected at the USGS gaging location but at the CR53 bridge crossing, approximately two miles upstream.

Table 12. WPLMN stream monitoring sites for the Roseau River Watershed

Site Type	Stream Name	USGS ID	DNR/MPCA ID	EQuIS ID
Subwatershed	Roseau River at Caribou, CR 53	05112000	E71005001, W71005002	S000-115

Average annual FWMCs of TSS, TP, and NO_3+NO_2-N for major watershed stations statewide are presented below, with the Roseau River Watershed highlighted. As shown in Figure 27, the Roseau River watershed has no data; this is because there is no major watershed or basin site in the watershed. This portion of the report will focus data collected at the subwatershed site.

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 general 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, released phosphorus from anoxic phosphorus sinks 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.

NO_3+NO_2-N levels measured at the Roseau River at Caribou were lower than most watersheds of similar size in the Red River Basin. A combined 54 samples were collected during the 2014 and 2015 monitoring seasons with a mean NO_3+NO_2-N concentration of 0.17 mg/L. The flow weighted mean concentrations were at or less than 0.1 mg/L, low values from a statewide perspective (since low concentrations occurred at the highest flows).

TSS levels measured at the Roseau River at Caribou were also lower than most watersheds of similar size in the Red River Basin. A combined 54 samples were collected during the 2014 and 2015 monitoring seasons with a mean TSS concentration of 7.4 mg/L. However, 13% of the samples collected exceeded the TSS standard for the northern river nutrient region (RNR) but 0% exceeded the standard for the southern RNR. The Roseau River Watershed lies within the southern RNR (western and southwest portions of the watershed) and the northern RNR.

Unlike TSS, TP concentrations measured from the Roseau River at Caribou were surprisingly comparable to most watersheds of similar size in the Red River Basin. A combined 54 samples were collected during the 2014 and 2015 monitoring seasons with a mean concentration of 0.111 mg/L. The flow weighted mean concentrations for 2014 and 2015 were 0.110 mg/L and 0.107 mg/L, respectively. Of the samples collected during the summer months of June, July and August, 10% exceeded the water quality standard for the southern RNR and 66% of the samples collected exceeded the standard for the northern RNR.

Substantial year-to-year variability in water quality occurs for most rivers and streams, including the Roseau River. Results for individual years are shown in the charts (Figure 28) below. More information, including results for subwatershed stations, can be found at the WPLMN website.

Figure 27. 2007-2015 average annual TSS, TP, and NO3-NO2-N flow weighted mean concentrations and runoff by major watershed.

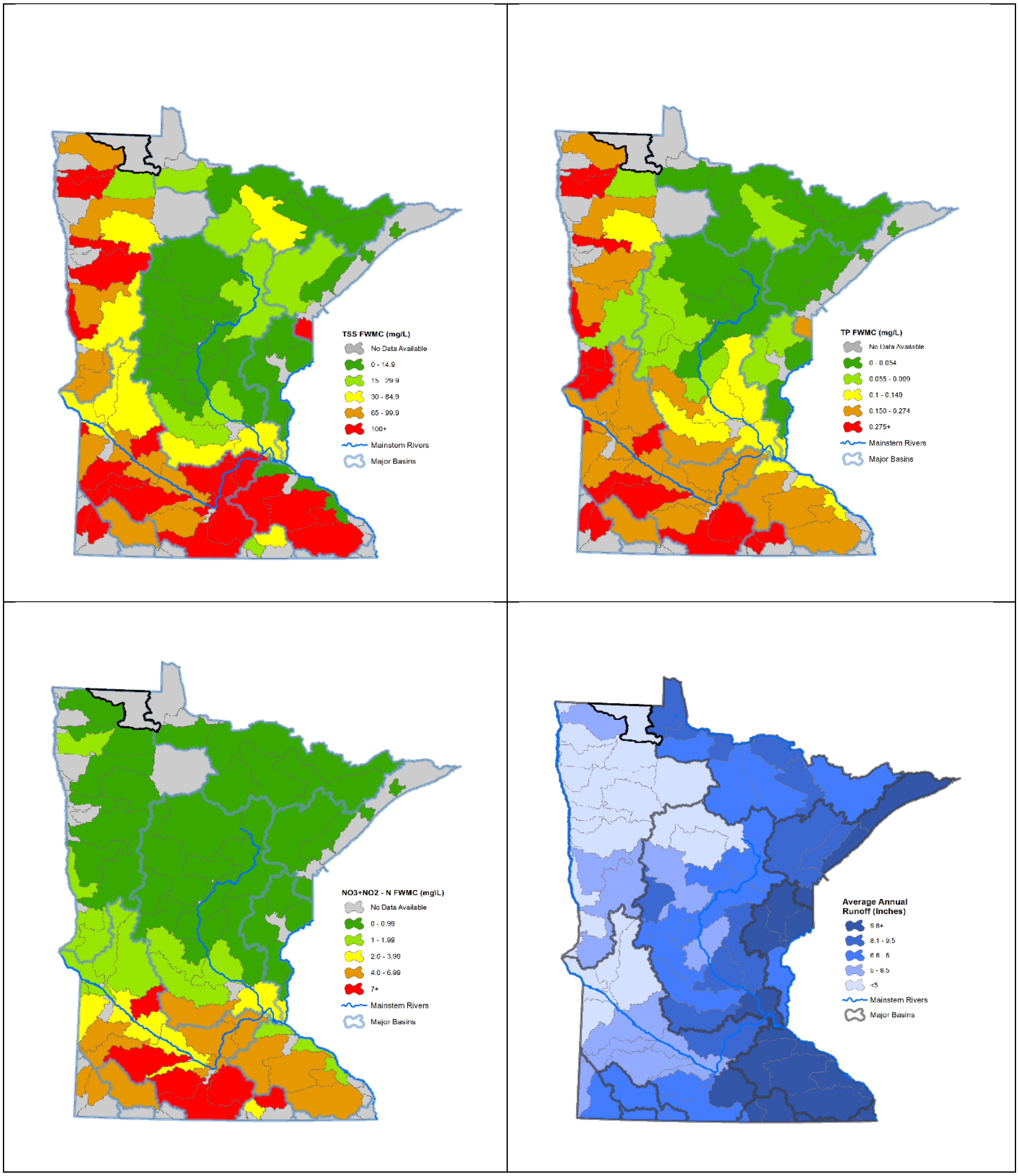


Figure 28. TSS, TP, and NO3+NO2-N Flow Weighted Mean Concentrations and Loads for the Roseau River at Caribou, Minnesota.

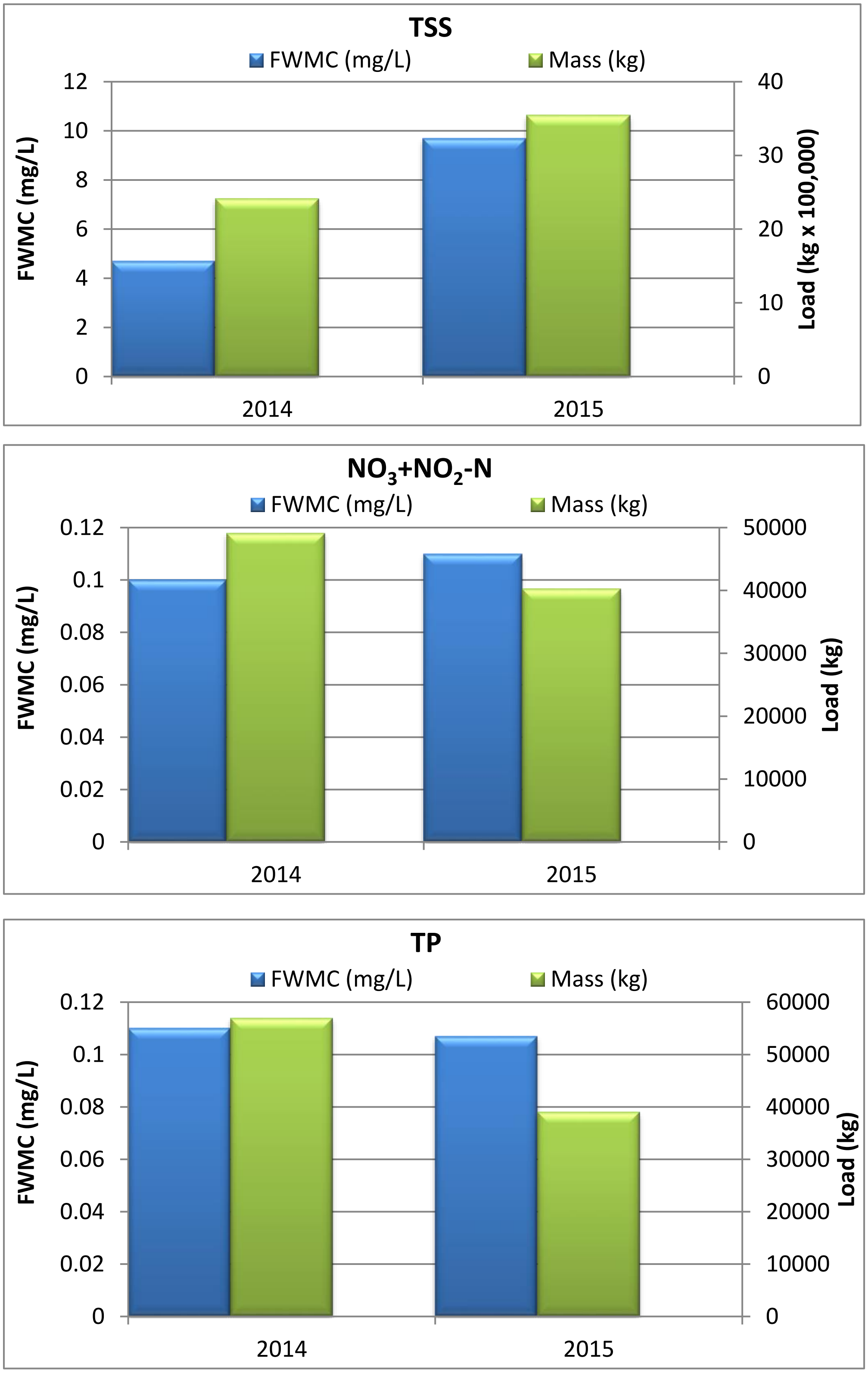
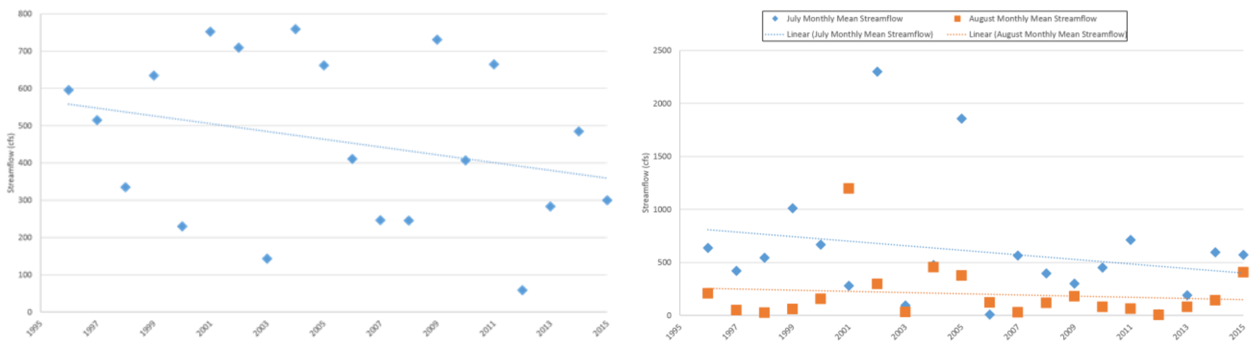


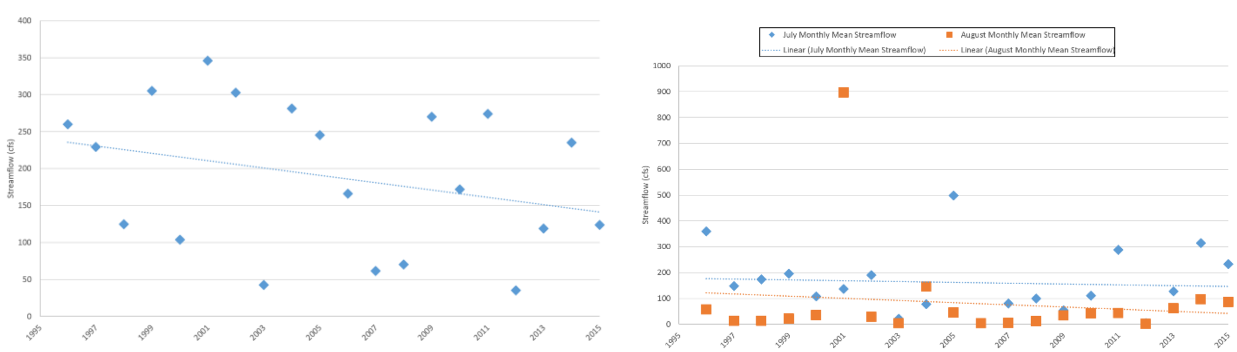
Figure 29. Annual mean (left) and monthly mean (right) streamflow for Roseau River at Ross, Minnesota (1996-2015) (Source: USGS 2018a)



Streamflow

Streamflow data from the United States Geological Survey's real-time streamflow gaging stations for two rivers in the Roseau River Watershed were analyzed for annual mean discharge and summer monthly mean discharge (July and August). Figure 29 (*left panel*) is a display of the annual mean discharge for the Roseau River at Ross, Minnesota from water years 1996 to 2015. Figure 29 (*right panel*) displays July and August mean flows for the same time frame for the same water body. Figure 30 is the annual (*left panel*) and monthly (*right panel*) mean streamflow for Roseau River below South Fork near the community of Malung for the same water years. Graphically, the data appears to be decreasing in all waterbodies over time, both annually and during July and August flows; however, not 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 30. Annual mean (left) and monthly mean (right) streamflow for Roseau River near Malung (1996-2015) (Source: USGS 2018b)



Wetland condition

The Roseau River Watershed is split between the Temperate Prairies and Mixed Wood Shield Ecoregion. Wetland condition, in the Mixed Wood Shield Ecoregion is generally very good, however, in the Temperate Prairies Ecoregion wetland condition is significantly lower quality. Based on plant community floristic quality, 84% of the wetlands in the Mixed Wood Shield Ecoregion are estimated to be in exceptional or good condition and there are 0% estimated to be in poor condition (Table 13). In the Temperate Prairies Ecoregion, the results are essentially opposite. In these locations significant extents of wetland area are dominated by invasive plants, particularly narrow-leaf cattail (*Typha angustifolia*), hybrid cattail (*Typha X glauca*), and reed canary grass (*Phalaris arundinacea*). These invasive plants often outcompete native species due to their tolerance of nutrient enrichment, hydrologic alterations and toxic pollutants such as chlorides (Galatowisch 2012) and thus strongly influence the composition and structure of the wetland plant community. In this watershed and other HUC-8 watersheds predominantly located within the Mixed Wood Shield Ecoregion water quality efforts should focus on protecting the quality wetland resource that is present including efforts to limit hydrologic alterations and the spread of invasive species which are known to rapidly and dramatically impact wetland quality.

Table 13. Wetland biological condition by major ecoregions based on floristic quality. Results are expressed as an extent (i.e., percentage of wetland acres) and include essentially all wetland types (MPCA 2015).

Vegetation Condition in All Wetlands			
Condition Category	**Mixed Wood Shield**	**Mixed Wood Plains**	**Temperate Prairies**
Exceptional	64%	6%	7%
Good	20%	12%	11%
Fair	16%	42%	40%
Poor		40%	42%

Figure 31. Stream Tiered Aquatic Life Use Designations in the Roseau River Watershed.

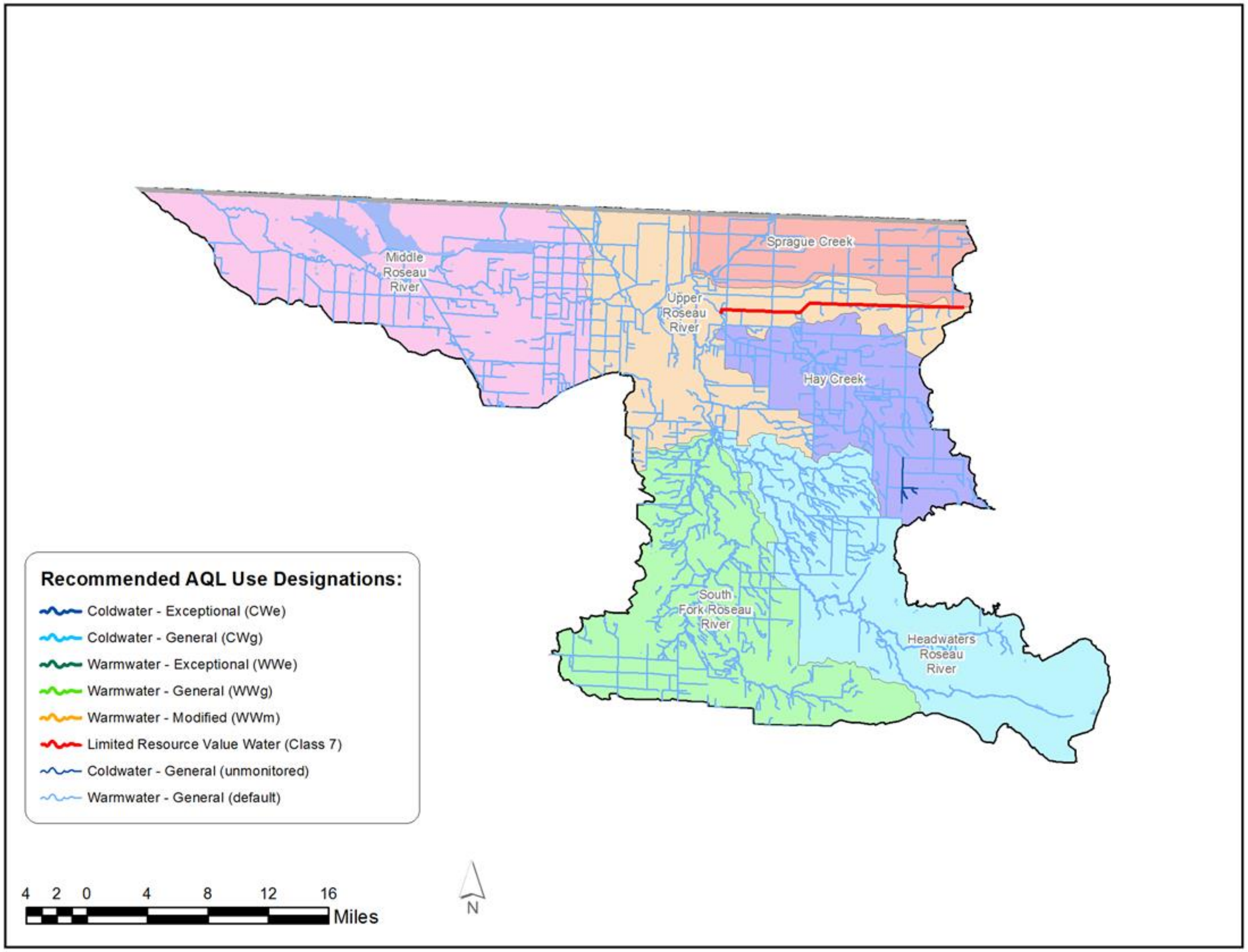


Figure 32. Fully supporting waters by designated use in the Roseau River Watershed.

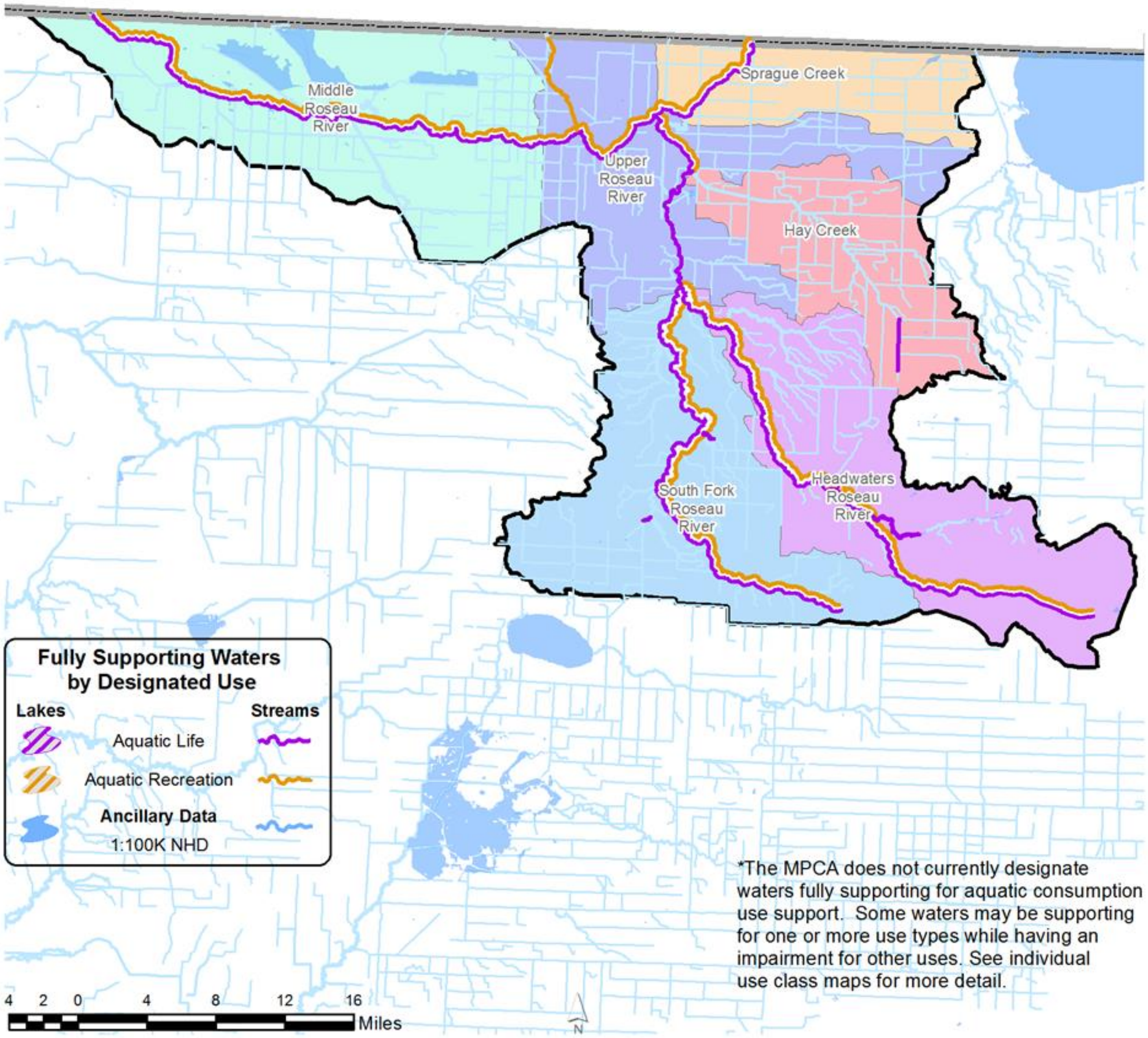


Figure 33. Impaired waters by designated use in the Roseau River. Watershed

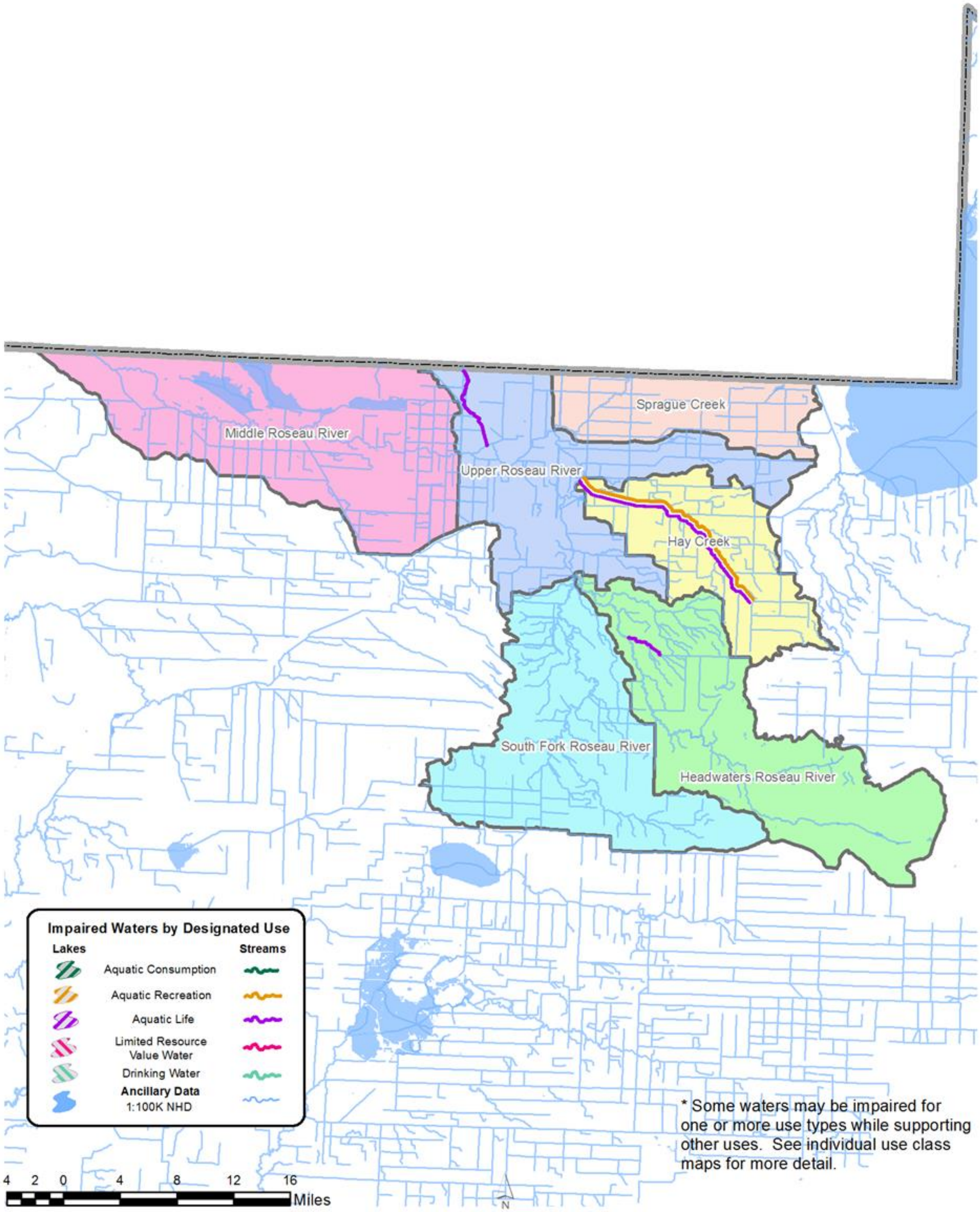


Figure 34. Aquatic consumption use support in the Roseau River Watershed.

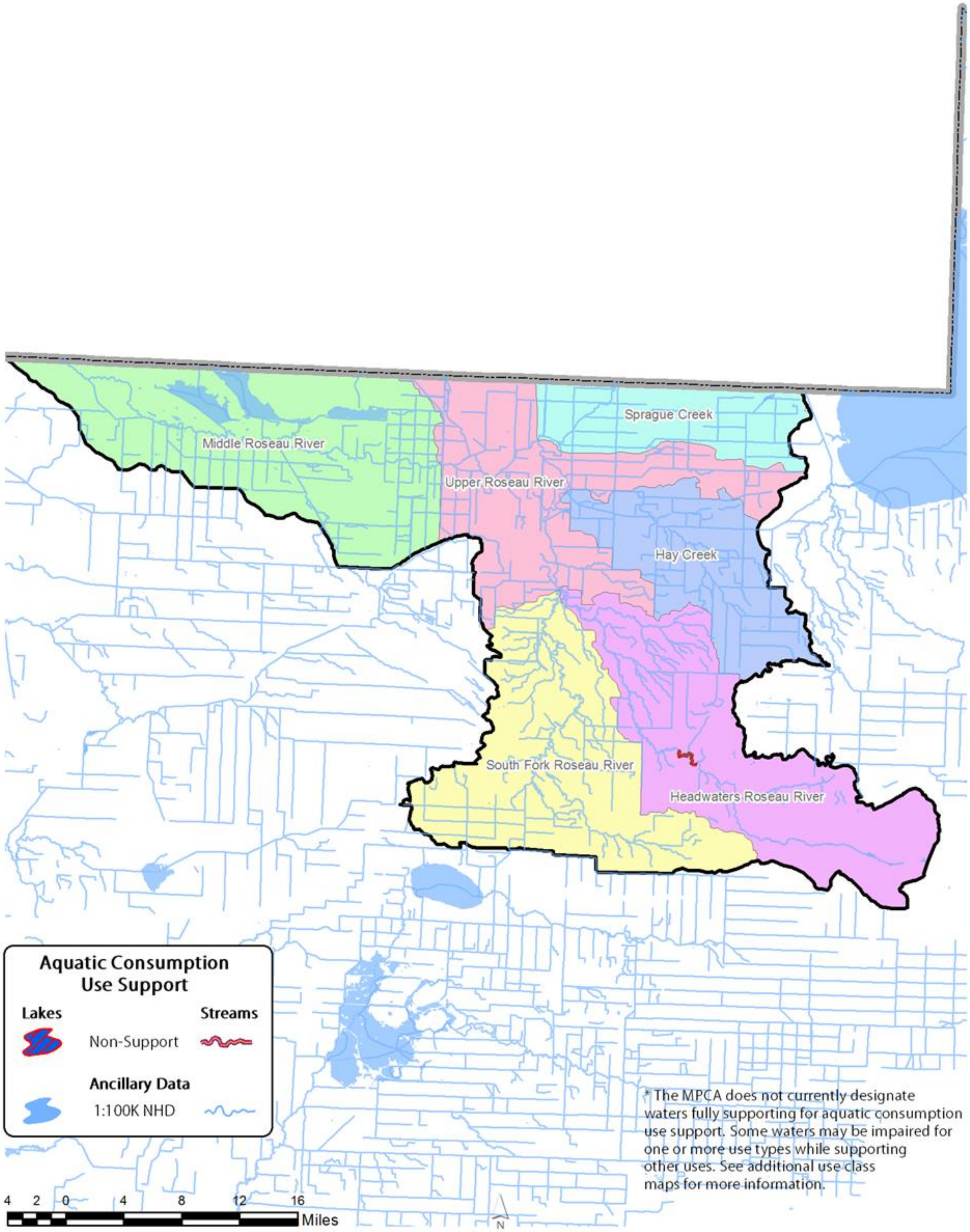


Figure 35. Aquatic life use support in the Roseau River Watershed.

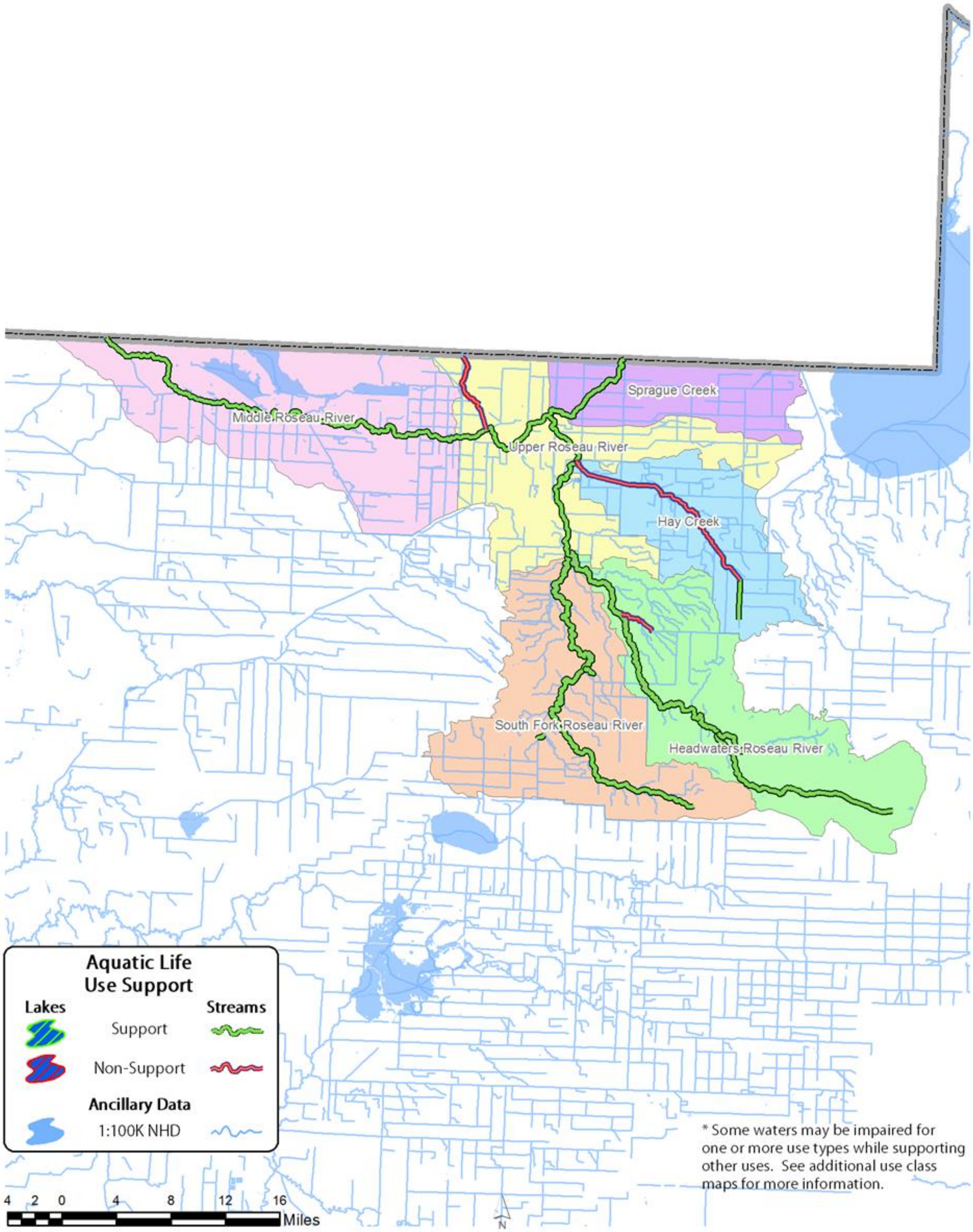
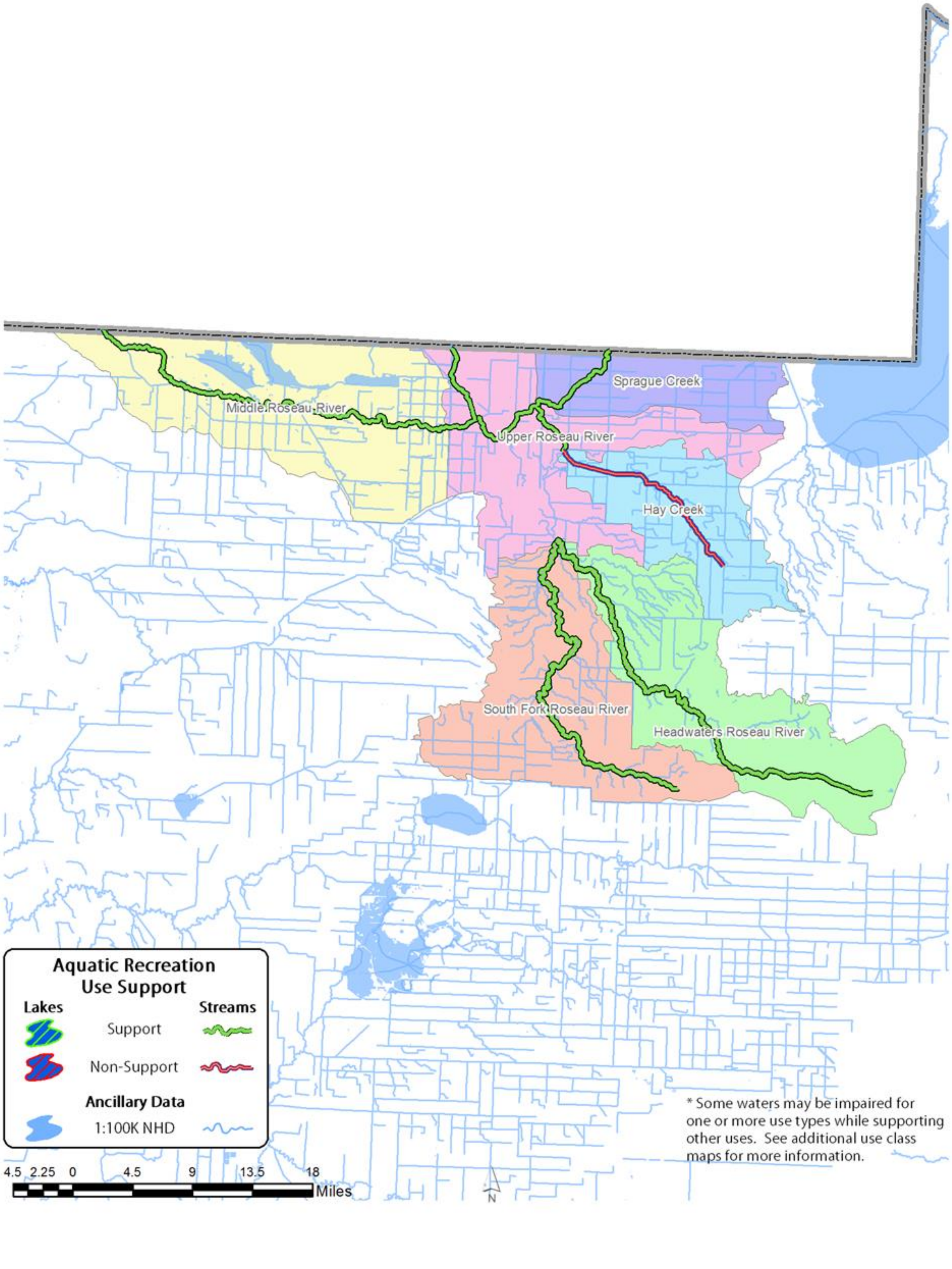


Figure 36. Aquatic recreation use support in the Roseau River Watershed.



Transparency trends for the Roseau 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. In the Roseau River Watershed, no trends were detected in streams and no long term monitoring occurred for Hayes Lake.

Table 14. Water clarity trends.

Roseau River Watershed	Streams	Lakes
Number of sites w/increasing trend	0	0
Number of sites w/decreasing trend	0	0
Number of sites w/no trend	10	0

In June 2014, the MPCA published its final trend analysis of river monitoring data collected 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.

Summaries and recommendations

Aquatic resources span a wide range of condition in the Roseau River Watershed. The mainstem Roseau River is in good condition, despite a long history of ditching, drainage, and diversion. While some tributaries are also in good condition (e.g., Mickinock Creek), others are in poor condition (e.g., Pine Creek). Water quality appears to be improving in some cases (e.g., Roseau River), but declining in others (e.g., Hay Creek). Some streams support diverse biological communities, including sensitive aquatic organisms that are rare in this part of the state (e.g., Longnose Dace in the Roseau River near the community of Malung), while other streams support relatively homogenous biological assemblages that are dominated by tolerant species (e.g., Severson Creek). The watershed's only natural lake, Roseau Lake, has been completely drained, but the watersheds only existing lake (Hayes Lake, an impoundment) is in good condition. The Roseau River Watershed is a land of contrasts; restoration and protection strategies should be developed to address the unique circumstances of each waterbody.

A large portion of the Roseau River Watershed lies within a 100-year floodplain. The modification of watercourses for the purpose of flood damage reduction has been a recurring theme since the early 20th century. Recent projects (e.g., Roseau East Diversion) have emphasized mitigation of water quality impacts and impacts to aquatic habitat, but the legacy effects of some older projects still remain. For example, the Pine Creek Diversion (completed in 1953) effectively cut the lower portion of Pine Creek off from its contributing watershed, routing most streamflow into large pools in the Roseau River Wildlife Management Area. Pine Creek is impaired for aquatic life based on poor fish IBI scores, likely due (in part) to this dramatic alteration of flow regime and watershed processes. Restoration plans for Pine Creek should include a restoration of hydrologic connectivity between the upper and lower reaches, and returning some semblance of a natural flow regime to the creek.

Among the impaired waters in need of restoration, Hay Creek and Severson Creek are notable in that conditions appear to have deteriorated since they were first monitored in 2005. For example, fish and macroinvertebrate IBI scores have declined on Hay Creek, particularly at the downstream monitoring location (station 05RD043) where, in intervening years, the channel was widened and setback levees installed for flood damage reduction. These modifications appear to have negatively impacted aquatic habitat; in 2005, habitat at 05RD043 rated "good", while recent surveys have rated habitat only "fair". Restoration efforts for Hay Creek should focus, in part, on improving aquatic habitat. At a broader scale, the channel alterations that will inevitably continue to occur across the Roseau River Watershed for flood damage reduction should consider potential impacts to water quality and aquatic habitat, and mitigation measures should be implemented if possible.

Protection candidates in the watershed include both the South Fork Roseau River and the upper portion of the Roseau River above the streams' confluence near the community of Malung. At their confluence, the two streams are nearly equal in size and drain mixed landscapes of forest, wetland, and agriculture. Water quality and aquatic habitat remain in good condition, although at least one impaired tributary (Severson Creek) could benefit from restoration efforts. A substantial portion of the upper Roseau River's catchment lies within Hayes Lake State Park and Beltrami Island State Forest, and a forested riparian corridor is present along most of the stream's length. These forested areas likely cool the upper Roseau River through shading, and contribute large wood to the stream, providing important habitat for aquatic organisms. Without these forested areas, it seems unlikely that the upper Roseau River would support what appears to be an isolated population of Longnose Dace, a sensitive coolwater fish that is rare in Northwest Minnesota. Its presence in the upper Roseau River is an indicator of good watershed health, and persistence of this species may depend on maintaining quality forest cover. Other high-quality forested streams in the upper portion of the Roseau River Watershed include Hansen Creek and Bemis Hill Creek.

Groundwater summary and recommendations

Groundwater protection should be considered both for quantity and for quality. Quantity is based on the amount of water withdrawn versus the amount of water being recharged to the aquifer. Groundwater withdrawals in the watershed have decreased at a statistically significant rate ($p<0.001$) from 1996 to 2015, which is designated for municipal water supply. Surface water withdrawals have increased where before 2010 there were no reported high capacity withdrawals. From 2010 to 2015, there was no trend for surface water withdrawals.

Ground water quality data is limited in the Roseau River Watershed. Baseline water quality data indicated that the northwest region has groundwater quality that is considered poor in the sand and gravel aquifers as well as the Cretaceous aquifers. When analyzing the single MPCA ambient monitoring well, there were detection flags for 11 different analytes during the five years' worth of available data. There were no exceedances to the MCLs. MDH determined that this area experienced some exceedances of the arsenic 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. The MPCA baseline water quality analysis of this region identified that arsenic was highest in buried sand and gravel aquifers along stagnation moraines. The pollution sensitivity of near-surface materials throughout the watershed is primarily ultra-low to low, but there are scattered areas with high pollution sensitivity throughout the watershed. These areas correlate with sand and gravel quaternary geology and may experience a possible risk of contamination due to high infiltration rates.

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.

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Appendix A. 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 (NH_3) - Ammonia is present in aquatic systems mainly as the dissociated ion NH_4^+, 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 NH_4^+ ions and -OH ions (ammonium hydroxide). If pH levels increase, the ammonium hydroxide becomes toxic to both plants and animals.

Appendix B. IWM water chemistry stations in the Roseau River Watershed

EQuIS ID	Biological station ID	WID	Waterbody name	Location	Aggregated 12-digit HUC
S008-406	15RD003	09020314-503	Roseau River	At CR 2, 0.5 mi. NW of Malung	0902031402
S004-288	15RD006	09020314-504	Roseau River	At CSAH 4, 4 mi. SE of Pencer	0902031401
S008-407	15RD002	09020314-501	Roseau River	At CR 115, 2 mi. W of Ross	0902031406
S000-116	15RD005	09020314-504	Roseau River	At CR 2, 0.5 mi. W of Malung	0902031401
S000-115	15RD007	09020314-501	Kittson	At CR 53, at Caribou	0902031406
S003-097	15RD004	09020314-508	Sprague Creek	At Hwy 310, 6.5 mi. N of Roseau	0902031404
S002-105	05RD043	09020314-505	Hay Creek	At CSAH 28, 3.5 mi. NE of Roseau	0902031403

Appendix C. IWM biomonitoring stations in the Roseau River Watershed

WID	Biological station ID	Waterbody name	Biological station location	County	HUC-10
09020314-505	05RD043	Hay Creek (County Ditch 7)	Upstream of CSAH 28, 3 mi. NE of Roseau	Roseau	0902031403
09020314-517	05RD083	Hansen Creek	Upstream of CSAH 19, 2 mi. W of Winner	Roseau	0902031401
09020314-505	05RD084	Hay Creek (County Ditch 9)	Downstream of CSAH 12, 9 mi. SE of Roseau	Roseau	0902031403
09020314-516	05RD085	Severson Creek (County Ditch 23)	Upstream of 450th Ave, 1.5 mi. N of Pencer	Roseau	0902031401
09020314-503	05RD128	Roseau River, South Fork	Downstream of CR 128, 12 mi. S of Roseau	Roseau	0902031402
09020314-501	15RD002	Roseau River	Downstream of CR 115, 2 mi. W of Ross	Roseau	0902031406
09020314-503	15RD003	Roseau River, South Fork	Downstream of CR 2, 0.5 mi. NW of Malung	Roseau	0902031402
09020314-508	15RD004	Sprague Creek	Downstream of Hwy 310, 6.5 mi. N of Roseau	Roseau	0902031404
09020314-504	15RD005	Roseau River	Upstream of CR 2, 0.5 mi. W of Malung	Roseau	0902031401
09020314-504	15RD006	Roseau River	Upstream of CSAH 4, 4 mi. SE of Pencer	Roseau	0902031401
09020314-501	15RD007	Roseau River	Downstream of CR 53, in Caribou	Kittson	0902031406
09020314-522	15RD011	Mickinock Creek	Upstream of private drive (38198 CR 122), 1 mi. SW of Torfin	Roseau	0902031402
09020314-540	15RD013	Paulson Creek	Downstream of 420th Ave, 2 mi. E/NE of Wannaska	Roseau	0902031402
09020314-541	15RD016	Severson Creek/County Ditch 23	Downstream of 220th St, 2 mi. NE of Pencer	Roseau	0902031401
09020314-512	15RD017	County Ditch 9	Downstream of 530th Ave, 10 mi. SW of Salol	Roseau	0902031403
09020314-501	15RD022	Roseau River	Downstream of CSAH 28, 3 mi. N of Roseau	Roseau	0902031405
09020314-508	15RD024	Sprague Creek	Adjacent to 410th Ave, 10 mi. NE of Roseau	Roseau	0902031404
09020314-501	15RD025	Roseau River	Downstream of Hwy 310, 5 mi. N of Roseau	Roseau	0902031405
09020314-502	15RD027	Roseau River	1 mi. upstream of CSAH 28, 1.5 mi. N of Roseau	Roseau	0902031405
09020314-542	15RD029	Pine Creek	Downstream of CR 118, 4 mi. N of Ross	Roseau	0902031405
09020314-503	15RD032	Roseau River, South Fork	Upstream of CSAH 8, 3 mi. SW of Wannaska	Roseau	0902031402
09020314-504	15RD033	Roseau River	Upstream of CSAH 19, 3 mi. W of Winner	Roseau	0902031401
09020314-503	15RD034	Roseau River, South Fork	Downstream of 410th Ave, 1.5 mi. W of Casperson	Roseau	0902031402

Appendix D. 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 E. 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
0902031401 (Headwaters Roseau River)							
09020314-504	15RD033	Roseau River	71	5	47	51.6	8/5/2015
09020314-504	15RD006	Roseau River	126	5	47	59.1	8/4/2015
09020314-504	15RD005	Roseau River	212	5	47	77.7	8/19/2015
09020314-516	05RD085	Severson Creek (County Ditch 23)	25	6	42	43.3	8/17/2016
09020314-517	05RD083	Hansen Creek	29	6	42	47.9	8/5/2015
09020314-517	05RD083	Hansen Creek	29	6	42	62.2	8/21/2013
0902031402 (South Fork Roseau River)							
09020314-503	15RD034	Roseau River, South Fork	41	6	42	41.4	8/16/2016
09020314-503	15RD032	Roseau River, South Fork	106	5	47	52.6	8/4/2015
09020314-503	05RD128	Roseau River, South Fork	146	5	47	62.7	8/4/2015
09020314-503	15RD003	Roseau River, South Fork	211	5	47	66.9	8/11/2015
09020314-522	15RD011	Mickinock Creek	44	6	42	60.6	8/4/2015
09020314-540	15RD013	Paulson Creek	23	6	42	53.8	6/17/2015
09020314-540	15RD013	Paulson Creek	23	6	42	63.9	8/4/2015
0902031403 (Hay Creek)							
09020314-505	05RD084	Hay Creek	37	6	42	60.0	8/4/2015
09020314-505	05RD043	Hay Creek	112	5	47	38.6	8/19/2015
09020314-505	05RD043	Hay Creek	112	5	47	48.0	8/16/2016
09020314-512	15RD017	County Ditch 9	7	11	35	50.7	8/12/2015
0902031404 (Sprague Creek)							
09020314-508	15RD024	Sprague Creek	229	5	47	61.0	8/19/2015
09020314-508	15RD004	Sprague Creek	286	5	47	64.9	10/7/2015
0902031405 (Upper Roseau River)							
09020314-502	15RD008	Roseau River	465	4	38	63.5	9/1/2015

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi^2	Fish class	Threshold	FIBI	Visit date
09020314-502	15RD027	Roseau River	479	4	38	60.1	9/10/2015
09020314-542	15RD029	Pine Creek	85	5	47	0.0	9/2/2015
09020314-542	15RD029	Pine Creek	85	5	47	29.3	8/16/2016
0902031406 (Middle Roseau River)							
09020314-501	15RD022	Roseau River	598	4	38	67.8	9/10/2015
09020314-501	15RD025	Roseau River	642	4	38	58.6	9/9/2015
09020314-501	15RD002	Roseau River	1105	4	38	71.8	9/2/2015
09020314-501	14RD300	Roseau River	1403	4	38	66.7	9/23/2014
09020314-501	15RD007	Roseau River	1408	4	38	57.9	10/7/2015

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

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi²	Invert class	Threshold	MIBI	Visit date
0902031401 (Headwaters Roseau River)							
09020314-504	15RD033	Roseau River	71	3	53	57.2	8/5/2015
09020314-504	15RD006	Roseau River	126	4	51	86.0	8/4/2015
09020314-504	15RD005	Roseau River	212	4	51	86.0	8/19/2015
09020314-541	15RD016	Severson Creek/County Ditch 23	20	4	51	40.0	8/11/2015
09020314-516	05RD085	Severson Creek (County Ditch 23)	25	4	51	24.0	8/11/2015
09020314-516	05RD085	Severson Creek (County Ditch 23)	25	4	51	43.9	8/18/2016
09020314-517	05RD083	Hansen Creek	29	4	51	58.1	8/21/2013
09020314-517	05RD083	Hansen Creek	29	4	51	71.0	8/5/2015
0902031402 (South Fork Roseau River)							
09020314-503	15RD034	Roseau River, South Fork	41	3	53	50.9	8/4/2015
09020314-503	15RD032	Roseau River, South Fork	106	4	51	81.0	8/4/2015
09020314-503	05RD128	Roseau River, South Fork	146	4	51	60.0	8/4/2015
09020314-503	15RD003	Roseau River, South Fork	211	4	51	64.0	8/12/2015
09020314-522	15RD011	Mickinock Creek	44	4	51	75.0	8/17/2016
09020314-540	15RD013	Paulson Creek	23	3	53	53.0	8/4/2015
0902031403 (Hay Creek)							
09020314-505	05RD084	Hay Creek	37	3	53	9.0	8/4/2015
09020314-505	05RD084	Hay Creek	37	3	53	22.0	8/24/2016
09020314-505	05RD043	Hay Creek	112	3	53	18.7	8/19/2015
09020314-505	05RD043	Hay Creek	112	3	53	22.9	8/17/2016
09020314-512	15RD017	County Ditch 9	7	8	32	29.7	8/11/2015
0902031404 (Sprague Creek)							
09020314-508	15RD024	Sprague Creek	229	4	51	71.6	8/19/2015
09020314-508	15RD004	Sprague Creek	286	4	51	83.5	10/7/2015
0902031405 (Upper Roseau River)							
09020314-502	15RD027	Roseau River	479	7	41	45.7	9/10/2015
09020314-542	15RD029	Pine Creek	85	7	41	39.6	9/2/2015

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi^2	Invert class	Threshold	MIBI	Visit date
09020314-542	15RD029	Pine Creek	85	7	41	47.7	8/17/2016
0902031406 (Middle Roseau River)							
09020314-501	15RD022	Roseau River	598	2	31	44.0	9/9/2015
09020314-501	15RD025	Roseau River	642	2	31	29.6	9/9/2015
09020314-501	14RD300	Roseau River	1403	2	31	35.6	9/23/2014
09020314-501	15RD007	Roseau River	1408	2	31	47.7	10/7/2015

Appendix G. Fish species found during biomonitoring surveys

Common name	Quantity of stations where present	Quantity of individuals collected
black bullhead	1	1
black crappie	5	8
blacknose dace	12	403
blacknose shiner	8	49
blackside darter	23	812
bluegill	4	6
brassy minnow	1	2
brook stickleback	12	134
brook trout	1	1
burbot	12	58
central mudminnow	20	415
channel catfish	2	2
chestnut lamprey	6	9
common carp	4	9
common shiner	20	705
creek chub	15	446
fathead minnow	12	80
finescale dace	5	28
Gen: redhorses	3	28
golden redhorse	7	44
Iowa darter	2	2
johnny darter	20	516
lamprey ammocoete	3	68
largemouth bass	11	114
longnose dace	1	2
mimic shiner	1	1
northern pike	20	206
northern redbelly dace	7	23
pearl dace	5	37
pumpkinseed	1	5
rock bass	13	89
sand shiner	4	12
sauger	1	1
shorthead redhorse	7	18
silver lamprey	2	2
silver redhorse	1	4
spotfin shiner	5	45
stonecat	2	2
tadpole madtom	11	49
trout-perch	7	52

Common name	Quantity of stations where present	Quantity of individuals collected
walleye	10	51
white sucker	24	425
yellow perch	6	33

Appendix H. Macroinvertebrate taxa found during biomonitoring surveys

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Hydrozoa	1	1
Oligochaeta	1	4
Tubificinae	7	13
Lumbriculidae	2	2
Enchytraeus	5	12
Henlea	1	2
Mesenchytraeus	1	1
Aulodrilus	6	26
Naididae	5	6
Naidinae	2	6
Stylaria	2	56
Pristina	1	1
Nais	9	89
Hirudinea	14	54
Valvata	2	3
Hydrobiidae	11	179
Lymnaeidae	5	6
Lymnaea stagnalis	3	16
Fossaria	1	2
Stagnicola	5	28
Ferrissia	11	85
Planorbidae	2	3
Gyraulus	10	69
Helisoma anceps	1	3
Promenetus exacuous	2	6
Planorbella	1	1
Physidae	1	33
Physa	1	67
Physella	21	894
Pisidiidae	16	180
Amphipoda	1	2
Gammarus	2	9
Hyalella	10	253
Orconectes	8	12
Heptageniidae	5	17
Heptagenia	2	14
Leucrocuta	4	34
Stenacron	11	51
Baetidae	3	15

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Baetis	5	12
Acentrella	1	4
Anafroptilum	1	19
Baetis intercalaris	8	227
Baetis brunneicolor	5	62
Baetis flavistriga	2	11
Isonychia	1	5
Leptophlebiidae	7	28
Eurylophella	4	15
Tricorythodes	5	28
Caenis	2	2
Caenis diminuta	8	41
Caenis hilaris	2	12
Baetisca	4	14
Ephemera	1	5
Hexagenia	1	2
Anisoptera	1	4
Aeshnidae	3	3
Anax junius	1	1
Aeshna	2	4
Boyeria vinosa	2	4
Basiaeschna janata	1	1
Gomphidae	1	2
Somatochlora	1	2
Somatochlora minor	2	2
Sympetrum corruptum	1	1
Corduliidae	1	1
Calopterygidae	1	13
Calopteryx	7	73
Calopteryx aequabilis	5	14
Coenagrionidae	7	25
Ischnura	1	1
Enallagma	1	5
Enallagma civile	1	1
Pteronarcys	3	6
Amphinemura	1	9
Capniidae	1	1
Taeniopteryx	1	1
Acroneuria lycorias	1	8
Paragnetina media	3	8
Perlesta	4	4
Corixidae	6	15

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Sigara	7	18
Trichocorixa	2	2
Hesperocorixa	2	9
Callicorixa	2	5
Cymatia americana	1	1
Neoplea striola	2	2
Belostoma flumineum	3	5
Ranatra	1	1
Gerridae	1	1
Haliplus	7	9
Dytiscidae	1	5
Desmopachria convexa	1	1
Ilybius	1	1
Coptotomus	1	1
Liodessus	7	93
Gyrinus	9	23
Dineutus	1	1
Hydraena	2	2
Hydrophilidae	1	2
Laccobius	1	1
Paracymus	1	1
Tropisternus	2	2
Enochrus	1	4
Helichus	3	4
Stenelmis	9	40
Dubiraphia	18	138
Optioservus	7	40
Ancyronyx variegatus	1	1
Macronychus glabratus	4	36
Sialis	2	2
Chimarra	2	2
Psychomyiidae	1	2
Hydropsychidae	3	16
Cheumatopsyche	21	366
Hydropsyche	6	170
Hydropsyche betteni	4	47
Hydropsyche incommoda	1	1
Hydropsyche simulans	1	2
Ceratopsyche	2	2
Ceratopsyche bronta	1	2
Ceratopsyche morosa	1	3
Ceratopsyche slossonae	2	22

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Hydroptilidae	2	2
Hydroptila	9	56
Phryganeidae	1	2
Ptilostomis	6	12
Limnephilidae	6	40
Limnephilus	1	1
Platycentropus	2	3
Pycnopsyche	2	6
Nemotaulius hostilis	1	2
Triaenodes	1	2
Mystacides	1	3
Oecetis	2	2
Oecetis avara	6	22
Nectopsyche exquisita	1	1
Nectopsyche diarina	10	50
Ceraclea	6	28
Lepidostoma	2	2
Brachycentrus numerosus	3	42
Micrasema	2	4
Helicopsyche borealis	8	104
Polycentropodidae	4	6
Polycentropus	2	5
Neureclipsis	13	170
Parapoynx	1	1
Tipulidae	1	1
Tipula	1	1
Ormosia	1	1
Dicranota	2	2
Dixidae	1	1
Dixella	1	1
Simulium	20	939
Ceratopogonidae	2	2
Atrichopogon	5	9
Ceratopogoninae	3	6
Tanypodinae	4	5
Macropelopia decedens	1	3
Ablabesmyia	10	24
Conchapelopia	2	3
Labrundinia	10	29
Larsia	1	1
Nilotanypus	1	1
Pentaneura	1	1

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Thienemannimyia Gr.	20	146
Zavrelimyia	4	5
Procladius	3	6
Potthastia	2	2
Orthocladiinae	4	7
Brillia	11	22
Chaetocladius	1	1
Corynoneura	11	20
Cricotopus	20	198
Eukiefferiella	4	5
Euryhapsis	1	1
Heterotrissocladius	1	4
Limnophyes	5	7
Metriocnemus	1	1
Nanocladius	3	4
Orthocladius	5	8
Parakiefferiella	1	1
Parametriocnemus	8	71
Pseudosmittia	1	1
Rheocricotopus	13	106
Synorthocladius	2	2
Thienemanniella	8	27
Tvetenia	5	13
Xylotopus par	1	2
Chironomini	3	5
Axarus	1	1
Cryptochironomus	4	5
Cryptotendipes	1	1
Dicrotendipes	8	43
Microtendipes	13	37
Nilothauma	2	4
Parachironomus	4	9
Paralauterborniella nigrohalterale	1	2
Paratendipes	2	2
Phaenopsectra	13	24
Polypedilum	21	690
Saetheria	1	1
Stenochironomus	14	65
Stictochironomus	1	2
Tribelos	2	6
Xenochironomus xenolabis	4	29
Pseudochironomus	1	5

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Tanytarsini	6	9
Cladotanytarsus	2	2
Micropsectra	11	86
Paratanytarsus	11	189
Rheotanytarsus	19	179
Stempellina	2	2
Stempellinella	11	19
Tanytarsus	20	183
Tabanidae	2	3
Empididae	5	6
Hemerodromia	9	15
Neoplasta	4	13
Ephydridae	1	2
Fridericia	4	9
Acerpenna pygmaea	10	211
Procloeon	2	3
Nemata	2	5
Orthocladius (Symposiocladius)	2	2
Acerpenna	9	129
Plauditus	1	2
Labiobaetis dardanus	1	1
Labiobaetis propinquus	12	110
Labiobaetis frondalis	3	112
Gomphus fraternus	1	1
Oecetis testacea	3	4
Acentrella parvula	1	3
Maccaffertium	10	42
Maccaffertium vicarium	1	4
Maccaffertium mediopunctatum	1	2
Maccaffertium mexicanum	1	1
Acari	18	164
Sparbarus	1	1
Iswaeon	10	74

Appendix I. 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 HUC-10 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
3	05RD083	Hansen Creek	5.0	11.3	16.7	15.3	21.3	69.7	good
3	05RD085	Severson Creek (County Ditch 23)	1.3	9.8	8.1	13.0	9.0	41.2	poor
2	15RD016	Severson Creek (County Ditch 23)	0.0	6.0	7.0	11.0	6.0	30.0	poor
2	15RD005	Roseau River	2.5	9.5	17.0	8.0	19.0	56.0	fair
2	15RD006	Roseau River	2.5	10.0	18.0	14.0	19.0	63.5	fair
2	15RD033	Roseau River	2.5	12.0	19.9	15.5	21.0	70.9	good
Average Habitat Results: *Headwaters Roseau River HUC-10*			**2.3**	**9.8**	**14.4**	**12.8**	**15.9**	**55.2**	**fair**
2	05RD128	Roseau River, South Fork	2.5	10.0	15.0	13.0	13.0	53.5	fair
2	15RD003	Roseau River, South Fork	5.0	11.5	18.4	16.0	13.0	63.9	fair
2	15RD011	Mickinock Creek	3.4	8.0	18.0	15.0	17.5	61.9	fair
3	15RD013	Paulson Creek	3.5	9.3	17.9	15.3	15.0	61.0	fair
2	15RD032	Roseau River, South Fork	2.5	9.0	18.1	16.0	15.0	60.6	fair
2	15RD034	Roseau River, South Fork	2.8	11.8	20.0	14.0	28.0	76.5	good
Average Habitat Results: *South Fork Roseau River HUC-10*			**3.3**	**9.9**	**17.9**	**14.9**	**16.9**	**62.9**	**fair**
4	05RD043	Hay Creek (County Ditch 7)	1.5	7.9	16.8	10.5	13.5	50.2	fair
3	05RD084	Hay Creek (County Ditch 9)	1.0	2.7	16.0	11.3	9.0	40.0	poor
2	15RD017	County Ditch 9	5.0	13.0	12.0	11.0	10.0	51.0	fair
Average Habitat Results: *Hay Creek HUC-10*			**2.5**	**7.8**	**15.0**	**10.9**	**10.8**	**47.1**	**fair**
2	15RD004	Sprague Creek	4.0	7.5	9.0	4.0	8.0	32.5	poor
2	15RD024	Sprague Creek	5.0	8.0	17.3	13.0	21.0	64.3	fair
Average Habitat Results: *Sprague Creek HUC-10*			**4.5**	**7.8**	**13.1**	**8.5**	**14.5**	**48.4**	**fair**
1	15RD008	Roseau River	3.0	9.0	8.0	8.0	12.0	40.0	poor
2	15RD022	Roseau River	1.5	8.5	13.0	12.0	8.0	43.0	poor
2	15RD025	Roseau River	1.5	8.5	9.0	5.0	8.0	32.0	poor
2	15RD027	Roseau River	1.5	8.5	14.0	5.0	6.0	35.0	poor
4	15RD029	Pine Creek	2.3	10.6	6.5	12.5	10.0	41.9	poor
Average Habitat Results: *Upper Roseau River HUC-10*			**2.0**	**9.0**	**10.1**	**8.5**	**8.8**	**38.4**	**poor**

# 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
2	14RD300	Roseau River	2.8	8.8	14.0	6.0	7.5	39.0	poor
1	15RD002	Roseau River	3.0	8.0	14.0	11.0	13.0	49.0	fair
2	15RD007	Roseau River	4.0	9.5	17.0	11.0	11.0	52.5	fair
Average Habitat Results: *Middle Roseau River HUC-10*			3.3	8.8	15.0	9.3	10.5	46.8	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)