Pine River Watershed Monitoring and Assessment Report

Minnesota Pollution Control Agency

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List of acronyms

AUID Assessment Unit Identification Determination

CCSI Channel Condition and Stability Index

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

DO dissolved oxygen

DOP Dissolved Orthophosphate

E Eutrophic

EPA U.S. Environmental Protection Agency

EQuIS Environmental Quality Information System

EXP Exceeds Criteria, Potential Impairment

EXS Exceeds Criteria, Potential Severe Impairment

FIBI Fish Index of Biotic Integrity

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

MDA Minnesota Department of Agriculture

MDH Minnesota Department of Health

MDNR Minnesota Department of Natural Resources

MIBI Macroinvertebrate Index of Biotic Integrity

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

NRCS Natural Resources Conservation Service

NS Not Supporting

NT No Trend

OP Orthophosphate

P Phosphorous

PCB Poly Chlorinated Biphenyls

RNR River Nutrient Region

SWAG Surface Water Assessment Grant

SWCD Soil and Water Conservation District

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

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Executive summary

The Pine River Watershed lies within the Northern Lakes and Forests Ecoregion of north central Minnesota. Encompassing an area of 562 square miles, this heavily forested watershed contains over 500 miles of streams and rivers, numerous wetlands, and over 400 lakes greater than 10 acres in size. The Whitefish Chain of Lakes and Pelican Lake, two prominent lakes used heavily for recreation, are located within the Pine River Watershed. Major rivers and streams include the Pine River, Little Pine River, South Fork Pine River, Daggett Brook, and Mud Brook. Residential development within the watershed is fairly light and primarily located around the communities of Breezy Point and Pine River. Limited amounts of agricultural land use, primarily pasture and hay, occur in the southeast portion of the watershed. The relative lack of development in the Pine River Watershed promotes good water quality and diverse biological communities.

In 2012 the Minnesota Pollution Control Agency (MPCA) began an intensive watershed monitoring (IWM) effort of surface waters within the Pine River Watershed. Twenty-four sites were sampled for biology at the outlet of variable sized sub-watersheds. As part of this effort, MPCA staff joined with local partners to complete stream water chemistry sampling at the outlets of five subwatersheds. In 2015, surface water bodies with sufficient data were assessed for aquatic life, aquatic recreation, and aquatic consumption use support. During this process, 24 stream segments (AUIDs) were assessed for aquatic life; nine of these were assessed for aquatic recreation. One hundred sixteen lakes were assessed for aquatic recreation and aquatic life.

Twenty out of 24 stream segments fully supported aquatic life use. The remaining four segments did not support aquatic life and were determined impaired. All segments assessed for aquatic recreation were fully supporting. Every aquatic life impairment was the result of poor fish and macroinvertebrate communities. Habitat degradation, resulting from excess sediment deposition, appears to be the most likely cause of most poor biological communities. Three of the impairments occurred in smaller headwater streams in watersheds that had a significant amount of land use disturbance immediately adjacent to the stream channel. Stream water chemistry monitoring results were generally good. Occasional low dissolved oxygen (DO) levels were observed; however, most were correlated with large precipitation events. Large amounts of precipitation can flush organic matter from wetlands and forests into streams. Many streams within the Pine River Watershed had considerable wetland influence within their drainage area.

Seventy-eight lakes fully supported aquatic recreation while only three newly assessed lakes did not. New water chemistry data from two impaired lakes confirmed their existing aquatic recreation impairment. Aquatic life indicators using fish and plant communities were not available for this assessment cycle. The limited amount of chloride samples collected from the lakes in this watershed indicates it is not presently a concern for aquatic life. Popular lakes within this watershed are coveted for their aesthetic and physical attributes. Some lakes in this watershed experience heavy shoreline development that may impact their long term water quality if current and future protection strategies are not adhered to.

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 waterbody so that it can once again support its designated use.

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

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

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

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

The watershed monitoring approach

The watershed approach is a 10-year rotation for monitoring and assessing waters of the state on the level of Minnesota's 80 major watersheds (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 2008) (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

Watershed Pollutant Load Monitoring Network

The Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term monitoring approach designed to measure levels of key pollutants in the state's watersheds 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. 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, local monitoring organizations and MPCA WPLMN staff to compute annual pollutant loads at 79 river monitoring sites across Minnesota. 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.

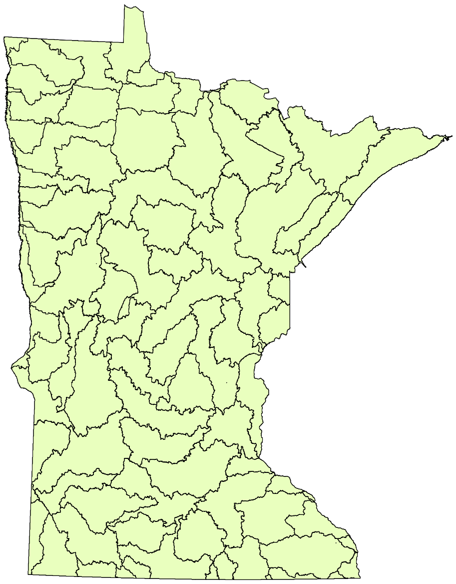


Figure 1. Major Watersheds within Minnesota (8-Digit HUC).

Intensive watershed monitoring

The IWM strategy utilizes a nested watershed design allowing the sampling of streams within watersheds from a coarse to a fine scale (Figure 2). Each watershed scale is defined by a hydrologic unit code (HUC). These HUCs define watershed boundaries for water bodies within a similar geographic and hydrologic extent. The foundation of this approach is the 80 major watersheds (8-HUC) within Minnesota. Using this approach many of the smaller headwaters and tributaries to the main stem river are sampled in a systematic way so that a more holistic assessment of the watershed can be conducted and problem areas identified without monitoring every stream reach. Each major watershed is the focus of attention for at least one year within the 10-year cycle.

River/stream sites are selected near the outlet of each of three watershed scales, 8-HUC, aggregated 12-HUC and 14-HUC (Figure 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 8-HUC scale. The outlet of the major 8-HUC watershed (purple 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 12-HUC is the next smaller subwatershed scale which generally consists of major tributary streams with drainage areas ranging from 75 to 150 mi^2. Each 12-HUC outlet (green dots in Figure 3) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use support. Within each aggregated 12-HUC, smaller watersheds (14 HUCs, typically 10-20 mi^2), are sampled at each outlet that flows into the major aggregated 12-HUC tributaries. Each of these minor subwatershed outlets is sampled for biology to assess aquatic life use support (red dots in Figure 3).

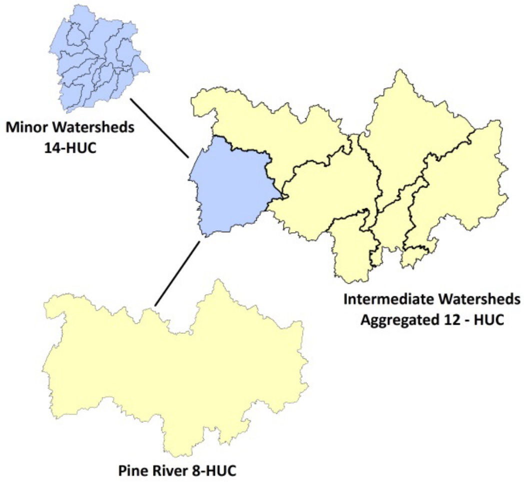


Figure 2. The intensive watershed monitoring design.

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 Pine River Watershed are shown in Figure 3 and are listed in Appendix 2, Appendix 4.2, and Appendix 4.3.

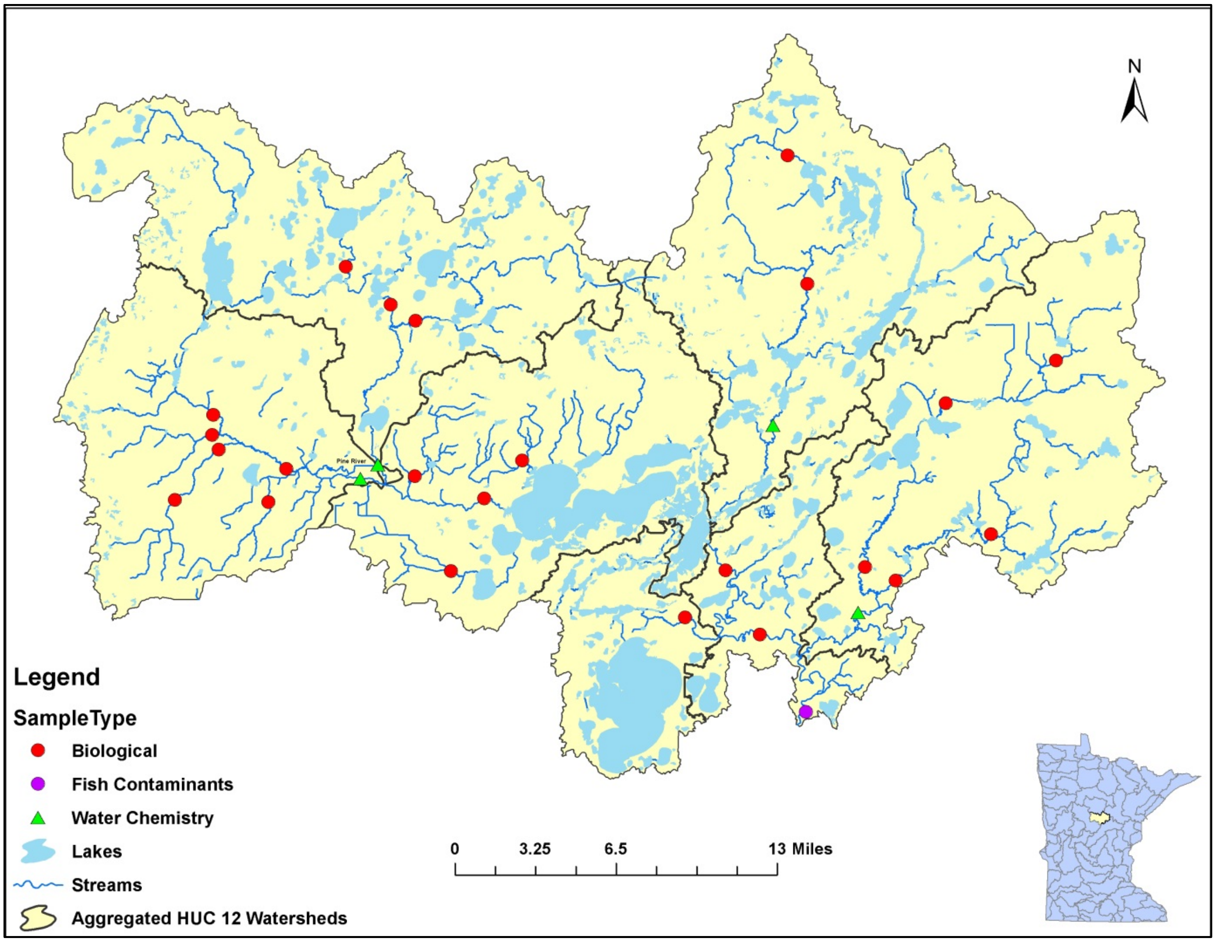


Figure 3. Intensive watershed monitoring sites for streams in the Pine River Watershed.

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 (SWCDs), watershed districts, nonprofits, and educational institutions to support lake and stream water chemistry monitoring. Local partners use the same monitoring protocols as the MPCA, and all monitoring data from SWAG projects are combined with the MPCA's to assess the condition of Minnesota lakes and streams. Preplanning and coordination of sampling with local citizens and governments helps focus monitoring where it will be most effective for assessment and observing long-term trends. This allows citizens/governments the ability to see how their efforts are used to inform water quality decisions and track how management efforts affect change. Many SWAG grantees invite citizen participation in their monitoring projects and their combined participation greatly expand our overall capacity to conduct sampling.

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

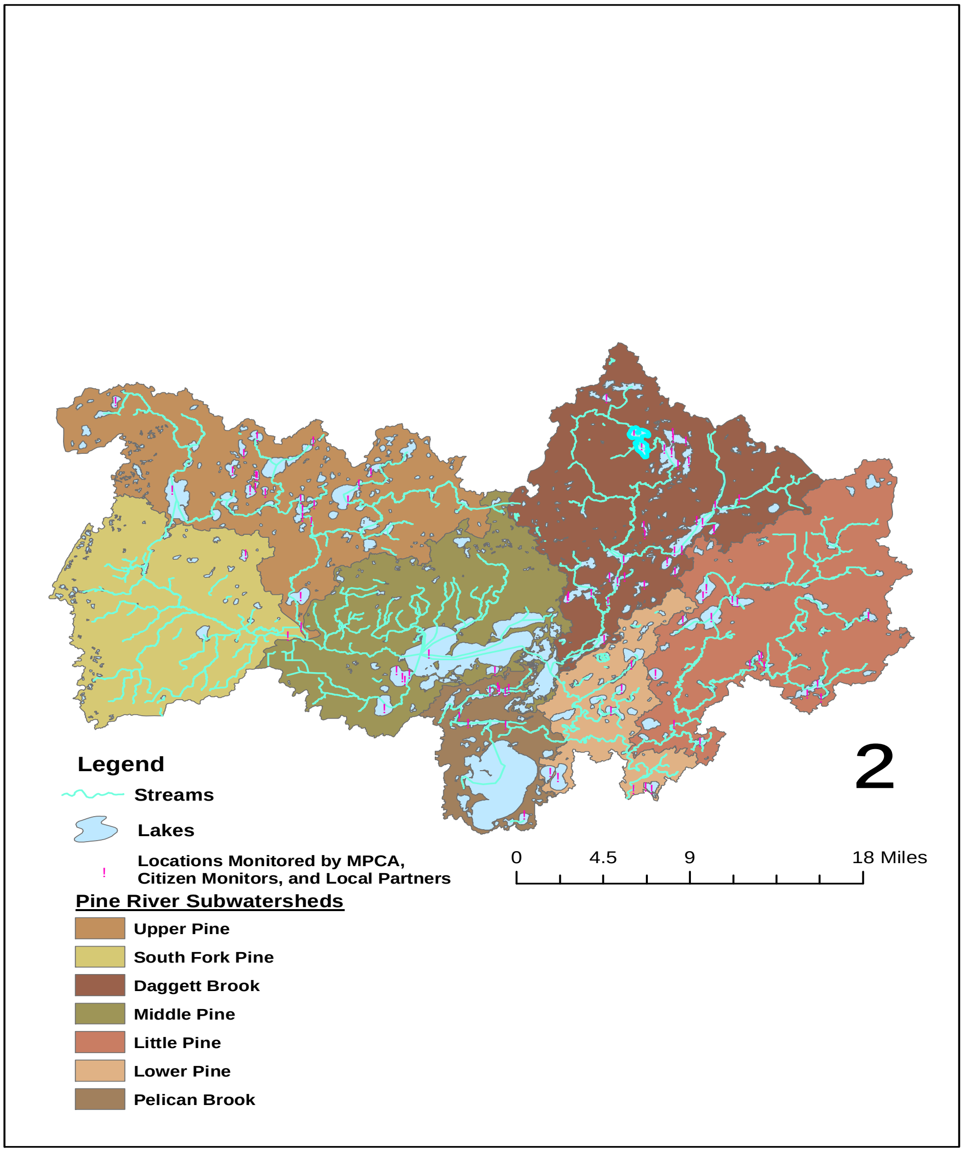


Figure 4. Monitoring locations of local groups, citizens, and the MPCA lake monitoring staff in the Pine River Watershed.

Assessment methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters that are determined to be supporting or non-supporting of their designated uses as evaluated by the comparison of monitoring data to criteria specified by Minnesota Water Quality Standards (Minn. R. ch. 7050 2008; https://www.revisor.leg.state.mn.us/rules/?id=7050). The assessment and listing process involves dozens of MPCA staff, other state agencies and local partners. The goal of this effort is to use the best data and best science available to assess the condition of Minnesota's water resources. For a thorough review of the assessment methodologies see: Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA 2014). https://www.pca.state.mn.us/sites/default/files/wq-iw1-04.pdf

Water quality standards

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

Protection of aquatic 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. To effectively use biological indicators, the MPCA employs the Index of Biotic Integrity (IBI). This index is a scientifically validated combination of measurements of the biological community (called metrics). An IBI is comprised of multiple metrics that measure different aspects of aquatic communities (e.g., dominance by pollution tolerant species, loss of habitat specialists). Metric scores are summed together and the resulting index score characterizes the biological integrity or "health" of a site. The MPCA has developed IBIs for fish and macroinvertebrates since these communities can respond differently to various types of pollution. Because the rivers and streams in Minnesota are physically, chemically, and biologically diverse, IBIs are developed separately for different stream classes to account for this natural variation. Further interpretation of biological community data is provided by an assessment threshold or biocriteria against which an IBI score can be compared within a given stream class. In general, an IBI score above this threshold is indicative of aquatic life use support, while a score below this threshold is indicative of non-support. Additionally, chemical parameters are measured and assessed against numeric standards developed to be protective of aquatic life, including pH, DO, un-ionized ammonia nitrogen, chloride, and turbidity.

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

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 waterbody can be safely consumed. For lakes, rivers and streams that are protected as a source of drinking water the MPCA primarily measures the concentration of nitrate in the water column to assess this designated use.

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, DO, 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 (8-HUC) 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 largely an automated process performed by logic programmed into a database application where all data from the 10 year assessment window is gathered; the results are referred to as 'Pre-Assessments'. Data filtered into the "Pre-Assessment" process is then reviewed to insure that data are valid and appropriate for assessment purposes. Tiered use designations are determined before data are assessed based on the attainment of the applicable biological criteria and/or an assessment of the habitat. Stream reaches are assigned the highest aquatic life use attained by both biological assemblages on or after November 28, 1975. Streams that do not attain the Exceptional or General Use for both assemblages undergo a Use Attainability Analysis (UAA) to determine if a lower use is appropriate. A Modified Use can be proposed if the UAA demonstrates that the General Use is not attainable as a result of legal human activities (e.g., drainage maintenance, channel stabilization) which are limiting the biological assemblages through altered habitat. Decisions to propose a new use are made through UAA workgroups which include watershed project managers and biology leads. The final approval to change a designated use is through formal rulemaking.

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

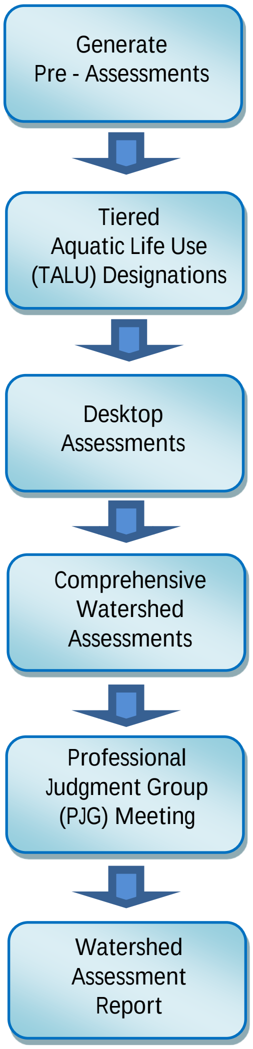


Figure 5. Flow chart of aquatic life use assessment.

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 2012) https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list for guidelines and factors considered when making such determinations.

The last step in the assessment process is the Professional Judgment Group meeting. At this meeting results are shared and discussed with entities outside of the MPCA that may have been involved in data collection or that might be responsible for local watershed reports and project planning. Information obtained during this meeting may be used to revise previous use attainment decisions (e.g., sampling events that may have been uncharacteristic due to annual climate or flow variation, local factors such as impoundments that do not represent the majority of conditions on the 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 10 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.

Watershed overview

The Pine River Watershed occupies 502,400 acres (562 square miles) of north central Minnesota. Most of the watershed lies within Cass and Crow Wing County; however, portions of the watershed are in Hubbard and Aitkin County. The Pine River originates near the Foothills State Forest in western Cass County. Along its path to the Mississippi River, the Pine River flows generally east and south. The river winds through undeveloped forests, small wetlands, and numerous lakes. Major tributaries include the South Fork of the Pine River and the Little Pine River. Other major streams found within the watershed include Pelican Brook, Daggett Brook, Mud Brook, and Arvig Creek. Over 441 lakes greater than 10 acres are within the Pine River Watershed. The Whitefish Chain of Lakes and Pelican Lake are the two most prominent lake systems. Most of the watershed is heavily forested and contains numerous wetlands. Considerable development occurs around the Whitefish Chain of Lakes and the community of Pine River. Municipalities found within the watershed include Pine River, Jenkins, Cross Lake, Manhattan Beach, Fifty Lakes, Breezy Point, and Emily.

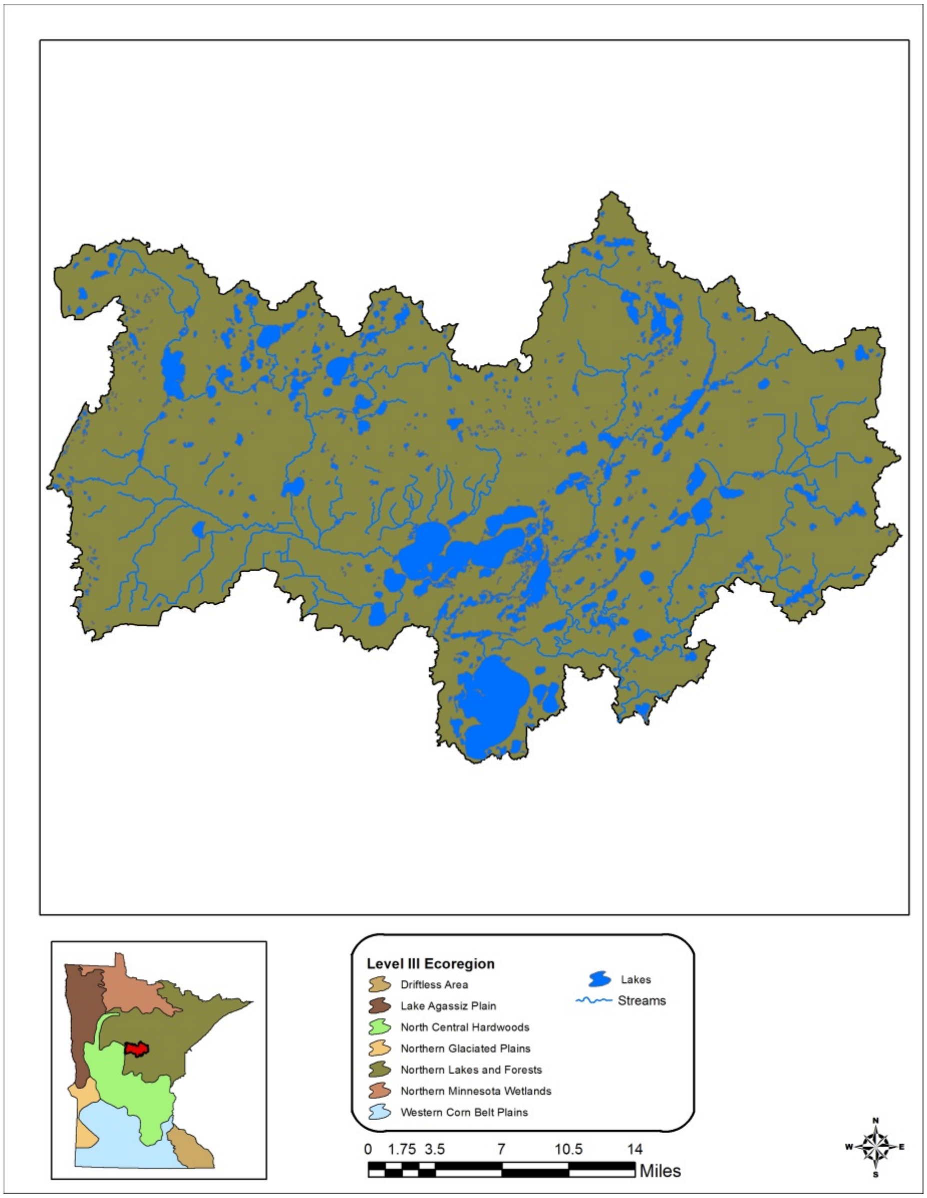


Figure 6. The Pine River Watershed within the northern lakes and forest ecoregion of north central Minnesota.

The Pine River Watershed lies within the Northern Lakes and Forests (NLF) ecoregion (Figure 6). The glacial soils of the NLF region are thick and nutrient poor (Omernik *et al.* 1988). Moraine hills, undulating till plains and lacustrine basins occur in the NLF ecoregion (Omernik *et al.* 1988). Northern hardwood forests and coniferous forests also commonly occur within this ecoregion (Omernik *et al.* 1988). The lakes in the watershed are often clear due to low nutrient input from the infertile soil and forested watersheds.

Land use summary

During early settlement the Pine River Watershed, like other watersheds associated with the Upper Mississippi River Valley, was an area rich in resources such as fur and timber. The fur trade industry began during the mid-seventeenth century and continued to be the most prominent industry of the Upper Mississippi River Valley until the mid-1800s when logging became the largest industry in Minnesota. The logging industry was instrumental in populating the state of Minnesota by providing jobs, raw materials for construction, and by creating markets for agriculture (Larson 2007). The expansion of the railroads used to haul lumber resources also assisted in opening areas of the Upper Mississippi River Valley to settlement. From 1860-1880 the population of Minnesota increased from 172,000 to 780,000 people (Larson 2007). By the early 1900s, almost all of the white pine in the state had been harvested. Many of the larger saw mills in the state closed down forcing the men they employed to find a new occupation (Larson 2007). Lumber companies sold large amounts of the cut over land to farmers and other prospective settlers (Larson 2007). Considerable time and labor had to be invested to clear the land of pine stumps. The soil on the land was often acidic and sandy or wetland soil that produced poor yields (Larson 2007). In Hubbard County alone, 90 farms were abandoned by 1920, 62 were abandoned from 1920-1923, and 79 were abandoned from 1924-1927 (Larson 2007). The abandonment of farms occurred in many other counties within the Upper Mississippi River Valley (Larson 2007).

Despite the dramatic loss of large tracts of pine during the 19th century, the Pine River Watershed is primarily forested (approximately 53.4%). Half of the forested land is state owned and half is held under private ownership (NRCS, 2014). Aspen, birch, spruce, and other conifer species are found throughout the watershed. Smaller scale logging operations still persist in various locations within the watershed. Agricultural land utilized for row crop production is limited by the presence of acidic and poorly drained soils; less than 2% of the Pine River Watershed is used for row crop production. Most agricultural land use occurs in the form of pasture and hay (approximately 5.7%). An estimate by the NRCS indicated 355 farms are located in the watershed; over half of those farms are small operations under 180 acres in size (NRCS 2014). The watershed is lake rich, accounting for 11.7% of the surface area in the Pine River Watershed. Over 400 lakes varying in size from 10 to over 7,000 acres are spread throughout the watershed. Wetlands occupy 24% of the watershed. Currently only 3.8% of the Pine River Watershed is developed; however, development pressure is steadily increasing. The Pine River Watershed is a part of the Central Lakes Region of Minnesota –one of the fastest growing regions in the state. The population of the Central Lakes Region is expected to increase 32% by 2030 (Gould, Walker, & Frazell 2009). Improvements in transportation have allowed people from more populated areas of the state better access to the region. Also, technological advances in communication are allowing individuals to work from home rather than travel to a centralized offices.

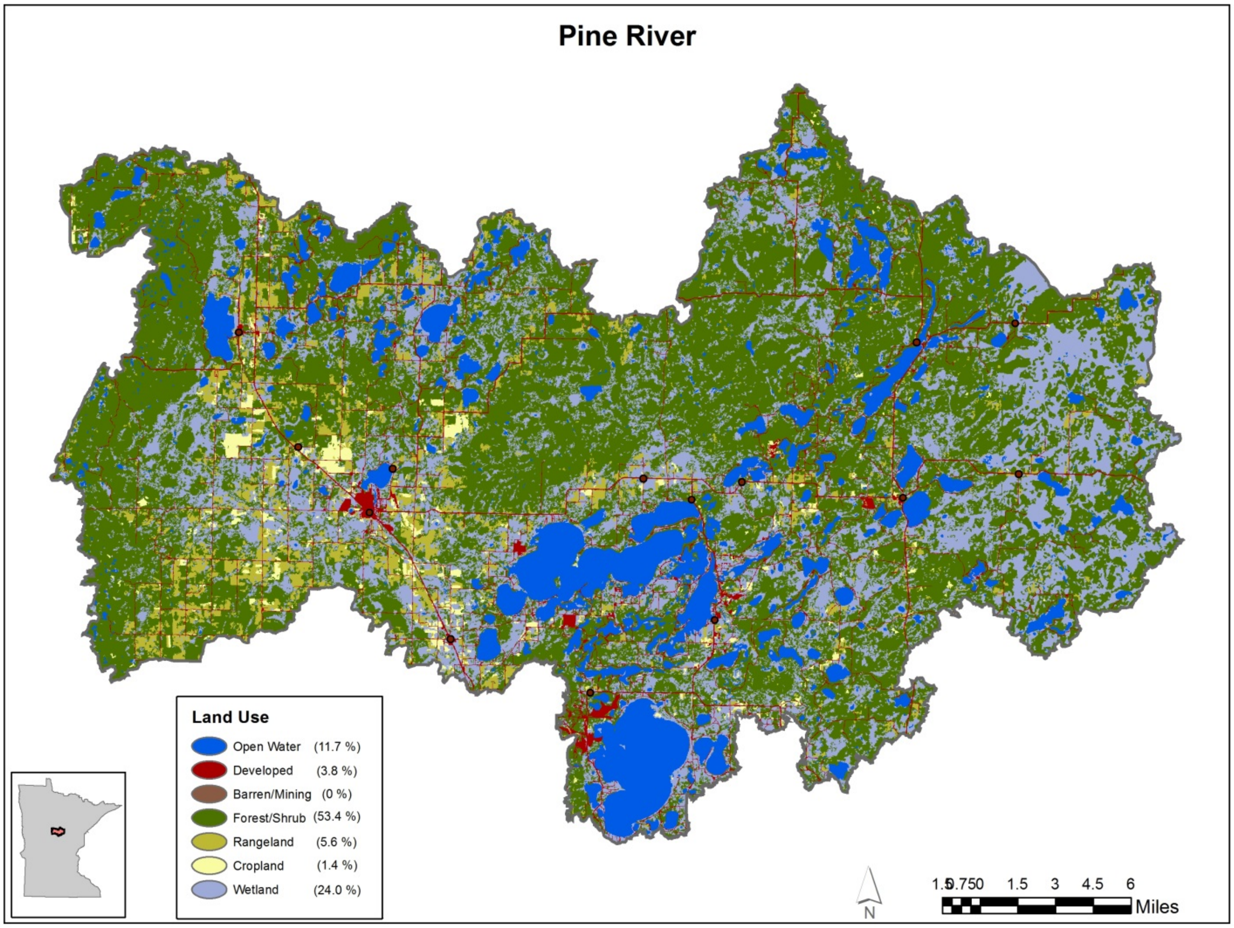


Figure 7. Land use in the Pine River Watershed.

Surface water hydrology

The Pine River originates from a series of small wetlands located approximately 3.5 miles southwest of Hackensack. Early in its course the river is a small, barely perceptible, low gradient stream coursing southward through the heavily forested region near the Foot Hills State Forest. The river enters the north side of Pine Mountain Lake and passes the community of Backus. After passing through the dam on the south end of Pine Mountain Lake, the Pine River flows predominantly eastward through several small developed lakes. The river consists of several small connecting channels between Bowen Lake, Lindsey Lake, Brockway Lake, and Lake Hattie. Dams are present on the outlet of Bowen Lake and Lake Hattie. From the outlet of Lake Hattie, the Pine River flows south for approximately five miles before entering Norway Lake. The community of Pine River is located on the southern shore of Norway Lake. The South Fork of the Pine River, a major tributary, joins the Pine River 1.5 miles downstream of the Norway Lake dam. The South Fork of the Pine River drains the southwest portion of the Pine River Watershed. Flowing from west to east, the South Fork of the Pine River is primarily low gradient and has a considerable amount of agricultural land use within its drainage area. After the confluence of the South Fork of the Pine River, the Pine River flows toward the east and the stream gradient increases. Swifter velocity and more frequent sections of riffle occur along the five mile stretch of river between the confluence of the South Fork of the Pine River and the Whitefish Chain of Lakes.

The Pine River enters the Whitefish Chain of Lakes on the western side of Whitefish Lake. The Whitefish Chain of Lakes covers 14,000 acres and consists of 14 interconnected lakes. Lake basin morphology varies considerably among lakes within the Whitefish Chain. Moderate to heavy development occurs around several lakes and within the vicinity of the Whitefish Chain of Lakes. Numerous tributaries flow directly into the lakes associated with this system. One of the more prominent tributaries to the lake system is Daggett Brook. Daggett Brook drains 149 square miles of the northeast portion of the Pine River Watershed. Flowing from north to south, Dagget Brook passes through heavily forested land, numerous wetlands, and several lakes before entering the Whitefish Chain of Lakes.

The Pine River exits the Whitefish Chain of Lakes through the Cross Lake Dam and flows toward the south. The river passes through an impounded wetland area on the north end of Pine Lake before flowing through Big Pine Lake dam. Pelican Brook joins the Pine River three miles downstream of Big Pine Lake dam. Pelican Brook flows east out of Ossawinnamakee Lake. After joining with Pelican Brook, the Pine River winds eastward through the Crow Wing State Forest for several miles before turning toward the south. At this location the Pine River is joined by the Little Pine River. The Little Pine River flows toward the southwest and drains 141 square miles of the eastern portion of the Pine River Watershed. Numerous wetlands and several lakes are within the Little Pine River drainage area. Mud Brook, a significant low gradient tributary, enters the Little Pine River a few miles upstream of Olander Road. Over much of its course, the Little Pine River is a low gradient wetland influenced stream; however, some sections of riffle do occur in the lower reaches. After the confluence of the Little Pine River, the Pine River continues winding south until it enters the Mississippi River. The average gradient of the Pine River from Norway Lake Dam to the confluence with the Mississippi River is 2.3 feet per mile (MDNR, 2014). Approximately 10% of the streams within the Pine River Watershed have been straightened or received other hydrologic alterations (Figure 9)Figure 9. Most watersheds in the north central and northeast region of Minnesota have a lower percentage of modified stream channels (Figure 8) when compared to other regions of the state.

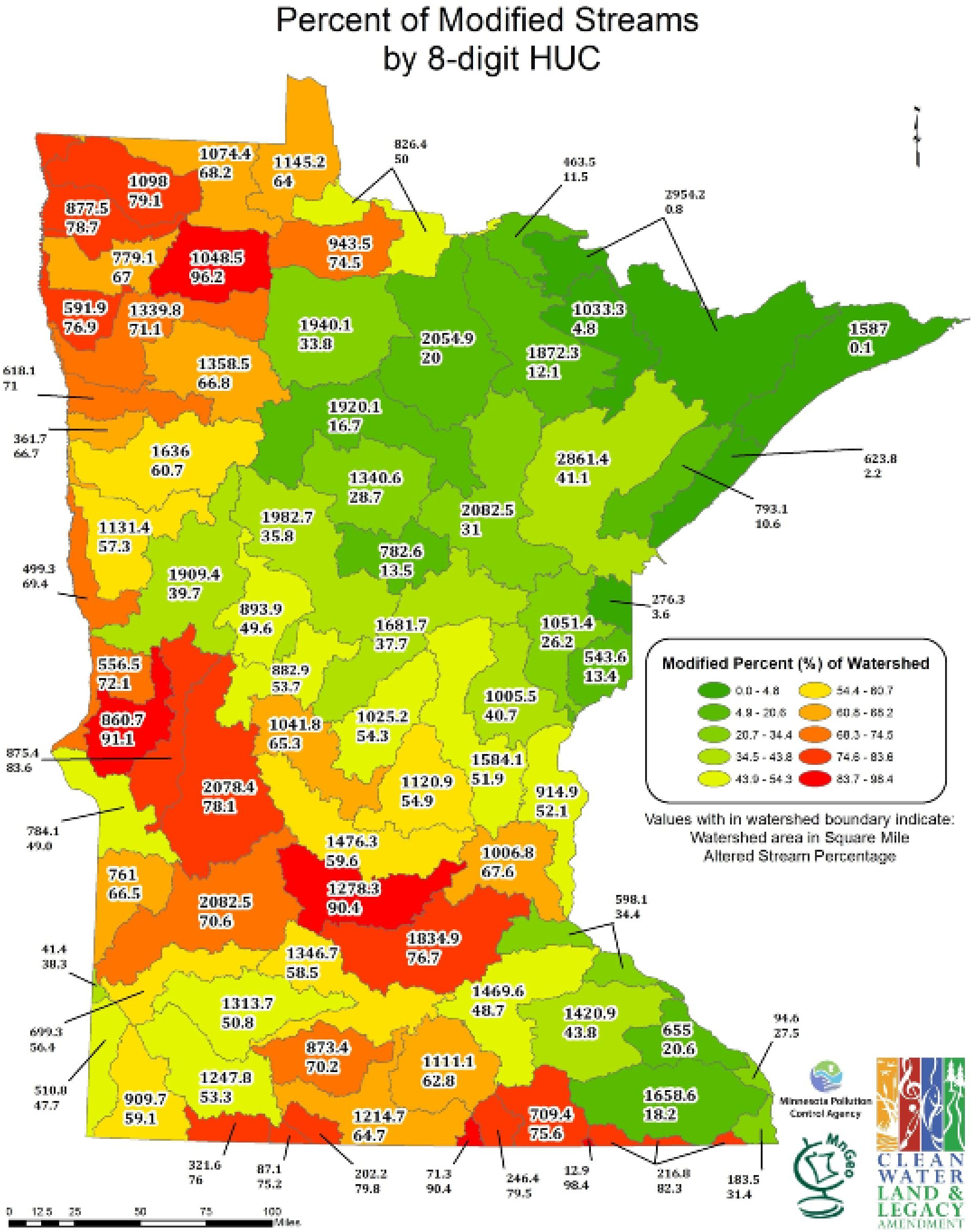


Figure 8. Map of percent modified streams by major watershed (8-HUC).

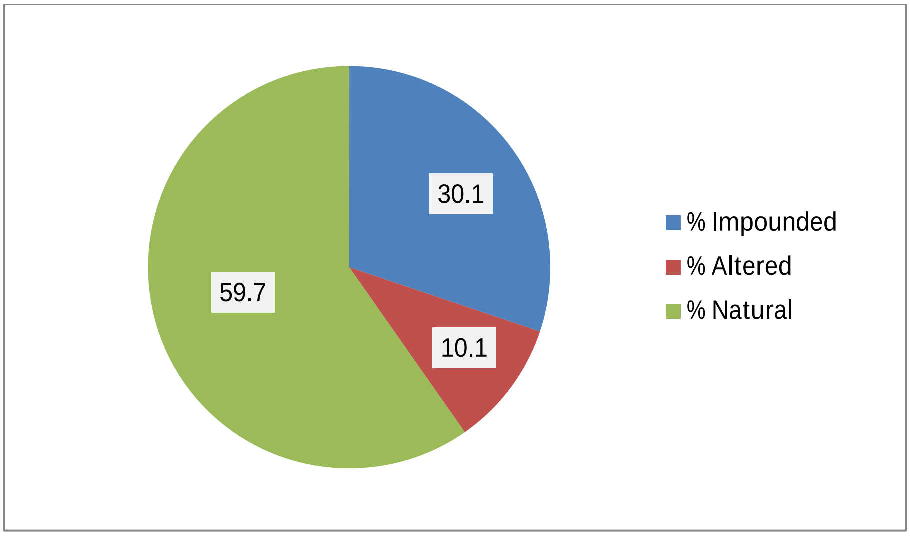


Figure 9. Comparison of natural to altered streams in the Pine River Watershed (percentages derived from the state-wide Altered Watercourse Project).

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 Pine River Watershed is 17.7˚C; and the mean winter temperature is -12.2˚C (Minnesota State Climatologists Office, 2003). Precipitation is the source of almost all water inputs to a watershed. Figure 10 shows two representations of precipitation for calendar year 2012. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the eastern portion of the state. According to this map, the Pine River Watershed area received 28 to 36 inches of precipitation in 2012. The display on the right shows the amount those precipitation levels departed from normal. For the Pine River area it shows that precipitation ranged from 2 inches below normal to 6 inches above normal.

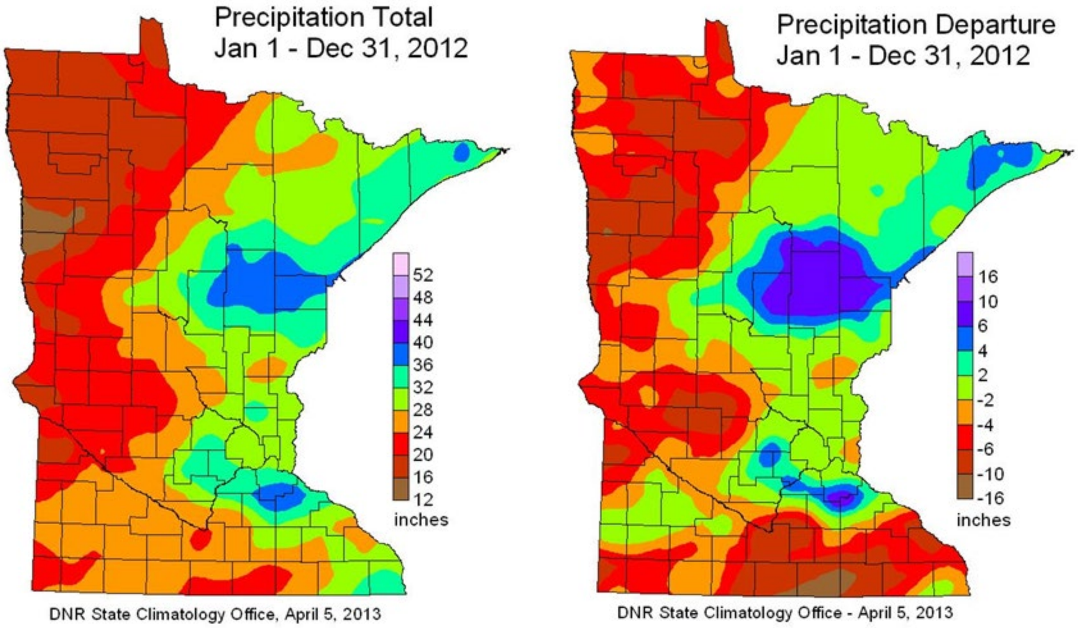


Figure 10. Statewide precipitation levels during 2012 water year.

The Pine River Watershed is located in the east central precipitation region. Figure 11 and Figure 12 (below) display the areal average representation of precipitation in east central Minnesota for 20 and 100 years, respectively. An areal average is a spatial average of all the precipitation data collected within a certain area presented as a single dataset. This data are taken from the Western Regional Climate Center, available as a link off of the University of Minnesota Climate website. Though rainfall can vary in intensity and time of year, rainfall totals in the east central region display no significant trend over the last 20 years. However, precipitation in east central Minnesota exhibits a statistically significant rising trend over the past 100 years (p=0.001). This is a strong trend and matches similar trends throughout Minnesota.

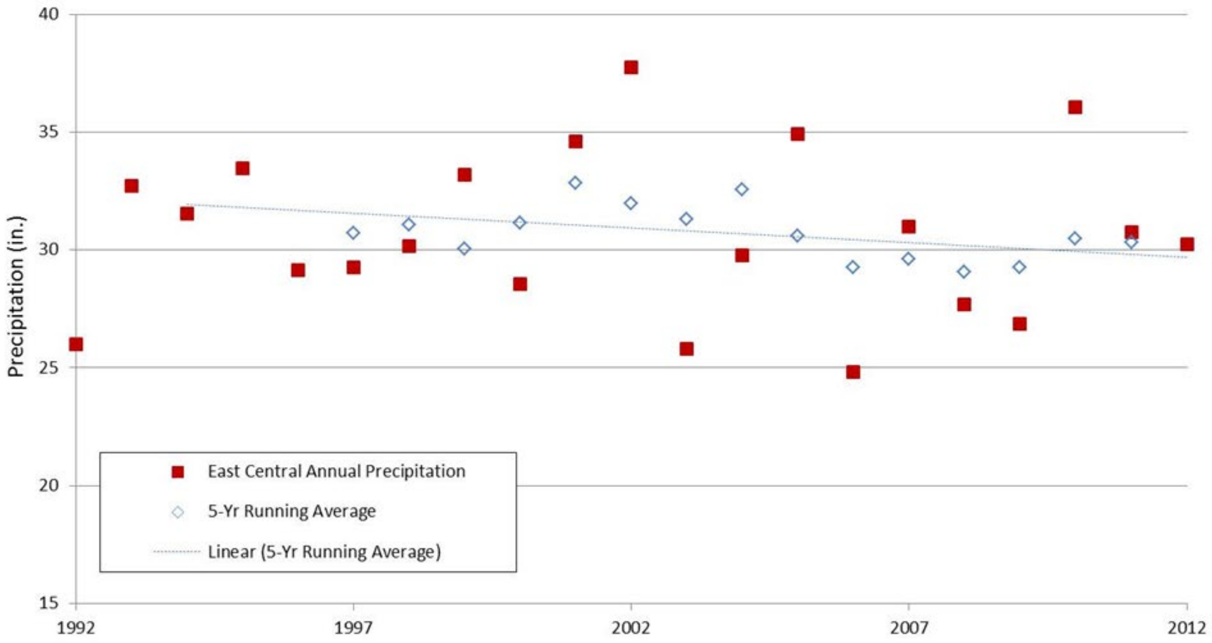


Figure 11. Precipitation trends in east central Minnesota (1992 - 2012) with five year running average.

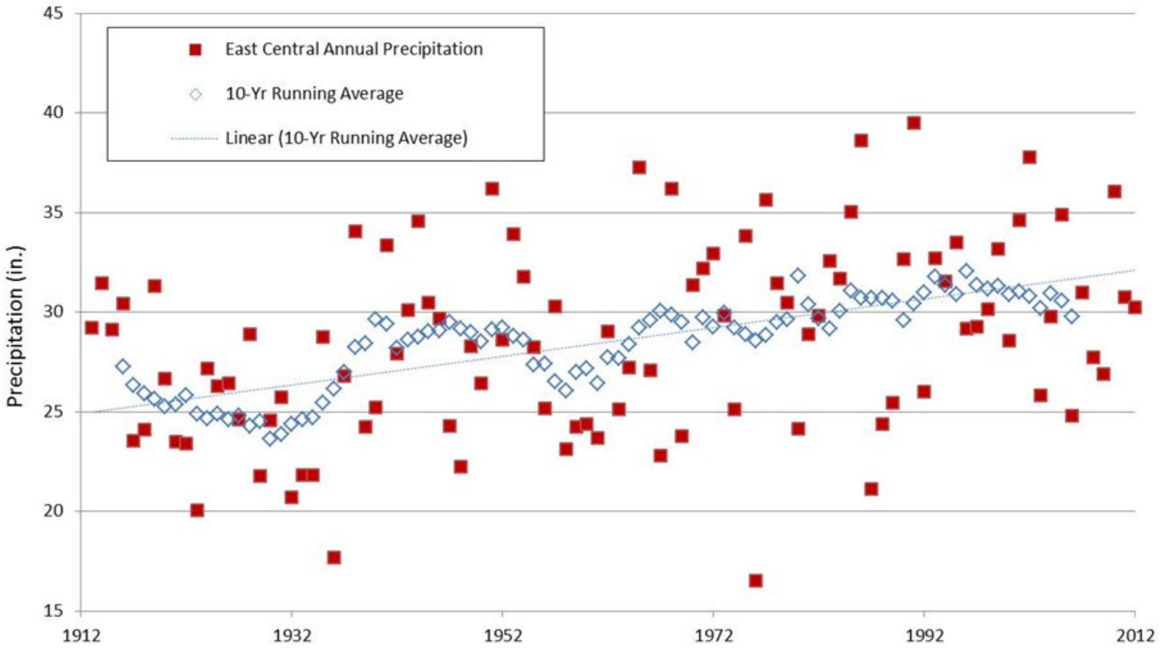


Figure 12. Precipitation trends in east central Minnesota (1912 - 2012) with 10 year running average.

Hydrogeology and groundwater quality

The Pine River Watershed is located in the northern area of the North Central hydrogeologic region (Figure 13). The watershed is within the Upper Mississippi River Basin and was formed by the advancement and retreating of the Wadena, Des Moines, and Rainy Glacial Lobes. This region is dominated by glacial deposits, such as glacial till, lacustrine basins, outwash plains, moraines, and beach ridges. The Wadena Lobe deposits are gray in color, calcareous with small amounts of shale, and are mainly outwash and drumlin fields. Similarly, the Des Moines Lobe deposits are gray, calcareous, but have a finer-texture than other glacial deposits. Finally, the Rainy Lobe deposits are primarily outwash with some drumlin fields as well, but they are identified as brown or gray in color and are non-calcareous. (MPCA, 1998)

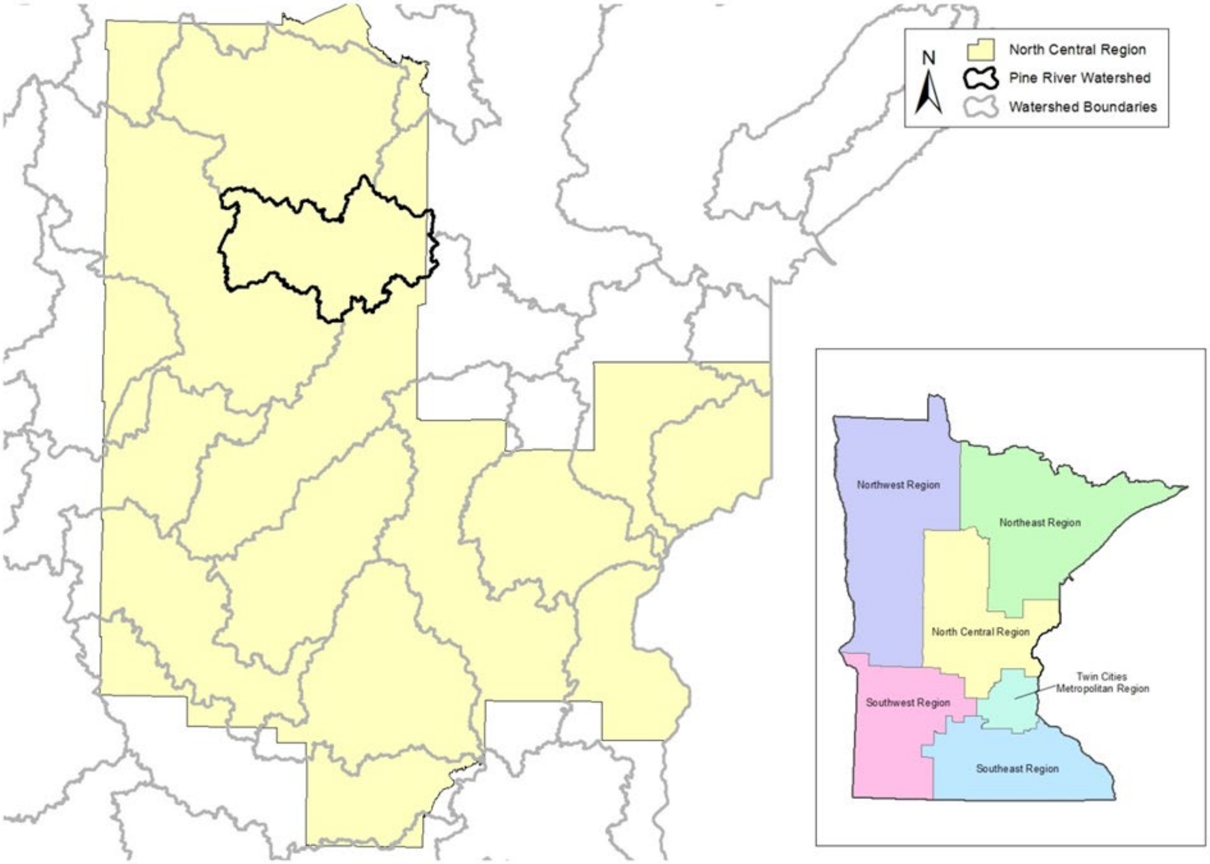


Figure 13. Pine River Watershed within the north central hydrogeologic region.

This region also primarily consists of surficial and buried sand and gravel aquifers. The surficial and buried drift aquifers are comprised of well-sorted sand and gravel. The main aquifer included in the surficial drift category is the Quaternary Water Table Aquifer (QWTA). This aquifer is a predominant source of groundwater withdrawal due to its saturated state; however, the aquifer is shallow with less than 10 feet of confining material at the land surface. Shallow aquifers tend to be very vulnerable to contamination from anthropogenic sources. The buried sand and gravel aquifers consist of confined and unconfined aquifers including the Quaternary Buried Artesian Aquifer (QBAA), the Quaternary Buried Unconfined Aquifer (QBUA), and the Quaternary Buried Undifferentiated Aquifer (QBUU). These aquifers are similar to the surficial aquifer, but they tend to be less responsive to groundwater recharge with longer travel paths (MPCA, 1998).

The Pine River Watershed falls within one of Minnesota's six Groundwater Provinces: the Central Province (Figure 14). This province is characterized by "sand aquifers in generally thick sandy and clayey glacial drift overlying Precambrian and Cretaceous bedrock. Fractured and weathered Precambrian bedrock is used locally as a water source" (MDNR, 2001).

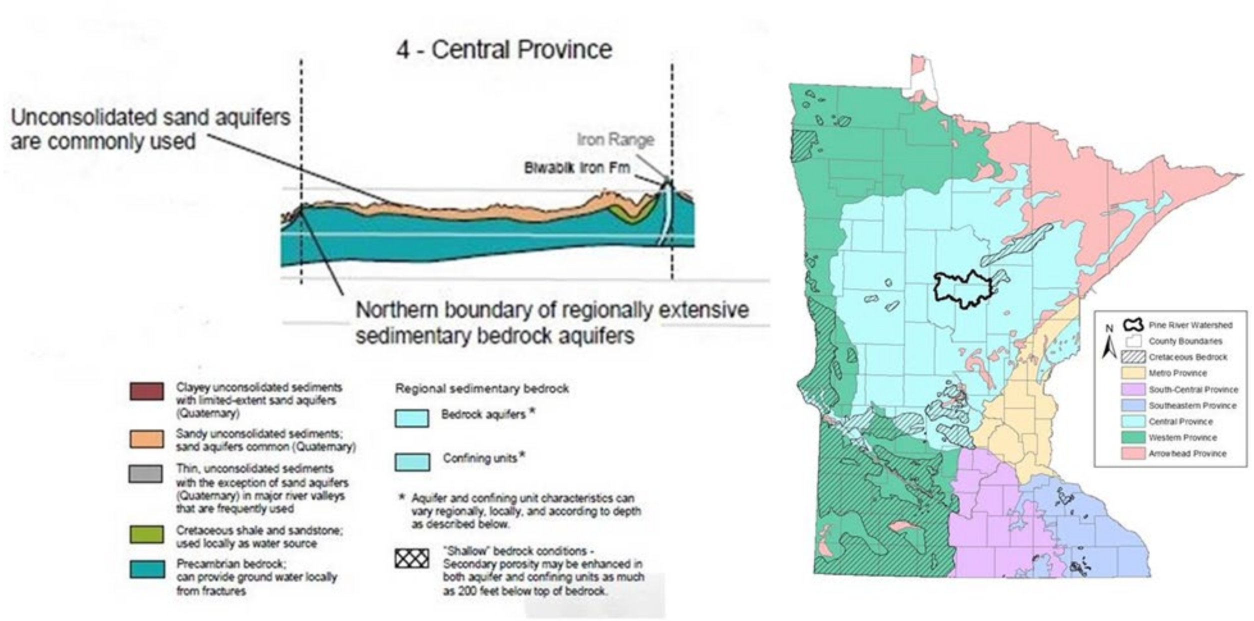


Figure 14. Central Province generalized cross section (Source: MDNR, 2001)

Recharge of these aquifers is important and limited to areas located at topographic highs, those with surficial sand and gravel deposits, and those along the bedrock/surficial deposit interface. Typically, recharge rates in unconfined aquifers are estimated at 20 to 25% of precipitation received, but can be less than 10% of precipitation where glacial clays or till are present (USGS 2007). For the Pine River Watershed, the primary average annual recharge rate to surficial materials is 6 to 8 inches per year, with areas in the eastern region recharging at a rate of 8 to 10 inches per year (Figure 15).

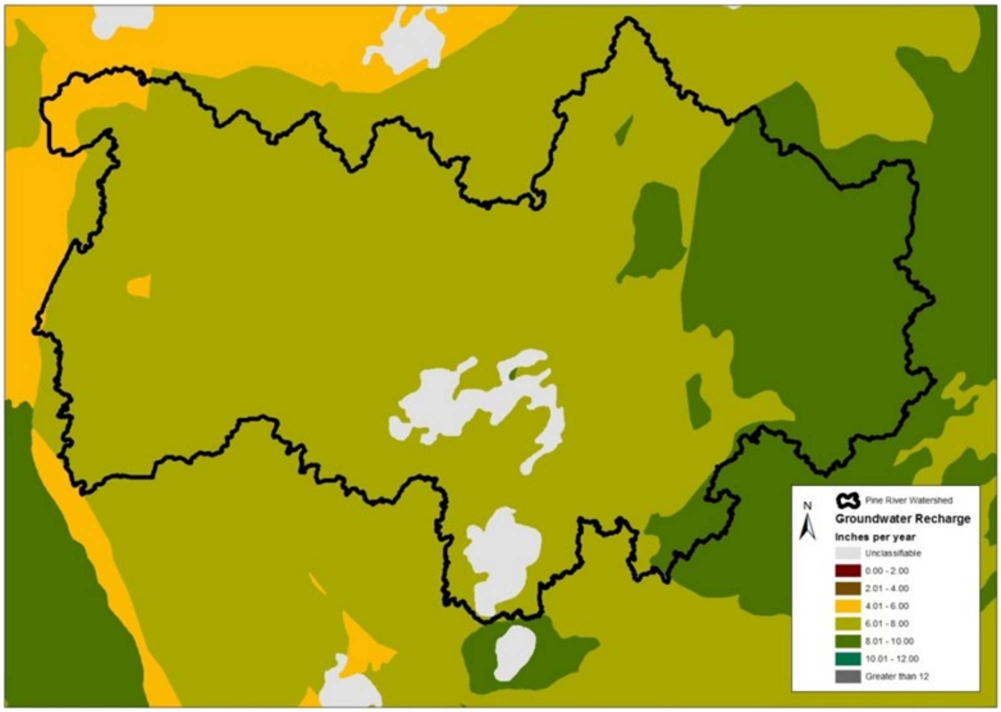


Figure 15. Average annual recharge rate to surficial materials in the Pine River Watershed (1971 - 2000).

High capacity withdrawals

The MDNR permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons/day or one 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.

The three largest permitted consumers of water in the state (in order) are municipalities, industry, and irrigation. The withdrawals within the Pine River Watershed are mostly for irrigation (major crop and non-crop) and municipal use (waterworks). The locations of permitted groundwater withdrawals within the Pine River Watershed are displayed in Figure 16.

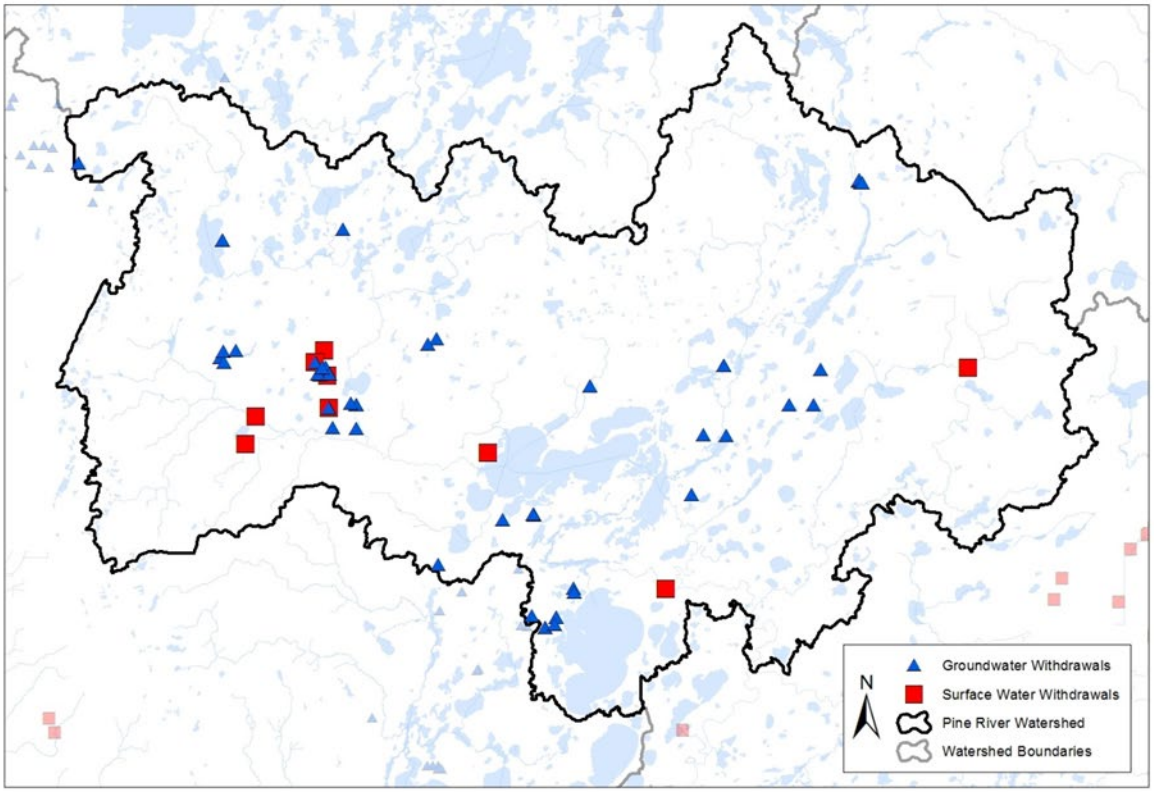


Figure 16. Locations of permitted groundwater withdrawals in the Pine River Watershed.

Total groundwater withdrawals from the watershed from 1991-2011 are displayed below as blue diamonds along with total surface water withdrawals as red squares (Figure 17). During this time period within the Pine River Watershed, groundwater withdrawals exhibit a statistically significant rising trend (p=0.001) while surface water withdrawals also exhibit a significant decreasing trend (p=0.01). Similarly, when observing the quaternary water table aquifer (QWTA), there is also a statistically rising trend from 1991-2011 (p= 0.001) (Figure 18).

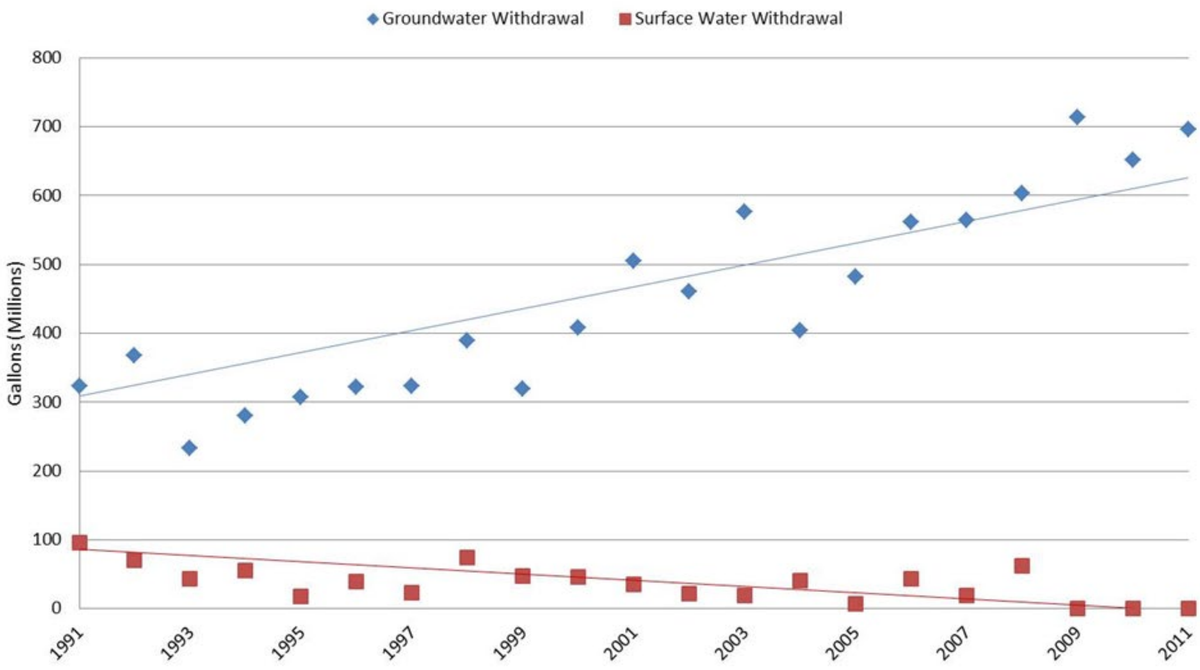


Figure 17. Total annual groundwater and surface water withdrawals in the Pine River Watershed (1991 - 2011).

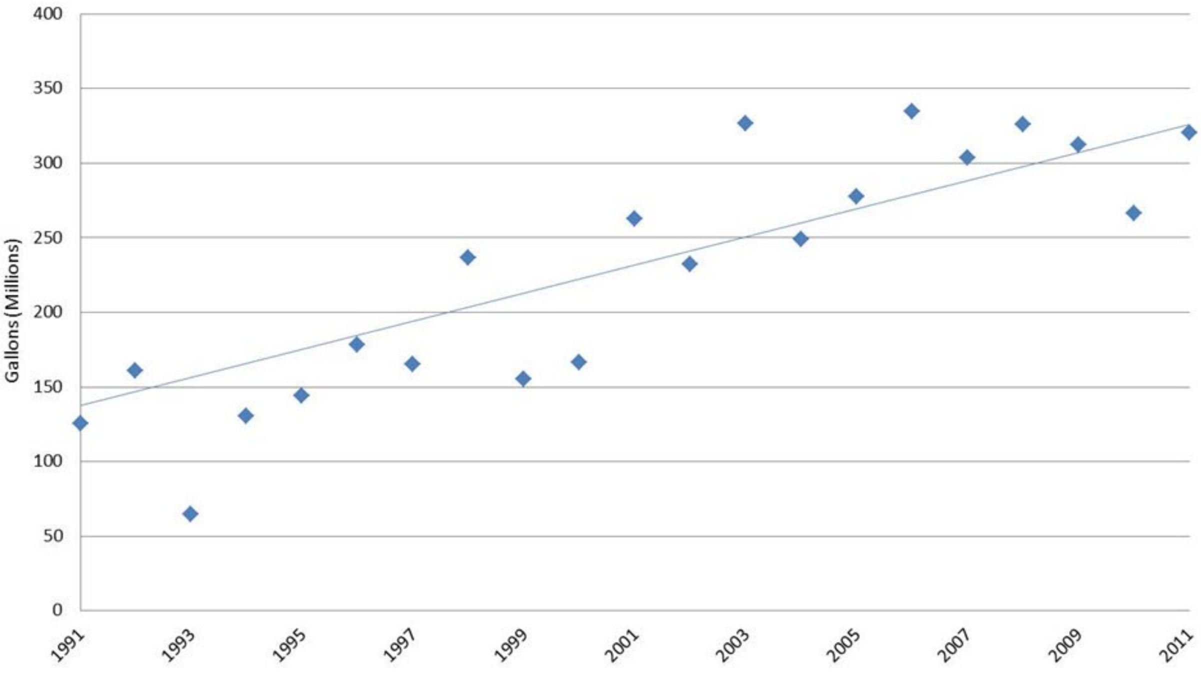
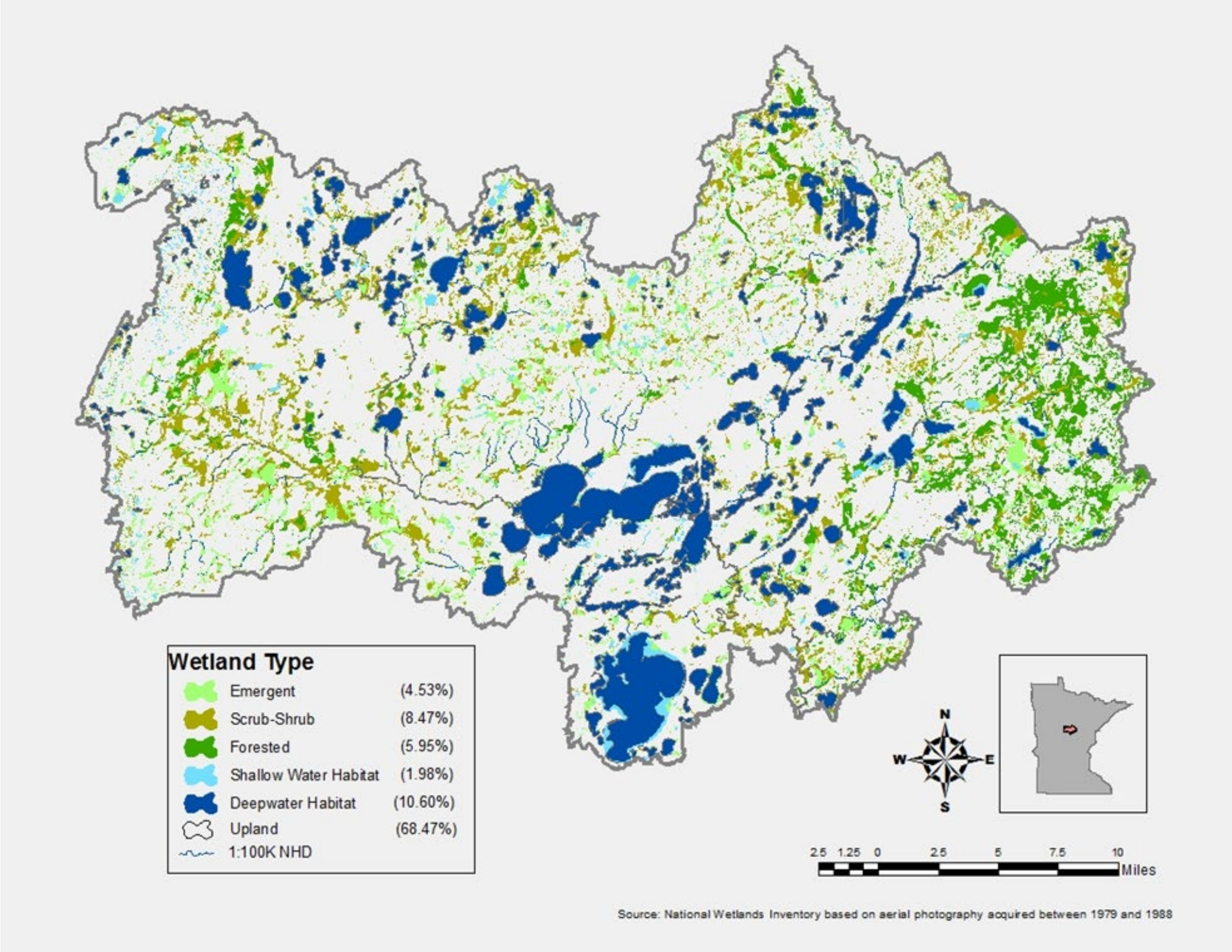


Figure 18. Quaternary water table aquifer withdrawals in the Pine River Watershed (1991 - 2011).

Wetlands

The Pine River Watershed surface geology primarily consists of ground moraine and outwash plains resulting mostly from the Rainy Lobe of the St. Croix Moraine Complex. This hill-valley and flat outwash till geology created ideal conditions for diverse wetland resources to develop in several hydrogeomorphic settings including; depressional, slope, fringing lakes, floodplains, and peatland flats. The Pine River Watershed is part of the Mississippi River drainage in the coniferous forest region of

Minnesota. Wetlands are 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 provide vital habitat for a wide variety of plants and wildlife (Mitsch and Gosselink 2007). Excluding open water portions of lakes, ponds, and rivers, the Pine River Watershed currently supports approximately 105,000 acres of wetlands which is roughly equivalent to 21% of the watershed area. Shrub scrub wetlands are the most extensive wetland class making up almost 9% of the watershed area, or just over 42,000 acres. Forested wetlands including hardwood swamps, coniferous swamps, and forested bogs comprise approximately 6.0% of the Pine River Watershed area. Wetlands dominated by herbaceous emergent vegetation (e.g., grasses, sedges, bulrushes or cattails) comprise roughly 23,000 acres or about 5% of the Pine River Watershed. Shallow water habitats occupy about 2% of the watershed area or nearly 10,000 acres (Figure 19).



Source: National Wetlands Inventory based on aerial photography acquired between 1979 and 1988

Figure 19. Distribution of wetlands and deep water habitats (lakes and rivers) by National Wetland Inventory type in the Pine River Watershed.

Digital soils data can be used to estimate the historic wetland extent prior to European settlement which initiated significant conversion of wetlands in much of Minnesota. There are a few caveats to keep in mind about using the Natural Resources Conservation Service (NRCS) digital soil survey (SSURGO) data: 1) since the SSURGO data are generated county by county there may be slight differences in some attribute interpretations across multiple counties; 2) soils in most deep water areas (lakes, rivers and permanently flooded wetlands) are not mapped in SSURGO; 3) there are differences in mapping resolution and approaches between SSURGO data and national wetland inventory (NWI) data which may lead to fine scale errors in interpretations between these two data sets; and 4) recent wetland restorations may not be adequately accounted for in watershed scale SSURGO or NWI datasets.

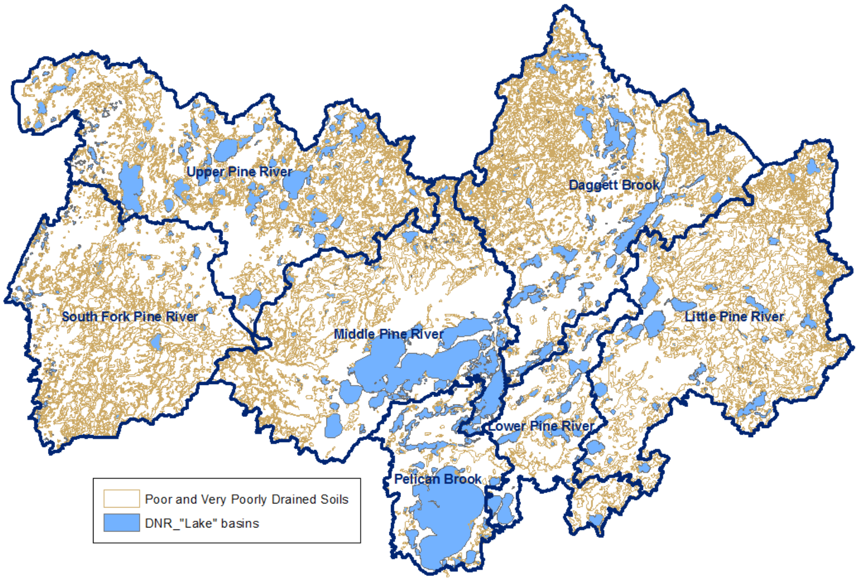


Figure 20. Availability of SSURGO soil data in the Pine River Watershed.

Analysis of SSURGO map units whose drainage condition was classed as “Poorly Drained” or “Very Poorly Drained” suggests that approximately 134,250 acres or 27.0% of the Pine River Watershed may have historically been wetland. Comparing this estimate to the 21% of the watershed mapped as wetland today represents a 6.0% estimated rate of wetland loss (note: a different source was used to generate the land use percentages for the watershed land use summary). Historic wetland loss estimates indicate the Upper, Middle, and South Fork Pine River Subwatersheds have lost 5.0%, 5.4%, and 7.4%, respectively. The Daggett Brook Subwatershed was estimated to have lost 12.8% of its historic wetlands - the greatest loss among all of the 12-HUC watersheds. The Little Pine River Subwatershed was estimated to have lost 4.7% of its historic wetlands. The two smallest subwatersheds, Lower Pine River and Pelican Brook, have similar estimated historical wetland area; the Lower Pine River has an estimated 0.5% loss while Pelican Brook has actually gained an estimated 1.8%. Wetland loss is not always attributed to drainage or filling activities, but can also result from conversion of wetlands to deep water habitats.

The NWI of the Pine River Watershed, based on imagery data from 1983, finds that contemporarily Pelican Brook supports the least amount of wetland (11.3%) compared with the other six aggregated 12-HUC watersheds in the Pine River Watershed. Additional changes to wetland extent have undoubtedly 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 period which is slated for completion in 2019. Work to update the north central lakes region of the state, including the Pine River Watershed, began in the fall 2015 and is expected to be completed in summer 2017 (for more information on the NWI update please refer to the following website: http://www.dnr.state.mn.us/eco/wetlands/nwi_proj.html).

Watershed-wide data collection methodology

Pollutant load monitoring

A pollutant load monitoring station is located on the Pine River on CSAH 11 near the city of Mission. 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 21). Correlations between concentration and flow exist for many of the monitored analytes. Also, these relationships can shift between storms or with season; therefore, 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 generally results in the distribution of samples over the entire flow range.

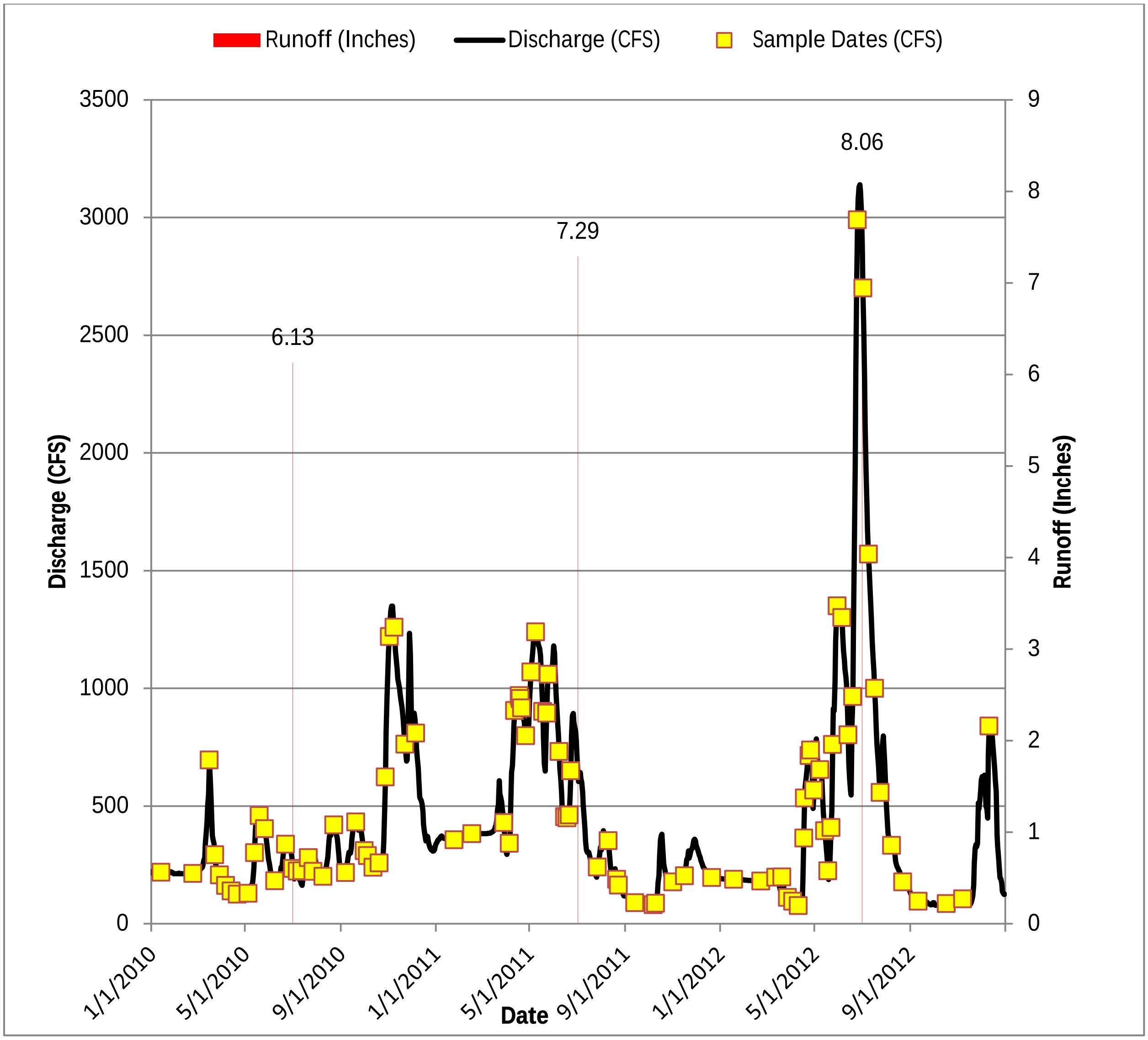


Figure 21. 2010 - 2012 hydrograph, sampling regime, and annual runoff for the Pine River near Mission, MN.

Annual water quality and daily average discharge data are coupled in the “Flux32,” pollutant load model, originally developed by Dr. Bill Walker. The model was recently upgraded by the U.S. Army Corp of Engineers and MPCA. The Flux 32 model allows the user to create concentration/flow regression equations to estimate pollutant concentrations and loads on days when samples were not collected. Primary outputs include annual and daily pollutant loads and flow weighted mean concentrations (pollutant load/total seasonal flow volume). Loads and flow weighted mean concentrations (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

Five water chemistry stations were sampled from May - September in 2012, and June - August in 2013, to provide sufficient water chemistry data to assess all components of the Aquatic Life and Recreation Use Standards. Following the IWM design, water chemistry stations were placed at the outlet of each aggregated 12-HUC subwatershed that was >40 square miles in area (purple circles and green triangles in (Figure 3). A SWAG was awarded to Crow Wing SWCD and Cass County Environmental Services to intensively collect water chemistry at these five outlet stations. Please refer to Appendix 2 – Intensive watershed monitoring water chemistry stations in the Pine River Watershed for locations of stream water chemistry monitoring sites. Appendix 1 lists the definitions of stream chemistry analytes monitored in this study. Intensive water chemistry collection stations were not placed near the outlets of the Middle Pine River and Pelican Brook subwatersheds due to numerous lakes and lack of riverine conditions. A biological station was placed at the Pelican Brook outlet and was assessed for aquatic life.

Stream flow methodology

The MPCA and MDNR joint stream water quantity and water quality monitoring data for dozens of sites across the state on major rivers, at the mouths of most of the state’s major watersheds, and at the mouths of some subwatersheds are available at the MDNR/MPCA Cooperative Stream Gaging webpage at: http://www.dnr.state.mn.us/waters/csg/index.html. The USGS maintains real-time stream flow gaging stations across the United States. Measurements can be viewed at http://waterdata.usgs.gov/nwis/rt

Stream biological sampling

The biological monitoring component of IWM in the Pine River Watershed was completed during the summer of 2012. A total of 23 sites were newly established across the watershed and sampled. These sites were located near the outlets of most minor 14 - HUC watersheds. In addition, two existing biological monitoring stations within the watershed were revisited in 2012. These monitoring stations were initially established as part of a random Upper Mississippi River Basin survey in 1999, or as part of a 2000 survey to collect data for biocriteria development. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2015 assessment was collected in 2012. A total of 24 stream segments (AUIDs) were sampled for biology in the Pine River Watershed. Waterbody assessments to determine aquatic life use support were conducted for 24 AUIDs. Biological information that was not used in the assessment process will be crucial to the stressor identification process and will also be used as a basis for long term trend results in subsequent reporting cycles.

To measure the health of aquatic life at each biological monitoring station, IBIs, specifically fish and invertebrate IBIs, were calculated based on monitoring data collected for each of these communities. A fish and macroinvertebrate classification framework was developed to account for natural variation in community structure which is attributed to geographic region, watershed drainage area, water temperature, and stream gradient. As a result, Minnesota’s streams and rivers were divided into seven distinct warm water classes and two cold water classes, with each class having its own unique Fish Index of Biotic Integrity (FIBI) and invertebrate 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). For IBI results for each individual biological monitoring station, see Appendix 4.2.

Fish contaminants

Mercury and PCBs were analyzed in fish tissue samples collected from the Pine River in 2013, by the MPCA biomonitoring staff. All other samples had previously been collected by MDNR fisheries staff. Twenty seven lakes in the watershed have also been tested for mercury and PCBs in 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.

Prior to 2006, mean mercury fish tissue concentrations were assessed for water quality impairment based on the Minnesota Department of Health's (MDH) 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 90th percentile) exceed 0.2 mg/kg of mercury, which is one of Minnesota's water quality standards for mercury. At least five fish samples are required per species to make this assessment and only the last 10 years of data are used for statistical analysis. MPCA's Impaired Waters Inventory includes waterways that were assessed as impaired prior to 2006, as well as more recently.

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 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. This implied that it was not necessary to continue widespread frequent monitoring of smaller river systems as is done with mercury. However, limited PCB monitoring was included in the watershed sampling design to ensure that this conclusion is still accurate. Impairment assessment for PCBs in fish tissue is based on the fish consumption advisories prepared by the MDH. If the consumption advice is to restrict consumption of a particular fish species to less than a meal per week because of PCBs, the MPCA considers the lake or river impaired. The threshold concentration for impairment is 0.22 mg/kg PCBs and more restrictive advice is recommended for consumption (one meal per month).

Lake water sampling

The MPCA sampled water chemistry on 15 lakes in the Pine River Watershed between 2012 and 2013. A SWAG was awarded to Crow Wing SWCD and Cass County Environmental Services to sample14 lakes in the watershed in 2012 and 2013. There are currently 45 volunteers enrolled in the MPCA's CLMP that are conducting lake monitoring within the watershed. Sampling methods are similar among monitoring groups and are described in the document entitled "MPCA Standard Operating Procedure for Lake Water Quality" found at http://www.pca.state.mn.us/publications/wq-s1-16.pdf. The lake water quality assessment standard requires eight observations/samples within a 10 year period for phosphorus, chlorophyll-a and Secchi depth.

Groundwater monitoring

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 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, and crustaceans) IBIs for evaluating the ecological condition or health of depressional wetlands. Recently the MPCA wetland plant monitoring effort 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 of Minnesota's wetland classes (types) in contrast to wetland IBIs which are used only in depressional or 'marsh' type wetlands having a seasonal to permanent water column. 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.

Individual subwatershed results

HUC-12 subwatersheds

Assessment results for aquatic life and recreation use are presented for each aggregated 12-HUC subwatershed within the Pine River Watershed. The primary objective is to portray all the full support and impairment listings within an aggregated 12-HUC subwatershed resulting from the complex and multi-step assessment and listing process (note: a summary table of assessment results for the entire 8-HUC watershed that includes 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 aggregated 12-HUC subwatersheds contain the assessment results from the 2014 Assessment Cycle as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2012 IWM effort, but also considers available data from the last 10 years.

The proceeding pages provide an account of each aggregated 12-HUC subwatershed. Each account includes a brief description of the subwatershed, and tables summarizing the results for each of the following: a) stream aquatic life and aquatic recreation assessments, b) stream habitat quality c) channel stability, and where applicable d) water chemistry for the aggregated 12 -HUC outlet, and e) 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 2012 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); determinations are made during the desktop phase of the assessment process (Figure 5. Flow chart of aquatic life use assessment.. Assessment of aquatic life is derived from the analysis of biological (fish and invertebrate IBIs), DO, turbidity, chloride, pH and un-ionized ammonia (NH3) data. 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-12 subwatershed as well as in the watershed-wide results and discussion section.

Stream habitat results

Habitat information documented during each fish sampling visit is provided in each aggregated 12-HUC subwatershed section. These tables convey the results of the Minnesota Stream Habitat Assessment

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

Stream stability results

Stream channel stability information evaluated during each invertebrate sampling visit is provided in each aggregated 12 -HUC 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 which may be related to changes in watershed hydrology, stream gradient, sediment supply, or sediment transport capacity. The CCSI was recently implemented in 2008, and is collected once at each biological station. Consequently, the CCSI ratings are only available for biological visits sampled in 2010 or later. The final row in each table displays the average CCSI scores and a rating for the aggregated 12 -HUC subwatershed.

Subwatershed outlet water chemistry results

These summary tables display the water chemistry results for the monitoring station representing the outlet of the aggregated 12-HUC 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. While not all of the water chemistry parameters of interest have established water quality standards, McCollor and Heiskary (1993) developed ecoregion expectations for a number of parameters that provide a basis for evaluating stream water quality data and estimating attainable conditions for an ecoregion. For comparative purposes, water chemistry results for the Pine River Watershed are compared to expectations developed by McCollor and Heiskary (1993) that were based on the 75th percentile of a long-term dataset of least impacted streams within each ecoregion.

Lake assessments

A summary of lake water quality is provided in the aggregated 12-HUC 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 Appendix 3.2. Lake models and corresponding morphometric inputs can be found in Appendix 5.2.

Upper Pine River Subwatershed HUC 0701010501-01

The Upper Pine River Subwatershed contains the headwaters of the Pine River and drains approximately 149 square miles of land within the northwestern portion of the watershed. The Pine River originates near the Foothills State Forest and flows southward into Pine Mountain Lake. After exiting Pine Mountain Lake, the river flows east and consists of several small connecting channels between Bowen Lake, Lindsey Lake, Brockway Lake, and Lake Hattie. Norway Brook, a small tributary draining the north central portion of the subwatershed, joins the Pine River between Brockway Lake and Lindsey Lake. From the outlet of Lake Hattie the Pine River flows south for approximately 1.5 miles before being joined by Lizzie Creek. The Pine River continues flowing southward several miles, passing through Norway Lake before entering the next subwatershed. Other major lakes within the Upper Pine River Subwatershed include Ada, Lizzie, and Big Portage. The land in the subwatershed is primarily forested (59.6%) followed by wetland (17.9%), open water (11.4%), range land (7.0%), developed land (2.7%), and cropland (1.3%). The communities of Pine River, Backus, Chickamaw Beach, and Pontoria are within the subwatershed. In 2012, the MPCA collected biological samples from three monitoring stations located on three stream segments (AUIDs) in the Upper Pine River Subwatershed. Intensive water chemistry monitoring was conducted at one station.

Table 1. Aquatic life and recreation assessments on stream reaches: Upper Pine River Subwatershed. Reaches are organized upstream to downstream in the table.

					Aquatic Life Indicators:								**Aquatic Rec. Indicators:**			
AUID ***Reach Name*, *Reach Description***	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Nutrients	**Aquatic Life**	**Aquatic Rec.**
07010105-669 Pine River Hattie Lake to Norway Lake	7.59	WWg	12UM119	Downstream of Division St W, 5.5 mi. N of Pine River	MTS	MTS	IF	-	MTS	MTS	-	-	MTS	-	SUP	SUP
07010105-599 Lizzie Creek Lizzie Lake to Pine River	3.97	WWg	12UM135	Upstream of Hwy 84, 5.5 mi. NE of Pine River	MTS	MTS	IF	-	-	IF	-	-	-	-	SUP	NA
07010105-671 Pine River Norway Lake to South Fork Pine R	2.89	WWg	12UM115	Downstream of Hwy 371, in Pine River	MTS	MTS	IF	-	MTS	IF	MTS	-	MTS	-	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ▨ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use; 🟨= insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 2. Minnesota Stream Habitat Assessment: Upper Pine River Subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph.	MSHA Score (0-100)	MSHA Rating
1	12UM119	Pine River	4.5	12.5	21.1	16	25	79.1	Good
2	12UM135	Ada Brook	5	9	14	12	17	57	Fair
1	12UM115	Pine River	2.6	10	17.5	12.5	15.5	58	Fair
Average Habitat Results: *Upper Pine River Subwatershed*			**4**	**10.5**	**17.5**	**13.5**	**19.2**	**64.7**	**Good**

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 3. Channel Condition and Stability Assessment: Upper Pine 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	12UM119	Pine River	6	10	4	3	23	stable
1	12UM115	Pine River	7	8	7	3	25	stable
1	12UM135	Lizzie Creek	11	22	22	3	58	moderately unstable
Average Stream Stability Results: *Upper Pine River Subwatershed*			**8**	**13.3**	**11**	**3**	**35.3**	**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 4. Outlet water chemistry results: Upper Pine River Subwatershed.

Station location:	Pine River, on Paul Bunyan Trail at Front Street, 0.5 miles Southeast of Pine River, MN
STORET/EQuIS ID:	S006-231
Station #:	12UM115

Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**# of WQ Exceedances[2]**
Un-ionized Ammonia	ug/L	10	1.44	5.29	3.14	40	0
Chloride	mg/L	11	2.91	6.68	4.46	230	0
Dissolved Oxygen (DO)	mg/L	21	7.2	14.5	9.33	5	0
pH		21	7.86	9.04	8.32	6.5 – 8.5	1
Secchi Tube	100 cm	21	100	100	100	40	0
Total suspended solids*	mg/L	11	1	5	2.36	15	0
Escherichia coli (geometric mean)	MPN/100ml	-	9	14.4	-	126	0
Escherichia coli	MPN/100ml	16	1	34.5	8.9	1260	0
Chlorophyll-a, Corrected	ug/L	-	-	-	-	-	-
Inorganic nitrogen (nitrate and nitrite)*	mg/L	11	0.03	0.03	0.03	-	-
Kjeldahl nitrogen	mg/L	11	0.3	1.14	0.58	-	-
Orthophosphate	ug/L	-	-	-	-	-	-
Pheophytin-a	ug/L	-	-	-	-	-	-
Phosphorus	ug/L	11	13	35	25.8	-	-
Specific Conductance	uS/cm	21	206	296	250	-	-
Temperature, water	deg °C	21	14.4	26.9	22.6	-	-
Sulfate*	mg/L	11	3	3	3	-	-
Hardness	mg/L	11	98.2	145	121.5	-	-

[1] Secchi Tube standards are surrogate standards derived from the total suspended solids standard of 15 mg/l.

***Minimum, Maximum, and Mean values for this parameter may have been calculated using non detect values, non detect limits vary between parameters**

[2] Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Upper Pine River Subwatershed, a component of the IWM work conducted between May and September from 2012 and 2013. This specific data does not necessarily reflect all data that was used to assess the AUID.

Table 5. Lake assessments: Upper Pine River Subwatershed.

Name	MDNR 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)	AQL Support Status	AQR Support Status
Tamarack	11-0150-00	29	O	-	-	-	IF	10	3	1.0	IF	IF
Hay	11-0199-00	363	M	51	17.1	-	I	13	4	4.2	NA	FS
Little Sand	11-0230-00	76	M	94	5.2	-	NT	-	-	3.8	NA	IF
Hattie	11-0232-00	578	M	92	4.9	4.3	NT	20	8	2.7	NA	FS
Little Portage	11-0236-00	44	M	-	-	-	NT	12	3	4.7	NA	IF
Deep Portage	11-0237-00	129	O	25	32.0	-	D	11	2	4.0	NA	FS
Tamarack	11-0241-00	44	O	-	-	-	IF	10	2	1.1	IF	IF
Hand	11-0242-00	278	O	52	17.4	5.2	NT	11	3	4.3	NA	FS
Sylvan	11-0246-00	109		64	7.9	-	IF	13	3	4.5	NA	FS
Ada	11-0250-00	945	M	43	18.3	6.4	I	12	5	4.4	NA	FS
Hand	11-0251-00	52	E	-	-	-		55	-	-	NA	IF
Harriet	11-0255-00	122		-	-	-	IF	8	1	1.5	NA	FS
Norway	11-0307-00	510	E	100	4.0	1.5	NT	31	11	2.3	IF	IF
Big Portage (West Bay)	11-0308-01	704	M	-	3.7	1.8	NT	22	6	2.4	IF	FS
Big Portage (East Bay)	11-0308-02	180	E	-	3.7	-	NT	20	6	2.4	NA	IF
Bowen	11-0350-00	182	M	28	7.6	-	IF	20	8	3.3	NA	FS
Five Point	11-0351-00	250	M	40	11.3	5.2	NT	18	7	4.0	NA	FS
Beuber	11-0353-00	129	E	68	9.8	-	IF	30	16	2.5	NA	IF
Ox Yoke	11-0355-00	177	O	53	12.8	-	NT	11	3	5.2	NA	FS
Rainy	11-0356-00	127	O	72	8.8	-	NT	-	-	4.3	NA	IF
Horseshoe	11-0358-00	258	O	39	15.5	6.4	NT	8	3	5.6	NA	FS
Island	11-0360-00	100	-	100	4.3	-	IF	32	9	2.2	NA	IF
Sanborn	11-0361-00	213	O	36	14.6	-	NT	9	2	5.3	NA	FS
Fawn	11-0362-00	47	-	64	8.8	-	IF	-	-	4.9	NA	IF
Johnson	11-0363-00	90	O	33	16.8	-	NT	-	-	5.5	NA	IF
Lind	11-0367-00	399	E	66	8.2	-	IF	26	12	2.7	NA	FS
Pine Mountain	11-0411-00	1572	M	54	23.8	6.4	NT	17	7	3.1	IF	FS

Name	MDNR 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)	AQL Support Status	AQR Support Status
Long	11-0454-00	135	O	62	14.6	-	IF	11	2	6.4	NA	FS
Jackpine	11-0460-00	147	O	-	1.8	-	IF	9	1	1.7	IF	FS
Variety	11-0463-00	147		43	8.8	-	IF	23	7	2.9	NA	FS
Unnamed	18-0413-00	27	M	-	-	-	IF	19	-	2.3	NA	IF
Clough	18-0414-00	240	M	100	2.4	-	IF	18	3	1.9	NA	FS
Jail	18-0415-00	178	E	67	6.7	-	IF	49	29	1.3	NA	NS
Lizzie	18-0416-00	403	M	100	4.6	-	IF	24	4	2.7	NA	FS

Abbreviations:	D -- Decreasing/Declining Trend	**H** – Hypereutrophic	**FS** – Full Support
	I -- Increasing/Improving Trends	**E** – Eutrophic	**NS** – Non-Support
	NT – No Trend	**M** – Mesotrophic	**IF** – Insufficient Information
		O - Oligotrophic	

Key for Cell Shading: ▨ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use

Summary

There were two assessed reaches on the Pine River in this subwatershed, each with one biological monitoring station. Station 12UM119 (07010105-669), the furthest upstream station, had one of the highest FIBI scores when compared to all other monitoring stations located on the Pine River. The fish sample contained several sensitive species, insectivores, lithophilic spawners (fish that use coarse substrate for spawning), and one intolerant species. The station also featured some of the best stream habitat in the Pine River Watershed. Coarse substrate, various macrophytes, large woody debris, and good channel development were present within the sampling reach.

Station 12UM115 (07010105-671) featured the lowest FIBI score when compared to all other stations located on the Pine River; however, both 2012 visit FIBI scores are passing. Compared to station 12UM119, the fish community at station 12UM115 featured fewer simple lithophilic spawners, fewer insectivores, and more trophic generalist species. Somewhat poorer stream habitat at station 12UM115 likely limits the fish community development. The habitat was characterized by sand substrate with limited amounts of coarse substrate and abundant aquatic macrophytes. Stations 12UM119 and 12UM115 both had good Macroinbertebrate Index of Biotic Integrity (MIBI) scores. Several trichoptera species were captured at both stations. Bacteria datasets for both reaches indicate fully supporting conditions for aquatic recreation. The low bacteria levels are consistent with undisturbed riparian land use and an absence of concentrated animal activity within the floodplain. Dissolved oxygen data are meeting standards but lack the early morning data requirements necessary for assessment.

Station 12UM135 was located on Lizzie Creek (also known as Ada Brook) approximately 1.4 miles downstream of Lizzie Lake. Lizzie Creek is a low gradient stream that features wetland like habitat: fine sediment, emergent macrophytes, and submergent macrophytes were present throughout. Surprisingly, 16 species of fish were captured, including several sensitive species and numerous wetland species. The FIBI score was good. Despite marginal macroinvertebrate habitat, the MIBI score was also good.

Twenty lakes had sufficient data to assess for aquatic recreation; of these, 19 were found to be fully supporting. The fully supporting lakes include flow through, seepage, and headwater basins such as Pine Mountain, Big Portage, Jackpine, and Ada. Water chemistry data collected from Horseshoe Lake indicate it is one of the highest quality lakes in Upper Pine River Subwatershed. The good water quality can be attributed to relatively undisturbed forest and wetland dominated land as well as light to moderate shoreline development. The development of lake protection strategies at a local level would be beneficial for maintaining the current water quality conditions of lakes in this subwatershed.

Jail Lake was assessed in 2011 based on data collected from 2006 - 2011. The lake is considered to have impaired aquatic recreation due to excessive nutrient levels. Secchi observations collected since the initial assessment indicate that the lake is still impaired. Poor land use practices in this small watershed could be a potential contributor to nutrient loading. Stressor identification will be imperative to developing effective restoration strategies.

Limited chloride data was available on six lakes in this subwatershed; all six fell well below the chronic standard of 230 mg/L. Elevated chloride concentrations are often due to excessive road salt contamination (typically found in metropolitan areas) or indirectly from a point source discharge such as in home water softeners. Neither of these inputs is of significant concern in the Pine River Watershed. For lakes meeting the chloride standard for aquatic life use, a policy decision has been made to assess the lake as insufficient information until a biological indicator is available.

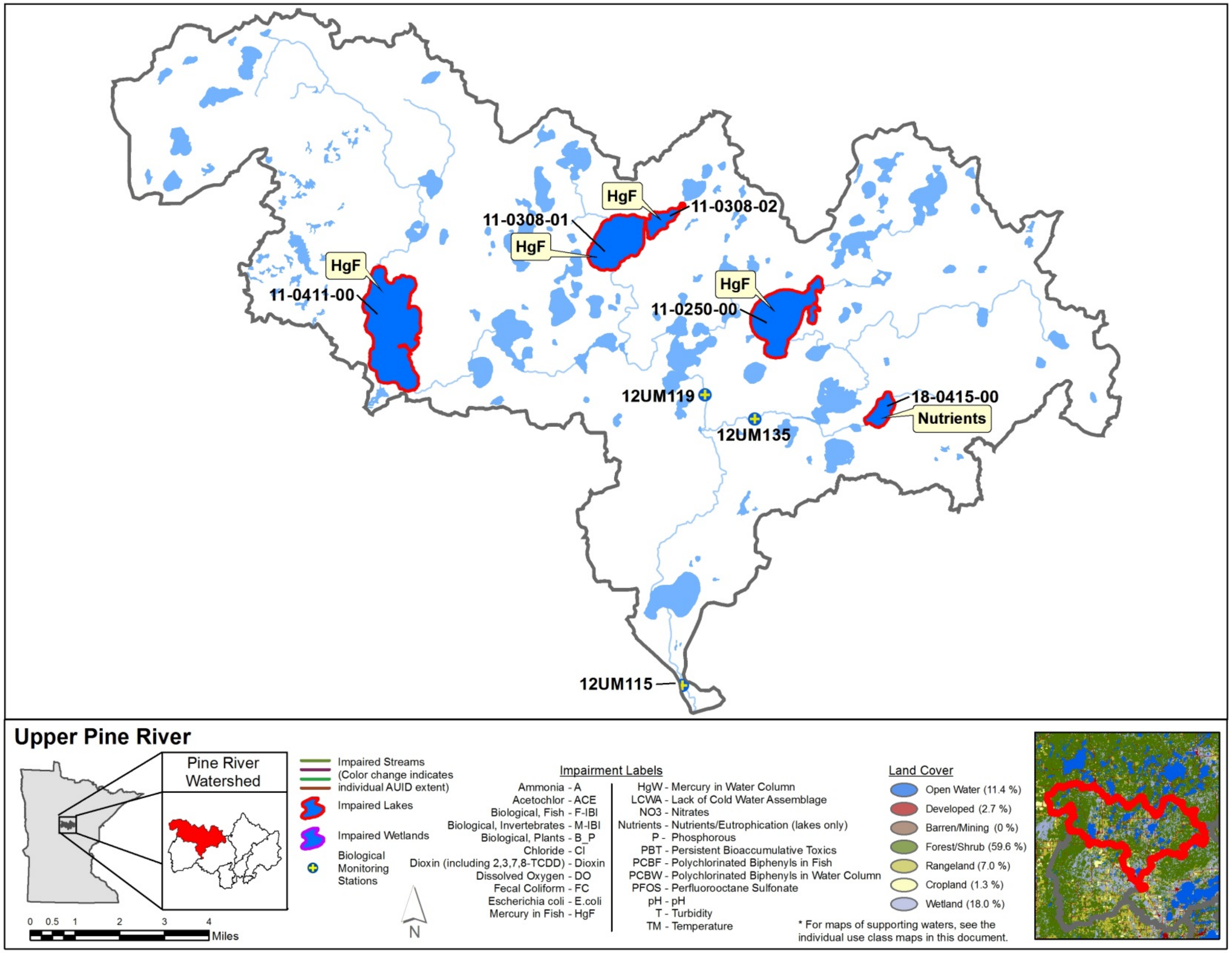


Figure 22. Currently listed impaired waters by parameter and land use characteristics in the Upper Pine River Subwatershed.

South Fork Pine River Subwatershed HUC 0701010502-01

The South Fork Pine River Subwatershed drains approximately 115 square miles of land within the western portion of the Pine River Watershed. The South Fork Pine River originates from a wetland located southwest of Backus and flows south along the edge of the Foothills State Forest. Two small tributaries, an unnamed creek and Cedar Creek, flow east out of the Foothills State Forest into the South Fork Pine River. The river continues flowing south for several miles before being joined by a small low gradient stream called Brittan Creek. The river turns toward the southeast after the confluence with Brittan Creek and encounters a larger tributary called Bungo Creek. Bungo Creek originates in the far southwestern corner of the Pine River Watershed and flows toward the northeast. The South Fork Pine River continues flowing south east for several miles before being joined by Wilson Creek. Similar to Bungo Creek, Wilson Creek originates in the far southwestern corner of the Pine River Watershed and flows toward the northeast. The South Fork Pine River winds eastward after the confluence of Wilson Creek. Behler Creek and several other small tributaries join the South Fork Pine River before it empties into the main stem of the Pine River. No major lakes occur within the South Fork Pine River Subwatershed; Cut, Cow, Boot, Scribner, and Eagle are small lakes near the headwater tributaries. The land in the subwatershed is primarily forested (58.5%) followed by wetland (20.9%) and range land (13.2%). Cropland (3.4%), developed land (2.2%), and open water (1.8%) account for small percentages of land within the subwatershed. The western edge of the community of Pine River is within the subwatershed. In 2012, the MPCA collected biological samples from seven monitoring stations located on six stream segments in the South Fork Pine River Subwatershed. Intensive water chemistry monitoring was conducted at one station.

Table 6. Aquatic life and recreation assessments on stream reaches: South Fork Pine River Subwatershed. Reaches are organized upstream to downstream in the table.

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			
07010105-572 Pine River, South Fork T138 R31W S26, north line to Brittan Creek	2.97	WWg	12UM120	Upstream of CSAH 25, 6 mi. NE of Pine River	MTS	MTS	IF	-	-	IF	-	-	-	SUP	NA
07010105-525 Brittan Creek Dabill Creek to South Fork Pine R	1.27	WWg	12UM140	Upstream of CSAH 25, 6 mi. W of Pine River	MTS	MTS	IF	-	-	IF	-	-	-	SUP	NA
07010105-528 Bungo Creek Unnamed creek to T138 R30W S31, east line	6.31	WWg	12UM139 12UM132	Downstream of 32nd St SW, 7 mi. SW of Pine River Downstream of CSAH 2, 5.5 mi. W of Pine River	MTS	MTS	IF	-	-	IF	IF	-	-	SUP	NA
07010105-531 Pine River, South Fork Bungo Creek to Hoblin Creek	4.33	WWg	12UM121	Upstream of 36th Ave SW, 3 mi. W of Pine River	EXS	MTS	IF	-	-	IF	-	-	-	IMP	NA
07010105-529 Wilson Creek T137 R30W S30, west line to Hoblin Creek	5.86	WWg	12UM133	Upstream of CR 171, 4 mi. SW of Pine River	MTS	EXS	IF	-	-	IF	-	-	-	IMP	NA
07010105-534 Pine River, South Fork Behler Creek to Pine River	1.71	WWg	12UM116	Downstream of CSAH 1, 1 mi. S of Pine River	MTS	MTS	IF	-	MTS	MTS	MTS	-	MTS	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ▨ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use; 🟨 = insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 7. Minnesota Stream Habitat Assessment: South Fork Pine 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
2	12UM120	Pine River, South Fork	5	10	9	9	12	45	Fair
2	12UM121	Pine River, South Fork	5	11	14.8	10	17.5	58.3	Fair
2	12UM140	Brittan Creek	4.5	11.7	10.9	12.5	18	57.6	Fair
2	12UM132	Bungo Creek	4.5	11	15.1	12.5	20	63.1	Fair
3	12UM139	Bungo Creek	5	12.5	19.1	12.6	20.6	69.9	Good
2	12UM133	Wilson Creek	1.2	10	16.4	13.5	21	62.6	Fair
1	12UM116	Pine River, South Fork	4	8.5	20	12	13	57.5	Fair
Average Habitat Results: *South Fork Pine River Subwatershed*			**4.1**	**10.6**	**15**	**11.7**	**17.4**	**59.1**	**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 8. Channel Condition and Stability Assessment: South Fork Pine 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
2	12UM120	Pine River, South Fork	11.5	17	19	2.5	50	moderately unstable
1	12UM121	Pine River, South Fork	6	9	20	3	38	fairly stable
2	12UM140	Brittan Creek	15	22	19	3	59	moderately unstable
2	12UM132	Bungo Creek	16	17.5	22	3	58.5	moderately unstable
2	12UM139	Bungo Creek	12	11.5	6	3	32.5	fairly stable
1	12UM133	Wilson Creek	4	14	11	3	32	fairly stable
1	12UM116	Pine River, South Fork	11	8	9	3	31	fairly stable
Average Stream Stability Results: *South Fork Pine River Watershed*			**10.7**	**14.1**	**15.1**	**2.9**	**43**	**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 9. Outlet water chemistry results: South Fork Pine River Subwatershed.

Station location:	Pine River, South Fork, Upstream of CSAH 1, 1 mile South of Pine River, MN						
STORET/EQuIS ID:	S007-101						
Station #:	12UM116						
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**# of WQ Exceedances[2]**
Un-ionized Ammonia	ug/L	9	0.15	4.47	1.9	40	0
Chloride	mg/L	11	2.15	6.4	3.7	230	0
Dissolved Oxygen (DO)	mg/L	20	2.92	12.9	7.8	5	4
pH		20	6.99	8.67	7.83	6.5 – 8.5	1
Secchi Tube	100 cm	20	83	100	98	40	0
Total suspended solids*	mg/L	11	1	6	3.5	15	0
Escherichia coli (geometric mean)	MPN/100ml	-	46	125	-	126	0
Escherichia coli	MPN/100ml	15	13.2	2419.6	182	1260	1
Chlorophyll-a, Corrected	ug/L	-	-	-	-	-	-
Inorganic nitrogen (nitrate and nitrite)*	mg/L	11	0.03	0.09	0.04	-	-
Kjeldahl nitrogen	mg/L	11	0.3	1.16	0.82	-	-
Orthophosphate	ug/L	-	-	-	-	-	-
Pheophytin-a	ug/L	-	-	-	-	-	-
Phosphorus	ug/L	11	37	107	72	-	-
Specific Conductance	uS/cm	20	150	358	275	-	-
Temperature, water	deg °C	20	12.7	25.1	20.8	-	-
Sulfate*	mg/L	11	3	3	3	-	-
Hardness	mg/L	11	77.6	182	130	-	-

[1] Secchi Tube standards are surrogate standards derived from the total suspended solids standard of 15 mg/l.

***Minimum, Maximum, and Mean values for this parameter may have been calculated using non detect values, non-detect limits vary between parameters**

[2] Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the South Fork Pine River Subwatershed, a component of the IWM work conducted between May and September from 2012 and 2013. This specific data does not necessarily reflect all data that was used to assess the AUID.

Table 10. Lake water aquatic recreation assessments: South Fork Pine River Subwatershed.

Name	MDNR 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)	AQL Support Status	AQR Support Status
Eagle	11-0342-00	115	O	-	-	-	NT	11	2	4.0	NA	FS

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

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

Summary

Stations 12UM120, 12UM121, and 12UM116 were located on three separate reaches of the South Fork Pine River. Station 12UM120 was located furthest upstream in the low gradient portion of the South Fork Pine River. Both the 2012 and 2013 visit FIBI scores were nearly exceptional. Both fish samples contained several sensitive species and some wetland species. Macroinvertebrates were also sampled in 2012 and in 2013. The 2012 MIBI was poor; however, the 2013 visit MIBI scored much higher. A period of high water preceding the 2012 sample may have negatively impacted the results. Station 12UM121 was located approximately 5 miles downstream of station 12UM120. Both the 2012 and 2013 visits had poor FIBI scores. Both samples featured high numbers of tolerant species, low numbers of insectivores, and low numbers of lithophilic spawners. An improperly installed culvert immediately downstream of the site may cause excess sediment to be deposited within the reach. Station 12UM116 was located on the lower segment of the South Fork Pine River that runs from Behler Creek to the Pine River. The 2012 visit FIBI score was exceptional. The fish sample contained abundant insectivores, later maturing species, and several sensitive species. The majority of the sampling reach consisted of wetland like habitat; however, limited areas of coarse substrate, including gravel and boulders, were present along with large woody debris. The MIBI score was fair and the community was representative of the low gradient stream habitat present within the sampling reach. Water chemistry data was also available for this reach of the South Fork Pine River. Four DO exceedances occurred over two years (2012-2013); however, three of the four exceedances occurred during high flow events. The reach was not considered impaired as the low DO levels are a natural response to riparian flushing of the wetlands and forests that are abundant in this subwatershed. Total Suspended Solids (TSS) and Secchi tube data easily meet both regional standards. Good TSS and Secchi values are often associated with watersheds that have minimal land and hydrologic alterations. Bacteria levels fully support aquatic recreation (only one exceedance occurred over a four year period).

Station 12UM140 was located on the segment of Brittan Creek that runs from the confluence of Dabill Creek to the South Fork Pine River. Brittan Creek is a low gradient stream with habitat consisting of fine sediment and little available cover other than overhanging vegetation and some woody debris. Low DO levels were measured at all fish and macroinvertebrate visits. Extensive beaver dams and wetlands present in the upstream contributing watershed likely contribute to the low DO levels. Surprisingly, the 2012 and 2013 visits produced some of the highest FIBI scores in the Pine River Watershed (79 and 78, respectively). Both fish samples were dominated by pearl dace - a species very sensitive to watershed disturbances yet able to thrive in wetland like environments. The MIBI score for the 2012 visit was poor; however, the 2013 visit MIBI score was passing. High flows during 2012 may have negatively influenced the sample. Limited water chemistry data was available for this segment of Brittan Creek. Some exceedances of the DO standard occurred but there was not enough data to make an assessment.

Stations 12UM139 and 12UM132 were both located on the same segment of Bungo Creek. Station 12UM139 was located furthest upstream near the headwaters of Bungo Creek. There were three visits to 12UM139 – two during 2012 and one in 2013. All samples contained high numbers of tolerant species; however, good numbers of lithophilic spawners and headwater species resulted in good FIBI scores. Stream habitat consisted primarily of fine substrate and several small sections of coarse substrate. The MIBI scores from the 2012 and 2013 visits were just below passing; however, both samples contained some sensitive taxa. Station 12UM132 was located one mile upstream of the confluence of Bungo Creek and the South Fork Pine River. Fish and macroinvertebrates were sampled in 2012 and 2013. Both FIBI scores were passing. The fish community and habitat at station 12UM132 was similar to the upstream station. The MIBI scores from both visits were very good. Sensitive taxa were present in all samples from station 12UM132. Only small water chemistry data sets were available for this segment of Bungo Creek. There were some exceedances of the DO standard but there was not enough data to make an assessment. The low DO values could be attributed to wetland influence.

Station 12UM133 was located on Wilson Creek one mile upstream of the confluence of Wilson Creek and the South Fork Pine River. The station was visited twice during 2012 and both FIBI scores were good. The most abundant species present in both samples were sensitive pearl dace. The MIBI score was poor and dominated by tolerant taxa. Habitat within the sampling reach consisted of fine sediment and limited amounts of small woody debris. The limited habitat likely contributed to the poor MIBI score.

The watershed contained many small lakes with limited access; as a result, Eagle Lake was the only lake with enough data for assessment. Eagle Lake easily met all three nutrient ecoregion standards. The mostly undeveloped shoreline and predominately forested watershed contributed to high water quality. Land conversion is more prevalent within this subwatershed; therefore proper water management practices will be vital as forest is increasingly replaced by open land uses.

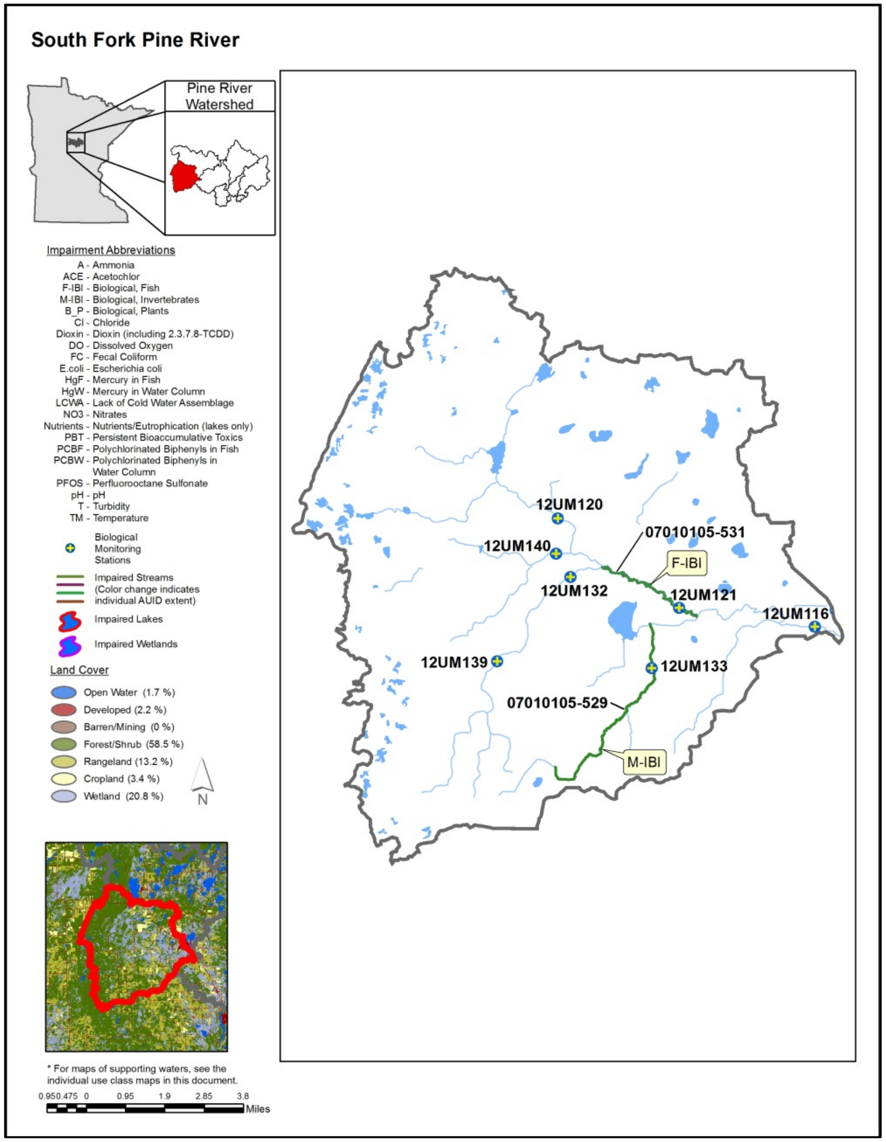


Figure 23. Currently listed impaired waters by parameter and land use characteristics in the South Fork Pine River Subwatershed.

Middle Pine River Subwatershed HUC 0701010504-01

The Middle Pine River Subwatershed drains approximately 131 square miles of land within the central portion of the Pine River Watershed. The subwatershed begins immediately after the confluence of the South Fork Pine River and Pine River. The Pine River flows east toward Whitefish Lake for approximately 1 mile before being joined by a small tributary named Arvig Creek. The Pine River continues flowing east after the confluence with Arvig Creek for approximately 5 miles before entering the Whitefish Chain of Lakes. The Whitefish Chain of Lakes consists of 14 interconnected lakes (including Upper Hay, Lower Hay, Whitefish, Big Trout, Hen, Rush, and Cross) covering an area of 14,000 acres. Moderate to heavy development occurs around most of the lakes in the chain. Numerous small tributaries flow directly into the Whitefish Chain of Lakes system – especially into Upper Whitefish Lake. Daggett Brook, one of the more prominent tributaries, drains 149 square miles of the northeast portion of the Pine River Watershed. Flowing from north to south, Daggett Brook passes through heavily forested land, numerous wetlands, and several lakes before entering the Whitefish Chain of Lakes. Another prominent tributary called Hay Creek originates just south of the community of Pine River. From its headwaters, Hay Creek flows toward the southeast through Upper Hay Lake and then turns toward the north before entering the White Fish Chain of Lakes at Lower Hay Lake. Other tributaries to the lake system include Thompson Creek, Willow Creek, and numerous unnamed creeks. Land within the watershed is primarily forested (43.0%) followed by wetland (25.8%), open water (18.7%), range land (7.9%), cropland (2.6%), and development (1.9%). The communities of Manhattan Beach, Jenkins, Ideal Corners, and Cross Lake are within the subwatershed. In 2012, the MPCA collected biological samples from three monitoring stations located on four stream segments within the Middle Pine River Subwatershed. Intensive water chemistry monitoring was conducted at one station.

Table 11. Aquatic life and recreation assessments on stream reaches: Middle Pine River Subwatershed. Reaches are organized upstream to downstream in the table.

					Aquatic Life Indicators:								**Aquatic Rec. Indicators:**			
AUID ***Reach Name*,** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Nutrients	**Aquatic Life**	**Aquatic Rec.**
07010105-509 Arvig Creek Rice Lake to Unnamed creek	1.17	WWg	99UM042	Upstream of C.R. 44, 2 mi. SE of Pine River	EXS	EXS	IF	-	-	IF	-	-	-	-	IMP	NA
07010105-672 Pine River South Fork Pine R to Whitefish Lk	6.18	WWg	12UM125	Upstream of CSAH 15, 5 mi. SE of Pine River	MTS	MTS	IF	-	-	IF	-	-	MTS	-	SUP	SUP
07010105-556 Hay Creek Unnamed creek to Unnamed creek	0.76	WWg	-	-	-	-	IF	-	-	MTS	-	-	MTS	-	IF	SUP
07010105-631 Willow Creek Headwaters to Unnamed creek	4.12	WWg	12UM129	Downstream of Long Farm Rd, 6 mi. E of Pine River	EXS	MTS	IF	-	-	IF	IF	-	-	-	IMP	NA

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

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

Key for Cell Shading: ◻ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use; 🟨 = insufficient information.

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

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

Table 12. Minnesota Stream Habitat Assessment: Middle Pine 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	99UM042	Arvig Creek	3	8.5	8	13	18	50.5	Fair
1	12UM125	Pine River	4	10.5	19.8	16	29	79.3	Good
2	12UM129	Wilson Creek	4.2	11.7	9.5	12.5	24.5	62.5	Fair
Average Habitat Results: *Middle Pine River Subwatershed*			**3.7**	**10.2**	**12.4**	**13.8**	**23.8**	**64.1**	**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 13. Channel Condition and Stability Assessment: Middle Pine 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	99UM042	Arvig Creek	7	6	7	2	22	stable
1	12UM125	Pine River	13	12	4	3	32	fairly stable
2	12UM129	Wilson Creek	13.5	21	22.5	4	31	fairly stable
Average Stream Stability Results: *Middle Pine River Subwatershed*			**11.1**	**13**	**11.1**	**4.5**	**28.3**	**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 14. Lake assessments: Middle Pine 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)	AQL Support Status	AQR Support Status
Island	18-0269-00	183	O	48	23.2	6.1	D	12	3	4.5	NA	FS
Hen	18-0270-00	128	M	-	-	5.5	NT	13	2	3.6	NA	IF
Ox	18-0288-00	242	O	50	22.6	4.9	NT	11	2	6.4	NA	FS
Whitefish	18-0310-00	7725	M	37	42.1	10.7	D	17	4	3.3	NA	FS
Rush	18-0311-00	757	M	56	32.0	6.4	NT	13	3	4.5	NA	FS
Cross Lake Reservoir	18-0312-00	1778	M	50	25.6	8.8	NT	16	3	4.1	NA	FS
Big Trout	18-0315-00	1364	O	28	39.0	14.6	NT	11	3	4.4	NA	FS
Pig	18-0354-00	191	M	-	17.1	7.3	D	16	4	4.0	NA	FS
Bertha	18-0355-00	337	M	36	19.5	8.5	D	16	3	4.1	NA	FS
Clamshell	18-0356-00	207	M	75	13.4	2.4	I	18	5	4.3	NA	FS
Arrowhead	18-0366-00	303	E	100	4.0	1.2	IF	26	8	2.6	NA	FS
Lower Hay	18-0378-00	700	M	31	30.5	14.9	NT	14	3	4.4	NA	FS
Upper Hay	18-0412-00	592	E	32	12.8	5.2	NT	35	6	2.1	NA	IF

Abbreviations:			
	D -- Decreasing/Declining Trend	**H** – Hypereutrophic	**FS** – Full Support
	I -- Increasing/Improving Trends	**E** – Eutrophic	**NS** – Non-Support
	NT – No Trend	**M** – Mesotrophic	**IF** – Insufficient Information
		O - Oligotrophic	

Key for Cell Shading: ◻ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use

Summary

Station 99UM042 was located on Arvig Creek 0.3 miles upstream of CSAH 44. The FIBI score (0) from the 2012 visit was the lowest FIBI score in the entire Pine River Watershed. The fish sample consisted of three tolerant species and nine individuals. In contrast, a fish sample obtained in 1999 from the same station contained 15 species of fish and 995 individuals. The FIBI score from that sample was 61. Macroinvertebrates were sampled in 2012 and 2013. Both MIBI scores are poor. An abnormally high amount of shifting fine sediment was present within the sampling reach. The limited amount of coarse substrate present was severely embedded. Upstream and downstream land use changes within the Arvig Creek watershed have severely degraded the fish and macroinvertebrate community. The stream segment is impaired for aquatic life based on the FIBI and MIBI score. Arvig Creek had insufficient water chemistry data to make a full assessment. The limited DO data that was available indicated exceedances in all three reaches, from the headwaters to the Pine River confluence. Additional monitoring conducted subsequent to the assessments indicated that low DO may occur throughout Arvig Creek. Upstream wetland complexes may be influencing DO concentrations in this watershed; therefore, more data collection will be needed to investigate sources of the stressor.

Station 12UM125 was located on the Pine River (07010105-672) approximately 1.25 miles upstream of Whitefish Lake. The 2012 visit FIBI score exceeded the exceptional use criteria. Longnose dace, an intolerant species, was the most abundant species sampled. The sample also contained high numbers of sensitive species, insectivores, and lithophilic spawners. Station 12UM125 had the second highest MSHA score (79.3) in the Pine River Watershed. Excellent stream habitat consisting of coarse substrate, woody debris, and abundant aquatic macrophytes was present. The MIBI score was not high enough to meet exceptional use criteria but was still good. A limited amount of water chemistry data was available for this reach of the Pine River. Bacteria data available on the Pine River indicate full support conditions. Total suspend solids (TSS) easily met regional standards, indicating that TSS is not limiting aquatic communities. Good TSS datasets are typically indicative of undisturbed land and hydrologic processes. Also, low bacteria levels indicate full support for aquatic recreation.

Biological data was not collected on Hay Creek (07010105-556); however, limited water chemistry data was available. Similar to other locations within the Pine River Watershed, total suspended solids (TSS) data easily met regional standards. Bacteria data indicated full support for aquatic recreation. Not enough DO data was available to assess aquatic life.

Station 12UM129 was located on Willow Creek just downstream of Longfarm Road. Both the 2012 and 2013 visit FIBI scores were poor. Both fish samples completely lacked headwater species and darters. Habitat within the sampling reach consisted of fine sediment, woody debris, and various aquatic macrophytes. Macroinvertebrates were sampled in 2012 and 2013; both visit MIBI scores were good. Follow up investigations to determine the cause of the poor fish communities has identified an area of severe erosional deposition downstream of the sampling reach. During normal flow conditions the sediment likely acts as a barrier to fish trying to move upstream. The stream segment is impaired for aquatic life based on the FIBI score.

Thirteen lakes in the Middle Pine River Subwatershed had data available within the 10 year assessment window; 11 of these had sufficient datasets available to make an aquatic recreation assessment. All eleven lakes with sufficient assessment data fully supported aquatic recreation. Most of the lakes in the subwatershed are either flow through lakes on the Pine River or indirectly connected to the river through other lakes or channels. The deep lake basins in the south eastern portion of the subwatershed known as the Whitefish Chain have good water quality despite high development density on shorelines. Deep lakes have the ability to assimilate higher amounts of phosphorus at depth without negatively impacting surface conditions until mixing occurs in the fall. Four lakes have a decreasing trend in historical Secchi data suggesting that a potential change in water quality could be imminent. Implementing development practices that limit runoff to the lakes will be very important.

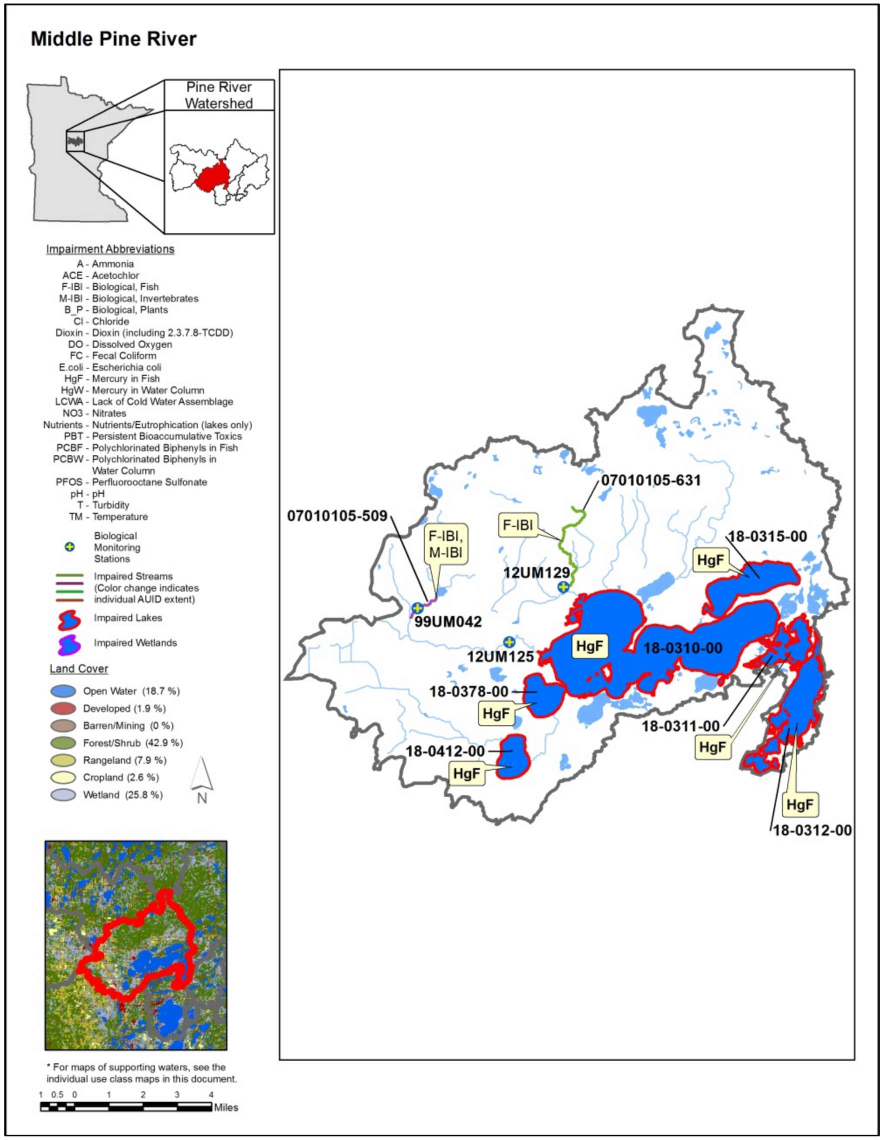


Figure 24. Currently listed impaired waters by parameter and land use characteristics in the Middle Pine River Watershed.

Daggett Brook Subwatershed HUC 0701010503-01

The Daggett Brook Subwatershed drains 149 square miles of land within the northeastern portion of the Pine River Watershed. Daggett Brook originates from a wetland area eight miles northwest of Outing and flows north several miles before turning toward the east. After flowing through a dam at the outlet of a large wetland, Daggett Brook flows toward the southeast and passes through Lake George and Washburn Lake. After exiting Washburn Lake, Daggett Brook flows south and is joined by the tributary Hay Creek. Hay Creek originates from the same area as Daggett Brook and flows toward the south instead of toward the north. Numerous beaver impoundments are present along the entire flow path of Hay Creek. After the confluence of Hay Creek, Daggett Brook continues flowing south for several miles before entering Mitchell Lake and then Eagle Lake. The tributary Fox Creek joins Daggett Brook one mile south of Eagle Lake. Daggett Brook continues south for several miles and enters Little Pine Lake on the eastern side of the Whitefish Chain of Lakes. Notable lakes within this sub watershed from north to south include: George, Washburn, Roosevelt, Mitchell, West Fox, East Fox, Little Pine and Daggett. Land within the subwatershed is primarily forested (66.5%) followed by wetland (19.9%), open water (9.9%), rangeland (1.6%), developed land (1.6%), and cropland (0.5%). The community of Fifty Lakes is within the subwatershed. In 2012, the MPCA collected biological samples from three stations located on three segments in the Daggett Brook Subwatershed. Intensive water chemistry monitoring was conducted at one station.

Table 15. Aquatic life and recreation assessments on stream reaches: Daggett Brook Subwatershed. Reaches are organized upstream to downstream in the table.

					Aquatic Life Indicators:								**Aquatic Rec. Indicators:**			
AUID ***Reach Name*,** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Nutrients	**Aquatic Life**	**Aquatic Rec.**
07010105-611 Daggett Brook Unnamed creek to Lake George	1.71	WWg	12UM123	Upstream of CSAH 55, 12.5 mi. SW of Remer	MTS	-	IF	-	-	IF	-	-	-	-	SUP	NA
07010105-561 Daggett Brook Hay Creek to Mitchell Lake	6.04	WWg	12UM128	Adjacent to CR 155, 9 mi. NE of Cross Lake	MTS	MTS	IF	-	-	IF	IF	-	-	-	SUP	NA
07010105-514 Daggett Brook Eagle Lake to Little Pine Lake	4.33	WWg	12UM118	Downstream of CSAH 1, 5.5 mi. NE of Cross Lake	MTS	MTS	IF	-	MTS	MTS	MTS	-	MTS	-	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ▨ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use; 🟨 = insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 16. Minnesota Stream Habitat: Daggett Brook 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	12UM123	Daggett Brook	5	10	3	13	10	41	Poor
1	12UM128	Daggett Brook	5	10	18	16	10	59	Fair
1	12UM118	Daggett Brook	2.5	12.5	20	13	20	68	Good
Average Habitat Results: *Daggett Brook Subwatershed*			**4.1**	**10.8**	**13.6**	**14**	**13.3**	**56**	**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 17. Channel Condition and Stability Assessment: Daggett Brook 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	12UM123	Daggett Brook	6	7	13	5	31	fairly stable
1	12UM128	Daggett Brook	9	6	11	3	29	fairly stable
1	12UM118	Daggett Brook	15	10	6	3	34	fairly stable
Average Stream Stability Results: *Daggett Brook Subwatershed*			**10**	**7.6**	**10**	**3.6**	**31.3**	**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 18. Outlet water chemistry results: Daggett Brook Subwatershed.

Station location:	Daggett Brook, at CSAH 1, 1.5 miles East of Fifty Lakes, MN						
STORET/EQuIS ID:	S006-229						
Station #:	12UM118						
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**# of WQ Exceedances[2]**
Un-ionized Ammonia	ug/L	9	0.94	4.8	2.6	40	0
Chloride	mg/L	11	1.29	2.4	2.02	230	0
Dissolved Oxygen (DO)	mg/L	20	5.95	11.32	8.17	5	0
pH		20	7.71	8.79	8.25	6.5 – 8.5	0
Secchi Tube	100 cm	20	100	100	100	40	0
Total suspended solids*	mg/L	11	1	5	2.8	15	0
Escherichia coli (geometric mean)	MPN/100ml	-	4.5	41.9	-	126	0
Escherichia coli	MPN/100ml	15	4.1	62	24.54	1260	0
Chlorophyll-a, Corrected*	ug/L	17	3	12	6.05	-	-
Inorganic nitrogen (nitrate and nitrite)*	mg/L	17	0.03	0.04	0.031	-	-
Kjeldahl nitrogen	mg/L	17	0.442	1.04	0.62	-	-
Orthophosphate	ug/L	-	-	-	-	-	-
Pheophytin-a	ug/L	-	-	-	-	-	-
Phosphorus	ug/L	20	22	260	41	-	-
Specific Conductance	uS/cm	20	162	254	217.1	-	-
Temperature, water	deg °C	20	13.68	25.91	21.92	-	-
Sulfate*	mg/L	11	3	3	3	-	-
Hardness	mg/L	11	93.9	118	103.65	-	-

[1] Secchi Tube standards are surrogate standards derived from the total suspended solids standard of 15 mg/l.

*Minimum, Maximum, and Mean values for this parameter may have been calculated using non detect values, non-detect limits vary between parameters

[2] Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Daggett Brook Subwatershed, a component of the IWM work conducted between May and September from 2012 and 2013. This specific data does not necessarily reflect all data that was used to assess the AUID.

Table 19. Lake assessments: Daggett Brook Subwatershed.

Name	MDNR 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)	AQL Support Status	AQR Support Status
Morrison	11-0006-00	153	-	98	15.2		IF	12	5	3.7	NA	FS
Leavitt	11-0037-00	120	M	29	18.3	8.8	NT	19	3	2.7	NA	FS
Roosevelt - North	11-0043-01	287	M	-	39.3	14.9	NT	17	4	3.7	NA	FS
Roosevelt - South	11-0043-02	1218	M	-	39.3	14.9	I	16	5	3.5	NA	FS
Lawrence	11-0053-00	218	M	38	21.6	5.8	NT	20	5	3.0	NA	FS
Washburn	11-0059-00	1586	M	48	33.8	6.4	I	14	5	3.9	IF	FS
George	11-0101-00	602	E	-	6.1	1.2	NT	34	25	1.8	IF	IF
Island	11-0102-00	344	M	-	3.0	-	NT	13	4	4.2	NA	FS
Pistol	11-0110-00	76	O	86	6.1	-	IF	12	52	0.9	IF	IF
Mitten	11-0114-00	106	-	90	8.5	-	IF	37	22	0.9	NA	NS
Stevens	11-0116-00	108	M	64	19.2	-	IF	16	7	2.9	NA	FS
Twenty-Six	11-0117-00	105	O	100	4.0	-	IF	10	10	2.2	FS	FS
Blue	18-0211-00	170	O	43	14.6	-	NT	7	3	7.5	NA	FS
Anna	18-0213-00	99	M	84	5.8	-	NT	16	4	3.8	NA	IF
Smokey Hollow	18-0220-00	123	M	46	7.6	-	NT	19	5	2.0	NA	FS
Wood	18-0222-00	90	M	52	12.5	-	IF	10	4	3.5	IF	IF
Butterfield	18-0231-00	194	M	74	6.1	-	I	17	4	4.4	NA	FS
Little Pine	18-0266-00	353	E	58	11.0	4.0	I	24	5	2.9	NA	FS
Daggett	18-0271-00	255	E	58	7.0	3.4	I	25	6	2.7	NA	FS
Kego	18-0293-00	289	E	62	6.1	3.4	D	33	9	2.0	NA	NS
Mitchell	18-0294-00	419	M	27	23.8	9.4	NT	22	5	2.4	NA	FS
Eagle (Main Bay)	18-0296-01	-	M	-	10.7	4.9	NT	22	6	2.8	NA	FS
Eagle (West Bay)	18-0296-02	-	M	-	10.7	-	IF	18	5	3.0	NA	IF
Eagle (East Bay)	18-0296-03	-	M	-	10.7	-	IF	20	6	2.7	NA	IF
West Fox	18-0297-00	448	M	29	16.8	7.0	NT	17	4	4.7	NA	FS
East Fox	18-0298-00	223	M	42	19.8	5.8	NT	15	3	5.1	NA	FS
Ross	18-0165-00	487	E	62	9.4	3.4	NT	25	14	1.5	IF	IF

Abbreviations:			
	D -- Decreasing/Declining Trend	**H** – Hypereutrophic	**FS** – Full Support
	I -- Increasing/Improving Trends	**E** – Eutrophic	**NS** – Non-Support
	NT – No Trend	**M** – Mesotrophic	**IF** – Insufficient Information
		O - Oligotrophic	

Key for Cell Shading: ▨ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use

Summary

Three biological monitoring stations were located on three separate reaches within the Daggett Brook Subwatershed; all stations were located on Daggett Brook. The upstream reach of Daggett Brook is low gradient with a heavy wetland influence. The biological station within this reach (12UM123) was located upstream of Lake George. The FIBI score was low but still supporting of aquatic life. Due to heavy wetland influence, DO levels likely fluctuate widely on this segment of Daggett Brook. The fish sample was dominated by tolerant taxa such as black bullheads and central mudminnows. Naturally occurring conditions restrict fish community development and allow only more tolerant species to survive. Most of the sampling reach could not be waded; therefore macroinvertebrates were not sampled. The stream segment is supporting aquatic life. Wetlands remain an influence in the middle reaches of Daggett Brook; however, frequent patches of coarse substrate were present throughout the sampling reach. The biological monitoring station (12UM128) in this reach was located 4.5 miles downstream of Washburn Lake. The FIBI score was good - multiple sensitive species and numerous insectivores were sampled. The MIBI score was also good at this station. The biological monitoring station (12UM118) on the lower reaches of Daggett Brook, from Eagle Lake to Little Pine Lake, has more gradient and less wetland influence. The riparian zone is wooded and not dominated by wetland vegetation. The FIBI score was good. The fish sample was dominated by bluegill and largemouth bass – two non-lithophilic nest guarding species. The abundance of these two species may be the result of lake influence from upstream Eagle Lake. Numerous sensitive species, insectivores, and lithophilic spawners were also present in the sample. Channel development was poor but coarse substrate occurred throughout the entire sampling reach. The MIBI score was also good at this station. This is the only reach on Daggett Brook that had sufficient data to assess aquatic recreation; the data strongly indicate full support. Low bacteria levels can be attributed to a largely undisturbed watershed. Total suspended solid (TSS) and surrogate Secchi tube datasets for this segment easily meet regional standards, indicating full support of aquatic life. The excellent TSS and Secchi tube values emphasize the pristine nature of the land and water quality within the subwatershed.

Water chemistry data was collected on twenty-seven lakes in the Daggett Brook Subwatershed. Eighteen of the twenty lakes that had sufficient data to make an assessment fully supported aquatic recreation. The abundance of undisturbed forest and wetland complexes throughout this subwatershed helps to protect the recreational quality of the lakes. High quality lakes such as Morrison, Leavitt, Lawrence, Roosevelt (north and south), and Blue are connected by small tributaries and have moderate shoreline development when compared to other nearby lakes in the watershed. Responsible shoreline management practices should continue where they occur. Additional implementation of lake friendly shoreline management practices will ensure that the high quality of these lakes is preserved.

Two lakes did not support aquatic recreation; one of them was Kego Lake, which was previously listed as impaired in 2010. The recent data collected from Kego Lake during 2010 and 2011 indicate phosphorus, chlorophyll-a, and Secchi exceedances still occur during the summer months. The lake is not a candidate for delisting at this time. An investigation of the stressors impacting Kego Lake will be necessary to address poor recreational water quality. Mitten Lake shows a consistent pattern of exceedances between 2012 and 2013. A detailed natural background review of Mitten Lake could not definitively conclude that elevated nutrient levels are solely attributed to natural processes. Further investigation will be needed to identify sources of nutrients that could be enriching Mitten Lake. Nearly all nutrient exceedances in George Lake occurred during the summer of 2012 when high flow events were prevalent throughout the Pine River Watershed. Additional data was collected in 2015 to examine conditions under normal precipitation and runoff rates.

There were limited chloride data on five lakes in this subwatershed; all five lakes had chloride levels well below the chronic standard of 230 mg/L. The highest concentration of 1.6 mg/L was observed on Wood Lake. For lakes meeting the chloride standard for aquatic life use, a policy decision has been made to assess the lake as insufficient information until a biological indicator is available.

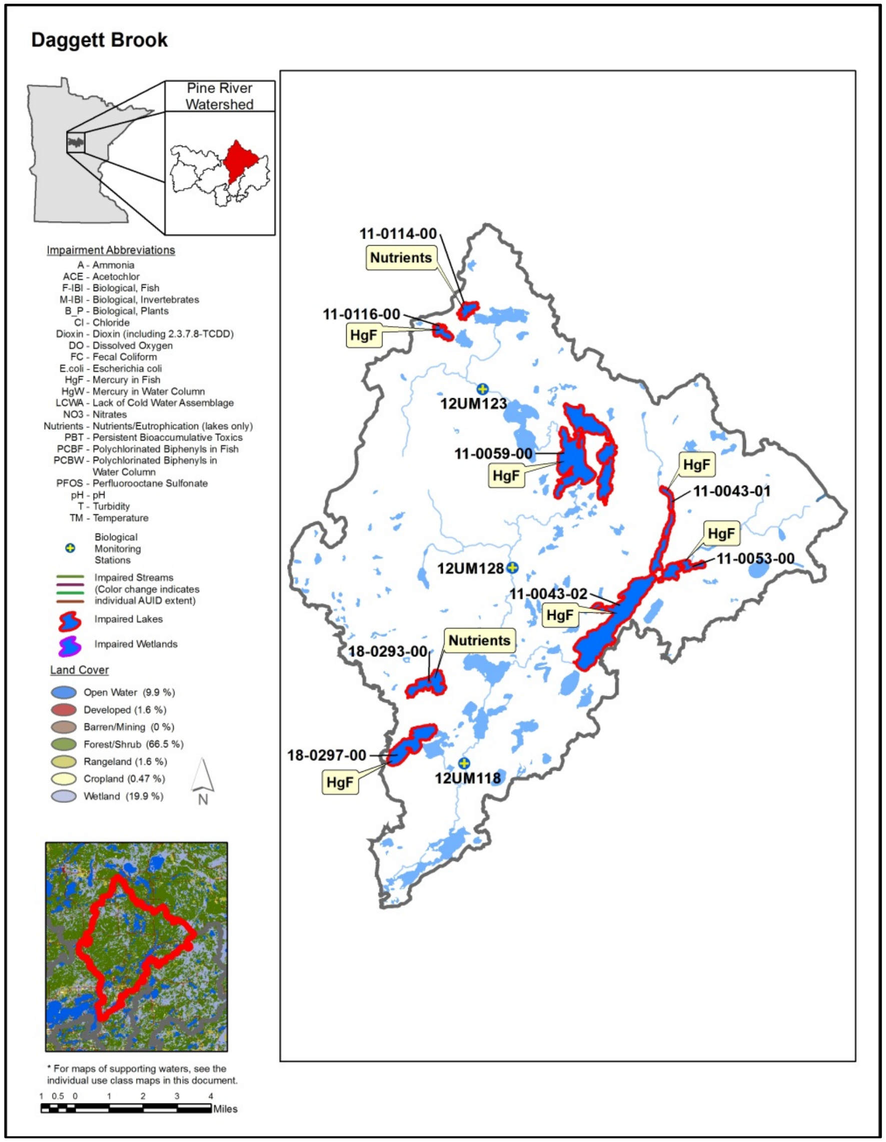


Figure 25. Currently listed impaired waters by parameter and land use characteristics in the Daggett Brook Subwatershed.

Pelican Brook Subwatershed HUC 0701010506-02

The Pelican Brook Subwatershed drains approximately 47 square miles of land within the south central portion the Pine River Watershed. Pelican Brook flows out of Ossawinnamakee Lake, passes through the dam, and winds eastward 5 miles before joining the Pine River. Pelican Lake, the largest lake within the Pine River Watershed, drains into Ossawinnamakee Lake through a small unnamed tributary. Lakes play a large part in the surface water hydrology within this subwatershed. Pelican is especially notable considering its size, development density, and intense recreational popularity. Other headwater lakes include Kimball, Clear, Star, and Bass. Land within the subwatershed is open water (37.5%), forest (35.3%), wetland (21.4%), developed (3.4%), rangeland (1.4%), and cropland (0.8%). The community of Breezy Point is within the Pelican Brook Subwatershed. In 2012, the MPCA collected biological samples from one station within the Pelican Brook Subwatershed.

Table 20. Aquatic life and recreation assessments on stream reaches: Pelican Brook Subwatershed. Reaches are organized upstream to downstream in the table.

					Aquatic Life Indicators:								Aquatic Rec. Indicators:			
AUID ***Reach Name*,** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Nutrients	**Aquatic Life**	**Aquatic Rec.**
07010105-517 Pelican Brook Ossawinnamakee Lake to Pine R	5.33	WWg	12UM141	Upstream of CSAH 3, 2.5 mi. S of Cross Lake	MTS	MTS	IF	-	-	IF	-	-	-	-	SUP	NA

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ▨ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use; 🟨 = insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.
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Table 21. Minnesota Stream Habitat Assessment: Pelican Brook 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	12UM141	Pelican Brook	5	10	15.6	12	18	60.6	Fair
Average Habitat Results: *Pelican Brook Subwatershed*			**5**	**10**	**15.6**	**12**	**18**	**60.6**	**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 22. Channel Condition and Stability Assessment: Pelican Brook 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	12UM141	Pelican Brook	12	9	20	3	44	fairly stable
Average Stream Stability Results: *Pelican Brook Subwatershed*			**12**	**9**	**20**	**3**	**44**	**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 23. Lake assessments: Pelican Brook Subwatershed.

Name	MDNR 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)	AQL Support Status	AQR Support Status
Young	18-0252-00	59	M	-	6.4	-	NT	13	3	7.1	NA	FS
East Twin	18-0257-00	26	M	-	8.5	-	IF	13	5	4.1	NA	FS
West Twin	18-0258-00	19	O	38	20.7	-	IF	8	3	5.1	NA	FS
Little Beaver	18-0279-00	14	O	-	-	-	IF	-	-	4.3	NA	IF
Pelican	18-0308-00	8379	O	47	31.7	6.7	I	10	3	5.3	IF	FS
Duck	18-0314-00	146	-	100	4.0	-	IF	15	3	3.2	NA	IF
Little Markee	18-0324-00	16	M	-	-	-	IF	18	5	2.8	NA	FS
Stevens	18-0325-00	33	-	-	-	-	-	10	2	-	NA	IF
Lougee	18-0342-00	201	M	72	16.2	-	I	17	4	3.5	NA	FS
Markee	18-0343-00	98	M	73	10.1	-	NT	12	7	4.3	NA	FS
Lynch	18-0347-00	62	M	-	-	-	NT	22	4	2.3	NA	FS
Shaffer	18-0348-00	88	E	-	-	-	IF	22	3	0.8	NA	IF
Unnamed	18-0350-00	25	E	-	-	-	NT	42	8	2.0	NA	IF
Little Pelican	18-0351-00	266	M	73	10.4	-	NT	14	4	4.2	NA	FS
Ossawinnamakee	18-0352-00	685	M	35	19.2	6.4	I	14	2	5.7	NA	FS
Little Round	18-0357-00	12	O	-	6.1	-	NT	-	-	4.8	NA	IF
Bass	18-0358-00	119	O	58	14.3	-	NT	10	3	5.2	NA	IF
Star	18-0359-00	125	O	37	25.3	-	I	11	2	5.3	NA	FS
Little Star	18-0360-00	46	M	25	9.1	-	NT	12	3	4.9	NA	FS
Kimball	18-0361-00	182	M	20	23.5	8.8	NT	13	2	5.3	NA	FS
Clear	18-0364-00	173	O	27	19.2	6.4	NT	8	3	5.3	NA	FS

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

Key for Cell Shading: ▨ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use

Summary

Station 12UM141 was located on Pelican Brook two miles downstream of Ossawinnamakee Lake. The FIBI score (76) was among the highest FIBI scores in the Pine River Watershed. Several sensitive species, high numbers of insectivores, and one intolerant species were present in the fish sample. Most of the habitat within the sampling reach was characteristic of a low gradient stream; however, several areas of rock substrate and swifter flow velocities were present. The MIBI score was very good as well, nearly attaining the exceptional use threshold. Several sensitive taxa were captured in the macroinvertebrate sample. There was not enough water chemistry data for assessment; however, pH, DO, and Secchi tube datasets suggest that the water quality is good. Due to the high developmental pressure in this watershed, an emphasis should be placed on developing monitoring and protection strategies to track and protect water quality.

Data was available for 21 lakes in the Pelican Brook Subwatershed; 14 of those lakes had sufficient data to assess aquatic recreation. All 14 lakes supported aquatic recreation. This subwatershed has some of the highest water quality in the entire Pine River Watershed despite having some of the highest development density ratios for both shoreline and upland areas. Pelican Lake is a large oligotrophic lake that is easily meeting ecoregion standards. Available Secchi trend data suggests the clarity is increasing. It is also the only lake in the subwatershed with available chloride data. Chloride levels were well below the chronic standard of 230 mg/L; the highest concentration observed was 2.3 mg/L. The aesthetic beauty of Pelican Lake attracts heavy recreational use by local citizens and tourists year round. Development in the watershed continues to increase, highlighting the need for effective water management practices. Proper shoreline management practices will help alleviate stress from dense development. The lake would appear to be a prime candidate for protection strategies through the Watershed Restoration and Protection (WRAPS) process. Maintaining good water quality will ensure that the benefits to the local economy will continue into the future. Ossawinnamakee and Kimball are some other highly developed, high quality lakes in the subwatershed that could benefit from WRAPS protection strategies.

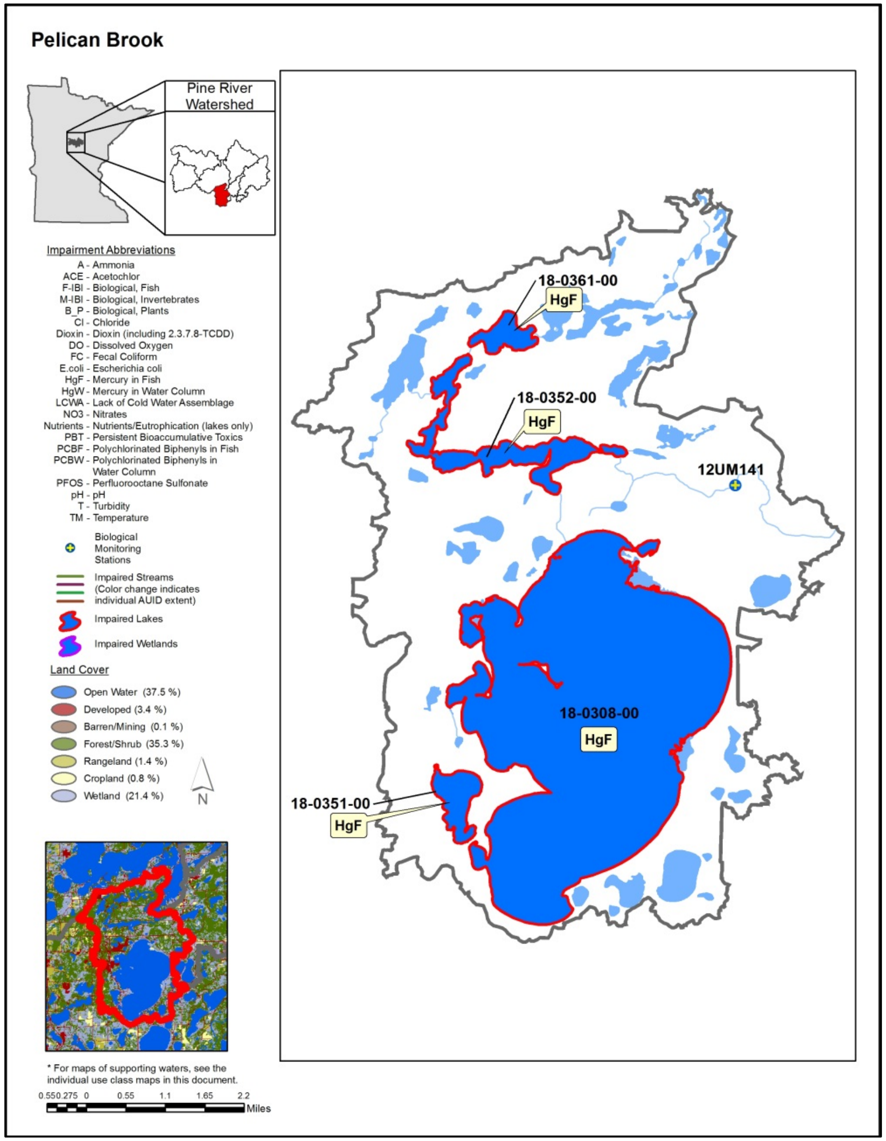


Figure 26. Currently listed impaired waters by parameter and land use characteristics in the Pelican Brook Subwatershed.

Little Pine River Subwatershed HUC 0701010505-01

The Little Pine River Subwatershed drains 141 square miles of land within the eastern portion of the Pine River Watershed. The Little Pine River originates from Little Pine Lake and flows southwest for a short distance before turning toward the south. Two small wetland ditches enter the Little Pine River before the river turns and flows toward the west. The river passes near the community of Little Pine and enters a shallow wetland called Duck Lake. After exiting Duck Lake the river turns toward the south, passing through Lake Mary and Emily Lake, and continuing for approximately 6 miles before being joined by Mud Brook. Mud Brook originates from Moulton Lake near the community of Little Pine. Mud Brook flows primarily toward the southwest, passing through several small lakes and wetlands before joining with the Little Pine River. After the confluence of Mud Brook, the Little Pine River continues flowing toward the southwest through several wetland areas before entering the Pine River. The land within the subwatershed is primarily forested (51.6%) followed by wetland (37.3%), open water (6.9%), development (1.8%), cropland (0.4%), and rangeland (1.9%). The communities of Little Pine and Emily are within the subwatershed. In 2012, the MPCA collected biological samples from five stations located on five stream segments within the Little Pine River Subwatershed. Water chemistry was intensively monitored at one station.

Table 24. Aquatic life and recreation assessments on stream reaches: Little Pine River Subwatershed. Reaches are organized upstream to downstream in the table.

					Aquatic Life Indicators:								Aquatic Rec. Indicators:			
AUID ***Reach Name*,** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Nutrients	**Aquatic Life**	**Aquatic Rec.**
07010105-578 Little Pine River Headwaters (Little Pine Lake 18-0176-00) to Duck Lake	5.92	WWg	12UM134	Downstream of Little Pine Rd, 6.5 mi. SE of Outing	-	MTS	IF	-	-	IF	-	-	-	-	SUP	NA
07010105-584 Little Pine River Lake Emily to Mud Brook	10.67	WWg	00UM017	Upstream of C.R. 36, 7 mi. S of Emily	MTS	MTS	IF	-	-	IF	-	-	-	-	SUP	NA
07010105-673 Mud Brook Lows Lake (18-0180-00) to Island Lake Dam	10.34	WWg	12UM127	Downstream of CR 106, 11 mi. E of Cross Lake	MTS	MTS	IF	-	-	IF	-	-	-	-	SUP	NA
07010105-677 Mud Brook Mud Lake (18-0198-00) to Little Pine River	2.08	WWg	12UM124	Downstream of Hwy 6, 7.5 mi. E of Cross Lake	MTS	-	IF	-	-	IF	-	-	-	-	SUP	NA
07010105-505 Little Pine River Mud Brook to Pine River	7.13	WWg	12UM117	Downstream of Olander Rd, 7 mi. SE of Cross Lake	MTS	MTS	IF	-	MTS	MTS	MTS	-	MTS	-	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: 🟥 = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use; 🟨 = insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 25. Minnesota Stream Habitat Assessment: Little Pine 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
2	00UM017	Little Pine River	5	13	21.4	14	25	74.8	Good
2	12UM127	Mud Brook	4.7	11	7.5	11.5	16.5	51.2	Fair
1	12UM124	Mud Brook	5	10	10	11	9	45	Fair
2	12UM117	Little Pine River	5	11	19.2	14.5	29	78.7	Good
Average Habitat Results: *Little Pine River Subwatershed*			**4.9**	**11.3**	**14.5**	**12.7**	**19.8**	**62.4**	**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 26. Channel Condition and Stability Assessment: Little Pine 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
3	00UM017	Little Pine River	8	10	6	4	28	fairly stable
2	12UM127	Mud Brook	9	10	17	3	39	fairly stable
1	12UM124	Mud Brook	8	5	15	1	29	fairly stable
2	12UM117	Little Pine River	15	12.5	8	3.5	39	fairly stable
Average Stream Stability Results: *Little Pine River Subwatershed*			**10**	**9.3**	**11.5**	**2.8**	**33.7**	**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 27. Outlet water chemistry results: Little Pine River Subwatershed.

Station location:	Little Pine River, at Orlander Road, 10 miles southwest of Crosslake, MN						
STORET/EQuIS ID:	S006-294						
Station #:	12UM117						
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**# of WQ Exceedances[2]**
Un-ionized Ammonia	ug/L	9	0.08	2.12	1.07	40	0
Chloride	mg/L	11	1.32	2.93	2.36	230	0
Dissolved Oxygen (DO)	mg/L	20	1	10	5.62	5	7
pH		20	6.75	8.39	7.77	6.5 – 8.5	0
Secchi Tube	100 cm	19	74	100	94	40	0
Total suspended solids*	mg/L	11	2	8	5	15	0
Escherichia coli (geometric mean)	MPN/100ml	-	49.2	52	-	126	0
Escherichia coli	MPN/100ml	15	10.9	648.8	81.23	1260	0
Chlorophyll-a, Corrected*	ug/L	17	1	15	6.23	-	-
Inorganic nitrogen (nitrate and nitrite)*	mg/L	17	0.03	0.11	0.05	-	-
Kjeldahl nitrogen	mg/L	17	0.525	1.52	0.98	-	-
Orthophosphate	ug/L	-	-	-	-	-	-
Pheophytin-a	ug/L	-	-	-	-	-	-
Phosphorus	ug/L	17	30	153	61	-	-
Specific Conductance	uS/cm	20	50	461	158.3	-	-
Temperature, water	deg °C	20	13.79	26.26	21.41	-	-
Sulfate*	mg/L	11	3	3	3	-	-
Hardness	mg/L	11	56.4	98.3	71.15	-	-

[1] Secchi Tube standards are surrogate standards derived from the total suspended solids standard of 15 mg/l.

***Minimum, Maximum, and Mean values for this parameter may have been calculated using non detect values, non detect limits vary between parameters**

[2] Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Little Pine River Subwatershed, a component of the IWM work conducted between May and September from 2012 and 2013. This specific data does not necessarily reflect all data that was used to assess the AUID.

Table 28. Lake assessments: Little Pine River Subwatershed.

Name	MDNR 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)	AQL Support Status	AQR Support Status
Moulton	01-0212-00	253	M	85	7.3	-	IF	16	13	0.8	IF	FS
Ross	18-0165-00	487	E	62	9.4	3.4	NT	25	14	1.5	IF	IF
Mud	18-0166-00	76	E	58	7.0	-	NT	-	-	1.1	NA	IF
TWIN (WEST BASIN)	18-0167-01	47	M	-	28.7	-	NT	13	6	1.6	NA	IF
TWIN (EAST BASIN)	18-0167-02	28	E	-	28.7	-	IF	25	8	1.3	NA	FS
Little Pine	18-0176-00	124	H	-	-	-	-	100	-	-	NA	IF
Lows	18-0180-00	302	E	100	3.0	-	IF	65	36.5	0.6	NA	NS
Island	18-0183-00	236	M	62	11.3	-	D	16	10	1.8	IF	IF
Mary	18-0185-00	398	E	33	10.4	5.2	NT	29	5	1.8	NA	FS
Perry	18-0186-00	157	M	92	6.7	-	IF	30	37	1.1	IF	IF
Dolney	18-0195-00	274	O	100	4.9	-	IF	10	2	4.0	IF	FS
Emily	18-0203-00	707	E	100	4.0	2.4	D	44	6	1.5	IF	NS
Dahler	18-0204-00	237	M	100	1.5	-	IF	-	-	2.3	NA	IF
Ruth	18-0212-00	601	M	34	11.9	5.8	I	23	5	5.3	IF	FS
Trout	18-0218-00	114	O	44	6.7	3.4	NT	9	4	4.1	IF	FS
Adney	18-0225-00	302	M	52	8.2	-	IF	16	7	3.8	NA	FS

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

Key for Cell Shading: ◻ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use

Summary

Stations 12UM134, 00UM017, and 12UM117 were located on three separate reaches of the Little Pine River. Station 12UM134, the most upstream station, was located approximately one mile downstream of Little Pine Lake. Only macroinvertebrates were sampled at this station. The MIBI score was passing. The biological monitoring station 00UM017, on the middle reach of the Little Pine River, was located approximately five miles downstream of Lake Emily. Fish were sampled at the station in 2012 and again in 2014. The 2012 visit FIBI score was good and the 2014 visit FIBI was exceptional. Both samples contained multiple sensitive species and insectivores; however, the 2014 sample contained a significantly higher number of the sensitive species longnose dace. High flow events during the spring and early summer of 2012 likely influenced the 2012 sample. The station had excellent habitat and one of the highest MSHA scores (75) in the entire Pine River Watershed. Extensive rock riffles, abundant macrophytes, coarse woody debris, and excellent channel development were present within the sampling reach. Macroinvertebrates were sampled from 2012-2014. Similar to the fish results, the MIBI score from 2012 was lower and likely the result of prolonged high water levels during that year. The 2013 and 2014 MIBI scores were higher but still lower than expected. Both the 2013 and 2014 sample was numerically dominated by a few tolerant taxa; however, other sensitive and intolerant taxa were present in the samples. This segment of the Little Pine River is fully supporting of aquatic life.

Station 12UM117 was located on the lowest segment of the Little Pine River that extends from Mud Brook to the Pine River. Fish were sampled during 2012 and 2013; macroinvertebrates were sampled consecutively from 2012-2014. The 2012 visit FIBI score was low but passing; the 2013 visit FIBI score was considerably higher. The 2013 sample contained higher numbers of sensitive species, more intolerant species, and more lithophilic spawners. The 2012 macroinvertebrate sample was non-reportable because some habitat types were not represented in the sample. Both the 2013 and the 2014 visit MIBI scores were just below the impairment threshold. Several tolerant taxa numerically dominate the samples, resulting in a lower MIBI score. Sensitive and intolerant taxa are present in both samples. An abundance of coarse substrate, a variety of cover types, and good channel development resulted in the highest MSHA score (80.6) in the entire Pine River Watershed. Although areas of riffle and higher gradient are present within the sampling reach, portions of the Little Pine River upstream of the sampling location consist of low gradient wetland like habitat. Biological communities at station 12UM117 are also influenced by Mud Brook, a low gradient stream that passes through a substantial amount of wetlands. Large rain events in 2012 likely flushed significant amounts of organic matter out of these wetlands and into Mud Brook. As a result, the communities at station 12UM117 were exposed to low DO levels whenever significant precipitation events occurred. DO levels remained low at station 12UM117 for a significant amount of time following the large rain events in June of 2012. The low DO levels and higher flow velocities likely contributed to the differences between the 2012 and 2013 fish samples. Dissolved oxygen readings from the water chemistry station located immediately upstream of 12UM117 confirm that the DO standard was often exceeded in 2012 during high flow events. Dissolved oxygen was not listed as an impairment because the low levels were determined to result from natural wetland flushing. Total suspended solids and Secchi tube readings easily meet regional standards indicating support for aquatic life. Bacteria levels indicate full support for aquatic recreation.

Stations 12UM127 and 12UM124 were located on two different reaches of Mud Brook. As previously mentioned, Mud Brook is a low gradient stream that is influenced by several lakes and numerous wetlands. The upstream station (12UM127) was visited in 2012 and 2013. Fish and macroinvertebrate scores were just below the impairment threshold. Habitat within the sampling reach consisted primarily of fine substrate and sparse cover. Low levels of DO were recorded at all fish and invertebrate visits. The sampling reach is very wetland influenced – wetlands occur in the immediate riparian zone and upstream. The naturally occurring low DO and reduced habitat are likely limiting the development of biological communities. Very little land use disturbance occurs within the surrounding watershed. The lower IBI scores are a result of natural phenomenon; this segment of Mud Brook is considered fully supporting of aquatic life. The downstream station (12UM124) was located one mile downstream of Mud Lake and visited once during 2012. The FIBI score was good. The fish sample was indicative of a wetland influenced low gradient stream. Macroinvertebrates were not sampled because the stream was too deep to wade. The channel winds through a fairly extensive wetland at the station location. Similar to the upstream reach, low levels of DO likely occur on this segment of Mud Brook.

There was sufficient data for nine lakes greater than 28 acres to assess them for aquatic recreation. Of these nine lakes, seven fully supported aquatic recreation and two did not. Adney and Ruth lakes are two high quality lakes with developed shorelines; both fully supported aquatic recreation. With high shoreline development densities on both lakes, it is imperative that responsible shoreline management practices continue into the future to maintain and protect water quality. The high water quality of other fully supporting lakes in this subwatershed can be attributed to mostly undisturbed upstream watersheds and responsible shoreline management. Limited chloride data was available on eight lakes in this subwatershed; all eight fell well below the chronic standard of 230 mg/L. The highest concentration of 5.8 mg/L was observed on Perry Lake. For lakes meeting the chloride standard for aquatic life use, a policy decision has been made to assess the lake as insufficient information until a biological indicator is available.

Lake Emily, a relatively shallow flow through lake on the Little Pine River, does not support aquatic recreation due to excess nutrients. The excess nutrients could be attributed to past water treatment practices and shoreline development adjacent to the lake. Lows Lake also does not support aquatic recreation. An extensive natural background review using various forms of county, state, and geospatial data determined that anthropogenic sources of phosphorus were unlikely to be causing eutrophication. Lows Lake is shallow; internal loading is likely causing the increased phosphorus concentrations in the water column. The contributing watershed is heavily forested, contains numerous wetland complexes, and has little human disturbance. After considering the watershed characteristics and modeling results, Lows Lake will be listed as impaired due to natural sources (4D category).

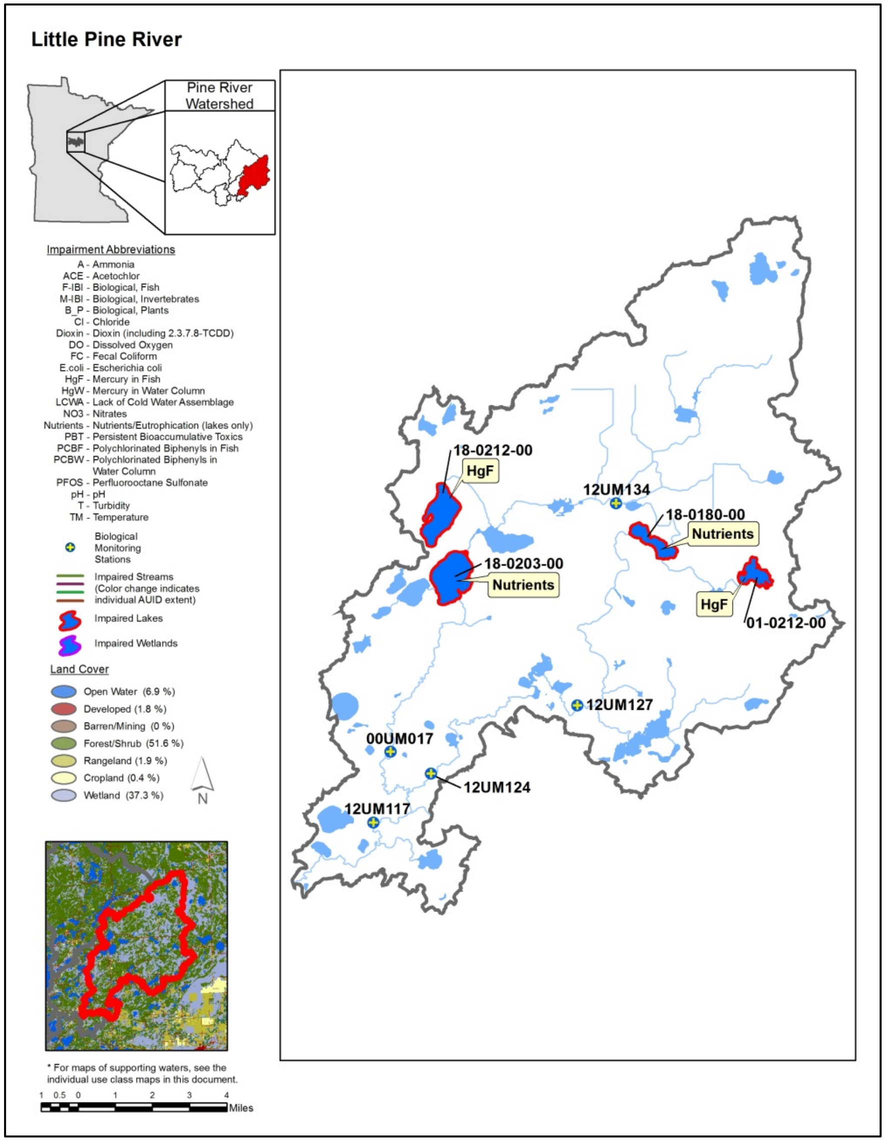


Figure 27. Currently listed impaired waters by parameter and land use characteristics in the Little Pine River Subwatershed.

Lower Pine River Subwatershed HUC 0701010506-01

The Lower Pine River Subwatershed drains approximately 47 square miles of land within the south central portion of the Pine River Watershed. The Pine River flows out of Cross Lake and winds southward for several miles before flowing into the upper portion of Pine Lake. The Pine River flows through the Pine Lake dam and continues southward several miles before being joined by the tributary Pelican Brook. Pelican Brook drains 48 square miles of land within the south central portion the Pine River Watershed. After the confluence of Pelican Brook the Pine River turns toward the east, passes through the Crow Wing State Forest, and then turns back toward the south. The Pine River flows southward for approximately one mile before being joined by a major tributary known as the Little Pine River. The Little Pine River drains 141 square miles of the eastern Pine River Watershed. After the confluence of the Little Pine River, the Pine River continues flowing southward for approximately five miles before entering the Mississippi River. Land within the subwatershed is primarily forested (48.9%) followed by wetland (31.4%), open water (12.2%), rangeland (3.2%), developed (1.9%), and cropland (2.3%). The community of Cross Lake is within the subwatershed. In 2012, the MPCA collected biological samples from three stations located on three stream segments within the Lower Pine River Subwatershed. Intensive water chemistry monitoring was conducted at one station.

Table 29. Aquatic life and recreation assessments on stream reaches: Lower Pine River Subwatershed. Reaches are organized upstream to downstream in the table.

					Aquatic Life Indicators:								**Aquatic Rec. Indicators:**			
AUID ***Reach Name*****,** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Nutrients	**Aquatic Life**	**Aquatic Rec.**
07010105-660 Pine River Cross Lake Dam to Unnamed creek	2.63	WWg	12UM131	Upstream of CSAH 36, 1 mi. SE of Cross Lake	MTS	MTS	IF	-	-	IF	-	-	MTS	-	SUP	SUP
07010105-662 Pine River Pine Lake Dam to Little Pine River	9.06	WWg	12UM149	North of CSAH 11, 3.5 mi. SE of Cross Lake	MTS	MTS	IF	-	-	IF	-	-	-	-	SUP	NA
07010105-504 Pine River Little Pine River to Mississippi R	5.84	WWg	12UM114	Upstream of CSAH 11, 8 mi. NW of Crosby	MTS	MTS	IF	-	MTS	MTS	MTS	-	MTS	-	SUP	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ⬜ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use; 🟨 = insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 30. Minnesota Stream Habitat Assessment: Lower Pine 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	12UM131	Pine River	3.5	10	22.5	15	25	76	Good
2	12UM149	Pine River	5	13.2	18	13	21.5	70.8	Good
1	12UM114	Pine River	5	13	16.2	10	23	67.2	Good
Average Habitat Results: *Lower Pine River Subwatershed*			**4.5**	**13.6**	**18.9**	**12.6**	**23.1**	**71.3**	**Good**

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 31. Channel Condition and Stability Assessment: Lower Pine 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	12UM131	Pine River	11	11	5	3	30	fairly stable
2	12UM149	Pine River	8	5	9	5	27	fairly stable
1	12UM114	Pine River	7	12	8	3	30	fairly stable
Average Stream Stability Results: *Lower Pine River Subwatershed*			**8.6**	**9.3**	**7.3**	**3.6**	**29**	**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 32. Outlet water chemistry results: Lower Pine River Subwatershed.

Station location:	Pine River, at CSAH 11, North of Crosby						
STORET/EQuIS ID:	S000-181						
Station #:	12UM114						
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**# of WQ Exceedances[2]**
Un-ionized Ammonia	ug/L	9	0.53	3.82	1.35	40	0
Chloride	mg/L	11	2.87	5.52	3.92	230	0
Dissolved Oxygen (DO)	mg/L	20	2.01	10.57	6.15	5	6
pH		20	7.32	8.37	7.88	6.5 – 8.5	0
Secchi Tube	100 cm	20	100	100	100	--	0
Total suspended solids*	mg/L	11	1	6	2.72	--	0
Escherichia coli (geometric mean)	MPN/100ml	-	6.9	27.8	-	126	0
Escherichia coli	MPN/100ml	15	8.4	167	30.54	1260	0
Chlorophyll-a, Corrected*	ug/L	17	1	6	2.76	-	-
Inorganic nitrogen (nitrate and nitrite)*	mg/L	17	0.03	0.086	0.033	-	-
Kjeldahl nitrogen	mg/L	17	0.326	1.27	0.58	-	-
Orthophosphate	ug/L	-	-	-	-	-	-
Pheophytin-a	ug/L	-	-	-	-	-	-
Phosphorus	ug/L	17	14	78	36.1	-	-
Specific Conductance	uS/cm	20	186	281	226.5	-	-
Temperature, water	deg °C	20	13.28	25.82	21.3	-	-
Sulfate*	mg/L	11	3	3	3	-	-
Hardness	mg/L	11	89	121	101.9	-	-

[1] Secchi Tube standards are surrogate standards derived from the total suspended solids standard of 15 mg/L.

***Minimum, Maximum, and Mean values for this parameter may have been calculated using non detect values, non-detect limits vary between parameters**

[2] Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Lower Pine River Subwatershed, a component of the IWM work conducted between May and September from 2012 and 2013. This specific data does not necessarily reflect all data that was used to assess the AUID.

Table 33. Lake assessments: Lower Pine River Subwatershed.

Name	MDNR 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)	AQL Support Status	AQR Support Status
Fool	18-0224-00	243	M	99	5.2	-	IF	24	11	1.9	NA	IF
Goodrich	18-0226-00	372	M	66	10.7	3.7	NT	18	3	4.7	NA	FS
O'Brien (Northeast Bay)	18-0227-02	81	O	-	14.9	6.4	I	11	2	5.6	NA	FS
Horseshoe (East Bay)	18-0251-01	591	M	-	17.1	3.7	I	15	6	4.7	NA	FS
Horseshoe (West Bay)	18-0251-02	319	M	-	17.1	3.7	NT	15	5	4.4	NA	FS
Pine	18-0261-00	375	M	99	5.2	1.2	IF	23	6	3.2	NA	FS
Velvet	18-0284-00	162	M	51	8.8	4.3	NT	15	5	3.3	NA	FS
Greer	18-0287-00	333	M	80	11.0	2.4	IF	13	6	2.7	IF	FS

A.0bbreviations:
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

Key for Cell Shading: ▢ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use

Summary

Three biological stations were located on three separate reaches of the Pine River. The upstream station (12UM131) was located on the segment that extends from Cross Lake to an unnamed tributary. The 2012 visit FIBI score was low but passing. All though several sensitive species were present, high numbers of bluegill and largemouth bass - both non-lithophilic nest guarding species - were present in the sample. Non-lithophilic nest guarding species may indicate that the environment is degraded because they are able to create and maintain nests with materials other than coarse substrate. High numbers of these types of species in a riverine environment result in a lower FIBI score. In this case, high numbers of bluegill and largemouth bass at station 12UM131 likely are the result of lake influence from Cross Lake. Habitat within the sampling reach was excellent: coarse substrate along with extensive riffles, deep pools, and various aquatic macrophytes were present. The MIBI score was fair. Several sensitive ephemeroptera and trichoptera species were present in the macroinvertebrate sample. Assessable water chemistry data was available on this segment of the Pine River. Bacteria data indicate this reach fully supports aquatic recreation. Total suspended solid (TSS) data, collected from this reach over a three year period, easily meet the regional standard of 15 mg/L and support aquatic life use.

The middle station (12UM149) was located within the Crow Wing State Forest. The station was visited in 2012 and 2014; both visit FIBI scores were good. At this location, the Pine River supports a very diverse fish community: 26 species of fish were captured during the 2012 visit and 24 were captured during the 2014 visit. Both fish samples contained multiple sensitive species, abundant lithophilic spawners, insectivores, and several juvenile game fish species. Two rare species, the pugnose shiner and the least darter, were present in both samples. Substrate within the sampling reach consisted primarily of sand along with areas of gravel and cobble. Good channel development, which included deep pools at bends and several riffles, enhanced the quality of the habitat at 12UM149. A variety of submergent and emergent macrophytes were also present. Macroinvertebrates were also sampled during 2012 and 2014. The MIBI score for the 2012 visit was good and the 2014 MIBI score was fair. Both samples featured sensitive taxa.

The lowest station (12UM114) was located on the segment of the Pine River that runs from the Little Pine River to the Mississippi River. Similar to station 12UM149, a diverse fish community of 27 species was sampled. The FIBI score was good. There were higher numbers of tolerant species, fewer lithophilic spawners, and less sensitive species than the sample collected at station 12UM149. Very few game fish were present during the 2012 survey. Almost the entire sampling reach consisted of sand – very little coarse substrate was present. Woody debris lined the banks of the reach but very little cover was present in the deeper mid channel sections. The limited amount of coarse substrate likely limits the abundance of lithophilic spawning species. Assessable water chemistry data was available for this segment of the Pine River. There were 95 DO samples collected within the 10 year assessment window, although Table 32 only reflects two years of IWM sampling. The DO standard was at times exceeded in this reach but the most severe exceedances occurred during high flow events in 2012 and 2013; these values should be considered anomalies. The low values were due to extreme flushing of riparian wetland and forest that sent DO values plummeting across the watershed. After removing these three exceedances, the DO dataset does not warrant listing an impairment. The pH dataset, collected across the 10 year assessment window, has only two exceedances of the standard. Bacteria data indicate full support conditions for aquatic recreation. Extensive TSS and surrogate Secchi tube data from this stream reach easily meets ecoregion standards and fully support for aquatic life.

Eight lakes in the subwatershed had data collected during the 10 year assessment window; of these, seven had sufficient data for assessment. The seven assessable lakes all exhibited good water quality and fully support aquatic recreation. Despite heavy shoreline development, Horseshoe and O’Brien Lakes had the highest water quality of all the lakes in the subwatershed. The good water quality of lakes in this watershed as a whole can be attributed to the largely undisturbed land use and responsible shoreline management practices. Continued advocacy for maintaining native shoreline vegetation and bank material will ensure that high water quality is maintained into the future. The development of protection strategies at a watershed level will also be beneficial. Limited chloride data was available for only one lake in this subwatershed. Chloride levels in Greer Lake were well below the chronic standard of 230 mg/L; the highest concentration observed was 2.9 mg/L. For lakes meeting the chloride standard for aquatic life use, a policy decision has been made to assess the lake as insufficient information until a biological indicator is available.

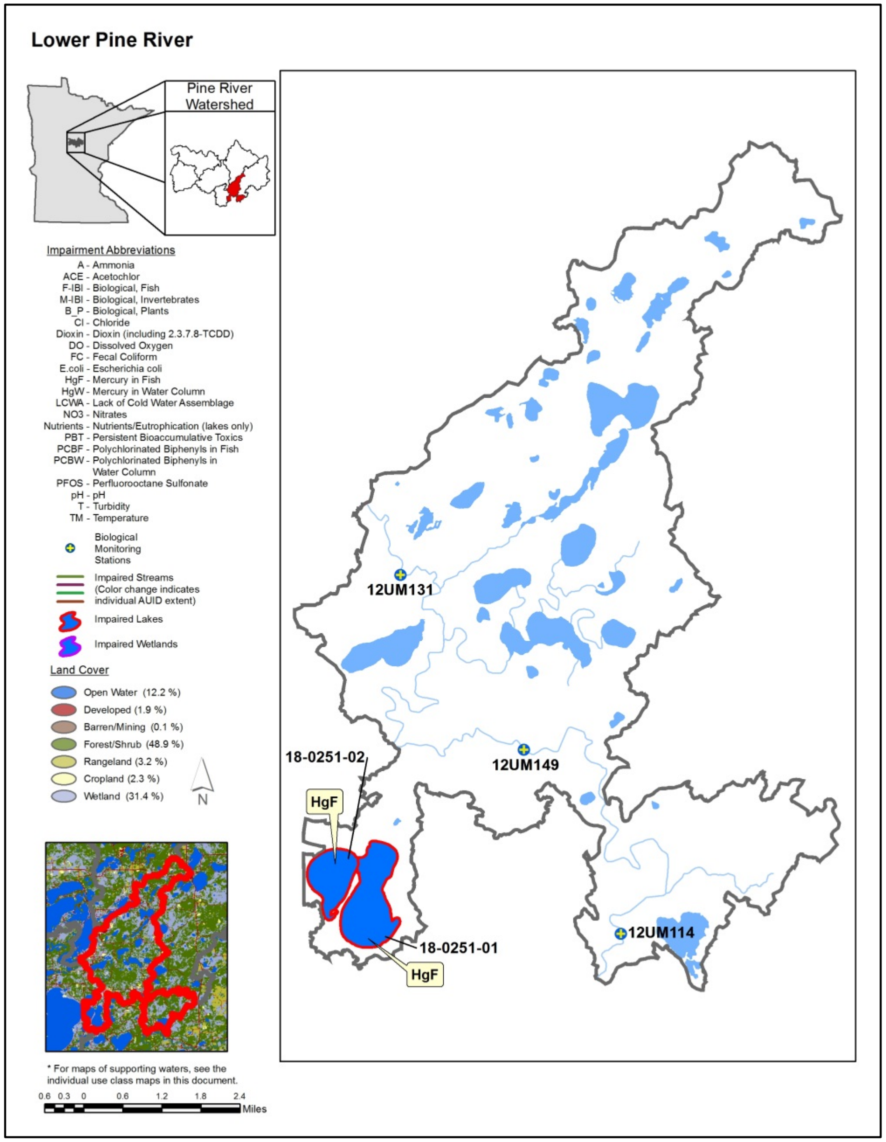


Figure 28. Currently listed impaired waters by parameter and land use characteristics in the Lower Pine River Subwatershed.

Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed unit of the Pine River Watershed, grouped by sample type. Summaries are provided for load monitoring data results near the mouth of the river, 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 Pine River Watershed.

Pollutant load monitoring

The pollutant load monitoring station on the Pine River is at CSAH 11 near Mission, Minnesota approximately one mile above the confluence with the Mississippi River. 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) (MPCA 2010a), each with unique nutrient standards. Of the state's three RNRs (North, Central, South), the Pine River's load monitoring station is located within the North RNR. Annual FWMCs were calculated and compared for years 2010-2012 (Figure 29, Figure 30, Figure 31, and Figure 32) and compared to the RNR standards. It should be noted that while a FWMC exceeding given water quality standard is generally a good indicator the waterbody is out of compliance with the River Nutrient Region 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 (MPCA 2010a), over the most recent 10 year period and not based on comparisons with FWMCs. 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 total suspended solids (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).

Within the North RNR, the TSS standard is 15 mg/L (MPCA 2010c); when greater than 10 percent of the individual samples exceed the standard the river is out of compliance. From 2010 – 2012, none of the samples exceeded the 15 mg/L standard. The computed FWMCs also did not exceed the standard as shown in Figure 29.

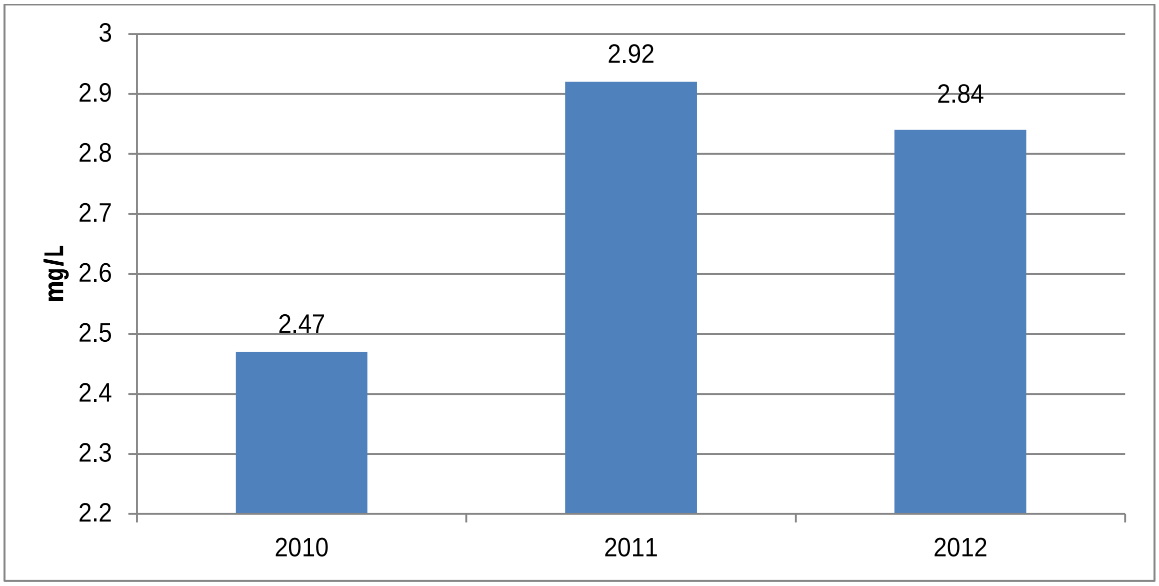


Figure 29. Total suspended solids flow weighted mean concentrations in the Pine River Watershed.

Table 34. Annual pollutant loads by parameter calculated for the Pine River.

	2010	2011	2012
Parameter	Mass (kg)	Mass (kg)	Mass (kg)
Total Suspended Solids	774,810	1,091,878	1,173,249
Total Phosphorus	6,974	10,737	
Ortho Phosphorus	1,581	3,346	4,431
Nitrate + Nitrite Nitrogen	14,840	33,023	15,378

Total phosphorus

Nitrogen (N), phosphorus (P), and potassium (K) 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 freshwater 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.

Within the North RNR, the TP standard is 0.050 ug/L as a summer average. Data collected from June through September (2010 through 2011) indicates that only 3 out of 94 individual samples exceeded the TP standard. None of the years had summer means greater than the standard. The 2012 total phosphorus data was not included due to analytical equipment errors at the MDH laboratory.

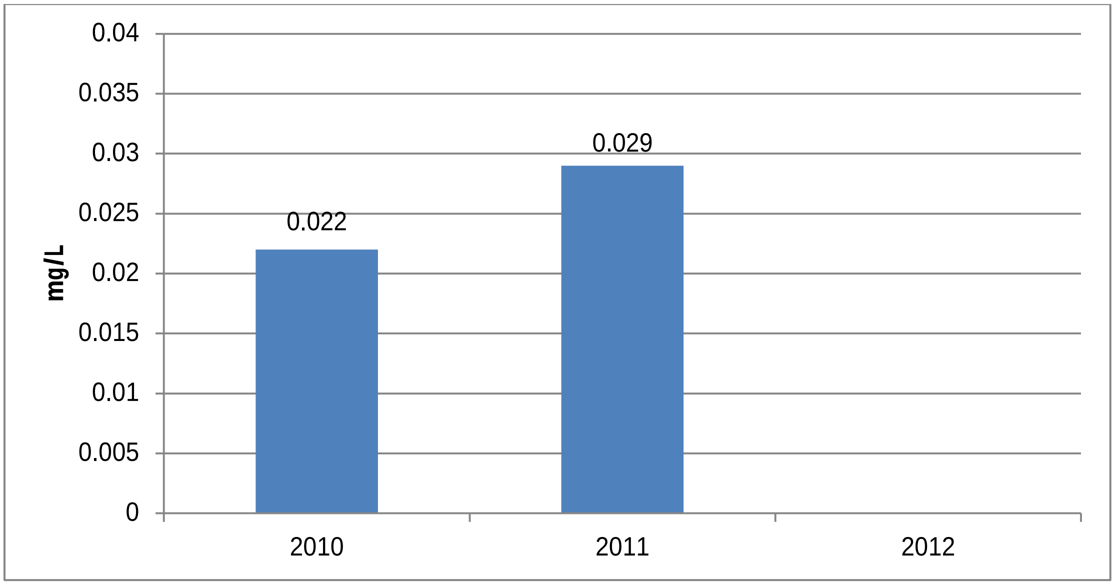


Figure 30. Total phosphorus flow weighted concentrations for the Pine River.

Dissolved orthophosphate

DOP is a water soluble form of phosphorus that is readily available to algae (bioavailable) (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.

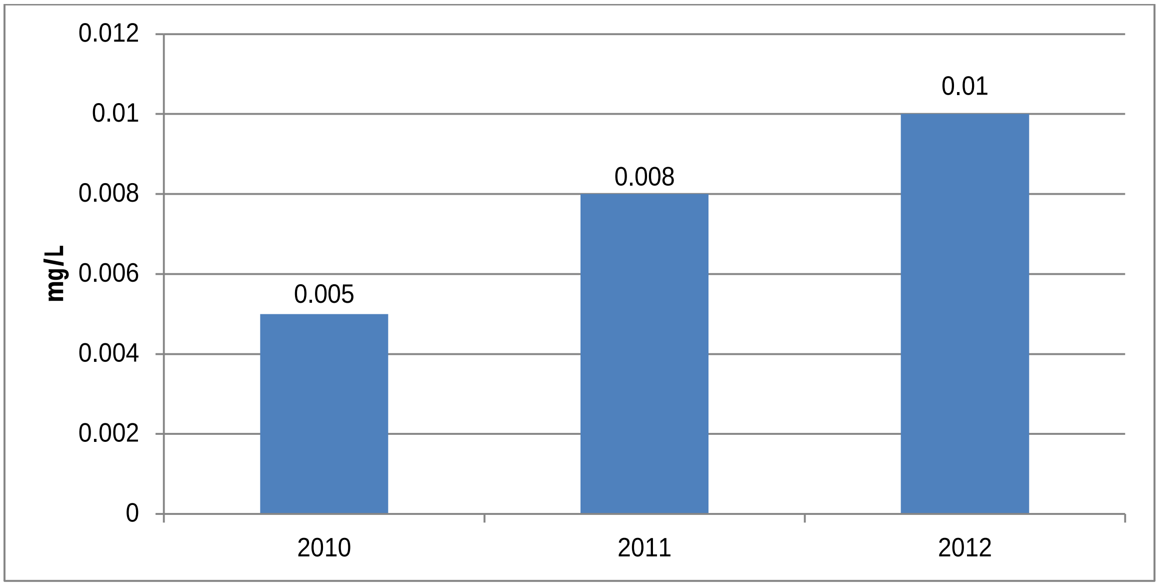


Figure 31. Dissolved orthophosphate flow weighted mean concentrations for the Pine River.

Nitrate plus nitrite - nitrogen

Nitrate and nitrite-nitrogen are inorganic forms of N 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 2010b). 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-N, with nitrite-nitrogen typically making up a small proportion of the combined total concentration. These and other forms of N 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, Aquatic Life Water Quality Standards Technical Support Document for Nitrate, Nov 2010).

Figure 32 shows the nitrate-N FWMCs over the three-year period for the Pine River monitoring site. The FWMC for all three years were below the acute and chronic nitrate-N standards. From 2010 through 2012, there were no exceedances of the draft chronic standard (Figure 32).

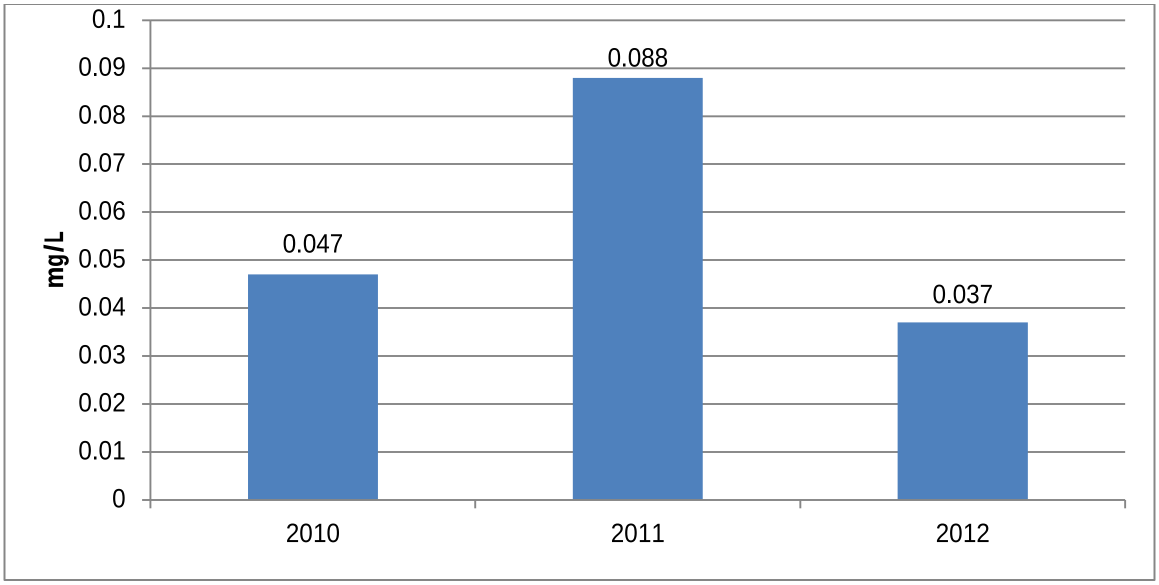


Figure 32. Nitrate + nitrite nitrogen flow weighted mean concentrations for the Pine River.

Stream water quality

Within the Pine River watershed, 25 of the 188 stream reaches had sufficient data to make an assessment for aquatic life and/or aquatic recreation Table 35. Of the assessed stream reaches, twenty fully supported aquatic life and four did not. All nine streams that were assessed for aquatic recreation were supporting.

Table 35. Assessment summary for stream water quality in the Pine River Watershed.

				Supporting		Non-supporting			
Watershed	**Area (acres)**	**# Total AUIDs**	**# Assessed AUIDs**	**# Aquatic Life**	**# Aquatic Recreation**	**# Aquatic Life**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
Pine River HUC 8	502,400	188	25	20	9	4	0	10	0
Little Pine	90739	29	5	5	1	0	0	0	0
Upper Pine	95488	41	3	3	2	0	0	0	0
Daggett Brook	95488	34	3	3	1	0	0	0	0
Lower Pine	30374	10	3	3	2	0	0	0	0
South Fork Pine	74074	40	6	4	1	2	0	0	0
Middle Pine	83981	30	4	1	2	2	0	10	0
Pelican Brook	30707	4	1	1	0	0	0	0	0

Lake water quality

One hundred and sixteen lakes greater than ten acres had some type of assessment data available, 78 of those were found to support aquatic recreation. Only three newly assessed lakes did not support aquatic recreation. Jail and Kego lakes were previously listed as having impaired aquatic recreation in 2012 and 2010, respectively. The recent data confirms the initial impairment decision so they will remain on the impairment list. Full support designations for aquatic life use on lakes were not possible due to the lack of biological data. Insufficient data was available for aquatic life or aquatic recreation use assessments on 56 lakes.

Table 36. Assessment summary for lake water chemistry in the Pine River Watershed.

			Supporting		Non-supporting			
Watershed	**Area (acres)**	**Lakes >10 Acres**	**# Aquatic Life**	**# Aquatic Recreation**	**# Aquatic Life**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
Pine River HUC 8	502,400	116	0	78	0	5	56	0
Little Pine	90739	15	0	7	0	2	15	0
Upper Pine	95488	33	0	20	0	1	19	0
Daggett Brook	95488	25	0	18	0	2	10	0
Lower Pine	30374	8	0	7	0	0	2	0
SouthFork Pine	74074	1	0	1	0	0	0	0
Middle Pine	83981	13	0	11	0	0	2	0
Pelican Brook	30707	21	0	14	0	0	8	0

Fish contaminant results

Fifteen fish species from the river and lakes were tested for contaminants. A total of 1,282 fish were tested between 1970 and 2013. Fish species are identified by codes that are defined by their common and scientific names in Table 37. Table 38 summarizes contaminant concentrations by waterway, fish species, and year. “No. Fish” indicates the total number of fish analyzed and “N” indicates the number of 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).

Fish from the Pine River were collected in 2013. The mean mercury concentration from five northern pike (NP) was above the 0.2 mg/kg water quality standard for mercury in fish tissue, as was the mercury concentration in one white sucker. Total PCB concentrations in two northern pike and the white sucker were below the reporting limit of 0.025 mg/kg.

All waters that are listed as impaired for mercury in fish are identified in Table 38 with a red asterisk (*); one asterisk indicates it is impaired and falls under the statewide mercury TMDL; two asterisks indicate the mercury levels were too high for inclusion in the statewide TMDL and they require a separate TMDL. Only six of the 27 lakes tested were not listed as impaired for mercury in fish tissue. Twelve of the lakes were impaired and covered under the statewide TMDL. The remaining nine lakes are impaired and require additional TMDLs. Pine River is not listed as impaired on the Impaired Waters List in 2014. That list was based on the fish collected in 2012. The results from Pine River’s northern pike in 2013 indicate the river will be listed as impaired in the next (2016) Impaired Waters List.

All the lakes requiring a TMDL had at least one fish species with the 90th percentile mercury concentration exceeding 0.57 mg/kg. From all tested fish in the Pine River watershed, the highest mercury concentration was 1.99 mg/kg in a northern pike from Stevens Lake, collected in 1996. A more recent fish collection in 2004 shows lower mercury levels in the northern pike but they remain high (mean mercury concentration was 0.72 mg/kg in 1996 and 0.55 mg/kg in 2004) . Most of the PCB concentrations in fish tissue from the lakes were below the reporting limit. The highest PCB concentration was 0.072 mg/kg in a cisco from Pelican Lake in 1993. Overall, the fish contaminant results shows PCBs have not been at levels of concern in the Pine River Watershed, whereas the mercury concentrations in fish tissue have are relatively high in the river and most of the tested lakes in the watershed. The Pine River will be added to the 2016 Impaired Waters List as a new impairment for mercury in fish tissue.

Table 37. Fish species codes, common names, and scientific names.

Species	Common Name	Scientific Name
BGS	Bluegill sunfish	*Lepomis macrochirus*
BKB	Black bullhead	*Ictalurus melus*
BKS	Black crappie	*Pomoxis nigromaculatis*
C	Common Carp	*Cyprinus carpio*
CIS (HER)	Cisco (Lake herring)	*Coregonus artedi*
LMB	Largemouth bass	*Micropterus salmoides*
LWH	Lake whitefish	*Coregonus clupeaformis*
ML	Muskellunge	*Esox masquinongy*
NP	Northern pike	*Esox Lucius*
RKB	Rock bass	*Ambloplites rupestris*
SF	Pumpkinseed sunfish	*Lepomis gibbosus*
SMB	Smallmouth bass	*Micropterus dolomieu*
SUF	Sunfish family	*Centrarchidae*
WE	Walleye	*Sander vitreus*
WSU	White sucker	*Catostomus commersoni*
YEB	Yellow bullhead	*Ictalurus natalis*
YP	Yellow perch	*Perca flavescens*

Table 38. Fish contaminants table.

Waterway	DOWID	Species	Year	Anatomy	No. Fish	Length (in)			Mercury (mg/kg)				PCBs (mg/kg)		
						Mean	Min	Max	N	Mean	Min	Max	N	Mean	Max
PINE RIVER	07010105	NP	2013	FILSK	5	14.8	12.7	18.1	5	0.273	0.228	0.360	2	<0.025	<0.025
		WSU	2013	FILSK	1	18.8			1	0.337			1	<0.025	
ADA*	11025000	BGS	1992	FILSK	10	6.6	6.6	6.6	1	0.044					
		CIS	1992	FILSK	2	14.8	14.8	14.8	1	0.034			1	0.021	
		NP	1992	FILSK	18	21.5	16.9	26.0	3	0.131	0.074	0.180	1	< 0.01	
			2004	FILSK	20	24.1	15.6	34.1	20	0.205	0.081	0.358			
			2012	FILSK	15	22.6	14.1	33.5	15	0.211	0.065	0.467			
		YP	2004	WHORG	2	7.4	7.4	7.4	1	0.053					
BIG PORTAGE*	11030800	BGS	2007	FILSK	10	7.4	7.4	7.4	1	0.052					
		LMB	2007	FILSK	4	11.5	9.8	13.1	4	0.128	0.096	0.157			
		NP	2007	FILSK	6	20.8	14.5	26.2	6	0.109	0.052	0.197			
		WE	2007	FILSK	6	21.2	18.8	25.4	6	0.291	0.232	0.425			
		YP	2007	FILSK	9	7.2	7.2	7.2	1	0.061					
BIG TROUT*	18031500	BGS	2011	FILSK	10	6.5	6.0	7.0	2	0.035	0.033	0.036			
		BKS	2011	FILSK	5	10.6	10.6	10.6	1	0.107					
		LMB	2011	FILSK	8	13.8	12.4	16.5	8	0.239	0.165	0.305			
		LWH	2011	FILSK	3	17.5	17.5	17.5	1	0.042					
		NP	2011	FILSK	8	23.8	19.5	28.6	8	0.329	0.246	0.433			
		WE	2011	FILSK	5	21.3	14.4	24.2	5	0.321	0.215	0.403			
CROSS LAKE RES. *	18031200	BGS	2005	FILSK	13	6.8	6.8	6.8	1	0.050					
			2011	FILSK	10	6.8	6.3	7.3	2	0.057	0.056	0.057			
		BKS	2005	FILSK	8	8.6	8.6	8.6	1	0.059					
		CIS	2005	FILSK	6	11.0	11.0	11.0	1	0.051					
			2011	FILSK	3	15.8	15.8	15.8	1	0.096					
		LMB	2005	FILSK	4	12.1	10.5	13.6	4	0.184	0.129	0.233			
			2011	FILSK	8	13.7	10.8	18.1	8	0.178	0.075	0.374			
		NP	2005	FILSK	5	23.9	20.6	26.4	5	0.312	0.196	0.430			
			2011	FILSK	6	21.0	17.5	27.2	6	0.278	0.152	0.449			
		WE	2005	FILSK	6	20.1	16.0	27.8	6	0.388	0.204	0.858			

Waterway	DOWID	Species	Year	Anatomy	No. Fish	Length (in)			Mercury (mg/kg)				PCBs (mg/kg)		
						Mean	Min	Max	N	Mean	Min	Max	N	Mean	Max
			2011	FILSK	8	18.7	12.5	27.5	8	0.266	0.138	0.475			
EMILY	18020300	BKS	2012	FILSK	8	8.3	7.8	8.8	2	0.059	0.054	0.064			
		NP	2012	FILSK	8	22.4	18.8	27.3	8	0.122	0.066	0.183			
		WE	2012	FILSK	3	20.2	15.7	22.5	3	0.370	0.316	0.438			
HORSESHOE	11035800	BGS	1992	FILSK	8	6.0	6.0	6.0	1	0.016					
		LMB	1992	FILSK	8	10.5	10.5	10.5	1	0.072					
		WE	1992	FILSK	17	16.8	12.4	20.5	3	0.098	0.055	0.130	1	< 0.01	
		WSU	1992	FILSK	15	19.6	18.4	20.7	2	0.069	0.037	0.100	1	< 0.01	
HORSESHOE*	18025100	BKS	2010	FILSK	5	8.4	8.4	8.4	1	0.045					
		LMB	2010	FILSK	8	14.0	11.6	15.5	8	0.354	0.179	0.586			
		NP	2010	FILSK	8	25.9	19.3	32.0	8	0.392	0.333	0.550			
		WE	2010	FILSK	4	21.5	17.8	24.1	4	0.796	0.202	1.087			
		YEB	2010	FILET	5	11.2	11.2	11.2	1	0.085					
KIMBALL**	18036100	BGS	2004	FILSK	10	6.5	6.5	6.5	1	0.099					
		CIS	2004	FILSK	6	11.3	11.3	11.3	1	0.081					
		NP	2004	FILSK	5	26.7	18.9	31.7	5	0.442	0.144	0.858			
		WE	2004	FILSK	5	20.9	13.5	27.3	5	0.431	0.170	0.907			
LAWRENCE**	11005300	BGS	2006	FILSK	8	7.1	7.1	7.1	1	0.124					
		BKS	2006	FILSK	5	7.5	7.5	7.5	1	0.087					
		NP	2006	FILSK	10	24.9	16.5	36.8	10	0.518	0.263	1.210			
		WE	2006	FILSK	12	19.8	16.0	24.7	12	0.645	0.217	1.346			
LITTLE EMILY	18020700	LMB	1981	WHORG	2	11.0	11.0	11.0	1	0.070					
		NP	1981	FILSK	6	20.6	20.6	20.6	1	0.100			1	< 0.025	
			1984	FILSK	5	22.3	22.3	22.3	1	0.090					
LITTLE PELICAN**	18035100	BGS	2010	FILSK	10	7.1	6.7	7.5	2	0.028	0.023	0.033			
		BKS	2010	FILSK	6	7.9	7.9	7.9	1	0.053					
		LMB	2010	FILSK	8	15.2	11.5	17.9	8	0.212	0.079	0.478			
		NP	2010	FILSK	9	25.4	15.8	35.8	9	0.362	0.096	0.929			
		YEB	2010	FILET	3	10.3	10.3	10.3	1	0.075					
LOWER HAY**	18037800	BGS	2011	FILSK	10	7.7	7.5	7.8	2	0.048	0.046	0.050			
		NP	2011	FILSK	8	22.3	19.5	29.5	8	0.207	0.118	0.290			

Waterway	**DOWID**	**Species**	**Year**	**Anatomy**	**No. Fish**	**Length (in)**			**Mercury (mg/kg)**				**PCBs (mg/kg)**		
						Mean	Min	Max	N	Mean	Min	Max	N	Mean	Max
		WE	2011	FILSK	8	22.9	19.5	26.2	8	0.318	0.198	0.746			
MOULTON**	01021200	BGS	2006	FILSK	5	7.5	7.5	7.5	1	0.218					
			2011	FILSK	10	7.2	6.8	7.6	2	0.176	0.141	0.210			
		BKS	2006	FILSK	6	9.6	9.6	9.6	1	0.347					
			2011	FILSK	10	9.1	8.5	9.7	2	0.238	0.190	0.286			
MOULTON (continued)		LMB	2007	FILSK	6	13.4	10.5	17.5	6	0.605	0.286	1.293			
		NP	1986	FILSK	4	20.6	20.6	20.6	1	0.800					
			2011	FILSK	8	22.8	18.5	31.2	8	0.539	0.323	0.997			
		WE	1986	FILSK	5	18.5	13.9	23.0	2	1.200	1.000	1.400			
			2006	FILSK	6	17.2	13.5	20.2	6	0.825	0.465	1.054			
			2011	FILSK	7	14.6	11.1	20.8	7	0.578	0.390	1.275			
		YEB	2011	FILET	5	11.4	11.4	11.4	1	0.338					
OSSAWINNAMAKEE**	18035200	LMB	2007	FILSK	5	13.5	12.8	14.2	5	0.286	0.120	0.717			
		NP	1985	FILSK	5	22.3	22.3	22.3	1	0.250					
		YP	1985	WHORG	10	4.2	4.2	4.2	1	0.040					
PAPOOSE	18020600	BKS	1985	FILSK	10	8.4	8.4	8.4	1	0.240					
		NP	1982	FILSK	5	23.2	23.2	23.2	1	0.590					
			1985	FILSK	5	22.2	22.2	22.2	1	0.770					
PAVELGRIT	11005500	YP	1981	WHORG	10	9.4	9.4	9.4	1	0.180					
PELICAN*	18030800	BGS	1993	FILSK	10	6.5	6.5	6.5	1	0.031					
		BKS	2007	FILSK	11	8.3	8.3	8.3	1	0.036					
		CIS	1993	FILSK	4	13.3	13.3	13.3	1	0.049			1	0.072	
		LMB	2007	FILSK	5	12.0	10.1	14.1	5	0.118	0.071	0.199			
		NP	1985	FILSK	13	21.5	18.6	24.8	3	0.120	0.060	0.200	1	< 0.05	
			1993	FILSK	23	23.0	18.5	27.3	3	0.143	0.100	0.200	1	0.020	
		SUF	2007	FILSK	12	6.8	6.8	6.8	1	0.042					
		WE	1985	FILSK	10	19.8	17.8	21.8	2	0.270	0.190	0.350	1	< 0.05	
			1993	FILSK	20	17.5	13.2	21.9	3	0.173	0.120	0.220	1	0.022	
PERRY	18018600	NP	1986	FILSK	12	21.8	17.6	25.6	3	0.187	0.140	0.220			
			2008	FILSK	5	21.3	18.9	23.0	5	0.109	0.081	0.152			
		WE	1986	FILSK	8	20.1	17.9	22.2	2	0.260	0.230	0.290			

Waterway	DOWID	Species	Year	Anatomy	No. Fish	Length (in)			Mercury (mg/kg)				PCBs (mg/kg)		
						Mean	Min	Max	N	Mean	Min	Max	N	Mean	Max
PINE MOUNTAIN*	11041100	BGS	1991	FILSK	6	6.3	6.3	6.3	1	0.033					
		BRB	1991	FILET	1	13.2			1	0.068					
		CIS	1991	FILSK	8	13.5	10.4	16.6	2	0.038	0.037	0.039	1	< 0.01	
		LMB	2011	FILSK	2	14.7	13.6	15.8	2	0.127	0.121	0.132			
		NP	1991	FILSK	14	21.9	17.3	26.6	3	0.127	0.081	0.160	1	< 0.01	
			2011	FILSK	3	20.2	14.6	26.4	3	0.149	0.063	0.309			
PINE MOUNTAIN* (continued)		SF	1991	FILSK	7	6.5	6.5	6.5	1	0.033					
		WE	1991	FILSK	18	19.5	12.3	25.0	4	0.263	0.100	0.430	1	< 0.01	
			2011	FILSK	6	17.3	15.3	19.3	6	0.134	0.110	0.177			
		WSU	1991	FILSK	12	16.6	11.9	20.2	3	0.043	< 0.02	0.078			
		YEB	1991	FILET	2	11.5	11.5	11.5	1	0.130					
ROOSEVELT**	11004300	BGS	2012	FILSK	8	7.0	6.6	7.4	2	0.060	0.059	0.061			
		BKS	2012	FILSK	5	9.0	9.0	9.0	1	0.077					
		LMB	2012	FILSK	4	12.8	11.6	14.0	4	0.179	0.153	0.190			
		NP	2012	FILSK	8	22.2	19.1	25.6	8	0.271	0.134	0.603			
		WE	2012	FILSK	7	21.3	14.9	29.9	7	0.330	0.152	0.591			
RUSH**	18031100	BGS	2011	FILSK	10	7.4	7.1	7.6	2	0.064	0.063	0.064			
		CIS	2011	FILSK	4	14.7	14.7	14.7	1	0.132					
		LWH	2011	FILSK	5	19.3	19.3	19.3	1	0.048					
		NP	2011	FILSK	8	24.5	21.8	30.5	8	0.374	0.184	0.757			
		WE	2011	FILSK	8	21.2	17.1	27.5	8	0.395	0.228	0.602			
RUTH*	18021200	BGS	1993	FILSK	10	7.4	7.4	7.4	1	0.120					
		BKS	2009	FILSK	10	8.8	8.2	9.4	2	0.075	0.062	0.087			
		LMB	2009	FILSK	4	12.6	11.2	14.6	4	0.245	0.215	0.303			
		NP	1993	FILSK	20	24.9	18.9	32.0	4	0.320	0.130	0.540	1	< 0.01	
			2009	FILSK	7	22.4	14.6	28.1	7	0.361	0.158	0.629			
		WE	1993	FILSK	5	19.8	17.4	22.1	2	0.290	0.260	0.320	1	0.015	
			2009	FILSK	7	18.1	14.5	21.0	7	0.313	0.251	0.397			
STEVENS**	11011600	BGS	1988	FILSK	14	6.4	6.1	6.6	3	0.150	0.140	0.160			
		LMB	1982	FILSK	4	13.3	13.3	13.3	1	0.490					
			1988	FILSK	3	15.5	13.6	17.8	3	0.487	0.260	0.780			

Waterway	**DOWID**	**Species**	**Year**	**Anatomy**	**No. Fish**	**Length (in)**			**Mercury (mg/kg)**				**PCBs (mg/kg)**		
						Mean	Min	Max	N	Mean	Min	Max	N	Mean	Max
		NP	1982	FILSK	6	22.6	17.8	27.3	3	0.467	0.310	0.580			
				WHORG	2	22.8	22.8	22.8							
			1988	FILSK	10	23.0	18.0	27.6	10	0.485	0.290	0.820			
			1996	FILSK	10	23.1	12.9	36.8	10	0.719	0.173	1.988			
			2004	FILSK	24	22.4	15.4	33.0	24	0.546	0.261	1.076			
		YP	2004	WHORG	4	5.8	5.8	5.8	1	0.146					
UPPER HAY*	18041200	BGS	2008	FILSK	10	8.9	8.9	8.9	1	0.040					
		LMB	2008	FILSK	5	13.2	10.5	17.8	5	0.156	0.088	0.317			
UPPER HAY (continued)		NP	2008	FILSK	5	22.5	16.8	26.7	5	0.117	0.043	0.214			
		WE	2008	FILSK	5	17.1	15.5	18.7	5	0.098	0.062	0.112			
		YEB	2008	FILET	6	12.4	12.4	12.4	1	0.089					
WASHBURN*	11005900	NP	1985	FILSK	13	23.0	17.0	30.2	3	0.397	0.220	0.560			
			1995	FILSK	5	21.0	21.0	21.0	1	0.300			1	< 0.01	
			1996	FILSK	8	17.7	9.8	28.1	8	0.188	0.065	0.313			
			2003	FILSK	24	19.4	16.0	24.5	24	0.263	0.126	0.461			
			2009	FILSK	12	19.5	16.4	22.1	12	0.225	0.132	0.320			
		WE	1985	FILSK	6	15.4	13.6	17.2	2	0.260	0.210	0.310	1	< 0.05	
			1995	FILSK	2	19.4	17.3	21.4	2	0.700	0.540	0.860			
			2003	FILSK	1	21.5			1	0.475					
		YP	2003	WHORG	10	8.0	6.2	10.4	3	0.080	0.068	0.087			
WEST FOX*	18029700	BGS	2008	FILSK	10	7.0	6.4	7.5	2	0.024	0.024	0.024			
		BKS	2008	FILSK	10	8.2	7.6	8.8	2	< 0.01	< 0.01	< 0.01			
		CIS	2008	FILSK	6	16.9	16.9	16.9	1	0.064					
		LMB	2008	FILSK	6	13.8	11.0	15.5	6	0.165	0.071	0.259			
		NP	2008	FILSK	7	18.4	14.3	20.8	7	0.141	0.095	0.198			
		WE	2008	FILSK	6	21.6	15.1	25.3	6	0.207	0.154	0.290			
WHITEFISH*	18031000	BGS	2005	FILSK	11	7.0	7.0	7.0	1	0.044					
		LMB	2005	FILSK	5	13.7	13.0	14.2	5	0.251	0.198	0.314			
			2006	FILSK	6	13.7	11.9	15.4	6	0.279	0.207	0.367			
		LWH	2005	FILSK	1	17.5			1	0.039					
		NP	1970	PLUG	1	20.4	20.4	20.4	1	0.300					

Waterway	**DOWID**	**Species**	**Year**	**Anatomy**	**No. Fish**	**Length (in)**			**Mercury (mg/kg)**				**PCBs (mg/kg)**		
						Mean	Min	Max	N	Mean	Min	Max	N	Mean	Max
WHITEFISH (continued)			1984	FILSK	5	21.7	21.7	21.7	1	0.330	0.330	0.330			
			1985	FILSK	9	22.3	17.5	26.6	3	0.377	0.240	0.470	1	< 0.05	
			2005	FILSK	6	21.9	20.0	26.2	6	0.255	0.224	0.289			
			2011	FILSK	14	21.4	18.4	25.8	14	0.288	0.193	0.381			
		SMB	2006	FILSK	1	16.1			1	0.202					
		WE	1984	FILSK	5	19.2	19.2	19.2	1	0.340					
			1985	FILSK	8	16.7	13.1	21.6	3	0.337	0.230	0.520	1	< 0.05	
			2005	FILSK	5	23.2	20.4	26.2	5	0.524	0.402	0.684			
		WSU	1970	PLUG	1	16.4			1	0.020					
			1984	FILSK	4	17.8	17.8	17.8	1	0.100					
		WSU	2005	FILSK	5	17.3	17.3	17.3	1	0.054					

* **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.**

****Impaired for mercury and categorized as EPA Class 5 and requires a separate TMDL from the Statewide TMDL**

1 Species codes are defined in Table FC1

2 Anatomy codes: FILSK – edible fillet, skin-on; FILET—edible fillet, skin-off; PLUG—dorsal muscle piece, without skin; WHORG—whole organism

Groundwater monitoring

Groundwater quality

The Pine River Watershed is located in central Minnesota with five types of aquifers: Paleozoic, Precambrian, Cretaceous, buried sand and gravel, and surficial sand and gravel aquifers. A baseline study conducted by the MPCA found that the groundwater quality in most of these aquifers in this region is considered very good when compared to other areas with similar aquifers (MPCA, 1998).

The results of this study identified few exceedances of drinking water criteria with nitrate being the greatest concern for this region (MPCA, 1998). The exceedances identified that concentrations occurred primarily in the surficial sand and gravel aquifers due to anthropogenic influences, while the other aquifers tend to be well protected and less likely to be contaminated. Any exceedances in the protected aquifers are mostly likely due to naturally occurring chemicals, such as boron, manganese, iron and arsenic. The primary volatile organic compounds (VOCs) that were identified were chemicals associated with well disinfection (chloroform), gasoline and fuel oils (toluene); however all VOC concentrations were below drinking water criteria.

There are currently seven MPCA Ambient Groundwater Monitoring wells in the Pine River Watershed. Figure 33 displays the locations of the wells within the Pine River Watershed. Green symbols represent ambient groundwater wells while blue symbols represent ambient groundwater wells sampled during the 2014 field season. The results from the more recent sampling events do not greatly differ from the results of the baseline study.

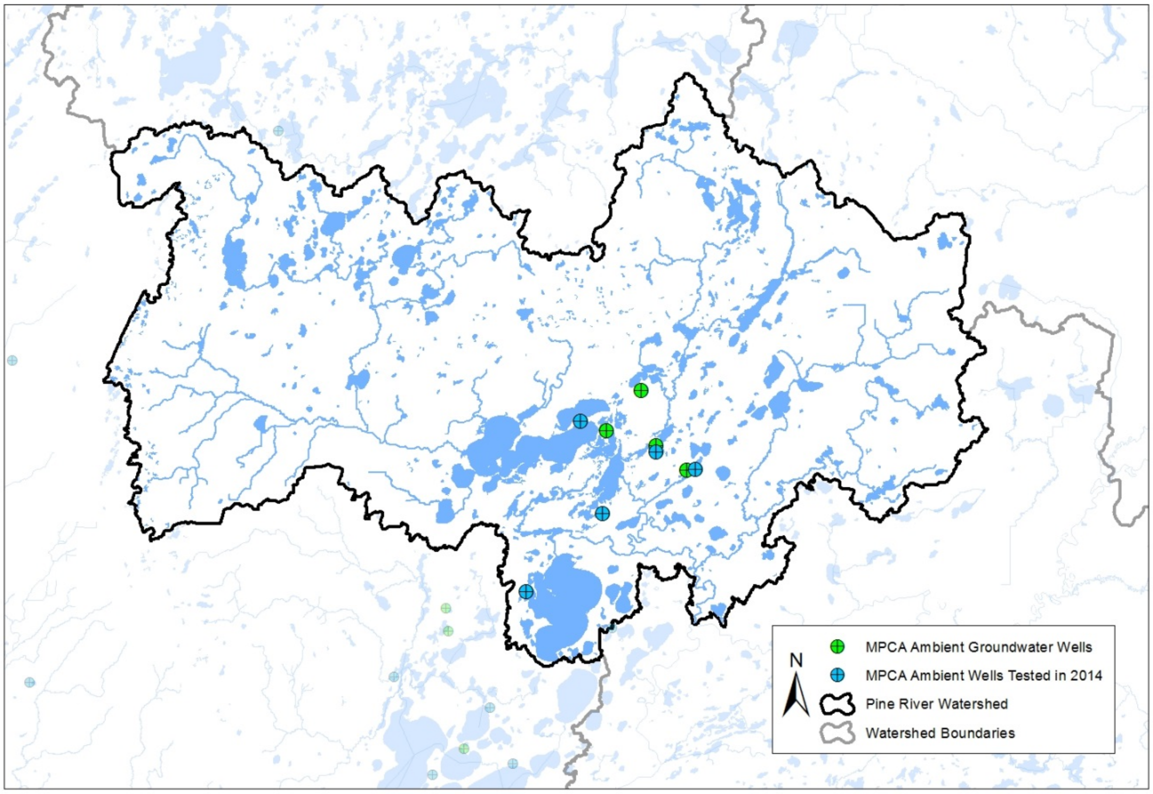


Figure 33. MPCA ambient groundwater monitoring well locations within the Pine River Watershed.

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 Pine River Watershed) is particularly vulnerable with respect to agricultural chemical movement due to the hydrogeologic conditions: shallow groundwater beneath coarse, sandy-textured soils.

In 2013, pesticides were detected in the Central Sands region but not at levels exceeding drinking water criteria (MDA, 2014). Nitrate, however, was present in 98% of the wells sampled and at a median concentration of 16.00 milligrams per liter (mg/L). Of those samples, 13% were at or below background level of 3 mg/L, 17%t were within 3.01 and 10.00 mg/L, and 68% were above drinking water standard of 10.00 mg/L (MDA, 2014). Though nitrate is not uncommon in agricultural areas, the median concentration is above the Health Risk Limit of 10 mg/L.

Additionally, a recent MPCA report on the statewide condition of Minnesota's groundwater found that the central Minnesota region has the highest median nitrate concentrations in the state, with approximately 40% of the shallow sand and gravel aquifer wells exceeding the maximum contaminant level of 10 mg/L (Kroening & Ferrey, 2013). High nitrate concentrations are typically associated with agricultural and urban land use overlying shallow aquifers, due to the sensitivity of the aquifer to human influence. Although there is concern for high nitrate concentrations, the concentrations have not significantly changed in the last 15 years (Kroening & Ferry, 2013) and the MDA's data implies that the concentrations are limited to the uppermost portions of the aquifers (Kroening & Ferry, 2013).

Another source of information on groundwater quality comes from the MDH. Mandatory testing for arsenic of all newly constructed wells has found that 10.4% of all wells installed from 2008 to 2013 have arsenic levels above the maximum contaminant level for drinking water of 10 micrograms per liter (MDH). In west central Minnesota, the there is a higher concern for arsenic contamination considering approximately 50% of 869 domestic wells sampled identified arsenic concentrations that exceeded the drinking standards (MDH, 2001; Kroening & Ferry, 2013) (Figure 34).

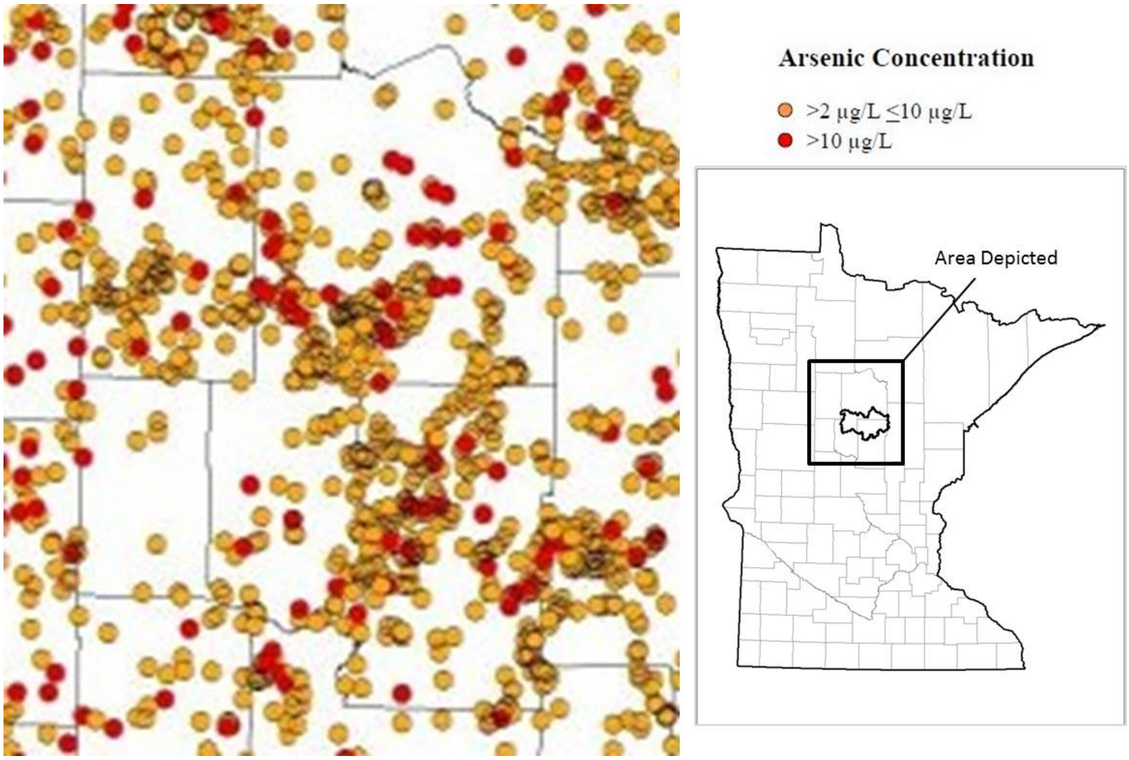


Figure 34. Arsenic occurrence in new wells in central Minnesota (2008-2012) (Source: MDH, 2012)

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.

There are currently no MDNR Observation Wells in the Pine River Watershed at this time.

Stream flow

The MDNR and MPCA cooperatively maintain a gaging station on the Pine River near Mission, Minnesota (site # 11051001). Data from 2008 through 2013 are available and are shown below in Figure 35.

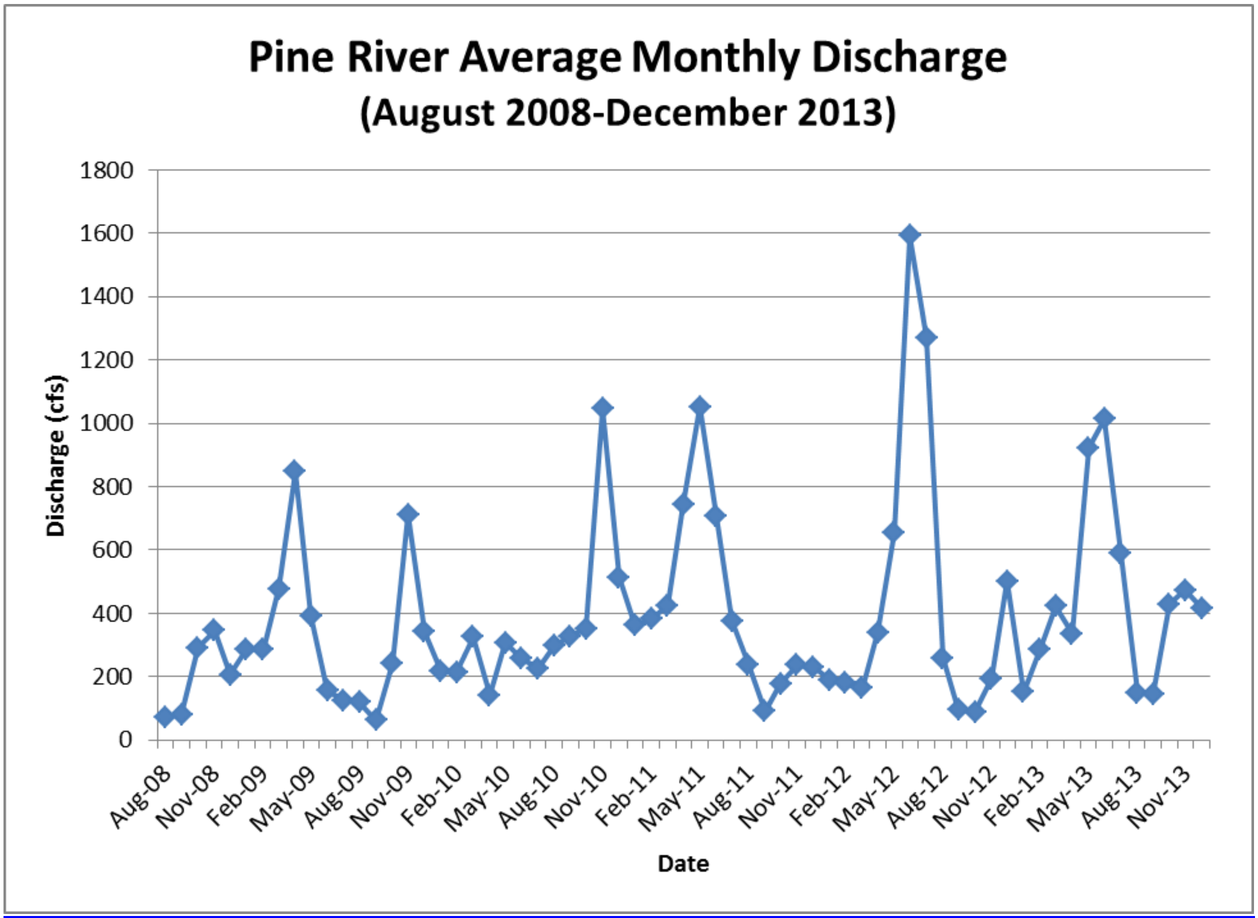


Figure 35. Mean monthly discharge measurements for July and August flows (1990-2010).

Wetland condition

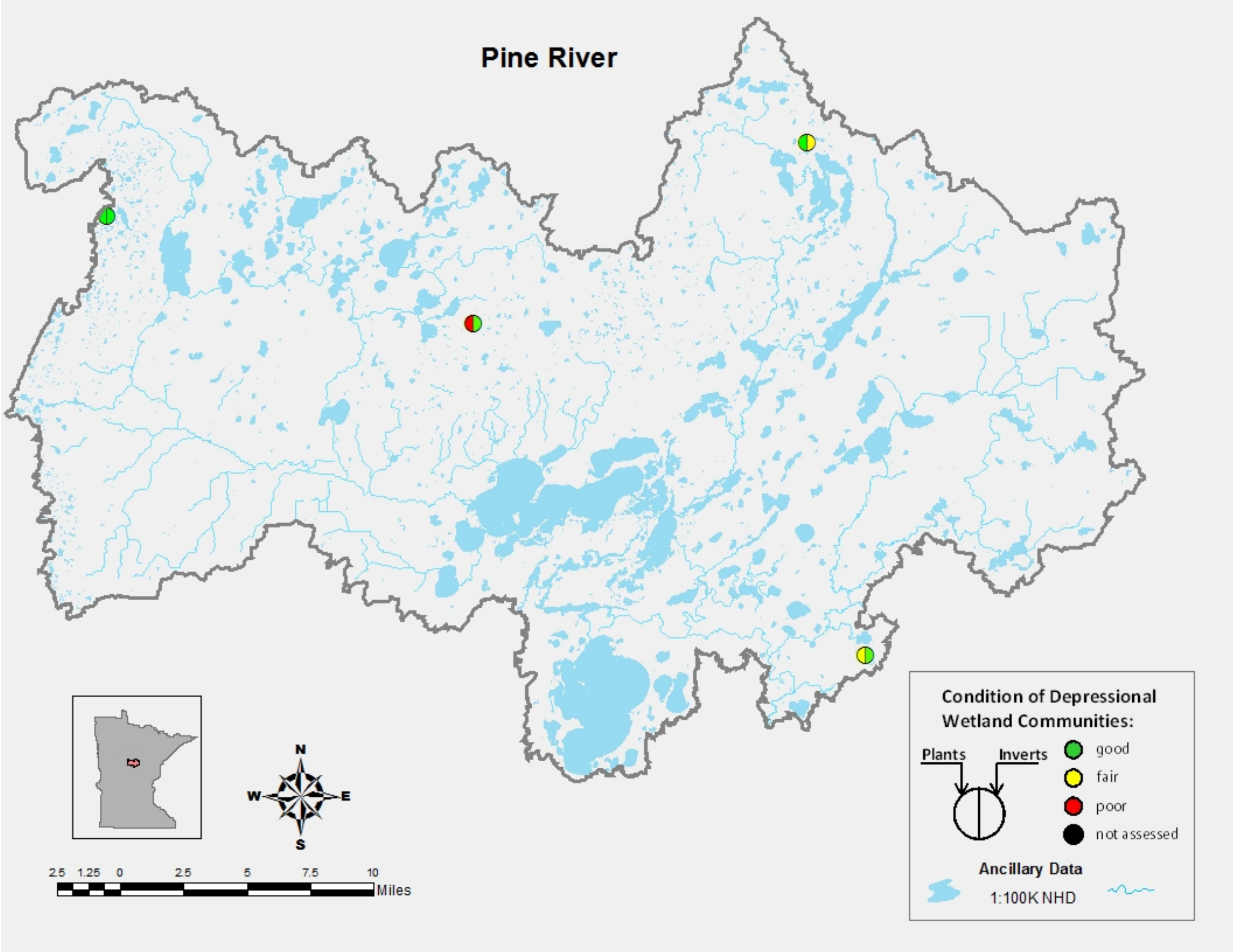


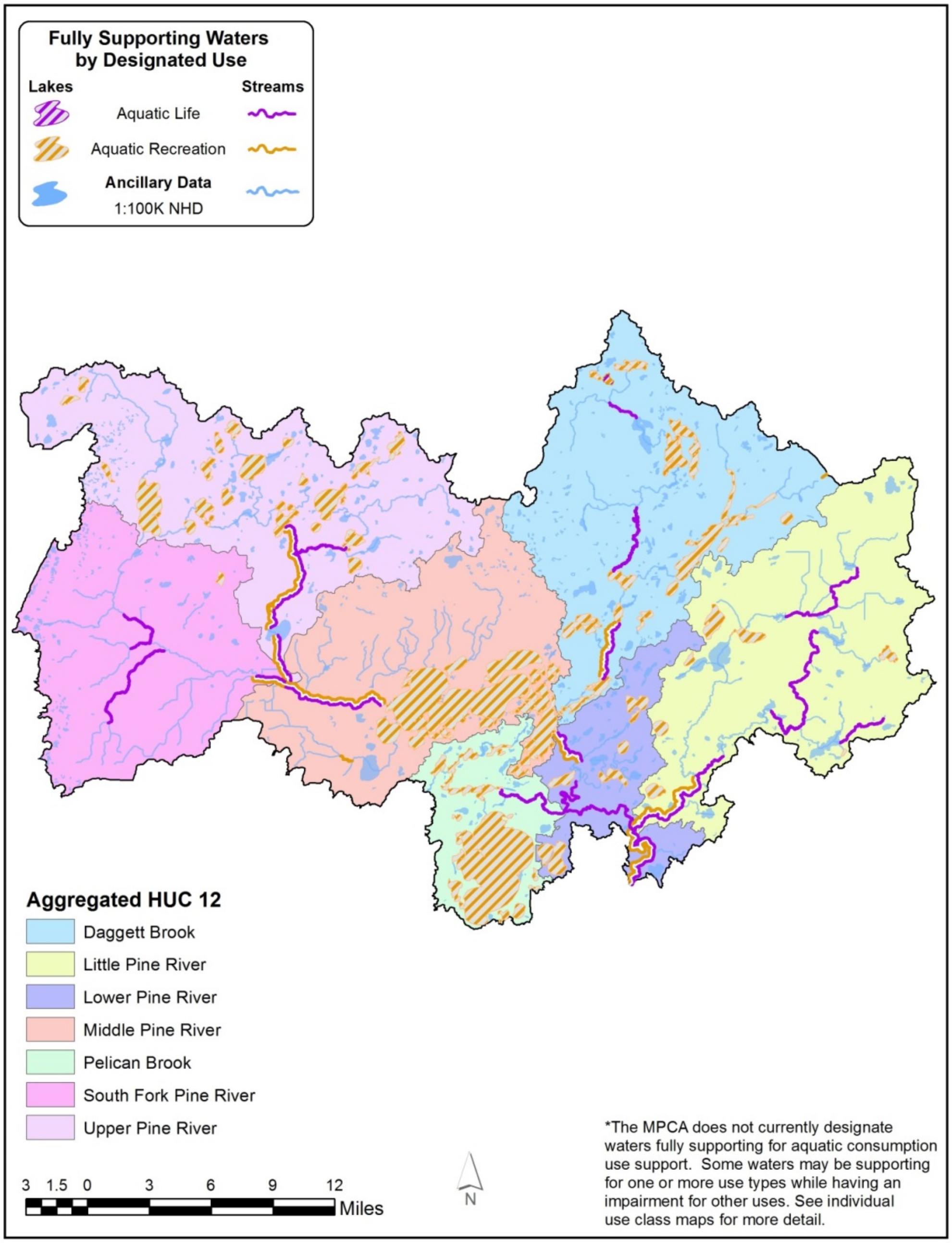
Figure 36. Depressional wetland IBI results (invertebrate and plant community indices) for four MPCA wetland biological study sites located in the Pine River Watershed.

Index of biotic integrity (IBI) based on plants and macroinvertebrates were used to determine the health of wetlands in this watershed. Both the invertebrate and plant IBIs are scored on a 0 to 100 scale with higher scores indicating better condition. These indicators were also used in a statewide survey of wetland condition stratified by Minnesota's three Level II ecoregions (Genet 2012, Genet 2015). The Pine River Watershed occurs entirely within the Mixed Wood Shield Ecoregion. Genet (2012) reported depressional wetland condition in the Mixed Wood Shield Ecoregion to be mostly in good condition. Based on the invertebrate indicator results in this ecoregion, Genet reported that 60% of the wetlands are in good condition, 29% were in fair condition and the remaining 11% of depressional wetlands were found to be in poor condition. Plant results were similar, where 54% of the wetlands were estimated to be in good condition, 29% were in fair condition and 17% were in poor condition.

IBI information was collected by the MPCA at four depressional wetlands in the Pine River Watershed. These sites were well distributed across the Pine River Watershed (Figure 36). One of these study sites (04Crow004) was sampled in 2004 as an initial IBI development data set for the Mixed Wood Shield Ecoregion. The other three wetland sites were sampled as part of the baseline statewide depressional wetland survey (Genet 2012).

Invertebrate community IBI scores at these four sites ranged from 65 to 94 (0 to 100 scale with 100 being high integrity). Three of these scores indicated good conditions and one site was in fair condition.

The difference between Good and Fair was set at the 25th percentile of IBI scores within a set of Ecoregion least disturbed reference sites (Genet 2012). The plant results from these four wetlands were slightly more variable and ranged from 37 to 82. One of the sites (09Crow138) was considered to be in poor condition, one was in fair condition and the remaining two sites were in good condition. Figure 37 illustrates the corresponding biological condition for these four wetlands based on invertebrate and plant IBIs. The Poor condition at 09Crow138 was in large part due to the significant plant cover of hybrid cattail (Typha X glauca) at this site. No watershed pattern is evident in this small set of wetland condition study sites however they do appear to parallel the statistical condition estimates of depressional wetlands in the Mixed Wood Shield Level II Ecoregion (Genet 2012).



*The MPCA does not currently designate waters fully supporting for aquatic consumption use support. Some waters may be supporting for one or more use types while having an impairment for other uses. See individual use class maps for more detail.

Figure 37. Fully supporting waters by designated use in the Pine River Watershed.

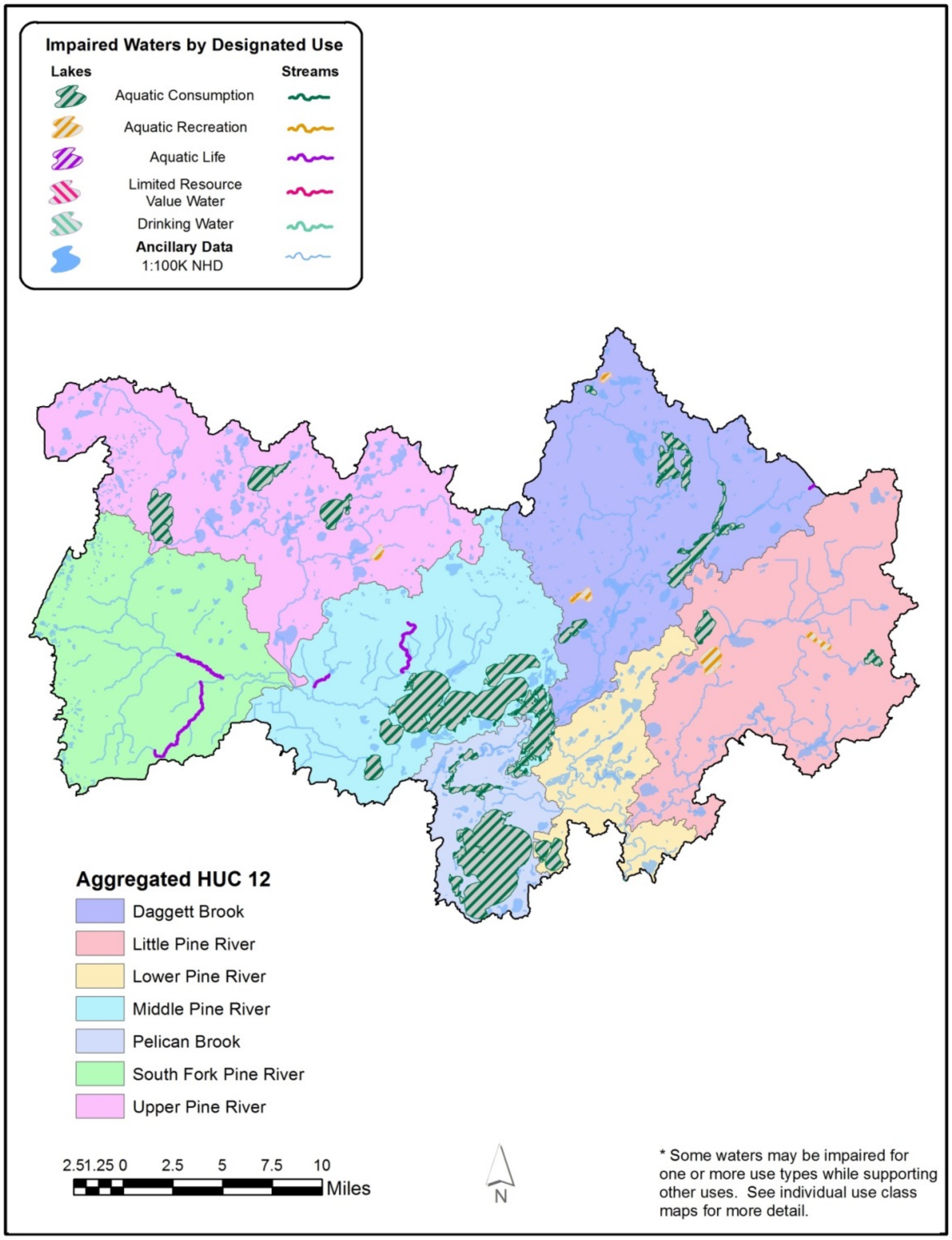
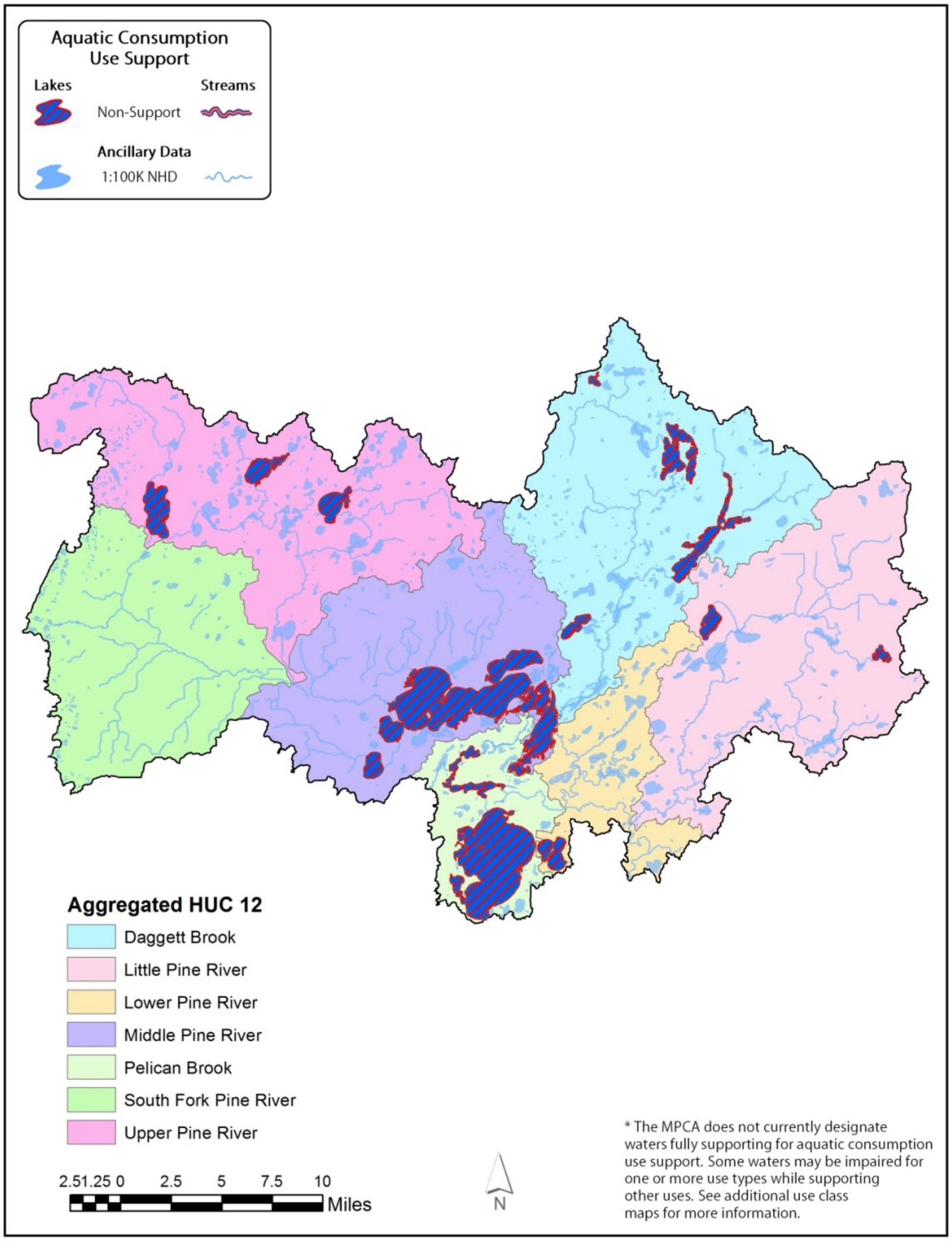


Figure 38. Impaired waters by designated use in the Pine River Watershed.



* The MPCA does not currently designate waters fully supporting for aquatic consumption use support. Some waters may be impaired for one or more use types while supporting other uses. See additional use class maps for more information.

Figure 39. Aquatic consumption use support in the Pine River Watershed.

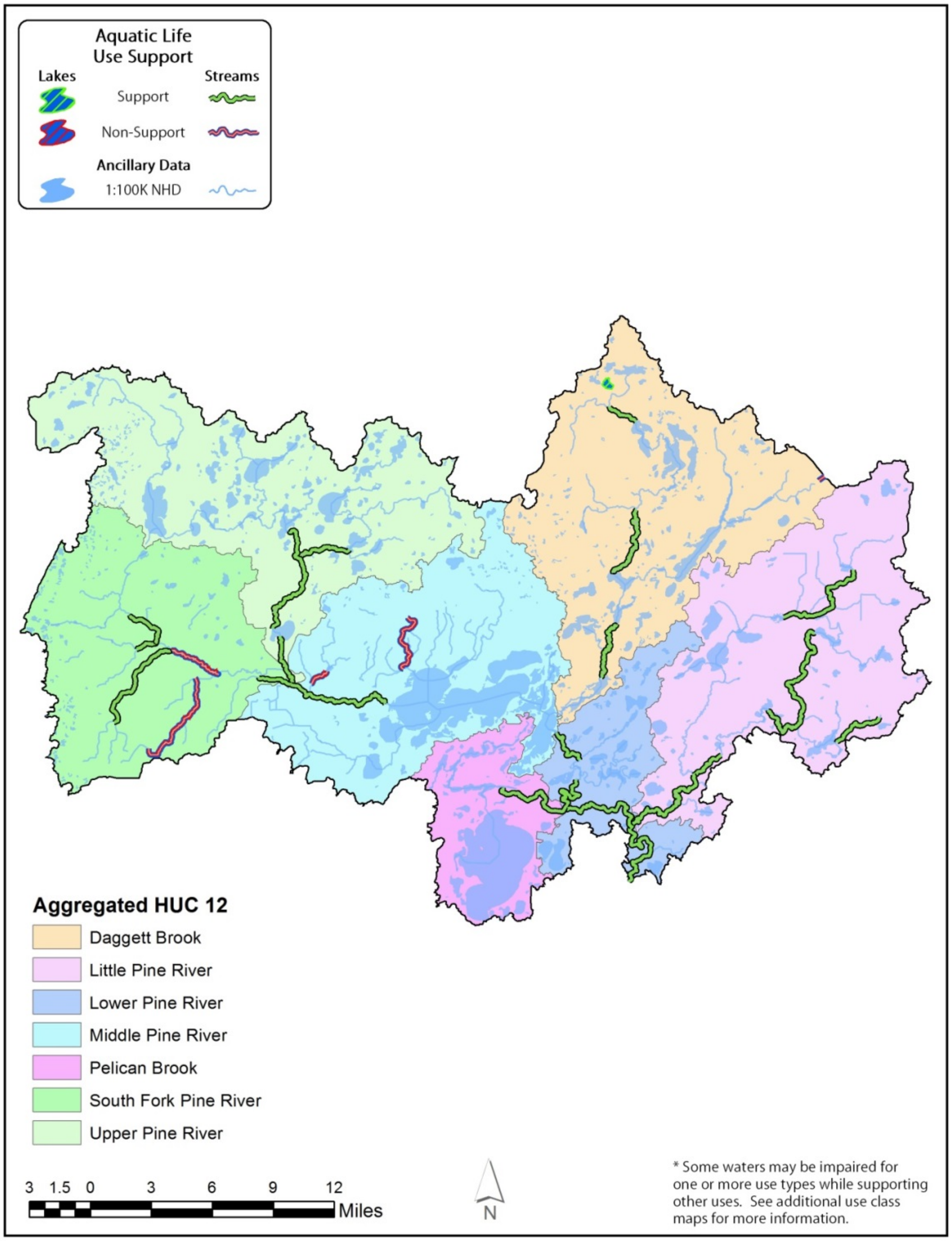


Figure 40. Aquatic life use support in the Pine River Watershed.

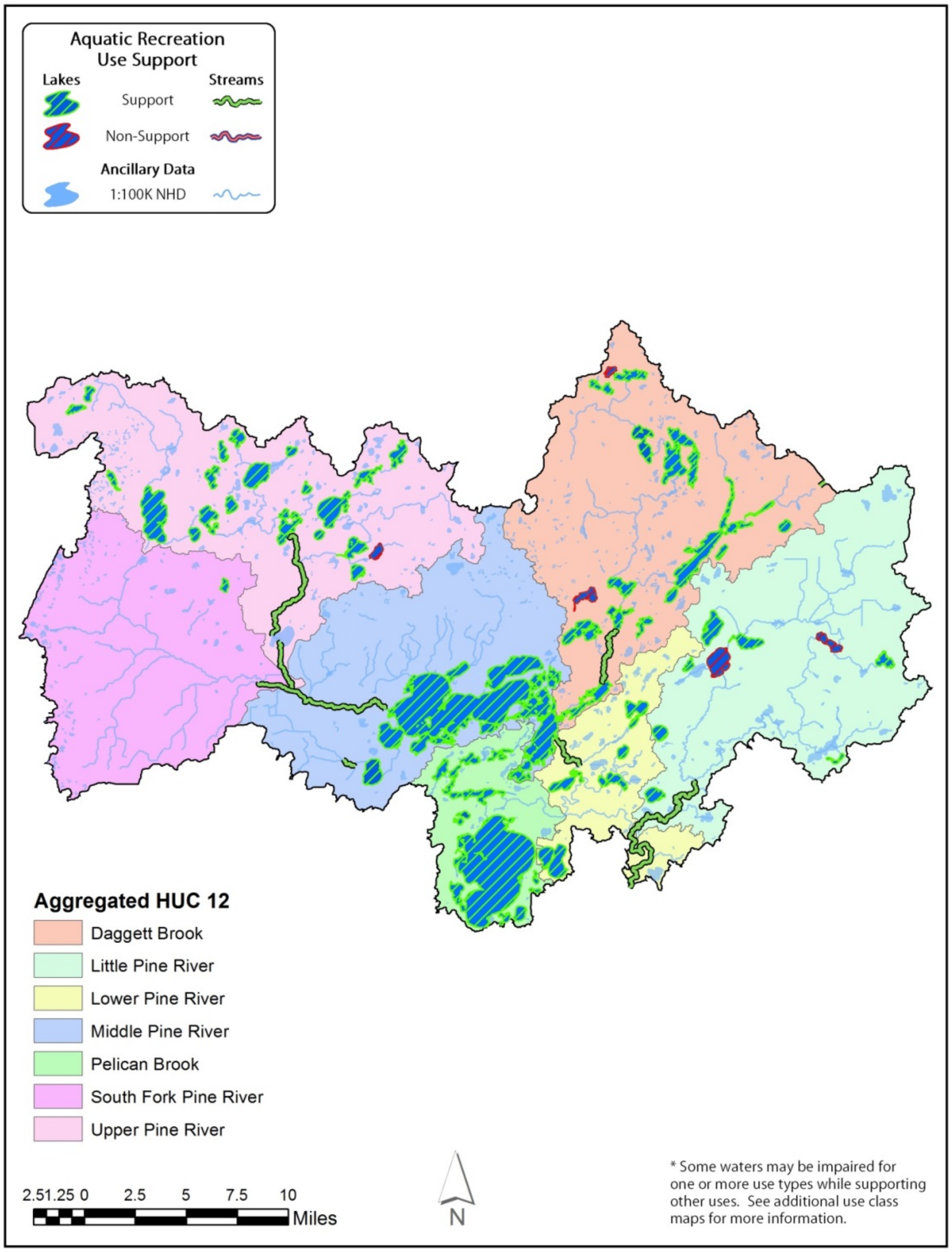


Figure 41. Aquatic recreation use support in the Pine River Watershed.

Water clarity trends at citizen monitoring sites

Citizen volunteer monitoring occurs at 23 stream and 72 lake stations throughout the Pine River Watershed. At this time, only one stream has sufficient data to calculate a long term trend, indicating no significant trend over the dataset. Fifteen lakes show an increasing trend in water clarity while10 appear to be declining in water clarity. Maintaining citizen data collection at these locations is vital to strengthen long term datasets. Local advocacy is necessary for recruiting new volunteer monitors within the watershed. Citizen monitoring data can be used to fill in data gaps between intensive watershed monitoring years and other local ongoing projects.

Table 39. Water clarity trends at citizen stream monitoring sites.

Pine River Watershed HUC 07010105	Citizen Stream Monitoring Program	Citizen Lake Monitoring Program
number of sites w/ increasing trend	0	15
number of sites w/ decreasing trend	0	10
number of sites w/ no trend	1	54

Remote sensing transparency data

Remote sensing data was used to describe lake transparency in areas where water chemistry data has not been collected or where access was difficult. With remote sensing data, comparisons can be made at the state and watershed scale. Remote sensing provides insight into water quality by estimating transparency values for lakes void of TP, Chl-a, or Secchi data. Satellite imagery is used with Secchi transparency measurements to form a relationship that allows for predictions of transparency values across the state. This provides a snap shot of lake transparency during the time of satellite pass over.

Currently, remote sensing data has been analyzed on approximately a five year basis from 1975 to 2008, with seven years of remote sensing data available. At this frequency the data allows for a simple average lake transparency value to be calculated at the state or watershed scale. Comparisons of lake transparencies may also be made between individual lakes during any single year. This data does not allow for trends analysis due to the small number of remote sensing data points available at this time.

Remote sensing data was used to describe lake transparencies on 147 lakes without water chemistry data in the Pine River Watershed (Figure 42). Of those, 122 had estimated transparencies greater than the Northern Lakes and Forest Ecoregion Eutrophication Standard of 2.0 m. Twenty- five lakes had estimates of transparencies that fell below the 2.0 m eutrophication standard; these lakes may warrant further investigation into water quality conditions. Other variables must be taken into account as well, such as lake depth and color (tannin stained), which may impact the remote sensing transparency data. Overall, transparencies look to be in good to excellent condition for the majority of lakes without water chemistry data. Lakes with excellent remote sensing lake transparency data may be considered candidates for protection strategies given their exceptional condition.

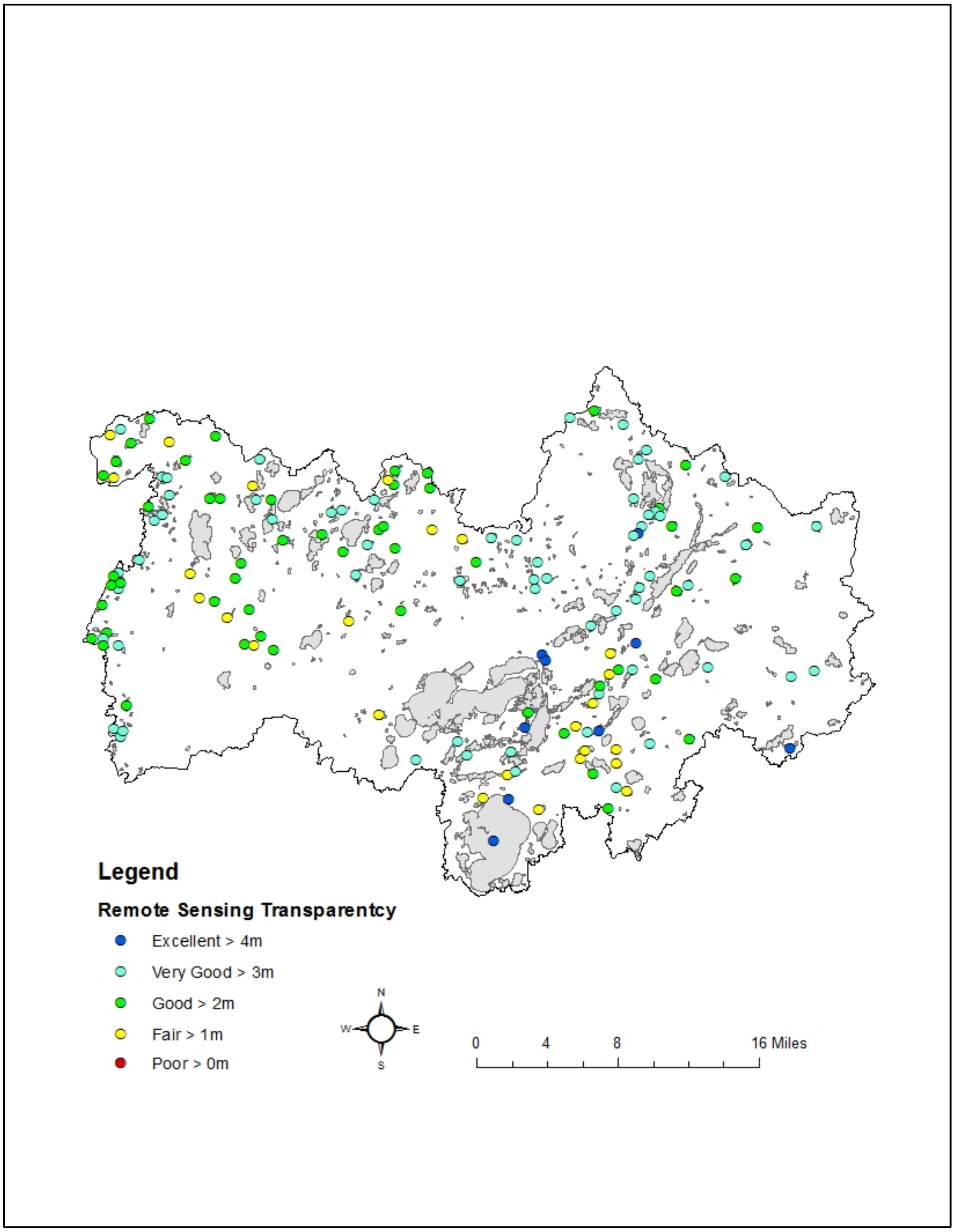


Figure 42. Remote sensing transparency data on lakes without observed water chemistry data within the Pine River Watershed.

Summaries and recommendations

Seventy-five species of fish have been documented in the Upper Mississippi River Basin. MPCA biological monitoring crews captured 50 species of fish during the IWM stream sampling in the Pine River Watershed. Two species of special concern, the least darter and pugnose shiner, were found at monitoring sites located on the lower reaches of the Pine River. Both species have similar habitat requirements: lakes and low velocity streams that have clear water and abundant vegetation (Becker 1983). Both the least darter and pugnose shiner are quite intolerant of turbidity, eutrophication, and vegetation removal (Becker). The prevalence of good water quality and low level of disturbance within the Pine River Watershed enables both species to persist in north central Minnesota. The same monitoring stations that featured the least darter and pugnose shiner also had the most diverse fish communities. Twenty six species of fish were collected at station 12UM149 and 27 species were collected downstream at station 12UM114. Walleye and smallmouth bass, which typically favor larger rivers, were only sampled from the Pine River at station 12UM149. The majority of the fish samples collected within the Pine River Watershed contained 15 – 20 species. Common shiners and central mudminnows were the two most commonly sampled species within the watershed. Both species were found at almost every monitoring site; however, considerably higher numbers of common shiners were collected. The common shiner is abundant throughout the Midwest. Common shiners use a wide range of habitats; however, they are most often found in small to medium sized clear water streams with sand and gravel substrate. The Pine River itself, as well as many other streams within the watershed, contains such habitat. Central mudminnows are also found throughout the Midwest. The central mudminnow prefers stagnant or slow flowing, vegetated waters commonly associated with wetlands and low gradient streams. Wetland habitat is very common along the margins of lakes and streams throughout the Pine River Watershed. Other commonly sampled species within the Pine River Watershed included yellow perch, northern pike, white sucker, johnny darters, largemouth bass, and bluegill. All of these species are commonly found in clear water lakes and streams throughout the Midwest.

Over half of all the samples collected from streams within the northern streams IBI class contained 40% or greater insectivorous taxa. Species such as the hornyhead chub, as well as most redhorse and darter species, are insectivores. Insectivores feed exclusively upon invertebrates and rely on the existence of a stable invertebrate population. Any disturbances within a watershed that cause a reduction in invertebrate abundance will also cause a reduction in insectivorous fish species. The persistence of a stable macroinvertebrate community at many locations within the Pine River Watershed indicates good water quality and low disturbance. Intolerant species were also present at many of the same locations where higher numbers of insectivores were collected. Intolerant species are very sensitive to degradation and their abundance will quickly decline following disturbance. The most common intolerant species collected in the Pine River Watershed was the longnose dace. Other intolerant species collected included the least darter, greater redhorse, pugnose shiner, and burbot.

A total of 285 unique macroinvertebrate genera were collected over the course of 38 sampling visits to the Pine River Watershed. Thirty five of these genera are considered intolerant and appeared at 53% of the sample visits. *Oxyethira,* a caddis, was the most frequently occurring sensitive taxa. The most numerous taxa were *Simulium, Hyalella, Polypedilum, Rheotanytarsus, Tanytarsus, Hydrobiidae, Iswaeon, Hydropsychidae, and Cheumatopsyche.* Many of these taxa represent moderate tolerance to disturbance and are ubiquitous across much of Minnesota. Much of the Pine River Watershed is lower gradient with only about 13% of streams having been hydrologically altered. The majority of the sites in this watershed have healthy macroinvertebrate communities present, due in large part to the relative lack of disturbance and corresponding habitat heterogeneity. Eighty-four percent of the sampling sites in the Pine River Watershed had course substrates present, wood or rocks, which are preferred habitats of many sensitive macroinvertebrate taxa. The overall macroinvertebrate community composition in the Pine River Watershed is strong as indicated by the prevalence of intolerant organisms, sensitivity of the most numerically dominate taxa, and the prevalence of coarse substrates available for macroinvertebrate colonization.

The majority of the streams within the Pine River Watershed featured biological communities that were in good condition. The prevalence of good stream habitat, as indicated by the MSHA scores, throughout the watershed greatly contributes to the health of these communities. Most stations located on the Pine River and Little Pine River had good MSHA scores. Many stations located on headwater streams, such as Brittan Creek and Bungo Creek, also scored well. The top ten highest quality stream resources within the Pine River Watershed are listed below in Table 40. The availability of coarse substrate at many of these locations provides the necessary habitat for invertebrates, lithophilic spawning fish species, and insectivorous fish. Vegetative cover, also present at many stations, is an essential habitat for many species of fish. Stable stream channel conditions throughout the watershed help to create and preserve stream habitat. The majority of the stations within the Pine River Watershed received a “fairly stable” channel stability rating. Stable channels and banks reduce the amount of sediment input into streams. Some natural stream bank erosion almost always occurs; however, destabilized banks resulting from human activities can release large amounts of sediment into the stream. Excess sediment deposition on the stream bed can completely cover coarse substrate, eliminating benthic invertebrate communities. The loss of coarse substrate may also contribute to a reduction in lithophilic spawning and insectivorous fish species.

Overall, land use within the Pine River Watershed is primarily forest and disturbance is minimal. The low number of biological impairments throughout the watershed is indicative of the relatively undisturbed surrounding land use. However, there are four stations that have impaired aquatic life. The poor condition of the biological communities at these stations may be attributed to poor land use practices that contribute to excess sediment within the stream bed. Disturbances that often lead to excess sedimentation through stream bank destabilization and/or overland runoff include row crop cultivation, livestock grazing, logging, and urban development. The aquatic life impairments within the watershed demonstrate the impact of surrounding land use on aquatic life. The impairments also demonstrate the need for land use strategies that minimize sediment inputs to streams. As development within the Pine River Watershed increases, careful consideration must be given to how land use changes may impact water quality. Given the excellent water quality and diverse biological communities, it is imperative to protect the Pine River Watershed from disturbances that result in degradation.

The water quality results also reflect the relatively undisturbed land patterns within the watershed. The low levels of bacteria throughout the watershed can largely be attributed to the lack of livestock (e.g., feedlots and pastures) within the riparian areas. Exceedances of the DO standard were quite common but they were attributed to heavy precipitation and subsequent high water levels during the IWM year of 2012 and, to a lesser extent 2013. The high water levels resulted in the flushing of riparian wetland and forests causing DO to plunge for a week or more in some cases. Overall, normal base flow water chemistry conditions indicated the watershed is in good overall health in terms of water quality.

Only three new lakes did not support aquatic recreation. Two lakes that were previously identified as impaired will remain on the list based on the review of recent data. Extensive natural background reviews were conducted on Lows and Mitten Lakes, two of the three newly listed lakes. Lows Lake was found to be impaired due to natural background conditions. Modeling strongly suggests that natural processes, such as internal loading, are causing the elevated nutrient levels in Lows Lake. Compared to Lows Lake, Mitten Lake has a smaller watershed with less disturbance potential (even when considering homes and septic systems on the lakeshore). Mitten Lake appeared to be the most likely candidate for listing as impaired due to natural background conditions; however, modeling results indicate anthropogenic inputs could be causing elevated nutrient levels. The results of the modeling, along with other supporting information, supported listing Mitten Lake as impaired.

The lakes in this watershed are unique considering that they have some of the best water quality in Minnesota coinciding with high shoreline development densities. The Whitefish Chain and Pelican Lake are where these two contrasting factors are exemplified the most. These two heavily developed lakes have very good water quality that does not appear to be degrading. Nevertheless, being proactive by following the protection measures currently in place and continued work on future protection plans will be crucial to maintain good water quality. Some of these lakes are large oligotrophic basins that can be very sensitive to increased nutrient enrichment. Shoreline development often plays a large role in water quality because it involves large scale manipulation of the riparian, bank, and near shore areas. These areas are typically modified from their natural state to improve recreational use of the shoreline area. Using a native vegetative buffer instead of manicuring riparian shoreline to the water's edge is beneficial for filtration of surface water runoff prior to reaching the lake. Fertilizing shoreline areas directly adjacent to the lake should be avoided under any circumstances. Bank alterations can potentially increase erosion from wave action and runoff. Near shore habitat is another vital component to shoreline management. Young of the year fish and other forage species use this habitat for shelter, as well as the small organisms that they prey upon for food. Many lakes in this watershed demonstrate that maintaining a healthy balance of these factors between providing recreational opportunities and preservation of water quality is an achievable goal that is worth striving for.

Table 40. Top 10 stream resources in the Pine River Watershed, as indicated by biological (FIBI and MIBI) and physical (MSHA) parameters.

Rank	Stream Name	Biological Station ID	Location of Biological Station	FIBI	MIBI	MSHA
1	Pelican Brook	12UM141	Upstream of CSAH 3, 2.5 mi. S of Cross Lake	76	70	60
2	Pine River	12UM125	Upstream of CSAH 15, 5 mi. SE of Pine River	64	70	79
3	Pine River	12UM119	Downstream of Division St W, 5.5 mi. N of Pine River	64	58	79
4	Little Pine River	00UM017	Upstream of C.R. 36, 7 mi. S of Emily	68	47	74
5	Brittan Creek	12UM140	Upstream of CSAH 25, 6 mi. W of Pine River	79	53	57
6	Little Pine River	12UM117	Downstream of Olander Rd, 7 mi. SE of Cross Lake	58	46	78
7	Bungo Creek	12UM132	Downstream of CSAH 2, 5.5 mi. W of Pine River	60	81	63
8	Lizzie Creek	12UM135	Upstream of Hwy 84, 5.5 mi. NE of Pine River	65	68	57
9	South Fork Pine River	12UM120	Upstream of CSAH 25, 6 mi. NE of Pine River	69	71	45
10	South Fork Pine River	12UM116	Downstream of CSAH 1, 1 mi. S of Pine River	65	50	57

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Appendix 1 – Water chemistry definitions

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

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

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

Orthophosphate (OP) – Orthophosphate is a water soluble form of phosphorus that is readily available to algae (bioavailable). While OPs 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 Pine River Watershed

Biological Station ID	STORET/ EQuIS ID	Waterbody Name	Location	12-digit HUC
12UM117	S006-294	Little Pine River	At Orlander Road, 10 miles southwest of Crosslake, MN	Little Pine River
12UM115	S006-231	Pine River	On Paul Bunyan Trail at Front Street, 0.5 miles Southeast of Pine River, MN	Upper Pine River
12UM118	S006-229	Daggett Brook	At CSAH 1, 1.5 miles East of Fifty Lakes, MN	Daggett Brook
12UM114	S000-181	Pine River	at CSAH 11, North of Crosby	Lower Pine River
12UM116	S007-101	Pine River, South Fork	Upstream of CSAH 1, 1 mile South of Pine River, MN	South Fork Pine River

Appendix 3.1 – AUID table of stream assessment results (by parameter and beneficial use)

AUID DESCRIPTIONS				USES							WATER QUALITY STANDARDS Aquatic Life Indicators:								Aquatic Rec. Indicators:	
Assessment Unit ID (AUID)	**Stream Reach Name**	**Reach Description**	**Reach Length (Miles)**	**Use Class**	**Aquatic Life**	**Aquatic Recreation**	**Aquatic Consumption**	**Drinking Water**	**303d listed impairments 2014**		**Fish**	**Macroinvertebrates**	**Dissolved Oxygen**	**Turbidity**	**Chloride**	**pH**	**NH3**	**Pesticides**	**Bacteria**	**Nutrients**
HUC 12: 0701010501-01 (Upper Pine River)																				
07010105-669	Pine River	Hattie Lake to Norway Lake	7.59	2Bg	FS	FS	NA	NA			MTS	MTS	IF	-	MTS	MTS	-	-	MTS	-
07010105-599	Lizzie Creek	Lizzie Lake to Pine River	3.97	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	-	-	-	-
07010105-671	Pine River	Norway Lake to South Fork Pine R	2.89	2Bg	FS	FS	NA	NA			MTS	MTS	IF	-	MTS	IF	MTS	-	MTS	-
HUC 12: 0701010502-01 (South Fork Pine River)																				
07010105-572	Pine River, South Fork	T138 R31W S26, north line to Brittan Creek	2.97	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	-	-	-	-
07010105-525	Brittan Creek	Dabill Creek to South Fork Pine R	1.27	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	-	-	-	-
07010105-528	Bungo Creek	Unnamed creek to T138 R30W S31, east line	6.31	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	IF	-	-	-
07010105-531	Pine River, South Fork	Bungo Creek to Hoblin Creek	4.33	2Bg	NS	NA	NA	NA			EXP	MTS	IF	-	-	IF	-	-	-	-
07010105-529	Wilson Creek	T137 R30W S30, west line to Hoblin Creek	5.86	2Bg	NS	NA	NA	NA			MTS	EXP	IF	-	-	IF	-	-	-	-
07010105-534	Pine River, South Fork	Behler Creek to Pine River	1.71	2Bg	FS	FS	NA	NA			MTS	MTS	IF	-	MTS	MTS	MTS	-	MTS	-
HUC 12: 0701010504-01 (Middle Pine River)																				
07010105-509	Arvig Creek	Rice Lake to Unnamed creek	1.17	2Bg	NS	NA	NA	NA			EXS	EXS	IF	-	-	IF	-	-	-	-
07010105-672	Pine River	South Fork Pine R to Whitefish Lk	6.18	2Bg	FS	FS	NA	NA			MTS	MTS	IF	-	-	IF	-	-	MTS	-
07010105-556	Hay Creek	Unnamed creek to Unnamed creek	0.76	2Bg	IF	FS	NA	NA			-	-	IF	-	-	MTS	-	-	MTS	-
07010105-631	Willow Creek	Headwaters to Unnamed creek	4.12	2Bg	NS	NA	NA	NA			EXS	MTS	IF	-	-	IF	IF	-	-	-
HUC 12: 0701010503-01 (Dagget Brook)																				
07010105-611	Daggett Brook	Unnamed creek to Lake George	1.71	2Bg	FS	NA	NA	NA			MTS	-	IF	-	-	IF	-	-	-	-
07010105-561	Daggett Brook	Hay Creek to Mitchell Lake	6.04	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	IF	-	-	-
07010105-514	Daggett Brook	Eagle Lake to Little Pine Lake	4.33	2Bg	FS	FS	NA	NA			MTS	MTS	IF	-	MTS	MTS	MTS	-	MTS	-
HUC 12: 0701010506-02 (Pelican Brook)																				
07010105-517	Pelican Brook	Ossawinnamakee Lake to Pine R	5.33	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	-	-	-	-

HUC 12: 0701010505-01 (Little Pine River)

07010105-578	Little Pine River	Headwaters (Little Pine Lake 18-0176-00) to Duck Lake	5.92	2Bg	FS	NA	NA	NA				MTS	IF	-	-	IF	-	-	-	-
07010105-584	Little Pine River	Lake Emily to Mud Brook	10.67	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	-	-	-	-
07010105-673	Mud Brook	Lows Lake (18-0180-00) to Island Lake Dam	10.34	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	-	-	-	-
07010105-677	Mud Brook	Mud Lake (18-0198-00) to Little Pine River	2.08	2Bg	FS	NA	NA	NA			MTS		IF	-	-	IF	-	-	-	-
07010105-505	Little Pine River	Mud Brook to Pine River	7.13	2Bg	FS	FS	NA	NA			MTS	MTS	IF	-	MTS	MTS	MTS	-	MTS	

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 2015 reporting cycle; 🟥= new impairment; 🟩= full support of designated use.

AUID DESCRIPTIONS				USES							WATER QUALITY STANDARDS Aquatic Life Indicators:								Aquatic Rec. Indicators:	
Assessment Unit ID (AUID)	**Stream Reach Name**	**Reach Description**	**Reach Length (Miles)**	**Use Class**	**Aquatic Life**	**Aquatic Recreation**	**Aquatic Consumption**	**Drinking Water**	**303d listed impairments 2014**		**Fish**	**Macroinvertebrates**	**Dissolved Oxygen**	**Turbidity**	**Chloride**	**pH**	**NH3**	**Pesticides**	**Bacteria**	**Nutrients**
HUC 12: 0701010506-01 (Lower Pine River)																				
07010105-660	Pine River	Cross Lake Dam to Unnamed creek	2.63	2Bg	FS	FS	NA	NA			MTS	MTS	IF	-	-	IF	-		MTS	-
07010105-662	Pine River	Pine Lake Dam to Little Pine River	9.06	2Bg	FS	NA	NA	NA			MTS	MTS	IF	-	-	IF	-			-
07010105-504	Pine River	Little Pine River to Mississippi R	5.84	2Bg	FS	FS	NA	NA			MTS	MTS	IF	-	MTS	MTS	MTS	-	MTS	-

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 2014 reporting cycle; 🟥= new impairment; 🟩= full support of designated use.

Appendix 3.2 – Assessment results for lakes in the Pine River Watershed

HUC 12	Name	MDNR Lake ID	Area (acres)	Trophic Status	Percent Littoral	Max Depth (m)	Mean Depth (m)	CLMP Trend	Mean TP (ug/L)	Mean Chl-a (m)	Mean Secchi (m)	AQL Support Status	AQR Support Status
Daggett	Morrison	11-0006-00	153	-	98	15.2	-	IF	12	5	3.7	NA	FS
Daggett	Leavitt	11-0037-00	120	M	29	18.3	8.8	NT	19	3	2.7	NA	FS
Daggett	Roosevelt - North	11-0043-01	287	M	-	39.3	14.9	NT	17	4	3.7	NA	FS
Daggett	Roosevelt - South	11-0043-02	1218	M	-	39.3	14.9	I	16	5	3.5	NA	FS
Daggett	Lawrence	11-0053-00	218	M	38	21.6	5.8	NT	20	5	3.0	NA	FS
Daggett	Washburn	11-0059-00	1586	M	48	33.8	6.4	I	14	5	3.9	IF	FS
Daggett	George	11-0101-00	602	E	-	6.1	1.2	NT	34	25	1.8	IF	IF
Daggett	Island	11-0102-00	344	M	-	3.0	-	NT	13	4	4.2	NA	FS
Daggett	Pistol	11-0110-00	76	O	86	6.1	-	IF	12	52	0.9	IF	IF
Daggett	Mitten	11-0114-00	106		90	8.5	-	IF	37	22	0.9	NA	NS
Daggett	Stevens	11-0116-00	108	M	64	19.2	-	IF	16	7	2.9	NA	FS
Daggett	Twenty-Six	11-0117-00	105	O	100	4.0	-	IF	10	10	2.2	FS	FS
Daggett	Blue	18-0211-00	170	O	43	14.6	-	NT	7	3	7.5	NA	FS
Daggett	Anna	18-0213-00	99	M	84	5.8	-	NT	16	4	3.8	NA	IF
Daggett	Smokey Hollow	18-0220-00	123	M	46	7.6	-	NT	19	5	2.0	NA	FS
Daggett	Wood	18-0222-00	90	M	52	12.5	-	IF	10	4	3.5	IF	IF
Daggett	Butterfield	18-0231-00	194	M	74	6.1	-	I	17	4	4.4	NA	FS
Daggett	Little Pine	18-0266-00	353	E	58	11.0	4.0	I	24	5	2.9	NA	FS
Daggett	Daggett	18-0271-00	255	E	58	7.0	3.4	I	25	6	2.7	NA	FS
Daggett	Kego	18-0293-00	289	E	62	6.1	3.4	D	33	9	2.0	NA	NS
Daggett	Mitchell	18-0294-00	419	M	27	23.8	9.4	NT	22	5	2.4	NA	FS
Daggett	Eagle (Main Bay)	18-0296-01	-	M	-	10.7	4.9	NT	22	6	2.8	NA	FS
Daggett	Eagle (West Bay)	18-0296-02	-	M	-	10.7	-	IF	18	5	3.0	NA	IF
Daggett	Eagle (East Bay)	18-0296-03	-	M	-	10.7	-	IF	20	6	2.7	NA	IF
Daggett	West Fox	18-0297-00	448	M	29	16.8	7.0	NT	17	4	4.7	NA	FS
Daggett	East Fox	18-0298-00	223	M	42	19.8	5.8	NT	15	3	5.1	NA	FS
Little Pine	Moulton	01-0212-00	253	M	85	7.3	-	IF	16	13	0.8	IF	FS
Little Pine	Ross	18-0165-00	487	E	62	9.4	3.4	NT	25	14	1.5	IF	IF
Little Pine	Mud	18-0166-00	76	E	58	7.0	-	NT	-	-	1.1	NA	IF
Little Pine	Twin (West Basin)	18-0167-01	47	M	-	28.7	-	NT	13	6	1.6	NA	IF
Little Pine	Twin (East Basin)	18-0167-02	28	E	-	28.7	-	IF	25	8	1.3	NA	FS

HUC 12	Name	MDNR Lake ID	Area (acres)	Trophic Status	Percent Littoral	Max Depth (m)	Mean Depth (m)	CLMP Trend	Mean TP (ug/L)	Mean Chl-a (m)	Mean Secchi (m)	AQL Support Status	AQR Support Status
Little Pine	Little Pine	18-0176-00	124	H	-	-	-	-	100			NA	IF
Little Pine	Lows	18-0180-00	302	E	100	3.0	-	IF	59	32	0.8	NA	NS
Little Pine	Island	18-0183-00	236	M	62	11.3	-	D	16	10	1.8	IF	IF
Little Pine	Mary	18-0185-00	398	E	33	10.4	5.2	NT	29	5	1.8	NA	FS
Little Pine	Perry	18-0186-00	157	M	92	6.7	-	IF	30	37	1.1	IF	IF
Little Pine	Dolney	18-0195-00	274	O	100	4.9	-	IF	10	2	4.0	IF	FS
Little Pine	Emily	18-0203-00	707	E	100	4.0	2.4	D	44	6	1.5	IF	NS
Little Pine	Dahler	18-0204-00	237	M	100	1.5	-	IF	-	-	2.3	NA	IF
Little Pine	Ruth	18-0212-00	601	M	34	11.9	5.8	I	23	5	5.3	IF	FS
Little Pine	Trout	18-0218-00	114	O	44	6.7	3.4	NT	9	4	4.1	IF	FS
Little Pine	Adney	18-0225-00	302	M	52	8.2	-	IF	16	7	3.8	NA	FS
Lower Pine	Fool	18-0224-00	243	M	99	5.2	-	IF	24	11	1.9	NA	IF
Lower Pine	Goodrich	18-0226-00	372	M	66	10.7	3.7	NT	18	3	4.7	NA	FS
Lower Pine	O'Brien (Northeast Bay)	18-0227-02	81	O	-	14.9	6.4	I	11	2	5.6	NA	FS
Lower Pine	Horseshoe (East Bay)	18-0251-01	591	M	-	17.1	3.7	I	15	6	4.7	NA	FS
Lower Pine	Horseshoe (West Bay)	18-0251-02	319	M	-	17.1	3.7	NT	15	5	4.4	NA	FS
Lower Pine	Pine	18-0261-00	375	M	99	5.2	1.2	IF	23	6	3.2	NA	FS
Lower Pine	Velvet	18-0284-00	162	M	51	8.8	4.3	NT	15	5	3.3	NA	FS
Lower Pine	Greer	18-0287-00	333	M	80	11.0	2.4	IF	13	6	2.7	IF	FS
Middle Pine	Island	18-0269-00	183	O	48	23.2	6.1	D	12	3	4.5	NA	FS
Middle Pine	Hen	18-0270-00	128	M	-	-	5.5	NT	13	2	3.6	NA	IF
Middle Pine	Ox	18-0288-00	242	O	50	22.6	4.9	NT	11	2	6.4	NA	FS
Middle Pine	Whitefish	18-0310-00	7725	M	37	42.1	10.7	D	17	4	3.3	NA	FS
Middle Pine	Rush	18-0311-00	757	M	56	32.0	6.4	NT	13	3	4.5	NA	FS
Middle Pine	Cross Lake Reservoir	18-0312-00	1778	M	50	25.6	8.8	NT	16	3	4.1	NA	FS
Middle Pine	Big Trout	18-0315-00	1364	O	28	39.0	14.6	NT	11	3	4.4	NA	FS
Middle Pine	Pig	18-0354-00	191	M	-	17.1	7.3	D	16	4	4.0	NA	FS
Middle Pine	Bertha	18-0355-00	337	M	36	19.5	8.5	D	16	3	4.1	NA	FS
Middle Pine	Clamshell	18-0356-00	207	M	75	13.4	2.4	I	18	5	4.3	NA	FS
Middle Pine	Arrowhead	18-0366-00	303	E	100	4.0	1.2	IF	26	8	2.6	NA	FS
Middle Pine	Lower Hay	18-0378-00	700	M	31	30.5	14.9	NT	14	3	4.4	NA	FS
Middle Pine	Upper Hay	18-0412-00	592	E	32	12.8	5.2	NT	35	6	2.1	NA	IF

HUC 12	Name	MDNR Lake ID	Area (acres)	Trophic Status	Percent Littoral	Max Depth (m)	Mean Depth (m)	CLMP Trend	Mean TP (ug/L)	Mean Chl-a (m)	Mean Secchi (m)	AQL Support Status	AQR Support Status
Pelican	Young	18-0252-00	59	M	-	6.4	-	NT	13	3	7.1	NA	FS
Pelican	East Twin	18-0257-00	26	M	-	8.5	-	IF	13	5	4.1	NA	FS
Pelican	West Twin	18-0258-00	19	O	38	20.7	-	IF	8	3	5.1	NA	FS
Pelican	Little Beaver	18-0279-00	14	O	-	-	-	IF	-	-	4.3	NA	IF
Pelican	Pelican	18-0308-00	8379	O	47	31.7	6.7	I	10	3	5.3	IF	FS
Pelican	Duck	18-0314-00	146	-	100	4.0	-	IF	15	3	3.2	NA	IF
Pelican	Little Markee	18-0324-00	16	M	-	-	-	IF	18	5	2.8	NA	FS
Pelican	Stevens	18-0325-00	33	-	-	-	-	-	10	2		NA	IF
Pelican	Lougee	18-0342-00	201	M	72	16.2	-	I	17	4	3.5	NA	FS
Pelican	Markee	18-0343-00	98	M	73	1-584	-	NT	12	7	4.3	NA	FS
Pelican	Lynch	18-0347-00	62	M	-	-	-	NT	22	4	2.3	NA	FS
Pelican	Shaffer	18-0348-00	88	E	-	-	-	IF	22	3	0.8	NA	IF
Pelican	Unnamed	18-0350-00	25	E	-	-	-	NT	42	8	2.0	NA	IF
Pelican	Little Pelican	18-0351-00	266	M	73	10.4	-	NT	14	4	4.2	NA	FS
Pelican	Ossawinnamakee	18-0352-00	685	M	35	19.2	6.4	I	14	2	5.7	NA	FS
Pelican	Little Round	18-0357-00	12	O	-	6.1	-	NT	-	-	4.8	NA	IF
Pelican	Bass	18-0358-00	119	O	58	14.3	-	NT	10	3	5.2	NA	IF
Pelican	Star	18-0359-00	125	O	37	25.3	-	I	11	2	5.3	NA	FS
Pelican	Little Star	18-0360-00	46	M	25	9.1	-	NT	12	3	4.9	NA	FS
Pelican	Kimball	18-0361-00	182	M	20	23.5	8.8	NT	13	2	5.3	NA	FS
Pelican	Clear	18-0364-00	173	O	27	19.2	6.4	NT	8	3	5.3	NA	FS
South Fork Pine	Eagle	11-0342-00	115	O		-	-	NT	11	2	4.0	NA	FS
Upper Pine	Tamarack	11-0150-00	29	O	-	-	-	IF	10	3	1.0	IF	IF
Upper Pine	Hay	11-0199-00	363	M	51	17.1	-	I	13	4	4.2	NA	FS
Upper Pine	Little Sand	11-0230-00	76	M	94	5.2	-	NT			3.8	NA	IF
Upper Pine	Hattie	11-0232-00	578	M	92	4.9	4.3	NT	20	8	2.7	NA	FS
Upper Pine	Little Portage	11-0236-00	44	M	-	-	-	NT	12	3	4.7	NA	IF
Upper Pine	Deep Portage	11-0237-00	129	O	25	32.0	-	D	11	2	4.0	NA	FS
Upper Pine	Tamarack	11-0241-00	44	O	-	-	-	IF	10	2	1.1	IF	IF
Upper Pine	Hand	11-0242-00	278	O	52	17.4	5.2	NT	11	3	4.3	NA	FS
Upper Pine	Sylvan	11-0246-00	109	-	64	7.9	-	IF	13	3	4.5	NA	FS
Upper Pine	Ada	11-0250-00	945	M	43	18.3	6.4	I	12	5	4.4	NA	FS
Upper Pine	Hand	11-0251-00	52	E	-	-	-	-	55	-	-	NA	IF
Upper Pine	Harriet	11-0255-00	122	-	-	-	-	IF	8	1	1.5	NA	FS
Upper Pine	Norway	11-0307-00	510	E	100	4.0	1.5	NT	31	11	2.3	IF	IF

HUC 12	Name	MDNR Lake ID	Area (acres)	Trophic Status	Percent Littoral	Max Depth (m)	Mean Depth (m)	CLMP Trend	Mean TP (ug/L)	Mean Chl-a (m)	Mean Secchi (m)	AQL Support Status	AQR Support Status
Upper Pine	Big Portage (West Bay)	11-0308-01	704	M	-	3.7	1.8	NT	22	6	2.4	IF	FS
Upper Pine	Big Portage (East Bay)	11-0308-02	180	E	-	3.7	-	NT	20	6	2.4	NA	IF
Upper Pine	Bowen	11-0350-00	182	M	28	7.6	-	IF	20	8	3.3	NA	FS
Upper Pine	Five Point	11-0351-00	250	M	40	11.3	5.2	NT	18	7	4.0	NA	FS
Upper Pine	Beuber	11-0353-00	129	E	68	9.8	-	IF	30	16	2.5	NA	IF
Upper Pine	Ox Yoke	11-0355-00	177	O	53	12.8	-	NT	11	3	5.2	NA	FS
Upper Pine	Rainy	11-0356-00	127	O	72	8.8	-	NT	-	-	4.3	NA	IF
Upper Pine	Horseshoe	11-0358-00	258	O	39	15.5	6.4	NT	8	3	5.6	NA	FS
Upper Pine	Island	11-0360-00	100	-	100	4.3	-	IF	32	9	2.2	NA	IF
Upper Pine	Sanborn	11-0361-00	213	O	36	14.6	-	NT	9	2	5.3	NA	FS
Upper Pine	Fawn	11-0362-00	47	-	64	8.8	-	IF	-	-	4.9	NA	IF
Upper Pine	Johnson	11-0363-00	90	O	33	16.8	-	NT	-	-	5.5	NA	IF
Upper Pine	Lind	11-0367-00	399	E	66	8.2	-	IF	26	12	2.7	NA	FS
Upper Pine	Pine Mountain	11-0411-00	1572	M	54	23.8	6.4	NT	17	7	3.1	IF	FS
Upper Pine	Long	11-0454-00	135	O	62	14.6	-	IF	11	2	6.4	NA	FS
Upper Pine	Jackpine	11-0460-00	147	O	-	1.8	-	IF	9	1	1.7	IF	FS
Upper Pine	Variety	11-0463-00	147	-	43	8.8	-	IF	23	7	2.9	NA	FS
Upper Pine	Unnamed	18-0413-00	27	M	-	-	-	IF	19	-	2.3	NA	IF
Upper Pine	Clough	18-0414-00	240	M	100	2.4	-	IF	18	3	1.9	NA	FS
Upper Pine	Jail	18-0415-00	178	E	67	6.7	-	IF	49	29	1.3	NA	NS
Upper Pine	Lizzie	18-0416-00	403	M	100	4.6	-	IF	24	4	2.7	NA	FS

Abbreviations:

FS – Full Support
NS – Non-Support
IF – Insufficient Information
N/A – Not Assessed

Key for Cell Shading: ▨ = existing impairment, listed prior to 2014 reporting cycle; 🟥 = new impairment; 🟩 = full support of designated use.

Appendix 4.1 – Minnesota statewide IBI thresholds and confidence limits

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

Appendix 4.2 – Biological monitoring results –FIBI (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
0701010501-01 (Upper Pine River)							
07010105-669	12UM119	Pine River	85.77	5	47	64	8/1/2012
07010105-599	12UM135	Ada Brook	44.32	7	42	65	8/2/2012
07010105-671	12UM115	Pine River	149.14	5	47	46	6/18/2012
07010105-671	12UM115	Pine River	149.14	5	47	51	9/6/2012
0701010502-01 (South Fork Pine River)							
07010105-572	12UM120	Pine River, South Fork	36.68	7	42	67	8/1/2012
07010105-572	12UM120	Pine River, South Fork	36.68	7	42	69	7/1/2013
07010105-531	12UM121	Pine River, South Fork	84.85	5	47	46	7/24/2012
07010105-531	12UM121	Pine River, South Fork	84.85	5	47	42	7/1/2013
07010105-525	12UM140	Brittan Creek	15.92	6	42	79	6/12/2012
07010105-525	12UM140	Brittan Creek	15.92	6	42	78	7/1/2013
07010105-528	12UM139	Bungo Creek	12.42	6	42	43	6/11/2012
07010105-528	12UM139	Bungo Creek	12.42	6	42	48	7/12/2012
07010105-528	12UM139	Bungo Creek	12.42	6	42	51	7/9/2013
07010105-528	12UM132	Bungo Creek	16.16	6	42	51	7/11/2012
07010105-528	12UM132	Bungo Creek	16.16	6	42	60	7/1/2013
07010105-529	12UM133	Wilson Creek	8.02	6	42	62	6/12/2012
07010105-529	12UM133	Wilson Creek	8.02	6	42	63	7/12/2012
07010105-534	12UM116	Pine River, South Fork	115.53	5	47	65	6/18/2012
0701010504-01 (Middle Pine River)							
07010105-509	99UM042	Arvig Creek	14.19	6	42	0	7/11/2012
07010105-672	12UM125	Pine River	286.88	5	47	64	7/24/2012
07010105-631	12UM129	Willow Creek	5.25	6	42	30	8/20/2012
07010105-631	12UM129	Willow Creek	5.25	6	42	20	7/9/2013
0701010503-01 (Daggett Brook)							
07010105-611	12UM123	Daggett Brook	21.58	7	42	41	6/18/2012
07010105-561	12UM128	Daggett Brook	66.31	5	47	53	8/7/2012
07010105-514	12UM118	Daggett Brook	124.35	5	47	58	7/16/2012

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Threshold	FIBI	Visit Date
0701010506-02 (Pelican Brook)							
07010105-517	12UM141	Pelican Brook	44.70	6	42	76	7/23/2012
0701010505-01 (Little Pine River)							
07010105-584	00UM017	Little Pine River	81.52	5	42	56	7/31/12
07010105-584	00UM017	Little Pine River	81.52	5	42	68	8/12/14
07010105-673	12UM127	Mud Brook	37.09	7	42	33	7/3/2012
07010105-673	12UM127	Mud Brook	37.09	7	42	39	9/9/2013
07010105-677	12UM124	Mud Brook	46.54	7	42	54	8/27/2012
07010105-505	12UM117	Little Pine River	132.51	5	47	48	8/6/2012
07010105-505	12UM117	Little Pine River	132.51	5	47	58	9/10/2013
0701010506-01 (Lower Pine River)							
07010105-660	12UM131	Pine River	550.90	4	38	39	7/31/2012
07010105-662	12UM149	Pine River	628.41	4	38	59	9/6/2012
07010105-662	12UM149	Pine River	628.41	4	38	48	8/14/2014
07010105-504	12UM114	Pine River	779.43	4	38	45	8/22/2012

Appendix 4.3 – Biological monitoring results- MIBI (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
Upper Pine River (0701010501-01)							
07010105-599	12UM135	Lizzie Creek	44.32	4	51	68.92	8/13/2012
07010105-669	12UM119	Pine River	85.77	3	53	58.66	8/13/2012
07010105-671	12UM115	Pine River	149.14	3	53	68.01	8/16/2012
South Fork Pine River (0701010502-01)							
07010105-525	12UM140	Brittan Creek	15.92	4	51	33.85	8/2/2012
07010105-525	12UM140	Brittan Creek	15.92	4	51	53.27	9/24/2013
07010105-528	12UM132	Bungo Creek	16.16	4	51	81.95	8/2/2012
07010105-528	12UM139	Bungo Creek	12.42	3	53	47.58	8/2/2012
07010105-528	12UM132	Bungo Creek	16.16	4	51	71.42	8/8/2013
07010105-528	12UM139	Bungo Creek	12.42	3	53	47.10	8/8/2013
07010105-529	12UM133	Wilson Creek	8.02	4	51	40.75	8/14/2012
07010105-531	12UM121	Pine River, South Fork	84.85	4	51	65.51	8/14/2012
07010105-534	12UM116	Pine River, South Fork	115.53	4	51	50.55	8/16/2012
07010105-572	12UM120	Pine River, South Fork	36.68	4	51	27.34	8/2/2012
07010105-572	12UM120	Pine River, South Fork	36.68	4	51	71.47	9/24/2013
Middle Pine River (0701010504-01)							
07010105-509	99UM042	Arvig Creek	14.19	3	53	19.26	8/16/2012
07010105-509	99UM042	Arvig Creek	14.19	3	53	32.05	8/19/2013
07010105-631	12UM129	Willow Creek	5.25	4	51	60.16	8/20/2012
07010105-631	12UM129	Willow Creek	5.25	4	51	62.31	8/19/2013
07010105-672	12UM125	Pine River	286.83	3	53	70.74	8/15/2012
Dagget Brook (0701010503-01)							
07010105-514	12UM118	Daggett Brook	124.35	3	53	58.21	8/15/2012
07010105-561	12UM128	Daggett Brook	66.31	4	51	64.25	8/7/2012
Little Pine River (0701010505-01)							
07010105-505	12UM117	Little Pine River	132.51	3	53	46.37	8/19/2013
07010105-505	12UM117	Little Pine River	132.51	3	53	42.73	8/27/2014
07010105-578	12UM134	Little Pine River	36.01	4	51	53.98	8/28/2012
07010105-584	00UM017	Little Pine River	81.52	3	53	37.57	8/15/2012

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Threshold	MIBI	Visit Date
07010105-584	00UM017	Little Pine River	81.52	3	53	47.98	8/19/2013
07010105-584	00UM017	Little Pine River	81.52	3	53	47.44	8/12/2014
07010105-673	12UM127	Mud Brook	37.09	4	51	47.50	8/15/2012
Lower Pine River (0701070506-01)							
07010105-504	12UM114	Pine River	779.63	1	49	49.35	8/22/2012
07010105-517	12UM141	Pelican Brook	44.70	4	51	70.67	8/16/2012
07010105-517	12UM141	Pelican Brook	44.70	4	51	67.96	8/16/2012
07010105-660	12UM131	Pine River	550.90	1	49	40.89	8/15/2012
07010105-660	12UM131	Pine River	550.90	1	49	47.22	8/15/2012
07010105-662	12UM149	Pine River	628.41	1	49	48.58	9/6/2012
07010105-662	12UM149	Pine River	628.41	1	49	45.95	8/14/2014

Appendix 5.1 – 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 5.2 – MINLEAP model estimates of phosphorus loads for lakes in the Pine 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
11-0037-00	Leavitt	19	38	3	13	2.7	1.7	52	1293	-	0.28	24.8	0.2	51.06	M
11-0043-01	Roosevelt - North	17	34	4	11	3.7	1.8	52	2866	-	0.35	54.92	0.3	47.23	M
11-0043-02	Roosevelt - South	16	27	5	8	3.5	2.3	53	4255	-	0.49	81.04	0.9	16.44	M
11-0053-00	Lawrence	20	38	5	13	3.0	1.7	52	1578	-	0.27	30.21	0.2	34.25	M
11-0059-00	Washburn	14	31	5	10	3.9	2	53	4477	17.8	0.4	85.07	0.5	13.25	M
11-0101-00	George	34	44	25	17	1.8	1.5	52	3184	28	0.16	60.84	<0.1	24.97	E
11-0232-00	Hattie	20	43	8	16	2.7	1.5	52	8702	-	0.18	166.98	0.1	71.39	M
11-0242-00	Hand	11	34	3	11	4.3	1.9	53	876	-	0.36	16.67	0.3	14.82	M
11-0250-00	Ada	12	27	5	8	4.4	2.3	53	1360	-	0.49	25.55	1	6.68	M
11-0307-00	Norway	31	48	11	19	2.3	1.4	52	15077	32.4	0.08	289.62	<0.1	140.33	E
11-0308-01	Big Portage (West Bay)	22	37	6	13	2.4	1.7	53	1215	30.4	0.31	22.91	0.2	8.04	M
11-0351-00	Five Point	18	23	7	7	4.0	2.5	55	173	-	0.57	3.16	1.7	3.12	M
11-0358-00	Horseshoe	8	21	3	6	5.6	2.8	55	164	-	0.61	2.98	2.2	2.85	O
11-0411-00	Pine Mountain	17	32	7	10	3.1	2	53	4571	21.2	0.4	86.9	0.5	13.66	M
18-0165-00	Ross	25	36	14	13	1.5	1.7	53	1543	28	0.31	29.36	0.2	14.9	E
18-0185-00	Mary	29	42	5	16	1.8	1.5	52	6123	-	0.19	117.5	0.1	72.95	E
18-0203-00	Emily	44	43	6	16	1.5	1.5	52	6729	23.7	0.17	128.95	0.1	45.07	E
18-0212-00	Ruth	23	23	5	6	5.3	2.6	54	441	17.3	0.58	8.09	1.7	3.33	M
18-0218-00	Trout	9	25	4	7	4.1	2.4	55	64	20.1	0.54	1.16	1.3	2.51	M
18-0226-00	Goodrich	18	36	3	12	4.7	1.8	53	1125	-	0.32	21.39	0.3	14.21	M
18-0227-02	O'Brien (Northeast Bay)	11	41	2	15	5.6	1.6	52	1140	-	0.22	21.87	0.1	66.71	O
18-0251-01	Horseshoe (East Bay)	15	26	6	7	4.7	2.4	55	383	-	0.53	6.98	1.3	2.92	M
18-0251-02	Horseshoe (West Bay)	15	25	5	7	4.4	2.4	55	193	-	0.54	3.5	1.3	2.71	M
18-0261-00	Pine	23	31	6	10	3.2	2	56	161	-	0.45	2.85	0.6	1.88	M
18-0266-00	Little Pine	24	47	5	18	2.9	1.4	52	15110	-	0.1	290.35	<0.1	203.25	M
18-0269-00	Island	12	20	3	5	4.5	2.9	56	94	-	0.63	1.69	2.7	2.28	M

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
18-0270-00	Hen	13	17	2	4	3.6	3.3	59	37	-	0.7	0.63	4.5	1.22	M
18-0271-00	Daggett	25	48	6	19	2.7	1.4	52	15275	-	0.08	293.59	<0.1	284.5	M
18-0284-00	Velvet	15	22	5	6	3.3	2.7	56	72	-	0.61	1.28	2.2	1.96	M
18-0287-00	Greer	13	37	6	13	2.7	1.7	53	834	23.6	0.3	15.83	0.2	11.75	M
18-0288-00	Ox	11	27	2	8	6.4	2.2	54	275	-	0.49	5.13	0.9	5.24	O
18-0293-00	Kego	33	37	9	13	2.0	1.7	53	963	-	0.3	18.34	0.2	15.68	E
18-0294-00	Mitchell	22	42	5	16	2.4	1.5	52	12252	-	0.19	235.34	0.1	138.79	M
18-0296-01	Eagle (Main Bay)	22	45	6	17	2.8	1.4	52	12550	-	0.13	241.12	<0.1	170.23	M
18-0297-00	West Fox	17	31	4	10	4.7	2	53	1242	-	0.42	23.6	0.5	13.02	M
18-0298-00	East Fox	15	37	3	13	5.1	1.7	52	1332	-	0.3	25.47	0.2	28.22	M
18-0308-00	Pelican	10	18	3	5	5.3	3.2	57	3340	19.1	0.68	58.86	3.9	1.74	O
18-0310-00	Whitefish	17	32	4	10	3.3	1.9	52	39936	-	0.39	763.05	0.4	24.41	M
18-0311-00	Rush	13	46	3	18	4.5	1.4	52	40022	-	0.12	769.16	<0.1	251.07	M
18-0312-00	Cross Lake Reservoir	16	43	3	16	4.1	1.5	52	55798	-	0.18	1071.89	0.1	148.97	M
18-0315-00	Big Trout	11	19	3	5	4.4	3.1	54	1377	-	0.65	25.61	3.2	4.64	O
18-0352-00	Ossawinnamakee	14	37	2	13	5.7	1.7	52	4432	-	0.3	84.78	0.2	30.58	M
18-0354-00	Pig	16	18	4	5	4.0	3.2	56	86	-	0.68	1.53	3.7	1.97	M
18-0355-00	Bertha	16	22	3	6	4.1	2.7	54	320	-	0.59	5.95	2	4.36	M
18-0356-00	Clamshell	18	20	5	5	4.3	2.9	64	37	-	0.68	0.57	3.6	0.69	M
18-0361-00	Kimball	13	29	2	9	5.3	2.1	53	481	-	0.45	9.13	0.7	12.39	O
18-0364-00	Clear	8	27	3	8	5.3	2.3	53	253	-	0.49	4.75	0.9	6.78	O
18-0366-00	Arrowhead	26	45	8	17	2.6	1.4	52	2417	-	0.13	46.28	<0.1	37.74	E
18-0378-00	Lower Hay	14	28	3	9	4.4	2.2	52	2927	-	0.46	55.85	0.8	19.71	M
18-0412-00	Upper Hay	35	27	6	8	2.1	2.2	54	702	-	0.49	13.12	0.9	5.48	M

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

Appendix 6 – Fish species found during biological monitoring surveys

Common Name	Quantity of Stations Where Present	Quantity of Individuals Collected
banded killifish	1	1
bigmouth shiner	2	3
black bullhead	10	237
black crappie	9	34
blackchin shiner	3	49
blacknose dace	14	539
blacknose shiner	8	66
bluegill	18	1823
bluntnose minnow	9	115
bowfin	9	22
brassy minnow	8	195
brook silverside	1	4
brook stickleback	16	188
brown bullhead	3	7
burbot	5	93
central mudminnow	23	1694
common shiner	22	2430
creek chub	13	1139
fathead minnow	7	223
finescale dace	2	11
golden shiner	11	98
greater redhorse	3	10
green sunfish	3	7
hornyhead chub	14	1386
hybrid sunfish	8	104
Iowa darter	6	8
johnny darter	19	1090
largemouth bass	18	545
least darter	2	10
logperch	9	721
longnose dace	8	1451
mimic shiner	6	71
mottled sculpin	8	242
northern pike	21	226
northern redbelly dace	8	250
pearl dace	6	294

Common Name	Quantity of Stations Where Present	Quantity of Individuals Collected
pugnose shiner	2	21
pumpkinseed	12	63
rock bass	16	895
sand shiner	1	1
shorthead redhorse	1	1
silver redhorse	1	3
smallmouth bass	2	19
spotfin shiner	5	37
spottail shiner	5	13
tadpole madtom	15	279
walleye	3	14
white sucker	20	1230
yellow bullhead	15	51
yellow perch	18	512

Appendix 7 – Macroinvertebrate species found during biological monitoring surveys

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
ACARI		
Acari	31	155
AMPHIPODA		
Amphipoda	1	3
Gammarus	3	9
Hyalella	37	1297
Hyalella azteca	1	117
COLEOPTERA		
Agabus	1	1
Anacaena	1	1
Ancyronyx variegatus	2	2
Dineutus	1	1
Dubiraphia	14	62
Dytiscidae	3	4
Elmidae	1	1
Gyrinus	5	7
Haliplus	11	27
Hydraena	6	17
Hydrochus	1	3
Hydrophilidae	2	2
Hygrotus	1	1
Liodessus	4	26
Macronychus	1	2
Macronychus glabratus	9	27
Neoporus	1	1
Optioservus	4	13
Peltodytes	1	1
Stenelmis	18	81
Tropisternus	2	3
DECAPODA		
Cambaridae	2	2
Orconectes	9	9
DIPTERA		
Ablabesmyia	29	139
Anopheles	9	18
Atherix	3	3
Atrichopogon	1	1
Bezzia	2	3
Bezzia / Palpomyia	4	8

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
DIPTERA (cont.)		
Brillia	5	8
Cardiocladius	1	4
Ceratopogonidae	4	6
Ceratopogoninae	7	9
Chironomini	9	22
Chironomus	7	69
Chrysops	2	2
Cladopelma	2	7
Cladotanytarsus	5	6
Clinotanypus	3	6
Conchapelopia	5	7
Corynoneura	12	23
Cricotopus	31	150
Cryptochironomus	3	3
Cryptotendipes	3	5
Dasyhelea	1	7
Diamesinae	1	1
Dicranota	1	1
Dicrotendipes	11	49
Dixella	3	4
Doncricotopus bicaudatus	1	2
Empididae	9	13
Endochironomus	9	67
Ephydridae	4	8
Eukiefferiella	2	2
Glyptotendipes	4	5
Guttipelopia	1	1
Gymnometriocnemus	1	1
Hemerodromia	20	107
Labrundinia	17	33
Larsia	4	9
Lauterborniella agrayloides	4	10
Limnophyes	6	12
Lopescladius	3	5
Mallochohelea	1	2
Micropsectra	8	54
Microtendipes	20	45
Nanocladius	3	4
Nilotanypus	6	8
Nilothauma	2	2
Odontomyia / Hedriodiscus	1	1

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
DIPTERA (cont)		
Orthocladiinae	5	12
Orthocladius	4	6
Orthocladius (Symposiocladius)	1	2
Parachironomus	2	2
Parakiefferiella	4	7
Paralauterborniella nigrohalterale	3	3
Paramerina	5	16
Parametriocnemus	9	16
Paratanytarsus	16	132
Paratendipes	4	7
Pentaneura	7	12
Phaenopsectra	13	26
Polypedilum	38	779
Procladius	13	25
Psectrocladius	7	9
Rheocricotopus	14	36
Rheotanytarsus	34	671
Saetheria	1	3
Serromyia	1	2
Simulium	33	1432
Stempellinella	16	46
Stenochironomus	11	22
Stratiomyidae	1	1
Synorthocladius	3	8
Tabanidae	1	1
Tanypodinae	17	42
Tanytarsini	19	58
Tanytarsus	32	553
Thienemanniella	22	60
Thienemannimyia	3	7
Thienemannimyia Gr.	32	257
Thienemannimyia senata	1	1
Tipula	4	7
Tribelos	2	5
Tvetenia	14	37
Xenochironomus xenolabis	3	6
Zavreliella maramorata	1	1
EPHEMEROPTERA		
Acentrella	1	1

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
EPHEMEROPTERA (cont)		
Acentrella parvula	2	6
Acentrella turbida	1	4
Acerpenna	18	106
Acerpenna pygmaea	15	120
Baetidae	13	41
Baetis	8	33
Baetis brunneicolor	6	36
Baetis flavistriga	5	39
Baetis intercalaris	6	29
Baetisca	3	3
Caenis	16	196
Caenis diminuta	4	40
Caenis Diminuta Gr.	6	156
Caenis hilaris	1	4
Caenis Hilaris Gr.	4	34
Callibaetis	1	1
Ephemerellidae	1	1
Heptageniidae	12	51
Iswaeon	18	480
Labiobaetis	3	3
Labiobaetis dardanus	2	5
Labiobaetis propinquus	18	130
Leptophlebia	2	71
Leptophlebiidae	12	42
Leucrocuta	5	12
Maccaffertium	15	119
Maccaffertium exiguum	2	2
Maccaffertium mediopunctatum	5	18
Maccaffertium terminatum	1	1
Maccaffertium vicarium	3	18
Paracloeodes minutus	1	1
Paraleptophlebia	5	108
Plauditus	4	18
Procloeon	5	18
Stenacron	6	18
Stenonema	1	11
Tricorythodes	14	48
GASTROPODA		
Amnicola	2	72
Ferrissia	9	53

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
GASTROPODA (cont)		
Fossaria	4	6
Gyraulus	8	19
Helisoma	2	4
Helisoma anceps	3	3
Hydrobiidae	24	534
Laevapex fuscus	1	3
Lymnaea stagnalis	3	3
Lymnaeidae	8	15
Menetus	2	2
Physa	23	147
Planorbella	4	4
Planorbidae	10	24
Planorbula armigera	1	1
Promenetus exacuous	3	4
Stagnicola	1	45
Valvata	4	12
Viviparidae	1	1
HEMIPTERA		
Aphididae	1	3
Belostoma	2	12
Belostoma flumineum	7	8
Belostomatidae	1	1
Corixidae	5	7
Hesperocorixa	1	1
Lethocerus	1	1
Mesovelia	2	2
Microvelia	2	2
Neoplea striola	11	41
Notonecta	3	3
Palmacorixa	1	1
Ranatra	2	2
Rhagovelia	1	1
Sigara	1	1
Trichocorixa	1	1
HIRUDINEA		
Hirudinea	14	41
HYDROZOA		
Hydrozoa	2	2
ISOPODA		
Caecidotea	1	2

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
LEPIDOPTERA		
Crambidae	3	4
Paraponyx	1	8
Petrophila	5	7
Pyralidae	2	2
Synclita	1	5
NEMATA		
Nemata	2	5
ODONATA		
Aeshna	5	30
Aeshna umbrosa	2	2
Aeshnidae	2	2
Anax	1	1
Anax junius	2	2
Argia	6	13
Argia apicalis	2	2
Basiaeschna janata	1	1
Boyeria	1	1
Calopterygidae	10	55
Calopteryx	15	40
Calopteryx aequabilis	7	20
Calopteryx maculata	1	1
Coenagrionidae	25	128
Enallagma	1	1
Epitheca	2	2
Epitheca canis	1	1
Gomphidae	4	4
Gomphus	2	2
Hetaerina americana	1	1
Ischnura	1	1
Libellulidae	1	1
Neurocordulia	1	4
Ophiogomphus	2	7
Ophiogomphus carolus	1	1
Somatochlora	3	6
OLIGOCHAETA		
Oligochaeta	28	295
PLECOPTERA		
Acroneuria	1	1
Acroneuria abnormis	2	2
Acroneuria lycorias	2	3

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
PLECOPTERA (cont)		
Isoperla	1	1
Paragnetina media	4	10
Perlidae	2	2
Perlodidae	1	1
Pteronarcys	1	1
TREPAXONEMATA		
Trepaxonemata	1	5
TRICHOPTERA		
Agarodes	1	1
Agarodes distinctus	1	1
Brachycentrus numerosus	6	97
Ceraclea	1	4
Ceratopsyche	14	104
Ceratopsyche bronta	1	1
Ceratopsyche morosa	4	138
Ceratopsyche slossonae	3	15
Cheumatopsyche	31	338
Chimarra	13	74
Glossosoma	1	1
Glossosomatidae	1	3
Helicopsyche	2	26
Helicopsyche borealis	9	148
Hydropsyche	16	85
Hydropsyche betteni	19	104
Hydropsyche incommoda	1	1
Hydropsyche placoda	3	38
Hydropsyche scalaris	1	1
Hydropsyche simulans	1	6
Hydropsychidae	26	370
Hydroptila	13	33
Hydroptilidae	9	21
Lepidostoma	5	9
Leptoceridae	10	20
Leptocerus	1	1
Leptocerus americanus	1	6
Limnephilidae	6	27
Limnephilus	1	13
Micrasema	4	13
Mystacides	4	9
Nectopsyche	4	8

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
Nectopsyche diarina	4	10
Nectopsyche exquisita	3	6
Neophylax concinnus	1	4
Neophylax fuscus	2	10
Neophylax oligius	3	9
Neureclipsis	8	18
Ochrotrichia	2	3
Oecetis	2	9
Oecetis Avara Gr.	6	14
Oecetis furva	4	4
Oecetis testacea	5	30
Oxyethira	20	105
Philopotamidae	1	2
Phryganeidae	6	8
Polycentropodidae	5	5
Polycentropus	2	2
Protoptila	3	19
Ptilostomis	6	9
Pycnopsyche	2	2
Triaenodes	5	8
TUBELLARIA		
Turbellaria	11	84
VENEROIDA		
Pisidiidae	31	206