Pomme de Terre River Watershed Monitoring and Assessment Report

Minnesota Pollution Control Agency

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Authors

MPCA Report Team
Pat Baskfield
Dave Christopherson
Chandra Carter
Tony Dingmann
Lee Engel
Dan Helwig
Kim Laing
Louise Hotka
Tim Larson
Bruce Monson
Katherine Pekarek-Scott
Steve Thompson
Kris Parson
Dana Vanderbosch

Contributors

Citizen Stream Monitoring Program Volunteers
Citizen Lake Monitoring Program Volunteers
Minnesota Department of Agriculture
Minnesota Department of Natural Resources
Pomme de Terre River Association
Minnesota Department of Health

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Minnesota Pollution Control Agency

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

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Abbreviations

AUID – Assessment Unit ID
CLMP – Citizen Lake Monitoring Program
CSMP – Citizen Stream Monitoring Program
CWP – Clean Water Partnership
EPA – Environmental Protection Agency
F-IBI – Fish Index of Biotic Integrity
FWMC – Flow Weighted Mean Concentration
HUC – Hydrologic Unit Code
MCEC – Metropolitan Council Environmental Services
MCL – Maximum Contaminant Level
MDNR – Minnesota Department of Natural Resources
MWLMP – Major Watershed Load Monitoring Program
M-IBI – Macroinvertebrate Index of Biotic Integrity
NTU – Nephelometric Turbidity Units
P-IBI – Plant Index of Biotic Integrity
PJG – Professional Judgment Group
SWAG – Surface Water Assessment Grant
TSS – Total Suspended Solids
USGS – United States Geological Survey
WMA – Wildlife Management Area
WPA - Waterfowl Production Areas

Executive Summary

The Pomme de Terre River watershed has a lake dominated headwater region, characterized by good water quality both in lakes and streams. There are seven lakes fully supporting of aquatic recreation and seven Assessment Unit IDs (AUIDs) fully supporting of aquatic life in the Upper Pomme de Terre and Pelican Creek watersheds. As the landscape and land use change in the middle portion of the watershed, so does the water quality. The change in water quality occurs south of Barrett Lake, where the ecoregion boundary exists, changing from the North Central Hardwood Forest (NCHF) ecoregion in the north to the Northern Glaciated Plains ecoregion in the middle and southern parts of the watershed. The land use also transitions here, changing from cropland with large areas of lakes, wetlands, and forest, to a crop-dominated landscape. Impairments are concentrated in this part of the watershed. Seven stream AUIDs are non-supporting in the middle and lower parts of the watershed; two for aquatic recreation, five for aquatic life, and two for aquatic consumption. Additionally, two wetlands are non-supporting of aquatic life in the southwest section of the watershed. Four lakes are non-supporting of aquatic recreation, and twelve are non-supporting of aquatic consumption. Of the 217 lakes and 29 stream AUIDs throughout the watershed, not all were able to be assessed due to insufficient data, limited resource waters, or predominantly channelized stream reaches.

Based on the nature of aquatic consumption impairments, the entire river is listed if values exceed the threshold on any part of the river. Subsequently, the aquatic consumption impairments span the entire length of the Pomme de Terre River, starting at the headwaters and extending to the mouth of the river. Nutrient concentrations are also high throughout the watershed, and the four lakes impaired for aquatic recreation are all impaired based on nutrient data. Nutrient concentrations and turbidity levels both steadily increase along the mainstem Pomme de Terre River, with the highest concentrations located in the most downstream section. Drywood Creek, located in the southwest part of the watershed, has the second highest nutrient and turbidity concentrations in the watershed after the downstream section of the Pomme de Terre River. Nitrate-nitrite nitrogen levels are highest during the month of April in both the lower Pomme de Terre River and Drywood Creek, and phosphorus levels are highest during April and July in Drywood Creek and highest during July in the lower Pomme de Terre River. The biological impairments for fish extend from Barrett Lake down to the mouth of the river, while turbidity, E. coli, and macroinvertebrate biological impairments extend from just south of Morris to the mouth of the river. Drywood Creek, which enters the Pomme de Terre River south of Morris, along with having high nutrient levels, is also impaired for fish, macroinvertebrates, turbidity, E. coli, and dissolved oxygen.

I. Introduction

Water is one of Minnesota's most abundant and precious resources. The Minnesota Pollution Control Agency (MPCA) is charged under both federal and state law with the responsibility of protecting the water quality of Minnesota's water resources. The MPCA's water management efforts are tied to the 1972 Federal Clean Water Act (CWA) requiring 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 the state's surface waters and to develop a list of water bodies that do not meet established standards. Such waters are referred to as "impaired waters" and the state must take appropriate actions to restore these waters, including the development of Total Maximum Daily Loads (TMDLs). A TMDL is a comprehensive study identifying all pollution sources causing or contributing to impairment and the reductions needed to restore a water body so that it can 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 be successful addressing and preventing problems, decision makers need good information about the status of the resources, potential and actual threats, options for addressing the threats, and data on 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.

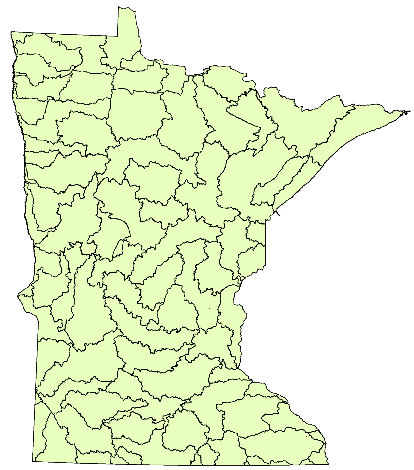
The passage of Minnesota's Clean Water Legacy Act provided a policy framework and initial resources to state and local governments to accelerate efforts to monitor, assess, restore, and protect surface waters. Funding from the Clean Water Fund allows a continuation of this work. In response, the MPCA has developed a watershed monitoring strategy that will promote an effective and efficient integration of water monitoring programs to provide a comprehensive assessment of water quality and expedite the restoration and protection process. This has permitted the MPCA to establish a strategy and goal to assess the condition of Minnesota's surface waters via a 10-year cycle and provides an opportunity to more fully integrate MPCA water resource management efforts in cooperation with local government and stakeholders, and to allow for coordinated development and implementation of water quality restoration and improvement projects.

The rationale behind the watershed approach is to intensively monitor the streams and lakes within a major watershed to determine the overall health of water resources, identify impaired waters, and to identify waters in need of additional protection efforts. Consequently, there is an opportunity to begin to address most, if not all, the impairments through a coordinated TMDL process at a watershed scale, rather than the reach by reach and parameter by parameter approach historically employed. A watershed approach will more effectively address multiple impairments resulting from the cumulative effects of point and nonpoint sources of pollution and further the CWA goal of protecting, restoring, and preserving the quality of Minnesota's water resources. This monitoring strategy was implemented in the Pomme de Terre River Watershed in the summer of 2007. This report provides a summary of all water quality assessment results at a watershed scale and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring, and monitoring conducted by local government units including Otter Tail, Swift, and Stevens Counties.

II. The Watershed Monitoring Approach

The watershed approach is a 10-year rotation for assessing waters of the state on the level of Minnesota's 81 major watersheds (Figure 1). The primary feature of the watershed approach is that it provides a unifying focus on the water resources within a watershed as the starting point for water quality assessment, planning, and result measures. 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 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 2008a) (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

Figure 1. Major watersheds within Minnesota

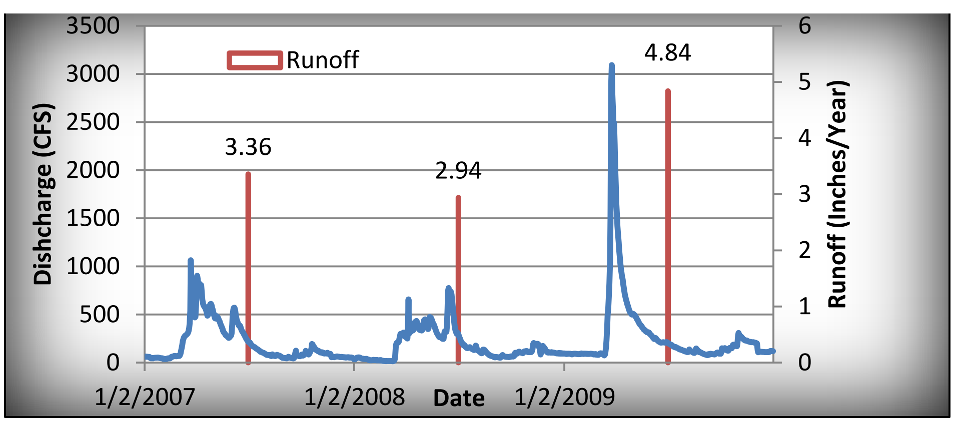


Load monitoring network

The first component of this effort is the Major Watershed Load Monitoring Program (MWLMP). The MWLMP is a long-term program designed to measure and compare regional differences and long-term trends in water quality on Minnesota's major rivers, including the Red, Rainy, St. Croix, Mississippi, Minnesota, and the outlets of major tributaries (8 digit Hydrologic Unit Code (HUC) scale watersheds) draining to these rivers. Initiated in 2007 and funded with appropriations from Minnesota's Clean Water Fund, the MWLMP's multi-agency monitoring approach combines site specific stream flow data from the U.S. Geological Survey (USGS) and Minnesota Department of Natural Resources (MDNR) flow gauging stations with water quality data collected by the Metropolitan Council Environmental Services (MCES), local monitoring organizations, and MWLMP staff to compute annual pollutant loads from these sites. When fully implemented, the MWLMP will monitor and compute pollutant loads at 82 stream sites across Minnesota. As of October 2010, 80 sites were in operation.

Water quality sampling occurs year round at all MWLMP sites. Thirty to thirty-five mid-stream grab samples are collected per site per year with sampling frequency greatest during periods of moderate to high flow (Figure 2).

Figure 2. Hydrograph and Inches of Runoff per Year for the Pomme de Terre River in Appleton



Frequent sampling during major runoff events is required to capture the largest pollutant loads and to accurately characterize shifting concentration/flow dynamics. 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 other flow ranges. 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.

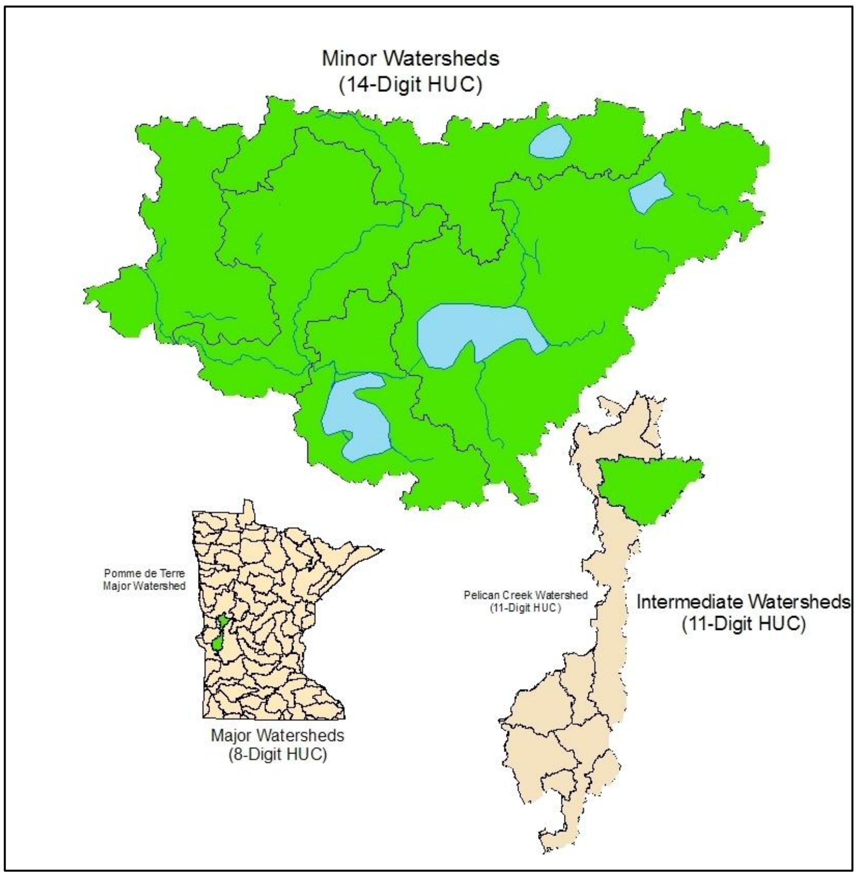
Annual water quality and daily average discharge data is input into the "Flux32" pollutant load model to create concentration/flow regression equations to estimate pollutant concentrations and loads on days when samples are not collected. Primary output includes annual pollutant loads, defined as the amount (mass) of a pollutant passing a stream location over a defined period of time. Also generated through modeling are flow weighted mean concentrations (FWMCs), an estimate of the average concentration of a pollutant within the total volume of water that passed the monitoring site during the monitoring period. FWMCs are computed by dividing the pollutant load by the total seasonal flow volume. Annual pollutant loads are calculated for total suspended solids (TSS), total phosphorus (TP), dissolved orthophosphate (DOP), and nitrate plus nitrite nitrogen (NO_2+NO_3).

In addition to providing comparative and trend information, data that is collected and generated by the MWLMP will also be used to assist in developing watershed protection and restoration plans, watershed models, and will be used to put the intensive watershed monitoring data into a longer-term context.

Intensive watershed monitoring

The intensive watershed monitoring strategy utilizes a nested watershed design allowing the aggregation of watersheds from a coarse to a fine scale. Sampling occurs in each of the state's 81 major watersheds once every 10 years. In this approach, river/ stream sites are selected near the outlet or "pour point" at all watershed scales, including intermediate-sized (approximately 11-digit HUC) and "minor" (14-digit HUC) watersheds (Figure 3). This approach provides holistic assessment coverage of rivers and streams without monitoring every single stream reach (see Figure 4 for an illustration of the monitoring site coverage within the Pomme de Terre River major watershed).

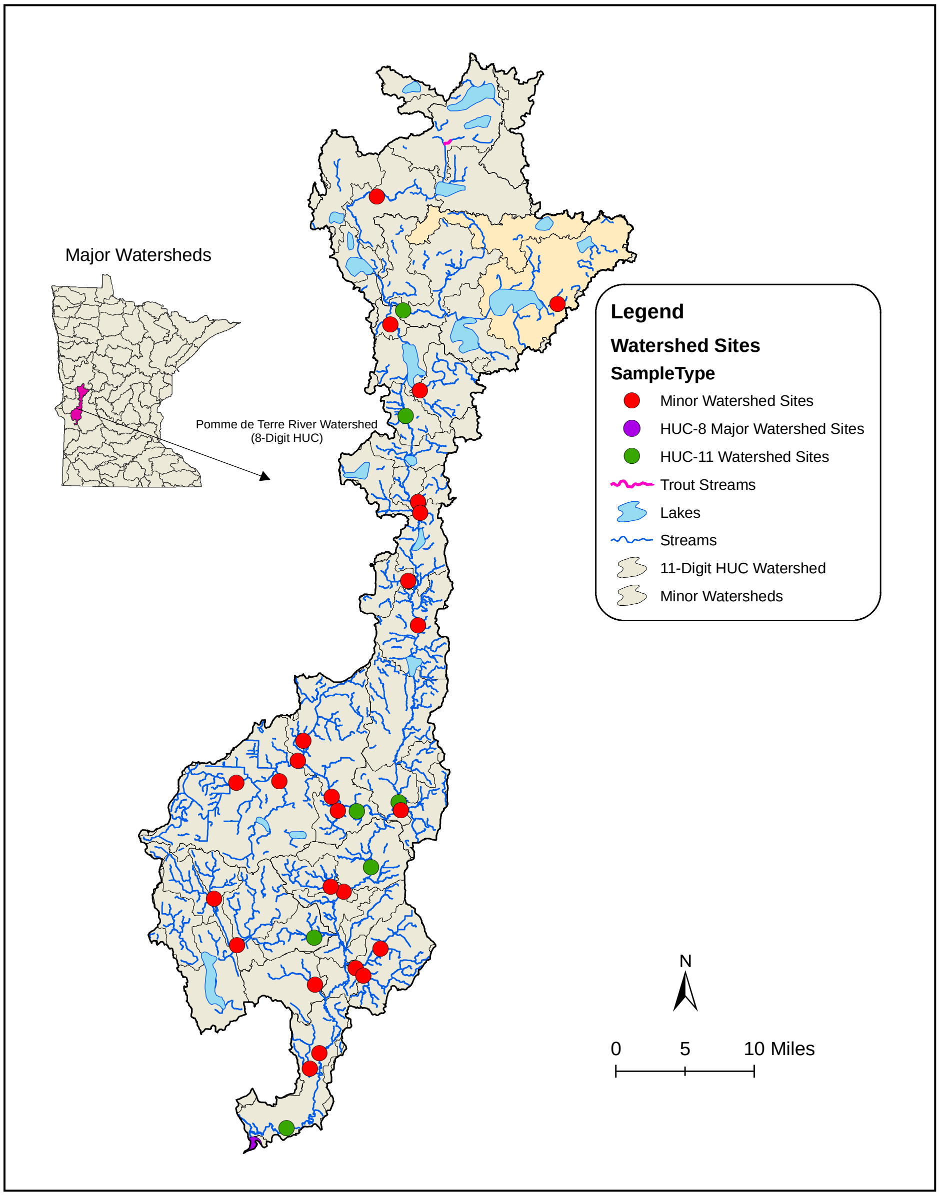
Figure 3. The intensive watershed monitoring design



The outlet of the major watershed (purple dot in Figure 4) is sampled for biology, water chemistry, and fish contaminants to allow for the assessment of aquatic life, aquatic recreation, and aquatic consumption use-support. Each 11-digit HUC pour point (green dots in Figure 4) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use-support. Watersheds this scale generally consist of major tributary streams with drainage areas ranging from 75 to 150 square miles. Lastly, most minor watersheds (typically 10-20 square miles) are sampled for biology to assess for aquatic life use support (red dots in Figure 4). Specific locations for sites sampled as part of the intensive monitoring effort in the Pomme de Terre River Watershed can be found in Appendix 1.

The second step of the intensive watershed monitoring effort consists of follow-up monitoring at areas determined to have impaired waters. This follow-up monitoring is designed to collect the information needed to initiate the stressor identification process in order to identify the source(s) and cause(s) of impairment that is required for TMDL development and implementation.

Figure 4. Intensive watershed monitoring stations in the Pomme de Terre River Watershed



Lake monitoring

The MPCA conducts and supports lake monitoring for a variety of objectives. Lake condition monitoring activities are focused on assessing the recreational use support of lakes and identifying trends over time. The MPCA also assesses lakes for aquatic consumption use support, based on fish-tissue and water-column concentrations of toxic pollutants. Lake monitoring was added to the watershed monitoring framework in 2009, so while there is some data available, not all of the lakes in the Pomme de Terre River watershed currently have enough information for assessment. While the MPCA conducts its own lake monitoring, it also passes through funding via Surface Water Assessment Grants (SWAGs) to local groups such as counties, soil and water conservation districts, watershed districts, nonprofits, and educational institutions. These local partners greatly expand our overall capacity to conduct lake monitoring. Many SWAG grantees invite citizen participation in their monitoring projects.

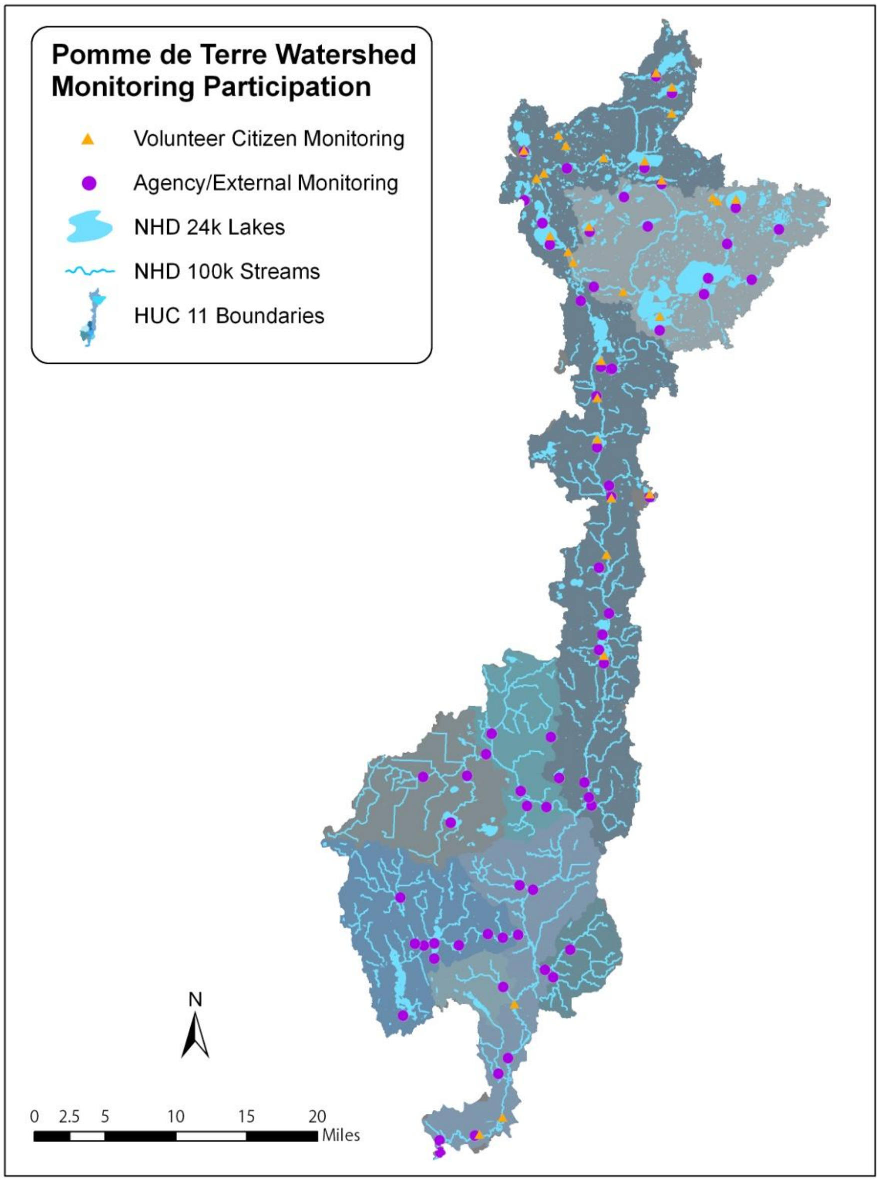
Even when pooling MPCA and local resources, we are not able to monitor all lakes in Minnesota. The primary focus of MPCA monitoring is lakes $\geq$500 acres in size (“large lakes”). These resources typically have public access points, they generally provide the greatest aquatic recreational opportunity to Minnesota’s citizens, and these lakes collectively represent 72 percent of the total lake area (greater than 10 acres) within Minnesota. Though our primary focus is on monitoring and assessing larger lakes, we are also committed to directly monitoring, or supporting the monitoring of, lakes between 100-499 acres (“small lakes”) for assessment purposes.

The annual SWAG Request for Proposals identifies the major watersheds that are scheduled for upcoming intensive monitoring and small lakes that have not been assessed. Many applicants choose these lakes to monitor; others select lakes that are in watersheds scheduled for later intensive monitoring. SWAG grantees conduct detailed sampling efforts following the same established monitoring protocols and quality assurance procedures used by the MPCA. All of the lake and stream monitoring data from SWAG projects is combined with the MPCA’s monitoring data to assess the condition of Minnesota lakes and streams.

Citizen and local monitoring

Citizen monitoring is an important component of the watershed monitoring approach. The MPCA coordinates two programs aimed at encouraging citizen surface water monitoring: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Like the permanent load monitoring network established at watershed pour points, sustained citizen monitoring can provide the long-term picture needed to help evaluate current status and trends. The advance identification of lake and stream sites that will be sampled by agency staff provides an opportunity to actively recruit volunteers to monitor those sites too, so that water quality data is available for the years before and after the intensive monitoring effort. This citizen-collected data help agency staff interpret the results from the intensive monitoring effort, which only occurs once every 10 years. It also allows interested parties to track any water quality changes that occur in the years between the intensive monitoring events. Coordinating with volunteers to focus monitoring efforts where it will be most effective for Clean Water Legacy planning and tracking purposes will help local citizens/governments see how their efforts are being used to inform water quality management decisions and affect change. Figure 5 provides an illustration of citizen monitoring data used for assessment in the Pomme de Terre River Watershed.

Figure 5. Citizen, local, and MPCA lake monitoring locations in the Pomme de Terre Watershed



III. Assessment Methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters that are determined to be supporting or non-supporting of their designated uses. 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 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 2010a) (http://www.pca.state.mn.us/index.php/download-document.html?gid=8601).

Water quality standards

Water quality standards are the fundamental benchmarks by which the quality of surface waters is measured. It is the water quality standards that are used to determine impairment. Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by Minnesota Water Quality Standards (Minn. R. ch. 7050 2008) (https://www.revisor.mn.gov/rules/?id=7050). 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. Protection of aquatic life means the maintenance of healthy, diverse, and successfully reproducing populations of aquatic organisms, including fish and macroinvertebrates. Protection of recreation means the maintenance of conditions suitable for swimming and other forms of water recreation. Protection of consumption means protecting citizens who eat fish from Minnesota waters or receive their drinking water from water bodies protected for this use.

Numeric water quality standards represent concentrations of specific pollutants in water that protect a specific designated use. Ideally, if the standard is not exceeded, the use will be protected. However, nature is very complex and variable, and the MPCA may use a variety of tools to fully assess designated uses. Assessment methodologies often differ by parameter and designated use, and consider multiple factors of the pollutants concentration; such as chronic value, maximum value, final acute value, magnitude, duration, and frequency.

Narrative standards are statements of conditions in and on the water, such as biological condition, that protect their designated uses. Interpretations of narrative criteria for aquatic life support 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 macroinvertebrate community. Biological monitoring is a direct means to assess aquatic life use support, as the aquatic community tends to integrate the effects of pollutants and stressors over time.

Assessment units

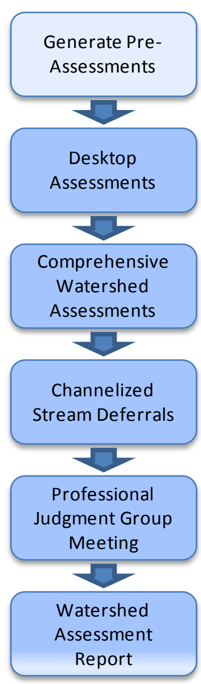
Assessments of use support in Minnesota are made for individual water bodies. The water body unit used for river systems, lakes, and wetlands is called the “assessment unit.” A stream or river assessment unit usually extends from one significant tributary stream to another or from the headwaters to the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

It is for these specific stream reaches or lakes that the data is 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 status

Conceptually, the process for determining use attainment status of a water body is similar for each designated use: comparison of monitoring data to established water quality standards. However, the complexity of that process and the amount of information required to make accurate assessments varies between uses. In part, the level of complexity in the assessment process depends on the strength of the dose-response relationship (i.e., if chemical B exceeds water quality criterion X, how often is beneficial use Y truly not being attained). For beneficial uses related to human health, such as drinking water, the relationship is well understood and, thus, the assessment process is a relatively simple interpretation of numeric standards. In contrast, assessing whether a water body 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 in the Pomme de Terre River watershed is outlined below and in Figure 6.

Figure 6. Flowchart of aquatic life use assessment process



The first step in the aquatic life assessment process is a comparison of the monitoring data to 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 using computer applications to analyze the data for potential temporal or spatial trends as well as to gain a better understanding of any attenuating circumstances that should be considered (e.g., flow, time/date of data collection, habitat).

The next step in the process is a Comprehensive Watershed Assessment meeting where reviewers convene to discuss the results of their desktop assessments for each individual water body. 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 2010a) for the guidelines and factors to consider when making such determinations.

New impairment determinations (i.e., water body not attaining beneficial use) are reviewed using GIS to determine if greater than 50 percent of the assessment unit is channelized. Excepting toxics and bacteria, the MPCA is deferring new impairments on channelized reaches until new aquatic life use standards have been developed as part of the tiered aquatic life use framework. The last step in the assessment process is the Professional Judgement Group (PJG) 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 have a vested interest in the outcomes of the assessment process. Information obtained during this meeting may be used to revise previous use attainment decisions. The result of this meeting is a compilation of the assessed waters which will be included in the watershed report. Impaired waters are placed on the draft 303(d) Impaired Waters List.

Data management

It is MPCA policy to use all credible and relevant monitoring data to assess surface waters and relies on data it collects along with data from other sources, such as sister agencies, local government, and volunteers. The data must meet rigorous quality-assurance protocols before being used. The MPCA stored surface monitoring data in the U.S. Environmental Protection Agency's (EPA) STORET system until it was recently replaced by EQuIS. All monitoring data required or paid for by MPCA was entered into the current agency database. Projects funded by MPCA include CWA Section 319 projects, Clean Water Partnership (CWP) projects, SWAG projects, and more recently, TMDL projects. Many local projects not funded by the MPCA choose to submit their data to the MPCA in database-ready format so that it may be utilized in the assessment process.

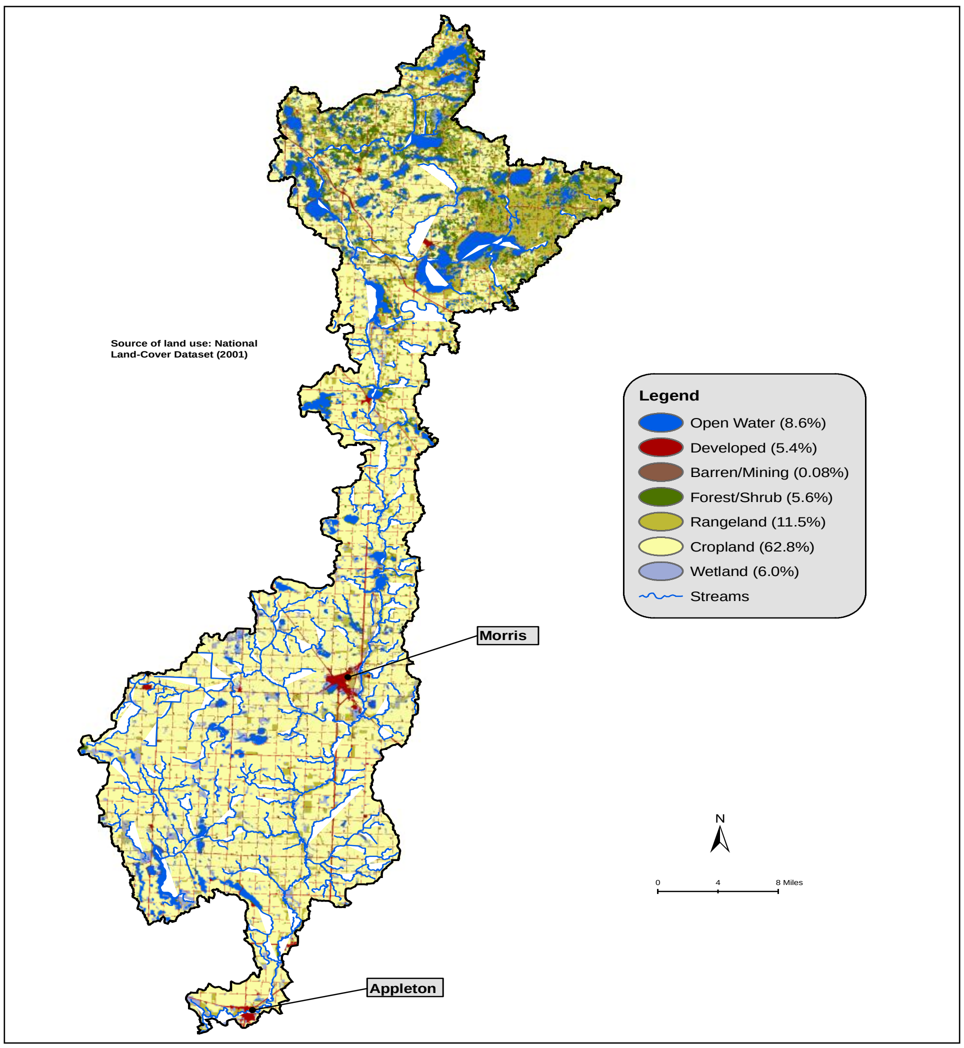
Period of record

The MPCA uses data collected over the most recent 10-year period for all water quality assessments. Generally, the most recent data from the 10-year assessment period is reviewed first when assessing toxic pollutants, eutrophication, and fish contaminants. Also, the more recent data for all pollutant categories may be given more weight by members during the comprehensive watershed assessment or professional judgment group meetings. The goal is to use data from the 10-year period that best represents the current water quality conditions. Using data over a 10-year period 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 are not required to make assessment.

IV. The Pomme de Terre River Watershed

The Pomme de Terre River watershed is located in the west-central portion of the state in the North Central Hardwood Forest (NCHF) and Northern Glaciated Plains ecoregions, and encompasses an area 559,968 acres in size (NRCS). The Pomme de Terre River watershed makes up the northern tip of the Minnesota River basin. The name 'Pomme de Terre' translates from French to apple of the earth, referencing potatoes. The Pomme de Terre River and its tributaries flow through six counties on its way to Marsh Lake in the Minnesota River: Otter Tail, Grant, Douglas, Big Stone, Swift, and Stevens. Stevens County comprises the largest area of the watershed. Morris and Appleton are the largest towns in the watershed, but the watershed is mostly rural, with developed areas making up only five percent of the land use (Figure 7). There is a combined population of about 16,000 people (U.S. Department of Agriculture [USDA]). The area is primarily agricultural, with 74 percent of the land used for cropland and

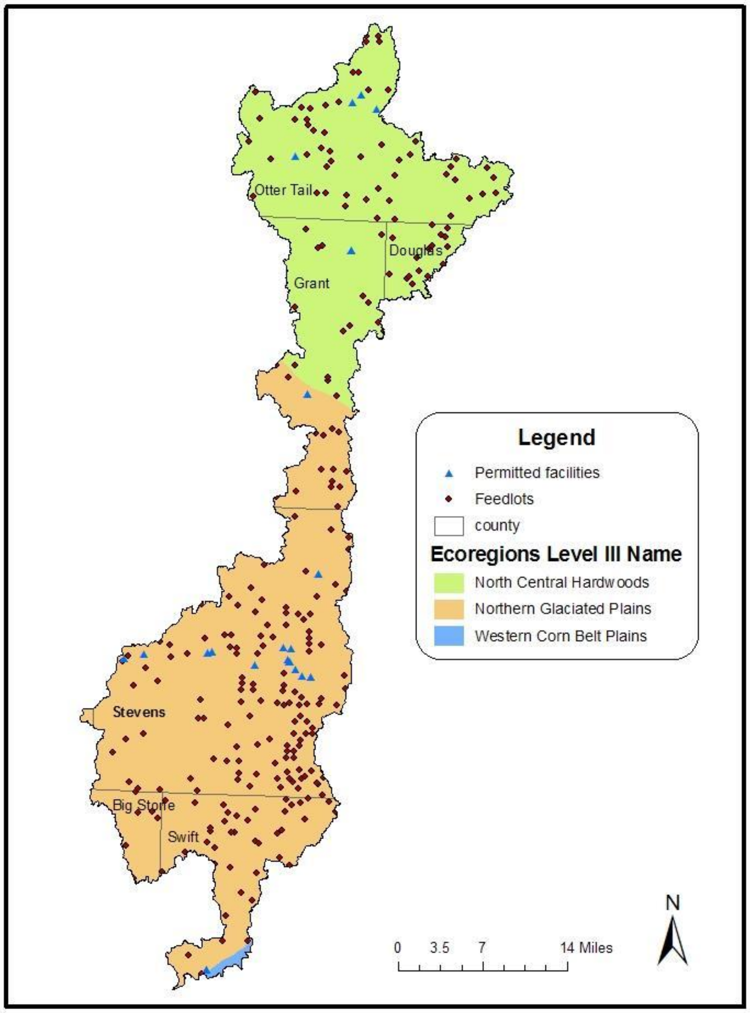
Figure 7. Land use in the Pomme de Terre River watershed



pasture. The majority of the cropland is planted with corn, soybeans, and spring wheat with a concentrated area of alfalfa near Morris (USDA). There are 15 permitted wastewater permits in the watershed, and 263 permitted feedlots throughout the watershed, which are concentrated in the southern part of the watershed near Morris (Figure 8).

The Pomme de Terre River watershed is long and narrow, with few large tributaries. The three main tributaries to the river are Pelican Creek, Muddy Creek, and Drywood Creek. The other tributaries are mostly intermittent streams with small drainages that often do not have flowing water throughout the summer months. The drainage area of the entire watershed is 880 square miles. The watershed is comprised of eight 11-digit HUC subwatershed units, with the Pomme de Terre River mainstem being split between the Upper and Lower Pomme de Terre units. Lakes and wetlands are prevalent in the watershed, particularly in the upper reach. Due to this prevalence, there are numerous Waterfowl Production Areas (WPAs) located among the 217 lakes and hundreds of wetlands. The upper half of the river is also characterized by a wetland riparian zone dominated by cattails. The river is very sinuous in areas, and is characterized by low gradient in the upper reach with an average of 2.63 ft/mi. South of Appleton, the gradient of the river increases to 4.59 ft/mi. as the elevation decreases on the way to the Minnesota River. In the six-mile stretch south of Appleton the elevation drop is about 50 feet (Bright et al. 1995). The United States Geological Survey (USGS) has a permanent flow station located in downtown Appleton (05294000), which averaged discharges of 221 cubic feet per second (cfs) in 2007 and 187 cfs in 2008, the main years that water quality and biological data was collected. The average discharge over the years of record from 1936 to 2009 is 140 cfs (USGS).

Figure 8. Ecoregions and locations of feedlots and permitted facilities in the Pomme de Terre Watershed



Stream monitoring began in 2007 in the Pomme de Terre River watershed as part of the intensive watershed monitoring project, and lake monitoring began in 2009. While the majority of data used for assessment was collected from 2007 to 2009, available data from the last 10 years was used for assessment. Thirty-two sites were sampled throughout the watershed for biology (locations are available in Appendix 2).

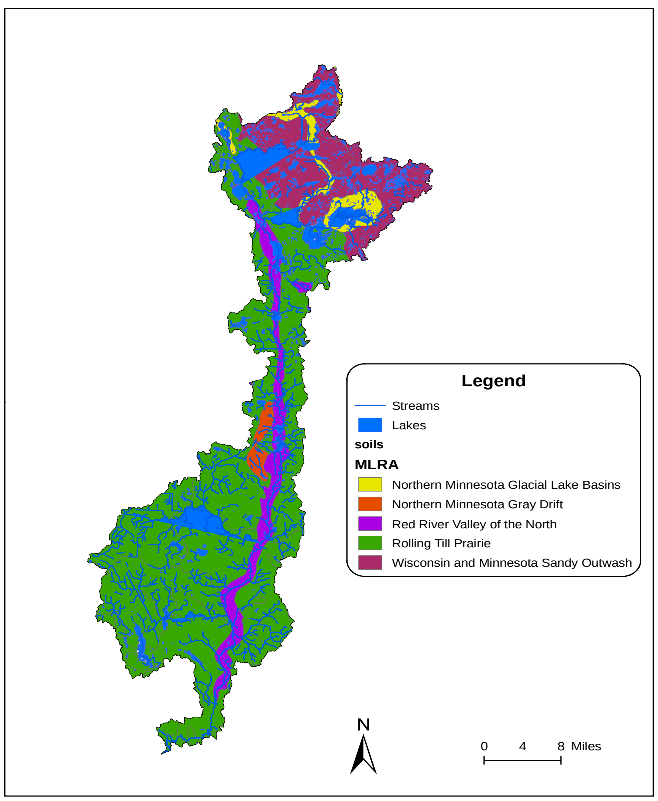
Seven sites were sampled for intensive water chemistry, and one site was sampled for fish contaminants (locations are available in Appendix 1). Due to the dryness of the later part of the summer, we were not able to sample all of the tributaries to the Pomme de Terre River for invertebrates, or sample water chemistry at all of the sites throughout the summer months. Based on 30-year averages of state climatology records, the 2007 water year precipitation departure from normal was about two inches below normal in the northern and central portions of the watershed, and four inches below normal in the southern portion.

Hydrogeologic setting

The geology and soils found within the Pomme de Terre River Watershed help explain the distribution and hydraulic connections of its water bodies. The pathways and duration water takes to move through the watershed has a direct effect on water quality.

The Pomme de Terre River Watershed falls within two of Minnesota's six major Groundwater Provinces (http://files.dnr.state.mn.us/natural_resources/water/groundwater/provinces/GWProvincesnoxlines.pdf). Much of the western and southern parts of the watershed lie in the Western Province. Much of the eastern and northern parts of the watershed lie in the Central Province. The Western Province is generally characterized by "clayey glacial drift overlying Cretaceous and Precambrian bedrock. Glacial drift and Cretaceous bedrock contain limited extent sand and sandstone aquifers, respectively." The Central Province is generally characterized by "sand aquifers in generally thick sandy and clayey glacial drift overlying Precambrian and Cretaceous bedrock. Fractured and weathered Precambrian bedrock is used locally as a water source" (MDNR 2001). Glacial sediments cover the entire Pomme de Terre River Watershed as evident by the five major land resource areas (MLRAs) found in the Pomme de Terre River watershed (Figure 9). These glacial sediments consist of till and outwash. Till is composed of an unsorted mixture of clay, silt, sand, and gravel. Till generally makes poor aquifers and can function as a confining or semi-confining layer. Outwash consists of sand and gravel deposits, which generally make good aquifers.

Figure 9. MLRA soil types in the Pomme de Terre Watershed

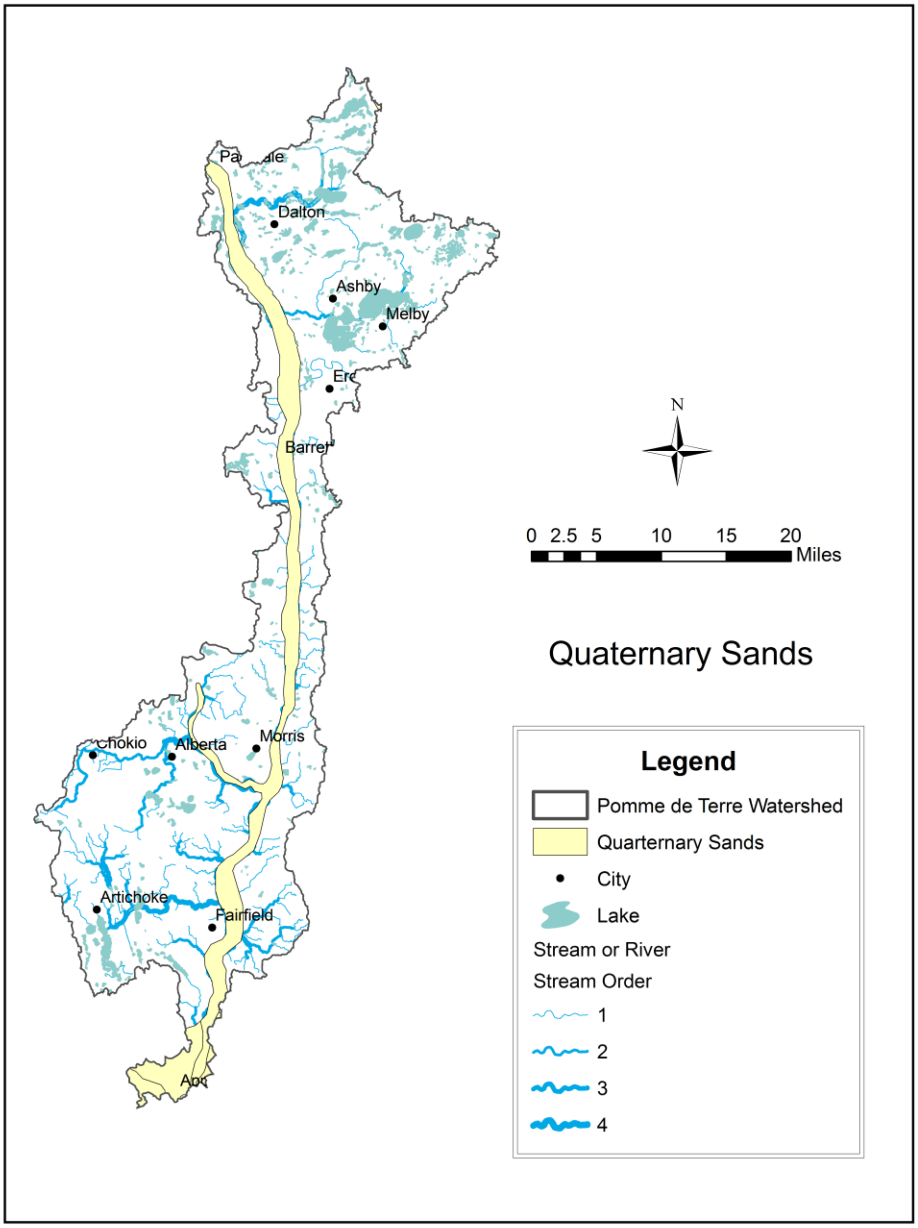


The significant aquifers in the Pomme de Terre River Watershed can be divided into two groups: surficial sand and gravel aquifers and buried sand and gravel aquifers. The surficial aquifers are unconfined; the buried aquifers can be either confined or unconfined. Because glacial melt-water streams from different glacial events often changed positions and varied in discharge volumes, the resulting confined aquifers vary in location, thickness, and aquifer quality (Delin 1986).

There are a large number of high quality confined aquifers within the Pomme de Terre River Watershed. Several of these aquifers coalesce with surficial aquifers near the Pomme de Terre River. All of these aquifers are used for domestic water supplies and several of them are tapped for irrigation.

The Pomme de Terre River valley was a glacial drainage-way and accumulated thick sand and gravel deposits along most of its length resulting in a long, narrow unconfined aquifer (Figure 10). It typically varies in thickness from 10 to 40 feet but reaches thicknesses of 100 feet in the northern part of the Pomme de Terre River Valley. The aquifer along the Pomme de Terre River Valley is in direct communication with the Pomme de Terre River.

Figure 10. Quarternary Sands in the Pomme de Terre Watershed



Regionally, groundwater flow is from the north to the south toward the Minnesota River at a gradient of about four feet/minute. Locally, groundwater moves from the valley sides through surficial sands and discharges into the Pomme de Terre River (Soukup et al. 1984). Water levels in the surficial aquifers fluctuate seasonally and on long-term basis in response to recharge and withdrawals. Generally, groundwater levels are highest in spring.

Groundwater quality and quantity

Groundwater quality and quantity are influenced by land use as well as naturally occurring conditions. The Pomme de Terre River Watershed does not have large urban areas and its water resources do not exhibit the problems typically associated with those environments, such as impacts from stormwater runoff or industrial contamination. Source water assessments of public water systems for specific communities in the watershed can be accessed from the Minnesota Department of Health Source Water Assessment website at http://www.health.state.mn.us/divs/eh/water/swp/swa/index.htm.

Nitrogen

Nitrogen is highly soluble and mobile in groundwater. Nitrogen can migrate from groundwater to surface water if there is a direct hydraulic connection between the aquifer and surface water. Nitrogen in groundwater at concentrations exceeding 10 milligrams per liter (mg/L) is considered a potential human health risk; it exceeds the Maximum Contaminant Level (MCL). Land use activities such as agricultural fertilizer applications, feedlots, and septic systems can be sources for nitrates in groundwater. These potential sources are present in the Pomme de Terre River Watershed. Much of the land use is agricultural, especially in the southern 3/4 of the watershed (Figure 7), including a large number of feedlots in the watershed (Figure 8). There has been limited ambient groundwater monitoring in the agricultural portion of the watershed. The Minnesota Department of Agriculture has three monitoring wells with nitrate data available. The concentrations of nitrate (as N) found in these three wells ranged from none detected to 24 mg/L.

Arsenic

Arsenic is a naturally occurring contaminant whose occurrence is most commonly associated with confined aquifers within Des Moines Lobe tills, which are common in the watershed. The EPA's drinking water standard (MCL) for arsenic, adopted on January 22, 2011, is 10 micrograms/liter (µg/l).

Arsenic is found in aquifers in the watershed at concentrations exceeding 50 µg/l. Arsenic is most commonly found in domestic wells or monitoring wells set in proximity to an upper confining unit, such as glacial till (Erickson and Barnes 2005). Arsenic could also potentially impact surface waters where confined aquifers coalesce with unconfined aquifers. There has been no monitoring for arsenic in surface waters in the Pomme de Terre River Watershed.

Irrigation

Significant irrigation occurs in the watershed, especially in the surficial aquifer adjacent to the Pomme de Terre River. A 1984 USGS study (Soukup et al. 1984) constructed an analytical model to estimate the effect on streamflow of pumpage from the surficial aquifer in the narrow, 50-mile reach of the Pomme de Terre River in Stevens and Grant Counties. The model indicated that 66 irrigation wells pumping at maximum potential yields could reduce stream flow by 77 cubic feet per second; this rate exceeds low base flow of the Pomme de Terre River. In 1984, the number of irrigation wells along that stretch of river was 43. Total annual withdrawals trended generally upward from 1993 until about 2006 when withdrawals appeared to begin leveling off. Higher withdrawals in the late 1980s probably reflect an increased demand due to drought conditions.

V. Watershed Wide Results and Discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed unit of the Pomme de Terre River watershed, grouped by sampling type. Summaries are provided for aquatic consumption results at select river and lake locations along the watershed, load monitoring data results near the mouth of the river, and aquatic life and aquatic recreation uses in lakes, streams, and wetlands throughout the watershed. 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 Pomme de Terre River major watershed.

Stream quality

Stream water quality decreases in the Pomme de Terre River watershed as it progresses downstream. Of the 29 stream AUIDs in the Pomme de Terre River watershed that have been sampled, seven AUIDs are non-supporting of aquatic life and/or aquatic recreation. Seven AUIDs in the watershed are fully supporting of aquatic life, but there was not enough E. coli data to call any of the AUIDs fully supporting of aquatic recreation. Fifteen AUIDs have not been assessed due to their classification as Class 7 limited water resource waters or the occurrence of channelized stream reaches. Seven new impairments were added to the Pomme de Terre River watershed during the 2010 assessment cycle; six on AUIDs with previous impairments, and one on a new AUID without previous impairments.

Throughout the watershed, five AUIDs are non-supporting of aquatic life and two AUIDs are non-supporting of aquatic recreation. The headwaters of the watershed are supporting of both aquatic life and aquatic recreation. While aquatic consumption impairments span the entirety of the watershed, aquatic life and aquatic recreation impairments occur only south of Barrett Lake, coinciding with landscape and land use changes. Barrett Lake is located at the ecoregion transition, which is also where land use changes to predominantly agricultural uses. South of Barrett Lake, the Pomme de Terre River has impaired fish communities through to the mouth of the river. Cumulative impacts cause impairments to be concentrated in the lower part of the watershed, downstream of Muddy Creek. Drywood Creek and the Pomme de Terre River south of Morris were both previously listed as impaired for turbidity and E. coli, and Drywood Creek was listed as impaired for fish, macroinvertebrates, and dissolved oxygen. There was not enough E. coli data (required 20 observations over a two-year period) to assess any new reaches, but Pelican and Muddy Creeks both had some elevated concentrations at over 2000 MPN/100ml (Appendix 5). While there is currently not a phosphorus standard, high readings based on the draft standard occur throughout the watershed on Pelican Creek, Drywood Creek, and the Pomme de Terre River. Along with Drywood and Muddy Creeks, the mainstem Pomme de Terre River also has high nitrate-nitrite nitrogen values compared to the ecoregion expectation, starting at the Pomme de Terre lakes just north of Morris and continuing on through to the mouth of the river.

Wetland quality

Wetlands are prevalent throughout the watershed, the majority of which are emergent wetlands. Of the four wetlands that were sampled for biology in the Pomme de Terre River watershed, two were assessed for support of aquatic life use. Both of the wetlands (located in the Lee and Golden Waterfowl Production Areas) were non-supporting of aquatic life for both plant and macroinvertebrate communities.

Lake quality

The complexity of the Pomme de Terre River watershed explains the wide spectrum of water quality observed within its lakes. Geology, land use, lake morphology, and watershed size must all be considered in order to fully understand water quality for individual water bodies. General patterns in good and poor water quality can be explained for regions with these similar characteristics. Throughout the watershed, the majority of large and or deep lakes have been sampled. Of the 217 lakes present, 30 lakes have some level of assessment data (Appendix 3). Eleven lakes have been fully assessed against water quality standards set for aquatic recreation, and the findings indicate that seven fully support aquatic recreational uses and four do not. Nineteen lakes have some water quality data, but the datasets are insufficient to allow for assessment.

Lakes clustered in the northern headwaters of the Pomme de Terre River watershed tend to have good water quality. The majority of assessed lakes are found to be fully supporting and are located within the Pelican Creek and the northern portion of the Upper Pomme de Terre HUC-11 watersheds. Geology and lake morphology are the main drivers of water quality in this area. Sandy outwash soils were deposited in the headwaters allowing for high groundwater inflow. In addition, lake basins in the headwaters are typically deep and allow for stratification and the storage of phosphorus in sediments. Lakes are in close proximity and have small catchments in the headwaters area, which reduces the potential that pollutants from runoff will flow into the lake. The highest percentages of forest and shrub land within the Pomme de Terre River watershed are located in the headwaters. These land use types reduce and filter overland flow, improving water quality entering lakes and streams.

Midway through the watershed, lake water quality diminishes. Assessed lakes in the southern portion of the Upper Pomme de Terre and Little Muddy Creek HUC-11 watersheds are found to be non-supporting. Very few lake basins are located in the mid- to southern portions of the watershed. Lake basins are shallow due to flat topography or formed by impoundments on the Pomme de Terre River. Flat topography and few lake basins result in large individual lake catchments. Lake impoundments on the Pomme de Terre River also have large watersheds, which include the entire watershed area drained north of the impoundment. The transition to clay loam soils reduces infiltration and promotes increased runoff. Land use is dominated by cropland because soils are ideal for growing crops. The combination of poor infiltration, cropland dominated land use, and large watershed area results in poor lake water quality.

Understanding the dynamics of how water travels through the Pomme de Terre River watershed is difficult because individual bodies of water cycle pollutants differently. Sources of nonpoint source pollutants are difficult to quantify; however, trends in water quality can be distinguished in areas with similar characteristics. In the Pomme de Terre River watershed, the northern headwaters behave differently than the mid- to southern portion of the watershed, and this explains why water quality is typically good in the northern headwaters and diminishes moving south.

Fish contaminant results

Pomme de Terre River: Mercury and PCB concentrations in fish fillets

Mercury and polychlorinated biphenyls (PCBs) were analyzed in fish tissue samples collected in 2003 and 2007. In 2003, black crappie, common carp, northern pike, and walleye were collected. In 2007, the same species, with the exception of black crappie, were collected again. After collection, the 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 laboratory performed all chemical analyses of fish tissue.

To assess mercury and PCBs fish tissue concentrations for water quality impairment, the last 10 years of data were used for statistical analysis; therefore, data from 2003 and 2007 were combined. The assessment of mercury levels is based on the 90th percentile of at least five fish samples of a top predator fish species. In this case, that included northern pike and walleye. The 90th percentile for northern pike was 0.339 mg/kg, and for walleye, 0.330 mg/kg (Table 1). Both species exceed the 0.2 mg/kg water quality standard for mercury in fish tissue. Therefore, the Pomme de Terre River is impaired for mercury in fish based on MPCA assessment guidelines.

The Pomme de Terre River qualifies for inclusion in the Minnesota Statewide Mercury TMDL (http://www.pca.state.mn.us/water/tmdl/tmdl-mercuryplan.html) because the 90th percentiles of mercury in fish tissue concentrations are less than the threshold of 0.572 milligrams/kilograms (mg/kg). The goal for the statewide mercury TMDL is for the 90th percentile of mercury concentrations in top predator species to be less than 0.2 mg/kg. Implementation of the mercury TMDL is focused primarily on reducing mercury emissions to the atmosphere, because wastewater point source discharges are less than one percent of the total mercury load to the state.

Table 1. Summary of results for mercury concentrations in fish and total fish length

Species			Mercury Concentration (mg/kg - ww)						Total Fish Length (in)	
Common Name	Scientific Name	Code	N	90th Percentile	Min	Max	Mean		Min	Max
Black Crappie	*Pomoxis nigromaculatis*	BKS	2	0.104	0.048	0.104	0.076		6.7	9.5
Common Carp	*Cyprinus carpio*	C	14	0.227	0.070	0.292	0.153		16.8	27.7
Northern Pike	*Esox lucius*	NP	14	0.339	0.127	0.375	0.220		15.3	29.2
Walleye	*Sander vitreus*	WE	38	0.330	0.101	0.442	0.215		9.6	22.3

As a benchmark for the mercury concentrations, summary statistics are shown for years 2000 to 2008 from the Minnesota Fish Contaminant Program database (Table 2). The common carp in the Pomme de Terre River have a mean mercury concentration equal to the mean throughout the state; whereas the other three species have mean mercury concentrations in the Pomme de Terre River that are well below the means from rivers and lakes throughout the state. Most of the high mercury concentrations in sport fish are found in northern Minnesota lakes because of the watershed and water chemistry characteristics of the northern waters.

Table 2. Mercury concentrations in select species from Minnesota's fish contaminant database (2000-2008)

Species			Mercury Concentration (mg/kg - ww)						Total Fish Length (in)	
Common Name	Scientific Name	Code	N	90th Percentile	Min	Max	Mean		Min	Max
Black Crappie	*Pomoxis nigromaculatis*	BKS	278	0.259	0.01	0.620	0.119		4.0	16.1
Common Carp	*Cyprinus carpio*	C	359	0.305	0.01	0.704	0.155		4.5	35.9
Northern Pike	*Esox lucius*	NP	5293	0.708	0.01	2.946	0.359		7.5	45.5
Walleye	*Sander vitreus*	WE	2525	0.724	0.021	2.627	0.337		6.8	29.7

PCBs are not analyzed for as intensively as mercury because, historically, PCBs have been a problem primarily downstream of large urban areas in large rivers, such as the Mississippi River, and in Lake Superior. PCBs concentrations were analyzed in the two largest carp in 2003 and the largest carp and walleye in 2007. All four individual fish had PCBs concentrations less than the reporting limit of 0.01 mg/kg-ww (Table 3). Consequently, there is no impairment caused by PCBs. There is no need to analyze smaller fish for PCBs, because the highest concentrations are expected in the larger fish.

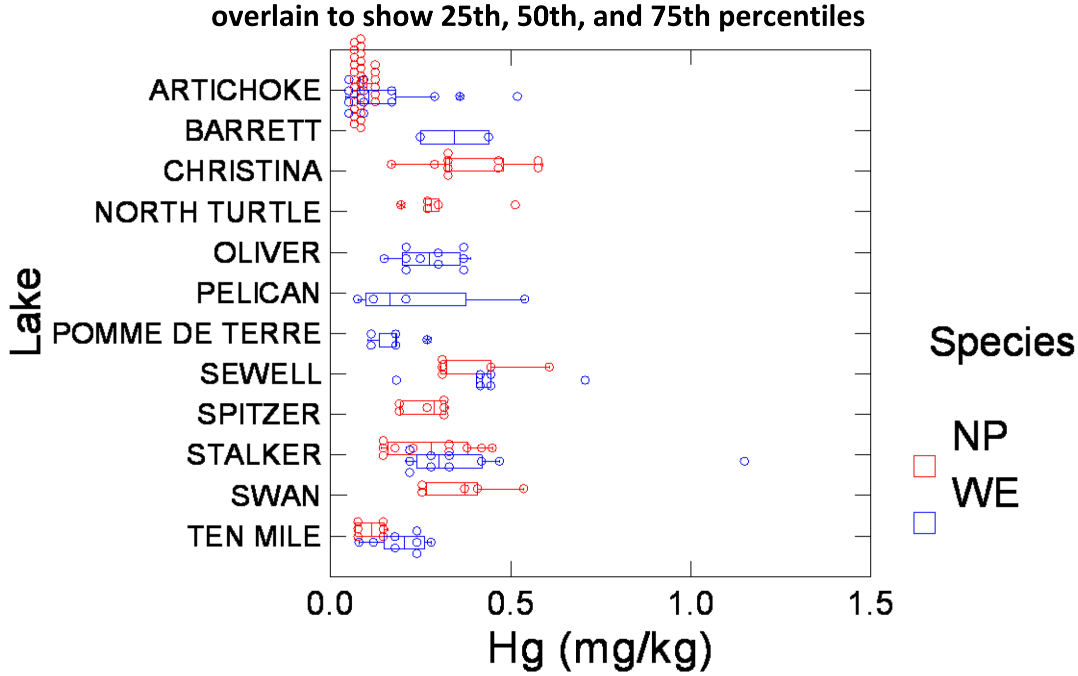
Table 3. Summary of results for PCB concentrations in carp and walleye

Species				PCBs Concentration		Total Fish Length (in)	
Common Name	Scientific Name	Code	N	(mg/kg - ww)		Minimum	Maximum
Common Carp	*Cyprinus carpio*	C	3	<0.01		23.3	27.7
Walleye	*Sander vitreus*	WE	1	<0.01		22.0	22.0

Mercury in Lakes from the Pomme de Terre

The 12 lakes that are impaired for mercury in fish are included in the Minnesota Statewide Mercury TMDL. PCBs were measured in a subset of fish and all sample concentrations were well below the threshold level for impairments. Figure 11 shows the distribution of the mercury concentrations for northern pike (NP) and walleye (WE) for each lake. Only those two species are shown because they have the higher mercury concentrations that caused the impairments. The box plot overlain on the sample points shows the interquartile range (25th to 75th percentile) and the median (50th percentile). The median concentration for northern pike from all 12 lakes was 0.16 mg/kg (n=78) and for walleye it was 0.24 mg/kg (n=58). The highest mercury concentration (1.15 mg/kg) was a 25-inch walleye from Stalker Lake. The average length of walleye in Stalker, excluding this large fish, was 15 inches. Sewell Lake had two fish samples with relatively high mercury concentrations: a 31-inch northern pike with a mercury concentration of 0.61 mg/kg and a 23-inch walleye with a mercury concentration of 0.71 mg/kg.

Figure 11. Mercury concentrations of northern pike (NP) and walleye (WE) with the box plot overlain to show 25th, 50th, and 75th percentiles



For new assessments of mercury and PCBs in fish tissue, the last 10 years of data are combined. One half of the lakes in this watershed were last sampled over 10 years ago (Barrett, 1991; Pelican, 1993; Christina, 1997; Ten Mile, 1997; Stalker, 1998; and Oliver, 1998). Therefore, a recommendation is to resample these lakes for mercury in fish.

Pollutant load monitoring

The Pomme de Terre River is monitored in Appleton before it discharges into Marsh Lake (on the Minnesota River). Annual FWMCs were calculated and compared for years 2007-2009 (Figures 12-15). It should be noted that while a FWMC exceeding a given water quality standard is generally a good indicator that the water body may be out of compliance with the standard, the rule does not always hold true. Waters of the state are listed as impaired based on the percentage of individual samples exceeding a given standard, generally 10 percent and greater (MPCA 2010a), over the most recent 10-year period (although data for all 10 years of the period are not required to make an assessment) and not based on comparisons with FWMCs. A river with a FWMC above a water quality standard, for example, would not be listed as impaired if less than 10 percent of the individual samples collected over the assessment period are above the standard.

Pollutant sources affecting rivers are often diverse and can be quite variable from one watershed to the next depending on land use, climate, soils, slopes, and other watershed factors. However, as a general rule, elevated levels of total suspended solids and nitrate plus nitrite-nitrogen are generally regarded as “nonpoint” source derived pollutants originating from many smaller diffuse sources such as urban or agricultural runoff. Excess total phosphorus and dissolved orthophosphate can be attributed to both “nonpoint” as well as “point” or end of pipe sources such as industrial or waste water treatment plants. Major “nonpoint” 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 (Figures 12 and 13) with DOP and nitrate-N concentrations tending to be lower (Figures 14, 15, and 16). In contrast, during years with high snow melt runoff and less intense rainfall events, TSS levels tend to be lower (Figure 12) while TP, DOP, and nitrate-N levels are elevated (Figures 13, 14, and 15).

Figure 12. Total Suspended Solids (TSS) Flow Weighted Mean Concentrations in the Northern Glaciated Plains Ecoregion for the Pomme de Terre River

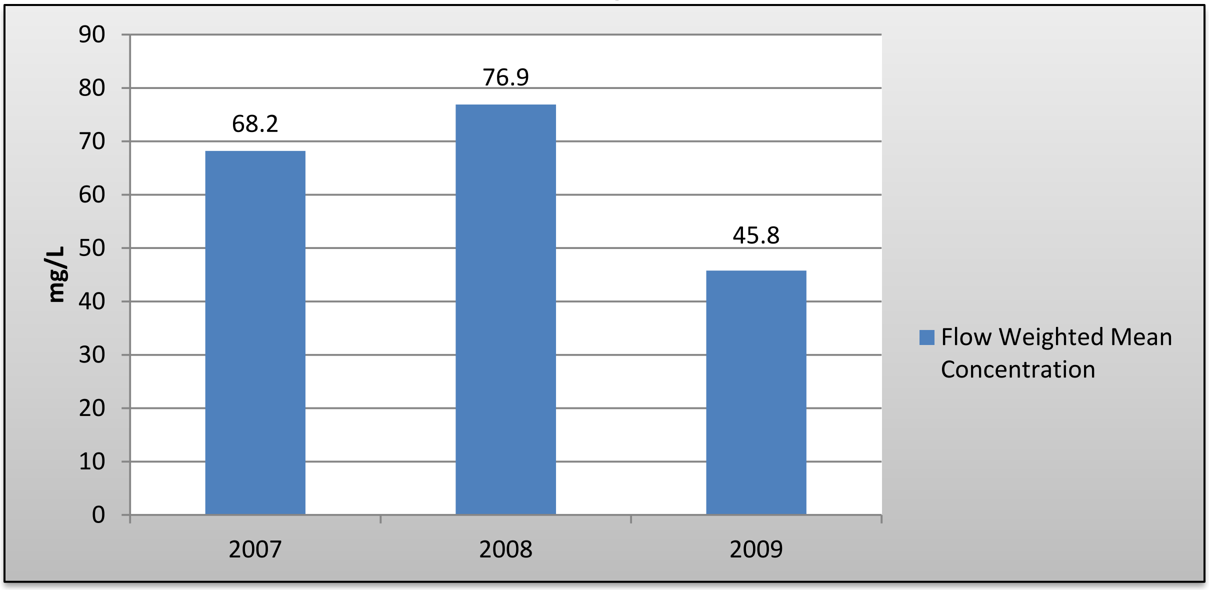


Figure 13. Total Phosphorus (TP) Flow Weighted Mean Concentrations for the Pomme de Terre River

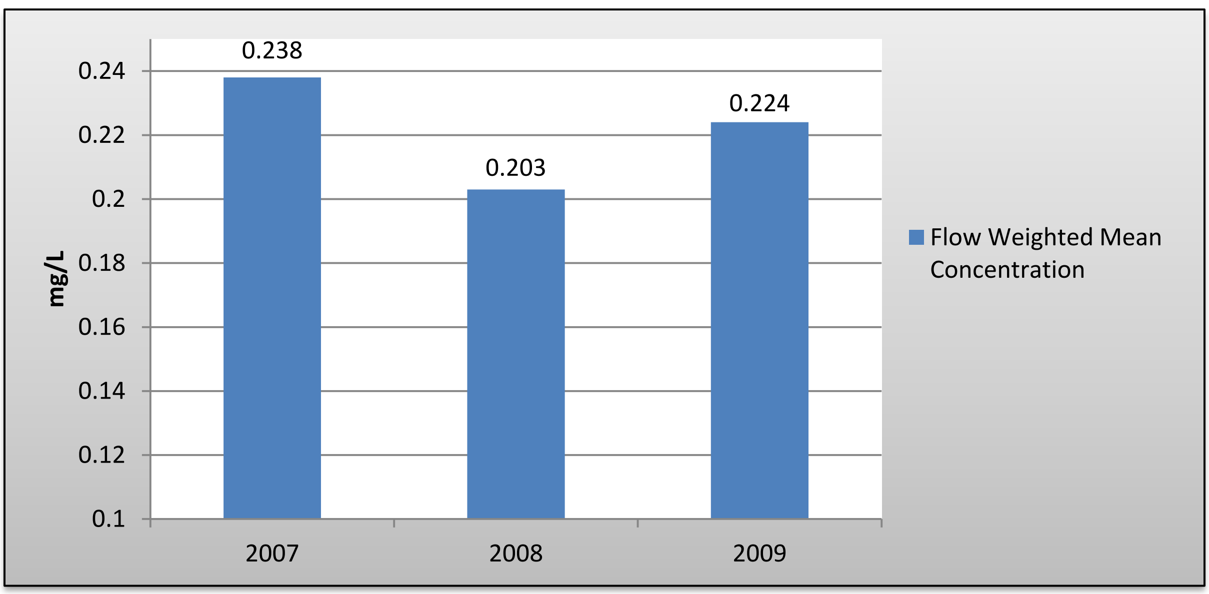


Figure 14. Dissolved Orthophosphate (DOP) Flow Weighted Mean Concentrations for the Pomme de Terre River

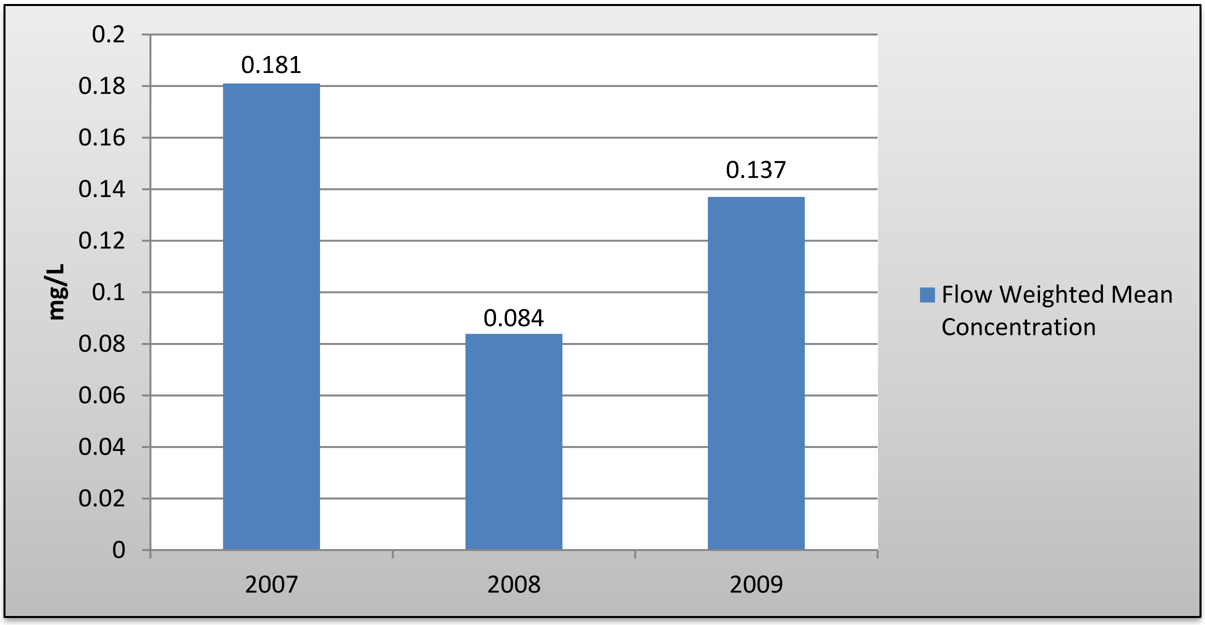


Figure 15. Nitrate + Nitrite Nitrogen (Nitrate-N) Flow Weighted Mean Concentrations for the Pomme de Terre River

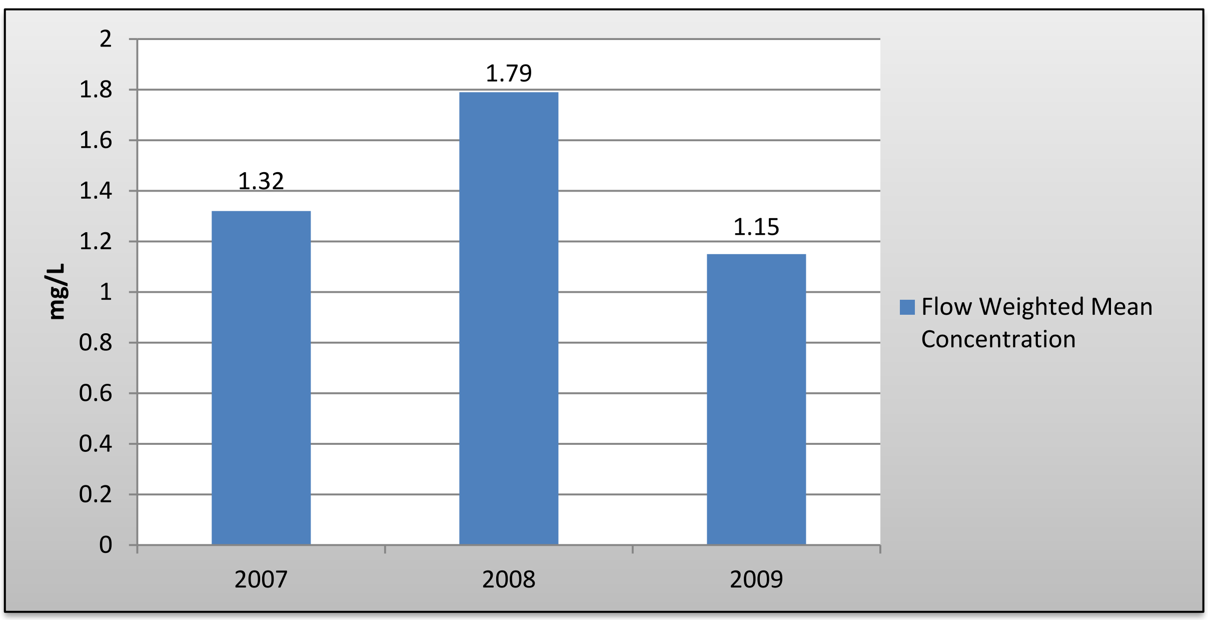


Table 4. Annual Pollutant Loads by Parameter Calculated for the Pomme de Terre River

	2007	2008	2009
Parameter	**Mass (kg)**	**Mass (kg)**	**Mass (kg)**
Total Suspended Solids	13,653,000	13,333,000	13,201,000
Total Phosphorus	48,000	36,000	64,000
Ortho Phosphorus	36,000	15,000	40,000
Nitrate + Nitrite Nitrogen	263,000	314,000	330,000

Total Suspended Solids (TSS)

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 Minnesota State University of Mankato [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 does not have a river standard for TSS but does have one for turbidity. Because turbidity is an optical measure and not a measure of mass, TSS “surrogate” standards for turbidity were developed for ecoregions of the state and are applicable to water quality data collected within each respective ecoregion. Total suspended solids concentrations in the Pomme de Terre River watershed with greater than 10 percent of the samples at or above 60 mg/L are considered out of compliance with the turbidity standard of 25 Nephelometric Turbidity Units (NTUs) for waters within the Northern Glaciated Plains Ecoregion (MPCA 2010a). In 2007 and 2008, 59 and 46 percent of the individual TSS samples, respectively, as well as computed flow weighted mean concentrations (68.2 and 76.9 mg/L, respectively) exceeded the 60 mg/L surrogate standard. In 2009, however, 23 percent of the individual TSS samples exceeded the surrogate standard while the TSS FWMC dipped below the 60 mg/L threshold (45.8 mg/L). During each of the three years, the samples with the highest recorded TSS concentrations were collected during the month of June. Annual TSS loads (Table 4) have shown a constant gradual decline from 2007 to 2009.

Total Phosphorus

Nitrogen (N), phosphorus (P), and potassium (K) are essential macronutrients and are required for growth by all animals and plants. Lack of sufficient nutrient levels in surface water often restricts the growth of aquatic plant species (University of Missouri Extension 1999). In 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 “nonpoint” source dominated watersheds, total phosphorus (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 currently moving from the “development phase” into the “approval phase.” Many years of water quality data from throughout Minnesota combined with previous analysis of Minnesota’s ecoregion patterns, resulted in the development of three “River Nutrient Regions” (RNR), each with unique standards. Of the state’s three proposed RNRs, the Pomme de Terre River’s load monitoring station is located within the south RNR which has a TP draft standard of 150 ug/L as a summer average. Summer average violations of one or more “response” variables (pH, biological oxygen demand (BOD), dissolved oxygen flux, chlorophyll-a) must also occur along with the numeric TP violation for the water to be listed. It must be noted that the TP standard is yet to be approved and this threshold must be considered draft until final approval. In 2007, 91 percent of the individual TP samples exceeded the 150 ug/L draft standard. In 2008 and 2009, sample concentrations were considerably lower at 63 and 48 percent, respectively, however still exceeding the draft standard. Observation of Figure 13 shows all TP FWMCs substantially above the draft standard, ranging from 203 µg/L to 238 µg/L.

Dissolved Orthophosphate

Dissolved Orthophosphate (DOP) is a water soluble form of phosphorus that is readily available to algae (bioavailable) (MPCA and MSUM 2009). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from wastewater treatment plants, noncompliant septic systems, and fertilizers in urban and agricultural runoff. Computation of DOP to TP ratios from 2007 to 2009 show 41 to 76 percent of TP is in the orthophosphate form, respectively.

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 2010b). 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, 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.

Environmentally, studies have shown that the elevated nitrate-nitrogen levels in the Minnesota River basin contribute to hypoxia (low levels of dissolved oxygen) in the Gulf of Mexico. This occurs by nitrate-nitrogen stimulating the growth of algae, which, through death and decay, consume large amounts of dissolved oxygen and, thereby, threaten aquatic life (MPCA and MSUM 2009).

Currently, nitrate-N standards are absent for Minnesota Rivers, but are in the MPCA's "development phase," with a scheduled adoption deadline of September 2012. Long-term monitoring of major watersheds throughout the Minnesota River Basin shows an increasing west to east gradient in nitrate plus nitrite-nitrogen FWMC's (Figure 16). Flow weighted mean concentrations in the western part of the basin (near the Pomme de Terre River) are at levels substantially less than those measured from watersheds within the middle and lower Minnesota. Calculations of the Pomme de Terre River's nitrate plus nitrite-nitrogen loads indicate yearly increases from 2007-2009 (Table 4).

Figure 16. Nitrate-Nitrogen concentrations in the Minnesota River basin

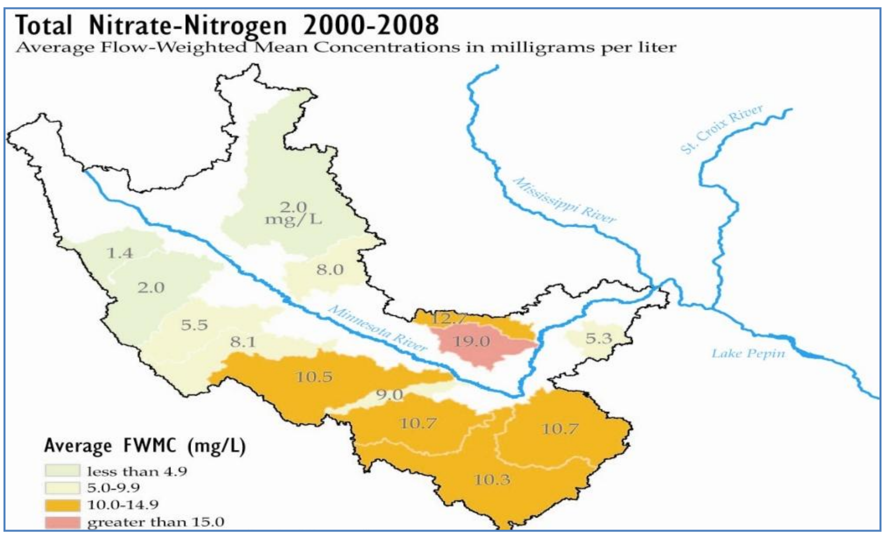


Figure 17. Fully supporting waters by designated use in the Pomme de Terre River watershed

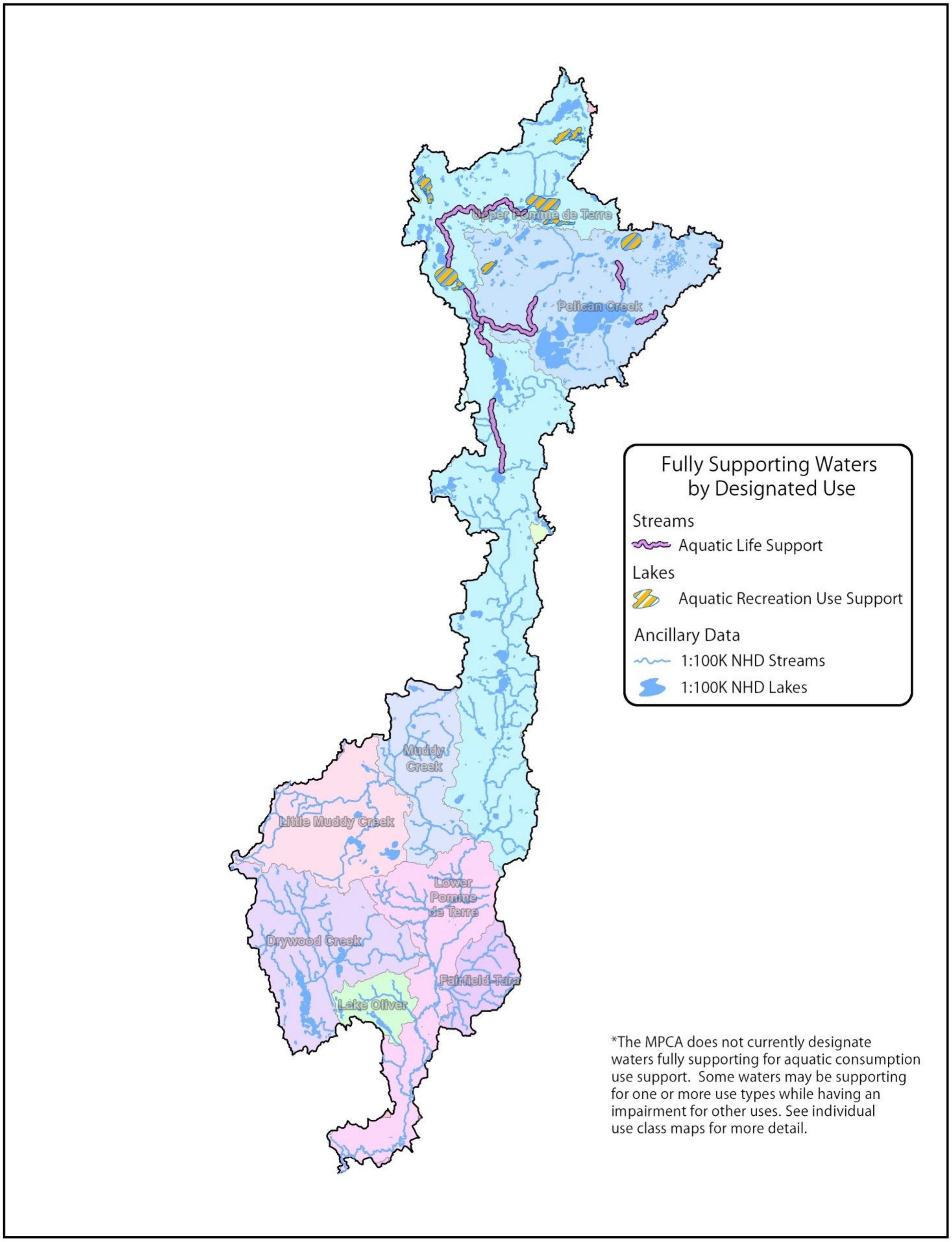


Figure 18. Impaired waters by designated use in the Pomme de Terre River watershed

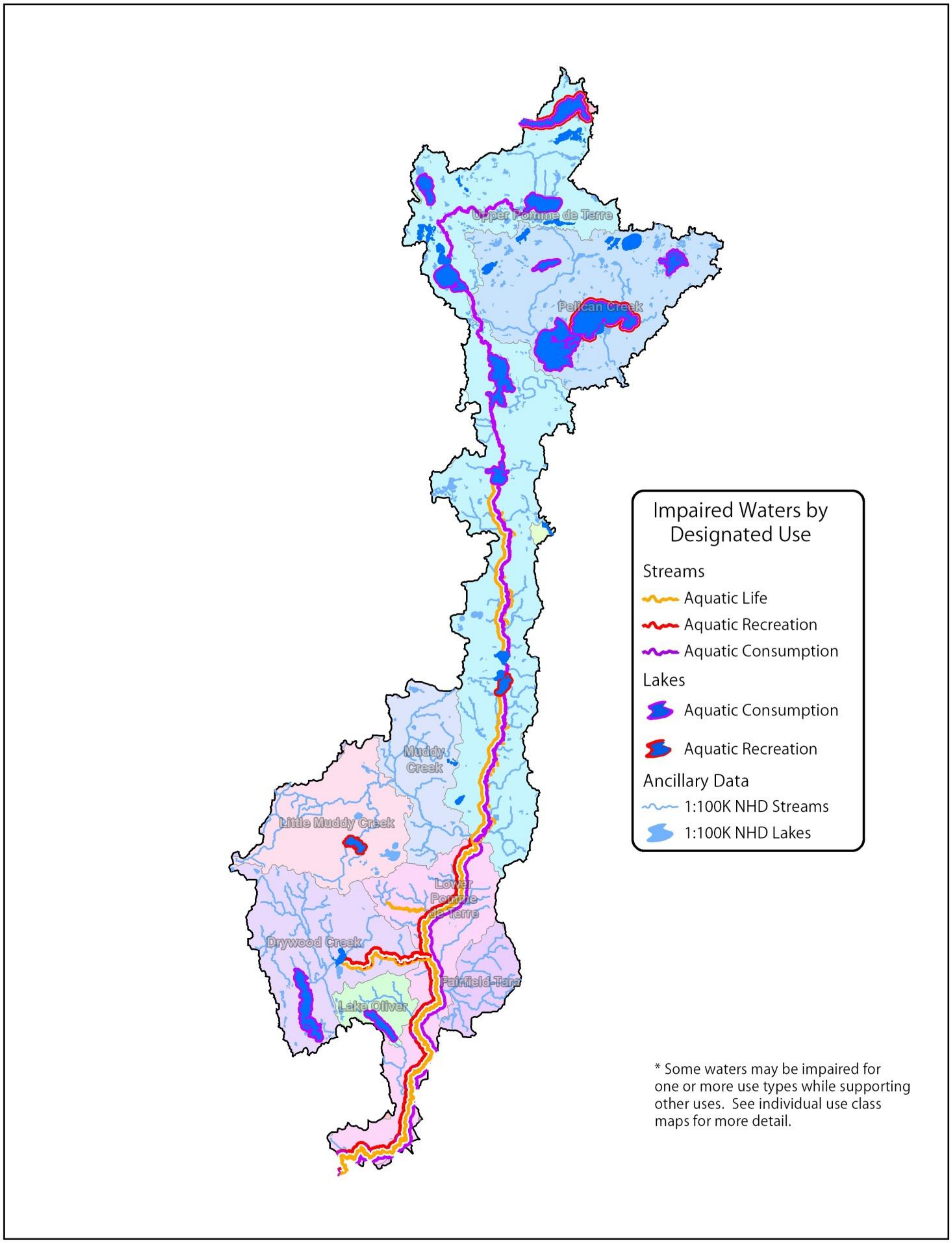


Figure 19. Aquatic consumption use support in the Pomme de Terre River watershed

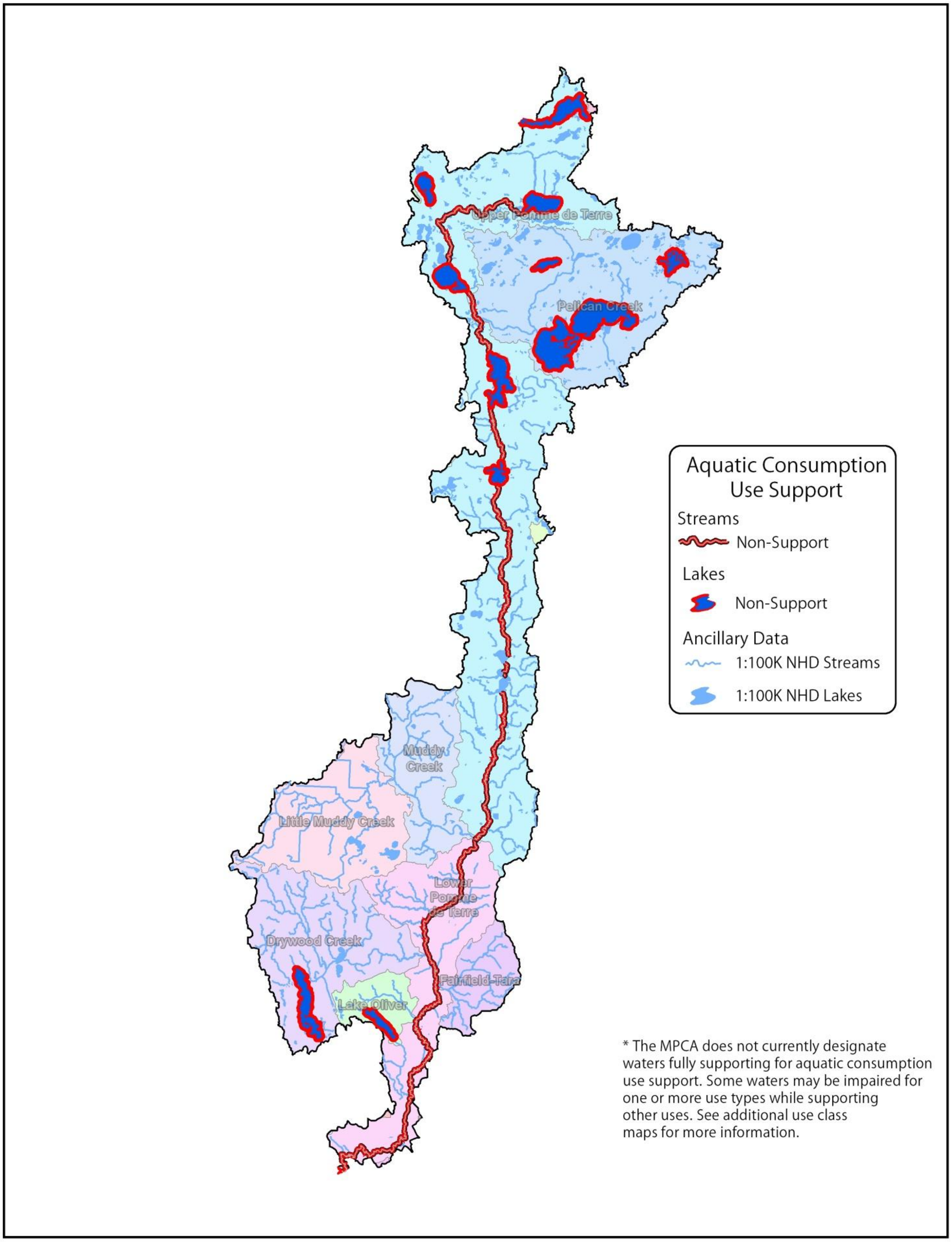


Figure 20. Aquatic life use support in the Pomme de Terre River watershed

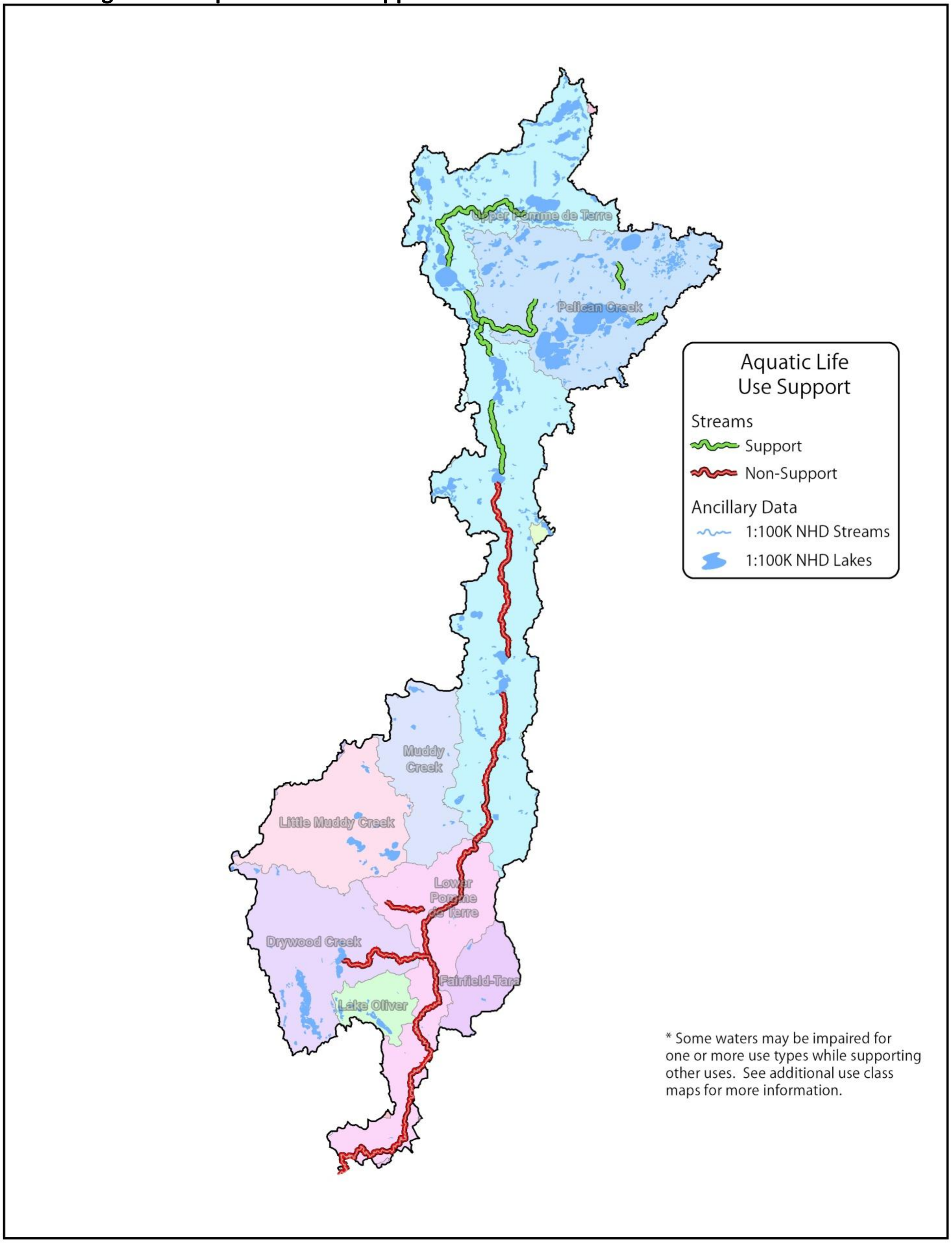
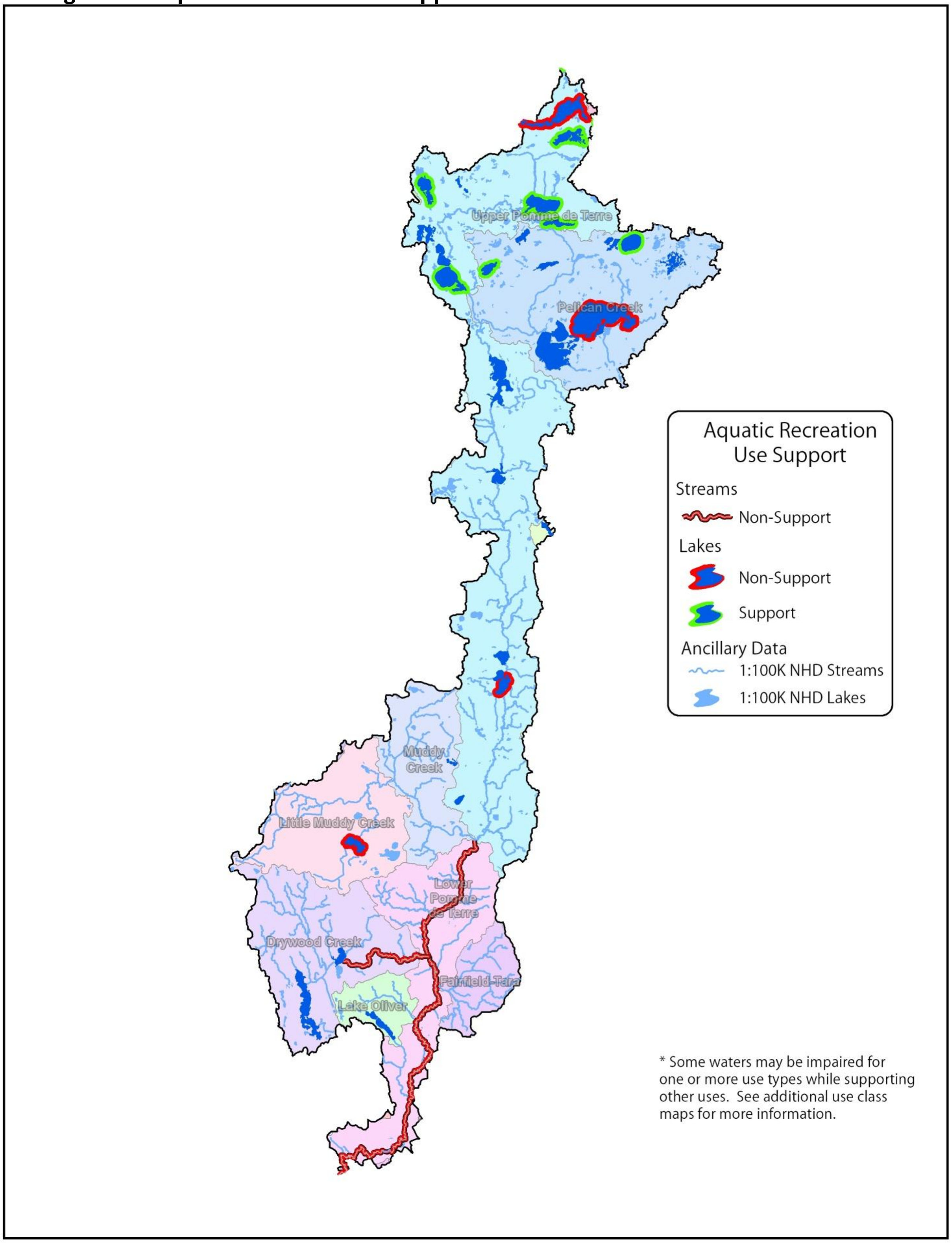


Figure 21. Aquatic recreation use support in the Pomme de Terre River watershed



VI. Individual Watershed Results

HUC-11 watershed units

Assessment results are presented for each of the HUC-11 watershed units within the Pomme de Terre River Watershed, enabling the assessment of all surface waters at one time and the ability to develop comprehensive TMDL studies on a watershed basis rather than the reach by reach and parameter by parameter approach historically employed. This scale provides a robust assessment of water quality condition in the 11-digit watershed unit and is a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The primary objective is to portray all the impairments within a watershed resulting from the complex and multi-step assessment and listing process. The graphics presented for each of the HUC-11 watershed units contain the assessment results from the most recent 2010 Assessment Cycle, as well as any impairment listings carried forward from previous assessment cycles. Discussion of assessment results will focus primarily on the 2007 intensive watershed monitoring effort, but will consider all available data from the last 10 years.

Given all the potential sources of data and differing assessment methodologies for indicators and designated uses, it is not currently feasible to provide results or summary tables for every monitoring station by parameter. However, a summary table of AUIDs by parameter is available in Appendix 4, and summary tables of water chemistry results for each of the intensive watershed stations representing the pour point of the HUC-11 watersheds are provided in Appendix 2. In addition to being used for assessment, the data can provide valuable insight on water quality characteristics and potential parameters of concern in the watershed. Not all water chemistry parameters of interest have developed water quality standards. McCollor and Heiskary (1993) developed ecoregion expectations for a number of water quality parameters in streams that provide a good basis for evaluating water quality data and estimating attainable water quality for an ecoregion. The expectations were based on the 75th percentile from a long-term dataset of least impacted streams.

Biological criteria has not yet been developed for all stream types; therefore, assessment of fish and macroinvertebrate community data for aquatic life use support was not possible at some sampling sites. Stream types that were not assessed include channelized streams or ditches, Class 7 limited use waters, and coldwater streams. Habitat assessment results taken during each fish sampling visit are included in the discussion of each site sampled for biology. The habitat assessment is a scoring system based on the categories of land use, riparian zone, instream zone (substrate, embeddedness, cover types and amounts), and channel morphology (depth variability, sinuosity, stability, channel development, velocity) combine for a total possible score of 100 points. Scores and ratings are included below with a discussion on the main factors leading to low scores. Along with a total score, habitat assessment provides information on available fish habitat, and land use and buffers along the immediate site reach. This information provides clues for stressors on fish communities such as eroding soils, which can result in siltation and lack of spawning substrates.

Upper Pomme de Terre River Watershed Unit – HUC 0702002010

The Upper Pomme de Terre River Watershed Unit has a drainage area of 478 square miles, and encompasses parts of Otter Tail, Grant, and Stevens Counties. The watershed unit includes the headwaters of the Pomme de Terre River as it flows west out of Stalker Lake. The watershed unit follows the river as it turns southward and flows through North Tenmile and Tenmile Lakes onto the mouth of Pelican Creek. The river then flows through Barrett and the Pomme de Terre lakes on its way to the city of Morris. The river has a wide floodplain along the reach from Pomme de Terre Lake to Morris. The upper section of the watershed unit contains numerous lakes and wetland complexes, including the above-mentioned flow-through lakes. After the Pomme de Terre chain of lakes, the percentage of open water diminishes and the landscape changes to predominantly agricultural land uses (Figure 22). The Pomme de Terre River itself is bordered by riparian wetland for most of this reach.

The watershed unit ends just prior to the confluence with Muddy Creek. The river is dammed as it flows through Morris, creating the Pomme de Terre Reservoir. The pour point of this watershed unit is represented by site 07MN009, located on the Pomme de Terre River in Morris.

Stream biological sampling

Eleven biological sampling events were conducted at 10 discrete stations within the Upper Pomme de Terre River Watershed Unit in 2007. Six stations in this watershed unit are located on the Pomme de Terre River main-stem: 03MN002, 03MN003, 07MN003, 07MN006, 07MN009, and 07MN014.

Site 03MN002 is located near the headwaters of the Pomme de Terre River. Sampled both in 2003 and 2007, the F-IBI scores are 56 and 69, respectively. Both scores are fully supporting for aquatic life, as are the M-IBI scores of 82 and 76. Downstream of the mouth of Pelican Creek, site 07MN006 has an F-IBI score of 68 and an M-IBI score of 78. These scores are both reflective of a fully supporting system for aquatic life. Site 07MN003, located downstream of Pomme de Terre Lake has an F-IBI score of 50 and an M-IBI score 60, which are also both fully supporting of aquatic life. South of Barrett Lake, site 03MN003 was sampled once in 2003 and twice in 2007 with F-IBI scores ranging from 20 to 31 and M-IBI scores of 47 to 71. Based on the 2003 fish sample, which scored below the threshold, the AUID 07020002-502 was listed during the 2006 cycle as non-supporting for aquatic life of fish as part of the Pomme de Terre Lake to Muddy Creek stretch. This AUID was split during the current assessment cycle to isolate the impairment. The previous AUID that was listed was 48 miles long. The current cycle lists the Barrett Lake to Muddy Creek reach as supporting for macroinvertebrates, but non-supporting of aquatic life for fish. This includes AUIDs 07020002-563 and 07020002-562. Other sites on these AUIDs include 07MN014 and 07MN009 with F-IBI scores of 41 and 35 and M-IBI scores of 68 and 63, respectively. These scores are fully supportive of aquatic life for macroinvertebrates. The F-IBI scores of 07MN014 and 07MN009 are close to the threshold, but are non-supporting of aquatic life for fish. Both the fish and macroinvertebrate IBI scores increased from 2003 to 2007, so while the system might be improving it is not yet fully supportive of aquatic life for fish.

Four sites were sampled on small tributaries to the Pomme de Terre River: 07MN002, 07MN004, 07MN007, and 07MN010 (AUIDs 07020002-525, -543, -544, and -540). The sites are all called unnamed creeks, and were not assessed due to channelization within the sampling reach at sites 07MN002, 07MN004, and 07MN007. Site 07MN010 was not assessed because even though the sampling reach was a natural channel, the majority of the AUID was channelized, deferring assessment. Habitat scores in this watershed unit ranged from 50 to 73, with three of the ten sites scoring in the good category, and seven scoring in the fair category. The highest scores in the Upper Pomme de Terre River Watershed unit are at the most northern sites 03MN001 and 07MN006, which also had the highest F-IBI scores, showing the importance of habitat to fish communities. Embeddedness and a predominance of habitat types with little variation (>95 percent runs) led to low substrate scores in the lower scoring sites. Low channel morphology scores also brought down the total scores at these sites, mainly due to a lack of riffles and a lack of channel development.

Stream water chemistry

Water chemistry was collected at sites 07MN003 and 07MN009 as part of the intensive watershed study. Temperature loggers deployed at these sites recorded an average summer temperature of 23.59°C and 23.66°C, respectively. In addition to intensive water chemistry data, both Otter Tail and Stevens Counties collected data on this stretch of the river. Also available is eight years of citizen volunteer water transparency data. Of the available data, there are no water quality standard exceedances with the chloride, pH, or un-ionized ammonia results, making them fully supporting for aquatic life.

Turbidity values are also fully supporting for aquatic life with 0.5 percent of values that exceed the standard of 25 NTU (with the exceedances occurring on AUIDs 07020002-562 & -565), which is much less than the 10 percent that is indicative of an impairment. However, 11 percent of the nitrate-nitrite nitrogen and values exceed ecoregion expectations (with the exceedances occurring on AUIDs 07020002-514 and -562). Along with the high nitrate-nitrite readings, AUID 07020002-562 is also where all of the exceedances of the proposed phosphorus standard occurred, resulting in 11 percent of readings above the proposed standard. The high nutrient readings are concentrated on the Pomme de Terre River mainstem south of Morris. There are insufficient data points to assess dissolved oxygen and E. coli on any individual AUID, since both parameters require 20 data points. Of the existing data, there are no E. coli values above the water quality standard. All measurements of dissolved oxygen in this unit also meet the standard except for one sample taken during biological sampling at site 03MN003, and five samples at a site north of the town of Barrett (AUID 07020002-565). Low dissolved oxygen conditions are likely caused for a limited distance by outflow from a large waterfowl production area (WPA) nearby.

Lake water chemistry

There are 122 lakes in the Upper Pomme de Terre River Watershed Unit, of which seven have been assessed for aquatic life; five are fully supporting, and two are non-supporting. Nine additional lakes have been sampled but do not currently have enough information for assessment.

Long Lake is a 373-acre mesotrophic lake with a catchment watershed area of 2521.4 hectares (6230.5 acres), and a catchment to lake surface area ratio of 17:1. In general, the catchment is relatively undeveloped, with the immediate watershed of the lake forest and rangeland dominated. Water quality data from 2006-2007 indicate low concentrations of Total Phosphorus (TP), Chlorophyll-a, and good Secchi transparency as compared to NCHF eutrophication standards (Appendix 4).

Stalker Lake is a 1,337-acre lake with a catchment watershed area of 14856.2 hectares (36710.6 acres), and a catchment to lake surface area ratio of 27:1. Located near the headwaters of the Pomme de Terre River, the outlet is located along the southwest shoreline of the lake. The catchment watershed is composed primarily of cropland, rangeland, and hardwood forest. Stalker Lake has a maximum depth of 95 feet and its morphometry is diverse with many humps and bars throughout the lake. Water quality data from 2008-2009 indicate that Stalker Lake has low concentrations of TP, Chlorophyll-a, and good Secchi transparency, as compared to the NCHF standards. Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant.

Swan Lake is a 725-acre deep mesotrophic lake with a catchment watershed area of 3604.2 hectares (8906.1 acres) and has a catchment to lake surface area ratio of 12:1. The majority of the lakeshore has been developed. Water quality data from 2008-2009 indicate that Swan lake has low concentrations of TP, Chlorophyll-a, and good Secchi transparency as compared to the NCHF standards. Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant.

Ten Mile Lake is a 1,408 acre mesotrophic lake with a catchment watershed area of 29436.9 hectares (72740.2 acres) and a catchment to lake surface area ratio of 52:1. The Pomme de Terre River flows through the lake, with the inlet located along the north shore, while the outlet is located along the south shore. Ten Mile Lake's land use is dominated by agricultural cropland, rangeland, and other water bodies. The numerous upstream lakes serve to trap and process TP from watershed runoff. Water quality data form 2008-2009 indicate that Ten Mile Lake has low concentrations of TP, Chlorophyll-a, and good Secchi transparency as compared to the typical NCHF standards. Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant.

North Turtle Lake is a 1,542-acre eutrophic lake with a catchment watershed area of 2878.9 hectares (7113.8 acres) and a catchment to lake surface area ratio of 5:1. There are no navigable inlets or outlets on the lake. North Turtle Lake's land use mostly consists of agricultural cropland, rangeland, and forest/shrub land. Water quality data from 2008-2009 indicate that North Turtle lake has high concentrations of TP, Chlorophyll-a, and good Secchi transparency as compared to the typical NCHF ecoregion values. Concentrations for individual sampling events during the 2008-2009 field seasons appear to fluctuate throughout the open water season. Calculations show water quality in North Turtle Lake is eutrophic and subject to nuisance algae blooms. Based on this data, it was determined that North Turtle Lake is non-supporting of aquatic recreation due to nutrients.

South Turtle Lake is a 648-acre moderately fertile lake with a catchment area of 4,437.8 hectares (10,966.2 acres) and has a catchment to lake surface area ratio of 17:1. The immediate watershed is composed primarily of agricultural land interspersed with hardwood woodlots. The maximum depth is 10.7 m; however, 63 percent of the lake is less than 4.6 m deep. The north and west shorelines have been extensively developed. Water quality data from 2008-2009 indicate that South Turtle Lake has low concentrations of TP, Chl-a, and good Secchi transparency as compared to NCHF standards. Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant.

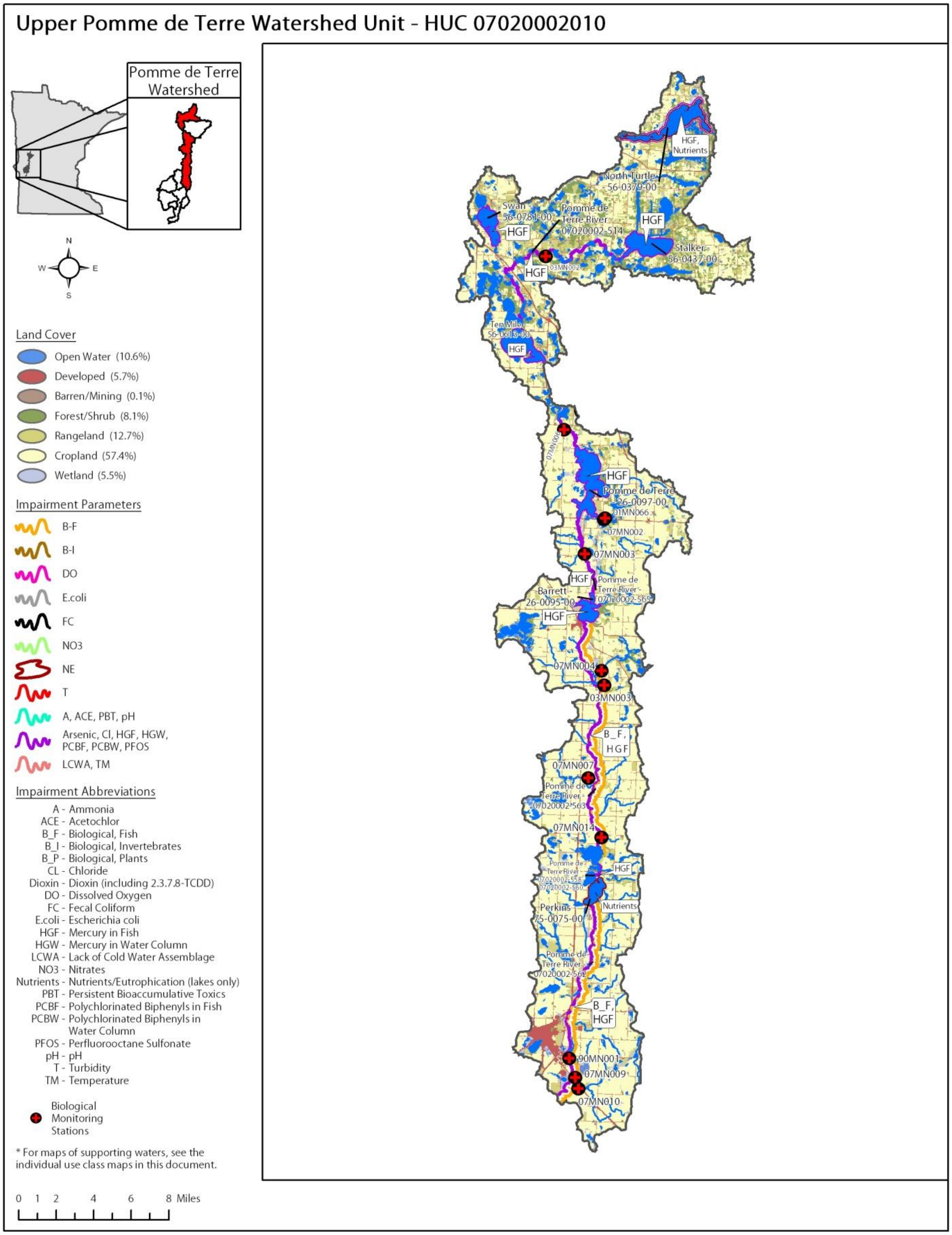
Perkins Lake is 504-acre shallow, turbid flow-through lake along the Pomme de Terre River. Perkins Lake catchment watershed area is 107684.5 hectares (266094.5 acres) and has a catchment to lake surface area ratio of 527:1. Nearly half of the land use in the catchment watershed is agricultural cropland. Large amounts of rangeland with interspersed forest/shrub land make up the remainder of the land use. Poor water quality, lack of submerged aquatic vegetation and degraded aquatic habitat has been described in lake survey reports since the initial survey in 1947. The river transports excessive amounts of nutrients and sediments through the lake. High total phosphorous and total suspended solid concentrations have been documented in annual water quality monitoring conducted by the Perkins Lake Association. Observations of dense blue-green algae blooms are common in July and August. Water quality data from 2000-2001 indicate that Perkins Lake has high concentrations of TP and poor Secchi transparency as compared to the typical NCHF ecoregion values. Concentrations for individual sampling events during the 2000-2001 field seasons appear to fluctuate throughout the open water season. Perkins Lake was previously listed as impaired for aquatic recreation based on nutrient data.

Upper Pomme de Terre River Watershed Unit summary

In summary, the AUID stream stretches from Stalker Lake to Barrett Lake are fully supporting of aquatic life for both fish and macroinvertebrates, while the stretch from Barrett Lake to Muddy Creek is non-supporting for fish. Perkins Lake, which is a flow-through lake on the impaired stretch of the Pomme de Terre River, is non-supporting of aquatic recreation based on phosphorus nutrient data. North Turtle Lake, in the upper part of the watershed, is also non-supporting of aquatic life based on phosphorus nutrient data. South Turtle Lake, however, is supporting of aquatic recreation. Almost the entire length of the Pomme de Terre River in this watershed was listed for non-supporting of aquatic consumption during the 2006 assessment cycle based on mercury data, starting at Stalker Lake. The lakes listed as non-supporting of aquatic consumption in the watershed unit are Stalker, North Turtle, Swan, Ten Mile, Pomme de Terre, and Barrett.

A flow station has been added above Perkins Lake that will be in place for three years; load monitoring stations should be added above and below the lake to determine concentrations coming in and out of the lake as nutrients are high both on the lake and on the river downstream. Studies and improvement activities on the lake will need to address the entire upstream portion of the Pomme de Terre River. Dissolved oxygen should be further investigated near the Blakesley WPA to determine the extent of the low readings. Dam removal or modification for fish migration should be considered throughout the reach on flow-through lakes with the Barrett Lake dam used as a model.

Figure 22. Currently listed impaired waters by parameter and land use characteristics in the Upper Pomme de Terre River



Pelican Creek Watershed Unit – HUC 07020002020

The Pelican Creek Watershed Unit spans parts of Otter Tail, Grant, and Douglas Counties and encompasses a drainage area of 134 square miles. Pelican Creek is one of the three main tributaries to the Pomme de Terre River. The watershed unit also houses a tributary to Pelican Creek, which flows through Lake Christina and Pelican Lake on its way to Pelican Creek. Pelican Creek has a wetland riparian area for most of the reach, except where pasture has been established. Lakes and grassland make up the majority of the land use in the eastern part of the watershed, with cropland dominant west of Pelican Creek (Figure 23). The watershed is represented by three biological sites: 03MN001, 07MN001, and 07MM054. The pour point of this watershed unit is represented by site 07MN001 on Pelican Creek.

Stream biological sampling

Four visits occurred at three sampling locations. Two unnamed tributaries to Lake Christina were sampled at sites 03MN001 and 07MN054. Site 03MN001, located on AUID 07020002-518, was sampled in 2003 and has an F-IBI score of 73 and an M-IBI score of 56. The data indicates full support of aquatic life for both fish and macroinvertebrates. The F-IBI scores for site 07MN054 on AUID 07020002-542, which was sampled twice in 2007, are 48 and 56 and the M-IBI score is 59. Two of the three IBI scores are above the threshold, but within the 90 percent confidence interval, and one is below the threshold but within the 90 percent confidence interval. The weight of evidence points toward full support of aquatic life use. Pelican Creek was represented by biological site 07MN001 on AUID 07020002-506, which has an F-IBI score of 60 and an M-IBI score of 66. Both scores indicate full support of aquatic life. All three sites in the Pelican Creek Watershed Unit had fair habitat scores ranging from 48 at site 07MN001 to 62 at site 03MN001, scoring low across all of the categories.

Stream water chemistry

Samples were taken at the pour point of Pelican Creek (07MN001) throughout the summer in 2007. Agency water monitoring is supplemented with citizen-collected water transparency data collected from 2002-2008. Of the chemistry data that has been collected, chloride data is fully supporting of aquatic life with no exceedances of the water quality standard of 230 mg/L. Although they each have values above the water quality standard, un-ionized ammonia, pH, and turbidity data are all fully supporting of aquatic life as turbidity and pH data require a 10 percent exceedance rate for impairments, and un-ionized ammonia data requires more than one exceedance of the standard. There was one value (10.05) above the pH water quality standard of 6.5-9, and one value (.07 mg/L) above the un-ionized ammonia water quality standard of .04 mg/L. There were seven turbidity values that exceeded the water quality standard of 25 NTU or the surrogate transparency tube standard of 20 cm, with the lowest transparency value being 10 cm. Nitrate-nitrite nitrogen data meets ecoregion expectations in all but one instance, but 83 percent of the phosphorus readings exceed the proposed standard.

The requisite 20 samples necessary to be able to assess for dissolved oxygen and E. coli were not taken. Of the available samples, three of the thirteen dissolved oxygen readings are below the standard of 5 mg/L with the lowest at 3.78 mg/L, and one of the E. coli measurements (2,000 organisms per 100 mL) was above the water quality standard of 1,260 organisms per 100 mL. A temperature logger deployed at the pour point site of 07MN001 recorded an average summer temperature of 23.2 °C.

Lake water chemistry

There are 61 lakes in the Pelican Creek Watershed Unit, of which three have been assessed for aquatic life. Two of the assessed lakes are fully supporting, and one is non-supporting. Seven additional lakes have been sampled but do not currently have enough information for assessment.

Lake Christina is a large, shallow lake that is nationally recognized as a critical staging area for migrating waterfowl. Lake Christina has a robust water quality data set with readings periodically taken from 1965 through 2007. Water levels have changed 2.97 feet, with 714 observations taken throughout the period of record. Rotenone treatments were used in 1987 and 2003 to reduce the carp population. This reduced disturbance of sediments and allowed aquatic macrophytes to re-establish, in turn improving water quality. Since the 2003 rotenone treatment, water quality data taken in 2006 shows a drastic reduction in the concentrations of TP, Chlorophyll-a, and improved Secchi transparency. Transitions from a turbid to clear water state are evident. Even with the improvements in water quality, Lake Christina is currently non-supporting of aquatic recreation.

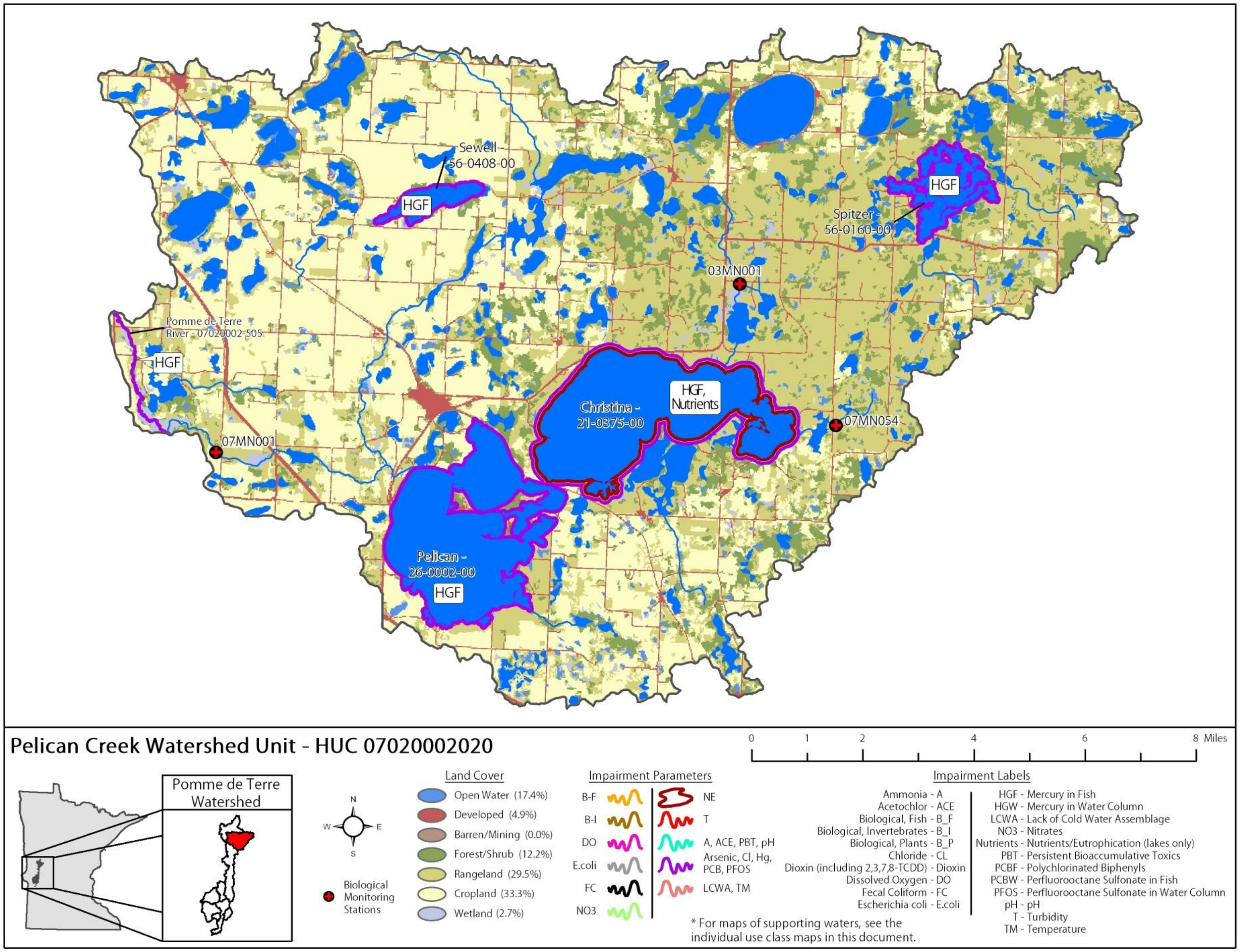
Clear Lake is fully supporting of aquatic recreation. Clear Lake is a small 390-acre, mildly eutrophic lake whose land use is dominated by agricultural cropland. Secchi readings have been taken since 1999, and water chemistry samples were taken during the summer of 2008 and 2009 by CLMP volunteers. The average TP and Chlorophyll-a concentrations for Clear Lake are well below impairment criteria for shallow lakes within the NCHF ecoregion.

Eagle Lake, an 898-acre mesotrophic lake, is also fully supporting of aquatic recreation. Land use mostly consists of agricultural cropland and rangeland with some areas of forest/shrubland and open water. Water quality data from 2008-2009 indicate that Eagle Lake has low concentrations of TP and Chl-a, and good Secchi transparency, as compared to the typical NCHF ecoregion values.

Pelican Creek Watershed Unit summary

Pelican Creek and its tributaries are fully supporting of aquatic life based on fish and macroinvertebrate data. Upstream of Pelican Creek, Lake Christina is impaired for aquatic recreation based on phosphorus nutrient data. Pelican Creek, downstream of Lake Christina, had elevated phosphorus levels, and should be further investigated. Clear and Eagle Lakes, which are both located in the upper parts of the watershed, are not directly connected to Pelican Creek or its tributaries but are both found to be fully supporting of aquatic recreation based on phosphorus data. Spitzer, Cristina, Pelican, and Sewell Lakes are all non-supporting of aquatic consumption based on mercury data. Due to some low readings, a diurnal probe should be placed at points along Pelican Creek to determine if there is a dissolved oxygen problem. Additional E. coli measurements should also be taken to complete the dataset.

Figure 23. Currently listed impaired waters by parameter and land use characteristic in the Pelican Creek Watershed Unit



Little Muddy Creek & Muddy Creek Watershed Units – HUC 07020002030 & 07020002040

Little Muddy Creek is its own unique 11-digit HUC watershed unit, but since the unit consists of the upstream portion of the mainstem of Muddy Creek, the Little Muddy Creek and Muddy Creek watershed units were combined for study purposes. Located within Stevens County, just west of the city of Morris, the primary land use in both watershed units is cropland (Figures 24 and 25). The drainage area of the combined watershed units is 144 square miles, consisting of Muddy Creek and its tributaries. The Little Muddy Creek watershed unit contains the headwaters of Muddy Creek, the upper reach of which is channelized. After flowing through the town of Chokio, the mainstem of Muddy Creek is classified as a Class 7 limited resource water. The Class 7 classification on Muddy Creek extends throughout the entirety of the Muddy Creek watershed unit to the mouth of the creek. Biological station 01MN032 represents the pour point of both watershed units.

Stream biological sampling

Seven biological stations were sampled within the watersheds in 2007: 07MN013, 07MN012, 07MN008, 07MN019, 07MN016, 07MN017, and 01MN032. Four sites were placed on AUID 07020002-511, located on the mainstem of Muddy Creek; 07MN008, 07MN013, 07MN016 and 01MN032. The other three sites (07MN012, 07MN017 and 07MN019) were located on an unnamed tributary to Muddy Creek (07020002-512, 07020002-539 and 07020002-538).

Sampling for fish occurred at all seven sites, but at only two sites for macroinvertebrates due to low or no flow conditions during the macroinvertebrate sampling season, which takes place in late summer. Assessment did not occur on five of the sites (07MN013, 07MN012, 07MN008, 07MN016, and 01MN032) for aquatic life due to their placement on Class 7 limited resource stream reaches. The other two sites, 07MN017 and 07MN019, were not assessed due to predominantly channelized stream reaches at the sampling locations. The three sites in the Little Muddy Creek watershed unit (07MN008, 07MN012, and 07MN013) had poor habitat assessment scores across all categories with scores ranging from 27 to 40. The poor scores are due in particular to a lack of cover for fish, sinuosity and run-riffle-pool complexes. All four sites in the Muddy Creek watershed unit had very poor substrate scores due to silt and sand dominated streambeds. Sites 07MN019 and 01MN032 had poor habitat scores of 36 and 37 respectively, with sites 07MN016 and 07MN017 scoring slightly better at 46 due to some depth variability along the stream reach.

Stream water chemistry

Water chemistry samples were taken at site 01MN032 during the summer of 2007, except during a low flow period in late summer. Both chloride and un-ionized ammonia samples are shown to be fully supporting with no exceedances of the water quality standards for a Class 7 limited resource water. There was insufficient E. coli data to assess for aquatic recreation, which requires a minimum of 20 observations. Of the data that was collected there was one violation (2000 organisms per 100 mL) of the water quality standard of 1260 organisms per 100 mL. There was also insufficient data to assess for dissolved oxygen, but the available data showed no exceedances of the Class 7 water quality standard of 1 mg/L. The dissolved oxygen readings did show a range of values, from 6.15 mg/L to 16.04 mg/L. All but one of the nitrate- nitrite Nitrogen and phosphorus results were above the ecoregion expectation and draft standard. A temperature logger deployed through early July showed an average temperature of 22.94 °C.

Lake water chemistry

There are 13 lakes in the Little Muddy and Muddy Watershed Units, one of which has been assessed; Hattie Lake. Hattie Lake is a hyper-eutrophic, shallow, turbid, polymictic lake. Hattie Lake's catchment watershed area is 3578.9 hectares (8843.6 acres) and has a large catchment to lake surface area ratio at 19:1. Land use is dominated by agricultural cropland while the lake catchment is relatively undeveloped. Water quality data was collected on Hattie Lake periodically from 1985 through 2009. The most recent two years of data show extremely high TP and Chl-a concentrations, which promote severe algal blooms. Mid to late summer peaks in TP are evident in both years. Water quality data for 2009 is compared to NGP lake eutrophication standards, and was determined to be non-supporting for aquatic recreation based on nutrient data.

Muddy Creek Watershed Unit summary

The Little Muddy and Muddy Creek watershed units are unable to be assessed for biology due to channelization and the limited use classification along the sampling reaches. Located along the unnamed tributary to Muddy Creek, Hattie Lake was found to be impaired for aquatic recreation based on nutrient data. Further downstream, Muddy Creek was found to be supporting of aquatic life based on both chloride and un-ionized ammonia data.

Figure 24. Currently listed impaired waters by parameter and land use characteristics in the Little Muddy Creek Watershed Unit

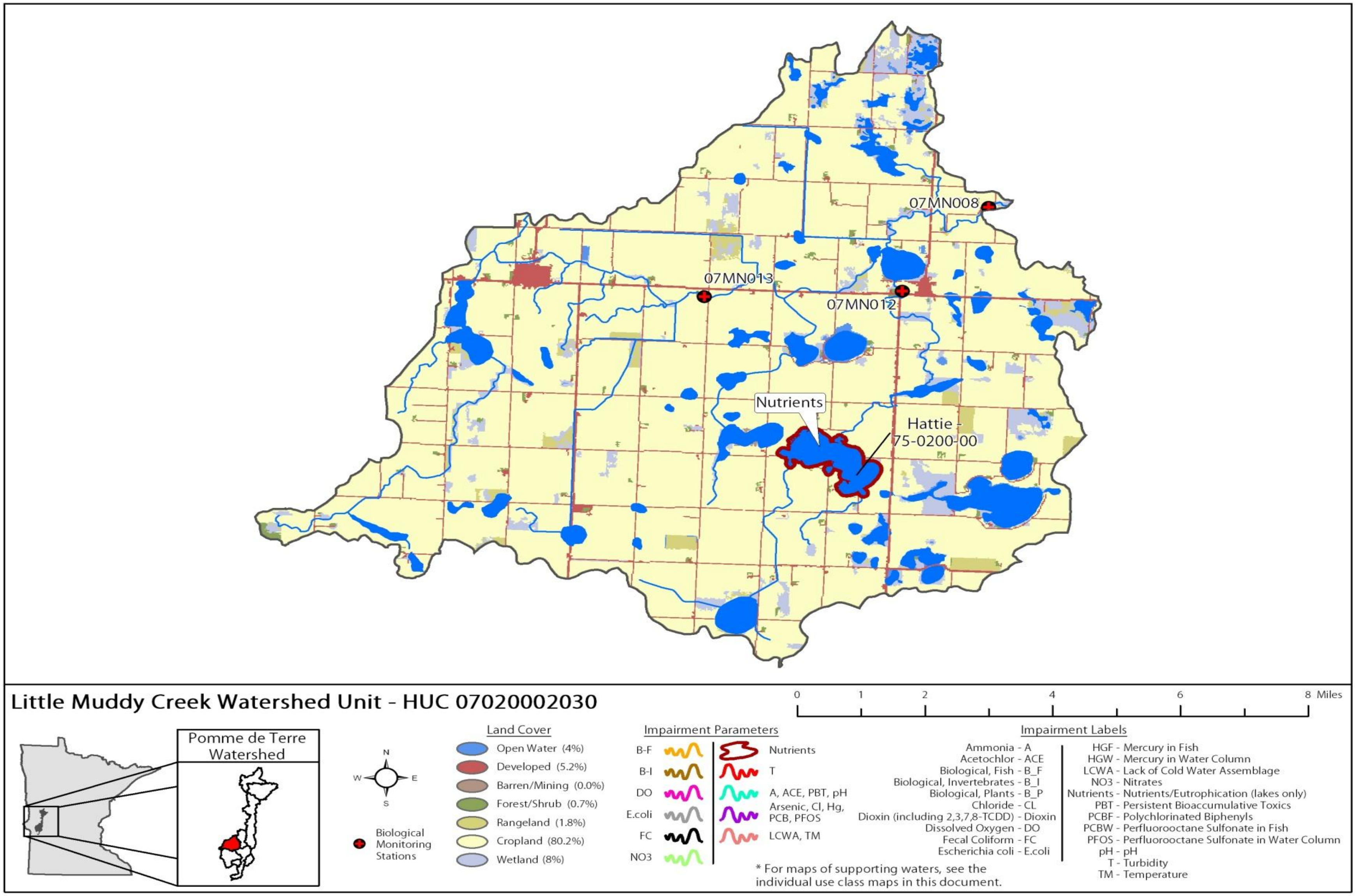
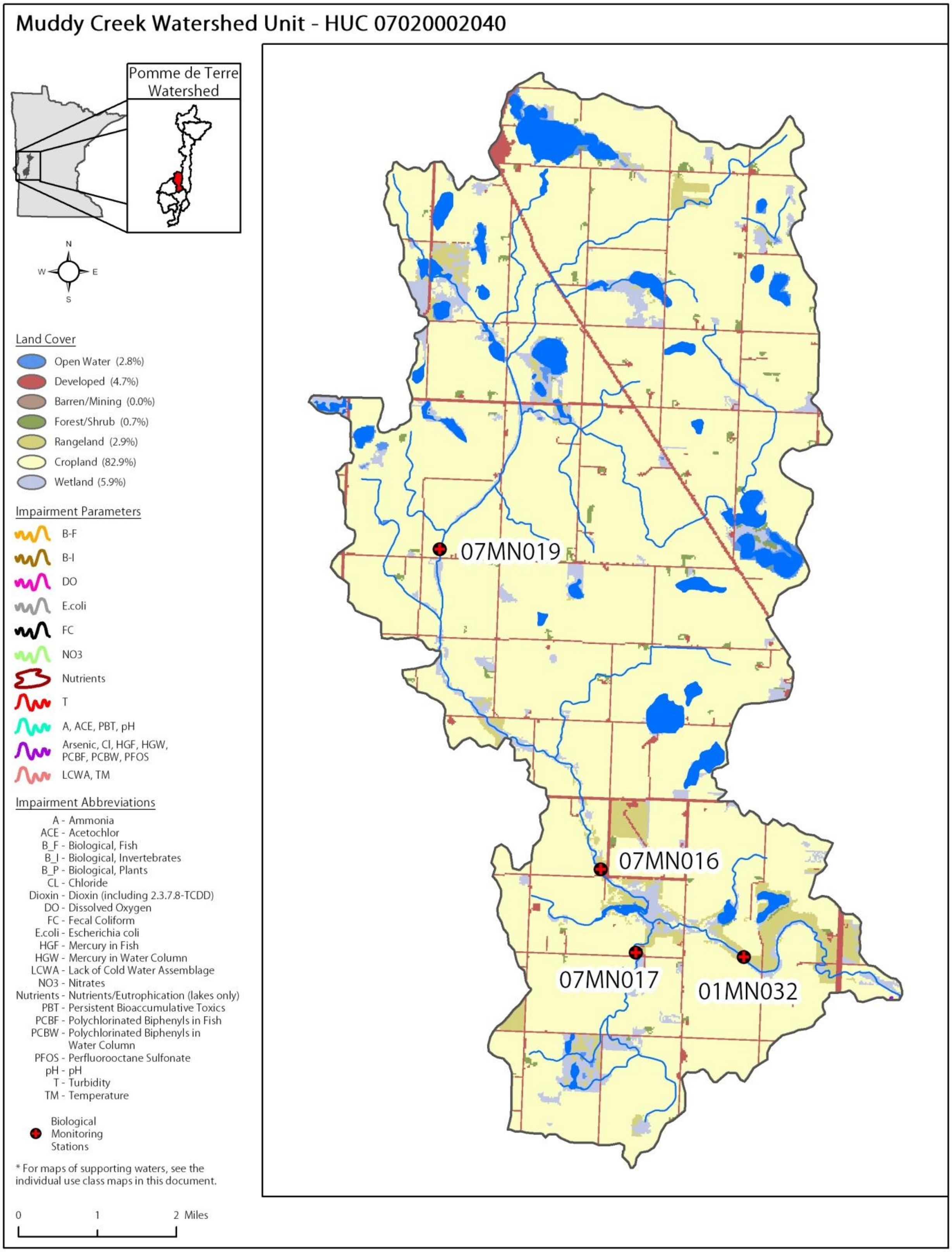


Figure 25. Currently listed impaired waters by parameter and land use characteristics in the Little Muddy Creek Watershed Unit



Lower Pomme de Terre River Watershed Unit – HUC 07020002050

The Lower Pomme de Terre River watershed unit extends from just south of Morris, and follows the Pomme de Terre River as it flows south to Appleton. Once the river reaches Appleton it flows westerly through town, and then changes direction back to flowing south for the last few miles on the way to the mouth of the river. The drainage area at the mouth of the Pomme de Terre River is 880 square miles. The watershed unit begins at the confluence with Muddy Creek, where the Pomme de Terre River watershed widens as a result. The area encompasses parts of Stevens and Swift counties, with land use comprised mostly of cropland (Figure 26). As the Pomme de Terre River moves south toward Appleton, it flows through small areas of wetland and forested riparian zones, which continue in patches to the mouth of the river.

A dam was removed from the Pomme de Terre River in downtown Appleton in 1999, just upstream of site 07MN032. With the removal of the impoundment, this stretch of the river was de-listed for a dissolved oxygen impairment during the 2006 assessment cycle as the low dissolved oxygen readings were determined to be reflective of Mill Pond, the impoundment, not the river itself. The pour point of the watershed unit is represented by site 07MN032 in Appleton.

Stream biological sampling

Seven biological stations were sampled within the watershed: 01MN069, 07MN011, 07MN021, 07MN027, 07MN028, 07MN029, and 07MN032. Site 01MN069 was sampled in 2001; the others were sampled in 2007. Seven of the sites were sampled for fish, and four were sampled for macroinvertebrates. Five of the sites are located on the Pomme de Terre River (AUID 07020002-501), while the other two are located on small, unnamed tributaries to the Pomme de Terre River.

Site 07MN011 is located upstream of the mouth of Drywood Creek, and has an F-IBI Score of 42 and an M-IBI score of 31. Both of these scores are right at the threshold. Site 07MN027 is located upstream of Appleton on Highway 12 at the site of a former dam that was removed during the late 1990s, and has an F-IBI score of 41 and an M-IBI score of 17. The fish score is at the threshold, but the macroinvertebrate data score poorly, falling below both the threshold and 90 percent confidence interval. These scores are indicative of a non-supporting system for aquatic life. Site 07MN032 is located in downtown Appleton, and has an F-IBI score of 49, and an M-IBI score of 27. The fish score is above the threshold, but is still within the 90 percent confidence interval. The macroinvertebrate score is below the threshold but within the confidence interval. Site 01MN069 is located west of Appleton, just prior to the river turning south on its way to the Minnesota River. This site has an F-IBI score of 54, which is the highest fish score in the AUID and is above both the threshold and 90 percent confidence interval. Site 07MN029 is the pour point site of the watershed, and is located just a few miles upstream of the mouth of the Pomme de Terre River in the Lac qui Parle WMA. This site has an F-IBI score of 36 and an M-IBI score of 34. The fish score is below the threshold, while the macroinvertebrate score is just above the threshold. These macroinvertebrate scores reflect impairment throughout the AUID, with three scores below the threshold and the other just slightly above the threshold. The fish scores are not as uniform, with the scores in the upper part of the watershed and the near the mouth of the river reflecting an impairment, while the scores right around Appleton are reflective of a healthy system. The weight of evidence throughout the watershed unit shows a system not fully functioning.

Of the two tributaries, site 07MN021 is located in the Bill Freeman WPA on AUID 07020002-551. The F-IBI score was 2 for this site, falling far below the threshold and 90 percent confidence interval, making it non-supporting of aquatic life for fish. Site 07MN028 is located north of Appleton, and was not assessed for aquatic life for fish due to its location on a predominantly channelized stream reach. This site scored poorly on the habitat assessment with a score of 43, due in particular to a lack of riffles, depth variability, sinuosity, and channel stability. The remaining sites in this watershed unit scored fairly well across the habitat assessment categories with scores ranging from 51 to 67, with the two highest scores at sites 01MN069 and 07MN032, which also had the highest F-IBI scores.

Stream water chemistry

Water chemistry was collected at two sites in 2007 as part of the Phase 1 project; one located south of Morris and the other in the city of Appleton. Both water chemistry sites are located on AUID 07020002-501, which at 48 miles long, is the largest AUID in the Pomme de Terre River watershed. The water chemistry location in Appleton has been sampled for over 40 years as part of the Milestone program. Water quality conditions show a stream stretch that has been compromised by high turbidity and bacteria, leading to this reach being listed as impaired for aquatic life in 2002 and aquatic recreation in 1994. A fecal coliform TMDL plan to control bacteria was approved in 2007 by the EPA. A turbidity TMDL will be submitted to the EPA in 2011 for final approval.

High nutrient values are present in this reach, with 40 percent of nitrate-nitrite nitrogen concentrations exceeding the ecoregion expectation, 58 percent of phosphorus concentrations above the proposed standard, and 12 percent of BOD results above the proposed standard. Since the reach was de-listed for dissolved oxygen in 2006, there have been no exceedances of the standard of 5 mg/L. Samples were recently analyzed for four common agricultural pesticides (atrazine, metolachlor, alachlor, and acetochlor), and were all found to be supporting of aquatic life. Likewise, a sizeable set of collections analyzed for pH, chloride, and un-ionized ammonia showed the system to be fully supporting with no exceedances of the water quality standards. A temperature logger deployed at site 07MN032 recorded an average summer temperature of 23.93 °C.

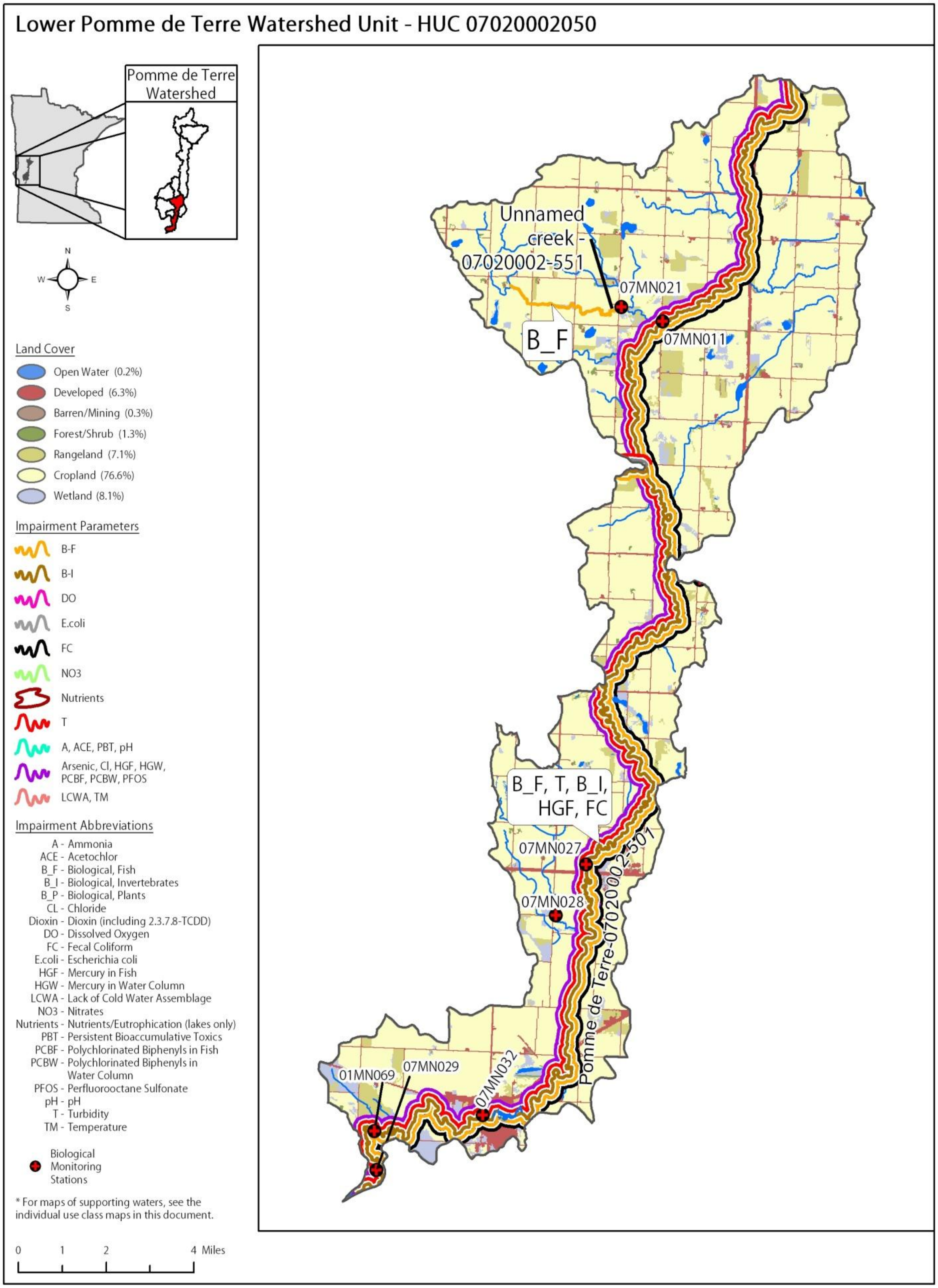
Lake water chemistry

There is one lake in the Lower Pomme de Terre River watershed unit (unnamed 76-0128), which has not been assessed.

Lower Pomme de Terre River Watershed Unit Summary

In summary, the Lower Pomme de Terre River watershed unit is non-supporting of aquatic life for turbidity, fish, and macroinvertebrates, aquatic recreation for fecal coliform, and aquatic consumption for mercury. Impairments within the entire Pomme de Terre River watershed cumulatively affect this lower watershed unit since it receives the effects of all of the upstream water. The watershed unit is fully supporting of aquatic life for pH levels, chloride, atrazine, metolachlor, alachlor, and acetochlor.

Figure 26. Currently listed impaired waters by parameter and land use characteristics in the Lower Pomme de Terre Watershed Unit



Drywood Creek Watershed Unit – HUC 07020002060

The Drywood Creek watershed unit has a drainage area of 102 square miles, and is located in parts of Big Stone, Swift, and Stevens Counties. The majority of the land use is agricultural, particularly near the downstream section of the river, where the riparian is heavily pastured (Figure 27). The upper section has numerous wetlands and lakes, including Drywood Lake (also called Griffin Lake). The pour point of this watershed unit is represented by site 07MN022 on Drywood Creek. Just upstream of site 07MN022, there is an old fish barrier dam that no longer restricts flow.

Stream biological sampling

Seven visits occurred in 2007 and 2008 at six sampling locations. Four sites are located on Drywood Creek (07MN022, 08MN087, 08MN088, and 08MN089), resulting in five samples. Drywood Creek (AUID 07020002-556) was found to be non-supporting of aquatic life for both fish and macroinvertebrates with F-IBI scores ranging from 24 to 54 and M-IBI scores ranging from 0 to 50. Two of the five F-IBI scores fall below the threshold, one of which is below the confidence interval and one within. Two other F-IBI scores are above the threshold but within the 90 percent confidence interval, and the final site is above both the threshold and the confidence interval. The weight of evidence points to an impairment for aquatic life for fish. The M-IBI scores are all below the threshold and 90 percent confidence interval except for one visit, which was below the threshold but within the confidence interval. There is no evidence of natural background conditions causing these low biological scores.

The two remaining sites in the watershed are located on AUIDs 07020002-515 at County Ditch No. 22 (01MN001) and 07020002-536 at Artichoke Creek (07MN031), neither of which was assessed for aquatic life for fish due to their location on predominantly channelized stream reaches. These sites were not sampled for macroinvertebrates due to low flow conditions in the late summer. All of the visits scored poorly across the habitat assessment categories with scores ranging from 28 to 48, due in particular to a lack of riparian buffers, erosive banks, and the predominance of fine substrates.

Wetland biological sampling

In addition to stream biological sampling, two unnamed wetlands in the Lee and Golden WPAs were sampled in the northern part of the watershed. The wetland located in the Golden WPA was sampled twice – once in 2002 and once in 2003. The M-IBI scores are 46 and 51, respectively and the Plant IBI scores (P-IBI) are 31 and 32, respectively. All four biological samples have scores below the threshold, and were listed as non-supporting for aquatic life in 2010 for both parameters.

Sampling occurred at the wetland located in the Lee WPA in 2002, 2003, and 2008 with resulting M-IBI scores ranging from 35-55, all below the threshold. The resulting P-IBI scores ranged from 24-41 during these visits, all falling far below the threshold. This wetland was also listed during the 2010 cycle as non-supporting of aquatic life for both macroinvertebrates and plants.

Stream water chemistry

Water chemistry samples were taken at nine sampling locations during 2007 and 2008. Samples were taken throughout the summer in 2007 at site 07MN022 except during a low flow period in August. A reach of Drywood Creek (AUID 07020002-556, Drywood Lake to Pomme de Terre River) was listed as impaired for aquatic recreation and aquatic life during the 2010 assessment cycle based on E. coli and turbidity data. Along with the turbidity and E. coli impairment listings, a dissolved oxygen impairment was added during the current assessment cycle. The dissolved oxygen data demonstrate a large diurnal swing including decisive exceedances of the standard of 5 mg/L, getting as low as 0.26 mg/L in the upper stretch closest to Drywood Lake, with 23 percent of the total dissolved oxygen readings below the water quality standard.

Chloride, un-ionized ammonia, and pH data are all supporting for aquatic life. There were no exceedances of the chloride or un-ionized ammonia standards, while two pH measurements (9.09 and 9.29) slightly exceeded the water quality of standard of 6.5-9. The two exceedances did not indicate an impairment (>10 percent violations, minimum 20 observations). Both nitrate-nitrite nitrogen and phosphorus samples often exceed criteria, with 46 percent of nitrate-nitrite nitrogen readings above the ecoregion expectation, and 100 percent of the phosphorus readings above the proposed standard. A temperature logger deployed through early July showed an average temperature of 23.25 °C.

Lake water chemistry

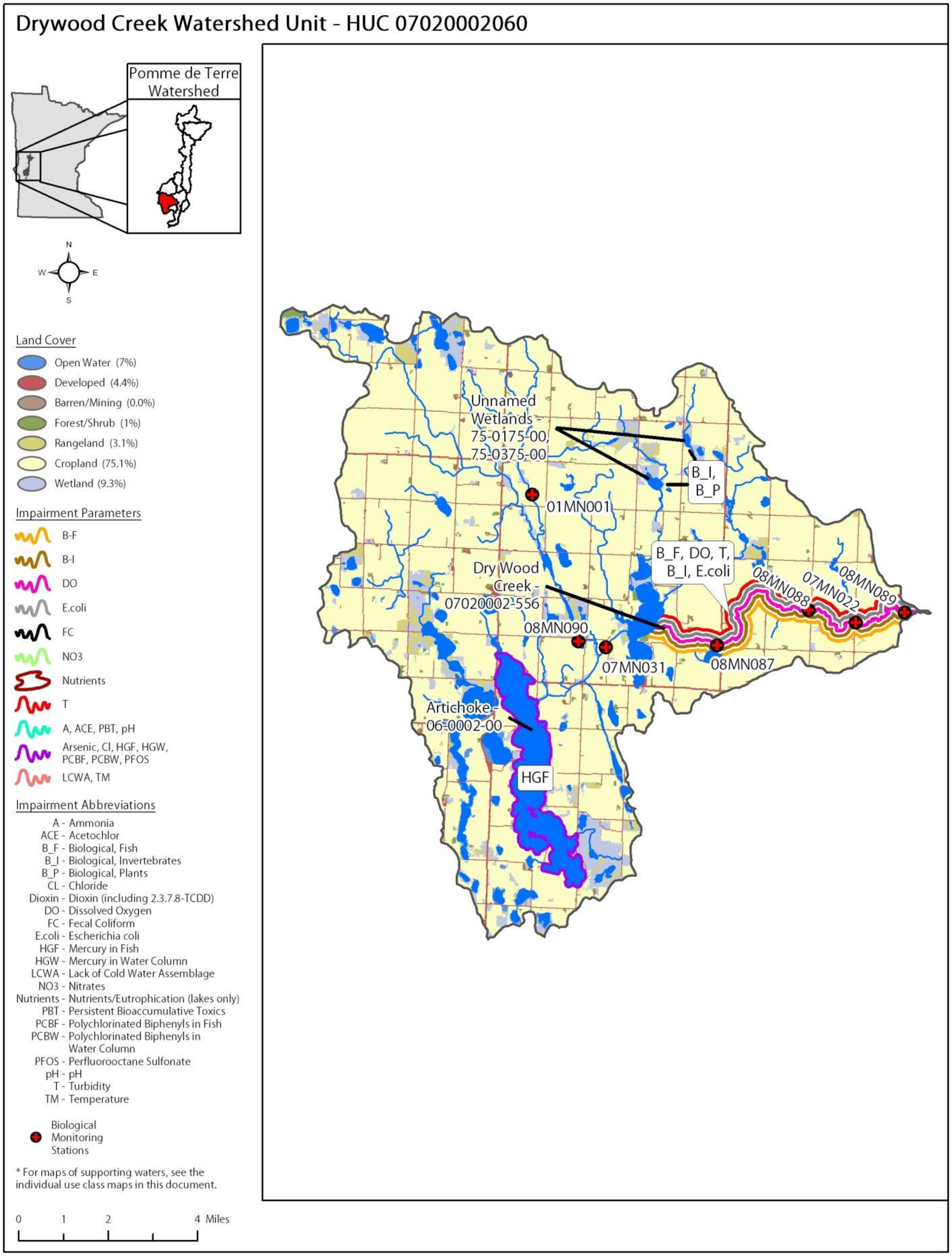
There are 13 lakes in the Drywood watershed unit, none of which have been assessed. Two have been sampled (Artichoke and North Drywood) but do not currently have enough information for assessment.

Artichoke Lake is a large 788-hectare (1,946 acre), shallow, productive lake located in eastern Big Stone County. Artichoke Lake currently has assessment level data; however, water chemistry values were highly variable. Since Artichoke Lake is part of the Sustaining Lake in a Changing Environment (SLICE) project, another year of data will be collected and aid in making assessment decisions. More information on Artichoke Lake through the SLICE project can be found at the following link: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/sentinel-lakes.html.

Drywood Creek Watershed Unit summary

Within the watershed unit, Drywood Creek is impaired along the reach from Drywood Lake to the mouth of the stream, for aquatic recreation and aquatic life based on E. coli, dissolved oxygen, turbidity, and biological (both fish and macroinvertebrates) data. Further upstream in the watershed, impairments exist on two wetlands that are tributaries to Drywood (Griffin) Lake, and Artichoke Lake is impaired for aquatic consumption based on mercury data. Due to the high readings of phosphorus and chlorophyll-a taken during one-time sampling as part of the National Lakes Assessment Project sampling on North Drywood Lake, the lake is likely part of the reason for the downstream impairments on Drywood Creek, and further readings are needed, along with monitoring of Artichoke Lake and and upstream wetlands to help pinpoint the source of the downstream impairments. A flow station has been placed at the pour point of Drywood Creek and will run for three years. Load monitoring should occur to coincide with this information.

Figure 27. Currently listed impaired waters by parameter and land use characteristics in the Drywood Creek Watershed Unit



Fairfield-Tara Watershed Unit – HUC 07020002070

The Fairfield-Tara Watershed Unit, located entirely within Swift County, has a drainage area of 29 square miles. The watershed consists of a small, unnamed tributary that flows into the Pomme de Terre River. Land use is predominantly cropland with scattered areas of wetlands and pasture (Figure 28). The watershed is represented by four visits at three biological sites: 07MN024, 07MN026, and 07MN030.

Stream biological sampling

Four biological samples were taken at three discrete stations within the watershed. Judicial Ditch 2 is represented by biological site 07MN030, located on AUID 07020002-549. The other two sites in the watershed are located on unnamed creeks on AUIDs 07020002-548 and 07020002-547. None of the sites were sampled for macroinvertebrates due to dry stream reaches in late summer. Sites 07MN024 and 07MN030 were not assessed for aquatic life for fish due to predominantly channelized stream reaches, and 07MN026 was not assessed due to water levels below base flow. No fish were collected at site 07MN026. Sites 07MN024 and 07MN026 scored poorly on habitat assessment across all categories with total scores of 29, but site 07MN030 scored well (69) based on good instream cover and channel morphology features.

Stream water chemistry

Pour point water chemistry was not collected because of the small size of the watershed unit. There is also no local data available. The one-time water chemistry samples taken during biological sampling show phosphorus levels above the proposed standard during all four visits; the highest value was 19 times the proposed standard with a value of 2.93 mg/L. Two of the sites (07MN030 and 07MN024) also had nitrate-nitrite nitrogen levels above the ecoregion expectation, with a high value of 17 mg/L.

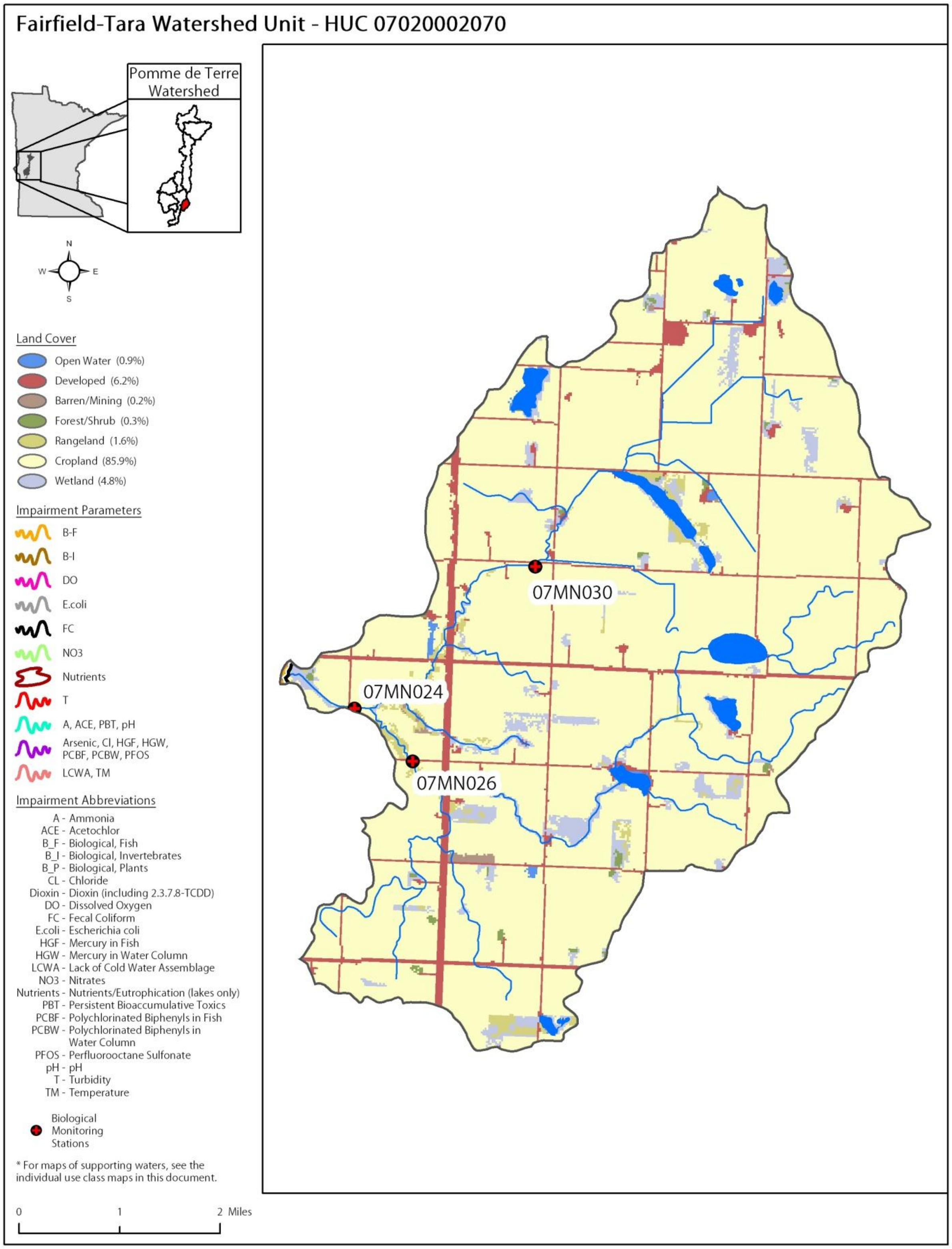
Lake water chemistry

There is no available lake data on the one lake (unnamed 75-0095) in the Fairfield-Tara watershed unit.

Fairfield-Tara Watershed Unit summary

Based on our limited data set within the watershed unit, there are currently no impairments within this watershed unit, but there is also no data to suggest fully supporting systems. Further samples should be collected throughout the watershed.

Figure 28. Land use and currently listed impaired waters by parameter in the Fairfield-Tara Watershed Unit



Lake Oliver Watershed Unit – HUC 07020002080

The Lake Oliver Watershed Unit, located in northeastern Swift County, drains an area of 20 square miles. The watershed consists of a small, unnamed tributary that flows into the Pomme de Terre River. The tributary is surrounded by riparian wetlands throughout most of its reach, and flows through a wetland complex before being ditched along the last mile prior to flowing into the Pomme de Terre River. Land use is predominantly cropland with scattered areas of wetlands and open water, including Lake Oliver (Figure 29). The watershed is represented by one biological site, 07MN025.

Stream biological sampling

The biological station is located on AUID 702020002-545. No fish were collected during sampling. The sample was not assessed for fish due to a predominantly channelized stream reach. Macroinvertebrates were not able to be sampled due to a dry stream reach in late summer. A low habitat assessment score (47) was due mainly to a dominance of fine substrates, a lack of depth variability, and a lack of channel development.

Stream water chemistry

Pour point water chemistry was not collected because of the small size of the watershed. There is also no local data available. The one-time water chemistry sample taken during biological sampling shows a phosphorus level (1.18 mg/L) above the proposed standard, and a dissolved oxygen value (2.45 mg/L) below the standard of 5 mg/L. A potential reason for the low dissolved oxygen reading is the wetland complex upstream of the site. Other parameters are within water quality standards and ecoregion expectations.

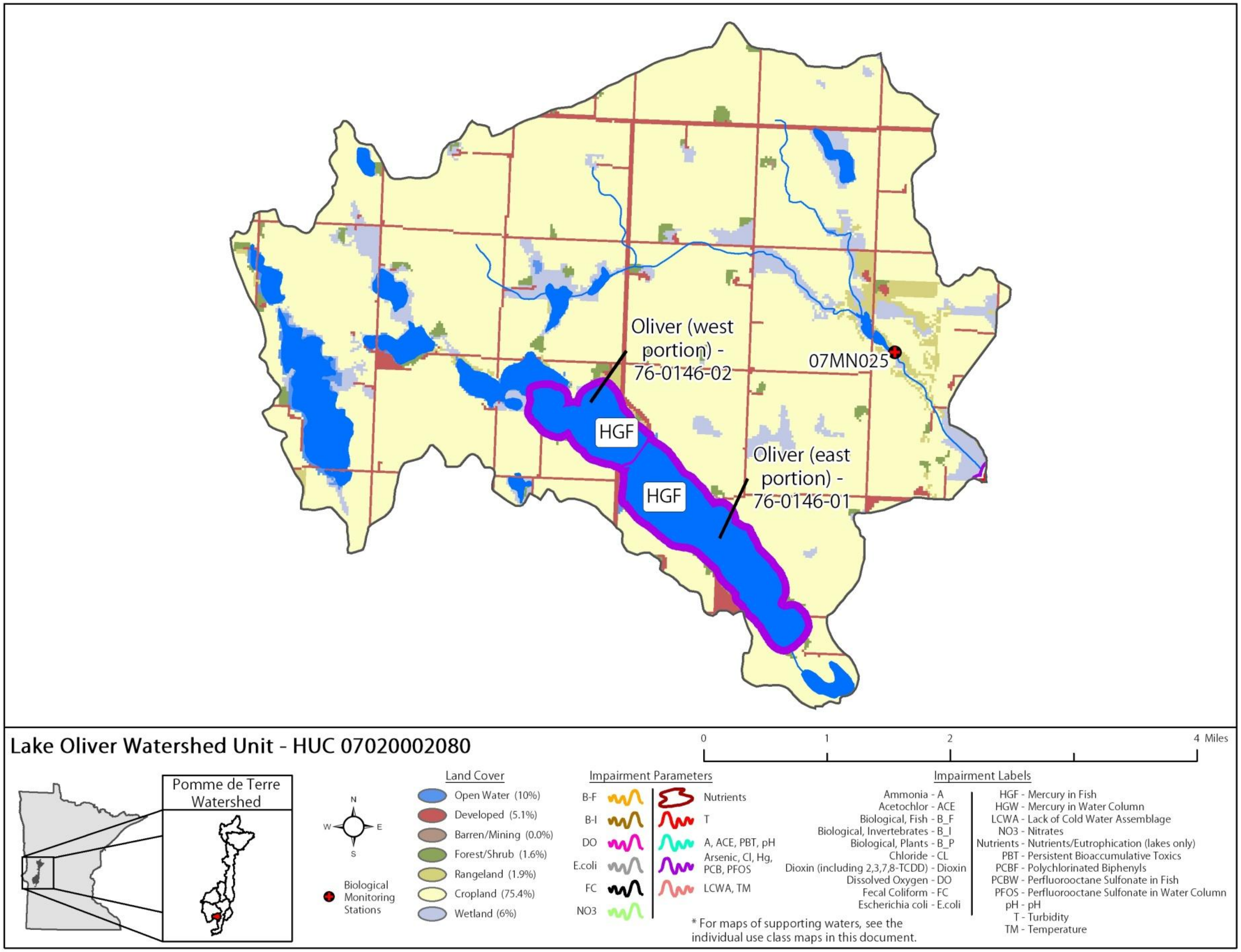
Lake water chemistry

There are five lake basins: Oliver, Oliver east portion, Oliver west portion, Large Henry, and unnamed 76-0161 in the Lake Oliver watershed unit, none of which have been assessed for aquatic recreation.

Lake Oliver Watershed Unit summary

The known impairments in the Lake Oliver watershed unit occur on the east and west portions of Lake Oliver, which are impaired for aquatic consumption based on mercury data. With the limited dataset, there are no other known impairments, nor is there data to suggest fully supporting systems within the watershed unit. Further samples should be collected throughout the watershed.

Figure 29. Land use and currently listed impaired waters by parameter in the Lake Oliver Watershed Unit



VII. Trends

Water chemistry samples have been taken on the Pomme de Terre River in Appleton since 1971. The following table show statistically significant trends of decreases in total phosphorus, total suspended solids, and biological oxygen demand values, and increases in chloride, and nitrate/nitrite values.

Pomme de Terre River HUC 07020002						
Period of Record: 1971 - present	Total Suspended	Biochemical Oxygen	Total	Nitrite/	Unionized	
Site: S000-195 (PT-10)	Solids	Demand	Phosphorus	Nitrate	Ammonia	Chloride
overall trend	no trend	decrease	decrease	increase	no trend	increase
avg. annual change		-2.1%	-1.4%	3.9%		1.6%
(range: lower limit		(-2.6%)	(-2.4%)	(1.0%)		(0.0%)
upper limit)		(-1.5%)	(-0.4%)	(9.3%)		(3.0%)
total change		-56%	-42%	280%		89%
(range: lower limit		(-65%)	(-61%)	(42%)		(0%)
upper limit)		(-46%)	(-14%)	(2153%)		(219%)
(p-value)		0.00	0.04	0.09		0.09
1995 - 2009 trend	decrease	no trend	no trend	no trend	no trend	no trend
avg. annual change	-3.1%					
(range: lower limit	(-5.1%)					
upper limit)	(0.0%)					
total change	-38%					
(range: lower limit	(-55%)					
upper limit)	(0%)					
(p-value)	0.10					

Citizen volunteer monitoring of stream (CSMP) and lakes (CLMP) occurs throughout the watershed, but is concentrated in the upper watershed. The table below shows that clarity in both lakes and streams has no statistically significant trend for the majority of sample sites, but there is a small subset of stream sites with a decrease in water clarity, and a small group of lake sites with an increase in water clarity.

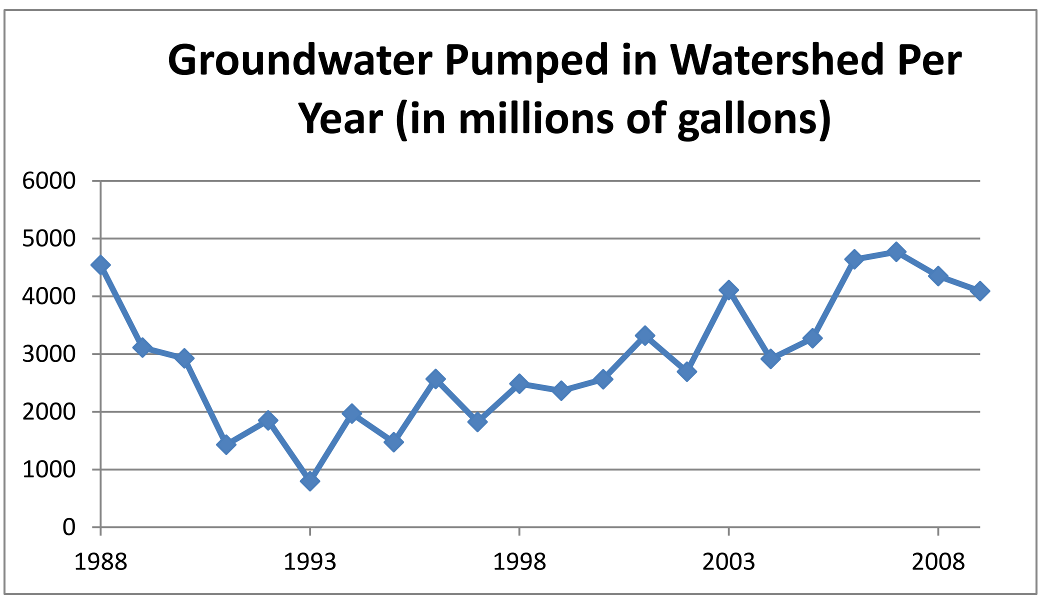
Pomme de Terre HUC 07020002	CSMP	CLMP
number of sites w/ increasing trend	1	4
number of sites w/ decreasing trend	3	1
number of sites w/ no trend	5	8

VIII. Summaries and Recommendations

Within the Minnesota River basin, the Pomme de Terre watershed has some of the best water quality, but there is still need for improvement as there are numerous stream reaches and lakes impaired for aquatic life, aquatic recreation, and aquatic consumption. Following are recommendations for further data collection and recommended steps to improve water quality in the watershed. Additional data needs include further dissolved oxygen and E. coli sampling in the Pelican Creek watershed, further water chemistry sampling in the Fairfield-Tara and Lake Oliver 11-digit HUCS, and completion of datasets for the unassessed lakes in the watershed. There is also a need for fish contaminant information taken on stream reaches further upstream in the watershed, and updated fish contaminant information on the lakes throughout the watershed as some of the data is more than 10 years old.

Nutrient levels are elevated throughout the watershed; high phosphorus readings in particular are prevalent throughout the watershed in both lakes and streams. While trends show that phosphorus readings have decreased over the years, concentrations are still a problem. Nutrient management should be explored watershed wide to reduce nutrient runoff into waterways. Along with nutrients, the effects of altered hydrology should also be explored, particularly in agricultural regions where drainage is used with high density. The effects of irrigation and municipal, commercial, and industrial wells on groundwater should also be investigated. There is a high concentration of feedlots in the watershed, with some located on geologically sensitive areas. Groundwater should be monitored in areas adjacent to the sensitive areas, as contaminants have the potential to migrate to both groundwater and surface water. Land use practices in these sensitive areas should be reviewed. Additional work is also needed to ascertain the effect of groundwater irrigation on the Pomme de Terre River as excessive irrigation can be a stressor to surface water quality. When baseflow groundwater recharge to streams is significantly restricted, streamflow volume can be reduced, stream temperature can rise, and contaminant concentrations in streams may increase. Figure 30 shows the historical trend for groundwater withdrawals from nondomestic water supply wells in the watershed.

Figure 30. Historical groundwater withdrawals (based on data from DNR SWUDS database)



To further improve the understanding of the hydrology of the watershed, the effects of high and low precipitation years should also be reviewed. In addition to the current station in Appleton, additional load monitoring stations should be added to locations in the upper section of the Pomme de Terre River and on Muddy Creek to help identify problem areas. Load monitoring stations should also be added to the recently installed flow stations above Perkins Lake and on Drywood Creek.

Along Drywood Creek, additional monitoring of lakes and wetlands in the upper part of the watershed (particularly upstream of Artichoke Lake) is needed to identify the source of sediment, nutrient, and dissolved oxygen issues downstream in the creek. The two impaired wetlands in the Drywood Creek watershed should also be further investigated. While Drywood Creek is the system with the most problems, even within unimpaired reaches, the highest F-IBI score was 73 out of a possible 100, with the majority of sites scoring 50 or less. The number of species tolerant to human disturbance increased in the downstream portion of the Pomme de Terre River watershed, contributing to the lower fish IBI scores in the lower Pomme de Terre and Drywood Creek systems located in the lower part of the watershed. The highest MSHA score was 72 out of 100, with the majority of sites scoring below 60, falling in the poor and fair categories. Recurring problems throughout the watershed were a lack of run-riffle-pool complexes, predominance of fine substrates, erosive banks, and embeddedness of coarse substrates when they were present. Stream stability should be quantified to further improve fish habitat. Best management practices such as erosion prevention should be implemented to reduce fine substrates that were prevalent throughout the watershed. Studies should also be done to identify possible dam removals or retrofitting of dams that would allow fish passage similar to the Barrett Lake dam.

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Appendix 1. Intensive chemistry monitoring stations in the Pomme de Terre River watershed

FieldNum	STORET ID	Water body Name	Location	11-digit HUC
07MN001	S004-410	Pelican Creek	160th Ave, 3 mi. SW of Ashby	07020002-020
07MN003	S002-057	Pomme de Terre River	CR 47, 4 mi. N of Barrett	07020002-010
07MN009	S004-411	Pomme de Terre River	Hwy 9, 2 mi. SE of Morris	07020002-010
01MN032	S004-412	Muddy Creek	CR 7, 3 mi SW of Morris	07020002-040
	S004-485	Pomme de Terre River	CR 78, 6 mi S of Morris	07020002-050
07MN032	S000-195	Pomme de Terre River	CR 59, in Appleton	07020002-050
07MN022	S004-413	Drywood Creek	520th St, 2 mi. NW of Fairfield	07020002-030

Appendix 2. Biological monitoring stations in the Pomme de Terre River watershed

FieldNum	Water body Name	Location	Drain Mi²
03MN002	Pomme de Terre River	Downstream of Dalton Rd, 2 mi. NW of Dalton	73.38
03MN003	Pomme de Terre River	Downstream of CR 38, 4 mi. SE of Barrett	360.08
07MN002	Trib. to Pomme de Terre River	Upstream of CR 24, 2 mi. W of Erdahl	10.68
07MN003	Pomme de Terre River	Upstream of CR 47, 4 mi. N of Barrett	316.54
07MN004	unnamed ditch	Downstream of CR 38, 3 mi. S of Barrett	7.20
07MN006	Pomme de Terre River	Downstream of CR 4, 4 mi. SW of Ashby	269.02
07MN007	Trib. to Pomme de Terre River	Upstream of CR 37, 5 mi. SW of Hoffman	9.33
07MN009	Pomme de Terre River	Upstream of Hwy 9, 2 mi. SE of Morris	463.91
07MN010	Trib. to Pomme de Terre River	Downstream of Hwy 9, 4 mi. SE of Morris	12.87
07MN014	Pomme de Terre River	Downstream of CR 76, 6 mi. SW of Hoffman	396.51
03MN001	Trib. to Lake Christina	Downstream of 113th St, 11 mi. S of Battle Lk	1.63
07MN001	Pelican Creek	Downstream of 160th Ave, 3 mi. SW of Ashby	131.93
07MN054	Trib. to Lake Christina	Upstream of CR 52, 6 mi. N of Evansville	2.62
07MN008	Muddy Creek	Upstream of 530th Ave, 1.5 mi. NE of Alberta	81.73
07MN012	Trib. to Muddy Creek	Downstream of Hwy 28, 0.25 mi. W of Alberta	19.60
07MN013	Muddy Creek	Upstream of 580th Ave, 3 mi. E of Chokio	28.60
01MN032	Muddy Creek	Downstream of CR 7, 3 mi SW of Morris	140.84
07MN016	Muddy Creek	Upstream of 240th St, 4 mi. E of Alberta	129.18
07MN017	Trib. to Muddy Creek	Downstream of CR 66. 5 mi. SE of Alberta	5.76
07MN019	Trib. to Muddy Creek	Upstream of CR 14, 3 mi. NE of Alberta	28.58
01MN069	Pomme de Terre River	Upstream of CR 51, 2.5 mi W of Appleton	870.04
07MN011	Pomme de Terre River	Upstream of CR 58, 9 mi. SE of Alberta	650.99
07MN021	Trib. to Pomme de Terre River	Downstream of CR 7, 8 mi. SE of Alberta	6.77
07MN027	Pomme de Terre River	Upstream of Hwy 12, 6 mi. N of Appleton	846.27
07MN028	Trib. to Pomme de Terre River	Downstream of CR 11, 6 mi. N of Appleton	4.81
07MN029	Pomme de Terre River	Downstream of CR 51, 3 mi. W of Appleton	874.50
07MN032	Pomme de Terre River	Upstream of CR 59, in Appleton	865.68
01MN001	County Ditch #22	Upstream of CR 54, 9 mi. S of Chokio	8.35
07MN022	Drywood Creek	Downstream of 520th St, 2 mi. NW of Fairfield	94.39
07MN031	Artichoke Creek	Upstream of 255th St, 3 mi. S of Artichoke	59.67
07MN024	Trib. to Pomme de Terre River	Upstream of 170th Ave, 10 mi. SW of Hancock	28.02
07MN026	Trib. to Pomme de Terre River	Upstream of 50th St NW, 9 mi. N of Holloway	11.72
07MN030	Judicial Ditch 63	Downstream of 70th St, 8 mi. SW of Hancock	11.96
07MN025	Trib. to Pomme de Terre River	Downstream of CR 59, 9 mi. N of Appleton	17.01

Appendix 3. Assessment status of lakes within 11 digit HUCs of the Pomme de Terre River Watershed

HUC 11 NAME	Area (acres)	Total Basins	Total Lakes	Full Support (FS)	Not Supported (NS)	Insufficient Data (IF)
Drywood Creek	65,101	32	13			2
Fairfield-Tara	18,677	3	1			
Lake Oliver	12,771	10	5			1
Little Muddy Creek	52,424	20	11		1	
Lower Pomme de Terre	67,435	5	2			
Muddy Creek	37,484	12	2			
Pelican Creek	95,786	155	61	2	1	7
Upper Pomme de Terre	210,289	228	122	5	2	9
Total	559,968	465	217	7	4	19

Appendix 4. Minnesota's ecoregion-based lake eutrophication standards

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

Appendix 5. Water chemistry results at the intensive watershed monitoring station pour point of each HUC11 watershed unit

(Bold values indicate potential exceedances of a water quality standard or ecoregion expectation.)

Data collected in 2007 at the station representing the pour point of Upper Pomme de Terre River Watershed Unit (07020002-010)

Station location:	Pomme de Terre River at Hwy 9, 2 mi. SE of Morris, MN											
Storet ID:	S004-411											
Station #:	07MN009											
Parameter	Chloride	D.O.	E. coli	NH_3	NO_2+ NO_3	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/l	mg/l	#/100ml	mg/l	mg/l		mg/l	mg/l	*u*S/cm	mg/l	˚C	cm
# Samples	12	13	12	11	13	11	13	13	12	12	13	13
Minimum	10	5.63	8	.001	<.05	7.89	.071	15	612	58.8	14.1	19
Maximum	37	9.86	150	.007	.5	8.4	.145	32	706	116	27.6	45
Mean[1]	13.5	7.78	54.8	.005	.148	8.15	.118	24	657.5	88.9	20.6	30.3
Median	11.5	6.92	70	.005	.12	8.2	.126	24	651.5	90.4	21.4	29
WQ standard[2]	230	5	126/1260	.04		6.5-9		60				20
# WQ exceedances[3]	0/12	0/13	0/12	0/11		0/11		0/13				1/13
NGP 75th percentile[4]					.43		.29		990		25	

Data collected in 2007 at the station representing the pour point of Pelican Creek Watershed Unit (07020002-020)

Station location:	Pelican Creek at 160th Ave, 3 mi. SW of Ashby, MN											
Storet ID:	S004-410											
Station #:	07MN001											
Parameter	Chloride	D.O.	E. coli	NH_3	NO_2+ NO_3	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/l	mg/l	#/100ml	mg/l	mg/l		mg/l	mg/l	*u*S/cm	mg/l	˚C	cm
# Samples	12	13	12	13	13	13	13	13	12	12	13	13
Minimum	6.2	3.78	20	.001	<.05	7.74	0.078	12	481	24.6	12.4	16
Maximum	46	9.43	2000	.07	.47	10.05	0.202	100	751	76.1	28	52
Mean[1]	10.58	6.56	228.5	.009	.094	8.26	0.149	41.08	539	40.26	19.3	30.6
Median	7.25	5.79	260	.004	.07	8.2	0.151	39	522	39.25	19.5	29
WQ standard[2]	230	5.0	126/ 1260	.04		6.5-9		100				20
# WQ exceedances[3]	0/12	3/13	1/12	1/13		1/13		0/13			0/13	3/13
NCHF 75th percentile[4]				0.2	0.12		0.17		310		24	

Data collected in 2007 at the station representing the pour point of Muddy Creek Watershed Unit (07020002-40)

Station location:	Muddy Creek at CR 7, 3 mi SW of Morris										
Storet ID:	S004-412										
Station #:	01MN032										
Parameter	Chloride	D.O.	E. coli	NH_3	NO_2+ NO_3	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/l	mg/l	#/100ml	mg/l	mg/l		mg/l	mg/l	*u*S/cm	mg/l	˚C	cm
# Samples	7	8	7	7	8	7	8	8	7	7	8	8
Minimum	16	6.15	25	.0008	.46	7.77	.15	6.4	1300	151	12.46	10
Maximum	25	16.04	2000	.006	2.6	8.58	.309	170	1640	820	25	48
Mean[1]	21.43	10.29	168.9	.004	1.22	8.18	.216	42.8	1529	593	19.35	31.25
Median	22	9	200	.004	1.15	8.3	.185	25	1578	672	19.9	34
WQ standard[2]		1	630/1260			6-9						
# WQ exceedances[3]		0/8	1/7			1/7						
NGP 75th percentile[4]					.43		.29	89	990		25	

Data collected in 2007 at the station representing the pour point of Lower Pomme de Terre River Watershed Unit (07020002-050)

Station location:	Pomme de Terre River at CR 59, in Appleton										
Storet ID:	S000-195										
Station #:	07MN032										
Parameter	Chloride	D.O.	E. coli	NH_3	NO_2+ NO_3	pH	TP	TSS	Spec. cond.	Sulfate	Temp	T-tube
Units	mg/l	mg/l	#/100m l	mg/l	mg/l		mg/l	mg/l	*u*S/cm	mg/l	˚C	cm
# Samples	12	13	12	11	13	11	13	13	11	12	13	13
Minimum	9.5	6.76	29	.001	<.05	8.12	.069	17	702	56.5	13.74	13
Maximum	36	11.2	390	.026	1.1	8.37	.209	110	816	181	27.1	26
Mean[1]	14.63	8.13	146.1	.006	.298	8.29	.171	67.6	723.9	127.2	20.74	16.5
Median	13	7.58	185	.004	.28	8.24	.178	66	715	123.5	20.8	15
WQ standard[2]	230	5	126/ 1260	.04		6.5-9		60				20
# WQ exceedances[3]	0/12	0/13	0/12	0/11		0/11		7/13				10/13
NGP 75th percentile[4]					.43		.29		990		25	

Data collected in 2007 at the station representing the pour point of Drywood Creek Watershed Unit (07020002-060)

Station location:	Drywood Creek at 520th St, 2 mi. NW of Fairfield											
Storet ID:	S004-413											
Station #:	07MN022											
Parameter	Chloride	D.O.	E. coli	NH_3	NO_2+ NO_3	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/l	mg/l	#/100ml	mg/l	mg/l		mg/l	mg/l	*u*S/cm	mg/l	˚C	cm
# Samples	7	8	7	7	8	7	8	8	6	7	8	8
Minimum	10	6.88	6	.0002	<.05	7.31	.161	7.2	695	173	13.46	17
Maximum	18	15.5	>2400	.018	1.2	8.46	.414	60	1174	368	22.9	62
Mean[1]	14.86	9.6	520	.008	.429	8.16	.346	19.48	945.7	244.9	19.43	41.5
Median	15	9.14	520	.005	.195	8.31	.374	11.1	923.5	392	19.7	46.5
WQ standard[2]	230	5	126/ 1260	.04		6.5-9		60				20
# WQ exceedances[3]	0/7	0/8	2/7	0/7		0/7		0/8				1/8
NGP 75th percentile[4]					.43		0.29		990		25	

[1]Geometric mean of all samples is provided for *E. coli*.
[2]Total suspended solids and Transparency tube standards are surrogate standards derived from the turbidity standard of 25.
[3]Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform.
[4]Based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993).

Appendix 6. Assessment of stream water quality in the Pomme de Terre watershed by parameter and designated use

					USES			BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS									ECOREGION EXPECTATIONS				CHANNELIZED	
National Hydrography Dataset (NHD) Assessment Segment ID	Stream Segment Name	Segment Description	NHD Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Aquatic Consumption	Fish	Macroinvertebrates	Acetochlor	Alachlor	Atrazine	Chloride	Bacteria (Aquatic Rec)	Metolachlor	Dissolved Oxygen	pH	Un-ionzed ammonia	Oxygen Demand (BOD)	Nitrite/Nitrate	Total Phosphorus	Suspended Solids	Fish IBI	Macroinvertebrate IBI
HUC 11: 07020002010 (Upper Pomme de Terre)																								
07020002-504	Pomme de Terre River	Pelican Cr to Pomme de Terre Lk	3.89	2B	FS	NA	NS	+	+															
07020002-505	Pomme de Terre River	Tenmile Lk to Pelican Cr	3.74	2B	FS	NA	NS															+		
07020002-514	Pomme de Terre River	Stalker Lk to Tenmile Lk	14.49	2B	FS	NA	NS	+	+											+		+		
07020002-525	Unnamed creek	Headwaters to Pomme de Terre Lk	10.04	2B	NA	NA	NA																47	18
07020002-528	Unnamed creek	Long Lk (56-0428-00) to Stalker Lk	0.61	2B	IF	NA	NA													+				
07020002-540	Unnamed creek	Unnamed cr to Pomme de Terre	1.2	2B	IF	NA	NA																47	
07020002-543	Unnamed creek	Headwaters to Pomme de Terre	1.35	2B	NA	NA	NA																38	
07020002-544	Unnamed creek	Headwaters to Pomme de Terre	2.48	2B	NA	NA	NA																31	
07020002-558	Pomme de Terre River	North Pomme de Terre Lk to Middle Pomme de Terre Lk	0.98	2B	IF	NA	NS										IF							
07020002-562	Pomme de Terre River	Perkins Lk to Muddy (Mud) Cr	16.68	2B	NS	IF	NS	-	+				+	IF		IF	+	+		-	+	+		
07020002-563	Pomme de Terre River	Barrett Lk to to North Pomme de Terre Lk	18.85	2B	NS	NA	NS	-	+								+			-	+	+		
07020002-565	Pomme de Terre River	Pomme de Terre Lk to Barrett Lk	7.76	2B	FS	IF	NS	+	+				+	IF			+	+		+	+	+		
HUC 11: 07020002020 (Pelican Creek)																								
07020002-506	Pelican Creek	T130 R41W S4, N line to Pomme de Terre R	9.52	2C	FS	IF	NA	+	+				+	IF			+	+		+	-	+		
07020002-518	Unnamed creek	Unnamed lk (56-0263-00) to Unnamed cr	2.26	2B	FS	NA	NA	+	+															
07020002-542	Unnamed creek	Headwaters to Lk Christine	2.06	2B	FS	NA	NA	+	+															
HUC 11: 07020002030 (Little Muddy Creek)																								
07020002-512	Unnamed ditch	T124 R43W S3, S line to Muddy Cr	1.01	7	NA	NA	NA																28	
HUC 11: 07020002040 (Muddy Creek)																								
07020002-511	Muddy Creek	T124 R44W S3, W line to Pomme de Terre R	22.32	7	NA	IF	NA						+	IF				+					31	18
07020002-538	Unnamed creek	Unnamed cr to Muddy Cr	1.73	2B	NA	NA	NA																20	
07020002-539	Unnamed creek	Unnamed cr to Muddy Cr	1.65	2B	NA	NA	NA																0	
HUC 11: 07020002050 (Lower Pomme de Terre)																								
07020002-501	Pomme de Terre River	Muddy (Mud) Cr to Minnesota R (Marsh Lk)	47.93	2B	NS	NS	NS	-	-	+	+	+	+	-	+	+	+	+	IF	-	-	-		
07020002-546	Unnamed creek	Unnamed cr to Pomme de Terre	3.44	2B	NA	NA	NA																13	
07020002-551	Unnamed creek	Unnamed cr to Unnamed cr	3.64	2B	NS	NA	NA	-																
HUC 11: 07020002060 (Drywood Creek)																								
07020002-515	County Ditch 22	Unnamed ditch to Unnamed cr	2.19	2B	NA	NA	NA																18	
07020002-536	Artichoke Creek	Unnamed cr to Dry Wood Lk	0.94	2B	NA	NA	NA																0	
07020002-556	Dry Wood Creek	Dry Wood Lk to Pomme de Terre R	10.12	2C	NS	NS	NA	-	-				+	-		-	+	+		-	-	-		
HUC 11: 07020002070 (Fairfield-Tara)																								
07020002-547	Unnamed creek	Unnamed cr to Pomme de Terre	1.11	2B	NA	NA	NA																0	
07020002-548	Unnamed creek	Unnamed cr to Unnamed cr	1.65	2B	NA	NA	NA																0	
07020002-549	Judicial Ditch 2	Judicial Ditch 63 to Unnamed cr	1.74	2B	NA	NA	NA																1	
HUC 11: 07020002080 (Lake Oliver)																								
07020002-545	Unnamed creek	Unnamed cr to Pomme de Terre	1.83	2B	NA	NA	NA																0	