Redeye River Watershed Monitoring and Assessment Report

Minnesota Pollution Control Agency

May 2014

Authors

MPCA Redeye River Watershed Report Team:
Anthony Dingmann, Dave Christopherson, David Duffey, Lee Engel, Bonnie Finnerty, Mark Gernes, Chuck Johnson, Benjamin Lundeen, Jim McArthur, Bruce Monson, Scott Niemela, Shawn Nelson, Kris Parson

Contributors / acknowledgements

Wadena County Soil and Water Conservation
Otter Tail County coalition of Lake Associations
Minnesota Department of Natural Resources
Minnesota Department of Health
Minnesota Department of Agriculture

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

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

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

Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 | www.pca.state.mn.us | 651-296-6300
Toll free 800-657-3864 | TTY 651-282-5332

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

Document number: wq-ws3-07010107b

List of acronyms

AUID Assessment Unit Identification Determination

CCSI Channel Condition and Stability Index

CD County Ditch

CI Confidence Interval

CLMP Citizen Lake Monitoring Program

CR County Road

CSAH County State Aid Highway

CSMP Citizen Stream Monitoring Program

CWA Clean Water Act

CWLA Clean Water Legacy Act

DOP Dissolved Orthophosphate

E Eutrophic

EQuIS Environmental Quality Information System

EX Exceeds Criteria (Bacteria)

EXP Exceeds Criteria, Potential Impairment

EXS Exceeds Criteria, Potential Severe Impairment

FS Full Support

FWMC Flow Weighted Mean Concentration

H Hypereutrophic

HUC Hydrologic Unit Code

IBI Index of Biotic Integrity

IF Insufficient Information

K Potassium

LRVW Limited Resource Value Water

M Mesotrophic

MCES Metropolitan Council Environmental Services

MDA Minnesota Department of Agriculture

MDH Minnesota Department of Health

MDNR Minnesota Department of Natural Resources

MINLEAP Minnesota Lake Eutrophication Analysis Procedure

MPCA Minnesota Pollution Control Agency

MSHA Minnesota Stream Habitat Assessment

MTS Meets the Standard?

N Nitrogen

Nitrate-N Nitrate Plus Nitrite Nitrogen

NA Not Assessed

NHD National Hydrologic Dataset

NH3 Ammonia

NS Not Supporting

NT No Trend

OP Orthophosphate

P Phosphorous

PCB Poly Chlorinated Biphenyls

PWI Protected Waters Inventory

RNR River Nutrient Region

SWAG Surface Water Assessment Grant

SWCD Soil and Water Conservation District

SWUD State Water Use Database

TALU Tiered Aquatic Life Uses

TKN Total Kjeldahl Nitrogen

TMDL Total Maximum Daily Load

TP Total Phosphorous

TSS Total Suspended Solids

USGS United States Geological Survey

WPLMN Water Pollutant Load Monitoring Network

Contents

List of figures

List of tables

Executive summary

The Redeye River Watershed (07010107) lies within the northwestern to north-central portion of the Upper Mississippi River Basin in central Minnesota. The watershed has 28 stream assessment units (AUIDs) and 73 lakes greater than 10 acres. The recreational value of lakes and streams are assets to the health and wealth of local economies throughout the watershed. Major rivers within the watershed are the Redeye, Leaf, and Wing. Major lakes in the watershed include Wolf, Gourd, and the chain of West, Middle, and East Leaf Lakes.

The Redeye River provides habitat for aquatic life, riparian corridors for wildlife, and recreational opportunities such as fishing, swimming, and canoeing for local communities. Today, 49% of its landscape is utilized for agriculture (crop and rangeland), forests 30%, wetlands 15%, water 2%, and 4% of the land is developed for housing, business and industrial complexes, county roads, and city streets.

In 2011, the Minnesota Pollution Control Agency (MPCA) initiated an intensive watershed monitoring (IWM) effort of the Redeye River Watershed's surface waters. Thirty-nine stream sites were sampled for biology at the outlets of variable sized subwatersheds within the Redeye River Watershed. These locations included the mouth of the Redeye River where it flows into the Leaf River, the outlet of the Leaf River before its confluence with the Crow Wing River, upstream outlets of major tributaries, and the headwaters of smaller streams. As part of this effort, MPCA staff joined with the Wadena County Soil and Water Conservation District and the Otter Tail County Coalition of Lake Associations (COLA) to complete stream and lake water chemistry sampling. In 2013, a holistic approach was taken to assess all of the watershed's surface waterbodies for support or non-support of aquatic life, recreation, and fish consumption, where sufficient data was available. Twenty-four stream segments (i.e. AUIDs) and 14 lakes were assessed in this effort (not all lake and stream AUIDs were able to be assessed due to insufficient data, modified channel condition or their status as limited resources waters).

Throughout the watershed, 14 AUIDs fully support aquatic life and three streams fully support aquatic recreation. Seven AUIDs do not support aquatic life and eight do not support aquatic recreation. Aquatic recreation impairments are due to high bacteria levels. Four AUIDS were not assessed for aquatic life because they were >50% channelized. Channelized reaches are currently not being assessed until new biological standards are developed. Biological quality at channelized streams ranged from poor too good for both fish and macroinvertebrates. Of the 73 lakes greater than 10 acres, 14 were monitored/had enough data to assess and all supported aquatic recreation.

Water resources in the Redeye River Watershed are found in a range of conditions, from very high water quality to significant impairment. The primary resource concerns in the watershed are wind and water soil erosion, surface and groundwater management/quality, and changing land use patterns. Increased development, wetland removal, and increased agriculture have all likely contributed increased sediment and pollutant loadings to surface waters, thus reducing populations of sensitive aquatic species.

Introduction

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

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

This watershed-wide monitoring approach was implemented in the Redeye River Watershed beginning in the summer of 2011 and concluding in summer of 2012. This report provides a summary of all water quality assessment results in the Redeye River Watershed and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring and monitoring conducted by local government units.

I. 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 81 major watersheds (Figure 1). 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 2007) (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

Watershed Pollutant Load Monitoring Network

Funded with appropriations from Minnesota's Clean Water Legacy Fund, the Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term program designed to measure and compare regional differences and long-term trends in water quality among Minnesota's major rivers including the Red, Rainy, St. Croix, Mississippi, and Minnesota, and the outlets of the major tributaries (8 digit HUC scale) draining to these rivers. Since the network's inception in 2007, the WPLMN has adopted a multi-agency monitoring design that combines site specific stream flow data from United States Geological Survey (USGS) and Minnesota Department of Natural Resources (MDNR) flow gaging stations, with water quality data collected by the Metropolitan Council Environmental Services (MCES), local monitoring organizations and Minnesota Pollution Control Agency WPLMN staff to compute annual pollutant loads at 79 river monitoring sites across Minnesota. The network is in the process of being expanded to the subwatershed level, effectively tripling the number of monitoring sites. Intensive water quality sampling occurs year round at all WPLMN sites. Data will also be used to assist with TMDL studies and implementation plans, watershed modeling efforts and watershed research projects.

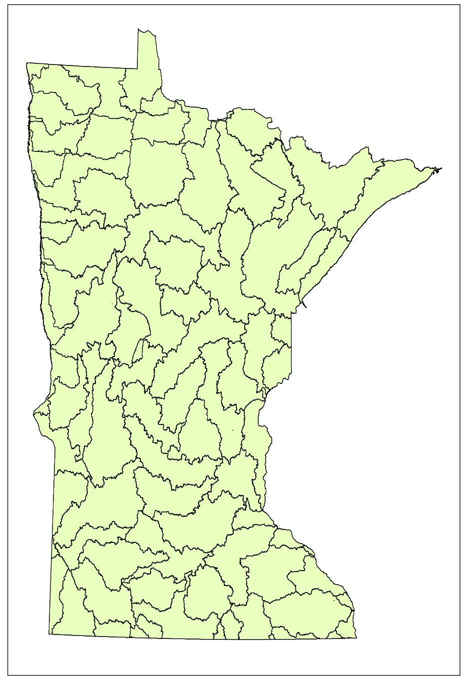

Figure 1. Major watersheds within Minnesota (8-Digit HUC)

Intensive watershed monitoring

The IWM strategy utilizes a nested watershed design allowing the sampling of streams within watersheds from a course to a fine scale. 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 81 major watersheds (HUC-8) 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, HUC-8, HUC-11 and HUC-14 (Figure 2). 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 HUC-8 scale. The outlet of the major HUC-8 watershed (red dot in Figure 3) 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 HUC-11 is the next smallest subwatershed scale which generally consists of major tributary streams with drainage areas ranging from 75 to 150 mi^2. Each HUC-11 outlet (yellow dots in Figure 3) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use support.

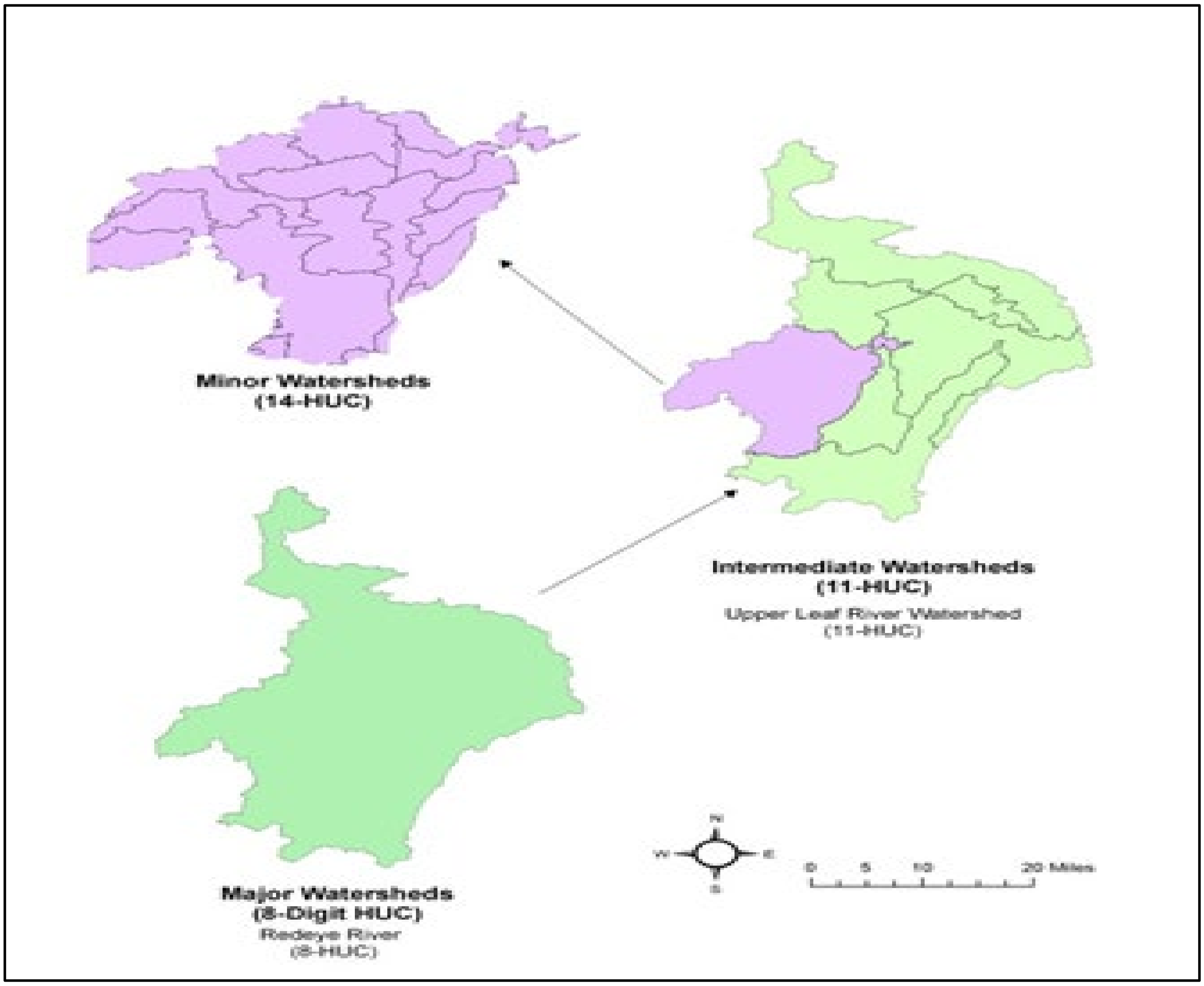

Figure 2. The intensive watershed monitoring design

Within each HUC-11, smaller watersheds (14 HUCs, typically 10-20 mi^2), are sampled at each outlet that flows into the major HUC-11 tributaries. Each of these minor subwatershed outlets is sampled for biology to assess aquatic life use support (green dots in Figure 3).

Within the IWM strategy, lakes are selected to represent the range of conditions and lake type (size and depth) found within the watershed. 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. Lakes are sampled monthly from May-September for a two-year period. There is currently no tool that allows us to determine if lakes are supporting aquatic life; however, a method that includes monitoring fish and aquatic plant communities is in development.

Specific locations for sites sampled as part of the intensive monitoring effort in the Redeye River Watershed are shown in Figure 3 and are listed in Appendix 2 and Appendix 3.2.

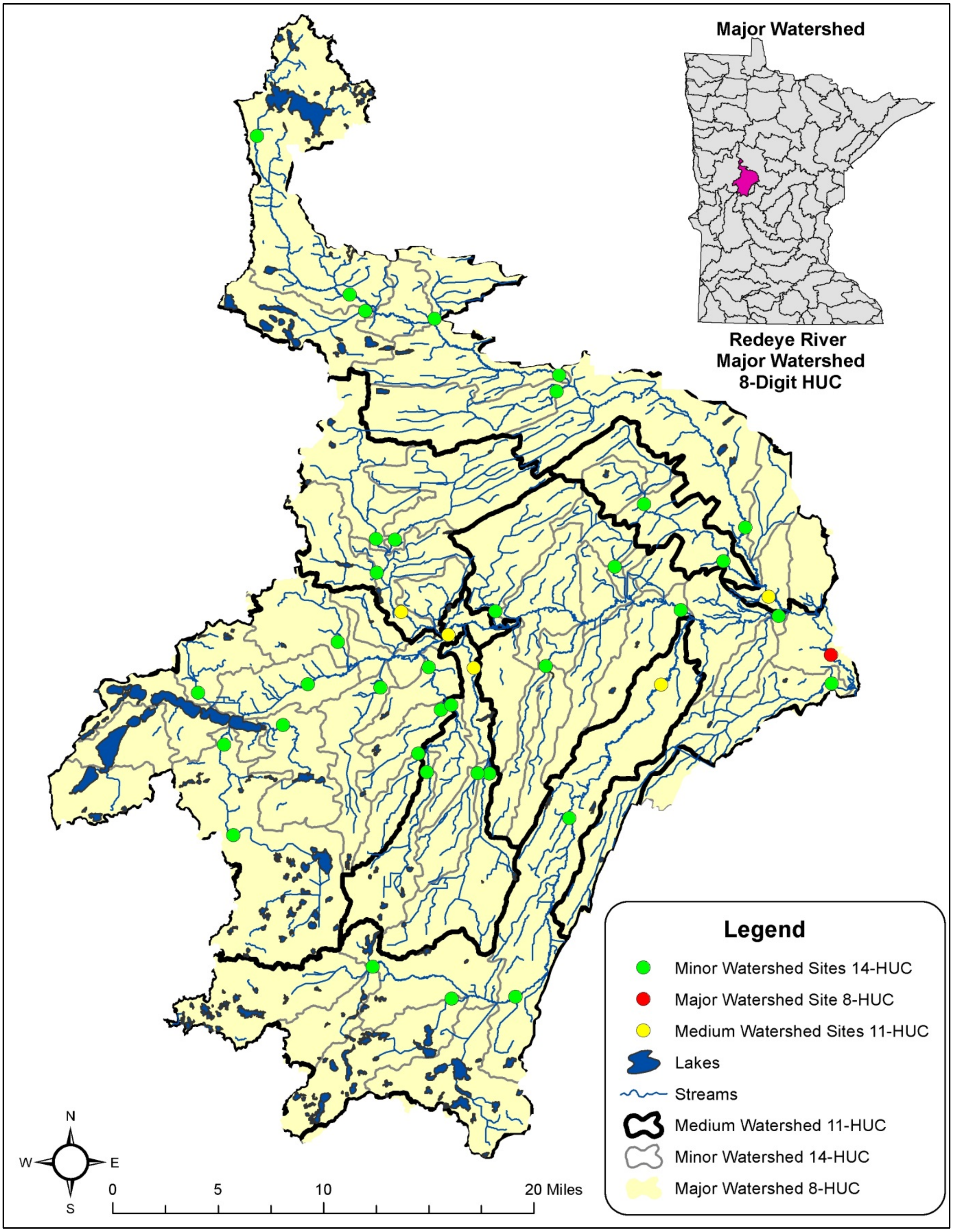

Figure 3. Intensive watershed monitoring sites for streams in the Redeye River Watershed

Citizen and local monitoring

Citizen and local monitoring is an important component of the watershed approach. The MPCA and its local partners jointly select the stream sites and lakes to be included in the IWM process. Funding passes from MPCA through Surface Water Assessment Grants (SWAGs) to local groups such as counties, soil and water conservation districts (SWCD), watershed districts, nonprofits and educational institutions to support lake and stream water chemistry monitoring. MPCA staff joined with the Wadena County SWCD and Water Conservation District and the Otter Tail County Coalition of Lake Associations (COLA) to complete stream and lake water chemistry sampling (locations shown as purple dots in Figure 4). Local partners use the same monitoring protocols as the MPCA, and all monitoring data from SWAG projects are combined with the MPCA's to assess the condition of Minnesota lakes and streams. Preplanning and coordination of sampling with local citizens and governments helps focus monitoring where it will be most effective for assessment and observing long-term trends. This allows citizens/governments the ability to see how their efforts are used to inform water quality decisions and track how management efforts affect change. Many SWAG grantees invite citizen participation in their monitoring projects and their combined participation greatly expand our overall capacity to conduct sampling.

The MPCA also coordinates two programs aimed at encouraging long term citizen surface water monitoring: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Like the permanent load monitoring network, having citizen volunteers monitor a given lake or stream site monthly and from year to year can provide the long-term picture needed to help evaluate current status and trends. Citizen monitoring is especially effective at helping to track water quality changes that occur in the years between intensive monitoring years. Figure 4 provides an illustration of the locations where citizen monitoring data were used for assessment in the Redeye River Watershed.

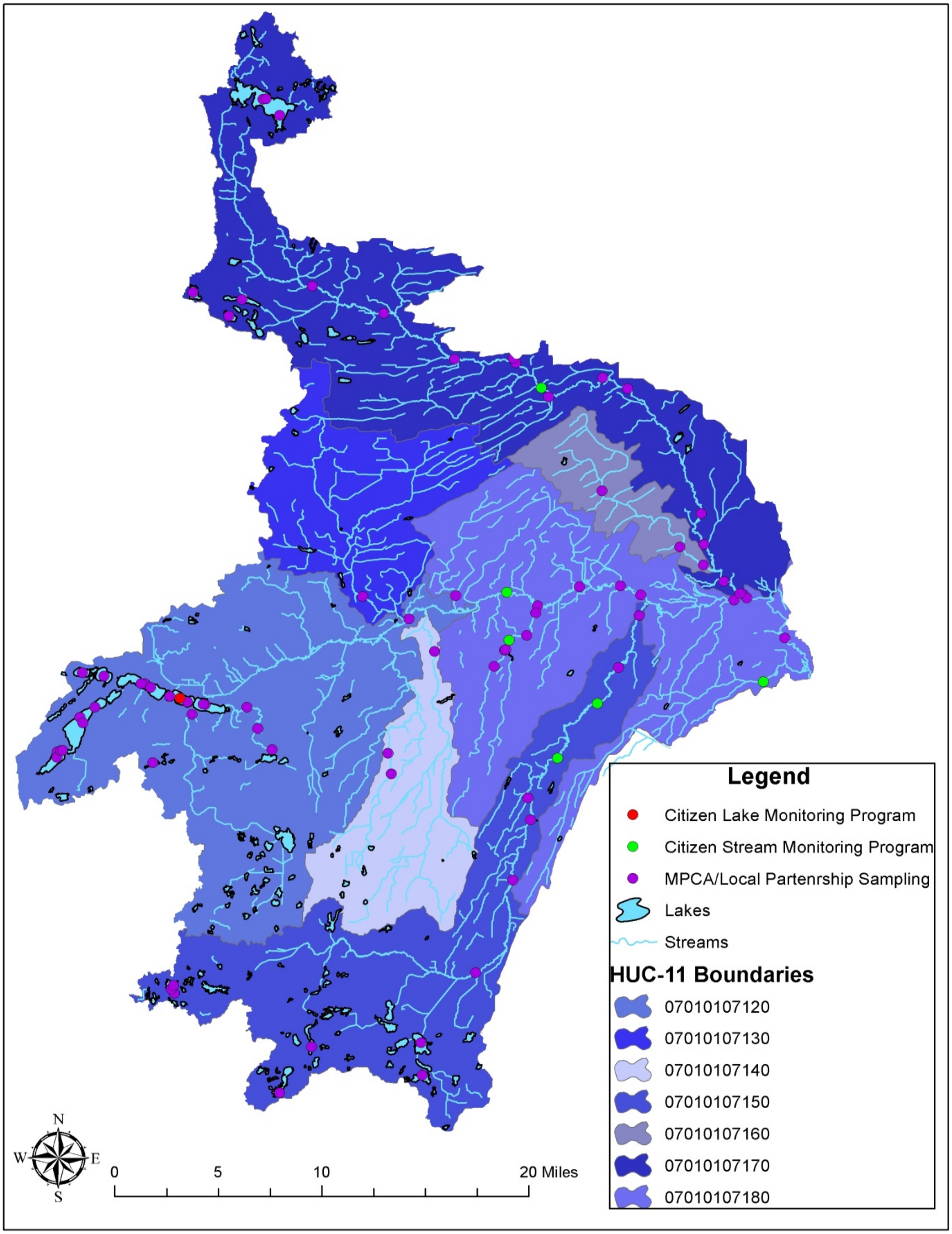

Figure 4. Monitoring locations of local groups, citizens and the MPCA lake monitoring staff in the Redeye River Watershed

II. 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 2007; 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 2010)* http://www.pca.state.mn.us/index.php/view-document.html?gid=16988.

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 life means the maintenance of a healthy aquatic community, including fish, invertebrates and plants. The sampling of aquatic organisms for assessment is called biological monitoring. Biological monitoring 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. Interpretations of narrative criteria for aquatic life in streams are based on multi-metric biological indices including the Fish Index of Biological Integrity (F-IBI), which evaluates the health of the fish community, and the Macroinvertebrate Index of Biological Integrity (M-IBI), which evaluates the health of the aquatic invertebrate community. Additionally, chemical parameters are measured and assessed against numeric standards developed to be protective of aquatic life, including pH, dissolved oxygen, un-ionized ammonia nitrogen, chloride and turbidity.

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

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

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

Assessment units

Assessments of use support in Minnesota are made for individual waterbodies. The waterbody unit used for river systems, lakes, and wetlands is called the "assessment unit". A stream or river assessment unit usually extends from one significant tributary stream to another or from the headwaters to the first tributary. A stream "reach" may be further divided into two or more assessment reaches when there is a change in use classification (as defined in Minn. R. ch. 7050) or when there is a significant morphological feature, such as a dam or lake, within the reach. Therefore, a stream or river is often segmented into multiple assessment units that are variable in length. The MPCA is using the 1:24,000 scale high resolution National Hydrologic Dataset (NHD) to define and index stream, lake and wetland assessment units. Each river or stream reach is identified by a unique waterbody identifier (known as its AUID), comprised of the USGS eight digit hydrologic unit code (HUC-8) plus a three character code that is unique within each HUC. Lake and wetland identifiers are assigned by the MDNR. The Protected Waters Inventory (PWI) provides the identification numbers for lake, reservoirs and wetlands. These identification numbers serve as the AUID 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 5.

The first step in the aquatic life assessment process is a comparison of the monitoring data to water quality standards. This is largely an automated process performed by logic programmed into a database application and the results are referred to as 'Pre-Assessments'. 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 attenuating circumstances that should be considered (e.g., flow, time/date of data collection, or habitat).

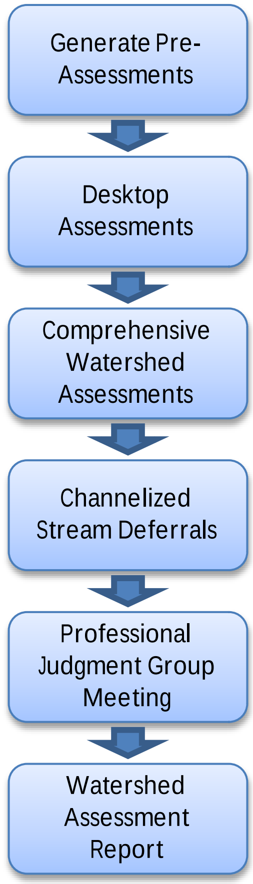

Figure 5. Flowchart of aquatic life use assessment process

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 2010) http://www.pca.state.mn.us/index.php/view-document.html?gid=16988 for guidelines and factors considered when making such determinations.

Any new impairment (i.e., waterbody not attaining its beneficial use) is first reviewed using Geographic Information System (GIS) to determine if greater than 50% of the assessment unit is channelized. Currently, the MPCA is deferring any new impairments on channelized reaches until new aquatic life use standards have been developed as part of the Tiered Aquatic Life Use (TALU) framework. For additional information, see: http://www.pca.state.mn.us/index.php/water/water-permits-and-rules/water-rulemaking/tiered-aquatic-life-use-talu-framework.html. However, in this report, channelized reaches with biological data are evaluated on a "good-fair-poor" system to help evaluate their condition (see Section IV and Appendix 5.1).

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 AUID). 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.

Data management

It is MPCA policy to use all credible and relevant monitoring data to assess surface waters. The MPCA relies on data it collects along with data from other sources, such as sister agencies, local governments and volunteers. The data must meet rigorous quality assurance protocols before being used. All monitoring data required or paid for by MPCA are entered into EQuIS (Environmental Quality Information System), MPCA's data system and are also uploaded to the U.S. Environmental Protection Agency's (EPA) data warehouse. Data for monitoring projects with federal or state funding are required to be stored in EQuIS (e.g., Clean Water Partnership, CWLA Surface Water Assessment Grants and TMDL program). Many local projects not funded by MPCA also choose to submit their data to the MPCA in an EQuIS-ready format so that the monitoring data may be utilized in the assessment process. Prior to each assessment cycle, the MPCA sends out a request for monitoring data to local entities and partner organizations.

Period of record

The MPCA uses data collected over the most recent ten year period for all water quality assessments. This time-frame provides a reasonable assurance that data will have been collected over a range of weather and flow conditions and that all seasons will be adequately represented; however, data for the entire period is not required to make an assessment. The goal is to use data that best represents current water quality conditions. Therefore, recent data for pollutant categories such as toxics, lake eutrophication and fish contaminants may be given more weight during assessment.

III. Watershed overview

Physical setting

From its source at Wolf Lake in Becker County (approximately 13 miles northwest of Menahga), the Redeye River flows southeast to its confluence with the Leaf River 10 miles north of Staples. The Leaf River then continues to flow southeast where it flows into the Crow Wing River 5 miles north of Staples. The Redeye River Watershed begins in Becker County and encompasses all or portions of Otter Tail, Todd, and Wadena Counties covering 899 square miles and draining approximately 575,360 acres. The watershed has a large wetland complex that runs through the center from west to east. North of this wetland complex the watershed is predominately hardwood forest and wetlands with scattered agricultural lands. South of the wetland complex the watershed is predominately agricultural lands with scattered wetlands, hardwood forests, and lakes (Figure 8).

The Redeye River Watershed lies within two of Minnesota's ecoregions (Figure 6). A small percentage of the watershed's northern portion lies within the Northern Lakes and Forests (NLF) while the remainder of the watershed lies in the North Central Harwood Forest (NCHF). The United States Department of Agriculture Major Land Resource Areas (MLRA) for the Redeye River Watershed includes three classifications: the extreme north and north central as well as the extreme southeastern portions of the watershed are classified as Northern Minnesota Gray Drift, the eastern two-thirds of the watershed and a thin band running to the west is classified as Central Minnesota Sandy Outwash, while the extreme southwest portion of the watershed is classified as Rolling Till Prairie (Figure 7). Soils in the Northern Minnesota Gray Drift are mostly loamy with some clayey and sandy soils (NRCS 2007). The Central Minnesota Sandy Outwash region ranges from well drained sandy soils on outwash plains to very poorly drained mineral and organic soils (NRCS 2007). The Rolling Till Prairie portion of the watershed has loamy glacial till soils with scattered sandy outwash and alluvial flood soils (NRCS 2007). The bedrock geology consists of primarily Precambrian crystalline rocks (NRCS 2007).

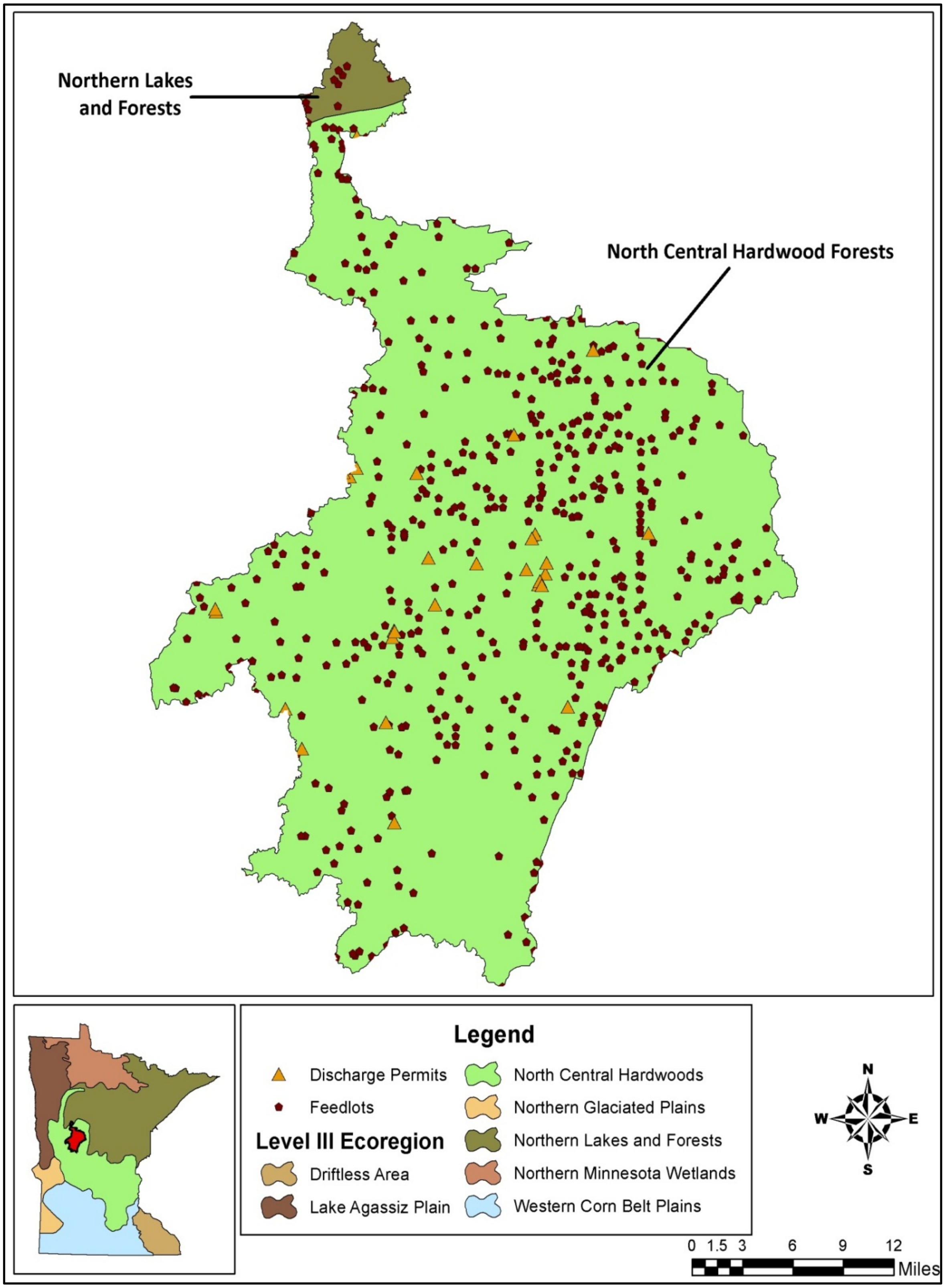

Figure 6. Ecoregions within the Redeye River Watershed

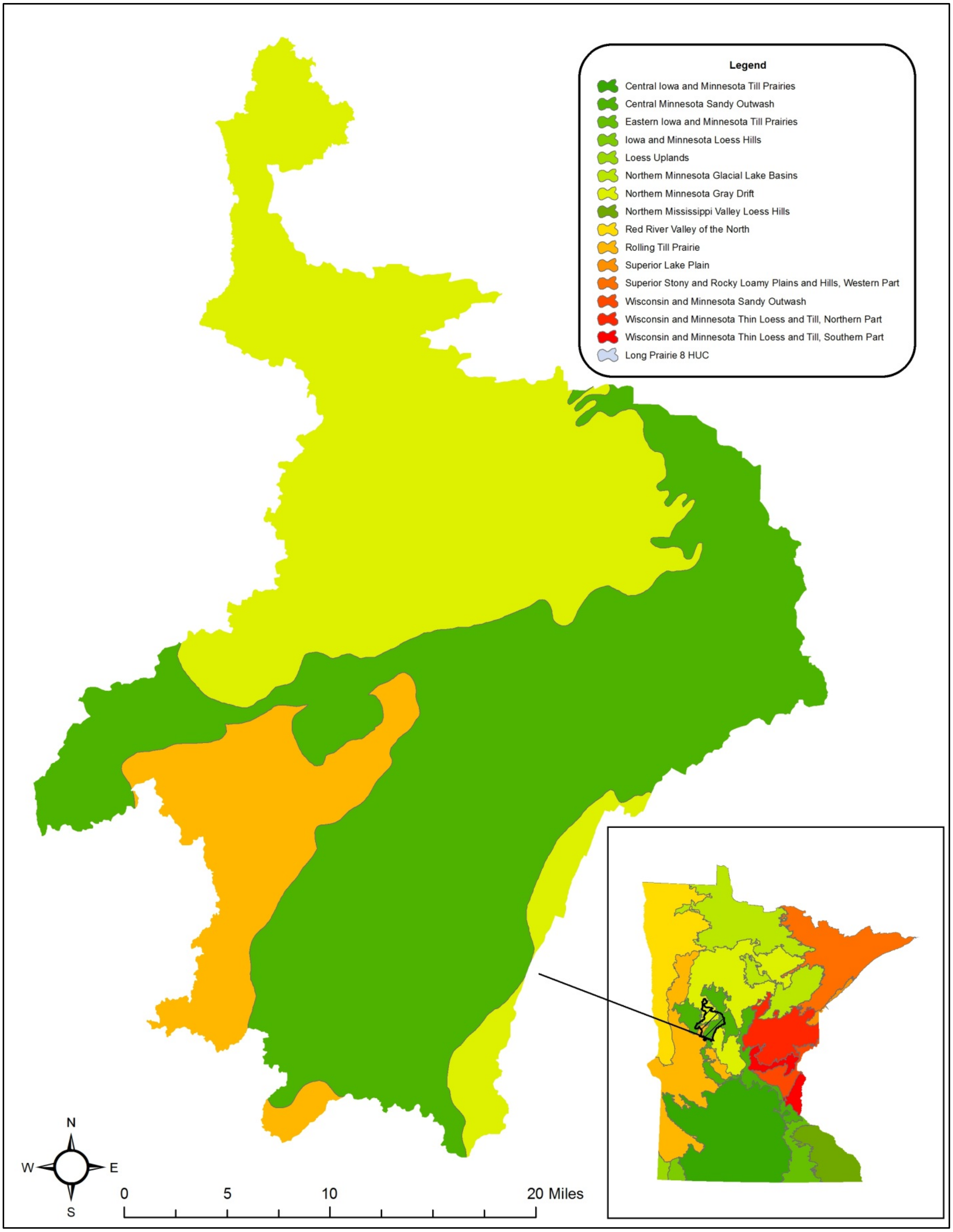

Figure 7. Major land resource areas and springs in the Redeye River Watershed

Land use summary

Many types of land use occur within the Redeye River Watershed including grass and cattail marshes, lakes, forests, and urban areas. However, the most common land use practices in the watershed are related to agriculture (range and cropland) which make up 24 and 25% of the land cover, respectively. The northern half of the watershed is more forested than the southern half which is predominately rangeland and agriculture. Although lakes are scattered throughout the entire watershed, a majority of them are in the western half of the watershed.

Land cover in the watershed is distributed as follows: 30.1% forest/shrub, 25.4% cropland, 23.9% grassland, 14.5% wetland, 1.5% open water, and 4.5% residential (Figure 8). Approximately 96% of the watershed's acreage is privately owned (NRCS 2007). Farmland occurs throughout the watershed, with most farms being smaller family farms, however some operations do exceed 1,000 acres in size. Forty-nine percent of the operations are less than 180 acres, 46% are from 180 to 1,000 acres and the remaining farms are greater than 1,000 acres (NRCS 2007). The most common crops grown in the watershed are small grains, corn, and soybeans (NRCS 2007).

2007 population estimates showed approximately 19,120 people reside within the Redeye River Watershed (NRCS 2007); equating to roughly 21 people per square mile. The largest population centers are located in the towns of Parkers Prairie, Wadena, and Sebeka.

Vegetation: The NLF consists primarily of coniferous and northern hardwood forests, which includes tree species such as yellow birch, maples, oaks, and many pine species. The NCHF ecoregion is comprised of mixture of forests, wetlands, cropland, and grasslands (EPA 2010). The forests consist mostly of sugar and red maples, yellow birch, aspen, spruce, hemlock, and white pine stands. A variety of wetland plant species occur, consisting mostly of rushes, cattails, and sedges (NRCS 2007).

Terrain: The NLF terrain is comprised of relatively nutrient-poor glacial soils, coniferous and northern hardwood forests, undulating till plains, morainal hills, broad lacustrine basins, and extensive sandy outwash plains. Soils in this ecoregion are thicker than in those in northern Minnesota and generally lack the arability of soils in adjacent ecoregions to the south (EPA 2010). The NCHF ecoregion is transitional between the predominantly forested NLF to the north and the agricultural ecoregions to the south. Land use/land cover in this ecoregion consists of a mosaic forests, wetlands and lakes, cropland agriculture, pasture, and dairy operations. The growing season is generally longer and warmer than that of the NLF and the soils are more arable and fertile, contributing to the greater agricultural component of land use (EPA 2010).

Wildlife: Whitetail deer, pheasants, rabbits, squirrels, coyote, multiple hawk species, and a variety of waterfowl species are common wildlife in both of the ecoregions. Common fish species include northern pike, walleye, bluegill, crappie, large and smallmouth bass, and many minnow species.

Land use/human activities: Private landowners make up nearly the entire watershed (96%) with crop and dairy farming make up a majority of the private landuse. State or federal owned lands make up the remaining land ownerships. Hunting for big and small game, upland birds, and waterfowl commonly take place within the watershed (NRCS 2007) as well as fishing on the many lakes.

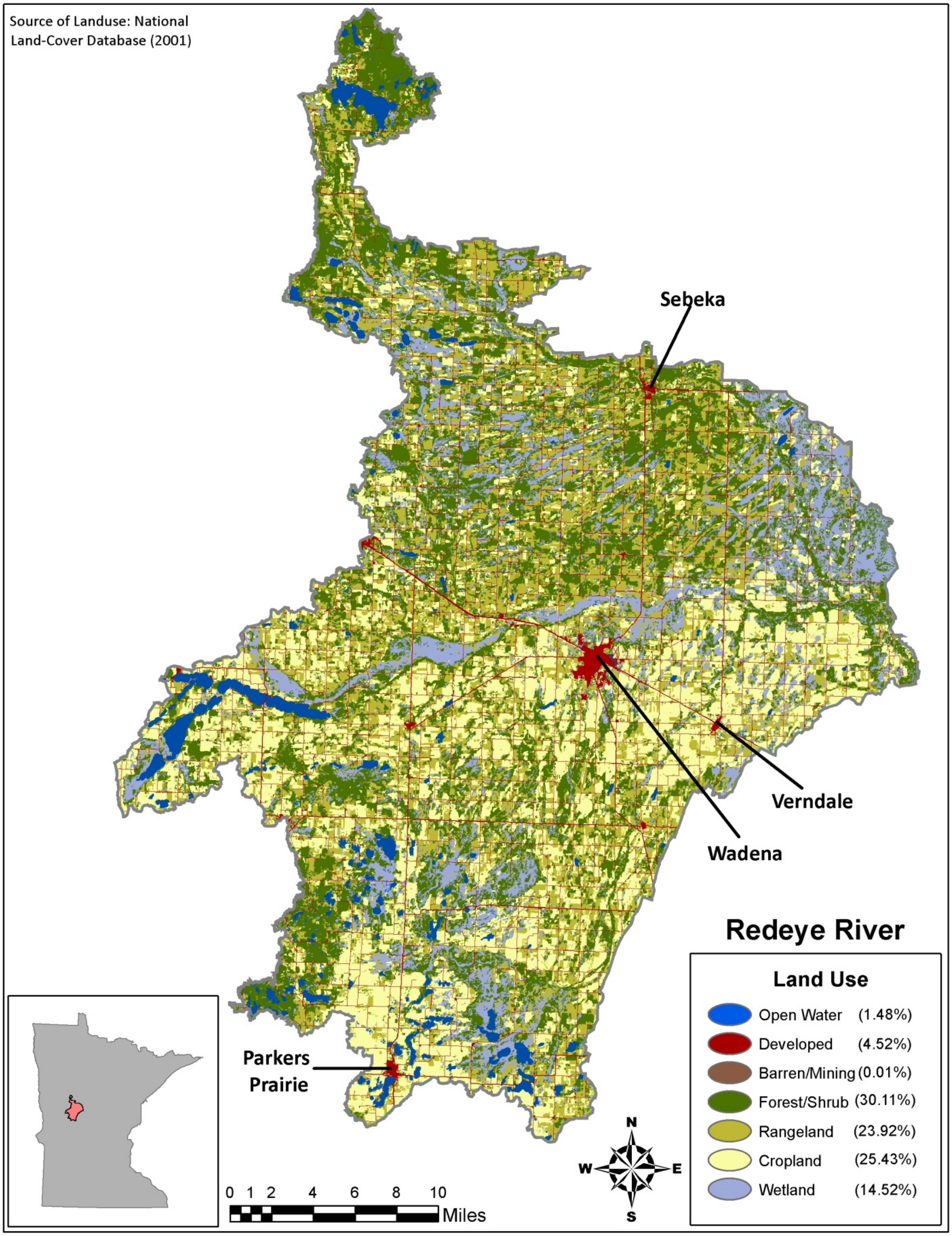

Figure 8. Land use in the Redeye River Watershed

Surface water hydrology

The highest elevation of the Redeye River Watershed is 1,483 feet above sea level found in the western and southwestern portions of the watershed with decreasing elevations across the eastern and northeastern portions of the watershed (NRCS 2007). Throughout its course, the Redeye River drops 456 feet to an elevation of 1,207 with an overall mean gradient of 4.8 feet per river mile. The western and southwestern portions of the watershed are lake-rich with a few lakes also occurring in the eastern portion of the watershed. The major lakes within the watershed include Miltona, Ida, Carlos, Le Homme Dieu, Latoka, Shamineau, Fish Trap, and Alexander Lakes. Several tributaries feed into the Redeye River mainstem including Moran, Turtle, and Eagle Creeks. Within the Redeye River Watershed there are a total of five MDNR documented dams, one of which is located on the mainstem Redeye River near the outlet from Wolf Lake and another on the Wing River near the town of Hewitt. The remaining three are located at the outlets of lakes or ponds.

Climate and precipitation

The ecoregion has a continental climate, marked by warm summers and cold winters. The mean annual temperature for Minnesota is 4.5˚C; the mean summer temperature for the Redeye River Watershed is 18.3˚C; and the mean winter temperature is -12.2˚C (Minnesota State Climatologists Office 2010).

Precipitation is the source of almost all water inputs to a watershed. The Redeye River Watershed area received 24-28 inches of precipitation in 2011 resulting in annual rainfall that ranged from two inches below normal in the northern reaches to two inches above normal in the southern portion (Figure 9).

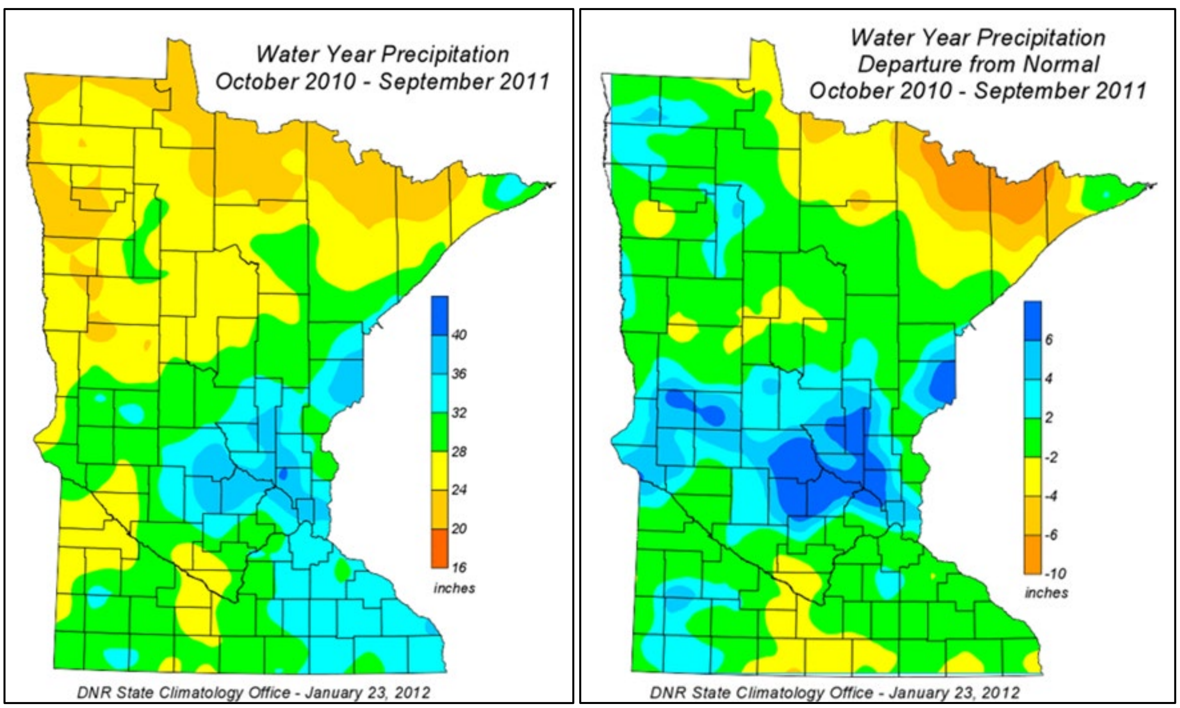

Figure 9. State-wide precipitation levels during the 2011 water year

Figure 10 displays the areal average representation of precipitation in west central Minnesota. An aerial average is a spatial average of all the precipitation data collected within a certain area presented as a single dataset. This data is taken from the Western Regional Climate Center, available as a link off of the University of Minnesota Climate website: http://www.wrcc.dri.edu/spi/divplot1map.html. Though rainfall can vary in intensity and time of year, rainfall totals in the west-central region display no significant trend over the last 20 years. However, precipitation in west central Minnesota exhibits a statistically significant rising trend over the past 100 years ($p=0.001$) (Figure 11). This is a strong trend and matches similar trends throughout Minnesota.

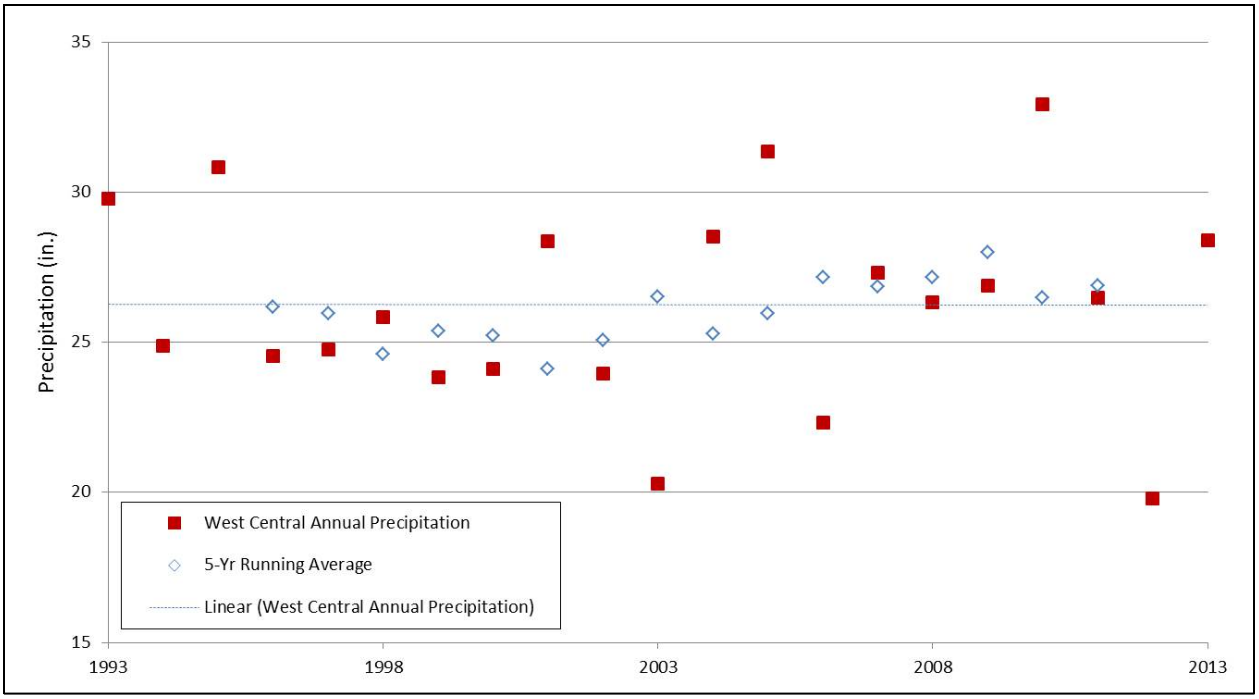

Figure 10. Precipitation trends in west central Minnesota (1993-2013) with five year running average

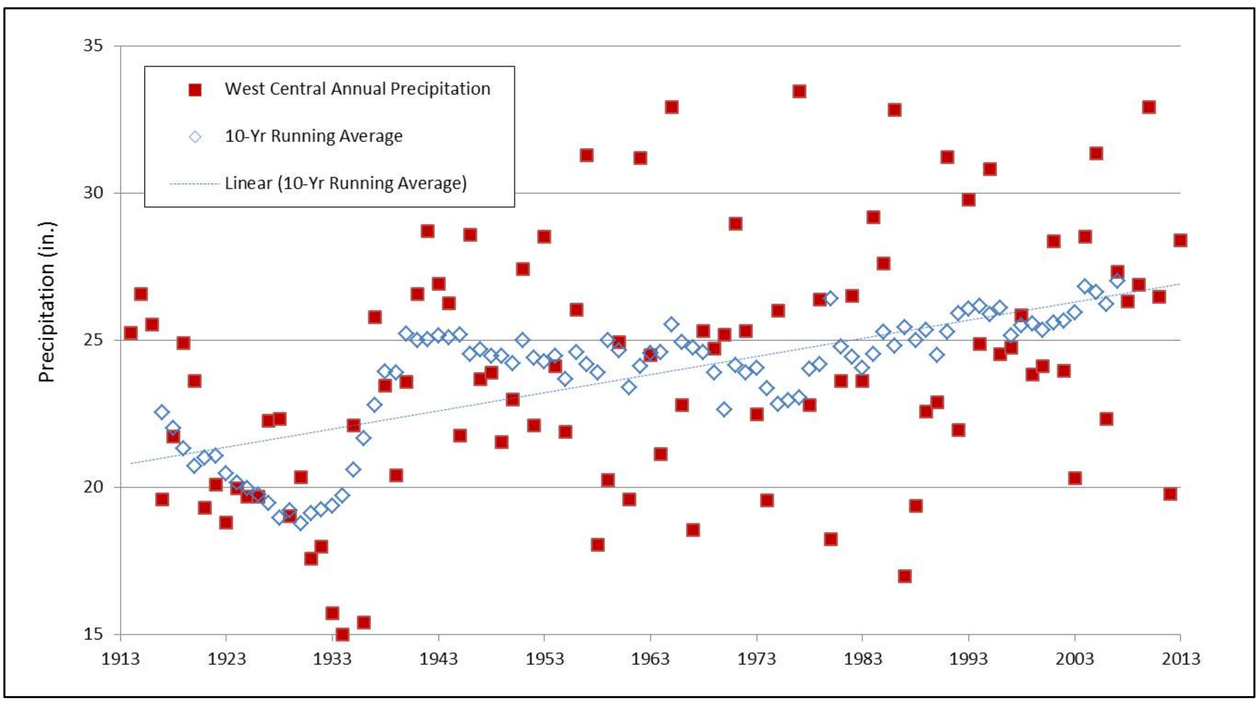

Figure 11. Precipitation trends in west central Minnesota (1913-2013) with ten-year running average

Hydrogeology

The hydrogeology of the Redeye River Watershed is dominated by glacial deposits, with the largest hydrologic feature being the outwash sands at the surface deposited by glacial activity (MPCA 1998). Most groundwater supplies are pumped from the surficial sand aquifers and a number of buried sand aquifers. In fact, within Todd County, in the southeast portion of the watershed, 99% of the wells are constructed in these shallow, quaternary sediments. These sands are very transmissible and as a result, water levels of surficial water bodies as well as base flow in the Redeye River are closely related to groundwater levels in the surficial aquifer (Peterson 2010).

Wetlands

The Redeye River Watershed is situated at the eastern edge of the historic prairie pothole region of western and south western Minnesota. The watershed's surface geology primarily consists of ground moraine and outwash plains resulting from Wadena Lobe glacial processes as part of the Alexandria Moraine complex. This hill, valley and flat outwash till geology created ideal conditions for a diverse wetland resource to develop in several hydrogeomorphic settings including depressional, slope, and floodplain flats.

IV. Watershed-wide data collection methodology

Watershed Pollutant Load Monitoring Network

A long term WPLMN stream monitoring station is located on the Leaf River on Highway 29 north of the city of Staples. Intensive water quality sampling occurs year round at this site. Twenty to 35 grab samples are collected at the site per year with sampling frequency greatest during periods of moderate to high flow (Figure 12). Because correlations between concentration and flow exist for many of the monitored analytes, and because these relationships can shift between storms or with season, computation of accurate load estimates requires frequent sampling of all major runoff events. Low flow periods are also sampled and are well represented but sampling frequency tends to be less as concentrations are generally more stable when compared to periods of elevated flow. Despite discharge related differences in sample collection frequency, this staggered approach to sampling generally results in samples being well distributed over the entire range of flows.

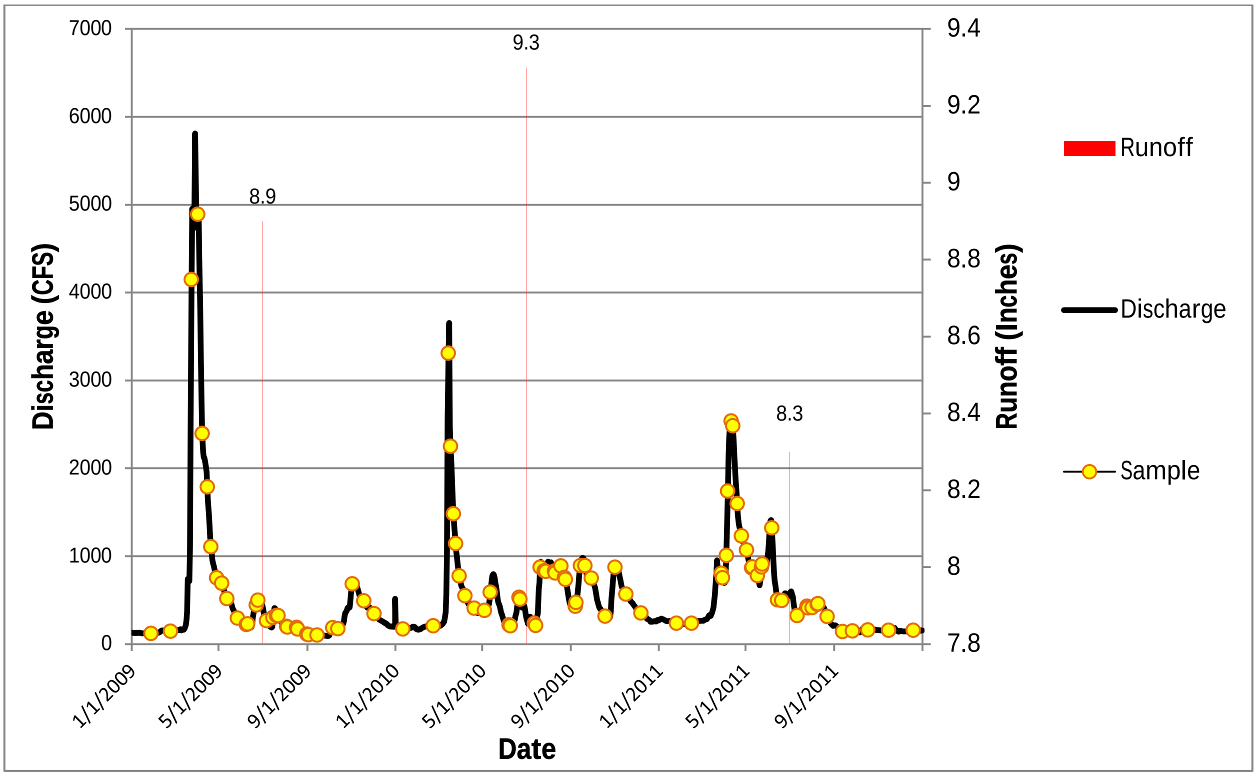

Figure 12. Hydrograph and annual runoff for the Leaf River near Staples, MN 2009-2011

Annual water quality and daily average discharge data are coupled in the “FLUX32,” pollutant load model, originally developed by Dr. Bill Walker and recently upgraded by the U.S. Army Corp of Engineers and MPCA. FLUX32 allows the user to create seasonal or discharge constrained concentration/flow regression equations to estimate pollutant concentrations and loads on days when samples were not collected. Primary output includes annual and daily pollutant loads and flow weighted mean concentrations (FWMC) (pollutant load/total seasonal flow volume). Loads and FWMC are calculated for total suspended solids (TSS), total phosphorus (TP), dissolved orthophosphate (DOP), nitrate plus nitrite nitrogen (nitrate-N) and total Kjeldahl nitrogen (TKN).

Stream water sampling

Six water chemistry stations were sampled from May thru September in 2011, and again June thru August of 2012, 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 HUC-11 subwatershed that was >40 square miles in area (yellow dots in Figure 3). A SWAG was awarded to Wadena

County to collect water chemistry data at all six water chemistry sampling 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).

Stream biological sampling

The biological monitoring component of the IWM in the Redeye River Watershed was completed during the summer of 2011. A total of 39 sites were established across the watershed and sampled. These sites were located near the outlets of the HUC-8, 11, and 14 watersheds. In addition, six existing biological monitoring stations within the watershed were revisited in 2013. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2013 assessment was collected in 2011. A total of 28 stream segments were sampled for biology in the Redeye River Watershed. Waterbody assessments to determine aquatic life use support were conducted for 24 stream segments. Waterbody assessments were not conducted for seven stream segments and nine sites because criteria for channelized reaches had not been developed prior to the assessments. Nonetheless, the 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. Qualitative ratings for non-assessed reaches area included in Appendix 5.1.

To measure the health of aquatic life at each biological monitoring station, indices of biological integrity (IBIs), specifically fish (F-IBI) and macroinvertebrate (M-IBI) IBIs, were calculated based on monitoring data collected for each of these communities. A fish and macroinvertebrate classification framework was developed to account for natural variation in community structure which is attributed to geographic region, watershed drainage area, water temperature and stream gradient. As a result, Minnesota's streams and rivers were divided into seven distinct warm water classes and two cold water classes, with each class having its own unique F-IBI and M-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 4.1). IBI scores higher than the impairment threshold and upper CI indicate that the stream reach supports aquatic life. Contrarily, scores below the impairment threshold and lower CI indicate that the stream reach does not support aquatic life. When an IBI score falls within the upper and lower confidence limits additional information may be considered when making the impairment decision such as the consideration of potential local and watershed stressors and additional monitoring information (e.g., water chemistry, physical habitat, observations of local land use activities). In 2014, new IBI thresholds were developed and used for biological assessments, including some follow up assessment in the Redeye River Watershed. While the majority of sites in this report were assessed in 2013 using the old thresholds, a small number of sites were assessed in 2014 using the new IBI thresholds. The IBI thresholds and results for each individual biological monitoring station can be found in Appendices 4.1, 4.2, and 4.3.

Fish contaminants

Mercury was analyzed in fish tissue samples collected from the Redeye/Leaf River and four lakes in the watershed. Polychlorinated biphenyls (PCBs) were measured in fish from the river, but not in any of the lakes. MPCA biological monitoring staff collected the fish from the river in 2011. MDNR fisheries staff collected all other fish.

Captured fish were wrapped in aluminum foil and frozen until they were thawed, scaled, filleted, and ground. The homogenized fillets were placed in 125 mL glass jars with Teflon™ lids and frozen until thawed for mercury or PCBs analyses. The Minnesota Department of Agriculture (MDA) Laboratory performed all mercury and PCBs analyses of fish tissue.

The Impaired Waters List is submitted every even year to the EPA for the agencies approval. MPCA has included waters impaired for contaminants in fish on the Impaired Waters List since 1998. Impairment assessment for PCBs and perfluorooctane sulfate (PFOS) in fish tissue is based on the fish consumption advisories prepared by the Minnesota Department of Health (MDH). If the consumption advice is to restrict consumption of a particular fish species to less than a meal per week because of PCBs or PFOS, the MPCA considers the lake or river impaired. The threshold concentration for impairment (consumption advice of one meal per month) is an average fillet concentration of 0.22 mg/kg for PCBs and 0.200 mg/kg (200 ppb) for PFOS.

Prior to 2006, mercury concentrations in fish tissue were assessed for water quality impairment based on the MDH's fish consumption advisory. An advisory more restrictive than a meal per week was classified as impaired for mercury in fish tissue. Since 2006, a waterbody has been classified as impaired for mercury in fish tissue if 10% of the fish samples (measured as the 90^{th} percentile) exceed 0.2 mg/kg of mercury, which is one of Minnesota's water quality standards for mercury. At least five fish samples per species are required to make this assessment and only the last 10 years of data are used for statistical analysis. MPCA's Impaired Waters List includes waterways that were assessed as impaired prior to 2006 as well as more recent impairments.

PCBs in fish have not been monitored as intensively as mercury in the last three decades due to monitoring completed in the 1970s and 1980s. These earlier studies identified that high concentrations of PCBs were only a concern downstream of large urban areas in large rivers, such as the Mississippi River and in Lake Superior. Therefore, continued widespread frequent monitoring of smaller river systems was not necessary. The current watershed monitoring approach includes screening for PCBs in representative predator and forage fish collected at the pour point stations in each major watershed.

Lake water sampling

MPCA received data from 17 lakes in the Redeye River Watershed and was able to assess 14 lakes for aquatic recreation use. MPCA collected water chemistry on eight lakes and a SWAG was awarded to the Otter Tail County COLA to collect water chemistry data on six Lakes. Lake water chemistry data collected through SWAG made it possible to assess these lakes for all components of the aquatic life and recreation use standards. In addition, there is currently one volunteer, Middle Leaf Lake, enrolled in the MPCA's CLMP that is conducting lake monitoring within the watershed. Data collected by volunteers allows for a more robust data set for aquatic recreation use assessment and provides trend data for years outside of the IWM schedule.

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

Groundwater quality

The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of chemicals including nutrients, metals, and volatile organic compounds. These ambient wells represent a mix of deeper domestic wells and shallow monitoring wells. The shallow wells interact with surface waters and exhibit impacts from human activities more rapidly. Available data from federal, state and local partners are used to supplement reviews of groundwater quality in the region.

Groundwater/surface water withdrawals

The MDNR permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons/day or 1 million gallons/year. Permit holders are required to track water use and report back to the MDNR yearly. Information on the program and the program database are found at:
http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

The changes in withdrawal volume detailed in this report are a representation of water use and demand in the watershed and are taken into consideration when the MDNR issues permits for water withdrawals. Other factors not discussed in this report but considered when issuing permits include: interactions between individual withdrawal locations, cumulative effects of withdrawals from individual aquifers, and potential interactions between aquifers. This holistic approach to water allocations is necessary to ensure the sustainability of Minnesota's groundwater resources.

Groundwater quantity

Monitoring wells from the MDNR Observation Well Network track the elevation of groundwater across the state. The elevation of groundwater is measured as depth to water in feet and reflects the fluctuation of the water table as it rises and falls with seasonal variations and anthropogenic influences. Data from these wells and others are available at: http://www.dnr.state.mn.us/waters/groundwater_section/obwell/waterleveldata.html.

Wetland monitoring

The MPCA began wetland biological monitoring and collecting associated wetland water chemistry in the early 1990s. This work has focused on depressional wetlands (i.e. marshes) which occur in a depressional geomorphic setting. This work resulted in the development of plant and macroinvertebrate (aquatic bugs, snails, leeches, and crustaceans) IBIs for evaluating the ecological condition or health of depressional wetlands. Both IBIs are on a 0 to 100 scale with higher scores indicating better condition. In 2011 the MPCA began using floristic quality assessment to assess the quality of all Minnesota wetland types based on plant communities. Wetland sampling protocols can be viewed at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/wetlands/wetland-monitoring-and-assessment.html. The MPCA does not monitor wetlands systematically by watershed. Depressional wetland IBIs have been used in a survey of wetland condition where results are summarized statewide and for each of Minnesota's level II ecoregions (Genet 2012). Depressional wetland condition results within this report are based on data from the statewide survey and earlier indicator development projects.

V. Individual subwatershed results

HUC-11 subwatersheds

Assessment results for aquatic life and recreation use are presented for each HUC-11 subwatershed within the Redeye River. The primary objective is to portray all the assessment results (i.e. waters that support and do not support their designated uses) within a HUC-11 subwatershed resulting from the complex and multi-step assessment and listing process. (A summary table of assessment results for the entire HUC-8 watershed including aquatic consumption, and drinking water assessments where applicable is included in Appendix 3). 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 HUC-11 subwatersheds contain the assessment results from the 2013 assessment cycle as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2011 IWM effort, but also considers available data from the last ten years.

The following pages provide an account of each HUC-11 subwatershed. Each account includes a brief description of the subwatershed, and summary tables of the results for each of the following: a) stream aquatic life and aquatic recreation assessments, b) biological condition of channelized streams and ditches, c) stream habitat quality d) channel stability, e) water chemistry for the HUC-11 outlet, and g) lake aquatic recreation assessments. Following the tables is a narrative summary of the assessment results and pertinent water quality projects completed or planned for the 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 subwatershed (i.e. where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2013 assessment process (2014 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 or thresholds); these determinations were made during the desktop phase of the assessment process (see Figure 5). Assessment of aquatic life is derived from the analysis of biological (fish and invertebrate IBIs), dissolved oxygen, turbidity, chloride, pH and un-ionized ammonia (NH_3) data, while the assessment of aquatic recreation in streams is based solely on bacteria (Escherichia coli or fecal coliform) data. Included in each table is the specific aquatic life use classification for each stream reach: cold water community (2A); cool or warm water community (2B); or indigenous aquatic community (2C). Stream reaches that do not have sufficient information for either an aquatic life or aquatic recreation assessment (from current or previous assessment cycles) are not included in these tables, but are included in Appendix 5.2 and Appendix 5.3. 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 HUC-11 subwatershed as well as in the watershed-wide results and discussion section.

Channelized stream evaluations

Biological criteria have not been developed yet for channelized streams and ditches; therefore, assessment of fish and macroinvertebrate community data for aquatic life use support is not yet possible for channelized streams in Minnesota. Though not an official assessment of aquatic life, a separate table within each HUC-11 summary provides a narrative rating of the condition of fish and macroinvertebrate communities at channelized streams based on the IBI results. The narrative ratings are based on aquatic life use assessment thresholds for each individual IBI class (see Appendix 5.1). IBI scores above this threshold are given a “good” rating, scores falling below this threshold by less than ~15 points (i.e., value varies slightly by IBI class) are given a “fair” rating, and scores falling below the threshold by more than ~15 points are given a “poor” rating. For more information regarding channelized stream evaluation criteria refer to Appendix 5.1.

Stream habitat results

Habitat information documented during each fish sampling visit is provided in each HUC-11 subwatershed section. These tables convey the results of the Minnesota Stream Habitat Assessment (MSHA) survey, which evaluates the habitat at the section of stream sampled for biology and can provide an indication of potential stressors (e.g., siltation, eutrophication) impacting fish and macroinvertebrate communities. The MSHA score is comprised of five scoring categories including adjacent land use, riparian zone, substrate, fish cover and channel morphology, which are summed for a total possible score of 100 points. Scores for each category, a summation of the total MSHA score, and a narrative habitat condition rating are provided in the tables for each biological monitoring station. Where multiple visits occur at the same station, the scores from each visit have been averaged. The final row in each table displays average MSHA scores and a rating for the HUC-11 subwatershed.

Stream stability results

Stream channel stability information evaluated during each macroinvertebrate sampling visit is provided in each HUC-11 subwatershed section. These tables display the results of the Channel Condition and Stability Index (CCSI) which rates the geomorphic stability of the stream reach sampled for biology. The CCSI rates three regions of the stream channel (upper banks, lower banks, and bottom) which may provide an indication of stream channel geomorphic changes and loss of habitat quality due to changes in watershed hydrology, stream gradient, sediment supply, or sediment transport capacity. The CCSI was recently implemented in 2007, and is collected once at each biological station. The final row in each table displays the average CCSI scores and a rating for the HUC-11 subwatershed.

Subwatershed outlet water chemistry results

These summary tables display the water chemistry results for the monitoring station representing the outlet of the HUC-11 subwatershed. This data along with other data collected within the 10 year assessment window can provide valuable insight on water quality characteristics and potential parameters of concern within the watershed. Parameters included in these tables are those most closely related to the standards or expectations used for assessing aquatic life and recreation.

Lake assessments

A summary of lake water quality is provided in the HUC-11 subwatershed sections where available data exists. For lakes with sufficient data, basic modeling was completed. Assessment results for all lakes in the watershed are available in Table 39. Lake models and corresponding morphometric inputs can be found in Appendix 7. Minnesota's ecoregion-based lake eutrophication standards can be found in Appendix 6.

Upper Leaf River Watershed Unit HUC 07010107120

The Upper Leaf River subwatershed is located in east central Otter Tail County and is the largest of the subwatersheds, draining an area of 203.9 square miles. This subwatershed contains the headwaters of the Leaf River, originating from Gourd Lake (56-0139-00). The Leaf River flows in a northeast direction towards the town of Bluffton where it turns and flows east to the Lower Leaf River subwatershed. The Upper Leaf subwatershed consists mostly of cropland and forest land cover, comprising 32 and 26% of the total land use respectively, followed closely by rangeland with 24% (Figure 13). The water chemistry monitoring station for this watershed is the outlet station 11UM060 on the Leaf River at County Road 77, in Bluffton.

Table 1. Aquatic life and recreation assessments on stream reaches in the Upper Leaf River HUC-11 subwatershed.

AUID *Reach Name*, *Reach Description*	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
07010107-511 ***Deer Creek,*** *Headwaters to Leaf River*	5.74	2B	11UM061	Upstream of CSAH 52, 2.5 mi. NE of Deer Creek	MTS	MTS	--	--	--	--	--	--	--	FS	NA
07010107-514 ***Leaf River,*** *Bluff Creek to Oak Creek*	1.46	2B	11UM060	Upstream of CSAH 77, in Bluffton	NA*	NA*	IF	MTS	--	MTS	MTS	--	EX	IF	NS
07010107-525 ***Willow Creek,*** *T133 R38W S11, South line to Leaf Lake*	5.86	2A	11UM066	Downstream of CSAH 50, 4 mi. N of Henning	MTS	MTS	--	--	--	--	--	--	--	FS	NA
07010107-528 ***Trib. to South Bluff Creek,*** *Unnamed Creek to South Bluff Creek*	2.16	2B	11UM071	Upstream of CSAH 73, 6 mi. SW of Wadena	MTS	MTS	--	--	--	--	--	--	--	FS	NA
07010107-531 ***South Bluff Creek,*** *Unnamed Creek to Leaf River*	4.32	2B	11UM068	Downstream of 330th St, 4 mi. W of Wadena	MTS	MTS	--	--	--	--	--	--	--	FS	NA
07010107-554 ***Trib to East Leaf Lake,*** *County Ditch 49 to East Leaf Lake*	6.41	2B	11UM065	Upstream of 530th Ave, 3.5 mi. W of Deer Creek	EXP	--	--	--	--	--	--	--	--	NS	NA

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

** Aquatic Life assessment and/or impairments for this site have been deferred until the adoption of Tiered Aquatic Life Uses due to the site being predominantly (>50%) channelized.

Table 2. Non-assessed biological stations on channelized AUIDs: Upper Leaf River subwatershed.

AUID *Reach Name,* *Reach Description*	Reach length (miles)	Use Class	Biological Station ID	Location of Biological Station	Fish IBI	Invert IBI
07010107-506 ***Leaf River,*** *Headwaters (Gourd Lake 56-0139-00) to Bluff Creek*	17.73	2B	11UM063	Downstream of CSAH 52, 3 mi. NW of Deer Creek	Poor	Fair
07010107-514 ***Leaf River,*** *Bluff Creek to Oak Creek*	1.46	2B	11UM060	Upstream of CSAH 77, in Bluffton	Good	Good
07010107-551 **Willow Creek,** *Unnamed Ditch to T133 R38W S14, North line*	6.7	2B	11UM067	Upstream of Hwy 210, 0.5 mi. E of Henning	Good	Good

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 5.2 and Appendix 5.3 for IBI results.

Table 3. Minnesota Stream Habitat Assessment (MSHA): Upper Leaf River subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score	MSHA Rating
1	11UM061	Deer Creek	2.5	14	17.45	13	25	71.95	Good
1	11UM060	Leaf River	3.75	11.5	19.25	9	20	63.5	Fair
1	11UM066	Willow Creek	4	13	20.4	13	31	81.4	Good
1	11UM071	Trib. To South Bluff Creek	0	13	12	15	12	52	Fair
1	11UM068	South Bluff Creek	3.25	10.5	15.8	13	27	69.55	Good
2	11UM065	Trib. to East Leaf Lake	2.5	11.75	9	10.5	18	51.75	Fair
1	11UM063	Leaf River	3.75	10.5	9	14	15	52.25	Fair
2	11UM067	Willow Creek	3.25	14	9.5	15.5	15	57.25	Fair
Average Habitat Results: *Upper Leaf River subwatershed*			**2.88**	**12.28**	**14.05**	**12.88**	**20.38**	**62.46**	**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)

Table 4. Channel Condition and Stability Assessment (CCSI): Upper Leaf River subwatershed.

# Visits	Biological Station ID	Stream Name	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11UM063	Leaf River	4	5	13	4	26	Stable
1	11UM065	Trib. to East Leaf Lake	7	10	11	2	30	Fairly Stable
1	11UM066	Willow Creek	10	11	8	3	32	Fairly Stable
1	11UM067	Willow Creek	7	17	15	1	40	Fairly Stable
1	11UM068	South Bluff Creek	13	18	12	3	46	Moderately Unstable
2	11UM061	Deer Creek	10	24	26	3	63	Moderately Unstable
1	11UM060	Leaf River	16	21	28	2	67	Moderately Unstable
2	11UM071	Trib. to South Bluff Creek	17	24	26	4	71	Moderately Unstable
Average Stream Stability Results: *Upper Leaf River subwatershed*			**10.5**	**16.25**	**17.38**	**2.75**	**46.88**	**Moderately Unstable**

Qualitative channel stability ratings
= stable: CCSI < 27 = fairly stable: 27 < CCSI < 45 = moderately unstable: 45 < CCSI < 80 = severely unstable: 80 < CCSI < 115 = extremely unstable: CCSI > 115

Table 5. Outlet water chemistry results: Upper Leaf River subwatershed.

Station Location:	**At CR 77, In Bluffton, MN**							
EQuIS ID:	**S005-732**							
Station #:	**11UM060**							
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**Median**	**WQ Standard**	**# of WQ Exceedances**
Ammonia-nitrogen	mg/L	8	0.00	0.05	0.01	0.00	0.04	1
Chloride	mg/L	0					230	
Dissolved oxygen (DO)	mg/L	25	4.0	10.5	7.5	7.5	5.0	1
pH	--	24	6.5	8.2	7.9	7.9	6.5-9.0	0
Transparency, tube with disk	cm	33	91	>100	100	>100	>20	0
Turbidity	FNU	0					25.0 NTU	
Escherichia coli	MPN/100mL	22	62	461	169	150	1260	0
Escherichia coli (geometric mean)	MPN/100mL	36	93	145		135	126	2
Chlorophyll-a, corrected	ug/L	0						
Pheophytin-a	ug/L	0						
Inorganic nitrogen (nitrate and nitrite)	mg/L	10	0.06	6.30	0.78	0.16		
Kjeldahl nitrogen	mg/L	10	0.4	1.1	0.8	0.8		
Phosphorus	ug/L	10	30	258	77	60		
Orthophosphate	ug/L	0						
Total suspended solids	mg/L	10	2.0	11.0	5.3	5.0		
Total volatile solids	mg/L	10	1.0	8.0	3.3	3.0		
Sulfate	mg/L	0						
Specific conductance	uS/cm	25	443	559	515	511		
Temperature, water	deg C	33	2.8	25.7	19.1	19.6		

Table 6. Assessed lakes in the Upper Leaf River subwatershed.

Name	DNR Lake ID	Area (acres)	Trophic Status	Percent Littoral	Max. Depth (m)	Mean Depth (m)	CLMP Trend	Mean TP (µg/L)	Mean chl-a (µg/L)	Mean Secchi (m)	AQR Support Status	AQL Support Status
Unnamed	56-0113-00	35	M					13.0	13.0	1.0	IF	IF
West Leaf	56-0114-00	729	M	28.0	15.7	6.9		19.5	9.0	2.7	FS	IF
Middle Leaf	56-0116-01	404	M	44.8	13.3	5.2	NT	19.6	7.5	3.0	FS	IF
East Leaf	56-0116-02	423	E	26.7	14.5	6.4		37.1	22.8	2.0	FS	IF
Gourd	56-0139-00	923	O	100.0	2.0	1.0*		10.0		1.1	IF	NA
Portage (main bay)	56-0140-01	269	O		15.1			10.2	2.9	4.1	FS	NA
Tamarack	56-0192-00	440	M	100.0	0.5	1.0*		14.3	2.0	1.0	FS	NA
Donald's	56-0200-00	217	M	50.0	13.3	4.8		17.2	4.2	3.4	FS	NA

Abbreviations:
D -- Decreasing/Declining Trend
I -- Increasing/Improving Trends
NT – No Trend

H – Hypereutrophic
E – Eutrophic
M – Mesotrophic
O - Oligotrophic

FS – Full Support
NS – Non-Support
IF – Insufficient Information

Summary

Fish IBI scores in the Upper Leaf River subwatershed were variable while M-IBI scores were consistently at or above thresholds. Four of the six assessable AUIDs fully supported aquatic life and only one AUID did not support aquatic life (Table 1).

The Leaf River exits East Leaf Lake on its north side, splitting into two AUIDs, each having one site. Both sites were channelized (not assessed) with the upstream site (11UM063) scoring poor for fish (lowest score in the subwatershed) and fair for macroinvertebrates, while the downstream site (11UM060) scored good for both fish and macroinvertebrates (Table 2). In-stream habitat differences (Table 3) between sites, specifically the lack of coarse substrate at 11UM063, may have been a contributing factor to the F-IBI differences. Gravel spawning species such as hornyhead chub and shorthead redhorse were found at 11UM060 but absent at 11UM063. Another possible contributor to the high F-IBI score at 11UM060 is its location just downstream of the confluence with Bluff Creek which may increase flow, and improve water chemistry on the Leaf River.

Willow Creek originates in the southern portion of the subwatershed and flows 12.5 miles north where it enters the south side of East Leaf Lake. Roughly one mile north of the town of Henning the stream splits into two AUIDs, with the downstream portion designated as coldwater and the upstream portion designated as warmwater. Each AUID had one site, both of which scored above their respective thresholds for F-IBI and M-IBI. These high scores are likely a result of the high MSHA ratings they received for land use, riparian, and cover (Table 3), and CCSI ratings of fairly stable (Table 4). Conversely, the lone aquatic life impairment within this subwatershed occurs on the tributary to East Leaf Lake (11UM065). Similar to 11UM063 where fish communities were poor, this site also lacked quality bottom substrate (Table 3).

Stream water quality data were available for the Leaf River from Bluff Creek to Oak Creek. This AUID is approximately 1.5 miles long. Water chemistry data were collected near the outlet of the Upper Leaf River subwatershed. The Leaf River did not meet the standard for bacteria and is considered impaired for aquatic recreation use. This impairment was based on two geometric mean exceedances (Table 5). No individual sampling event exceeded the water quality standard of 1260 MPN/100ml. Since bacteria can be high at times and moderate or low at other times, recreational use can be limited. Water chemistry data appeared to meet aquatic life standards.

The distribution of lakes in the Upper Leaf River subwatershed is skewed towards the western border of the watershed. These lakes were formed during the last glaciation and are depressional lakes in sandy outwash. As a result, lake characteristics are diverse in this region consisting of a mixture of deep and shallow basins. Surrounding land use primarily consists of cropland and pasture with wetland drainages and forested regions intermixed. Eight lakes had water quality information available in the Upper Leaf River watershed (Table 6).

Seven lakes are located in the headwaters of the Leaf River which, originates at the pour point of East Leaf Lake. Six of these lakes had sufficient data for aquatic recreation use assessment. These lakes include West Leaf, Middle Leaf, East Leaf, Portage, Tamarack, and Donald's. Gourd Lake did not have sufficient data for aquatic recreation assessment. Two distinct drainages enter the chain of West, Middle, and East Leaf Lakes. Donald's Lake and Portage Lake appear to have limited connectivity but may diffusely discharge during wet periods through a wetland complex into West Leaf Lake. Tamarack Lake and Gourd Lake are both large shallow lakes that discharge into West Leaf Lake from the south. All lakes with sufficient data were found to fully support aquatic recreation, indicating that algal blooms should not impact recreational use. One additional lake, Unnamed 56-0113-00, was part of the 2012 National Lake Assessment (NLA) study and was sampled one time on July 23, 2012. More information on the lakes included in the NLA survey can be found on the EPA's webpage at http://water.epa.gov/type/lakes/lakessurvey_index.cfm.

Overall, the water quality of these lakes is good and currently meets aquatic recreation standards. However, these lakes need to be protected in order to maintain their current water quality conditions. Lakes with high connectivity to one another have the potential to transport excess nutrients downstream. This is a concern when contributing lake catchments are large and surrounding land use is predominantly agriculture and pasture. East

Leaf Lake had the lowest TP, Chl-a, and Secchi reading of all lakes sampled in the Upper Leaf River subwatershed. This is likely a result of the lake being the last in the chain of lakes before the beginning of the Leaf River. In addition East Leaf Lake also has two tributaries that drain large portions of the watershed from the south through Willow Creek and an Unnamed Creek. Best land management practices need to be implemented to limit additional nutrient inputs into East Leaf Lake.

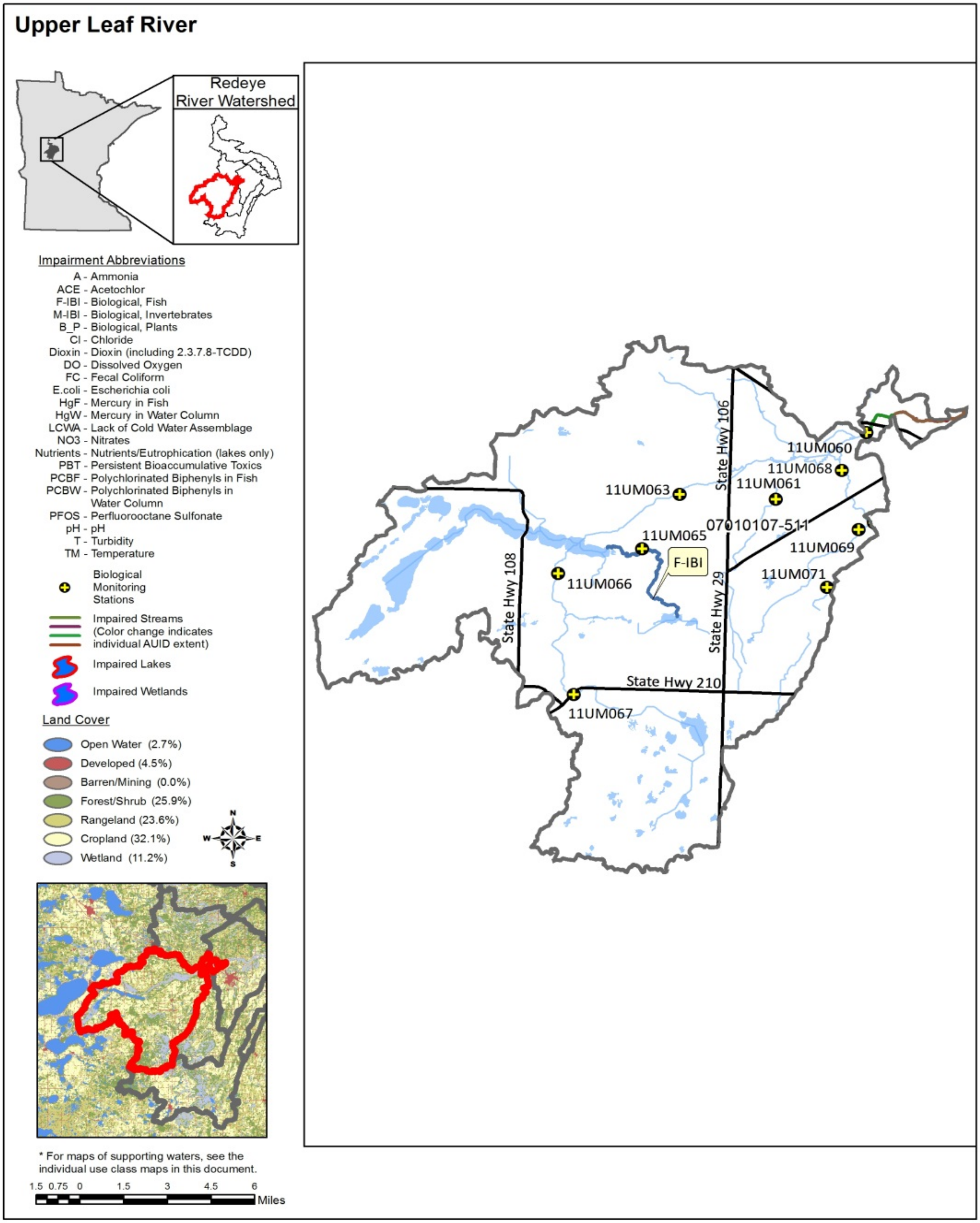

Figure 13. Currently listed impaired waters by parameter and land use characteristics in the Upper Leaf River subwatershed

Bluff Creek Watershed Unit HUC 07010107130

The Bluff Creek subwatershed, located in northeastern Otter Tail and a small portion of extreme western Wadena counties, encompasses an area of 78.7 square miles. The subwatershed drains to the 17.8-mile long Bluff Creek, which flows southeast to its confluence with the Leaf River one-half mile southeast of the town of Bluffton. The tributaries to Bluff Creek include Blue Creek, tributary to Bluff Creek, as well as many unnamed ditches and creeks. The land use consists predominantly of forest and rangeland, comprising 37 and 27% of the watershed, respectively (Figure 14). The water chemistry monitoring station for this subwatershed is the outlet station 11UM056 on Bluff Creek at 585th Avenue, two miles northwest of Bluffton.

Stream assessments

Table 7. Aquatic life and recreation assessments on streams reaches in the Bluff Creek HUC-11 subwatershed.

AUID ***Reach Name,*** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Aquatic Life Indicators:** Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	**Aquatic Life**	**Aquatic Rec.**
07010107-515 ***Bluff Creek,*** *Headwaters to Leaf River*	17.83	2C	11UM056 11UM058	Upstream of 585th Ave, 2 mi. NW of Bluffton Downstream of CSAH 56, 3.5 mi. E of New York Mills	MTS	MTS	IF	--	--	MTS	MTS	--	EX	FS	NS
07010107-541 ***Blue Creek,*** *Unnamed Creek to Bluff Creek*	5.01	2B	11UM059	Downstream of CSAH 56, 4.5 mi. E of New York Mills	MTS	MTS	--	--	--	--	--	--	--	FS	NA

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

** Aquatic Life assessment and/or impairments for this site have been deferred until the adoption of Tiered Aquatic Life Uses due to the site being predominantly (>50%) channelized.

Table 8. Non-assessed biological stations on channelized AUIDs: Bluff Creek subwatershed.

AUID ***Reach Name,*** *Reach Description*	**Reach length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Fish IBI**	**Invert IBI**
07010107-556 ***Trib. to Bluff Creek,*** *Unnamed Lake (56-1324-00) to Bluff Creek*	1.69	2B	11UM057	Upstream of 573rd Ave, 4 mi. E of New York Mills	Good	Poor

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 5.2 and Appendix 5.3 for IBI results.

Table 9. Minnesota Stream Habitat Assessment (MSHA): Bluff Creek subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	11UM056	Bluff Creek	2.5	11	22	16	31	82.5	Good
1	11UM057	Trib. To Bluff Creek	2.5	11	20.1	13	19	65.6	Fair
1	11UM058	Bluff Creek	0	1	10	14	17	42	Poor
1	11UM059	Blue Creek	1.5	10	19.1	12	29	71.6	Good
Average Habitat Results: *Bluff Creek subwatershed*			**1.63**	**8.25**	**17.8**	**13.75**	**24**	**65.43**	**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)

Table 10. Channel Condition and Stability Assessment (CCSI): Bluff Creek subwatershed.

# Visits	Biological Station ID	Stream Name	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11UM058	Bluff Creek	4	5	24	4	37	Fairly Stable
1	11UM056	Bluff Creek	10	10	13	5	38	Fairly Stable
1	11UM059	Blue Creek	8	18	22	4	52	Moderately Unstable
Average Stream Stability Results: *Bluff Creek subwatershed*			**7.33**	**11**	**19.67**	**4.33**	**42.33**	Fairly Stable

Qualitative channel stability ratings

= stable: CCSI < 27 = fairly stable: 27 < CCSI < 45 = moderately unstable: 45 < CCSI < 80 = severely unstable: 80 < CCSI < 115 = extremely unstable: CCSI > 115

Table 11. Outlet water chemistry results Bluff Creek subwatershed.

Station Location:	At 585th Ave, 2 mi. NW of Bluffton, MN							
EQuIS ID:	S006-849							
Station #:	11UM056							
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**Median**	**WQ Standard**	**# of WQ Exceedances**
Ammonia-nitrogen	mg/L	8	0.00	0.00	0.00	0.00	0.04	0
Chloride	mg/L	0					230	
Dissolved oxygen (DO)	mg/L	26	5.3	12.2	8.3	8.2	5.0	0
pH	--	25	7.7	8.5	8.1	8.1	6.5-9.0	0
Transparency, tube with disk	cm	34	78	>100	98	100	>20	0
Turbidity	FNU	0					25.0 NTU	
Escherichia coli	MPN/100mL	23	64	548	177	138	1260	0
Escherichia coli (geometric mean)	MPN/100mL	0	132	173		137	126	3
Chlorophyll-a, corrected	ug/L	0						
Pheophytin-a	ug/L	0						
Inorganic nitrogen (nitrate and nitrite)	mg/L	11	<0.03	0.17	0.04	<0.03		
Kjeldahl nitrogen	mg/L	11	0.4	1.3	0.9	0.9		
Phosphorus	ug/L	11	48	129	86	85		
Orthophosphate	ug/L	0						
Total suspended solids	mg/L	11	3.0	8.0	5.3	5.0		
Total volatile solids	mg/L	11	2.0	6.0	3.4	3.0		
Sulfate	mg/L	0						
Specific conductance	uS/cm	26	371	614	519	531		
Temperature, water	deg C	34	3.9	27.1	19.6	20.9		

Summary

There are two sites on Bluff Creek (AUID 07010107-515) with different habitat and IBI score relationships. The most upstream site (11UM058) had a poor MSHA score (Table 9), specifically for land use, riparian, and substrate which coincided with the lowest F-IBI score. However, this site had the highest M-IBI score in the subwatershed. The downstream site (11UM056) had a good MSHA and F-IBI score but the M-IBI score was only slightly above the impairment threshold. Similarly, F-IBI scores in the smaller tributaries of Blue Creek (11UM0059) and Unnamed Creek (11UM057) were associated with high MSHA scores but correspondence with habitat and M-IBI was poor.

Overall within this subwatershed, where good habitat conditions exist the fish communities thrive. However other factors appear to be limiting the macroinvertebrate communities. Land use along the stream corridors resulted in poor MSHA scores for that particular metric (Table 9**)** which may contribute to the poor biological community results in some locations. However, the limited water chemistry data collected during biological sampling did not indicate any serious issues that would have a direct effect on the biological communities.

Stream water quality data were available for Bluff Creek from its headwaters to the Leaf River. This AUID is approximately 18 miles long. Water chemistry data were collected near the outlet of the Bluff Creek subwatershed. Bluff Creek exceeded the standard for bacteria and is considered impaired for aquatic recreation use. This impairment was based on three geometric mean exceedances (Table 11). No individual sampling event exceeded the water quality standard of 1260 MPN/100ml. Since bacteria can be high at times and moderate or low at other times, recreational use can be limited. It was noted that cattle had direct access to the stream in this reach which may be contributing to the elevated bacteria measurements.

The Bluff Creek subwatershed did not have any assessable lakes.

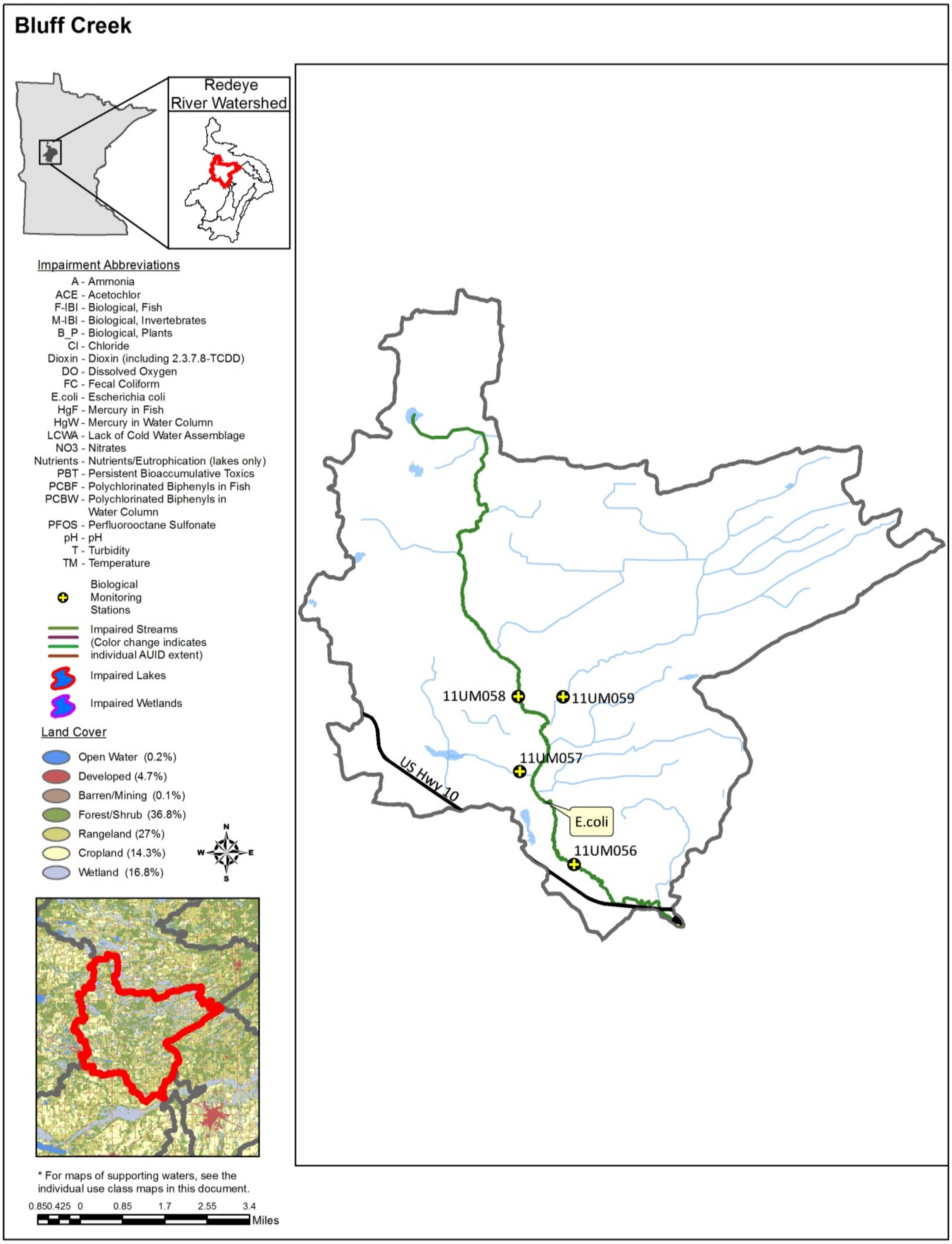

Figure 14. Currently listed impaired waters by parameter and land use characteristics in the Bluff Creek subwatershed

Ridge Creek Watershed Unit HUC 07010107140

The Ridge Creek subwatershed encompasses 60.6 square miles and is located in southeastern Otter Tail County and a very small portion of northwestern Todd County. The subwatershed includes two significant tributaries to the Leaf River. South Bluff Creek originates in a large wetland/wooded area and flows north, where it enters the Upper Leaf River subwatershed approximately three miles south of Bluffton. Oak Creek also originates in a large wetland/wooded area and flows north until its confluence with the Leaf River approximately one mile east of Bluffton. In addition, many unnamed tributaries and creeks contribute to South Bluff and Oak creeks. The land use is mostly cropland and forest, comprising 30 and 29%, respectively (Figure 15). The water chemistry monitoring station for this subwatershed is represented by the outlet station 11UM073 on Oak Creek at Highway 29, 2.5 miles west of Wadena.

Stream assessments

Table 12. Aquatic life and recreation assessments on assessed AUIDs in the Ridge Creek HUC-11 subwatershed.

AUID *Reach Name* Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators:								Bacteria	Aquatic Life	Aquatic Rec.
					Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides			
07010107-516 ***Oak Creek,*** *Unnamed Ditch to T134 R36W S3, North line*	17.43	2C	11UM073 11UM075	Downstream of Hwy 29, 2.5 mi. W of Wadena Downstream of 280th St, 4.5 mi. SW of Wadena	MTS	MTS	--	MTS	--	MTS	MTS	--	EX	FS	NS
07010107-530 ***South Bluff Creek,*** *Unnamed Creek to Unnamed Creek*	11.26	2B	11UM070	Upstream of 610th Ave, 4 mi. SW of Wadena	MTS	MTS	--	--	--	--	--	--	--	FS	NA
07010107-553 ***South Bluff Creek,*** *Unnamed Ditch to Unnamed Creek*	18.94	2B	11UM072	Upstream of 280^{th} St, 5.5 mi. SW of Wadena	EXP	EXP	--	--	--	--	--	--	--	NS	NA

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment;
EXS = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

Table 13. Minnesota Stream Habitat Assessment (MSHA): Ridge Creek watershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
2	11UM070	South Bluff Creek	0	12	16.9	10.5	23.5	62.9	Fair
2	11UM072	South Bluff Creek	0	9.5	9	13.5	13	45	Fair
1	11UM073	Oak Creek	0	12	10	13	21	56	Fair
1	11UM075	Oak Creek	1.25	2	9	13	15	40.25	Poor
Average Habitat Results: ***Ridge Creek subwatershed***			**0.31**	**8.88**	**11.23**	**12.5**	**18.13**	**51.04**	**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)

Table 14. Channel Condition and Stability Assessment (CCSI): Ridge Creek subwatershed.

# Visits	Biological Station ID	Stream Name	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
2	11UM070	South Bluff Creek	10	8	12	3	33	Fairly Stable
2	11UM072	South Bluff Creek	4	15	11	3	33	Fairly Stable
1	11UM073	Oak Creek	9	10	12	3	34	Fairly Stable
1	11UM075	Oak Creek	22	17	26	3	68	Moderately Unstable
Average Stream Stability Results*: Ridge Creek subwatershed*			**11.25**	**12.5**	**15.25**	**3**	**42**	**Fairly Stable**

Qualitative channel stability ratings
= stable: CCSI **< 27** **= fairly stable: 27 < CCSI < 45** **= moderately unstable: 45 < CCSI < 80** **= severely unstable: 80 < CCSI < 115** **= extremely unstable: CCSI > 115**

Table 15. Outlet water chemistry results: Ridge Creek subwatershed.

Station Location:	At Hwy 29, 2.5 mi. W of Wadena, MN							
EQuIS ID:	S001-433							
Station #:	11UM073							
Parameter	Units	# of Samples	Minimum	Maximum	Mean	Median	WQ Standard	# of WQ Exceedances
Ammonia-nitrogen	mg/L	10	0.00	0.00	0.00	0.00	0.04	0
Chloride	mg/L	0					230	
Dissolved oxygen (DO)	mg/L	25	6.2	11.6	8.5	8.4	5.0	0
pH	--	25	7.8	8.7	8.1	8.1	6.5-9.0	0
Transparency, tube with disk	cm	33	96	>100	99	>100	>20	0
Turbidity	FNU	0					25.0 NTU	
Escherichia coli	MPN/100mL	20	36	461	181	152	1260	0
Escherichia coli (geometric mean)	MPN/100mL	36	139	183		174	126	3
Chlorophyll-a, corrected	ug/L	0						
Pheophytin-a	ug/L	0						
Inorganic nitrogen (nitrate and nitrite)	mg/L	10	0.19	2.37	0.91	0.70		
Kjeldahl nitrogen	mg/L	10	0.4	0.9	0.6	0.6		
Phosphorus	ug/L	10	18	56	34	33		
Orthophosphate	ug/L	0						
Total suspended solids	mg/L	10	1.5	15.0	7.0	6.0		
Total volatile solids	mg/L	10	1.0	11.0	4.0	3.0		
Sulfate	mg/L	0						
Specific conductance	uS/cm	25	555	687	615	612		
Temperature, water	deg C	33	3.3	23.8	17.4	18.3		

Summary

The Ridge Creek subwatershed is comprised of two main waterways; Bluff and Oak creeks. Oak Creek has one AUID with two sites (Figure 15), both of which had high F-IBI and M-IBI scores. Interestingly, these high scores correlated with poor (11UM075) and fair (11UM073) MSHA scores (Table 13), indicating that habitat may not be limiting biological communities on this stream.

South Bluff Creek is divided into two AUIDs, each having one site. The upstream AUID (07010107-553) has impaired fish and macroinvertebrates (Table 12). The biological monitoring site (11UM072) had the second lowest MSHA score and the lowest F-IBI and M-IBI scores in the subwatershed. Habitat at the downstream site (11UM070) was better and correlated with high F-IBI and M-IBI scores. Substrate differences indicated by the MSHA scores (Table 13) indicate that finer substrate sediments are present at 11UM072, which is also reflected in the fish species composition. Gravel dwelling species such as blacknose dace and hornyhead chub were sampled at 11UM070 but absent at 11UM072. Pictures from these sites show that both have moderate flow, areas of dense macrophytes, and are located within active pastures. The site location similarities indicate that in-stream habitat differences, specifically the fine substrates at the lower South Bluff Creek site (11UM072), may be limiting the biological communities.

Overall, although the biological communities with this subwatershed received generally high IBI scores, three of the four biological monitoring sites received the worst possible MSHA score for land use within the riparian corridor. In addition, the low substrate scores indicate that fine sediments are present and are settling within these streams, which may be from sources such as stream bank erosion and/or overland runoff. The settling of these sediments may be embedding the coarse substrate and thus eliminating habitat and spawning areas for stream fish.

Stream water quality data were available for Oak Creek from unnamed ditch T134 R36W S3 to 1.4 miles upstream of the Leaf River confluence. This AUID is approximately 14.2 miles long. Water chemistry data were collected near the outlet of the Ridge Creek subwatershed. Oak Creek exceeded the standard for bacteria and is considered impaired for aquatic recreation use. This impairment was based on three geometric mean exceedances (Table 15). No individual sampling event exceeded the water quality standard of 1260 MPN/100ml. Since bacteria can be high at times and moderate or low at other times, recreational use can be limited.

There were no assessable lakes within this subwatershed.

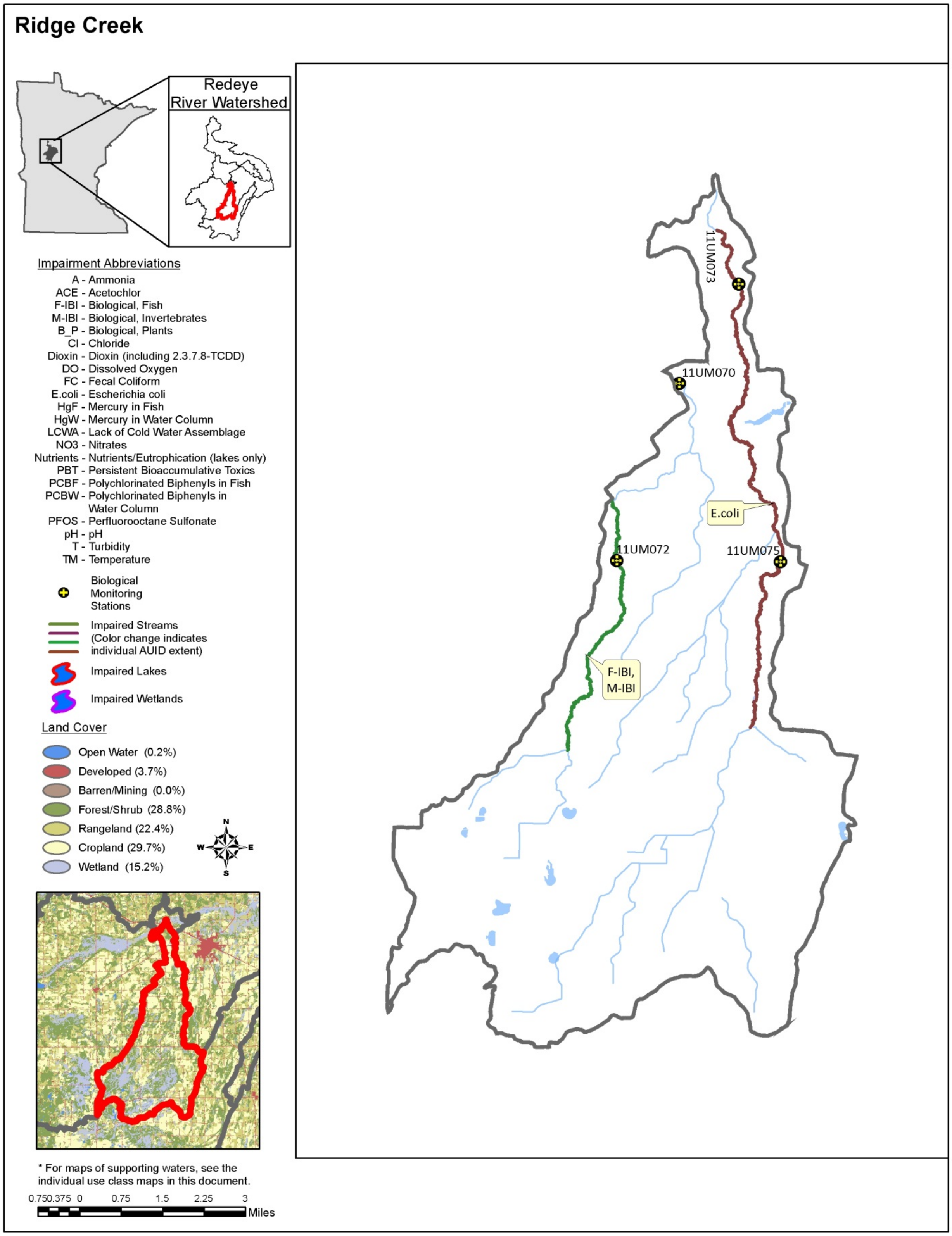

Figure 15. Currently listed impaired waters by parameter and land use characteristics in the Ridge Creek subwatershed

Wing River Watershed Unit HUC 07010107150

The Wing River subwatershed encompasses the southernmost portion of the watershed as well as some of the eastern portion, draining an area of 157.8 square miles. The subwatershed is located in southeastern Otter Tail, extreme northwestern Todd, and southwestern Wadena counties. Within this subwatershed, the Wing River originates in a large wetland area and flows east for approximately 10 miles before turning and flowing north. The river flows through the town of Hewitt on its way to its confluence with the Leaf River, approximately 7 miles northeast of the town of Wadena. The tributaries to the Wing River in this subwatershed include County Ditch 13 and many unnamed creeks and ditches. The most prevalent land use within the watershed is cropland (38%), while forest and rangeland both make up roughly 22% of the landscape, respectively (Figure 16) The water chemistry monitoring station for this watershed unit is represented by the station 11UM076 on the Wing River at County Highway 23, 2.5 miles north of Verndale.

Stream assessments

Table 16. Aquatic life and recreation assessments on assessed AUIDs in the Wing River HUC-11 subwatershed.

AUID *Reach Name* Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
07010107-559 ***Wing River,*** *Headwaters (Wing River Lake 56-0043-00) to Hwy 210 Bridge*	25.17	2B	11UM078 11UM080 13UM183	Upstream of 645th Ave, 4 mi. SW of Bertha Downstream of 578th Ave, 5.5 mi. NE of Parkers Prairie DS of CR 73, 3.2 mi S of Hewitt	EXP	MTS	--	--	--	--	--	--	--	NS	NA
07010107-560 ***Wing River,*** *Hwy 210 Bridge to Leaf River*	23.0	2B	11UM076 11UM077	Downstream of CSAH 23, 2.5 mi. N of Verndale Downstream of 490th St, 1 mi. N of Hewitt	MTS	MTS	IF	MTS	--	MTS	MTS	--	EX	FS	NS

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).
Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support
Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.
*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.
** Aquatic Life assessment and/or impairments for this site have been deferred until the adoption of Tiered Aquatic Life Uses due to the site being predominantly (>50%) channelized.

Table 17. Non-assessed biological stations on channelized AUIDs: Wing River subwatershed.

AUID ***Reach Name,*** *Reach Description*	Reach length (miles)	Use Class	Biological Station ID	Location of Biological Station	Fish IBI	Invert IBI
07010107-549 ***County Ditch 13,*** *North Maple Lake to Wing River*	2.91	2B	11UM079	Upstream of CSAH 42, 6.5 mi. NE of Parkers Prairie	Fair	Fair

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 5.2 and Appendix 5.3 for IBI results.

Table 18. Minnesota Stream Habitat Assessment (MSHA): Wing River subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	11UM076	Wing river	1.75	9.5	8	7	19	45.25	Fair
1	11UM077	Wing River	3	10.5	17.7	13	21	65.2	Fair
1	11UM078	Wing River	4	8.5	20	10	20	62.5	Fair
1	11UM079	County Ditch 13	2.5	11	9	3	1	26.5	Poor
1	11UM080	Wing River	5	11	10	14	17	57	Fair
1	13UM183	Wing River	4	12	18.1	16	28	78.1	Good
Average Habitat Results: *Wing River subwatershed*			**3.375**	**10.42**	**13.8**	**10.5**	**17.67**	**55.76**	**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)

Table 19. Channel Condition and Stability Assessment (CCSI): Wing River subwatershed.

# Visits	Biological Station ID	Stream Name	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11UM078	Wing River	8	6	9	4	27	Fairly Stable
1	11UM080	Wing River	7	5	13	4	29	Fairly Stable
1	11UM077	Wing River	4	9	22	3	38	Fairly Stable
1	11UM076	Wing River	8	7	19	4	38	Fairly Stable
1	11UM079	County Ditch 13	6	7	26	3	42	Fairly Stable
1	13UM183	Wing River	13	19	11	2	45	Fairly Stable
Average Stream Stability Results: *Wing River subwatershed*			**7.6**	**8.8**	**16.6**	**3.3**	**36.5**	**Fairly Stable**

Qualitative channel stability ratings

= stable: CCSI < 27 = fairly stable: 27 < CCSI < 45 = moderately unstable: 45 < CCSI < 80 = severely unstable: 80 < CCSI < 115 = extremely unstable: CCSI > 115

Table 20. Outlet water chemistry results: Wing River subwatershed.

Station Location:	Wing River at CSAH 23, 2.5 mi. N of Verndale, MN							
EQuIS ID:	S002-958							
Station #:	11UM076							
Parameter	Units	# of Samples	Minimum	Maximum	Mean	Median	WQ Standard	# of WQ Exceedances
Ammonia-nitrogen	mg/L	10	0.00	0.00	0.00	0.00	0.04	0
Chloride	mg/L	0					230	
Dissolved oxygen (DO)	mg/L	25	6.5	9.5	7.8	7.8	5.0	0
pH	--	25	7.2	8.3	8.0	8.0	6.5-9.0	0
Transparency, tube with disk	cm	34	40	>100	89	>100	>20	0
Turbidity	FNU	0					25.0 NTU	
Escherichia coli	MPN/100mL	20	71	1203	262	182	1260	0
Escherichia coli (geometric mean)	MPN/100mL	0	195	225		203	126	3
Chlorophyll-a, corrected	ug/L	0						
Pheophytin-a	ug/L	0						
Inorganic nitrogen (nitrate and nitrite)	mg/L	11	<0.03	3.34	1.39	1.33		
Kjeldahl nitrogen	mg/L	10	0.3	1.0	0.6	0.7		
Phosphorus	ug/L	10	0	0	0	0		
Orthophosphate	ug/L	0						
Total suspended solids	mg/L	10	3.0	16.0	8.1	8.0		
Total volatile solids	mg/L	10	1.0	7.0	4.1	3.8		
Sulfate	mg/L	0						
Specific conductance	uS/cm	25	472	659	554	546		
Temperature, water	deg C	34	0.0	25.6	18.1	18.9		

Table 21. Assessable lakes within the Wing River subwatershed.

Name	DNR Lake ID	Area (acres)	Trophic Status	Percent Littoral	Max. Depth (m)	Mean Depth (m)	CLMP Trend	Mean TP (µg/L)	Mean chl-a (µg/L)	Mean Secchi (m)	AQR Support Status	AQL Support Status
West Annalaide	56-0005-00	296	M	100.0	1.2	1.0*		19.0	3.9	1.0	FS	NA
Mary	56-0010-00	256	M	100.0	1.5	1.0*		20.6	3.6	2.1	FS	NA
Horsehead	56-0022-00	193	E	100.0	2.2	1.0*		32.7	11.0	2.3	FS	NA
Adley	56-0031-00	249	E	99.6	6.0	1.5		45.5	23.9	1.8	FS	NA
Unnamed	56-0094-00	23	H					212.0		1.8	IF	NA

Abbreviations:
D -- Decreasing/Declining Trend
I -- Increasing/Improving Trends
NT – No Trend

H – Hypereutrophic
E – Eutrophic
M – Mesotrophic
O - Oligotrophic

FS – Full Support
NS – Non-Support
IF – Insufficient Information

Summary

The Wing River subwatershed is composed of two assessable AUIDs (both on the Wing River) and one non-assessable AUID (County Ditch 13). The Wing River is divided into two AUIDs which are split at the Highway 210 bridge in Hewitt where a dam is located; the downstream AUID (07010107-560) is supporting while the upstream AUID (07010107-559) is non-supporting of aquatic life.

The upstream section of the Wing River has three sites and has an impaired fish community (Table 16). The most upstream site (11UM080) had the highest F-IBI score in the subwatershed while the two downstream sites scored below the thresholds (Appendix 4.2). A macroinvertebrate sample was not taken at 11UM080; however the two downstream sites had good M-IBI scores, both being well above the threshold. MSHA scores did not show any noticeable habitat differences (Table 18) between the sites. However, sample pictures show slow flow, heavy wetland riparian, and dense floating macrophytes across the channel at 11UM080. In contrast, 11UM078 and 13UM183 had stronger flow, nearly absent wetland riparian, some boulders, and fewer floating macrophytes. These stream characteristics may be a contributing factors to the differences in F-IBI scores from upstream to downstream, as well as factors contributing to good M-IBI scores at the two downstream sites (Appendix 4.3). One time water chemistry samples taken at the time of biological sampling showed elevated nitrogen concentrations at 11UM080 (3.81 mg/L) with much lower concentrations at 11UM078 (0.156 mg/L) and 13UM183 (0.344 mg/L).

The two sites on the downstream section of the Wing River fully supported aquatic life. F-IBI and M-IBI scores were somewhat variable with the upstream site (11UM077) having a lower F-IBI but higher M-IBI score than the downstream site (11UM076) (Appendices 4.2 and 4.3). Stream habitats at these sites varied greatly, with 11UM077 having good substrate and cover, where 11UM076 was severely lacking these characteristics (Table 18). However, the poor habitat conditions found at 11UM076 do not appear to limit the biology. Water chemistry samples taken at the time of fish sampling did show elevated nitrogen levels (2.18 mg/L) at 11UM076 versus at 11UM077 (0.236 mg/L).

The dam at Hewitt, although small, potentially prohibits fish passage which in turn effects colonization of fish species upstream within the Wing River and its tributaries. Although the number of fish taxa did not change above or below the dam, the presence of larger, long lived species declined above the dam. Species such as shorthead and silver redhorse were present below the dam but absent above, and although present above the dam, the abundance of white sucker declined above the dam. These findings suggest that the dam in Hewitt is having a negative effect on the ability of fish species to migrate upstream on the Wing River.

Only one tributary to the Wing River was sampled within this subwatershed, making it difficult to draw conclusions about smaller waterways in general. However County Ditch 13 had the lowest M-IBI and second lowest F-IBI scores in the subwatershed. The stream has been channelized and consequently it has a poor MSHA score, due primarily to low MSHA metric scores for fish cover and channel morphology (Table 18).

Stream water quality data were available for the Wing River from the HWY 210 bridge to the Leaf River. This AUID is approximately 23.0 miles long. Water chemistry data were collected near the outlet of the Wing River subwatershed. The Wing River exceeded the standard for bacteria and is considered impaired for aquatic recreation use. This impairment was based on three geometric mean exceedances. No individual sampling event exceeded the water quality standard of 1260 MPN/100ml. Since bacteria can be high at times and moderate or low at other times, recreational use can be limited.

Lakes in this region are typically shallow and have watersheds that primarily consist of cropland and pasture. Four lakes in the Wing River subwatershed had sufficient data for aquatic recreation use assessment (Table 21). West Annalaide, Mary, Horsehead, and Adley lakes were found fully support aquatic recreation, indicating that algal blooms should not impact recreational use. Unnamed 56-0094-00 Lake had high concentrations of phosphorus, but an assessment was not conducted because of insufficient data.

Adley and Horsehead lakes, although fully supporting aquatic recreation, had the highest concentrations of TP, Chl-a, and Secchi of assessed lakes in this subwatershed. Both lakes have development in their lake catchments,; primarily the town of Parkers Prairie. Water quality should be considered prior to further development around these lakes. Mary and West Annalaide Lakes are connected by diffuse wetland systems and discharge through West Annalaide Lake Ditch. Both of these lakes are shallow and have large surface areas and small watersheds. Wind mixing redistributes sediments throughout the water column which causes internal loading of phosphorous. Additional phosphorous loading into these systems should be minimized, particularly since these lakes are susceptible to internal loading of phosphorus, and land use is dominated by cropland and pasture.

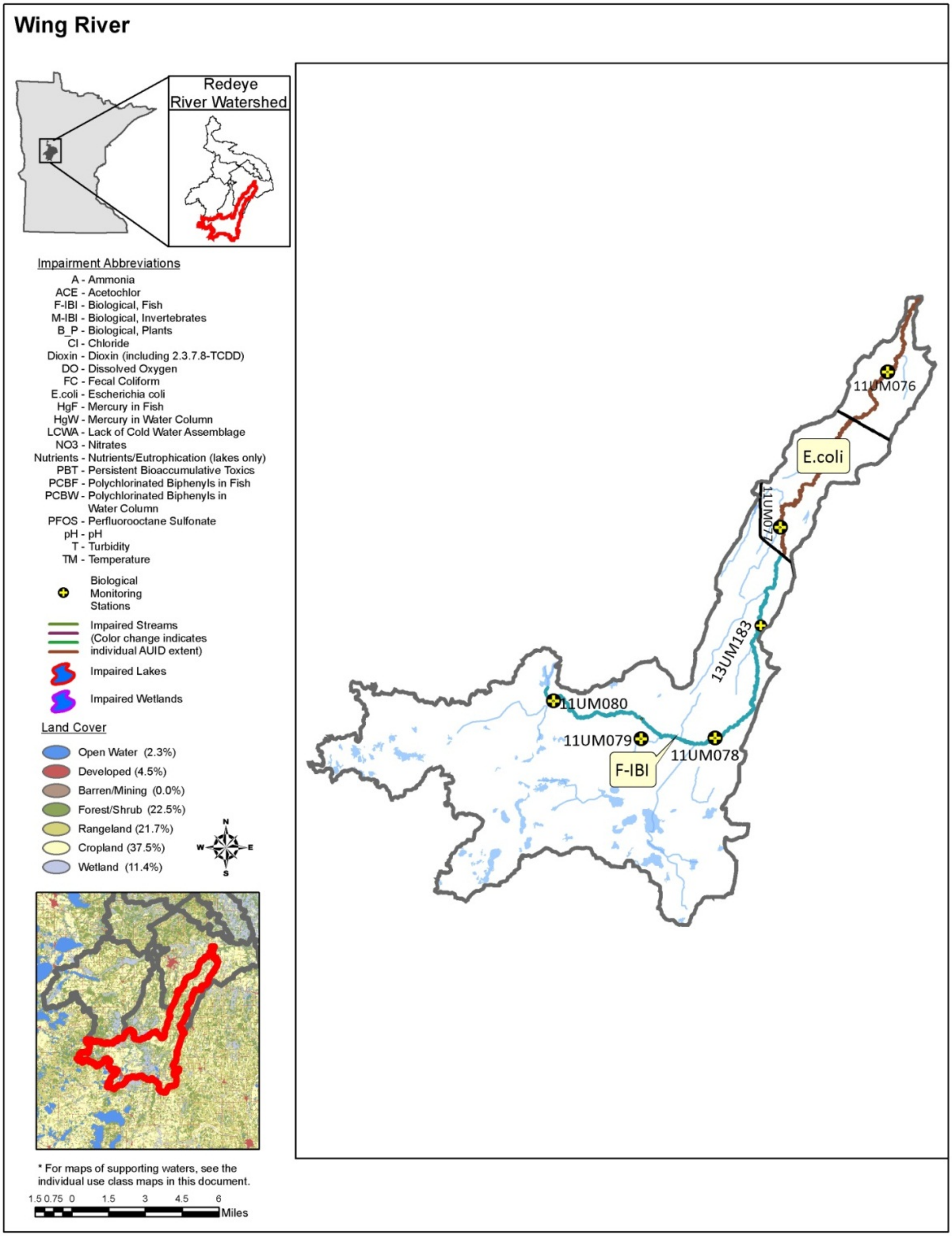

Figure 16. Currently listed impaired waters by parameter and land use characteristics in the Wing River subwatershed

Hay Creek Watershed Unit HUC 07010107160

The Hay Creek subwatershed is located in northwestern and central Wadena County and is the smallest of the watershed units, encompassing an area of 29.2 square miles. Hay Creek is the lone major waterway within the subwatershed, originating two miles southeast of the town of Sebeka and flowing southeast to its confluence with the Leaf River, approximately ten miles northeast of the town of Wadena. The smaller tributaries within this watershed consist of unnamed ditches and creeks. The creek flows through a forest and rangeland dominated landscape, making up 41 and 28% of the subwatershed, respectively (Figure 17). The Hay Creek subwatershed did not have a water chemistry station.

Table 22. Aquatic life and recreation assessments on assessed AUIDs in the Hay Creek HUC-11 subwatershed.

AUID *Reach Name* Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
07010107-513 ***Hay Creek,*** *Headwaters to Redeye River*	17.29	2B	11UM044 11UM045**	Downstream of 204th St, 8.5 mi. NE of Wadena Downstream of 230th St., 5 mi. SE of Sebeka	MTS	MTS	--	MTS	--	--	MTS	--	IF	FS	IF

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

** Aquatic Life assessment and/or impairments for this site have been deferred until the adoption of Tiered Aquatic Life Uses due to the site being predominantly (>50%) channelized.

Table 23. Non-assessed biological stations on channelized AUIDs: Hay Creek subwatershed.

AUID *Reach Name,* Reach Description	Reach length (miles)	Use Class	Biological Station ID	Location of Biological Station	Fish IBI	Invert IBI
07010107-513 ***Hay Creek,*** *Headwaters to Redeye River*	17.29	2B	11UM045	Downstream of 230th St., 5 mi. SE of Sebeka	Fair	NA

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 5.2 and Appendix 5.3 for IBI results.

Table 24. Minnesota Stream Habitat Assessment (MSHA): Hay Creek subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	11UM044	Hay Creek	3.75	12	8	3	23	49.75	Fair
1	11UM045	Hay Creek	3.75	11	12	14	12	52.75	Fair
Average Habitat Results: *Hay Creek subwatershed*			**3.75**	**11.5**	**10**	**8.5**	**17.5**	**51.25**	**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)

Table 25. Channel Condition and Stability Assessment (CCSI): Hay Creek subwatershed.

# Visits	Biological Station ID	Stream Name	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11UM044	Hay Creek	4	15	6	1	26	Stable
Average Stream Stability Results: *Hay Creek subwatershed*			**4**	**15**	**6**	**1**	**26**	**Stable**

Qualitative channel stability ratings

= stable: CCSI < 27 = fairly stable: 27 < CCSI < 45 = moderately unstable: 45 < CCSI < 80 = severely unstable: 80 < CCSI < 115 = extremely unstable: CCSI > 115

Summary

Given its small size and lack of significant tributaries, only two sites were sampled within the Hay Creek subwatershed, both of which were located on the Hay Creek mainstem (Figure 17). Although the upstream site (11UM045) was channelized, it had a higher MSHA score, specifically better fish cover, however a significantly lower F-IBI score than the downstream site (11UM044) (Table 24). Macroinvertebrates were not sampled at 11UM045, thus comparisons between the two sites were not able to be made, although the M-IBI at 11UM044 scored at its respective threshold. One-time water chemistry samples taken during fish sampling did not show any concentrations that would affect biological communities.

There was no water chemistry station nor any assessable lakes located within the Hay Creek subwatershed.

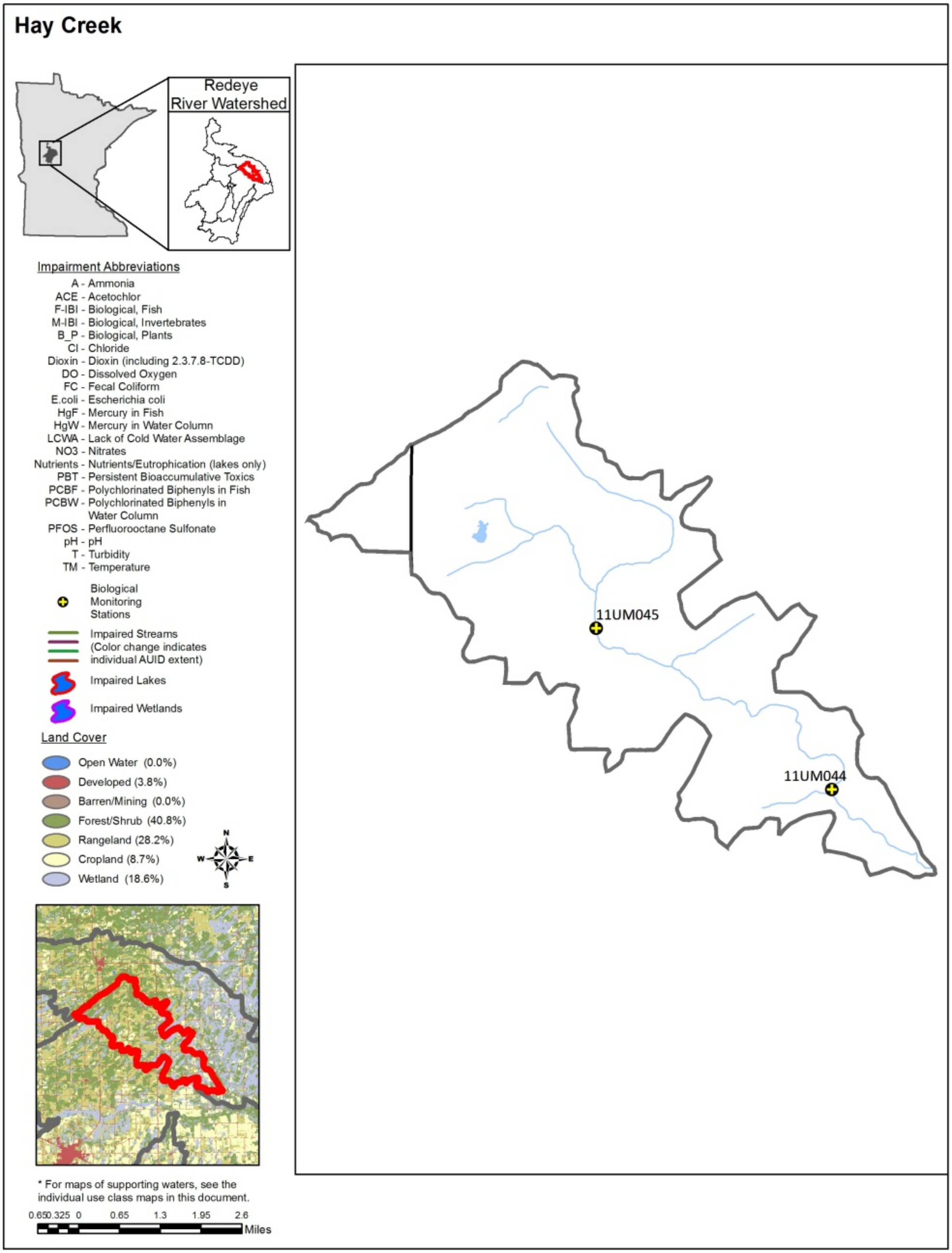

Figure 17. Currently listed impaired waters by parameter and land use characteristics in the Hay Creek subwatershed

Redeye River Watershed Unit HUC 07010107170

The Redeye River subwatershed begins at Wolf Lake in southeastern Becker County and encompasses 200.9 square miles. From here it flows south into northeastern Otter Tail County then southeast into central Wadena County. Tributaries within the subwatershed include County Ditch 27, Cat and Hay Creeks, and many unnamed ditches and creeks. Land use within the subwatershed is largely forested (41%) but also has rangeland and wetlands making up 24 and 20% of the landscape, respectively (Figure 8). The water chemistry monitoring station for this watershed is represented by station 11UM043 on the Redeye River at 221st Ave, eight miles northeast of Verndale.

Stream assessments

Table 26. Aquatic life and recreation assessments on assessed AUIDs in the Redeye River HUC-11 subwatershed.

AUID *Reach Name* Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators:								Bacteria	Aquatic Life	Aquatic Rec.
					Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides			
07010107-502 ***Redeye River,*** *Hay Creek to Leaf River*	3.32	2B	10EM198 11UM043	Upstream of CR 26, 3 mi. N of Central Downstream of 221st Ave, 8 mi. NE of Verndale	MTS	MTS	MTS ***	MTS	--	MTS	MTS	--	IF	FS	IF
07010107-503 ***Redeye River,*** *Headwaters (Wolf Lake 03-0101-00) to Hay Creek*	62.88	2B	10EM022 11UM046 11UM048 11UM051 11UM052**	N (downstream) of Hwy 227, 2.5 mi. E of Sebeka Downstream CR 164, 8 mi. SE of Sebeka Upstream of 290th St, 1.5 mi. NW of Sebeka Downstream of 555th Ave, 11 mi. NW of Sebeka Upstream of CSAH 36, 3.5 mi. NE of Evergreen	MTS	MTS	MTS ***	MTS	--	MTS	MTS	--	EX	FS***	NS
07010107-539 ***Unnamed Creek,*** *Unnamed Creek to Redeye River*	0.38	2B	--	--	--	--	--	MTS	--	--	MTS	--	MTS	NA	FS

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment;
EXS = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).
Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support
Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.
*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.
** Aquatic Life assessment and/or impairments for this site have been deferred until the adoption of Tiered Aquatic Life Uses due to the site being predominantly (>50%) channelized.
*** Data collected after the 2013 assessments cycle was considered in making this assessment decision, it should be considered unofficial until the 2014 assessment cycle.

Table 27. Non-assessed biological stations on channelized AUIDs: Redeye River subwatershed.

AUID *Reach Name*, *Reach Description*	Reach length (miles)	Use Class	Biological Station ID	Location of Biological Station	Fish IBI	Invert IBI
07010107-503 ***Redeye River,*** *Headwaters (Wolf Lake 03-0101-00) to Hay Creek*	62.88	2B	11UM052	Upstream of CSAH 36, 3.5 mi. NE of Evergreen	Good	Poor

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 5.2 and Appendix 5.3 for IBI results.

Table 28. Minnesota Stream Habitat Assessment (MSHA): Redeye River subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	10EM022	Redeye River	3.25	14	19.15	14	24	74.74	Good
1	10EM198	Redeye River	3.75	12	17.5	14	20	67.25	Good
1	11UM043	Redeye River	2.5	8	20.6	13	21	65.1	Fair
1	11UM046	Redeye River	4	10	16.2	12	20	62.2	Fair
1	11UM048	Redeye River	3.75	10.5	18	16	24	72.25	Good
1	11UM051	Redeye River	4.5	10.5	14	14	19	62	Fair
1	11UM052	Redeye River	4	12	9	9	12	46	Fair
Average Habitat Results: *Redeye River subwatershed*			**3.68**	**11**	**16.35**	**13.14**	**20**	**64.17**	**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)

Table 29. Channel Condition and Stability Assessment (CCSI): Redeye River subwatershed.

# Visits	Biological Station ID	Stream Name	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11UM051	Redeye River	5	7	6	5	23	Stable
1	11UM048	Redeye River	10	8	6	4	28	Fairly Stable
1	11UM052	Redeye River	5	15	7	5	32	Fairly Stable
1	11UM043	Redeye River	8	10	16	3	37	Fairly Stable
1	11UM046	Redeye River	17	26	25	3	71	Moderately Unstable
Average Stream Stability Results: *Redeye River subwatershed*			**9**	**13.2**	**12**	**4**	**38.2**	**Fairly Stable**

Qualitative channel stability ratings

= stable: CCSI < 27 = fairly stable: 27 < CCSI < 45 = moderately unstable: 45 < CCSI < 80 = severely unstable: 80 < CCSI < 115 = extremely unstable: CCSI > 115

Table 30. Outlet water chemistry results: Redeye River subwatershed.

Station Location:	At 221st Ave, 8 mi. NE of Verndale, MN							
EQuIS ID:	S006-848							
Station #:	11UM043							
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**Median**	**WQ Standard**	**# of WQ Exceedances**
Ammonia-nitrogen	mg/L	10	0.00	0.00	0.00	0.00	0.04	0
Chloride	mg/L	0					230	
Dissolved oxygen (DO)	mg/L	25	6.1	9.4	7.5	7.3	5.0	0
pH	--	25	7.6	8.4	8.0	8.1	6.5-9.0	0
Transparency, tube with disk	cm	34	68	>100	97	>100	>20	0
Turbidity	FNU	0					25.0 NTU	
Escherichia coli	MPN/100mL	20	46	219	105	96	1260	0
Escherichia coli (geometric mean)	MPN/100mL	36	97	131		119	126	1
Chlorophyll-a, corrected	ug/L	0						
Pheophytin-a	ug/L	0						
Inorganic nitrogen (nitrate and nitrite)	mg/L	10	<0.03	2.98	0.35	0.05		
Kjeldahl nitrogen	mg/L	10	0.3	0.9	0.7	0.7		
Phosphorus	ug/L	10	24	89	64	68		
Orthophosphate	ug/L	0						
Total suspended solids	mg/L	10	0.0	7.0	3.4	3.5		
Total volatile solids	mg/L	10	0.0	5.0	2.4	2.5		
Sulfate	mg/L	0						
Specific conductance	uS/cm	25	329	522	458	469		
Temperature, water	deg C	34	3.3	23.3	17.7	18.5		

Table 31. Assessable lakes within the Redeye River subwatershed.

Name	DNR Lake ID	Area (acres)	Trophic Status	Percent Littoral	Max. Depth (m)	Mean Depth (m)	CLMP Trend	Mean TP (µg/L)	Mean chl-a (µg/L)	Mean Secchi (m)	AQR Support Status	AQL Support Status
Wolf	03-0101-00	1,453	M	100.0	4.3	1.9		22.6	6.4	2.0	FS	IF
Bear	56-0069-00	217	E	66.3	9.9	3.1		25.9	10.9	2.4	FS	NA
Edna	56-0070-00	131	M	100.0	1.9	1.3		17.5	4.1	1.2	FS	NA
Mud	56-0132-00	155	M	100.0	1.7	1.0*		21.2	5.5	1.3	FS	NA

Abbreviations:
D -- Decreasing/Declining Trend
I -- Increasing/Improving Trends
NT – No Trend

H – Hypereutrophic
E – Eutrophic
M – Mesotrophic
O - Oligotrophic

FS – Full Support
NS – Non-Support
IF – Insufficient Information

Summary

All biological sites within the Redeye River subwatershed are located on the Redeye River mainstem. The Redeye River is divided into two assessable AUIDs at the Hay Creek confluence. The upstream AUID (07010107-503) is nearly 63 miles long and has five biological sites, while the downstream AUID (07010107-502) is roughly three miles long and has two sites. The biological indicators for both AUIDs meet standards and thus both fully support aquatic life (Table 26).

Both fish and macroinvertebrate communities on the Redeye River were positively correlated with stream habitat. Site 11UM052 (near the headwaters) was the lone channelized site in this subwatershed. The site had the lowest MSHA score (Table 28), specifically for substrate, fish cover, and channel morphology, and the lowest F-IBI and M-IBI scores. All remaining sites had high MSHA scores, especially for substrate and fish cover which resulted in all F-IBI and M-IBI scores meeting their respective thresholds, at times by wide margins (Appendix 4.2). The number of fish species sampled at each site was similarly correlated, as only nine species were found at 11UM052, but between 17 and 22 species were sampled at the remaining sites, respectively (Appendix 8). Included in these high species samples were several sensitive taxa such as hornyhead chub, northern redbelly dace, and Iowa darter. These data suggest that biological communities are thriving where good habitat and natural conditions exist, versus altered conditions and/or poor habitat. Future plans should be made to protect the quality habitat in and around the Redeye River to ensure healthy aquatic biological communities. One time water chemistry samples taken at all sites during biological monitoring did not show any elevated nutrient levels.

Stream water quality data were available for the Redeye River from Hay Creek to the Leaf River. Water chemistry data were collected near the outlet of the Redeye River subwatershed. The Redeye River exceeded the standard for bacteria based on one geometric mean exceedance which was slightly above the standard (Table 30). As a result this reach was not listed as impaired for aquatic recreation. More bacteria data will need to be collected in order to determine if an actual impairment is present. No individual sampling event exceeded the water quality standard of 1260 MPN/100ml. Since data shows bacteria levels are typically low aquatic recreation use is likely not in need of limitation.

Dissolved oxygen levels taken in 2010 and 2011 showed a short period in mid-summer where readings on the Redeye River (AUID 07010107-503) were occasionally below state standards. Continuous dissolved oxygen data from July 2 through July 24, 2013 contradicted the earlier grab samples indicating that the dissolved oxygen levels did not drop below the state standard during this time frame. The continuous dissolved oxygen readings from 2013 were considered more reliable and representative of the stream. As a result, both AUIDs meet dissolved oxygen standards and fully support aquatic life. These changes however must be considered unofficial until the 2014 assessment cycle is completed.

Lakes in this region are typically shallow and have watersheds that primarily consist of forest, cropland, and pasture. Four lakes in the Redeye River subwatershed had sufficient data for aquatic recreation use assessment (Table 31). All four, Wolf, Bear, Edna, and Mud lakes, were found to fully support aquatic recreation use, indicating that algal blooms should not impact recreational opportunities on these lakes.

Wolf Lake is located in the northern portion of the subwatershed and serves as the headwaters for the Redeye River. Wolf Lake has a large surface area and is shallow. The catchment is mostly forested with a mixture of cropland and pasture. Best land management practices need to be promoted to limit nutrient inputs in order to maintain current water quality conditions in Wolf Lake. Edna and Mud lakes are small shallow lakes with small contributing lake catchments. Bear Lake has a larger catchment and in turn had the lowest concentrations of TP and Chl-a, and Secchi of assessed lakes in this subwatershed. Bear Lake is considerably deeper than the other assessed lakes in this watershed; however, the lake does have a long fetch, which could allow for wind mixing (promoting internal phosphorus loading) during the summer months. Forested areas along these lakes serve as a buffer for excess nutrients entering the lake during runoff events. It is critical that these natural areas are protected in order to maintain good water quality.

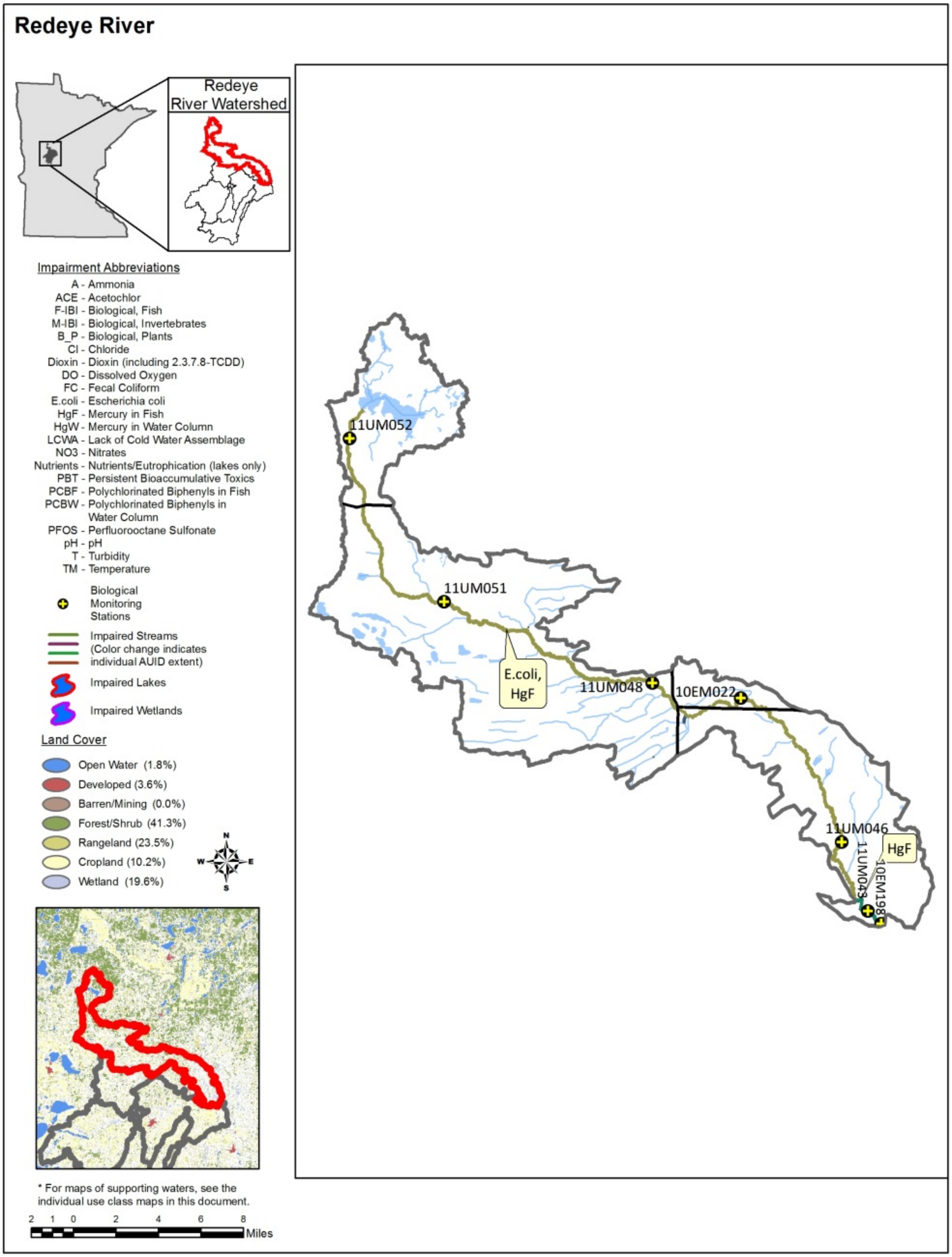

Figure 18. Currently listed impaired waters by parameter and land use characteristics in the Redeye River subwatershed

Lower Leaf River Watershed Unit HUC 07010107180

The horseshoe shaped Lower Leaf River subwatershed is located in the east-central portion of the watershed. The 167.9 square mile subwatershed encompasses portions of eastern Otter Tail, southwestern Wadena, and northwestern Todd counties. The Leaf River flows eastward until its confluence with the Redeye River. The river then turns south where it enters the Crow Wing River approximately 15 miles east of Wadena. Tributaries within the subwatershed include Union, Hay, and Whisky creeks, and many unnamed ditches and creeks. Land use within the subwatershed is largely a mix of three types: Cropland (30%), Forest (25%), and Range (25%) (Figure 19). The water chemistry monitoring station for this subwatershed is represented by outlet station 11UM040 on the Leaf River at County Highway 29, seven miles northwest of Staples.

Stream assessments

Table 32. Aquatic life and recreation assessments on assessed AUIDs in the Lower Leaf River HUC-11 subwatershed.

AUID *Reach Name*, *Reach Description*	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
07010107-501 ***Leaf River,*** *Leaf River to Crow Wing River*	8.18	2B	11UM040	Downstream of CSAH 29, 7 mi. NW of Staples	MTS	--	MTS	MTS	--	MTS	MTS	--	MTS	FS	FS
07010107-504 ***Leaf River,*** *Wing River to Redeye River*	7.38	2B	11UM042	Upstream of CSAH 26, 8 mi. N of Aldrich	MTS	MTS	MTS	MTS	--	MTS	MTS	--	MTS	FS	FS
07010107-505 ***Leaf River,*** *Oak Creek to Wing River*	16.28	2B	11UM053	Upstream of 180th St, 7 mi. NE of Wadena	MTS	MTS	EXS ***	MTS	--	--	MTS	--	EX	NS	NS
07010107-508 ***Union Creek,*** *Whisky Creek to Leaf River*	4.84	2A	00UM095** 13UM177	Downstream of 150th St., DS of Wadena WWTP Downstream of Alfred Road NE, 0.5 mi NE of Wadena	NS ***	NS ***	EXS ***	MTS	--	--	MTS	--	EX	NS	NS
07010107-509 ***Union Creek,*** *Headwaters to Whisky Creek*	6.79	2A	13UM176	Upstream of Colfax Ave. SE in Wadena	MTS	NS ***	--	--	--	--	--	--	--	NS	NA
07010107-526 ***Trib. to Redeye River,*** *T134 R33W S18, West Line to Leaf River*	5.89	2A	11UM041	Upstream of CR 123, 5.5 mi. NW of Staples	NA*	NA*	IF	MTS	--	--	MTS	--	EX	IF	NS
07010107-557 ***Trib. to Leaf River,*** *Unnamed Creek to Leaf River*	2.44	2B	11UM055	Upstream of CSAH 75, 3 mi. NW of Wadena	MTS	EXS	--	--	--	--	--	--	--	NS	NA

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

** Aquatic Life assessment and/or impairments for this site have been deferred until the adoption of Tiered Aquatic Life Uses due to the site being predominantly (>50%) channelized.

*** Data collected after the 2013 assessments cycle was considered in making this assessment decision, it should be considered unofficial until the 2014 assessment cycle.

Table 33. Non-assessed biological stations on channelized AUIDs: Lower Leaf River subwatershed.

AUID ***Reach Name,*** *Reach Description*	Reach length (miles)	Use Class	Biological Station ID	Location of Biological Station	Fish IBI	Invert IBI
07010107-508 ***Union Creek,*** *Whisky Creek to Leaf River*	4.84	2A	00UM095	Downstream of 150th St., DS of Wadena WWTP	Poor	Fair
07010107-526 ***Trib. to Leaf River*** *T134 R33W S18, West Line to Leaf River*	5.89	2A	11UM041	Upstream of CR 123, 5.5 mi. NW of Staples	Good	Fair

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 5.2 and Appendix 5.3 for IBI results.

Table 34. Minnesota Stream Habitat Assessment (MSHA): Lower Leaf River subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	00UM095	Union Creek	2.5	8.5	8	14	7	40	Poor
1	11UM040	Leaf River	2.75	10.5	14	12	23	62.25	Fair
1	11UM041	Trib. to Leaf River	2.5	10	14	11	23	60.5	Fair
1	11UM042	Leaf River	1.25	14	18	14	24	71.25	Good
1	11UM053	Leaf River	2.5	15	8	9	17	51.5	Fair
1	11UM055	Trib. To Leaf River	1.5	4.5	23.7	13	30	72.7	Good
1	13UM177	Union Creek	0.5	13	16	16	17	62.5	Fair
1	13UM176	Union Creek	0	9	12	13	15	49	Fair
Average Habitat Results: *Lower Leaf River subwatershed*			**1.68**	**10.56**	**14.21**	**12.75**	**19.5**	**58.71**	**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)

Table 35. Channel Condition and Stability Assessment (CCSI): Lower Leaf River subwatershed.

# Visits	Biological Station ID	Stream Name	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11UM042	Leaf River	8	5	4	5	22	Stable
1	11UM041	Trib. to Redeye River	4	5	11	5	25	Stable
1	11UM055	Trib. to Leaf River	10	9	4	4	27	Stable
1	11UM040	Leaf River	12	12	14	3	41	Fairly Stable
1	00UM095	Union Creek	14	14	14	3	45	Moderately Unstable
1	11UM053	Leaf River	12	16	30	4	62	Moderately Unstable
1	13UM176	Union Creek	12	22	17	2	53	Moderately Unstable
1	13UM177	Union Creek	9	22	20	3	54	Moderately Unstable
Average Stream Stability Results: *Lower Leaf River subwatershed*			**10.13**	**18.75**	**14.25**	**3.63**	**41.13**	**Fairly Stable**

Qualitative channel stability ratings

= stable: CCSI < 27 = fairly stable: 27 < CCSI < 45 = moderately unstable: 45 < CCSI < 80 = severely unstable: 80 < CCSI < 115 = extremely unstable: CCSI > 115

Table 36. Outlet water chemistry results: Lower Leaf River subwatershed.

Station Location:	At CSAH 29, 7 mi. NW of Staples, MN							
EQuIS ID:	S001-931							
Station #:	11UM040							
Parameter	Units	# of Samples	Minimum	Maximum	Mean	Median	WQ Standard	# of WQ Exceedances
Ammonia-nitrogen	mg/L	10	0.00	0.01	0.00	0.00	0.04	0
Chloride	mg/L	0					230	
Dissolved oxygen (DO)	mg/L	25	5.7	9.4	7.5	7.5	5.0	0
pH	--	25	7.6	8.4	8.0	8.1	6.5-9.0	0
Transparency, tube with disk	cm	34	66	>100	97	>100	>20	0
Turbidity	FNU	0					25.0 NTU	
Escherichia coli	MPN/100mL	20	34	162	86	79	1260	0
Escherichia coli (geometric mean)	MPN/100mL	46	64	86		84	126	0
Chlorophyll-a, corrected	ug/L	19	0.0	5.0	2.2	2.0		
Pheophytin-a	ug/L	19	0.0	2.0	1.0	1.0		
Inorganic nitrogen (nitrate and nitrite)	mg/L	12	0.09	1.24	0.65	0.66		
Kjeldahl nitrogen	mg/L	19	0.3	0.9	0.6	0.6		
Phosphorus	ug/L	19	34	590	90	60		
Orthophosphate	ug/L	0						
Total suspended solids	mg/L	10	1.0	8.0	4.6	3.8		
Total volatile solids	mg/L	10	1.0	5.0	2.6	2.5		
Sulfate	mg/L	0						
Specific conductance	uS/cm	25	383	576	510	516		
Temperature, water	deg C	34	2.2	25.8	18.6	18.5		

Summary

The Lower Leaf River subwatershed is the most downstream subwatershed before the confluence with the Crow Wing River. The Leaf River mainstem consists of three AUIDs. The most upstream AUID (07010107-505) begins in the eastern portion of the Upper Leaf River subwatershed and continues through half of the Lower Leaf River subwatershed. Dissolved oxygen (DO) sampling in 2011 found several readings near the impairment threshold so further testing was performed. Results from 2013 concluded that this stretch of the Leaf River was in fact impaired due to low DO and thus has an impairment of aquatic life use (Table 32). The impairment decision is not official until the 2014 assessments are completed. The DO concentrations recover downstream of AUID -505 and are not considered to be impaired.

Despite the upstream DO impairment, fish communities within the Leaf River all score above the upper confidence limit. The F-IBI and MSHA scores showed a positive relationship with the highest F-IBI score (89) correlating with the highest MSHA score (71), and the lowest F-IBI score (57) correlating with the lowest MSHA score (51) (Table 34 and Appendix 4.2). Several sensitive species were found in the Leaf River including hornyhead chub, mottled sculpin, burbot, and longnose dace. In addition, many larger bodied, longer lived species were found as well including greater and shorthead redhorse, walleye, and white sucker. A macroinvertebrate sample was not taken at 11UM040, however communities at 11UM042 and 11UM053 did not fare as well as the fish, scoring at or slightly below the threshold, respectively (Appendix 4.2). Overall, fish abundance on the Leaf River appears to be dependent on good habitat while macroinvertebrate communities, though not impaired, do not appear to thrive as well, even where good habitat conditions exist.

Union Creek is classified as a coldwater stream and is divided into two assessable AUIDs, with a total of three sites. The AUIDs are divided at Whisky Creek where the Wadena Wastewater Treatment Plant (WWTP) discharge enters the stream. The fish communities are slightly above the threshold at the most upstream site (13UM176), however the biological condition declines downstream of the WWTP with the higher abundance of tolerant species such as bullheads and northern pike. Macroinvertebrate communities at all sites are impaired. Habitat in and along Union Creek may be a contributing factor to the poor biological communities as all sites scored poorly for land use and channel morphology (Table 34). Nutrient concentrations are elevated downstream of the WWTP. Upstream of the WWTP, 13UM176 had a nitrogen concentration of 1.37 mg/L, where downstream of the WWTP had higher concentrations of 2.18 mg/L (00UM095) and 2.3 mg/L (13UM177), respectively. Total Phosphorus results were similar with 13UM176 being 0.039 mg/L, 00UM095 being 0.18 mg/L, and 13UM177 having a 0.157 mg/L concentrations. Overall, biological communities within Union Creek are in poor condition, specifically downstream of the WWTP. A combination of the poor surrounding land use practices and the discharge from the Wadena WWTP may be having a negative effect on the biological communities.

The two smaller tributaries sampled within this subwatershed both had results similar to the Leaf River mainstem sites, with F-IBI scores well above their respective thresholds and M-IBI scores slightly below the thresholds (Appendices 4.2 and 4.3). Both sites had high MSHA scores, specifically for channel morphology and fish cover (Table 34) and also had CCSI ratings of stable (Table 35). Factors other than habitat appear to be limiting the macroinvertebrate communities within these tributary streams.

Stream water quality data were available for the Leaf River from the Redeye River to the Wing River. This AUID is approximately eight miles long. Water chemistry data were collected near the outlet of the Lower Leaf River subwatershed. The Leaf River meets the standard for bacteria and fully supports aquatic recreation. Bacteria data had no geometric mean exceedances or individual sampling event exceedances of the water quality standard of 1260 MPN/100ml (Table 36). Levels of bacteria in this reach were low, suggesting that bacteria should not limit recreational use.

There were no assessable lakes within this subwatershed.

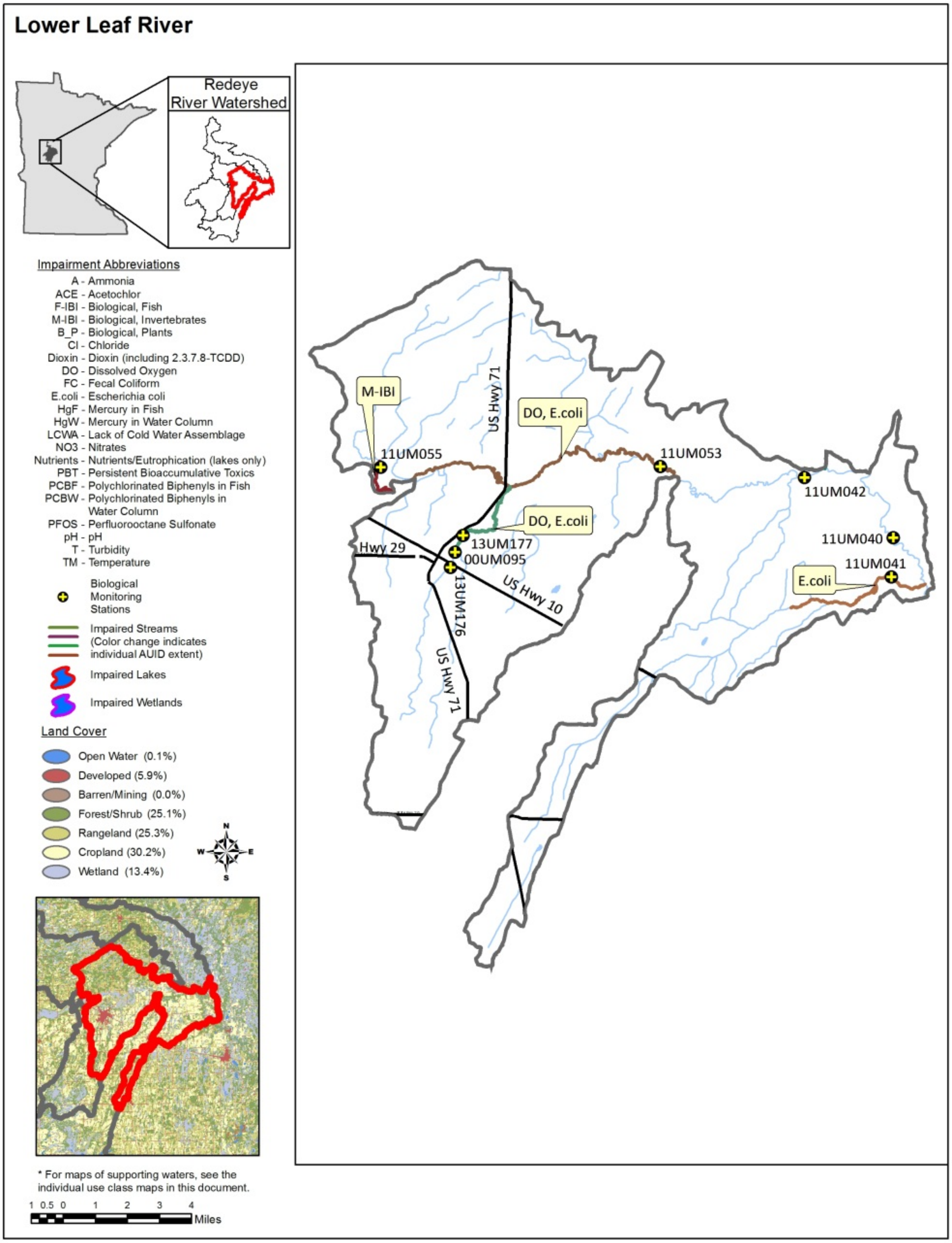

Figure 19. Currently listed impaired waters by parameter and land use characteristics in the Lower Leaf River subwatershed

VI. Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire HUC-8 Redeye River Watershed, grouped by sample type. Summaries are provided for load monitoring data results near the mouth of the Leaf River, for aquatic life and recreation uses in streams and lakes throughout the watershed, and for aquatic consumption results at select river and lake locations along the watershed. Additionally, groundwater monitoring results and long-term monitoring trends 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 Redeye River Watershed.

Watershed Pollutant Load Monitoring Network

A long term WPLMN station is located at the Leaf River crossing on Highway 29 north of Staples. Many years of water quality data from throughout Minnesota combined with previous analysis of Minnesota's ecoregion patterns, resulted in the development of three "River Nutrient Regions" (RNR), each with unique nutrient standards (MPCA, 2008). Of the state's three RNRs (North, Central, South), the Red Eye River's load monitoring station is located within the Central RNR.

Annual FWMCs were calculated and compared for years 2009-2011 (Figure 20, Figure 21, Figure 22, and Figure 23) and compared to the RNR standards (only TP and TSS draft standards are available for the Central RNR). It should be noted that while a FWMC exceeding given water quality standard is generally a good indicator the water body is out of compliance with the RNR standard, the rule does not always hold true. Waters of the state are listed as impaired based on the percentage of individual samples exceeding the numeric standard, generally 10% and greater, over the most recent 10 year period and not based on comparisons with FWMCs (MPCA, 2012). A river with a FWMC above a water quality standard, for example, would not be listed as impaired if less than 10% of the individual samples collected over the assessment period were above the standard.

Pollutant sources affecting rivers are often diverse and can be quite variable from one watershed to the next depending on land use, climate, soils, slopes, and other watershed factors. However, as a general rule, elevated levels of TSS and nitrate plus nitrite-nitrogen (nitrate-N) are generally regarded as "non-point" source derived pollutants originating from many small diffuse sources such as urban or agricultural runoff. Excess TP and DOP can be attributed to either "non-point" as well as "point", or end of pipe, sources such as industrial or waste water treatment plants. Major "non-point" sources of phosphorus include dissolved phosphorus from fertilizers and phosphorus adsorbed to and transported with sediment during runoff.

Within a given watershed, pollutant sources and source contributions can also be quite variable from one runoff event to the next depending on factors such as canopy development, soil saturation level, and precipitation type and intensity. Surface erosion and in-stream sediment concentrations, for example, will typically be much higher following high intensity rain events prior to canopy development, rather than after low intensity post-canopy events where less surface runoff and more infiltration occur. Precipitation type and intensity influence the major course of storm runoff, routing water through several potential pathways including overland, shallow and deep groundwater, and/or tile flow. Runoff pathways along with other factors determine the type and levels of pollutants transported in runoff to receiving waters and help explain between-storm and temporal differences in FWMCs and loads, barring differences in total runoff volume. During years when high intensity rain events provide the greatest proportion of total annual runoff, concentrations of TSS and TP tend to be higher with DOP and nitrate-N concentrations tending to be lower. In contrast, during years with high snow melt runoff and less intense rainfall events, TSS levels tend to be lower while TP, DOP, and nitrate-N levels tend to be elevated. In many cases, it is a combination of climatic factors from which the pollutant loads are derived.

Total suspended solids

Water clarity refers to the transparency of water. 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. By definition, turbidity is caused primarily by suspension of particles that are smaller than one micron in diameter in the water column.

Analysis has shown a strong correlation to exist between the measures of TSS and turbidity. The greater the level of TSS, the murkier the water appears and the higher the measured turbidity. High turbidity results in reduced light penetration that harms beneficial aquatic species and favors undesirable algae species (MPCA and MSUM, 2009). An overabundance of algae can lead to increases in turbidity, further compounding the problem. Periods of high turbidity often occur when heavy rains fall on unprotected soils. Upon impact, raindrops dislodge soil particles and overland flow transports fine particles of silt and clay into rivers and streams (MPCA and MSUM, 2009).

Currently, the state of Minnesota's TSS standards are in development and must be considered draft standards until approved. Within the Central RNR, the river would be considered impaired when greater than 10% of the individual samples exceed the TSS draft standard of 30 mg/L (MPCA, 2011). Calculations from 2009 through 2011 show 0, 3, and 0% of the individual TSS samples exceeded the 30 mg/L draft standard, respectively. In addition, the computed FWMCs for the three sampling years were well below the 30 mg/L draft standard (Figure 20). Although the data may not reflect long-term trends, neither TSS FWMCs nor loads showed a trend while annual loads showed an increase from 2009 to 2010 but drastically decline in 2011 (Figure 20 and Table 37). Often, there is a strong correlation between pollutant loads and annual runoff volume; the differences may be due strictly to differences in annual runoff volume (Figure 12).

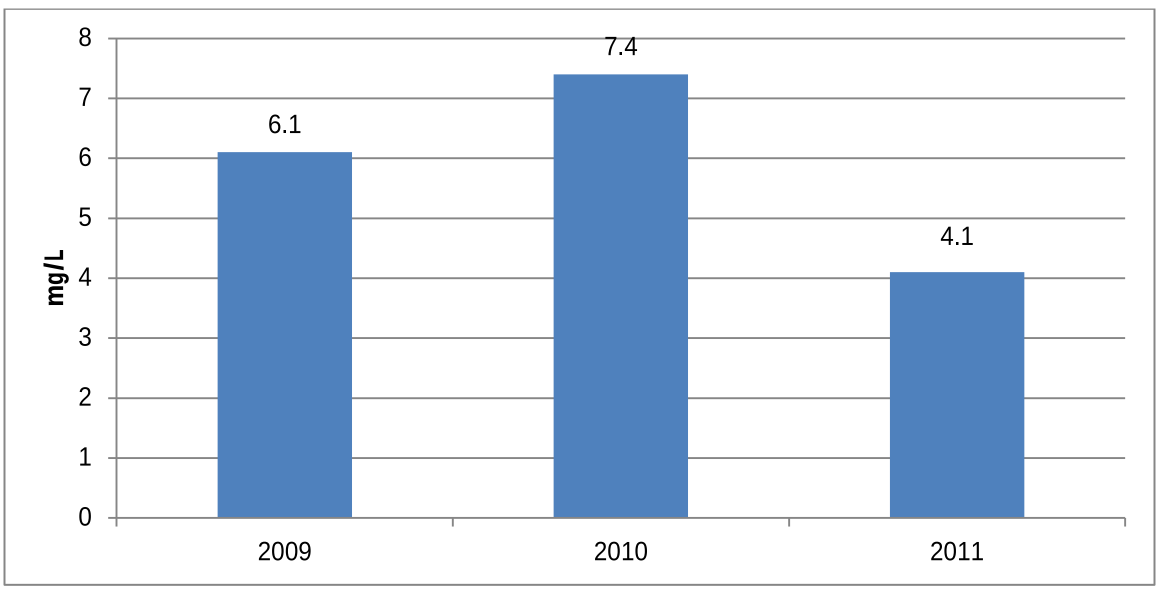

Figure 20. Total Suspended Solids (TSS) flow weighted mean concentrations for the Leaf River near Staples

Table 37. Annual pollutant loads by parameter calculated for the Red Eye River watershed.

	2009	2010	2011
Parameter	**Mass (kg)**	**Mass (kg)**	**Mass (kg)**
Total Suspended Solids	3,188,845	3,823,519	1,952,640
Total Phosphorus	40,421	48,240	28,614
Ortho Phosphorus	19,700	22,381	14,628
Nitrate + Nitrite Nitrogen	443,597	254,863	263,893

Total phosphorus

Nitrogen, phosphorus, and potassium are essential macronutrients and are required for growth by all animals and plants. Lack of sufficient nutrient levels in surface water often restricts the growth of aquatic plant species (University of Missouri Extension, 1999). In freshwaters such as lakes and streams, phosphorus is typically the nutrient limiting growth; increasing the amount of phosphorus entering a stream or lake will increase the growth of aquatic plants and other organisms. Although phosphorus is a necessary nutrient, excessive levels overstimulate aquatic growth in lakes and streams resulting in reduced water quality. The progressive deterioration of water quality from overstimulation of nutrients is called eutrophication where, as nutrient concentrations increase, the surface water quality is degraded (University of Missouri Extension, 1999). Elevated levels of phosphorus in rivers and streams 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 (University of Missouri Extension, 1999). In non-point source dominated watersheds, TP concentrations are strongly correlated with stream flow. During years of above average precipitation, TP loads are generally highest.

Total phosphorus standards for Minnesota's rivers are also in development and must be considered draft standards until approved. Within the Central RNR, the TP draft standard is 0.1 mg/L as a summer average. Summer average violations of one or more "response" variables (pH, biological oxygen demand, dissolved oxygen flux, chlorophyll-a) must also occur along with the numeric TP violation for the water to be listed. Concentrations from 2009, 2010 and 2011 show that 0, 34, and 8% of the individual TP samples exceeded the 0.1 mg/L draft standard, respectively. FWMCs from 2009 to 2011 are less than the draft standard at 0.077, 0.093, and 0.060 mg/L, respectively (Figure 21). At this site, TP concentrations are generally highest during the spring and summer.

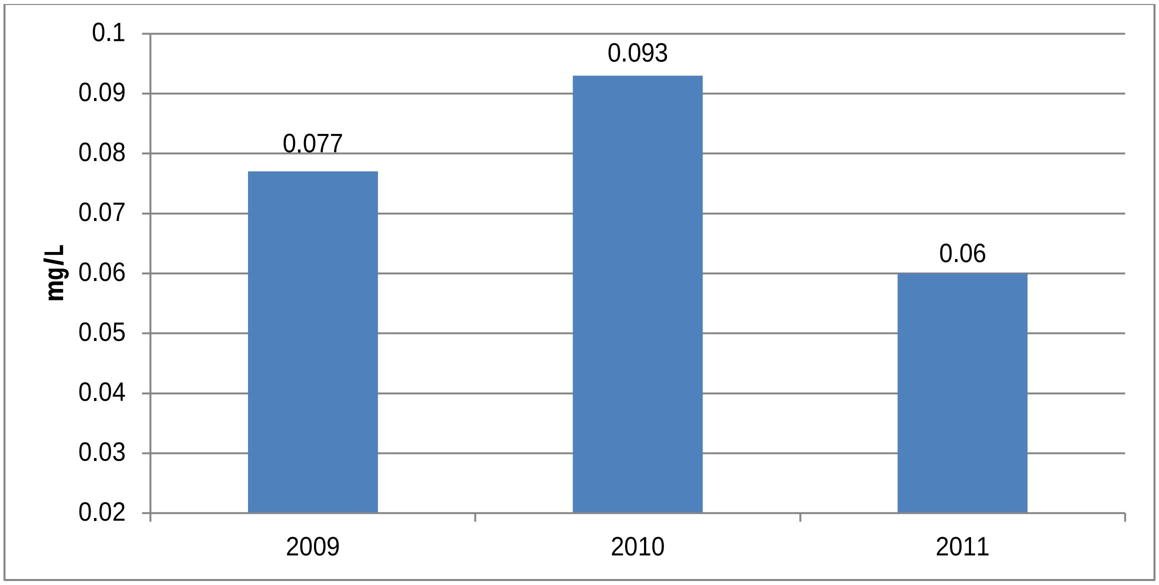

Figure 21. Total Phosphorus (TP) flow weighted mean concentrations for the Leaf River near Staples

Dissolved orthophosphate

Dissolved Orthophosphate (DOP) is a water soluble form of phosphorus that is readily available for plant uptake (MPCA and MSUM, 2009). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from waste water treatment plants, noncompliant septic systems, and fertilizers in urban and agricultural runoff. The 2009 through 2011 FWMC ratio of DOP to TP shows that approximately 50% of TP is in the orthophosphate form.

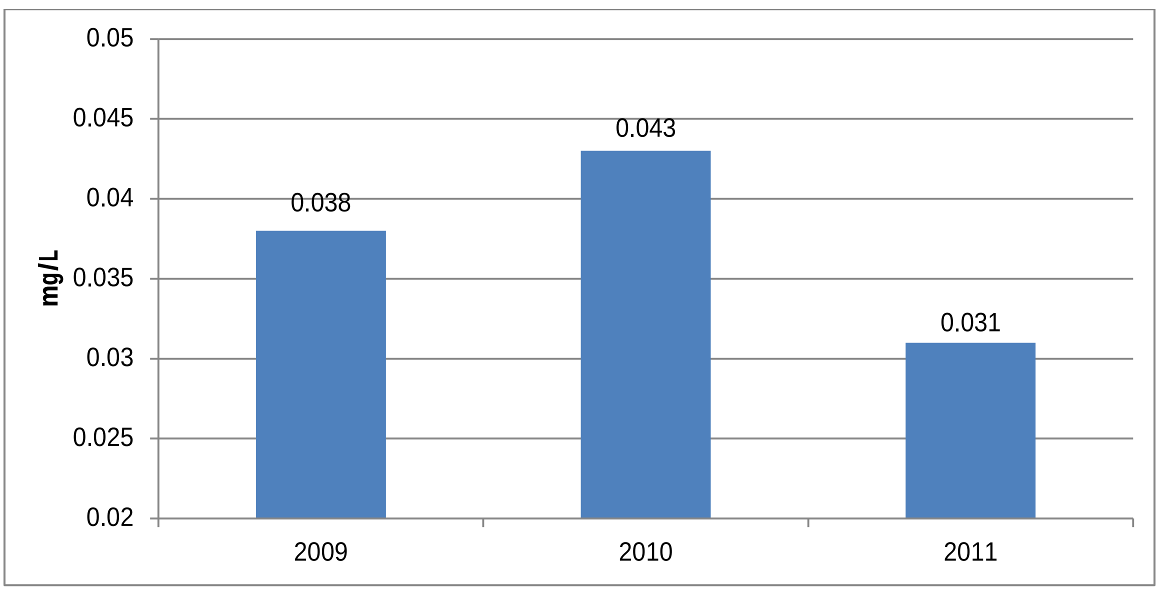

Figure 22. Dissolved Orthophosphate (DOP) flow weighted mean concentrations for the Leaf River near Staples

Nitrate plus nitrite - nitrogen

Nitrate and nitrite-nitrogen are inorganic forms of nitrogen present within the environment that are formed through the oxidation of ammonia-nitrogen by nitrifying bacteria (nitrification). Ammonia-nitrogen is found in fertilizers, septic systems, and animal waste. Once converted from ammonia-nitrogen to nitrate and nitrite-nitrogen, they too, like phosphorus, can stimulate excessive levels of some algae species in streams (MPCA, 2008). Because nitrate and nitrite-nitrogen are water soluble, transport to surface waters is enhanced through agricultural drainage. The ability of nitrite-N to be readily converted to nitrate-nitrogen is the basis for the combined laboratory analysis of nitrate plus nitrite-nitrogen, 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.

Nitrate- N can also be a common toxicant to aquatic organisms in Minnesota's surface waters, with invertebrates appearing to be the most sensitive to nitrate toxicity. Draft nitrate-N standards have been proposed (2012) for the protection of aquatic life in lakes and streams. The draft acute value (maximum standard) for all Class 2 surface waters is 41 mg/L nitrate-N for a 1-day duration, and the draft chronic value for Class 2B (warm water) surface waters is 4.9 mg/L nitrate-N for a 4-day duration. In addition, a draft chronic value of 3.1 mg/L nitrate-N (4-day duration) was determined for protection of Class 2A (cold water) surface waters (MPCA, 2010).

Nitrate-N FWMCs from 2009 through 2011 for the Redeye River Watershed were 0 .849, 0.493 and 0.558 mg/L, respectively (Figure 23). Calculations of the Red Eye River watershed's annual nitrate-N loads do not show an obvious relationship to the annual runoff volume over the three year sampling period (Figure 12).

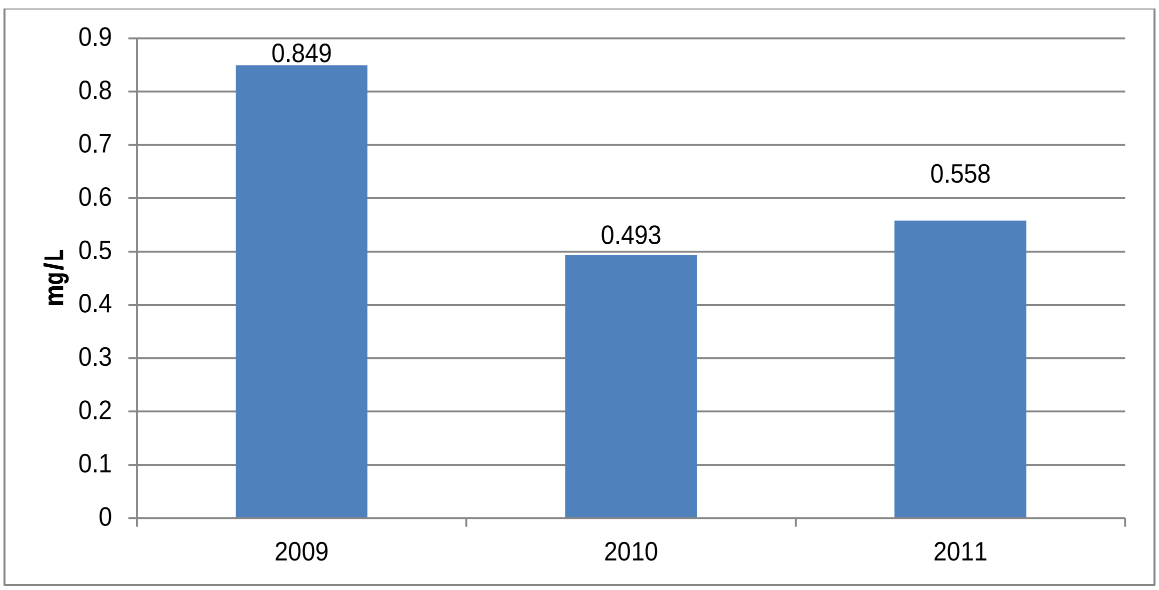

Figure 23. Nitrate + Nitrite Nitrogen (Nitrate-N) flow weighted mean concentrations for the Leaf River near Staples.

Stream water quality

Within the Redeye River Watershed, 24 of the 28 stream AUIDs were assessed (Table 38). Of the assessed streams, 14 fully supported aquatic life and three streams fully supported aquatic recreation. Seven AUIDs are non-supporting for aquatic life and eight are non-supporting for aquatic recreation.

Overall, water quality conditions are fair with one main stressor spread throughout the Redeye River Watershed. Bacteria impairments were found in 8 of 13 assessed AUIDs with sources of the bacteria likely being a function of anthropogenic stressors and land use. Dissolved oxygen impairments are less of a stressor within the watershed but present, occurring in two AUIDs, (Leaf River and Union Creek). Turbidity, chloride and pH were at appropriate levels, with no impairments occurring in the watershed.

Table 38. Assessment summary for stream water quality in the Redeye River Watershed.

				Supporting		Non-Supporting			
Watershed	**Area (acres)**	**# Total AUIDs**	**# Assessed AUIDs**	**# Aquatic Life**	**# Aquatic Recreation**	**# Aquatic Life**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
Redeye River HUC 8	**575,360**	**28**	**24**	**14**	**3**	**7**	**8**	**4**	**0**
07010107120	130,496	8	6	4	0	1	1	1	0
07010107130	50,368	3	2	2	0	0	1	0	0
07010107140	38,784	3	3	2	0	1	1	0	0
07010107150	100,992	3	2	1	0	1	1	0	0
07010107160	18,688	1	1	1	0	0	0	1	0
07010107170	128,576	3	3	2	1	0	1	1	0
07010107180	107,456	7	7	2	2	4	3	1	0

Biological monitoring

Fish

Historically, throughout the Upper Mississippi River Basin, there have been 84 different species of fish sampled. Although the Redeye River Watershed only encompasses a small portion of the Upper Mississippi River Basin, 47 fish species were sampled during this survey. This watershed does not have any fish species identified by the MDNR as endangered; however it does have one threatened species (pugnose shiner) and one species of special concern (least darter). The MDNR has also identified two aquatic invasive species that exist within this watershed, Eurasian water milfoil and zebra mussels.

Some species were found at many sites with high densities, while other species were found at limited sites in low numbers. The most commonly found fish species within the watershed were the central mudminnow and white sucker, which were both sampled at 38 of 39 sites. However the species sampled in the highest numbers was the common shiner, totaling 3,541 individuals (found at 31 of 39 sites). Other species that were commonly found throughout the watershed included blacknose dace, creek chub, johnny darter, and northern pike, all of which were sampled at roughly 75% of the sites. A number of species were only sampled at one site and in low numbers such as bowfin, common carp, spottail shiner, blackchin shiner and weed shiner. A list of the species sampled, how many sites each species were sampled at, and the total number of individuals can be found in Appendix 8.

Macroinvertebrates

Many of the streams reaches sampled for macroinvertebrates within the Redeye River Watershed lacked coarse substrate. One-quarter of macroinvertebrate samples came from rock and/or woody debris habitat. The remainders of the samples were collected from overhanging vegetation or submerged aquatic macrophytes. The lack of coarse substrate is likely due to the geological characteristics of the watershed, many of the streams are low gradient by nature and/or the substrates were inaccessible with current sampling protocols. In addition, the lack of some habitats may be related to the stream channel alterations that have taken place in many of the headwater and middle order streams in this watershed. Based on recent estimates, 50% of the streams within this watershed have altered channels (Figure 39). The lack of coarse substrates due to unnatural stream alterations and sedimentation can significantly impact macroinvertebrate taxonomic diversity.

Overall, a total of 207 genera, representing 38 families of macroinvertebrates were collected throughout the Redeye River Watershed. The most commonly collected macroinvertebrates from low gradient streams consisted of snails from the genus *Physa*, midges from the genera *Polypedium, Rheotanytarsus, Micropsectra* and *Tanytarsus*, and beetles from the genus *Dubiraphia*. The most commonly collected macroinvertebrates from higher gradient streams included midges from the genera *Rheotanytarsus, Thienemannimyia*, mayfly from the genus *Iswaeon*, blackflies from the genus *Simulium*, and scuds from the genus *Hyalella.* Of the seven coldwater streams assessed within the Redeye River Watershed, the most commonly collected macroinvertebrate taxa included blackfly from the genus *Simulium,* mayflies species *Baetis* brunneicolor and *Labiobaetis propinquus,* Caddisfly from the genera *Brachycentrus* and *Chematopsyche,* and midges from the genera *Thienemannimyia* and *Polypedilum.* Many of these taxa are ubiquitous in their distribution across the state and many are tolerant of stressors. *Iswaeon* is a Baetid mayfly often observed from slow moving streams throughout the state and is intolerant of stressors. Approximately 28% of the taxa encountered in the Redeye River Watershed are representative of tolerant taxa.

Lake water quality

Fourteen of 73 lakes were assessed within the Redeye River Watershed. Of the assessed lakes all 14 were found to be supporting of aquatic recreation and none of the assessed lakes were found to be non-supporting. As indicated by aquatic recreation assessment of lakes water quality is in good condition. Lakes are a highly valued resource and steps should be taken to protect and maintain current water quality conditions.

Table 39. Assessment summary for lake water chemistry in the Redeye River Watershed.

			Supporting		Non-supporting			
Watershed	Area (acres)	Lakes >10 Acres	# Aquatic Life	# Aquatic Recreation	# Aquatic Life	# Aquatic Recreation	Insufficient Data	# Delistings
HUC 8	**575,360**	**73**	**-**	**14**	**-**	**0**	**7**	**0**
7010107170	128,576	11	-	4	-	0	1	0
7010107130	50,368	2	-	-	-	0	-	0
7010107160	18,688	0	-	-	-	0	-	0
7010107180	107,456	0	-	-	-	0	-	0
7010107120	130,496	30	-	6	-	0	6	0
7010107150	100,992	30	-	4	-	0	1	0
7010107140	38,784	0	-	-	-	0	-	0

Fish contaminant

The Redeye/Leaf River was tested in 1998 and 2011. Adley Lake (Lake ID 56-0031) had been tested in 1998 and 2011 as well. Wolf Lake was tested in 2009 and the two Leaf lakes were tested in 2010. A total of 182 fish have been analyzed for mercury from the river and lakes. Fish species are identified by codes that are defined by their common and scientific names in Table 40.

Table 41 is a summary of contaminant concentrations by waterway, fish species, and year. The table shows which contaminants, species, and years were sampled within a given lake. "No. Fish" indicates the total number of fish analyzed and "N" indicates the samples. The number of fish exceeds the number of samples when fish are combined into a composite sample. This was typically done for panfish, such as bluegill sunfish (BGS) and yellow perch (YP). Since 1989, most of the samples have been skin-on fillets (FILSK) or for fish without scales (catfish and bullheads), skin-off fillets (FILET).

In 2011, two northern pike and two shorthead redhorse from the Redeye/Leaf River were tested for PCBs and the measurements were below the reporting limit of 0.025 mg/kg (Table 41). Mercury was measured in the same two species in 2011 and had similar ranges and mean mercury concentrations. In 1998, six walleye were tested for mercury and eight white suckers were composited in one sample. Again, the mercury levels were similar among the fish species.

Adley, East Leaf, and West Leaf lakes were listed as impaired for mercury in fish tissue in the 2012 Draft Impaired Waters List. Adley Lake was listed as impaired in 2002 because of mercury concentrations in northern pike that were collected in 1998. The recent 2011 collection of northern pike from Adley showed even higher mercury concentrations (Table 41). The northern pike from 2011 were much bigger, as indicated by the range and mean fish lengths. Three of the eight northern pike collected in 2011 had mercury levels around 0.6 mg/kg, which is very high; whereas four of the northern pike were between 0.2 and 0.3 mg/kg. From all tested fish in the Redeye watershed, the highest mercury concentration was 0.614 mg/kg in a northern pike from Adley Lake. The East Leaf and West Leaf lakes were listed as impaired for mercury in fish tissue because of northern pike collected from both lakes in 2010 (90^{th} percentiles 0.34 mg/kg and 0.22 mg/kg, respectively).

Wolf Lake had one walleye collected in 2009 with a mercury concentration of 0.405 mg/kg, but it was not listed as impaired, because a minimum of five fish per species are needed to make an impairment assessment. One fish is, however, sufficient for fish consumption advisory; consequently, the MDH has an advisory for walleye in Wolf Lake of one meal per month for the sensitive population of pregnant women, women who may become pregnant and children under age 15.

Redeye (Leaf) River was added to the 2014 Draft Impaired waters List for mercury in fish tissue. The 90th percentile mercury concentration in both the northern pike and the shorthead redhorse from the river exceeded the impairment threshold (water quality standard in fish tissue) of 0.2 mg/kg (0.22 and 0.25 mg/kg, respectively).

Overall, the fish contaminant results shows PCBs are not a concern in the Redeye River, although mercury in fish tissue remains a concern for the river and three of the four tested lakes.

Table 40. Fish species codes, common names, and scientific names.

Species	Common Name	Scientific Name
BGS	Bluegill sunfish	*Lepomis macrochirus*
BKS	Black crappie	*Pomoxis nigromaculatis*
NP	Northern pike	*Esox Lucius*
SRD	Shorthead redhorse	*Moxostoma macrolepidotum*
WE	Walleye	*Sander vitreus*
WSU	White sucker	*Catostomus commersoni*

Table 41. Summary statistics of mercury and PCBs, by waterway-species-year.

Waterway	AUID	Location	Species	Year	Anatomy	No. fish	Length (in)			Mercury (mg/kg)				PCBs (mg/kg)	
							Mean	Min	Max	N	Mean	Min	Max	N	Value
Redeye / Leaf River	07010107 -503, -502, -501, -506, -514, -505, -504	11UM040	NP	2011	FILSK	5	12.9	10.8	15.4	5	0.163	0.133	0.218	2	< 0.025
			SRD	2011	FILSK	5	16.9	15.8	17.7	5	0.148	0.085	0.254	2	< 0.025
		RM 0.4-1.8	WE	1998	FILSK	6	14.5	13.7	15.2	6	0.157	0.130	0.220		
			WSU	1998	FILSK	8	15.7			1	0.130				
Adley*	56003100		BGS	2011	FILSK	10	7.4	7	7.8	2	0.097	0.091	0.102		
			BKS	1998	FILSK	10	9.3			1	0.100				
			NP	1998	FILSK	10	17.8	14.8	21.2	10	0.177	0.090	0.360		
				2011	FILSK	8	22.5	18.8	24.8	8	0.403	0.222	0.614		
			WSU	1998	FILSK	6	18.4			1	0.140				
East Leaf*	56011600		BGS	2010	FILSK	30	7.4	6.9	7.9	6	0.051	0.050	0.052		
			NP	2010	FILSK	24	19.4	14.8	23.5	24	0.166	0.117	0.218		
			WSU	2010	FILSK	12	16.3	16.3	16.3	3	0.104	0.104	0.104		
West Leaf*	56011400		BGS	2010	FILSK	9	6.5	5.9	7.0	2	0.068	0.043	0.093		
			NP	2010	FILSK	8	20.3	15.1	25.7	8	0.256	0.177	0.339		
			WSU	2010	FILSK	5	14.3			1	0.030				
Wolf	03010100		BGS	2009	FILSK	13	4.85	4.2	5.5	2	0.032	0.031	0.032		
			BKS	2009	FILSK	4	5.1			1	0.112				
			NP	2009	FILSK	8	15.5	13.8	18.2	8	0.115	0.084	0.136		
			WE	2009	FILSK	1	15.4			1	0.405				

* Impaired for mercury in fish tissue as of 2012 Draft Impaired Waters List; categorized as EPA Class 4a for waters covered by the Statewide Mercury TMDL.

Groundwater quality

Groundwater quality in north central Minnesota, including Redeye River Watershed is generally good. The 1998 Baseline Report by the MPCA of the north central region found that while the surficial aquifers may contain higher concentrations of chemicals which are mobile in soil like nitrate and chloride, most chemicals were detected at levels below drinking water criteria.

The MPCA's Ambient Groundwater Monitoring program has sampled three sites within the Redeye River Watershed (Figure 24). Results from these wells did not indicate a significant change from the baseline study findings.

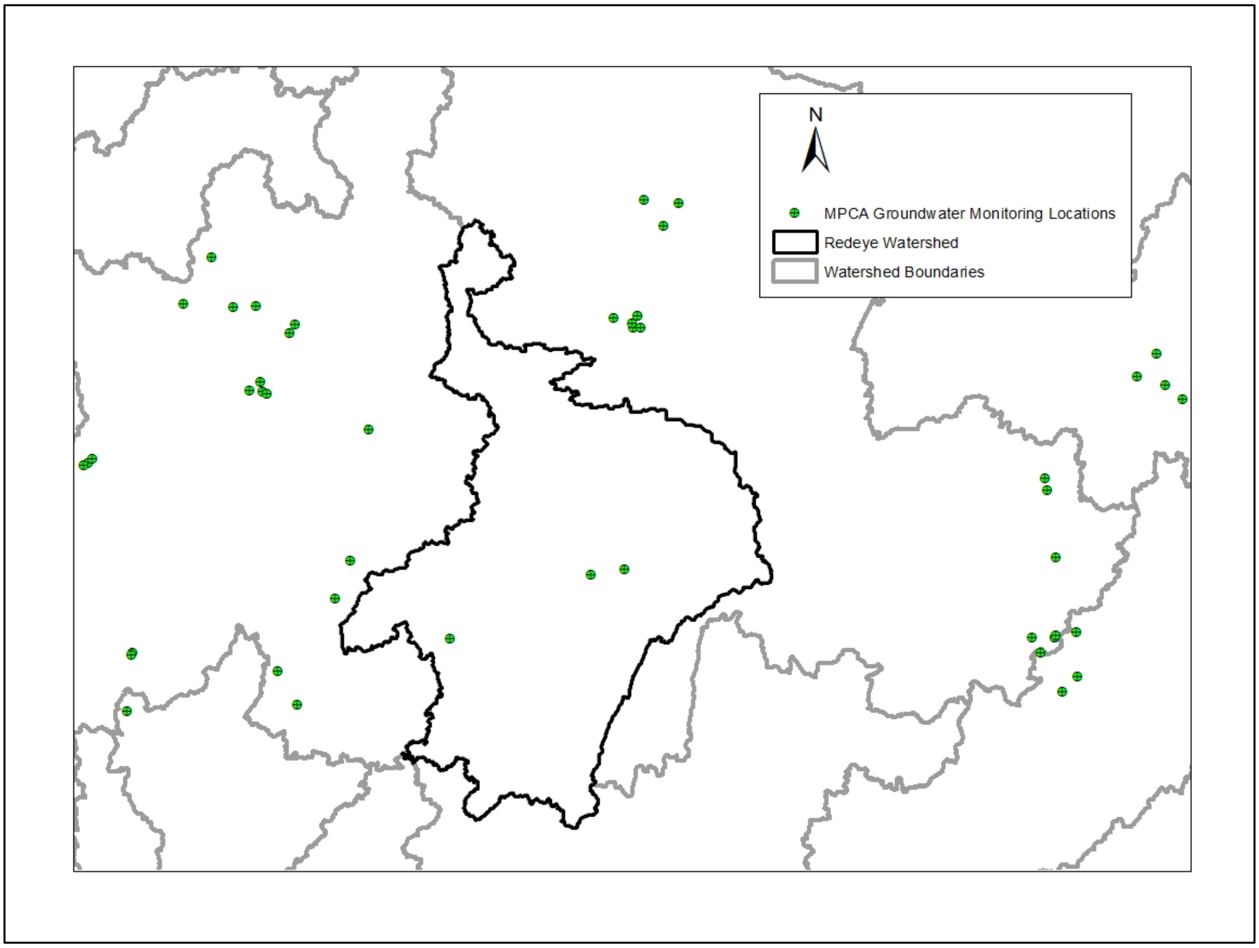

Figure 24. MPCA ambient groundwater monitoring well locations in and around the Redeye River Watershed

The MDA is responsible for monitoring groundwater quality in agricultural areas of the state. The geographic area known as the central sands (which encompasses the Redeye watershed) is particularly vulnerable with respect to agricultural chemical movement due to the hydrogeological conditions of shallow groundwater beneath coarse, sandy-textured soils.

In 2012, pesticides were detected in the Central Sands region but not at levels exceeding drinking water criteria. Nitrate, however, was present in 98% of the wells sampled and at a median concentration of 15 mg/L. Of those samples, 18% were at or below background level of 3 milligrams per liter (mg/L) and 59% were above 10 mg/L. Though nitrate is not uncommon in agricultural areas, the median concentration is above the Health Risk Limit of 10 mg/L.

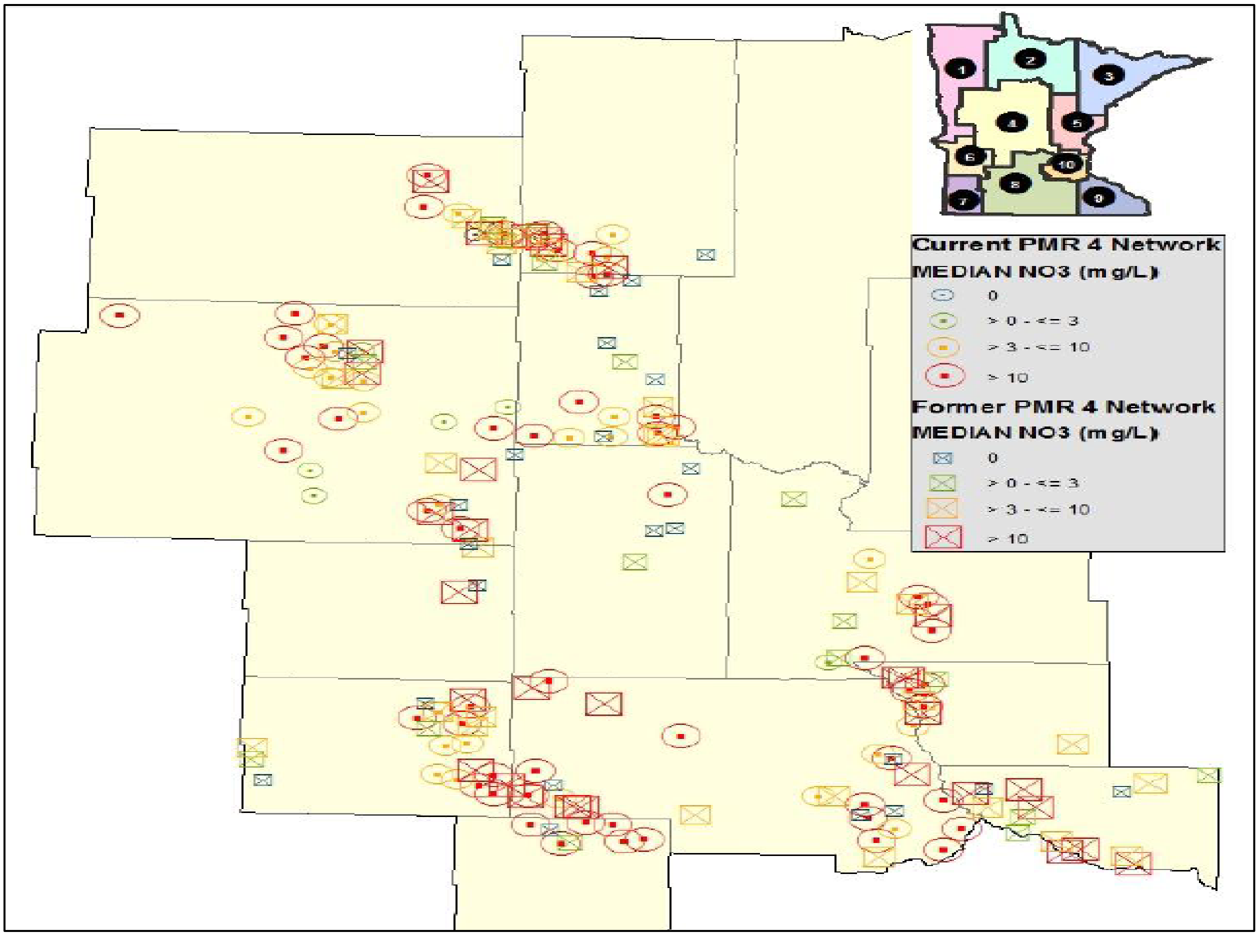

Figure 25. Minnesota Department of Agriculture Pesticide Monitoring Region 4 current and former network median nitrate concentrations

Groundwater/surface water withdrawals

The three largest permitted consumers of water in the state (in order) are municipalities, industry and irrigation. The withdrawals within the Redeye River Watershed are mostly for irrigation and industrial use.

Locations of groundwater withdrawals from the watershed from 1991-2011 are displayed below as blue diamonds with total surface water withdrawals as red squares (Figure 26). During this time period within the Redeye River Watershed, groundwater withdrawals exhibit a significant rising trend (p=0.001) while surface water withdrawals exhibit no trend (p=0.1).

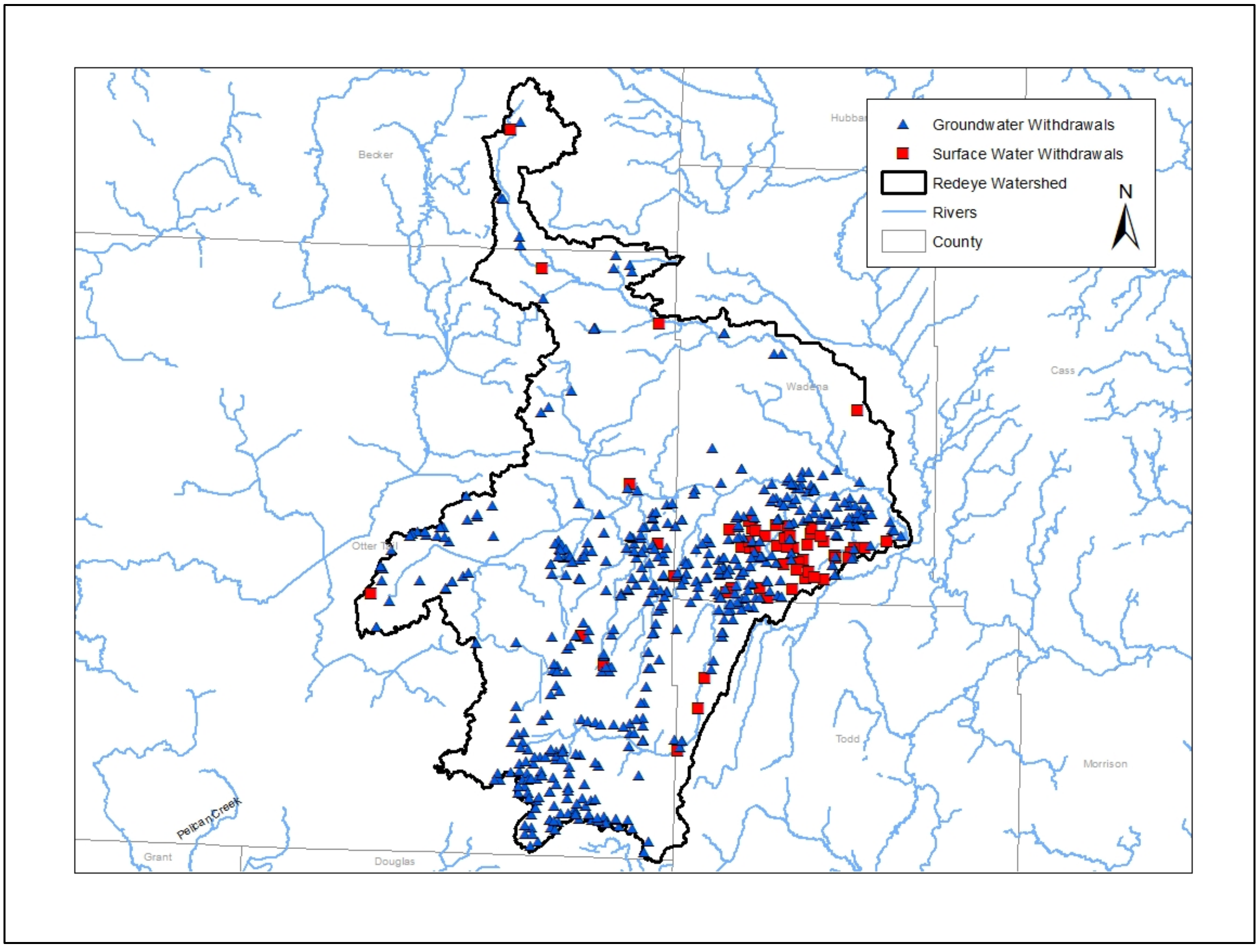

Figure 26. Locations of permitted groundwater withdrawals in the Redeye River Watershed

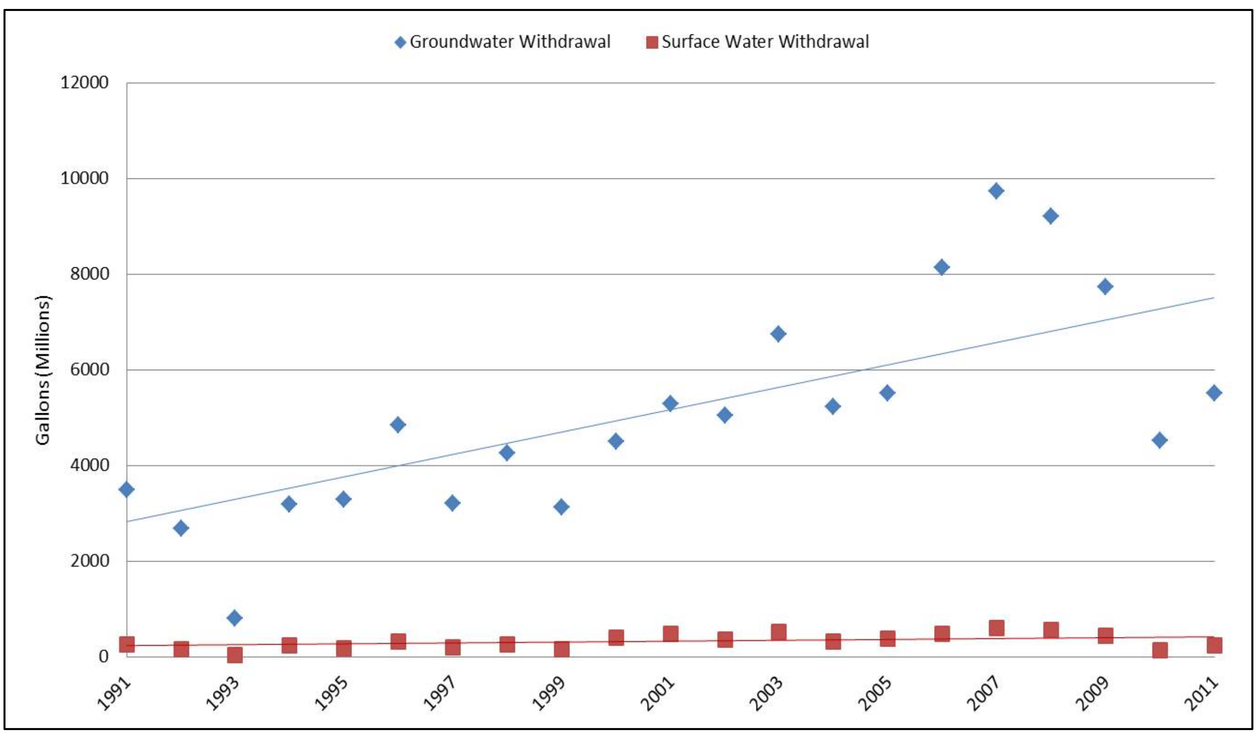

Figure 27. Total annual groundwater and surface water withdrawals in the Redeye River Watershed (1991-2011)

More specifically, withdrawals from the shallow water table aquifer within the watershed have increased significantly (p=0.001) over the same time period (1991-2011) (Figure 28).

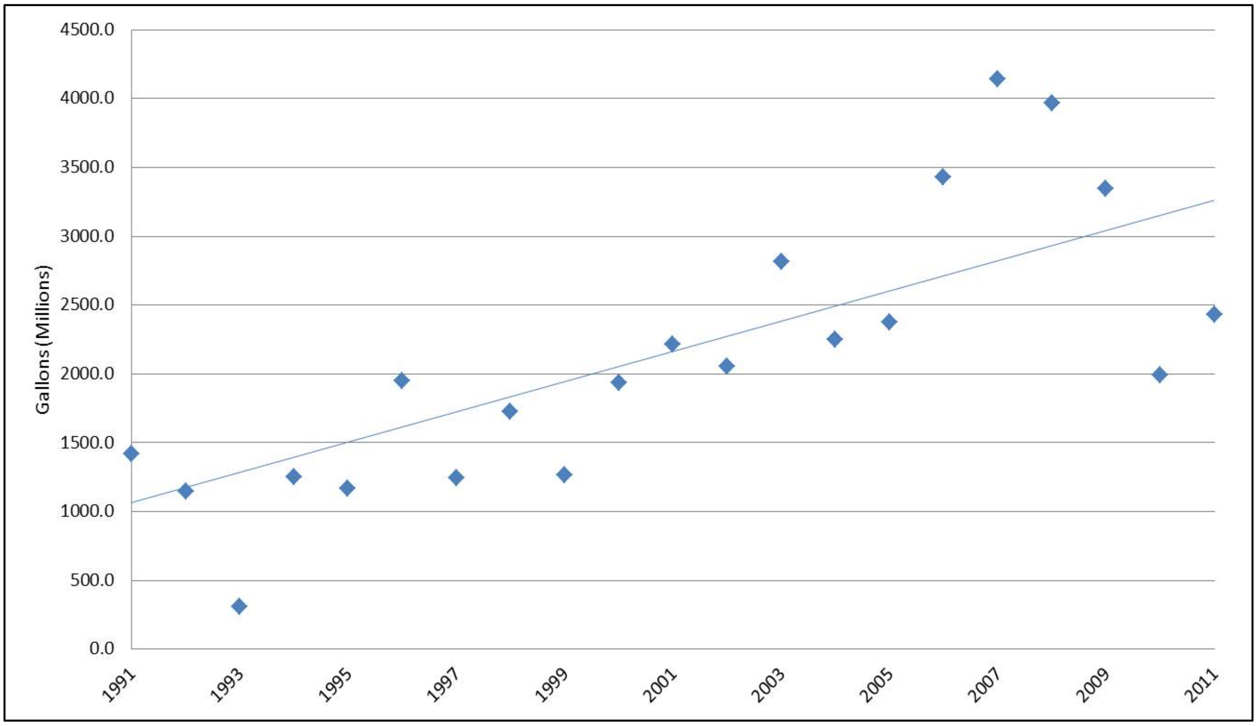

Figure 28. Total quaternary water table aquifer withdrawals in the Redeye River Watershed (1991-2011)

Groundwater quantity

Two observation wells (80021 and 56026) throughout the Redeye River Watershed were chosen based on data availability and geologic location within the watershed. Neither observation well exhibits a statistically significant trend in groundwater elevation change (Figure 29 and Figure 30).

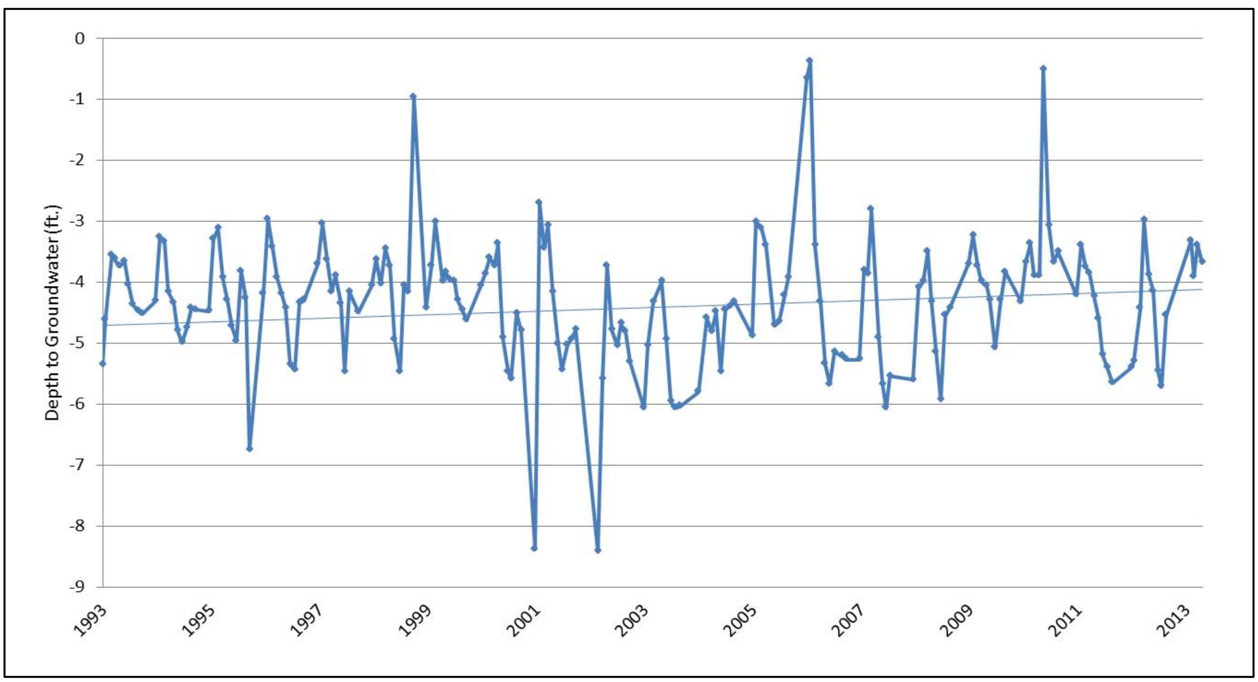

Figure 29. Observation well 80021, located in the northeast area of Redeye River Watershed near Blue Grass, MN in Wadena County (1993-2013)

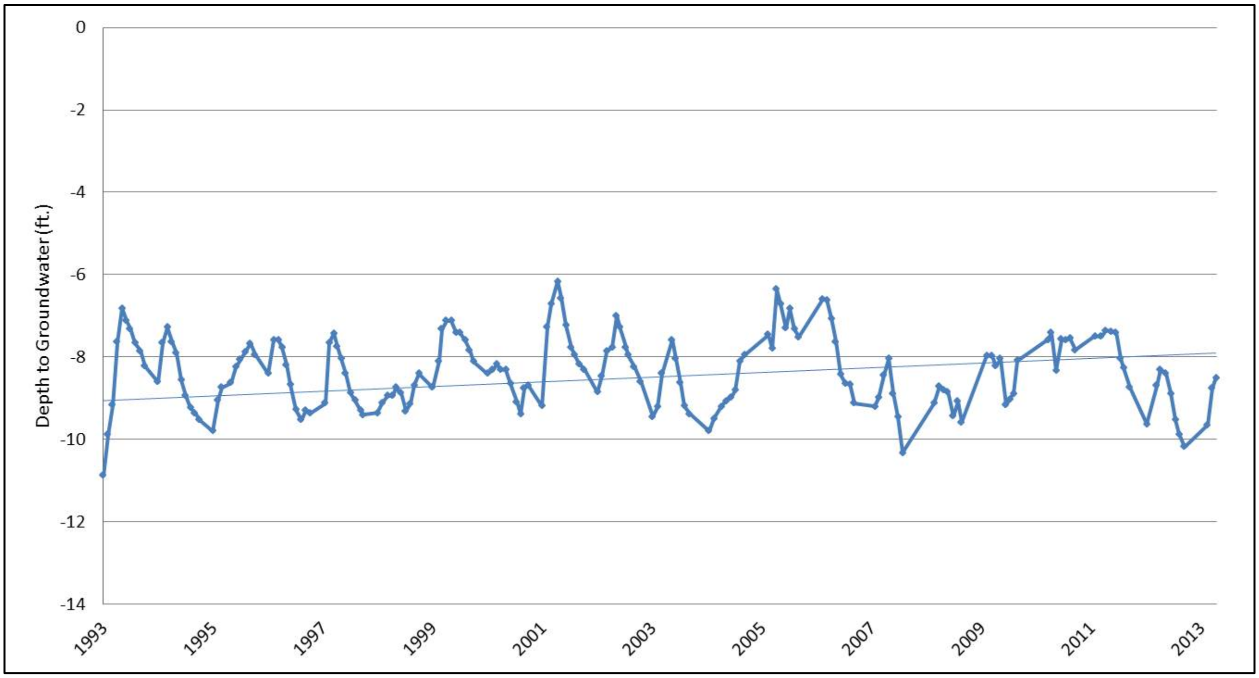

Figure 30. Observation well 56026, located in the south central area of Redeye River Watershed near Henning, MN in Otter Tail County (1993-2013)

Stream flow

The MDNR and MPCA maintain cooperative stream gauging sites across the state recording precipitation, discharge, flow and chemistry. Figure 31 displays the available discharge data from the Leaf River stream gauging site near Staples, Minnesota. Seasonal fluctuations in discharge are very prevalent on this graph.

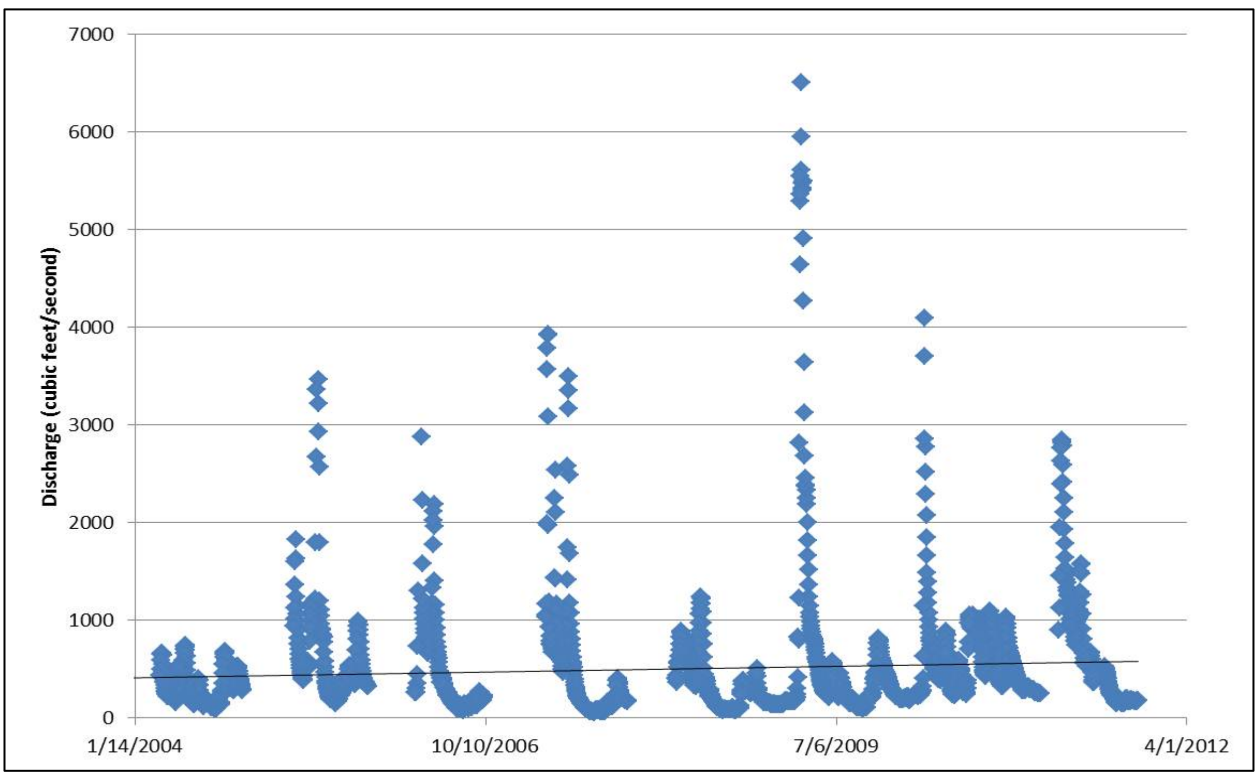

Figure 31. Daily discharge of the Leaf River near Staples, MN (2003-2011)

Wetlands

Wetlands are recognized as important ecosystems; they slow and retain water on the land, and thereby provide flood reduction and pollutant treatment for protection or restoration of downstream waters, as well as providing vital wildlife habitat (Mitsch and Gosselink 2007). Excluding open water portions of lakes, ponds, and rivers, the Redeye River Watershed currently supports approximately 129,000 acres of wetlands, which is roughly equivalent to 22% of the watershed area. Wetlands with herbaceous emergent vegetation including grasses, sedges, bulrushes or cattails, comprise roughly 60,000 acres or about 11% of the watershed, followed by scrub shrub and forested wetlands each which cover about 5.6% of the watershed or about 32,000 acres. Broad-leaved wetland-dependent deciduous tree species such as American Elm, Aspen, and Black Ash comprise ~ 2.1 % of the watershed, needle-leaved wetland deciduous tree species (Tamarack) dominate ~3.3 % of the forested wetland watershed area, and approximately 0.2 % of the watershed is covered by needle-leaved wetland evergreen species such as Balsam Fir, Black Spruce and White Cedar. Shallow water wetland habitats are the least common wetland class covering roughly 4,000 acres or 0.7% of the Redeye River Watershed (Figure 32).

Upper parts of the watershed, particularly the Upper Leaf River, Ridge Creek and Wing River subwatersheds support more wetland area and they tend to be less connected to the stream network. In the flatter outwash areas found primarily in the east-central and lower region of the Redeye watershed, wetlands are typically more closely associated with the stream network. These estimates and distribution observations represent a snapshot of the location, type, and extent of wetlands in the Redeye River Watershed around 1980, which is the year that aerial imagery was acquired to develop National Wetlands Inventory (NWI) maps in this part of Minnesota. Changes to wetlands have likely occurred since the early 1980s, though the NWI remains the best data available to estimate wetland extent. Minnesota natural resource agencies are cooperating to update the state NWI over a 10-year schedule which is slated for completion in 2019 with the north central and northwest regions of the state, including the Redeye watershed, being the last areas of the state where the NWI is planned to be updated.

Soils data can be used to estimate the historic wetland extent prior to European homesteading and settlement which initiated significant conversion of wetlands in much of Minnesota. Analysis of Natural Resources Conservation Service (NRCS) digital soil survey map units (SSURGO) which are classed as “all hydric” suggest approximately 186,000 acres of wetland, or 32% of the Redeye River Watershed, occurred prior to settlement. Comparing the area of all hydric SSURGO map units with contemporary NWI data for this watershed finds approximately 32% of the historic wetland extent within the Redeye River Watershed have been converted to other land cover types, mostly in an effort to improve agricultural cropping opportunities and other development enterprises including road and municipal development.

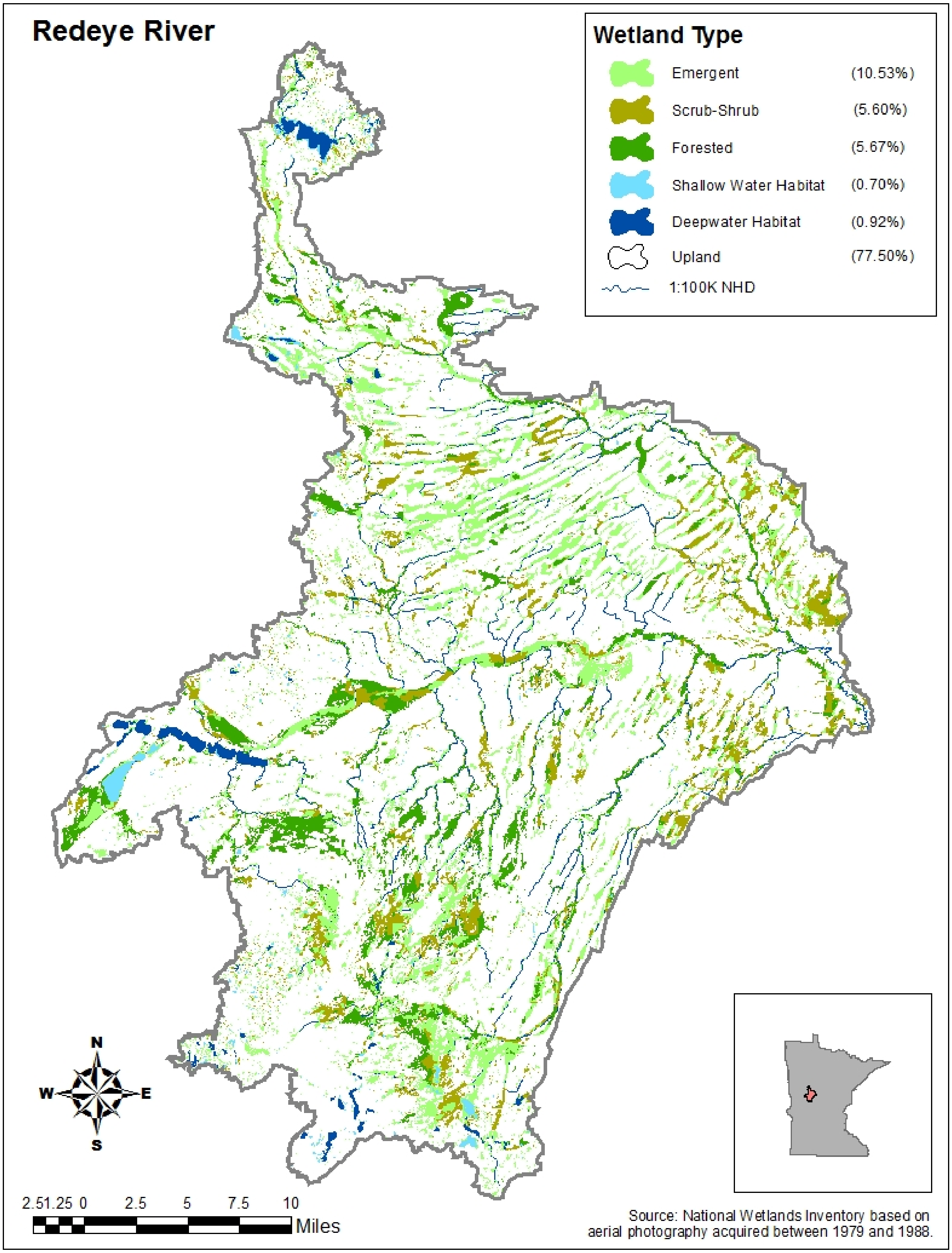

Figure 32. Distribution of wetlands by National Wetland Inventory type within the Redeye River HUC-8 watershed

Wetland loss rates are not consistent across the Redeye watershed. Table 42 presents estimates of historic wetland as well as estimated percent wetland area converted within HUC-11 subwatersheds.

The Upper Leaf River subwatershed, entirely within, and the Wing River subwatershed, mostly within, Ottertail County have lost approximately 21% of their historic wetland extent. In contrast, the Lower Leaf River which occurs mostly in Wadena County and had fewer historic wetlands, has lost an estimated 35% of its historic wetland extent. County loss rates are relevant in that the state Wetland Conservation Act (WCA) is administered partially based on extent of historic wetland area remaining in the county. Becker, Ottertail and Todd counties are recognized within the WCA as supporting 50-80% of their historic wetland extent and Wadena County is recognized as supporting greater than 80% of its historic wetland extent.

Table 42. Redeye River Watershed historic wetland extent based on hydric soil data for each HUC-11 subwatershed.

11-digit subwatershed name	Area (acres) SSURGO 'all hydric' map units	Wetland area (NWI – acres)	Percent wetland loss
Upper Leaf River	36741	28927	21.3
Bluff Creek	18466	12405	32.8
Ridge Creek	17108	12264	28.3
Wing River	28913	22848	21.0
Hay Creek	6011	4346	27.7
Redeye River	45100	31565	30.0
Lower Leaf River	33808	21870	35.3

Wetland condition

The MPCA began biological monitoring of wetlands in the early 1990s, focusing on wetlands with emergent vegetation (i.e., marshes) in a depressional geomorphic setting. This work resulted in the development of plant and macroinvertebrate (aquatic bugs, snails, leeches, & crustaceans) indices of biological integrity (IBIs) for evaluating the ecological condition or health of depressional wetlands. Recently the MPCA wetland monitoring group has begun transitioning toward use of Floristic Quality Assessment (FQA) for assessing wetland condition based on the plant community. Future watershed wetland assessment reports will begin to use FQA wetland assessment results. One advantage to the FQA approach is the methods have been adapted to assess all wetland types which occur in Minnesota.

Both the macroinvertebrate and plant IBIs are scored on a 0 to 100 scale with higher scores indicating better condition. These indicators have been used in a statewide survey of wetland condition where results can be summarized statewide and for each of Minnesota's ecoregions (Genet 2012). Approximately 95% of the Redeye River Watershed occurs in the Mixed Wood Plains Level II Ecoregion and 5% in the Mixed Wood Shield Ecoregion in the northern reaches of the Redeye River subwatershed. Wetland condition in the Mixed Wood Plains Ecoregion is in an intermediate condition compared with Minnesota's other two Level II Ecoregions. Invertebrate index results found 15% of depressional wetlands are in poor condition while 44% of these marsh-type wetlands are statistically estimated to be in good condition (Genet 2012). Plant index results show 18% of the depressional wetlands are estimated to be in good condition and 61% in poor condition. Invasive plants, particularly narrow-leaf cattail (*Typha angustifolia*) and hybrid cattail (*Typha* X *glauca*) as well as reed canary grass (*Phalaris arundinacea*) are attributable in-part to the difference between invertebrate and plant results as their ubiquity in marshes within this region of the state is detrimental to plant community health. These invasive plants readily invade wetland habitats outcompeting native species (Genet 2012). Their invasiveness is aided by their tolerance of nutrient enrichment, hydrologic alterations and toxic pollutants such as chlorides (Galatowitsch 2012). In contrast, statistical estimates of depressional wetland condition in the Mixed Wood Shield Ecoregion based on the M-IBI found 60% of the wetlands to be considered to be in good condition and the plant IBI for wetlands found 54% of the depressional wetlands to be in good condition.

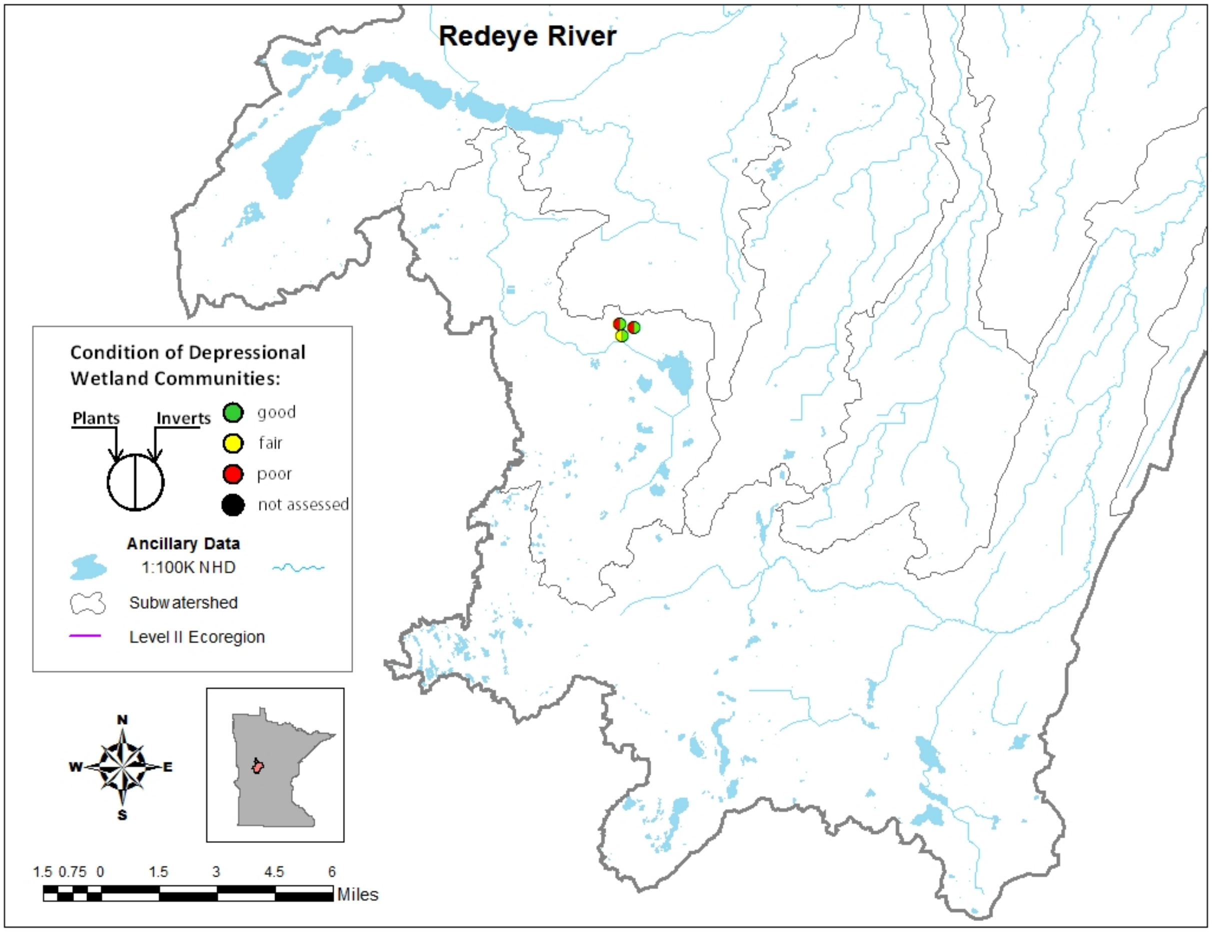

Figure 33. Depressional wetland IBI results (invertebrate and plant community indices) for the MPCA wetland biological study sites located in the Redeye River HUC-8 watershed

MPCA ambient wetland biological condition data has been collected at only three depressional wetlands in the Redeye River Watershed. All of these sites are located in the Upper Leaf River watershed. Invertebrate and plant condition results for these sites are presented in Figure 33. Two of these wetland study sites (07OTTE103 & 07OTTE167) were randomly selected to estimate wetland quality in the Mixed Wood Plains Ecoregion during an initial survey in 2007, and 12OTTE179 was sampled as part of a state depressional wetland survey conducted in 2012. Invertebrate community IBI scores at these three sites range from 68 to 73 (0 to 100 scale with 100 being high integrity). All of these scores represent a 'Good' condition, where the difference between Good and Fair is set at the 25th percentile of reference site (i.e. least disturbed) scores within the Mixed Wood Plains Ecoregion (Genet 2012). The plant results from these three randomly selected wetlands show somewhat different results. The plant scores ranged from 34 to 46 where 07OTTE103 and 12OTTE179 are considered to be in 'Fair' condition and 07OTTE167 is considered to be in 'Poor' condition. The Poor condition at 07OTTE167 is in large part due to the significant plant cover of hybrid cattail (Typha X glauca). No watershed pattern is evident in this small closely clustered set of wetland condition study sites however they do appear to parallel the statistical condition estimates of depressional wetlands in the Mixed Wood Plains Level II Ecoregion (Genet 2012).

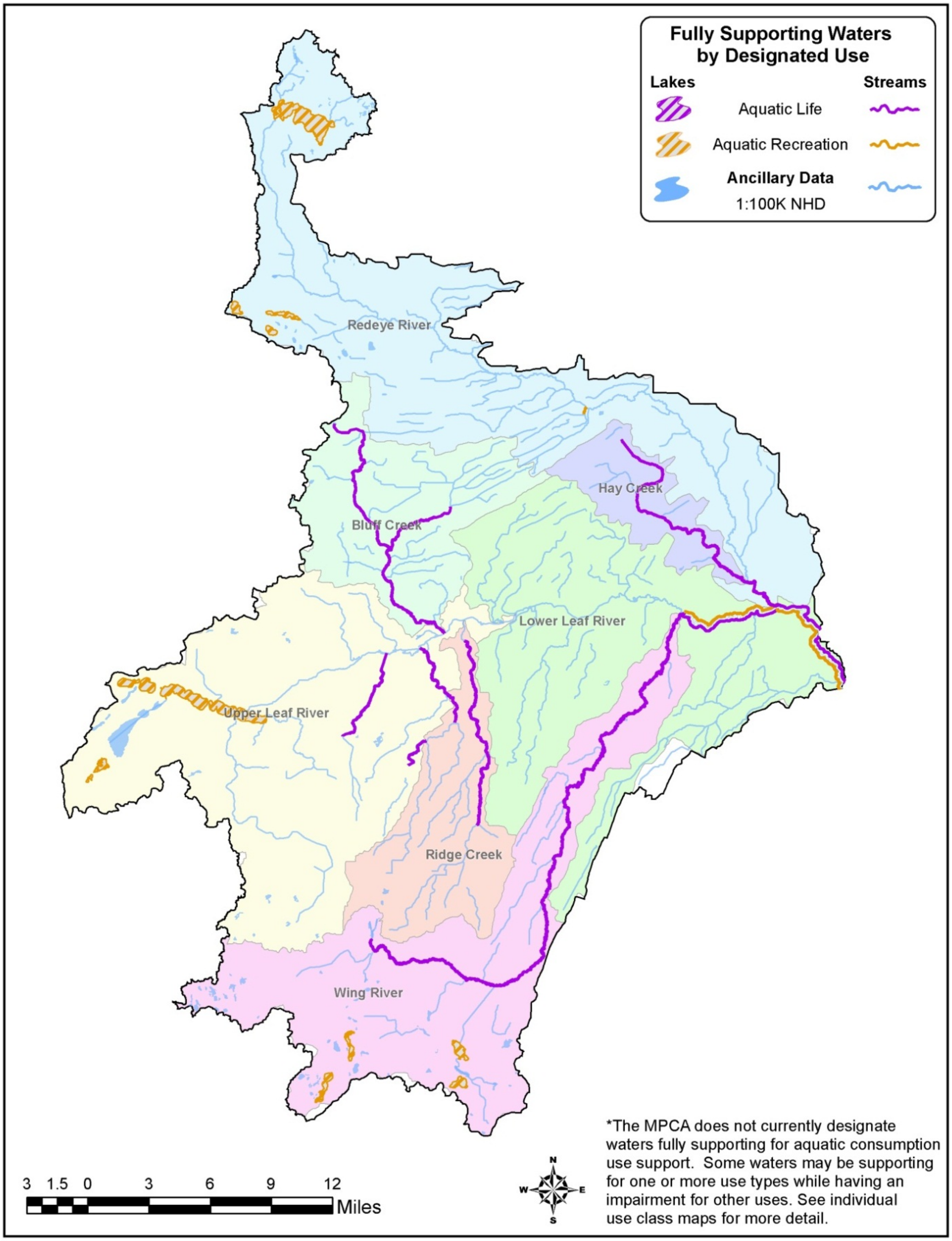

Figure 34. Fully supporting waters by designated use in the Redeye River Watershed

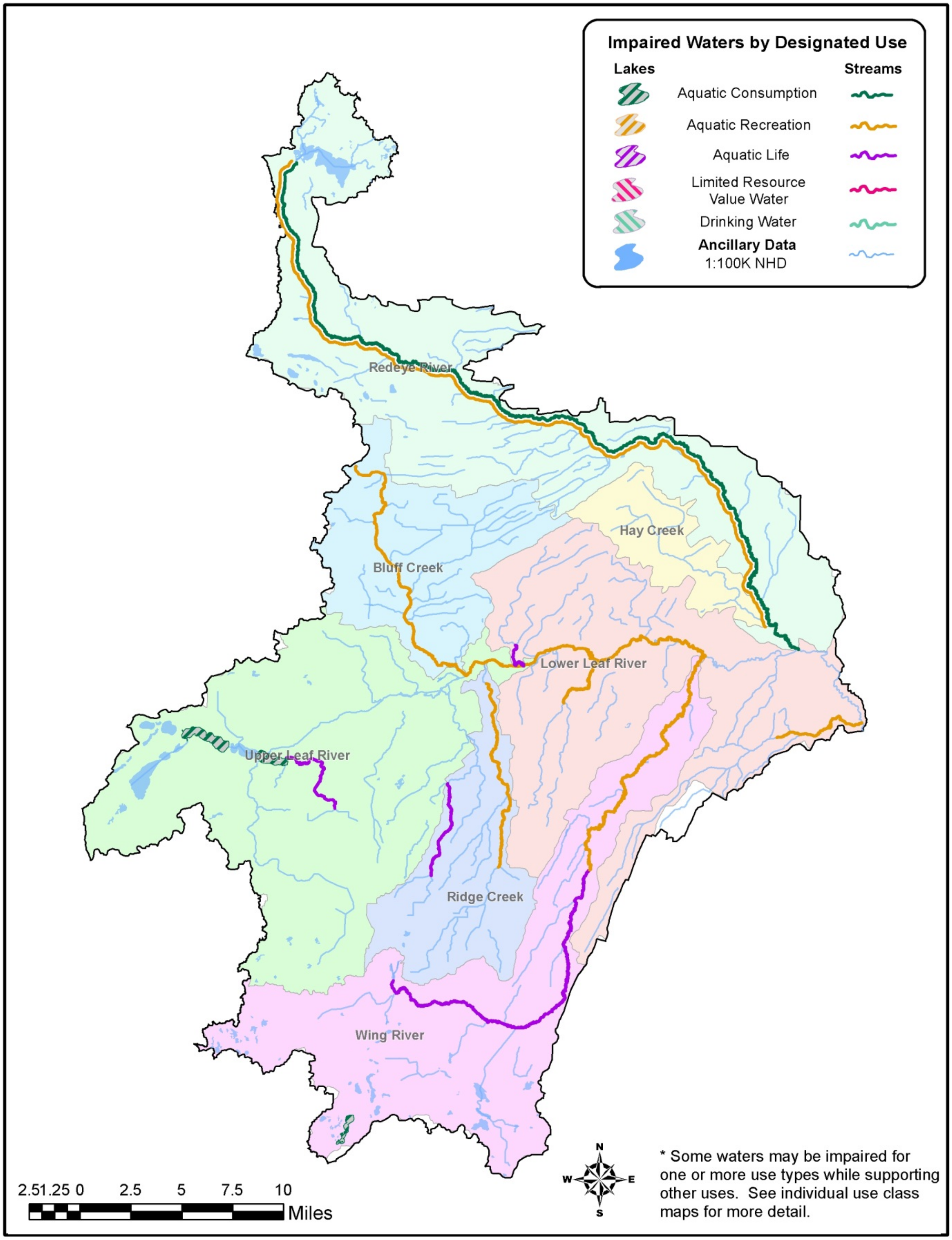

Figure 35. Impaired waters by designated use in the Redeye River Watershed

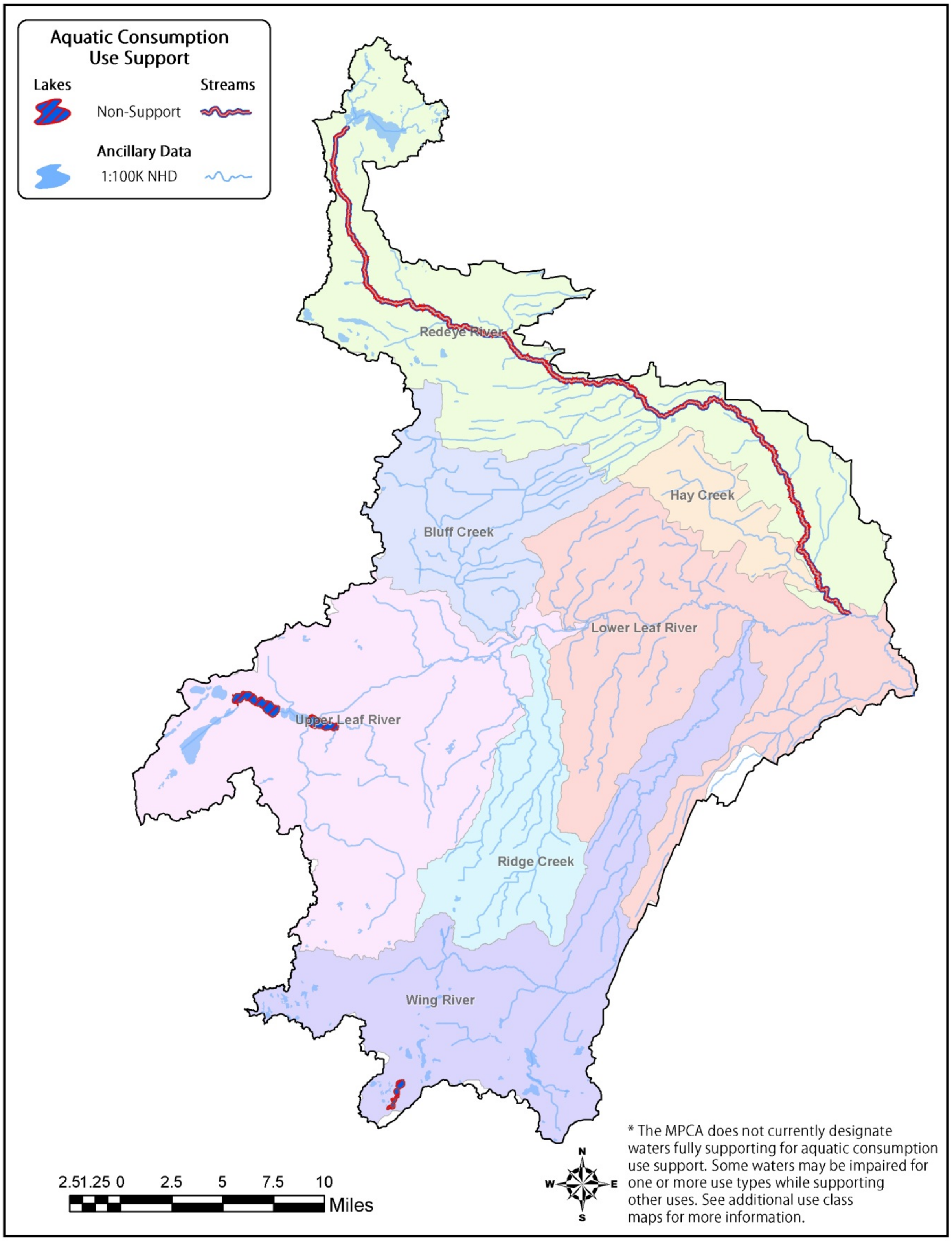

Figure 36. Aquatic consumption use support in the Redeye River Watershed

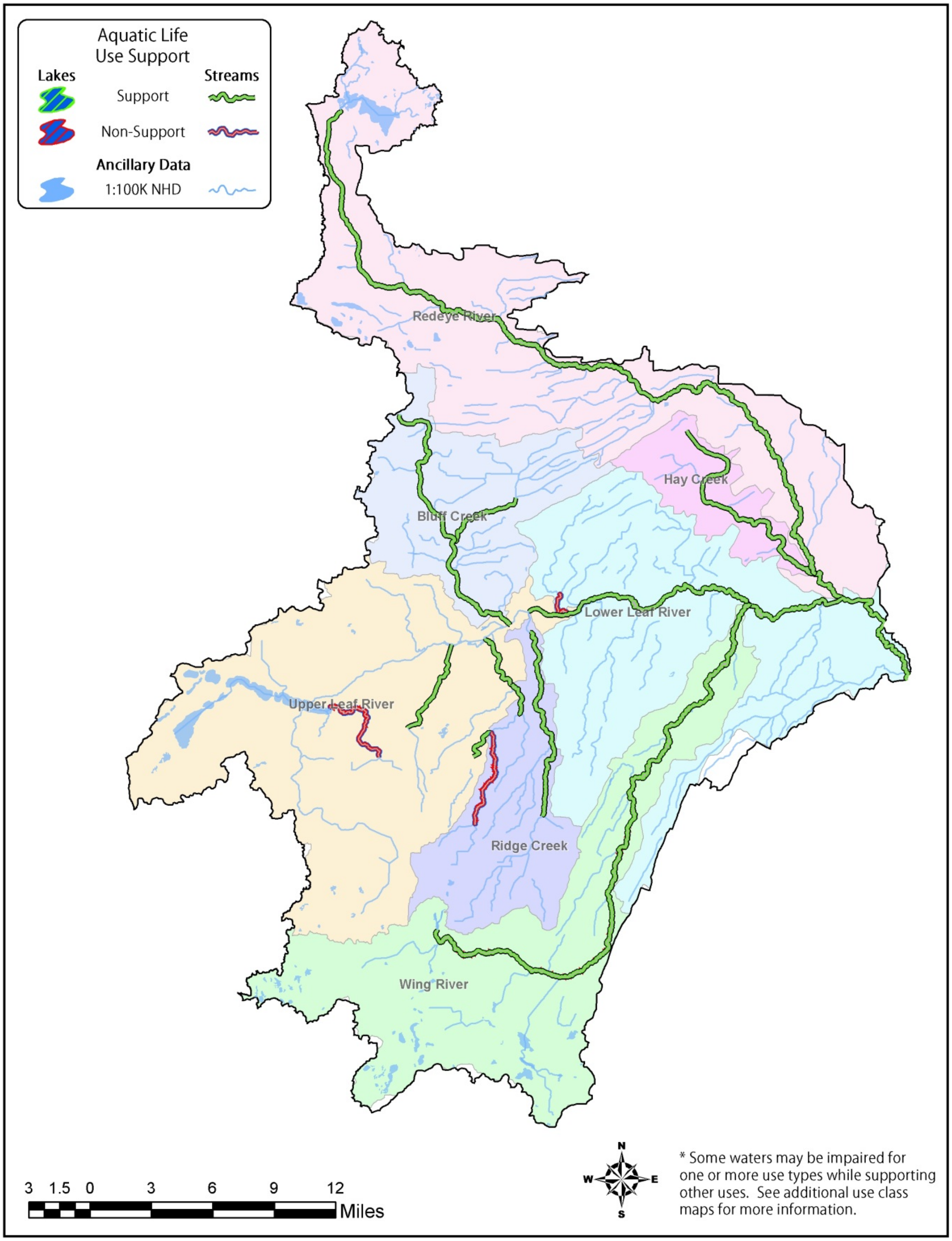

Figure 37. Aquatic life use support in the Redeye River Watershed

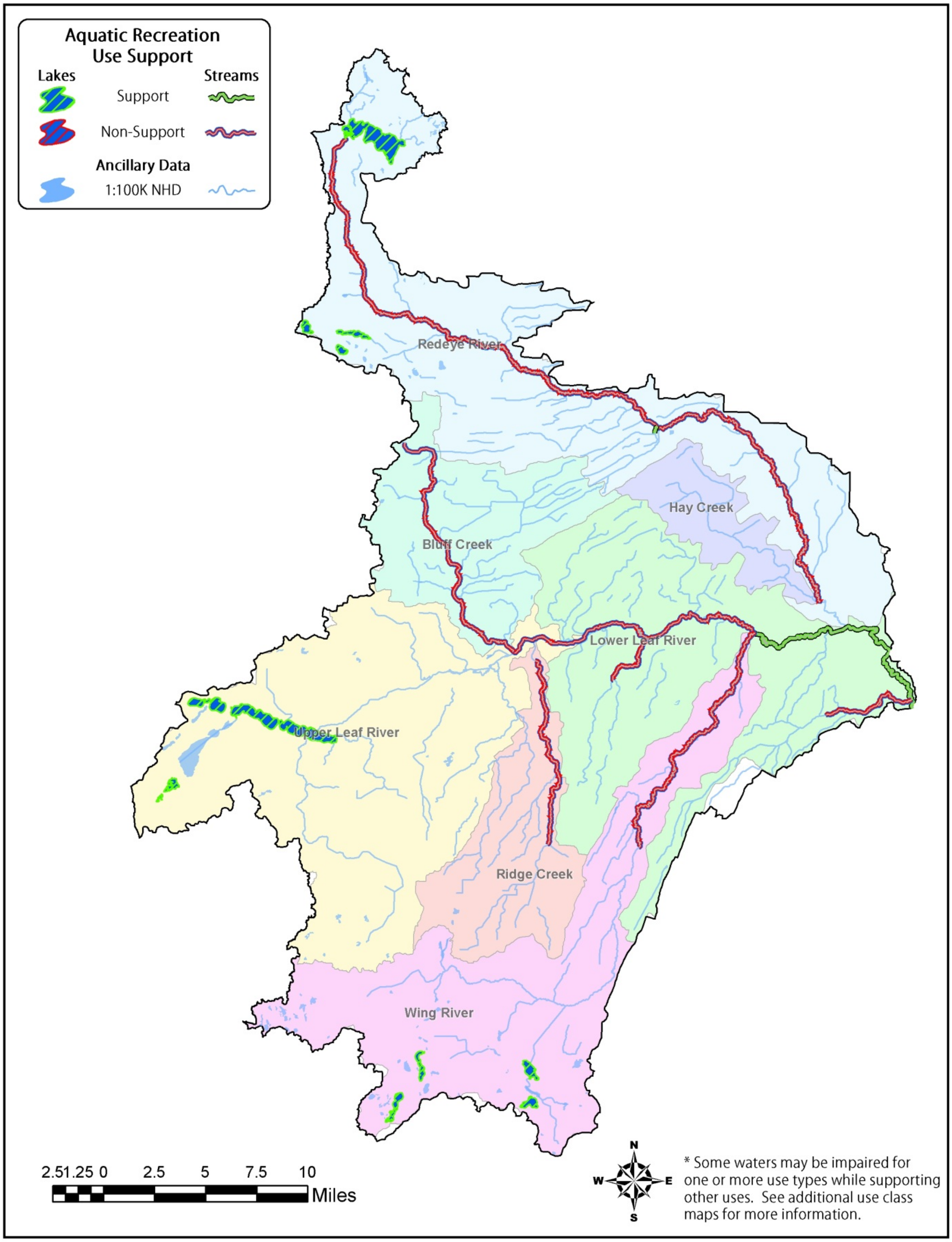

Figure 38. Aquatic recreation use support in the Redeye River Watershed

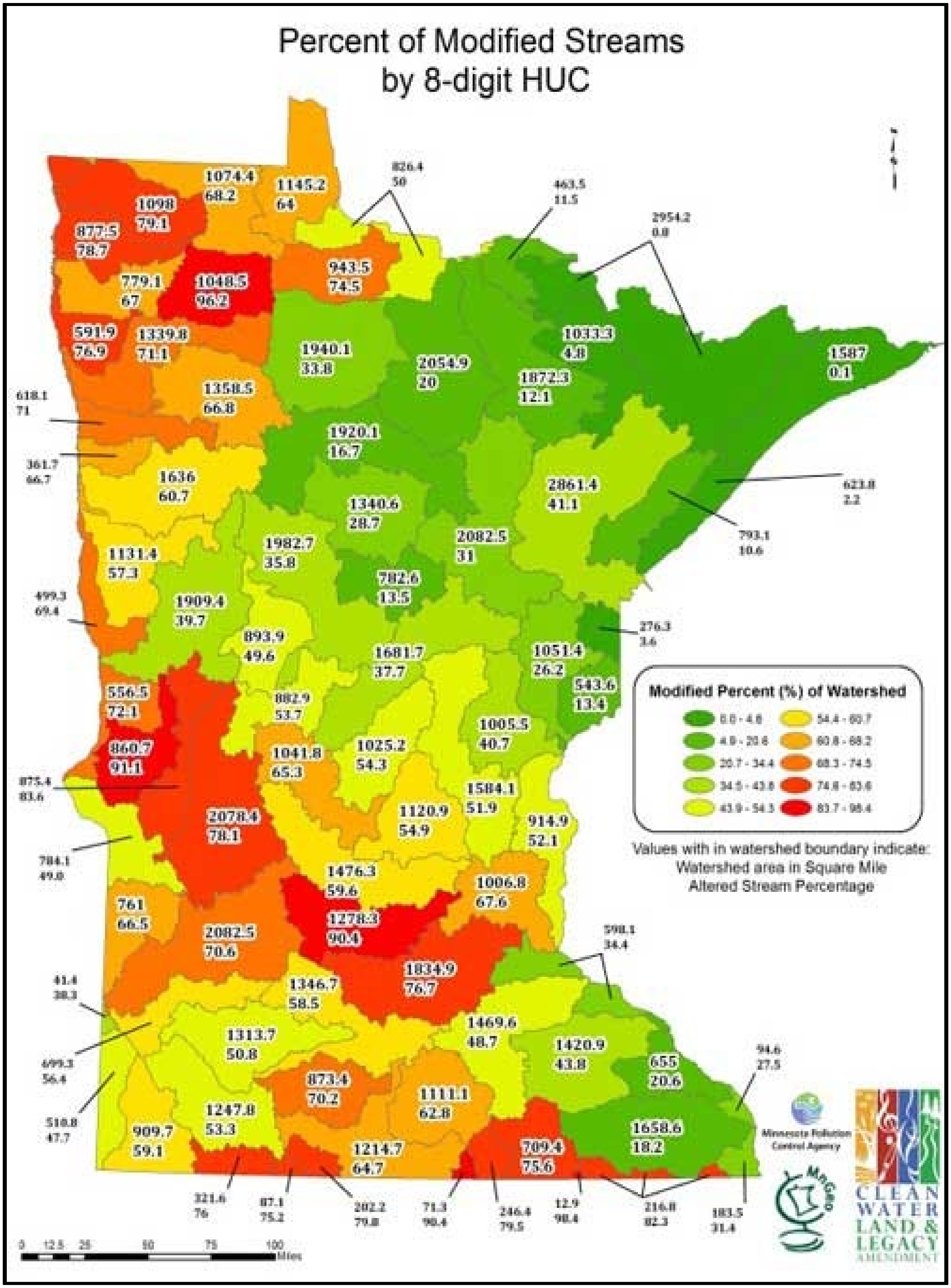

Figure 39. Map of percent modified streams by 8-digit HUC

VII. Summaries and recommendations

Streams

Although the Redeye River Watershed begins in a lake-rich region of the state, the watershed makes a quick transition into a mix of landscapes including wetlands, forest, cropland, and rangeland. Cropland and rangeland make up nearly half of the watersheds landscape, specifically in the southern half (Figure 8). Although channelized streams are not abundant within this watershed, they are present, with one-quarter (10 out of 40) of the biological monitoring sites being located on channelized streams.

The high percentage of rangeland and cropland do not appear to be having an effect on the turbidity of the water, however they may be having an effect on bacteria levels. Bacteria (*Escherichia coli*) is the largest impairment concern, which exceeded the standard in five of the six watersheds where it was sampled. As a result of these elevated levels, eight AUIDs are considered impaired for aquatic recreation. It should be noted, that all bacteria impairment were a result of two or three exceedances of the geometric mean; no individual samples exceeded the one time sample standard of 1260 MPN/100ml. Dissolved oxygen (DO) assessments were conducted on six AUIDs with two exceeding the standard. The DO impairment on the Leaf River appeared to have little effect on the biological communities, as both fish and macroinvertebrate IBI scores indicated full support at all monitoring sites. In general, DO levels in the Leaf River were only slightly below the standard during the evening and early morning hours. The Union Creek DO impairment, however, may be having an effect on the biological communities, as both fish and macroinvertebrate IBI scores were well below their respective thresholds. Although DO is low in this reach, it may not be the only contributing factor to poor biological communities. Poor land use practices and the contribution of flow to Union Creek from the Wadena WWTP may also be contributing factors to the poor biological communities. Although sampled at few sites, the other aquatic life indicators (pH, chloride, and NH_3) all met their respective thresholds. In total, the AUIDs assessed for aquatic life in this watershed resulted in 14 being considered supporting and 7 being non-supporting. Assessed AUIDs for aquatic recreation resulted in t3 being considered supporting and 8 being non-supporting.

Habitat within this watershed was generally fair with only four sites receiving a poor MSHA score. MSHA metrics that most often influenced the poor overall MSHA scores included the land use metric. Low land use scores indicate a greater potential for in-stream disturbances due to poor land use practices, primarily in agricultural and urban areas. In addition, the in-stream substrate metric was low at many sites indicating that fine sediments are settling into streams and potentially impacting biological communities. The fine sediments embed coarse substrates and potential spawning and/or cover areas for aquatic fish and macroinvertebrates. At sites where the fine substrate material was most prevalent, fish species that spawn on gravel or coarse substrates were absent and more tolerant species dominated. Habitat ratings for riparian, channel morphology and fish cover were moderate to high for a majority of sites, which is typical of areas where mostly non-channelized streams are present.

Within the Redeye River Watershed, there are four dams (Boyle 2013), three located on ponds/lakes and one on the Wing River. Dams create recreational opportunities for fishing and camping and also aid in water storage and flood control. However, dams can also restrict water flow to downstream areas, create impoundments upstream, alter stream flow, and prevent fish migration, among other impacts. Certain fish species migrate upstream to reach suitable spawning habitat; however some dams create barriers and prevent fish from reaching these areas. As noted in the Wing River subwatershed summary, this particular dam appears to be having an effect on fish migration upstream of the dam. Longer lived, large bodied fish such as shorthead and silver redhorse were present below the dam but not above the dam and white sucker abundance decreased above the dam.

The poor in-stream substrate and the bacteria impairments negatively impact the aesthetic and recreational value of rivers and streams in the Redeye River Watershed, as well as the adjoining downstream waters and the biological communities that reside there. In order to limit the amount of fine sediments and bacteria entering streams in the watershed, steps should be taken to identify and limit the sources

Examples of actions that could help improve these issues:

- Establish or repair riparian zones using native vegetation and/or trees
- Protect any current riparian buffer zones and quality stream habitat
- Reduce the amount of agricultural, livestock, and urban runoff
- Evaluate dam locations (specifically the Wing River dam) and possible negative effects on fish and/or macroinvertebrate communities
- Continued monitoring to evaluate and document declining or improving conditions

An emphasis should be given to maintaining natural vegetative buffer areas along shorelines to prevent overland runoff and reduce erosion potential, and should be considered a key protection strategy to maintain the existing high quality of lakes and streams in this watershed.

Some of the top aquatic resources found in this watershed include Deer Creek (07010107-511), Redeye River (07010107-502 and -503), and Willow Creek (07010107-525). A complete list of the top six most valuable aquatic sites within this watershed as indicated by biological (F-IBI & M-IBI) and physical (MSHA) parameters are displayed in Table 43. Those sites and streams that have exceptional biological, chemical, and physical parameters are worthy of additional protections in order to preserve their valuable aquatic resources.

Table 43. Top six aquatic resources in the Redeye River Watershed as indicated by biological (F-IBI & M-IBI) and physical (MSHA) parameters.

Rank	Stream Name	Biological Station ID	Biological Station Location
1	Deer Creek	11UM061	Upstream of CSAH 52, 2.5 mi. NE of Deer Creek
2	Redeye River	10EM198	Upstream of CR 26, 3 mi. N of Central
3	Leaf River	11UM042	Upstream of CSAH 26, 8 mi. N of Aldrich
4	Willow Creek	11UM066	Downstream of CSAH 50, 4 mi. N of Henning
5	South Bluff Creek	11UM068	Downstream of 330th St, 4 mi. W of Wadena
6	Blue Creek	11UM059	Downstream of CSAH 56, 4.5 mi. E of New York Mills

Lakes

The assessed lakes within the Redeye River Watershed all had good water quality with no lakes being impaired for aquatic recreation. As noted in many HUC-11 summaries above, riparian areas around these lakes should be protected to ensure the quality of these lakes into the future. Three of the assessed lakes in the Redeye River Watershed were considered impaired for aquatic consumption due to elevated levels of mercury in fish.

Groundwater

Local groundwater conditions may vary, but due to the surficial geology and heavy agricultural use, nitrate is a potential contaminant of concern in the Redeye River Watershed. The MDA regularly samples groundwater across the region for nitrate. To protect human health, the MDH encourages well owners to test their water supply for nitrate on a regular basis.

The direct correlation of increasing groundwater withdrawals and decreasing surficial water quantity has been documented in other areas of Minnesota such as Little Rock Creek and White Bear Lake. A detailed cause and effect relationship between withdrawals and water quantity is beyond the scope of this report. However, the data do indicate a continued increase in groundwater withdrawals from the watershed. More stream flow information would be beneficial for determining trends in groundwater/surface water interactions. Also, expanded and continued study of groundwater/surface water interactions should be a priority, due to the transmissive surficial geology and rising trend in groundwater use in this watershed, as well as neighboring watersheds like the Crow Wing and Long Prairie rivers.

Future and ongoing work

Progress is currently being made to complete a watershed-wide TMDL and Watershed Restoration and Protection Strategy (WRAPS) that will highlight the steps needed to restore and protect the water quality within the Redeye River Watershed.

Literature cited

Boyle, Jason. 2013. Dam Safety Engineer, Minnesota Department of Natural Resources. Personal Contact.

Environmental Protection Agency (EPA), 2010. Ecoregions of Minnesota. http://www.epa.gov/wed/pages/ecoregions/mn_eco.htm

Galatowitsch, S.A. 2012. Why invasive species stymie wetland restoration; Society of Wetland Scientists Research Brief, No. 2012-0001. 4 pp. http://www.sinauer.com/ecological-restoration.html

Genet, J. A. 2012. Status and Trends of wetland s in Minnesota: Depressional Wetland Quality Baseline. Minnesota Pollution Control Agency, Biological Monitoring Program, St. Paul, Minnesota. 80 pp. http://www.pca.state.mn.us/index.php/view-document.html?gid=17741

McCollor, S., and S. Heiskary. 1993. Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions. Addendum to Fandrei, G., S. Heiskary, and S. McCollor. 1988. Descriptive Characteristics of the Seven Ecoregions in Minnesota. Division of Water Quality, Program Development Section, Minnesota Pollution Control Agency, St. Paul, Minnesota. 140 p.

Minnesota Pollution Control Agency (MPCA). 2007a. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List. Environmental Outcomes Division, Minnesota Pollution Control Agency, St. Paul, Minnesota.

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

Minnesota Pollution Control Agency (MPCA). 2007a. Watershed Approach to Condition Monitoring and Assessment. Appendix 7 *in* Biennial Report of the Clean Water Council. Minnesota Pollution Control Agency, St. Paul, Minnesota.

MPCA (2008). Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria. http://www.pca.state.mn.us/index.php/view-document.html?gid=6072

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

Minnesota Pollution Control Agency (MPCA). 2010c. Guidance Manual for Assessing the Quality of Minnesota Surface Water for the Determination of Impairment: 305(b) Report and 303(d) List. Environmental Outcomes Division, Minnesota Pollution Control Agency, St. Paul, Minnesota.

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

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

Minnesota Pollution Control Agency and Minnesota State University of Mankato (2009). State of the Minnesota River, Summary of Surface Water Quality Monitoring 2000-2008. http://mrbdc.mnsu.edu/sites/mrbdc.mnsu.edu/files/public/reports/basin/state_08/2008_fullreport1109.pdf?field_pubtitle_value=State+of+the+Minnesota+River&field_pubauthor_value=&body_value=&taxonomy_vocabulary_1_tid%255B%255D=1258&=Apply

Minnesota Rules Chapter 7050. 2007. Standards for the Protection of the Quality and Purity of the Waters of the State. Reviser of Statutes and Minnesota Pollution Control Agency, St. Paul, Minnesota.

Mitsch, W.J. and J.G. Gosslink. 2007. Wetlands, 4th ed. Wiley Publ, Hoboken, NJ. 600 pages.

Peterson, Todd A. 2010. Geologic Atlas of Todd County, Minnesota. Minnesota Department of Natural Resources. County Atlas Series C-18. Part B. Plates 7-10.

State Climatology Office- MNDNR Division of Ecological and Water Resources. 2010. http://www.climate.umn.edu/doc/hydro_yr_pre_maps.htm.

National Resource Conservation Service (NRCS). 2007. Rapid Watershed Assessment: Redeye (Leaf River) (MN) HUC: 07010107. NRCS. USDA. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022049.pdf.

University of Missouri Extension. 1999. Agricultural Phosphorus and Water Quality. Pub. G9181. http://extension.missouri.edu/publications/DisplayPub.aspx?P=G9181.

Appendix 1. Water chemistry definitions

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

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

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

Orthophosphate - Orthophosphate (OP) is a water soluble form of phosphorus that is readily available to algae (bioavailable). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from waste water 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.

Specific Conductance - The amount of ionic material dissolved in water. Specific conductance is influenced by the conductivity of rainwater, evaporation and by road salt and fertilizer application.

Temperature - Water temperature in streams varies over the course of the day similar to diurnal air temperature variation. Daily maximum temperature is typically several hours after noon, and the minimum is near sunrise. Water temperature also varies by season as doe's air temperature.

Total Kjehldahl 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.

Total Suspended Volatile Solids (TSVS) - Volatile solids are solids lost during ignition (heating to 500 degrees C.) They provide an approximation of the amount of organic matter that was present in the water sample. ‘‘Fixed solids’’ is the term applied to the residue of total, suspended, or dissolved solids after heating to dryness for a specified time at a specified temperature. The weight loss on ignition is called ‘‘volatile solids.’’

Unnionized 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 Redeye River Watershed

Biological Station ID	STORET / EQuIS ID	Waterbody Name	Location	11-digit HUC
11UM060	S005-732	Leaf River	Upstream of CR 77, In Bluffton	07010107120
11UM056	S006-849	Bluff Creek	At 585th Ave, 2 mi. NW of Bluffton	07010107130
11UM073	S001-433	Oak Creek	At Hwy 29, 2.5 mi. W of Wadena	07010107140
11UM076	S002-958	Wing River	At CSAH 23, 2.5 mi. N of Verndale	07010107150
11UM043	S006-848	Redeye River	Downstream of 221st Ave, 8 mi. NE of Verndale	07010107170
11UM040	S001-931	Redeye River	At CSAH 29, 7 mi. NW of Staples	07010107180

Appendix 3. AUID table of stream assessment results (by parameter and beneficial use)

AUID DESCRIPTIONS				USES					BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS						
Assessment Unit ID (AUID)	Stream Reach Name	Reach Description	Reach Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Drinking Water	303d listed impairments 2012	Fish	Macroinvertebrates	Dissolved Oxygen	Turbidity	Chloride	pH	NH3	Pesticides	Bacteria (Aquatic Recreation)
HUC-11: 07010107020 (Upper Leaf River)																	
07010107-511	Deer Creek	Headwaters to Leaf River	5.74	2B	FS	NA	--	--	MTS	MTS	--	--	--	--	--	--	--
07010107-514*	Leaf River	Bluff Creek to Oak Creek	1.46	2B	IF	NS	--	E. coli	NA	NA	IF	MTS	--	MTS	MTS	--	EX
07010107-525	Willow Creek	T133 R38W S11, S line to Leaf Lake	5.86	2A	FS	NA	NA	--	MTS	MTS	--	--	--	--	--	--	--
07010107-528	Trib. to South Bluff Creek	Unnamed Creek to South Bluff Creek	2.16	2B	FS	NA	--	--	MTS	MTS	--	--	--	--	--	--	--
07010107-531	South Bluff Creek	Unnamed Creek to Leaf River	4.32	2B	FS	NA	--	--	MTS	MTS	--	--	--	--	--	--	--
07010107-554	Trib. to East Leaf Lake	CD 49 to East Leaf Lake	6.41	2B	NS	NA	--	B_F	EXP	--	--	--	--	--	--	--	--
HUC-11: 07010107030 (Bluff Creek)																	
07010107-515	Bluff Creek	Headwaters to Leaf River	17.83	2C	FS	NS	--	E. coli	MTS	MTS	--	--	--	MTS	MTS	--	EX
07010107-541	Blue Creek	Unnamed Creek to Bluff Creek	5.01	2B	FS	NA	--	--	MTS	MTS	--	--	--	--	--	--	--
HUC-11: 07010107040 (Ridge creek)																	
07010107-516	Oak Creek	Unnamed Ditch to T134 R36W S3, N line	14.23	2C	FS	NS	--	E. coli	MTS	MTS	--	MTS	--	MTS	MTS	--	EX
07010107-530	South Bluff Creek	Unnamed Creek to Unnamed Creek	2.22	2B	FS	NA	--	--	MTS	MTS	--	--	--	--	--	--	--
07010107-553	South Bluff Creek	Unnamed Ditch to Unnamed Creek	6.67	2B	NS	NA	--	B_F, B_I	EXP	EXP	--	--	--	--	--	--	--
HUC-11: 07010107050 (Wing River)																	
07010107-559	Wing River	(Wing River Lake 56-0043-00) to Hwy 210 bridge	25.17	2B	NS	NA	--	B_F	EXP	MTS	--	--	--	--	--	--	--
07010107-560	Wing River	Hwy 210 bridge to Leaf River	23	2B	FS	NS	--	E. coli	MTS	MTS	IF	MTS	--	MTS	MTS	--	EX
HUC-11: 07010107060 (Hay Creek)																	
07010107-513	Hay Creek	Headwaters to Redeye River	17.29	2B	FS	IF	--	--	MTS	MTS	--	MTS	--	--	MTS	--	IF
HUC-11: 07010107070 (Redeye River)																	
07010107-502	Redeye River	Hay Creek to Leaf River	3.32	2B	FS	IF	--	--	MTS	MTS	MTS	MTS	--	MTS	MTS	--	IF
07010107-503	Redeye River	Headwaters (Wolf Lake 03-0101-00) to Hay Creek	62.88	2B	FS	NS	--	E. coli	MTS	MTS	MTS	MTS	--	MTS	MTS	--	EX
07010107-539	Unnamed Creek	Unnamed Creek to Redeye River	0.38	2B	NA	FS	--	--	--	--	--	MTS	--	--	MTS	--	MTS

Appendix 3. AUID table of stream assessment results (by parameter and beneficial use) (cont.)

AUID DESCRIPTIONS				USES						BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS						
Assessment Unit ID (AUID)	Stream Reach Name	Reach Description	Reach Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Drinking Water	303d listed impairments 2012		Fish	Macroinvertebrates	Dissolved Oxygen	Turbidity	Chloride	pH	NH3	Pesticides	Bacteria (Aquatic Recreation)
HUC-11: 07010107020 (Upper Leaf River)																		
07010107-501	Leaf River	Redeye River to Crow Wing River	8.18	2B	FS	FS	--	--		MTS	--	MTS	MTS	--	MTS	MTS	--	MTS
07010107-504	Leaf River	Wing River to Redeye River	7.38	2B	FS	FS	--	--		MTS	MTS	MTS	MTS	--	MTS	MTS	--	MTS
07010107-505	Leaf River	Oak Creek to Wing River	16.28	2B	NS	NS	--	E. coli		MTS	MTS	EXS	MTS	--	--	MTS	--	EX
07010107-508	Union Creek	Whisky Creek to Leaf River	4.84	2A	NS	NS	IF	E. coli		NS	NS	EXS	MTS	--	--	MTS	--	EX
07010107-509	Union Creek	Headwaters to Whisky Creek	6.79	2A	NS	IF	--	--		MTS	EXP	--	--	--	--	--	--	--
07010107-526	Trib. to Redeye River	T134 R33W S18, W line to Leaf River	5.89	2A	IF	NS	IF	E. coli		NA	NA	IF	MTS	--	--	MTS	--	EX
07010107-557	Trib. to Leaf River	Unnamed Creek to Leaf River	2.44	2B	NS	NA	--	B_I		MTS	EXS	--	--	--	--	--	--	--

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets standards or ecoregion expectations (MT/MTS), Potential Exceedance (EXP), Exceeds standards or ecoregion expectations (EX/EXS).
Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use. *Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

Appendix 4.1. Minnesota statewide IBI thresholds and confidence limits

Class #	Class Name	Use Class	Old Threshold	New Threshold	Confidence Limit	Upper	Lower
Fish							
1	Southern Rivers	2B, 2C	46	49	±11	60	38
2	Southern Streams	2B, 2C	45	50	±9	59	41
3	Southern Headwaters	2B, 2C	51	55	±7	62	48
10	Southern Coldwater	2A	45	50	±9	59	41
4	Northern Rivers	2B, 2C	35	38	±9	47	29
5	Northern Streams	2B, 2C	50	47	±9	56	38
6	Northern Headwaters	2B, 2C	40	42	±16	58	26
7	Low Gradient	2B, 2C	40	42	±10	52	32
11	Northern Coldwater	2A	37	35	±10	45	25
Invertebrates							
1	Northern Forest Rivers	2B, 2C	51.3	49	±10.8	59.8	38.2
2	Prairie Forest Rivers	2B, 2C	30.7	31	±10.8	41.8	20.2
3	Northern Forest Streams RR	2B, 2C	50.3	53	±12.6	65.6	41.4
4	Northern Forest Streams GP	2B, 2C	52.4	51	±13.6	64.6	37.4
5	Southern Streams RR	2B, 2C	35.9	37	±12.6	49.6	34.4
6	Southern Forest Streams GP	2B, 2C	46.8	43	±13.6	56.6	39.4
7	Prairie Streams GP	2B, 2C	38.3	41	±13.6	54.4	27.4
8	Northern Coldwater	2A	26	32	±12.4	34.4	19.6
9	Southern Coldwater	2A	46.1	43	±13.8	57.8	29.2

Appendix 4.2. Biological monitoring results – fish IBI (assessable reaches)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Threshold	FIBI	Visit Date
HUC-11: 07010107020 Upper Leaf River subwatershed							
	11UM066	Willow Creek	46.01	6	42	64	15-Aug-11
	11UM061	Deer Creek	14.71	6	42	68	21-Jun-11
	11UM065	Unnamed creek	15.58	6	42	34	11-Jul-12
	11UM068	South Bluff Creek	45.86	6	42	63	16-Aug-11
	11UM071	Unnamed creek	6.45	6	42	45	20-Jun-11
HUC-11: 07010107030 Bluff Creek subwatershed							
	11UM056	Bluff Creek	67.27	5	47	63	16-Aug-11
	11UM058	Bluff Creek	21.06	7	42	44	13-Sep-11
	11UM059	Blue Creek	23.60	6	42	49	10-Jun-11
HUC-11: 07010107040 Ridge Creek subwatershed							
	11UM070	South Bluff Creek	30.35	6	42	60	21-Jun-11
	11UM070	South Bluff Creek	30.35	6	42	65	17-Aug-11
	11UM072	South Bluff Creek	15.49	6	42	31	17-Aug-11
	11UM072	South Bluff Creek	15.49	6	42	46	20-Jun-11
	11UM073	Oak Creek	37.98	6	42	72	16-Aug-11
	11UM075	Oak Creek	24.75	6	42	71	20-Jun-11
HUC-11: 07010107050 Wing River subwatershed							
	11UM076	Wing River	151.39	5	47	54	31-Aug-11
	11UM077	Wing River	130.87	5	47	37	17-Aug-11
	11UM077	Wing River	130.87	5	47	44	23-Jul-13
	11UM078	Wing River	106.57	5	47	30	17-Aug-11
	11UM080	Wing River	34.36	7	42	57	28-Sep-11
	13UM183	Wing River	118.12	5	47	41	23-Jul-13
HUC-11: 07010107060 Hay Creek subwatershed							
	11UM044	Hay Creek	26.69	7	42	68	31-Aug-11

Appendix 4.2. Biological monitoring results – fish IBI (assessable reaches) (cont.)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Threshold	FIBI	Visit Date
HUC-11: 07010107070 Redeye River subwatershed							
	10EM022	Redeye River	144.10	5	47	56	23-Aug-10
	10EM198	Redeye River	217.15	5	47	75	22-Jun-11
	11UM043	Redeye River	216.09	5	47	76	29-Aug-11
	11UM046	Redeye River	169.25	5	47	65	01-Sep-11
	11UM048	Redeye River	107.93	5	47	50	16-Aug-11
	11UM051	Redeye River	50.40	7	42	85	16-Aug-11
HUC-11: 07010107080 Lower Leaf River subwatershed							
	11UM040	Leaf River	857.44	4	38	61	10-Aug-11
	11UM042	Leaf River	624.19	4	38	89	29-Aug-11
	11UM053	Leaf River	52.4	5	50	57	31-Aug-11
	11UM055	Unnamed Creek	50.3	6	42	47	10-Jun-11
	13UM176	Union Creek	8.71	11	35	36	22-Jul-13
	13UM177	Union Creek	18.51	11	35	32	9-Sept-13

Appendix 4.3. Biological monitoring results-macroinvertebrate IBI (assessable reaches)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Threshold	MIBI	Visit Date
HUC-11: 07010107020 Upper Leaf River subwatershed							
	11UM066	Willow Creek	46.01	5	37	56.53	15-Aug-11
	11UM071	Unnamed creek	6.45	6	43	61.99	24-Aug-11
	11UM068	South Bluff Creek	45.86	4	51	53.03	16-Aug-11
	11UM061	Deer Creek	14.71	4	51	68.26	24-Aug-11
HUC-11: 07010107030 Bluff Creek subwatershed							
	11UM056	Bluff Creek	67.27	3	53	53.71	24-Aug-11
	11UM058	Bluff Creek	21.06	4	51	60.85	01-Sep-11
	11UM059	Blue Creek	23.60	4	51	48.84	25-Aug-11
HUC-11: 07010107040 Ridge Creek subwatershed							
	11UM070	South Bluff Creek	30.35	3	53	66.84	17-Aug-11
	11UM072	South Bluff Creek	15.49	6	43	46.95	17-Aug-11
	11UM073	Oak Creek	37.98	4	51	65.65	16-Aug-11
	11UM075	Oak Creek	24.75	6	43	72.58	24-Aug-11
HUC-11: 07010107050 Wing River subwatershed							
	11UM078	Wing River	106.57	5	37	51.18	24-Aug-11
	11UM076	Wing River	151.39	4	51	53.65	25-Aug-11
	11UM077	Wing River	130.87	6	43	71.99	30-Aug-11
	13UM183	Wing River	118.12	5	37	59.1	24-Sept-13
HUC-11: 07010107060 Hay Creek subwatershed							
	11UM044	Hay Creek	26.69	4	51	52.93	09-Aug-11

Appendix 4.3. Biological monitoring results-macroinvertebrate IBI (assessable reaches) (cont.)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Threshold	MIBI	Visit Date
HUC-11: 07010107070 Redeye River subwatershed							
	10EM022	Redeye River	144.10	3	53	50.20	10-Aug-11
	11UM046	Redeye River	169.25	4	51	74.33	09-Aug-11
	11UM048	Redeye River	107.93	3	53	65.83	25-Aug-11
	11UM051	Redeye River	50.40	4	51	58.11	25-Aug-11
	10EM198	Redeye River	217.15	3	53	64.00	10-Aug-11
	11UM043	Redeye River	216.09	3	53	63.86	29-Aug-11
HUC-11: 07010107080 Lower Leaf River subwatershed							
	11UM053	Leaf River	444.66	4	51	51.68	12-Sep-11
	11UM055	Unnamed creek	18.71	3	53	29.35	25-Aug-11
	11UM042	Leaf River	624.19	1	49	42.14	29-Aug-11
	13UM176	Union Creek	8.71	8	32	17.2	24-Sept-13
	13UM177	Union Creek	18.51	8	32	22.2	24-Sept-13

Appendix 5.1. Good/fair/poor thresholds for biological stations on non-assessed channelized AUIDs

Ratings of **Good** for channelized streams are based on Minnesota's general use threshold for aquatic life (Appendix 4.1). Stations with IBIs that score above this general use threshold would be given a rating of **Good**. The **Fair** rating is calculated as a 15 point drop from the general use threshold. Stations with IBI scores below the general use threshold, but above the **Fair** threshold would be given a rating of **Fair**. Stations scoring below the Fair threshold would be considered **Poor**.

Class #	Class Name	Good	Fair	Poor
Fish				
1	Southern Rivers	>38	38-24	<24
2	Southern Streams	>44	44-30	<30
3	Southern Headwaters	>50	50-36	<36
4	Northern Rivers	>34	34-20	<20
5	Northern Streams	>49	49-35	<35
6	Northern Headwaters	>39	39-25	<25
7	Low Gradient Streams	>39	39-25	<25
Invertebrates				
1	Northern Forest Rivers	>51	52-36	<36
2	Prairie Forest Rivers	>31	31-16	<16
3	Northern Forest Streams RR	>50	50-35	<35
4	Northern Forest Streams GP	>52	52-37	<37
5	Southern Streams RR	>36	36-21	<21
6	Southern Forest Streams GP	>47	47-32	<32
7	Prairie Streams GP	>38	38-23	<23

Appendix 5.2. Channelized stream reach and AUID IBI scores-fish (non-assessed)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Good	Fair	Poor	FIBI	Visit Date
HUC-11: 07010107020 Upper Leaf River subwatershed									
	11UM060	Leaf River	295.85	5	>49	49-35	<35	67	17-Aug-11
	11UM063	Leaf River	124.22	5	>49	49-35	<35	32	28-Sep-11
	11UM067	Willow Creek	30.01	6	>39	39-25	<25	64	11-Jul-12
HUC-11: 07010107030 Bluff Creek subwatershed									
	11UM057	Unnamed Creek	12.98	6	>39	39-25	<25	74	10-Jun-11
HUC-11: 07010107050 Wing River subwatershed									
	11UM079	County Ditch 13	25.50	6	>39	39-25	<25	34	14-Jun-11
HUC-11: 07010107060 Hay Creek subwatershed									
	11UM045	Hay Creek	15.61	7	>39	39-25	<25	35	10-Jul-12
HUC-11: 07010107070 Redeye River subwatershed									
	11UM052	Redeye River	23.34	6	>39	39-25	<25	46	17-Aug-11
HUC-11: 07010107080 Lower Leaf River subwatershed									
	00UM095*	Union Creek	8.89	11	>47	47-27	<27	23	16-Aug-11
	11UM041*	Trib. to Leaf River	33.55	11	>47	47-27	<27	50	25-Jul-11

*Good/Fair/Poor ratings have yet to be developed for channelized coldwater stream reaches. These rating are based on IBI threshold values found in Appendix 4.1.

Appendix 5.3. Channelized stream reach and AUID IBI scores-macroinvertebrate (non-unassessed)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Good	Fair	Poor	MIBI	Visit Date
HUC-11: 07010107020 Upper Leaf River subwatershed									
	11UM060	Leaf River	295.85	3	>50	50-35	<35	52.64	29-Aug-11
	11UM063	Leaf River	124.22	6	>47	47-32	<32	50.52	31-Aug-11
	11UM067	Willow Creek	30.01	4	>52	52-37	<37	47.28	15-Aug-11
HUC-11: 07010107030 Bluff Creek subwatershed									
	11UM057	Unnamed Creek	12.98	4	>52	52-37	<37	36.53	01-Sep-11
	11UM057	Unnamed Creek	12.98	4	>52	52-37	<37	49.97	01-Sep-11
HUC-11: 07010107050 Wing River subwatershed									
	11UM079	County Ditch 13	25.50	6	>47	47-32	<32	41.46	24-Aug-11
HUC-11: 07010107070 Redeye River subwatershed									
	11UM052	Redeye River	23.34	4	>52	52-37	<37	17.76	17-Aug-11
HUC-11: 07010107080 Lower Leaf River subwatershed									
	00UM095	Union Creek	8.89	8	>38.4	38.4-13.6	<13.6	25.74	16-Aug-11
	11UM041	Trib. To Leaf River	33.55	8	>38.4	38.4-13.6	<13.6	30.84	29-Aug-11
	13UM177	Union Creek	18.51	8	>38.4	38.4-13.6	<13.6	22.2	24-Sept-13

*Good/Fair/Poor ratings have yet to be developed for channelized coldwater stream reaches. These rating are based on IBI threshold values found in Appendix 4.1.

Appendix 6. Minnesota’s ecoregion-based lake eutrophication standards

Ecoregion	TP µg/L	Chl-a µg/L	Secchi meters
NLF – Lake Trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
NCHF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2B) Shallow lakes	< 60	< 20	> 1.0
WCBP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCBP & NGP – Aquatic Rec. Use (Class 2B) Shallow lakes	< 90	< 30	> 0.7

Appendix 7. MINLEAP model estimates of phosphorus loads for lakes in the Redeye River Watershed

Lake ID	Lake Name	Obs TP (µg/L)	MINLEAP TP (µg/L)	Obs Chl-a (µg/L)	MINLEAP Chl-a (µg/L)	Obs Secchi (m)	MINLEAP Secchi (m)	Avg. TP Inflow (µg/L)	TP Load (kg/yr)	Background TP (µg/L)	%P Retention	Outflow (hm3/yr)	Residence Time (yrs)	Areal Load (m/yr)	Trophic Status
03-0101-00	Wolf	22.6	53	6.4	22.0	2.0	1.3	168.0	1205.0	28.0	0.68	7.19	1.6	1.22	M
56-0005-00	West Annalaide	19.0	84	3.9	43.0	1.0	0.8	155.0	628.0	27.5	0.46	4.05	0.3	3.38	M
56-0010-00	Mary	20.6	52	3.6	21.0	2.1	1.3	202.0	93.0	35.2	0.74	0.46	2.2	0.45	M
56-0022-00	Horsehead	32.7	86	11.0	44.0	2.3	0.8	154.0	460.0	36.3	0.44	2.98	0.3	3.82	E
56-0031-00	Adley	45.5	66	23.9	30.0	1.8	1.1	161.0	311.0	29.2	0.59	1.94	0.8	1.92	E
56-0069-00	Bear	25.9	43	10.9	16.0	2.4	1.5	169.0	172.0	25.3	0.74	1.02	2.7	1.16	E
56-0070-00	Edna	17.5	52	4.1	21.0	1.2	1.3	184.0	66.0	26.8	0.72	0.36	1.9	0.67	M
56-0114-00	West Leaf	19.5	42	9.0	15.0	2.7	1.6	157.0	1210.0	21.8	0.74	7.69	2.6	2.61	M
56-0116-01	Middle Leaf	19.6	64	7.5	29.0	3.0	1.1	151.0	1862.0	24.7	0.58	12.30	0.7	7.15	M
56-0116-02	East Leaf	37.1	75	22.8	36.0	2.0	0.9	150.0	4105.0	23.9	0.50	27.44	0.4	15.24	E
56-0132-00	Mud	21.2	67	5.5	31.0	1.3	1.0	167.0	134.0	30.0	0.60	0.80	0.8	1.28	M
56-0140-01	Portage (main bay)	10.2	53	2.9	22.0	4.1	1.3	198.0	103.0	43.9	0.73	0.52	2.1	0.48	O
56-0192-00	Tamarack	14.3	65	2.0	29.0	1.0	1.1	170.0	329.0	27.5	0.62	1.93	0.9	1.09	M
56-0200-00	Donalds	17.2	29	4.2	9.0	3.4	2.1	189.0	98.0	24.6	0.85	0.52	8.1	0.59	M

Abbreviations: **H** – Hypereutrophic; **E** – Eutrophic; **M** – Mesotrophic; **O** – Oligotrophic; --- No data

Appendix 8. Fish species found during biological monitoring surveys

Common Name	Quantity of Stations Where Present	Quantity of Individuals Collected
bigmouth shiner	9	101
black bullhead	14	164
black crappie	2	3
blackchin shiner	1	22
blacknose dace	27	1075
blacknose shiner	12	160
bluegill	5	14
bluntnose minnow	5	135
bowfin	1	2
brassy minnow	7	89
brook stickleback	19	303
brown bullhead	2	2
burbot	19	390
central mudminnow	38	2371
common carp	1	3
common shiner	31	3541
creek chub	30	689
fathead minnow	11	103
finescale dace	2	7
Gen: common sunfishes	1	5
Gen: redhorses	4	16
golden shiner	7	430
greater redhorse	6	11
green sunfish	4	7
hornyhead chub	18	1359
Iowa darter	4	8
johnny darter	31	989
largemouth bass	11	30
logperch	7	62
longnose dace	12	235
mottled sculpin	25	11
northern pike	29	341
northern redbelly dace	15	403
pearl dace	13	322

Appendix 8. Fish species found during biological monitoring surveys (cont.)

Common Name	Quantity of Stations Where Present	Quantity of Individuals Collected
pumpkinseed	8	26
rock bass	14	203
sand shiner	2	3
shorthead redhorse	12	79
silver redhorse	3	3
spottail shiner	1	1
tadpole madtom	10	70
walleye	4	5
weed shiner	1	7
white sucker	38	1229
yellow bullhead	6	10
yellow perch	11	79