Sand Hill River Watershed Monitoring and Assessment Report

Minnesota Pollution Control Agency

June 2014

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

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Document number: wq-ws3-09020301b

List of acronyms

AUID Assessment Unit Identification Determination

CCSI Channel Condition and Stability Index

CD County Ditch

CI Confidence Interval

CLMP Citizen Lake Monitoring Program

CR County Road

CSAH County State Aid Highway

CSMP Citizen Stream Monitoring Program

CWA Clean Water Act

CWLA Clean Water Legacy Act

DOP Dissolved Orthophosphate

E Eutrophic

EQuIS Environmental Quality Information System

EX Exceeds Criteria (Bacteria)

EXP Exceeds Criteria, Potential Impairment

EXS Exceeds Criteria, Potential Severe Impairment

FS Full Support

FWMC Flow Weighted Mean Concentration

H Hypereutrophic

HGM Hydrogeomorphic

HUC Hydrologic Unit Code

IBI Index of Biotic Integrity

IF Insufficient Information

K Potassium

LRVW Limited Resource Value Water

M Mesotrophic

MCES Metropolitan Council Environmental Services

MDA Minnesota Department of Agriculture

MDH Minnesota Department of Health

MDNR Minnesota Department of Natural Resources

MINLEAP Minnesota Lake Eutrophication

Analysis Procedure

MPCA Minnesota Pollution Control Agency

MSHA Minnesota Stream Habitat Assessment

MTS Meets the Standard?

N Nitrogen

Nitrate-N Nitrate Plus Nitrite Nitrogen

NA Not Assessed

NHD National Hydrologic Dataset

NH3 Ammonia

NS Not Supporting

NT No Trend

NWI National Wetland Inventory

OP Orthophosphate

P Phosphorous

PCB Poly Chlorinated Biphenyls

PWI Protected Waters Inventory

RNR River Nutrient Region

SWAG Surface Water Assessment Grant

SWCD Soil and Water Conservation District

SWUD State Water Use Database

TALU Tiered Aquatic Life Uses

TKN Total Kjeldahl Nitrogen

TMDL Total Maximum Daily Load

TP Total Phosphorous

TSS Total Suspended Solids

USGS United States Geological Survey

WPLMN Water Pollutant Load Monitoring Network

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Executive summary

The Sand Hill River Watershed (SHRW) (HUC 09020301), located within the Red River Basin, drains 708,469 acres in northwestern Minnesota and eastern North Dakota. The focus of this watershed monitoring and assessment report is on the 395,249 acre (55.8%) portion of the watershed in Polk, Norman and Mahnomen Counties of Minnesota (NRCS 2007). The SHRW is bordered on the north by the Red Lake River and Clearwater Watersheds; the Marsh and Wild Rice River Watershed form the southern border. Major rivers and streams within the watershed include the Sand Hill River and Kittleson Creek. Numerous unnamed ditches and smaller tributaries also occur within the watershed. The Red River of the North flows through this watershed but it was not part of the survey. The mainstem will be monitored, assessed and reported on following a new large river sampling and assessment effort that will begin on the Red River in 2015.

In 2011 the Minnesota Pollution Control Agency (MPCA) began an intensive watershed monitoring (IWM) effort of the surface waters within the SHRW. Nineteen sites were sampled for biology at the outlet of variable sized sub-watersheds. In 2012 the surface water bodies within the watershed were assessed for aquatic life, aquatic recreation, and aquatic consumption use support. Six stream segments (AUIDs) and 11 lakes were assessed. In addition, five stream segments were not assessed due to insufficient data, modified channel condition or their status as limited resource waters.

Every stream segment assessed along the main stem of the Sand Hill River failed to meet aquatic life and aquatic recreation use standards. Excessive bacteria resulted in all of the aquatic recreation impairments. Most aquatic life impairments in the lower Sand Hill River were the result of excess turbidity and/or low dissolved oxygen (DO). In general, fish and macro-invertebrate communities were good in the lower reaches of the Sand Hill. Connectivity issues are limiting the passage of certain migratory fish species and contributing to the aquatic life impairments in the Upper Sand Hill River Subwatershed. Kittleson Creek, a major tributary to the Sand Hill River, is the only stream segment in the watershed indicating full support for both aquatic life and aquatic recreation. The natural sections of Kittelson Creek which were used for assessment have a relatively undisturbed riparian area, likely contributing to the good in-stream habitat conditions and healthy biological community.

Seven of the 11 assessed lakes fully supported recreation uses. Excess nutrient levels resulting from poor land use practices resulted in aquatic recreation impairments on nearly half of the assessed lakes.

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 (TMDL). A TMDL is a comprehensive study identifying all pollution sources causing or contributing to impairment and an estimation of the reductions needed to restore a water body so that it can once again support its designated use.

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

The passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and the initial resources for state and local governments to accelerate efforts to monitor, assess, restore, and protect surface waters. This work is implemented 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. This strategy provides an opportunity to more fully integrate MPCA water resource management efforts in cooperation with local government and stakeholders 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 identify waters in need of 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. A 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 SHRW beginning in the summer of 2011. This report provides a summary of all water quality assessment results in the SHRW and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring, and monitoring conducted by local government units.

I. The watershed monitoring approach

The watershed approach is a 10-year rotation for monitoring and assessing waters of the state at the level of Minnesota's 81 major watersheds (Figure 1). The major benefit of this approach is the integration of monitoring resources to provide a more complete and systematic assessment of water quality at a geographic scale useful for the development and implementation of effective TMDLs, project planning, effectiveness monitoring, and protection strategies. The following paragraphs provide details on each of the four principal monitoring components of the watershed approach. For additional information see: *Watershed Approach to Condition Monitoring and Assessment* (MPCA 2008) (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

Pollutant load monitoring network

Funded with appropriations from Minnesota's Clean Water Legacy Fund, the Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term program designed to measure and compare regional differences and long-term trends in water quality among Minnesota's major rivers including the Red, Rainy, St. Croix, Mississippi, and Minnesota, as well as outlets of major tributaries (8 digit HUC scale) draining to these rivers. Since the program's inception in 2007, the WPLMN has adopted a multi-agency monitoring design that combines site specific stream flow data from United States Geological Survey (USGS) and Minnesota Department of Natural Resources (MDNR) flow gaging stations with water quality data collected by the Metropolitan Council Environmental Services (MCES), local monitoring organizations, and Minnesota Pollution Control Agency WPLMN staff to compute annual pollutant loads at 79 river monitoring sites across Minnesota. 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.

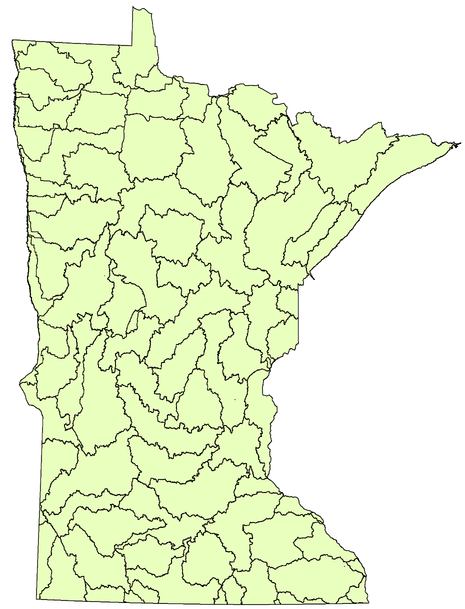

Figure 1. Major watersheds within Minnesota

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 1 and 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 81 major watersheds 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. 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, water chemistry, and fish contaminants to allow for the assessment of aquatic life, aquatic recreation, and aquatic consumption use support. The 11-HUC is the next smaller watershed scale which generally consists of major tributary streams with drainage areas ranging from 75 to 150 mi^2. Each 11-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 11-HUC, smaller watersheds (typically 10-20 mi^2) are sampled at each outlet that flows into the major 11-HUC tributaries. Each of these minor watershed outlets is sampled for biology (fish and macroinvertebrates) to assess aquatic life use support (red dots in Figure 3).

Within the IWM strategy, lakes are selected to represent the range of conditions and lake type (size and depth) found within the watershed. Lakes most heavily used for recreation (all those greater than 500 acres and at least 25% of lakes 100-499 acres) are monitored for water chemistry to determine if recreational uses, such as swimming and wading, are being supported. Lakes are sampled monthly from May-September for a two-year period. There is currently no tool that allows us to determine if lakes are supporting aquatic life, but 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 SHRW are shown in Figure 3 and are listed in Appendix 4.2, Appendix 4.3, Appendix 5.2 and Appendix 5.3.

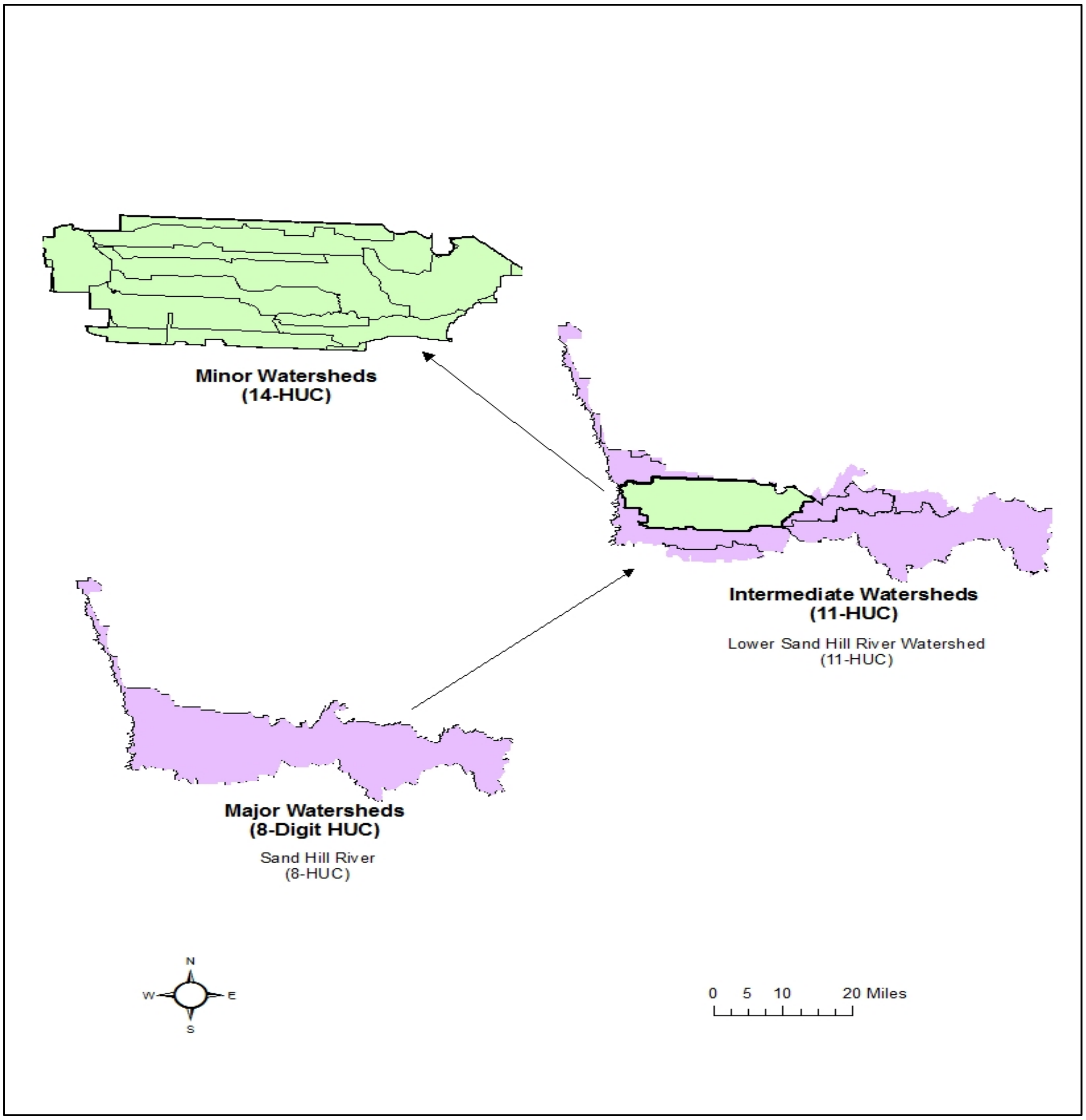

Figure 2. The intensive watershed monitoring design

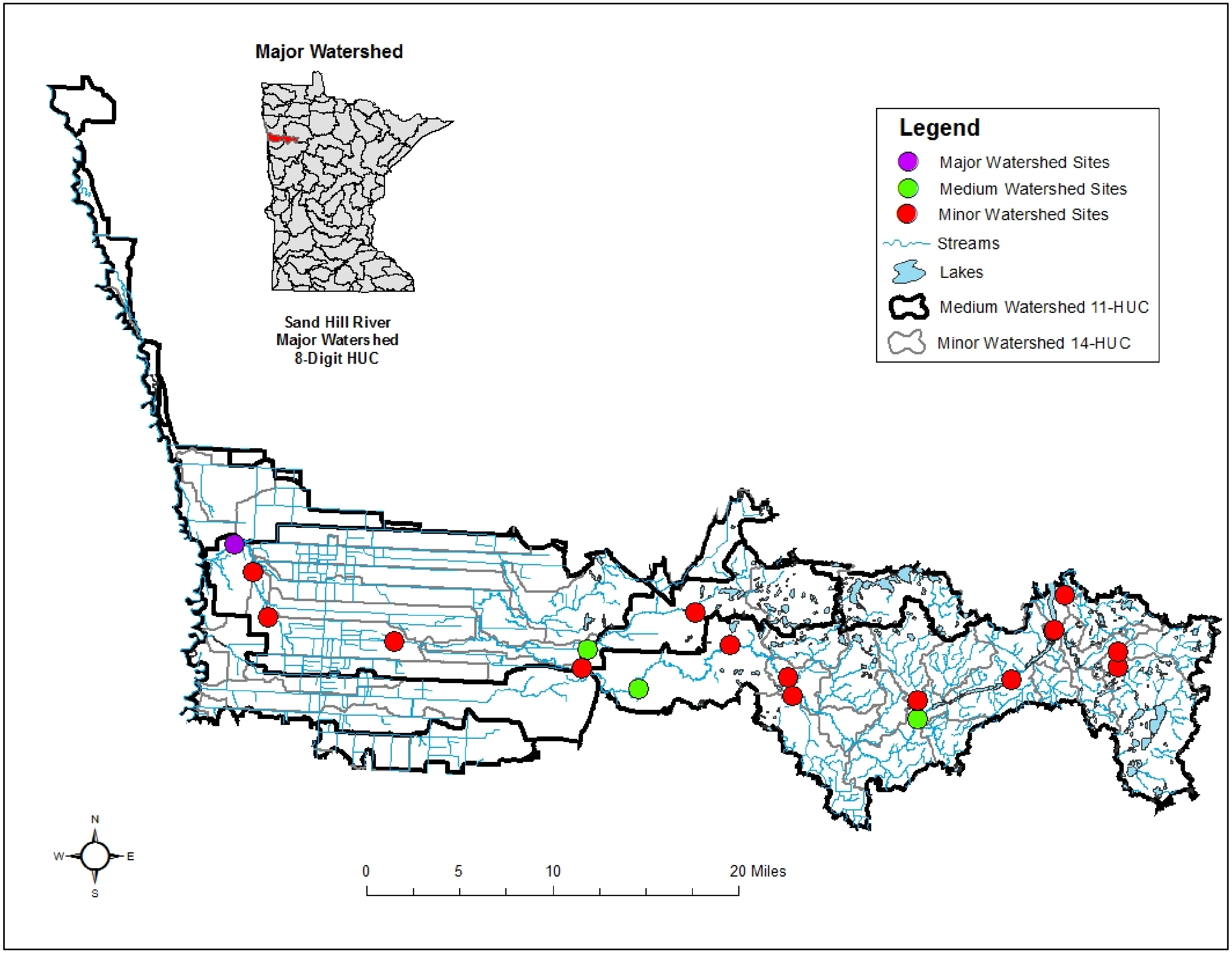

Figure 3. Intensive watershed monitoring sites for streams in the Sand Hill River Watershed

Citizen and local monitoring

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

The MPCA also coordinates two programs aimed at encouraging long term citizen surface water monitoring: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Like the permanent load monitoring network, having citizen volunteers monitor a given lake or stream site monthly and from year to year can provide the long-term picture needed to help evaluate current status and trends. Citizen monitoring is especially effective at helping to track water quality changes which 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 SHRW.

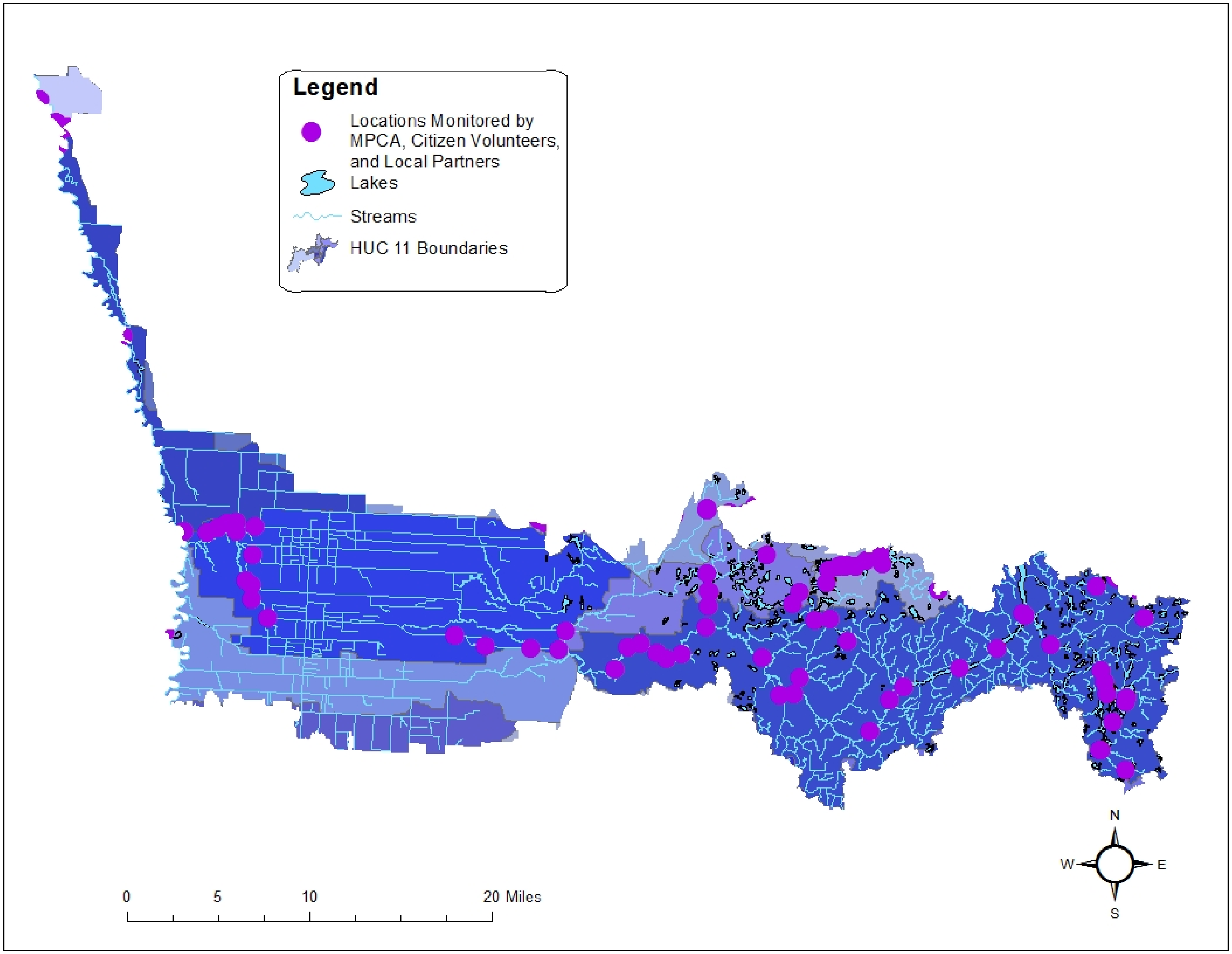

Figure 4. Monitoring locations of local groups, citizens, and the MPCA lake monitoring staff in the Sand Hill River Watershed

II. Assessment methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters which 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 methodology, see: *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List* (MPCA 2012). http://www.pca.state.mn.us/index.php/view-document.html?gid=16988.

Water quality standards

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

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

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

Protection of consumption means protecting citizens who eat fish from Minnesota waters or receive their drinking water from waterbodies protected for this beneficial use. The concentrations of mercury and polychlorinated biphenyls (PCBs) in fish tissue are used to evaluate whether or not fish are safe to eat in a lake or stream and to issue recommendations regarding the frequency that fish from a particular water body can be safely consumed. For lakes, rivers, and streams which 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 Class 7 limited resource value waters (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, aesthetics and 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 which 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 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 provides the identification numbers for lake, reservoirs, and wetlands. These identification numbers serve as the AUID and are composed of an eight-digit number indicating county, lake, and bay for each basin.

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

Determining use attainment

For beneficial uses related to human health, such as drinking water or aquatic recreation, the relationship is well understood and thus the assessment process is a relatively simple comparison of monitoring data to numeric standards. In contrast, assessing whether a waterbody supports a healthy aquatic community is not as straightforward and often requires multiple lines of evidence to make use attainment decisions with a high degree of certainty. Incorporating a multiple lines of evidence approach into MPCA's assessment process has been evolving over the past few years. The current process used to assess the aquatic life use of rivers and streams is outlined below and in Figure 5.

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

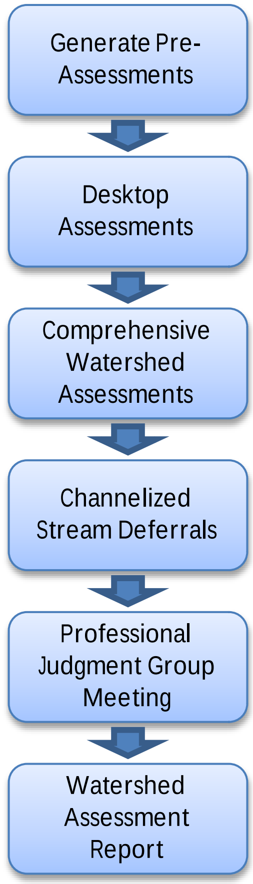

Figure 5. Flowchart of aquatic life use assessment process

The next step in the process is a Comprehensive Watershed Assessment meeting where reviewers convene to discuss the results of their desktop assessments for each individual waterbody. Implementing a comprehensive approach to water quality assessment requires a means of organizing and evaluating information to formulate a conclusion utilizing multiple lines of evidence. Occasionally, the evidence stemming from individual parameters are not in agreement and would result in discrepant assessments if the parameters were evaluated independently. However, the overall assessment considers each piece of evidence to make a use attainment determination based on the preponderance of information available. See the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List* (MPCA 2012) http://www.pca.state.mn.us/index.php/view-document.html?gid=16988 for guidelines and factors considered when making such determinations.

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

The last step in the assessment process is the Professional Judgement 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, collected during the most recent 10-year period, 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 iare entered into EQuIS (Environmental Quality Information System), MPCA's data system, and also uploaded to the U.S. Enivornmental Protection Agency's (EPA) data warehouse. Monitoring projects with federal or state funding are required to store data in EQuIS (e.g., Clean Water Partnership, CWLA Surface Water Assessment Grants, 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.

III. Watershed overview

The SHRW, HUC-09020301, is located in northwestern Minnesota and eastern North Dakota and is part of the Red River Basin. From its source at Sand Hill Lake, the Sand Hill River flows 101 miles to its confluence with the Red River of the North near the town of Climax. Unless noted otherwise, statistics reported in the watershed overview section are for the entire watershed including that portion of the watershed lying within North Dakota. The Minnesota portion covers 395,249 of the 708,469 total watershed acres (55.8%) and lies within three Minnesota counties: Polk, Norman, and Mahnomen (NRCS, 2007). The watershed in Minnesota is bordered to the north by the Red Lake River and Clearwater watersheds and to the south by the Wild Rice and Marsh watersheds.

The vast majority of the watershed is located in the Lake Agassiz Plain (LAP) Level III ecoregion with a very small portion in the North Central Hardwoods Forests (NCHF) EPA Level III ecoregions (Figure 6). The LAP is dominated by glacial sediments and glacial landforms deposited from the Des Moines Lobe of Wisconsin Glaciation approximately 12,000 years ago. These sediments are dominated by thick layers of silt and clay that form a very flat landscape ideal for farming (EPA, 2010).

The SHRW has three Major Land Resource Areas (Figure 6). Making up much of the watersheds western half is the Red River Valley of the North; this area can be characterized by lake plain with remnants of gravelly beaches left behind from glacial Lake Agassiz. Most of the watersheds eastern half, from the beach ridges to the headwaters of the Sand Hill River, is considered Rolling Till Prairie. This nearly flat landscape is comprised of small depressions and ill-refined drainages. Running a north-south corridor along the far eastern edge of the watershed is the northern Minnesota Clay Drift. Formed by a series of glaciations, this area is characterized by moraines, outwash plains, drumins and lake plains (NRCS, 2006).

Topography within the Minnesota portion of the watershed can be broken into three regions: the glacial lake bed deposits in the west, the beach ridge area in the center, and the glacial moraine in the east. The LAP is characterized by flat deposits of lake sediment comprised of clay and silt. East of the lake bed is the beach ridge area which comprises the old shoreline of Lake Agassiz. The beach ridge formation was formed by fluctuating lake levels which shaped the landscape. This formation follows a north-south corridor approximately eight miles wide through the center of the watershed and is located on the eastern boundary of the lake plain (Houston Engineering Inc., 2011). The glacial moraine area is located east of the beach ridge. This area makes up most of the eastern half of the watershed and is characterized by small lakes, wetlands and rolling terrain.

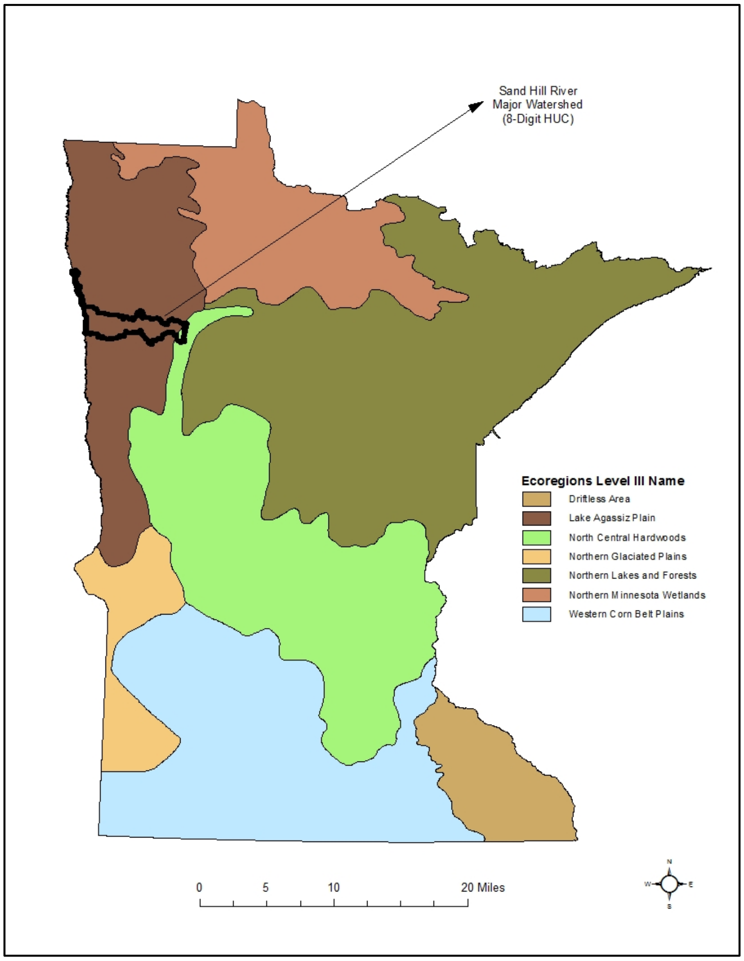

Figure 6. The Sand Hill River Watershed within the Lake Agassiz Plain and North Central Hardwoods ecoregions of northwestern Minnesota

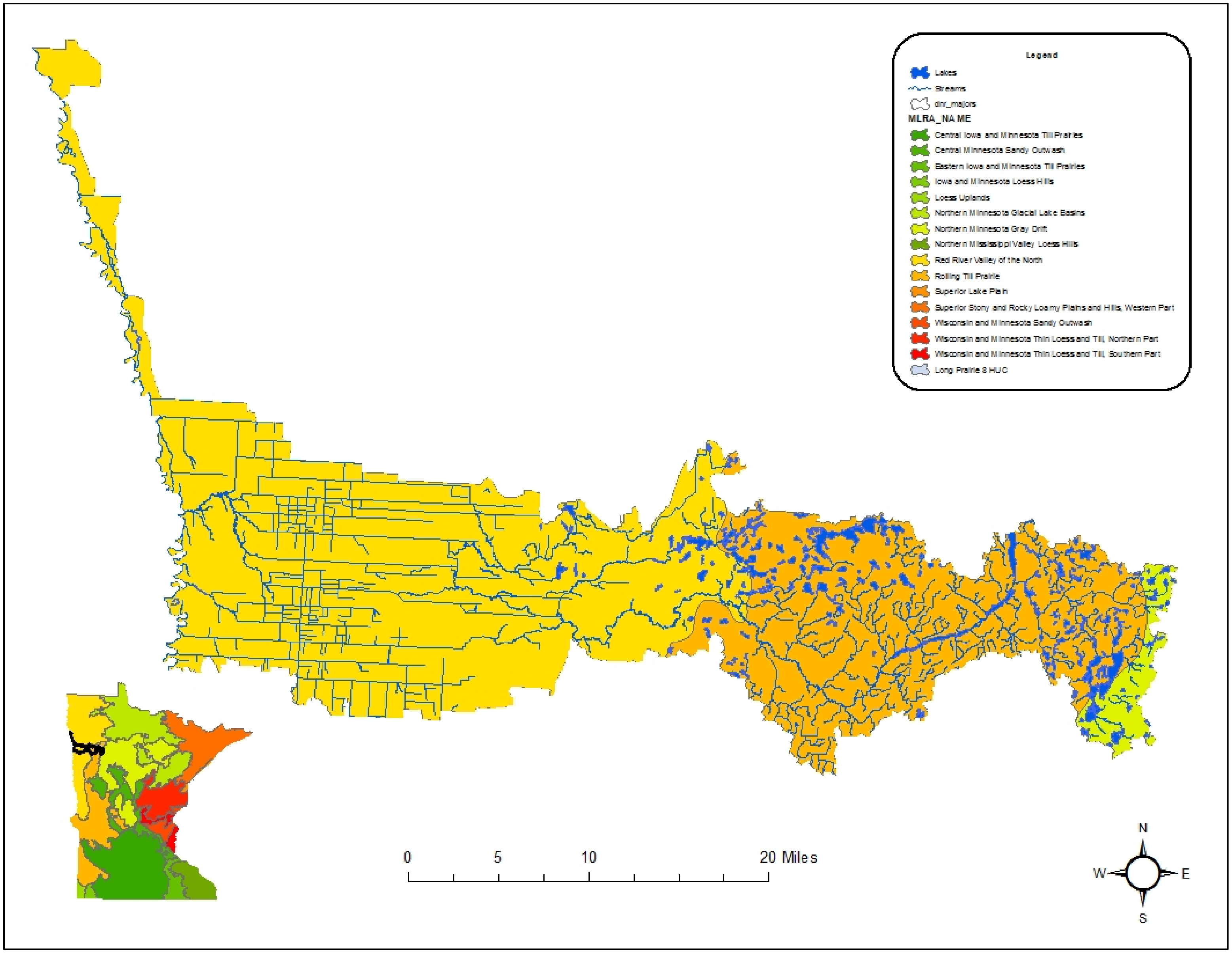

Figure 7. Major land resource areas in the Sand Hill River Watershed

Land use summary

Prior to western settlement, areas of tall grass prairie and low lying wetlands dominated the landscape. After the turn of the century, much of the watershed's rolling prairies and native vegetation were replaced by cultivated crops. Due to its flat topography and silt-clayey lake washed till, the vast majority of the landscape is classified as poorly drained and therefore prone to severe flooding.

Approximately 81% (557,576 acres) of the watershed is considered cropland (NRCS, 2007). The largest concentration follows a line from the western edge of the beach ridges to eastern North Dakota. Over the past nine decades, the watershed has seen a steady change in its crop production. In the middle 1900s, rye, oats, and hay were common within the watershed. In the 1970s, there was a push for increased sugar beet and sunflower production. More recently, the majority of agricultural practices have switched to row crops, with soybean and corn being the biggest producers.

The land cover distribution in the Minnesota portion of the watershed is as follows: 74.2% cropland, 6.9% wetlands, 5.8% rangeland, 5.6% developed, 5% forest, 2.6% open water, and 0.01% barren.

Land ownership within the watershed is dominated by private landowners (98%), many of which farm. Of the 695 farming operators in the watershed, 68% are full time and 32% are part time. There are an estimated 108 small farms of approximately 50 acres or less and 254 farms of 1000 acres or more. The average farm is 151 acres, with 57% being less than 500 acres. There are 38 registered feed lots within the watershed, with 84% being cattle operations and 16% being swine operation (NRCS, 2007).

When looking at the Minnesota potion of the watershed alone, the population is much less at 5,267 people (U.S. Census 2009 estimate). About two-thirds (3,371) are concentrated in the small cities of Beltrami (78), Climax (271), Fertile (939), Foston (1,718), Winger (212) and Nielsville (153).

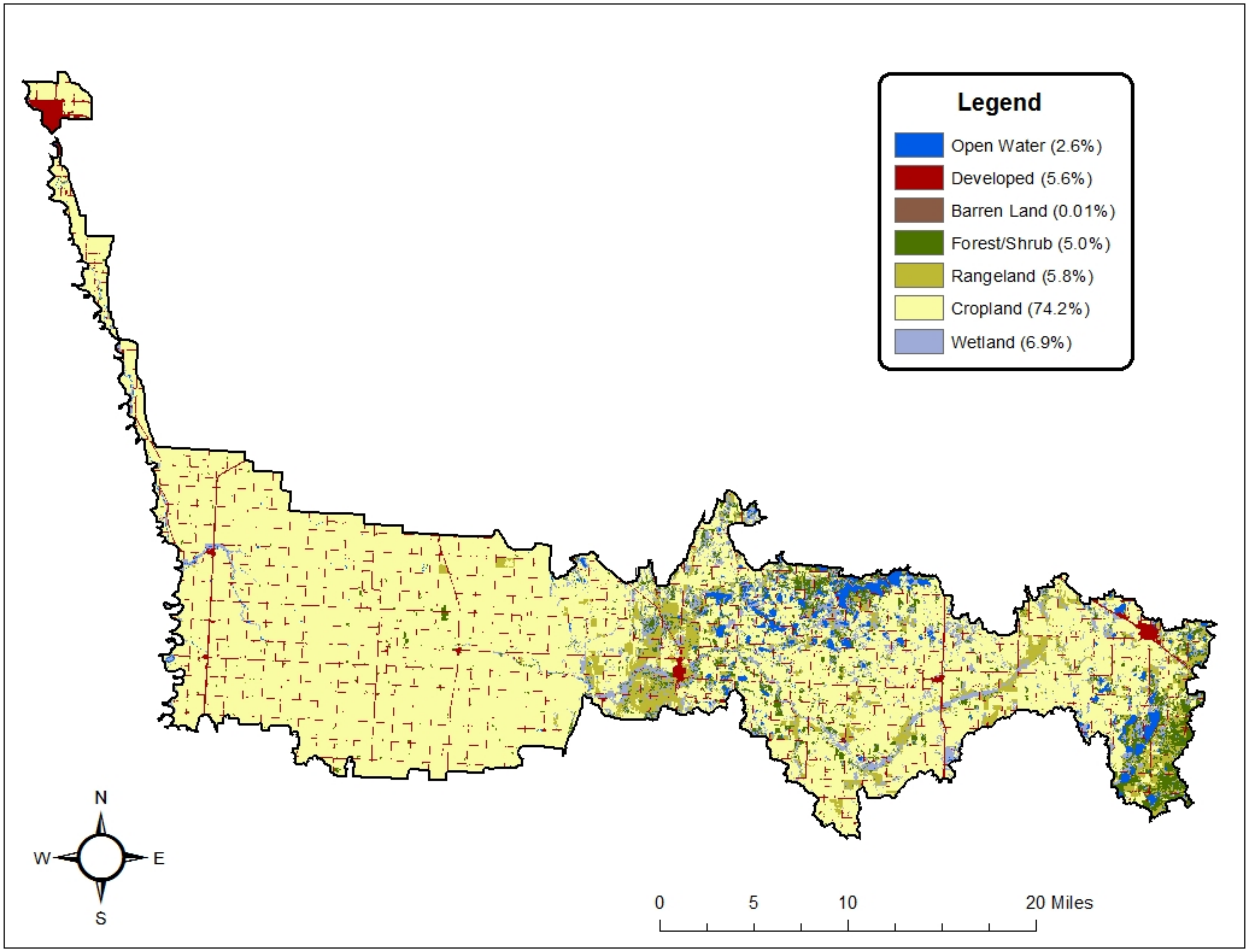

Figure 8. Land use within the Minnesota portion of the Sand Hill River Watershed

Surface water hydrology

The Sand Hill River originates in Sand Hill Lake near Fosston and travels 101 miles to its confluence with the Red River of the North near the town of Climax. The river travels east to west and drains approximately 432.2 square miles. With the exception of Kittleson Creek, there are very few natural tributaries to the Sand Hill River. Kittleson Creek originates at Kittleson Lake, 2.5 miles north of Fertile. The stream flows southwesterly 12.4 miles before its confluence with the Sand Hill River, 5.5 miles west of Fertile (Groshens, 2006).

In its natural state, the Sand Hill River flowed around the north side of the town of Beltrami. Just downstream of Beltrami, the river channel was poorly defined and prone to severe flooding. In an effort to reduce flooding and regulate drainage, the U.S. Army Corps of Engineers (USACE) began a study of the river. The overall purpose of the plan was "Flood Control and Improvement of the Sand Hill River Channel". From 1955 to 1958, the USACE completed a project which straightened or abandoned more than 18 miles of the Sand Hill River downstream of Fertile. Also included in the project was the construction of four "drop control" structures to improve overall drainage for agriculture purposes and to minimize flooding around the town of Beltrami (USACE, 2013). The drop structures created a six to eight foot change in bed grade and reduced the flood profiles in the Lower Sand Hill River Subwatershed (HUC-11).

In addition to the four drop structures, there are two dams along the Sand Hill River. The furthest upstream dam is located at the outlet of Sand Hill Lake. This dam was built in 1956 with the purpose of regulating water levels for recreational purposes. The next downstream dam is located just north of Rindal, on a tributary to the Sand Hill River.

Similar to the main stem Sand Hill River, many of the tributary streams in this region were historically altered to increase drainage. According to the altered watercourse project conducted by the MPCA, 530.8 of the 744.2 stream miles within the watershed are considered altered (71%). The remaining stream miles are natural (215.1 miles).

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 SHRW is 19.4˚C; and the mean winter temperature is -13.3˚ C (Minnesota State Climatologists Office, 2003).

Figure 9 shows recent precipitation trends in Minnesota for calendar year 2011 and 2012. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the southeast portion of the state. To its right is a depiction of how that precipitation total deviated from normal. When observing the precipitation averages for these years, the SHRW was slightly drier than normal in both 2011 and in 2012.

According to this map, the SHRW received 16 to 20 inches of precipitation in 2011, which was approximately 4 to 10 inches lower than normal. In 2012, the watershed received 12 to 16 inches, with precipitation ranging from 6 to 10 inches below normal.

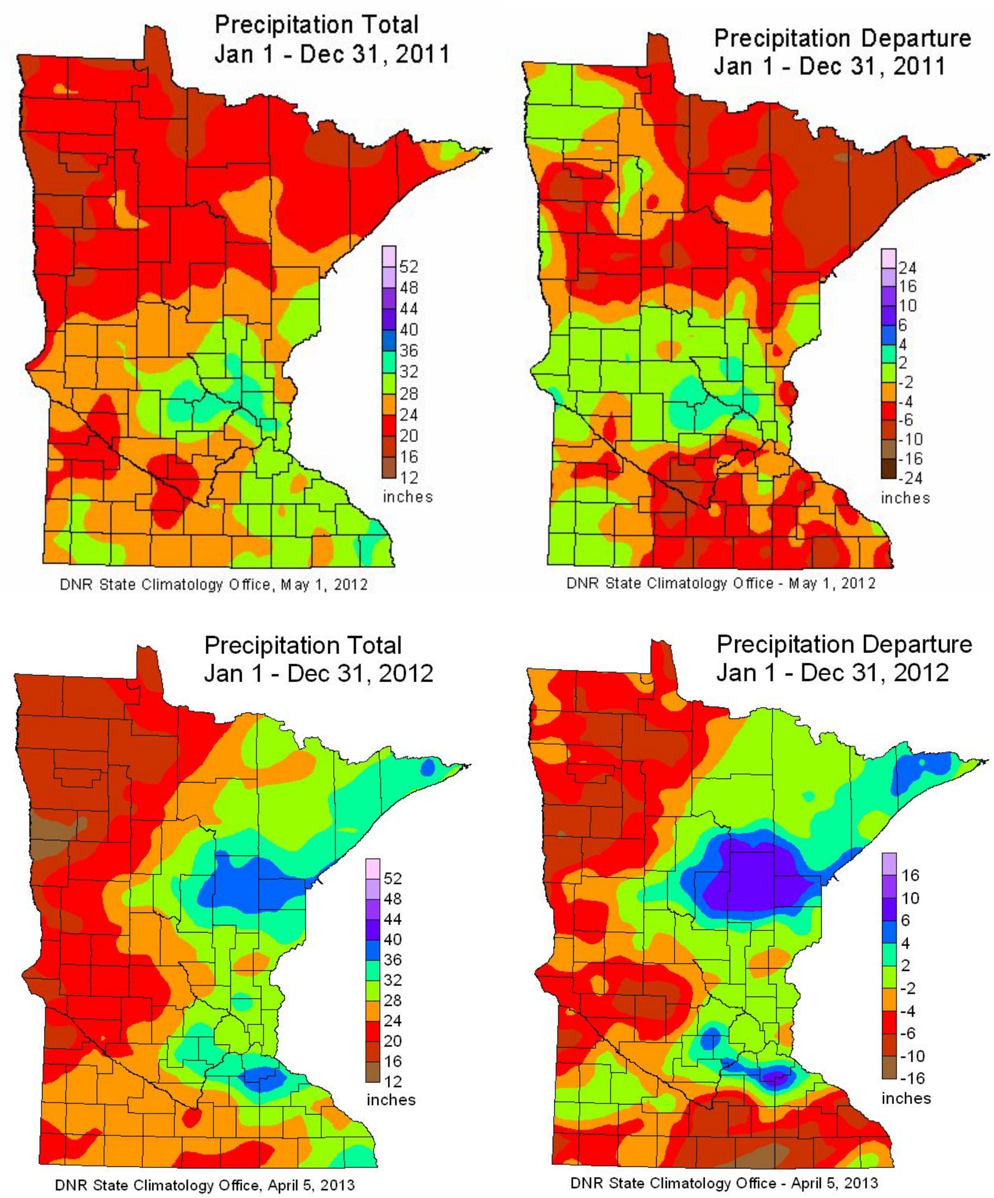

Figure 9. State-wide precipitation levels during the 2011 (above) and 2012 (below)

Figure 9 displays the areal average representation of precipitation in northwest Minnesota. An areal average is a spatial average of all the precipitation data collected within a certain area presented as a single dataset. This data is taken from the Western Regional Climate Center, available as a link on the University of Minnesota Climate website: http://www.wrcc.dri.edu/spi/divplot1map.html. Rainfall in the northwest region displays no significant trend over the last 20 years. Though rainfall can vary in intensity and time of year, it would appear that northwest Minnesota precipitation has not changed dramatically over this time period.

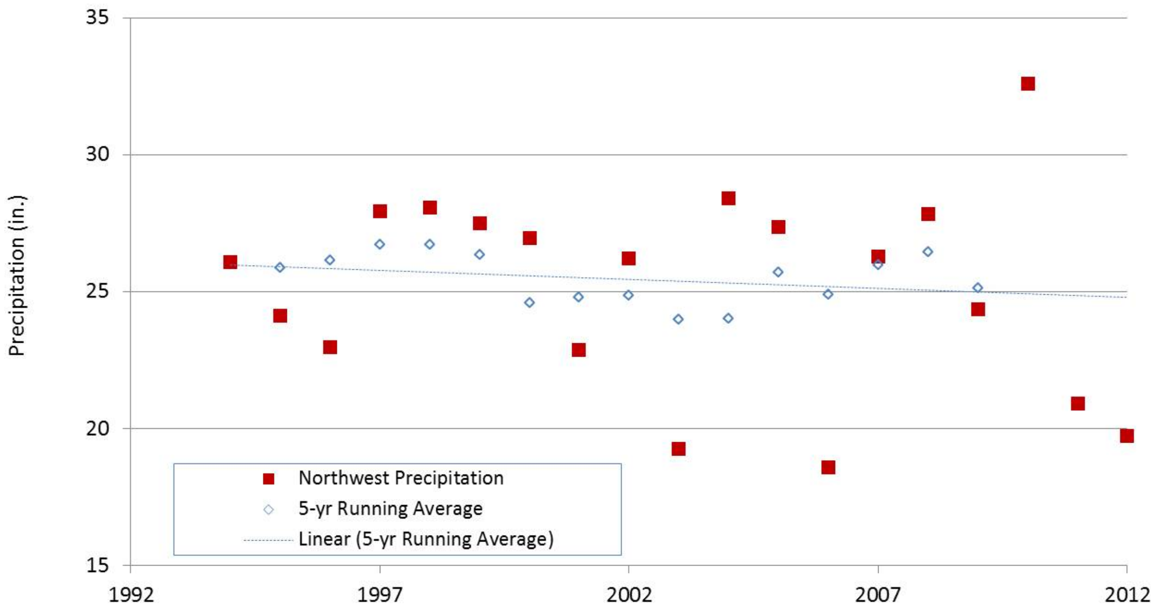

Figure 10. Precipitation trends in northwest Minnesota (1992-2012) with five year running average

Precipitation in northwest 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.

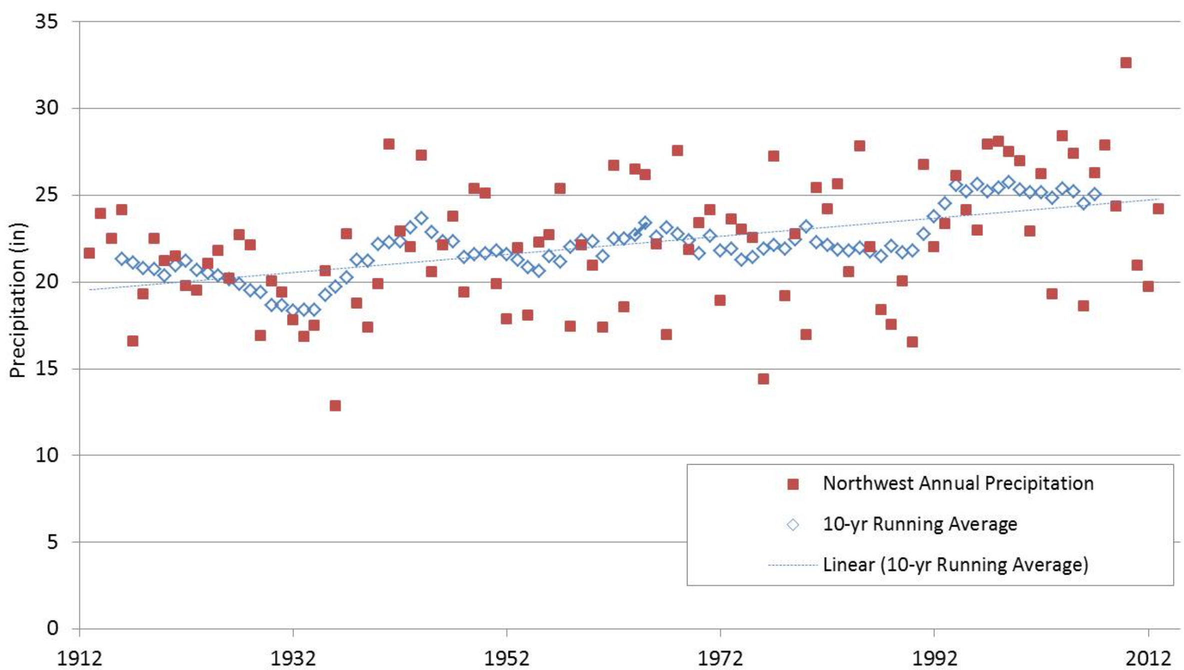

Figure 11. Precipitation trends in northwest Minnesota (1913-2013) with 10- year running average

Hydrogeology

The SHRW is located within the Lake Agassiz Basin in northwest Minnesota. This basin is composed of thick lacustrine sediments, averaging 150 to 300 feet deep and underneath up to 95 feet of silt and clay lacustrine deposits from glacial Lake Agassiz (USGS, 2013). The lake was formed in the Hudson Bay drainage during the last deglaciation, leaving behind two distinct hydrogeologic features - beach ridges and the lake plain. The beach ridges are remnants of the shorelines of Lake Agassiz, and are characterized by sandy, coarse-textured deposits and disjoined aquifers. In these disconnected aquifers, water will collect and move horizontally through the ridge and form wetlands and springs at the bases.

The lake plain aquifers are covered with thick lake deposits which are recharged primarily from areas with stagnation moraines to the east. These areas are where glaciers "stagnated", deposited coarse-grained material and left behind rough topography. These areas are important for regional groundwater recharge in the entire northwestern portion of the state; they average 5 inches of recharge per year, but can account for up to 10 inches (MPCA, 1998) and are located in the eastern portion of the SHRW.

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 SHRW, the average annual recharge rate to surficial materials is zero to two inches per year in the western portion of the watershed and 4 to 6inches per year in the eastern areas (Figure 12).

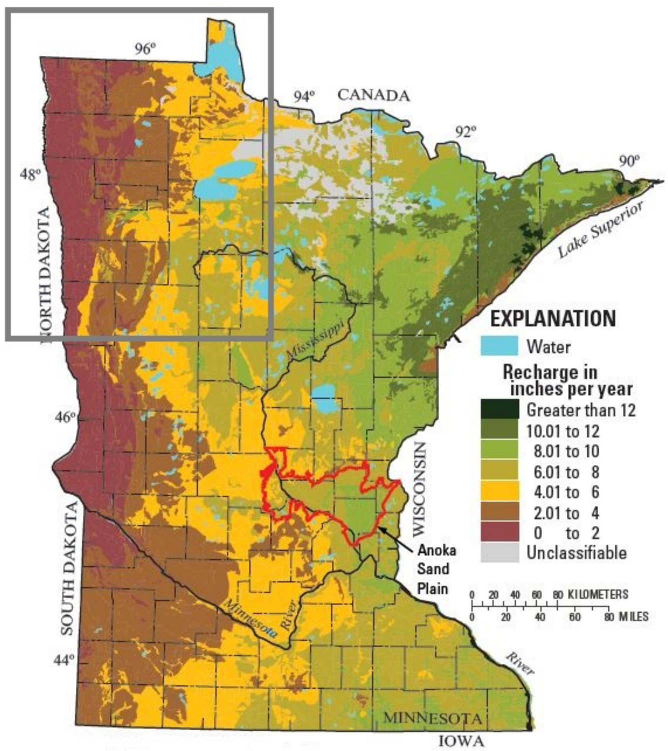

Figure 12. Average annual recharge rate to surficial materials in Minnesota (1971-2000) (USGS, 2007)

Wetlands

Wetlands are relatively uncommon in the SHRW. National Wetlands Inventory (NWI) data estimate 23,550 acres of wetlands present—which is approximately 6% of the watershed area (Figure 13). This wetland extent is below the state wetland average of 19% (Kloiber and Norris 2013). The emergent wetlands in the SHRW are typically dominated by grasses, sedges, bulrushes and/or cattails.

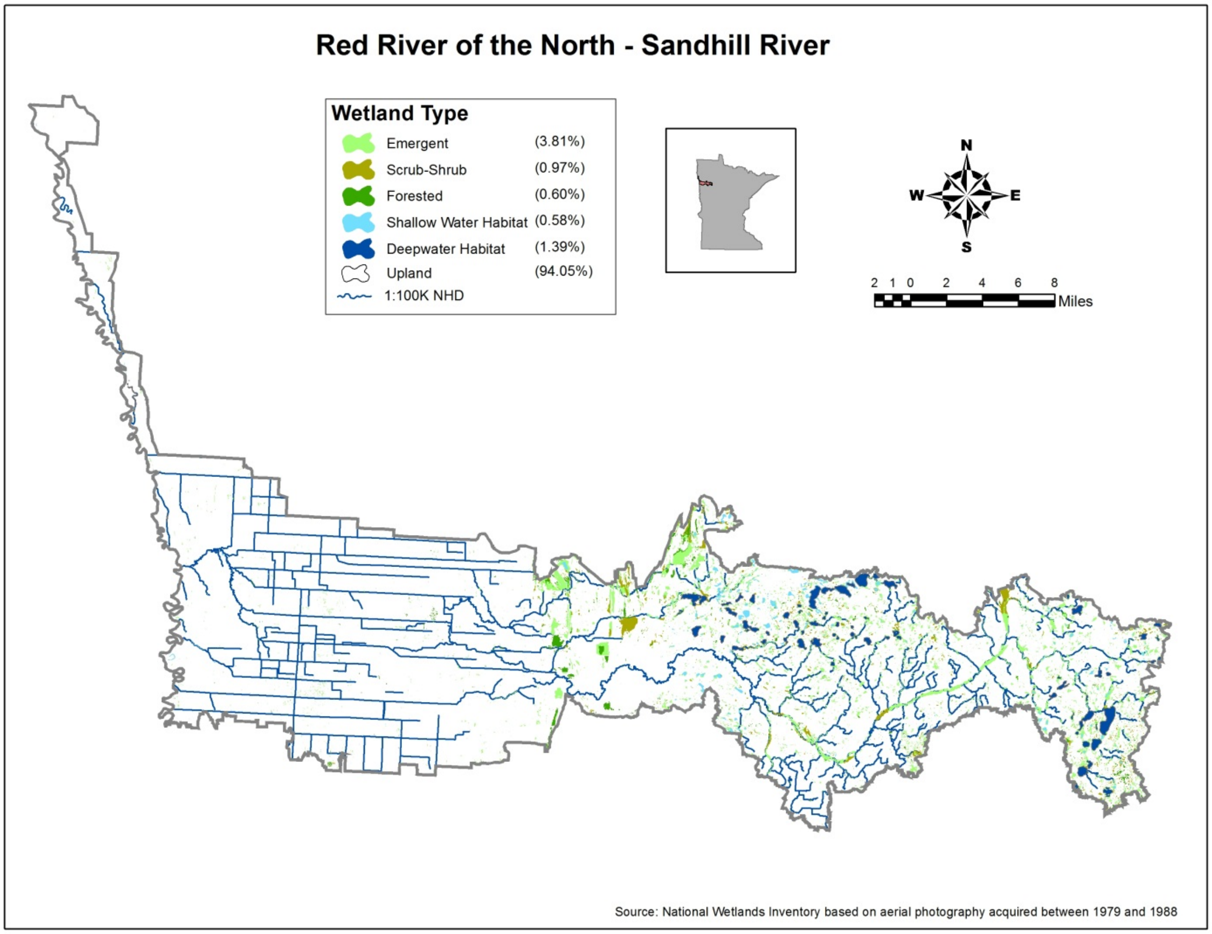

Figure 13. Wetlands and surface water in the Sand Hill River Watershed. Wetland data is from the National Wetlands Inventory

Historically, wetlands were much more prevalent in the SHRW than today. Digital soil survey data is available for the entire watershed and can be used to roughly approximate the historical wetland extent by totaling the mapped hydric soils present—which form under wetland conditions and can persist after drainage. Soil map units designated as "all hydric" total 165,171 acres or 42% of watershed. Based on this estimate and the current wetland extent estimate from NWI—the SHRW has lost approximately 86% of its wetlands. This loss rate is similar to other watersheds in the state where widespread drainage networks have been established to improve the land for agriculture.

The three predominant glacial landforms in the SHRW (MNGS, 1997) each support a prevalence of different hydrogeomorphically (HGM) functioning wetland types (Smith et al. 1995). Ground and stagnation moraines—typified by hilly terrain with many depressions caused by sediment transported/deposited during glacial advance—generally occupy the eastern half of the watershed. The predominant HGM type in this landform is depressional wetlands that receive and gather surface water from their immediate surroundings in discrete basins. Depressional wetlands may be connected to the surface water network of the watershed or they may be isolated. There are numerous areas of groundwater discharge along the narrow band of glacial lake beach ridges that create saturated soil conditions and the accumulation of peat. These are known as slope HGM type wetlands. Calcareous fens—an uncommon wetland type with alkaline (pH > 6.7) peat that supports a number of rare plant species—form where the groundwater discharge is mineral-rich. Calcareous fens are Outstanding Resource Value Waters (ORVW; Minn. R. Ch. 7050 2008; (https://www.revisor.leg.state.mn.us/rules/?id=7050) and four designated calcareous fens occur in the watershed northwest of Fertile. Finally, the glacial lake plain that occupies the western portion of the watershed historically had little capacity to drain surface water—promoting saturated soil conditions over expansive areas. The mineral flat HGM type wetlands that formed due to these factors have in large part been drained to increase agriculture production—representing the largest share of wetland losses in the watershed.

The MPCA is actively developing methods and building capacity to conduct wetland quality monitoring and assessment. Our primary approach is biological monitoring—where changes in biological communities may be indicating a response to human-caused stressors. The MPCA has developed macroinvertebrate and vegetation Indices of Biological Integrity (IBIs) for depressional wetlands. For more information about the depressional wetland IBIs (including sampling procedures), please visit: (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/wetlands/wetland-monitoring-and-assessment.html)

The MPCA currently does not monitor wetlands systematically by watershed. Alternatively, the overall status and trends of wetland quality in the state (and by level II ecoregions; White and Omernik 2007) is being tracked through probabilistic monitoring. Probabilistic monitoring refers to the process of randomly selecting sites to monitor; from which, an unbiased estimate of the resource can be made. Sites are assessed as good/fair/poor according to the plant and invertebrate IBIs independently and results are extrapolated to the estimated population of depressional wetlands. The MPCA has completed an initial baseline of depressional wetland quality (MPCA 2012; http://www.pca.state.mn.us/index.php/view-document.html?gid=17741) the results of which may be used to approximate wetland conditions in the SHRW.

Statewide there are relatively high proportions of depressional wetlands in good and fair quality when measured by the invertebrate IBI, but a more even distribution of quality—with a majority (45%) being in poor condition—when measured by the plant IBI (Table 1). The agriculturally dominated Temperate Prairies ecoregion has the lowest rates of depressional wetlands that are in good condition. Approximately half of the depressional wetlands are rated as poor for both plants and invertebrates. As the majority of the watershed (with the exception of the very eastern two-three miles) is in the Temperate Prairies ecoregion—general wetland condition for both plants and invertebrates is expected to be relatively poor in the Sand Hill.

Table 1. The relative proportions of depressional wetland condition categories (good/fair/poor) observed statewide and in the Temperate Prairies ecoregion. Proportions are based on the estimated number of wetland basins with results reported separately for plants and invertebrates.

	Plants		Invertebrates	
Condition Category	**Statewide**	**Temperate Prairies**	**Statewide**	**Temperate Prairies**
Good	30%	17%	57%	33%
Fair	25%	28%	32%	20%
Poor	45%	54%	11%	47%

A total of six depressional wetland monitoring sites have been sampled by the MPCA in the watershed (Figure 14). Results from these six sites are better than expected given the results from the broader Temperate Prairies ecoregion. Sites were rated as 4 good/0 fair/2 poor for plants and 5 good/1 fair/0 poor for invertebrates. Unfortunately, making any strong conclusions from these results to represent wetland conditions for the watershed is limited by the small sample size.

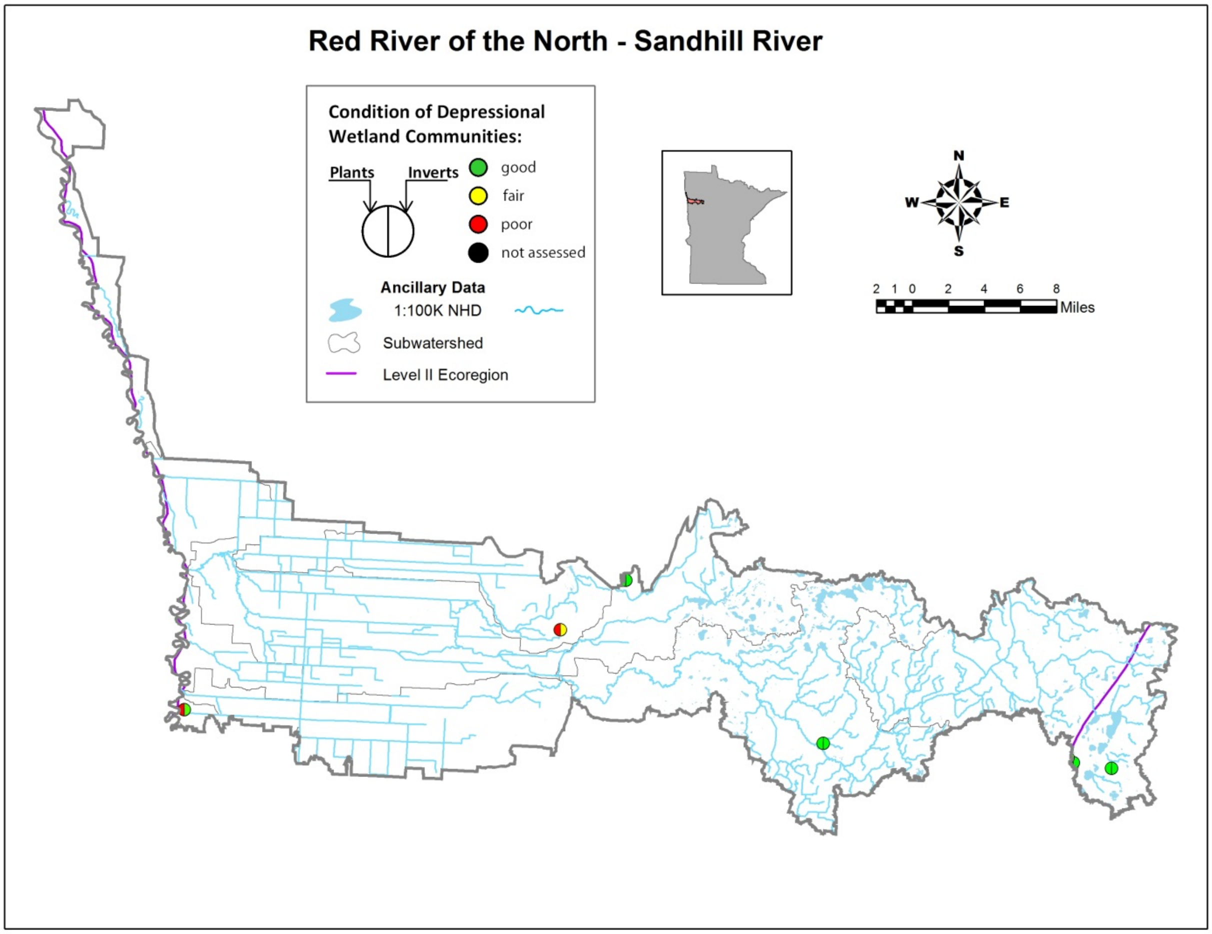

Figure 14. MPCA depressional wetland monitoring sites and condition categories for both plants and invertebrates in the Sand Hill River Watershed

IV. Watershed-wide data collection methodology

Load monitoring

Intensive water quality sampling occurs throughout the year at all WPLMN sites. Between 20 and 34 mid-stream grab samples were collected per year at the Sand Hill River on U.S. Highway 75 at Climax, (Figure 15). Because correlations between concentration and flow exist for many of the monitored analytes, and because these relationships can shift between storms or with season, computation of accurate load estimates requires frequent sampling of all major runoff events. Low flow periods are also sampled and are well represented but sampling frequency tends to be less as concentrations are generally more stable when compared to periods of elevated flow. Despite discharge related differences in sample collection frequency, this staggered approach to sampling generally results in samples being well distributed over the entire range of flows.

Annual water quality and daily average discharge data are coupled in the "Flux32," pollutant load model, originally developed by Dr. Bill Walker and recently upgraded by the USACE and the MPCA. Flux32 allows the user to create seasonal or discharge constrained concentration/flow regression equations to estimate pollutant concentrations and loads on days when samples were not collected. Primary outputs include annual and daily pollutant loads and flow weighted mean concentrations (pollutant load/total flow volume). Loads and flow weighted mean concentrations (FWMC) are calculated for total suspended solids (TSS), total phosphorus (TP), dissolved orthophosphate (DOP), and nitrate plus nitrite nitrogen ($NO_3 + NO_2$-N).

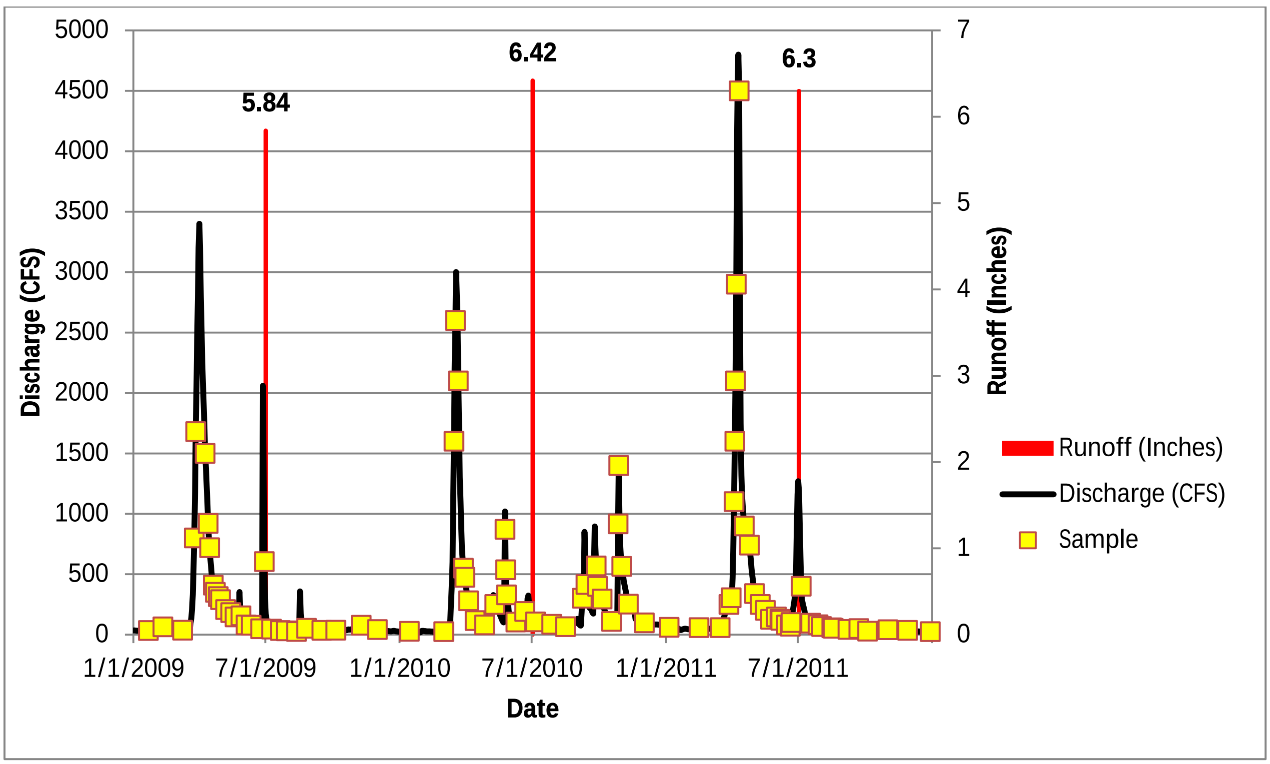

Figure 15. Hydrograph and annual runoff for the Sand Hill River near Climax (2009-2011).

Annual water quality and daily average discharge data are loaded into the "Flux32" pollutant load model to create concentration/flow regression equations. These derived equations are used to estimate pollutant concentrations and loads for days when samples were not collected. Primary outputs include: annual pollutant loads which are defined as the amount (mass) of a pollutant passing a stream location over a defined period of time and, FWMC which are an estimate of the average concentration of a pollutant within the total volume of water that passed the monitoring site during the monitoring period. Flow-weighted mean concentrations are computed by dividing the estimated annual pollutant load by the total daily flow volume.

Stream water sampling

Four water chemistry stations were sampled from May through September in 2011, and again June through August of 2012, to provide sufficient water chemistry data to assess all components of the aquatic life and recreation use standards. Following the IWM design, water chemistry stations were placed at the outlet of each HUC-11 subwatershed which was greater than 40 square miles in area (purple circles and green circles in (Figure 3). A SWAG was awarded to the International Water Institute which collected samples at all of the four stations co-located with the IWM design and water chemistry stations. See Appendix 2 for locations of stream water chemistry monitoring sites. See Appendix 1 for definitions of stream chemistry analytes monitored in this study). Three 11 HUC subwatersheds, the Red River of the North, Vineland, and Nielsville, do not contain water chemistry stations as the streams in these watersheds are very small, intermittent, and drain directly to the Red River, one of the state's five large rivers. The Red River of the North will be comprehensively monitored in 2015 and 2016 to determine aquatic life use support as part of the large river monitoring strategy. Currently there is a volunteer enrolled in the MPCA's CSMP conducting monitoring on the Sand Hill River in the Upper Sand Hill River Subwatershed. Sampling methods are similar among monitoring groups and are described in the document entitled *"Standard Operating Procedures Intensive Watershed Monitoring – Stream Water Quality Component"* found at http://www.pca.state.mn.us/index.php/view-document.html?gid=16141.

Stream biological sampling

The biological monitoring component of the IWM in the SHRW was completed during the summer of 2011. A total of 14 new sites were established across the watershed. These sites were located near the outlets of most minor HUC-14 watersheds. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2013 assessment was collected in 2011. A total of 11 AUIDs were sampled for biology in the SHRW. Waterbody assessments to determine aquatic life use support were conducted for five AUIDs. Waterbody assessments were not conducted for six AUIDs because they were primarily channelized reaches and criteria for channelized reaches had not been developed prior to the assessments. Nonetheless, the biological information that was not used in the assessment process will be crucial to the stressor identification process and will also be used as a basis for long term trend results in subsequent reporting cycles. Qualitative ratings for non-assessed reaches area included in Appendix 5.2 and Appendix 5.3.

To measure the health of aquatic life at each biological monitoring station, IBIs, specifically fish and macroinvertebrate IBIs, were calculated based on monitoring data collected for each of these communities. A fish and macroinvertebrate classification framework was developed to account for natural variation in community structure which is attributed to geographic region, watershed drainage area, water temperature and stream gradient. As a result, Minnesota's streams and rivers were divided into seven distinct warm water classes and two cold water classes, with each class having its own unique fish IBI and macroinvertebrate 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, Appendix 4.3, Appendix 5.2 and Appendix 5.3.

Fish contaminants

Mercury was analyzed in fish tissue samples collected from the Sand Hill River and Union Lake. Polychlorinated biphenyls were measured in three fish species collected by the MPCA biomonitoring staff from the river in 2011. The MDNR fisheries staff collected fish from Union Lake.

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

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

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

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

Lake water sampling

There are 39 natural lakes greater than 10 acres in the watershed. In general, lakes are located primarily in two headwater subwatersheds, the Upper Sand Hill River and Kittleson Creek. The three HUC-11 subwatersheds that do not contain chemistry stations, the Red River of the North, Vineland, and Nielsville, also do not contain assessed lakes. Most of the small lakes in the watershed have no public access and as a result, little or no historical water quality data collected. Of the 39 larger lakes in the watershed, only 11 have assessment level data. Two major lakes with assessment level data, Union and Sarah, are located outside the boundaries of an HUC-11subwatershed considered in this report, but are located within the 8 HUC boundary of the Red River of the North - Sand Hill Watershed; they will be considered along with the Upper Sand Hill River HUC-11 subwatershed for purposes of this report. Currently volunteers enrolled in the CLMP are conducting lake monitoring on these two lakes, Union and Sarah. 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.

Stream flow

The USGS maintains real-time streamflow gaging stations across the United States. The gaging station on the Sand Hill River is in Climax. Measurements can be viewed at http://waterdata.usgs.gov/nwis/rt.

V. Individual subwatershed results

HUC-11 subwatersheds

Assessment results for aquatic life and recreation use are presented for each HUC-11 subwatershed within the SHRW. The primary objective is to portray all the assessment results (i.e. waters that support and do not support their designated uses) within an 11-HUC subwatershed resulting from the complex and multi-step assessment and listing process. A summary table of assessment results for the entire 8-HUC watershed including aquatic consumption, and drinking water assessments (where applicable) is included in Appendix 3.1. This scale provides a robust assessment of water quality condition at a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The graphics presented for each of the HUC-11 subwatersheds contain the assessment results from the 2013 assessment cycle as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2011 IWM effort, but also considers available data from the last 10 years.

The proceeding pages provide an account of each HUC-11 subwatershed. Each account includes a brief description of the subwatershed, and summary tables of the results for each of the following: a) stream aquatic life and aquatic recreation assessments, b) biological condition of channelized streams and ditches, c) stream habitat quality d) channel stability, and where applicable e) water chemistry for the HUC-11 outlet, and f) lake aquatic recreation assessments. Following the tables is a narrative summary of the assessment results and pertinent water quality projects completed or planned for the subwatershed. A brief description of each of the summary tables is provided below.

Stream assessments

A table is provided in each section summarizing aquatic life and aquatic recreation assessments of all assessable stream reaches within the subwatershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2013 assessment process (2014 EPA reporting cycle). Impairments from previous assessment cycles are also included and are distinguished from new impairments via cell shading (see footnote section of each table). These tables also denote the results of comparing each individual aquatic life and aquatic recreation indicator to their respective criteria (i.e., standards); determinations made during the desktop phase of the assessment process (see Figure 5). Assessment of aquatic life is derived from the analysis of biological (F-IBIs and M-IBIs), DO, turbidity, chloride, pH and un-ionized ammonia (NH_3) data, while the assessment of aquatic recreation in streams is based solely on bacteria (*Escherichia coli or fecal coliform*) data. Included in each table is the specific aquatic life use classification for each stream reach: cold water community (2A); cool or warm water community (2B); or indigenous aquatic community (2C). Stream reaches which do not have sufficient information for either an aquatic life or aquatic recreation assessment (from current or previous assessment cycles) are not included in these tables, but are included in Appendix 5.2 and Appendix 5.3. Where applicable and sufficient data exists, assessments of other designated uses (e.g., class 7, drinking water, aquatic consumption) are discussed in the summary section of each HUC-11 subwatershed as well as in the Watershed-Wide Results and Discussion section.

Channelized stream evaluations

Biological criteria has not been developed yet for channelized streams and ditches, therefore, assessment of fish and macroinvertebrate community data for aquatic life use support is not yet possible for channelized streams in Minnesota. Though not an official assessment of aquatic life, a separate table within each HUC-11 summary provides a narrative rating of the condition of fish and macroinvertebrate communities at channelized streams based on the IBI results. The narrative ratings are based on aquatic life use assessment thresholds for each individual IBI class (see Appendix 5.1).

Index of Biotic Integrity scores above this threshold are given a "good" rating, scores falling below this threshold by less than ~15 points (i.e., value varies slightly by IBI class) are given a "fair" rating, and scores falling below the threshold by more than ~15 points are given a "poor" rating. For more information regarding channelized stream evaluation criteria refer to Appendix 5.1.

Stream habitat results

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

Stream stability results

Stream channel stability information evaluated during each macroinvertebrate sampling visit is provided in each HUC-11 subwatershed section. These tables display the results of the Channel Condition and Stability Index (CCSI) which rates the geomorphic stability of the stream reach sampled for biology. The CCSI rates three regions of the stream channel (upper banks, lower banks, and bottom) which may provide an indication of stream channel geomorphic changes and loss of habitat quality 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 the 2011 biological visits. The final row in each table displays the average CCSI scores and a rating for the HUC-11 watershed.

Watershed outlet water chemistry results

These summary tables display the water chemistry results for the monitoring station representing the outlet of the HUC-11 watershed. 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 SHRW 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 HUC-11 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 6.2.

Nielsville Subwatershed HUC 09020301090

The Nielsville Subwatershed, located in Norman and Polk counties, encompasses 75.3 square miles. This subwatershed is dominated by channelized streams that drain to the Red River of the North. From north to south within this watershed, these ditches include County Ditch (CD) 77, Judicial Ditch (JD) 52 and JD 54. JD 77 starts one half mile downstream of County State Aid Highway (CSAH) 74 and flows west 10 miles to its confluence with the Red River of the North. JD 2 is located one mile south of JD 77 along the Polk and Norman county border. JD 2 starts in the northeastern corner of the subwatershed and flows 13 miles west to its confluence with CD 57. Following this confluence, the ditch switches names to JD 52 and flows an additional 6.5 miles west to its confluence with the Red River of the North. Continuing toward the south, JD 54 is located 1 mile south of the Polk and Norman county line. JD 54 starts 1 mile downstream of Highway 9 and parallels 330th Avenue for 13.5 miles to its confluence with the Red River of the North. Land cover within this subwatershed is dominated by row crop agriculture (92%) and developed land associated with farming (4.4%). The remaining land use consists of wetlands (1.8%), forest (0.5%) and range (0.2%). Nielsville is the only town within the watershed boundaries. Due to the intermittent nature of these streams, no biological monitoring stations were sampled and no water chemistry station was established.

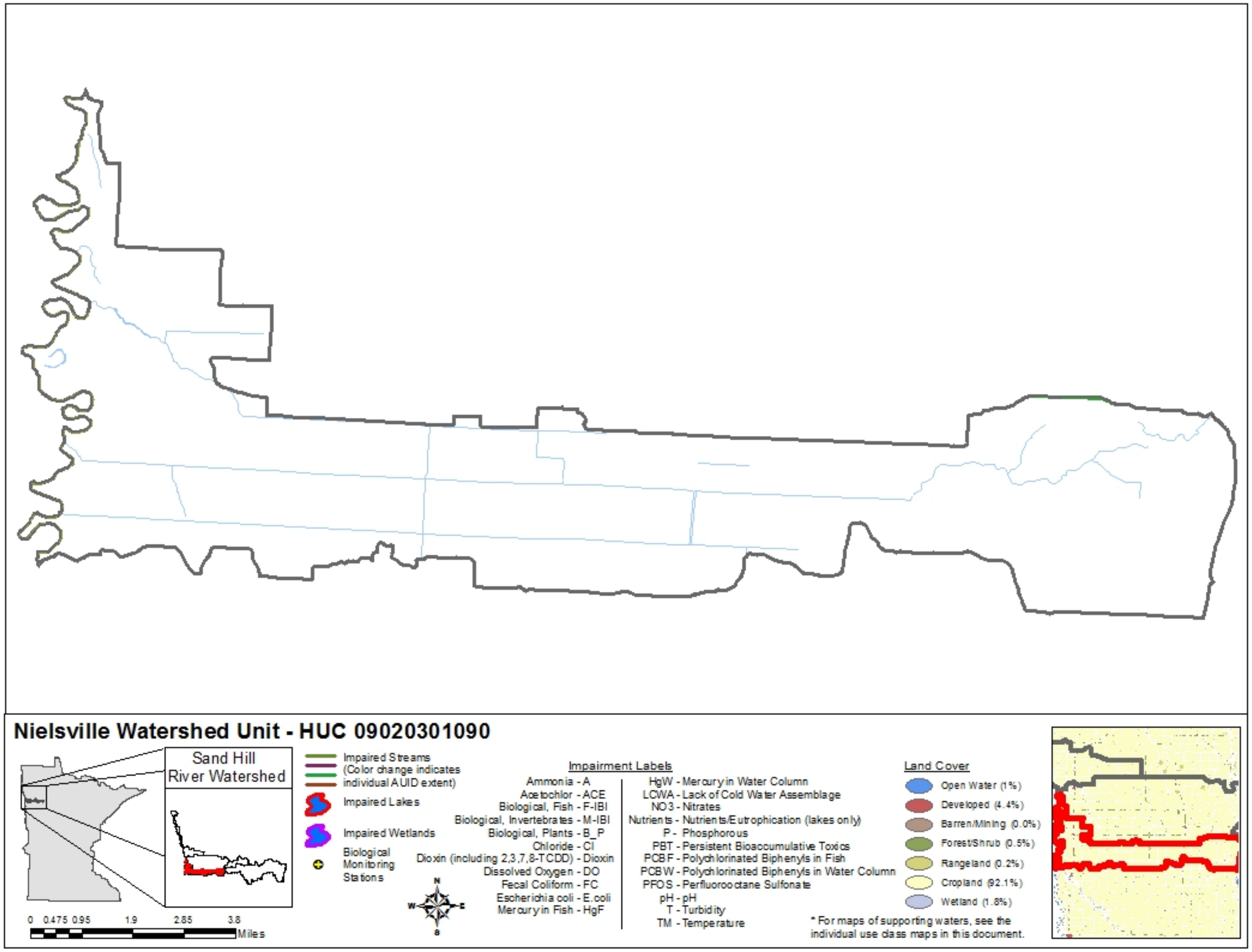

Figure 16. Currently listed impaired waters by parameter and land use characteristics in the Nielsville Subwatershed

Upper Sand Hill River Subwatershed HUC 09020301100

The Upper Sand Hill River Subwatershed is located in Polk, Norman, and Mahnomen counties. Encompassing an area of 231 square miles, the subwatershed is the largest within the Sand Hill River HUC-8 Watershed. As the name implies, the Upper Sand Hill River Subwatershed contains the headwaters of the Sand Hill River, which originates at Sand Hill Lake. After flowing out of Sand Hill Lake, the Sand Hill River travels 101 miles to its confluence with the Red River of the North, 1.5 miles southwest of Climax. Much of the Sand Hill River within this subwatershed has not been channelized; however many of its tributaries have been historically channelized to assist in drainage. The tributaries include: CD 16, CD 17 (Garden Slough), Maple Creek and numerous unnamed ditches that eventually drain into the Sand Hill River. Land use within this subwatershed is predominately cropland (60.6%). A significant amount of range (11.3%), wetlands (10.6%) and forest (8.9%) also exist within the subwatershed. Two intensive water chemistry stations were established in the subwatershed on the Sand Hill River (11RD014, 11RD009).

Table 2. Aquatic life and recreation assessments on streams reaches in the Upper Sand Hill River Subwatershed. Reaches are organized downstream to upstream in the table.

AUID ***Reach Name,*** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Aquatic Life Indicators:** Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	**Aquatic Life**	**Aquatic Rec.**
09020301-542 ***Sand Hill River*** *CD 17 to Kittleson Creek*	32.09	2B	11RD014 11RD070 11RD071	Upstream of 450th St SW, 3 mi. SW of Fertile Downstream of 110th Ave SE, 2 mi. NE of Fertile Upstream of CSAH 1 (440th Ave SE), 5 mi. E of Fertile	EXS	MTS	IF	MTS	MTS	MTS	MTS	--	EX	NS	NS
09020301-541 ***Sand Hill River*** *Headwaters to CD 17*	38.13	2B	05RD052 11RD002** 11RD009	Upstream of 260th Ave SE, ~8 miles SE of Fosston Upstream of CSAH 1 (320th Ave SE), 2.5 mi. SW of Fosston Upstream of CR 107, 3 mi. SW of Winger	EXS	EXS	EXP	EXS	MTS	MTS	MTS	--	EX	NS	NS
09020301-515 ***County Ditch 17*** *Garden Slough to Sand Hill River*	0.28	2B	11RD012	Upstream of 450th St SE, 1.5 mi. NW of Rindall	MTS	EXP	--	--	--	--	--	--	--	NS	NA
09020301-539 ***Unnamed Creek*** *Unnamed Creek to Sand Hill River*	2.04	2B	11RD008	Downstream of 350th Ave SE, 2 mi. SW of Winger	NA	NA	--	--	--	--	--	--	--	NA*	NA

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

Table 3. Non-assessed biological stations on channelized AUIDs in the Upper Sand Hill River Subwatershed.

AUID ***Reach Name,*** *Reach Description*	Reach length (miles)	Use Class	Biological Station ID	Location of Biological Station	Fish IBI	Invert IBI
09020301-541 ***Sand Hill River*** *Headwaters to CD 17*	38.13	2B	11RD002	Upstream of CSAH 1 (320th Ave SE), 2.5 mi. SW of Fosston	Good	Poor
09020301-538 ***County Ditch 48*** *Unnamed Creek to Sand Hill River*	3.85	2B	11RD001	Upstream of CSAH 1 (320th Ave SE), 2 mi. SW of Fosston	Good	Fair
09020301-540 ***County Ditch 55*** *Upstream of 290th St SE, 4.5 mi. NW of Fosston*	3.07	2B	11RD004	Upstream of 290th St SE, 4.5 mi. NW of Fosston	Fair	--
09020301-512 ***County Ditch 16*** *CD 55 to Sand Hill River*	2	2B	07RD003 11RD003	Upstream of CSAH 31 (410th St SE), 5 mi. W of Fosston Downstream of CSAH 31, 4 mi. S of New Munich	Good Good	Fair Good
09020301-539 ***Unnamed Creek*** *Unnamed Creek to Sand Hill River*	2.04	2B	11RD008	Downstream of 350th Ave SE, 2 mi. SW of Winger	Good	--

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 4.3 for IBI results.

Table 4. Minnesota Stream Habitat Assessment (MSHA) for the Upper Sand Hill 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	05RD052	Sand Hill River	0	6	10.75	6	11	33.75	Poor
2	07RD003	County Ditch 16	0	11	20	15	19	65	Fair
3	11RD001	County Ditch 48	0	5	14.4	11	16	46.4	Fair
4	11RD002	Sand Hill River	0	5	14	14	16	49	Fair
5	11RD003	County Ditch 16	0	10	16	11	8	45	Fair
6	11RD004	County Ditch 55	1.75	6	9	7	5	28.75	Poor
7	11RD008	Trib. to Sand Hill River	0	13	26.8	17	27	83.8	Good
8	11RD009	Sand Hill River	1.25	10	10.75	12	18	52	Fair
9	11RD012	Garden Slough	1.25	12	11.5	16	16	56.75	Fair
10	11RD014	Sand Hill River	5	14	19	12	28	78	Good
11	11RD070	Sand Hill River	0	8.5	10	16	20	54.5	Fair
12	11RD071	Sand Hill River	0	6	10.2	16	23	55.2	Fair
Average Habitat Results: *Upper Sand Hill River Subwatershed*			**1.23**	**9.15**	**14.88**	**11.45**	**17.35**	**54.05**	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 5. Channel Condition and Stability Assessment (CCSI) for the Upper Sand Hill River Subwatershed.

# Visits	Biological Station ID	Stream Name	Stream Type	Upper Banks (43-4)	Lower Banks (46`-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11RD009	Sand Hill River	MHL	5	5	9	3	22	Stable
1	11RD012	Garden Slough	MHL	15	22	22	4	63	Moderately Unstable
1	11RD014	Sand Hill River	MHL	22	21	8	4	55	Moderately Unstable
1	11RD070	Sand Hill River	MHL	19	22	14	3	58	Moderately Unstable
1	11RD071	Sand Hill River	MHL	24	21	28	3	76	Moderately Unstable
Average Stream Stability Results: *Upper Sand Hill River Subwatershed*				**17**	**18.2**	**16.2**	**3.4**	**54.8**	**Moderately Unstable**

Qualitative channel stability ratings
= Stable: CCSI < 27 = Fairly stable: 27 < CCSI < 45 = Moderately unstable: 45 < CCSI < 80 = Severely unstable: 80 < CCSI < 115 = Extremely unstable: CCSI > 115

Table 6. Lake water aquatic recreation assessments: Upper Sand Hill River Subwatershed.

Name	DNR Lake ID	Area (acres)	Trophic Status	% Littoral	Max. Depth (m)	Avg. Depth (m)	CLMP Trend	Mean TP (µg/L)	Mean chl-a (µg/L)	Secchi Mean (m)	Support Status
Ketchum	44-0152-00	156	E	100	5.2	1.5		87	67.0	0.4	NS
Allen	44-0157-00	145	M	100	1.0	1.0		24	3.1	0.8	FS
Simonson	44-0162-00	107	M	100		1.0		17	2.1	2.5	FS
Sand Hill	60-0069-00	483	E	100	5.2	1.5		40	12.6	1.2	FS
Unnamed	60-0078-00	16	O					10	2.2	1.4	IF
Hilligas	60-0093-00	132	E	100	2.4	1.0		40	12.2	1.2	FS
Uff	60-0119-00	129	H	100	2.4	1.0		131	69.7	0.3	NS
Sarah	60-0202-00	310	E	51	8.2	3.8	NT	26	127.0	2.9	FS
Union	60-0217-00	799	M	48	25.3	5.7	NT	19	5.0	2.9	IF
Unnamed	60-0234-00	108	E								IF
Unnamed	60-0236-00	118	E	100	3.6	1.0		69	45.0	0.5	NS
Rindahl	60-0238-00	29	M					20	4.9	1.8	IF
Arthur	60-0309-00	120	E	100	4.9	1.0		53	19.7	1.3	FS

Table 7. Outlet water chemistry results Upper Sand Hill River Subwatershed (1).

Station location	**Sand Hill River at County Road 107 (100th St) 2.5 miles southwest of Winger, MN**
STORET/EQuIS ID	**S006-559**
Station #	**11RD009 / 09020301-541**

Parameter	Units	# of Samples	Minimum	Maximum	Mean	WQ Standard[1]	# of WQ Exceedances[2]
Ammonia-nitrogen	mg/L	5	0.0002	0.0022	0.0009	0.04	
Chloride	mg/L	5	9.6	14.0	11.8	230	
Dissolved Oxygen (DO)	mg/L	23	1.9	12.0	5.9	5	9
pH		23	7.6	8.4	8.0	6.5-9	
Secchi tube/Transparency Tube	100 cm	23	6	67	19	>20	17
Turbidity	FNU	23	2.7	98.0	42.5	25	18
Escherichia coli (Geometric Mean)	MPN/100 ml	15	110	208	-	126	3
Escherichia coli	MPN/100ml	15	133	2420	894	1260	4
Inorganic nitrogen (nitrate and nitrite)	mg/L	20	0.0	1.5	0.3		
Kjeldahl nitrogen	mg/L	20	0.4	1.5	1.0		
Phosphorus	ug/L	20	40	288	144		
Specific Conductance	uS/cm	23	537	782	698		
Temperature, water	deg °C	23	11.6	26.5	19.9		
Total suspended solids	mg/L	20	7	81	40		
Total volatile solids	mg/L	20	3	21	9		

[1]Total suspended solids and Transparency tube standards are surrogate standards derived from the turbidity standard of 25.

****Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Upper Sand Hill River Subwatershed, a component of the IWM work conducted in 2011 and 2012. This specific data does not necessarily reflect all data that was used to assess the AUID.**

Table 8. Outlet water chemistry results Upper Sand Hill River Subwatershed (2).

Station location	Sand Hill River at 350th Ave SW, 4 miles southwest of Fertile, MN						
STORET/EQuIS ID	S003-136						
Station #	11RD014/ 09020301-542						
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**# of WQ Exceedances[2]**
Ammonia-nitrogen	mg/L	4	0.0003	0.0043	0.0018	0.04	
Chloride	mg/L	5	8.5	24.9	14.0	230	
Dissolved Oxygen (DO)	mg/L	36	7.1	12.7	10.4	5	
pH		36	7.8	8.5	8.2	6.5-9	
Secchi tube/Transparency Tube	100 cm	35	23	100	81	>20	
Turbidity	FNU	36	0.1	24.9	3.9	25	
Escherichia coli (Geometric Mean)	MPN/100 ml	12	36	255	-	126	1
Escherichia coli	MPN/100ml	12	25	326	100	1260	
Chlorophyll-a, Corrected	ug/L	16	2	12	5		
Inorganic nitrogen (nitrate and nitrite)	mg/L	35	0.0	3.9	0.3		
Kjeldahl nitrogen	mg/L	35	0.3	3.4	0.8		
Orthophosphate	ug/L	15	0.008	0.115	0.040		
Pheophytin-a	ug/L	16	1	7	2		
Phosphorus	ug/L	35	29	241	83		
Specific Conductance	uS/cm	36	563	830	651		
Temperature, water	deg °C	36	-0.04	28.30	17.30		
Total suspended solids	mg/L	35	2	64	9		
Total volatile solids	mg/L	35	1	15	3		

[1]Total suspended solids and Transparency tube standards are surrogate standards derived from the turbidity standard of 25.

****Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Upper Sand Hill River Subwatershed, a component of the IWM work conducted in 2011 and 2012. This specific data does not necessarily reflect all data that was used to assess the AUID**

Summary

Twelve biological monitoring stations were sampled in the Upper Sand Hill River Subwatershed. Six of the stations were not channelized and therefore used for assessment. Within this subwatershed the Sand Hill River is split into two AUIDs with very different habitats. From its headwaters to Garden Slough (AUID 09020301-541), the Sand Hill River flows through a vast wetland; the river is shallow, slow moving, and by dominated fine substrates. Downstream of CD 17 (AUID 09020301-542) along the beach ridges, the river picks up significant gradient. This section of the Sand Hill River has good channel development (riffle, run, pool) and can potentially provide spawning and seasonal habitat for migratory fish.

Immediately downstream of this subwatershed, the Sand Hill River becomes channelized. In an attempt to control drainage and reduce flooding, four grade control structures (drop structures) were installed along a five mile stretch of the Sand Hill River immediately downstream of this subwatershed. While structures like these can benefit drainage and reduce flooding, they also alter hydrologic connectivity. The structures restrict the movement of migratory fish causing changes in population dynamics and community structure (Brooker, 1981; Tiemann et al., 2004).

Three biological stations (11RD014, 11RD070, 11RD071) were sampled for fish and invertebrates (See Figure 17) on the lowest reach of the Upper Sand Hill River mainstem. The lowest station (11RD014) has an excellent MSHA score (78), good numbers of an intolerant minnow species (longnose dace), and the highest F-IBI score of the three stations on this AUID. However, this station lacks the longer lived, migratory species normally found in streams of this size (e.g. redhorse, smallmouth bass, walleye). Consequently, all three stations had impaired fish communities. In contrast, the macroinvertebrate communities were better. Two of the three stations (11RD014, 11RD070) sampled for macroinvertebrates were very good (i.e. scores were above the upper confidence interval). In fact, the middle station (11RD070) had the highest score in the entire Sand Hill River HUC-8 watershed (75). These high scores are likely a result the abundance and diversity of several sensitive macroinvertebrate taxa; namely mayflies from the genera *Baetis* sp., *Baetisca*, *Labiobaetis*, *Maccaffertium*, *Procloeon* and *Iswaeon* and caddisflies from the genera*Ceratopsyche sp.*, *Oecetis*, *Brachycentrus* and *Polycentropus.* The absence of migratory fish species combined with the relatively good macroinvertebrate community data on the main stem Sand Hill River suggests (AUID 09020301-542) that a loss in connectivity (longitudinal) from fish barriers in the upper section of the Lower Sand Hill River Subwatershed may be contributing to the impairment of the fish community along AUID 09020301-542.

The fish and macroinvertebrate impairment along the Sand Hill River from the Headwaters to CD 17 (09020301-542) could also be affected by the fish barriers, however, it appears other factors such as low DO, high levels of turbidity, high levels of nutrients, lack of suitable habitat (absence of coarse substrates), lack of flow and warm water temperatures appear to be contributing factors. Macroinvertebrate communities collected throughout this AUID are dominated by many tolerant and ubiquitously occurring taxa; namely snails from the genera *Ferrissia*, *Physa* and *Valvata*, *Oligochaeta*, midges from the genera *Chironomus*, *Dicrotendipes*, *Parakiefferiella* and *Polypedilum* and mayflies from the genera *Caenis*, *Callibaetis*, *Tricorythodes* and *Pseudocloeon*. The fish communities are dominated by species that are highly tolerant to low DO including fathead minnow, brook stickleback and yellow perch.

Stream water quality data were available to assess two reaches of the Sand Hill River - from the headwaters to CD 17 and then downstream to Kittleson Creek (AUID 09020301-542). The 38-mile reach from the headwaters to CD 17 (AUID 09020301-541) was previously impaired for aquatic life use due to DO and turbidity exceedances; these impairments continue with this assessment cycle. In addition, this segment does not support aquatic recreation due to three geometric mean E. coli exceedances. Downstream, the segment of the Sand Hill River from CD 17 to Kittleson Creek was also found to be impaired for aquatic recreation due to elevated bacteria; however, current DO and turbidity data are meeting aquatic life standards.

The Upper Sand Hill River Subwatershed is the most lake-rich subwatershed in the SHRW. Thirteen of the thirty-one lakes over 10 acres were reviewed for aquatic recreation (Table 6). With the exception of lakes Union and Sarah, the lakes are predominantly shallow basins. Rindahl, Union, and an unnamed lake in the headwaters (60-0078-00) all had insufficient data to assess. One additional year of data collection is needed to assess Union lake but the limited data set currently shows it is meeting standards. Union Lake has one of the longest continuous Secchi records in the CLMP with over 29 years of transparency data. This transparency data, collected by volunteers on Union, currently shows no trend. Detailed reports of the advanced citizen lake monitoring conducted on Union Lake were produced in 2007. Union is scheduled to be monitored in 2014.

Three of the nine assessed lakes had elevated phosphorus and chlorophyll-a concentrations which exceeded the water quality standards. The three lakes - Ketchum, Uff, and an Unnamed (60-0236-00) lake - are located in the northwest portion of the drainage area. The other six lakes were found to support aquatic recreation use as they met the eutrophication standards. Allen, Simonson, Sand Hill, Hilligas, and Arthur are shallow lakes (Table 6) and all met the shallow lake standards. Sarah was the only "deep" lake assessed within this watershed and it met the corresponding lake eutrophication standards.

It will be important to ensure the water quality of those lakes which met standards is protected so no measurable degradation occurs. Arthur Lake is notable in this regard as its phosphorus and chlorophyll-a concentrations are very close to the water quality standards and relatively small increases in phosphorus could cause the lake to become impaired. Most of the lakes which meet the eutrophication standards are in a headwaters region with relatively intact watersheds and moderate amounts of forest and wetlands. However, conversion of forest to cropland and/or developed land uses can increase nutrient loads to the lakes, which would have a detrimental impact on the quality and uses of these lakes. This is particularly true for the shallow lakes which have limited ability to assimilate nutrients, and can exhibit increased algal blooms and excessive plant growth as a result of increased nutrient loading.

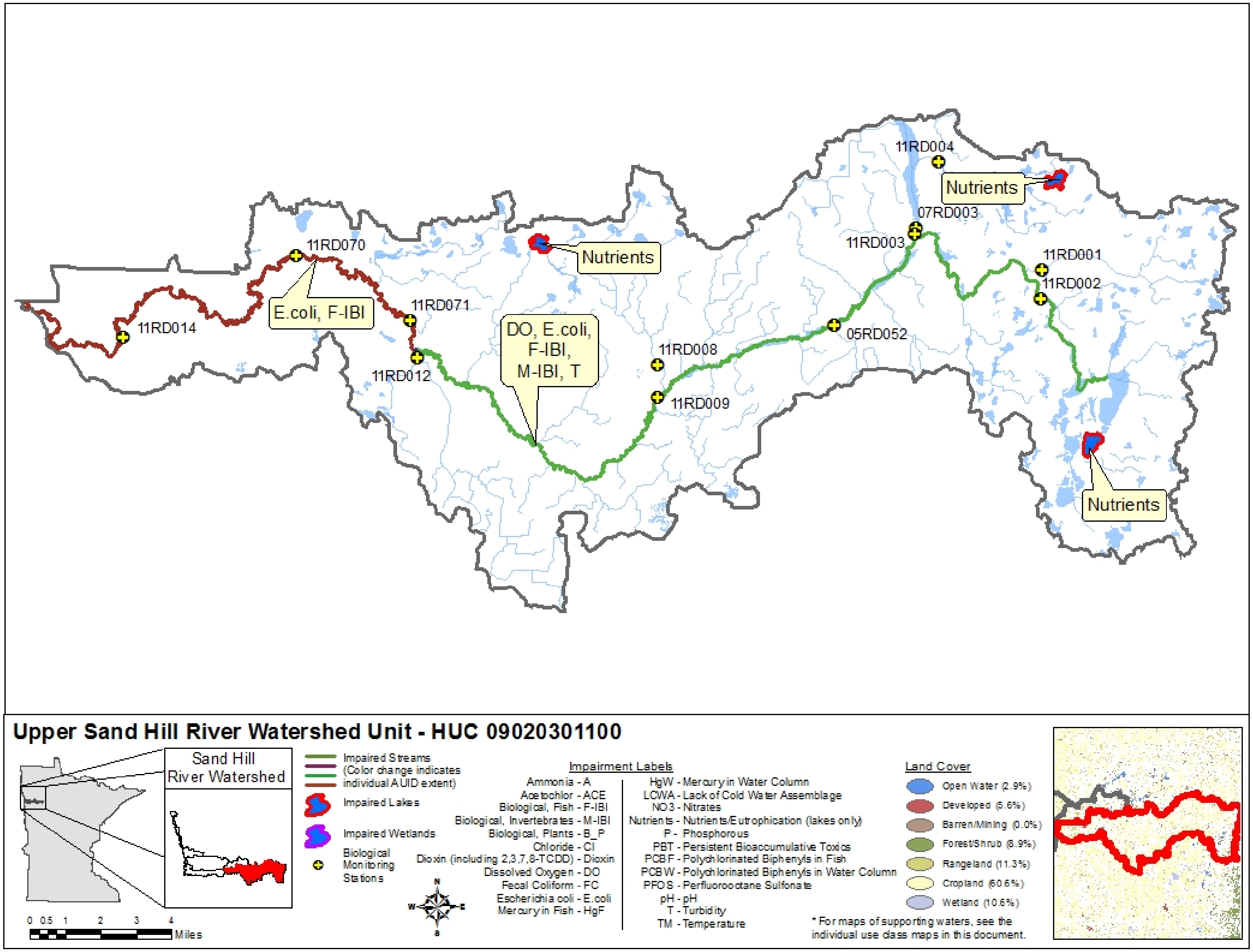

Figure 17. Currently listed impaired waters by parameter and land use characteristics in the Upper Sand Hill River Subwatershed

Kittleson Creek Subwatershed HUC 09020301110

The Kittleson Creek Subwatershed, located in Polk County, encompasses 39.8 square miles. Kittleson Creek originates in Kittleson Lake and travels 12.4 miles southwest to its confluence with the Sand Hill River, 5.5 miles west of Fertile. There are no major tributaries to Kittleson Creek, only small unnamed ditches that become dry or intermittent during summer months. Nearly half of the land use within the watershed is row crop (45.4%) or range (11.6%). The remaining land use consists of wetland (16.6%), forest (11.6%), open water (7.0%), and developed (4.7%). The majority of open water and forest occur in the far northeastern portion of this subwatershed where small unnamed lakes with wooded shoreline dominate the area. Notable lakes include Kittleson Lake, Halverson Lake and Lake Arthur. There are no towns within the watershed. The water chemistry monitoring station (11RD015) on Kittleson Creek is located off the County Hwy 1 Bridge crossing 5.5 mi. NW of Fertile.

Table 9. Aquatic life and recreation assessments on streams reaches in the Kittleson Creek Subwatershed. Reaches are organized downstream to upstream in the table.

AUID ***Reach Name,*** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Aquatic Life Indicators:** Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	**Aquatic Life**	**Aquatic Rec.**
09020301-508 ***Kittleson Creek*** *Headwaters to Sand Hill River*	12.44	2C	05RD107 11RD015**	Upstream of Hwy 32 S, 2.5 mi. N of Fertile Upstream of CSAH 1 (430th St SW), 5.5 mi. W of Fertile	MTS	MTS	IF	MTS	MTS	MTS	MTS	--	MTS	FS	FS

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

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

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

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

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

Table 10. Non-assessed biological stations on channelized AUIDs in the Kittleson Creek Subwatershed.

AUID ***Reach Name,*** *Reach Description*	Reach length (miles)	Use Class	Biological Station ID	Location of Biological Station	Fish IBI	Invert IBI
09020301-508 ***Kittleson Creek*** *Headwaters to Sand Hill River*	12.44	2C	11RD015	Upstream of CSAH 1 (430th St SW), 5.5 mi. W of Fertile	Poor	--

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 4.3 for IBI results.

Table 11. Minnesota Stream Habitat Assessment (MSHA) for the Kittleson Creek Subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
2	05RD107	Kittleson Creek	4.4	11.5	14.3	9	29	68.18	Good
1	11RD015	Kittleson Creek	4	12	15.25	13	10	54.25	Fair
Average Habitat Results: *Kittleson Creek Subwatershed*			**4.19**	**11.75**	**14.78**	**11**	**19.5**	**61.21**	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 12. Outlet water chemistry results: Kittleson Creek Subwatershed.

Station location	Kittleson Creek at 330th Ave., southwest crossing, 5.6 miles west of Fertile, MN						
STORET/EQuIS ID	S004-187						
Station #	09020301-508						
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**# of WQ Exceedances[2]**
Ammonia-nitrogen	mg/L	2	0.0022	0.0033	0.0028	0.04	
Chloride	mg/L	5	4.6	6.3	5.3	230	
Dissolved Oxygen (DO)	mg/L	48	5.3	13.1	8.9	5	
pH		48	7.5	8.4	7.9	6.5 - 9	
Secchi tube/Transparency Tube	100 cm	47	14	100	69	>20	1
Turbidity	FNU	48	0.1	43.3	7.8	25	1
Escherichia coli (geometric mean)	MPN/100ml	21	51	101		126	
Escherichia coli	MPN/100ml	21	11	1553	186	1260	1
Chlorophyll-a, Corrected	ug/L	14	1	16	4		
Inorganic nitrogen (nitrate and nitrite)	mg/L	31	0.0	1.3	0.1		
Kjeldahl nitrogen	mg/L	31	0.4	1.8	0.8		
Orthophosphate	ug/L	15	0.008	0.152	0.031		
Pheophytin-a	ug/L	14	1.0	2.0	1.1		
Phosphorus	ug/L	31	0.0	0.3	0.1		
Specific Conductance	uS/cm	48	315	998	492		
Temperature, water	deg °C	48	0.4	26.5	16.6		
Total suspended solids	mg/L	31	1	104	14		
Total volatile solids	mg/L	31	2	21	4		

[1]Secchi Tube/Transparency tube standards are surrogate standards derived from the turbidity standard of 25.

****Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Kittleson Creek Subwatershed, a component of the IWM work conducted between May and September in 2011 and 2012. This specific data does not necessarily reflect all data that was used to assess the AUID.**

Table 13. Lake water aquatic recreation assessments: Kittleson Creek Subwatershed.

Name	DNR Lake ID	Area (acres)	Trophic Status	% Littoral	Max. Depth (m)	Avg. Depth (m)	CLMP Trend	Mean TP (µg/L)	Mean chl-a (µg/L)	Secchi Mean (m)	Support Status
Unnamed	60-0281-00	12.1	M					13	3.0	3.4	IF
Kittleson	60-0327-00	297.5	E	100	2.4	1		86.8	35.1	0.4	NS
Halverson	60-0228-00	154.4	E	100	3.9	1		56	16.4	1.1	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

Summary

Two biological monitoring stations were sampled on Kittleson Creek (AUID-09020301-508) but only one (05RD107) was unchannelized. The biological communities are generally good, and the excellent habitat conditions are likely contributing to these results. Station 05RD107 had excellent channel morphology that consisted of good channel development, clean course substrate and various types of flow velocities (fast, moderate, slow, eddies). All of these factors provide a suitable habitat for lithophilic spawners (darter species). The macroinvertebrate sample consisted of a few intolerant/ sensitive taxa, mainly caddisflies.

The channelized reach's station (11RD015) was visited once for fish monitoring and given a rating of poor. Low water levels during late fall prevented the collection of macroinvertebrates. In spite of the poor fish results the habitat was at this station was better than expected. A low score for channel morphology is driving the overall MSHA score down at this site. This is not unexpected as channelized stations typically have lower channel morphology metric scores for sinuosity, channel development, depth variability and flow velocity. However, the other stream habitat variables at this site were good and indicated there is some stability with the habitat in this stream. Similar to the Upper Sand Hill River Subwatershed, the Kittelson Creek Subwatershed is upstream of the drop control structures. The drop control structures are likely impacting fish communities in Kittleson Creek.

Water quality data were available along Kittelson Creek from the headwaters to the Sand Hill River. Kittelson Creek is meeting the water quality standards for both aquatic life and aquatic recreation. Only one sample exceeded standards for both E.coli and DO; a frequency well below the required 10% to be determined impaired.

Two of the 11 lakes within the subwatershed that were assessed had a suffficient sample size to assess for aquatic recreation (Table 13). Standards from the NCHF were used to assess these Red River Valley (RRV) lakes, as ecoregion-specific standards for the RRV have not been developed. Land use and other watershed characteristics in this traditional area of RRV are often similar to the NCHF and are therefore appropriate. Kittleson Lake did not meet the corresponding shallow lake standards. However, Halverson Lake, also a shallow lake, did meet standards. Shallow lakes have limited ability to assimilate nutrients and are often susceptible to internal loading of nutrients. As with the other previously mentioned shallow lakes, slight increases in phosphorus loading could result in the lake exceeding standards, which would likely result in an increased frequency of severe algal blooms. It will be important to minimize any future increases in nutrient loading and to seek reductions in current sources of excess nutrients whenever possible.

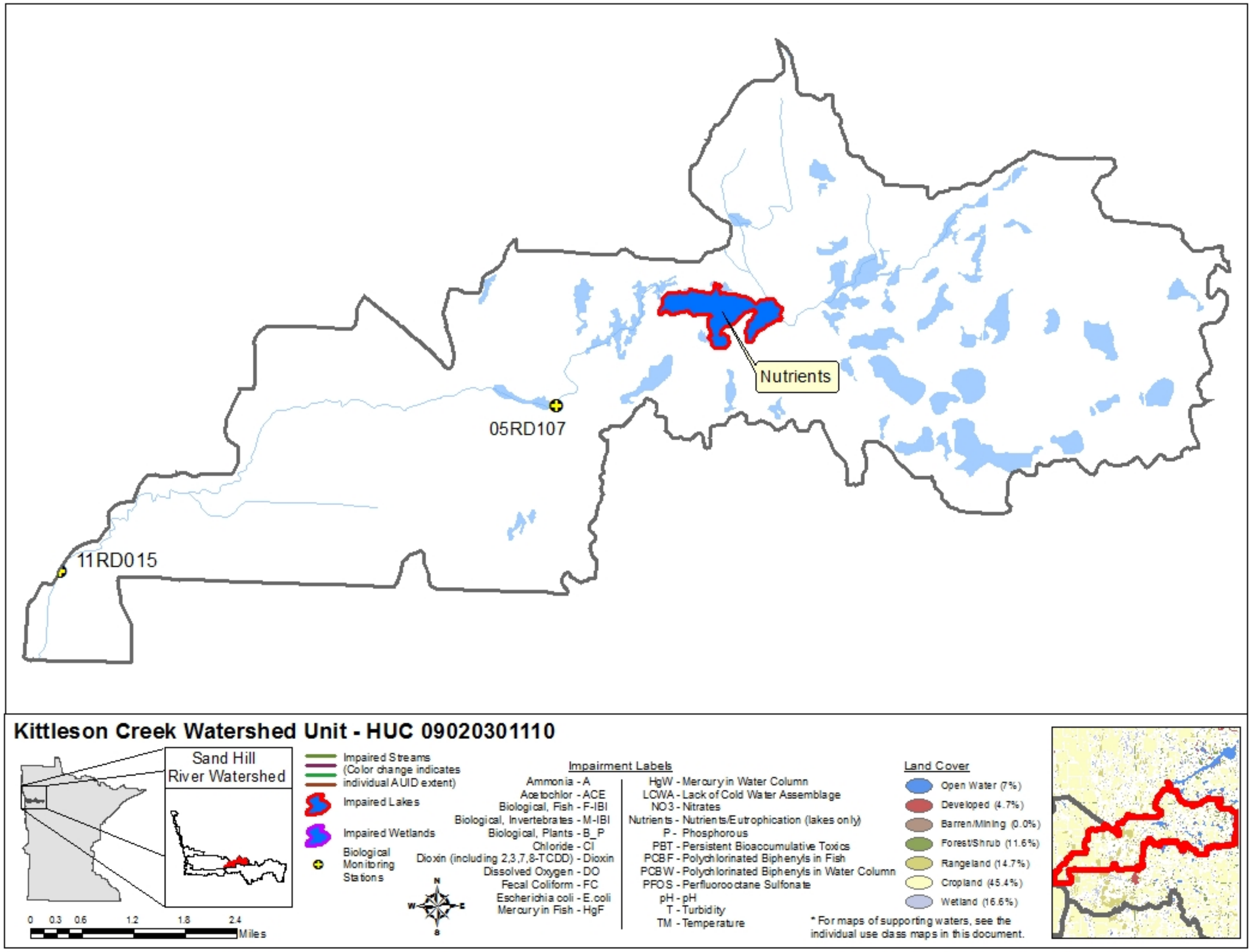

Figure 18. Currently listed impaired waters by parameter and land use characteristics in the Kittleson Creek Subwatershed

Lower Sand Hill River Subwatershed HUC 09020301120

The Lower Sand Hill River Subwatershed, located in Polk County, encompasses 155.7 square miles. As the name implies, this subwatershed contains the last section of the Sand Hill River before its confluence with the Red River of the North. From 1955 to 1958, the USACE implemented a flood control project that straightened the river and abandoned 18 miles of the Lower Sand Hill River. As part of this project, four drop structures were constructed to aid in flood control. The structures created six to eight foot changes in bed grade that are impassible for migratory fish species. The channelized section of the Sand Hill River begins just downstream of the confluence with Kittleson Creek and flows 16.7 miles. The final 14.22 miles of the main stem is a predominately natural channel as it flows northwest to its confluence with the Red River of the North. The dominant land use within this watershed is cropland (91.9%). The remaining land use consists of developed (4.7%), wetland (1.5%), forest (0.9%), and range (0.7%). The water chemistry monitoring station (11RD028) and outlet for the entire Sand Hill Watershed is upstream of the Hwy 75 bridge crossing in Climax. There are no assessable lakes in this subwatershed

Table 14. Aquatic life and recreation assessments on streams reaches in the Lower Sand Hill River Subwatershed. Reaches are organized downstream to upstream in the table.

					Aquatic Life 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	**Aquatic Life**	**Aquatic Rec.**
09020301-537 ***Sand Hill River*** *Unnamed Creek to Red River*	14.22	2B	05RD018 11RD021** 11RD028	Downstream of 400th St. SW, ~1.5 miles SE of Climax Upstream of 340th Ave SW, 4 mi. SE of Climax Upstream of Hwy 75, in Climax	MTS	MTS	MTS	EXS	MTS	MTS	MTS	--	EX	NS	NS
09020301-536 **Sand Hill River** *Kittleson Creek to Unnamed Creek*	16.74	2B	07RD007 11RD016	Downstream of CSAH 14, 9 mi. E of Nielsville Downstream of 170th Ave SW, 6 mi. SE of Beltrami	NA	NA	IF	EXS	MTS	MTS	MTS		EX	NA*	NS

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

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

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

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

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

Table 15. Non-assessed biological stations on channelized AUIDs in the Lower Sand Hill River Subwatershed.

AUID *Reach Name*, *Reach Description*	Reach length (miles)	Use Class	Biological Station ID	Location of Biological Station	Fish IBI	Invert IBI
09020301-537 ***Sand Hill River*** *Unnamed Creek to Red River*	14.22	2B	11RD021	Upstream of 340th Ave SW, 4 mi. SE of Climax	Good	Good (2)
09020301-536 **Sand Hill River** *Kittleson Creek to Unnamed Creek*	16.74	2B	07RD007 11RD016	Downstream of CSAH 14, 9 mi. E of Nielsville Downstream of 170th Ave SW, 6 mi. SE of Beltrami	Good Good	Good Good

See Appendix 5.1 for clarification on the good/fair/poor thresholds and Appendix 4.3 for IBI results.

Table 16. Minnesota Stream Habitat Assessment (MSHA) for the Lower Sand Hill 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	05RD018	Sand Hill River	0	8.5	14.65	5	17	45.15	Fair
2	07RD007	Sand Hill River	2	9	15.2	6	24	56.2	Fair
3	11RD016	Sand Hill River	0	10	20	7	11	48	Fair
4	11RD021	Sand Hill River	0	6	12	5	4	27	Poor
5	11RD028	Sand Hill River	2.5	11	13.7	14	26	67.2	Good
Average Habitat Results: Lower Sand Hill River Subwatershed			**0.9**	**8.9**	**15.11**	**7.4**	**16.4**	**48.71**	Fair

Qualitative habitat ratings

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

Table 17. Channel Condition and Stability Assessment (CCSI) for the Lower Sand Hill River Subwatershed.

# Visits	Biological Station ID	Stream Name	Stream Type	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11RD016	Sand Hill River	TC	19	9	7	3	38	Fairly Stable
1	11RD028	Sand Hill River	MHL	13	18	11	2	44	Fairly Stable
Average Stream Stability Results: *Lower Sand Hill River Subwatershed*				**16**	**13.5**	**9**	**2.5**	**41**	**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: Lower Sand Hill River Subwatershed.

Station location:	**Sand Hill River at US 75 on north end of Climax, MN**						
STORET/EQuIS ID:	**S002-099**						
Station #:	**09020301-537**						
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**# of WQ Exceedances[2]**
Ammonia-nitrogen	mg/L	5	0.0006	0.0039	0.0019	0.04	
Chloride	mg/L	5	10	24	15	230	
Dissolved Oxygen (DO)	mg/L	54	6.3	15.4	9.3	5	
pH		55	7.6	8.7	8.3	6.5 - 9	
Secchi tube/Transparency Tube	100 cm	55	2.5	>100	22.5	>20	
Turbidity	FNU	55	3.9	273.4	48.1	25	42
Escherichia coli (geometric mean)	MPN/100ml	15	101	375		126	3
Escherichia coli	MPN/100ml	15	66	1120	321	1260	
Chlorophyll-a, Corrected	ug/L	21	1.0	13.5	4.4		
Inorganic nitrogen (nitrate and nitrite)	mg/L	47	0.0	4.3	0.4		
Kjeldahl nitrogen	mg/L	47	0.0	2.6	0.8		
Orthophosphate	ug/L	29	0.003	0.342	0.075		
Pheophytin-a	ug/L	21	1	19	3		
Phosphorus	ug/L	47	0.01	0.45	0.10		
Specific Conductance	uS/cm	55	407	795	626		
Temperature, water	deg °C	55	-0.07	27.7	16.2		
Total suspended solids	mg/L	47	4	430	66		
Total volatile solids	mg/L	47	1	41	9		

[1]Secchi Tube/Transparency tube standards are surrogate standards derived from the turbidity standard of 25.

****Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Lower Sand Hill River Subwatershed, a component of the IWM work conducted between May and September in 2011 and 2012. This specific data does not necessarily reflect all data that was used to assess the AUID.**

Summary

The Lower Sand Hill River Subwatershed contains five biological stations and two AUIDs (09020301-536, 09020301-537). Fish and macroinvertebrates were sampled at all stations; biological communities were in good condition. All sites met their aquatic life criteria, with many scoring well above their corresponding IBI thresholds. Although biology looked good, turbidity levels were high and confirmed a previous listing from 2010. Additionally, both sections of the Sand Hill River do not support aquatic recreation due to high levels of E.coli.

Three biological monitoring stations were sampled on the most downstream portion of the Sand Hill River in this subwatershed (AUID 09020301-537). F-IBI and M-IBI scores met expected standards, with most scoring above their upper confidence limit. MSHA scores along this mainly natural segment are variable ranging from good to poor.

Two biological stations (07RD007 and 11RD016) were sampled for fish and macroinvertebrates along the most upstream AUID (09020301-536) of this subwatershed. IBI scores for both assemblages were above their respective threshold. The F-IBI exceeded the upper confidence limit at the furthest downstream station (07RD007). Several water control structures between the two biological stations likely serve as barriers to fish migration into upstream habitats (See Figure 19). The fish assemblage at 07RD007 (below barriers) includes several large bodied, longer-lived species characteristic of free-flowing riverine habitats (channel catfish, shorthead redhorse, silver redhorse, greater redhorse, smallmouth bass and walleye). Despite having similar habitat scores, similar channel stability (Table 17) and only 5% less watershed area, these species were not present above the fish barriers. Although the species composition at 11RD016 does suggest good water quality, the lack of large bodied, longer lived species indicate the water control structures may have a detrimental influence on the upstream fish community of the Sand Hill River and its tributaries.

Figure 19. Image of grade control structure upstream of 11RD016 on the Sand Hill River (AUID -09020301-536)

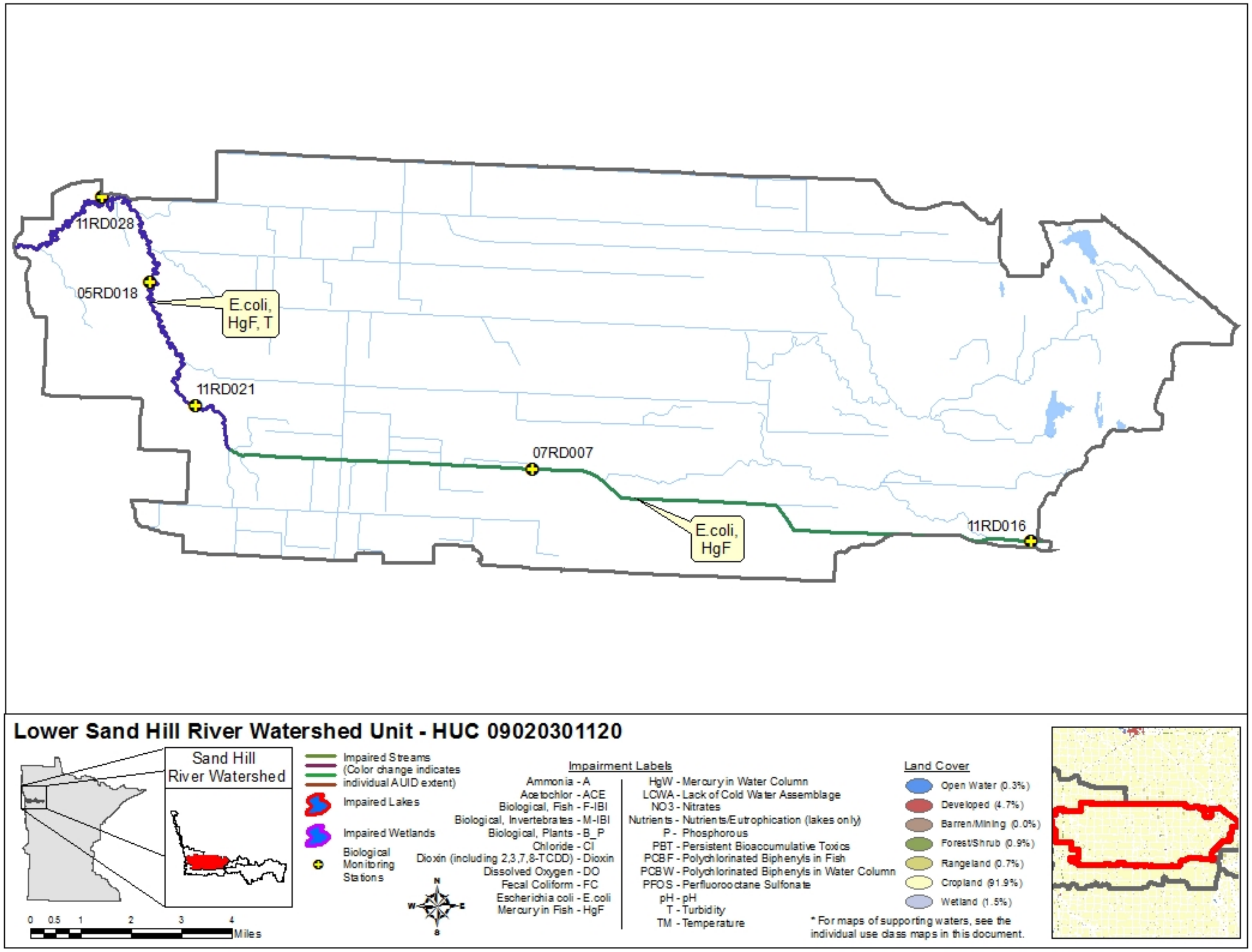

Figure 20. Currently listed impaired waters by parameter and land use characteristics in the Lower Sand Hill River Subwatershed

Vineland Subwatershed HUC 09020301130

The Vineland Subwatershed, located in Polk County, drains 55.1 square miles. The subwatershed contains a 39.17 mile segment of the Red River of the North located immediately downstream of its confluence with the Sand Hill River. Most of the tributaries to the Red River within this subwatershed are ditches that become dry; due to their ephemeral nature crews were not able to sample biology or obtain water chemistry sampled from these streams. The Red River of the North mainstem will be monitored and assessed in 2015 using a recently developed large river monitoring strategy. Land cover within this subwatershed is dominated by row crop agriculture (85.9%). The remaining land cover is made up of developed land (6.5%), wetlands (4.1%), open water (2.8%), forest (0.5%), and range (0.2%). There are no major towns within this subwatershed.

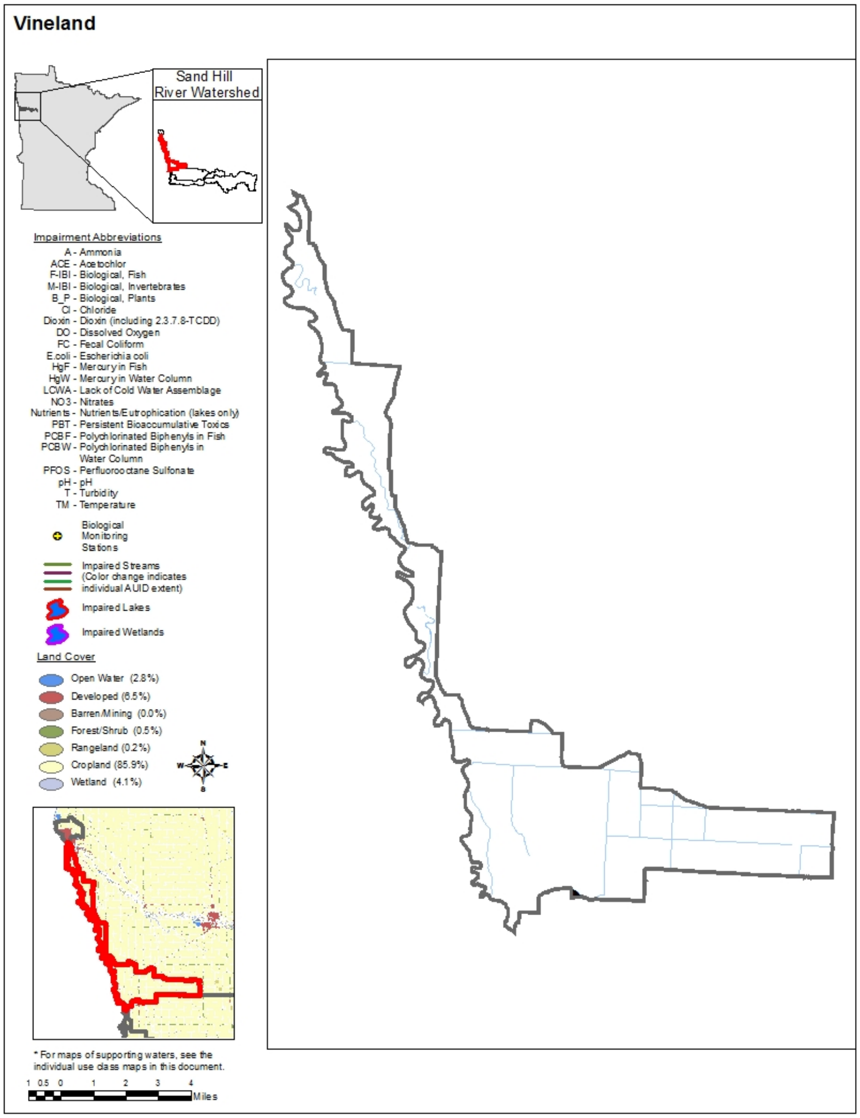

Figure 21. Currently listed impaired waters by parameter and land use characteristics in the Vineland Subwatershed

Red River of the North Subwatershed HUC 09020301140

The Red River of the North Subwatershed is located in Polk County. Draining a total of 7.5 square miles, this is the smallest subwatershed within the Sand Hill River HUC 8 watershed. The only waterway within the subwatershed boundary is a 3.87 mile segment of the Red River of the North. No biological monitoring or water chemistry stations were established. Land cover within this subwatershed consists of cropland (58%), developed (37.9%), open water (2.2%), wetland (1.2%), range (0.4%), and forest (0.3%). East Grand Forks is the only city, and it accounts for much of the western half of the watershed.

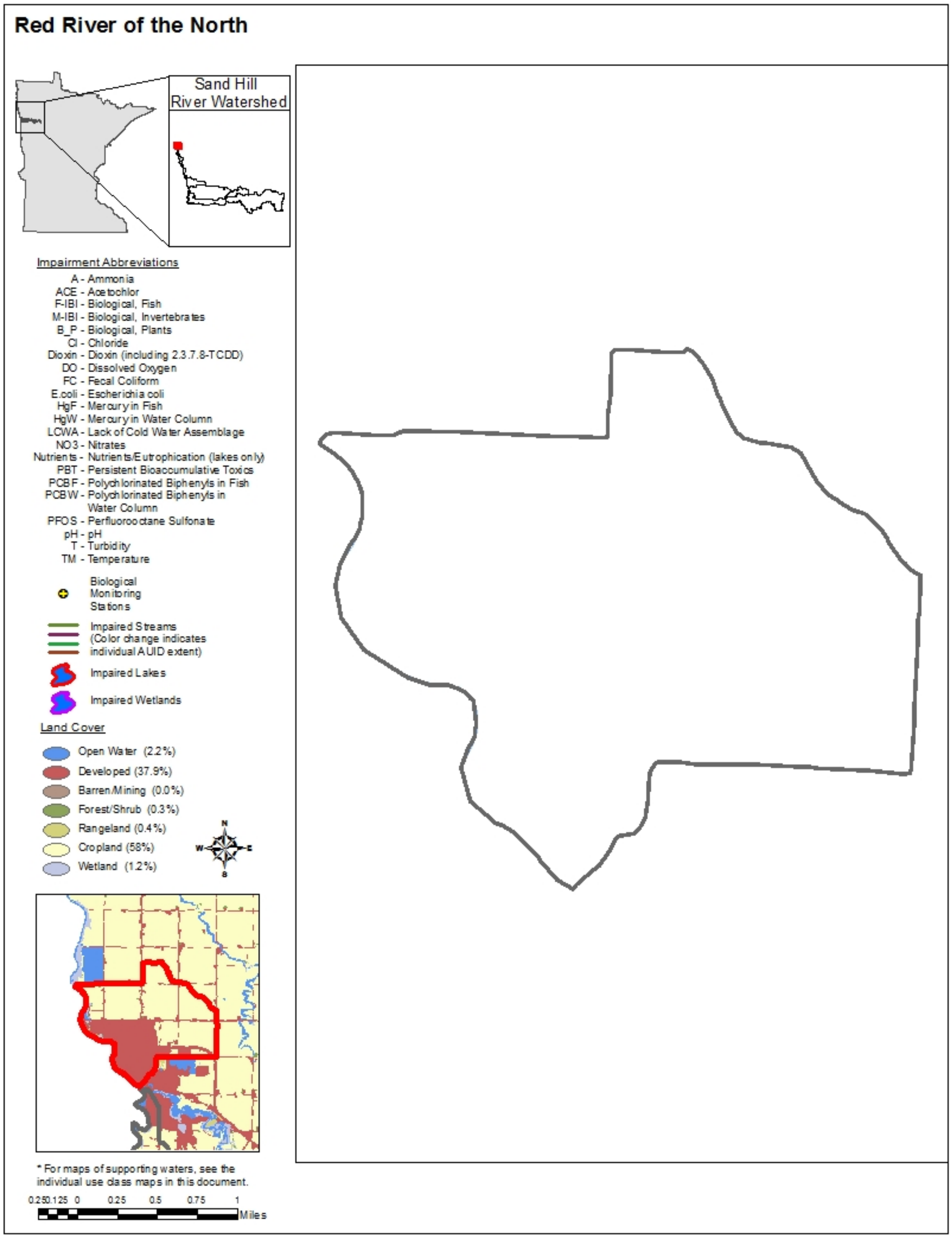

Figure 22. Currently listed impaired waters by parameter and land use characteristics in the Red River of the North Subwatershed

VI. Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed of the Sand Hill River, 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 SHRW.

Pollutant load monitoring

The Sand Hill River is monitored on US Highway 75 at Climax, approximately three river miles above the confluence with the Red River of the North. Many years of water quality data from throughout Minnesota combined with the previous analysis of Minnesota's ecoregion patterns, resulted in the development of three "River Nutrient Regions" (RNR), each with unique nutrient standards (MPCA, 2008). Of the state's three RNRs (North, Central, South), the Sand Hill River's monitoring station is located within the South RNR.

Annual flow weighted mean concentrations (FWMCs) were calculated and compared for years 2009-2011 (Figure 23-26) and compared to the RNR standards (only TP and TSS draft standards are available for the South RNR). It should be noted that while a FWMC exceeding a given water quality standard is generally a good indicator that the water body is out of compliance with the RNR standard, the rule does not always hold true. Waters of the state are listed as impaired based on the percentage of individual samples exceeding the numeric standard, generally 10% and greater, over the most recent 10 year period and not based on comparisons with FWMCs (MPCA, 2012). A river with a FWMC above a water quality standard, for example, would not be listed as impaired if less than 10% of the individual samples collected over the assessment period were above the standard.

Pollutant sources affecting rivers are often diverse and can be quite variable from one watershed to the next depending on land use, climate, soils, slopes, and other watershed factors. However, as a general rule, elevated levels of TSS and nitrate plus nitrite-nitrogen ($NO_3 + NO_2$-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 both "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 and DOP and $NO_3 + NO_2$-N concentrations tend 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, $NO_3 + NO_2$-N levels tend to be elevated.

Total Suspended Solids

Water clarity refers to the transparency of water. Turbidity is a measure of the lack of transparency or "cloudiness" of water due to the presence of suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter, and plankton or other microscopic organisms. By definition, turbidity is caused primarily by suspension of particles that are smaller than one micron in diameter in the water column.

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

Currently, the state of Minnesota's TSS standards are considered to be draft standards until approved. Within the South RNR, the river would be considered impaired when greater than 10% of the individual samples exceed the TSS draft standard of 65 mg/L. (MPCA, 2011). From 2009-2011, 53%, 87%, and 51% of the samples exceeded the 65 mg/L draft standard, respectively. Table 19 displays the total annual loads, which indicates TSS and FWMCs loads to be lowest in 2010. Often, there is a strong correlation between pollutant loads and annual runoff volume; the differences may be due strictly to differences in annual runoff volume (Figure 15).

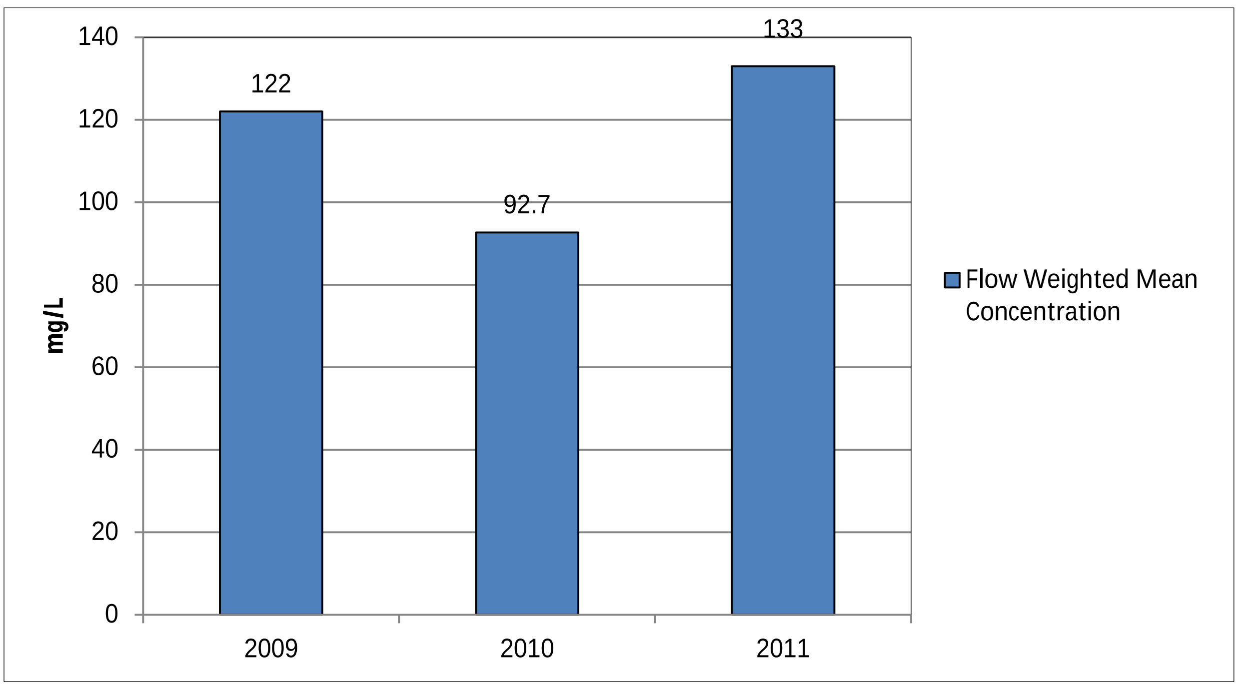

Figure 23. Total Suspended Solids (TSS) flow weighted mean concentrations in the Sand Hill River.

Table 19. Annual pollutant loads by parameter calculated for the Sand Hill River near Climax, MN (2009-2011).

	2009		2010		2011	
Parameter	**Mass (kg)**	**FWM (mg/L)**	**Mass (kg)**	**FWM (mg/L)**	**Mass (kg)**	**FWM (mg/L)**
Total Suspended Solids	21650003	122	18007259	92.7	25332080	133
Total Phosphorus	40510	0.229	47342	0.244	44698	0.234
Ortho Phosphorus	13472	0.076	31075	0.160	20621	0.108
Nitrate + Nitrite Nitrogen	91638	0.518	186549	0.960	446373	2.34

Total Phosphorus

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

Total phosphorus standards for Minnesota's rivers are considered draft standards until approved. Within the South RNR, the TP draft standard is 0.150 mg/L as a summer average. Summer average violations of one or more "response" variables (pH, biological oxygen demand, DO flux, chlorophyll-a) must also occur along with the numeric TP violation for the water to be listed. A comparsion of the data collected during from June through September from 2009 to 2011, showed TP exceedences occurred 10, 78, and 29% of the time respectively. Although there were exceedences to the draft standard, only 2010 had summer averages greater than the draft standard (0.203 mg/L). Figure 24 illustrates FWMCs greater than the draft standard, albeit this includes all data throughout the year (not just summer values). Table 1 shows annual loads which exhibit similar traits as the FWMCs.

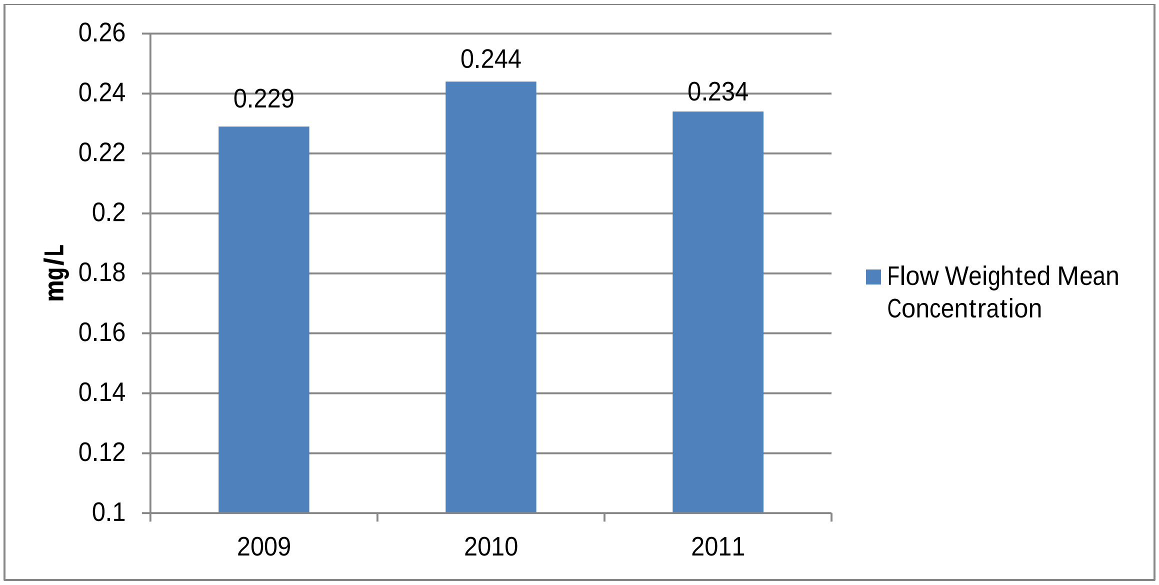

Figure 24. Total Phosphorus (TP) flow weighted mean concentrations for the Sand Hill River

Dissolved Orthophosphate

Dissolved Orthophosphate is a water soluble form of phosphorus that is readily available for plant uptake (MPCA and MSUM, 2009). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from waste water treatment plants, noncompliant septic systems, and fertilizers in urban and agricultural runoff. The DOP:TP ratio of FWMCs from the three years were between 33%, 66% and 46%, respectively. Figure 25 and Table 19 show similar trends between years as seen with TP. This is not uncommon due to the relationship between DOP and TP.

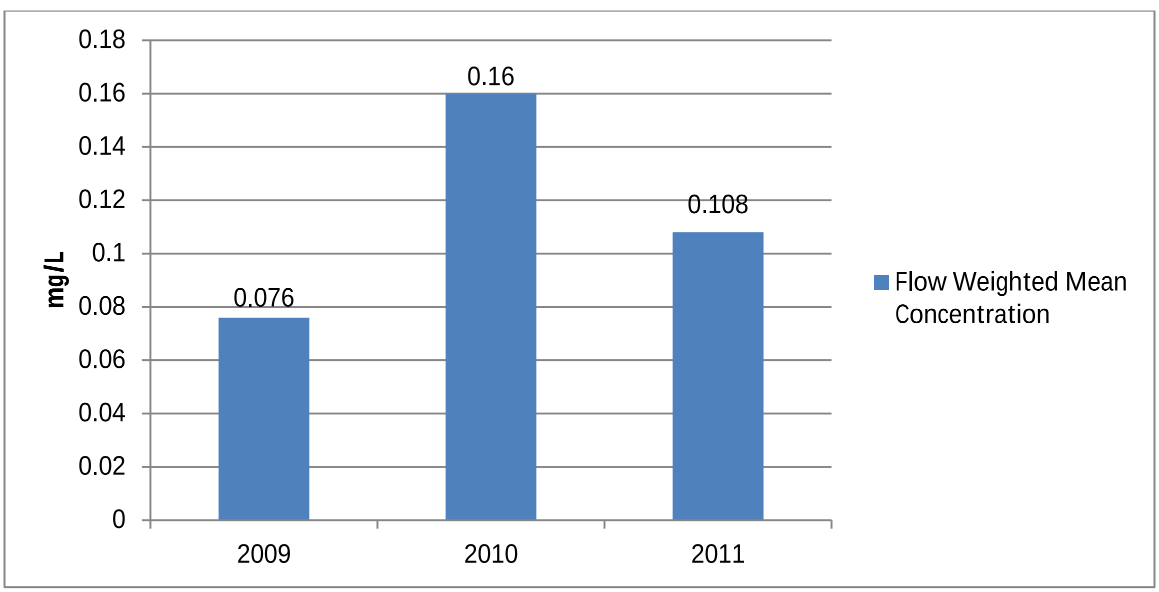

Figure 25. Dissolved Orthophosphate (DOP) flow weighted mean concentrations for the Sand Hill River

Nitrate plus Nitrite - Nitrogen

Nitrate and nitrite-nitrogen are inorganic forms of nitrogen present within the environment that are formed through the oxidation of ammonia-nitrogen by nitrifying bacteria (nitrification). Ammonia-nitrogen is found in fertilizers, septic systems, and animal waste. Once converted from ammonia-nitrogen to nitrate and nitrite-nitrogen, they too, like phosphorus, can stimulate excessive levels of some algae species in streams (MPCA, 2008). Because nitrate and nitrite-nitrogen are water soluble, transport to surface waters is enhanced through agricultural drainage. The ability of nitrite-N to be readily converted to nitrate-nitrogen is the basis for the combined laboratory analysis of nitrate plus nitrite-nitrogen, with nitrite-nitrogen typically making up a small proportion of the combined total concentration. These and other forms of nitrogen exist naturally in aquatic environments; however concentrations can vary drastically depending on season, biological activity, and anthropogenic inputs.

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

Figure 26 shows the $NO_3 + NO_2$-N FWMCs over the three-year period for the Sand Hill River monitoring site. The FWMC for all three years were below the draft acute and chronic nitrate-N standards. Between 2009 and 2011, there were no exceedences of the draft acute standard and no exceedences of the draft chronic 4-day duration standard. Table 19 displays the annual loads which increased over the three year period which corresponds to the increase in FWMCs. The elevated FWMC in 2011 is attributed to higher nitrogen concentrations during higher flow periods (March and July of 2011).

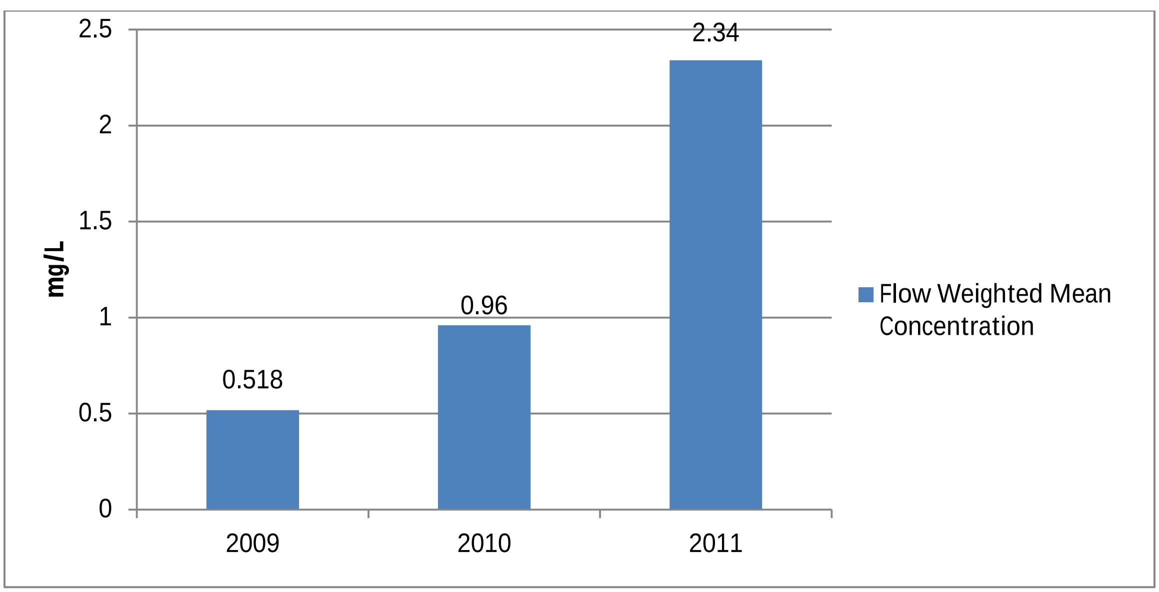

Figure 26. Nitrate + Nitrite Nitrogen (Nitrate-N) flow weighted mean concentrations for the Sand Hill River

Stream water quality

Six of the thirty-eight stream AUIDs in the watershed were assessed (Table 20). Of the assessed streams, only one stream fully supported aquatic life and aquatic recreation (Kittleson Creek). The remaining AUIDs with reportable data were not assessed for aquatic biology because greater than 50% of the AUID is channelized or the biological station fell on a channelized stream reach on the AUID. Also, some stations within the watershed were never sampled because of low flows (Table 20).

Throughout the watershed, eight AUIDs do not support aquatic life and/or recreation. Of those AUIDs, four do not support aquatic life and four do not support aquatic recreation. Turbidity remains a problem along much of the Sand Hill River. New bacteria impairments were identified throughout the entire length of the Sand Hill River.

Table 20. Assessment summary for stream water quality in the Sand Hill Watershed.

				Supporting		Non-supporting			
Watershed	**Area (acres)**	**# Total AUIDs**	**# Assessed AUIDs**	**# Aquatic Life**	**# Aquatic Recreation**	**# Aquatic Life**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
Red River of the North-Sandhill **09020301**	**395,583**	**38**	**6**	**1**	**2**	**4**	**4**	**1**	**0**
09020301090	48,210	2		0	0	0	0	0	0
09020301100	147,854	10	3	0	0	3	2	0	0
09020301110	25,457	1	1	1	1	0	0	0	0
09020301120	99,655	17	2	0	0	1	2	1	0
09020301130	35,254	6	3	0	0	0	0	2	0
09020301140	4,828	2	0	0	1	0	0	1	0

Lake water quality

As noted previously, the Red River Valley ecoregion does not have dedicated lake water quality standards; water quality standards from the NCHF ecoregion were applied to lakes within the SHRW where land use is similar. Three HUC-11 subwatersheds, the Red River of the North, Vineland, and Nielsville, do not contain assessed lakes. Of the 39 lakes greater than 10 acres in the watershed, 11 had assessment level data. Out of those 11, seven supported aquatic recreation and four were impaired for aquatic recreation with excess nutrients/eutrophication (Table 21).

Table 21. Assessment summary for lake water chemistry in the Sand Hill Watershed.

			Supporting	Non-supporting		
Watershed	**Area (acres)**	**Lakes >10 Acres**	**# Aquatic Recreation**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
Red River of the North-Sand Hill **9020301**	**395,583**	**39**	**7**	**4**	**8**	**0**
9020301090	48,210	0	0	0	0	0
9020301100	147,854	28	6	3	6	0
9020301110	25,457	7	1	1	2	0
9020301120	99,655	1	0	0	0	0
9020301130	35,254	0	0	0	0	0
9020301140	4,828	0	0	0	0	0

Biological monitoring

Fish

The Minnesota portion of the Red River Basin encompasses approximately 37,100 square miles in 21 counties. The SHRW encompasses about 3% of this area (1,107 square miles). Historically, 86 different species of fish have been sampled in the Red River basin. Forty five of these species were found during this survey. This watershed does not have any endangered fish species or species of special concern. The only invasive fish or aquatic plant species known to exist in this watershed, is the exotic common carp.

Along the main stem Sand Hill River, fish communities improve moving downstream. One potential threat to fish communities within the watershed is the loss of longitudinal connectivity along the Sand Hill River. Four low head dams along the channelized section of the Sand Hill River appear to prevent fish migration into upper portions of the watershed where adequate water quality and habitat exists. Several game fish were sampled downstream of the drop control structures including smallmouth bass, walleye, sauger and channel catfish. Despite the absence of these species upstream of the structures, sensitive minnow species were present (e.g. longnose dace) which indicates that certain stretches of the river have good water quality.

Many of the channelized tributaries to the Sand Hill River contained tolerant species which have the ability to adapt to some of the most degraded resources. The most common and abundant species was the fathead minnow, with 1,557 individuals sampled at all but one station (11RD028). Fathead minnows are a pioneering species that are able to live in streams with little habitat and/or extremely low DO. These conditions were found at many of the ditches in the upper portions of the watershed. The next two commonly occurring species were the creek chub (17 sites) and central mudminnow (15 sites), both of which are highly tolerant. Nine different fish species were sampled at only one station (see Appendix 7). Five of these species were considered sensitive. These species were generally limited to main stem reaches or Kittleson Creek, where habitat conditions are generally good.

Macroinvertebrates

The SHRW provides a unique geologic setting for colonization of biological communities. The beach ridge, a remnant land form from the recesses of glacial Lake Agassiz, provides gradient to an otherwise flat terrain once dominated by tall grass prairies and low lying wetland habitats. The increased stream gradient has a positive influence on macroinvertebrate communities, many of the most sensitive taxa were found along these reaches.

Unfortunately, the landscapes within this watershed have gone through many changes in the last century. Many of the changes were a result of human demands for agricultural production and other development. Many of the wetlands have been drained and many of the stream channels have been straightened to accommodate these needs. As a result, many of the natural habitats have been physically removed or indirectly lost due to these alterations. The removal of coarse substrates, indirect suffocation of coarse substrate with fine sediments, and subsequent loss of natural riffle/run/pool sequences, often have a negative and lasting effect on macroinvertebrate communities. Tolerant taxa often move into these degraded systems, as many are insensitive to low DO, fine sediment, suspended solids, homogenous habitats, warmer water and in some instances nutrient enriched waters.

While many sensitive taxa were collected from natural segments of this watershed, it is no surprise that the dominant macroinvertebrates collected are some of the most tolerant taxa found throughout the state. Some of these taxa include midges from the genera *Cricotopus*, *Dicrotendipes* and *Polypedilum*, mayflies from the genus *Tricorythodes*, and snails from the genera *Ferrissia* and *Physa* (Appendix 8) Where natural stream channels remain or channelized streams have been left to remeander, the macroinvertebrate communities generally perform to standards. Therefore it will be crucial to maintain these habitats in order to preserve the sensitive taxa that remain

Fish contaminant results

Ten fish species from the Sand Hill River and Union Lake (Lake ID 60-0217) were tested for mercury and/or PCBs. A total of 25 fish were tested from the Sand Hill River and 28 fish from Union Lake in 2011 and 2012, respectively. Fish species are identified by codes which are defined by their common and scientific names in Table 21.

Table 22 is a summary of contaminant concentrations by waterway, fish species, and year. The table shows which contaminants, species, and years were sampled. "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).

Of the six fish species collected from the Sand Hill River in 2011 all were tested for mercury and three species were tested for PCBs. The Sand Hill River's channel catfish (CHC) mercury concentrations were mostly below the state water quality standard for mercury in fish tissue (0.2 mg/kg); only one out of the seven catfish (the largest) exceeded the standard. Of the eight golden redhorse (GRH) from the Sand Hill River, the two largest individuals exceeded the standard. All six of the sauger (SAG) from Sand Hill River exceeded the standard and they had the highest mercury concentrations. The highest individual mercury concentration was 0.924 mg/kg in a 14.4 inch (total length) sauger. The two shorthead redhorse (SRH) were below the standard. The one walleye (WE) collected from the Sand Hill River had a mercury level of 0.357 mg/kg. In Union Lake, the bluegill sunfish (BGS), black crappie (BKS), and common carp (C) had low mercury concentrations. Two of five northern pike (NP) and two of five walleye from Union Lake exceeded the standard.

The high mercury concentrations in sauger from the Sand Hill River, and northern pike and walleye in Union Lake, prompted recommendations for inclusion on the Draft 2014 Impaired Waters List.

The two largest channel catfish and golden redhorse, as well as the one river redhorse, from the Sand Hill River were also tested for PCBs. Concentrations of PCBs were all below the reporting limit of 0.025 mg/kg.

Overall, the fish contaminant results shows PCBs are not a concern in the Sand Hill River. Mercury concentrations in fish from the Sand Hill River and Union Lake were sufficiently high for classification as impaired for mercury in fish tissue.

Table 22. Fish species codes, common names, and scientific names.

SPECIES	COMMON NAME	SCIENTIFIC NAME
BGS	Bluegill sunfish	*Lepomis macrochirus*
BKS	Black crappie	*Pomoxis nigromaculatis*
C	Common Carp	*Cyprinus carpio*
CHC	Channel catfish	*Ictalurus punctatus*
GRH	Golden redhorse	*Moxostoma erythrurum*
NP	Northern pike	*Esox Lucius*
RRH	River redhorse	*Moxostoma carinatum*
SAG	Sauger	*Sander canadense*
SRH	Silver redhorse	*Moxostoma anisurum*
WE	Walleye	*Sander vitreus*

Table 23. Summary statistics of mercury and PCBs, by waterway-species-year.

							Length (in)			Mercury (mg/kg)				PCBs (mg/kg)		
WATERWAY	AUID	LOCATION	SPECIES[1]	YEAR	ANAT-OMY[2]	No. fish	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Max
Sand Hill River*	09020301 -536, -537	11RD028	CHC	2011	FILET	7	16.2	12.6	23.1	7	0.181	0.135	0.350	2	< 0.025	< 0.025
			GRH	2011	FILSK	8	13.9	12.1	15.0	8	0.184	0.122	0.277	2	< 0.025	< 0.025
			RRH	2011	FILSK	1	21.2	21.2	21.2	1	0.446			1	< 0.025	
			SAG	2011	FILSK	6	14.1	13.0	16.4	6	0.620	0.431	0.924			
			SRH	2011	FILSK	2	13.0	12.5	13.4	2	0.137	0.133	0.141			
			WE	2011	FILSK	1	14.0	14.0	14.0	1	0.357					
Union*	60021700		BGS	2012	FILSK	7	7.0	6.5	7.4	2	0.048	0.041	0.055			
			BKS	2012	FILSK	6	10.2	10.2	10.2	1	0.096					
			C	2012	FILSK	5	24.0	24	24	1	0.081					
			NP	2012	FILSK	5	19.3	15.8	23.6	5	0.158	0.061	0.267			
			WE	2012	FILSK	5	18.7	17.5	20	5	0.189	0.161	0.217			

* Recommended for 2014 Draft Impaired Waters List for Mercury in Fish Tissue.

1 Species codes are defined in Table BM1

2 Anatomy codes: FILSK – edible fillet

Groundwater monitoring

Groundwater quality

The SHRW is located in northwest Minnesota with three types of aquifers: Cretaceous, buried sand and gravel, and surficial sand and gravel aquifers. There is currently no MPCA ambient groundwater monitoring wells within the Sand Hill Watershed. However, a baseline study conducted by the MPCA found that the median concentrations of most chemicals in the sand and gravel aquifers in this region were slightly higher, while iron and sulfate were much higher, than concentrations in similar aquifers statewide (MPCA, 1998).

The MDA monitors pesticide and nitrate levels on an annual basis in groundwater across agricultural areas in the state. The SHRW lies within MDA's Pesticide Monitoring Region 1 (PMR 1). No pesticides were detected above drinking water standards in 2011 or 2012. Nitrates were detected in 57% of the samples collected from Region 1. Most of those detections were below the drinking water standard of 10.00 mg/L. Results of this sampling are available on the MDA website at http://www.mda.state.mn.us/chemicals/pesticides/maace.aspx.

The MDH requires testing for arsenic of all newly constructed wells in the state. This testing has found that, statewide, 10.4% of all wells installed from 2008 to 2013 have arsenic levels above the maximum contaminant level (MCL) for drinking water of 10 micrograms per liter. In northwest Minnesota, the majority of new wells are within the water quality standards for arsenic levels, but there are some exceedances (Figure 27).

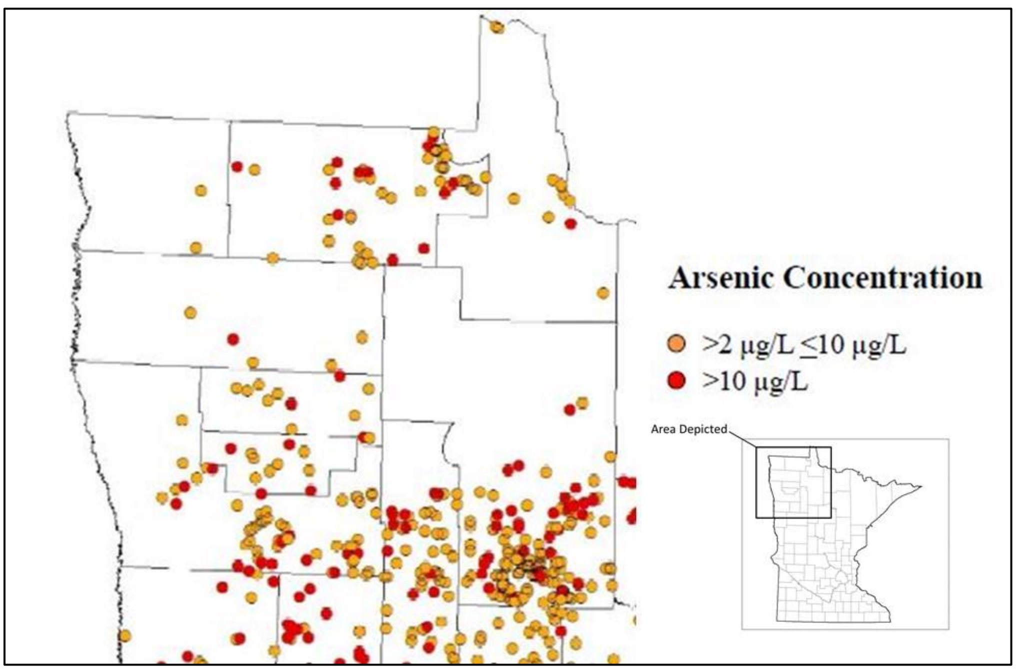

Figure 27. Arsenic occurrence in new wells in northwest Minnesota (2008-2012) (Source: MDH)

Groundwater/surface water withdrawals

Displayed in Figure 28 are the locations of permitted groundwater and surface water withdrawals in the SHRW. Blue symbols are groundwater withdrawals and red are surface water, taken from lake, stream or other surface water features.

The three largest permitted consumers of water in the state (in order) are municipalities, industry and irrigation. The withdrawals within the SHRW are primarily for irrigation and municipal use.

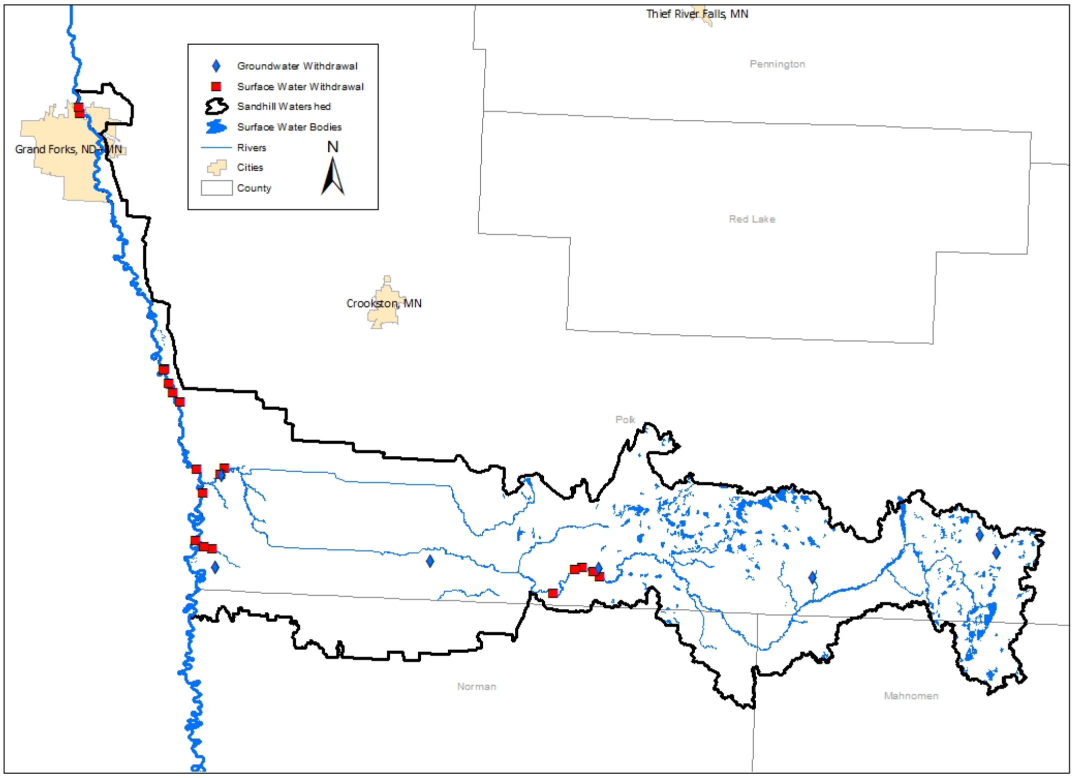

Figure 28. Locations of permitted ground and surface withdrawals in the Sand Hill River Watershed

The graph below displays total groundwater withdrawals from the watershed from 1991-2011 as blue diamonds with total surface water withdrawals as red squares. During this time period within the SHRW, groundwater withdrawals exhibit a significant rising trend (p=0.01) while surface water withdrawals exhibit no significant trend. The data is taken from the MDNR Water Use Permit database. http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

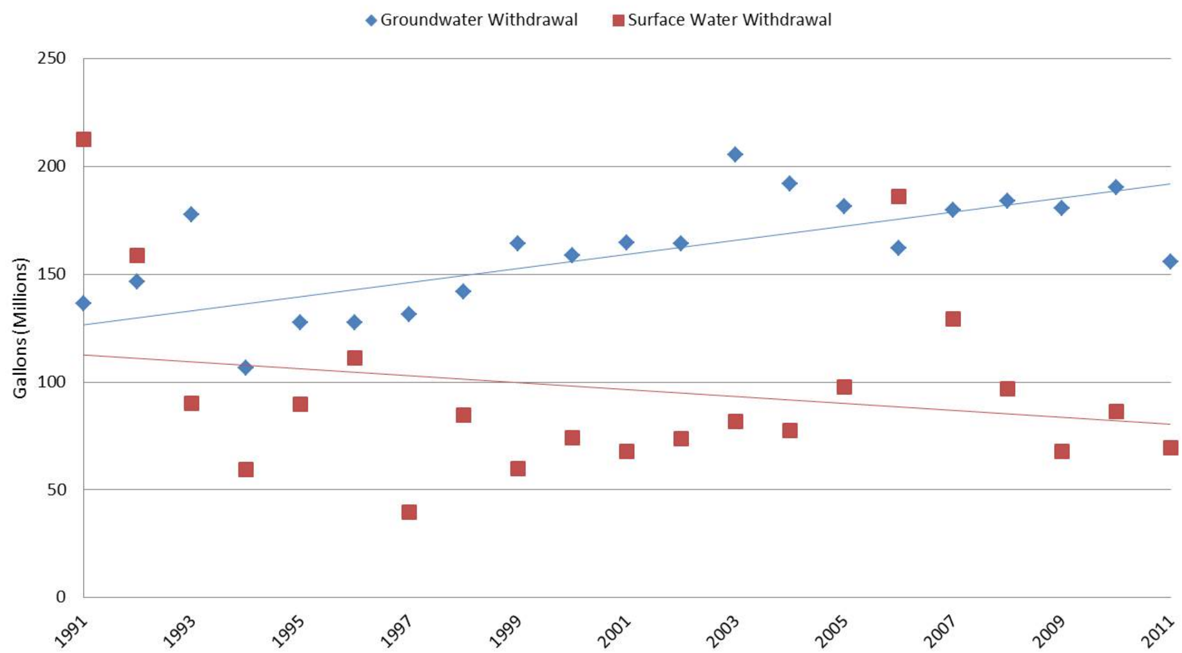

Figure 29. Total annual groundwater and surface water withdrawals in the Sand Hill River Watershed (1991-2011)

Stream flow

Stream flow for the Sand Hill River at Climax from 1992 to 2012 was analyzed for annual mean discharge and summer (July and August) monthly mean discharge Figure 30. The data shows that there is an increase in stream flow over time, but there is no statistically significant trend. Figure 31 displays July and August mean flows for the last 20 years for the same water body. Both months show a decreasing flow trend, but the level of significance is not high. By way of comparison, summer month flows have declined at a statistically significant rate at a majority of streams selected randomly for a study of statewide trends.

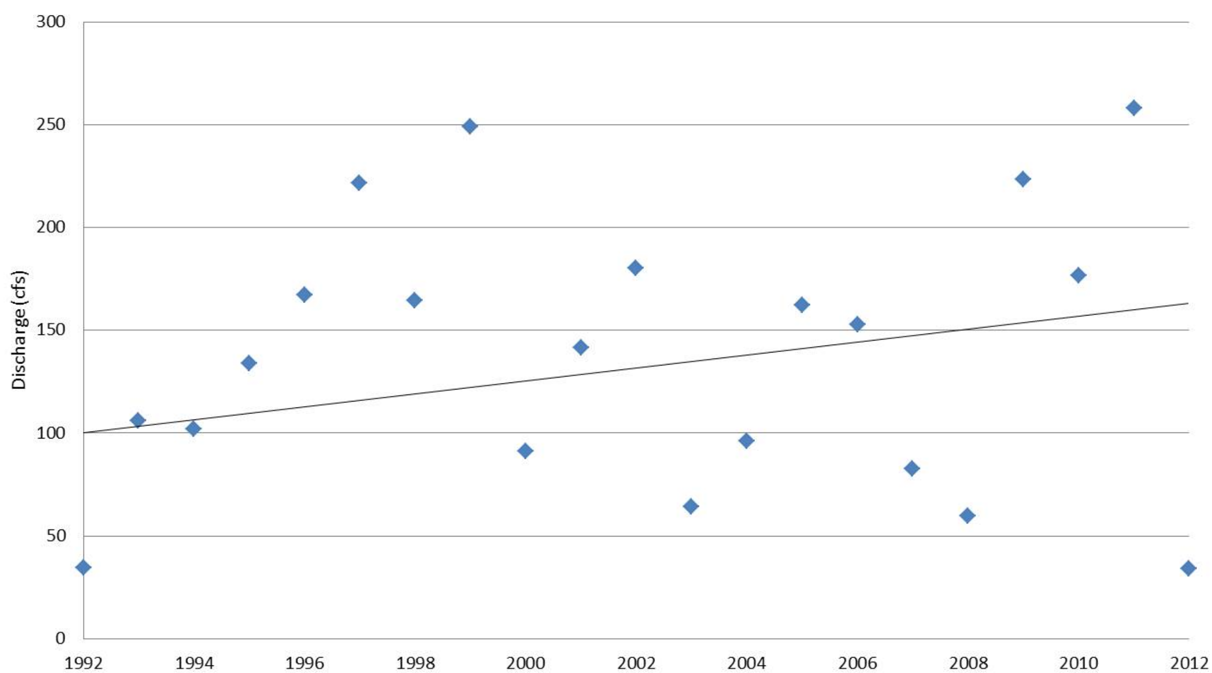

Figure 30. Annual Mean Discharge for Sand Hill River at Climax, MN (1992-2012)

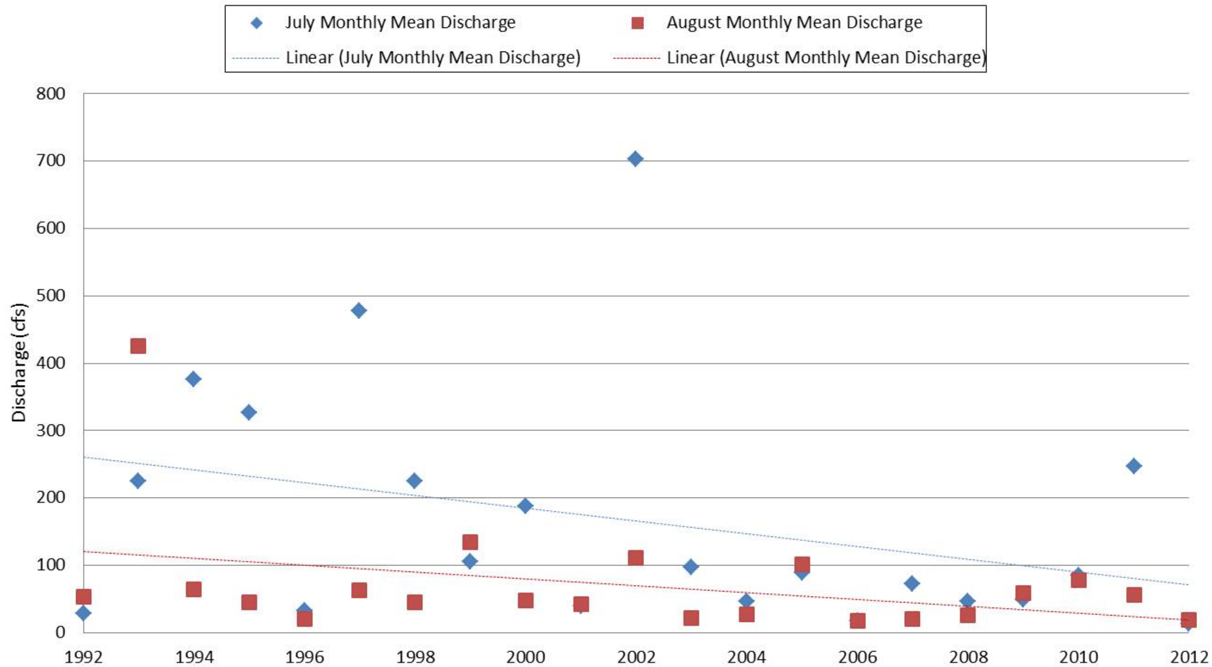

Figure 31. Mean monthly discharge measurements for July and August flows for Sand Hill River at Climax, MN (1992-2012

Stressor identification

Stressor identification (SI) is a formal and rigorous methodology for determining the causes, or "stressors", that are likely contributing to the biological impairment of aquatic ecosystems (EPA, 2000). The SI process is prompted by the assessment of biological monitoring data indicating that an impairment has occurred. The biological monitoring data for the Sand Hill River Watershed (SHRW) were assessed as part of the development of this report. Two reaches of the Sand Hill River (i.e., Headwaters to CD 17/AUID # 09020301-541 and CD 17 to Kittleson Creek/AUID # 09020301-542) and one reach of CD 17 (i.e., Garden Slough to Sand Hill River/AUID # 09020301-515) did not support healthy fish and/or macroinvertebrate communities. For the purposes of SI, each of these impaired reaches will be referred to by their three digit AUID suffix.

To inform future SI efforts, MPCA staff developed a list of potential stressors that may be adversely affecting the aquatic ecosystems of the impaired reaches of the watershed. The stressors were identified through a comprehensive review of available information for the watershed, including water quality and quantity data, as well as existing plans and reports, including this report, the *Sand Hill River Watershed District's Watershed Management Plan* (Sand Hill River Watershed District, 2012), the *Watershed Conditions Report: Sand Hill River Watershed* (Sand Hill River Watershed District, 2011), the *Red River Valley Biotic Impairment Assessment* (MPCA, 2009), and the *Red River Basin Stream Survey Report: Sand Hill River* (Groshens, 2006). A summary of the potential stressors for the SHRW is provided below:

Loss of connectivity

Connectivity in aquatic ecosystems refers to how waterbodies and waterways are linked to each other on the landscape and how matter, energy, and organisms move throughout the system (Pringle, 2003). Dams and other water control structures alter stream flow, water temperature regime, and sediment transport processes; each of which can cause changes in fish and macroinvertebrate assemblages (Cummins, 1979; Waters, 1995). These structures alter hydrologic (longitudinal) connectivity, often obstructing the movement of migratory fish and causing a change in the population and community structure (Brooker, 1981; Tiemann et al., 2004).

Figure 32. Grade control structure on the Sand Hill River

According to the USACE (2013) and Sand Hill River Watershed District (2012), the Sand Hill Lake outlet dam is the only existing dam on the Sand Hill River; Reach 541 begins at the outlet of Sand Hill Lake. The dam was constructed in 1956 and is owned by the MDNR. In addition to the dam, there are four grade control structures on the Sand Hill River, located immediately downstream of Reach 542. These structures were constructed as part of the Sand Hill Ditch Flood Control Project, which was completed in 1954 (Sand Hill River Watershed District, 2012). Figure 32 displays one of these structures. There are no dams or water control structures located along Reach 515.

Connectivity appears to be a large contributing factor to the aquatic life impairment in the lower sections of the Upper Sand Hill River Subwatershed. The four water control structures downstream of this watershed are serving as fish barriers to longer lived migratory species (eg. redhorse, walleye, channel catfish) that would normally inhabit streams of this size. The MPCA collected these species downstream of the barriers but they were entirely absent at stations above. Habitat at stations along the Sand Hill River above the barriers were generally good, especially the section from the barriers to the Kittleson Creek confluence. Sensitive minnow species were present (e.g. longnose dace) indicating that habitat might not be limiting fish and macroinvertebrate communities.

Flow regime alteration

According to Mitch and Gosselink (2007), drainage practices can upset the natural flow regime of streams, resulting in increased and quicker peak discharges following rain events and reduced baseflows during dry periods. High flows can result in the direct displacement of fish and macroinvertebrates downstream if they are unable to move into tributaries or refuges along the margins of the river, or if refuges are not available. The intensification of channel shear stresses associated with increased flows may cause the mobilization of sediment, woody debris, and plant materials, as well as increased channel

Figure 33. Channelized segment of the Sand Hill River

scouring and bank destabilization. Diminished baseflows result in decreased wetted width, cross sectional area, and water volume. Aquatic organisms require adequate living space, and when flows are reduced beyond normal baseflow, habitat can be scarce and the competition for resources increases.

The hydrology of the SHRW has been substantially altered, primarily to expedite drainage for agricultural purposes. Examples of such alterations include ditching, the channelization of natural streams, wetland drainage, and subsurface tiling. While many of these modifications occurred 50 or more years ago (i.e., ditching and channelization), subsurface tiling is a relatively new practice in the region that is increasing in extent. According to the Statewide Altered Watercourse Project dataset, 51% of the waterways in the Upper Sand Hill River Subwatershed, which includes the drainage areas for the biologically impaired reaches of the SHRW, have been altered by ditching and/or channelization. Figure 33 displays an example of a channelized segment of Reach 541 of the Sand Hill River. Also, according to the Restorable Depressional Wetland Inventory, there are 5,427 acres of restorable wetlands in the Upper Sand Hill River Subwatershed. The drainage of these wetlands, many of which were closed basins, has reduced the water storage capacity of the landscape. As a result of these hydrologic alterations, streams in the watershed can be described as "flashy", where multiple peak flows occur, along with periods of very low discharge (Groshens, 2006).

Lack of in-stream habitat

Habitat is a broad term encompassing all aspects of the physical, chemical, and biological conditions needed to support a biological community (EPA, 2012). Healthy aquatic biotic communities often have access to diverse instream habitat, enabling fish and macroinvertebrate habitat specialists to prosper. In-stream habitat is primarily a function of channel geomorphology (Rosgen, 1996) and flow (Bovee, 1986). Biotic population changes can result from decreases in the availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (EPA, 2012).

The MPCA's Stream Habitat Assessment was used to evaluate the quality and quantity of habitat present at each of the biological monitoring sites in the SHRW. A majority of sites along the biologically impaired reaches of the watershed received a "fair" rating (5), while one site was rated "good" and one site was rated "poor". Many of the sites had extremely low scores in the In-stream Zone Substrate and Channel Morphology assessment categories. According to Groshens (2006), streams in the watershed have the potential to provide quality in-stream habitat; however, channel instability and high sediment loads are reducing both habitat quality and quantity.

Excess suspended sediment

Turbidity and TSS are measurements of the amount of sediment suspended in the water, whether mineral (e.g., soil particles) or organic (e.g., algae). Although sediment delivery and transport are important natural processes for all stream systems, sediment imbalance (i.e., either excess sediment or lack of sediment) can result in the loss of habitat, as well as direct harm to aquatic organisms. As described by Waters (1995), excess suspended sediment can cause harm to fish and macroinvertebrates through two major pathways: 1) direct, physical effects (e.g., abrasion of gills and avoidance behaviors) and 2) indirect effects (e.g., loss of visibility and increase in sediment oxygen demand). Excess fine sediment deposition on benthic habitat has been proven to adversely impact fish and macroinvertebrate species that depend on clean, coarse stream substrates for feeding, refugia, and/or

Figure 34. Turbidity impaired segment of the Sand Hill River

reproduction (Newcombe and MacDonald. 1991). Elevated levels of turbidity and TSS can also reduce the penetration of sunlight and thus impede photosynthetic activity and limit primary production (Munavar et al., 1991; Murphy et al., 1981).

The 2012 Impaired Waters List included a reach of the Sand Hill River (Headwaters to Kittleson Creek/AUID #09020301-509) for turbidity affecting aquatic life; this reach was later split into Reaches 541 and 542. However, the impairment associated with this reach is proposed to be isolated to Reach 541 in the draft 2014 Impaired Waters List based upon data indicating that Reach 542 meets the state turbidity standard. Figure 34 displays an image of the turbidity impaired Reach 541 of the Sand Hill River.

Low dissolved oxygen

The concentration of dissolved oxygen (DO) changes seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column. If DO becomes limited or fluctuates dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995; Davis, 1975; Nebeker et al., 1992). Hieskary et al. (2010) observed several strong negative relationships between fish and macroinvertebrate metrics and DO flux. In most streams and rivers, the critical conditions for DO usually occur during the late summer, when water temperatures are high and stream flows are reduced to baseflow. As the temperature of water increases, the saturation level of DO decreases. High water temperatures also raise the DO needs for many species of fish (Raleigh et al., 1986). Low DO can be an issue in streams with slow currents, excessive temperatures, high biological oxygen demand, and/or high groundwater seepage (Hansen, 1975).

The 2012 Impaired Waters List included a reach of the Sand Hill River (Headwaters to Kittleson Creek/AUID #09020301-509) for low DO affecting aquatic life; this reach was later split into Reaches 541 and 542. However, the impairment associated with this reach is proposed to be isolated to Reach 541 in the draft 2014 Impaired Waters List based upon data indicating that Reach 542 meets the state DO standard.

Pesticide toxicity

A pesticide is defined by the EPA (2012) as "any substance intended for preventing, destroying, repelling or mitigating any pest". Pesticides (e.g., herbicides, insecticides, and fungicides) are commonly used in the agricultural industry and may cause biological impairment if they are present in water or sediment at sufficient concentrations. The most common pathway for pesticides to enter surface water is through runoff or leaching.

The MDA routinely collects and analyzes water samples from selected locations throughout the state to determine the identity, concentration, and frequency of detections of pesticides in Minnesota's ground and surface water resources. In 2011, the MDA sampled the Sand Hill River and detected the presence of acetochlor, atrazine, desethylatrazine, and simazine, all of which are common agricultural pesticides.

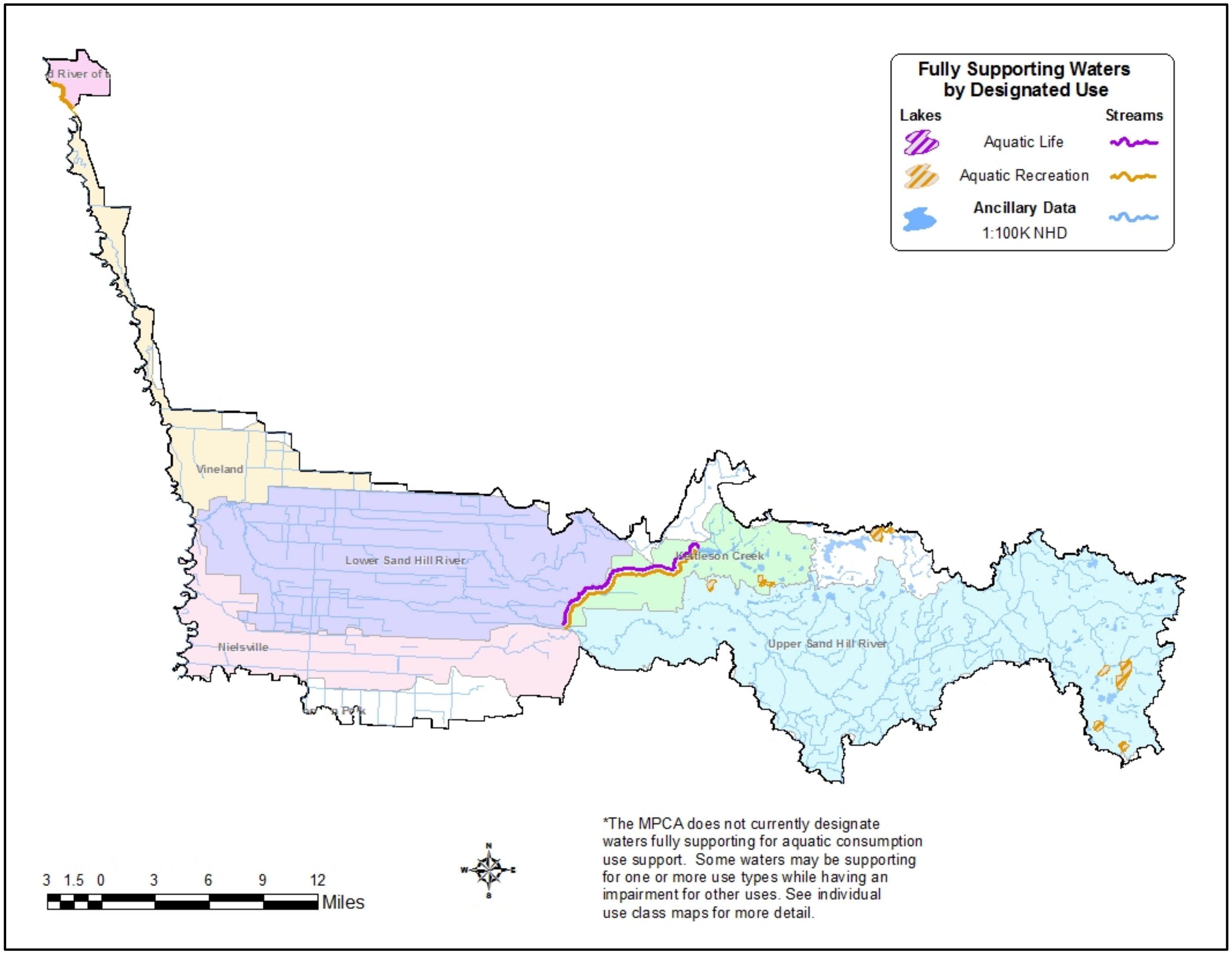

Figure 35. Fully supporting waters by designated use in the Sand Hill River Watershed

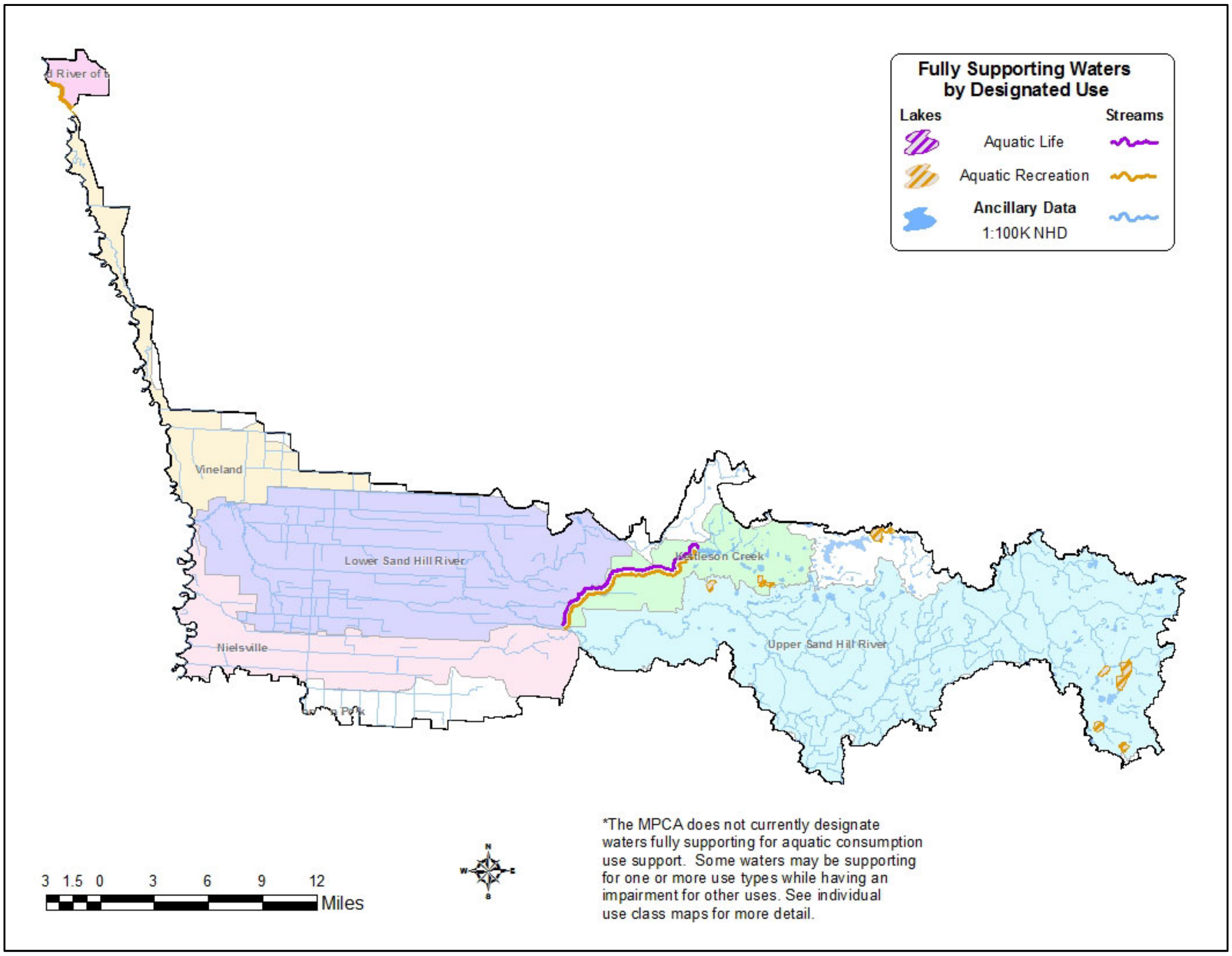

Figure 36. Impaired waters by designated use in the Sand Hill River Watershed

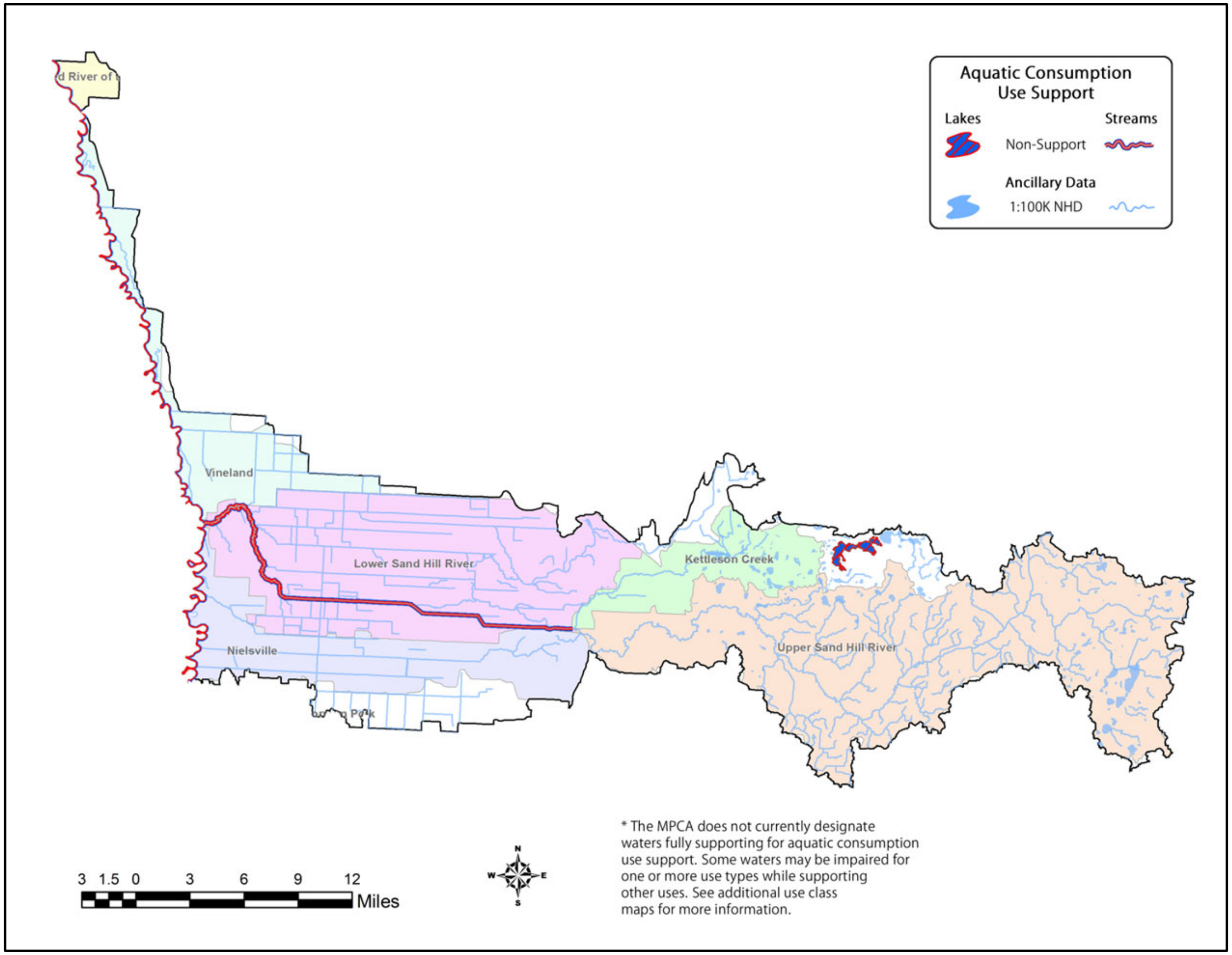

Figure 37. Aquatic consumption use support in the Sand Hill River Watershed

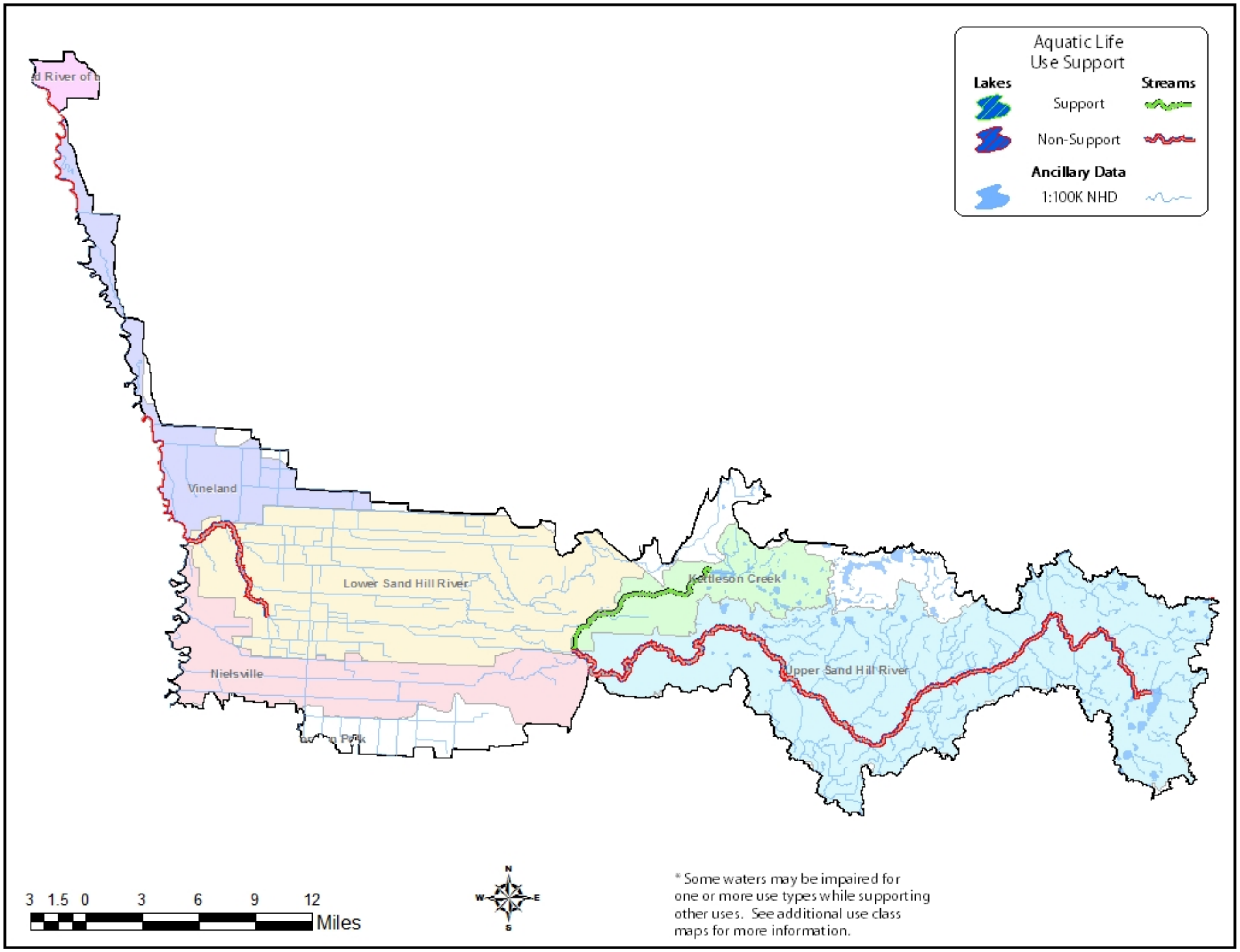

Figure 38. Aquatic life use support in the Sand Hill River Watershed

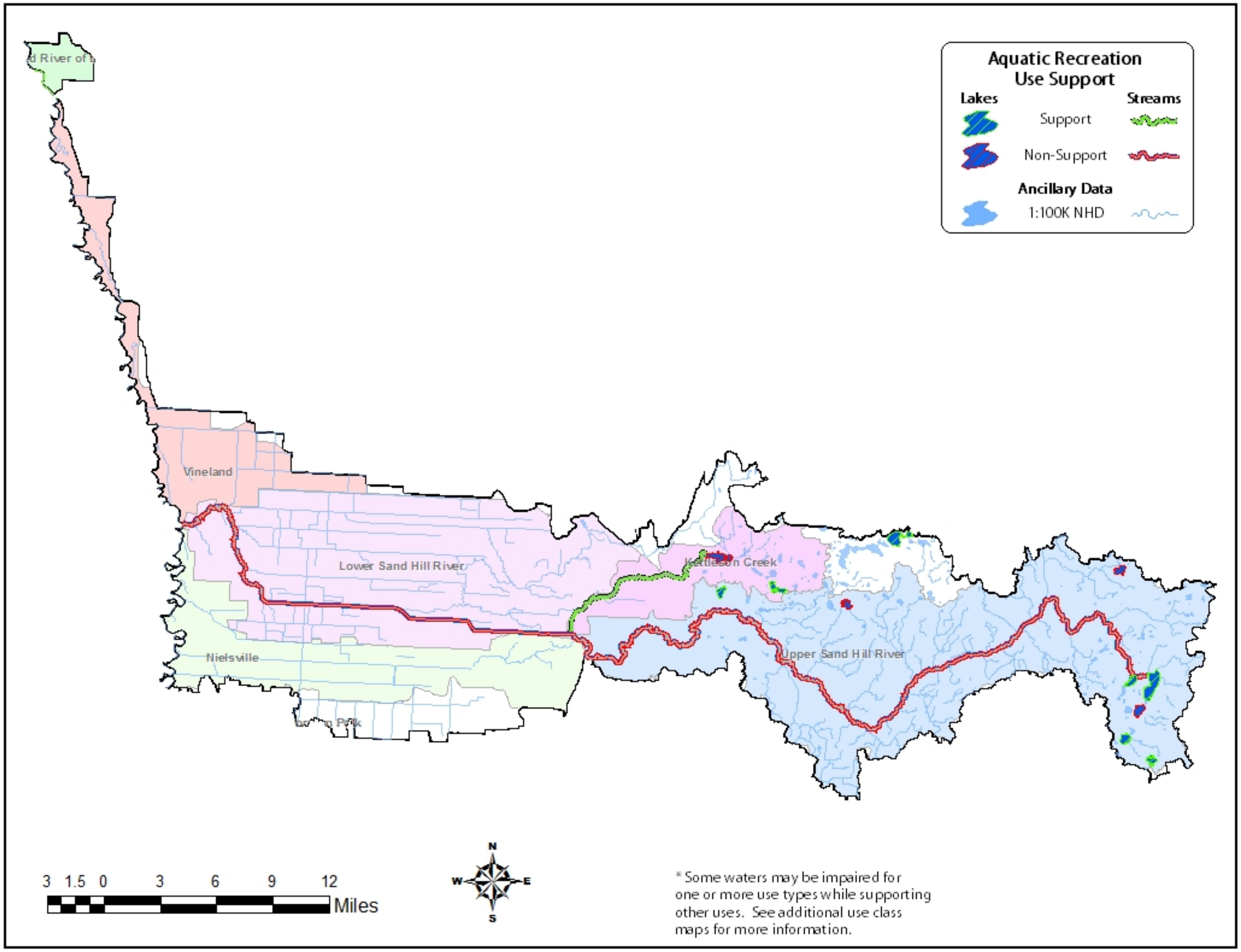

Figure 39. Aquatic recreation use support in the Sand Hill River Watershed

VII. Summaries and recommendations

Once dominated by tall grass prairie, rolling hills, and low lying wetlands, the landscape of the Sand Hill River Watershed has changed over the past century. The changes, mainly created by human development of the watershed, have had a cumulative effect on its rivers streams and lakes. Since early settlement, the landscape in the watershed has been managed to increase agricultural production. Due to the region's poorly drained soils, many of the rivers and streams were altered to create extensive ditch networks to increase drainage. The alterations have included ditching, stream channelization, tiling, the creation of dams, and altering or removing many of the watershed's wetlands. By altering streams and draining wetlands, the water storage capacity on the landscape has been drastically reduced which has had a negative effect on the overall water quality.

Today, much of the surface waters in the Sand Hill River are considered "flashy", with high peak flows following rain events and extremely low flows during dry periods. To control drainage and reduce flooding, dams and other water control structures were created along the Sand Hill River. While these structures can control flooding, they alter connectivity along streams which can obstruct migratory fish passage. These structures may also alter stream flow, water temperature, and sediment transport processes - each of which can cause changes in fish and macroinvertebrate assemblages (Cummins, 1979; Waters, 1995). Connectivity appears to be a large contributing factor to the aquatic life impairment in the lower sections of the Upper Sand Hill River Subwatershed. The four water control structures downstream of this watershed are serving as fish barriers to longer lived migratory species (eg. redhorse, walleye, channel catfish) that would normally inhabit streams of this size. The MPCA collected these species downstream of the barriers but they were entirely absent at stations above. Habitat at stations along the Sand Hill River above the barriers were generally good, especially the section from the barriers to the Kittleson creek confluence. Sensitive minnow species were present (e.g. longnose dace) indicating that habitat might not be limiting fish and macroinvertebrate communities.

As a whole, habitat conditions vary greatly throughout the watershed with better habitat found along portions of the Upper Sand Hill River where the river retains its natural channel. In contrast, with the exception of Kittleson Creek, many of the Sand Hill River's tributary streams have generally poor habitat and show signs of severe degradation. Due to the flashy nature of these streams, much of the macroinvertebrate habitat (e.g. overhanging vegetation, aquatic macrophytes) becomes either flushed out during peak flows or becomes less available during dry periods. In addition, excess sedimentation has filled in pools and embedded coarse substrates that are needed by sensitive fish and macroinvertebrates.

Elevated bacteria levels were found on all four reaches of the Sand Hill River, which can indicate conditions that are unsafe for swimming and secondary body contact such as fishing. Sources of bacteria that have the potential to cause water borne illnesses in streams include outdated or underperforming septic systems and animal waste (e.g., livestock, pets, wildlife). Excess sedimentation has contributed to much of the watershed being impaired by turbidity, including most of the main stem Sand Hill River. Rivers and streams in the watershed have been heavily modified to promote agricultural drainage and stream channelization, which is a likely cause for these impairments. Drainage can cause scouring of stream banks as flashier flows enlarge stream channels, exacerbating bank erosion.

Overall, rivers and streams in the SHRW appear to be in poor condition. Biological communities vary greatly, and hydrologic alterations by means of agricultural drainage and stream channelization appear to be affecting necessary habitats to support healthy biological communities. Also, barriers to fish migrations are contributing to aquatic life impairments in the Upper Sand Hill River Subwatershed and fish passage should be restored to allow access to the upper reaches of the Sand Hill River by migrating fish species. In order to bring turbidity and bacteria values on the Sand Hill River back into compliance with state standards, considerable measures should be taken on a watershed wide scale to ascertain critical areas contributing to the impairments. In addition, steps should be taken to improve the riparian areas and land uses around the river and its tributaries. Some examples of actions that could improve the conditions are:

- Establish/reestablish vegetative buffers along riparian zones with native vegetation and trees.
- Promote water retention within the basin through practices that do not compromise stream connectivity.

The surficial geology of the Red River Valley is such that conditions for groundwater recharge are ideal in only a few areas around topographic highs and in the presence of surficial sand and gravel deposits. Preservation of these areas is critical to maintaining sufficient groundwater availability for consumptive use. Management of groundwater resources should be a topic of interest for this watershed given that groundwater withdrawals have shown a statistically significant increase and areas of substantial groundwater recharge are also limited within the watershed.

Lake water quality within the watershed indicates a trend towards impairment as the natural landscape is altered. Most of the lakes in the watershed are shallow lakes which are susceptible to any excess input of nutrients like phosphorus. Lake water quality varies widely within the headwater subwatersheds, indicating a variety of contributing factors are likely responsible for varying water conditions. Overall, four lakes were assessed as not supporting aquatic recreation and seven lakes were assessed as supporting aquatic recreation. Aquatic recreation impairments for lakes in the watershed are due to excess nutrients which can cause unsightly and sometimes toxic algal blooms. In addition, wind mixing in shallow lakes can suspend sediment in the water, reintroducing phosphorus attached to soil particles in the water column. Protection of those lakes currently meeting standards will be necessary so no measurable degradation occurs. This is particularly true for the shallow lakes that have limited ability to assimilate nutrients which can lead to excessive plant growth as a result of increased nutrient loading. It will be important to minimize any future increases in nutrient loading, and where possible, to seek reductions in current sources of excess nutrients.

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Appendix

Appendix 1 - Water chemistry definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

Appendix 2 - Intensive watershed monitoring water chemistry stations in the Sand Hill River Watershed

Biological Station ID	STORET / EQuIS ID	Waterbody Name	Location	11-digit HUC
11RD014	S003-136	Sand Hill River	At 350th Ave SW, 5 mi. SW of Fertile	09020301100
11RD015	S004-187	Kittleson Creek	At CR 1, 5 mi. W of Fertile	09020301110
11RD009	S006-559	Sand Hill River	At 100th St/CR 107, 2.5 mi. SW of Winger	09020301100
11RD028	S002-099	Sand Hill River	At Hwy 75 in Climax	09020301120

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

AUID DESCRIPTIONS				USES							BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS						
Assessment Unit ID (AUID)	Stream Reach Name	Reach Description	Reach Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Aquatic Consumption	Drinking Water	303d listed impairments 2012		Fish	Macroinvertebrates	Dissolved Oxygen	Turbidity	Chloride	pH	NH3	Pesticides	Bacteria (Aquatic Recreation)
HUC 12: 09020301100 (Upper Sand Hill River)																			
09020301-512	County Ditch 16	CD 55 to Sand Hill River	2	2B	NA	NA					NA	NA							
09020301-515	County Ditch 17	Garden Slough to Sand Hill River	0.28	2B	NS	NA					MTS	EXP							
09020301-538	County Ditch 48	Unnamed Creek to Sand Hill River	3.85	2B															
09020301-539	Unnamed Creek	Unnamed Creek to Sand Hill River	2.04	2B	NA	NA					NA	NA							
09020301-540	County Ditch 55	Unnamed Creek to County Ditch 15	3.07	2B	NA	NA					NA	NA							
09020301-541	Sand Hill River	Headwaters to CD 17	38.13	2B	NS	NS					EXS	EXS	EXP	EXP		MTS	MTS		EX
09020301-542	Sand Hill River	CD 17 to Kittleson Creek	32.09	2B	NS	NS					EXS	MTS	IF	MTS		MTS	MTS		EX
HUC 12: 09020301110 (Kittleson Creek)																			
09020301-508	Kittleson Creek	Headwaters to Sand Hill River	12.44	2C	FS	FS					MTS	MTS	IF	MTS		MTS	MTS		MTS
HUC 12: 09020301120 (Lower Sand Hill River)																			
09020301-519	County Ditch 6	County Ditch 6	1.16	2B	IF	NA					--	--	IF			EXP			
09020301-537	Sand Hill RIver	Sand Hill River	14.22	2B	NS	NS					MTS	MTS	MTS	EXS		MTS	MTS		EX

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets standards or ecoregion expectations (MT/MTS), Potential Exceedence (EXP), Exceeds standards or ecoregion expectations (EX/EXS).
Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use. *Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.
† AUID 07080201-503 is listed in the table twice since the 29 mile AUID spanned the length of two different HUCs (07080201010 and 07080201030)

Appendix 3.2 - Assessment results for lakes in the Sand Hill River Watershed

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (acres)	Max Depth (m)	Watershed Area (acres)	% Littoral	Mean depth (m)	Support Status
44-0151-00	LaDuc	Mahnomen	09020301100	NCHF	72.9		7831			NA
44-0152-00	Ketchum	Mahnomen	09020301100	NCHF	155.9	5.2	1897	100	1.5*	NS
44-0154-00	Frethem	Mahnomen	09020301100	NCHF	54.0		5232			NA
44-0156-00	Unnamed	Mahnomen	09020301100	NCHF	10.8		2552			NA
44-0157-00	Allen	Mahnomen	09020301100	NCHF	145.4	1	4599	100	1*	FS
44-0162-00	Simonson	Mahnomen	09020301100	NCHF	107.4		755	100	1*	FS
54-0008-00	Unnamed	Norman	09020301100	RRV	12.2		11070			NA
54-0009-00	Unnamed	Norman	09020301100	RRV	12.1		10274			NA
54-0012-00	Unnamed	Norman	09020301100	RRV	28.6		10524			NA
60-0067-00	Unnamed	Polk	09020301100	NCHF	44.7		288			NA
60-0069-00	Sand Hill	Polk	09020301100	NCHF	483.3	5.2	4783	100	1.5*	FS
60-0070-00	Unnamed	Polk	09020301100	NCHF	15.8		14570			NA
60-0071-00	Labrie	Polk	09020301100	NCHF	52.6	1.8	16854			NA
60-0075-00	Unnamed	Polk	09020301100	RRV	15.7		103			NA
60-0078-00	Unnamed	Polk	09020301100	RRV	15.6		3001			IF
60-0079-00	Unnamed	Polk	09020301100	NCHF	13.3		849			NA
60-0093-00	Hilligas	Polk	09020301100	NCHF	131.5	2.4	16854	100	1*	FS
60-0094-00	Unnamed	Polk	09020301100	RRV	22.4		474			NA
60-0119-00	Uff	Polk	09020301100	RRV	129.4	2.4	699	100	1*	NS
60-0149-00	Unnamed	Polk	09020301100	RRV	11.0		2708			NA
60-0179-00	Unnamed	Polk	09020301100	RRV	21.3		1547			NA
60-0181-00	Matson	Polk	09020301100	RRV	41.2		2227			NA
60-0202-00	Sarah	Polk	09020301100	RRV	309.8	8.2	6263	51	3.8	FS
60-0217-00	Union	Polk	09020301100	RRV	799.0	25.3	12452	48	5.7	IF
60-0226-00	Unnamed	Polk	09020301110	RRV	78.5		3439			NA

60-0228-00	Halverson	Polk	09020301110	RRV	154.4	3.9	2230	100	1*	FS
60-0234-00	Unnamed	Polk	09020301100	RRV	107.7		393			IF
60-0236-00	Unnamed	Polk	09020301100	RRV	118.3	3.6	2126	100	1*	NS
60-0237-00	Maltrod	Polk	09020301100	RRV	17.7		215			NA
60-0238-00	Rindahl	Polk	09020301100	RRV	29.2		542			IF
60-0280-00	Unnamed	Polk	09020301110	RRV	15.0		6948			NA
60-0281-00	Unnamed	Polk	09020301110	RRV	12.1		7077			IF
60-0301-00	Cable	Polk	09020301110	RRV	78.7		4219			NA
60-0309-00	Arthur	Polk	09020301100	RRV	120.0	4.9	1415	100	1*	FS
60-0325-00	Unnamed	Polk	09020301110	RRV	89.9		9730			NA
60-0327-00	Kittleson	Polk	09020301110	RRV	297.5	2.4	14035	100	1*	NS
60-0332-00	Chicog	Polk	09020301120	RRV	48.6		684			NA
60-0346-00	Unnamed	Polk	09020301100	NCHF	16.4		1355			NA
60-0484-00	Unnamed	Polk	09020301100	RRV	16.2		460			NA

Abbreviations: **FS** – Full Support **N/A** – Not Assessed
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.
*These depths were created by MPCA Staff.

Appendix 4.1 - Minnesota statewide IBI thresholds and confidence limits

Class #	Class Name	Use Class	Threshold	Confidence Limit	Upper	Lower
Fish						
1	Southern Rivers	2B, 2C	39	±11	50	28
2	Southern Streams	2B, 2C	45	±9	54	36
3	Southern Headwaters	2B, 2C	51	±7	58	44
10	Southern Coldwater	2A	45	±9	58	32
4	Northern Rivers	2B, 2C	35	±9	44	26
5	Northern Streams	2B, 2C	50	±9	59	41
6	Northern Headwaters	2B, 2C	40	±16	56	24
7	Low Gradient	2B, 2C	40	±10	50	30
11	Northern Coldwater	2A	37	±10	47	27
Invertebrates						
1	Northern Forest Rivers	2B, 2C	51.3	±10.8	62.1	40.5
2	Prairie Forest Rivers	2B, 2C	30.7	±10.8	41.5	19.9
3	Northern Forest Streams RR	2B, 2C	50.3	±12.6	62.9	37.7
4	Northern Forest Streams GP	2B, 2C	52.4	±13.6	66	38.8
5	Southern Streams RR	2B, 2C	35.9	±12.6	48.5	23.3
6	Southern Forest Streams GP	2B, 2C	46.8	±13.6	60.4	33.2
7	Prairie Streams GP	2B, 2C	38.3	±13.6	51.9	24.7
8	Northern Coldwater	2A	26	±12.4	38.4	13.6
9	Southern Coldwater	2A	46.1	±13.8	59.9	32.3

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

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Threshold	FIBI	Visit Date
HUC 11: 09020301100 Upper Sand Hill River							
09020301-515	11RD012	County Ditch 17	18.15	6	40	74	14-Jun-11
09020301-541	05RD052	Sand Hill River	85.93	5	50	37	11-Aug-05
09020301-541	11RD009	Sand Hill River	119.35	5	50	34	01-Aug-11
09020301-542	11RD014	Sand Hill River	233.46	5	50	46	02-Aug-11
09020301-542	11RD070	Sand Hill River	220.43	5	50	34	22-Aug-11
09020301-542	11RD071	Sand Hill River	182.34	5	50	31	23-Aug-11
HUC 11: 07080201110 (Kittleson Creek)							
09020301-508	05RD107	Kittleson Creek	25.22	6	40	53	07-Aug-06
09020301-508	05RD107	Kittleson Creek	25.22	6	40	67	25-Jul-06
HUC 11: 07080201120 (Lower Sand Hill River)							
09020301-537	05RD018	Sand Hill River	359.15	1	39	56	13-Jul-06
09020301-537	05RD018	Sand Hill River	359.15	1	39	56	09-Aug-06
09020301-537	11RD028	Sand Hill River	462.51	1	39	66	23-Aug-11

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

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Threshold	MIBI	Visit Date
HUC 11: 09020301100 (Upper Sand Hill River)							
09020301-515	11RD012	County Ditch 17	18.15	5	35.9	29.65	09-Aug-11
09020301-541	05RD052	Sand Hill River	85.93	6	46.8	37.79	24-Aug-05
09020301-541	11RD009	Sand Hill River	119.35	6	46.8	34	09-Aug-11
09020301-542	11RD014	Sand Hill River	233.46	5	35.9	53.17	09-Aug-11
09020301-542	11RD070	Sand Hill River	220.43	5	35.9	75.07	09-Aug-11
09020301-542	11RD071	Sand Hill River	182.34	5	35.9	42.95	23-Aug-11
HUC 11: 07080201110 (Kittleson Creek)							
09020301-508	05RD107	Kittleson Creek	25.22	6	46.8	50.82	24-Aug-05
HUC 11: 07080201120 (Lower Sand Hill River)							
09020301-537	05RD018	Sand Hill River	359.15	7	38.3	45.79	07-Sep-05
09020301-537	11RD028	Sand Hill River	462.51	5	35.9	37.19	09-Aug-11

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

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

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

Appendix 5.2 - Channelized stream reach and AUID IBI scores-FISH (unassessed)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Good	Fair	Poor	FIBI	Visit Date
HUC 11: 09020301100 (Upper Sand Hill River)									
09020301-538	11RD001	County Ditch 48	10.00	6	100 - 40	39-25	24-0	64	13-Jun-11
09020301-541	11RD002	Sand Hill River	31.56	6	100 - 40	39-25	24-0	50	14-Jun-11
09020301-512	07RD003	County Ditch 16	15.19	6	100 - 40	39-25	24-0	70	07-Aug-07
09020301-512	11RD003	County Ditch 16	15.22	6	100 - 40	39-25	24-0	57	14-Jun-11
09020301-540	11RD004	County Ditch 55	9.81	6	100 - 40	39-25	24-0	37	03-Aug-11
HUC 11: 09020301110 (Kitttleson Creek)									
09020301-508	11RD015	Kittleson Creek	54.13	5	100 - 50	49-35	34-0	34	15-Jun-11
HUC 11: 07080201120 (Lower Sand Hill River)									
09020301-537	11RD021	Sand Hill River	340.78	1	100 - 39	38-24	23 - 0	66	03-Aug-11
09020301-537	07RD007	Sand Hill River	314.22	1	100 - 39	38-24	23 - 0	57	07-Aug-07
09020301-537	11RD016	Sand Hill River	300.12	5	100 - 50	49-35	34 - 0	56	02-Aug-11

Appendix 5.3 - Channelized stream reach and AUID IBI scores-macroinverbrates (unassessed)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Good	Fair	Poor	MIBI	Visit Date
HUC 11: 09020301100 (Upper Sand Hill River)									
09020301-538	11RD001	County Ditch 48	10.00	7	100-39	38-23	22-0	23.12	08-Aug-11
09020301-541	11RD002	Sand Hill River	31.56	7	100-39	38-23	22-0	8.48	23-Aug-11
09020301-512	07RD003	County Ditch 16	15.19	7	100-39	38-23	22-0	33.58	14-Aug-07
09020301-512	07RD003	County Ditch 16	15.19	7	100-39	38-23	22-0	46.80	08-Aug-11
HUC 11: 09020301120 (Lower Sand Hill River)									
09020301-537	11RD021	Sand Hill River	340.78	7	100-39	38-23	22-0	47.03	23-Aug-11
09020301-537	07RD007	Sand Hill River	314.22	7	100-39	38-23	22-0	42.14	15-Aug-07
09020301-537	11RD016	Sand Hill River	300.12	5	100-37	36-21	20-0	51.28	09-Aug-11

Appendix 6.1 - 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 6.2 - MINLEAP model estimates of phosphorus loads for lakes in the Sand Hill 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
44-0152-00	Ketchum	87	63	67	28	0.4	1.1	163	167	0.0	0.62	1.02	0.9	1.62	E
44-0157-00	Allen	24	88	3	45	0.8	0.8	154	376	0.0	0.43	2.44	0.2	4.15	M
44-0162-00	Simonson	17	63	2	28	2.5	1.1	173	72	0.0	0.64	0.41	1.0	0.95	M
60-0069-00	Sand Hill	40	59	13	26	1.2	1.1	166	431	0.0	0.64	2.59	1.1	1.33	E
60-0093-00	Hilligas	40	111	12	64	1.2	0.7	149	1328	0.0	0.26	8.89	0.1	16.7	E
60-0119-00	Uff	130	59	70	25	0.3	1.1	180	70	0.0	0.67	0.39	1.3	0.74	H
60-0202-00	Sarah	26	53	13	21	2.9	1.3	157	525	0.0	0.67	3.35	1.4	2.67	E
60-0228-00	Halverson	55	74	16	36	1.1	0.9	161	192	0.0	0.54	1.20	0.5	1.92	E
60-0236-00	Unnamed	69	78	45	38	0.5	0.9	158	180	0.0	0.51	1.14	0.4	2.38	E
60-0309-00	Arthur	53	71	20	33	1.3	1.0	163	125	0.0	0.57	0.76	0.6	1.57	E
60-0327-00	Kittleson	87	95	23	51	0.4	0.8	152	1129	0.0	0.38	7.43	0.2	6.17	E

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

Appendix 7 – Fish species found during biological monitoring surveys

Common Name	Quantity of Stations Where Present	Quantity of Individuals Collected
bigmouth shiner	8	111
black bullhead	15	74
black crappie	2	2
blacknose dace	10	521
blackside darter	8	48
brassy minnow	11	262
brook stickleback	13	1146
brown bullhead	2	2
burbot	1	1
central mudminnow	15	1503
channel catfish	4	77
common carp	3	14
common shiner	13	530
creek chub	17	886
emerald shiner	1	5
fathead minnow	18	1557
finescale dace	2	115
freshwater drum	3	6
golden redhorse	4	59
golden shiner	3	6
goldeye	1	3
greater redhorse	1	3
green sunfish	6	23
Iowa darter	9	108
johnny darter	9	185
largemouth bass	1	7

Common Name	Quantity of Stations Where Present	Quantity of Individuals Collected
longnose dace	7	478
northern pike	2	2
northern redbelly dace	14	1292
pearl dace	9	791
pumpkinseed	1	1
quillback	1	1
sand shiner	3	99
sauger	3	23
shorthead redhorse	3	14
silver redhorse	4	12
smallmouth bass	2	4
spotfin shiner	4	148
spottail shiner	1	6
stonecat	2	11
trout-perch	4	94
walleye	3	5
white bass	1	4
white sucker	14	479
yellow perch	16	326

Appendix 8 – Macro-Invertebrate species found during biological monitoring surveys

Taxonomic Name	Quantity of Individuals Collected	Number of Stations Where Present
Acari		
Acari	51	12
Amphipoda		
Hyalella	56	6
Coleoptera		
Anacaena	3	1
Crenitis	1	1
Dubiraphia	153	12
Dytiscidae	1	1
Gymnochthebius	1	1
Gyrinidae	1	1
Gyrinus	5	2
Haliplus	5	4
Helichus	8	2
Helophorus	1	1
Hydrophilus	0	1
Laccophilus	7	4
Liodessus	21	4
Macronychus	9	3
Macronychus glabratus	47	5
Optioservus	15	5
Peltodytes	3	2
Stenelmis	57	11
Crustacea		
Cambaridae	1	1
Crambidae	4	3

Taxonomic Name	Quantity of Individuals Collected	Number of Stations Where Present
Orconectes	9	12
Diptera		
Ablabesmyia	20	9
Acricotopus	1	1
Antocha	12	2
Atherix	12	4
Brillia	22	10
Ceratopogonidae	1	1
Ceratopogoninae	7	5
Chironomini	19	9
Chironomus	44	3
Cladotanytarsus	2	1
Clinotanypus	2	1
Coenagrionidae	65	8
Corynoneura	6	4
Cricotopus	228	14
Cryptochironomus	23	5
Cryptotendipes	1	1
Culicoides	1	1
Dicranota	2	1
Dicrotendipes	176	10
Empididae	6	3
Enallagma	7	3
Endochironomus	1	1
Ephydridae	32	10
Eukiefferiella	28	3
Glyptotendipes	40	2
Hayesomyia sonata	1	1

Taxonomic Name	Quantity of Individuals Collected	Number of Stations Where Present
Hemerodromia	3	2
Labrundinia	28	11
Limnophyes	6	3
Limonia	1	1
Micropsectra	26	7
Microtendipes	24	6
Muscidae	1	1
Nanocladius	6	4
Nilotanypus	1	1
Orthocladiinae	12	7
Orthocladius	15	6
Parachironomus	2	1
Parakiefferiella	21	4
Paralauterborniella nigrohalterale	4	3
Paramerina	4	1
Parametriocnemus	10	5
Paraphaenocladius	1	1
Paratanytarsus	75	8
Paratendipes	4	3
Phaenopsectra	57	6
Polypedilum	905	19
Probezzia	1	1
Procladius	15	4
Psychoda	1	1
Rheocricotopus	24	6
Rheotanytarsus	174	14
Saetheria	16	2
Sciomyzidae	1	1

Taxonomic Name	Quantity of Individuals Collected	Number of Stations Where Present
Simuliidae	5	1
Simulium	178	10
Stempellina	1	1
Stempellinella	3	3
Stenochironomus	16	4
Stictochironomus	1	1
Tabanidae	3	3
Tanypodinae	28	8
Tanytarsini	7	4
Tanytarsus	49	10
Thienemanniella	51	11
Thienemannimyia	73	9
Thienemannimyia Gr.	34	6
Tipula	1	1
Tribelos	2	2
Tvetenia	5	2
Zavrelimyia	2	1
Ephemeroptera		
Acentrella	1	1
Acentrella parvula	22	4
Acerpenna	1	1
Acerpenna pygmaeus	7	1
Baetidae	22	3
Baetis	27	3
Baetis brunneicolor	6	2
Baetis flavistriga	13	2
Baetis intercalaris	57	5
Baetisca lacustris	1	1

Taxonomic Name	Quantity of Individuals Collected	Number of Stations Where Present
Caenis	92	10
Caenis youngi	23	5
Caenis tardata	9	3
Callibaetis	3	1
Centroptilum	4	2
Heptagenia	10	3
Heptageniidae	43	5
Hexagenia	3	1
Isonychia	8	2
Iswaeon	21	4
Labiobaetis propinquus	90	7
Maccaffertium	45	6
Maccaffertium luteum	18	2
Paracloeodes minutus	2	1
Procloeon	12	4
Pseudocloeon	52	3
Stenacron	52	4
Stenacron interpunctatum	3	1
Stenonema	14	1
Tricorythodes	454	9
Gastropoda		
Ferrissia	242	8
Fossaria	1	1
Gyraulus	7	3
Hydrobiidae	8	1
Lymnaeidae	6	4
Physa	218	13
Planorbella	0	3

Taxonomic Name	Quantity of Individuals Collected	Number of Stations Where Present
Pseudosuccinea	2	1
Stagnicola	0	2
Valvata	82	1
Hemiptera		
Belostoma	4	4
Belostoma flumineum	1	3
Corixidae	11	3
Lethocerus		1
Metrobates	1	1
Neoplea	2	2
Neoplea striola	11	5
Palmacorixa	3	1
Ranatra		1
Trichocorixa	8	2
Hirudinea		
Hirudinea	20	8
Lepidoptera		
Paraponyx	1	1
Megaloptera		
Nigronia	1	1
Mollusca		
Pisidiidae	58	11
Unionidae	3	1
Nematoda		
Nematoda	2	1
Odonata		
Aeshnidae	2	2
Anax		1

Taxonomic Name	Quantity of Individuals Collected	Number of Stations Where Present
Calopterygidae	47	10
Calopteryx	23	5
Calopteryx aequabilis	5	5
Gomphidae	2	2
Hetaerina	11	3
Ischnura	1	1
Libellula		1
Somatochlora		1
Oligochaeta		
Oligochaeta	362	16
Plecoptera		
Acroneuria	3	1
Acroneuria abnormis	1	1
Paragnetina media	4	2
Pteronarcys	7	5
Trichoptera		
Brachycentrus	7	2
Brachycentrus numerosus	163	7
Ceraclea	2	1
Ceratopsyche	22	2
Ceratopsyche alhedra	8	1
Ceratopsyche slossonae	11	3
Ceratopsyche vexa	1	1
Cheumatopsyche	54	10
Cyrnellus fraternus	3	1
Hydropsyche	13	5
Hydropsyche betteni	3	1
Hydropsyche cuanis	4	2

Taxonomic Name	Quantity of Individuals Collected	Number of Stations Where Present
Hydropsyche simulans	2	1
Hydropsychidae	22	8
Hydroptila	68	5
Hydroptilidae	12	3
Leptoceridae	2	1
Limnephilidae	2	2
Mystacides	6	2
Nectopsyche	38	1
Nectopsyche candida	79	2
Nectopsyche diarina	7	1
Neureclipsis	7	1
Oecetis avara	6	1
Phryganeidae	5	2
Polycentropodidae	1	1
Polycentropus	4	3
Potamyia	1	1
Ptilostomis	1	1
Pycnopsyche	2	1
Rhyacophila	1	1
Triaenodes	86	1
Turbellaria		
Turbellaria	2	2