Watershed health

June 2020

Rainy River – Rainy Lake Watershed Monitoring and Assessment Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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List of acronyms

BCG Biological Condition Gradient

CI Confidence Interval

CSAH County State Aid Highway

CWA Clean Water Act

DO Dissolved Oxygen

DOP Dissolved Orthophosphate

EPA Environmental Protection Agency

EQuIS Environmental Quality Information System

EXS Fail Standard

FQA Floristic Quality Assessment

FR Forest Road

FWMC Flow Weighted Mean Concentration

GLA Glacial Lake Agassiz

HGM Hydrogeomorphic

HUC Hydrologic Unit Code

IBI Index of Biotic Integrity

IC Inconclusive Information

IF Insufficient Information

IJC International Joint Commission

IMP Impaired (Fails Standards)

IWM Intensive Watershed Monitoring

LRVW Limited Resource Value Water

MCL Maximum Contaminant Level

MDA Minnesota Department of Agriculture

MDH Minnesota Department of Health

MDNR Minnesota Department of Natural Resources

MGS Minnesota Geological Survey

MLRA Major Land Resource Areas

MN Minnesota

MPARS MDNR Permitting and Reporting System

MPCA Minnesota Pollution Control Agency

MSHA Minnesota Stream Habitat Assessment

MTS Meets the Standard

NA Not Assessed

NA Not Assessed

NHD National Hydrologic Dataset

NH3 Un-Ionized Ammonia

NLF Northern Lakes and Forest

NMW Northern Minnesota Wetlands

NO_3+NO_2-N nitrate plus nitrite nitrogen

NRCS Natural Resources Conservation Service

NWI National Wetlands Inventory

OP Orthophosphate

PCB Poly Chlorinated Biphenyls

PCoA Packaging Corporation of America

PFAS Poly- and Perfluoroalkyl Substances

PFOS Perfluorooctane Sulfonate

PWI Public Waters Inventory

RRRL Rainy River – Rainy Lake

SSTS Subsurface Sewage Treatment Systems

SUP Full Support (Meets Criteria)

SWAG Surface Water Assessment Grant

SWCD Soil and Water Conservation District

TKN Total Kjeldahl Nitrogen

TMDL Total Maximum Daily Load

TP Total Phosphorous

TSS Total Suspended Solids

UAA Use Attainability Analysis

USDA United States Department of Agriculture

USGS United States Geological Survey

VNP Voyageurs National Park

WID Waterbody Identification Number

WIMN What's In My Neighborhood

WPLMN Watershed Pollutant Load Monitoring Network

WRCC Western Regional Climate Center

Executive summary

The Rainy River – Rainy Lake (RRRL) Watershed (09030003) lies along the Canadian border in northern Minnesota (MN) and encompasses approximately 7,407 mi^2 or 4,740,563 acres; only 6.3% is in MN (463.47 mi^2). There are 27 lakes (>10 acres) and 16 stream reaches in the Minnesota portion of the watershed. Streams are generally small to moderate in size, short, low gradient, and drain large wetlands within the historic extent of Glacial Lake Agassiz; many are direct tributaries to Rainy Lake (69-0694-00). The watersheds surface and ground water resources are important to the region's economy, supplying drinking water and recreational opportunity. Lakes and streams also provide habitat for aquatic life and riparian corridors for wildlife. The border waters not only produce some of the highest quality fisheries in the state but also offer visitors many scenic and natural views. Rainy Lake is the focal point of this watershed and is the third largest lake in the state of Minnesota. Today over 98% of the RRRL Watershed is undeveloped, although much of the watersheds forests are harvested for timber production. Hunting, fishing, hiking, are common activities are commonly enjoyed by the people who live in, and visit the watershed. Large tracts of public land exist within this watershed, including country land, national and state forests, wildlife management areas, scientific and natural areas, and a national park.

In 2017, the Minnesota Pollution Control Agency (MPCA) began an intensive watershed monitoring (IWM) effort of surface waters within the RRRL Watershed. Five stream stations were sampled for biology at the outlets of variable sized drainages. These locations included both the mainstem Rat Root River and the East Branch of the Rat Root River. As part of this effort, MPCA staff joined with Koochiching County Soil and Water Conservation District (SWCD) to conduct stream water chemistry sampling at the outlets of the Rat Root River and the East Branch of the Rat Root River. In 2019, rivers, streams, and lakes with sufficient data were assessed to determine if they supported aquatic life, recreation, and consumption. In addition to the data collected by MPCA, the assessors considered data from other state and federal agencies, local units of government, lake associations, and/or individuals. In all, four stream segments and one lake was assessed for aquatic life and recreation.

All four of the assessed streams fully supported aquatic life and/or recreation. Although several lakes were impaired for aquatic consumption (mercury in fish), all lakes clearly met recreational use goals. The high recreational lake quality reflects the undisturbed nature of their contributing watersheds. In the remote northeastern region of the watershed where obtaining water quality samples may be difficult, lake clarity data suggests that these lakes are suitable for recreation.

Overall, water quality conditions are good and can be attributed to the forest and wetlands that dominate land cover within the RRRL Watershed. However, in parts of this watershed, total suspended solids (TSS) and dissolved oxygen (DO) may at times exceed the state standards. The underlying fine sediments and generally flat topography of the region, a function of this regions geologic past, likely contribute to the TSS and DO exceedances. Increases in anthropogenic stressors, such as historical and recent forest cover changes, flow alterations, and the draining of wetlands, may locally affect aquatic life health. Where standards are being met, protection strategies to maintain good water quality are important.

Introduction

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

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

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

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

This watershed-wide monitoring approach was implemented in the Rainy River – Rainy Lake (RRRL) Watershed beginning in the summer of 2017. This report provides a summary of all water quality assessment results in the RRRL Watershed and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring and monitoring conducted by local government units.

The watershed monitoring approach

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

Watershed pollutant load monitoring

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

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

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

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

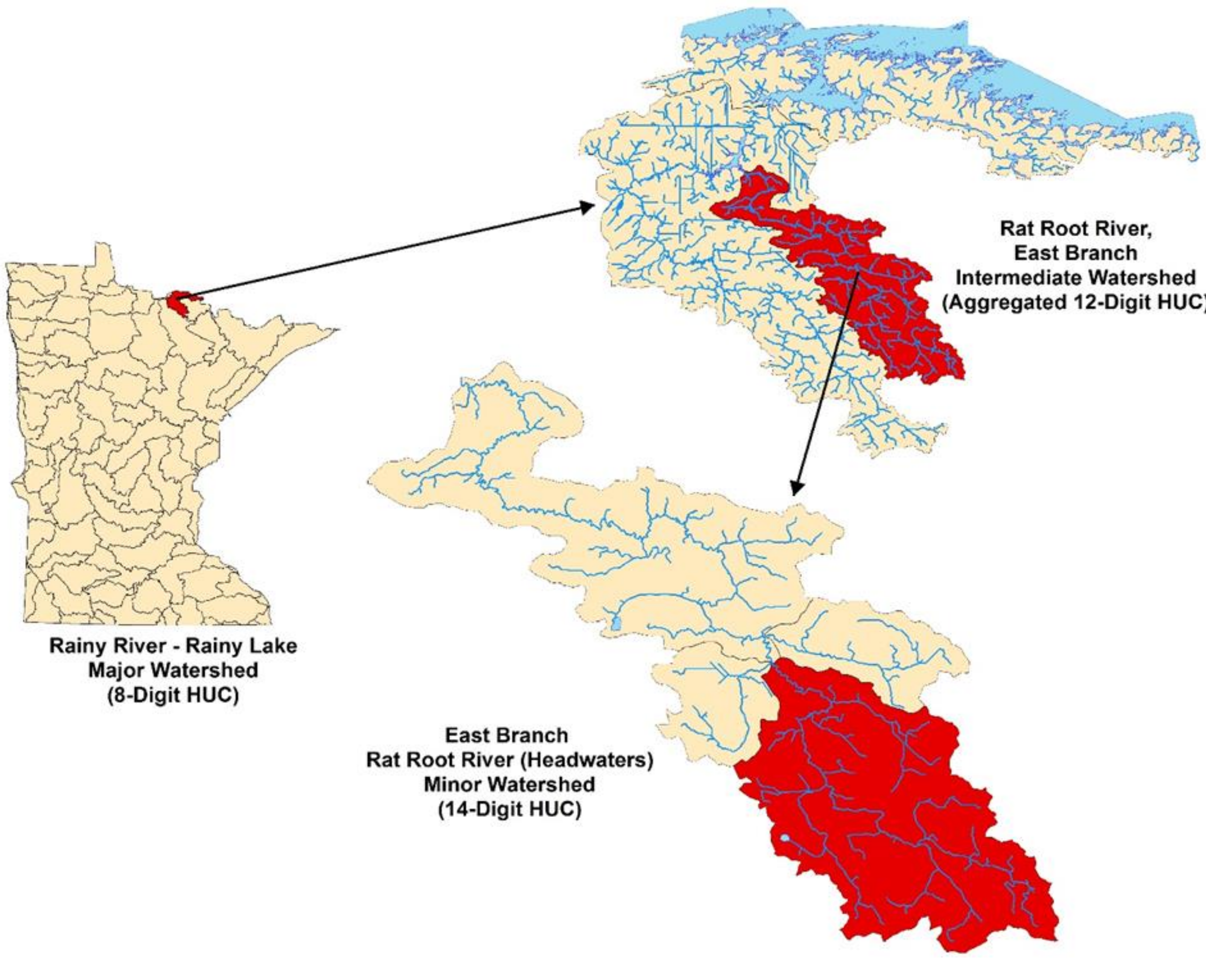
The program utilizes state and federal agencies, universities, local partners, and MPCA staff to collect water quality and flow data to calculate nitrogen, phosphorus, and sediment pollutant loads.

Intensive watershed monitoring

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

River/stream sites are selected near the outlet of each of three watershed scales, 8-HUC, aggregated 12-HUC and 14-HUC (Figure 1). Within each scale, different water uses are assessed based on the opportunity for that use (i.e., fishing, swimming, supporting aquatic life such as fish and insects). The major river watershed is represented by the 8-HUC scale. The outlet of the major 8-HUC watershed (purple dot in Figure 2) is sampled for biology (fish and macroinvertebrates), water chemistry and fish contaminants to allow for the assessment of aquatic life, aquatic recreation and aquatic consumption use support. The aggregated 12-HUC is the next smaller subwatershed scale which generally consists of major tributary streams with drainage areas ranging from 75 to 150 mi^2. Each aggregated 12-HUC outlet (green dots in Figure 2) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use support. Within each aggregated 12-HUC, smaller watersheds (14 HUCs, typically 10-20 mi^2), are sampled at each outlet that flows into the major aggregated 12-HUC tributaries. Each of these minor subwatershed outlets is sampled for biology to assess aquatic life use support (red dots in Figure 2). Specific locations for sites sampled as part of the intensive monitoring effort in the RRRL Watershed are shown in Figure 2 and are listed in Appendix 2 and 3.

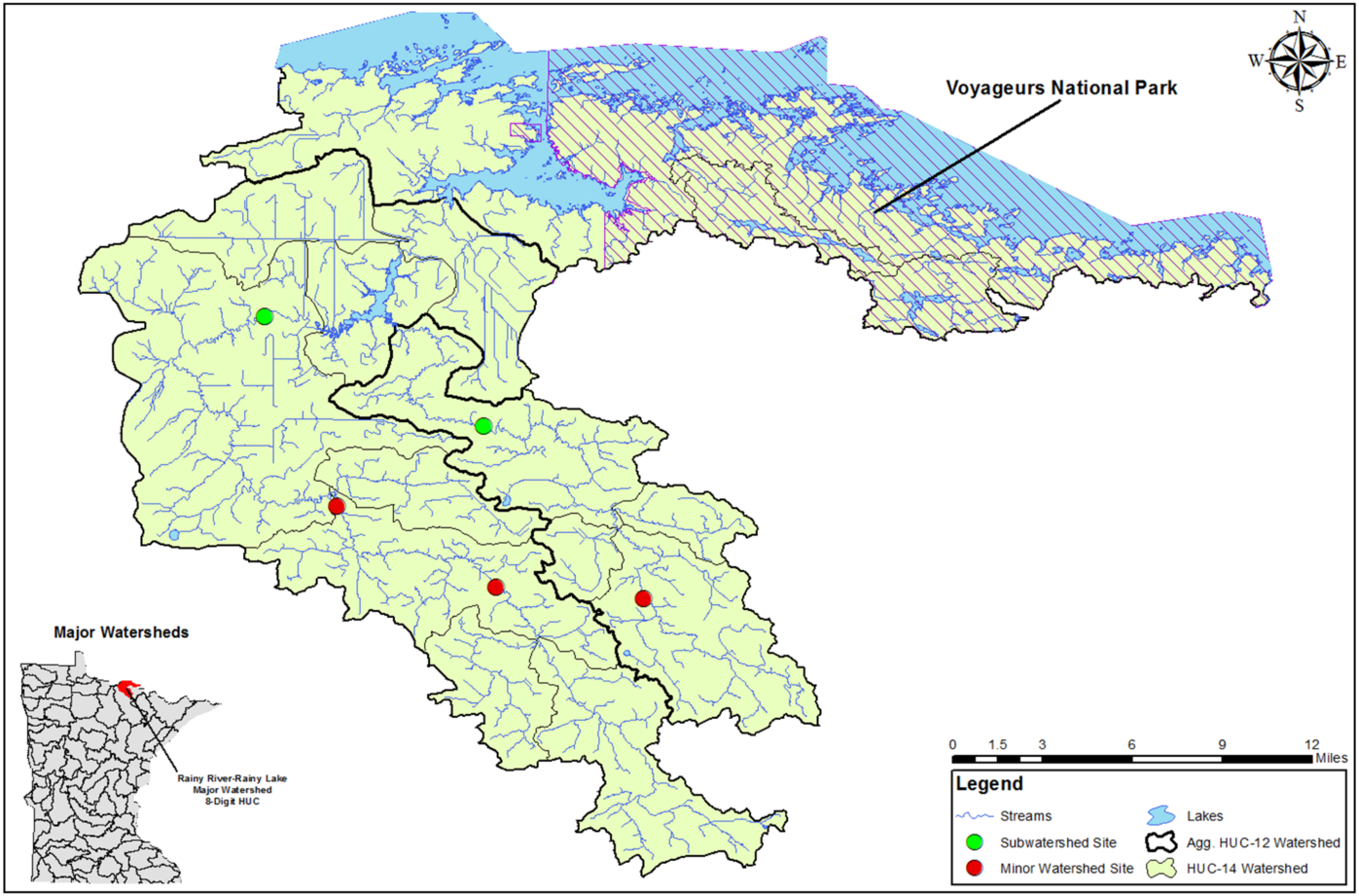
Figure 1. The Intensive Watershed Monitoring (IWM) design.



Lake monitoring

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

Figure 2. Intensive watershed monitoring stations for streams in the RRRL Watershed.

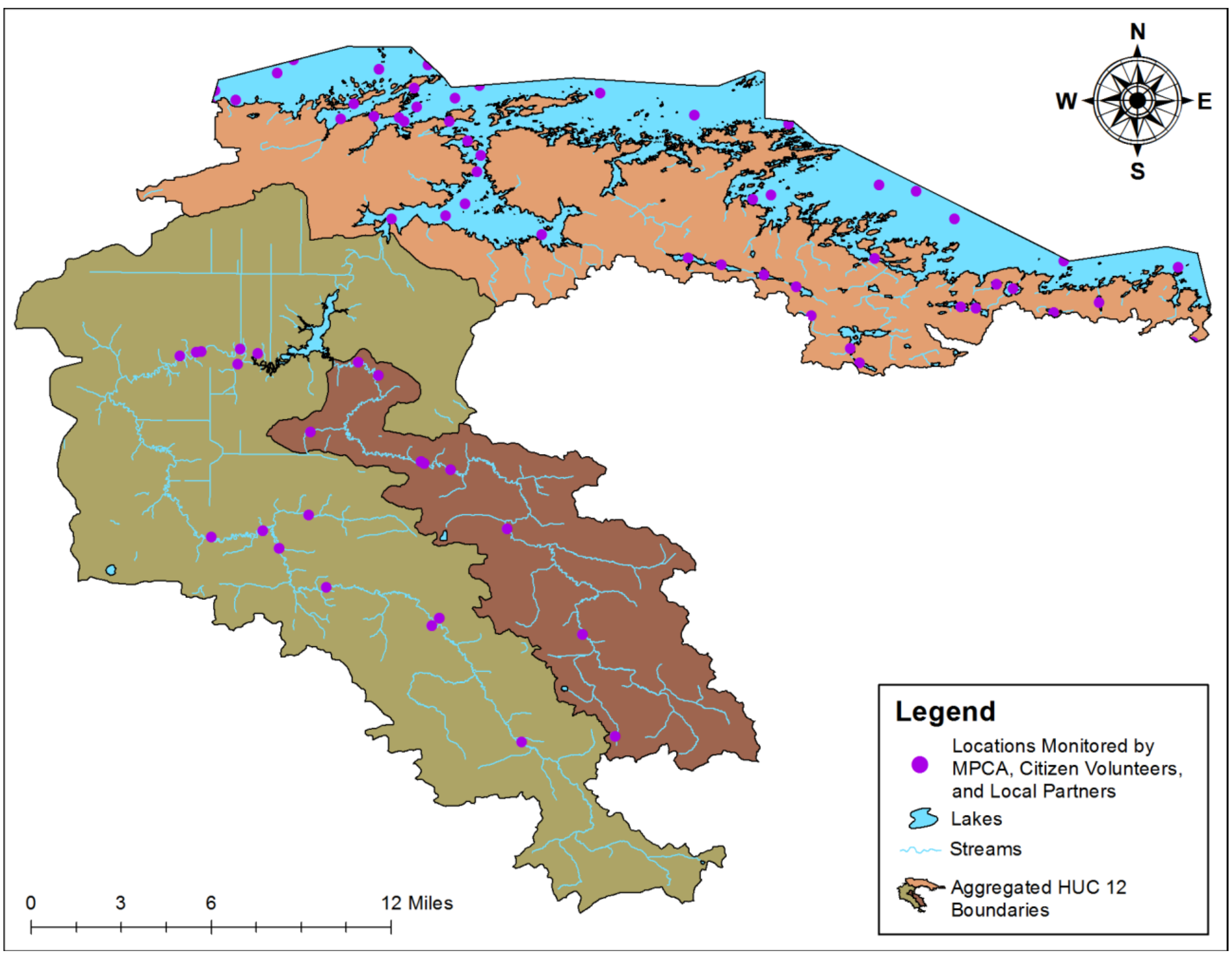


Citizen and local monitoring

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

The MPCA also coordinates two programs aimed at encouraging long term citizen surface water monitoring: the Citizen Lake Monitoring Program and the Citizen Stream Monitoring Program. Like the permanent load monitoring network, having citizen volunteers monitor a given lake or stream site monthly and from year to year can provide the long-term picture needed to help evaluate current status and trends. Citizen monitoring is especially effective at helping to track water quality changes that occur in the years between intensive monitoring years. Figure 3 provides an illustration of the locations where citizen monitoring data were used for assessment in the RRRL Watershed.

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



Assessment methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters that are determined to be supporting or non-supporting of their designated uses as evaluated by the comparison of monitoring data to criteria specified by Minnesota Water Quality Standards (Minn. R. ch. 7050 2008; https://www.revisor.leg.state.mn.us/rules/?id=7050). The assessment and listing process involves dozens of MPCA staff, other state agencies and local partners. The goal of this effort is to use the best data and best science available to assess the condition of Minnesota's water resources. For a thorough review of the assessment, methodologies see: *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA 2016)*. https://www.pca.state.mn.us/sites/default/files/wq-iw1-04i.pdf.

Water quality standards

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

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

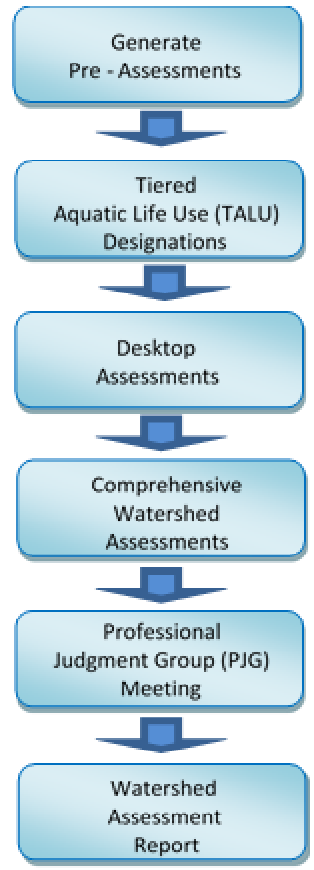
Protection for aquatic life uses in streams and rivers are divided into three tiers: Exceptional, General, and Modified. Exceptional Use waters support fish and macroinvertebrate communities that have minimal changes in structure and function from the natural condition. General Use waters harbor "good" assemblages of fish and macroinvertebrates that can be characterized as having an overall balanced distribution of the assemblages and with the ecosystem functions largely maintained through redundant attributes. Modified Use waters have been extensively altered through legacy physical modifications which limit the ability of the biological communities to attain the General Use. Currently the Modified Use is only applied to streams with channels that have been directly altered by humans (e.g., maintained for drainage). These tiered aquatic life uses are determined before assessment based on the attainment of the applicable biological criteria and/or an assessment of the habitat (MPCA 2018). For additional information, see: MPCA's tiered aquatic life uses (TALU) framework.

Table 1. Tiered aquatic life use standards.

Tiered aquatic life use	Acronym	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.
Cold water General	CWg	2Ag	Cold water 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.
Cold water Exceptional	CWe	2Ae	Cold water Stream protected for aquatic life and recreation, capable of supporting and maintaining an exceptional and balanced, integrated, adaptive community of cold water aquatic organisms that meet or exceed the Exceptional Use biological criteria.

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

Figure 4. Flowchart of aquatic life use assessment process.



Assessment units

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

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

Determining use attainment

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

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

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

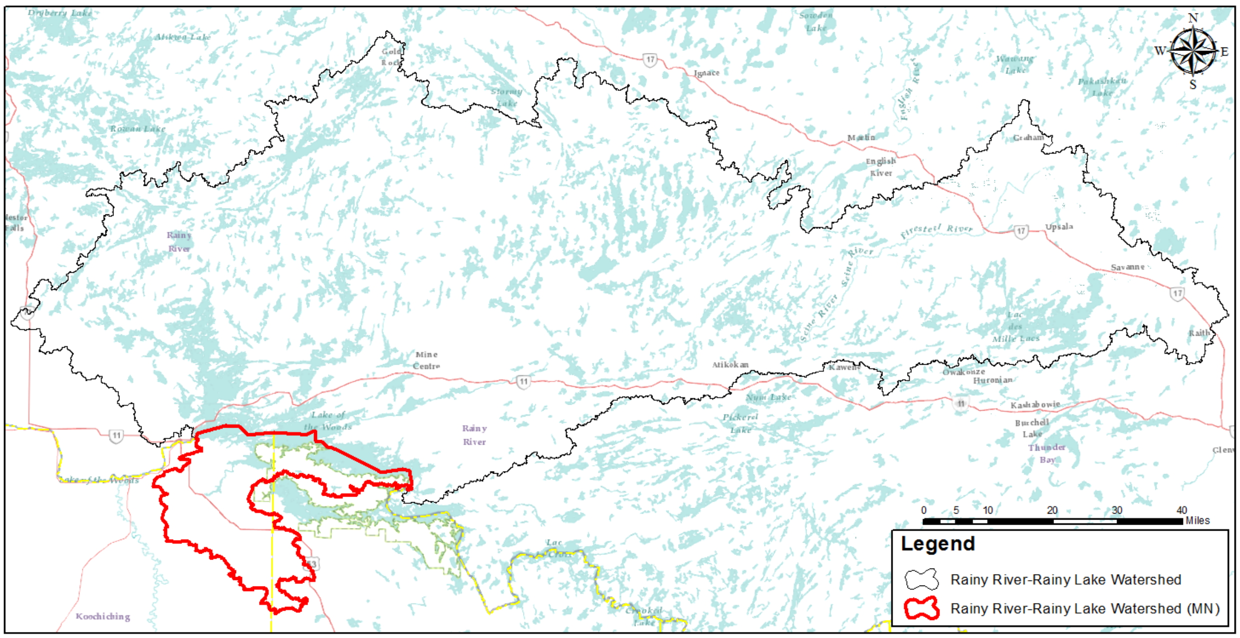
The next step in the process is a Comprehensive Watershed Assessment meeting where reviewers convene to discuss the results of their desktop assessments for each individual waterbody. Implementing a comprehensive approach to water quality assessment requires a means of organizing and evaluating information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

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

Watershed overview

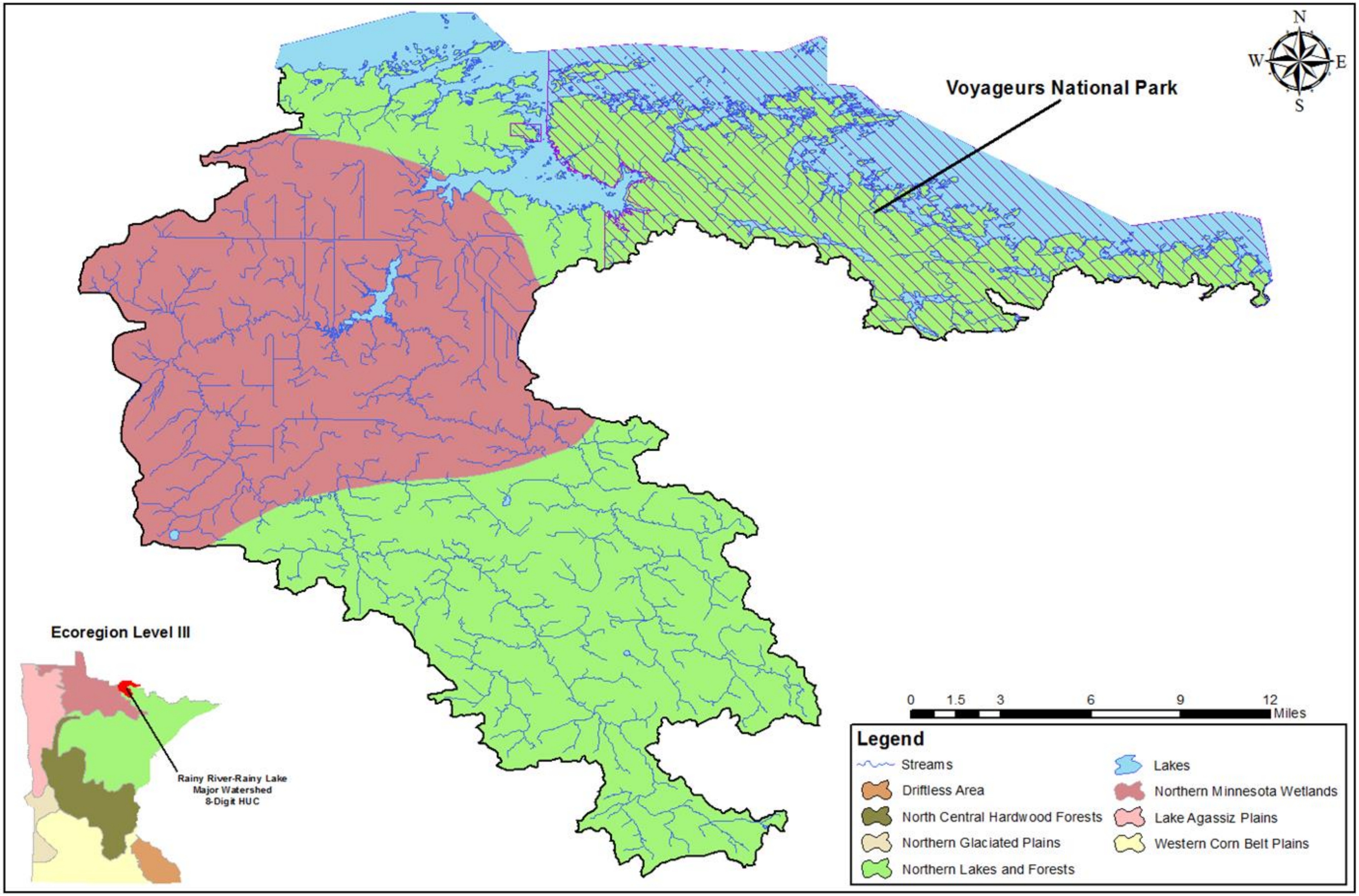
The RRRL Watershed (HUC 09030003) occupies a cumulative total of 7,407 mi^2 or 4,740,563 acres of land between Minnesota and the Canadian providence of Ontario (Figure 5). Only 6.3% (463.47 mi^2) of this watershed lies within United States of America. The portion within Minnesota consists of the Rat Root River, which drains to Rainy Lake, and the direct drainage along the southern shore of Rainy Lake; **statistics from the Canadian portion are not included in this report (unless further mentioned)**. Elevations within this watershed range from a high of 1,522 feet above sea level to its lowest point at 1,104 feet. The largest portion of this watershed is within Koochiching County (66.5%), with a smaller proportion in Saint Louis County (33.5%).

Figure 5. The RRRL Watershed and the portion within Minnesota.



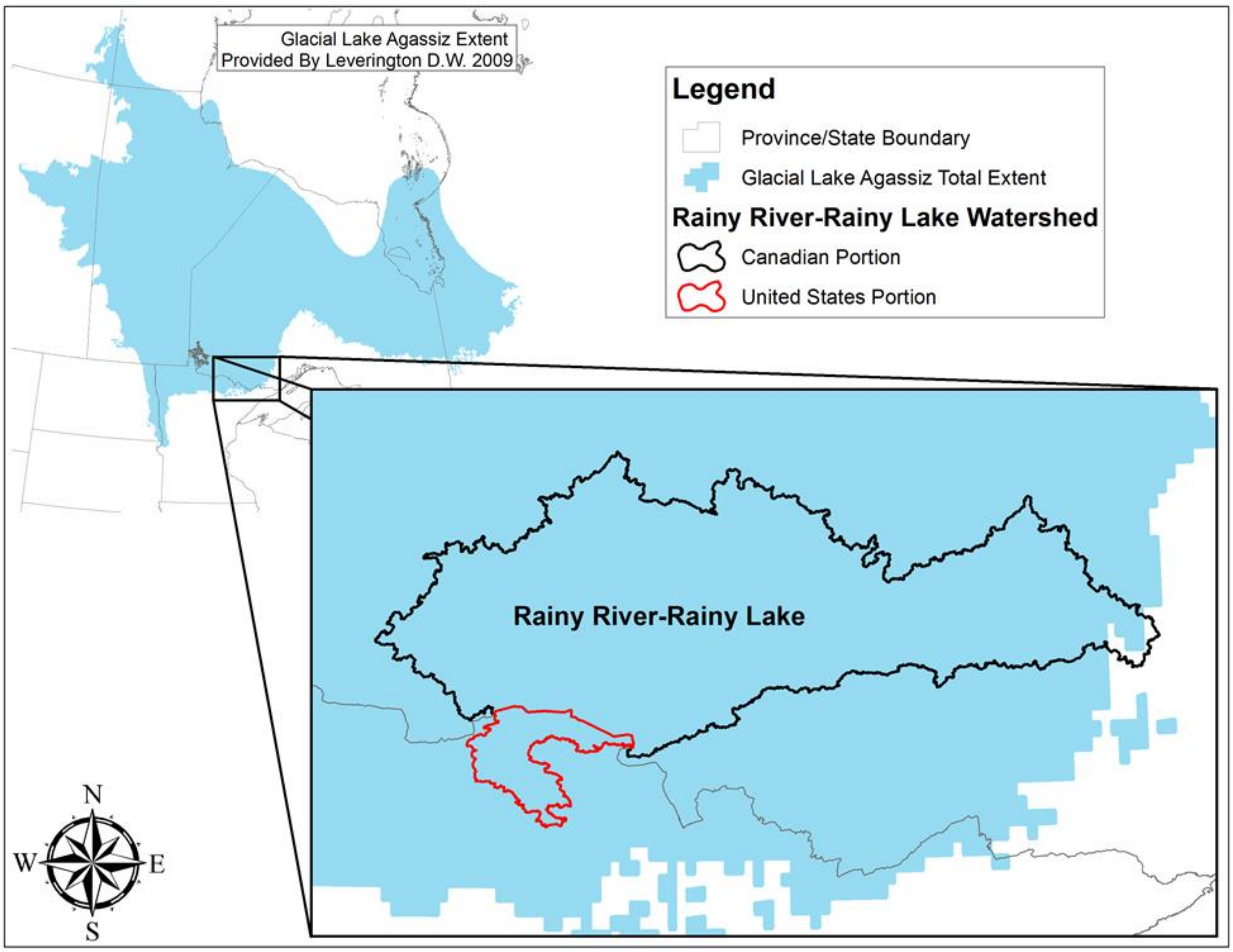
The RRRL Watershed lies within the transition between the Northern Minnesota Wetlands (NMW) and the Northern Lakes and Forest (NLF) ecoregions (Figure 6). The NLF encompasses 67.1% of this watershed and is dominated by relatively nutrient-poor glacial soils, which supports the growth of coniferous and northern hardwood forest (Omernik et al 1988). This heavily forested ecoregion is made up of many steep, rolling hills, broad lacustrine basins, and extensive sandy outwash plains. Soils within this ecoregion lack the arability of soils in the adjacent ecoregions to the south. Lakes are numerous in numbers throughout the NLF ecoregions and are clearer and less productive than those that are located to the south. Throughout the NLF many Precambrian granitic bedrock outcropping exist between shallow-to-deep moraine deposits left by the last glacier retreat that dates back to 12,000 years ago (Omernik et al 1988).

Figure 6. The RRRL Watershed within the Northern Minnesota Wetlands and the Northern Lakes and Forests ecoregion of Minnesota.



Although only making up 32.9% of the watershed, the NMW ecoregion encompasses the majority of the lower reaches of the Rat Root River drainage (Figure 6). This flat terrain was formerly occupied by a broad glacial lake (Figure 7) that has left this area as a vast and nearly level marsh (Omernik et al 1988). Elevation varies little, with very few lakes present. Watersheds can be difficult to define within this region because of the flat terrain and the numerous drainage ditches that have been constructed. Soils within this ecoregion are mainly defined by its poor drainage, with Ochraqualfs forming in poorly drained lacustrine materials and Eutroboralfs in better-drained areas (Omernik et al 1988). Most of this ecoregion is covered by swamp and boreal forest vegetation; including tamaracks, black spruce, northern white cedar, and black ash. While the less common upland portions are covered by red maples, mountain maples, balsam fir, and quaking aspen.

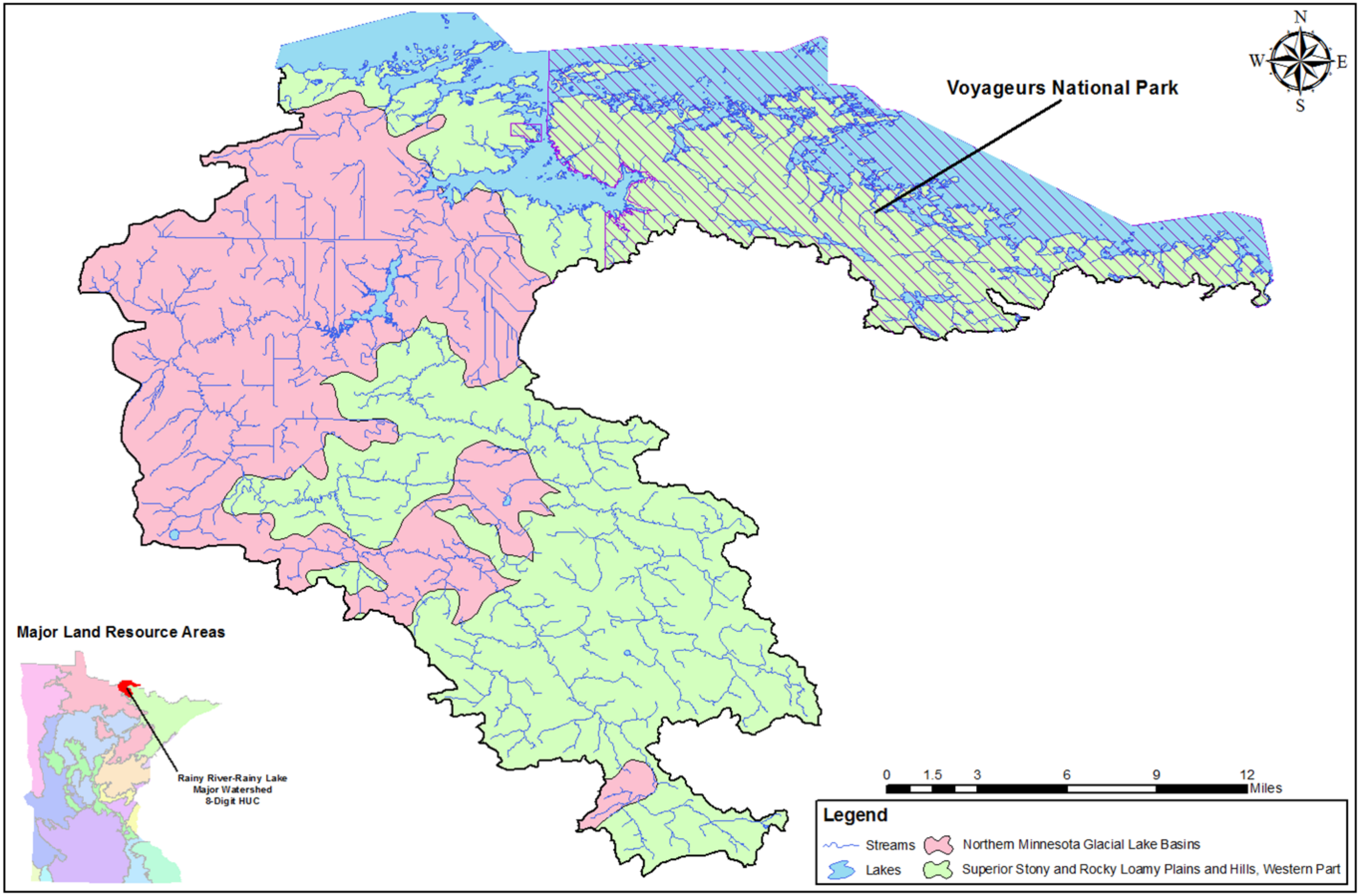
Figure 7. Approximate total extent of Glacial Lake Agassiz over 5,000 years in relation to the RRRL Watershed.



The United States Department of Agriculture (USDA) Major Land Resource Areas (MLRA) for the RRRL Watershed includes two classifications (Figure 8). The majority (66.7%) of the watershed is classified as Superior Stony and Rocky Loamy Plains and Hills, Western Part, while a smaller portion of it in the western side is classified as Northern Minnesota Glacial Lake Basin (33.3%). The Superior Stoney and Rocky Loamy Plains and Hills, Western Part is very diverse in soil types and can be a very shallow to deep dense loamy till, coarse glacial drift and outwash, silty glaciolacustrine sediment, local loess, alluvium, and organic material (NRCS 2006a). Bedrock outcrops are common in many places and the topography is gently sloping to very steep in locations. Bogs and large wetland complexes are common in the headwaters of many subwatersheds. Given the geologic history of the valley, some natural springs can be found throughout this watershed.

The Northern Minnesota Glacial Lake Basin has very deep sandy to clayey soils and are poorly drained (Figure 8). An extensive amount of organic soils occur in this MLRA, with a higher concentration of it in the Glacial Lake Agassiz (GLA) Basin (NRCS 2006a). The glacial deposits are underlined by crystalline metamorphic rocks, with some lake-modified glacial till present. Ditches have been constructed in portions of this MLRA to improve drainage of wet areas (Figure 11). Much of this modified drainage occurs in the lower reaches of the Rat Root River drainage.

Figure 8. Major Land Resource Areas (MLRA) in the RRRL Watershed.



Land use summary

Historically, land cover in the RRRL Watershed was largely forested wetlands with a mixture of brushland, open water, and upland forest (MDNR 2017). Pre-settlement vegetation was dominated by old growth forest of black spruce, tamarack, quaking aspen, white pine, paper birch and red pine (Waters 1977). The uplands were dependent on infrequent low lying fires that cleared out thick brush and alders to regenerate saplings (Larson 2007). Stream corridors were heavily forested and provided ample shade to tributary streams. The corridors consisted of small patches of thick alder, marsh, and sedge meadows in the river's meanders and abandoned oxbows (Waters 1977).

Although a large portion of the current land use within the RRRL Watershed is still forest, the discovery of western Lake Superior by settlers in the late 1600s changed this area in many ways. The area was already well used by Native Americans who had developed numerous canoe trails and portages throughout the region. By the time explorers discovered these routes in the late 1600s, or were shown it, the trails were virtually in their present day form (Waters 1977).

This entire watershed and the surrounding area eventually came to be known as the Voyageur's Highway and was a lifeline to the North American fur trade. The route from Grand Portage to Rainy Lake began to be recorded in 1731 when the La Verendrye's company landed at Grand Portage Bay and passed over into the string of lakes to build an outpost on Rainy Lake. Portages that were developed between these numerous waterbodies connected the Pigeon River to Rainy Lake and further downstream to Lake of the Woods. This magnificent route, with its dark virgin forests, blue lakes, and whitewater cascades was a major trail for the French-Canadian canoeman (Waters 1977). Canoemen were typically recruited from the lands along the north shore of the St. Lawrence River, with many individuals originating from Normandy. These voyageurs traveled the vast expansions of the great lakes before reaching Grand Portage and the Pigeon River. Other routes (Kaministikwia River) were first used by the French to access this area (Lac La Croix) for 30-years before discovering this shorter and less grueling route.

In 1770, several companies combined to create the famed North West Company, which plied along the fur trade routes into North American interior for nearly 50 years (Water 1977). The North West Company ended its use of the Grand Portage route in 1803 with the fear of duties attached by the assertion of territorial rights by the newly established United States. This company re-established the original route into the Quetico-Superior through the Kamainistikwia River until 1821. The Grand Portage route continued to be used by the John Jacob Astor's American Fur Company, along with its working force of voyageurs, until 1842 (Waters 1977). As the use of this route for fur trade dwindled, it gave way to other endeavors that were to bring civilization to the Rainy River country. By the 1860s, the trade of this entire area was serviced by land transportation through St. Paul and the upper Red River Valley, which was primarily faster and cheaper. Although the fur trade opened the northern wilderness to the Europeans, other industries such as logging quickly became an important economic driver. This region was settled following the fur trade and not the logger's ax like other areas of the state.

Many of the rivers of the RRRL Watershed did not play a major role in the timber harvest of the border lake country due to their shortness and ruggedness. The harvest of this timber began in 1893 and lasted until about 1930 when the great depression and other factors brought operations to a halt (Waters 1977). Logging first began on the Canadian side of the border, along with settlement, agriculture, railroads, and industry. The White and Red Pine were particularly high quality on the Minnesota side of the border and was intensively harvested during this period. Steamboats first appeared on the Rainy River and other larger border lakes, including Rainy Lake, beginning in the 1870s and were in operation until the turn of the century. These steam tugs were the principal form of transporting lumber and other goods until they were replaced by the development of the railroad. The arrival of the railroad to International Falls in 1907 spurred the development of the milling industry in that area (Waters 1977).

Between 1910 and 1911, the Minnesota and Ontario Power Company built a paper mill and a sawmill in International Falls. This company, also known as Mando, operated for 27 years and ran over 186 logging camps throughout that time frame. The peak of the logging era in the area was 1917, with readily available timber being exhausted by 1937. Much of the smaller mills throughout the area began to close.

The border lake country was first recognized for its special recreational value over two centuries ago when the first explorers visited the area. Although their lifestyle was deadly serious, they did note the beauty of the wild environment, with its sweeping lakes, broad forests, rock outcroppings, and roaring cascades (Waters 1977). Even during the logging era there was a recognition of the importance of this area for its recreational potential and an interest in protecting the remaining virgin timberland for its aesthetic value. In 1909, Theodore Roosevelt designated a million acres into the Superior National Forest, and in subsequent years, the forest was expanded its present size of three million acres. Still, there was pressure to develop roads and hydropower dams throughout the region. As a result of these pressures, the Shipstead-Nolan Act of 1930 was passed to prevent the alteration of existing water levels and logging along natural shoreline. Pressures to develop the area continue today. Dams, mining, motorized recreational use, and logging place added pressure on the regions water resources. Many citizen groups are active throughout this watershed to protect its intrinsic value. The chain of lakes and forest trails that connected Grand Portage to Rainy Lake eventually became the Voyageur's Highway. This route eventually was incorporated into the present-day Superior National Forest and Voyageurs National Park (VNP; Figure 9). Only the far western portion of the Superior National Forest lies within this watersheds boundaries.

A national park designation for this region was debated for decades in northern Minnesota. At the beginning of the logging era in 1891, the Minnesota State Legislature petitioned the United States government to establish a park along the border. The Park Service made its initial recommendations to establish a National Park in this area in 1964 and later established VNP in 1975. This park now incorporates over 160,000 acres, including over 60,000 acres of water. The main waterbodies within this park include Kabetogama, Namakan, and Rainy Lake. Two state forests are located within the boundary of this watershed including Kabetogama and Koochiching State Forest.

Currently, about 49% of the land within this watershed is owned by the State of Minnesota, with the second largest ownership being the Federal Government (21%) (Figure 11; USGS 2008). Forest is the most extensive land use, with many lakes and rivers interlaced throughout this watershed. Today, land cover within the Minnesota portion of the RRRL Watershed is distributed as follows: 47.82% wetlands, 31.62% forest/shrub, 16.50% open water, 2.69% rangeland, 1.33% developed, 0.02% row-crop agriculture, and 0.02% barren/mining (Figure 10; USGS 2008). Over 98% of the RRRL Watershed is undeveloped and utilized for timber production, hunting, fishing, canoeing, hiking, and other recreational opportunities. Timber production occurs on both private and public land throughout this watershed at varying degrees of intensity. Large tracts of public land exist within this watershed, including county land, national and state forests, wildlife management areas, scientific and natural areas, and national parks.

The Natural Resources Conservation Service (NRCS) estimates the watershed population at 3,375 people but that includes a portion (442.01 mi^2) of the Rainy River-Headwaters Watershed that once was considered to be a part of this watershed (NRCS 2006b). Using this data it is estimated that there is roughly about four people per square mile. A large percentage of the population in the RRRL Watershed live in the vicinity of International Falls and Ranier, Minnesota. However, only a small portion of each city lies within the watershed. International Falls has an estimated population of 6,424 and Ranier has 145 residents (US Census Bureau 2019). Ray is an unincorporated community in Koochiching County and is the largest "town" in the RRRL Watershed. This community was named for Edwin Ray Lewis, who was a surveyor and lumberman (Upham 1920).

Figure 9. Land ownership in the RRRL Watershed.

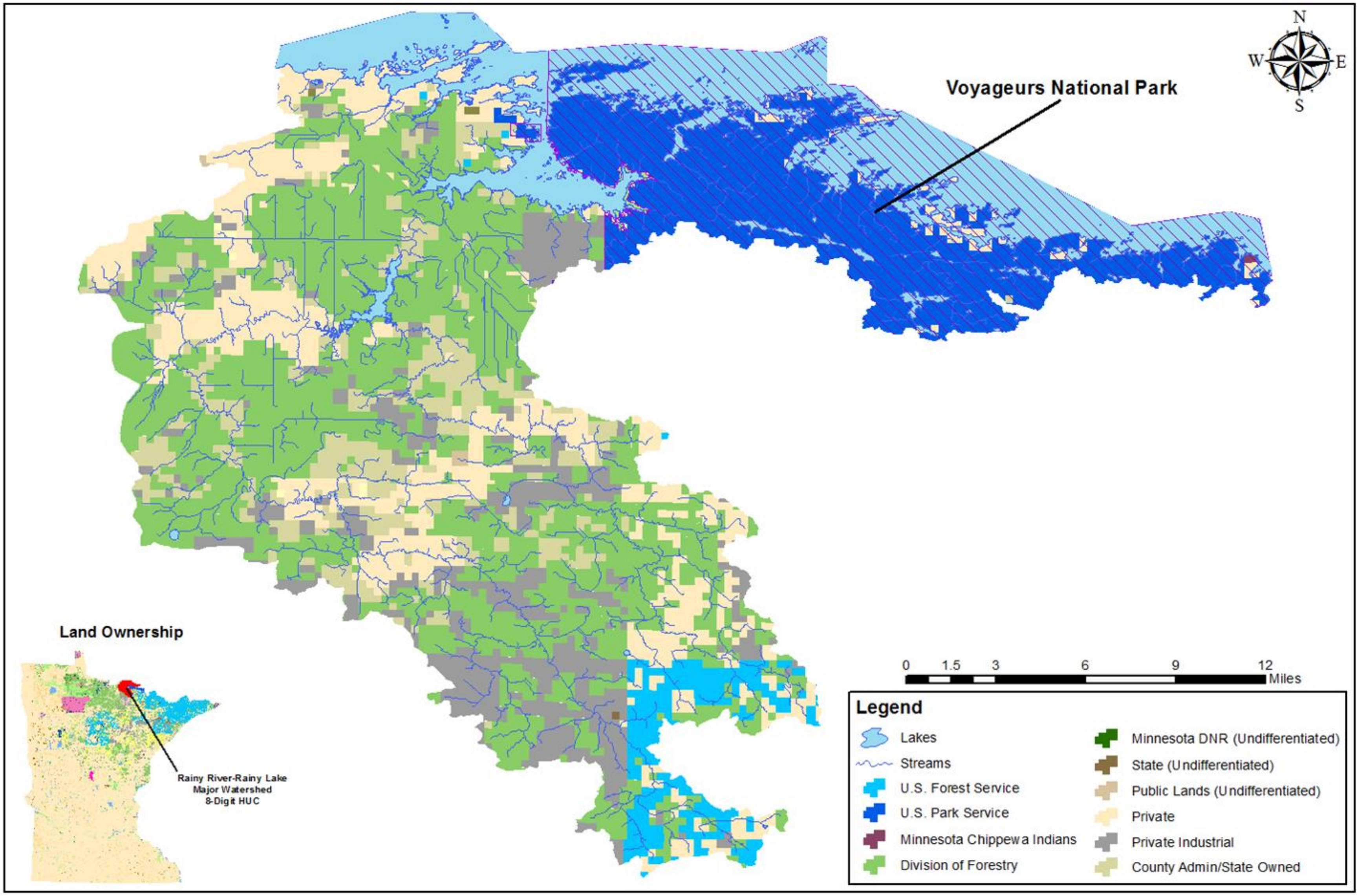
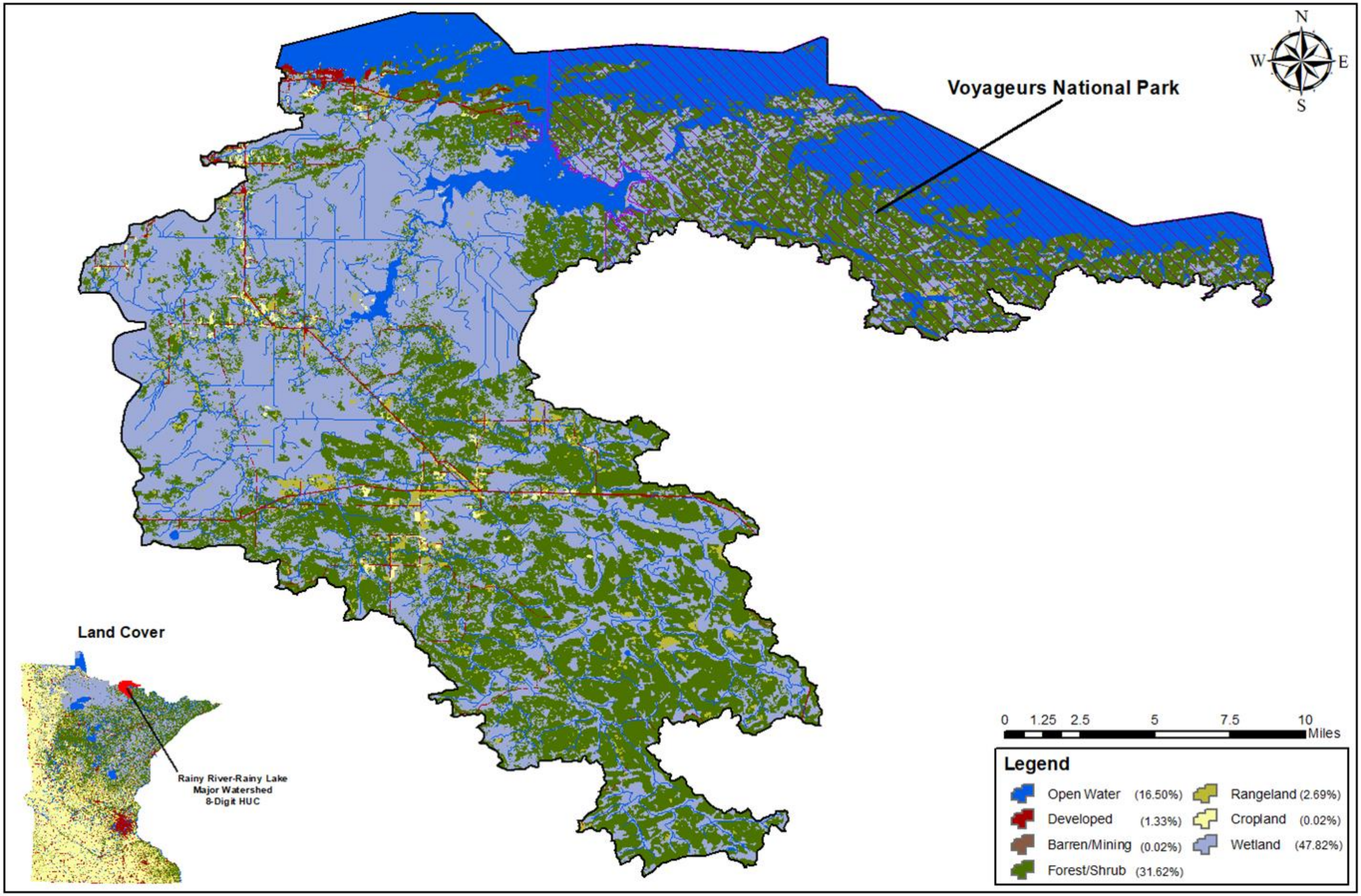


Figure 10. Land cover in the RRRL Watershed.



Surface water hydrology

The RRRL Watershed contains three intermediate watersheds (12-digit Aggregated HUC) and 15 minor watersheds (14-digit HUC). Major rivers include the Rat Root River and the East Branch Rat Root River. In addition, many smaller tributaries flow directly into lakes and into other major tributaries. The RRRL Watershed is comprised of two distinctly different areas. The eastern portion lies within the Canadian Shield, which is a broad plain of eroded ancient rock covering much of central Canada and portions of northern Minnesota. Most of this bedrock is extremely hard, with the exception of some weak spots where glaciers have scarred the landscape in a westward direction (Waters 1977). This pattern is evident throughout the border lakes region of Minnesota and Ontario. The Canadian Shield, although locally rugged, is a vast area that is regionally flat. The region consists of a great maze of navigable waterways that permitted relatively easy access by Native Americans, Voyageurs, and the present day recreational user. On the western side of the watershed lies the historical extent of GLA, with poorly drained soils that contain vast bogs and swamplands. Rivers and streams flow over nearly flat glacial clays, with very few to no lakes present. Some rock outcroppings occur where bedrock and moraines peak through the relatively thin veneer of lake clay (Waters 1977).

A total of 27 lakes greater than 10 acres and 106,349 acres of wetlands exist within this watershed. The majority of the lakes are found along the international border and function as water storage for continued stream flow throughout the season. With a surface area of 328.4 square miles (mi^2) and a contributing watershed of 14,419.7 mi^2, Rainy Lake (69-0694-00) is the focal point of this watershed. Its catchment includes the Rat Root River drainage (1.7%), the direct drainage to Rainy Lake (1.0%; US only), the rest of the RRRL Watershed (HUC 09030003) within Canada (46.4%), the Vermilion River Watershed (HUC 09030002 – 7.2%), and the Rainy River-Headwaters Watershed (HUC 09030001 – 43.7%). Vermilion and Rainy River-Headwaters Watersheds (7,340.99 mi^2) enter this watershed through Kettle Falls from Namakan Lake (69-0693-00).

There are dams at the inlet and outlet of Rainy Lake (USACE 2013). The inlet dam at Kettle Falls is located between Namakan/Rainy Lake and was originally built in 1914 (Nute 1950). The Kettle Falls dam consists of two smaller dams, with one located entirely in Canada (Squirrel Falls) and the other straddling the international border (Kettle Falls). In addition to the two main dammed channels, there are two natural overflows from Namakan and Kabetogama to Rainy Lake. Bear portage connects Namakan to Rainy Lake just east of Kettle Falls, while Gold Portage to the west connects Kabetogama Lake to Black Bay of Rainy Lake (LOTWCB 2020). The two channels permit uncontrolled flow to Rainy Lake when the upstream waterbodies are at its higher summer levels. These two dams were last modified in 1999 and are still in operation today by the Packaging Corporation of America (PCoA) (formerly Boise Cascade Corporation). Both are primarily used to maintain lake levels and recreational use on both Namakan and Kabetogama Lake (69-0845-00).

The Upper Rainy River dam, located at the outlet of Rainy Lake, preceded both the Kettle/Squirrel Falls dam and was built in 1909. This u-shaped dam spans across the international border with Canada (LOTWCB 2020). The Rainy River drains 21,152.7 mi^2, with over 69% of its total drainage area flowing through this dam. Two companies, the PCoA (United States of America) and the H_2O Power Limited Partnership (Canada), are responsible for its operation and maintenance. Both companies are subject to regulatory oversight by the International Rainy-Lake of the Woods Watershed Board of the International Joint Commission (IJC). The IJC is a bi-national organization created out of the International Boundary Waters Treaty of 1909 for the purpose of handling boundary water issues between the United States of America and Canada (IJC 2017). The IJC has the authority to regulate the water levels to avoid emergency levels on Rainy and Namakan Lake, as well as to benefit the ecological health of its waterways (IRNLRC 2016). The first formal rule curve (water level regulation) for each lake was adopted in 1949 and modified in further orders issued in 1970 and 2000 (IJC 2017). More information on these rule curves can be found on the IJC Website and the 2015 Rainy and Namakan Lake Rule Curve Review.

Thousands of lakes greater than 10 acres are in the Ontario, Canada portion of the watershed (Figure 5). The most prominent lakes are the Rainy (northern portion), Lac des Mille Lacs, Otukamamoan, Kaiashkons, and Clearwater West Lake. Carved from hard igneous rock by glaciers, these lakes are typically cold, deep, rocky, clear, and well-oxygenated (Waters, 1977). Many of these lakes are narrow, long and straight, oriented in the same way that glaciers proceeded throughout the landscape. This topography is a canoeist paradise, with many islands and rocky points. Many of these lakes are interconnected by water routes and short streams, with relatively easy portages between waters that are not navigable. Magnificent rapids and waterfalls can usually be found at the outlet of lakes where rock rims have dammed up water.

Several longer and larger stream systems exist within this watershed, with the majority of them lying north of the Canadian border. The more notable rivers within Ontario, Canada include: Atikokan, Heron, Pipestone, Trout, Turtle, and the Seine River. The Rat Root River is the largest river system on the American side of the RRRL Watershed. The headwaters of the Rat Root River begins in a forested wetland and flows 46.9 miles to the northwest before abruptly turning east. It continues an additional 11.6 miles before entering Rat Root Lake (36-0006-00). The east branch of the Rat Root River also begins in a forested wetland and flows 42.8 miles to the northwest before meeting with the waters of the main stem in Rat Root Lake. Rat Root Lake connects to Black Bay of Rainy Lake (69-0694-00) through a short channel and drains a total area of 283.9 mi^2. Waters from this area eventually enter the Rainy River before flowing 85.1 miles to Lake of the Woods, where it continues down the Winnipeg River to Lake Winnipeg, and finally, by way of Canada's Nelson River, to Hudson Bay. Stream characteristics vary greatly throughout the watershed based on the geological history of the region. Most streams have not been channelized (Figure 11). Overall, channelization in the watershed is relatively low compared to other watersheds within the State of Minnesota (Figure 12),

Figure 11. Comparison of natural to altered streams in the RRRL Watershed (percentages derived from the statewide-altered watercourse project).

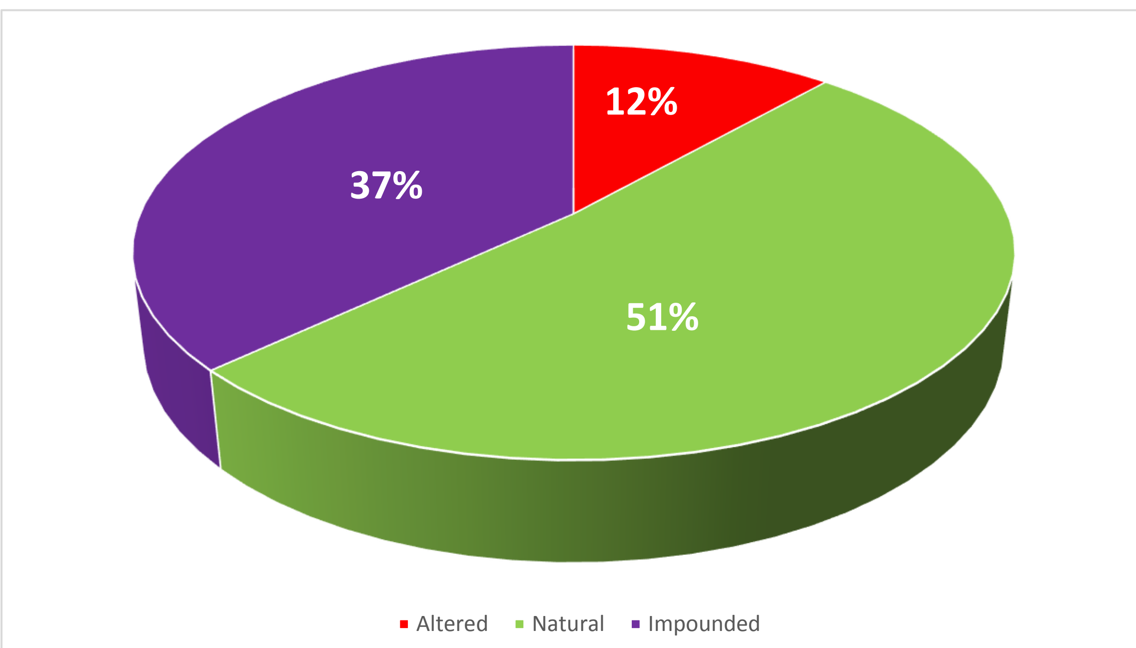
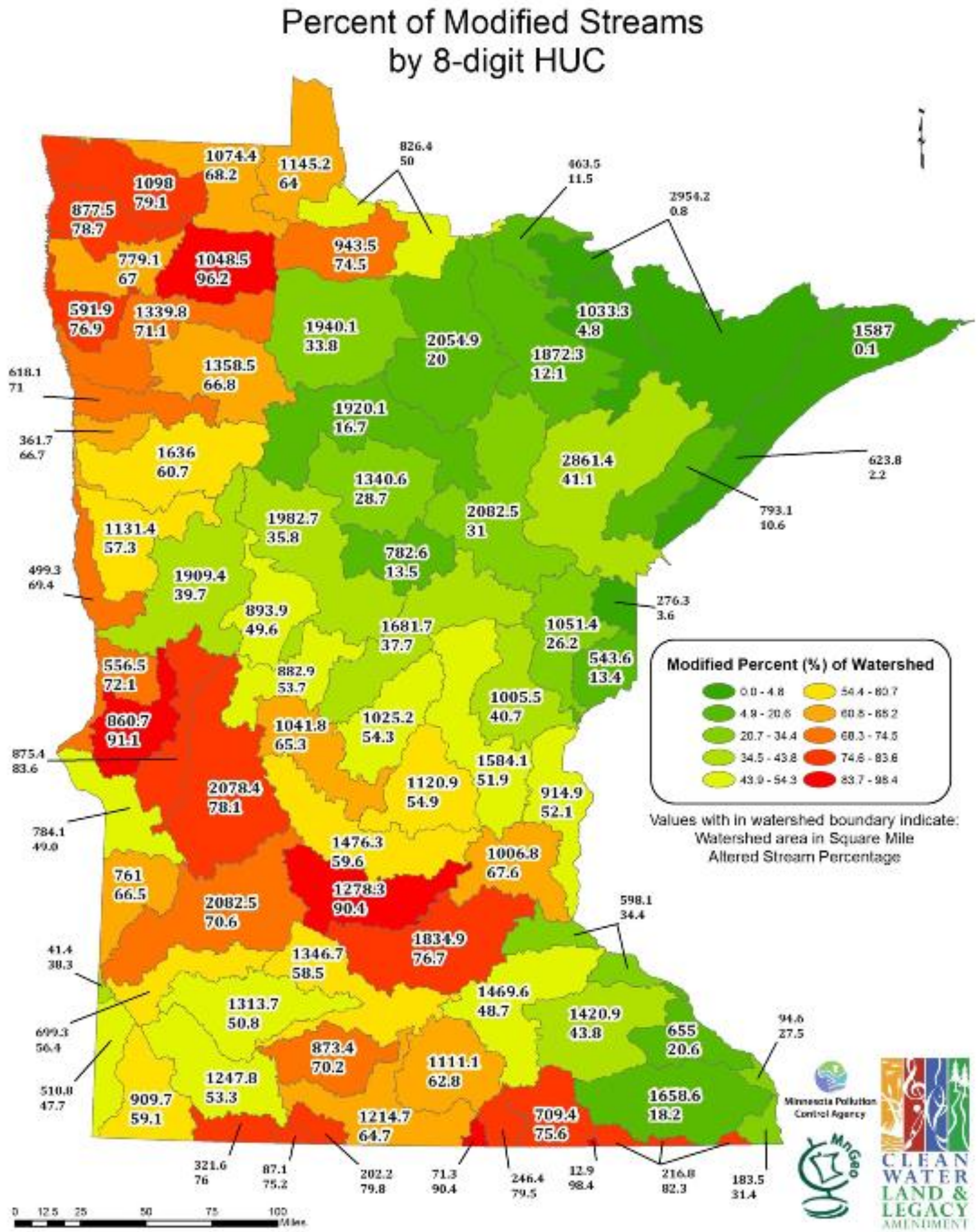


Figure 12. Map of percent modified streams by major watershed (8-HUC).

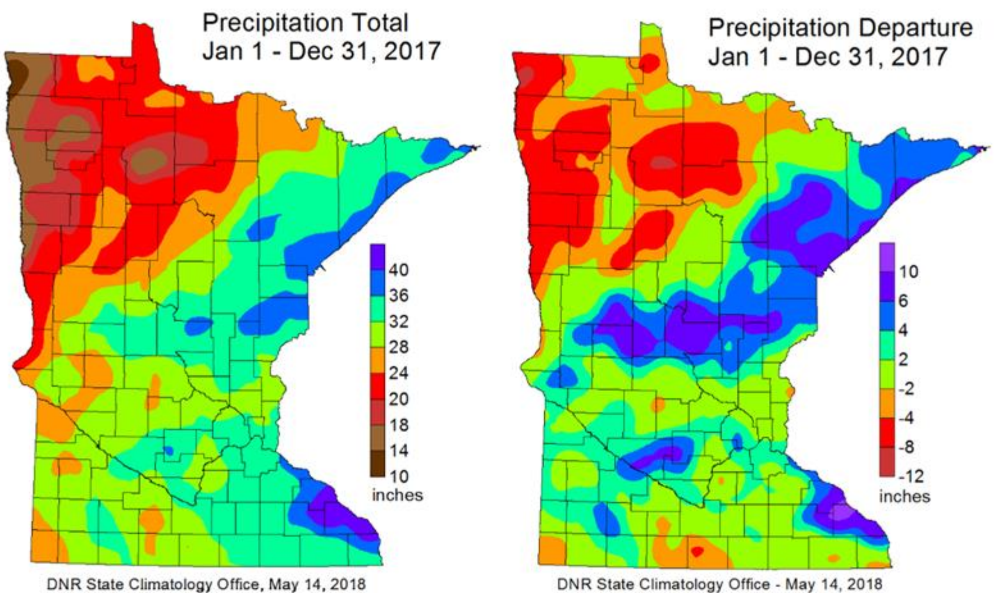


Climate and precipitation

Minnesota has a continental climate, marked by warm summers and cold winters. The mean annual temperature is 4.5˚C for the state of Minnesota, while the mean summer (June-August) temperature for the RRRL Watershed is 17.3˚C and the mean winter (December-February) temperature is -14.1˚ C (MDNR 2020c).

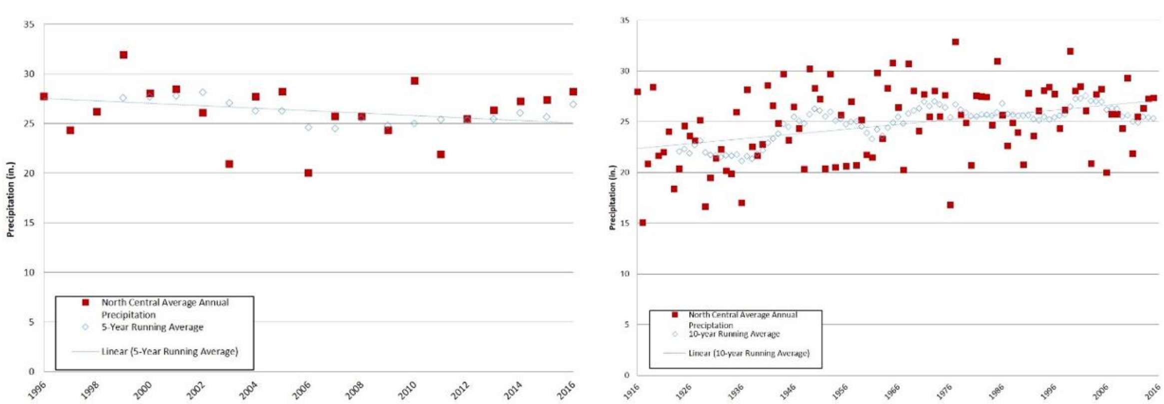
Precipitation is an important source of water input to a watershed. Figure 13 displays two representations of precipitation for calendar year 2017. On the left is total precipitation, and according to this figure, the RRRL Watershed area received 20 to 24 inches of precipitation in 2017. The display on the right shows the amount that precipitation levels departed from normal. The watershed area experienced precipitation that ranged from two to four inches below normal in 2017.

Figure 13. Statewide precipitation total (left) and precipitation departure (right) during 2017 (MDNR 2018).



The majority of the watershed is located in the North Central precipitation region. Figure 14 displays the areal average representation of precipitation for 20 and 100 years, *left and right respectively*. However, rainfall can vary in intensity and time of year, rainfall totals in this region displays no significant trends over the last 20 years. However, precipitation exhibits a significant rising trend over the past 100 years ($p<0.001$). This is a strong trend and matches other regions throughout Minnesota.

Figure 14. Precipitation trends in NE Minnesota from 1997-2016 (left) and 1918-2017 (right) (WRCC 2019).



Hydrogeology and groundwater quality

Hydrogeology

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

Surficial and Bedrock Geology

Surficial geology is identified as the earth material located below the topsoil and overlying the bedrock. The majority of the RRRL Watershed is primarily exposed bedrock with open water and peat formation. The areas with glacial sediment have a depth to bedrock ranging up to approximately 250 feet and are comprised of deposits predominately associated with the Des Moines and Rainy ice lobes, as well as post-glacial alterations to that sediment. The geomorphology includes glacial lake sediment, lake modified till, ground moraines and peat.

Bedrock is the main mass of rocks that form the Earth, located underneath the surficial geology and can typically be seen in only a few places where weathering has exposed the bedrock. Precambrian bedrock lies under the extent of the RRRL Watershed, much of which is exposed. The main terrane groups include the Quetico and Wabigoon subprovinces (Jirsa et al 2011). The rock types that are found in the uppermost bedrock include basalt, gneiss, granite, greywacke, and paragneiss (Morey & Meints 2000).

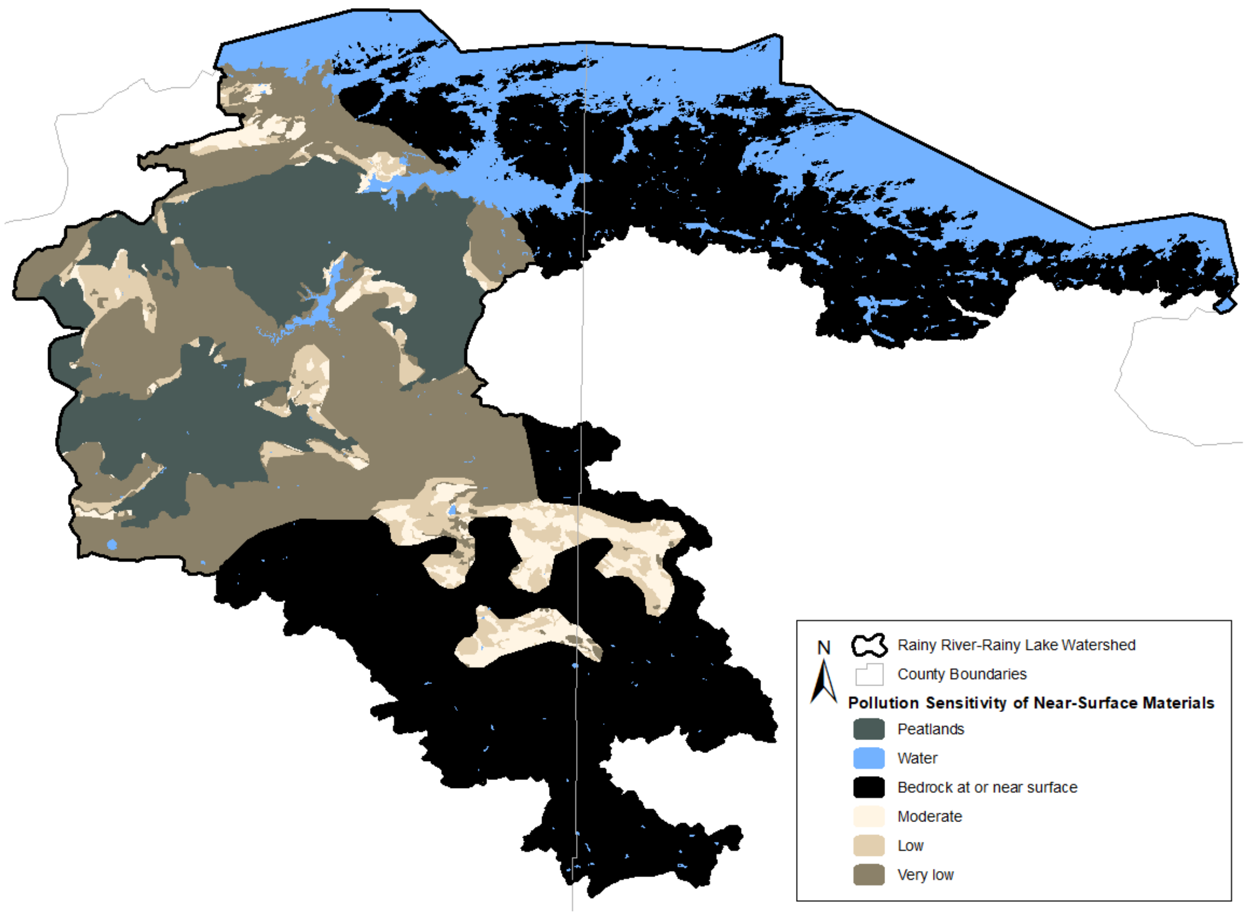
Aquifers

Groundwater aquifers are layers of water-bearing units that readily transmit water to wells and springs (USGS 2019). 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. The RRRL Watershed is completely within the Arrowhead Groundwater Province. The Arrowhead Province consists of Precambrian rocks that are exposed at the surface or underlying thin layer of glacial drift (MDNR 2001). The general availability of groundwater for areas that are within this province is limited in surficial sands, buried sands, and within the bedrock, but can be found locally in faults and fractures (MDNR 2001; MDNR 2020a).

Groundwater Pollution Sensitivity

Bedrock aquifers are typically covered with thick till, which normally makes them better protected from contaminant releases at the land surface. It is also less likely that withdrawals from wells would have a direct and significant impact on local surface water bodies. In contrast, surficial aquifers are typically more likely to 1) be vulnerable to contamination, 2) have direct hydrologic connections to local surface water, and 3) influence the quality and quantity of local surface water. A 2016 statewide evaluation of pollution sensitivity of near-surface materials completed by the MDNR 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 RRRL Watershed is predominately bedrock at or near the land surface and open water. What areas are not in these two categories are peatlands and low to very low pollution sensitivity. There are few areas of moderate pollution sensitivity scattered throughout the watershed, but it is very limited (Figure 15) (MDNR 2016).

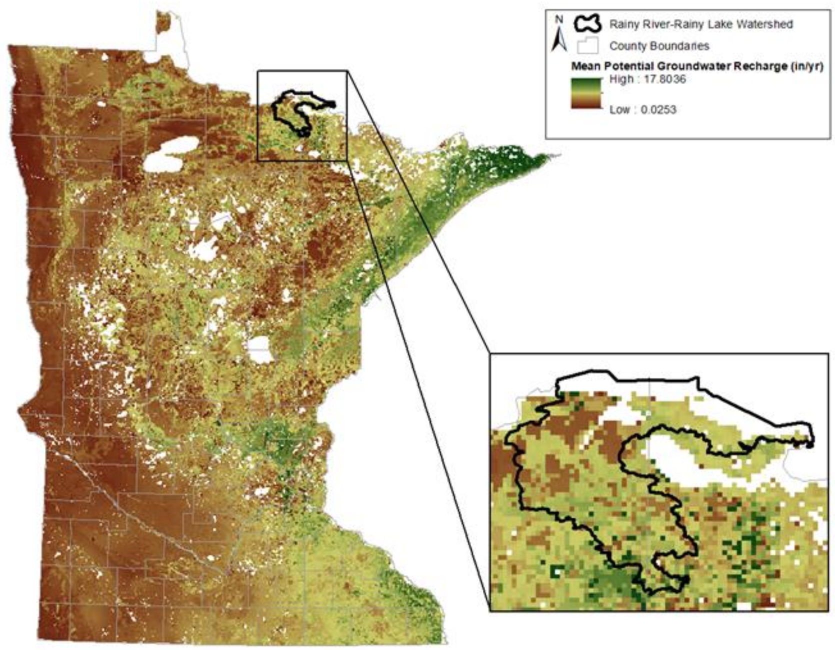
Figure 15. Pollution sensitivity of near-surface materials for the RRRL Watershed (MDNR 2016).



Groundwater Potential Recharge

Recharge of groundwater 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 16). 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 RRRL Watershed, the average annual potential recharge rate to surficial materials ranges from 1.0 to 17.4 inches per year, with an average of 6.6 inches per year. In comparison, the statewide average potential recharge is estimated to be four inches per year with 85% of all recharge ranging from three to eight inches per year.

Figure 16. Average annual potential recharge rate to surficial materials in the RRRL Watershed (1996-2010) (USGS 2015).



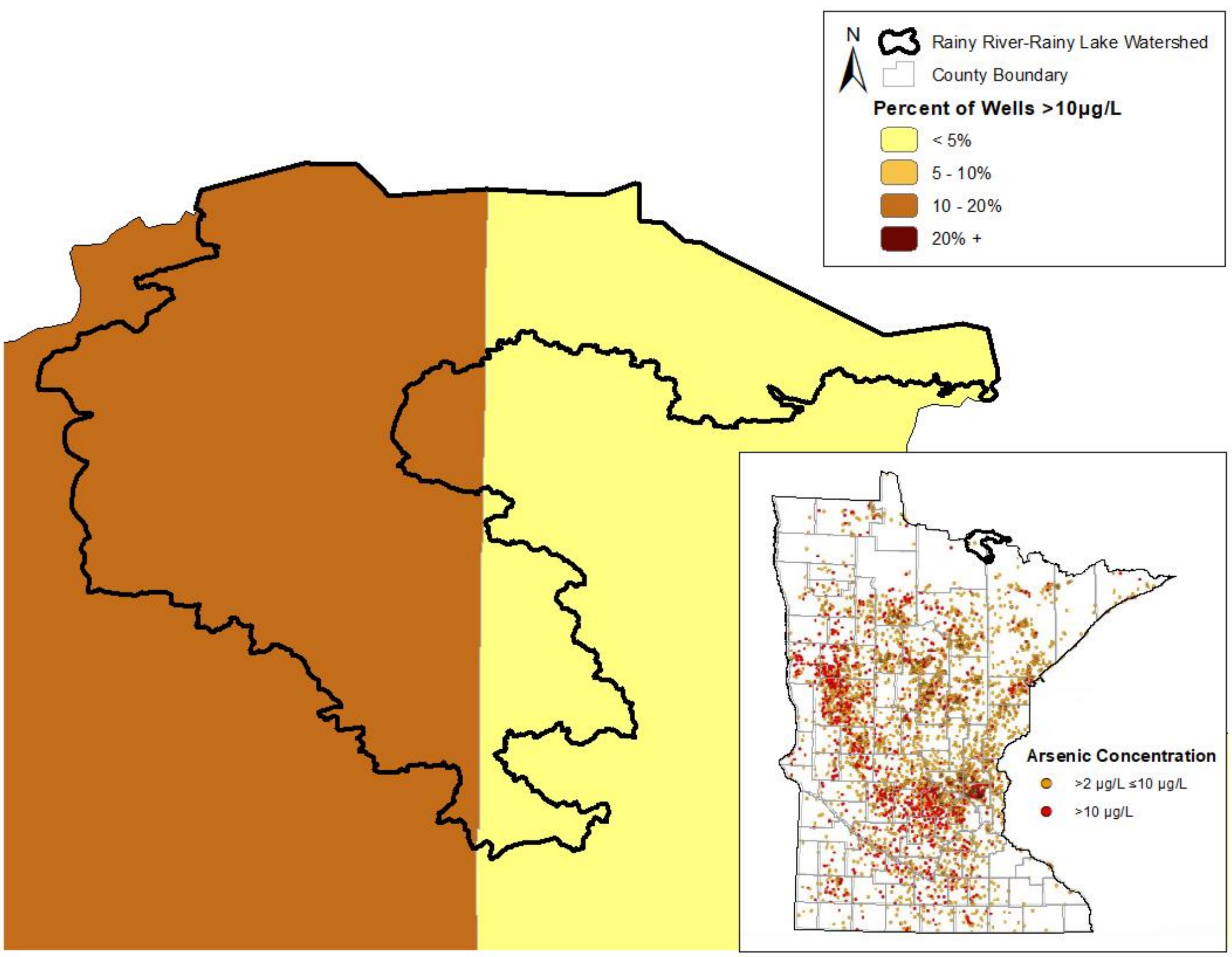
Groundwater quality

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 utilizing a mix of shallow monitoring wells and deeper domestic wells. However, there are currently no ambient groundwater wells located within this watershed; therefore, available data from federal, state and local partners are used to supplement reviews of groundwater quality in the region.

From 1992 to 1996, the MPCA conducted baseline water quality sampling and analysis of Minnesota's principal aquifers. The RRRL Watershed lies within the Northeast Region. This region reported good groundwater quality in most aquifers (MPCA 1999). Trace inorganic chemicals may be of concern locally and volatile organic compounds were detected in this region, with the most commonly identified compounds associated with well disinfection, atmospheric deposition, and fuel oils (MPCA 1999). All detections were within health risk limits.

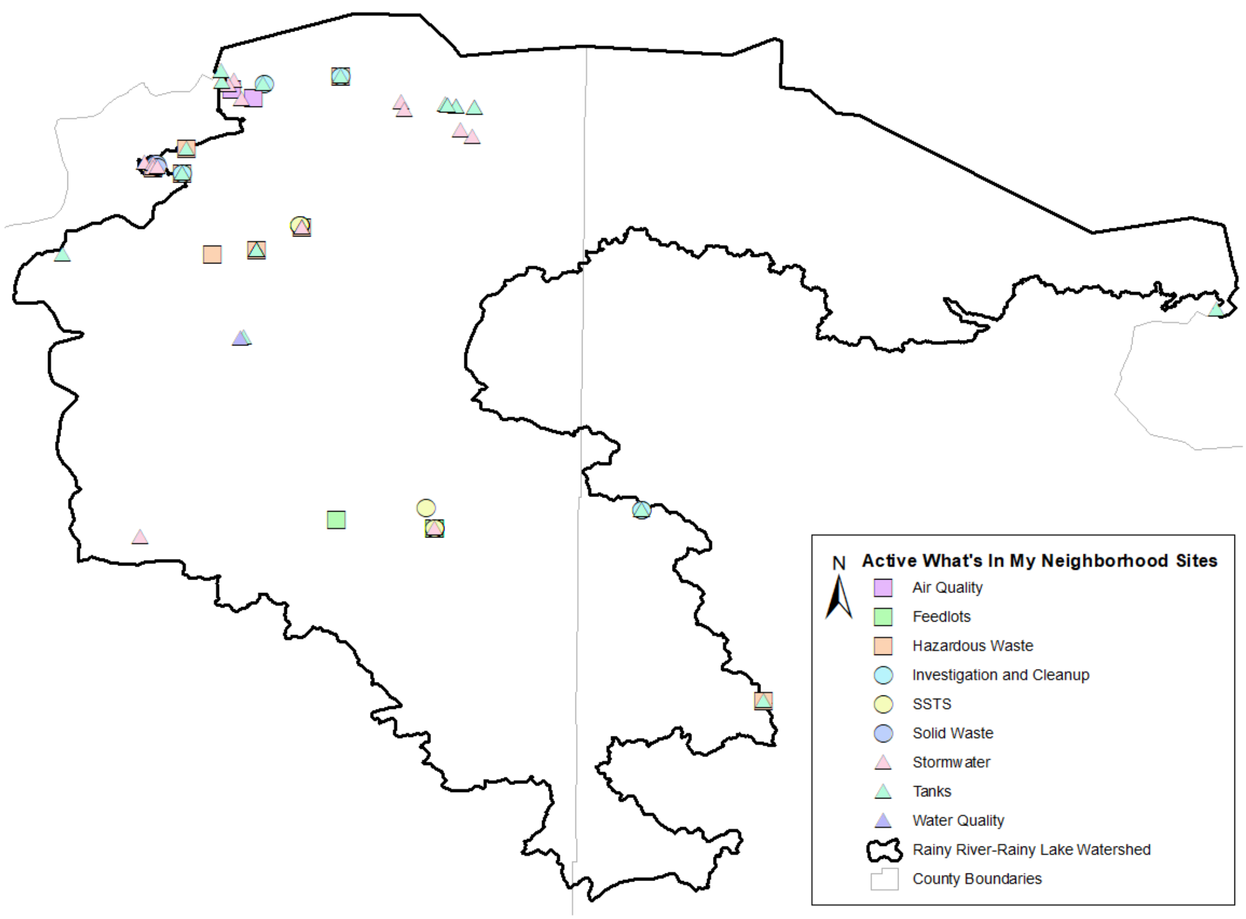
Mandatory testing by the Minnesota Department of Health (MDH) for arsenic, a naturally occurring but potentially harmful contaminant for humans, of all newly constructed wells has found that an average of 10% of all wells installed after 2008 have arsenic levels above the maximum contaminant level (MCL) for drinking water of 10 ug/L (MDH, 2020). In the RRRL Watershed, the majority of new wells are within the water quality standards for arsenic levels, but there are exceedances to the MCL. By county, the percentages of wells identified with concentrations exceeding the MCL are as follows: Koochiching (12.5%) and Saint Louis (3.8%) (MDH 2020) (Figure 17). It is important to reiterate that the percentages of arsenic concentration exceedances are per county, not specifically for RRRL 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 17. Percent wells with arsenic occurrence greater than the MCL for the RRRL Watershed (2008-2017) (MDH 2020).



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: 1) potentially contaminated sites, and includes contaminated properties, formerly contaminated sites, and those that are being investigated for suspicion of being contaminated, and 2) businesses that have applied for and received different types of environmental permits and registrations from the MPCA. In the RRRL Watershed, there are currently 150 active sites identified by WIMN: 39 tanks (aboveground and underground), 36 stormwater sites (construction and industrial), 35 hazardous waste sites, 19 subsurface sewage treatment systems (SSTS), 9 investigation and cleanup sites, 5 feedlots, 4 air quality sites, 2 solid waste sites, and 1 water quality site (wastewater) (Figure 18). 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 18. Active "What's In My Neighborhood" site programs and locations for the RRRL Watershed (MPCA 2020).

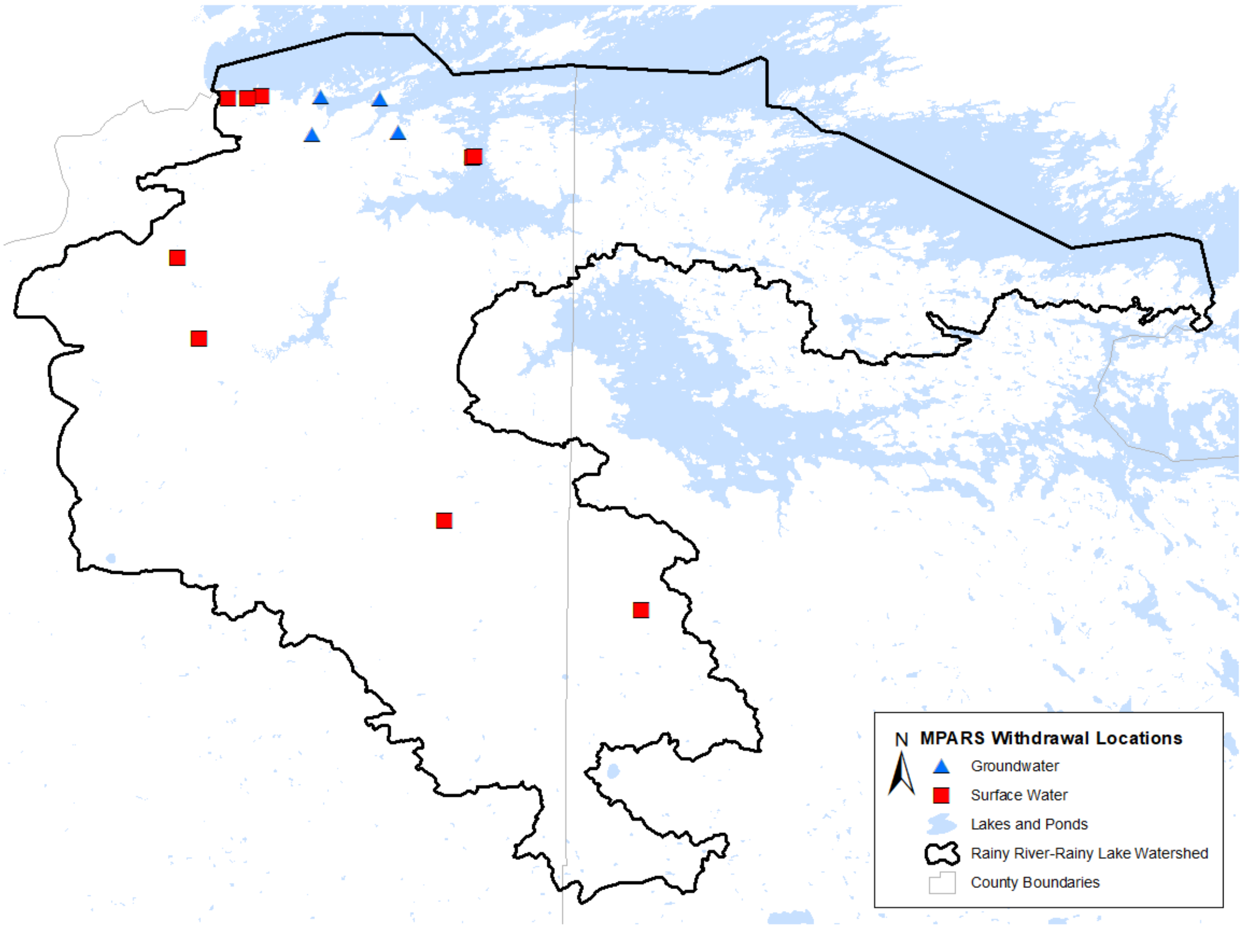


Groundwater quantity

The Department of Natural Resources 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 usage to the MDNR annually. The three largest permitted consumers of water in the state are (in order) power generation, public water supply (municipals), and industrial processing (MDNR 2020b). According to the most recent MDNR Permitting and Reporting System (MPARS), there was not enough data reported to conduct statistical analysis on withdrawals in the RRRL

Watershed. Figure 19 displays total permitted high capacity withdrawal locations within the watershed. Although there are permits allowed for groundwater withdrawal, the majority of water is withdrawn from surface water sources due to the limited groundwater availability in this watershed.

Figure 19. Locations of permitted high capacity withdrawals within the RRRL Watershed.



Wetlands

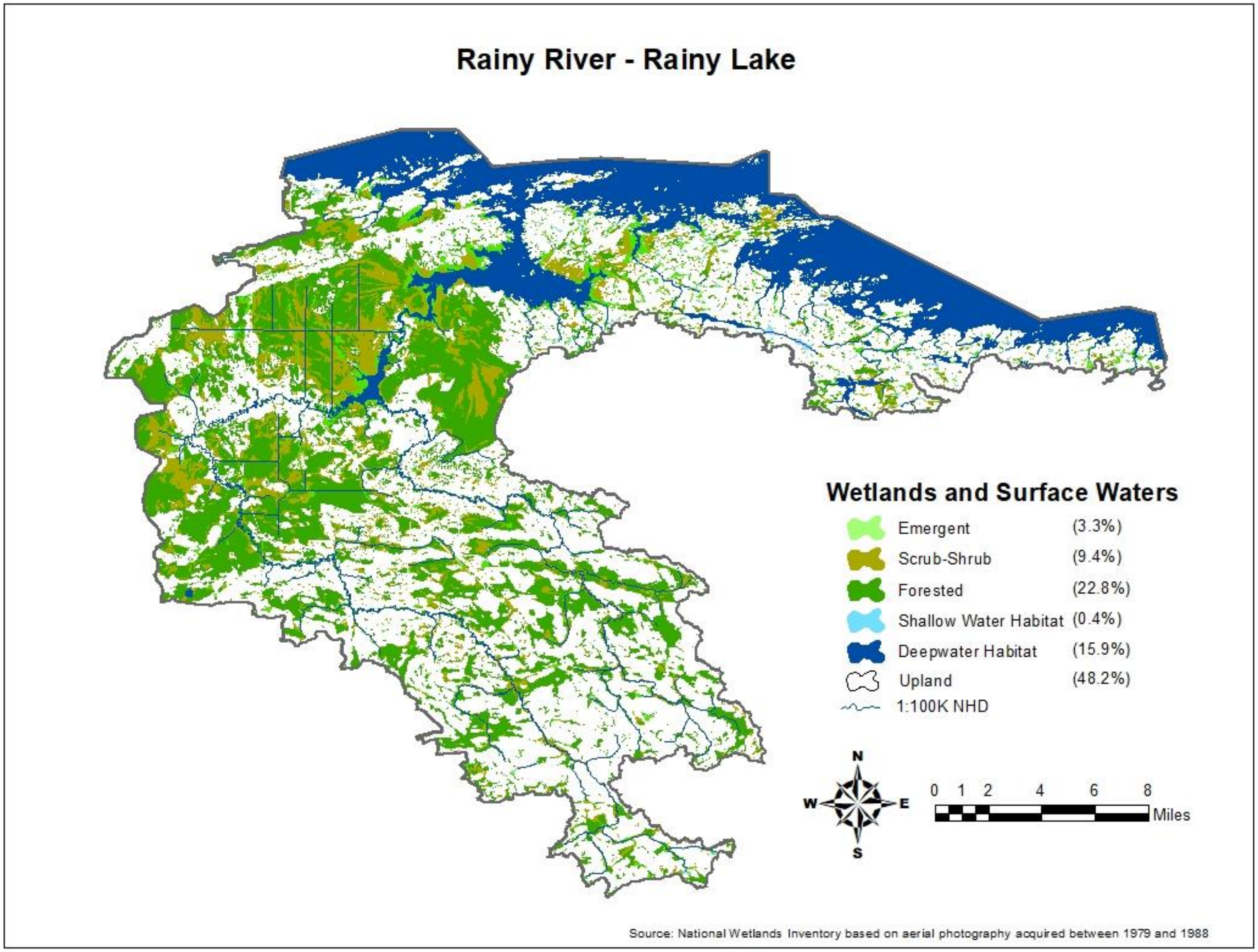
Wetlands cover a significant portion of the RRRL Watershed. National Wetlands Inventory (NWI) data estimate 106,349 acres of wetlands—which covers approximately 36% of the watershed (Figure 20). This is greater than the statewide wetland coverage rate of 19% (Kloiber and Norris 2013) and is more than twice as much as the lake and stream area combined (Figure 20). Coniferous swamps and bogs (i.e., forested wetlands) are the predominant wetland type and are primarily composed of black spruce, tamarack, and/or white cedar. Scrub-shrub wetland (chiefly in the form of open bogs that have a carpet of *Sphagnum* moss and abundant low ericaceous shrubs), is also extensive in the RRRL Watershed.

Two distinct glacial landforms are present in the RRRL Watershed (corresponding to the Omernik Level III ecoregion boundaries; Figure 6), which has led to contrasting hydrogeomorphic (HGM) wetland patterns in the watershed (MGS 1997). The northern and southern lobes of the watershed consist of glacial scouring and moraines from multiple glacial advances that left behind the distinctive topographic relief of Minnesota's canoe country. Numerous small to large sized wetlands have formed in the depressions and swales left behind. Due to the relatively cool-wet climate of the region, many of these HGM depressional and larger organic flat wetlands are peat forming swamps and bogs—where organic soils have developed due to saturated conditions. A notable exception are the pond and fresh meadow complexes created by beaver activity—particularly on the Kabetogama Peninsula which has one of the highest concentration of beaver created wetland in the world (Johnston 2017). The central portion of watershed is a glacial lake plain created by GLA (Figure 6). The extremely flat landscape that remained following GLA had little capacity to drain surface water—promoting saturated soil conditions and peatland formation over expansive areas. The predominant water exchange in organic flat wetlands is through precipitation and evapotranspiration (Smith et al 1995). As peat has low hydrologic conductivity, excess precipitation can slowly runoff via overland saturation flow along very low elevation gradients—providing source water for streams (Acreman & Holden 2013). Source water from organic flat wetlands often has low pH, low dissolved oxygen, and is high in dissolved organic matter. The majority of the streams in the RRRL Watershed appear to have significant source water contributions from large peatlands or smaller organic flat wetlands

The majority of the pre-settlement wetlands remain intact in the RRRL Watershed, which is typical for northeastern Minnesota as development pressure is low and a significant portion are protected public lands. Two extensive ditch networks were made in peatlands along the Rat Root River. Similar to other large peatland drainage efforts in Minnesota the ditches were largely unsuccessful, resulting in localized wetland impacts in proximity to the ditches.

The RRRL Watershed supports some notable wetland features. A number of the large peatlands have formed the distinctive patterns of raised bogs and water tracks with occasional minerotrophic groundwater fed fens. Two of the patterned peatlands have been protected as the East and West Rat Root River Peatland Scientific and Natural Areas. In addition, wild rice populations have been documented in Rat Root and Rainy Lakes.

Figure 20. Wetlands and surface water in the RRRL Watershed.



Watershed-wide data collection methodology

Lake water sampling

An abundance of water quality data (via VNP, USGS, and others) was already available for Rainy Lake; therefore, no water quality sampling was conducted in association with the intensive watershed monitoring approach. Smaller lakes in this watershed were not sampled through this effort due to access challenges. 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 (MPCA 2018b). The lake recreation use assessment requires eight observations/samples within a 10-year period (June to September) for phosphorus, chlorophyll-a and Secchi depth. Chloride, sulfate, and nitrates are sampled at a subset of waters that have been identified as being impacted by chloride inputs, are designated wild rice waters, or have a designated drinking water use.

Stream water sampling

Two water chemistry stations were sampled from May thru September in 2017, and again June thru August of 2018, to provide sufficient water chemistry data to assess all components of the aquatic life and recreation use standards. Following the IWM design, water chemistry stations were placed at the outlet of each aggregated 12 HUC subwatershed that was >40 square miles in area (purple circles and green circles/triangles in (Figure 12). A SWAG was awarded to the Koochiching County SWCD for collecting water chemistry data at two locations (See Appendix 2 for locations of stream water chemistry monitoring sites). See Appendix 1 for definitions of stream chemistry analytes monitored in this study). Other smaller tributaries were not monitored for intensive water chemistry due to overall subwatershed size and limited access to downstream locations ideal for data collection.

Stream flow methodology

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

Stream biological sampling

The biological monitoring component of the intensive watershed monitoring in the RRRL Watershed was completed during the summer of 2017. A total of five sites were established across the watershed and sampled. These sites were located near the outlets of most minor HUC-14 watersheds. In addition, there was one existing biological monitoring station within the watershed. This monitoring station was initially established as part of a random Rainy River Basin wide survey in 2005. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2019 assessment was collected in 2017. A total of four WIDs were sampled for biology in the RRRL Watershed. Waterbody assessments to determine aquatic life use support were conducted for two WIDs. Biological information that was not used in the assessment process will be crucial to the stressor identification process and will also be used as a basis for long term trend results in subsequent reporting cycles.

To measure the health of aquatic life at each biological monitoring station, indices of biological integrity (IBIs), specifically fish and invert IBIs, were calculated based on monitoring data collected for each of these communities (MPCA 2017a). A fish and macroinvertebrate classification framework was developed to account for natural variation in community structure which is attributed to geographic region, watershed drainage area, water temperature and stream gradient (Sandberg et al 2014 &

Chirhart et al 2014). As a result, Minnesota's streams and rivers were divided into seven distinct warm water classes and two cold water classes, with each class having its own unique fish IBI and invert IBI. Each IBI class uses a unique suite of metrics, scoring functions, impairment thresholds, and confidence intervals (CIs) (For IBI classes, thresholds and CIs, see Appendix 5). IBI scores higher than the impairment threshold and upper CI indicate that the stream reach supports aquatic life. Contrarily, scores below the impairment threshold and lower CI indicate that the stream reach does not support aquatic life. When an IBI score falls within the upper and lower confidence limits additional information may be considered when making the impairment decision such as the consideration of potential local and watershed stressors and additional monitoring information (e.g., water chemistry, physical habitat, observations of local land use activities). For IBI results for each individual biological monitoring station, see Appendix 6 and 7.

Fish contaminants

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

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

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

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

Before 2008, mercury in fish tissue was assessed for water quality impairment based on MDH's fish consumption advisory, the same as PCBs. With the adoption of a water quality standard for mercury in edible fish tissue, a waterbody is classified as impaired for mercury in fish tissue if 10 percent 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 for a single year.

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 (DOP), nitrate plus nitrite nitrogen (NO_3+NO_2-N), and total Kjeldahl nitrogen (TKN).

More information can be found at the WPLMN website.

Groundwater monitoring

The MPCA maintains an Ambient Groundwater Monitoring Network that monitors the aquifers that are most likely to be polluted with non-agricultural chemicals. The purpose is to identify any changes in groundwater quality from normal, day-to-day practices. This network primarily targets shallow aquifers that underlie areas in urban areas, due to the higher tendency of vulnerability to pollution, and acts as an "early warning system" for groundwater quality changes. The MPCA's Ambient Groundwater Monitoring Network consists of approximately 270 wells, most of which are shallow monitoring wells in sand and gravel aquifers, but also include deeper domestic wells, often located in the Prairie du Chien-Jordan aquifers.

Most wells in this early warning network contain water that was recently recharged into the groundwater, some even less than one year old. The wells in the early warning network are distributed among several different settings to determine the effect land use has on groundwater quality. These assessed land use settings are: 1) sewered residential, 2) residential areas that use subsurface sewage treatment systems (SSTS) for wastewater disposal, and 3) commercial or industrial, and 4) undeveloped (remote forested areas). 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 network wells generally are collected annually by MPCA staff. This sampling frequency provides sufficient information to determine trends in groundwater quality. The water samples are analyzed to determine the concentrations of over 100 chemicals, including nitrate, chloride, and VOCs. Furthermore, a subset of PFAS and CEC samples are collected in addition to the ambient groundwater suite.

Information on groundwater monitoring methodology is taken from the Kroening report: The Condition of Minnesota's Groundwater Quality, 2013-2017 (2019). To download ambient groundwater monitoring data, please refer to: https://www.pca.state.mn.us/data/groundwater-data

Wetland monitoring

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

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

Individual aggregated 12-HUC subwatershed results

Aggregated 12-HUC subwatersheds

Assessment results for aquatic life and recreation use are presented for each Aggregated HUC-12 subwatershed within the RRRL Watershed. The primary objective is to portray all the full support and impairment listings within an aggregated 12-HUC subwatershed resulting from the complex and multi-step assessment and listing process. This scale provides a robust assessment of water quality condition at a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The graphics presented for each of the aggregated HUC-12 subwatersheds contain the assessment results from the 2019 assessment cycle as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2017 intensive watershed monitoring effort, but also considers available data from the last 10 years.

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

Stream assessments

A table is provided in each section summarizing aquatic life and aquatic recreation assessments of all assessable stream reaches within the aggregated HUC-12 subwatershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2017 assessment process (2014 U.S. Environmental Protection Agency [EPA] reporting cycle); however, impairments from previous assessment cycles are also included and are distinguished from new impairments via cell shading (see footnote section of each table). These tables also denote the results of comparing each individual aquatic life and aquatic recreation indicator to their respective criteria (i.e., standards); determinations made during the desktop phase of the assessment process (see Figure 4). Assessment of aquatic life is derived from the analysis of biological (fish and macroinvertebate IBIs), dissolved oxygen, total suspended solids, chloride, pH, total phosphorus, chlorophyll-a, biochemical oxygen demand and un-ionized ammonia (NH_3) data, while the assessment of aquatic recreation in streams is based solely on bacteria (Escherichia coli) data. Included in each table is the specific aquatic life use classification for each stream reach: cold water community (2A) or cool or warm water community (2B). Where applicable and sufficient data exists, assessments of other designated uses (e.g., class 7, drinking water, aquatic consumption) are discussed in the summary section of each aggregated HUC-12 subwatershed as well as in the Watershed-wide results and discussion section.

Lake assessments

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

Rat Root River Aggregated 12-HUC HUC 0903000318-01

The Rat Root River Subwatershed drains 209.25 square miles of Koochiching (93.0%) and Saint Louis Counties (7.0%) and is the largest subwatershed within the RRRL Watershed. The headwaters of this subwatershed begins in a forested wetland and flows 46.92 miles to the northwest before abruptly turning east. From here, the Rat Root River continues an additional 11.64 miles before entering Rat Root Lake (36-0006-00) and eventually Rainy Lake (69-0694-00). Several unnamed streams contribute their water to the Rat Root River. There are a total of two lakes greater than 10 acres, with the most prominent being Rat Root Lake. This subwatershed is dominated by wetlands (60.04%) and forest (34.73%). Only 2.31% is rangeland, 1.22% development, 0.96% open water, 0.74% row-crop agriculture, and there is no barren/mining (USGS 2008). Much of the land within this subwatershed is owned and managed by local, state, and federal entities (USGS 2008). The watershed includes portions of the Superior National Forest, Kabetogama State Forest, Koochiching State Forest, and Rat Root River Peatland Scientific & Natural Area. Intensive water chemistry sampling was conducted at the outlet of the subwatershed upstream of County Road 97, 1.5 miles NW of Ericsburg on the Rat Root River. The outlet is represented by water chemistry station S007-612 and biological station 17RN001.

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

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)
09030003-634 ***Rat Root River*** *Headwaters to Unnamed Creek*	17RN004 17RN003	30.44	WWg	MTS	MTS	IF	IF	IF	- -	IF	IF	- -	- -	SUP	- -
09030003-635 ***Rat Root River*** *Unnamed Creek To E Branch Rat Root River*	17RN001	28.12	WWg	MTS	- -	NA*	EXS	EXS	MTS	MTS	MTS	- -	IC	IC	SUP

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

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

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

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

* Dissolved Oxygen assessment was deemed not assessable due to contributing wetland influence and potential stagnant conditions from upstream waterbodies.

Summary

The Rat Root River Subwatershed had two assessable stream segments (Table 2), containing three biological and one chemistry monitoring stations (Appendix 2 and 3). One reach (-634) met the applicable standards or criteria and fully supported aquatic life, while the other reach (-635) had inconclusive information to make a determination (Figure 22). In-stream habitat was fair overall (Appendix 10). The generally lower habitat scores in this subwatershed are likely due to a combination of factors, including the low stream gradient and lack of coarse substrates. Habitat at the headwater station (17RN004) was poor and likely related to the low gradient nature of this reach; low gradient streams tend to have less riffle habitat and lack coarse substrates (Figure 21). Fish cover varied between stations but was relatively poor in the lower reaches of Rat Root River (17RN001). Fine clay sediments, a consequence of deposition from GLA that once covered this landscape, dominate the lower reaches. MPCA staff also observed stream instability and mass wasting throughout the majority of the Rat Root River and other streams in the subwatershed.

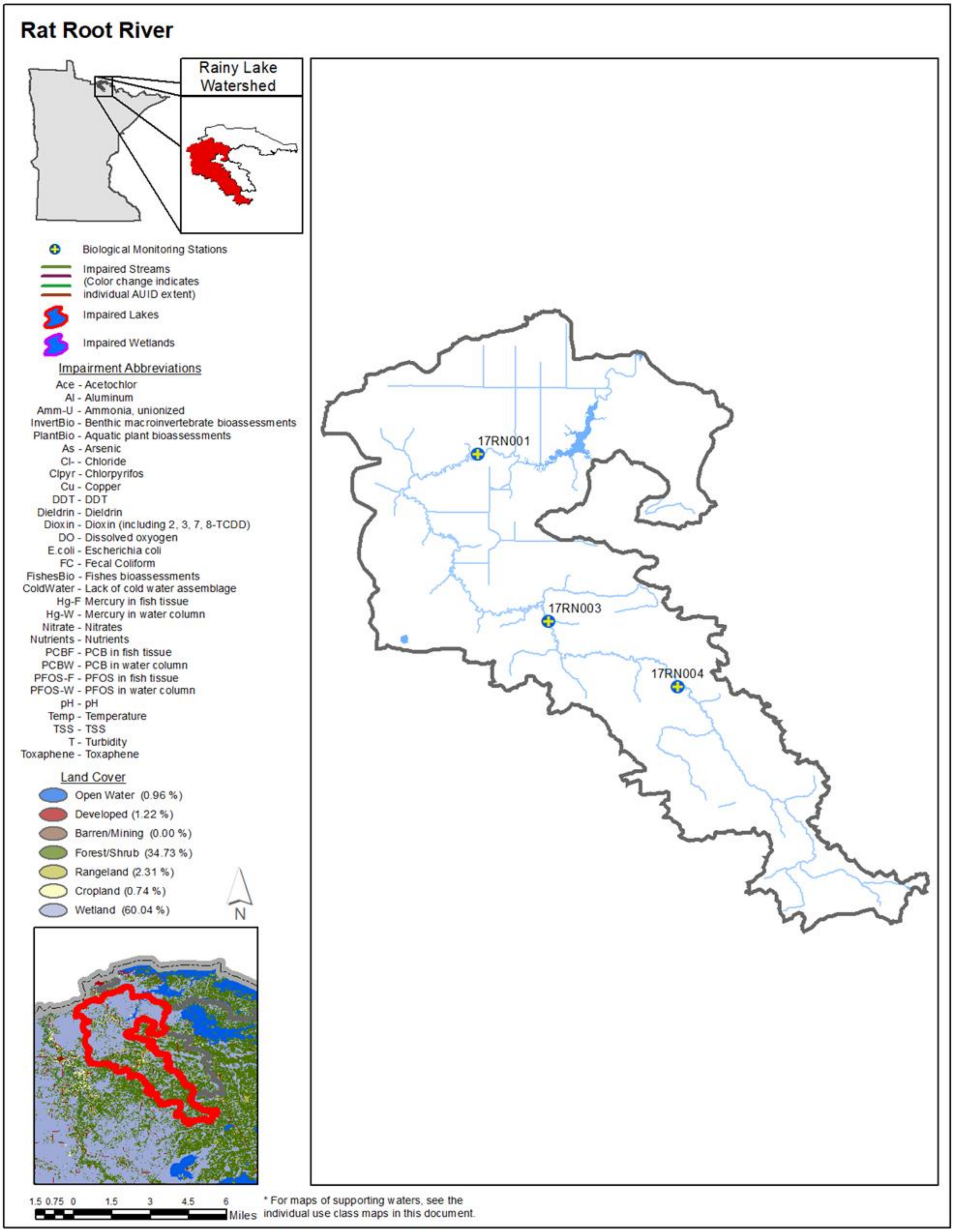
All three biological monitoring stations were located on the Rat Root River (Figure 22). A total of 23 species of fish and 2,281 individuals were captured between the three stations in 2017. The biological condition varied along the Rat Root River (-634 & -635). The most upstream and downstream stations met the applicable standard for fish while the middle station was just below the impairment threshold (Appendix 6). Stream gradient was much lower at the headwater station (0.08 m/km) in comparison to the middle station (0.62 m/km). Consequently, the upstream station (17RN004) was assessed using the Low Gradient Fish-IBI and scored 76.9, which is well above the exceptional use threshold (Appendix 5). The station was dominated by several fish species that are typical of low gradient streams including both pearl dace and brassy minnows. The Biological Condition Gradient (BCG) at this headwater station was a tier 2, reflecting a community with minimal changes to biological composition or function. Seventy-three percent of the species captured at the upstream station were also found at the middle Rat Root River station. Although species composition was similar between these two stations, the fish IBI scores were very different. The middle station (17RN003) was assessed using the Northern Streams fish IBI class and had a fish IBI score of 40.8, which is below the impairment threshold but within the lower confidence interval. Low numbers of late-maturing and intolerant individuals negatively impacted the middle stations fish IBI. A BCG score of four indicated a community that had lost some sensitive species but where biological functions were largely maintained.

Benthic macroinvertebrates were only monitored at the middle station during the summer of 2017 and indicated support for aquatic life (Appendix 5). The macroinvertebrate IBI score was one point below the general use threshold but within the confidence interval of the Northern Forest Streams Glide-Pool class (Appendix 7). This BCG tier 3 station contained several sensitive macroinvertebrate species but species richness, predator species (non-midges), and the lack of collector filtering species numbers were low. High sediment loads occur naturally in the Rat Root River system, likely a function of the underlying geology, and may explain the low numbers of collector filtering species. Biologists considered these factors when assessing the stream reach as supporting aquatic life.

The water chemistry data also reflected the natural environmental conditions unique to this area. Low dissolved oxygen concentrations are likely associated with natural wetland environments and the "backwater" effect from downstream damming. Healthy fish communities stood in contrast to the TSS and Secchi tube data that indicates that the Rat Root River has high levels of total suspended solids and low water clarity; once again, likely a function of the fine, glacially derived sediments that are found in this area. Because the available biological and chemistry data were somewhat contradictory, a decision was made collect more macroinvertebrate data before listing this water as impaired for suspended solids and water clarity. Bacterial levels were low, suggesting good conditions for aquatic recreation use.

Figure 21. The Rat Root River from downstream to upstream taken during fish sampling, depicting riparian and stream habitat at biological monitoring stations. Upper Left: 17RN001, Upper Right: 05RN186 (existing station sampled in 2005), Lower Left: 17RN003, Lower Right: 17RN004

Figure 22. Currently listed impaired waters by parameter and land use characteristics in the Rat Root River Aggregated 12-HUC.



Rat Root River, East Branch Aggregated 12-HUC HUC 0903000318-02

The Rat Root River, East Branch Subwatershed drains 74.63 square miles of Koochiching (52.3%) and Saint Louis Counties (47.7%) and is the smallest subwatershed within the RRRL Watershed. The headwaters of this subwatershed begins in a forested wetland and flows 42.76 miles to the northwest before exiting this subwatershed and entering the Rat Root Lake. Several unnamed streams contribute their water to the Rat Root River, East Branch. There are two lakes greater than 10 acres, with the most prominent being Little Lake. This subwatershed is dominated by forest (54.52%) and wetlands (40.38%). Only 3.25% is rangeland, 1.28% development, 0.39% row-crop agriculture, 0.18% open water, and there is no barren/mining (USGS 2008). A portion of this watershed lies within the Superior National Forest, Kabetogama State Forest, Koochiching State Forest, and East Rat Root River Peatland Scientific & Natural Area. Much of the land within this subwatershed is owned and managed by local, state, and federal entities (USGS 2008). Intensive water chemistry sampling was conducted at the outlet of the subwatershed upstream of CSAH 3, 2 miles North of Ray on the Rat Root River, East Branch. The outlet is represented by water chemistry station S009-450 and biological station 17RN006.

Table 3. Aquatic life and recreation assessments on stream reaches: Rat Root River, East Branch Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

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)**
09030003-632 ***Rat Root River, East Branch*** *Headwaters to Unnamed Creek*	17RN007	20.37	WWg	MTS	- -	IF	IF	IF	- -	IF	IF	- -	- -	SUP	- -
09030003-633 ***Rat Root River, East Branch*** *Unnamed Creek to Rat Root River*	17RN006	22.39	WWg	MTS	MTS	IF	EXS	EXS	MTS	MTS	MTS	- -	- -	SUP	SUP

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

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

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

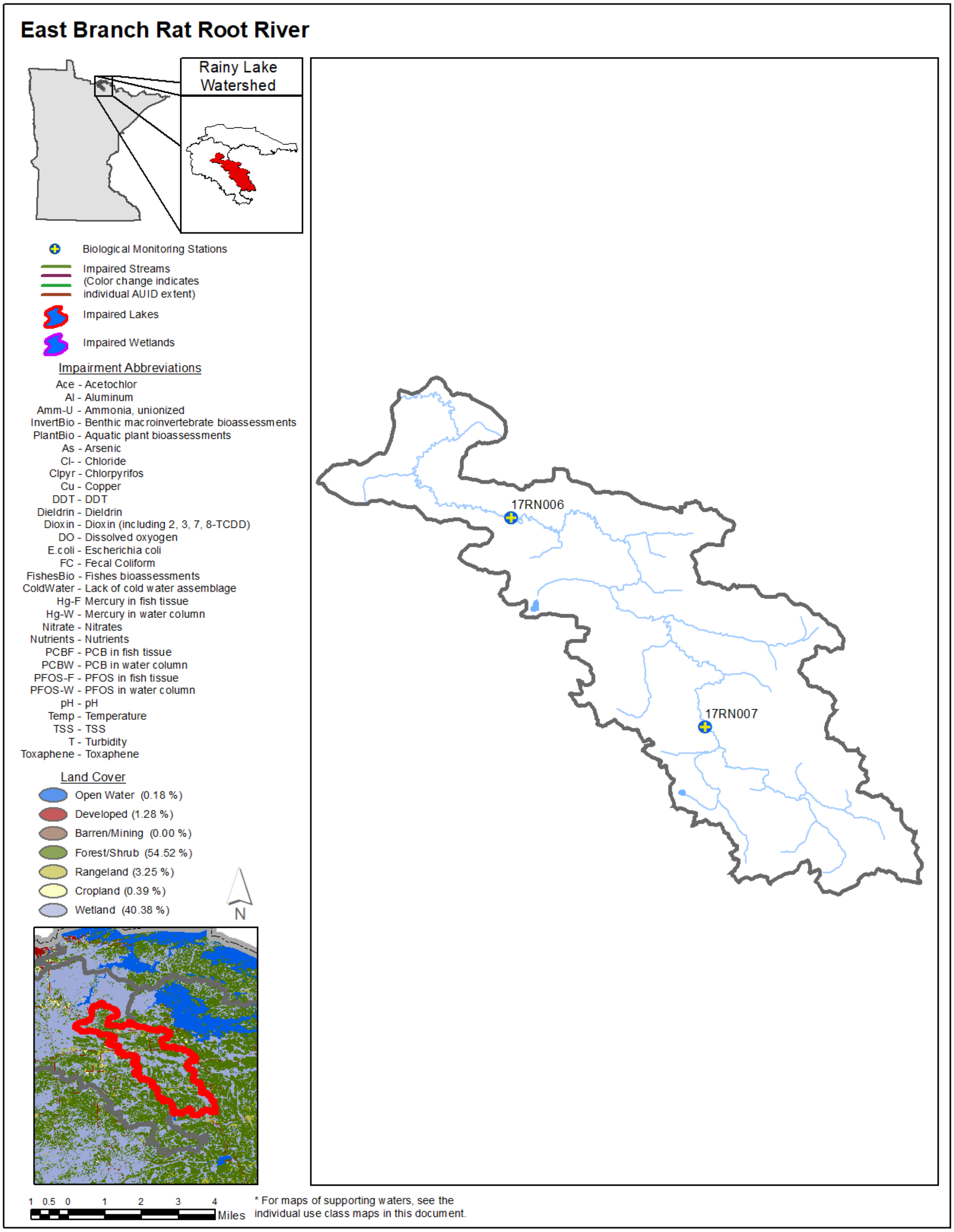
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water

Summary

The Rat Root River, East Branch Subwatershed had two assessable stream segments (Table 3), containing two biological and one chemistry monitoring stations (Appendix 2 and 3). Both stream segments met the applicable standards or criteria and fully supported aquatic life (Figure 23). In-stream habitat was in fair condition, with both of the highest MPCA Stream Habitat Assessment (MSHA) scores in the entire watershed (Appendix 10). Three fish visits were conducted at the two biological monitoring stations, with fish IBI scores meeting aquatic life standards (Appendix 5). Fish species composition differed between the two biological monitoring stations but both stations had good overall stream health (Appendix 6). A total of 18 species, comprised of individuals typical of a warm-water streams (common shiner, creek chub, white sucker, central mudminnow) were surveyed. The upstream station (17RN007) was dominated by northern redbelly dace and pearl dace, species typical of a healthy headwater stream. A macroinvertebrate sample collected at the downstream station (17RN006) concurred with the fish results that the Rat Root River, East Branch was in good condition (Appendix 7).

Water chemistry data for streams in this subwatershed reflect the natural environmental conditions of this area. Total suspended solids and water clarity are often below water quality standards (not meeting). Considering biological communities are in healthy conditions, and no other known water chemistry parameter is posing a potential threat to aquatic life, the reach was not considered impaired for total suspended solid and Secchi tube. Bacteria concentrations are indicative of good recreational water quality.

Figure 23. Currently listed impaired waters by parameter and land use characteristics in the Rat Root River, East Branch Aggregated 12-HUC.



Rainy Lake Aggregated 12-HUC HUC 0903000319-01

The Rainy Lake Subwatershed drains 179.54 square miles of Saint Louis (58.4%) and Koochiching Counties (41.6%). This subwatershed lies along the international border between the United States and Canada with additional drainage on the Canadian side. Rainy Lake (69-0694-00) extends across this subwatershed from east to west, with multiple named and unnamed tributary streams. Both the Rainy River-Headwaters and Vermilion River Watersheds (HUC-8) contribute their waters (7,340.99 mi^2) to this subwatershed through Kettle Falls. There are two water-control dams located at Kettle Falls where the outflow from Namakan Lake (69-0693-00) enters the lake. In addition, a small channel connecting Kabetogama Lake (69-0845-00) to Black Bay of Rainy Lake was created when lake levels increased as the result of the Kettle Falls Dam. The Rat Root River is the only major tributary from the Minnesota side but several large rivers (Rat, Pipestone, Seine, Turtle, and Manomin Rivers) enter Rainy Lake from the Canadian side. There are a total of 23 lakes greater than 10 acres, with the most prominent being Rainy, Shoepack, Locator, and Peary Lake. This subwatershed is dominated by open water (40.56%), forest (35.90%), and wetlands (21.75%) with only 1.06% development, 0.46% is rangeland, 0.24% row-crop agriculture, and 0.03% barren/mining (USGS 2008). A portion of this watershed lies within the Voyageurs National Park, Gold Portage Wildlife Management Area, Koochiching State Forest, and West Rat Root River Peatland Scientific & Natural Area. Much of the land within this subwatershed is owned and managed by local, state, and federal entities (USGS 2008). As a result of the overall remoteness, short tributary streams, and many large bodies of water, there was no biological monitoring from this subwatershed. However, chemistry data was obtained from several lakes.

Table 4. Lake assessments: Rainy Lake Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi trend	Aquatic life indicators: Fish IBI	Aquatic life indicators: Chloride	Aquatic life indicators: Pesticides	Aquatic recreation indicators: Total phosphorus	Aquatic recreation indicators: Chlorophyll-a	Aquatic recreation indicators: Secchi	Aquatic life use	Aquatic recreation use
Rainy	69-0694-00	45792	18	Deep Lake	NLF	NT	--	IF	--	MTS	MTS	MTS	IF	FS
Peary	69-0833-00	111	15	Deep Lake	NLF	--	--	MTS	--	--	--	MTS	IF	IF
Fishmouth	69-0834-00	31	28	Deep Lake	NLF	--	--	--	--	--	--	IF	--	IF
Unnamed	69-0835-00	36	12	Deep Lake	NLF	--	--	MTS	--	--	--	MTS	IF	IF
Oslo	69-0838-00	97	36	Deep Lake	NLF	--	--	--	--	--	--	IF	--	IF
Boot	69-0868-00	53	25	Deep Lake	NLF	--	--	--	--	--	--	IF	--	IF
Shoepack	69-0870-00	305	24	Deep Lake	NLF	--	--	MTS	--	--	--	EXS	IF	IF
Quill	69-0871-00	83	46	Deep Lake	NLF	--	--	--	--	--	--	IF	--	IF
Loiten	69-0872-00	96	49	Deep Lake	NLF	--	--	--	--	--	--	IF	--	IF
Locator	69-0936-00	134	52	Deep Lake	NLF	--	--	MTS	--	--	--	IF	IF	IF
War Club	69-0937-00	81	40	Deep Lake	NLF	--	--	--	--	--	--	IF	--	IF

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

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

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

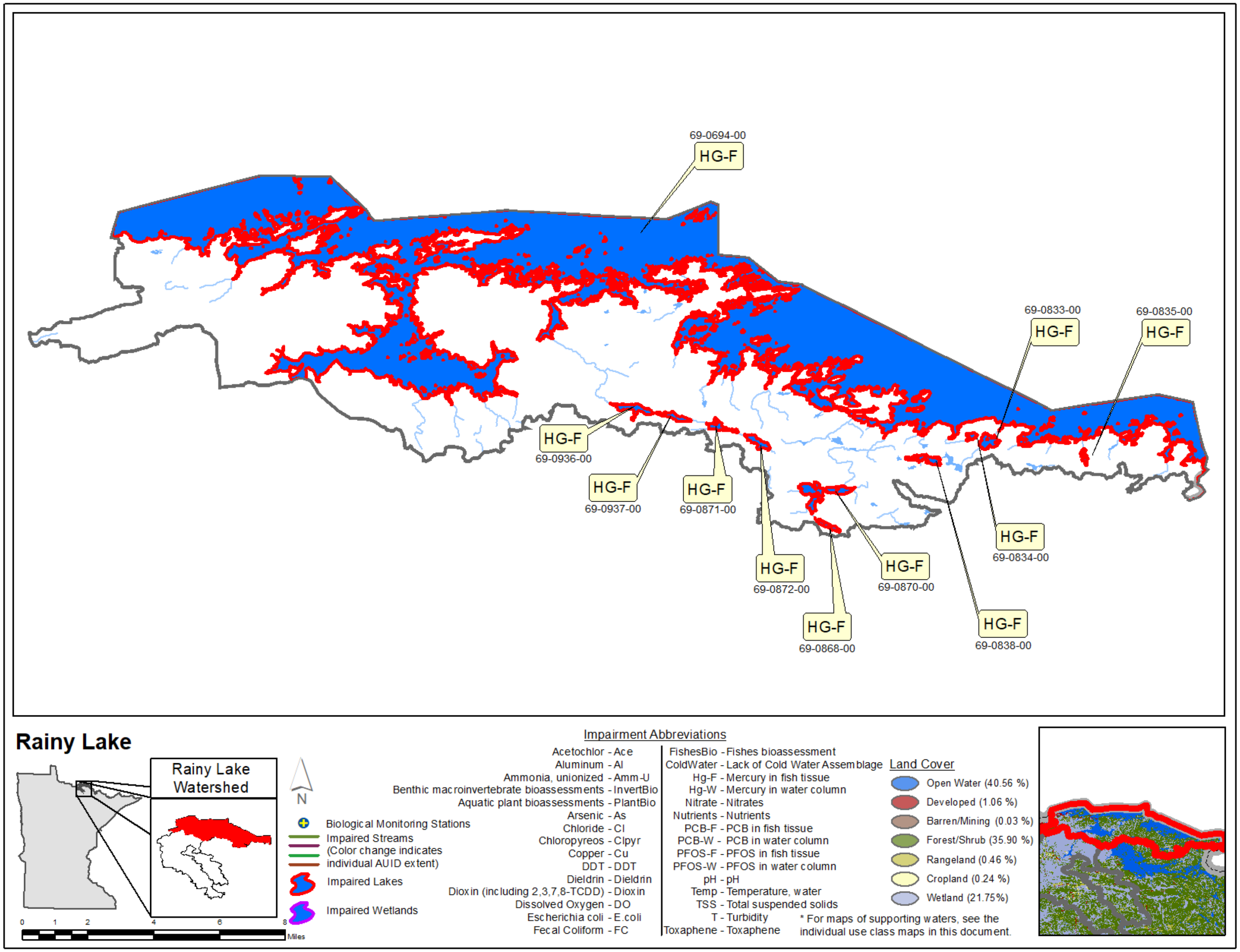
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)

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

Summary

The Rainy Lake Subwatershed had no assessable stream segments (Figure 24) and one lake assessed for aquatic recreation (Table 4). Rainy Lake is a prominent resource important for both recreation and the economy of the region, while also playing a large role in the water quality of the Rainy River. Total Phosphorus and Chlorophyll-a datasets for aquatic recreation use assessment are relatively small given the popularity of the lake. However, an extensive water clarity dataset bolstered by citizen monitoring provides a good historical record of conditions in Rainy Lake. The recreational water quality is in good condition, clearly meeting regional goals reflective of a contributing watershed that is generally intact forest and wetland environments. Water clarity appears to be stable with no long term trend detected. The continued strong presence of citizen monitoring is important to track water clarity changes into the future between gaps of more extensive monitoring efforts. Protecting water quality of Rainy Lake is imperative because citizens and local economies depend on it (Appendix 11). Voyageurs National Park conducts water quality monitoring on a number of more remote lakes in this subwatershed. Overall, those clarity datasets indicate good recreational water quality. More nutrient and chlorophyll-a data would be needed to conduct a complete assessment. Limited chloride data collected in lakes in this watershed suggest that it is not a potential stressor to aquatic communities.

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



Watershed-wide results and discussion

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

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

Stream water quality

Four of the 16 stream WIDs were assessed (Table 5). All of the assessed WIDs supported aquatic life and/or recreation. In total, three streams fully supported aquatic life and two streams fully supported aquatic recreation. None of the WIDs were classified as limited resource waters.

Overall, water quality conditions are good, and reflect the forests and wetlands that dominate the land cover within the RRRL Watershed. Problem areas do occur and persist throughout this watershed but are limited to the lower reaches where stressors from hydrological modifications, historical land use practices, and other natural processes may accumulate. Total suspended solids are elevated in the lower reaches of the Rat Root River mainstem and East Branch. Sources of the sediment are likely a function of the watershed's geologic setting, the river's geomorphology, and altered hydrology. Dissolved oxygen often exceeded standards in the lower portion of the Rat Root River (-635). This area has had very little disturbance in the last few decades; the exceedances are likely attributed to altered hydrology, the high proportion of wetlands in the watershed, and the local geology. Bacteria levels were low throughout this watershed. Biological communities were generally in good condition throughout the watershed. Additional sampling of the lower Rat Root River through the stressor identification process may provide more insight into the exceedance of the DO standard.

Table 5. Assessment summary for stream water quality in the RRRL Watershed.

Watershed	Area (mi²)	# Total WIDs	# Assessed WIDs	Supporting		Non-supporting		Insufficient data	# Delistings
				# Aquatic life	# Aquatic recreation	# Aquatic life	# Aquatic recreation		
Rainy River – Rainy Lake **HUC 8**	**463.42**	**16**	**4**	**3**	**2**	**0**	**0**	**1**	**0**
Rat Root River	209.25	7	2	1	1	0	0	1	0
Rat Root River, East Branch	74.63	5	2	2	1	0	0	0	0
Rainy Lake	179.54	4	0	0	0	0	0	0	0

Lake water quality

There was enough data to assess aquatic recreation on Rainy Lake, which is clearly meeting water quality standards for this region (Table 6). Limited data from the other remote lakes in this watershed prevented a full assessment. However, water clarity data suggests that recreational water quality of these lakes appears good. Chloride does not appear to be a problem for aquatic life in these lakes.

Table 6. Assessment summary for lake water chemistry in the RRRL Watershed.

Watershed	Area (mi²)	Lakes >10 acres	Supporting		Non-supporting		Insufficient data	# Delistings
			# Aquatic life	# Aquatic recreation	# Aquatic life	# Aquatic recreation		
Rainy River – Rainy Lake **HUC 8**	**463.42**	**27**	**0**	**1**	**0**	**0**	**10**	**0**
Rat Root River	209.25	2	0	0	0	0	0	0
Rat Root River, East Branch	74.63	2	0	0	0	0	0	0
Rainy Lake	179.54	23	0	1	0	0	10	0

Biological monitoring

Fish

The Rainy River Basin spans a total of 26,882.4 square miles within Minnesota Ontario and Manitoba. Seventy-four different species of fish can be found within this basin (Hatch et al 2012). Although the RRRL Watershed is only a small percentage (1.7%; Minnesota Only) of the entire basin, 25 fish species were sampled during this monitoring (Appendix 9). Historically, fisheries management activities have focused on lake management and game fish populations.

The Rainy River Basin does not have any endangered or threatened species under federal law but the watershed does have six fish species listed by the state of Minnesota as being of special concern (MDNR 2013). These species include; *Ichthyomyzon fossor* (northern brook lamprey), *Acipenser fulvescens* (lake sturgeon), *Coregonus zenithicus* (shortjaw cisco), *Couesius plumbeus* (lake chub), *Lepomis gulosus* (warmouth), and *Lepomis peltastes* (northern longear sunfish). Many introduced and invasive fish species are known to exist within the basin, including *Osmerus mordax* (rainbow smelt)*, salmo trutta* (brown trout)*, salvelinus fontinalis* (brook trout)*, Lepomis gulosus* and *Micropterus dolomieu* (smallmouth bass). Many of the fish species were either introduced during historical stocking efforts or likely transported by recreational users. Although the warmouth is an introduced species within this basin, it is still listed as a species of special concern throughout the state of Minnesota. Other introduced plants and organisms include curly-leaf pondweed, Heterosporis, purple loosestrife, and spiny water flea (*Bythotrephes longimanus*). Streams and lakes near population centers and other heavily used recreational areas are the most vulnerable to aquatic invasive species. No introduced species were encountered during sampling for this assessment.

Some fish species occurred in high densities while others had a more limited distribution and low numbers of individuals. The most ubiquitous fish species within this watershed were the *Luxilus cornutus* (common shiner), *Catostomus commersonii* (white sucker), and *Notemigonus crysoleucas* (golden shiner), which occurred at all of the stations (Appendix 9). The common shiner was one of the most encountered species and was the most abundant fish captured during biological monitoring within this watershed. Numerous other species of fish were encountered at the majority of the stations, including *Semotilus atromaculatus* (creek chub), *Umbra limi* (central mudminnow), *Hybognathus hankiinsoni* (brassy minnow), *Etheostoma nigrum* (johnny darter) and *Ameiurus melas* (black bullhead). Fish that were encountered during sampling consisted of warm-water riverine species, typical of conditions within the watershed.

Certain attributes of the fish community, such as pollution tolerance, trophic (feeding) habits, reproductive traits, habitat preferences, species richness, and life history strategies can provide insight into the quality of the streams in which they inhabit. These attributes not only help in identifying a streams status but also in identifying environmental stressors that may be contributing to aquatic life impairments. Fish species that are known to be intolerant or sensitive to disturbances are almost always a good indication of quality stream habitat, water chemistry, and connectivity. On the contrary, a fish assemblage that is dominated by tolerant species is likely an indication of poor water quality, habitat, and/or other natural or anthropogenic factors. Though most samples had some tolerant fish species, most streams had a robust population of sensitive or intolerant fish. Anthropogenic stressors were few throughout this watershed and resulted in sufficient habitat and water chemistry to support these assemblages. The most frequently captured sensitive species was the pearl dace, which was found at three of the five stations with a total of 602 individuals captured. Overall, the presence of relatively sensitive species and the mixture of tolerant species indicated fair to good water quality.

Macroinvertebrates

Only two stations (40%) were sampled for benthic macroinvertebrates in 2017. Of the 78 unique taxonomic groupings observed within this watershed, approximately 18% of these represent intolerant individuals. The most numerous genus observed were *Stenacron* (mayflies), *Leptophlebia* (mayflies), *Thienemannimyia* (non-biting midges), *Baetis* (mayflies), and *Cheumatopsyche* (net-spinning caddisflies). The macroinvertebrate surveys did not identify species that are considered to be endangered, threatened, or species of special concern. However, many of the specimens collected during these surveys could be representative of species on this list, based on their known range, distribution, and habitat requirements. Many of the macroinvertebrate communities in the RRRL Watershed are representative of good water quality. These catchments should be managed to maintain their good quality.

Watershed-wide condition

Fish and macroinvertebrate communities throughout the RRRL Watershed are in generally good condition. The relatively low amount of anthropogenic stressors within the RRRL Watershed likely contributes to the good quality of its waterways. Most fish and macroinvertebrate IBI scores were near or meeting aquatic life use standards. The spatial variability in habitat, water chemistry, and flow conditions may all play a role in the overall diversity of sensitive and tolerant species. Both habitat and the biological communities are likely strongly influenced by the regions geologic past that includes sediments deposited by an immense glacial lake and a landscape formed by the advance and retreat of glaciers (Figure 7).

Fish contaminant results

Mercury and polychlorinated biphenyls (PCBs) were analyzed in fish tissue samples collected from 14 lakes in the watershed (Table 7). All concentrations of PCBs were less than the reporting limit. Three species in Rainy Lake were tested for PFOS in 2010 and all measurement were less than the reporting limit. Only one lake, Rod Smith Pond, is not on the Impaired Waters List for mercury in fish tissue. It was sampled in 2005 and had a single northern pike, which was above the 0.2 mg/kg water quality standard but did not meet the minimum of five fish for assessment. The rainbow trout collected at the same time were well below the standard (mercury concentration in a composite sample of six trout was 0.027 mg/kg). Rainy Lake has a strong record of fish collections between 1971 and 2015. During that time, Northern Pike and Walleye were sampled 14 years and 12 years, respectively. The mean mercury concentrations in both species remained surprisingly steady throughout the period: long-term means were 0.555 mg/kg and 0.472 mg/kg for the Northern Pike and Walleye.

Table 7. Fish contaminants: summary of fish length, mercury, PCBs, and PFOS by waterway-species-year.

WID	Waterway	Species	Year	Anatomy	Total Fish	Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)		
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max
36-0008-00	MOOSE**	Black crappie	1995	FILSK	10	1	9.9	9.9	9.9	0.200	0.200	0.200							
		Northern pike	1995	FILSK	11	3	26.6	23.5	30.3	0.683	0.640	0.750	1	0.01	0.01	Y			
36-0078-00	ROD SMITH POND	Northern pike	2005	FILSK	1	1	14.0	14.0	14.0	0.242	0.242	0.242	1	0.01	0.01	Y			
		Rainbow trout	2005	FILSK	6	1	10.7	10.7	10.7	0.027	0.027	0.027	1	0.01	0.01	Y			
69-0694-00	RAINY**	Black crappie	1971	PLUG	3	3	11.5	10.0	12.5	0.200	0.160	0.270							
			1995	FILSK	8	1	9.9	9.9	9.9	0.300	0.300	0.300							
			2002	FILSK	2	1	7.9	7.9	7.9	0.173	0.173	0.173							
			2010	FILSK	1	1	7.5	7.5	7.5								1	<4.81	<4.81
			2012	FILSK	5	1	11.3	11.3	11.3	0.211	0.211	0.211							
		Burbot (Eelpout)	2001	FILET	4	1	22.3	22.3	22.3	0.332	0.332	0.332							
		Lake whitefish	2001	FILSK	3	1	19.6	19.6	19.6	0.135	0.135	0.135	1	0.02	0.02	Y			
		Northern pike	1971	PLUG	14	14	22.5	12.1	33.0	0.539	0.110	0.870							
			1974	PLUG	74	74	21.3	16.0	31.0	0.596	0.180	1.830							
			1976	PLUSK	82	82	19.5	11.5	29.4	0.385	0.110	1.380							
			1982	FILSK	4	1	27.8	27.8	27.8	0.720	0.720	0.720	1	0.025	0.025	Y			
			1985	FILSK	48	12	23.9	17.9	31.0	0.638	0.150	0.990							
			1990	FILSK	10	3	26.8	21.8	30.1	0.923	0.600	1.300	3	0.011	0.014				
			1995	FILSK	13	13	24.9	16.9	38.8	0.528	0.057	1.365							
			1996	FILSK	10	10	26.0	18.6	35.0	0.467	0.161	1.406							
			1997	FILSK	8	8	23.0	19.0	28.0	0.448	0.180	0.900	2	0.01	0.01	Y			
			2002	FILSK	5	5	23.2	20.4	26.5	0.592	0.480	0.740							
			2004	FILSK	16	16	22.7	18.9	32.6	0.383	0.193	0.759							
			2006	FILSK	19	19	24.3	17.6	30.1	0.399	0.136	0.752							
			2009	FILSK	13	13	25.3	19.6	34.5	0.625	0.207	1.100							
			2015	FILSK	6	6	23.6	15.9	28.6	0.525	0.281	0.725							
		Sauger	1971	PLUG	20	20	10.8	6.8	15.0	0.541	0.220	1.200							
			1982	FILSK	4	1	14.1	14.1	14.1	0.480	0.480	0.480	1	0.025	0.025	Y			
			1990	FILSK	4	2	14.1	11.4	16.7	1.020	0.640	1.400	2	0.01	0.01	Y			
			1995	FILSK	6	2	13.3	12.6	13.9	0.765	0.710	0.820							
			2001	FILSK	5	5	11.6	10.6	12.1	0.771	0.333	1.184							
			2002	FILSK	5	5	13.7	12.9	15.1	0.628	0.443	0.982							
		Smallmouth bass	1990	FILSK	1	1	13.2	13.2	13.2	0.420	0.420	0.420	1	0.01	0.01	Y			

WID	Waterway	Species	Year	Anatomy	Total Fish	Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)		
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max
			1995	FILSK	2	1	12.8	12.8	12.8	0.250	0.250	0.250							
			2002	FILSK	5	5	10.6	10.0	11.2	0.276	0.208	0.369							
		Walleye	1971	PLUG	56	56	14.7	7.0	22.3	0.406	0.140	1.040							
			1974	PLUG	97	97	14.6	11.0	22.0	0.469	0.210	1.190							
			1976	PLUSK	147	147	15.7	10.0	23.5	0.422	0.130	1.320							
			1982	FILSK	2	1	16.8	16.8	16.8	0.480	0.480	0.480	1	0.025	0.025	Y			
			1985	FILSK	45	9	17.2	13.1	22.1	0.503	0.330	0.820							
			1990	FILSK	23	3	17.8	14.0	22.1	0.643	0.410	1.000	3	0.01	0.01	Y			
			1995	FILSK	19	6	18.8	13.0	27.0	0.533	0.170	1.550	1	0.01	0.01	Y			
			1996	FILSK	5	5	16.0	7.5	23.3	0.356	0.128	0.910							
			1997	FILSK	10	10	15.1	12.3	21.7	0.404	0.190	0.980	2	0.01	0.01	Y			
			2002	FILSK	5	5	17.8	15.1	21.3	0.575	0.315	1.010							
			2010	FILSK	5	5	14.8	10.6	20.9								5	<4.88	<4.95
			2012	FILSK	6	6	16.0	12.1	22.9	0.380	0.197	0.806							
			2015	FILSK	8	8	16.6	11.2	23.8	0.495	0.187	1.244							
		White sucker	1982	FILSK	4	1	17.1	17.1	17.1	0.150	0.150	0.150	1	0.025	0.025	1			
			1995	FILSK	5	1	18.1	18.1	18.1	0.160	0.160	0.160							
		Yellow perch	1995	FILSK	9	1	8.5	8.5	8.5	0.150	0.150	0.150							
			1997	FILSK	6	1	9.7	9.7	9.7	0.300	0.300	0.300							
			2004	WHORG	10	2	6.2	5.8	6.6	0.040	0.035	0.044							
			2006	WHORG	10	4	6.7	6.1	7.5	0.061	0.053	0.065							
			2010	FILSK	5	5	7.9	5.9	10.0								5	<4.68	<4.9
			2015	FILSK	10	1	8.7	8.7	8.7	0.162	0.162	0.162							
69-0833-00	PEARY*	Northern pike	1988	FILSK	10	5	22.1	16.2	27.8	0.440	0.140	0.920							
			2001	FILSK	24	24	19.4	11.7	24.0	0.397	0.234	0.677							
			2018	BIOPSY	9	9	19.9	16.3	24.3	0.414	0.172	0.771							
69-0834-00	FISHMOUTH*	Northern pike	1997	FILSK	4	4	20.3	16.3	22.8	0.419	0.282	0.493							
			2001	FILSK	8	8	19.4	18.3	20.7	0.482	0.326	0.605							
			2009	FILSK	14	14	22.5	15.5	26.0	0.868	0.324	1.194							
69-0835-00	RYAN**	Northern pike	1997	FILSK	8	8	17.6	15.6	19.2	1.513	0.825	2.530							
			1998	FILSK	5	5	18.6	13.0	22.9	1.413	0.454	2.354							
			2001	FILSK	25	25	17.5	15.4	19.7	1.264	0.775	2.413							
			2004	FILSK	18	18	18.1	13.6	20.2	1.073	0.494	1.517							
		Yellow perch	2004	WHORG	1	1	5.9	5.9	5.9	0.122	0.122	0.122							
69-0838-00	OSLO**	Northern pike	1997	FILSK	5	5	22.1	17.5	24.7	1.002	0.439	1.305							
			2010	FILSK	7	7	21.2	17.9	24.2	1.206	0.772	1.591							

WID	Waterway	Species	Year	Anatomy	Total Fish	Samples	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)				PFOS (mg/kg)		
							Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL	N	Mean	Max
69-0839-00	BROWN**	Northern pike	1997	FILSK	5	5	22.9	19.1	31.9	1.023	0.472	2.518							
			2004	FILSK	17	17	21.0	18.5	25.1	0.587	0.284	1.148							
69-0868-00	BOOT**	Muskellunge	1999	FILSK	6	6	24.7	20.8	29.1	1.115	0.380	1.780	1	0.01	0.01	Y			
		Yellow perch	1999	WHORG	6	1	6.2	6.2	6.2	0.150	0.150	0.150							
69-0870-00	SHOEPACK**	Muskellunge	1988	FILSK	1	1	28.1	28.1	28.1	2.200	2.200	2.200	1	0.01	0.01	Y			
			1999	FILSK	19	19	26.3	21.4	29.0	2.171	0.880	3.460	1	0.01	0.01	Y			
		Yellow perch	1999	WHORG	10	10	5.9	5.2	6.6	0.392	0.230	0.710							
69-0871-00	QUILL*	Largemouth bass	2002	FILSK	6	6	11.6	9.1	14.0	0.387	0.294	0.613							
69-0872-00	LOITEN**	Largemouth bass	2001	FILSK	19	19	13.2	10.5	17.9	0.563	0.272	1.389							
		Yellow perch	2001	WHORG	8	1	1.7	1.7	1.7	0.088	0.088	0.088							
69-0936-00	LOCATOR**		2003	WHORG	9					0.045	0.020	0.079							
		Northern pike	1988	FILSK	10	4	22.0	19.3	26.0	0.785	0.620	1.200							
			2000	FILSK	21	21	23.0	17.2	29.6	0.881	0.340	1.540							
			2010	FILSK	15	15	24.0	17.0	31.6	1.353	0.866	2.269							
		Yellow perch	2000	WHORG	1	1	2.2	2.2	2.2	0.080	0.080	0.080							
69-0937-00	WAR CLUB**	Northern pike	1988	FILSK	6	2	20.9	19.1	22.7	0.625	0.560	0.690							
			2000	FILSK	14	14	21.4	15.5	31.1	0.589	0.310	0.990							
		Yellow perch	2000	WHORG	10	10	2.4	2.1	2.9	0.095	0.080	0.120							

* Impaired for mercury in fish tissue as of 2018 Draft Impaired Waters Inventory; categorized as EPA Category 4a for waters covered by the Statewide Mercury TMDL.

** Impaired for mercury in fish tissue as of 2018 Draft Impaired Waters Inventory; categorized as EPA Category 5 for waters needing a TMDL.

1 Anatomy codes: BIOPSY—biopsy plug, skin-off; FILSK – edible fillet, skin-on; FILET—edible fillet, skin-off; WHORG—whole organism.

Pollutant load monitoring

The WPLMN has one subwatershed site within the RRRL Watershed as shown in Table 8. Average annual FWMCs of TSS, TP, and NO_3+NO_2-N for major watershed stations statewide are presented below, with the RRRL Watershed highlighted (Figure 25). 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; this can be expressed in inches.

Table 8. WPLMN stream monitoring site for the RRRL Watershed.

Site Type	Stream Name	USGS ID	DNR/MPCA ID	EQuIS ID
Subwatershed	Rat Root River nr International Falls, CR145	NA	H74033011	S007-612

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 and phosphorus adsorbed to and transported with sediment during runoff.

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

When compared with other major watersheds throughout the state, Figure 25 shows the average annual TSS, TP, and NO_3+NO_2-N FWMCs to be several times lower for the RRRL Watershed than watersheds in the southern and western part of Minnesota, but in line with the forested watersheds found in the northeastern and north central regions of the state.

Substantial year-to-year variability in water quality occurs for most rivers and streams, including the Rat Root River. Results for individual years are shown in the charts below (Figure 26). More information can be found at the WPLMN website.

Figure 25. 2007-2016 Average Annual TSS, TP, and NO_3-NO_2-N flow weighted mean concentrations, and runoff by major watershed.

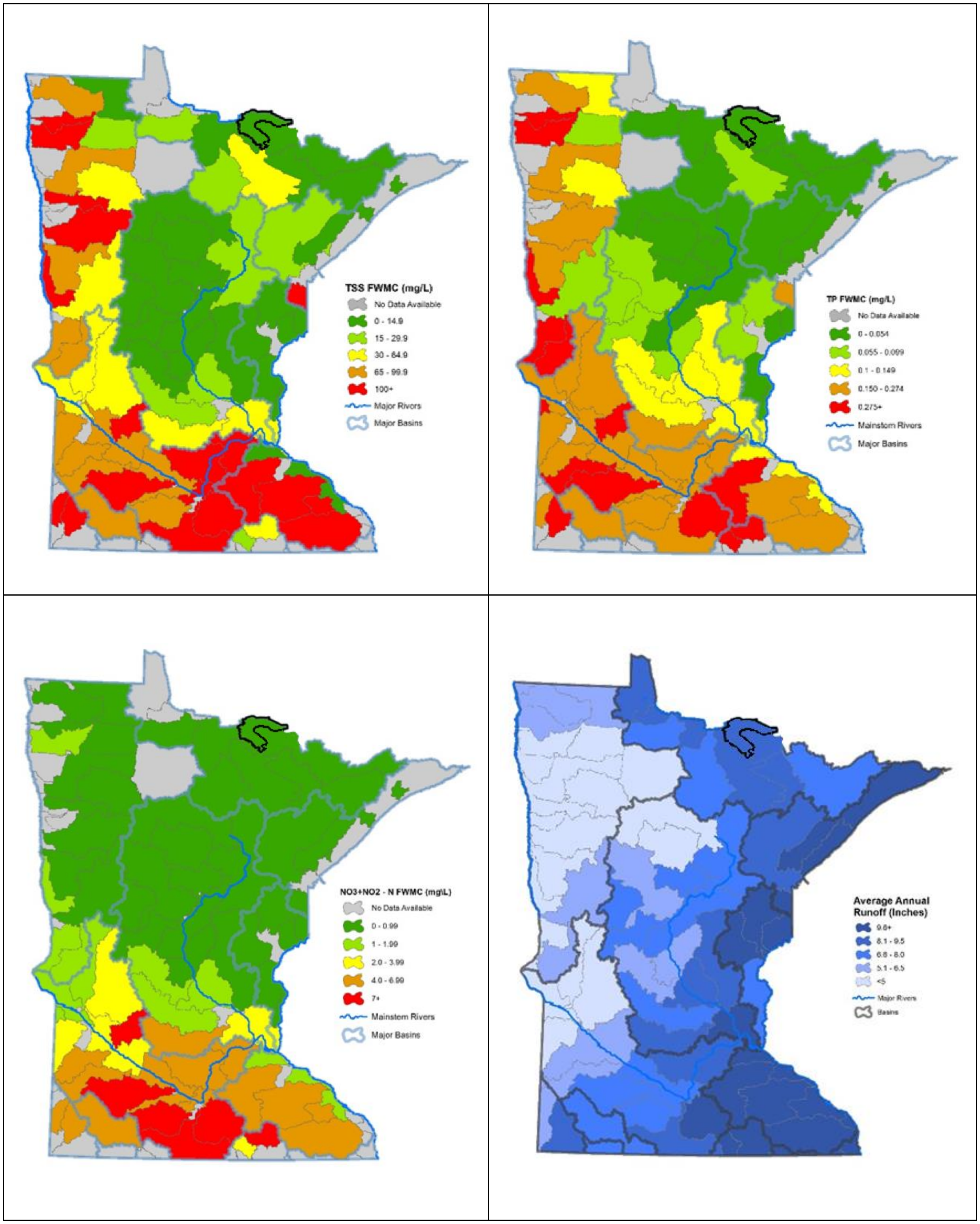
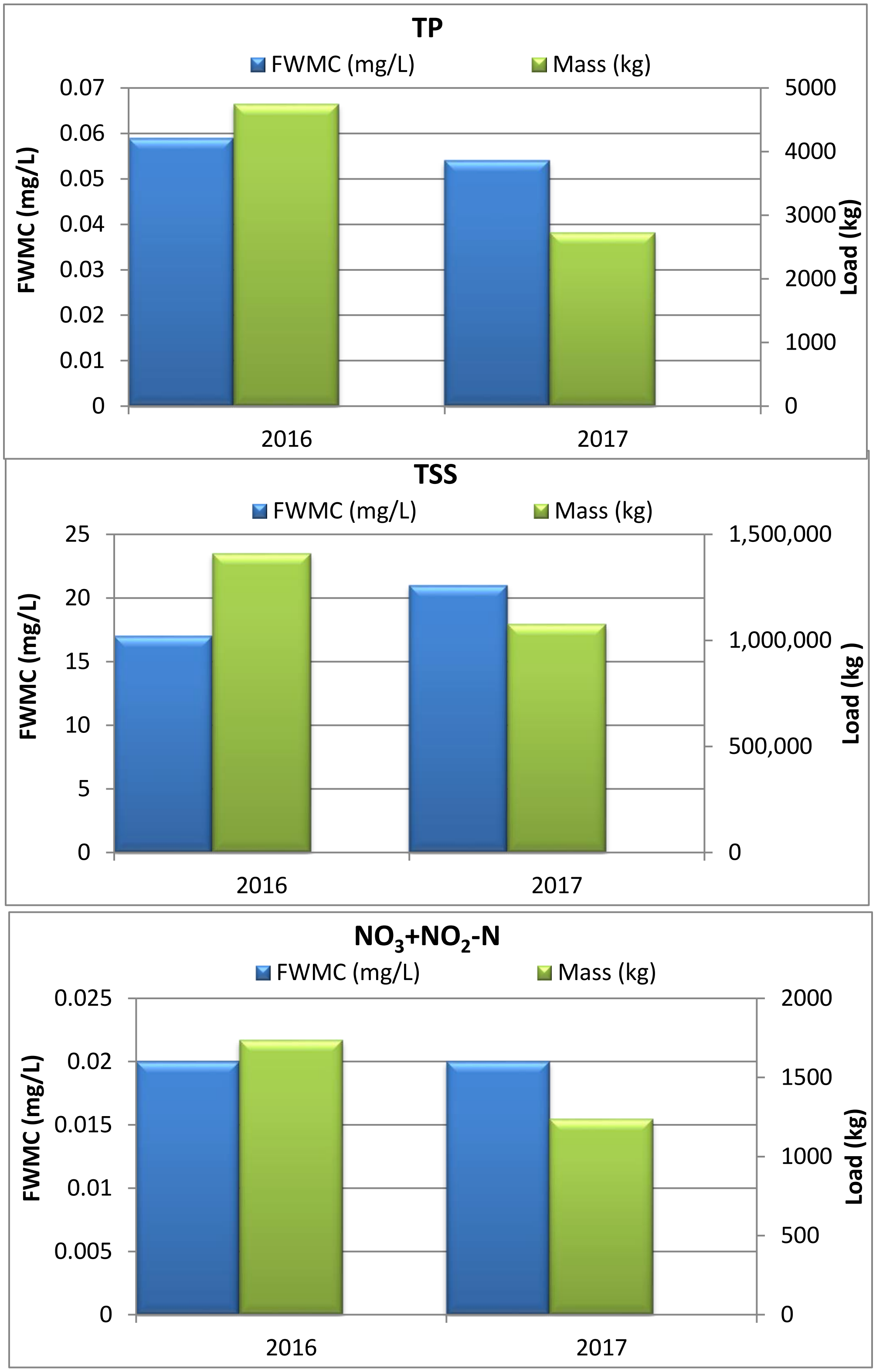


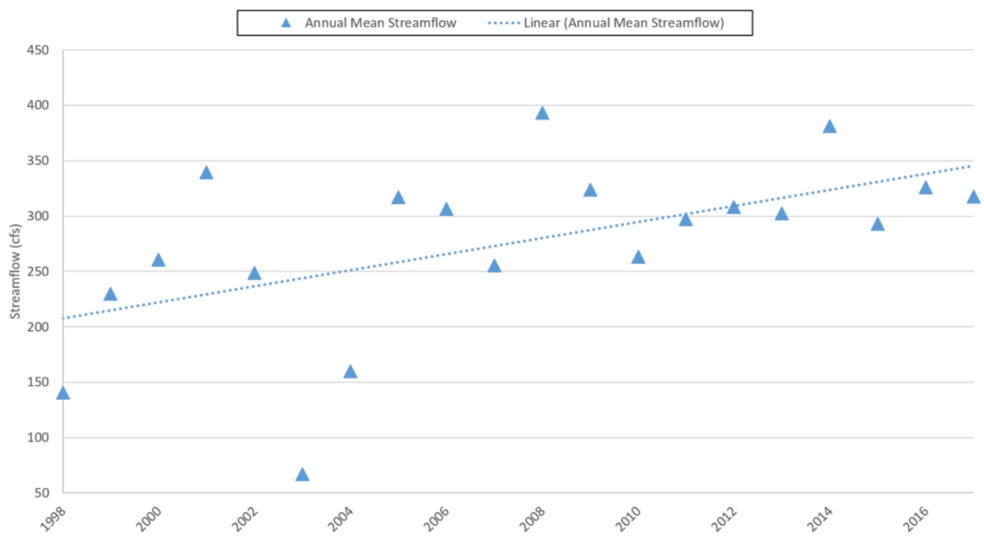
Figure 26. TSS, TP, and NO_3+NO_2-N flow weighted mean concentrations and loads for the Rat Root River near International Falls, CR145.

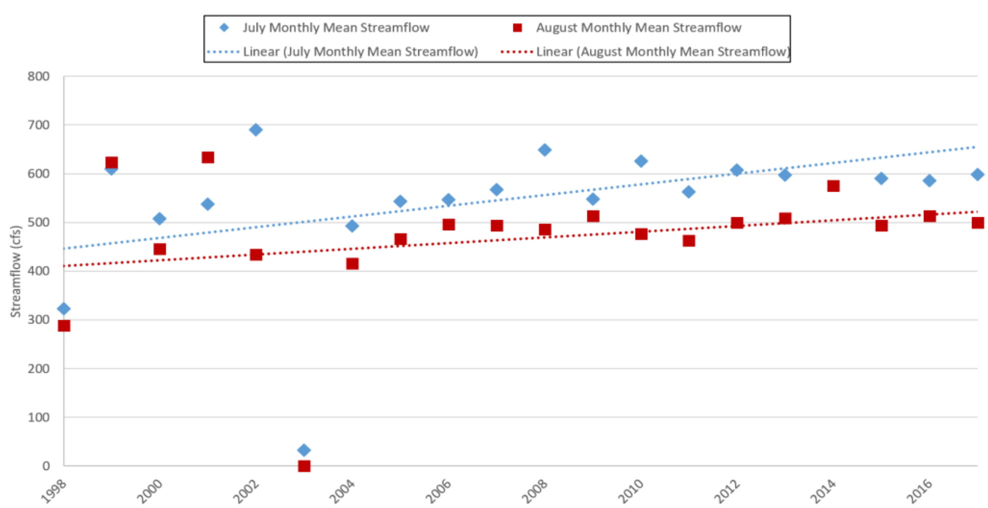


Stream flow

Stream flow data from the United States Geological Survey's real-time streamflow gaging stations for one river in the RRRL Watershed was analyzed for annual mean and summer monthly mean discharge (July and August). Figure 27 (*top*) is a display of the annual mean discharge for the Gold Portage Outlet from Kavetogama Lake near Ray, MN from water years 1998 to 2017. The data shows that streamflow appears to be increasing over time ($p<0.05$). Figure 27 displays July and August mean flows for the same time frame, for the same water body. Graphically, the data also appears to be slightly increasing in July and August ($p<0.05$ and $p<0.1$, respectively). 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 27. Annual mean (top) and monthly mean (bottom) streamflow for the Gold Portage Outlet from Kabetogama Lake near Ray, MN (1998-2017) (USGS 2020).





Wetland condition

Wetland vegetation quality is generally high in Minnesota (Bourdaghs et al 2019). This is driven by the large share of wetlands located in Minnesota's northern forest ecoregion where development and resulting wetland quality impacts are much less widespread compared to the rest of the state. Wetlands that are in exceptional or good condition have had few (if any) measurable changes in their expected native species composition or abundance distribution. Wetland vegetation quality is largely degraded outside of northern Minnesota, where non-native plant species (most notably Reed canary grass and Narrow leaf or Hybrid cattail) have replaced native wetland plant communities over the majority of the remaining wetlands (Bourdaghs et al 2019).

As the entire RRRL Watershed lies within Minnesota's northern forest ecoregion, wetland vegetation quality in the watershed is expected to be high overall. An estimated 74% of the wetlands in the ecoregion are in good to exceptional vegetation condition (Bourdaghs et al 2019). Wetland quality impacts in the watershed are likely localized. Primary impacts to wetland vegetation quality include hydrology alterations associated with peatland ditch networks and roadbeds and logging impacts in coniferous swamps.

Figure 28. Stream tiered aquatic life use designations in the RRRL Watershed.

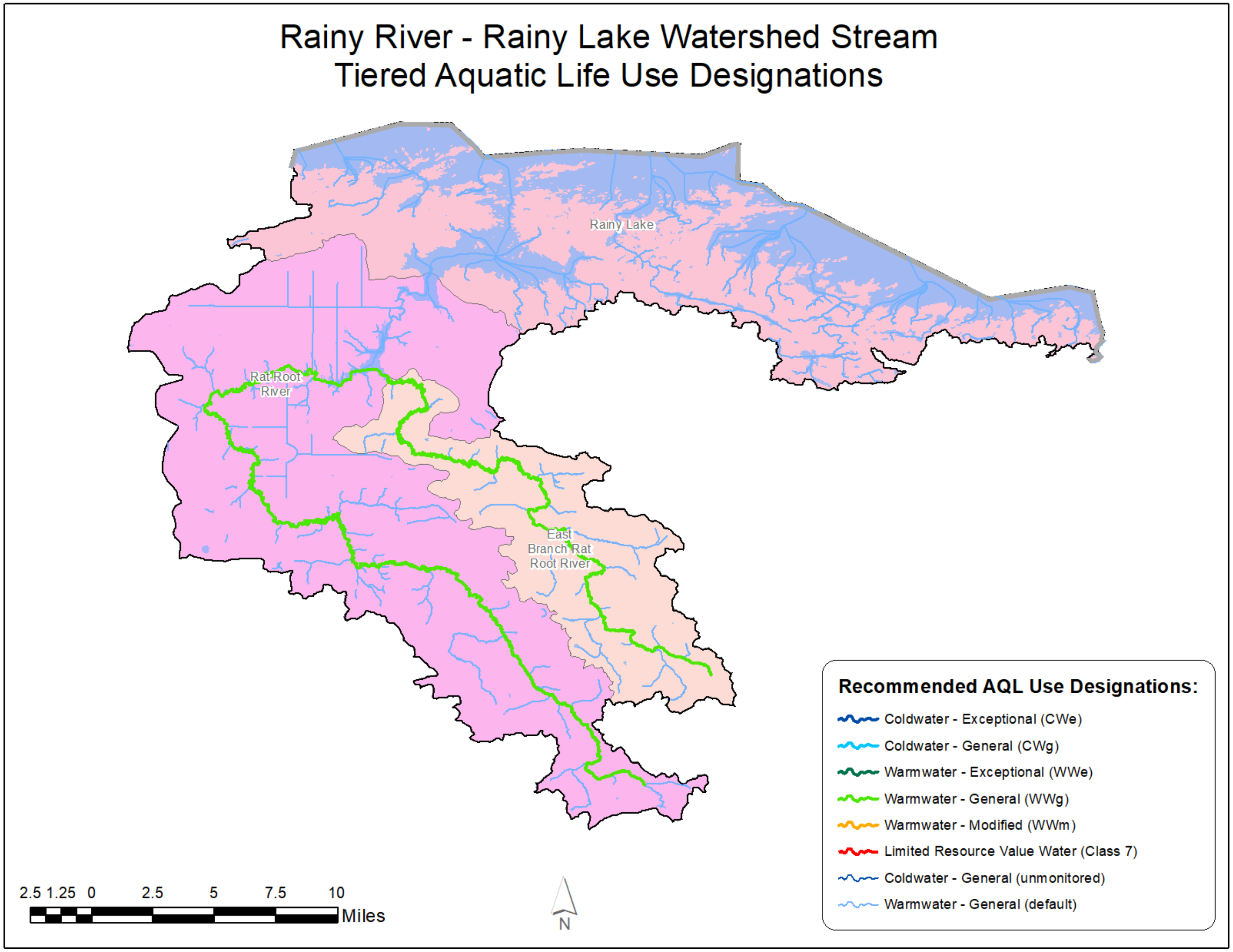


Figure 29. Fully supporting waters by designated use in the RRRL Watershed.

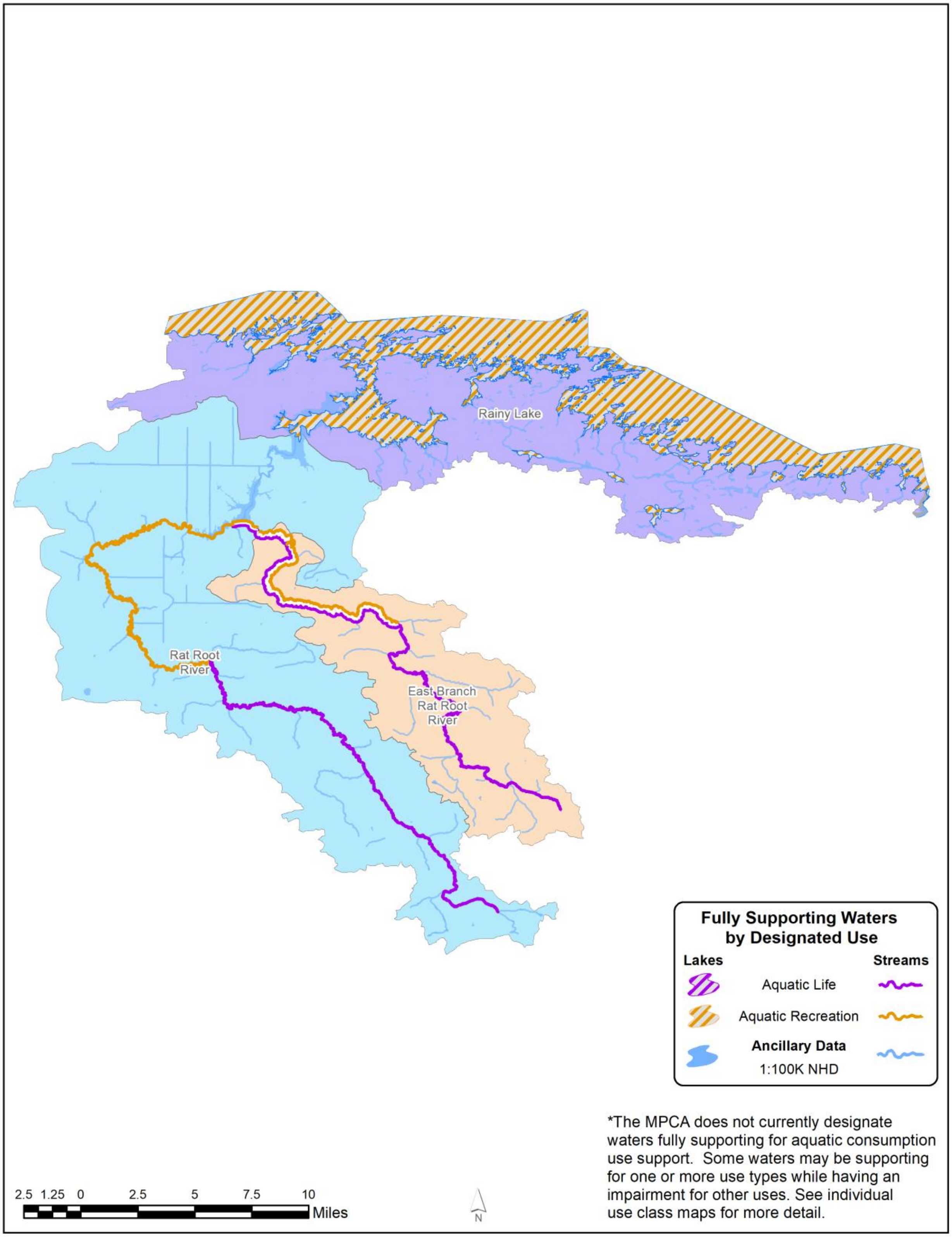


Figure 30. Impaired waters by designated use in the RRRL Watershed.

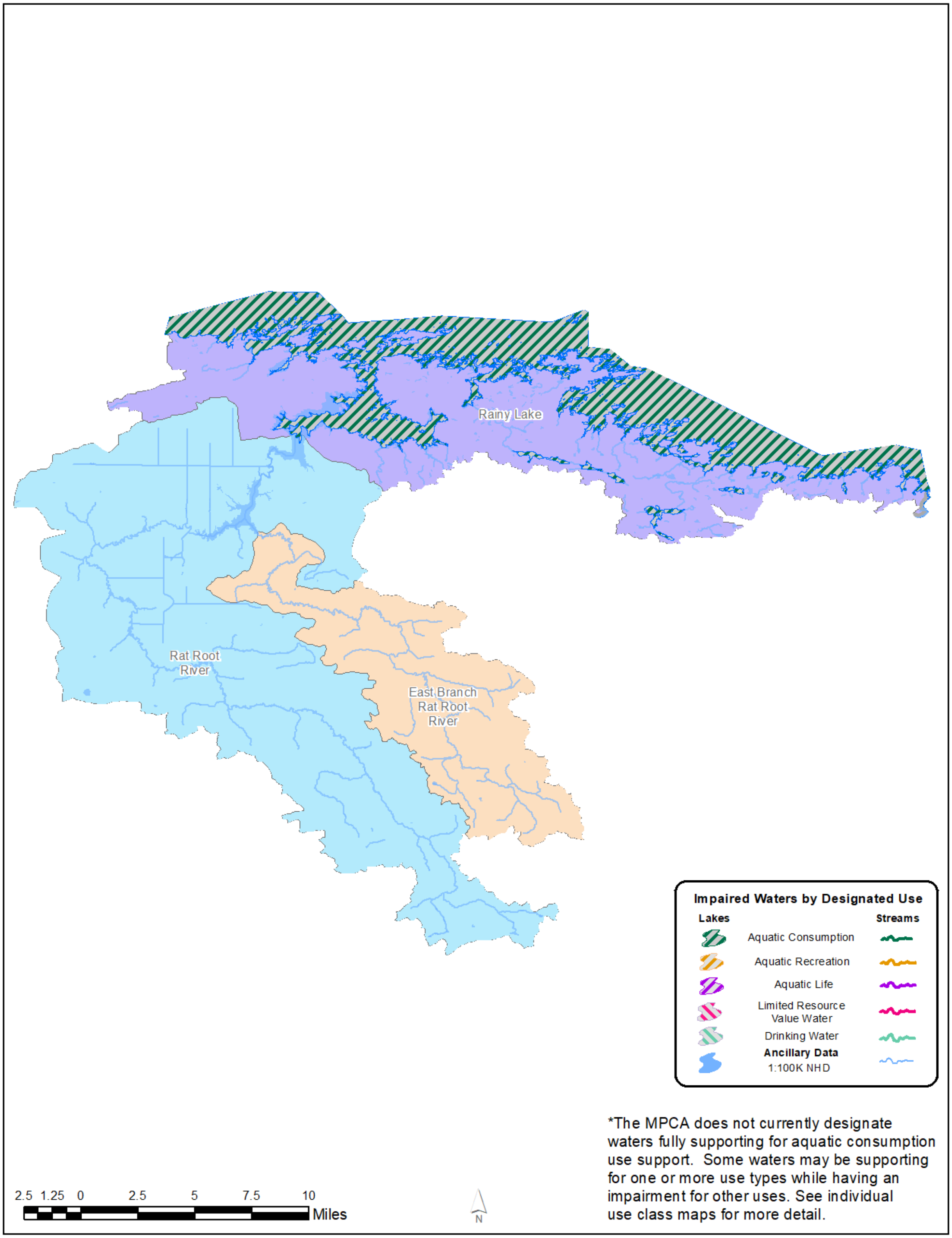


Figure 31. Aquatic consumption use support in the RRRL Watershed.

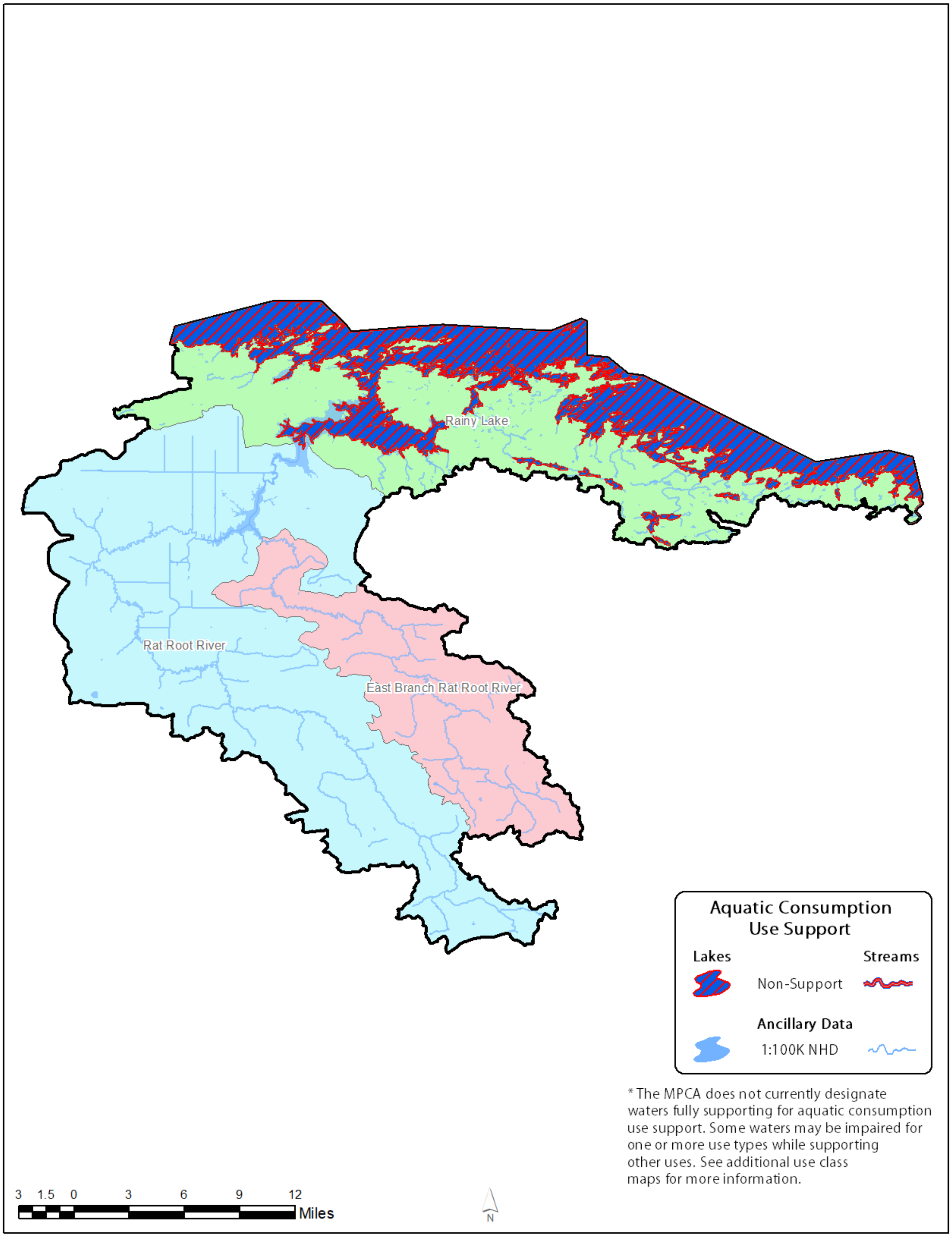


Figure 32. Aquatic life use support in the RRRL Watershed.

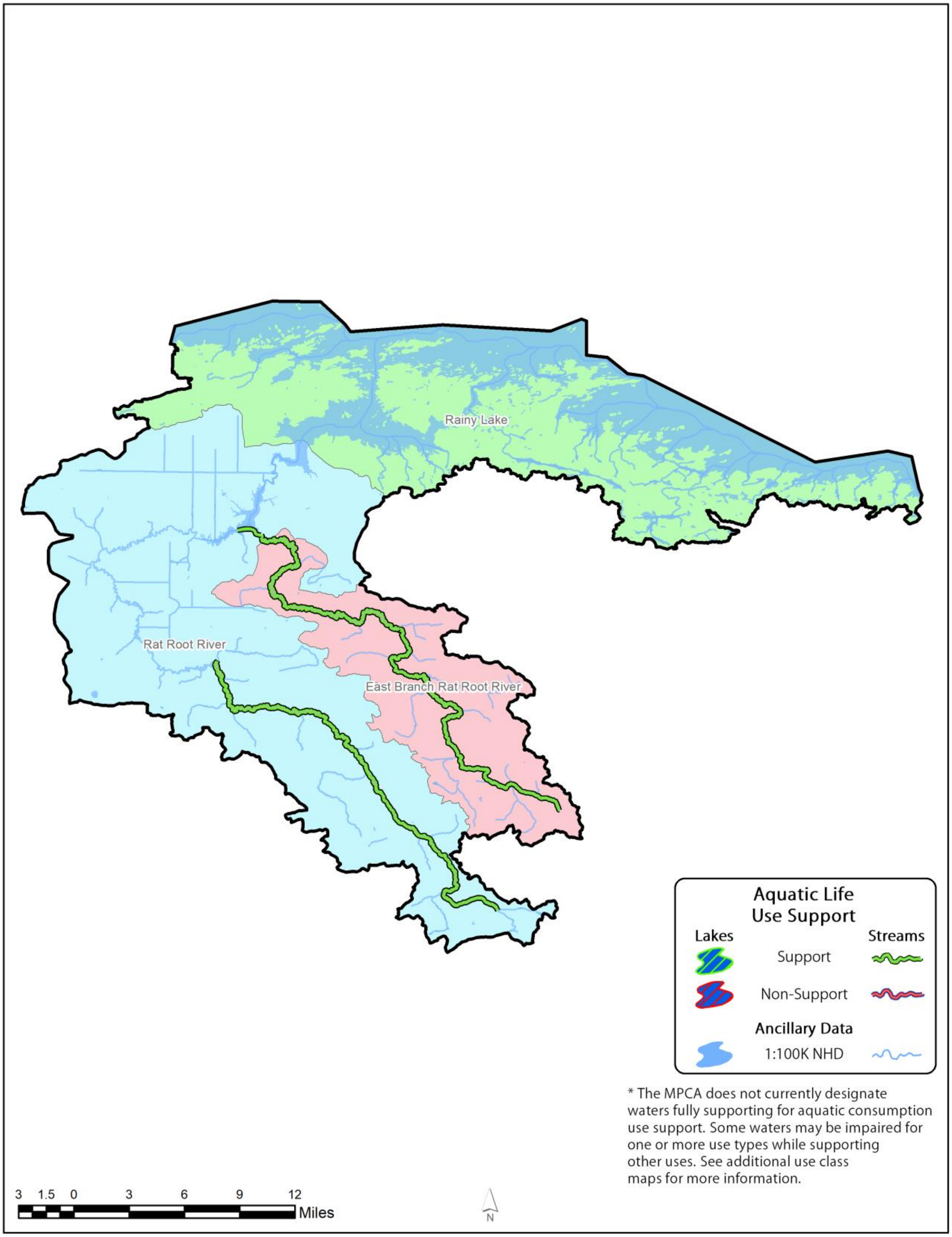
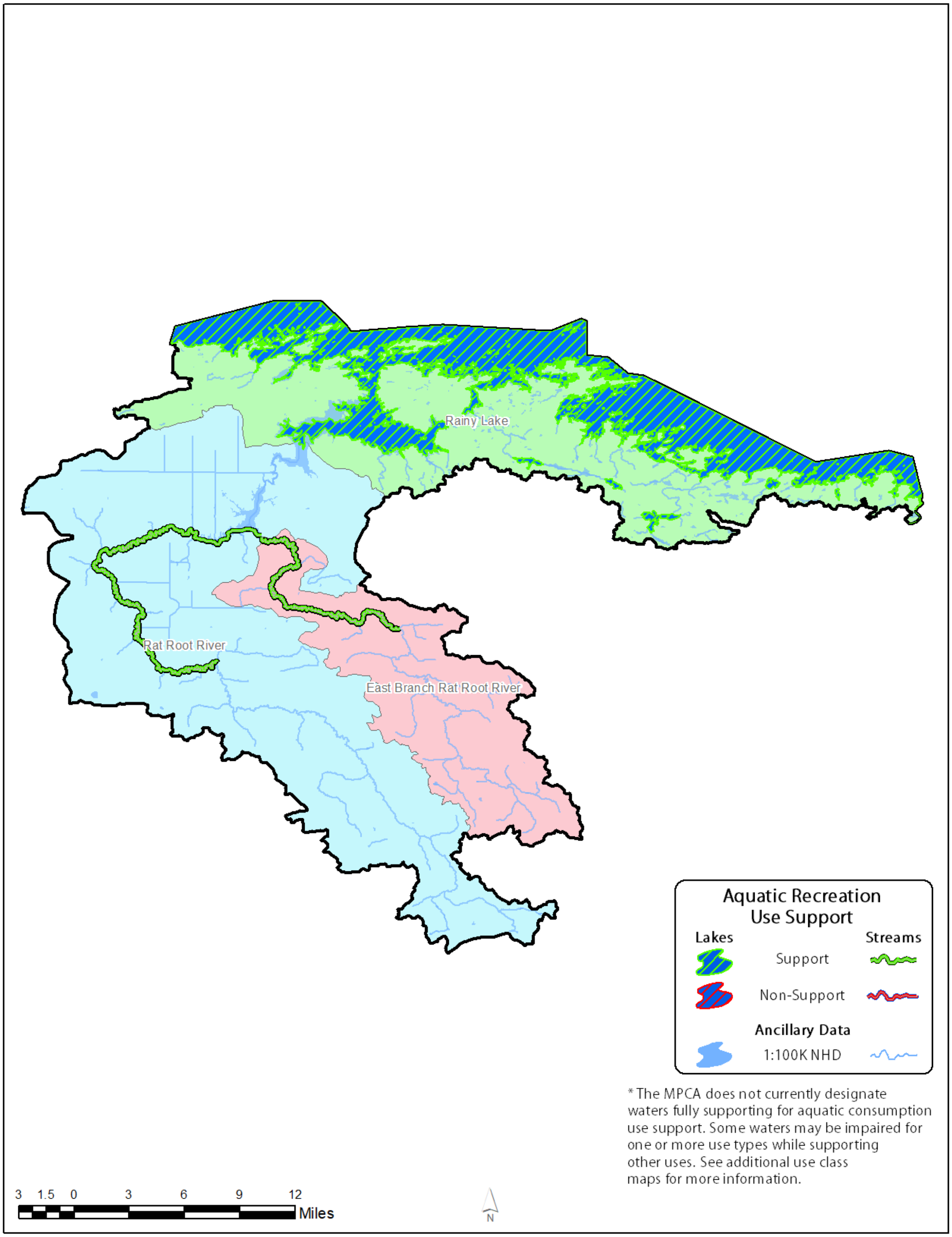


Figure 33. Aquatic recreation use support in the RRRL Watershed.



Transparency trends for the Rainy River – Rainy Lake Watershed

MPCA completes annual trend analysis on lakes and streams across the state based on long-term transparency measurements (Table 9). 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.

Citizen volunteer monitoring occurs at Rainy Lake in this watershed. Water clarity shows no trend based on this historical dataset. Larger transparency datasets available for the Rat Root River and East Branch Rat Root River show no trend in water clarity change over time.

Table 9. Water clarity trends.

Rainy River - Rainy Lake HUC 09030003	Streams	Lakes
Number of sites w/increasing trend	0	0
Number of sites w/decreasing trend	0	0
Number of sites w/no trend	2	1

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

Priority waters for protection and restoration in the Rainy River – Rainy Lake Watershed

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

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

The results for selected indicators and the risk priority ranking for each lake are shown in Appendix 11. Protection priority should be given to lakes that are particularly sensitive to an increase in phosphorus with a documented decline in water quality (measured by Secchi transparency), a comparatively high percentage of developed land use in the area, or monitored phosphorus concentrations close to the water quality standard. In the RRRL Watershed, lakes fall into the same category due to the uniformity of undisturbed land use and existing good water quality. All of these lakes are currently meeting water quality standards. Notably, the large size of Rainy Lake translates to a 5% load reduction goal that would be a significant achievement. This could be viewed as further evidence that preventing degradation of water quality through proactive protection practices will prevent a long term decrease in water quality towards future impairment.

Summaries and recommendations

The Rainy River – Rainy Lake (RRRL) Watershed lies along the Canadian border in Northern Minnesota, with over 93% of the watershed in Canada. The focal point of this watershed is Rainy Lake, which is Minnesota's 3rd largest lake, and is best known for its world class fishery, rocky outcroppings, and being the headwaters of the Rainy River. This entire watershed, including much of northern Minnesota, is comprised of interconnected waterways and vast forests. Recreational opportunities are abundant throughout this forested landscape with its streams and lakes as major focal points. This scenic watershed is less than 30% privately owned leaving the majority of the land undeveloped and open to the public (USGS 2008). The undeveloped nature of this watershed is undoubtedly a key reason for the high water quality found in the majority of the RRRL Watershed.

All of the assessed stream reaches met the goals that have been established for both fish and macroinvertebrates. At times, fish and macroinvertebrate IBI scores were significantly better than the biological impairment thresholds (Appendix 6 and Appendix 7). While the fish and macroinvertebrates met their respective goals, total suspended solids (TSS) and dissolved oxygen (DO) at times exceeded state standards. Water chemistry standard exceedances can negatively influence biological composition, diversity, and overall health. In the RRRL watershed, fish and macroinvertebrate communities still meet state standards, although barely so in some cases. The chemistry exceedances may be due at least in part to the natural characteristics of the upstream drainage. Fine sediments deposited by GLA tend to be more erosive and readily suspend in flowing water. Low DO concentrations are often seen in streams like those in the RRRL watershed that are heavily influenced by wetlands and the "backwater" effect from downstream damming. Overall, the health of aquatic life in the RRRL watershed appears to be good despite some chemistry indicators suggesting potential stressor influence (Figure 32). The Watershed Restoration and Protection Strategy should focus on preventing an increase in anthropogenic stressors, such as forest cover change, drainage of wetlands, and other development that may increase the negative influence of these stressors.

Stream habitat, as indicated by the Minnesota Stream Habitat Assessment (MSHA) scores, ranged from poor to fair. Land use and riparian area scores were generally high due to the lack of watershed development but in-stream habitat did not fare as well. Most scores for substrate, fish cover, and channel morphology were below the fiftieth percentile. Fish cover tended to be higher in the low gradient headwater reaches where there was usually more diverse habitat available. In some cases, high quality in-stream habitat may mitigate the negative consequences of other stressors.

The good water quality of lakes in the RRRL Watershed reflect a region dominated by forests and wetlands, a region mostly untouched by urban or agricultural land uses. Overall, recreational lake quality is good (Figure 33). Local monitoring programs provided valuable data on water clarity in the remote lake basins in the northeastern portion of the watershed. The data collected by our partners will be key to tracking long-term changes in lake quality as northern Minnesota's environment and climate continues to evolve. Rainy Lake, one of the gems of northern Minnesota, has a good historical record of water clarity dating back to the late 1970's indicating good conditions for aquatic recreation. The water quality of Rainy Lake is important to the Rainy River, which would likely follow suit if water quality in the lake begins to diminish. The importance of Rainy Lake and Rainy River to the regions economy further strengthens the case to protect against future water quality degradation. Local, small scale management practices initiated by lakeshore owners (e.g. avoiding fertilizer application when practical, planting native vegetation, bank stabilization, controlling leaf and lawn clippings) may seem small on an individual basis but when broadly implemented across an entire lake shed can be a very effective protection strategy.

Groundwater protection should be considered for both quantity and quality. Quantity is based on the amount of water withdrawn versus the amount of water being recharged to the aquifer. Surface water levels have decreased significantly in the last 20 years ($p<0.001$), possibly in part due to the lack of groundwater availability. The average potential groundwater recharge rate is above the state average and streamflow has been increasing. While fluctuations due to seasonal variations are normal, long term changes in water levels are important to recognize. Data on groundwater quality was limited for this watershed. Regional water quality data indicated that the Northeast region is overall good, with any detections of chemicals in aquifers due to natural geological processes, including exceedances to the arsenic MCL. The majority of the watershed is comprised of exposed bedrock, open water and peatlands. Areas not in these categories had moderate to very low pollution sensitivity ratings of the near surface materials. While it may appear that this watershed does not exhibit a great risk for groundwater contamination, it is important to continue to monitor potentially harmful sites in order to inhibit possible water pollution. Additional and continued monitoring will increase the understanding of the health of the watershed and its groundwater resources. Adoption of best management practices will benefit both surface and groundwater.

Overall, lakes and streams within the RRRL Watershed have benefited from little developmental pressure (Figure 29 & Figure 30). However, these systems are highly sensitivity to anthropogenic stressors like most waterbodies in northern Minnesota. A continued vigilance is necessary to monitor areas where developmental pressures are occurring or where they are expected to occur. Stream instability and mass wasting is likely the result of soil types found within the Rat Root River corridor where GLA deposited clay and clayey silts. Sources of the sediment and turbidity are numerous, and are a function of the watershed's geological setting, the river's geomorphology and current/historical land use practices. Water quality is impacted by the high sediment load in the form of excessive turbidity. The fine sediments are ultimately deposited into the slower, low gradient portions of streams in the Rat Root River drainage, Rat Root Lake, and Rainy Lake. Aquatic consumption impairments, caused primarily by atmospheric deposition of mercury from the global burning of fossils fuels, are one of the widest spread impairments found in this watershed (Figure 31). Natural vegetative buffers along shorelines, a key protection strategy to maintain high quality lakes, should be encouraged to prevent overland runoff and reduce erosion potential.

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Appendix 1 – Water chemistry definitions

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

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

Nitrate plus Nitrite – Nitrogen (NO_3+$N0_2$-N) – 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 (NO_3+NO_2-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 (OP) – Orthophosphate is a water soluble form of phosphorus that is readily available to algae (bioavailable). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from wastewater treatment plants, noncompliant septic systems and fertilizers in urban and agricultural runoff.

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

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

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

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

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

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

Appendix 2 - Intensive watershed monitoring water chemistry stations in the Rainy River – Rainy Lake Watershed

EQuIS ID	Biological station ID	WID	Waterbody Name	Location	Aggregated 12-digit HUC
S009-293	17RN001	09030003-635	Rat Root River	Upstream of Hwy 53, 1.5 mi. NW of Ericsburg	0903000318-01
S009-450	17RN006	09030003-633	Rat Root River, East Branch	Upstream of CSAH 3, 2 mi. N of Ray	0903000318-02

Appendix 3 - Intensive watershed monitoring biological monitoring stations in the Rainy River – Rainy Lake Watershed

WID	Biological Station ID	Waterbody name	Biological station location	County	Aggregated 12-digit HUC
09030003-635	17RN001	Rat Root River	Upstream of Hwy 53, 1.5 mi. NW of Ericsburg	Koochiching	0903000318-01
09030003-634	17RN003	Rat Root River	End of FR 174 (Old Hwy 217), 4.5 mi. W of Ray	Koochiching	0903000318-01
09030003-634	17RN004	Rat Root River	Upstream of FR 161, 3.5 mi. S of Ray	Koochiching	0903000318-01
09030003-633	17RN006	Rat Root River, East Branch	Upstream of CSAH 3, 2 mi. N of Ray	Koochiching	0903000318-02
09030003-632	17RN007	Rat Root River, East Branch	Upstream of unnamed FR, 4.5 mi. NW of Arbutus	Saint Louis	0903000318-02

Appendix 4 - Other biological monitoring stations in the Rainy River – Rainy Lake Watershed

WID	Biological Station ID	Waterbody name	Biological station location	County	Aggregated 12-digit HUC
09030003-635	05RN186	Rat Root River	2 miles upstream of CSAH 217, 11 mi. E of Littlefork	Koochiching	0903000318-01

Appendix 5 – Minnesota statewide index of biological integrity (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	71	49	NA	±11
2	Southern Streams	2B	66	50	35	±9
3	Southern Headwaters	2B	74	55	33	±7
10	Southern Coldwater	2A	82	50	NA	±9
4	Northern Rivers	2B	67	38	NA	±9
5	Northern Streams	2B	61	47	35	±9
6	Northern Headwaters	2B	68	42	23	±16
7	Low Gradient	2B	70	42	15	±10
11	Northern Coldwater	2A	60	35	NA	±10
Invertebrates						
1	Northern Forest Rivers	2B	77	49	NA	±10.8
2	Prairie Forest Rivers	2B	63	31	NA	±10.8
3	Northern Forest Streams RR	2B	82	53	NA	±12.6
4	Northern Forest Streams GP	2B	76	51	37	±13.6
5	Southern Streams RR	2B	62	37	24	±12.6
6	Southern Forest Streams GP	2B	66	43	30	±13.6
7	Prairie Streams GP	2B	69	41	22	±13.6
8	Northern Coldwater	2A	52	32	NA	±12.4
9	Southern Coldwater	2A	72	43	NA	±13.8

Appendix 6 - Biological monitoring results - fish IBI

National Hydrography Dataset (NHD) Assessment Segment WID	Biological Station ID	Stream Segment Name	Drainage Area (mi^2)	Fish Class	Threshold	FIBI	Visit Date
HUC 12: 0903000318-01 (Rat Root River)							
09030003-635	17RN001	Rat Root River	145.2	Northern Streams	47	69.6	8/22/2017
09030003-635	05RN186	Rat Root River	87.1	Northern Streams	47	36.1	8/1/2006
09030003-634	17RN003	Rat Root River	73.0	Northern Streams	47	40.8	7/25/2017
09030003-634	17RN004	Rat Root River	49.0	Low Gradient	42	76.9	7/24/2017
HUC 12: 0903000318-02 (Rat Root River, East Branch)							
09030003-633	17RN006	Rat Root River, East Branch	63.1	Northern Streams	47	58.6	8/23/2017
09030003-633	17RN006	Rat Root River, East Branch	63.1	Northern Streams	47	57.5	7/25/2017
09030003-632	17RN007	Rat Root River, East Branch	20.8	Low Gradient	42	79.8	7/25/2014

Appendix 7 - Biological monitoring results - macroinvertebrate IBI

National Hydrography Dataset (NHD) Assessment Segment WID	Biological Station ID	Stream Segment Name	Drainage Area (mi^2)	Invert Class	Threshold	MIBI	Visit Date
HUC 12: 0903000318-01 (Rat Root River)							
09030003-635	05RN186	Rat Root River	87.1	Northern Forest Streams GP	51	30.3	8/15/2006
09030003-634	17RN003	Rat Root River	73.0	Northern Forest Streams GP	51	50.2	9/7/2017
HUC 12: 0903000318-02 (Rat Root River, East Branch)							
09030003-633	17RN006	Rat Root River, East Branch	63.1	Northern Forest Streams RR	53	54.6	9/7/2017

Appendix 8 – Fish species found during biological monitoring

Common Name	Scientific Name	Quantity of stations where present	Quantity of individuals collected
common shiner	*Luxilus cornutus*	6	1071
creek chub	*Semotilus atromaculatus*	5	746
northern redbelly dace	*Phoxinus eos*	2	622
pearl dace	*Margariscus margarita*	3	602
central mudminnow	*Umbra limi*	5	565
white sucker	*Catostomus commersonii*	6	404
brassy minnow	*Hybognathus hankinsoni*	4	191
johnny darter	*Etheostoma nigrum*	4	179
fathead minnow	*Pimephales promelas*	3	121
finescale dace	*Phoxinus neogaeus*	1	113
brook stickleback	*Culaea inconstans*	3	96
golden shiner	*Notemigonus crysoleucas*	6	82
blacknose dace	*Rhinichthys atratulus*	1	35
yellow perch	*Perca flavescens*	1	34
black crappie	*Pomoxis nigromaculatus*	1	22
black bullhead	*Ameiurus melas*	4	17
logperch	*Percina caprodes*	3	16
iowa darter	*Etheostoma exile*	3	7
trout-perch	*Percopsis omiscomaycus*	3	5
blacknose shiner	*Notropis heterolepis*	1	5
spottail shiner	*Notropis hudsonius*	1	5
northern pike	*Esox lucius*	2	4
shorthead redhorse	*Moxostoma macrolepidotum*	2	2
mimic shiner	*Notropis volucellus*	1	1
walleye	*Sander vitreus*	1	1

Appendix 9 – Macroinvertebrate species found during biological monitoring

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Acari	1	1
Acerpenna	1	2
Acerpenna pygmaea	1	22
Acroneuria	1	3
Aeshna	1	1
Amnicola	1	1
Aquarius	1	1
Atrichopogon	1	4
Aulodrilus	1	1
Baetis	1	21
Baetis brunneicolor	1	1
Baetis intercalaris	2	44
Boyeria	1	1
Boyeria vinosa	2	4
Caenidae	1	1
Caenis	1	4
Caenis diminuta	2	25
Ceratopogoninae	1	1
Cheumatopsyche	1	56
Chironomini	2	5
Chironomus	1	1
Corixidae	1	3
Corynoneura	1	1
Cricotopus	1	8
Dicranota	1	1
Dicrotendipes	1	1
Dubiraphia	2	3
Ephydridae	1	1
Eurylophella	3	4
Gomphidae	1	1
Hemerodromia	1	12
Heptageniidae	1	1
Hexagenia	1	2
Hyalella	1	5
Hydraena	1	2
Hydropsyche betteni	1	15
Hydropsychidae	2	4
Labrundinia	1	1
Lepidostoma	1	1

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Leptophlebiidae	3	162
Libellulidae	1	1
Limnephilidae	1	1
Lymnaeidae	1	1
Mallochohelea	1	1
Micrasema rusticum	1	2
Microtendipes	2	27
Natarsia	2	1
Nyctiophylax	1	7
Oligochaeta	1	11
Optioservus	2	5
Orthocladiinae	1	1
Orthocladius	1	2
Orthocladius (Symposiocladius)	1	1
Parakiefferiella	2	43
Paraleptophlebia	1	1
Phaenopsectra	1	1
Pisidiidae	1	2
Polycentropodidae	1	1
Polypedilum	3	35
Procloeon	2	3
Pycnopsyche	1	1
Rheotanytarsus	1	2
Sialis	2	5
Sigara	2	13
Simulium	1	26
Stenacron	3	185
Stenelmis	2	7
Stenochironomus	3	43
Taeniopteryx	1	1
Tanypodinae	2	4
Tanytarsini	1	1
Tanytarsus	2	6
Thienemannimyia Gr.	3	86
Tipula	1	1
Tribelos	2	1
Tubificinae	1	1
Xylotopus par	2	6

Appendix 10 – Minnesota stream habitat assessment results for the Rainy River – Rainy Lake Watershed

Habitat information documented during each fish and macroinvertebrate 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 (MPCA 2017b). Scores for each category, a summation of the total MSHA score, and a narrative habitat condition rating are provided in the tables for each biological monitoring station. Where multiple visits occur at the same station, the scores from each visit have been averaged. The final row in each table displays average MSHA scores and a rating for the aggregated HUC-12 subwatershed.

# Visits	Biological station ID	Reach name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel (0-36)	MSHA Score (0-100)	MSHA Rating
1	17RN001	Rat Root River	4	10.5	18	7	14	53.5	Fair
1	05RN186*	Rat Root River	5	15	5	13	18	56	Fair
2	17RN003	Rat Root River	5	10.25	14.15	5	15	49.4	Fair
2	17RN004	Rat Root River	5	11.5	7.5	9	11.5	44.5	Poor
Average Habitat Results: *Rat Root River Aggregated 12 HUC*			4.75	11.81	11.16	8.5	14.63	50.85	Fair
3	17RN006	Rat Root River, East Branch	5	10.83	17.77	8.67	22	64.27	Fair
1	17RN007	Rat Root River, East Branch	5	11	11	17	14	58	Fair
Average Habitat Results: *Rat Root River, East Branch Aggregated 12 HUC*			5	10.92	14.38	12.84	18	61.14	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)

* = Sampled in 2005

Appendix 11 – Lake protection and prioritization results

Lake ID	Lake Name	Mean TP	Trend	% Disturbed Land Use	5% load reduction goal	Priority
69-0694-00	Rainy	19.2	No evidence of trend	1%	20852	C
69-0833-00	Peary	16.3		0%	7	C
69-0834-00	Fishmouth	5.0		0%	0	C
69-0835-00	Unnamed (Ryan)	8.0		0%	0	C
69-0838-00	Oslo	5.0		0%	1	C
69-0839-00	Brown	5.0		0%	2	C
69-0868-00	Boot	12.7		0%	1	C
69-0870-00	Shoepack	23.3		0%	22	C
69-0871-00	Quill	5.0		0%	2	C
69-0872-00	Loiten	5.0		0%	1	C
69-0936-00	Locator	8.8		0%	6	C
69-0937-00	War Club	5.0		0%	2	C