Watershed

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Lac qui Parle River Watershed Restoration and Protection Strategy Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Key terms and abbreviations

Altered hydrology: Changes in the amount of and way that water moves through the landscape. Examples of altered hydrology include changes in river flow, precipitation, subsurface drainage, impervious surfaces, wetlands, river paths, vegetation, and soil conditions. These changes can be climate- and/or human-caused.

Animal Units (AU): A term typically used in feedlot regulatory language. One animal unit is roughly equivalent to 1,000 pounds of animal but varies depending on the specific animal.

Assessment Unit Identifier (AUID): The unique waterbody identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment (AQL): The presence and vitality of AqL is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to AqL if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment (AQR): Streams are considered impaired for impacts to AqR if fecal bacteria standards are not met. Lakes are considered impaired for impacts to AqR if total phosphorus and either chlorophyll-a or Secchi disc depth standards are not met.

Best Management Practice (BMP): A term used to describe a type of water pollution control. Can be a structural practice that is physically built to capture water and treat pollution, or a management practiced used to limit or control pollution, usually at its source.

Biological Impairment: A biological impairment is an impairment to the AqL beneficial use due to a low fish and/or aquatic macroinvertebrate (bug) IBI score.

Designated (or Beneficial) Use: Water bodies are assigned a designated use based on how the water body is used. Typical beneficial uses include drinking, swimming, fishing, fish consumption, agricultural uses, and limited uses. Water quality standards for pollutants or other parameters are developed to determine if water bodies are meeting their designated use.

Flow-weighted Mean Concentration (FWMC): The total mass of a pollutant delivered (by water) over a set period of time by the total volume of water over that same period of time. Typical units are milligrams per liter (mg/L).

Geographic Information Systems (GIS): A geographic information system or geographical information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. https://en.wikipedia.org/wiki/Geographic_information_system

Hydrologic Simulation Program-Fortran (HSPF): A computer model developed to simulate hydrology and water quality at the watershed scale.

Hydrologic Unit Code (HUC): A HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Minnesota River Basin is assigned a HUC-4 of 0702 and the Lac qui Parle River Watershed is assigned a HUC-8 of 07020003.

Impairment: Waterbodies are listed as impaired if water quality standards are not met for designated uses including AqL, AqR, and aquatic consumption.

Index of Biotic Integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Limited Resource Value (LRV): Streams of LRV are streams, or ditches, with limited beneficial use. Standards for LRV waters are designed to protect aesthetic qualities, secondary body contact use, and groundwater for use as a potable water supply.

Nonpoint source pollutants: Pollutants that are from diffuse sources; most of these sources are not regulated. Nonpoint sources include agricultural field run-off, agricultural drain tile discharge, storm water from smaller cities and roads, bank, bluff, and ravine failures, atmospheric deposition, failing septic systems, animals, and other sources.

Point Source Pollutant: Pollutants that can be directly attributed to one location; generally, these sources are regulated by permit. Point sources include wastewater treatment plants, industrial dischargers, storm water discharge from larger cities, and storm water runoff from construction activity (construction storm water permit).

Pollutant: Parameters (e.g. bacteria, total suspended solids, etc.) that have a water quality standard and can be tested for directly. Pollutants affect all beneficial uses.

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or pollutant source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stream Class: a classification system for streams to specify the stream's beneficial or designated uses.

> **Stream Class 2B**: The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated AqL and their habitats. These waters shall be suitable for AqR of all kinds, including bathing, for which the waters may be usable.
>
> **Stream Class 7 waters**: The quality of Class 7 waters of the state shall be such as to protect aesthetic qualities, secondary body contact use, and groundwater for use as a potable water supply.

Stream reach: "A section of a stream or river along which similar hydrologic conditions exist, such as discharge, depth, area, and slope… The term is often used by hydrologists when they're referring to a small section of a stream or river rather than its entire length." (USGS 2019)

Stressor (or biological stressor): A term for the parameters (e.g., altered hydrology, dams preventing fish passage, etc.) that were identified as adversely impacting AqL in a biologically-impaired stream reach or lake.

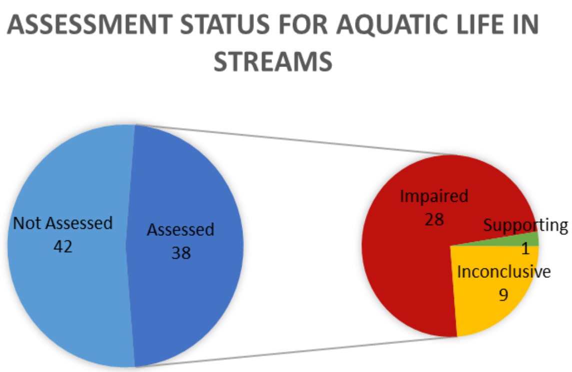
Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

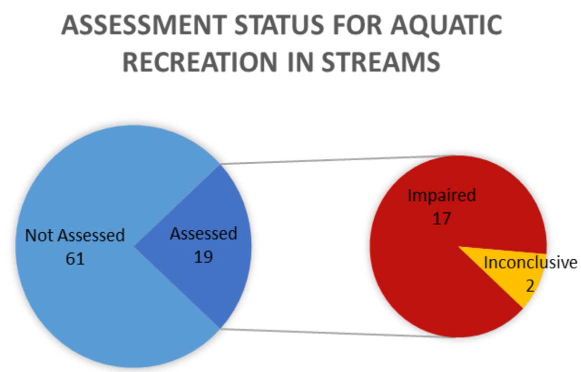
Yield (water, pollutant, crop, etc.): the amount of mass, volume, or depth per unit land area (e.g. lbs/ac, in/ac)

Executive summary

The State of Minnesota uses a "Watershed Approach" to assess and address the water quality of each of the state's 80 major watersheds on a 10-year cycle. This report summarizes the Minnesota Pollution Control Agency's (MPCA) Watershed Approach work findings, addressing the fishable, swimmable status of surface waters in the Lac qui Parle River Watershed. This work relied on a scientific approach by the MPCA staff, but also developed and vetted results using a team of state and local watershed partners (Soil and Water Conservation Districts [SWCDs], counties, and other state agencies). Another important aspect of this work was a robust civic engagement process, which identified challenges, opportunities, and recommendations to achieve higher adoption of conservation practices within the watershed.

The majority of monitored stream reaches and lakes in the Lac qui Parle Watershed are not meeting water quality standards for aquatic life (AqL; fishing) and aquatic recreation (AqR; swimming), as illustrated in the pie charts below.





Several water body pollutants and stressors were identified. A source assessment, goals, and 10-year targets were developed for each pollutant and stressor. The pollutants and stressors along with their goals and 10-year targets are summarized in Section 2.1.3.

The report presents a strategies table that estimates the total changes necessary for all monitored waters to be restored and protected. A strategies table that estimates how each watershed can meet its 10-year targets is also presented. Seventy-five percent of land use in Minnesota's portion of the Lac qui Parle River Watershed is cultivated crops. Therefore, the largest opportunity for water quality improvement is from this land use. However, all land uses should make improvements to help restore and protect waters. Restoration depends on greater adoption of best management practices (BMPs), including the following high priority practices: grassed waterways, reduced tillage, cover crops, improved fertilizer and manure management, increased crop diversity, buffers, and improved pasture management.

Priority areas for surface water quality restoration and protection are presented throughout the Watershed Restoration and Protection Strategy (WRAPS) Report including goals maps, modeled pollutant yields, and Geographic Information System (GIS) modeled hydrologic alteration.

The means to restore and protect the watershed (i.e. the strategies) are fairly well understood. However, challenges with political boundaries (Minnesota-South Dakota border) could hamper restoration efforts. The Lac qui Parle River Watershed needs to develop working groups with its partners in South Dakota to develop protection and restoration approaches within the whole watershed and ensure many sources of pollutants are reduced and managed.

1. Watershed background and description

1.1 Watershed Approach and WRAPS

The State of Minnesota uses a "Watershed Approach" (MPCA 2020d) to assess and address the water quality within each of the state's 80 major watersheds, on a 10-year monitoring and assessment cycle. In each cycle of the Watershed Approach, rivers, lakes, and wetlands across the watershed are monitored and assessed, waterbody restoration and protection strategies and local plans are developed, and conservation practices are implemented. Watershed Approach assessment work started in the Lac qui Parle River Watershed in 2015.

Much of the information presented in this report was produced in earlier Watershed Approach work, prior to the development of the WRAPS report. However, the WRAPS report presents additional data and analyses. To ensure the WRAPS strategies and other analyses appropriately represent the Lac qui Parle River Watershed, local and state natural resource and conservation professionals (referred to as the WRAPS Local Work Group (LWG); see group members listed on inside of front cover) were convened to help inform and advise on the development of the report.

Two key products of this WRAPS report are the strategies table and the priorities table. The strategies table outlines high-level strategies and estimated adoption rates necessary to restore and protect waterbodies in the Lac qui Parle River Watershed, including social strategies that are key to achieving the physical strategies. The priorities table presents criteria to identify priority areas for water quality improvement, including specific examples of waterbodies and areas that meet the prioritizing criteria. Additional tools and data layers that can be used to refine priority areas and target strategies within those priority areas are provided within this report.

In summary, the ***purpose*** of the WRAPS report is to summarize work completed in this first cycle of the Watershed Approach in the Lac qui Parle River Watershed, which started in 2015. The ***scope*** of the report is surface waterbodies and their AqL and AqR beneficial uses as currently assessed by the MPCA. The primary ***audience*** for the WRAPS report is local planners, decision makers, and conservation practice implementers; watershed residents, neighboring downstream states, agricultural business, governmental agencies, and other stakeholders are additional audiences.

This WRAPS report is not a regulatory document but is legislatively required per the (updated) Clean Water Legacy legislation on WRAPS (ROS 2020). This report is designed to meet these requirements, including an opportunity for public comment, which was provided via a public notice in the State Register from June 7, 2021 to July 7, 2021. The WRAPS report summarizes an extensive amount of information. The reader may want to review the supplementary information provided (links and references in document) to fully understand the summaries and recommendations made within this document.

1.2 Watershed Description

The Lac qui Parle River Watershed (8-digit Hydrologic Unit Code [HUC-08] 07020003) is located in southwest Minnesota, straddling the border between South Dakota and Minnesota (**Figure 1**), and is located near the headwaters of the Minnesota River Basin. Originating at its upmost elevation in South Dakota, the Lac qui Parle River begins at the outlet of Hendricks Lake near the town of Hendricks, Minnesota. Several tributaries feed the Lac qui Parle River from South Dakota into Minnesota, either directly flowing into the Lac qui Parle River (Lazarus and Canby Creeks) or into the West Branch of the Lac qui Parle River (Lost, Crow, Monigham, Cobb, and Florida Creeks), which joins the Lac qui Parle River near Dawson, Minnesota. Additionally, a smaller southern tributary (Tenmile Creek) joins with the Lac qui Parle River further downstream from Dawson near the watershed outlet. The Lac qui Parle River converges with the Minnesota River at Lac qui Parle State Park near the outlet of the Minnesota River Headwaters Watershed (HUC-08 07020001), about nine miles northwest of Montevideo, Minnesota.

Total watershed area for the entire Lac qui Parle River Watershed is approximately 1,100 square miles (704,000 acres), of which Minnesota contains roughly 760 square miles (487,600 acres). The watershed overlaps three Minnesota counties, Lac qui Parle County (covering 66% of the Minnesota portion of the watershed area), Yellow Medicine County, and Lincoln County. Minnesota towns within the watershed include Marietta, Madison, Dawson, Boyd, Canby, and Hendricks. Canby is the most populated city in the watershed at just over 1,700 residents.

Approximately half of the Lac qui Parle River Watershed (south and west portions) lies within the Northern Glaciated Plains (NGP) U.S. Environmental Protection Agency (EPA) Level III ecoregion, while the eastern half lies within the Western Corn Belt Plains (WCBP) ecoregion. The NGP ecoregion has a flat to gently rolling topography with a high density of wetlands and very fertile soils. The WCBP ecoregion consists of level to gently rolling glacial till plains and hilly loess plains with warm, moist soils making it one of the most productive corn and soybean areas of the world. The majority of the sizable lakes within the watershed are located in South Dakota. Hendricks Lake (1,530 ac), which straddles the border near the southern end of the watershed, and Del Clark Lake, near Canby, Minnesota, are important lakes to the citizens of the watershed.

Additional Lac qui Parle River Watershed resources

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Lac qui Parle River Watershed**:** https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022731.pdf

Minnesota Department of Natural Resources (DNR) Watershed Assessment Mapbook for the Lac qui Parle River Watershed: http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_24.pdf

Minnesota Department of Natural Resources (DNR) Watershed Characterization Report for Lac qui Parle River Watershed: https://wrl.mnpals.net/islandora/object/WRLrepository%3A3341

Minnesota Pollution Control Agency Watershed Page for Lac qui Parle River Watershed: https://www.pca.state.mn.us/water/watersheds/lac-qui-parle-river

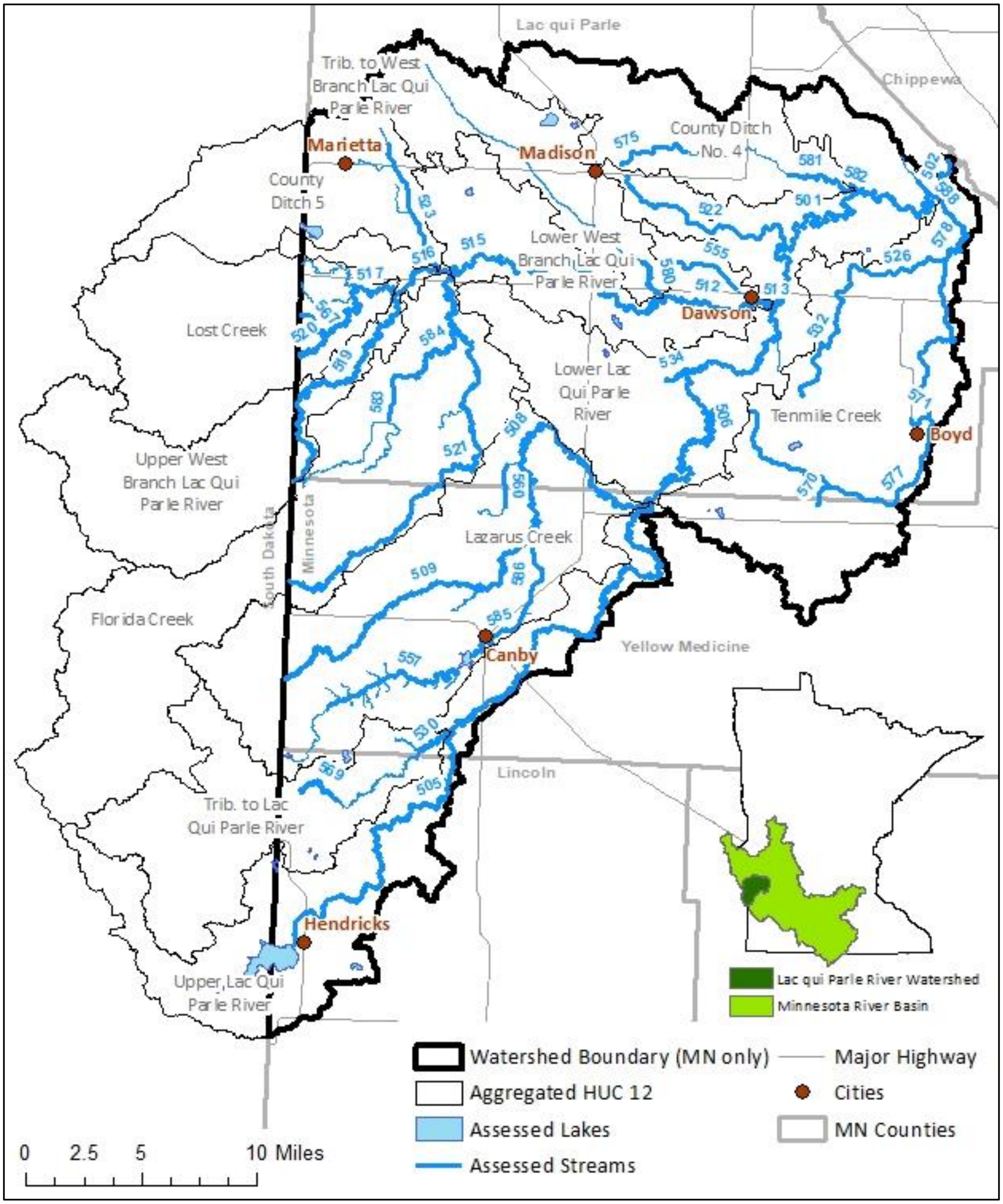


Figure 1. The Lac qui Parle River Watershed location. The thicker blue streamlines are assessed stream reaches with a unique Assessment Unit Identifier (AUID) and labeled by the last 3-digits of the AUIDs.

The topography of the Lac qui Parle River Watershed slopes west to east with the highest elevation on the Coteau de Prairies geologic feature in South Dakota, and the lowest at the confluence with the Minnesota River (**Figure 2**). The Coteau de Prairies is a plateau where two glacial lobes, James on the west and Des Moines on the east, parted around it (Lusardi and Dengler 2017). The steepest relief is near the border of South Dakota and another area of high relief is where the watershed intersects the Minnesota River Valley.

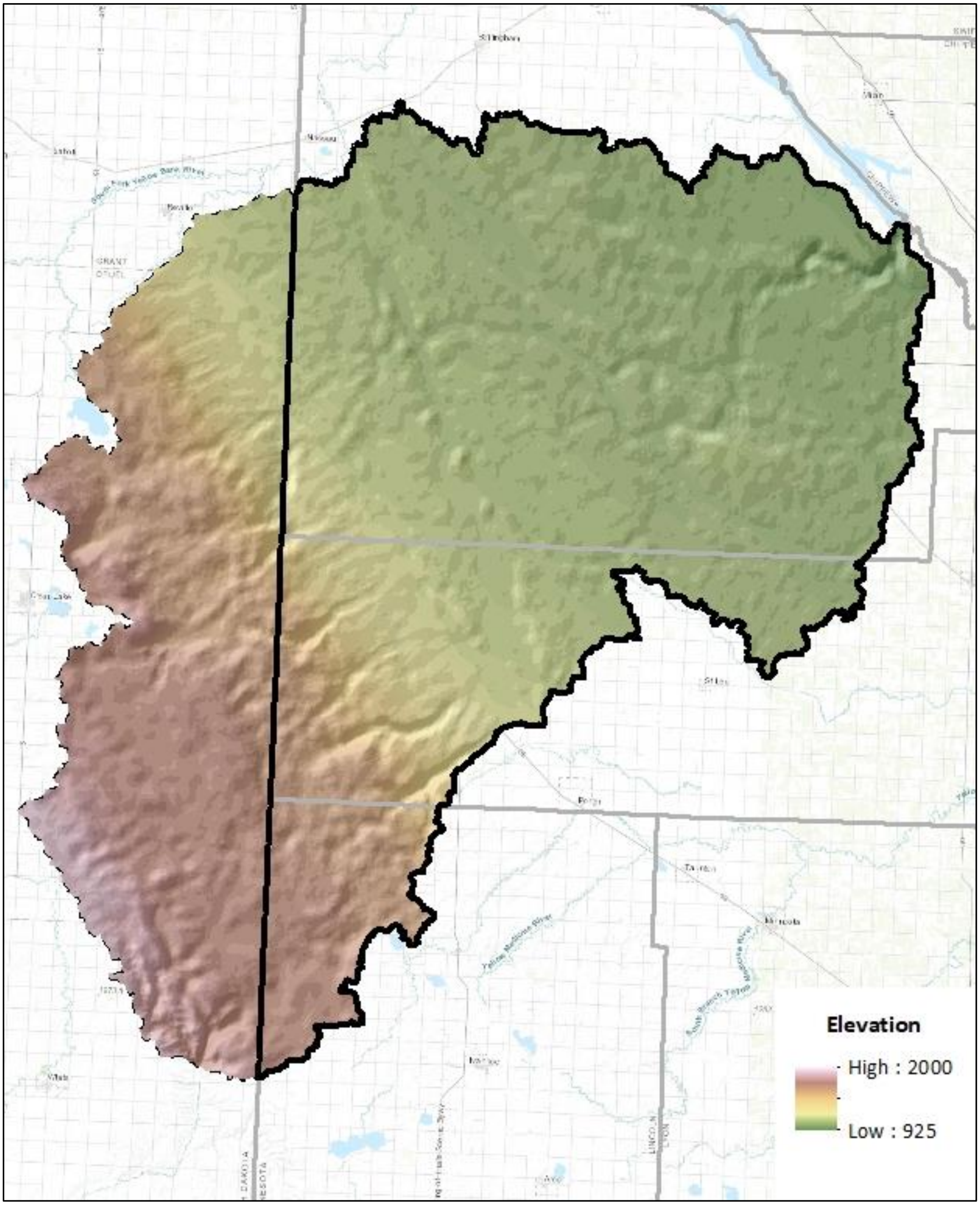


Figure 2. Elevation of the Lac qui Parle River Watershed. The elevation is determined from light detection and ranging (LiDAR) imagery (scale in feet).

1.3 Environmental Justice

The MPCA is committed to making sure that pollution does not have a disproportionate impact on any group of people which is the principle of environmental justice (MPCA 2021a). This means that all people, regardless of their race, color, national origin or income, benefit from equal levels of environmental protection and have opportunities to participate in decisions that may affect their environment or health. Identification of areas of environmental justice concern is an initial first step to identify areas where additional consideration or effort is needed to evaluate the potential for disproportionate adverse impacts, to consider ways to reduce those impacts, and to ensure meaningful community engagement as described in MPCA's environmental justice framework.

The MPCA uses the U.S. Census tract as the geographic unit to identify areas of environmental justice concerns. The agency considers a census tract to be an area of concern for environmental justice if it meets one or both of these demographic criteria:

- The number of people of color is greater than 50%; or
- More than 40% of the households have a household income of less than 185% of the federal poverty level

Additionally, the MPCA considers communities within Tribal boundaries as areas of environmental justice concern. No part of the Lac qui Parle River Watershed in Minnesota is located within the boundary of a Native American Reservation (USCB 2018). However, Lac qui Parle County is of interest for the Lower Sioux Indian Community of Minnesota, Upper Sioux Community of Minnesota, and Sisseton-Wahpeton Oyate; Yellow Medicine County is of interest for the Lower Sioux Indian Community of Minnesota and Upper Sioux Community of Minnesota; and Lincoln County is of interest for the Lower Sioux Indian Community of Minnesota.

No areas within the Lac qui Parle River Watershed were identified as areas of environmental justice concerns. While no areas within the watershed were specifically identified, the MPCA will continue to work with tribes and other stakeholders with interest in the watershed.

1.4 Assessing Water Quality

Assessing water quality is a complex process with many steps including: developing water quality standards, monitoring the water, ensuring the monitoring data set is comprehensive and accurately represents the water, and local professional review. A summary of some process information and steps is below.

Water Quality Standards

Waters throughout the state are not likely to be as pristine as they would be under undisturbed, “natural background” conditions. However, waterbodies are still expected to support designated (or beneficial) uses including fishing (AqL), swimming (AqR), and eating of fish (aquatic consumption). Water quality standards (also referred to as “standards”) are set after extensive review of data about the pollutant concentrations that support different designated uses, as well as estimation of natural background water quality conditions.

Water Quality Monitoring and Assessment

To determine if water quality is supporting its designated use, data on the waterbody are compared to relevant standards. When pollutants/parameters in a waterbody meet the standard (usually when the monitored water quality is better than the water quality standard), the waterbody is considered supporting of beneficial uses. When pollutants/parameters in a waterbody do not meet the water quality standard, the waterbody is considered impaired. If the monitoring data sample size is not robust enough to ensure that the data adequately represent typical conditions within the waterbody, or if monitoring results seem unclear regarding the condition of the waterbody, an assessment is delayed until further data are collected; this is referred to as an inconclusive or insufficient finding.

Several different parameters are considered for the assessment of each designated use. For AqR assessment, streams are monitored for bacteria and lakes are monitored for clarity and algae-fueling phosphorus. For AqL assessment, streams are monitored for both AqL populations and pollutants that are harmful to these populations. Lakes are monitored for AqL populations (fish populations). A water is considered impaired for AqL populations (referred to as "bio-impaired") when low or imbalanced fish or bug populations are found (as determined by the Index of Biological Integrity [IBI] score).

This WRAPS report summarizes the assessment results; however, the full report is available at Lac qui Parle River Watershed Monitoring and Assessment Report (MPCA 2018).

Stressor Identification

When streams are found to be bio-impaired, the cause of bio-impairment is studied and identified in a process called stressor identification (SID). SID identifies the parameters negatively affecting the AqL populations, referred to as "stressors". Stressors can be pollutants like nitrate, phosphorus, or sediment or nonpollutants like degraded habitat or high flow. Stressors are identified using the Causal Analysis/Diagnosis Decision Information System (CADDIS; EPA 2019) process. In short, stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. This WRAPS report summarizes the SID results, but the full report is available at Lac qui Parle River Watershed SID Report (MPCA 2020b).

Summary of Beneficial Uses, Pollutants, and Stressors

Pollutants and stressors both affect beneficial uses and must be addressed to bring waters to a supporting status. However, they are identified in different ways: pollutants are compared to the water quality standards directly, while stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. Often times, pollutants and stressors can be complex and interconnected. Furthermore, an identified stressor can be more of an effect than a cause, and will therefore have additional stressors and/or sources driving the problem. The difference between a pollutant and a stressor and a brief summary of how pollutants and stressors are identified is illustrated in **Figure 3**.

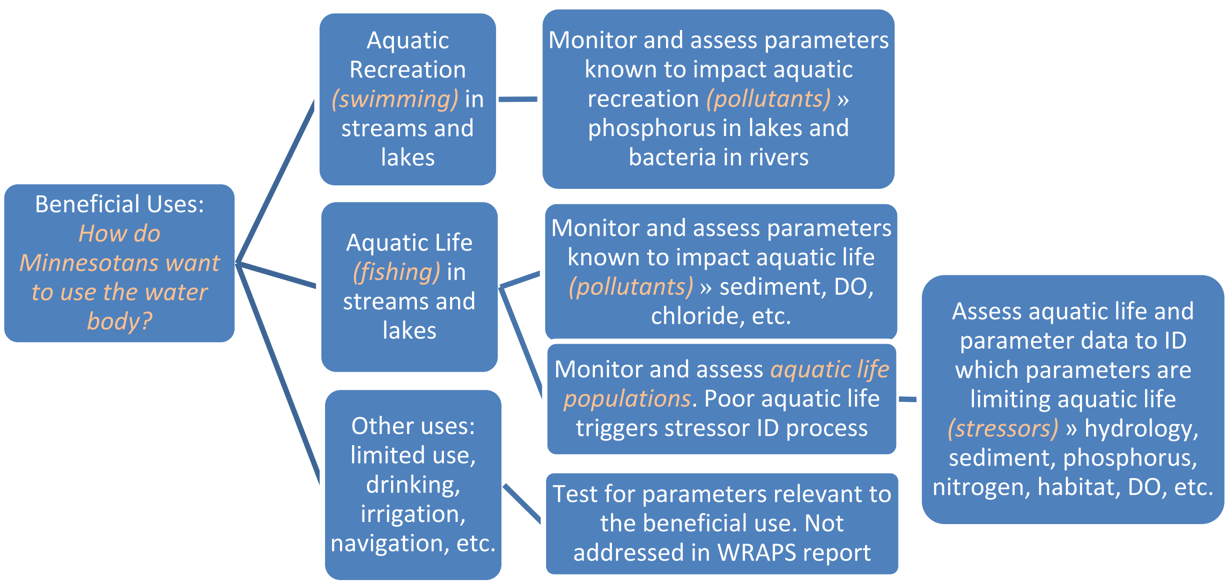


Figure 3. The process for identifying pollutants and stressors, which is a different process for each.

Monitoring Plan

Data from three water quality monitoring programs enables water quality condition assessment and creates a long-term data set to track progress towards water quality goals. These monitoring programs include Intensive Watershed Monitoring (IWM), Watershed Pollutant Load Monitoring Network, and Citizen Stream and Lake Monitoring Program. These programs are summarized below. BMPs implemented by Local Government Units (LGUs) will be tracked through the Board of Water and Soil Resources (BWSR's) e-Link system. These programs will continue to collect and analyze data in the Lac qui Parle River Watershed as part of Minnesota's Water Quality Monitoring Strategy (MPCA 2011). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. Monitoring locations for all three programs can be seen in **Figure 4**.

These monitoring programs contain various types of monitoring. The data from all types of water quality and quantity monitoring will be analyzed to measure progress and effectiveness of implementation strategies, identify data gaps, and determine changing conditions in the Lac qui Parle River Watershed.

IWM (MPCA 2012) was designed to assess the aquatic health of an entire major watershed through intensive biological and water chemistry sampling. The goal of this approach is to provide assessment data of the state's streams and lakes for AqL, AqR, and aquatic consumption use support in each of the state's 80 major watersheds on a rotating 10-year cycle. These uses are assessed to make sure that the goals of the Clean Water Act are being met; having "fishable, swimmable" waters.

The IWM data provide a periodic but intensive "snapshot" of water quality throughout the watershed. This program collected water quality and biological data at 64 stream and 2 lake monitoring stations across the watershed in 2015 and 2016. To measure progress across the watershed the MPCA will re-visit and re-assess the watershed starting in 2026.

IWM performed by the MPCA staff does not produce enough chemistry data to allow for chemical assessments based on the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List (MPCA 2019a). In order to assist the IWM in achieving its goal of assessing the aquatic health of an entire major watershed, planning and communication between the MPCA biological monitoring staff and local water monitoring staff is paramount. It is only through joint monitoring of the chosen sites that they can be assessed.

Watershed Pollutant Load Monitoring Network (MPCA 2013a) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment loads, and nutrient loads. In the Lac qui Parle River Watershed, there is an annual site near the outlet of the Lac qui Parle River and two seasonal (spring through fall) subwatershed sites near Dawson, Minnesota.

Citizen Stream and Lake Monitoring Program (MPCA 2013b) data provide a continuous record of waterbody transparency throughout much of the watershed. This program relies on a network of private citizen volunteers who make monthly lake and river measurements throughout the year. At the time of this report, six citizen monitoring locations exist in the Lac qui Parle River Watershed.

Progress towards meeting the protection and restoration goals, including the total maximum daily load (TMDL) goals, will be measured by regularly monitoring the water quality and tracking total BMP implementation in the watershed. It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. Factors that may mean slower progress include limits in funding or landowner acceptance, challenging fixes (e.g., unstable bluffs and ravines, invasive species) and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters, especially where high-impact fixes are slated to occur.

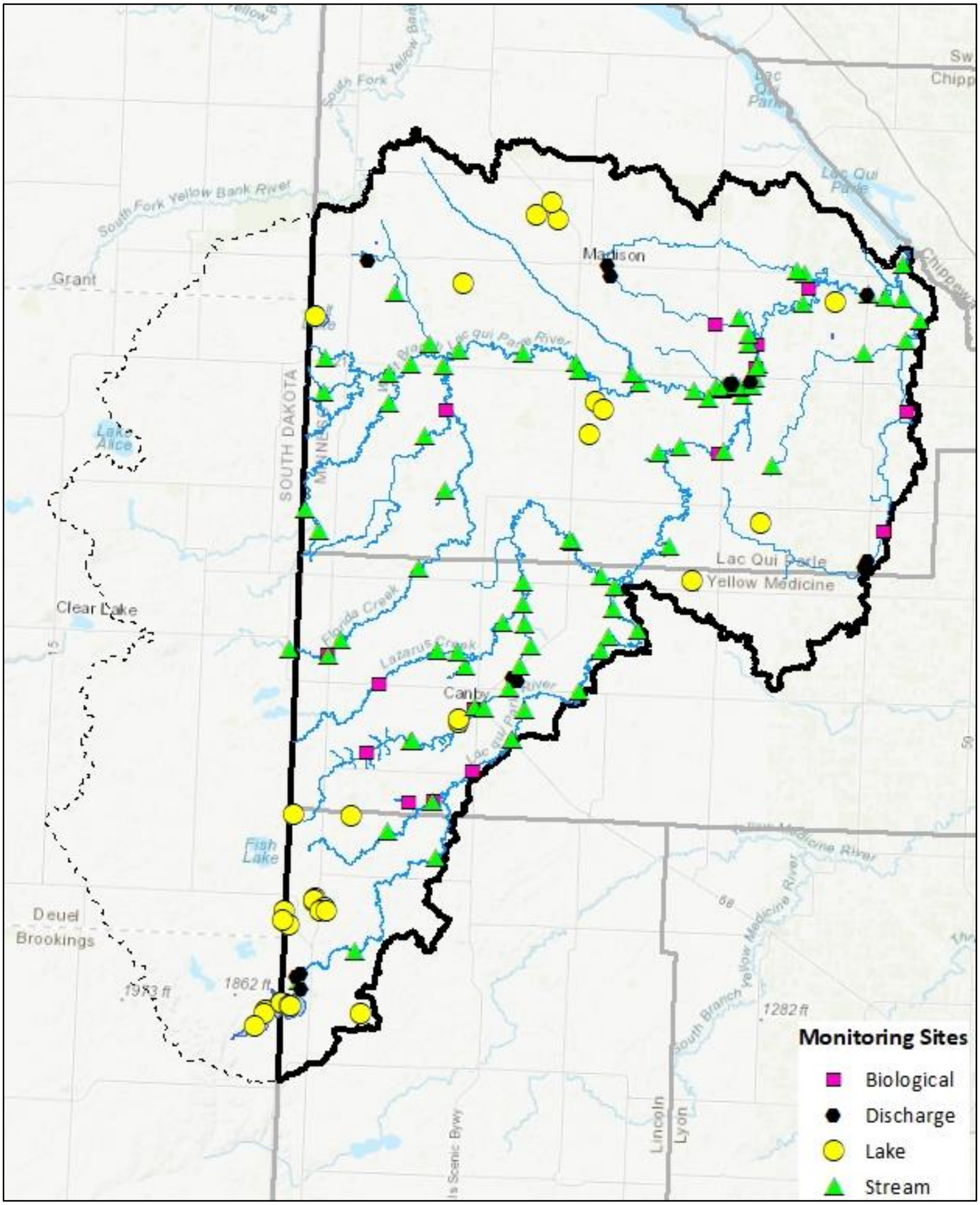


Figure 4. Monitoring locations in the Lac qui Parle River Watershed.

Computer Modeling

While monitoring for pollutants and stressors is generally extensive, not every stream or lake can be monitored due to financial and logistical constraints. Computer modeling can extrapolate the known conditions of the watershed to areas with less monitoring data. Computer models, such as Hydrological

Simulation Program - FORTRAN (HSPF; USGS 2014), represent complex natural phenomena with numeric estimates and equations of natural features and processes. HSPF incorporates data including: stream pollutant monitoring, land use, weather, soil type, etc. to estimate flow, sediment, and nutrient conditions within the watershed. Building a Picture of a Watershed (MPCA 2014a) explains the model's uses and development. Information on the HSPF development, calibration, and validation in the Lac qui Parle River Watershed are available in Minnesota River Headwaters and Lac qui Parle River Basin Watershed Model Development-Final Report (Tetra Tech 2016). The Lac qui Parle HSPF model can be utilized through the Scenario Application Manager (SAM; RESPEC 2021), a user-friendly graphical user interface developed to utilize the HSPF model, and is available for download.

HSPF model data provide a reasonable estimate of pollutant concentrations across watersheds. The output can be used for source assessment, TMDL calculations, and prioritizing and targeting conservation efforts. However, these data are not used for impairment assessments since monitoring data are required for those assessments. Modeled pollutant and stressor yields are presented throughout this report and will be indicated as such.

2. Watershed conditions

A waterbody's "condition" refers to its ability to support AqL (fishable) and AqR (swimmable). This section summarizes the condition of lakes and streams in the Lac qui Parle River Watershed, and provides information regarding water quality data and associated impairments. For waterbodies found not fishable and/or swimmable, the reason for these conditions - the pollutants and/or stressors – are identified. Information presented in this section is a compilation of many scientific analyses and reports. Information on the pollutants and stressors is summarized from the Lac qui Parle River Watershed Monitoring and Assessment Report (MPCA 2018) and the Lac qui Parle River Watershed SID Report (MPCA 2020b); the reader should reference those reports for additional details. Data for individual streams and lakes can be reviewed utilizing the MPCA's surface water data search tool.

This WRAPS report covers the impairments to AqR and AqL along with protecting waterbodies that are not assessed as impaired. **Figure 5** shows the assessed waters in the Lac qui Parle River Watershed by affected use [AqL, AqR, and limited resource value (LRV)]. The results for the AqL assessment overlay the results for the AqR and LRV, with the AqL results shown on the inside and AqR and LRV results shown around the outside. Several lakes and stream reaches are impaired for aquatic consumption due to mercury and Polychlorinated Biphenyls (PCBs). The Statewide Mercury TMDL (MPCA 2015) has been published and Statewide Safe-Eating Guidelines is available from the Minnesota Department of Health (MDH 2021) to address these impairments.

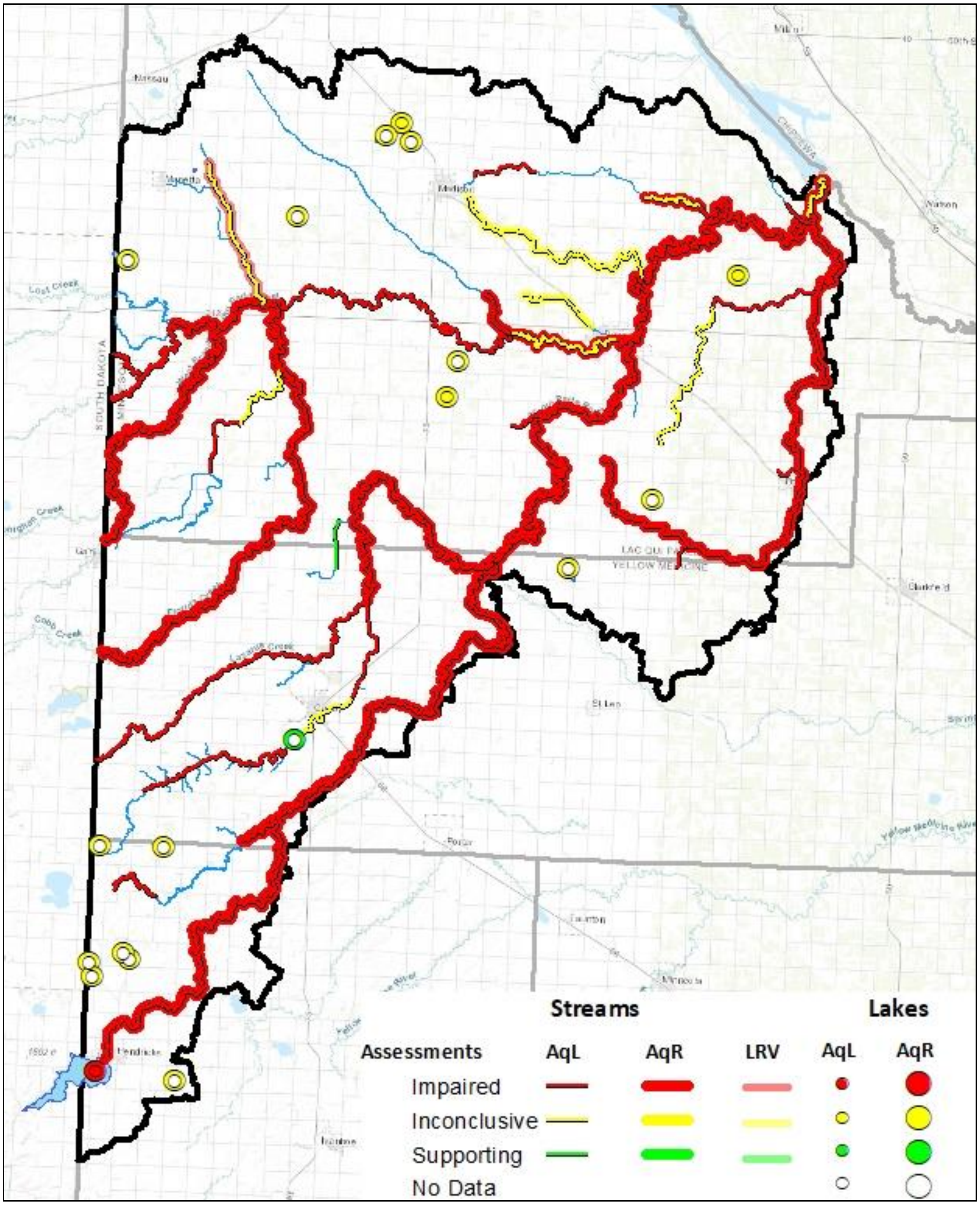


Figure 5. Assessment status of lakes and streams in Lac qui Parle River Watershed.

2.1 Condition status

This section provides a general overview of watershed conditions and provides the overall **status** of water bodies in the watershed, an overview of the potential **sources** of pollution, and summarizes the **goals** for each identified pollutant and stressor. **Section 2.3** provides the status, sources, and goals for each identified pollutant and stressor.

2.1.1 Status Overview

A breakdown of the total number of waterbodies (monitored and not monitored) and the assessment results (impaired, supporting, inconclusive, or deferred) are presented in **Figure 6** for streams. **Table 1** provides the monitoring and assessment results for assessed streams by stream reach and assessed pollutant. **Table 2** provides results for lakes.

Streams

In the Lac qui Parle River Watershed, 38 of the 80 defined stream reaches were assessed for AqL use, AqR use, or both (**Figure 6**). Of the assessed streams, only one stream was considered fully supporting of AqL; no streams were fully supporting of AqR.

Throughout the watershed, 32 stream reaches are nonsupporting for AqL and/or recreation. Of those reaches, 28 are nonsupporting for AqL and 17 are nonsupporting for AqR. The current assessment status of stream reaches in the Lac qui Parle River Watershed is provided in **Table 1**.

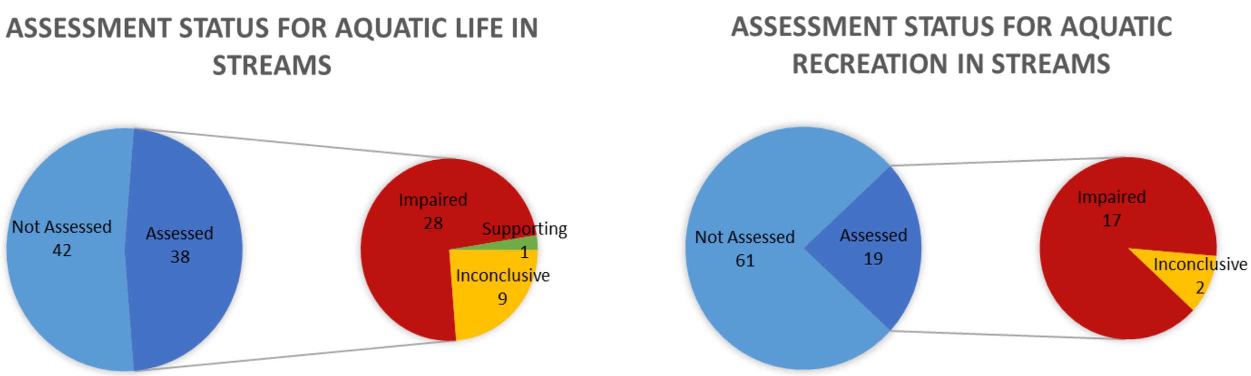


Figure 6. Assessments of streams in the Lac qui Parle River Watershed.

Table 1. Assessment status of stream reaches in the Lac qui Parle River, presented (mostly) from upstream to downstream.

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach description	Aquatic life									Aquatic rec	
				Assessment	Fish IBI	Macroinvertebrate IBI	Dissolved oxygen	Turbidity/TSS	River Eutrophication	Chloride	Unionized ammonia	pH	Assessment	Bacteria
County Ditch 5 0702000303-02	523	County Ditch 5	T118 R46W S23, north line to W Br Lac qui Parle R	?			?				+	+	X	X
Lost Creek 0702000303-03	517	Lost Creek	Crow Timber Cr to W Br Lac qui Parle R	X	X	X	X	+	?	+	+	+	X	X
	520	Crow Timber Creek	MN/SD border to Lost Cr	X	?	X	?	?	?			?		
	567	Unnamed creek	Unnamed cr to Unnamed cr	X	+	X	?	?	?					
Upper West Branch Lac qui Parle River 0702000303-01	516	Lac qui Parle River, West Branch	Lost Cr to Florida Cr	X	X	X	?	X	?	+	+	+	X	X
	519	Lac qui Parle River, West Branch	MN/SD border to Lost Cr	X	X	+	?	+	?	+	+	+	X	X
Tributary to West Branch Lac qui Parle River 0702000305-02	580	Unnamed creek	-96.1517, 44.9533 to W Br Lac qui Parle R	X	X	X		+	?	+	?	+	X	X
Florida Creek 0702000304-01	521	Florida Creek	MN/SD border to W Br Lac qui Parle R	X	X	X	?	X	?	+	+	+	X	X
	583	Cobb Creek	Unnamed cr to -96.3457, 44.8724	X	+	X	?	?	?					
	584	Cobb Creek	-96.3457, 44.8724 to Florida Cr	?				?						
Lower West Branch Lac qui Parle River 0702000305-01	512	Lac qui Parle River, West Branch	Unnamed cr to Unnamed ditch	?		?	?	?	?		+	+	X	X
	513	Lac qui Parle River, West Branch	Unnamed ditch to Lac qui Parle R	X	+	X	?	+	?	+	+	+	X	X
	515	Lac qui Parle River, West Branch	Florida Cr to Unnamed cr	X	X	+	?	?	?		?	?		
	555	Judicial Ditch 4	Headwaters to Unnamed cr	?			?				?	?	?	
Tributary to Lac qui Parle River 0702000301-02	530	Unnamed creek	Unnamed cr to Lac qui Parle R	X	X	X	?	X	?	+	+	+	X	X
	569	Unnamed creek	Unnamed cr to Unnamed cr	X	X	?	?	?	?		?	?		
Upper Lac qui Parle River 0702000301-01	505	Lac qui Parle River	Headwaters (Lk Hendricks 41-0110-00) to Lazarus Cr (Canby Cr)	X	X	X	+	X	?	+	+	+	X	X
County Ditch 4 0702000307-02	575	Unnamed ditch	Headwaters to Unnamed ditch	X	X	X	?	?	?			?		
	581	Unnamed ditch (County Ditch 4)	Unnamed ditch to CSAH 20	?			?	+	?	+	+	+	X	X
	582	Unnamed ditch (County Ditch 4)	CSAH 20 to Lac qui Parle R	X	X	X	?					?		

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach description	Aquatic life									Aquatic rec	
				Assessment	Fish IBI	Macroinvertebrate IBI	Dissolved oxygen	Turbidity/TSS	River Eutrophication	Chloride	Unionized ammonia	pH	Assessment	Bacteria
County Ditch 27 0702000307-03	522	County Ditch 27	Headwaters to Lac qui Parle River	?			?				?	?	?	
Tenmile Creek 0702000306-01	526	County Ditch 34	Unnamed ditch to Tenmile Cr	X	+	X	?	?	?			?		
	532	County Ditch 34	Headwaters to Unnamed ditch	?				?						
	570	Unnamed ditch	Unnamed ditch to Tenmile Cr	X	+	X	?	?	?			?		
	571	Unnamed ditch	Unnamed ditch to Tenmile Cr	X	+	X	?	?	?			?		
	577	Tenmile Creek	Headwaters to CSAH 18	X	X	X	?	+	?		?	?	X	X
	578	Tenmile Creek	CSAH 18 to Lac qui Parle R	X	X	X	+	?	?	+	+	+	X	X
Lower Lac qui Parle River 0702000307-01	501	Lac qui Parle River	W Br Lac qui Parle R to Tenmile Cr	X	?	X	X	X	?	+	+	+	X	X
	502	Lac qui Parle River	Tenmile Cr to Minnesota R	?		?	?	?	?	+	+	+	X	X
	506	Lac qui Parle River	Lazarus Cr (Canby Cr) to W Br Lac qui Parle R	X	?	+	?	X	?		+	+	X	X
	534	Unnamed creek	CD 29A to Lac qui Parle R	X	X		?	?	?		?	?		
	588	Unnamed creek	-95.9114, 45.012 to Lac qui Parle R	X	X	X								
Lazarus Creek 0702000302-01	508	Lazarus Creek (Canby Creek)	Canby Cr to Lac qui Parle R	X	X	X	?	X	?	+	+	+	X	X
	509	Lazarus Creek	MN/SD border to Canby Cr	X	X	X	?	?	?		?	?		
	557	Canby Creek	T114 R46W S21, south line to Del Clark Lk	X	X	X	?	?	?		?	?		
	560	Judicial Ditch 1	Unnamed ditch to CD 42	+	+	+	?	?	?		?	?		
	585	Canby Creek	Del Clark Lk to CSAH 3	?				?						
	586	Canby Creek	CSAH 3 to Lazarus Cr	X	X	+	?	?	?		?	?		

+	= found to meet the water quality standard or full support
X	= does not meet the water quality standard or impaired
?	= the data collected was insufficient to make a finding
<blank>	= no data

Lakes

A total of 19 lakes were assessed for AqR in the Lac qui Parle River Watershed. Of these, 1 was assessed as impaired, 17 were inconclusive, and 1 was in full support. There were four lakes assessed for AqL with one being impaired, three inconclusive, and no lakes in full support (**Table 2**). Lake Hendricks is the highest profile lake within the watershed, with considerable data available for assessment, resulting in a new AqL use impairment and a confirmed recreation use impairment. Lake Hendricks does show small signs that water quality may be improving. Despite heavy land use modification and altered hydrology within the contributing watershed, Del Clark Lake is highlighted as meeting AqR use criteria.

Table 2. Assessment status of lakes in the Lac qui Parle River Watershed.

HUC-10 Subwatershed	Lake ID	Lake	Aquatic Life	Aquatic recreation
County Ditch 5 0702000303-02	37-0229-00	Salt	--	?
Tributary to West Branch Lac qui Parle River 0702000305-02	37-0107-00	Unnamed (Madison WMA)	--	?
	37-0148-00	Unnamed (Arena)	--	?
Lower West Branch Lac qui Parle River 0702000305-01	37-0103-00	Cory	--	?
	37-0154-00	Unnamed	--	?
Tributary to Lac qui Parle River 0702000301-02	41-0102-00	West Twin	--	?
	41-0108-00	East Twin	--	?
Upper Lac qui Parle River 0702000301-01	41-0110-00	Hendricks	X	X
	41-0116-00	Unnamed	--	?
	41-0095-00	Kvernmo Marsh	--	?
	41-0115-00	Unnamed	--	?
County Ditch 4 0702000307-04	37-0134-02	Unnamed – Southwest Portion	?	?
Tenmile Creek 0702000306-01	87-0102-00	Miller	--	?
	37-0056-00	Unnamed	--	?
Lower Lac qui Parle River 0702000307-01	37-0100-00	Unnamed	?	?
	37-0026-01	Andrew	?	?
Lazarus Creek 0702000302-01	41-0109-00	Unnamed	--	?
	87-0180-00	Del Clark	--	+
	41-0142-00	Unnamed	--	?

X	= impaired
+	= fully supporting
?	= insufficient data to make an assessment
--	= not assessed

Stressors of biologically-impaired river reaches

Within the Lac qui Parle River Watershed, a total of 27 stream reaches were listed as having impaired AqL use, based on fish and/or macroinvertebrate community assessments. Eight are impaired based on aquatic macroinvertebrate bioassessments, 5 are a result of fish bioassessments, and 14 are impaired based on both. Causes of biologically-impaired communities were evaluated by the MPCA with reach-specific stressors fully explained in the Lac qui Parle River Watershed SID Report (MPCA 2020b). Eight common stressors were determined to be the causes of the biologically-impaired communities. Those stressors and the results of the investigation are summarized in **Table 3**. Individual stressors are discussed in detail in **Section 2.3.**

Table 3. Primary stressors to aquatic life in biological impaired reaches in the Lac qui Parle River Watershed (MPCA 2020b).

Stream Name	AUID (last 3-digits)	Aquatic Life Impairment	Primary Stressors: Dissolved Oxygen	Eutrophication	Nitrate	TSS	Habitat	Flow Alteration	Connectivity	Temperature	Chloride
Lac qui Parle River	501	Macroinvertebrates, DO, Turbidity	o	●	o	●	●	---	---	---	o
Lac qui Parle River	505	Fish, Macroinvertebrates, Turbidity	o	●	o	●	●	●	●	---	---

Stream Name	AUID (last 3-digits)	Aquatic Life Impairment	Primary Stressors								
			Dissolved Oxygen	Eutrophication	Nitrate	TSS	Habitat	Flow Alteration	Connectivity	Temperature	Chloride
Lazarus Creek	508	Fish, Macroinvertebrates, Turbidity	o	●	o	●	●	●	---	---	---
Lazarus Creek	509	Fish, Macroinvertebrates	o	o	o	●	●	●	---	---	---
West Branch Lac qui Parle River	513	Macroinvertebrates	---	o	---	---	o	o	---	---	---
West Branch Lac qui Parle River	515	Fish	---	o	---	---	●	o	●	---	---
West Branch Lac qui Parle River	516	Fish, Macroinvertebrates, Turbidity	---	o	---	o	●	---	---	---	---
Lost Creek	517	Fish, Macroinvertebrates, DO	●	●	o	---	●	---	---	---	o
West Branch Lac qui Parle River	519	Fish	---	o	---	o	●	---	---	---	---
Crow Timber Creek	520	Macroinvertebrates	o	●	o	---	●	---	---	---	o
Florida Creek	521	Fish, Macroinvertebrates, Turbidity	---	●	---	●	●	●	---	---	---
County Ditch 34	526	Macroinvertebrates	o	●	●	o	●	●	---	---	---
Unnamed Creek	530	Fish, Macroinvertebrates, TSS	---	●	---	●	o	---	---	---	---
Unnamed Creek	534	Fish	●	●	o	o	●	●	---	---	o
Canby Creek	557	Fish, Macroinvertebrates	---	o	o	o	o	●	●	●	---
Unnamed Creek	567	Macroinvertebrates	o	●	o	---	●	---	---	---	o
Unnamed Creek	569	Fish	●	●	o	●	●	o	●	---	---
Unnamed ditch	570	Macroinvertebrates	●	●	●	o	●	●	---	---	---
Unnamed ditch	571	Macroinvertebrates	●	●	●	o	●	●	---	---	---
Unnamed ditch	575	Fish, Macroinvertebrates	●	●	o	o	●	●	---	---	---
Tenmile Creek	577	Fish, Macroinvertebrates	●	●	●	o	●	●	---	---	---
Tenmile Creek	578	Fish, Macroinvertebrates	o	●	o	o	o	●	---	---	---
Unnamed Creek	580	Fish, Macroinvertebrates	●	o	o	---	●	●	---	---	---
Unnamed ditch (CD 4)	582	Fish, Macroinvertebrates	o	o	o	o	●	●	---	---	---
Cobb Creek	583	Macroinvertebrates	---	●	o	●	●	●	---	---	---
Canby Creek	586	Fish	o	o	o	o	●	●	●	---	---
Unnamed Creek	588	Fish, Macroinvertebrates	o	●	o	o	o	●	●	---	o

Key: ● = identified as a stressor; o = inconclusive; --- = not a stressor

Stressors of biologically-impaired lakes

One lake within the Lac qui Parle River Watershed, Hendricks (41-0110-00), was assessed as biologically impaired based on the fish community. The cause of the biologically-impaired community was evaluated by the Minnesota Department of Natural Resources (DNR) and detailed in the Minnesota River – Headwaters and Lac qui Parle River Watershed SID Report – Lakes (DNR 2021a). A summary of the results of the SID evaluation is listed in **Table 4.** A detailed discussion of the supporting stressor is described in **Section 2.3**.

Table 4. Summary of lake SID results for the Lac qui Parle River Watershed.

Lake name	AUID	Candidate causes[1]			
		Eutrophication (excess nutrients)	Physical habitat alteration	Altered interspecific competition	Pesticide application
Hendricks	41-0110-00	+	0	0	0

[1] "+" supports the case for the candidate cause as a stressor and "0" indicates that evidence is inconclusive as to whether the candidate cause is a stressor.

2.1.2 Sources Overview

This section provides a brief introduction and overview of the sources of pollutants and stressors in the Lac qui Parle River Watershed. A source summary for each pollutant or stressor is provided in **Section**

2.3. Sources of pollutants and stressors can be grouped into two categories: point sources and nonpoint sources. Point sources are sources of pollutants or stressors which discharge from a discrete location, or point. Examples include discharge from a wastewater treatment plant or an industrial discharger and are typically regulated to ensure any discharge does not degrade water quality conditions. Nonpoint sources are pollutant or stressor sources which run off the landscape and typically come from diffuse locations. A summary of the distribution of nonpoint sources and point sources in the watershed are shown in **Figure 7**, based on the HSPF model results.

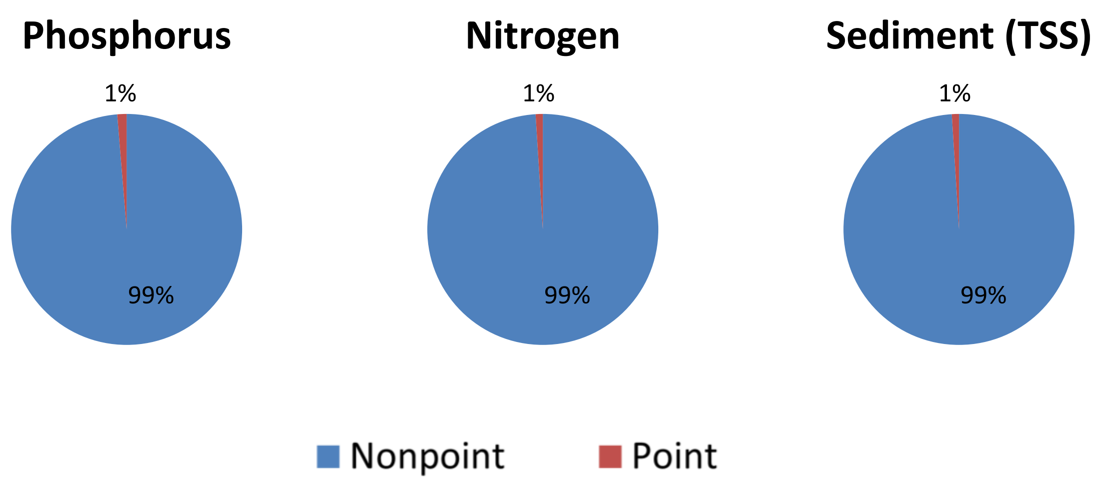


Figure 7. Overall breakdown of nonpoint source vs. point source pollution in Lac qui Parle River Watershed, based on the HSPF model results.

Nonpoint sources contribute the majority of phosphorus, nitrogen, and sediment in the Lac qui Parle River Watershed, contributing 99% for all three pollutants. Bacteria is not modeled by HSPF and will be discussed later. A summary of point and nonpoint sources in the watershed follows.

Point Sources

Point sources are regulated through National Pollutant Discharge Elimination System (NPDES) permits. Regulations of NPDES permits vary, depending on the type of point source. Some permittees are not allowed to discharge (e.g. Confined Animal Feedlot Operations (CAFO) permits), some are allowed to discharge but must treat and measure effluent pollutants to ensure permit requirements are met (e.g. wastewater treatment plant permits), and some permits only allow discharge under special circumstances or require the use of BMPs to limit the discharge of pollutants (e.g. construction permits).

Municipal and Industrial Wastewater

Municipal and industrial wastewater point sources have discharge and monitoring requirements specified in the facility permits to ensure pollutant levels in their discharge support water quality goals. The industrial and municipal facilities within the watershed are listed in **Table 5**. Because these systems often require discharge monitoring, their total contributions can be calculated. The estimated contributions of these facilities to the total loads delivered by the Lac qui Parle River Watershed are: 1.3% of nitrogen, 1.0% of phosphorus, and 0.1% of TSS. Estimates are based on HSPF model results. The annual loads by wastewater discharge for nitrogen, phosphorus, and TSS are presented in **Section 2.3**.

While the overall impact of these point sources on total pollutant loads is minimal, they can be substantial sources at times of low flow. Refer to the TMDLs (**see Section 2.4**) for more information on the impact of point sources on impaired reaches.

Municipal, Construction, and Industrial Stormwater

Stormwater systems in some communities, dependent on size and location, are regulated under the Municipal Separate Storm Sewer System (MS4) program, which requires the use of BMPs to reduce pollutants. There are no regulated MS4 areas within the Lac qui Parle River Watershed.

Construction stormwater (CSW) is runoff from construction sites. Construction projects that disturb: (a) one acre of soil or more, (b) less than one acre of soil but are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but determined to pose a risk to water quality require an NPDES permit. These projects are required to use BMPs to reduce pollutant runoff. Based on CSW permit data, less than 1% of the Lac qui Parle River Watershed land area is impacted by construction projects a year.

Similar to construction projects, industrial stormwater (ISW) sites are regulated through the NPDES program. Industrial facilities must have either no discharge or manage discharge with sufficient BMPs to protect water quality. Five individual NPDES permits in the watershed are provided in **Table 5.**

Table 5. Point sources in the Lac qui Parle River Watershed.

HUC-10 Subwatershed	Point source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
Judicial Ditch No 19-Lac qui Parle River (070200030102)	Hendricks WWTP	MN0021121	Municipal wastewater	Yes[1]	Permit does not currently contain a TP effluent limit
Judicial Ditch No 19-Lac qui Parle River (070200030102)	GCC Ready Mix	MNG490249	Industrial stormwater	No	
Canby Creek (070200030203)	Canby WWTP	MNG580154	Municipal wastewater	Yes[1]	Permit does not currently contain a TP effluent limit
Canby Creek (070200030203)	GCC Ready Mix	MNG490249	Industrial stormwater	No	
Lower County Ditch No 5 (070200030306)	Marietta WWTP	MNG580160	Municipal wastewater	Yes[1]	Permit does not currently contain a TP effluent
West Branch Lac qui Parle River (070200030503)	Dawson WWTP	MN0021881	Municipal wastewater	Yes[1]	TP WLA for Lac qui Parle Lake is more restrictive than current limit, will need review
West Branch Lac qui Parle River (070200030503)	Ag Processing Inc	MN0040134	Industrial wastewater	Yes[1]	Permit does not currently contain a TP effluent limit
Headwaters Tenmile Creek (070200030601)	Central Specialties Inc	MNG490071	Industrial stormwater	No	
Headwaters Tenmile Creek (070200030601)	Central Specialties Inc	MNG490071	Industrial stormwater	No	

HUC-10 Subwatershed	Point source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
County Ditch No 34 (070200030602)	Ag Processing Inc	MN0040134	Industrial stormwater	No	
County Ditch No 27 (070200030703)	Madison WWTP	MN0051764	Municipal wastewater	Yes[1]	Permit does not currently contain a TP effluent limit
Lac qui Parle River (070200030705)	PURIS Proteins LLC	MN0048968	Industrial wastewater	No	

[1]Allocation assigned for Lac qui Parle Lake (37-0046-01) TMDL in the Minnesota River Headwaters Watershed TMDL (MPCA 2021b).

CAFO Feedlots

Feedlots (MPCA 2021d) are animal operations (either open lots or buildings) used in intensive animal farming where manure accumulates, and vegetative cover cannot be maintained. Manure is typically applied to cropland as fertilizer and to build soil health. Manure contains high levels of bacteria and nutrients, and therefore, feedlot and manure management have a potential to impact water quality. Large feedlots are regulated as point sources and discussed here. Other animal operations and land-applied feedlot manure are considered nonpoint sources and discussed in the nonpoint source section below. In total, 87,286 animal units (AUs; see feedlots link above for conversions of animal types to AUs) in 259 feedlots are located within the Lac qui Parle River Watershed (**Figure 8**). On average, this translates to roughly 179 AUs per 1,000 acres. 28,188 (32%) of AUs reside in 23 permitted CAFOs, which are regulated as point sources.

NPDES permits are required for facilities that meet the definition of a Large CAFO and have discharges. Either a State Disposal System (SDS) or NPDES permit is required by state rule for feedlots with 1,000 AUs or more. Having and complying with an NPDES permit allows some enforcement protection if a facility discharges due to a 25-year, 24-hour precipitation event (approximately 4.68” in 24 hours) and the discharge does not contribute to a water quality impairment. Large CAFOs permitted with an SDS permit or those not covered by a permit must contain all runoff, regardless of the precipitation event. Therefore, many Large CAFOs in Minnesota have chosen to have an NPDES permit, even if discharges have not occurred in the past at the facility. Considering large CAFOs are not allowed to discharge, their impact on total pollutant loads is minimal from the facility itself.

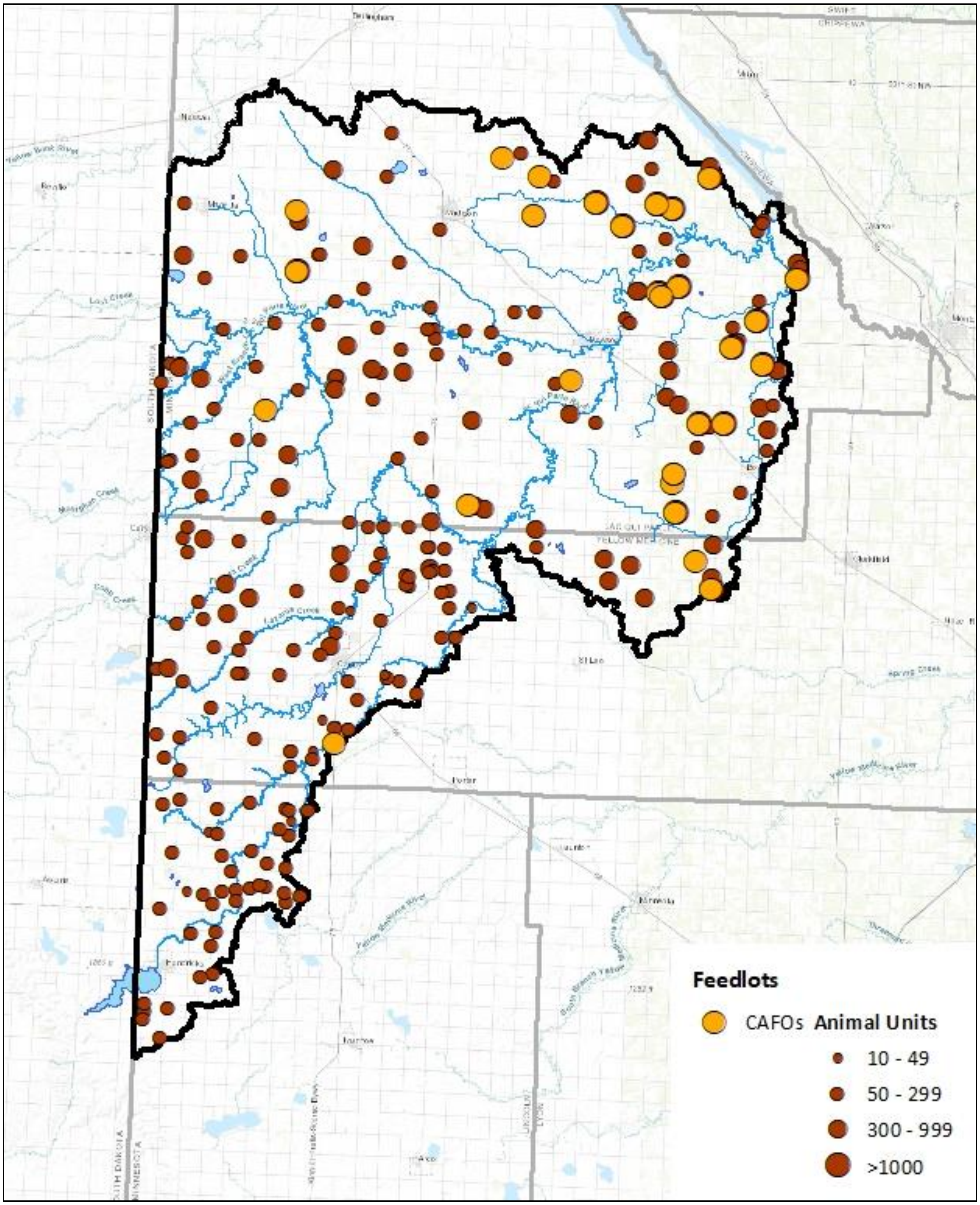


Figure 8. CAFOs and animal units in the Lac qui Parle River Watershed. The primary animal types in the watershed are swine (69.4%), cattle (29.3%), poultry (1.1%), and sheep (0.2%).

Nonpoint Sources

With a generally low input of pollutants/stressors from point sources, nonpoint sources are the dominant source of pollutants/stressors in the Lac qui Parle River Watershed. Nonpoint sources of pollutants/stressors are a result of the way that the landscape is managed. Human impacts may increase or decrease nonpoint sources of pollutants/stressors depending on how those pollutants/stressors are managed or mitigated with BMPs. This section summarizes typical forms of nonpoint sources.

Nonpoint sources of pollutants/stressors typically travel to a waterbody from the land around the waterbody (watershed) in response to precipitation. Once the area where precipitation falls cannot hold more water, water and the pollutants/stressors it carries will move via surface runoff, artificial drainage networks, or groundwater pathways to streams and lakes. The pollutants/stressors can be of natural origin (like tree leaves breaking down), human-accelerated natural origin (like excessive streambank erosion from altered hydrology), or of human origin (like fertilizer and manure applied on fields and lawns).

Land Cover/Land Use

The current land use in the Lac qui Parle River Watershed are shown in **Figure 9**. The watershed, as a whole, is dominated by cropland and row crop farming, accounting for 65.7% of total watershed area, and 75% of Minnesota's portion of the watershed. Rangeland (pasture and grasslands) makes up the second most prevalent land use type at 20.1% of the watershed. The remaining land use types are split amongst wetlands (7.0%), developed (4.6%), open water (1.6%), forests and shrubs (0.90%), and barren (0.06%).

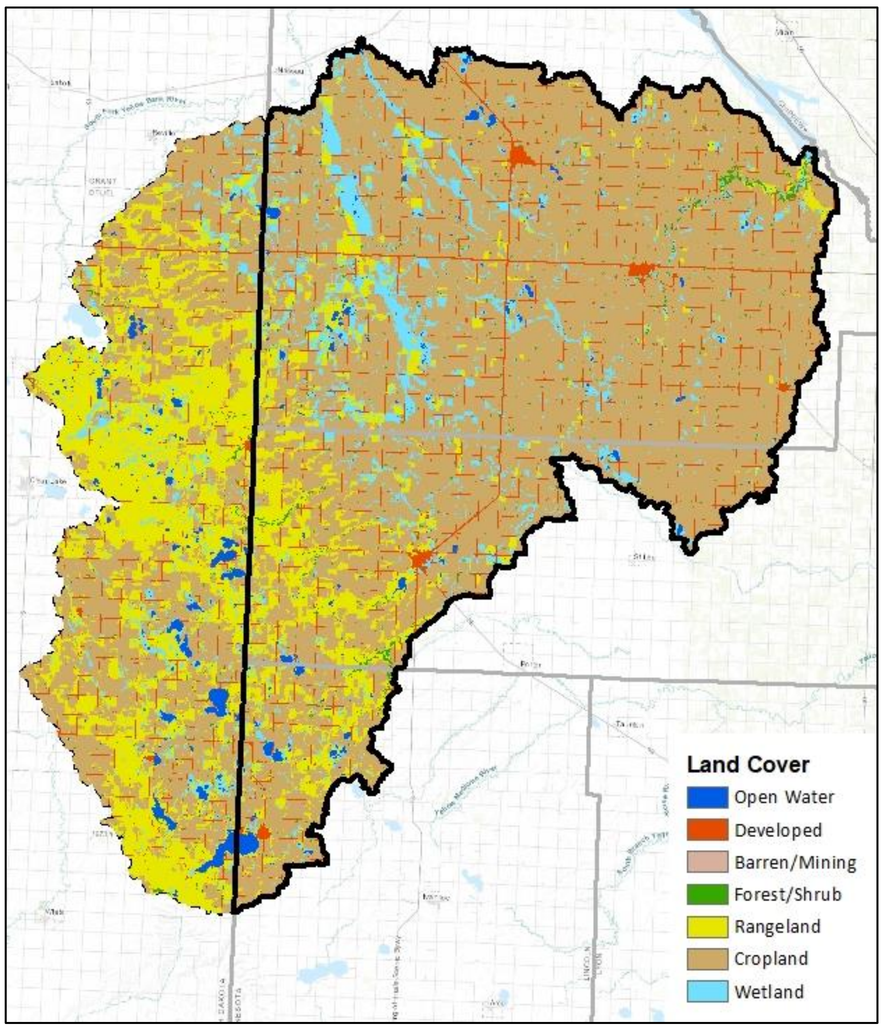


Figure 9. Land use in the Lac qui Parle River Watershed.

Changes in land cover/land use can have significant impacts on a watershed's hydrology and water quality. Before European settlement, the landscape of the Lac qui Parle River Watershed was mostly bluestem prairie, while the Minnesota River valley is described as Northern Floodplain Forest (Kuchler 1964). The Marschner pre-European settlement vegetation map only shows the watershed in Minnesota and estimates that natural land cover was 92% prairie, 7% wet prairie, 1% river bottom forests, and <1% lakes and open water (**Figure 10**).

After European settlement, drastic changes occurred to the landscape to make it more conducive to agricultural practices. The wet areas were drained, prairies were plowed, and forests cut down in order to produce crops. Over time, drainage practices have improved and become more efficient, and commodity demands have changed from corn and small grains to corn and soybeans.

Similar to much of southern Minnesota, the Lac qui Parle River Watershed has seen drastic changes in cropping systems since the 1920s, from mainly corn and small grains to almost completely corn and soybeans (**Figure 11**). While most of southern Minnesota saw these changes start in the 1940s and peak in the early 1970s, the Lac qui Parle River Watershed has seen many of these changes occur since the mid-1970s. Different crop types can have markedly different effects on water quantity and quality. For example, the timing and magnitude of water use and movement can be substantially different for small grains versus row crops like corn and soybeans. Less evapotranspiration (ET) in spring and more ET in mid-summer (**Figure 12**), results in more precipitation entering rivers in spring and less entering in mid-summer.

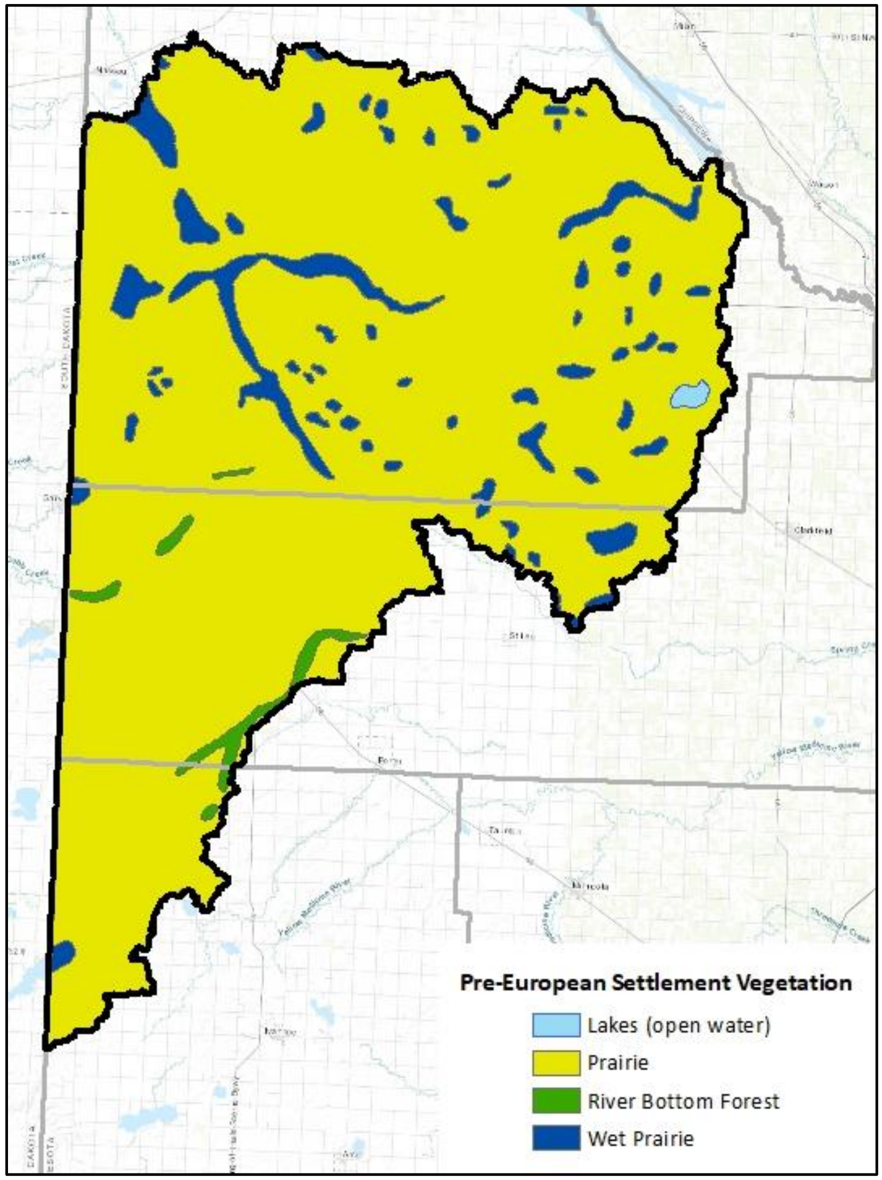


Figure 10. Marschner's pre-European settlement vegetation for the Lac qui Parle River Watershed (DNR 1994).

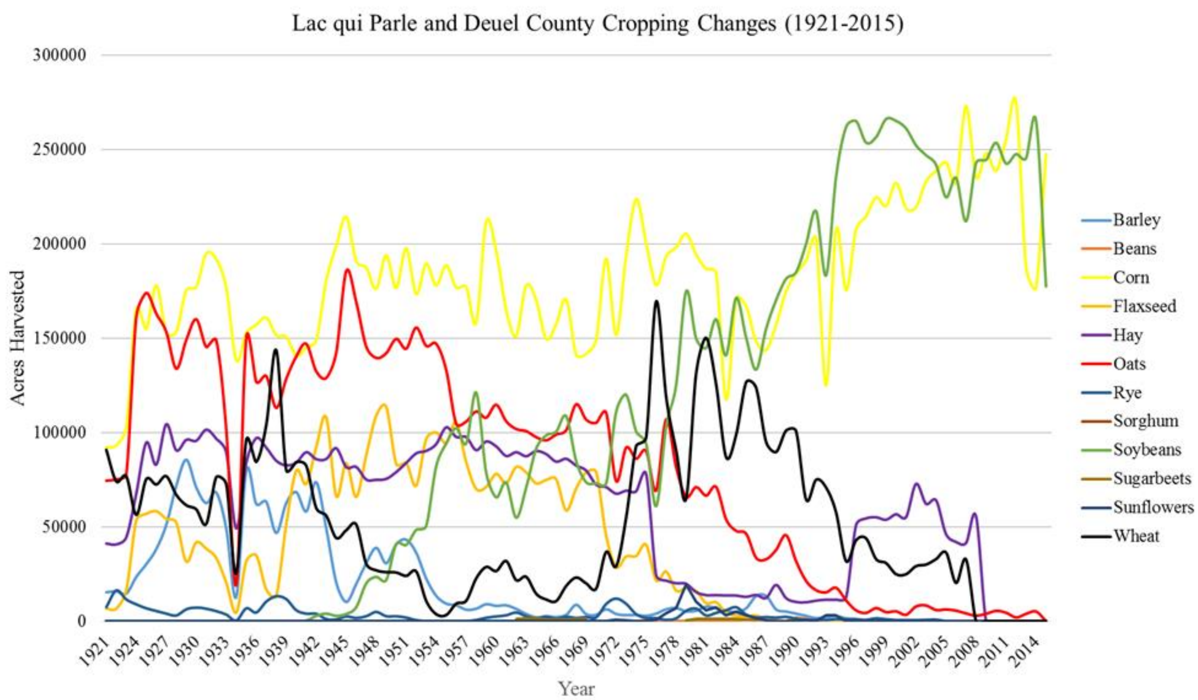


Figure 11. Cropping history in Deuel and Lac qui Parle Counties from 1921-2015 (DNR 2019).

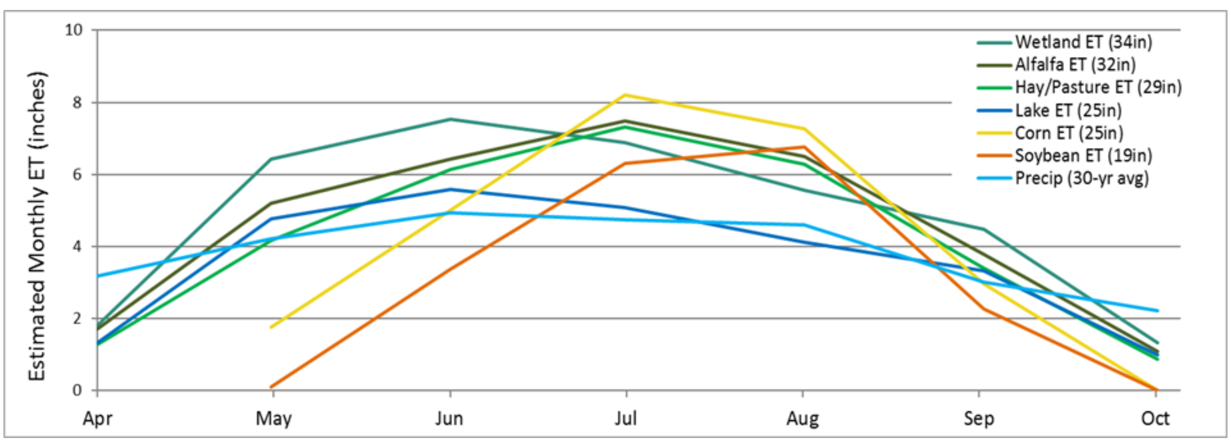


Figure 12. The timing of ET rates by crop type. Data sources in Appendix 5.6.

Farm and City Runoff

Typically, highly manipulated land uses contribute higher levels of pollutants/stressors compared to more naturalized areas. Grasslands and forests tend to have lower contributions of pollutants/stressors compared to many cultivated crop fields, urban developments, and over-grazed pastures.

While highly manipulated (urban and agricultural) land often does contribute higher levels of pollutants/stressors, the impacts can be reduced by adequately managing/mitigating with sufficient BMPs. As demonstrated by sustainable agriculture (UCS 2017), farming and clean water do not have to be mutually exclusive. For instance, a farm that incorporates nutrient management practices, conservation tillage, cover crops, grassed waterways, and buffers will contribute substantially fewer pollutants/stressors than if those BMPs were not used. Also, contributions of pollutants and stressors can be reduced when land uses such as cultivated crops adhere to industry recommendations (for instance the application of fertilizer/manure as documented in the Commercial Nitrogen and Manure Fertilizer… Management Practices [MDA 2014]). Likewise, city stormwater systems can be designed and built for zero or minimal runoff (depending on the size and intensity of the rain event).

While some agricultural and urban runoff has been reduced using sufficient BMPs, additional BMPs need to be adopted to achieve water quality goals and cleaner water. The MPCA Healthier Watersheds Accountability Report (MPCA 2020a) shows that over 2,300 BMPs have been installed in the Lac qui Parle River Watershed between 2004 and 2019. In addition, at the end of 2020, the Agricultural Water Quality Certification Program (MDA 2020) has certified more than 2,118 acres in the Minnesota portion of the Lac qui Parle River Watershed. These farms have been certified by MDA that their impacts to water quality are adequately managed/mitigated. While these producers and others have incorporated sufficient BMPs to protect water quality, much of the cultivated crops, pastures, urban development, and residential landscape are not adequately managed/mitigated with BMPs.

Other Feedlots, Manure Application, and Pastures

Only the largest feedlots are regulated as point sources (discussed in section above). 59,168 (67%) AUs in 236 feedlots are not regulated as point sources (feedlots not meeting Large CAFO criteria). However, these facilities are still regulated and may only have discharge/runoff that meets a maximum pollutant concentration (using a designated estimation tool). Small animal operations (<10 AUs in shoreland or <50 AUs elsewhere) are not considered feedlots and are not regulated. AU counts associated with the nonregulated operations are not available but can be presumed to be relatively small. All feedlots in the Minnesota portion of the Lac qui Parle River Watershed are shown in **Figure 8**.

Feedlots within close proximity to waterbodies (referred to as shoreland) may pose a disproportionately high risk to water quality if runoff is not prevented or treated. In the Lac qui Parle River Watershed, approximately 4,384 (5%) AUs in 35 feedlots are in shoreland, of which 34 are open lot facilities. Open lots can be particularly high risk, because manure is not contained within a structure and may run off more readily.

Because most feedlots are regulated to have minimal runoff, the largest water quality risk associated with feedlots is from land-applied manure. Like other types of fertilizer application, the location, method, rate, and timing of manure application are important considerations to estimate the impact and likelihood of runoff. Feedlots can create a large amount of manure that is usually stockpiled on site until field conditions and the crop rotation allow for application as a fertilizer. The timing of manure spreading can decrease the likelihood of bacteria entering nearby waterbodies. Late-winter spreading of manure on frozen soil can result in surface runoff during precipitation events. Deferring manure application until soils have thawed decreases overland runoff during precipitation events. Incorporating manure into the subsoil is a preferred BMP to reduce bacteria and nutrient runoff, as injected manure reduces the risk of surface runoff associated with large precipitation events.

Grassland and pasture accounts for 10% of the land use in Minnesota's portion of the Lac qui Parle River Watershed. Often, pastures are located directly adjacent to waterbodies and therefore can disproportionately impact waterbodies if not properly managed. Perennial vegetation, like that of pasture, typically provides an overall benefit to water quality compared to inadequately managed/mitigated urban and cultivated cropland uses. However, when pasture is overgrazed (indicated by too little vegetation), especially adjacent to a waterbody, these areas can be sources of pollutants/stressors. Furthermore, when cattle access streams, the delicate streambank habitat is trampled, the stream geomorphology is negatively impacted (DNR 2020), and streambank erosion is accelerated.

Septic Systems and Unsewered Communities

Well-functioning individual and small community wastewater treatment systems generally pose little risk to waters. When these systems fail or do not offer ample treatment, these systems can pose a risk to water quality. Failing subsurface sewage treatment systems (SSTSs), also known as septic systems, near waterways can be a source of bacteria and nutrients to streams and lakes, especially during low flow periods when these sources continue to discharge and runoff driven sources are not active. In addition, failing SSTSs with an insufficient dry zone between the leach field and bedrock or saturated zone or improperly designed SSTSs can result in the transfer of phosphorus to groundwater and surface waters.

Counties are required to submit annual reports to the MPCA regarding SSTS within their respective boundaries. Data reported is aggregate by each county so the location of SSTSs are not known to the State of Minnesota. SSTS data from each county from 2016 is shown in **Figure 13** and annual reports by counties in the watershed indicate that failing SSTS range from 0.95 (Lac qui Parle) to 3.07 (Lincoln) systems per 1,000 acres. At this concentration, failing septic systems are unlikely to contribute substantial amounts of pollutants/stressors to the total annual loads. However, the impacts of failing SSTS on water quality may be pronounced in areas with high concentrations of failing SSTS or at time of low precipitation and/or flow.

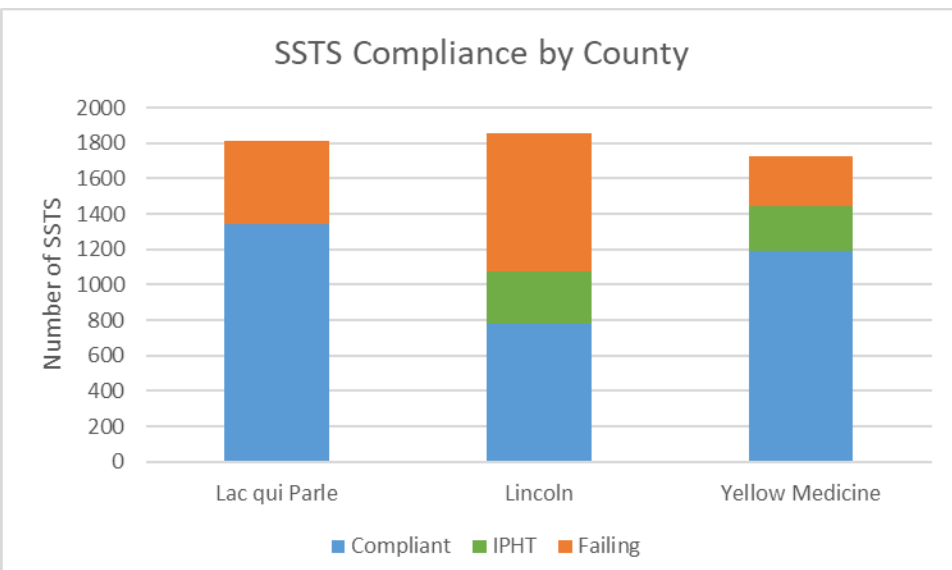


Figure 13. SSTS compliance in 2016 for each county in the Lac qui Parle River Watershed.

Unsewered or under-sewered communities (MPCA 2020c) are clusters of five or more homes or businesses on small lots where individual or small community systems do not provide sufficient sewage treatment (including straight pipes). Many of these have been upgraded, but a handful of unsewered or under-sewered areas (Louisburg, Rosen, and Lac qui Parle Village) still exist in the Lac qui Parle River Watershed.

Drainage

In the Minnesota portion of the Lac qui Parle River Watershed, 66% of the stream miles with a definable stream channel are ditched (**Figure 14**; MPCA 2019b). This is comparable to the ditching rate of the Minnesota River Basin (67%). Ditches typically lack many natural stream features: they tend to be simple, straight, and uniform in depth. In contrast, natural streams tend to be complex, meandering, and variable in depth. Ditch features result in unnatural flow dynamics such as excessive flow speed and have poor geomorphic and biologically important features (i.e. lack of riffle and pool formation and excessive bank failures).

While agricultural and urban drainage can negatively affect water resources, the historical perspective of agricultural and infrastructural benefits of drainage are important to recognize. European settlers drained wetlands to settle and farm lands. For decades, the government further encouraged drainage to reduce pests, increase farmable lands, and clear lands for roads and infrastructure. Today, drainage is still encouraged by some agricultural interest to increase crop production. Drainage is necessary for crop production and development in certain circumstances; however, drainage impacts can be better managed/mitigated to reduce impacts to waterbodies.

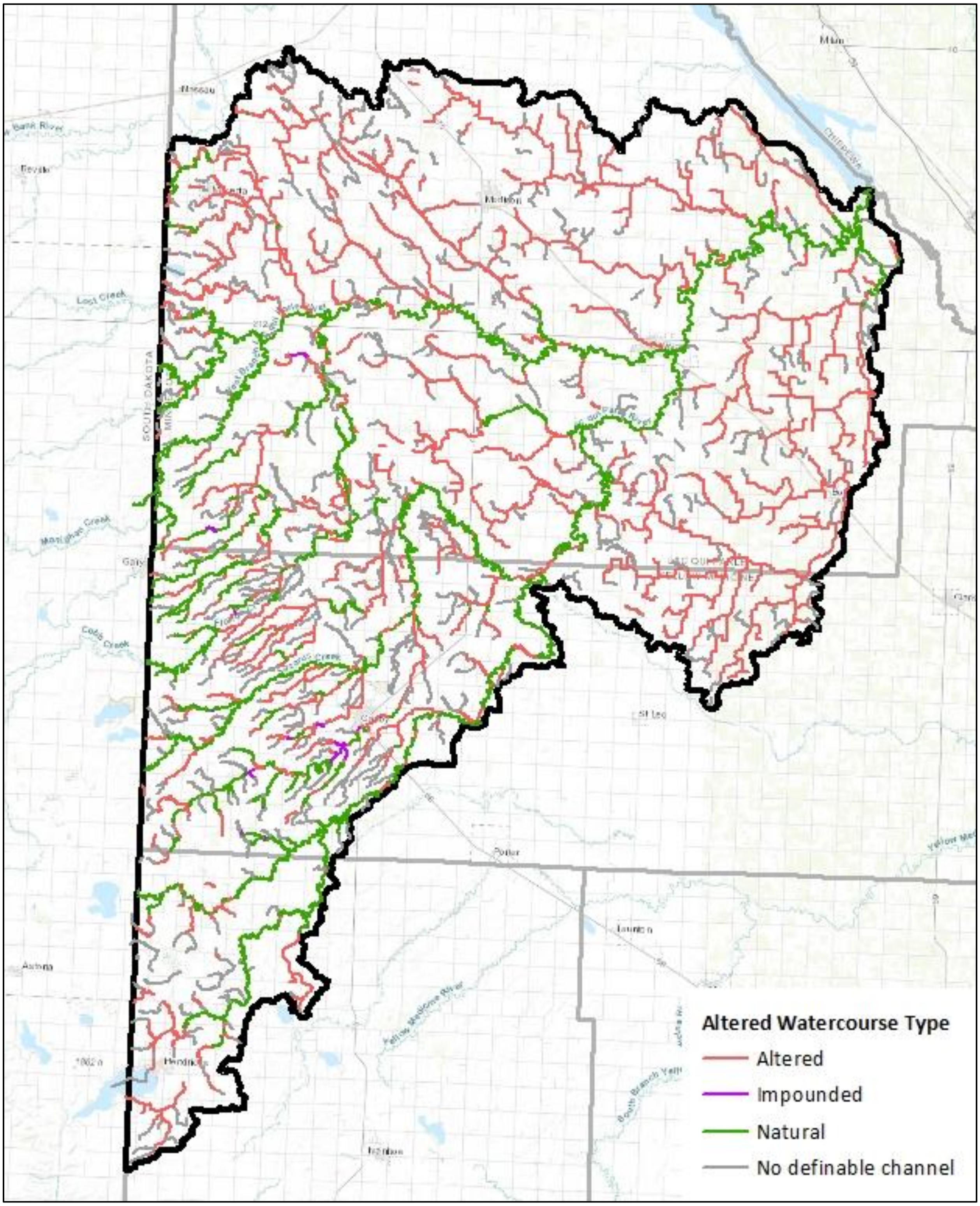


Figure 14. Altered watercourses in the Lac qui Parle River Watershed.

Waterfowl

Waterfowl contribute a portion of bacteria to streams in the Lac qui Parle River Watershed. Waterfowl can contribute bacteria to streams and lakes, directly or through surface runoff. Waterfowl contribute bacteria to the watershed by directly defecating into waterbodies and along the shorelines. They contribute bacteria by living in waterbodies, living near conveyances to waterbodies, or when their waste is delivered to water bodies in stormwater runoff. Areas such as state parks, national wildlife refuges, golf courses, state forest, and other conservation areas provide habitat for wildlife and are potential sources of bacteria due to the relatively high density of waterfowl.

Waterfowl populations were estimated by the U.S. Fish and Wildlife Service by utilizing pond level models that estimates breeding duck pairs. This model was developed from annual waterfowl populations surveys that have been conducted since the late 1980s (Reynolds et. al. 2006). The results of the model are used primarily for conservation planning, however, they can be utilized for estimating waterfowl densities as well.

High Risk Areas

While some highly manipulated land uses can adequately manage pollutant contributions by adopting sufficient BMPs, some areas within a landscape are particularly sensitive from a water quality perspective. For instance, the area or buffer around waterbodies is particularly sensitive. Crops or lawn turf directly adjacent to a stream or lake can cause more pollutants/stressors to enter waterbodies, accelerate erosion, and destroy sensitive habitat. On the contrary, a high quality, naturalized vegetative buffer adjacent to a waterbody can help capture pollutants/stressors, stabilize the streambank, and provide habitat to sensitive aquatic species. Other particularly sensitive areas include flood plains, high slope areas, and areas with highly erodible soils.

Source Summary

Primary nonpoint pollutant concerns within the Lac qui Parle Watershed include total phosphorus (TP), total suspended solids (TSS), and bacteria (*E. coli*). Sources of TSS and TP are similar, via erosion, while bacteria is attributed to failing SSTSs, nonpoint source application, or point source release. The effects of nutrient and organic matter enrichment characteristically result in low dissolved oxygen (DO) concentrations and are reflective of impacted aquatic ecosystems (high decomposition, low primary production, and/or elevated water temperatures). Known pollutant sources are summarized for each impaired stream reach in **Table 6**, based on source summary information (**Section 2.3**). Magnitudes are based on if the source is significant (high (>20%), moderate (5%-20%), or low (<5%); blank cells means not a source).

Table 6. Sources in impaired stream reaches in the Lac qui Parle River Watershed. Relative magnitudes of contributing sources are indicated.

HUC-10 Subwatershed	River/Reach (AUID) or Lake (ID)	Pollutant	Pollutant sources												
			Fertilizer & manure run-off	WWTPs/Industrial Stormwater	Failing septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank Erosion/excessive peak flows	Channelization	Upstream influences	Farmed-through headwater streams	Livestock in stream channel	Tile drainage	Increase flows
County Ditch 5 0702000303-02	County Ditch 5 (523)	Bacteria	●	○	○	●									
Lost Creek 0702000303-03	Lost Creek (517)	DO					⭘			⭘	⭘		⭘		
		Bacteria	●	○	○	⭘					⭘				
Upper West Branch Lac qui Parle River 0702000303-01	Lac qui Parle River, West Branch (516)	Bacteria	●	○	○	⭘					⭘		●		
		Turbidity					⭘	●	●	●	⭘		●	⭘	●
	Lac qui Parle River, West Branch (519)	Bacteria	●	○	○	●					⭘		●		
Tributary to West Branch Lac qui Parle River 0702000305-02	Unnamed creek (580)	Bacteria	●	○	○	⭘					⭘				
Florida Creek 0702000304-01	Florida Creek (521)	Turbidity					⭘		●	⭘	⭘			⭘	●
		Bacteria	●	○	○						⭘				
Loer West Branch Lac qui Parle River 0702000305-01	Lac qui Parle River, West Branch (512)	Bacteria	●	○	○	⭘					⭘				
	Lac qui Parle River, West Branch (513)	Bacteria	●	○	○	⭘					⭘				
Tributary to Lac qui Parle River 0702000301-02	Unnamed creek (530)	Bacteria	●	○	○	●					⭘				
		TSS					⭘			⭘	⭘			⭘	
Upper Lac qui Parle River 0702000301-01	Lac qui Parle River (505)	Turbidity					⭘	●	●	●	⭘			⭘	●
		Bacteria	●	○	○	⭘					⭘				
County Ditch 4 0702000307-02	Unnamed ditch (County Ditch 4) (581)	Bacteria	●	○	○	⭘					⭘				
Tenmile Creek 0702000306-01	Tenmile Creek (577)	Bacteria	●	○	○	⭘					⭘				
	Tenmile Creek (578)	Bacteria	●	○	○	⭘					⭘				
Lower Lac qui Parle River 0702000307-01	Lac qui Parle River (501)	Bacteria	●	○	○	⭘					⭘				
		DO		○	○		⭘			⭘	⭘			⭘	
		Turbidity		○	○		⭘		●	⭘	⭘			⭘	●
	Lac qui Parle River (502)	Bacteria	●	○	○	⭘					⭘				
	Lac qui Parle River (506)	Bacteria	●	○	○	⭘					⭘				
		Turbidity					⭘			⭘	⭘			⭘	●
Lazarus Creek 0702000302-01	Lazarus Creek (Canby Creek) (508)	Bacteria	●	○	○						⭘	⭘			
		Turbidity				⭘	⭘			⭘	⭘	⭘		⭘	●

Key: ● = High ⭘ = Moderate ○ = Low "Blank" = Not a source

2.1.3 Goals and Targets Overview

Water quality goals for the Lac qui Parle River Watershed are intended to help waterbodies meet water quality goals both within and downstream of the watershed (e.g. Gulf Hypoxia goals). In addition, they work towards state-wide goals of fishable and swimmable surface waters. Goals for the Lac qui Parle River Watershed (**Table 6**) were set after analyzing the monitoring and assessment data, HSPF model results, TMDL studies, and state-wide reduction goals. The selected goals integrate multiple levels of goals into one watershed-wide goal. Subwatershed goals (for individual stream reaches and lakes) are presented for waterbodies where TMDLs have been completed and are available. The TMDL studies include the draft Lac qui Parle River Watershed TMDL (developed concurrently with this WRAPS report; see MPCA Lac qui Parle River webpage), the Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low DO TMDL Assessment Report (Wenck 2013), and the SD Department of Environment & Natural Resources Watershed Protection Program TMDL (SDDENR 1999) for Lake Hendricks.

The specific goal for every lake and stream reach is to meet water quality standards for all relevant parameters and to support downstream water quality goals. However, in order to more easily communicate water quality goals to watershed managers and to make the identification of strategies and adoption rates more straight-forward, the multiple levels of goals were integrated into one average or surrogate watershed-wide goal for the major watershed. Likewise, because water quality standards do not include a specific method to calculate a reduction goal, surrogate goals for individual streams and lakes were calculated from available TMDL information.

For parameters that are the effect of other pollutants/stressors (e.g. Fish-Index of Biotic Integrity (F-IBI), Macroinvertebrate-IBI (M-IBI), and DO), a numeric goal was estimated for the identified pollutants/stressors which caused the impaired parameter. For instance, in the case of biologically-impaired streams (where the AqL impairment was due to a low F-IBI or M-IBI), the goal is to have the fish and/or macroinvertebrate populations meet the IBI score threshold. However, there is not a tool or model available to estimate the magnitude or change needed to meet this F-IBI or M-IBI threshold. Therefore, numeric goals for the stressors causing the biologically-impairments (e.g. sediment, phosphorus, nitrogen, etc.) are the surrogate goal.

Interim water quality goals called “10-year targets” were developed and input from the WRAPS LWG was requested. The 10-year targets allow opportunities to adaptively manage implementation efforts. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals are presented in **Table 7**.

The 10-year targets for each pollutant/stressor were developed by including downstream reduction goals, statewide targets and input from the LWG. MPCA views these targets as aspirational and recognizes implementation projects and measurable improvements in water quality, aquatic biology and stream health take time to show in water quality data. In addition, implementation efforts will produce different reductions at different watershed scales. For example, implementation in a small subwatershed will have higher reductions for that subwatershed than what will show at the outlet of the Lac qui Parle River Watershed. If these targets are not achieved within the 10-year timeframe, this should not be construed as a failure. Rather, it should be considered as a starting point for adaptive management and adjusted accordingly as additional information, science, and collective knowledge are obtained. LGUs have the ability to refine targets in the development of a One Watershed, One Plan or local water plan.

Table 7. Watershed-wide protection and restoration goals and 10-year targets for the Lac qui Parle River Watershed.

Parameter (Pollutant/Stressor)	**Current Status**	**Water Quality Goal Summary**	**Watershed-wide Goal**	**10-year Target**	**Years to Reach Goal** (from 2020)
Habitat	Stressor in 22 stream reaches; inconclusive in 5.	Increase in average MSHA scores. Aquatic life not stressed by poor habitat.	54% increase in the average MSHA score to 66	15% ↑	75
Phosphorus/ Eutrophication	Stressor in 18 stream reaches; inconclusive in 9 stream reaches; impaired in 1 lake and supporting in 1 lake.	Summer average stream phosphorus concentrations below 150 ug/L. Aquatic life not stressed by phosphorus. Summer average lake concentration below 90 ug/L. Meet Minnesota's phosphorus and Lac qui Parle Lake reduction goals for watershed.	35% reduction	10% ↓	60
Altered Hydrology	Stressor in 17 stream reaches; inconclusive in 3.	Aquatic life populations are not stressed by altered hydrology (too high or too low river flow). Hydrology is not accelerating other parameters (sediment, etc.). Decrease intermediate flood peaks (2-yr to 10 yr events)	Increase storage by 0.39 inch (20,986 acre-ft) across watershed	Increase storage by 0.1 inch (3,329 acre-ft) across watershed	40
Bacteria	17 stream reach impairments.	Average monthly *E. coli* geomean of stream samples is below 126 org/100mL and average monthly *E. coli* geomean for class 7 stream samples is below 630 org/100mL.	14%-86 % reduction of bacteria, Average of 52%	10% ↓	65
Sediment	1 stream reach impaired for TSS; 6 impaired for turbidity; Stressor in 8 streams reaches; inconclusive in 13 stream reaches.	90% of stream concentrations are below 65 mg/L. Aquatic life populations are not stressed by sediment.	0%-72% reduction, average of 25%	10% ↓	45
Nitrogen	Stressor in 4 stream reaches; inconclusive in 17 stream reaches.	Aquatic life not stressed by nitrate. Protect groundwater and drinking water throughout the watershed. Meet Minnesota's nitrogen reduction goal for watershed.	45% reduction	20% ↓	65
Connectivity	Stressor in 6 stream reaches	Aquatic life populations not stressed by human-caused barriers.	Address identified barriers	Address identified barriers	45
Parameters that are impacted/addressed by the above pollutants and stressors					
Macroinvertebrate Bioassessments	22 stream reaches impaired	Aquatic life populations are measured and numerically scored with IBIs. IBIs meet thresholds based on stream class/use	Because these are in response to (caused by) the above pollutants/stressors, the other watershed-wide goals are the (indirect) goals for these parameters	Meet other 10-year targets	60
Fish Bioassessments	19 stream reaches impaired				60
Dissolved Oxygen	2 stream reach impairments; Stressor in 8 stream reaches; inconclusive in 11 stream reaches.	Minimum concentrations of 5 mg/L in all streams. Aquatic life not stressed by low dissolved oxygen.			60

2.2 Water quality trends

Trends were calculated for the Lac qui Parle River, near the town of Lac qui Parle, for phosphorus, sediment and nitrogen. There is no significant trend in all three of the parameters (**Table 8**).

Table 8. Water quality trends of the Lac qui Parle River, near Lac qui Parle.

Parameter	Years of Data	Trend
Total suspended solids	2007-2017	No trend
Total phosphorus	2007-2011, 2014-2017	No trend
Nitrite/Nitrate	2007-2017	No trend

The MPCA completes annual trend analysis on lakes and streams across the state based on long-term transparency measurements. The data collection for this work relies heavily on volunteers across the state and also incorporates any agency and partner data submitted to EQuIS. Citizen volunteer monitoring occurs at three streams and one lake in the watershed. Water clarity data collected from Lake Hendricks has revealed a long-term trend in improving water clarity (MPCA 2018).

Statistical long-term trends in pollution concentration of water pollutants at 80 locations were analyzed to identify trends in Minnesota's water quality and reported in Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites (MPCA 2014d). The Lac qui Parle River Watershed was not included in this study due to not enough data; however, trends can be inferred from neighboring watersheds included in the study. The closest sites to the Lac qui Parle River include the Pomme de Terre River, Yellow Medicine River, and the Minnesota River at the Bridge on CSAH-21, three miles northeast of Delhi, Minnesota. The Minnesota River was included because it is the most upstream site on the Minnesota River and represents a summation of water conditions in its drainage area, including the Lac qui Parle River. **Table 9** shows the trends in five water quality parameters from the three sites.

Table 9. Water quality trends of the Pomme de Terre River, Yellow Medicine River, and Minnesota River (MPCA 2014d).

Parameter	Historical trend (1971-2009)	Recent trend (1995-2009)
Pomme de Terre (PT-10)		
Total suspended solids	no trend	-38%
Biochemical oxygen demand	-56%	no trend
Total phosphorus	-42%	no trend
Nitrite/Nitrate	+280%	no trend
Chloride	+89%	no trend
Yellow Medicine (YM-0.5)		
Total suspended solids	-52%	-83%
Biochemical oxygen demand	-56%	-53%
Total phosphorus	-63%	-57%
Nitrite/Nitrate	+29%	no trend
Chloride	+148%	no trend
Minnesota River (MI-212)		
Total suspended solids	-32%	-49%
Biochemical oxygen demand	no trend	no trend
Total phosphorus	-20%	-43%
Nitrite/Nitrate	no trend	-67%
Chloride	little data	little data

In general, decreasing trends can be seen in TSS, BOD, and TP. Increasing trends are seen in nitrate/nitrite and chloride. These trends are typical of what is seen throughout the state and should be similar to what is happening in the Lac qui Parle River Watershed.

The DNR conducted a trend analysis on the precipitation and hydrology in the watershed (DNR 2019). Results from that trend analysis are included in the Altered Hydrology section (**Section 2.3.3**). In general, a trend in precipitation totals appears to be insignificant; however, from 1941 through 1983 there was a declining trend in precipitation, and from 1984 through 2015 there has been an increasing trend. For streamflow volumes, annual total stream volumes have increased significantly since 1992, averaging 112,926 acre-ft per year for 1965 through 1991, to 216,616 acre-ft per year for 1992 through 2018. Further discussion on the changes in hydrology are discussed in **Section 2.3.3**.

2.3 Identified Pollutants and Stressors

This section discusses identified pollutants and stressors individually, and in detail. Discussions include: the assessments (MPCA 2018) and/or SID (MPCA 2020b) of each identified pollutant/stressor, the sources or causes of the pollutant/stressor, what areas may be contributing higher amounts of the pollutant/stressor, and the amount of pollutant/stressor reduction needed to meet water quality goals.

The following further details each stressor and pollutant source, describing and/or illustrating:

- **Status**: the streams and lakes known to be impacted, not impacted, or where more information is needed for the given pollutant and/or stressor;
- **Sources**: a detailed source assessment for the watershed; and
- **Goals and Targets**: estimated reduction or improvements needed to meet water quality standards and goals in order to protect or restore waterbodies in and downstream of Lac qui Parle River Watershed.

Refer to **Section 1.3** (Assessing Water Quality) for a summary of how waterbodies are monitored and assessed, the SID process, and the difference between a pollutant and stressor.

2.3.1 Habitat

Habitat is a broad term encompassing all aspects of the physical, chemical, and biological conditions needed to support a biological community. Degraded habitat reduces the amount of suitable habitat needed for all aspects of aquatic life: feeding, shelter, reproduction, etc. This report refers to habitat as physical stream habitat.

Poor, or lack of, habitat is a stressor of the physical habitat structure including geomorphic characteristics and vegetative features (Griffith et al. 2010). Habitat is only investigated as a stressor when a biological impairment is identified. Physical habitat is often interrelated to other stressors (e.g., sediment, flow, DO). Poor habitat can be the result of many kinds of disturbance. Specific habitats that are required by a healthy biotic community can be minimized or altered by practices on the landscape by way of resource extraction, agriculture, urbanization, and industry. These landscape alterations can lead to reduced habitat availability such as decreased riffle habitat, or reduced habitat quality such as embedded gravel substrates. Biotic population changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (Griffith et al. 2010).

The MPCA Stream Habitat Assessment (MSHA; MPCA 2017b) is used to score habitat. The assessment considers floodplain, riparian, instream, and channel morphology attributes. The MSHA scores above 66 are "good"; scores between 45 and 66 are fair, and scores below 45 are poor. The MSHA score is an important factor used to assess if degraded habitat is a stressor to biological impaired streams.

2.3.1.1 Status

Of the biologically impaired stream reaches, degraded habitat was identified as a stressor in 22 and inconclusive in 5. The SID evaluation of habitat results are tabulated in **Table 10** and shown in **Figure 15** with the MSHA scores. Red indicates a stressor (habitat is problematic in that reach), and yellow indicates habitat is inconclusive as a stressor (more data is needed to determine if habitat is problematic in that reach).

Table 10. SID results for loss of habitat as a stressor in the stream reaches of the Lac qui Parle River Watershed.

Stream, Reach description	AUID (Last 3 digits)	Loss of Habitat	Stream, Reach description	AUID (Last 3 digits)	Loss of Habitat	Stream, Reach description	AUID (Last 3 digits)	Loss of Habitat
Lac qui Parle River	501	X	Crow Timber Creek	520	X	Unnamed ditch	571	X
Lac qui Parle River	505	X	Florida Creek	521	X	Unnamed ditch	575	X
Lazarus Creek	508	X	County Ditch 34	526	X	Tenmile Creek	577	X
Lazarus Creek	509	X	Unnamed Creek	530	?	Tenmile Creek	578	?
West Branch Lac qui Parle River	513	?	Unnamed Creek	534	X	Unnamed Creek	580	X
West Branch Lac qui Parle River	515	X	Canby Creek	557	?	Unnamed ditch (CD 4)	582	X
West Branch Lac qui Parle River	516	X	Unnamed Creek	567	X	Cobb Creek	583	X
Lost Creek	517	X	Unnamed Creek	569	X	Canby Creek	586	X
West Branch Lac qui Parle River	519	X	Unnamed ditch	570	X	Unnamed Creek	588	?

X	Impaired/Exceeds/Stressor
?	Insufficient Data/Inconclusive

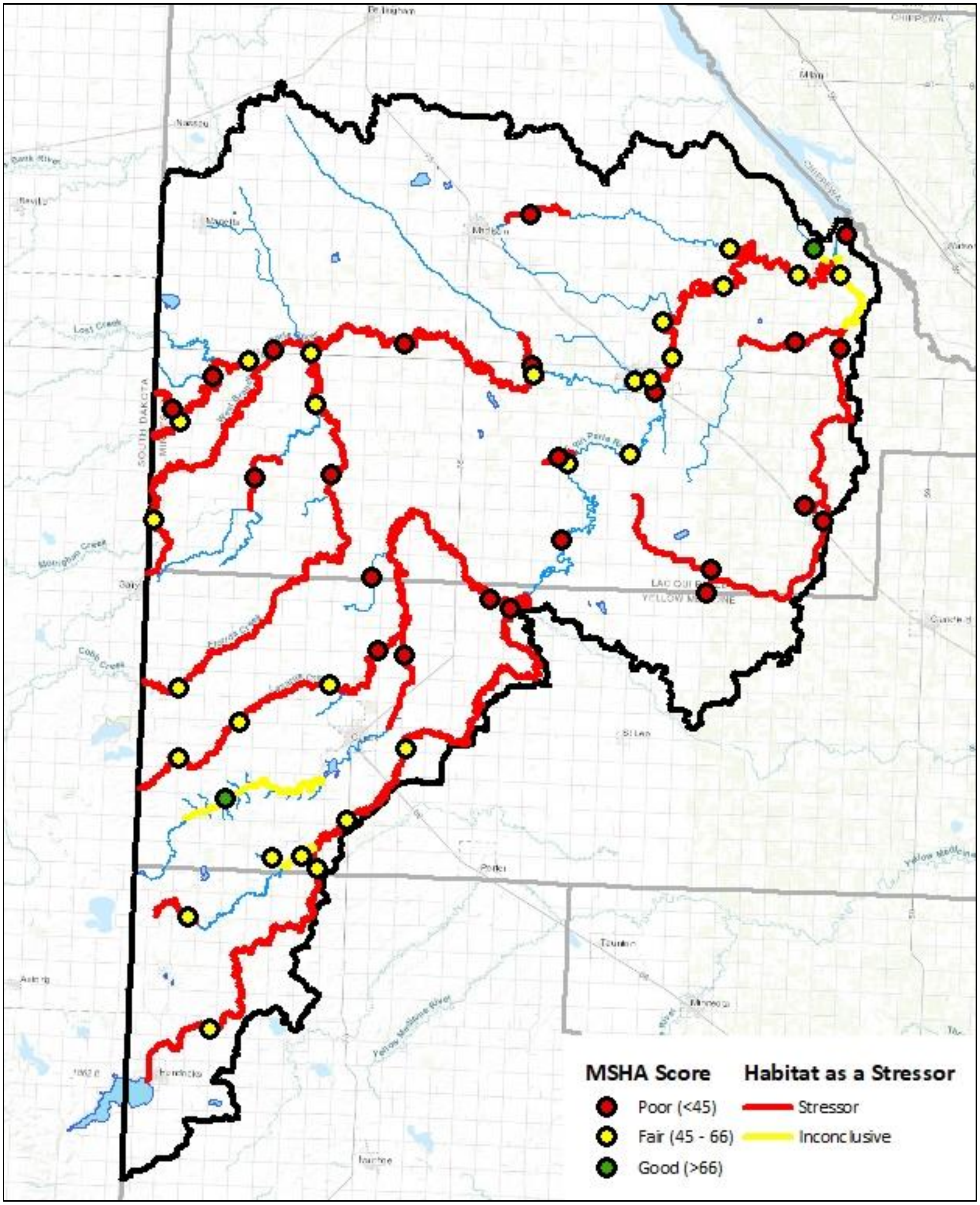


Figure 15. Loss of habitat as a stressor, status of streams in the Lac qui Parle River Watershed.

2.3.1.2 Sources

The identified physical habitat issues (**Table 11**) show a complex, interconnected set of factors that are driven primarily by a couple stressors. Excessive sedimentation and/or channel instability were identified in all 22 streams (**Table 11**); additional issues such as limited depth variability and sparse in-stream cover are closely related to channel instability and sediment issues. These stressors are primarily the result of altered hydrology, which causes bank instability and increased channel migration, which then chokes streams with the excess sediment, limiting or eliminating necessary habitat. A minimal or degraded riparian zone and/or poor surrounding land use was identified for all 22 habitat-impaired streams; additional issues including lack of shading are closely related to land use and riparian buffer issues. Riparian areas can be damaged by the effects of altered hydrology which often causes excessive bank erosion or can be damaged by changing the natural vegetation (typically forest or prairie) to a different land use. In summary, most of the habitat problems are driven by altered hydrology and poor riparian land uses.

Table 11. The identified problems with physical habitat identified in the Lac qui Parle River Watershed Stressor ID Report (MPCA 2020b).

Stream AUID (last 3-digit)	Identified physical habitat issues
Canby Creek (586)	A lack of channel development and severe embeddedness of fine substrates.
Cobb Creek (583)	No riffles, no pools, no coarse substrates, and bank erosion.
County Ditch 34 (526)	Moderate to severe embeddedness, small buffer causing erosion.
Crow Timber Creek (520)	Heavy streambank erosion and embeddedness of coarse material.
Florida Creek (521)	Heavy erosion, a lack of depth variability and channel development, and embeddedness of fine substrates.
Lac qui Parle River (505)	Lack of depth variability and a lateral riffle, fine and coarse embedded sediment.
Lazarus Creek (508)	Unstable system with a high sediment supply, bank slumping, channel widening, mid channel deposition, and riffles choked with sediment.
Lazarus Creek (509)	No depth variability and bank erosion, lacked a riparian buffer.
Lost Creek (517)	Heavy streambank erosion and embeddedness of coarse material.
Tenmile Creek (577)	Moderate to severe embeddedness, entrenched, dominated by silt, lacking riffle and pool stream features, no floodplain connectivity, and poor stability.
Tenmile Creek (578)	Erosion, moderate to severe embeddedness, deeply incised, without access to its floodplain, but dominated by gravel substrate with riffles and deep pools present.
Unnamed Creek (534)	Erosion or excess sedimentation, moderate to severe embeddedness.
Unnamed Creek (567)	Heavy streambank erosion and embeddedness of coarse material.
Unnamed Creek (569)	Lack of depth variability and channel development, and embeddedness of fine substrates.
Unnamed Creek (580)	Moderate embeddedness of fine sediment, with silt being the only substrate found. Depth variability and channel development were both lacking, and no riffles were present.
Unnamed ditch (570)	Moderate to severe embeddedness.
Unnamed ditch (575)	Lacked shade, cover for fish, depth variability and channel development and had moderate embeddedness of coarse substrates with fine sediments.
Unnamed ditch (CD 4) (582)	Eroding banks and over widened riffles.

Stream AUID (last 3-digit)	Identified physical habitat issues
West Branch Lac qui Parle River (516)	Lack of depth variability, channel development, and embeddedness of coarse substrates with fine substrates.
West Branch Lac qui Parle River (519)	Bank trampling, heavy erosion, and a lack of cover for fish and macroinvertebrates.

2.3.1.3 Goal and 10-year Target

Currently, the 49 MSHA scores in the watershed range from 7.0 to 71.75, with an average of 42.7 (MPCA 2018). Scores tended to be fair to poor, with a good score at some sites. The target for habitat is for the average MSHA score in the watershed to be greater than 66 ("good"). This goal represents a 54% increase in the average MSHA score. The 10-year target is a 15% increase in the MSHA score. Since scores are mostly due to surrounding land use, altered hydrology and degraded riparian zones, these stressors should be addressed to meet the 10-year target. These goals are revisable and will be revisited in the One Watershed, One Plan development and the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address habitat are summarized in **Section 3**.

2.3.2 Phosphorus/Eutrophication

Phosphorus (P) is an essential nutrient for plants, animals, and humans. It is also a common element in agricultural fertilizers, manure, and organic wastes in sewage and industrial discharges. Phosphorus is the nutrient primarily responsible for eutrophication in surface waters in Minnesota. Excess phosphorus in lakes, rivers, and streams causes excessive algae to grow. Algae-covered water is less attractive for fishing and swimming and degrades conditions necessary for fish, macroinvertebrates, wildlife, and plants to thrive. Excessive phosphorus impacts AqL by changing food chain dynamics, impacting fish growth and development, increasing algal growth, and decreasing DO within a waterbody when algae die and decompose.

Excessive phosphorus also impacts AqR in lakes by fueling algal growth and eutrophication, making water undesirable, and sometimes dangerous for humans and pets to swim in due to potential presence of toxic blue-green algae.

Phosphorus in water exists in two main forms: dissolved (soluble) and particulate (attached to or a component of particulate matter). Orthophosphorus is the primary dissolved form of phosphorus and is readily available to algae and aquatic plants. Particulate phosphorus can change from one form to another (called cycling) in response to a variety of environmental conditions. A portion of particulate phosphorus is contained in organic matter such as algae, plant and animal tissue, waste solids, or other organic matter. Microbial decomposition of organic compounds can convert organic particulate P to dissolved P. Some of the P in soil mineral particles can also be converted to dissolved P both in the water column and during chemical and physical changes in bottom sediment. Because phosphorus changes form, most scientists measure TP.

High phosphorus conditions alone do not necessitate its identification as a pollutant or stressor: eutrophic response conditions must also be observed. Because of this, some waterbodies may have high phosphorus concentrations but are not identified as impaired or stressed. In these cases, reducing phosphorus is still typically necessary to support downstream goals.

2.3.2.1 Status

According to the SID report, elevated phosphorus, algal growth, DO fluctuations, and the preponderance of biological metric response indicate eutrophication is a stressor in 18 reaches, inconclusive in 9, and no streams have phosphorus ruled out. Of the 30 stream reaches that were assessed for river eutrophication, 0 were full supporting, 30 were inconclusive, and 0 were impaired. Of the lakes assessed, 1 was impaired, 1 was supporting, and 17 had insufficient information for assessment. **Figure 16** shows the status of stream reaches and lakes that were assessed for phosphorus. The results for the pollutant assessment overlay the results for the stressor assessment, with the pollutant results shown on the inside and stressor results shown around the outside. **Table 12** tabulates the stream status and **Table 13** tabulates the lake status.

In addition to the streams and lakes above, Lac qui Parle River drains into Lac qui Parle Lake -SE Bay (37-0046-01), which is impaired by excessive nutrients (phosphorus). The Lac qui Parle River is considered a contributing source of phosphorus to Lac qui Parle Lake. The Lac qui Parle River accounts for 19% of the TP load to the lake. From the Lac qui Parle River load, 79% comes from Minnesota's portion of the watershed (MPCA 2021b).

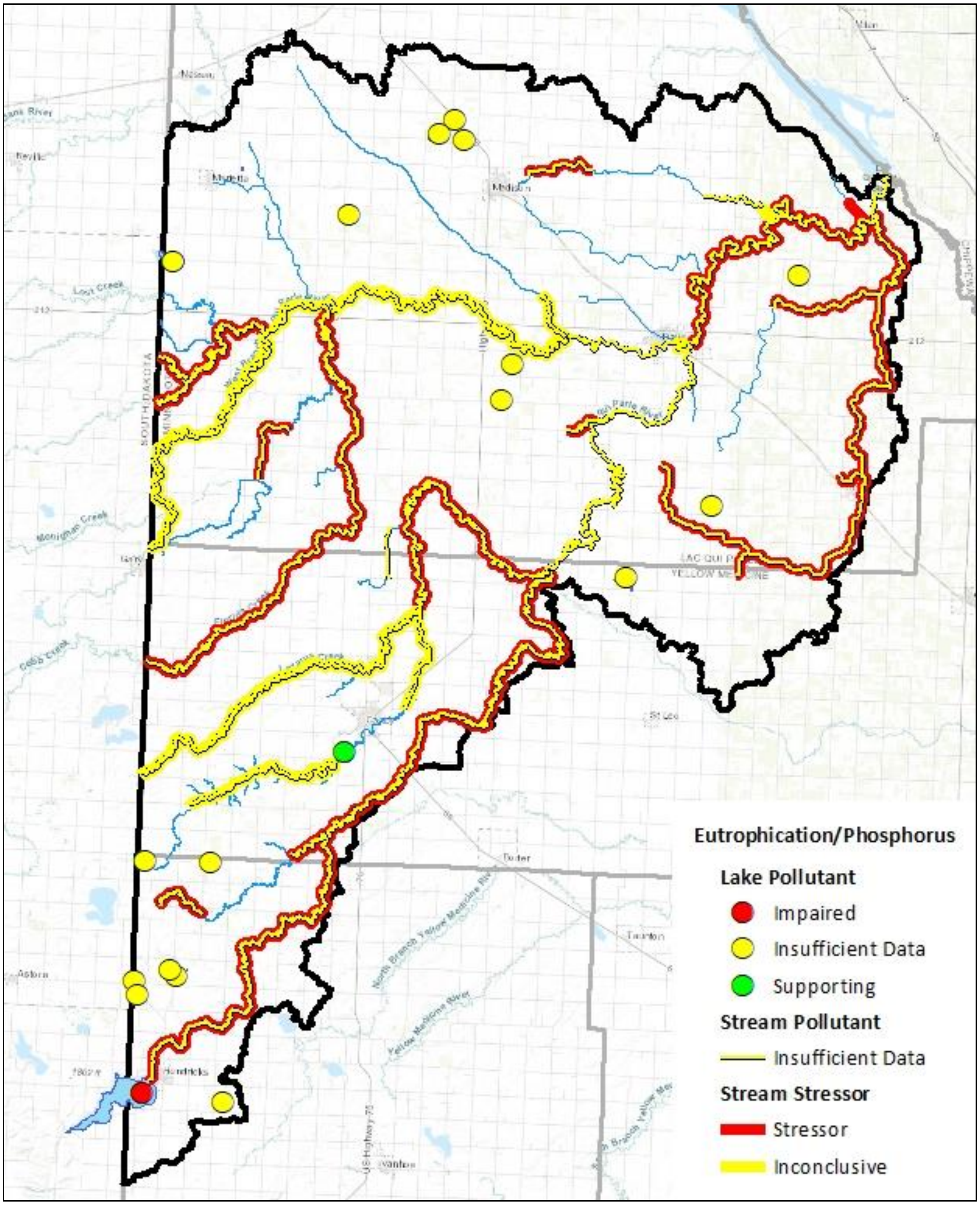


Figure 16. Phosphorus assessment and stressor identification status of streams in the Lac qui Parle River Watershed.

Table 12. Assessment and stressor identification results for phosphorus as a pollutant or stressor in stream reaches in the Lac qui Parle River Watershed.

Stream, Reach description	AUID (Last 3 digits)	Eutrophication, as a Pollutant	Eutrophication, as a Stressor	Stream, Reach description	AUID (Last 3 digits)	Eutrophication, as a Pollutant	Eutrophication, as a Stressor
Lac qui Parle River	501	?	X	Unnamed Creek	534	?	X
Lac qui Parle River	502	?		Canby Creek	557	?	?
Lac qui Parle River	505	?	X	Judicial Ditch 1	560	?	
Lac qui Parle River	506	?		Unnamed Creek	567	?	X
Lazarus Creek	508	?	X	Unnamed Creek	569	?	X
Lazarus Creek	509	?	?	Unnamed ditch	570	?	X
West Branch Lac qui Parle River	512	?		Unnamed ditch	571	?	X
West Branch Lac qui Parle River	513	?	?	Unnamed ditch	575	?	X
West Branch Lac qui Parle River	515	?	?	Tenmile Creek	577	?	X
West Branch Lac qui Parle River	516	?	?	Tenmile Creek	578	?	X
Lost Creek	517	?	X	Unnamed Creek	580	?	?
West Branch Lac qui Parle River	519	?	?	Unnamed ditch	581	?	
Crow Timber Creek	520	?	X	Unnamed ditch	582		?
Florida Creek	521	?	X	Cobb Creek	583	?	X
County Ditch 34	526	?	X	Canby Creek	586	?	?
Unnamed Creek	530	?	X	Unnamed Creek	588		X

Table 13. Assessment results for phosphorus as a pollutant in lakes in the Lac qui Parle River Watershed.

Lake ID	Lake	Aquatic recreation	Lake ID	Lake	Aquatic recreation
37-0026-01	Andrew	?	41-0102-00	West Twin	?
37-0056-00	Unnamed	?	41-0108-00	East Twin	?
37-0100-00	Unnamed	?	41-0109-00	Unnamed	?
37-0103-00	Cory	?	41-0110-00	Hendricks	X
37-0107-00	Unnamed (Madixon WMA)	?	41-0115-00	Unnamed	?
37-0134-02	Unnamed-Southwest Portion	?	41-0116-00	Unnamed	?
37-0148-00	Unnamed (Arena)	?	41-0142-00	Unnamed	?
37-0154-00	Unnamed	?	87-0102-00	Miller	?
37-0229-00	Salt	?	87-0180-00	Del Clark	+
41-0095-00	Kvernmo Marsh	?			

+	Supporting/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
<blank>	Not Assessed

The Lac qui Parle River Watershed has a phosphorus flow weighted mean concentrations (FWMC) that is several times higher than watersheds in north central and northeast Minnesota, but a FWMC that is in-line with the agriculturally rich watersheds found in the corn-belt region (northwest to southern regions) of the state, as shown by WPLMN monitoring data (**Figure 17**).

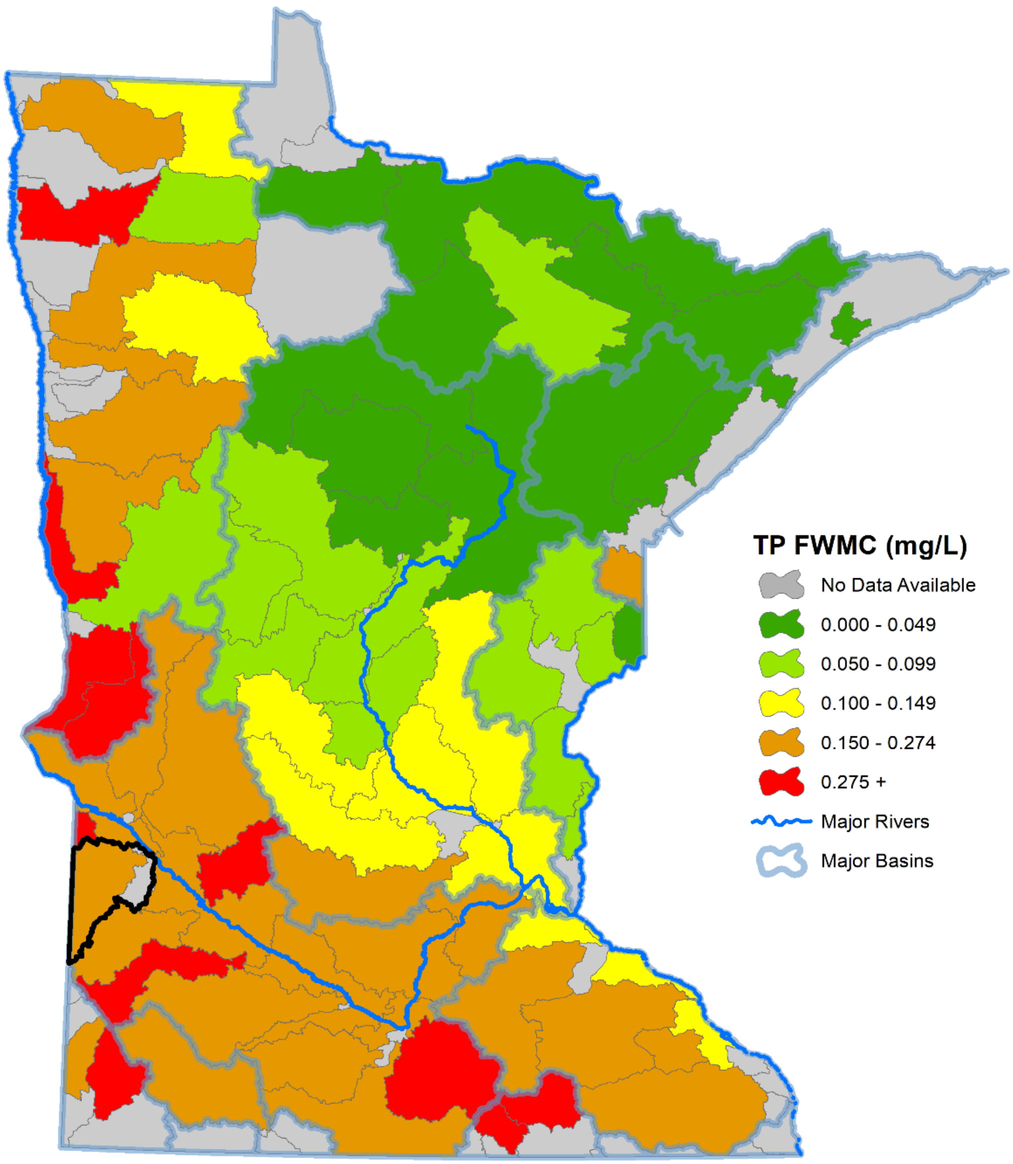


Figure 17. A statewide perspective of phosphorus flow weighted mean concentration for the Lac qui Parle River Watershed using WPLMN monitoring data.

2.3.2.2 Sources

Phosphorus sources are dominated by nonpoint sources in the Lac qui River Watershed. Average annual point source contributions for the years of 1996 through 2017 are estimated at approximately 1.0% of the Lac qui Parle River Watershed's phosphorus load, based on the HSPF model, with the rest derived from nonpoint sources**.** Annual loads from point sources are provided in **Figure 18** from 2000 to 2020. **Figure 19** provides average annual source load estimates (by land use and pathways) as determined by the HSPF model. High-till and low-till cropland are the dominant sources of phosphorus in the watershed followed by developed, forest/scrubland and pasture.

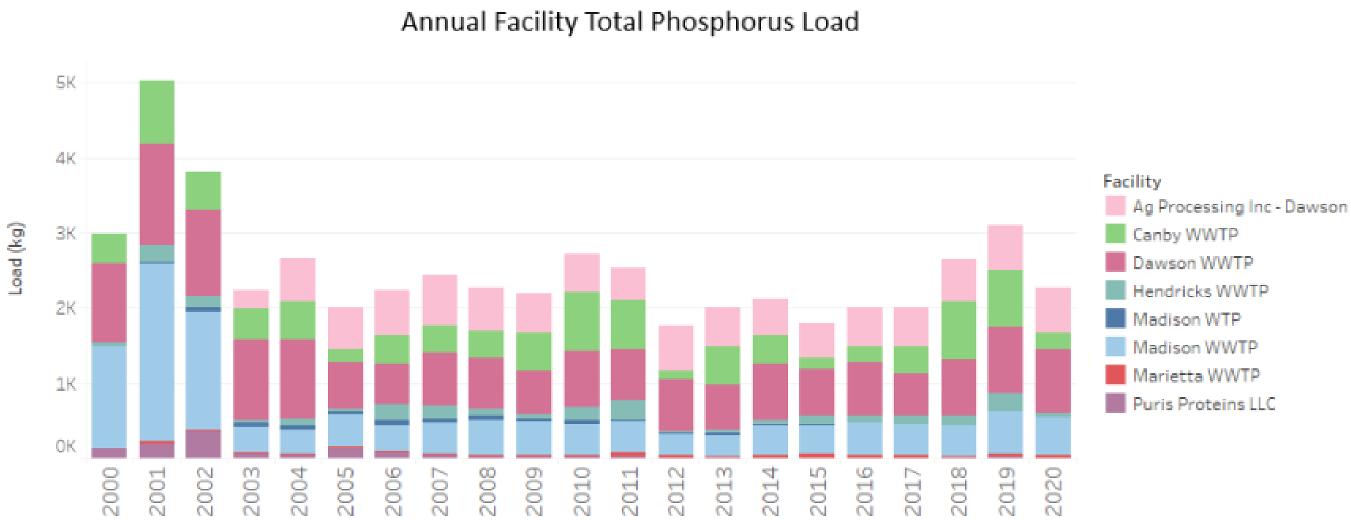


Figure 18. Annual facility total phosphorus load. Observed and estimated total phosphorus loads (kg) annually by permitted facilities in the Lac qui Parle River Watershed from 2000 - 2020.

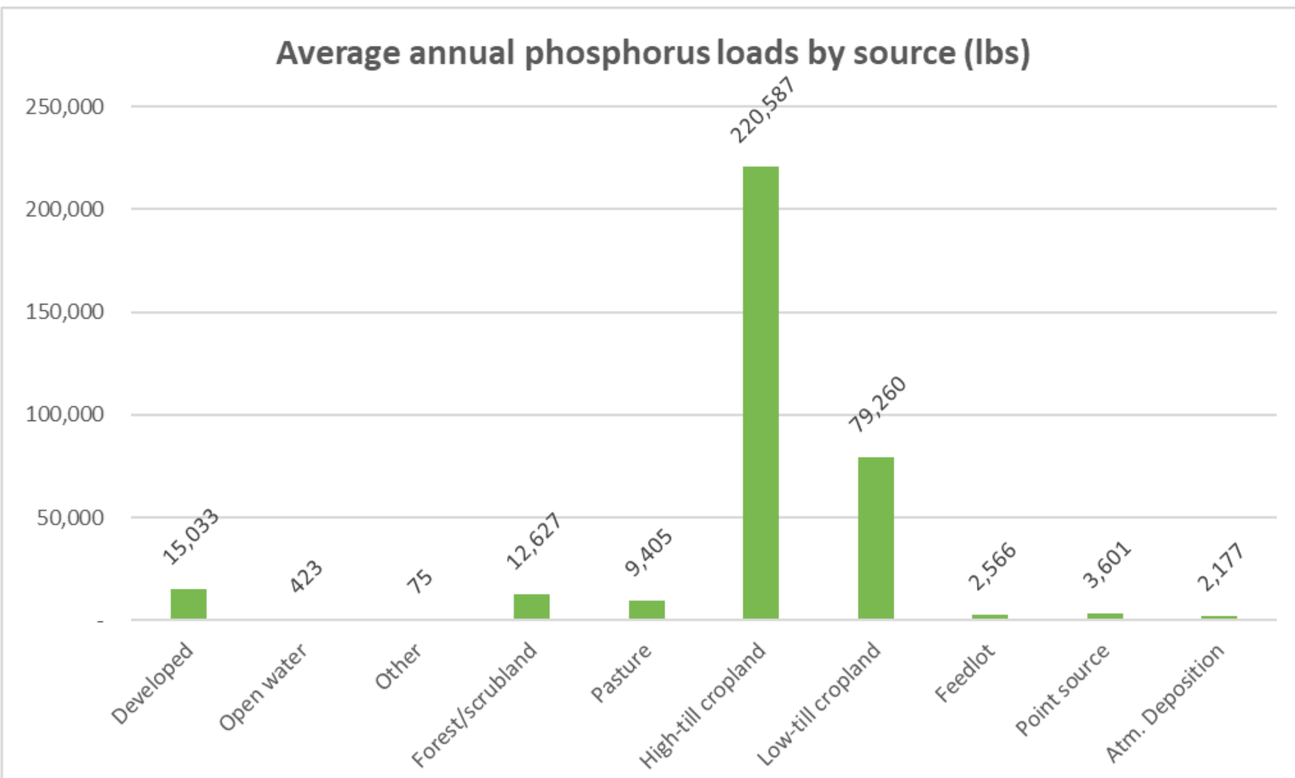


Figure 19. Phosphorus source assessment in the Lac qui Parle River at the outlet of the watershed, based on HSPF model results.

Figure 20 provides the average annual FWMC for phosphorus in the subwatersheds in the Lac qui Parle River Watershed. The FWMC of phosphorus ranges from 0.052 mg/L to 0.449 mg/L. Tenmile Creek, County Ditch 27, County Ditch 4, and County Ditch 29a show the highest phosphorus FWMCs.

Internal phosphorus loads in lakes are not explicitly accounted for in the source assessment. Internal loads are a product of excessive, legacy phosphorus contributions from a lake's watershed, and little of the internal load is natural. When planning for lake restoration, however, knowing the magnitude of internal load is important in developing the specific strategies to address the impairment. Planners should consult the TMDL or additional lake modeling or studies to estimate internal load accordingly.

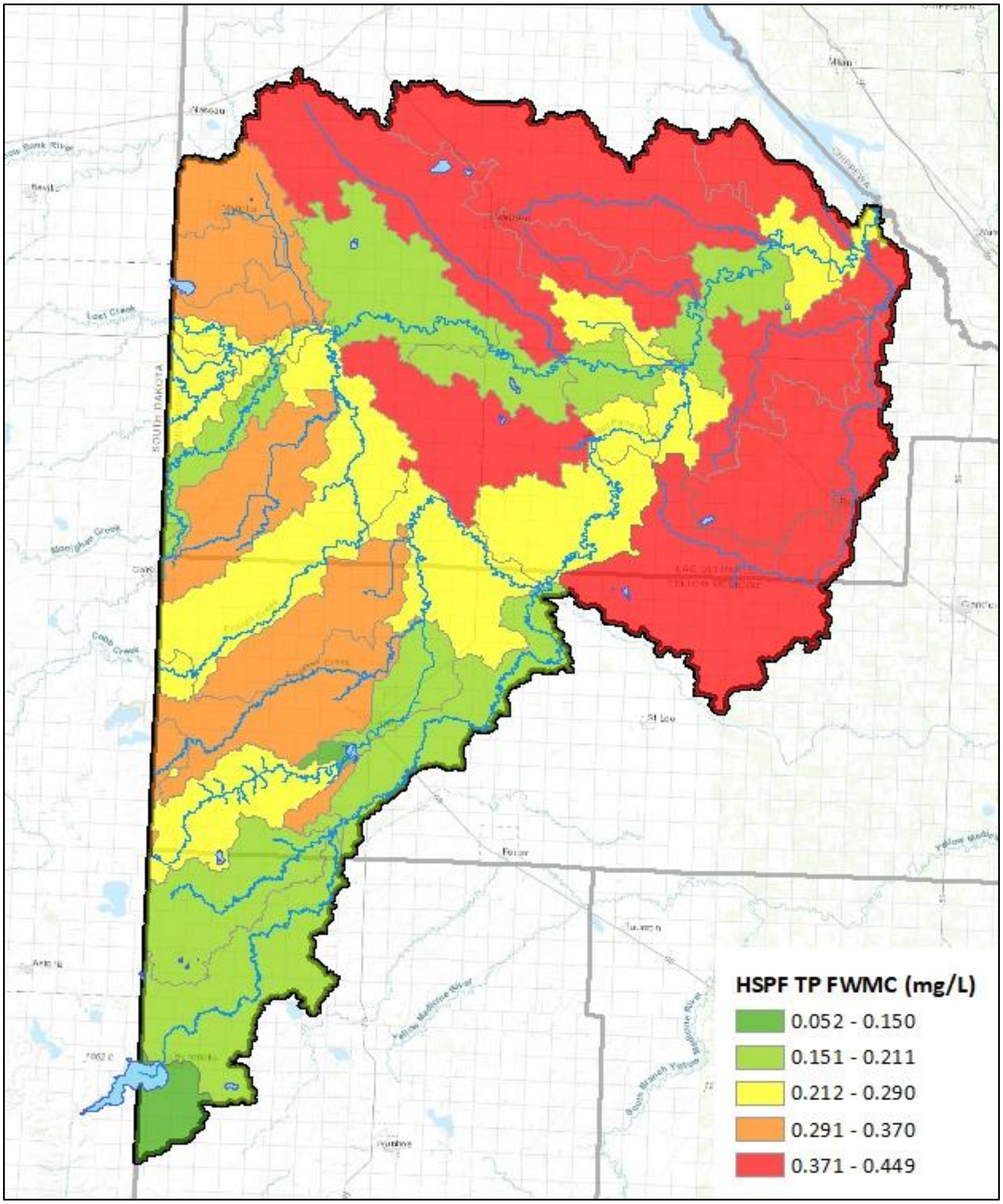


Figure 20. Average annual flow-weighted mean concentrations of TP in the Lac qui Parle River Watershed based on the HSPF model results.

2.3.2.3 Goal and 10-year Target

Lac qui Parle Lake-SE Bay (32-0057-01) has a phosphorus load reduction goal of 35% based on reducing inputs from the Lac qui Parle River. Lake Hendricks has a reduction goal of 50%, but only covers a small portion of the southern tip of the watershed. The statewide goal based on the Minnesota Nutrient Reduction Strategy (NRS; MPCA 2014b), calls for a 45% load reduction (with an interim 20% reduction by 2025) in the Mississippi River Basin, which includes the Minnesota River Basin. Of the load reduction called for in the NRS, a 33% reduction has already been achieved in the Mississippi River Basin, with a 12% load reduction remaining. The watershed-wide load reduction goal for the Lac qui Parle River Watershed will follow the more restrictive goal of 35% for Lac qui Parle Lake-South East Bay. The reaches not stressed by phosphorus have a protection goal. **Figure 21** provides the subwatershed reduction goals, based on the HSPF results and meeting a FWMC TP concentration of 0.150 mg/L.

The 10-year target is a 10% decrease in phosphorus load. These goals are revisable and will be revisited in the One Watershed, One Plan development and the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for phosphorus reductions are summarized in **Section 3**.

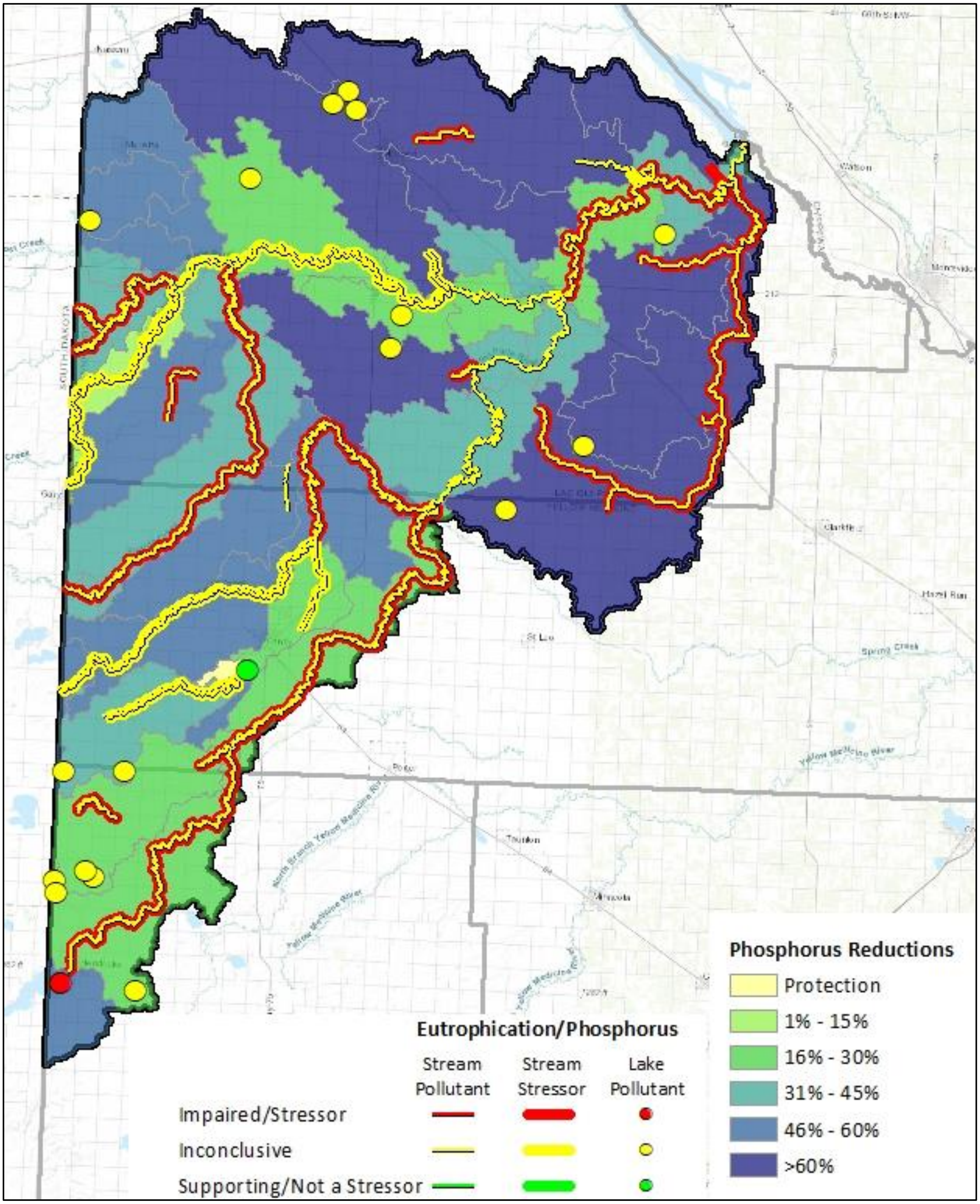


Figure 21. Total Phosphorus reduction goals in the Lac qui Parle River Watershed.

2.3.3 Altered Hydrology

Altered hydrology can directly harm AqL by affecting the amount of water in the stream; both too little and too much stream flow impact AqL. Furthermore, altered hydrology accelerates the movement and amount of other pollutants and stressors (nutrients, sediment, etc.) reaching waterbodies.

2.3.3.1 Status

Altered hydrology was assessed in biologically-impaired stream reaches (MPCA 2020b) as flow alteration. Flow alteration was identified in 17 stream reaches as a stressor, 7 had flow alteration ruled out as a stressor, and 3 were inconclusive based on available data. **Table 14** provides the assessments for flow alteration as a stressor and **Figure 22** shows the location of the streams. In the streams where flow alteration was identified as a stressor, excessive/peak streamflow, low/absent streamflow, and channelization were found to be directly impacting the bio-impaired streams.

Altered hydrology is only investigated when a biological impairment is identified, but the sources of altered hydrology (discussed later in this section) are common across the watershed. Therefore, altered hydrology is likely negatively impacting water quality watershed-wide, despite being identified as a stressor in only select locations.

Table 14. Assessment results for altered hydrology as a stressor in the Lac qui Parle River Watershed (MPCA 2020b).

Stream, Reach description	**AUID (Last 3 digits)**	Flow Alteration	Stream, Reach description	AUID (Last 3 digits)	Flow Alteration	Stream, Reach description	AUID (Last 3 digits)	Flow Alteration
Lac qui Parle River	501	+	Crow Timber Creek	520	+	Unnamed ditch	571	X
Lac qui Parle River	505	X	Florida Creek	521	X	Unnamed ditch	575	X
Lazarus Creek	508	X	County Ditch 34	526	X	Tenmile Creek	577	X
Lazarus Creek	509	X	Unnamed Creek	530	+	Tenmile Creek	578	X
West Branch Lac qui Parle River	513	?	Unnamed Creek	534	X	Unnamed Creek	580	X
West Branch Lac qui Parle River	515	?	Canby Creek	557	X	Unnamed ditch (CD 4)	582	X
West Branch Lac qui Parle River	516	+	Unnamed Creek	567	+	Cobb Creek	583	X
Lost Creek	517	+	Unnamed Creek	569	?	Canby Creek	586	X
West Branch Lac qui Parle River	519	+	Unnamed ditch	570	X	Unnamed Creek	588	X

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor

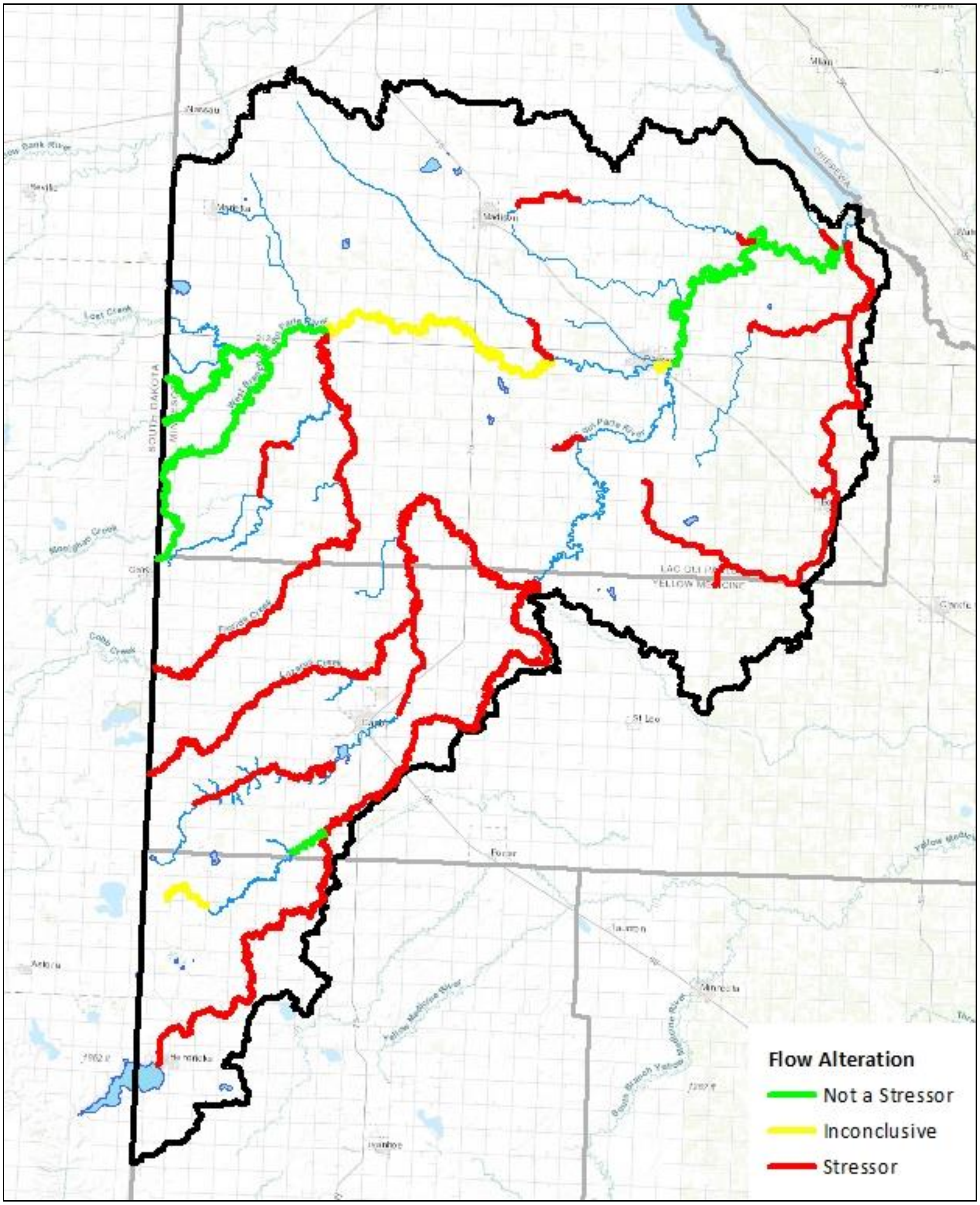


Figure 22. Flow alteration as a stressor status of biologically impaired streams in the Lac qui Parle River Watershed.

2.3.3.2 Sources

Hydrology is the study of the amount of water and way that water moves through the landscape. Streamflow in Minnesota (Novotny & Stefan 2007) and across the contiguous United States (Lins and Slack 1999, McCabe, and Wolock 2002) has been changing during the past century, with flows in the period starting from the 1970s to the beginning of the 21st century tending to be higher than during the early to mid-1900s (Ryberg et al. 2014). In general, the leading candidate causes of altered hydrology can be categorized into two primary groups: climatic changes and landscape changes. Examples of climatic changes include changes in annual precipitation volumes, surface air temperature, timing of the spring snowmelt, annual distribution of precipitation, and rainfall characteristics (timing, duration, and intensity). Examples of landscape changes include changes in land use/land cover, increased imperviousness (urbanization), subsurface (tile) and surface drainage, wetland removal/restoration, groundwater pumping, flow retention and regulation, and increased storage (both in-channel and upland).

In the Lac qui Parle River Watershed, there are several causes of altered hydrology. These causes include both landscape and climate changes, ranging from crop and vegetative changes to soil and drainage changes. This subsection discusses the various causes of altered hydrology and the pathways in which water travels from the land to waterbodies. This information is necessary to inform how to mitigate the negative impacts of altered hydrology.

SID (MPCA 2020b) analyzed specific altered hydrology issues of the biologically impaired stream reaches in the Lac qui Parle River Watershed (see **Table 15**) following EPA's developed methods. The issues analyzed for flow alteration were channelization, tile drainage, and increased flows and variability in flows. Channelization and tile drainage alter the natural flow regime by moving water through the system at a higher velocity, increasing the impact of high flow events and increasing the magnitude of low flow periods, both of which affect biological communities. Increased flow events can cause increased bank erosion and bedload sedimentation, affecting fish species that rely on clean substrate for habitat. Low flow periods that are below normal baseflow affect AqL by decreasing habitat and increasing competition for resources. Additional information about stressor determinations can be found in the Lac qui Parle River Watershed Stressor ID Report (MPCA 2020b).

Table 15. The specific sources of altered hydrology identified in the Stressor Identification Report (MPCA 2020b).

Stream	AUID (last 3-digits)	Flow Alteration		
		Channelization	Tile Drainage/ Land Use	Increased Flows/Variability in Flows
Lac qui Parle River	505	X		X
Lazarus Creek	508	X	X	X
Lazarus Creek	509	X	X	X
Florida Creek	521	X	X	X
County Ditch 34	526	X	X	X
Unnamed Creek	534	X	X	X
Canby Creek	557	X	X	X
Unnamed ditch	570	X	X	X
Unnamed ditch	571	X	X	X
Unnamed ditch	575	X	X	X
Tenmile Creek	577	X	X	X
Tenmile Creek	578	X	X	X
Unnamed Creek	580		X	X
Unnamed ditch (CD 4)	582		X	X

Stream	AUID (last 3-digits)	Flow Alteration		
		Channelization	Tile Drainage/ Land Use	Increased Flows/Variability in Flows
Cobb Creek	583	X	X	X
Canby Creek	586	X	X	X
Unnamed Creek	588		X	X

Changing streamflow

An ecological streamflow analysis was conducted on the USGS gaging station (USGS# 05300000) in the Lac qui Parle River near Lac qui Parle, Minnesota, using principles laid out in Protecting Aquatic Life from Effects of Hydrologic Alteration (Novak et al. 2016). Detailed discussion of the streamflow analysis can be found in **Appendix 5.2**. The analysis was conducted to determine what flow characteristics are altered. To quantify the change in streamflow, a benchmark (historic) condition (1965 through 1991) was established, based on a change in the slope of a cumulative streamflow for the period of record (see **Appendix 5.2** for further details), compared to modern streamflow conditions (1992 through 2018). Although data exists prior to 1965, the analysis limited the data period to equal intervals to limit any statistical bias due to differing sample sizes. A minimum of a 20-year period reasonably ensures stable estimates of streamflow predictivity (Gan et al 1991; Olden & Poff 2003), and sufficient duration to capture climate variability and interdecadal oscillations found in climate (McCabe et al. 2004, Novotny and Stefan 2007).

Figure 23 shows the change in the flow duration curves (FDCs) between the two periods. The flow duration curve plots daily average flows against the rate of exceedance (i.e. return period). For example, flows with a 10% exceedance rate on any given day are considered high flows. In Minnesota, these flows are associated with the spring snowmelt or large rainfall events. At the other end of the flow spectrum, Flows with a 90% or greater exceedance rate are considered low flows, mostly occurring during drier periods or during the winter months when water cannot easily flow to the river.

As seen in **Figure 23**, flows across the entire flow spectrum have increased between the two periods. The change in shape of the flow curves can also indicate potential changes occurring in the watershed. The modern period shows that the very largest (peak) flows have stayed relatively unchanged while high, mid-range, and low flows have increased significantly, causing a flattening of the curve.

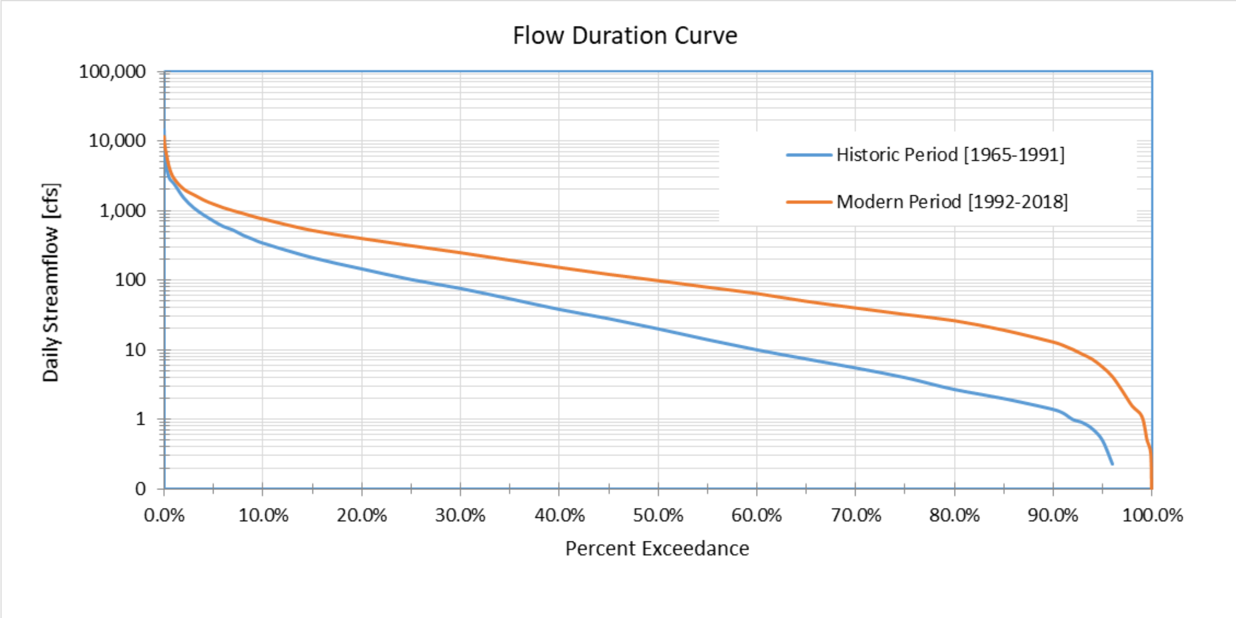


Figure 23. Flow duration curve. This flow duration curve is for Lac qui Parle River near Lac qui Parle River, MN (USGS# 05300000) and compares two periods, a "historic" benchmark condition (1965-1991) and the modern condition (1992-2018).

Figure 24 shows the average monthly flow volumes for each period, as acre-feet per month. Flows have increased across all months, which confirms the upward shift shown in the flow duration curve (**Figure 23**).

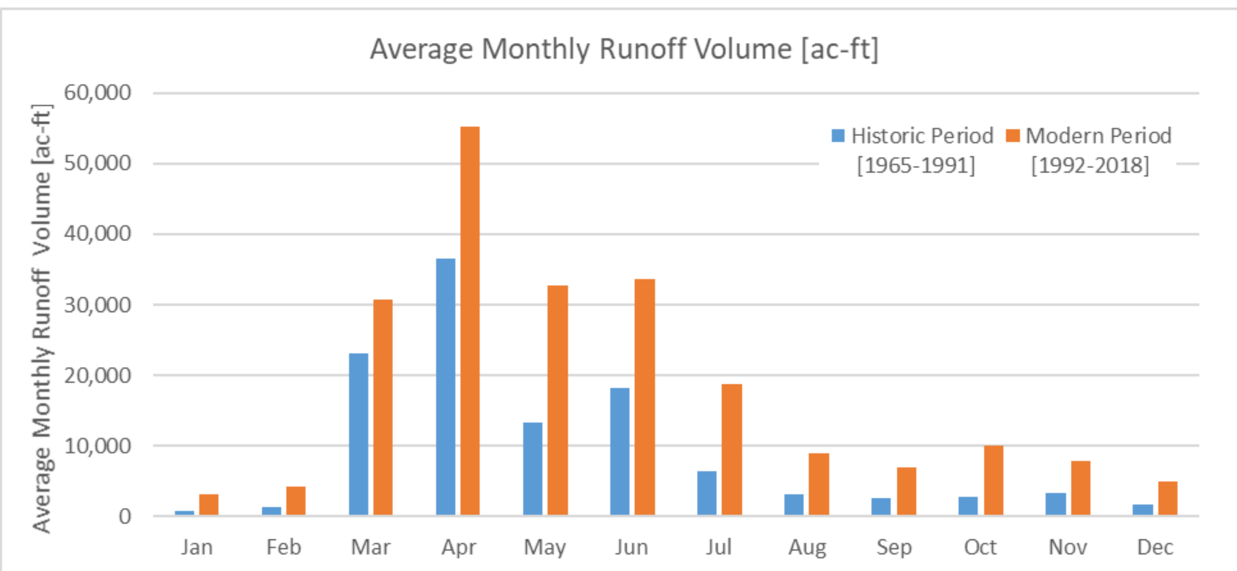


Figure 24. Average monthly flow volumes. The average monthly flow volumes (acre-ft/month) for Lac qui Parle River near Lac qui Parle River, MN (USGS# 05300000), compares two periods, a "historic" benchmark condition (1965-1991) and the "modern" condition (1992-2018).

The distribution of monthly flow volumes as a percentage of average annual flow is shown in **Figure 25.** While the relative contribution of flows in the fall and winter months have increased due to higher precipitation, land use changes, and drainage, the spring and early summer months still exhibit the vast majority of the annual flow (**Figure 24**). Stabilizing the hydrology of the Lac qui Parle River Watershed requires employing practices that will hold back some of the spring and early summer runoff and metering it out at a more gradual rate. See **Section 3.3** for more information on these practices.

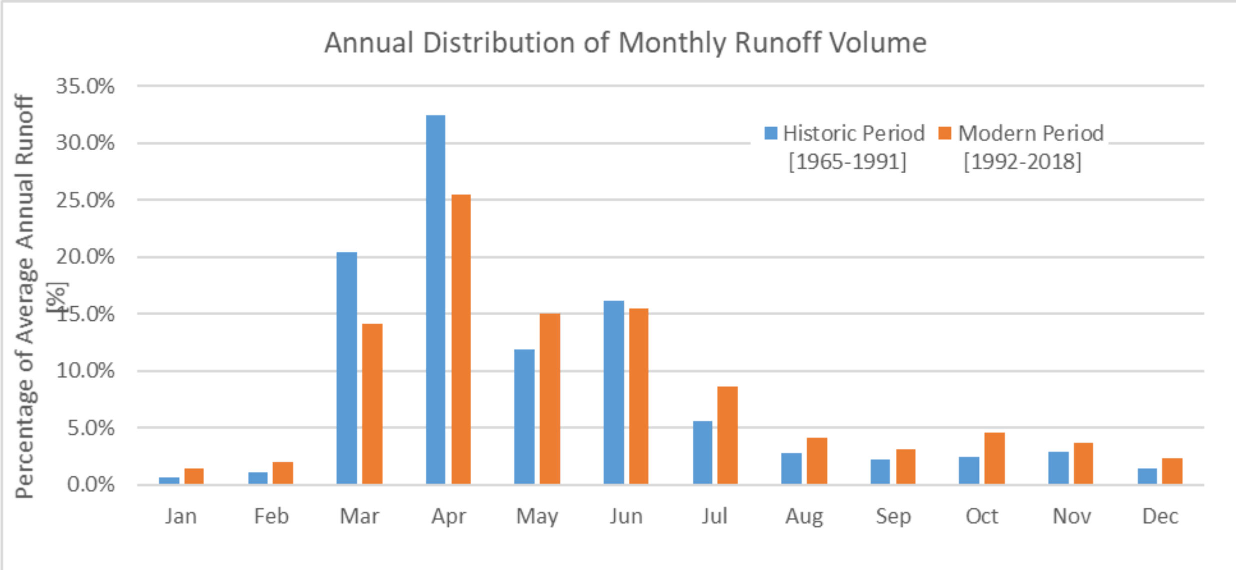


Figure 25. Average monthly flow distribution. The average monthly flow distribution is presented as a percentage of annual flow for Lac qui Parle River near Lac qui Parle River, MN (USGS# 05300000), comparing two periods, a "historic" benchmark condition (1965-1991) and the "modern" condition (1992-2018).

The long-term daily flow record was used to determine the changes in streamflow metrics between two periods: a "historic" benchmark period (1965 through 1991) and the "modern" period (1992 through 2018). The relative changes in select flow metrics are provided in **Table 16**. The results are consistent with what is occurring in neighboring streams. A full description of the metrics and methods used to conduct the analysis can be found in **Appendix 5.2**.

The structure and therefore function of ecological systems are often driven by "nonnormal" events; e.g., low flows associated with drought, and higher flows which inundate the floodplain. The metrics used to complete the ecological streamflow analysis go beyond FDCs and month flow distributions (see **Appendix 5.2**) and were preferentially selected to reflect the variability in specific characteristics of the annual hydrograph, and include peak discharges, runoff volumes and hydrograph shape. Each metric was specifically selected to represent a flow condition believed to be of ecological or geomorphological importance, in the absence of causal information. The metrics were grouped into categories, based on their ecological relevance. The groups are related to: (1) the condition of habitat, (2) aquatic organism life cycles, (3) riparian floodplain (lateral) connectivity, and (4) geomorphic stability and capacity to transport sediment. The metrics related to the condition of aquatic habitat are related to the flows needed to maintain winter flows for fish and AqL. The metrics related to the aquatic organism life cycle are related to the shape of the annual hydrograph and timing of discharges associated with ecological cues. The metrics related to the riparian floodplain (lateral) connectivity represent the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water–groundwater interactions. The metrics related to geomorphic stability and capacity are related to the channel forming discharge. An increase is interpreted as an increased risk of stream channel susceptibility to erosion.

The results of the metrics for ecological stream analysis are shown in **Table 16** by group and include the metrics within the group to classify alteration, the percent change in the metric (% change), if the metric is altered, and if the metrics within a group are altered. The metrics are shown to increase if a 15% or greater change has occurred between the two periods, decrease if the metric has a -15% or less change, and remain unchanged if it is between -15% and 15% change. The groups were determined to increase, decrease, or remain unchanged if the majority of metrics in the groups have increased, decreased, or remain unchanged. As shown in **Table 16,** all flow metrics except the highest flows (riparian floodplain (lateral) connectivity group) have increased.

In the riparian floodplain connectivity group, the downward trends in the 50 and 100-year peak discharge might seem to contradict increases in annual flow volume. Modern flow peaks are not as high as the maximum flow rates of the historic periods, but they occur more frequently and/or are sustained longer. This can be seen in the average number of days above the 10-year historic flow, increasing from three days to eight days. The peaks in the hydrograph are smaller, but the recession is slower and longer with multiple days of higher flows over a longer period. This leads to more volume but lower peak flows. In other words, there are more frequent larger volume storms, but they are not extreme events.

Table 16. Altered hydrology summary for Lac qui Parle River near Lac qui Parle, MN (USGS Station #05300000).

Group	Metric	% Change	Altered Hydrology Metric[1]	Evidence of Altered Hydrology for Group
Condition of Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	>1000%	+	Yes, Increasing
	10-year, Annual Minimum 7-day Mean Daily Discharge	>1000%	+	
	Median November Flow	412%	+	
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	31% -to->341%	+	Yes, Increasing
	Distribution of Monthly Runoff Volumes	-31% -to- 129%	+	
	Timing of Annual Peak Discharge	10%	o	
	Timing of Annual Minimum Discharge	-15%	-	
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	-0.25%	o	No change to slightly decreasing
	50-year Peak Discharge Rate	-14%	o	
	100-year Peak Discharge Rate	-19%	-	
	Average Cumulative Volume above the Historic 10-year Peak Discharge	100%	+	
	Average Cumulative Volume above the Historic 50-year Peak Discharge	NA	NA	
	Average Cumulative Volume above the Historic 100-year Peak Discharge	NA	NA	
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	34%	+	Yes, Increasing
	2-year Peak Discharge Rate	25%	+	
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	43%	+	
	Average Cumulative Volume above the Historic 2-year Peak Discharge	44%	+	
	Duration above the Historic 1.5-year Peak Discharge	65%	+	
	Duration above the Historic 2-year Peak Discharge	28%	+	
	Flow Duration Curve	20% -to- 815%	+	

[1]"+" = greater than 15% change in metric; "-" less than -15% change in metric, and "o" = no change in metric (between -15% and 15% change).

The following discusses potential changes to the climate and the landscape that are related to and causing these changes in streamflow. A more detailed discussion on the streamflow analysis provided above can be found in **Appendix 5.2** and a general discussion on the changes in hydrology in the Lac qui Parle River Watershed can be found in the DNR's Lac qui Parle River Watershed Characterization Report (DNR 2019).

Changing Precipitation

Precipitation data were analyzed from 1941 through 2015 by the DNR (DNR 2019). A Geographical Information Systems (GIS)-based version of Thiessen Polygons, an area-weighting method for interpolating point data, was employed to quantify precipitation data on the watershed scale; this method was utilized because gridded precipitation data are not available for the portion of the watershed in South Dakota. Four precipitation stations—Dawson, Minnesota, Clear Lake, South Dakota, Canby, Minnesota, and Brookings 2 NE, South Dakota—with long periods of record and few missing daily values were used in the analyses.

For the total period of record, there appears to be insignificant changes in annual precipitation totals, however, from 1941 through 1983 there was a declining trend in precipitation and from 1984 through 2015 there has been an increasing trend (**Figure 26**). The overall average precipitation is 25.17 inches for the period of record and the 7-year moving average has shown normal variability between the 25th and 75th percentiles.

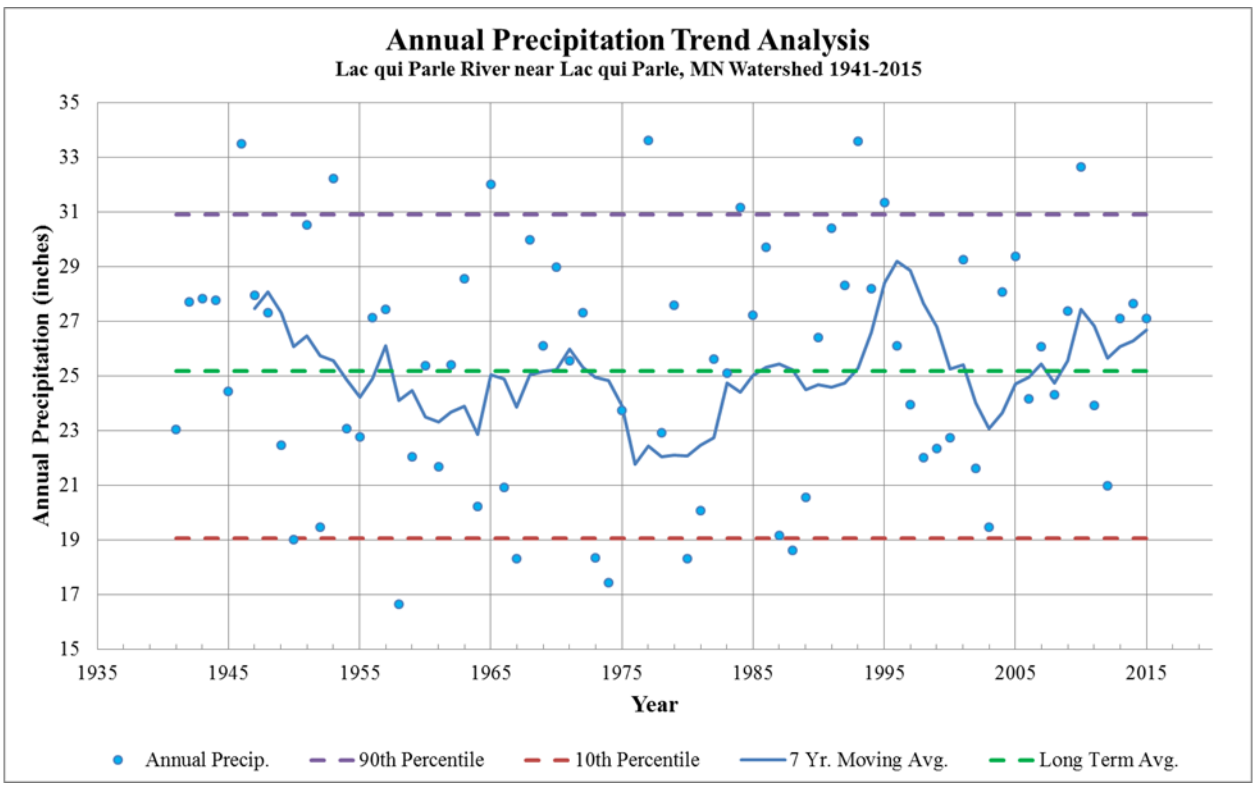


Figure 26. Annual precipitation trends in the Lac qui Parle River Watershed, based on the South Dakota Climate Division 3 (DNR 2019).

Based on a division of the precipitation record into 15-year increments, average annual precipitation during the periods beginning in 1941 and 2001 was approximately 3% greater than the long-term average, while the period beginning in 1971 was nearly 6% less (**Figure 27**). The 1971 through 1985 period of record had three out of the six years with precipitation lower than the 25th percentile (i.e. approximately 19 inches of precipitation), weighing down the overall average for those 15 years. The line for 7-year moving average annual precipitation depicts a similar trend (**Figure 26**). When the record was divided into 15-year increments to analyze average annual inches of seasonal precipitation, (1) there was an upward trend in the fall, (2) winter and spring did not display noteworthy trends, and (3) summer displayed more variability, and the periods beginning in 1941 and 1956 had greater combined precipitation than those beginning in 1986 and 2001 (**Figure 27**).

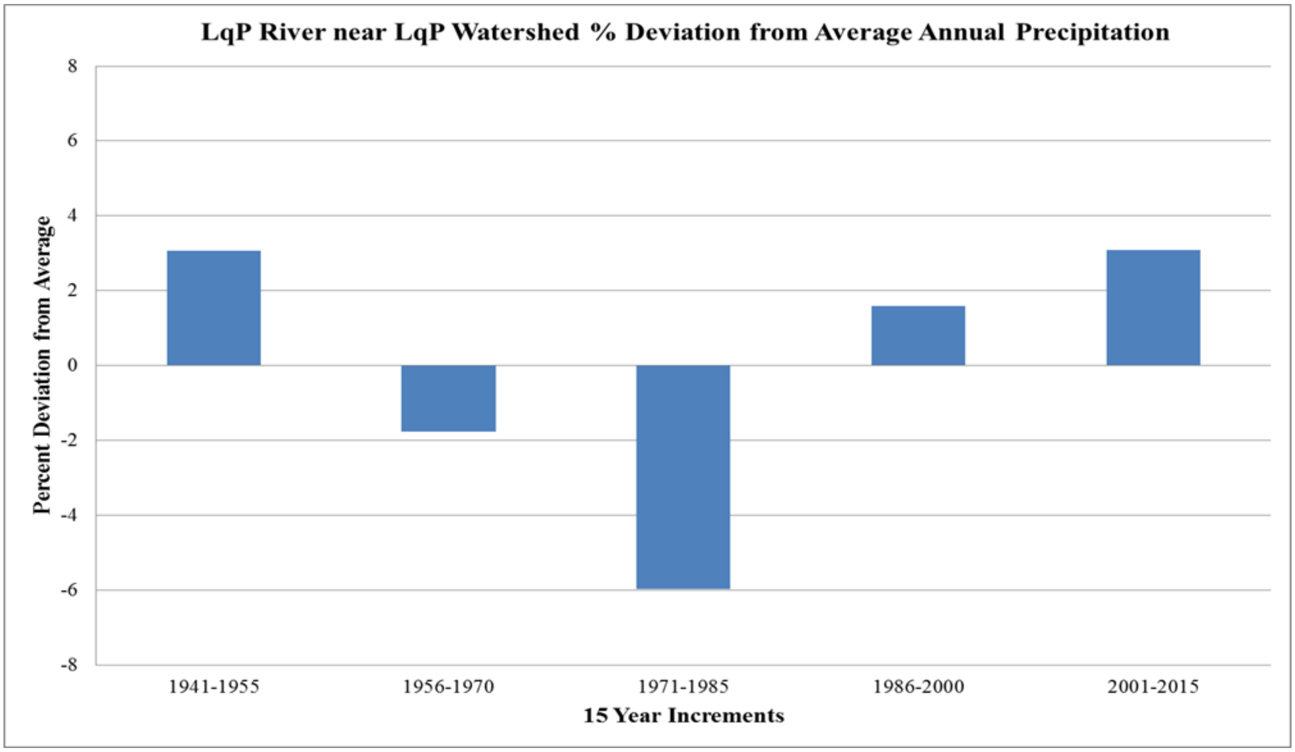


Figure 27. Percent deviation of average annual precipitation broken into 15-year increments (DNR 2019).

To show the seasonality shift in precipitation, seasonal precipitation data were broken into two time frames: 1941 through 1983 and 1984 through 2015 (**Figure 28**). The percentage of cumulative annual precipitation in the summer decreased by 1.57% and increased by 2.67% in the fall from the pre- to post-1984 time period. Additionally, the average annual inches of seasonal precipitation increased by 19.23% in fall for the post- time period (**Figure 29**).

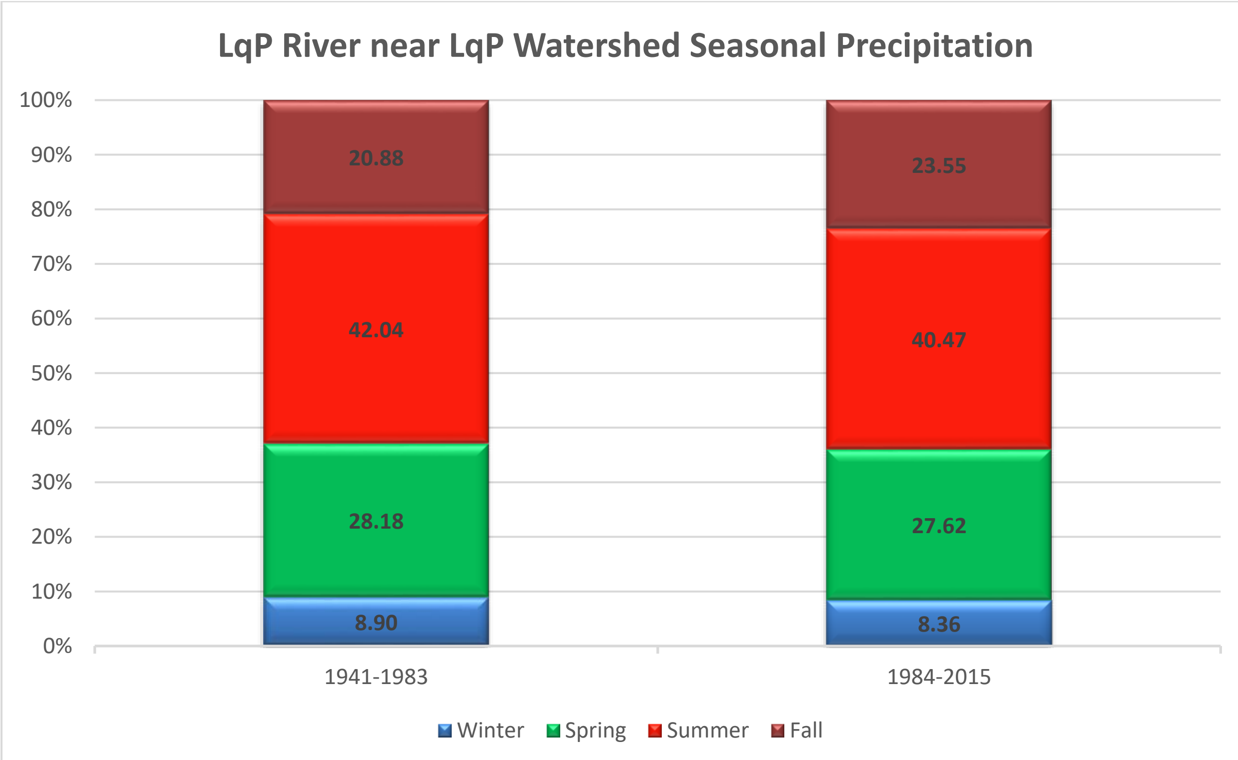


Figure 28. Percent of annual precipitation by season between two periods (1941-1983 and 1984-2015).

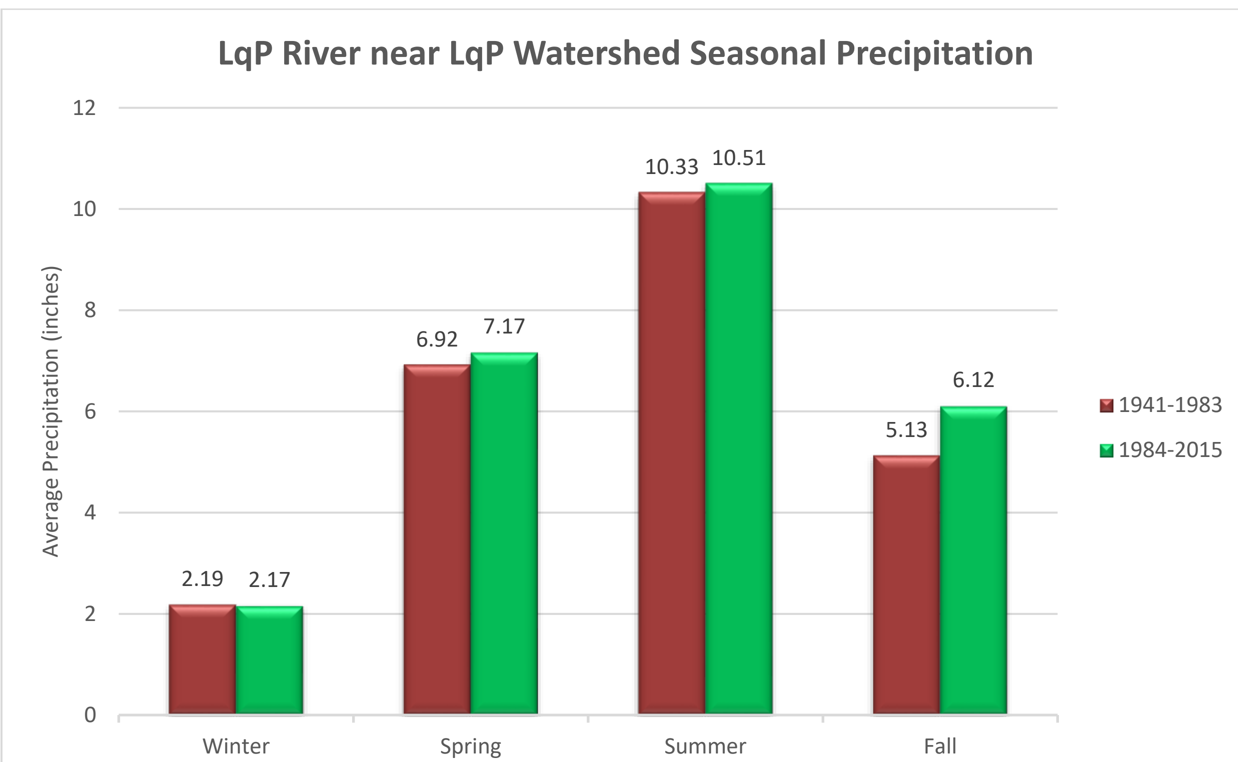


Figure 29. Average seasonal precipitation for two periods (1941-1983 and 1984-2015).

The percentage of cumulative annual precipitation in the summer decreased by 1.57% and increased by 2.67% in the fall from the “pre” to “post” period. Additionally, the average annual seasonal precipitation increased by 19.23% in fall for the “post” period.

An analysis of daily precipitation events (i.e. 0.5-1", 1-1.5", 1.5-2", 2-3", and 3+" of total precipitation over a 24-hour period) showed the number of days per year for each category increased from the pre- to the post-1984 periods, except for the 1-1.5" category. When the record was divided into 15-year increments, similar trends were observed for the periods beginning in 1941, 1986, and 2001 in one group and 1956 and 1971 in another; however, the 1-1.5" category, showed a general downward trend over the 5 periods (**Figure 30**).

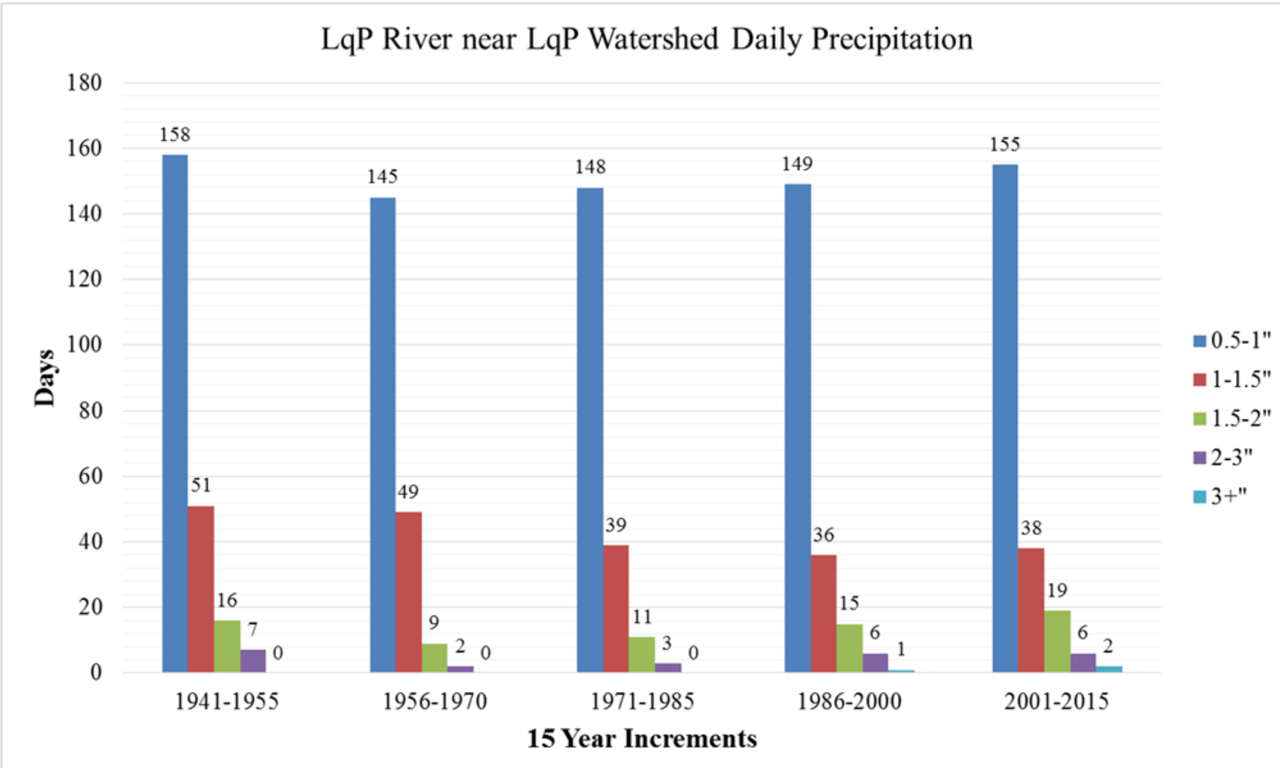


Figure 30. Number of rain events per 15-year increment by intensity (DNR 2019).

Changing Landscape

A discussion on the changing landscape in the Lac qui Parle River Watershed is provided in Section 2.1.2. Schottler et al. (2013) discussed how changes in cropping rotations from small grains to soybeans has shown relationships with changes in runoff relationships. In order to evaluate cropping changes in the Lac qui Parle River Watershed, data were collected from the National Agricultural Statistics Service (NASS), compiled, and assessed. Natural Resources Conservation Service (NRCS) Land Capability Classification data were utilized to define land suitable for cultivation (Class I-IV) in the portion of each county in the watershed and the entirety of each county in the watershed. The resulting percentage was multiplied by NASS county-level data for acres planted to corn, soybeans, wheat/oats, and hay/alfalfa to determine the amount of each crop type in the watershed on an annual basis. Data for acres planted was utilized because it more accurately represents true land cover impacts, whereas harvested acreage could be markedly less due to several variables, particularly intra-yearly weather events.

The percentage of watershed planted to soybeans and wheat/oats has diverged substantially since the mid-1970s, with the former increasing from approximately 10% to over 30% and the latter decreasing from 30% to less than 3% (**Figure 31**). The percentage of watershed planted to corn was roughly 20% in the mid-1980s and increased steadily to a high of nearly 35% by the early 2010s. The percentage of watershed planted to corn and soybeans was slightly more than one third in the mid-1980s and increased steadily to nearly two thirds in the last decade. The difference in the percentage of watershed planted to corn in Minnesota versus South Dakota was roughly 5% in the mid-1980s but increased to 15% currently. Soybeans have maintained a separation of roughly 15% since the mid-1970s. The percentage of wheat/oats planted in both states' respective portions of the watershed has been very similar since the early 1970s (DNR 2019). During the decade from 2006 through 2015, the percentage of the watershed planted to corn and soybeans increased by 7.34% and perennial grass cover decreased by 7.87% (**Figure 32**). The loss of CRP acres is a likely a significant driver of the loss of perennial grass cover as CRP acres for the three counties in the Lac qui Parle River Watershed has decreased by 28% from 2006 through 2015.

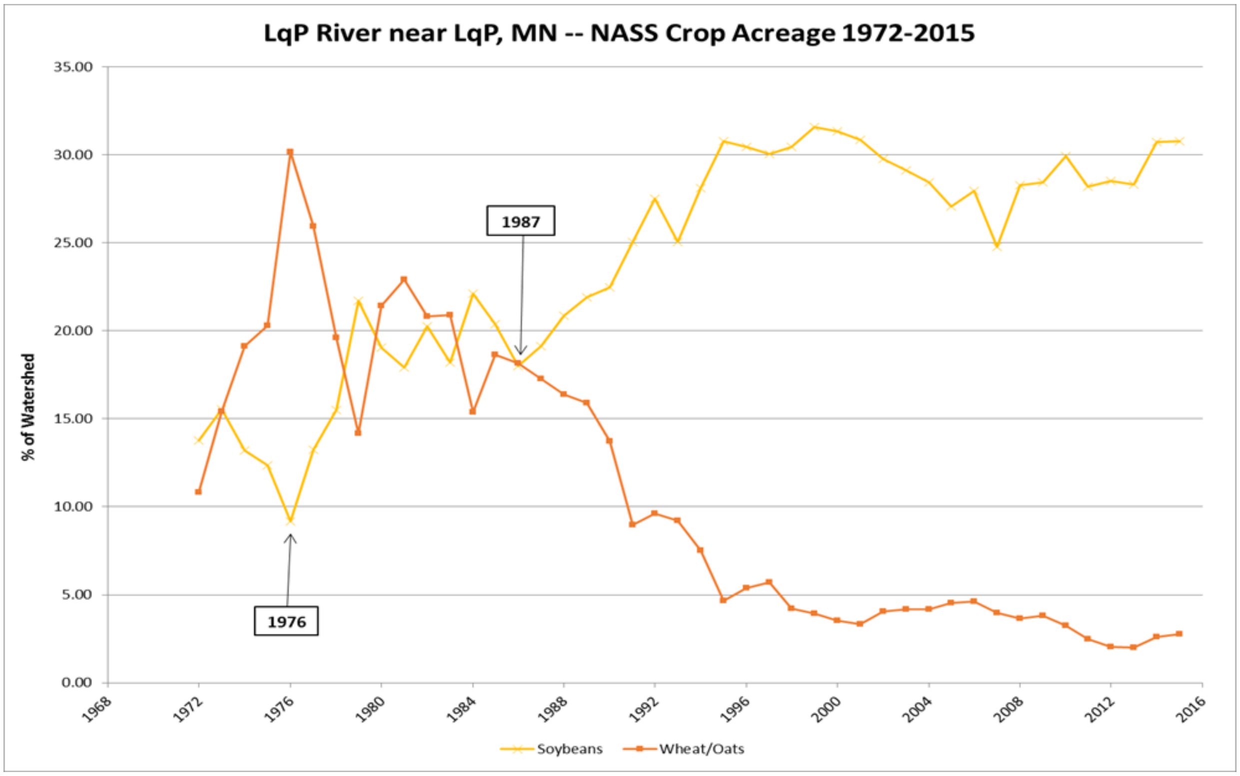


Figure 31. Cropping area planted to soybeans and small grains in the Lac qui Parle River Watershed since 1972.

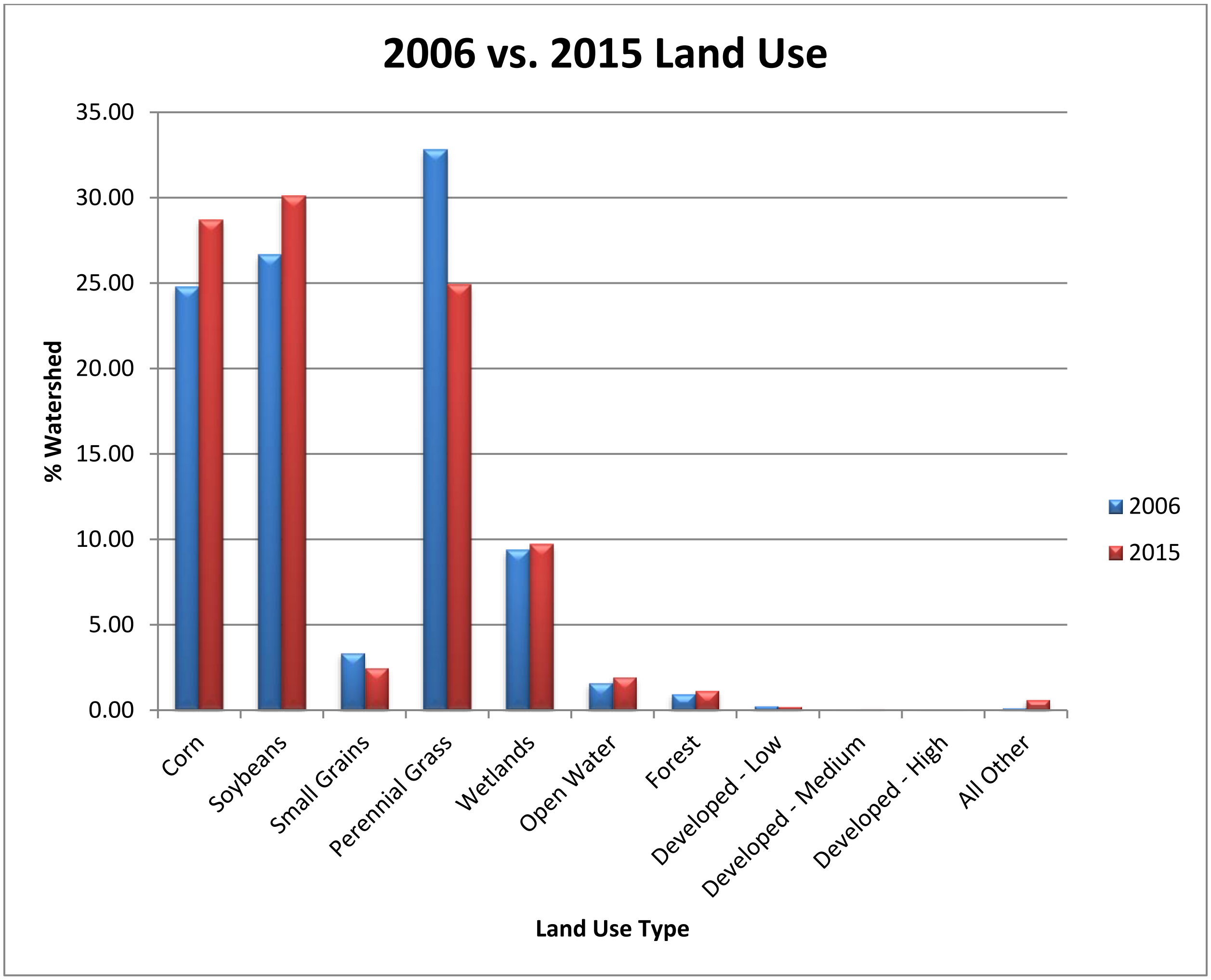


Figure 32. Land use changes in the Lac qui Parle River Watershed from 2006-2016 (from NASS CropScape, USDA 2016).

Sources of streamflow

The distribution of average annual runoff by land use type (by land use and pathways), based on HSPF model estimates is shown in **Figure 33**. Values are based on the HSPF model and depend on how the HSPF model partitioned the watershed during development. Average annual point source contributions for the years 1996 through 2017 contribute approximately 1.0% of the Lac qui Parle River Watershed's runoff with the rest derived from nonpoint sources. High-till cropland is the dominant source followed by low-till cropland, forest/scrubland, pasture, and developed lands. It should be noted, different crop types can have markedly different effects on water quantity and quality. For example, the timing and magnitude of water use and movement can be substantially different for small grains versus row crops like corn and soybeans. Increasing the percentage of cropland used for small grains could reduce runoff volumes and peaks in the Lac qui Parle River Watershed. Differing crop types were not independently modeled and, therefore, all crop types were grouped together.

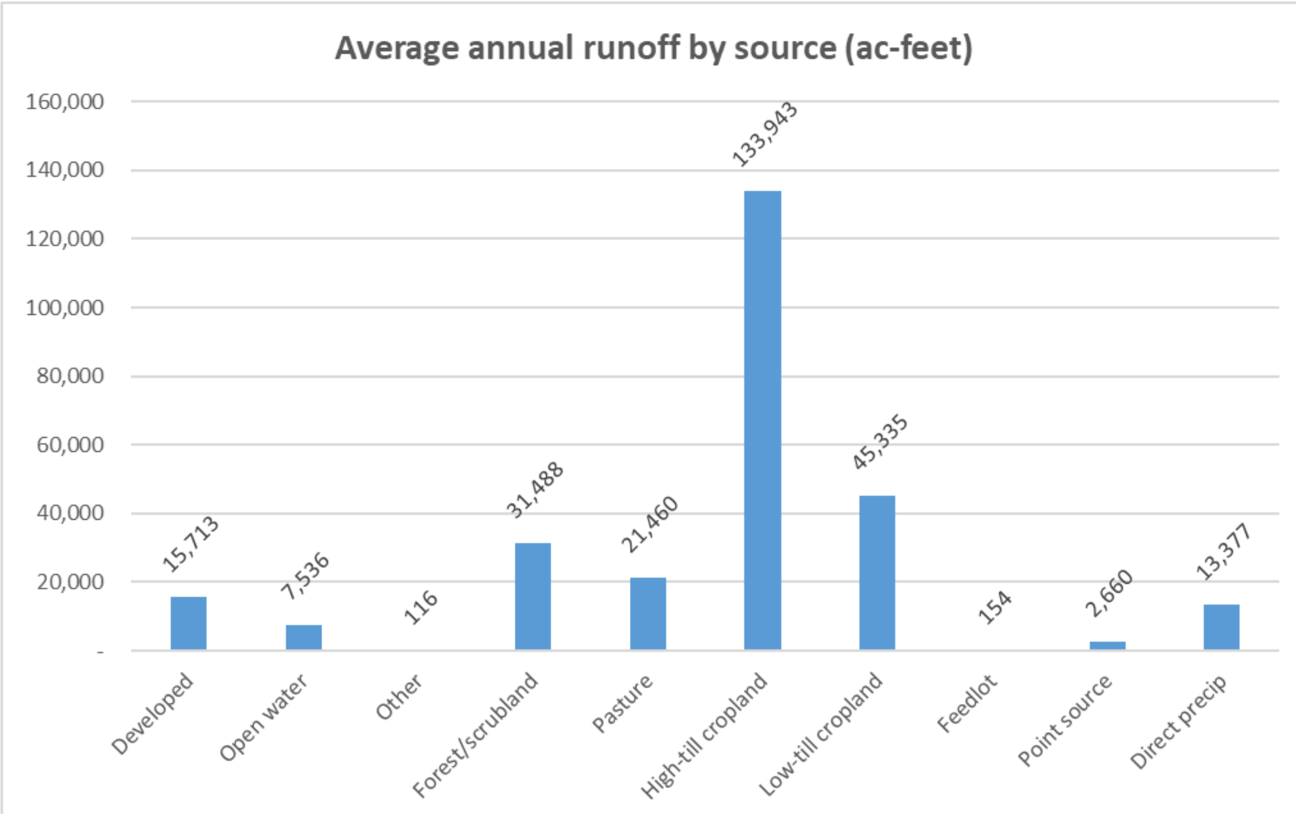


Figure 33. Estimated distribution of average annual runoff by source (land use type), based on HSPF model results (1996-2017).

The magnitude of runoff across the watershed is shown in **Figure 34** as runoff depth (in inches). Runoff depth is an area-average yield of runoff based on the total annual runoff volume (in acre-ft/yr) divided by the drainage area (in acres) and is equivalent to rainfall depth. The runoff depths range from 2.5 inches to 4.1 inches, with the higher depths occurring in the eastern half of the watershed that is dominated by cropland.

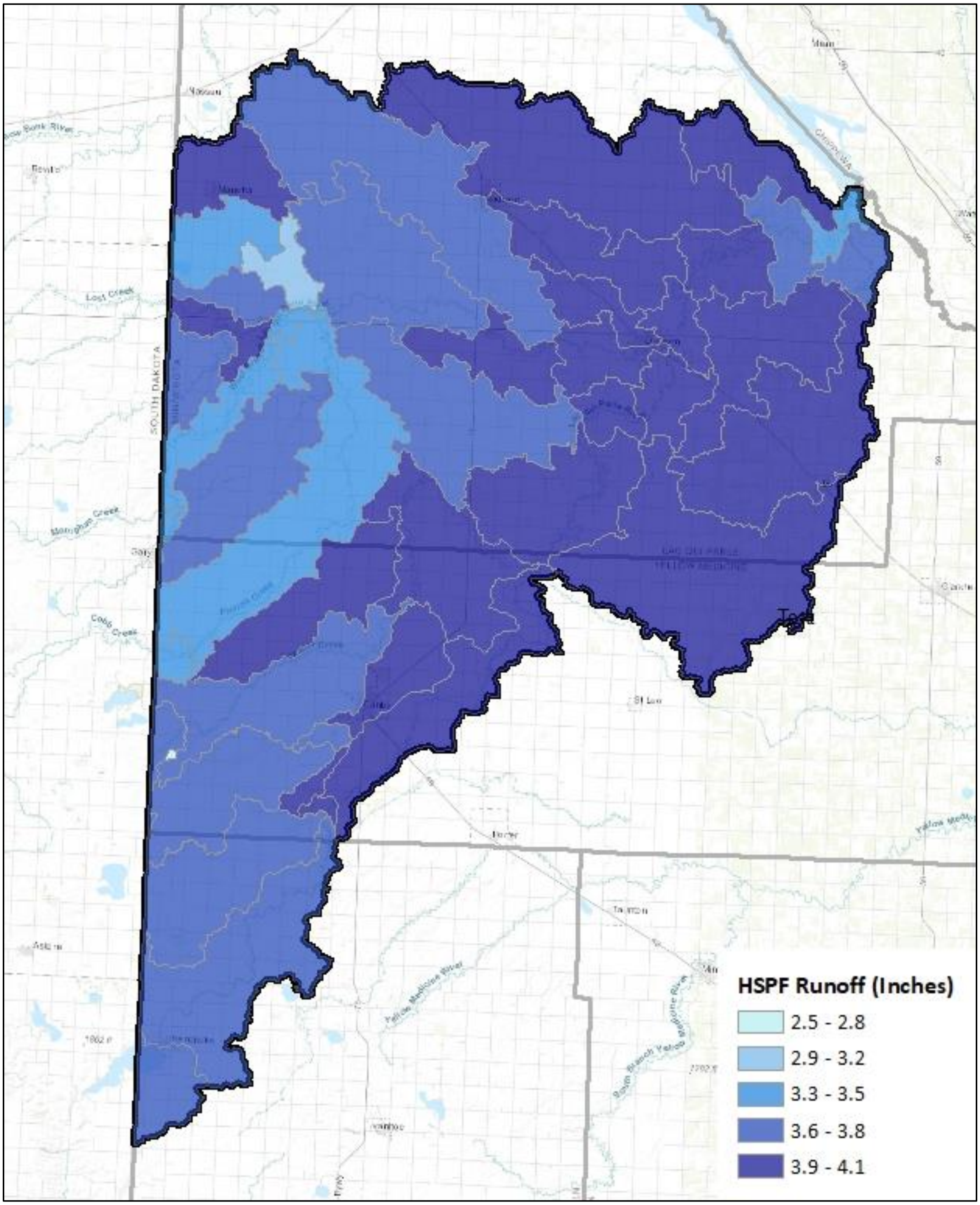


Figure 34. Runoff depth (in inches) in the Lac qui Parle River Watershed based on the HSPF model results. Runoff depth is presented as a yield and taken as the total annual runoff (in acre-ft) divided by the area (in acres).

Factors for prioritization

Changes in landscape vegetation, development, and drainage can increase how fast rainfall runoff reaches stream channels. This creates a stronger pulse of flow, followed later by decreased baseflow levels. According to the authors of a review on flow effects (Poff et al. 1997), “Streamflow quantity and timing are critical components of water supply, water quality, and the ecological integrity of river systems. Indeed, streamflow, which is strongly correlated with many critical physicochemical characteristics of rivers, such as water temperature, channel geomorphology, and habitat diversity, can be considered a ‘master variable’...” Increasing surface water runoff and seasonal variability in stream flows has the potential for both indirect and direct effects on fish populations (Schlosser 1990).

The inverse effect to an increase of streamflow with artificial subsurface drainage and surface ditches is seen in the reduction of baseflow conditions during periods of low precipitation. Within this watershed, there are times where baseflows within upland tributaries drastically drop and dry up later in the summer.

Carlisle et al. (2011) found a strong correlation between diminished streamflow and impaired biological communities. Numerous studies have found conventional trapezoidal ditches to be inferior to natural streams in terms of sediment transport capacity and channel stability over time (Urban and Rhoads 2004; Landwehr and Rhoads 2003). Conventional ditches are designed to handle low frequency, high-magnitude flood events. This design may not support adequate water depth and velocities for transporting sediment and maintaining stream features (e.g., glide, riffle, run, pool) during low to moderate flow periods. The common result is excess sedimentation of the stream bed as particles become immobile and aggrade over time. In general, this design does not provide good habitat for aquatic species or provide stability of its streambed and stream banks (MPCA 2020b).

As described in the analysis above, altered hydrology in the Lac qui Parle River Watershed is the result of a complex, interrelated set of natural and anthropogenic factors. Changes in climate including amount, timing, and intensity of rainfall have increased the amount of water available to make its way to surface waters through surface run-off, drainage and interflow. Anthropogenic factors including the increased percent of altered channels (MPCA 2019b), increased imperviousness (MRLCC 2016), loss of wetland areas, increased nonperennial crops (such as corn and soybeans) (CropScape 2016), tile drainage, and connectivity issues related to road crossings have further exacerbated changes in climate patterns. Regardless of the relative importance of climatic and anthropogenic factors on altered hydrology, resource professionals will need to focus on land management, and to a lesser degree structural practices, to stabilize hydrology in the Lac qui Parle River Watershed. Estimates of anthropogenic change are shown in **Figure 35**, by subwatershed. These metrics can be used to prioritize areas to develop mitigation strategies to improve hydrologic conditions.

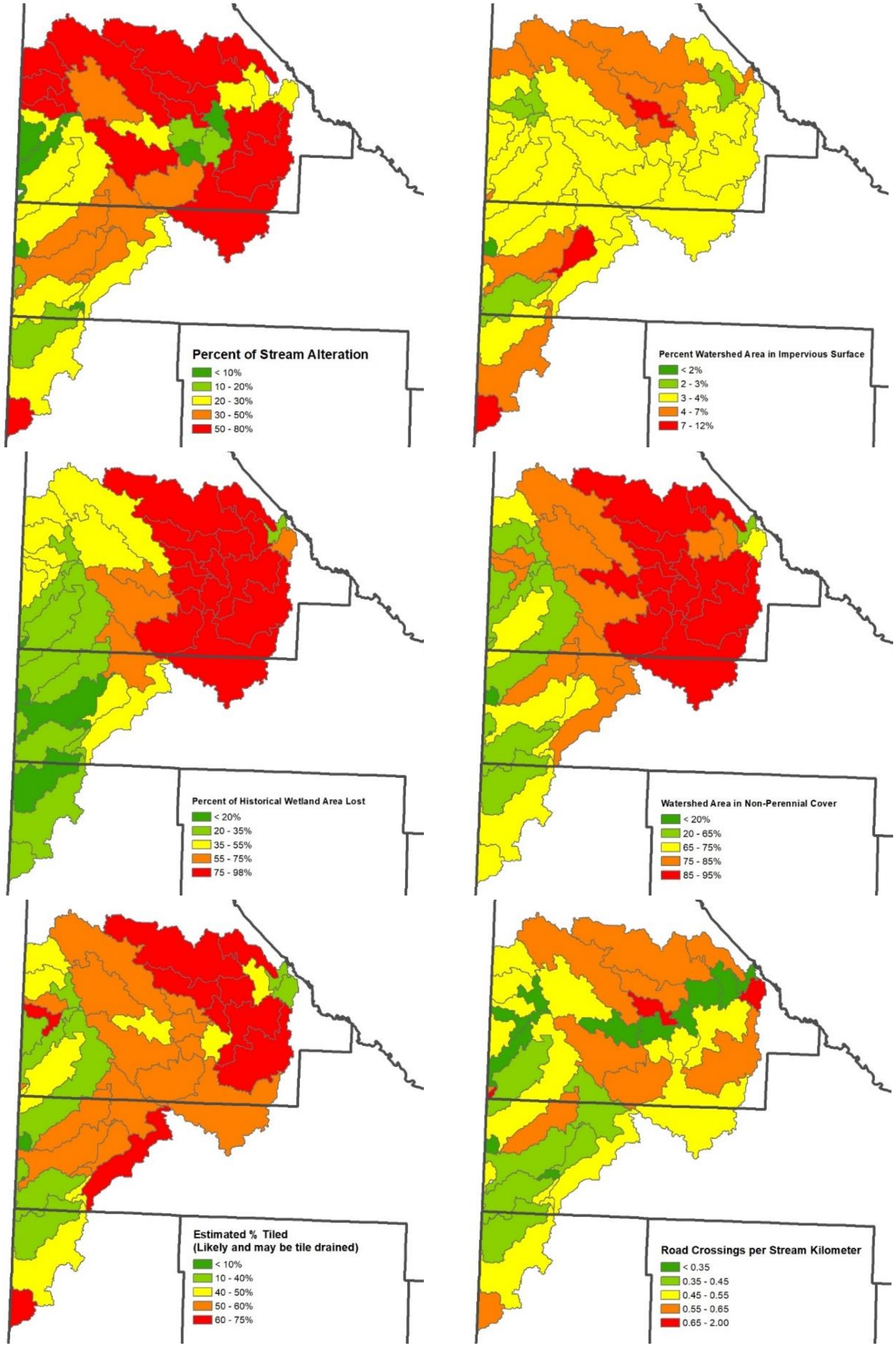


Figure 35. Factors contributing to altered hydrology in the Lac qui Parle River Watershed.

2.3.3.3 Goal and 10-year Target

The watershed-wide goal for altered hydrology was determined by taking the average of two methods. The first method sets a storage goal as the increased volume above the historic 1.5-year flood. This event is typically assumed to be the channel forming flow event, and flows above it generally cause most of the streambank erosion. **Table 17** provides the flow metrics relating to the 1.5-year flood. The difference in the average annual cumulative volume between the “historic” and modern periods is 17,229 acre-ft/year of water, or 0.34 inches taken over the whole watershed (614,400 acres draining to USGS Site #05300000). Partitioning this to Minnesota’s portion of the Lac qui Parle River Watershed (399,572 Minnesota acres draining to USGS Site#05300000) results in a storage goal of 11,320 ac-ft/year.

The second method sets a storage goal based on the change in the FDC between the “historic” and modern periods (**Figure 23**). The goal is based on the change of expected value of the FDCs, or a probabilistic average of the change in flow across the flow spectrum. By weighting the change in flows between the two FDCs with the percent exceedance (change of occurring on any given day), a storage goal can be established based on its likelihood of occurring and accounts for changes across the whole flow regime. The estimate storage goal for this method is 22,958 acre-ft/year or 0.45 inches (614,400 acres draining to USGS Site #05300000). Partitioning this to Minnesota’s portion of the Lac qui Parle River Watershed (399,572 Minnesota acres draining to USGS Site#05300000) results in a storage goal of 14,982 ac-ft/year. For more information on how the storage goals were estimated, see **Appendix 5.2**.

Table 17. Analysis of the 1.5-year flood.

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
1.5-Year Peak Discharge, Q(1.5) [cfs]	1,114	1,492	34.0%	+
Number of years with Discharge (Q) > Q_H (1.5)	18	20	11.1%	+
Average number of days per year Q > Q_H (1.5)	16	26	65.1%	+
Average annual cumulative volume > Q_H (1.5) [ac-ft]	40,006	57,235	43.1%	+

The storage goal for the Lac qui Parle River Watershed is approximately 17,200 to 23,000 acre-ft/year (0.34-0.45 inches), with an average of 0.39 inches across the whole watershed. Partitioning this to Minnesota’s portion of the Lac qui Parle River Watershed (399,572 Minnesota acres draining to USGS Site# 05300000) results in a storage goal of 12,986 ac-ft/year

The 10-year target is to increase storage in the watershed by 0.1 inches, or about 3,329 acre-ft/year for Minnesota’s portion of the Lac qui Parle River Watershed (399,572 Minnesota acres draining to USGS Site#05300000). Strategies to accomplish these goals include increasing soil storage, increasing conventional storage practices, and/or increasing infiltration of water on the landscape, which will increase groundwater contributions (baseflow) to streams during dry periods. These goals are revisable and will be revisited in the One Watershed, One Plan development and the next iteration of the Watershed Approach.

2.3.4 Bacteria

Countless species of bacteria can be found across the landscape and in our waterways. Most bacteria are beneficial, serving as food for larger organisms and playing critical roles in natural processes, such as decomposition of organic matter and food digestion. But a small percentage of bacteria (approximately 10%) are harmful and, if ingested, can cause severe illness and even death. As they relate to water quality, bacteria (in the forms of *E. coli* or fecal coliform) are indicators of animal or human fecal matter in the waters. Elevated bacteria levels can make AqR unsafe due to the potential for severe illnesses when coming in contact with these bacteria.

2.3.4.1 Status

Of the 17 stream reaches assessed for bacteria as a pollutant, all 17 were impaired. **Table 18** lists the assessed stream reaches and **Figure 36** illustrates the results. All 17 streams have an approved or draft fecal or *E. coli* TMDL. Nine streams impaired for fecal coliform are addressed in the Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low DO TMDL Assessment Report (Wenck 2013). Eight streams impaired by *E. coli* are addressed in the Lac qui Parle River Watershed TMDL (MPCA 2021c), that was developed in conjunction with this report.

Table 18. Assessment results for bacteria as a pollutant in streams in the Lac qui Parle River Watershed.

Stream, Reach description	AUID (Last 3 digits)	Bacteria	Stream, Reach description	AUID (Last 3 digits)	Bacteria	Stream, Reach description	AUID (Last 3 digits)	Bacteria
Lac qui Parle River	501	X	West Branch Lac qui Parle River	513	X	Unnamed Creek	530	X
Lac qui Parle River	502	X	West Branch Lac qui Parle River	516	X	Tenmile Creek	577	X
Lac qui Parle River	505	X	Lost Creek	517	X	Tenmile Creek	578	X
Lac qui Parle River	506	X	West Branch Lac qui Parle River	519	X	Unnamed Creek	580	X
Lazarus Creek	508	X	Florida Creek	521	X	Unnamed ditch	581	X
West Branch Lac qui Parle River	512	X	County Ditch 5	523	X			

X	Impaired/Exceeds/Stressor

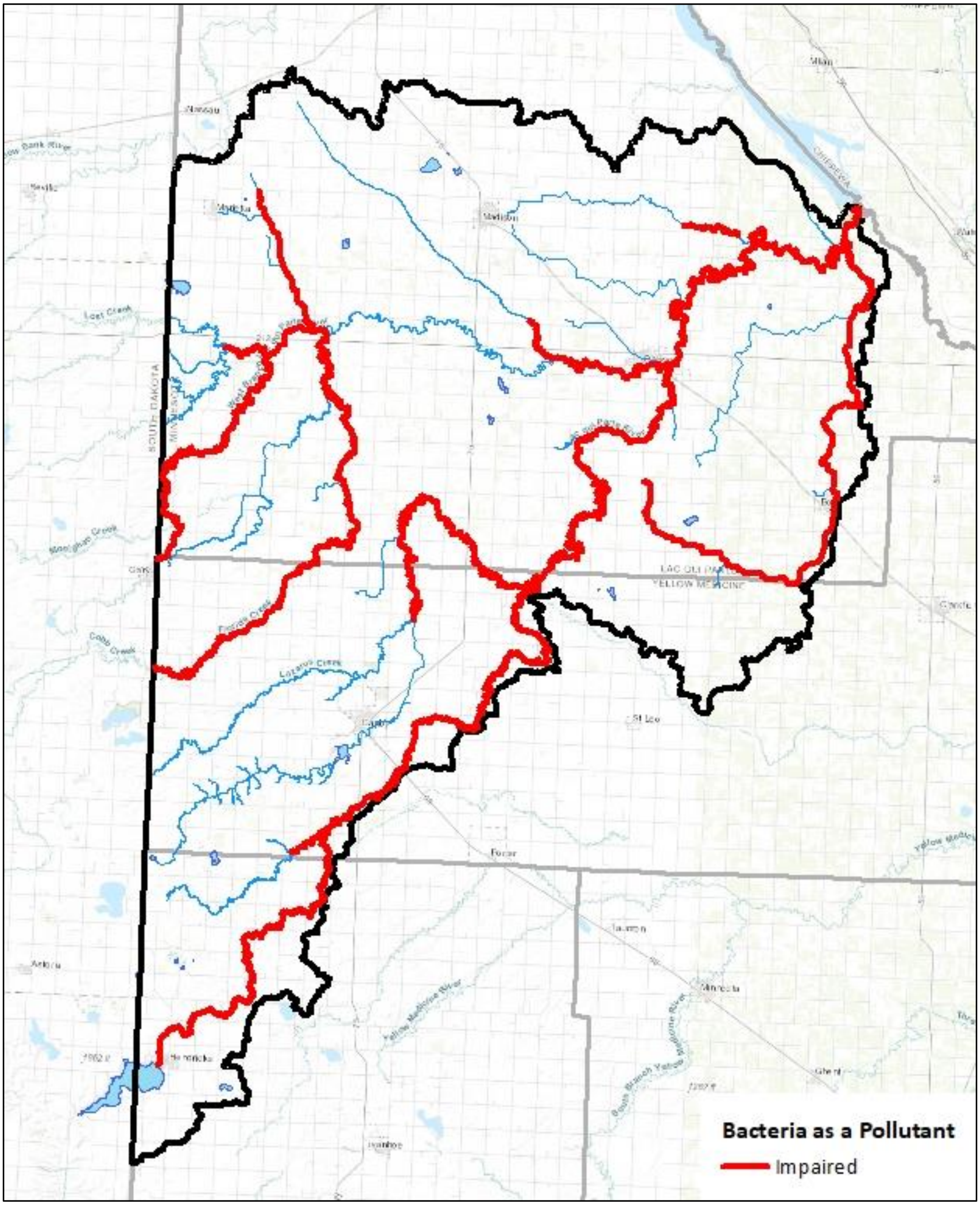


Figure 36. Bacteria assessment status of streams in the Lac qui Parle River Watershed.

2.3.4.2 Sources

Bacteria in Minnesota's lakes and streams mainly come from sources such as failing septic systems, wastewater treatment plant releases, livestock, and urban stormwater. Waste from pets and wildlife is another, lesser source of bacteria. In addition to bacteria, human and animal waste may contain pathogens such as viruses and protozoa that could be harmful to humans and other animals.

The behavior of bacteria and pathogens in the environment is complex. Levels of bacteria and pathogens in a body of water depend not only on their source, but also weather, current, and water temperature. As these factors fluctuate, the level of bacteria and pathogens in the water may increase or decrease. Some bacteria can survive and grow in the environment while many pathogens tend to die off with time.

A literature review conducted by Emmons and Oliver Resources (EOR 2009) for the MPCA summarizes factors that have either a strong or a weak relationship to bacteria contamination in streams (**Table 19**). Bacteria sourcing can be very difficult due to the bacteria's ability to persist, reproduce, and migrate in unpredictable ways. Therefore, the factors associated with bacterial presence provide some confidence to bacterial source estimates.

Table 19. Summary of factor relationships associated with bacteria source estimates of streams (EOR 2009).

Strong relationship to fecal bacteria contamination in water	**Weak** relationship to fecal bacteria contamination in water
• High storm flow (the single most important factor in multiple studies) • % rural or agricultural areas greater than % forested areas in the landscape • % urban areas greater than forested riparian areas in the landscape • High water temperature • High % impervious surfaces • Livestock present • Suspended solids	• High nutrients • Loss of riparian wetlands • Shallow depth (bacteria decrease with depth) • Amount of sunlight (increased UV-A deactivates bacteria) • Sediment type (higher organic matter, clay content and moisture; finer-grained) • Soil characteristics (higher temperature, nutrients, organic matter content, humidity, moisture and biota; lower pH) • Stream ditching (present or when increased) • Epilithic periphyton present • Presence of waterfowl or other wildlife • Conductivity

It has been suggested that *E. coli* bacteria has the capability to reproduce naturally in water and sediment which should be considered when identifying bacteria sources. Two Minnesota studies describe the presence and growth of "naturalized" or "indigenous" strains of *E. coli* in watershed soils (Ishii et al. 2010), and ditch sediment and water (Sadowsky et al. 2015). The latter study suggests persistence (implying growth and division) of *E. coli* strains naturally in the environment and considered these as "background". However, the authors caution about extrapolating data from their study watershed to other regions.

Sources of fecal bacteria are typically widespread and often intermittent. In the Lac qui Parle River Watershed, the *E. coli* standard is exceeded across all flow conditions for which data were available, indicating a mix of source types. A qualitative approach was used to identify permitted, such as wastewater and permitted AFOs, and nonpermitted sources, such as humans, livestock, wildlife, and self-propagation, in the watershed. The relative significance of each source at a given time depends largely on climate, land management, and stream flow conditions. **Table 20** provides population estimates of potential bacteria sources for Minnesota's portion of the Lac qui Parle River.

Table 20. Bacteria sources from Minnesota for the outlet of Lac qui Parle River (AUID 07020003-502).

Category	Source	Animal units or individuals
Livestock[1]	Horse	93
	Pig	58,273
	Cattle	27,793
	Chicken/Turkey	958
	Other Livestock	169
Wildlife[2]	Deer[3]	5,479
	Waterfowl[4]	5,838
	Geese[5]	3,265
	Other[6]	5,479
Human (population #)	Failing Septic Systems[7]	1,710
	WWTP Effluent[8]	6
Domestic Animals	Improperly Managed Pet Waste[9]	2,266

[1]Animal units based on registered feedlots (https://gisdata.mn.gov/dataset/env-feedlots).

[2] Wildlife numbers represent total number of individual animals.

[3]Deer populations based on DNR "Status of Wildlife populations, Fall 2009" (https://www.dnr.state.mn.us/publications/wildlife/populationstatus2009.html).

[4]Duck population calculated by U.S. Fish and Wildlife Service utilizing "Thunderstorm" Maps for the Prairie Pothole Region.

[5] Geese population estimates were taken from the state-wide DNR's Minnesota Spring Canada Goose Survey, 2009 (Rave 2009).

[6]Other wildlife includes such animals as swallows, beaver, raccoons, coyote, foxes, and squirrels and taken as the same population as deer.

[7]Reported as population size in watershed based on county SSTS inventory (MPCA 2017a) and drainage area size. Assumes 3 persons per failing system.

[8]Reported as number of WWTPs.

[9] Number of households in watershed multiplied by 0.58 dogs/ household.

2.3.4.3 Goal and 10-year Target

The watershed-wide goal for bacteria in the Lac qui Parle River Watershed is a 52% reduction, to an average monthly *E. coli* geomean of 126 cfu/mL in-stream concentration. The subwatershed load reduction goals range from 14% to 86%, based on the overall reductions from the TMDL reports (see **Section 2.4**). Subwatershed load reductions are shown in **Figure 37**, based on the TMDL load reductions.

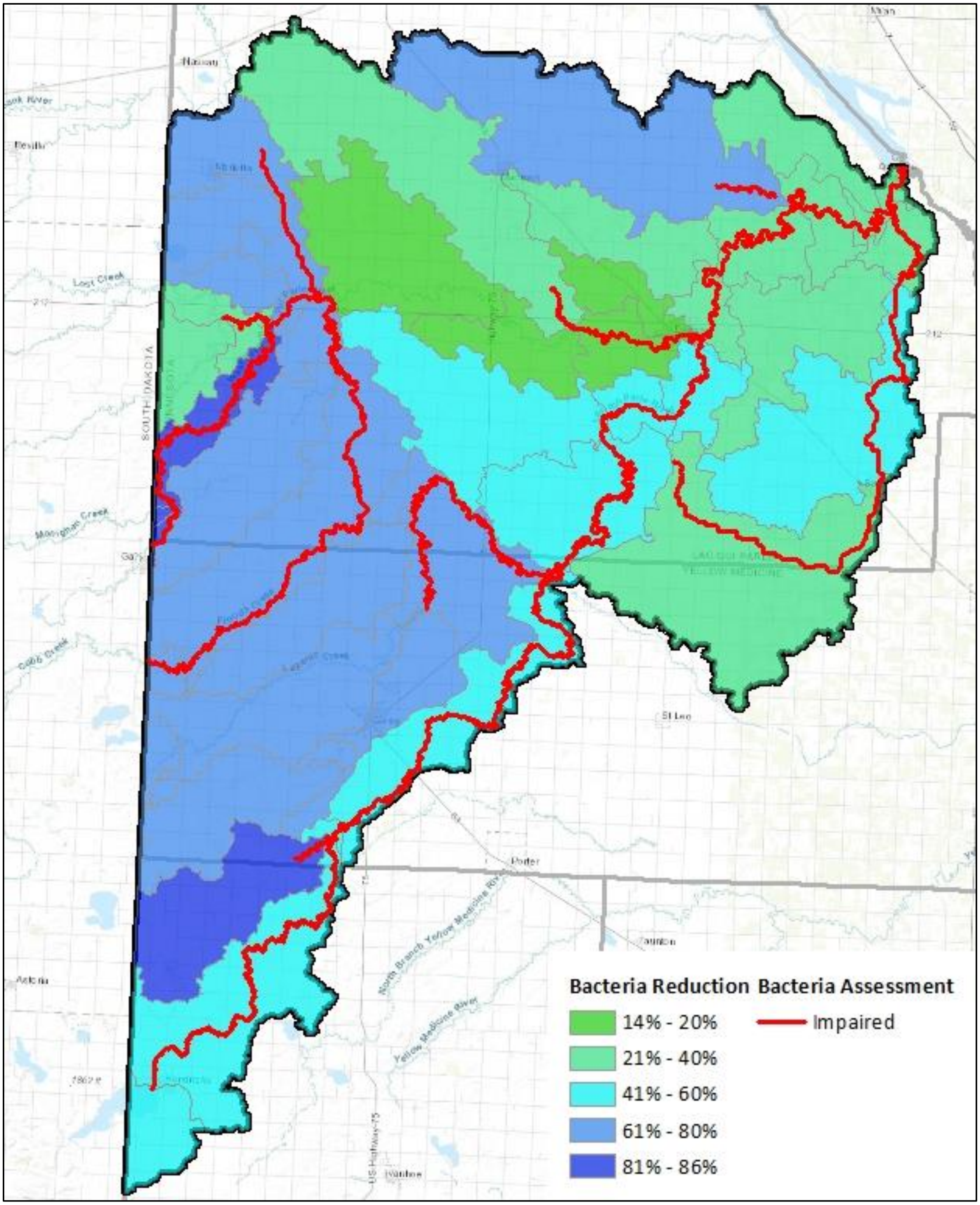


Figure 37. Bacteria load reduction goals in the Lac qui Parle River Watershed. The subwatershed reductions range from 14% to 86%, based on load reductions from TMDLs.

The 10-year target agreed to by the WRAPS LWG is a watershed-wide 10% load reduction in stream bacteria. These goals are revisable and will be revisited in the One Watershed, One Plan development and the next iteration of the Watershed Approach Strategies to meet the goals and 10-year targets. Methods to prioritize regions for bacteria reductions are summarized in **Section 3**.

2.3.5 Sediment

Sediment and other suspended material in water impacts AqL by reducing visibility which hampers feeding, clogging gills which reduces respiration, and smothering substrate which limits reproduction. Excessive TSS also indirectly affects AqL by reducing the penetration of sunlight, limiting plant growth and increasing water temperatures. Sediment also impacts downstream waters used for navigation (larger rivers) and recreation (lakes).

The water quality standard for sediment utilizes TSS, which is mostly composed of sediment. Other components of TSS include algae and other solids. Sediment is the focus of this section of the report and issues related to the algae portion of TSS are due to excessive phosphorus (eutrophication) and addressed in the phosphorus section (**Section 2.3.2**).

2.3.5.1 Status

Of the stream reaches assessed for sediment as a pollutant, 7 are impaired, 6 are supporting, and 20 are inconclusive. Of the biologically impaired stream reaches, sediment as a stressor was identified in 8, was not a stressor in 6, and was inconclusive in 13.

Seven stream reaches have a turbidity or a draft TSS TMDL. Six streams impaired by turbidity are addressed in the Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low DO TMDL Assessment Report (Wenck 2013). One stream impaired by TSS is addressed in the Lac qui Parle River Watershed TMDL (MPCA 2021c), that was developed in conjunction with this WRAPS report.

Figure 38 shows the status of stream reaches that were assessed for sediment (TSS). The results for the pollutant assessment overlay the results for the stressor assessment, with the pollutant results shown on the inside and stressor results shown around the outside. **Table 21** tabulates the stream status.

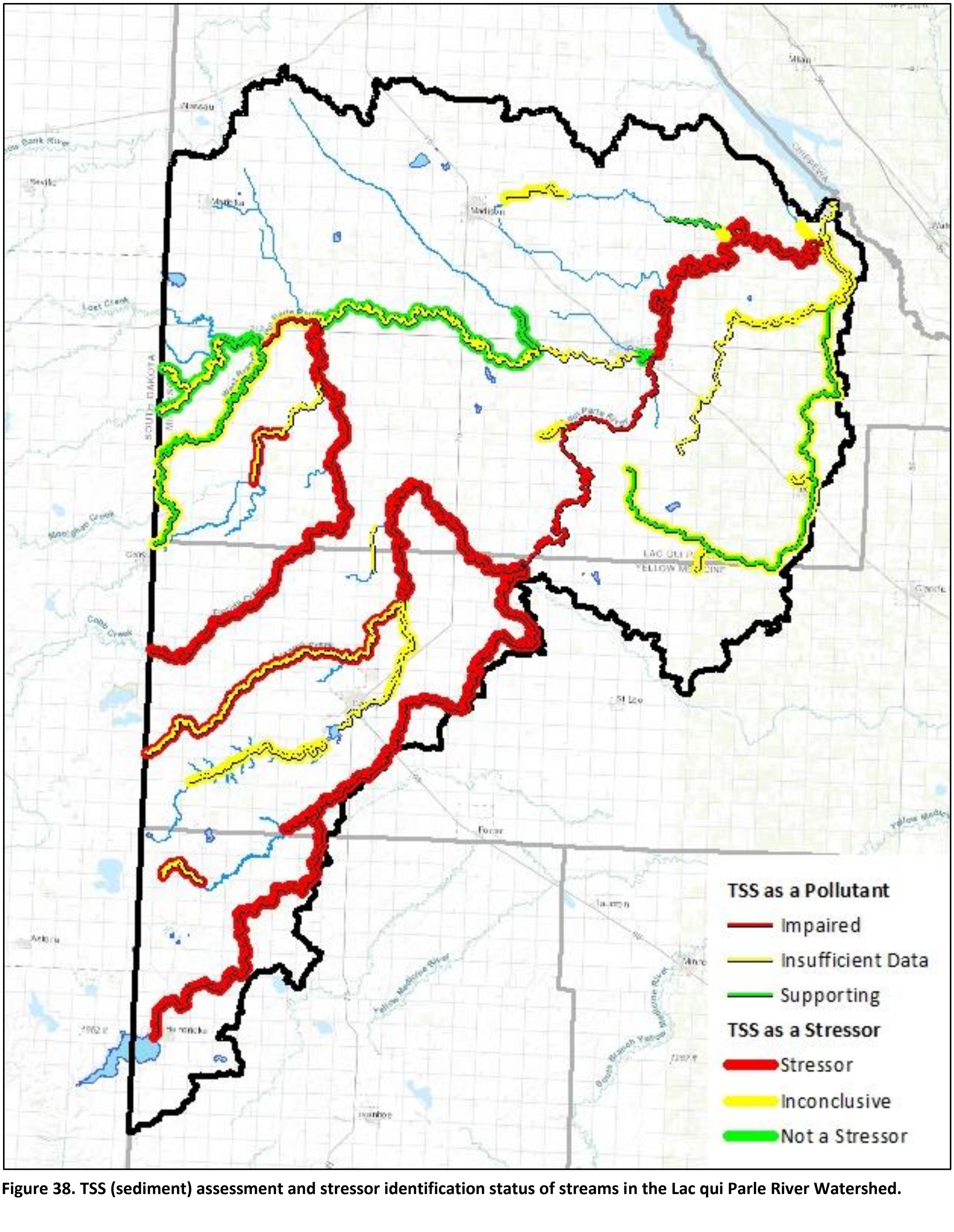


Figure 38. TSS (sediment) assessment and stressor identification status of streams in the Lac qui Parle River Watershed.

Table 21. Assessment and stressor identification results for turbidity/TSS as a pollutant or stressor in streams in the Lac qui Parle River Watershed.

Stream, Reach description	AUID (Last 3 digits)	Turbidity/TSS, as a Pollutant	Turbidity/TSS, as a Stressor	Stream, Reach description	AUID (Last 3 digits)	Turbidity/TSS, as a Pollutant	Turbidity/TSS, as a Stressor
Lac qui Parle River	501	X	X	Unnamed Creek	534	?	?
Lac qui Parle River	502	?		Canby Creek	557	?	?
Lac qui Parle River	505	X	X	Judicial Ditch 1	560	?	
Lac qui Parle River	506	X		Unnamed Creek	567	?	+
Lazarus Creek	508	X	X	Unnamed Creek	569	?	X
Lazarus Creek	509	?	X	Unnamed ditch	570	?	?
West Branch Lac qui Parle River	512	?		Unnamed ditch	571	?	?
West Branch Lac qui Parle River	513	+	+	Unnamed ditch	575	?	?
West Branch Lac qui Parle River	515	?	+	Tenmile Creek	577	+	?
West Branch Lac qui Parle River	516	X	?	Tenmile Creek	578	?	?
Lost Creek	517	+	+	Unnamed Creek	580	+	+
West Branch Lac qui Parle River	519	+	?	Unnamed ditch	581	+	
Crow Timber Creek	520	?	+	Unnamed ditch	582		?
Florida Creek	521	X	X	Cobb Creek	583	?	X
County Ditch 34	526	?	?	Cobb Creek	584	?	
Unnamed Creek	530	X	X	Canby Creek	585	?	
County Ditch 34	532	?		Canby Creek	586	?	?
				Unnamed Creek	588		?

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
<blank>	Not Assessed

The Lac qui Parle River Watershed's TSS FWMC is several times higher than major watersheds in north central and northeast Minnesota, but a FWMC that is in-line with the agriculturally rich major watersheds found in the corn-belt region (northwest to southern regions) of the state, as shown by WPLMN monitoring data (**Figure 39**).

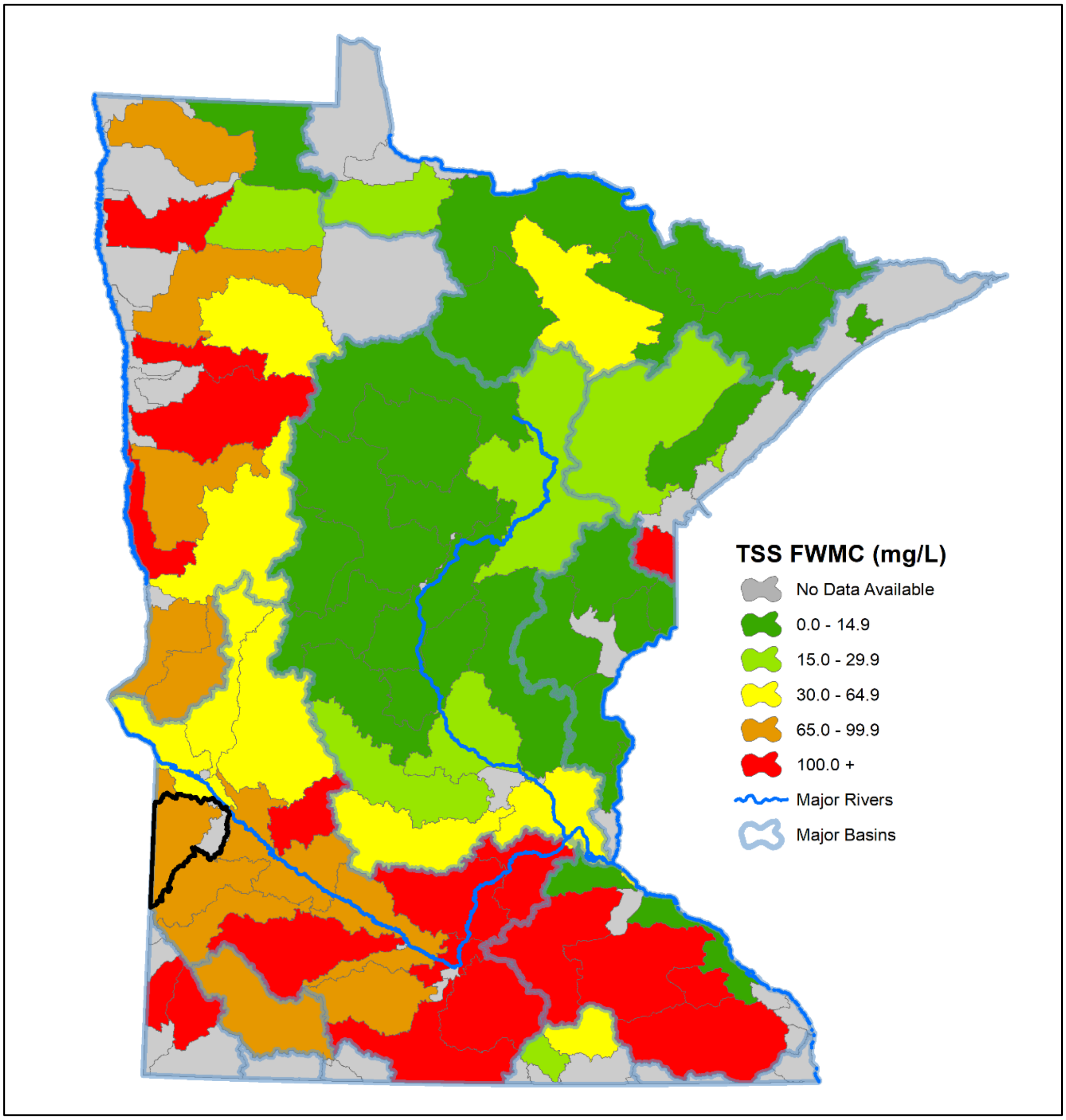


Figure 39. A statewide perspective of TSS flow weighted mean concentration for the Lac qui Parle River Watershed using WPLMN monitoring data.

2.3.5.2 Sources

Sediment sources are dominated by nonpoint sources in the Lac qui River Watershed. Average annual point source contributions for the years 1996 through 2017 are estimated at approximately 0.1% of the Lac qui Parle River Watershed's sediment load with the rest derived from nonpoint sources, according to the HSPF model. Annual loads from point sources are provided in **Figure 40** from 2000 to 2020.

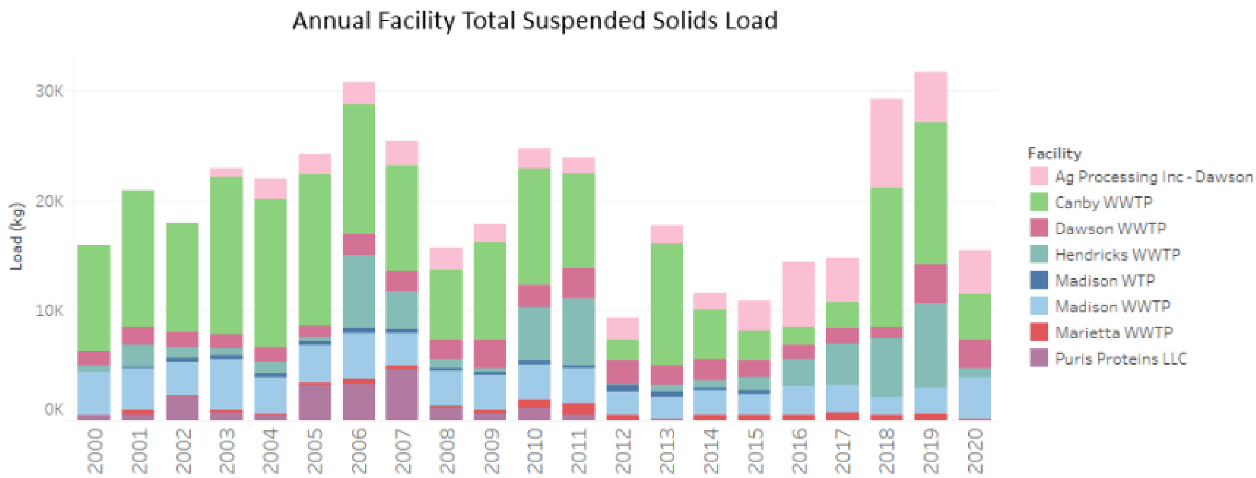


Figure 40. Annual facility total suspended solids load. Observed and estimated annual TSS loads (kg) by facilities in the Lac qui Parle River Watershed, from 2000 - 2020.

Figure 41 provides average annual source load estimates (by land use and pathways) as determined by the HSPF model. Near channel sources such as stream bank and bluff erosion are the dominant sources of TSS load in the watershed followed by high-till, and low-till cropland. While some amount of channel migration and associated bank/bluff erosion is natural, altered hydrology has substantially increased streamflow, causing excessive bank/bluff erosion. The DNR (DNR 2010) discusses the multiple causes of streambank erosion, including how altered hydrology influences stream bank erosion.

Upland sediment contributions typically happen when bare soils erode after rains or during snowmelt. Upland erosion includes farm field surface and gully erosion, sediment that is washed away from roads and developed areas, and surface erosion from other areas.

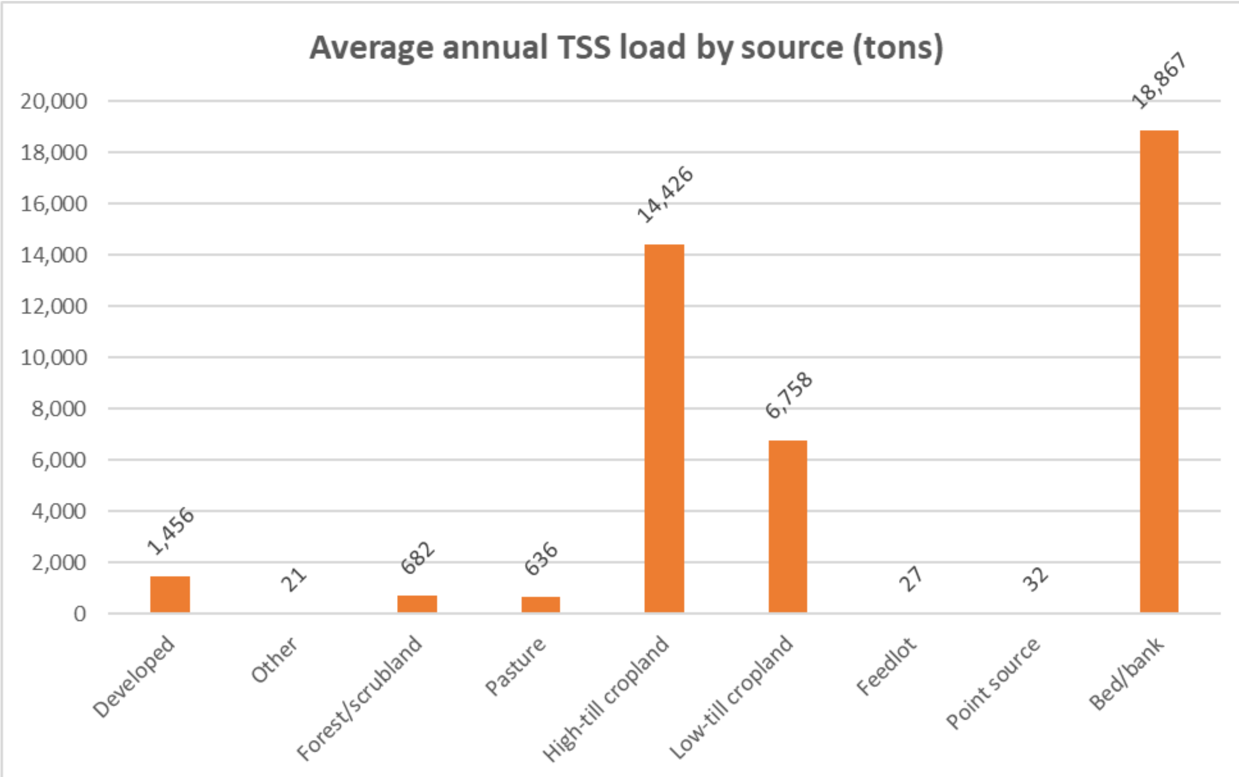


Figure 41. Sediment source assessment in the Lac qui Parle River at the outlet of the watershed, based on HSPF model results.

Figure 42 shows TSS FWMCs in the subwatersheds of the Lac qui Parle River Watershed as modeled by HSPF. Subwatershed TSS FWMCs range from 19 mg/L to 146 mg/L. According to the HSPF model, the highest TSS FWMCs occur near the convergence of the West Branch Lac qui Parle River and Lac qui Parle River, and near the outlet of the Lac qui Parle River. In addition, Judicial Ditch No 1 shows a high TSS FWMC, when compared to surrounding areas.

The SID report provides information on the sources for the TSS-stressed stream reaches. Most TSS-stressed reaches likely receive excess sediment from streambank erosion. Many of these stream reaches are impacted by altered hydrology, including flow alteration and altered channels.

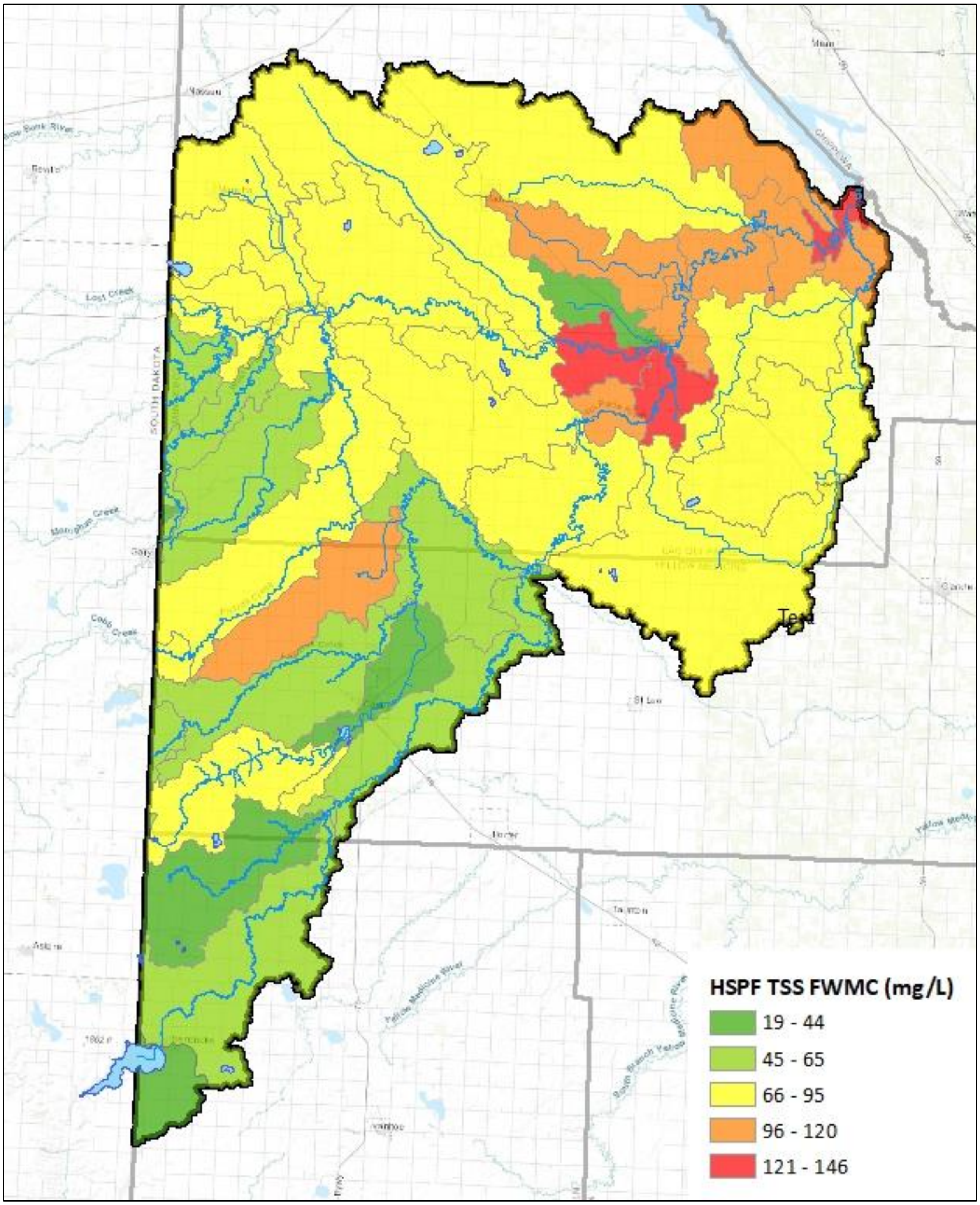


Figure 42. Average annual flow weighted mean concentrations of TSS (sediment), based on HSPF results.

2.3.5.3 Goal and 10-year Target

The watershed-wide sediment goal for the Lac qui Parle River Watershed is a 25% reduction in stream TSS FWMC to reach a FWMC of 65 mg/L. Subwatershed goals were calculated where TMDL data are available and range from a 0% to 72% load reduction. The 0% load reductions are due to the current TSS standard being less restrictive than the previous turbidity standard. Subwatershed goals are illustrated below (**Figure 43**), based on the HSPF results and meeting a FWMC of 65 mg/L. There is one stream reach impaired by and four stream reaches stressed by sediment and are included in a subwatershed identified as needing protection. This is the result of enough water quality samples violating the water quality standard to list them as impaired or stressing the biological communities. However, overall modeled flow weighted means indicate these stream reaches are often meeting water quality standards. The importance of this distinction is mostly administrative and should not impact implementation of BMPs. The BMPs that are implemented for protection also help restore streams as well as the BMPs implemented for restoration also help protect streams.

The 10-year target agreed to by the WRAPS LWG is a watershed-wide 10% FWMC reduction in TSS. These goals are revisable and will be revisited in the One Watershed, One Plan development and the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for sediment reductions are summarized in **Section 3**.

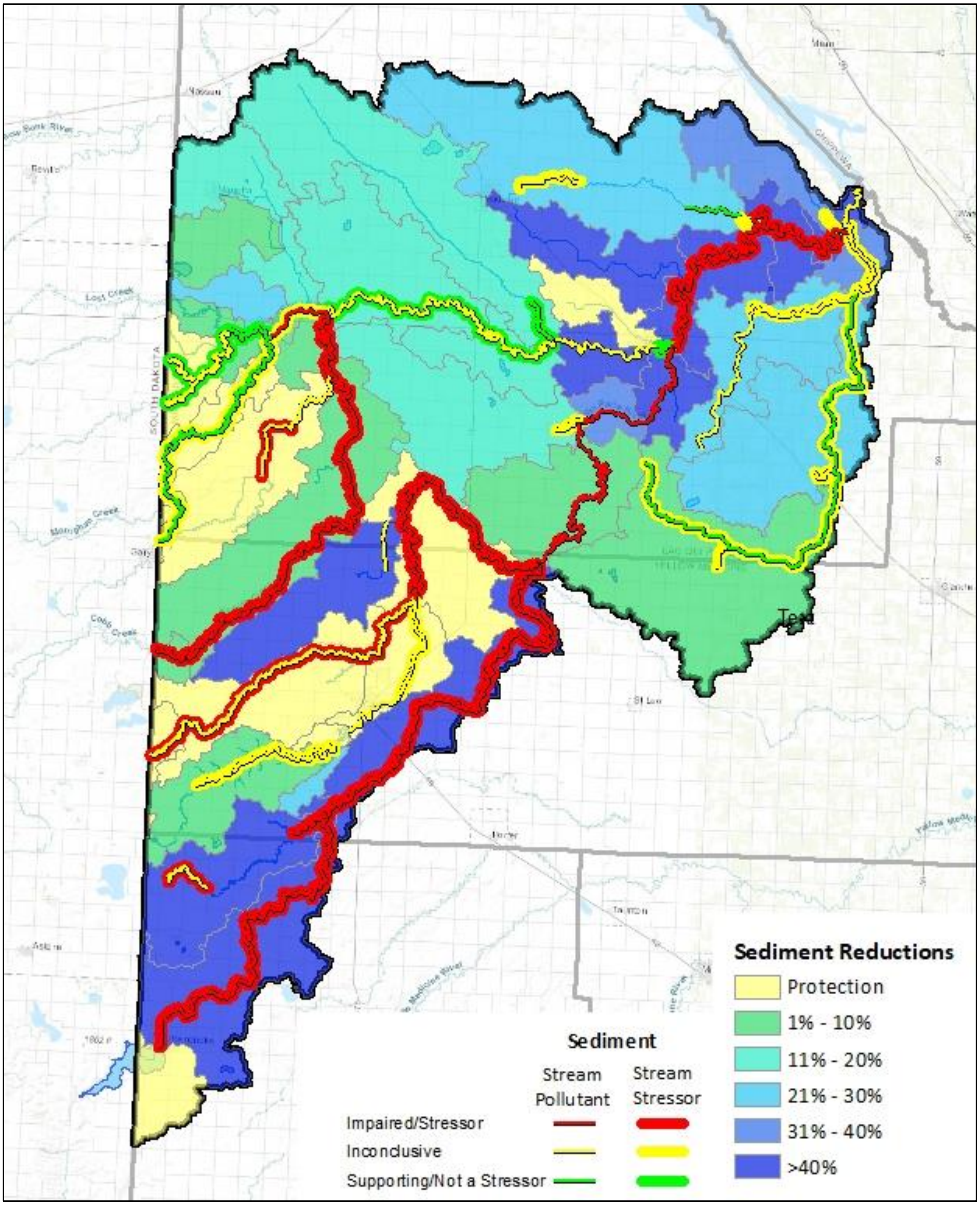


Figure 43. TSS (sediment) load reduction goals in the Lac qui Parle River Watershed, based on HSPF results.

2.3.6 Dissolved Oxygen

DO refers to the concentration of oxygen gas within the water column. Oxygen diffuses into the water from the atmosphere and from the release of oxygen from aquatic plants as a result of photosynthesis. Adequate DO is important for the support, growth, and reproduction of AqL (MPCA 2018).

Low DO, or highly fluctuating concentrations of DO, can have detrimental effects on many fish and macroinvertebrate species. Many species of fish avoid areas where DO concentrations are below 5 mg/L. Additionally, fish growth rates can be significantly affected by low DO levels (Doudoroff and Warren 1965). Human activities can be driving factors which change the DO concentrations of water resources. Nutrient content of surface waters is commonly influenced (often increased) by human activities and can result in excess aquatic plant growth. This situation often leads to a decline in daily minimum oxygen concentrations and an increase in the magnitude of daily DO concentration fluctuations due to greater oxygen production by plants during the daytime, increased usage of oxygen by plants at night, and the decay of the excess organic material, which is a process that consumes oxygen. Humans may also directly add organic material to waterbodies through municipal or industrial effluents. These forms of pollution increase the risk of eutrophication, which can also lead to low DO.

2.3.6.1 Status

Of the 33 stream reaches assessed, 2 were fully supporting, 2 were impaired, and 29 had insufficient information to complete an assessment. Additionally, 27 streams were investigated for low DO as a stressor in biologically impaired stream reaches. Of the 27 biologically impaired stream reaches, 8 were identified as having low DO as a stressor, 8 were classified as not a stressor, and 11 were inconclusive. **Figure 44** shows the assessment results and/or stressor status for low DO in the Lac qui Parle Watershed. The results for the pollutant assessment overlay the results for the stressor assessment, with the pollutant results shown on the inside and stressor results shown around the outside. **Table 22** tabulates the results for each assessed stream reach.

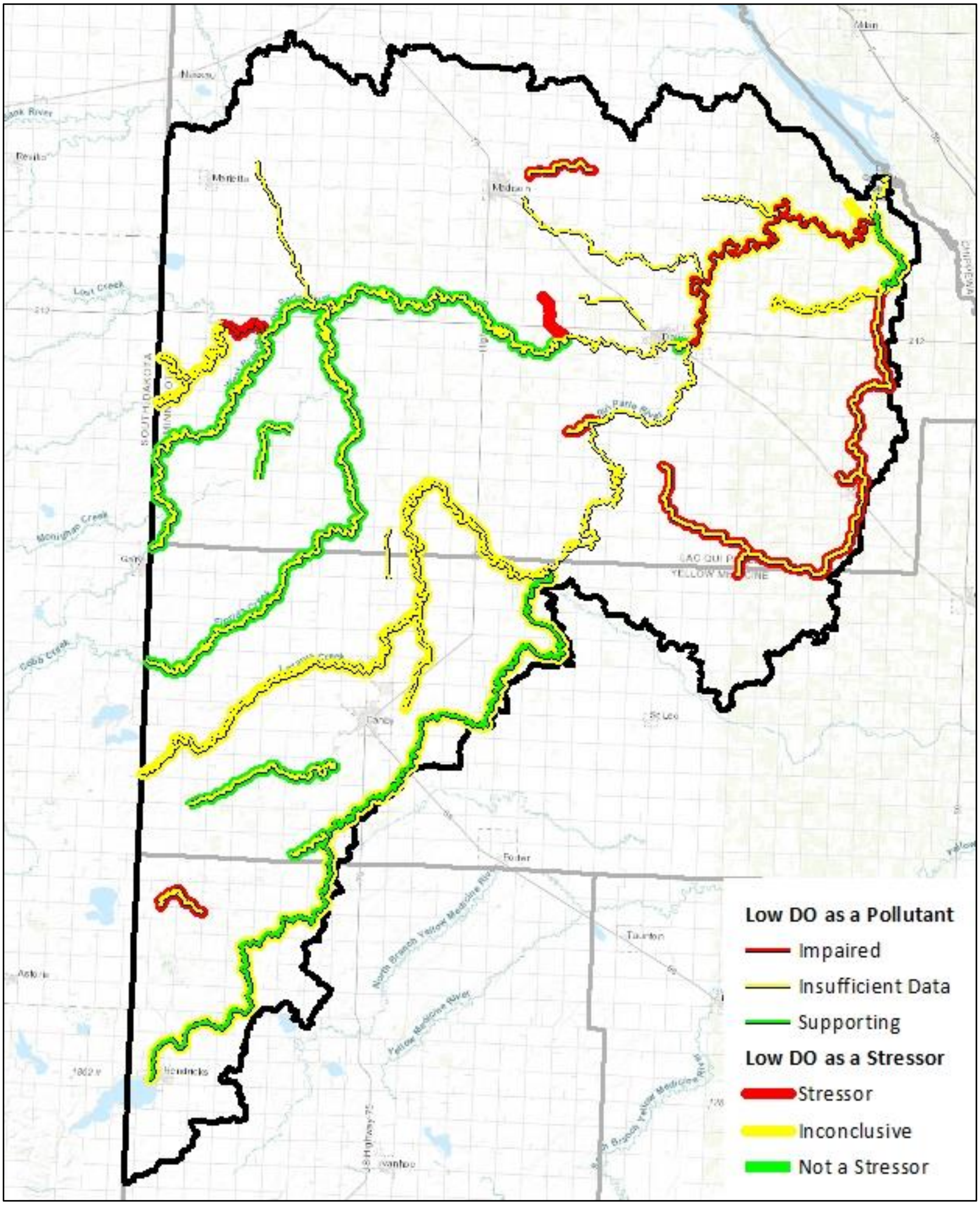


Figure 44. Dissolved oxygen assessment and stressor identification status of streams in the Lac qui Parle River Watershed.

Table 22. Assessment results for low dissolved oxygen as a pollutant and/or stressor in streams in the Lac qui Parle River Watershed.

Stream, Reach description	AUID (Last 3 digits)	Low DO, as a Pollutant	Low DO, as a Stressor	Stream, Reach description	AUID (Last 3 digits)	Low DO, as Pollutant	Low DO, as a Stressor
Lac qui Parle River	501	X	?	Unnamed Creek	534	?	X
Lac qui Parle River	502	?		Judicial Ditch 4	555	?	
Lac qui Parle River	505	+	?	Canby Creek	557	?	+
Lac qui Parle River	506	?		Judicial Ditch 1	560	?	
Lazarus Creek	508	?	?	Unnamed Creek	567	?	?
Lazarus Creek	509	?	?	Unnamed Creek	569	?	X
West Branch Lac qui Parle River	512	?		Unnamed ditch	570	?	X
West Branch Lac qui Parle River	513	?	+	Unnamed ditch	571	?	X
West Branch Lac qui Parle River	515	?	+	Unnamed ditch	575	?	X
West Branch Lac qui Parle River	516	?	+	Tenmile Creek	577	?	X
Lost Creek	517	X	X	Tenmile Creek	578	+	?
West Branch Lac qui Parle River	519	?	+	Unnamed Creek	580		X
Crow Timber Creek	520	?	?	Unnamed ditch	581	?	
Florida Creek	521	?	+	Unnamed ditch	582	?	?
County Ditch 27	522	?		Cobb Creek	583	?	+
County Ditch 5	523	?		Canby Creek	586	?	?
County Ditch 34	526	?	?	Unnamed Creek	588		?
Unnamed Creek	530	?	+				

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
<blank>	Not Assessed

2.3.6.2 Sources

Low DO in waterbodies is caused by: 1) excessive oxygen use, which is often caused by the decomposition of algae and plants whose growth is fueled by excess phosphorus and/or 2) too little re-oxygenation, which is often caused by minimal turbulence or warm water temperatures. Low DO levels can be exacerbated in over-widened channels because these streams move more slowly, tend to be shallower, and have more direct sun warming.

2.3.6.3 Goal and 10-year Target

The goal for DO is to reach the minimum standard of 5 mg/L and for diurnal DO flux to be less than 4.5 mg/L. Since DO is primarily a response of other stressors, the effective goal and 10-year target for DO are to meet the altered hydrology, phosphorus, and habitat goals and 10-year targets. In addition, many streams had insufficient information to complete an assessment. A related goal is monitoring additional stream reaches to determine if they are supporting or not supporting.

These goals are revisable and will be revisited in the One Watershed, One Plan development and the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address altered hydrology, phosphorus, and habitat are summarized in **Section 3**.

2.3.7 Nitrogen

Nitrogen (N) is one of the most abundant and widely distributed elements in nature and is present virtually everywhere on the planet in one or more of its many chemical forms. Nitrate (NO_3) and nitrite (NO_2) are components of the natural nitrogen cycle in aquatic ecosystems. Nitrate is a mobile form of N that is commonly found in ground and surface waters. Nitrite anions are naturally present in soil and water and are readily converted to nitrate by microorganisms as part of the nitrification process of the nitrogen cycle. As a result, nitrate is far more abundant than nitrite and generally the dominant form of N where total N levels are elevated.

Excessive nitrogen can be toxic to fish and macroinvertebrates, and even at small concentrations can limit sensitive species. Nitrate affects aquatic organisms by limiting their ability to carry oxygen through their body, which contributes to disease susceptibility and death. Nitrate was evaluated as a stressor for biologically impaired streams. Nitrate is also a major concern to human health. Excessive nitrate in drinking water causes methemoglobinemia, also known as blue baby syndrome (MDH 2019b). Due to this health risk, excessive nitrogen in drinking water can necessitate expensive treatments. Minnesota currently has a standard for drinking water which applies to one reach, Canby Creek (07020003-557), in the Lac qui Parle River Watershed. There was insufficient data for this reach to make an assessment for a drinking water beneficial use. Finally, eutrophication causing the Gulf Hypoxic Zone is due to excessive nitrogen contributions from the Mississippi River Basin, which includes the Lac qui Parle River Watershed.

2.3.7.1 Status

Of the biologically impaired stream reaches, nitrogen (nitrate) as a stressor was identified in 4 reaches, ruled out in 6, and inconclusive in 17. **Figure 45** illustrates the stream reaches assessed for nitrogen and **Table 23** tabulates those results. Nitrogen in groundwater, while outside the scope of the WRAPS report, is a related concern as nitrogen in groundwater originates from surface waters.

The primary concern for drinking water sources in the Lac qui Parle River Watershed is nitrogen concentration. Local partners may consider focusing nitrogen BMPs in the Drinking Water Supply Management Areas (DWSMAs) due to the mutual benefits of protecting drinking water supplies.

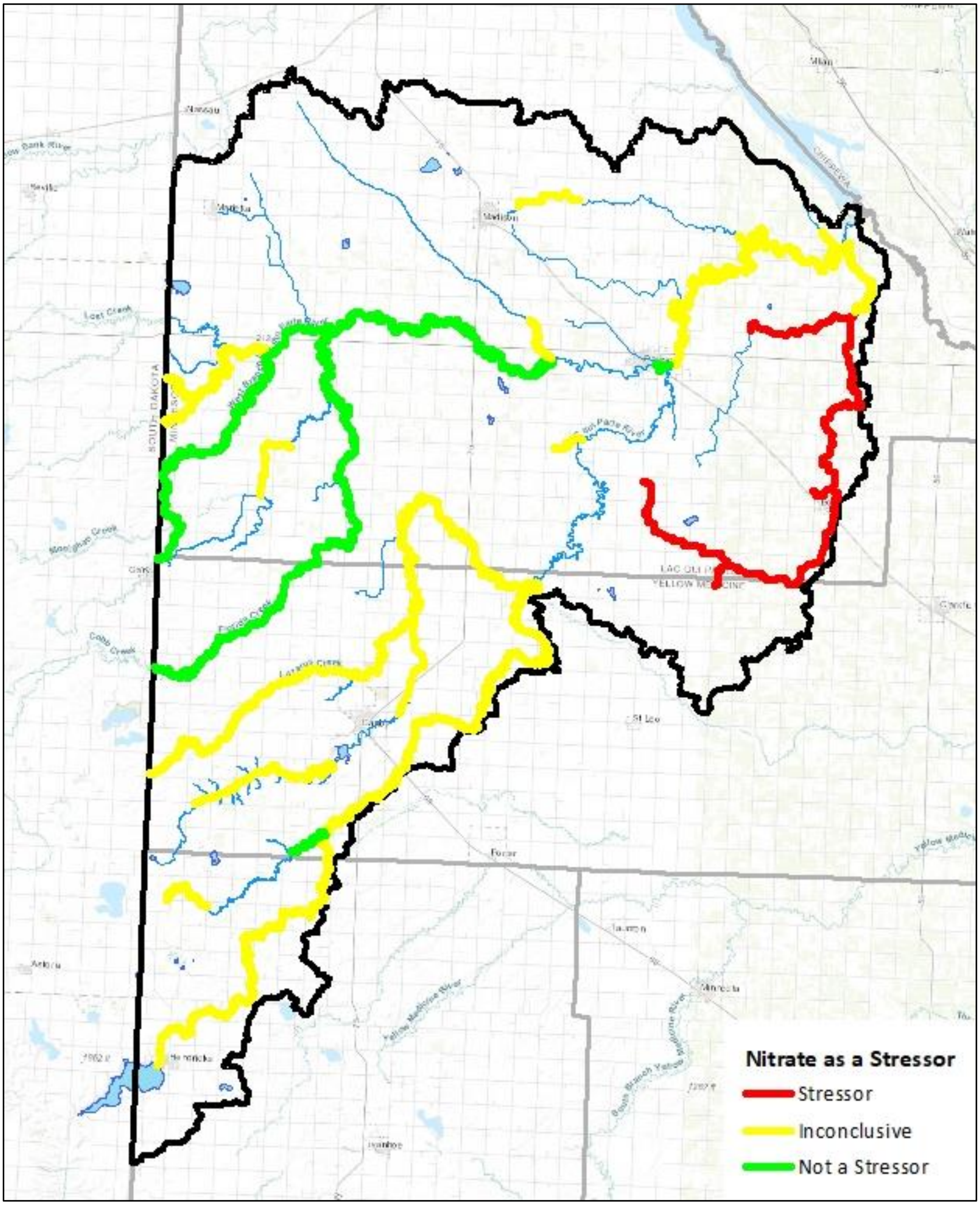


Figure 45. Nitrate identified as a stressor in streams in the Lac qui Parle River Watershed.

Table 23. Stressor identification results for nitrogen (nitrate) as a stressor in biologically impaired streams in the Lac qui Parle River Watershed.

Stream, Reach description	AUID (Last 3 digits)	Nitrate as a stressor	Stream, Reach description	AUID (Last 3 digits)	Nitrate as a stressor	Stream, Reach description	AUID (Last 3 digits)	Nitrate as a stressor
Lac qui Parle River	501	?	Crow Timber Creek	520	?	Unnamed ditch	571	X
Lac qui Parle River	505	?	Florida Creek	521	+	Unnamed ditch	575	?
Lazarus Creek	508	?	County Ditch 34	526	X	Tenmile Creek	577	X
Lazarus Creek	509	?	Unnamed Creek	530	+	Tenmile Creek	578	?
West Branch Lac qui Parle River	513	+	Unnamed Creek	534	?	Unnamed Creek	580	?
West Branch Lac qui Parle River	515	+	Canby Creek	557	?	Unnamed ditch (CD 4)	582	?
West Branch Lac qui Parle River	516	+	Unnamed Creek	567	?	Cobb Creek	583	?
Lost Creek	517	?	Unnamed Creek	569	?	Canby Creek	586	?
West Branch Lac qui Parle River	519	+	Unnamed ditch	570	X	Unnamed Creek	588	?

The Lac qui Parle River Watershed's nitrogen FWMC is several times higher than watersheds in north central and northeast Minnesota, but a FWMC that is in-line with the agriculturally rich watersheds found in the corn-belt region (northwest to southern regions) of the state, as shown by WPLMN monitoring data (**Figure 46**).

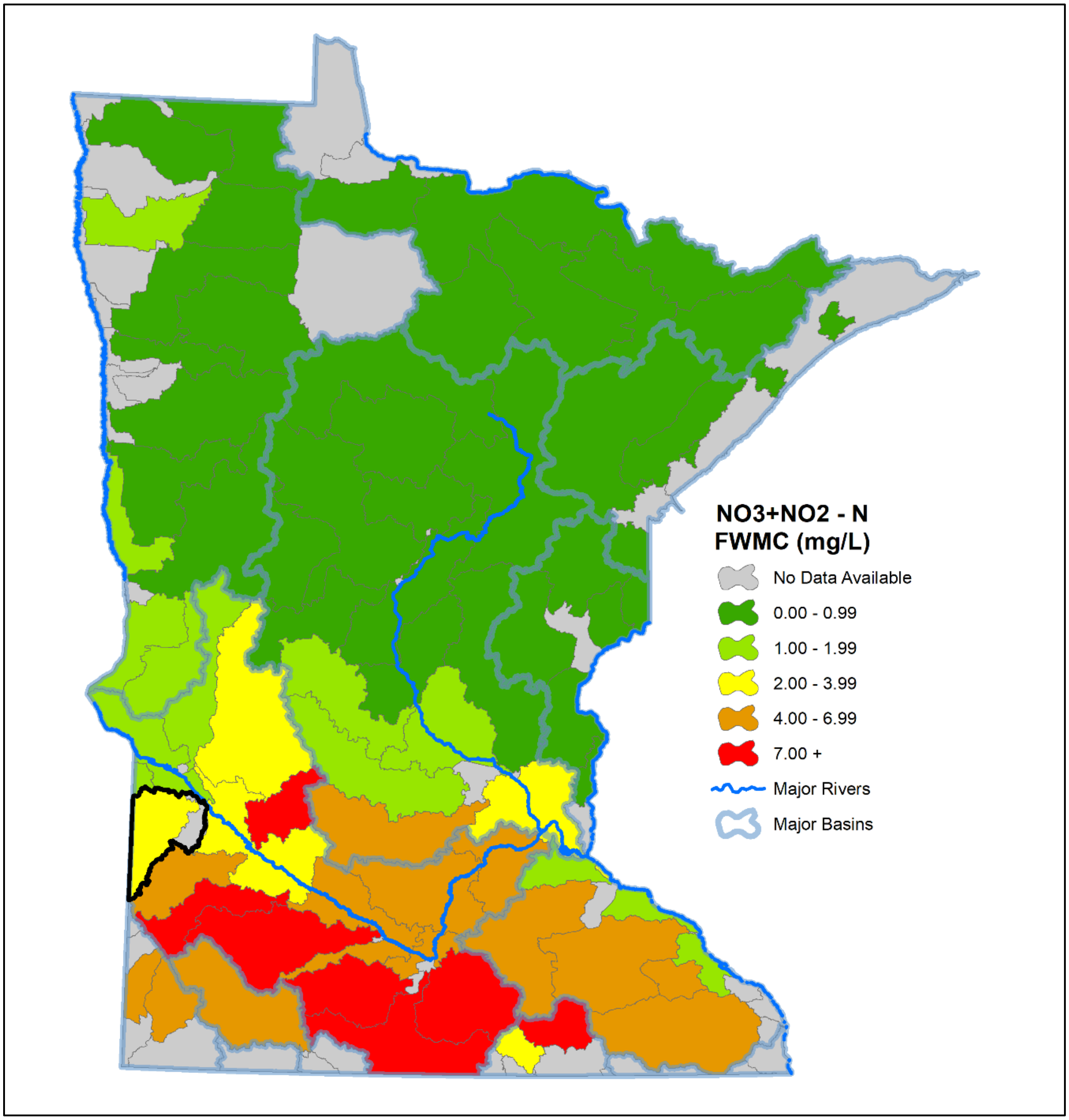


Figure 46. A statewide perspective of nitrogen flow weighted mean concentration for the Lac qui Parle River Watershed using WPLMN monitoring data.

2.3.7.2 Sources

Nitrogen sources are dominated by nonpoint sources in the Lac qui Parle River Watershed. Average annual point source contributions for the years 1996 through 2017 are estimated at approximately 1.3% of the Lac qui Parle River Watershed's nitrogen load with the rest derived from nonpoint sources, based on HSPF modeling. Annual loads from point sources are provided in **Figure 47**, from 2000 to 2020. **Figure 48** provides average annual source load estimates (by land use and pathways) as determined by the HSPF model. High-till cropland is the dominate nitrogen source in the watershed followed by low-till cropland, forest/scrubland, pasture, and developed lands.

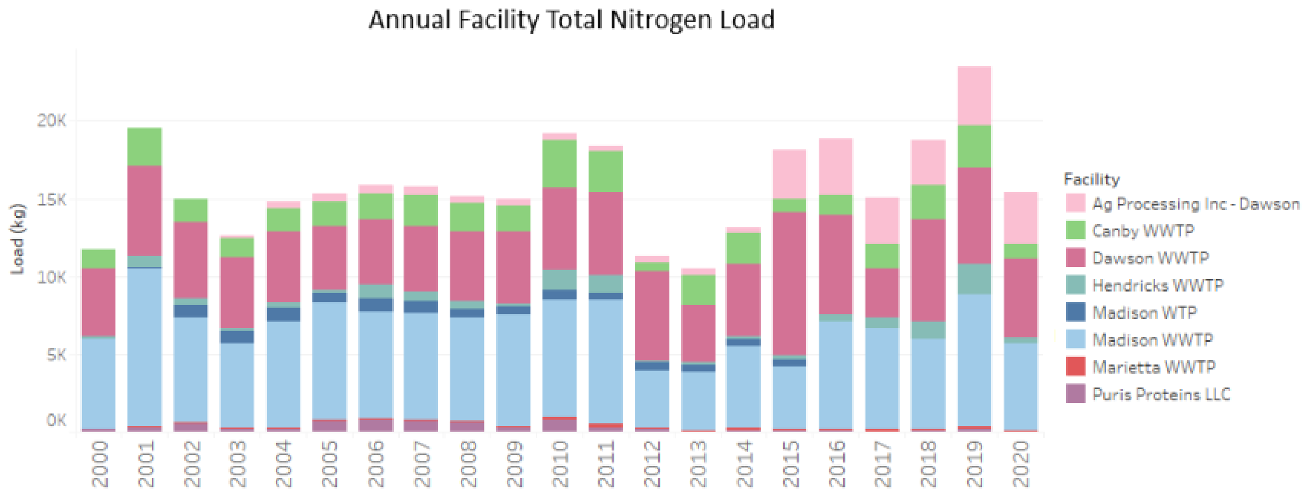


Figure 47. Annual facility total nitrogen load. Observed and estimated total nitrogen load from facilities in the Lac qui Parle River Watershed from 2000 - 2020.

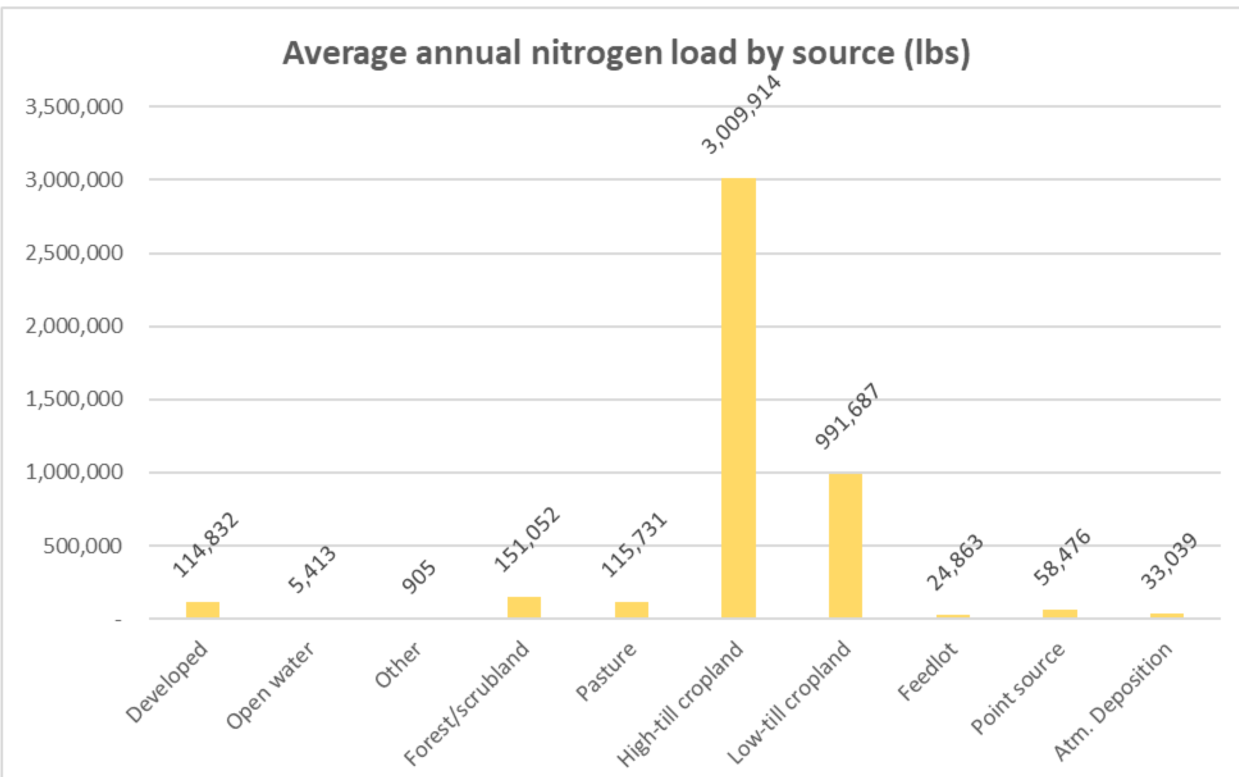


Figure 48. Total nitrogen source assessment in the Lac qui Parle River at the outlet of the watershed, based on HSPF model results.

Figure 49 shows the average annual FWMC of Total Nitrogen (TN) across the watershed, as modeled by HSPF. The average annual FWMC of TN ranges from 1.6 mg/L to 5.9 mg/L. Highest modeled FWMC are in Tenmile Creek, Tributary to West Branch, and County Ditch 4 subwatersheds.

2.3.7.3 Goal and 10-year Target

The watershed goal for nitrogen is the statewide goal of a 45% reduction, based on the *Minnesota Nutrient Reduction Strategy* (MPCA 2014b), which calls for a 45% reduction from the Minnesota portion of the Mississippi River Basin as a whole. The reaches not stressed by nitrogen have a protection goal. The 10-year target is a 20% decrease in nitrogen, based on the 2025 interim goal. Individual stream reach reductions may be more or less than the basin-wide goal based on specific stream conditions. However, individual stream reduction goals were not calculated because no nitrate TMDLs were completed.

These goals are revisable and will be revisited in the One Watershed, One Plan development and the next iteration of the Watershed Approach to meet the goals and 10-year targets. Methods to prioritize regions for nitrogen reductions are summarized in **Section 3**.

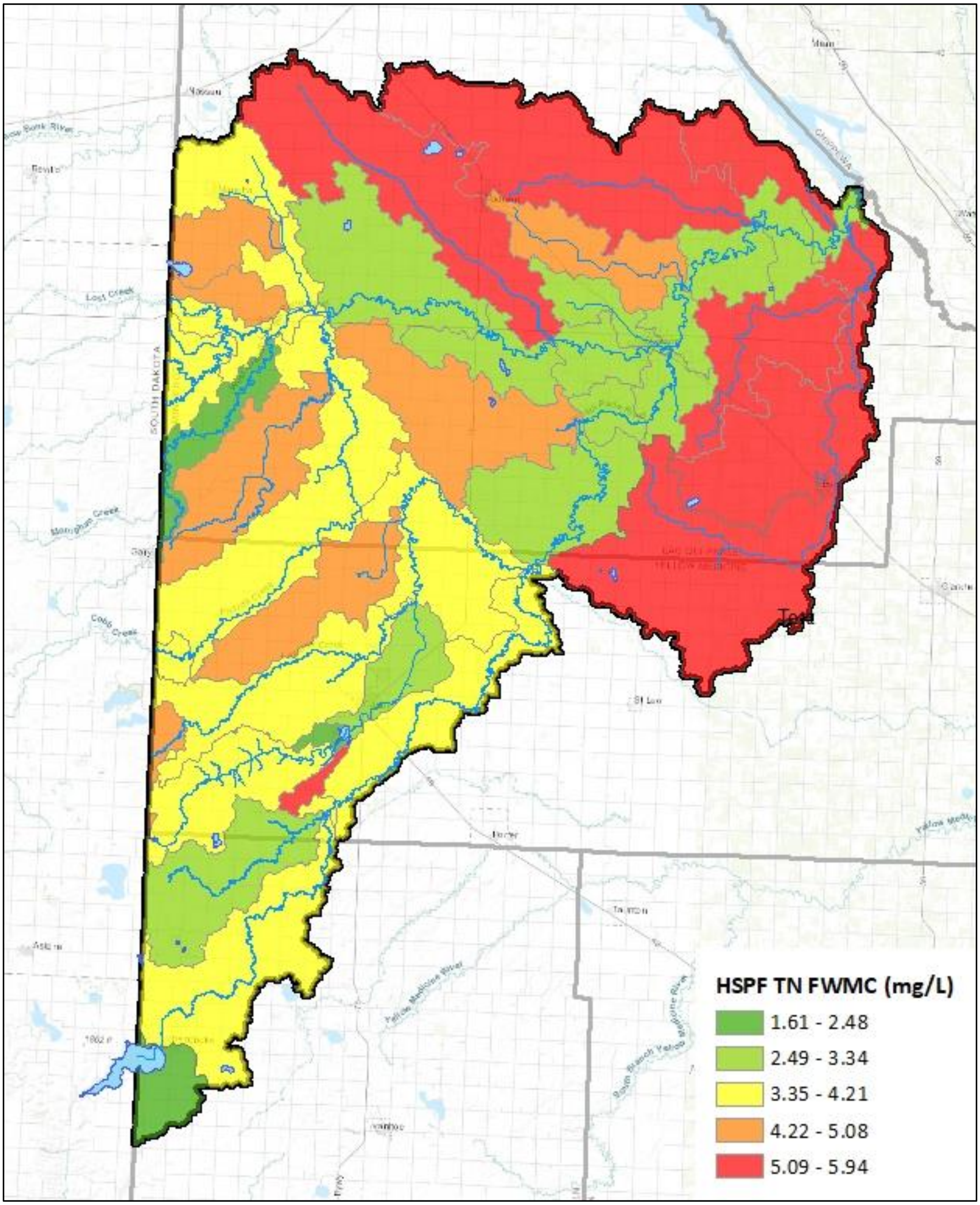


Figure 49. Average annual flow-weighted mean concentrations of TN in the Lac qui Parle River Watershed based on the HSPF model results.

2.3.8 Connectivity

Natural connections in a watershed can be one of the most important, yet most overlooked components of watershed health. Alterations of connectivity can have large impacts on fish communities due to the installation of barriers within their natural habitat range (DNR 2019).

Connectivity, as identified in the report, refers to the longitudinal connectivity of a stream, or the upstream to downstream connectivity of a stream. Lateral connectivity, or the connectivity of a stream to its floodplain, is briefly discussed below but is not the focus of the assessments for lack of connectivity as a stressor.

2.3.8.1 Status

Lack of connectivity as a stressor was identified in 6 streams and ruled out in 21 stream reaches. **Table 24** provides the assessment results for lack of connectivity as a stressor and **Figure 50** illustrates those assessments.

Table 24. Assessment results for lack of connectivity, as a stressor, in biologically impaired streams of the Lac qui Parle River Watershed.

Stream, Reach description	AUID (Last 3 digits)	Lack of connectivity	Stream, Reach description	AUID (Last 3 digits)	Lack of connectivity	Stream, Reach description	AUID (Last 3 digits)	Lack of connectivity
Lac qui Parle River	501	+	Crow Timber Creek	520	+	Unnamed ditch	571	+
Lac qui Parle River	505	X	Florida Creek	521	+	Unnamed ditch	575	+
Lazarus Creek	508	+	County Ditch 34	526	+	Tenmile Creek	577	+
Lazarus Creek	509	+	Unnamed Creek	530	+	Tenmile Creek	578	+
West Branch Lac qui Parle River	513	+	Unnamed Creek	534	+	Unnamed Creek	580	+
West Branch Lac qui Parle River	515	X	Canby Creek	557	X	Unnamed ditch (CD 4)	582	+
West Branch Lac qui Parle River	516	+	Unnamed Creek	567	+	Cobb Creek	583	+
Lost Creek	517	+	Unnamed Creek	569	X	Canby Creek	586	X
West Branch Lac qui Parle River	519	+	Unnamed ditch	570	+	Unnamed Creek	588	X

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor

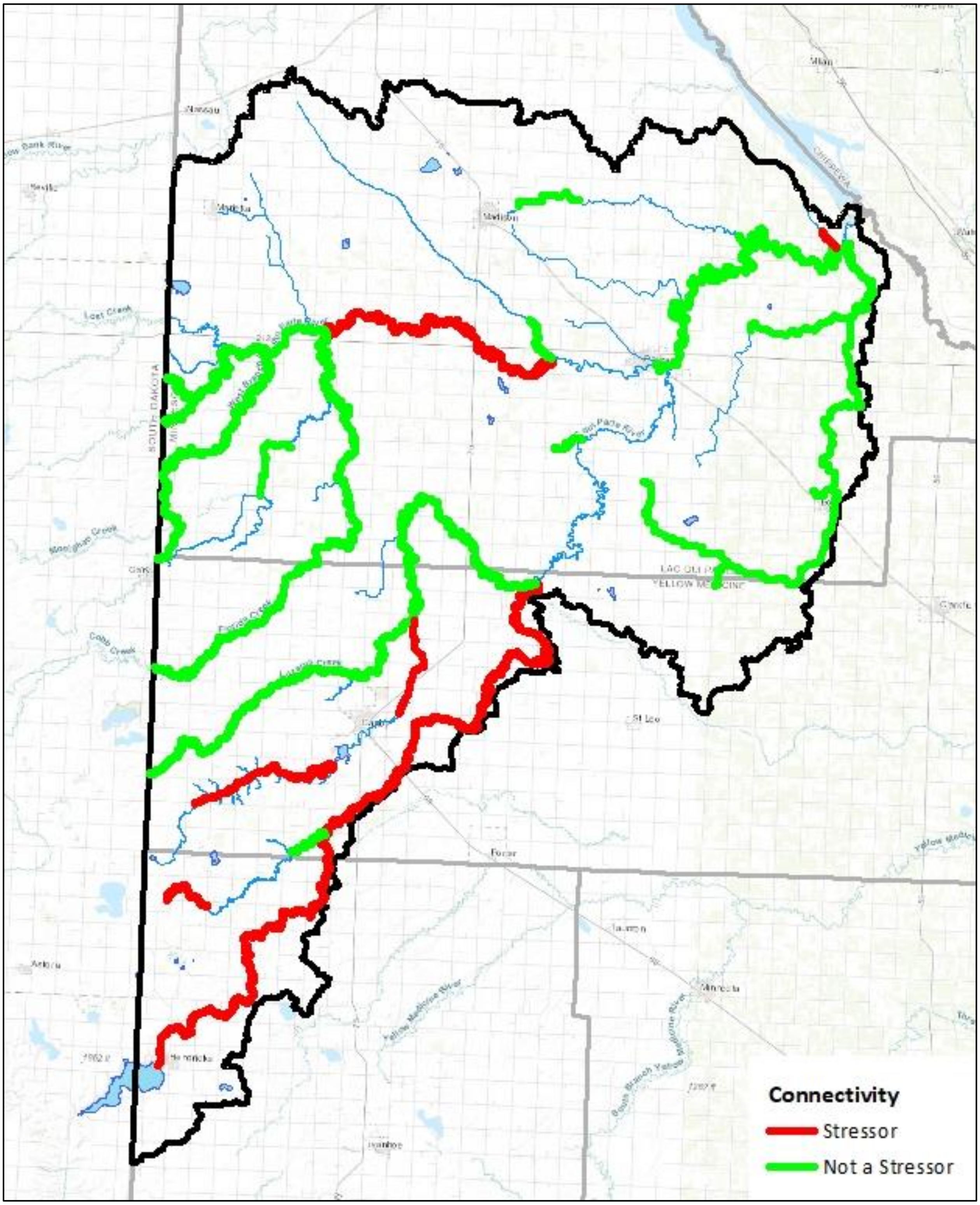


Figure 50. Loss of connectivity identified as a stressor in streams in the Lac qui Parle River Watershed.

2.3.8.2 Sources

Of the six stream reaches stressed by lack of connectivity, one is impacted by migration barriers during low flow, two are impacted by perched or under sized culverts, two are impacted by dams, and one is impacted by a floodway diversion. **Table 25** identifies the specific sources of connectivity issues by stream reach, as identified in the SID report (MPCA 2020b).

Table 25. The specific sources of connectivity issues for stream reaches in the Lac qui Parle River Watershed, as identified in the Stressor Identification Report (MPCA 2020b).

Stream	AUID (last 3-digits)	Connectivity Sources			
		Migration Barriers during low flows	Perched/ Under Sized Culvert	Dams	Floodway Diversion
Lac qui Parle River	505				X
West Branch Lac qui Parle River	515		X		
Canby Creek	557			X	
Unnamed Creek	569	X	X		
Canby Creek	586			X	
Unnamed Creek	588		X		

Further discussion on connectivity issues in the watershed are provided in the DNR's Watershed Characterization Report (DNR 2019). The DNR's longitudinal connectivity analysis found 23 potential fish barriers within the watershed, with only 2 MPCA biological monitoring sites upstream of these barriers. The two barriers downstream of MPCA biological sites are both water retention structures; one on Lazarus Creek, and one on Canby Creek. The MPCA biological sites affected by these barriers are 15MN102 (Lazarus Creek) and 09MN093 (Canby Creek). These analyses are not considered complete. In order to fully understand how many crossings are barriers to fish passage, it is important for a complete crossing inventory. See DNR guidance on stream crossing assessment for more information.

Prior to 2010, there was a low head dam on the Lac qui Parle River in Dawson that effectively blocked fish migration; however, this dam was removed and rock arch rapids was installed in its place. Removal of the dam restored fish migration potential to 16 MPCA biological monitoring sites on the West Branch Lac qui Parle River. However, there is a private field crossing about three miles upstream of Dawson that is a barrier at most flows until it is inundated. The landowner is currently working on a plan to replace the crossing with a structure that does not create a fish barrier.

DNR (2019) conducted a GIS analysis and found 1,646 road and stream intersections in the Lac qui Parle River Watershed. The high density of crossings in the watershed, especially in the steeper reaches near the Prairie Coteau, often result in crossings that do not allow fish passage in high flows as stream velocities increase through culverts that are not sized appropriately for the channel and the floodplain. The increased velocities also create local channel incision and increased bank erosion.

Floodplain connectivity is still prevalent in the Lac qui Parle River Watershed in sites that have not been ditched; however, future incision in channels that are already incised could reduce this connection. Floodplains are very important for river stability as they reduce the amount of water the channel has to transport; thus less energy is held within the channel. As channels incise and have to convey more water and energy, bank and bed erosion increase dramatically, resulting in TSS impairments, channel succession, and loss of habitat. Floodplains also store water, treat nutrients, provide refuge for aquatic animals during high flows, and are critical for spawning and nursery habitat for some species (DNR 2019).

Floodplain connectivity was assessed at eight geomorphology survey sites throughout the watershed. Out of eight survey reaches, seven sites had adequate floodplain connectivity (i.e. not entrenched), while one site did not have floodplain connectivity (i.e. entrenched). The one entrenched site was a drainage ditch in the headwaters of the Tenmile Creek watershed. See the Lac qui Parle River Watershed Characterization Report (DNR 2019) for further information.

2.3.8.3 Goal and 10-year Target

The goal for connectivity for the Lac qui Parle River Watershed is to mitigate or remove connectivity issues where relevant or feasible. The 10-year target for the watershed is to assess undersized culverts and connectivity issues to determine if they are the main stressors to the reach prior to investing in upgrades and develop plans to upgrade or mitigate connectivity issues. Upgrades or mitigation may not be cost effective if other stressors (altered hydrology, nutrients, habitat, sediment, etc.) have a larger impact on the aquatic communities. This goal is revisable and should be revisited during One Watershed, One Plan development and the next iteration of the WRAPS cycle.

2.4 TMDL summary

This section covers the existing TMDLs in the Lac qui Parle River Watershed. Three TMDL studies have been completed in Lac qui Parle River Watershed. A watershed-wide TMDL was completed in tandem with this WRAPS report, covering 10 impairments in 9 streams. In 2013, a bacteria, turbidity, and DO TMDL was conducted in the Lac qui Parle River and Yellow Bank River Watersheds which included 15 impairments in 8 stream reaches in the Lac qui Parle River Watershed. In 1999, South Dakota's Department of Environment & Natural Resources developed a TMDL for TP and accumulated sediment for Lake Hendricks, which was approved by EPA Region 8 in April 1999; MPCA also reviewed and accepted this TMDL. All streams and lakes with a TMDL are listed in **Table 26**. All TMDL tables, including load capacity, load allocation, and waste load allocations are provided in **Appendix 5.1**.

Table 26. Streams with drafted or approved TMDLs in the Lac qui Parle River Watershed.

AUID	Waterbody	Impairment/ Parameter	Beneficial Use[3]	Listing Year	TMDL Year	Estimated Percent Load Reduction
07020003-501	Lac qui Parle River, W Br Lac Qui Parle R to Tenmile Cr	Dissolved oxygen	AQL	1994	2013	26% (SOD/BOD)[6]
		Turbidity	AQL	2006	2013	66%[5]
		Fecal Coliform	AQR	2006	2013	17%[4]
07020003-502	Lac qui Parle River, Tenmile Cr to Minnesota R	Escherichia coli	AQR	2018	2021	39%
07020003-505	Lac qui Parle River, Headwaters (Lk Hendricks 41-0110-00) to Lazarus Cr (Canby Cr)	Turbidity	AQL	2006	2013	72%[5]
		Fecal Coliform	AQR	2006	2013	56%[4]
07020003-506	Lac qui Parle River, Lazarus Cr (Canby Cr) to W Br Lac Qui Parle R	Turbidity	AQL	2006	2013	75%[5]
		Fecal Coliform	AQR	2006	2013	42%[4]
07020003-508	Lazarus Creek (Canby Creek), Canby Cr to Lac Qui Parle R	Turbidity	AQL	2006	2013	34%[5]
		Fecal Coliform	AQR	2006	2013	68%[4]

AUID	Waterbody	Impairment/ Parameter	Beneficial Use[3]	Listing Year	TMDL Year	Estimated Percent Load Reduction
07020003-512	Lac qui Parle River, West Branch, Unnamed cr to Unnamed ditch	Mercury in fish tissue[1]	AQC	2010	2010	NA
		Fecal Coliform	AQR	2006	2013	14%[4]
07020003-513	Lac qui Parle River, West Branch, Unnamed ditch to Lac Qui Parle R	Escherichia coli	AQR	2018	2021	64%
07020003-515	Lac qui Parle River, West Branch, Florida Cr to Unnamed cr	Mercury in fish tissue[1]	AQC	2010	2010	NA
07020003-516	Lac qui Parle River, West Branch, Lost Cr to Florida Cr	Mercury in fish tissue[1]	AQC	2010	2010	NA
		Turbidity	AQL	2010	2013	0%[5]
		Fecal Coliform	AQR	2006	2013	67%[4]
07020003-517	Lost Creek, Crow Timber Cr to W Br Lac Qui Parle R	Escherichia coli	AQR	2018	2021	21%
07020003-519	Lac qui Parle River, West Branch, MN/SD border to Lost Cr	Escherichia coli	AQR	2018	2021	86%
		Mercury in fish tissue[1]	AQC	2010	2010	NA
07020003-521	Florida Creek, MN/SD border to W Br Lac Qui Parle R	Turbidity	AQL	2006	2013	0%[5]
		Fecal Coliform	AQR	2006	2013	69%[4]
07020003-523	County Ditch 5, T118 R46W S23, north line to W Br Lac Qui Parle R	Escherichia coli	LRV	2018	2021	44%[8]
07020003-530	Unnamed creek, Unnamed cr to Lac Qui Parle R	Escherichia coli	AQR	2018	2021	85%
		Total suspended solids	AQL	2018	2021	55%
07020003-577	Tenmile Creek, Headwaters to CSAH 18	Fecal Coliform[2]	AQR	2006	2013	42%[4]
07020003-578	Tenmile Creek, CSAH 18 to Lac Qui Parle R	Fecal Coliform[2]	AQR	2006	2013	38%[4]
07020003-580	Unnamed creek, -96.1517, 44.9533 to W Br Lac Qui Parle R	Escherichia coli	AQR	2018	2021	38%
07020003-581	Unnamed ditch (County Ditch 4), Unnamed ditch to CSAH 20	Escherichia coli	AQR	2018	2021	61%
87-0180-00	Del Clark	Mercury in fish tissue	AQC	2004	2007	NA
41-0110-00	Hendricks	Mercury in fish tissue	AQC	1998	2008	NA
		Nutrient/eutrophication biological indicators	AQR	2010	1999	50%

[1]Part of the state-wide Mercury TMDL.
[2] Carry forward impairment from 07020003-511.
[3]AQC = Aquatic Consumption, AQL = Aquatic Life, AQR = Aquatic Recreation.
[4]Based on current assessment period and a flow weighted summer geometric mean
[5]Based on current assessment period and on TSS concentration deviation from standard. Turbidity was more restrictive than the current TSS standard, resulting in some of the turbidity impairments needing 0% reduction.
[6]Primary stressors and TMDLs based on sediment oxygen demand (SOD) and biological oxygen demand (BOD).
[7]Primary stressors and TMDLs based on phosphorus and eutrophication.
[8]Reduction based on the daily standards of 1,260 org/100mL.

The load reductions provided in **Table 26** are either from the TMDL reports or estimated using current water quality data if reductions were not provided in the TMDL report. For the turbidity impairments, the load reductions are based on the current TSS standard. Some of the turbidity impairments show that no load reduction is required. This is due to those TMDLs using a surrogate to develop the TMDL that was more restrictive (lower) than the current TSS standard and will need to be revisited during the next Watershed Approach cycle.

Some of the waterbodies in the Lac qui Parle River Watershed are impaired by mercury; however, the WRAPS report does not cover toxic pollutants. For more information on mercury impairments, see the statewide mercury TMDL on the MPCA website at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

2.5 Protection considerations

Preventing the degradation of waterbodies that are nearing an impacted state can be as important as achieving water quality standards in those waterbodies that are already impaired. Preventing the further degradation of a waterbody can prevent listing, but more importantly avoid what are frequently more costly restoration efforts. In fact, restoration efforts might never result in the return of a lake to the original aquatic use or AqR standard, such as has been found for some shallow lakes and wetlands. Strategies to protect and restore degraded waterbodies identified in **Section 3** are critical to ensuring that water quality goals are achieved and sustain continued use of the resources.

Lakes

Many Minnesota lakes have water quality that is substantially better than their applicable standards, especially throughout the north-central and northeastern parts of the state. According to the DNR's phosphorus sensitivity analysis and lake prioritization (DNR 2011), the Lac qui Parle River Watershed includes several lakes with phosphorus levels that well-exceed the standard but are not listed as impaired due to insufficient data to properly assess. The comparison of current lake TP concentrations to an ecoregion specific standard facilitates prioritization and implementation strategies for these lakes which may keep lakes from future degradation or future designation as impaired.

To ensure that impaired and unimpaired lakes alike are protected from further degradation, the degree of sensitivity to change should be considered when determining a protection strategy to implement. Protection for lakes that meet water quality standards can be prioritized considering the following attributes:

- waters meeting water quality standards but with downward trends in water quality;
- waters having known or anticipated future water quality threats;
- waters with suspected but not confirmed impairments;
- shallow lakes, which are especially sensitive to nutrient loading or watershed activities; and
- high-quality or unique waters deserving special attention.

Nutrient load reduction goals for TP for each lake, both impaired and unimpaired, are summarized in **Table 27**, relative to the lake standard (depth and ecoregion) as well as the current condition and targeted goals, calculated using DNR's lake phosphorus sensitivity analysis. In the Lac qui Parle River Watershed, highest protection priority is recommended for three lakes not assessed as impaired: Del Clark, Salt and Bohemian. Del Clark is the only basin with sufficient data to render a complete assessment, which was found to support recreational use.

Table 27. Summary of lake prioritization for the Lac qui Parle River Watershed for eutrophication (TP) risk. This analysis utilized the DNR's lake phosphorus sensitivity analysis for calculations.

Lake Name	AUID	Eco-region	Depth Class	Impaired (Y/N)?	Phosphorus Standard [ug/L]	Current Condition [ug/L]	Target Mean TP [ug/L]	Target TP Load Reduction [lbs/yr]	Priority Class
Del Clark	87-0180-00	NGP	Deep	N	65	38	32	43	Higher
Unnamed (Bohemian)	41-0109-00	NGP	Shallow	N	90	101	85	0.09	Highest
Hendricks	41-0110-00	NGP	Shallow	Y	90	170	143	210	Impaired
Salt	37-0229-00	NGP	Shallow	N	90	175	146	0.21	Highest
Cory	37-0103-00	WCBP	Shallow	N	90	233	195	110	High
West Twin	41-0102-00	NGP	Shallow	N	90	323	270	22	High
Unnamed (Arena)	37-0148-00	WCBP	Shallow	N	90	404	338	123	High

Streams

Designation of streams as candidates for protection or restoration is important in aligning with BWSR's Nonpoint Priority Funding Plan for Clean Water Funding Implementation and Minnesota's Clean Water Roadmap. For this reason, analyzed streams are designated as either "protection" or "restoration" based on water quality data. Streams within the "protection" category are divided into three subcategories: Above Average Quality, Potential Impairment Risk, and Threatened Impairment Risk. Streams within the "restoration" category are divided into two subcategories: Low Restoration Effort and High Restoration Effort. This more refined categorization reflects priorities in the Nonpoint Priority Funding Plan for Clean Water Funding Implementation. Each stream reach receives a classification for each measured water quality parameter (e.g. TP – low restoration effort, *E. coli* – potential impairment risk, etc.).

All streams not included in this analysis that are currently supporting AqL and AqR in the watershed are also candidates for protection. Over time, if these waters are not subject to protection strategies, they may or may not become impaired. For these streams, the protection strategy consists of working toward ensuring the existing loads for the critical duration periods are not exceeded. Protection strategies include improving upland and field surface runoff controls and improving livestock and manure management. Strategies for addressing protection of these waters are discussed in more detail in **Section 3** of this report.

A brief summary of the protection or restoration classifications for stream reaches can be seen in **Table 28**. A more detailed description of methods used to determine priority classes can be found in **Section 3.1.**

Table 28. Stream priority classification for streams in the Lac qui Parle River Watershed.

Name	AUID	Protection			Restoration	
		Above Average Quality	Probable Impairment Risk	Threatened Impairment Risk	Low Restoration Effort	High Restoration Effort
Lac qui Parle River, W Br Lac qui Parle R to Tenmile Cr	501	N				DO, *E. coli*, TP, TSS
Lac qui Parle River, Tenmile Cr to Minnesota R	502	N	DO			*E. coli*, TP, TSS
Lac qui Parle River, Headwaters (Lk Hendricks 41-0110-00) to Lazarus Cr (Canby Cr)	505	N	DO			*E. coli*, TP, TSS

Name	AUID	Protection			Restoration	
		Above Average Quality	Probable Impairment Risk	Threatened Impairment Risk	Low Restoration Effort	High Restoration Effort
Lac qui Parle River, Lazarus Cr (Canby Cr) to W Br Lac qui Parle R	506	N	DO			*E. coli*, TP, TSS
Lazarus Creek (Canby Creek), Canby Cr to Lac qui Parle R	508	N	DO, TP			*E. coli*, TSS
Lac qui Parle River, West Branch, Unnamed cr to Unnamed ditch	512	N	DO	TSS		*E. coli*, TP
Lac qui Parle River, West Branch, Unnamed ditch to Lac qui Parle R	513	N, TSS	DO		TP	*E. coli*
Lac qui Parle River, West Branch, Lost Cr to Florida Cr	516	DO, N	TP, TSS			*E. coli*
Lost Creek, Crow Timber Cr to W Br Lac qui Parle R	517	N, TSS			TP	DO, *E. coli*
Crow Timber Creek, MN/SD border to Lost Cr	519	DO, N			TP	*E. coli*, TSS
Florida Creek, MN/SD border to W Br Lac qui Parle R	521	N	DO	TP	TSS	*E. coli*
County Ditch 5, T118 R46W S23, north line to W Br Lac qui Parle R	523	DO, N, TP, TSS				*E. coli*
Unnamed creek, Unnamed cr to Lac qui Parle R	530	DO, N				*E. coli*, TP, TSS
Judicial Ditch 4, Underground portion	563	TSS	DO, TP	N		*E. coli*
Tenmile Creek, Headwaters to CSAH 18	577	DO, N, TSS	TP			*E. coli*
Tenmile Creek, CSAH 18 to Lac qui Parle R	578	DO	N, TP			*E. coli*, TSS
Unnamed creek, -96.1517, 44.9533 to W Br Lac qui Parle R	580	N, TSS				DO, *E. coli*, TP
Unnamed ditch (County Ditch 4), Unnamed ditch to CSAH 20	581	TSS	N, TP	DO		*E. coli*

Groundwater

Additional protection concerns in the watershed relate to groundwater and drinking water protection. The main supply of drinking water to the residents and businesses in the Lac qui Parle River Watershed is groundwater – either from private wells, community wells, or rural water suppliers.

The City of Canby has a highly vulnerable drinking water system and the City of Madison has a moderately vulnerable drinking water system, which indicates a connection between groundwater and surface water in the watershed. Lincoln Pipestone Rural Water's Burr wellfields have moderate and low vulnerability. Contaminants on the surface can move into the drinking water aquifers more quickly in these vulnerable areas and are connected to the surface water resources in the watershed.

The City of Dawson has low vulnerability to contamination due to its deeper aquifers that are fairly well protected. There is also the potential for contamination through unused and abandoned wells. Ensuring abundant and high-quality supplies of groundwater is critical; especially in light of altered hydrology and the impacts on groundwater recharge.

Nitrogen infiltration is a potential risk to ground water in the Lac qui Parle River Watershed. As a means to protect groundwater, nitrogen fertilizer application is restricted in the fall and on frozen soils in cropland in vulnerable groundwater areas (MDA 2021). The restriction also applies to municipal DWSMAs of public water supply wells with nitrate-nitrogen at or in excess of 5.4 mg/L. Vulnerable groundwater areas are defined as having coarse textured soils, shallow bedrock, or karst geology, which nitrate can easily move through, and are designated by quarter section. The cropland in vulnerable groundwater areas in the Lac qui Parle River Watershed that have fall nitrogen fertilizer application restrictions for the year 2021 is shown in **Figure 51**. Areas subject to fall application restrictions are updated annually and can be viewed on an interactive vulnerable groundwater area map located on the MDA [Vulnerable Groundwater Area Map](#) website (MDA 2021).

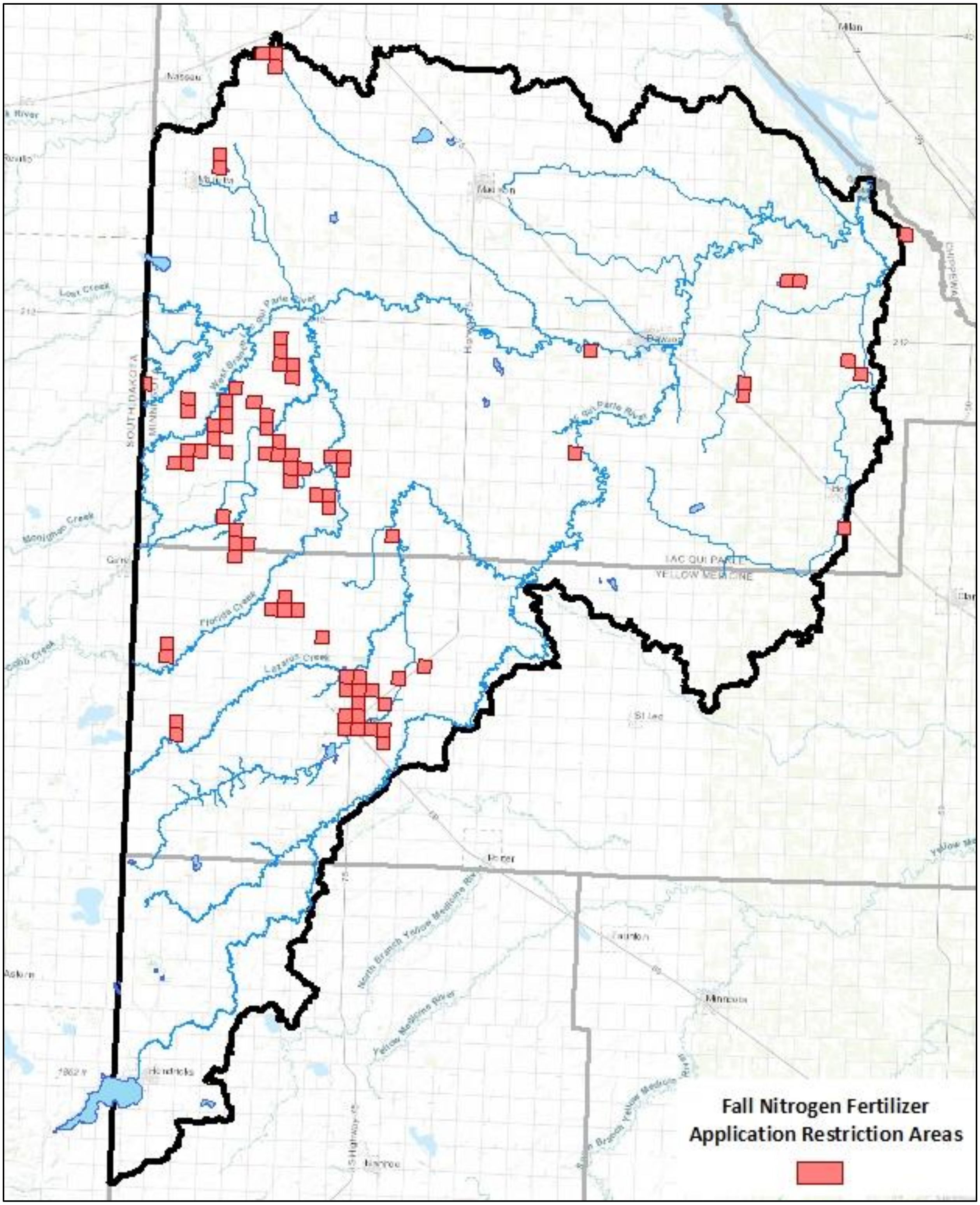


Figure 51. Fall nitrogen fertilizer application restriction areas in the Lac qui Parle River Watershed.

3. Prioritizing and implementing restoration and protection

This WRAPS report summarizes priority areas for targeting actions to improve water quality, and identifies point sources and nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources is included.

Provided in the following sections are the results of such prioritization and strategy development. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed, it is imperative to create social capital (trust, networks and positive relationships) with those who will be needed to voluntarily implement BMPs. Thus, effective and ongoing civic engagement is a crucial part of the overall plan.

The successful implementation of restoration and protection strategies also requires a combined effort from multiple entities within the Lac qui Parle River Watershed, including local and state partners (e.g. SWCDs, the MPCA, DNR, and BWSR). By bringing these groups together in the decision-making process, it will increase the transparency and eventual success of the implementation. The management organizations will also work with landowners within the Lac qui Parle River Watershed through typical outreach programs to help identify implementation priorities. Collaboration and compromise will also ensure that identified priorities and strategies are incorporated into local plans, future budgeting, and grant development.

The implementation strategies provided in this section are the result of watershed modeling efforts by HSPF and PTMapp, and professional judgment based on what is known at this time and should be considered approximate. Furthermore, many strategies are predicated on needed funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

This section and report culminate in a table of "Restoration and Protection Strategies", a tool intended to provide high-level information on the changes necessary to restore and protect waters within the Lac qui Parle River Watershed. The tools provided in this section provide a solid foundation for local water resource planning.

3.1 Targeting of geographic areas

To address the widespread water quality impairments in agriculturally dominated landscapes such as the Lac qui Parle River Watershed, comprehensive and layered BMP suites are likely necessary. A conceptual model displaying this layered approach is presented by Tomer et al. (2013; **Figure 52**). This conceptual model to address water quality in agricultural watersheds uses 1) soil health principles as a base: nutrient management, reduced tillage, crop rotation, etc., then 2) in-field water control: grassed waterways, controlled drainage, filter strips, etc., then 3) below-field water controls: wetlands, impounds, etc., and then 4) riparian management: buffers, stabilization, restoration, etc. Another model to address widespread nutrient problems is presented in the *Minnesota Nutrient Reduction Strategy* (MPCA 2014b), which calls for four major steps involving millions of acres statewide: 1) increase fertilizer use efficiencies, 2) increase and target living cover, 3) increase field erosion control, and 4) increase drainage water retention. A third example of a comprehensive, layered approach is being demonstrated with a "Treatment Train" approach in the Elm Creek Watershed (BWSR 2018), which has demonstrated layered strategies including: 1) upland: cover crops and nutrient management, 2) tile treatment: treatment wetlands and controlled drainage, and 3) in-stream: woody debris and stream geomorphology restoration.

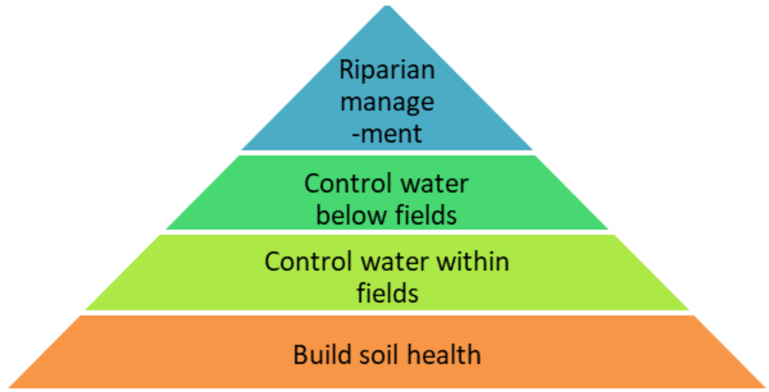


Figure 52. Conceptual model to address water quality in agricultural watersheds (Tomer et al 2013).

No matter how land management and BMPs are finally implemented, there will likely need to be a concerted effort of practices on the landscape, at the transition between landscape and waterbodies (shoreline and streambank), and in-stream or in-lake management.

3.1.1 Protection and Restoration Classification

Stream reaches were prioritized and classified into protection or restoration classes based on existing water quality data. Both protection and restoration classes are further divided into subclasses. Streams within the "protection" category are divided into three subcategories: above average quality, potential impairment risk, and threatened impairment risk. Streams within the "restoration" category are divided into two subcategories: low restoration effort and high restoration effort.

Stream protection and restoration categories were determined based on 10 years of water quality data from 2008 through 2017 for 5 parameters: DO, TSS, TP, inorganic nitrogen (NO2 + NO3), and *E. coli*. The lower limit on the number of samples required for this analysis is five for DO, TSS, TP, and inorganic nitrogen, and three samples in a given month for *E. coli*. This is less than what is required for MPCA to assess streams against state standards, in order to categorize more stream reaches and parameters into protection/restoration subcategories. Depending on the parameter, there may be further requirements for assessments that were not considered for this analysis (which also allowed for more streams and parameters to be categorized). The standards (i.e., concentration) for each parameter that are used for assessments are the same ones used for this analysis. It should be noted, there may be small differences between the MPCA assessments and results from this analysis, due to only looking at the primary pollutant and smaller sample sizes than MPCA methods.

The following are some of the requirements needed for MPCA assessments. Class 2 stream assessments require 12 (for TP) or 20 (for DO and TSS) samples over 2 years and at least 5 samples in a given month for *E. coli*. Determining whether an impairment caused by eutrophication is present requires assessment of not only TP, but response parameters as well (chlorophyll-a, five-day biochemical oxygen demand [BOD], diel DO flux, or pH levels). Nitrogen is currently assessed only for drinking water in Class 1 waters (Minn. R. 7050.0220-0221). The drinking water quality standard for inorganic nitrogen of 10 mg/L was applied to all streams to show where nitrogen might be elevated. Due to the differences between methods used for this analysis and for assessments, a restoration classification may not mean a waterbody is impaired for a specific parameter. In addition, classifications are by parameter; therefore, a stream may be classified as above average quality for one parameter (e.g. DO) and high restoration effort for another parameter (e.g. *E. coli*).

Descriptions of the stream categories and water quality attributes for each class are provided below. The surface waters analyzed for protection and restoration classifications are shown in **Figure 53** with water quality parameters and their classification. Results are tabulated in **Appendix 5.7**.

Protection Categories

All streams currently supporting AqL and AqR are candidates for protection. Over time, these waters could be subjected to land uses or stressors that could cause them to become impaired. For streams and rivers, the protection strategy consists of working toward ensuring the existing loads for the critical duration periods are not exceeded.

<u>Above Average Quality</u> - A reach of a stream (i.e., Assessment Unit Identification Number [AUID]) is exhibiting above average quality for a water quality parameter if one of the following conditions are met:

1. The data requirements of MPCA assessment methods are met, there's no impairment, and the 90^{th} percentile (TSS, DO), average (TP, NO2+NO3), or the geometric mean (*E. coli*) of concentrations is less than 75% of the numeric water quality standard; or
2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), no samples exceed the numeric water quality standard, and the 90^{th} percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations is less than 75% of the numeric water quality standard.

<u>Potential Impairment Risk</u> - An AUID is exhibiting potential impairment risk for a water quality parameter if water quality conditions are "near" but not exceeding the numeric water quality standard as determined by meeting one of the following conditions:

1. The data requirements of MPCA assessment methods are met and the 90^{th} percentile (TSS, DO), average (TP, NO2+NO3), or the geometric mean (*E. coli*) of concentrations exceeds 75% , but is less than 90% of the numeric water quality standard; or

2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations exceeds 75% of the numeric water quality standard, but does not exceed 90% of the numeric water quality standard.

Threatened Impairment Risk - An AUID is exhibiting threatened impairment risk for a water quality parameter if water quality conditions are "very near" and which periodically exceed the numeric water quality standard as determined by meeting at least one the following conditions:

1. The data requirements of MPCA assessment methods are met and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations exceeds 90% , but is less than the numeric water quality standard; or

2. The data requirements of MPCA assessment methods are not met but there are 25% or more of the data requirements (i.e. five or more samples for TSS and DO and three or more samples of TP and *E. coli*) and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations is less than the numeric water quality standard, but greater than 90%, of the water quality standard.

Restoration Categories

Stream reaches in the "restoration" categories fail to achieve some minimum threshold water quality condition. Example minimum threshold conditions include failure to achieve numeric water quality standards or a condition considered degraded or unstable such as areas of accelerated stream bank erosion, which can further contribute to degradation of water quality. Restoration classifications are further divided into low restoration effort and high restoration effort.

Low Restoration Effort - Low restoration effort is defined as a degraded condition but a condition near the designated minimum threshold, for a given parameter. An example is an AUID where the numeric water quality standard is exceeded (and therefore is "impaired"), but with restoration has a high probability of attaining the numeric water quality standard for the parameter as determined by meeting at least one of the following conditions:

1. The data requirements of MPCA assessment methods are met and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations exceeds the numeric water quality standard but is less than 125% of the numeric standard; or

2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli* and TP) and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations exceeds the numeric water quality standard but is less than 125% of the numeric standard.

High Restoration Effort - High restoration effort waterbodies are degraded and are no longer near the designated threshold for a given parameter. These surface waters have a lower probability of attaining the numeric water quality standard and may require a large effort to attain water quality compliance. Classifying an AUID as High Restoration Effort is contingent on meeting at least one of the following conditions:

1. The data requirements of MPCA assessment methods are met, there is an impairment, and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) exceeds 125% of the water quality standard.
2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli* and TP) and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) exceeds 125% of the water quality standard or 25% of those samples exceed the water quality standard.

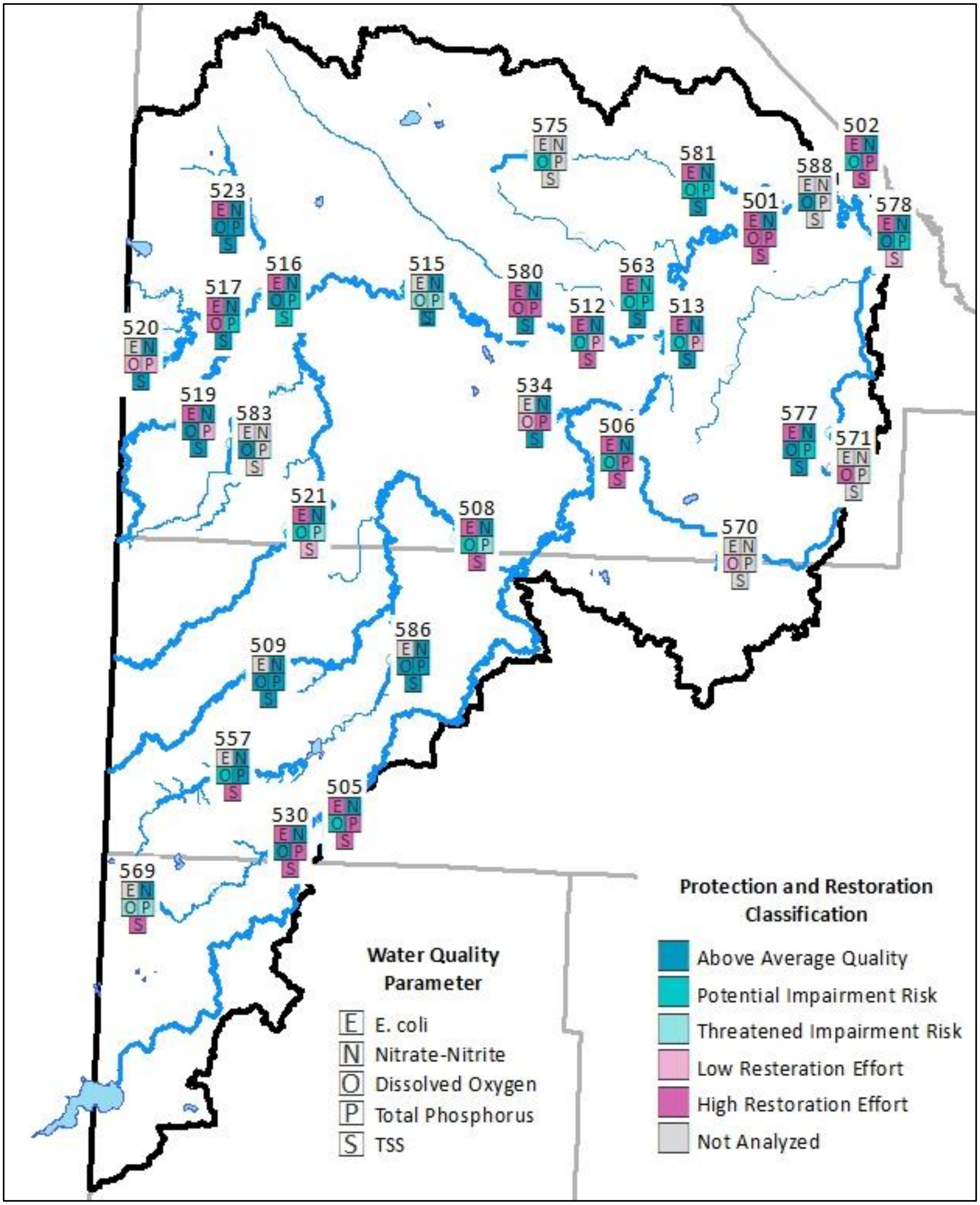


Figure 53. Protection and restoration classification. Stream reaches in the Lac qui Parle River Watershed that were analyzed for protection and restoration classifications. Each stream reach shows water quality parameters colored coded with classification their determined protection or restoration category. These results can be found in tabulated form in Appendix 5.7.

3.1.2 Prioritization and Goals

Conservation implementation plans (e.g. BWSR's One Watershed, One Plan) that are developed subsequent to the WRAPS report should use the WRAPS report and other information to ***prioritize*** and

target waterbodies with cost-effective strategies and set ***measurable*** goals to determine the effectiveness of implementation.

Prioritizing is the process of selecting priority areas or issues based on justified water quality, environmental, or other concerns. Priority areas can be further refined by considering additional information, such as water quality, environmental, or conservation practice effectiveness models or concerns, ordinances and rules, areas to create habitat corridors, areas of high public interest/value, and many more that can be selected to meet local needs. Several priority areas have been identified throughout this report, as shown in the goals maps, the FWMC maps, and the altered hydrology analysis. These and additional priority areas are summarized in **Table 29**. These priorities were developed in conjunction with the WRAPS LWG.

Table 29. Priority areas in the Lac qui Parle River Watershed.

Priority Areas	Description	Examples	Applicable WRAPS data
"Impaired waters-High Restoration Effort" subwatersheds and contributing areas that have a CWA Section 303d listed impairment where large reductions are needed.	High Restoration Effort are degraded and are no longer near the designated threshold for a given parameter. These surface waters have a lower probability of attaining the numeric water quality standard and may require a large effort to attain water quality compliance. High Restoration Effort surface waters are impaired with water quality exceeding 125% of the water quality standard.	Examples include reaches shown in **Figure 53**. Most of the Lac qui Parle River mainstem is classified as a high restoration effort stream for *E. coli* and TSS.	Restoration: High Restoration Effort Map based on available water quality data and TMDL tables where TMDLs have been completed.
"Impaired waters-Low Restoration Effort" subwatersheds and contributing areas that have a CWA Section 303d listed impairment with smaller reduction goals.	Low Restoration Effort is defined as a degraded condition but a condition near the designated minimum threshold, for a given parameter. An example is a portion of a river or stream where the numeric standard is exceeded (and therefore is "impaired"), but with implementation has a high probability of attaining the numeric water quality standard for the parameter. Surface waters are defined as a Low Restoration Effort if water quality exceeds, but is within 125%, of the water quality standard.	Examples include reaches shown in **Figure 53**. Florida Creek is classified as low restoration effort for TSS.	Restoration: Low Restoration Effort Map based on available water quality data and TMDL tables where TMDLs have been completed.
"Protection waters-Threatened Impairment Risk" waters that are supporting their beneficial use and meeting water quality standards but are threatened to become impaired.	Surface waters exhibiting Threatened Impairment Risk are defined as those portions of a river or stream with water quality conditions "very near" and may periodically exceed numeric standards but are not listed on the CWA Section 303d list. Surface waters are defined as Threatened Impairment Risk if water quality is within 90% of the numeric standard.	Examples include reaches shown in **Figure 53**. Four streams are classified as threatened for phosphorus, including Florida Creek.	Protection: Threatened Impairment Risk Map based on available water quality data and MPCA Monitoring and Assessment Report.
"Protection waters-Potential Impairment Risk" areas that are supporting the beneficial use and meeting water quality standards but could become impaired if condition degrades further.	Potential Impairment Risk for a water quality parameter is defined as those portions of a river or stream with water quality conditions approaching, or "near" but not exceeding the numeric water quality standard for a given parameter. Surface waters are defined as Potential Impairment Risk if water quality is less than 90% but greater than 75% of the numeric standard.	Examples include reaches shown in **Figure 53**. Many streams in the watershed are classified as potential impairment risk for DO and phosphorus. Specific examples include the mainstem Lac qui Parle River to the convergence with the West Branch Lac qui Parle River for DO.	Protection: Potential Impairment Risk Map based on available water quality data and MPCA Monitoring and Assessment Report.
"Protection waters-Above Average Quality" areas that are supporting the beneficial use, meeting the water quality standard, or not stressed by a specific parameter and not threatened to become impaired.	Surface waters exhibiting Above Average Quality for a water quality parameter are defined as those portions of a river or stream that have no impairments, fully supporting their beneficial use, and not currently at risk of a potential impairment. Surface waters are defined as Above Average Quality if water quality is less than 75% of the numeric standard.	Examples include reaches shown in **Figure 53**. Examples of above average water quality include most streams in the watershed where nitrate data was collected (using the drinking water standard). Specific examples include the mainstem of the Lac qui Parle River.	Protection: Above Average Quality Map based on available water quality data and MPCA Monitoring and Assessment Report.

Priority Areas	Description	Examples	Applicable WRAPS data
"Insufficient information waters" are areas that may show poor water quality but have insufficient data to be fully assessed.	Insufficient information waters are waterbodies that have been identified as having insufficient water quality information to assess, per MPCA assessment criteria that show potential for impairment.	Lost Creek is currently impaired for low DO but not enough information was available to develop a TMDL. Numerous streams show high phosphorus but do not have the secondary information to assess as impaired. These include Lac qui Parle River (505), Lac qui Parle River, West Branch (512, 513), and Unnamed Creek (530). More information is needed in these reaches to fully assess and develop TMDLs during the next cycle.	MPCA Monitoring and Assessment Report and SID Report.
"High Contributing Areas" subwatersheds or areas that contribute the "most" pollution to impaired waters.	The high contributing areas are subwatersheds that contribute the highest level of pollution in the watershed. Targeting these subwatersheds will produce the highest and most cost-effective load reductions. The high contributing areas are defined as the top 25% contributing subwatersheds.	High contributing areas in the Lac qui Parle River Watershed are shown in **Figure 54** –**Figure 57**. Areas with consistently high pollution loads for TSS, TP, and TN include the areas near the convergence of the Lac qui Parle River and the West Branch Lac qui Parle River.	HSPF priority mapping, source assessment information, Monitoring and Assessment Report, and TMDL.
"Areas of local concern" areas that are of high public interest and represent "high value" natural resources.	Areas of local concern are waterbodies and areas that are important to the residents of the watershed and are considered high value natural resources, such as a popular fishing lake.	Lake Hendricks and Del Clark Lake have been identified as waterbodies of high local concern. Lake Hendricks is impaired for aquatic recreation and Del Clark Lake was classified as a higher protection priority lake. Both can be prioritized as areas of local concern.	The use of civic engagement can be utilized to determine these areas. Once determined, the priority mapping, source assessment, and strategies table can help local partners prioritize the areas of local concern.
"Altered Hydrology" areas and subwatersheds are areas with highly hydrologically-altered subwatersheds.	Many impairments and stressors to surface waters can be attributed to changes in hydrology. Targeting areas with significant hydrologic alteration can improve conditions in many downstream impairments.	Indicators of potential altered hydrology metrics are shown in **Figure 35**. Altered hydrology is the third most commonly identified stressor in the watershed and a driver of most other stressors like sediment, habitat, and nitrogen.	A GIS analysis of altered hydrology is presented in section 2.3.3 in the Altered Hydrology section. This map can be used, or the six layers used to create this map can be weighted differently. Areas with a higher score indicate more alteration. A gage analysis shows a storage goal.

The waterbodies within the watershed that are nearly impaired (threatened impairment risk) and barely impaired (low restoration effort) are likely to see the greatest benefit from the implementation of BMPs. To protect the nearly impaired or other unimpaired waterbodies and restore the barely impaired or other impaired waterbodies in the watershed, BMPs will need to be implemented within the watershed. BMPs must be positioned in locations within the watershed that will provide the greatest water quality benefit for the money. Additional resources were necessary to find feasible places on the landscape to locate BMPs.

Additional tools used for determining Restoration and Protection Strategies

As part of past and current local planning within the watershed, water quality models and enhanced geospatial water quality products were developed. Advances in watershed assessment tools allow for the rapid identification of at-risk areas for natural resource degradation as well as feasible placement locations for cost-effective BMPs and structural conservation practices. These models will be used to analyze runoff quantity, target sources of sediment, total nitrogen, and TP, and identify opportunities for BMP and conservation practice implementation.

The watershed-based results developed under this WRAPS effort utilized:

- Hydrologic Simulation Program – FORTRAN (HSPF)
- Hydrologic Simulation Program – FORTRAN Scenario Application Manager (HSPF-SAM)

Hydrologic Simulation Program – FORTRAN

The HSPF model was chosen as one of the primary watershed modeling tools to simulate hydrology and water quality for this WRAPS effort. HSPF makes use of meteorological data, agricultural tillage information, and a host of additional land use and management information. Products from the HSPF model include a temporal history (1995 through 2012 for this analysis) of water quantity, runoff flow rate, and concentration, load, and yield estimates for sediment and nutrients (among other parameters).

Many of the rivers within the Lac qui Parle River Watershed are impaired by sediment and stressed by nutrients. As such, the HSPF model created for the Lac qui Parle River Watershed was used to help identify major subwatersheds and stream reaches that have higher potential for exporting nutrients and sediment to downstream resources. Subwatersheds were prioritized by ranking the area-averaged yields (mass/acre/year) for TP, TN, TSS, and unit runoff (volume/acre/year). This can aid in the effort to identify areas within the Lac qui Parle River Watershed where restoration and protection strategies would be most beneficial.

Figure 54 through **Figure 57** demonstrate the use of this product. The Highest Priority (Highest 90% - darkest green) areas are the catchments delivering the highest yield (mass or volume per unit area) of the listed water quality parameter (runoff, TSS, TP, and TN) to the Lac qui Parle River outlet. In addition, a water quality index map (**Figure 58**) combines the rankings of TSS, TP, and TN to prioritize subwatersheds for overall water quality. These maps and associated data can be used to target subwatersheds that deliver the largest amount of the specified pollutant to the watershed outlet, allowing watershed managers to more effectively place practices within the drainage area.

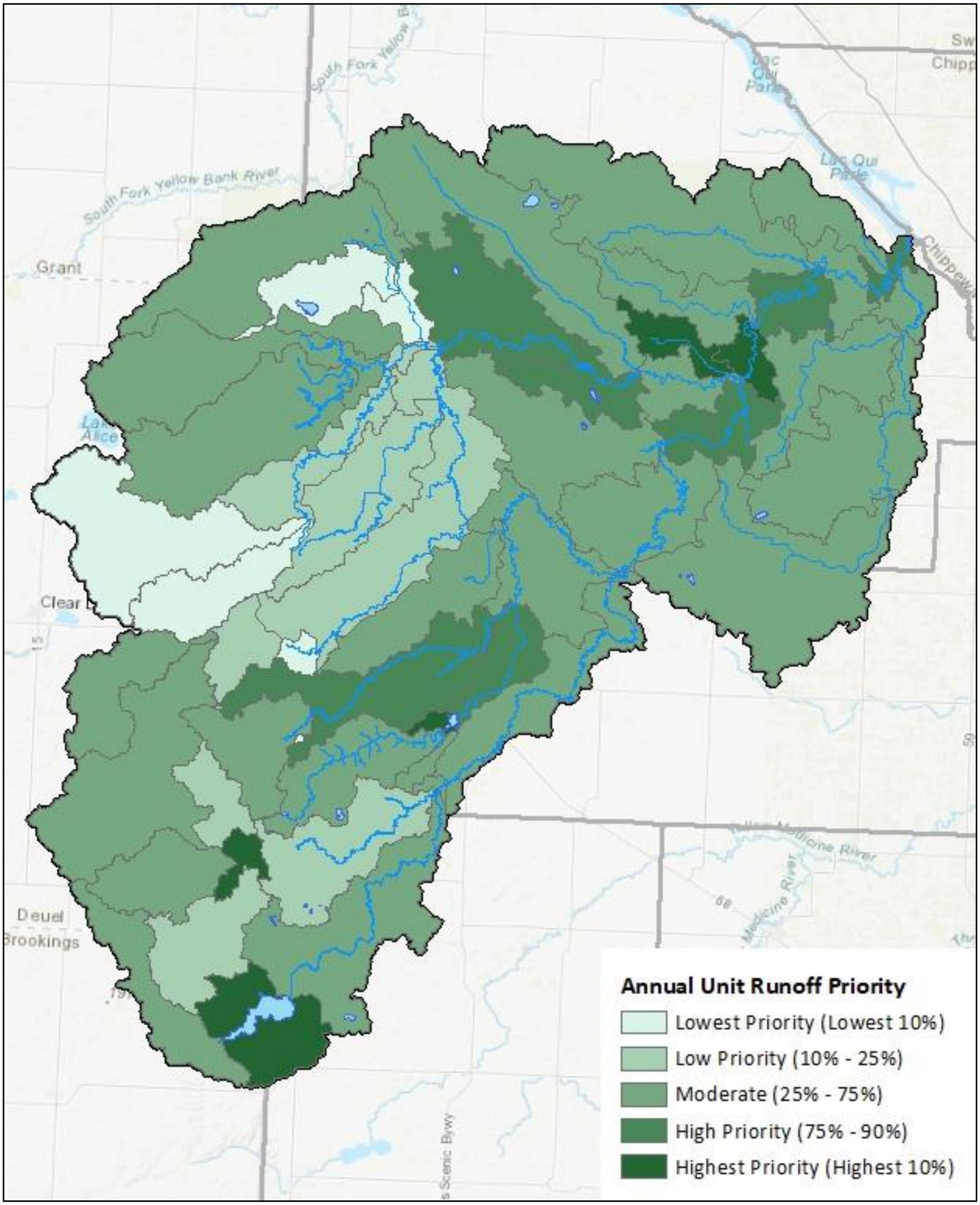


Figure 54. Subwatershed implementation priorities for the stressor altered hydrology, using average (1995-2012) annual unit runoff as modeled by HSPF.

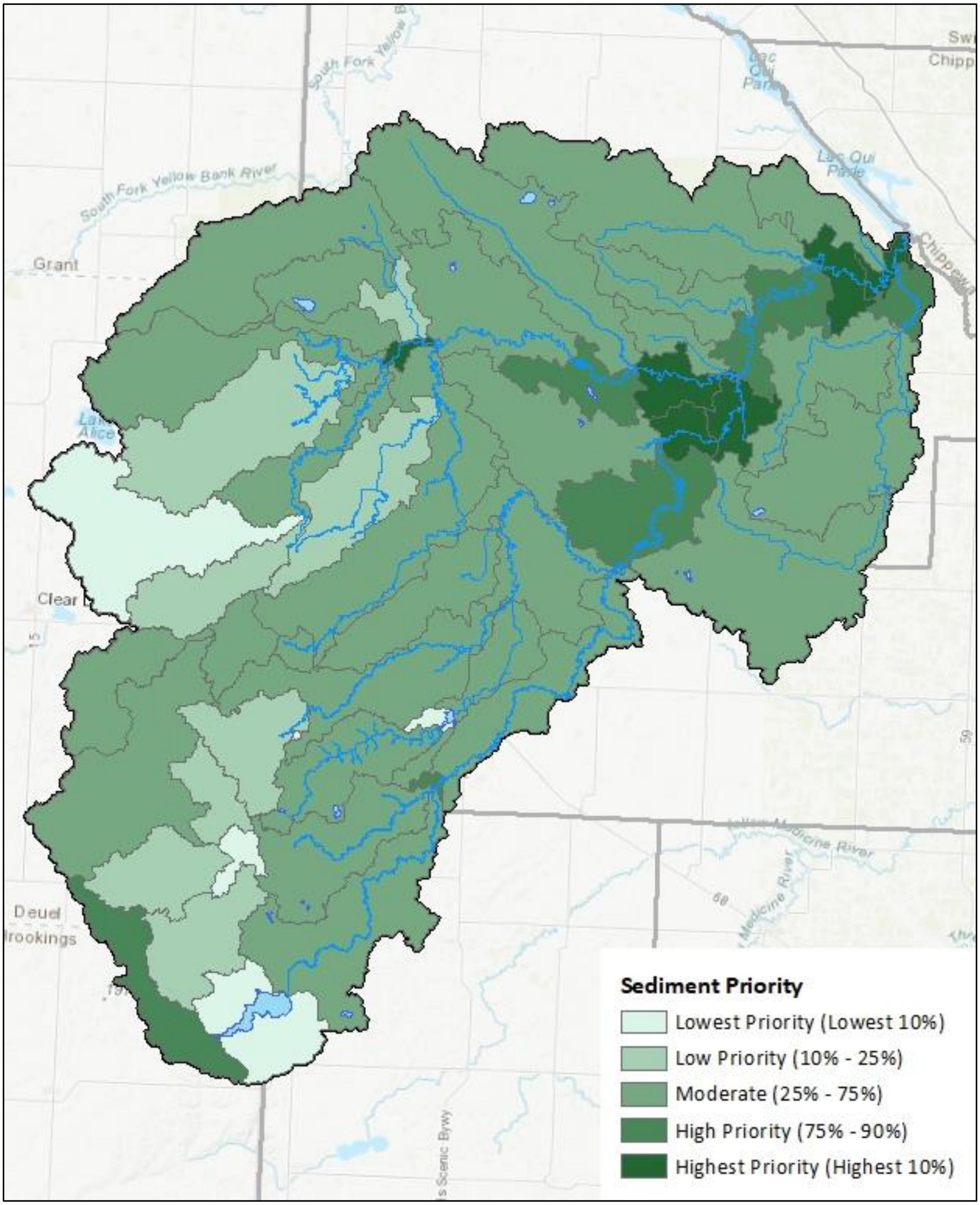


Figure 55. Subwatershed implementation priorities for the stressors elevated turbidity and loss of habitat, using average (1995-2012) total sediment yields as modeled by HSPF.

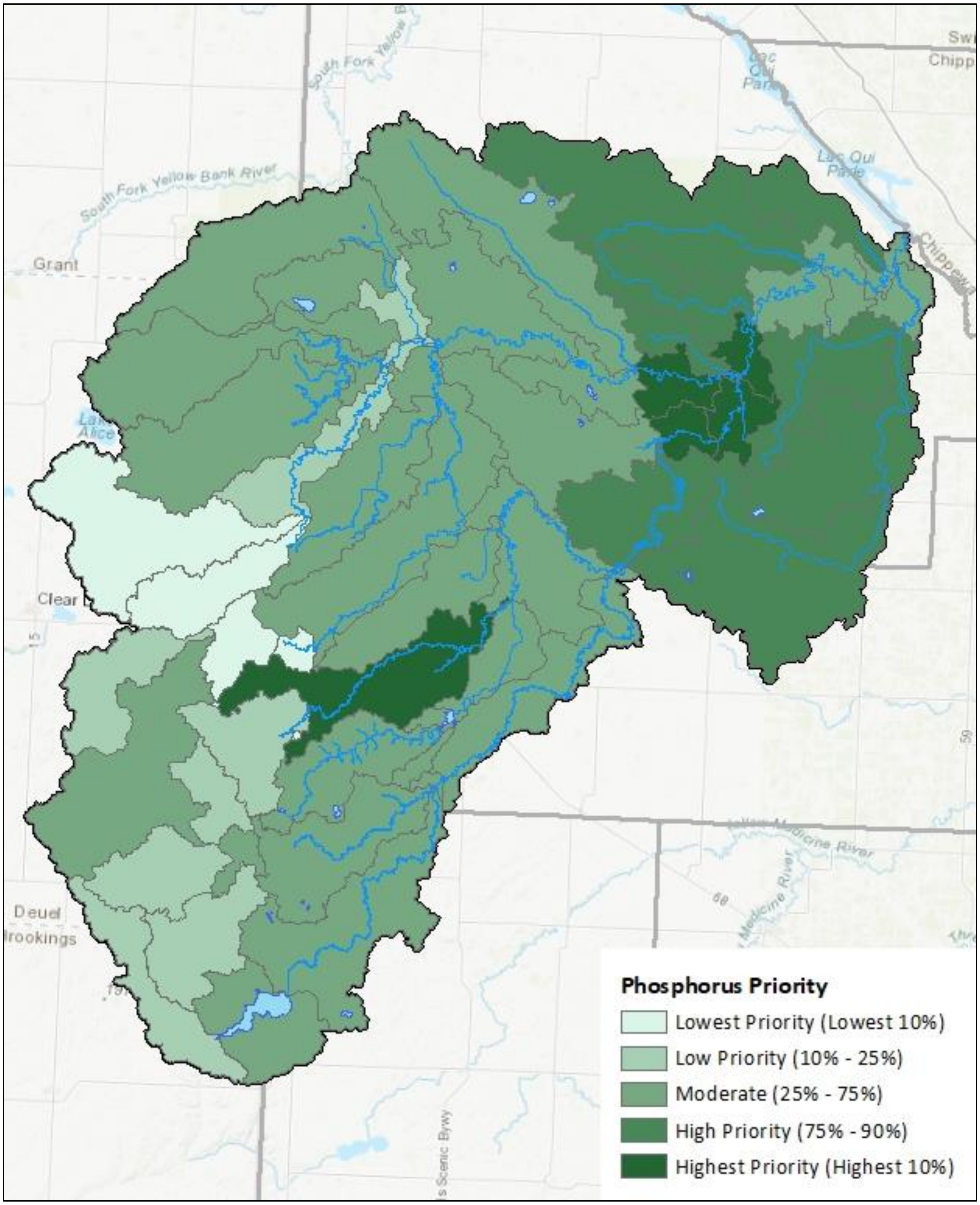


Figure 56. Subwatershed implementation priorities for the stressor excessive nutrients, using average (1995-2012) total phosphorus yields as modeled by HSPF.

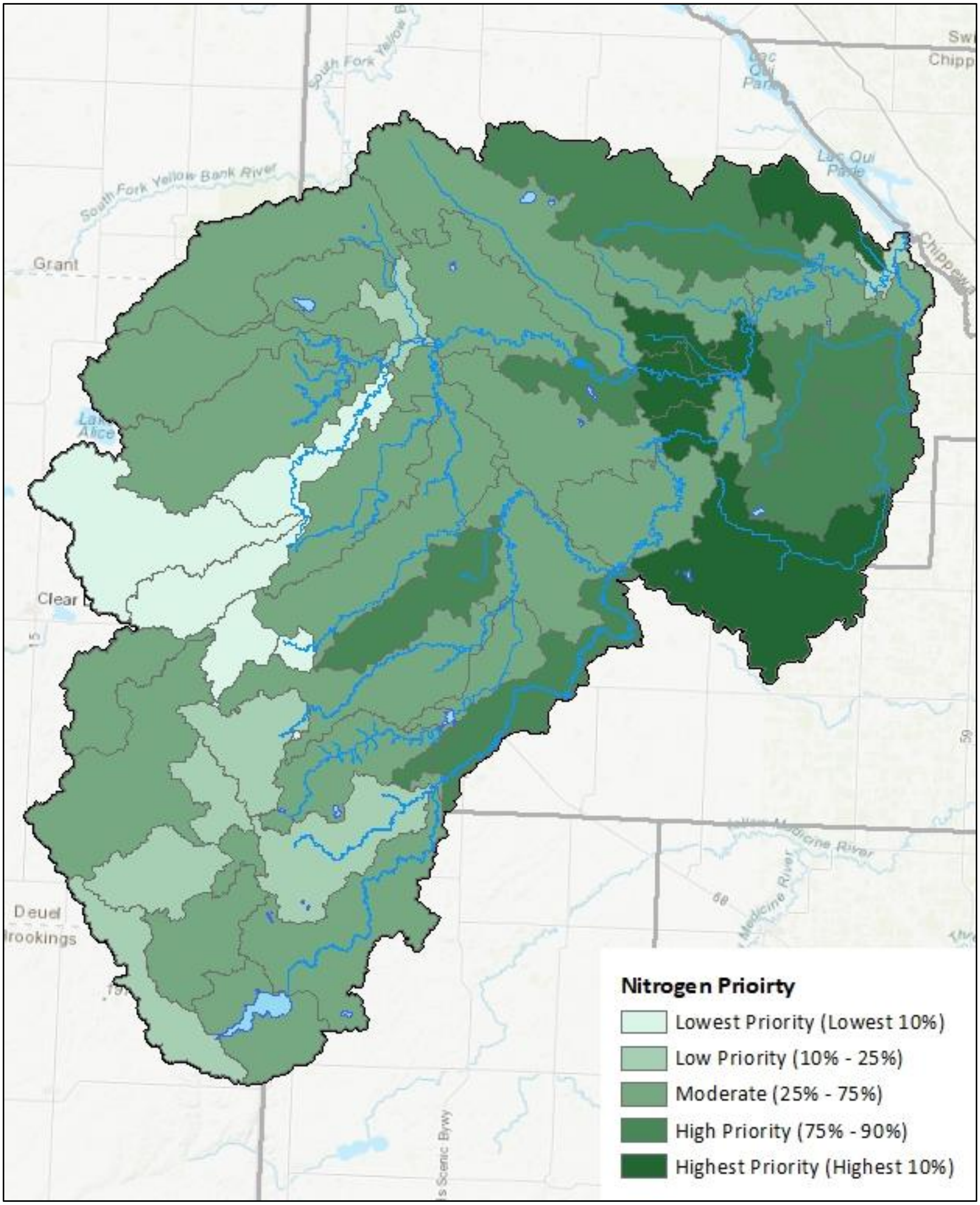


Figure 57. Subwatershed implementation priorities for the stressor excessive nutrients, using average (1995-2012) total nitrogen yields as modeled by HSPF.

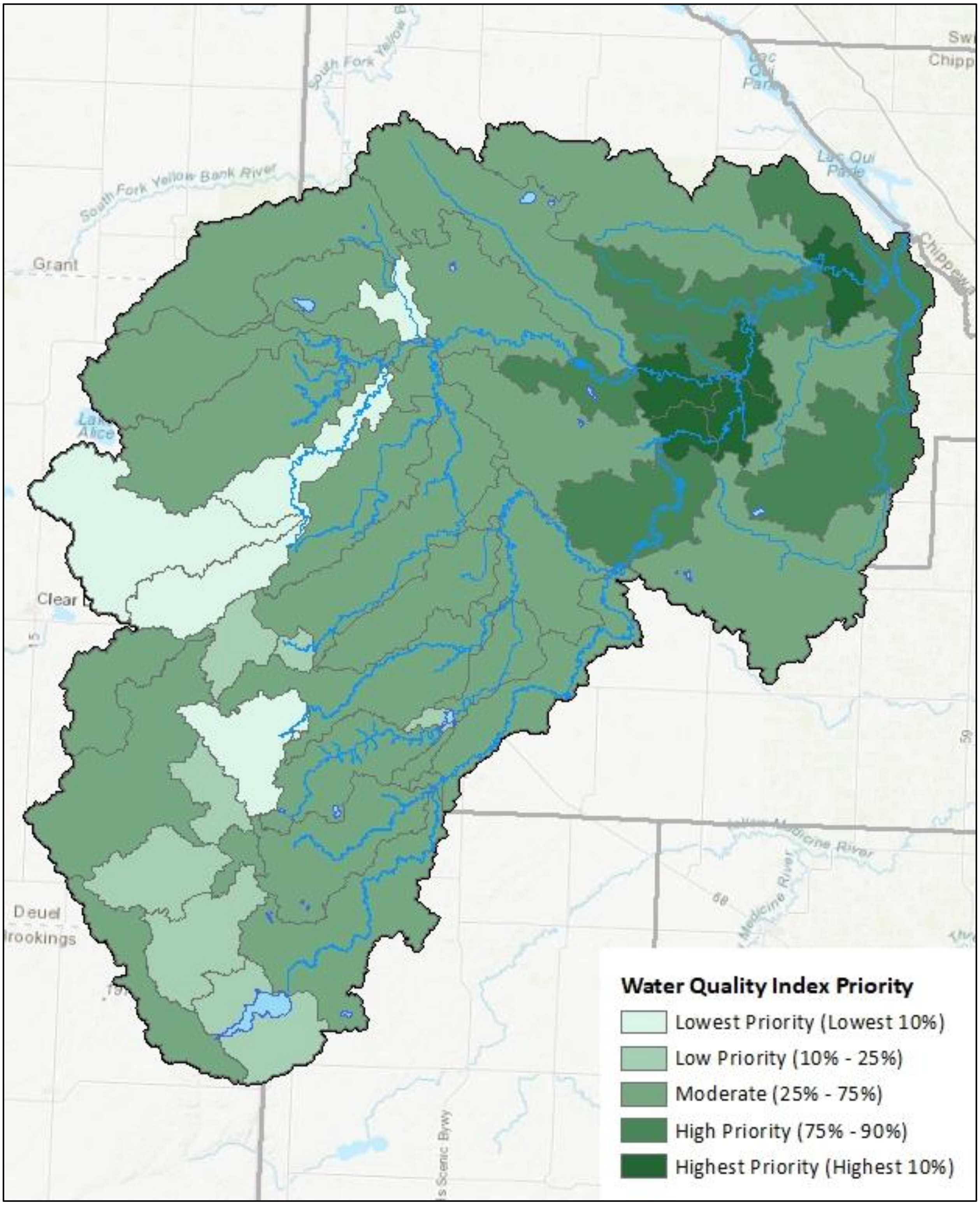


Figure 58. Overall subwatershed implementation priorities, using the average (1995-2012) water quality index.

HSPF Scenario Application Manager

The HSPF - SAM made use of the existing HSPF model to estimate sediment, total nitrogen, and TP load reductions based on several BMP implementation scenarios. The scenarios were determined based on information gathered from stakeholder meetings. Each scenario was selected to reach a specific reduction goal for a given parameter. **Table 30** provides a summary of the estimated load reductions resulting from implementation of the BMPs for the various scenarios. These results demonstrate the magnitude of change that is necessary. The scenarios listed below are titled with the name of the stream reach (AUID-3 digits), pollutant the scenario was developed for, and the percent reduction goal for the pollutant. A target optimization tool was utilized in select scenarios to order and determine the placement of BMPs in basins. These scenarios are titled with optimized. The description of the scenarios and list of BMP scenarios, including acres, can be seen in **Appendix 5.3**. This information can aid in the effort to identify areas within the Lac qui Parle River Watershed where restoration and protection strategies would be most beneficial.

Table 30. Estimated load reductions based on various BMP implementation scenarios for three impaired reaches within the Lac qui Parle River Watershed.

Scenario Name	Percent Reduction of Annual Reach Load		
	TSS	TP	TN
Unnamed Creek (-530) TSS 10 optimized	10	12	9
Unnamed Creek (-530) TSS 10	29	40	32
Unnamed Creek (-530) TSS 55 optimized	31	54	47
Unnamed Creek (-530) TSS 55	31	54	47
LqP River (-502) TP 25	17	28	28
LqP River (-502) TP 45	25	48	53
LqP River (-502) TN 25	13	23	27
LqP River (-502) TN 45	20	44	48
LqP River (-502) TSS 10	23	32	30
LqP River (-502) TSS-1	28	59	65
LqP River (-502) TSS-2	27	53	55
LqP River (-502) TSS-3	30	70	78
LqP River (-502) TSS-4 including South Dakota	30	70	80

Additional Tools

Statewide resources to assess the environmental benefits, hydrology, and other associated data to inform watershed plans are available online and by download. Available resources are summarized in **Table 31**.

Table 31. Review of public data available online or by download to assist with watershed or project analysis within the Lac qui Parle River Watershed.

Tools	Description	How can the tool be used?	Notes	Link to information and data
Ecological ranking tool (Environmental Benefit Index - EBI)	The EBI is the aggregation of three Geographic Information System (GIS) raster data layers including soil erosion risk, water quality risk, and habitat quality. The 30-meter grid cells in each layer contain scores from 0-100. The sum of all three scores is the EBI score (max of 300). A higher score indicates a higher priority for restoration or protection.	The three data layers can be used separately, or the sum of the layers (EBI) can be used to identify priority areas for restoration or protection projects. The layers can be weighted or combined with other layers to better reflect local values.	A GIS data layer that shows the 5% of each 8-digit watershed in Minnesota with the highest EBI scores is available for viewing in the MPCA 'water quality targeting' web map, and download from MPCA.	MPCA Web Map[1] MPCA download[2]
Zonation	This tool serves as a framework and software for large-scale spatial conservation prioritization, and a decision support tool for conservation planning. The tool incorporates values-based priorities to help identify areas important for protection and restoration.	Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells).	The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses.	Software[3]
Restorable wetland inventory	A GIS data layer that shows potential wetland restoration sites across Minnesota. Created using a compound topographic index (CTI) (10-meter resolution) to identify areas of ponding, and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) soils with a soil drainage class of poorly drained or very poorly drained.	Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface and ground water quality, and reducing flood damage risk.	The GIS data layer is available for viewing and download on the Minnesota 'Restorable Wetland Prioritization Tool' website.	Restorable Wetlands[4]

Tools	Description	How can the tool be used?	Notes	Link to information and data
National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. These data have been used for fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of this data set is to identify riparian buffers around rivers.	The layers are available on the USGS website.	USGS[5]
Light Detection and Ranging (LiDAR)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the Minnesota Geospatial Information Office (MGIO) website.	MGIO[6]
Prioritize, Target, and Measure Application (PTMApp)	An operational application for prioritizing watershed resources of concern and issues impacting resources of concern, targeting fields for the implementation of nonpoint source BMPs and Conservation Practices (CPs), and estimating measurable water quality improvements that would result from BMP and CP targeted implementation plans.	It was specifically designed for use by local governmental units (LGU) in rural areas of the state, to facilitate the estimation of water quality benefits associated with the implementation of BMPs and CPs, as required under the Clean Water Accountability Act (CWAA) of 2013.	Ability to evaluate at the watershed scale: 1) Determine feasible locations for BMPs, and 2) Estimate the cost and water quality benefits of potential BMPs.	Documentation[7] PTMApp-Desktop download[8]
Board of Water and Soil Resources (BWSR) Landscape Resiliency Strategies	These webpages describe strategies for integrated water resources management to address soil and water resource issues at the watershed scale, and to increase landscape and hydrological resiliency in agricultural areas.	In addition to providing key strategies, the webpages provide links to planning programs and tools such as Stream Power Index, PTMApp, Nonpoint Priority Funding Plan, and local water management plans.	These data layers are available on the BWSR website. The MPCA download link offers spatial data that can be used with GIS software to make maps or perform other geography-based functions.	Landscape Resiliency - Water Planning[9] Landscape Resiliency - Agricultural Landscapes[10] MPCA download[11]

1 http://mpca.maps.arcgis.com/apps/Viewer/index.html?appid=0b76cfbbd4714b1ba436fdc707be479c
2 https://gisdata.mn.gov/dataset/env-ebi-top-5
3 https://www.helsinki.fi/en/researchgroups/digital-geography-lab/software-developed-in-cbig
4 http://www.mnwetlandrestore.org/links-contact/data-download/
5 https://www.usgs.gov/core-science-systems/ngp/national-hydrography
6 http://www.mngeo.state.mn.us/chouse/elevation/lidar.html
7 https://ptmapp.bwsr.state.mn.us/User/Documentation
8 https://ptmapp.bwsr.state.mn.us/User/PTMAppDesktop
9 https://bwsr.state.mn.us/practices/climate_change/Water_Planning.pdf
10 https://bwsr.state.mn.us/practices/climate_change/Agricultural_Landscapes.pdf
11 https://www.pca.state.mn.us/data/spatial-data

Climate protection co-benefit of strategies

Many agricultural BMPs which reduce the load of nutrients and sediment to receiving waters also act to decrease emissions of greenhouse gases (GHGs) to the air. Agriculture is the third largest emitting sector of GHGs in Minnesota. Important sources of GHGs from crop production include the application of manure and nitrogen fertilizer to cropland, soil organic carbon oxidation resulting from cropland tillage, and carbon dioxide (CO_2) emissions from fossil fuel used to power agricultural machinery or in the production of agricultural chemicals. Reduction in the application of nitrogen to cropland through optimized fertilizer application rates, timing, and placement is a source reduction strategy. Conservation cover, riparian buffers, vegetative filter strips, field borders, and cover crops reduce GHG emissions as compared to cropland with conventional tillage.

The USDA NRCS has developed a ranking tool for cropland BMPs that can be used by local units of government to consider ancillary GHG effects when selecting BMPs for nutrient and sediment control. Practices with a high potential for GHG avoidance include conservation cover, forage and biomass planting, no-till and strip-till tillage, multi-story cropping, nutrient management, silvopasture establishment, other tree and shrub establishment, and shelterbelt establishment. Practices with a medium-high potential to mitigate GHG emissions include contour buffer strips, riparian forest buffers, vegetative buffers and shelterbelt renovation. Swan, *et al.* (2020) provides a longer, more detailed assessment of cropland BMP effects on GHG emission.

3.2 Public participation

Public participation and engagement refers to education, outreach, marketing, training, technical assistance, and other methods of working with stakeholders to achieve water resource management goals. Public participation efforts vary greatly depending on the water quality topic and location.

Public participation was a major focus during the Lac qui Parle River Watershed Approach from 2015 through the summer of 2020. The MPCA worked with county and SWCD staff, the Lac qui Parle – Yellow Bank Watershed District, consultants, citizens, and other state agency staff. There were three components to the Lac qui Parle River Watershed WRAPS public participation effort: 1) education about the watershed and water quality, 2) provide information about the project, and 3) gather input from watershed stakeholders.

Education

A boot camp consisted of the watershed coordinator, the MPCA staff biologists, and Lac qui Parle SWCD staff hosting sophomore biology students from Dawson – Boyd High School for a demonstration day to learn about water sampling and quality. Topics included water quality impairments, monitoring and assessing processes, performing chemical and biological samples, and viewing real samples of fish and macroinvertebrates found in the watershed. The MPCA biologists concluded the event with a live fish shocking that the students very much enjoyed. This was one of the most successful public engagement events and requests were made by teachers to hold similar events in the future.

Two rain barrels were installed with students at their schools (Hendricks Middle School and St. Peter's in Canby), and a third rain barrel was installed with residents of Hilltop Assisted Living in Madison. A Family Fun Evening at Stonehill Park near Canby was held where families were given opportunities to play water-based games, including water balloon toss and minnow races. Additionally, an education station with multiple booths and demonstrations was available for children to find quiz answers and receive prizes. Multiple local partnering SWCD staff assisted with the event and brought aquatic robots to show families, which was very much enjoyed by attendees.

Annual canoe trips were a much anticipated event by the public with attendance reaching a peak in 2018 at 29 paddlers. Weather and safety concerns prevented a trip in 2016. The 2017 canoe trip included 13 participants, while 23 people attended in 2019.

Four retractable banners were created. Two of the banners were created early in the project timeframe. One banner highlighted the WRAPS process, and the other gave an overview of what a watershed is. These banners were highlighted at public meetings, fair booths, and the Family Fun Evening education station. Two remaining banners were created towards the end of the project, with one banner highlighting civic engagement events held, and a second banner highlighting water impairments within the watershed. These banners will be used at future events and meetings, including One Watershed, One Plan and the next WRAPS cycle. They will additionally be used when setting up booths at fairs and other events where information can be shared.

Four signs were designed and installed. Each sign gave some watershed and WRAPS project background, in addition to history/information relevant to the installation sites. The signs were installed at the Lac qui Parle River headwaters in Hendricks, at Stonehill Park outside of Canby, the Rock Rapids Park on the West Branch of the Lac qui Parle River in Dawson, and the Lac qui Parle County Park.

Disseminating project information

The watershed coordinator consistently attended and provided project updates, including annual township meetings (cancelled in 2020 due to Covid-19), and once as a guest for Kiwanis, Lake Hendricks Improvement Association, Corn & Soybean Growers annual meetings, and Lac qui Parle Study Club. Additionally, a booth was annually set up at the Lac qui Parle County fair and updates were given per request for the Lac qui Parle SWCD board. County commissioners were also given updates as asked. Area II board meetings were attended regularly with updates given. Annual resource commission meetings were attended and provided updates in Lac qui Parle, Yellow Medicine, and Lincoln Counties by the watershed coordinator.

Ten radio programs were held as needed or when relevant content was available to share. Content covered included promotion of public events (rain barrel installations, canoe trips, Family Fun Evening, landowner workshop). Also covered was Professional Judgement Group results, SID sampling, fair booths, and highlights of the WRAPS project.

A meeting for elected officials was held towards the end of the project. While attendance was moderate, at least one representative from each county and SWCD were present and able to return project information to their respective agencies to assist with potential questions from constituents.

A website was updated semi – annually with event highlights.

Gathering Input

Input from citizens and local water resource managers was important in the development of the Lac qui Parle River WRAPS Report. The project started with a survey to get a sample of opinions from citizens about water quality in the watershed. This helped inform the education component of the project. The survey had a range of participants from where they lived, their age, and their role in the watershed.

Survey results indicate there is a perception the water is somewhat polluted resulting from all activities in the watershed. The survey also indicates everyone has a responsibility to restore and protect the water in the watershed; however, the decision making should remain local. Survey results are available in **Appendix 5.5.**

Public meetings/workshops were held to provide information, discuss reports, and gather feedback used in the finalization of restoration and protection strategy priorities. A public meeting held in Canby in July, 2019, was attended by only two landowners, while a separate public workshop was held in Madison in February, 2019, where nine citizens attended.

A workshop was also held to obtain farmer, landowner and local government partner input on preferred BMPs. This information was obtained through a survey containing a suite of possible practices that were locally relevant. Workshop attendees were requested to rank each parameter (i.e. sediment, nitrogen, phosphorus) as well as the practices within each parameter in order of most (high score) to least (low score) importance relative to the other practices in that parameter category. Practices were then ranked from highest to lowest with emphasis given to the top five discrete practices as shown in the **Table 32**. Preferred practices focused on improving upland and field surface runoff controls, including practices that reduce soil erosion and field runoff or otherwise minimize sediment from leaving farmland. The results were used to help develop the restoration and protection strategies needed to achieve the water quality reduction goals and targets in the watershed.

Table 32. Summary of practice scores from farmers' workshop on practice preferences.

Parameter	Example BMPs/actions	Partners	Land Owners	Total
Total Suspended Solids (TSS)	Water and sediment basins, terraces	308.5	121	429.5
Total Suspended Solids (TSS)*	Residue management – conservation tillage	300.5	125	425.5
Total Suspended Solids (TSS)	Cover crops	318	105	423
Total Suspended Solids (TSS)	Grassed waterways	287	119	406
Phosphorus (TP)	Strategies to reduce sediment from fields (see above - upland field surface runoff)	284.5	111	395.5
Total Suspended Solids (TSS)	Open tile inlet controls – riser pipes, French drains	285	106	391

*not related to a discrete BMP

Future plans

Local water resource managers are developing a One Watershed, One Plan comprehensive local water management plan, an overall watershed management plan to align local water planning efforts. Under One Watershed, One Plan, local stakeholders prioritize water resources, develop targeting strategies, and develop implementation plans to protect and restore waterbodies in the watershed. This WRAPS report will aid local stakeholders develop the One Watershed, One Plan.

Public notice for comments

An opportunity for public comment on the draft Lac qui Parle River WRAPS Report was provided via a public notice in the *State Register* from June 7, 2021 to July 7, 2021. No comment letters were received as a result of the public comment period.

3.3 Restoration and protection strategies

The Lac qui Parle River Watershed has numerous areas and waterbodies in need of protection or restoration. Collaborative efforts between local and state partners (i.e., SWCDs, LqPYBWD, MPCA, DNR, and BWSR) led to a list of water quality restoration and protection strategies for the watershed. Restoration strategies are targeted at decreasing stressors and sources related to the measured impairments within the watershed. Due to the somewhat homogeneous nature of the watershed, most of the suggested strategies are applicable throughout the watershed.

Restoration of impaired waterways within the Lac qui Parle River Watershed will not be an easy task. Habitat loss, eutrophication, and altered hydrologic conditions are the primary stressors to AqL within the impaired stream reaches of the watershed. These stressors have led to dramatic changes in the biological communities of the watershed.

The extensive networks of surface and subsurface drainage have led to increased flow volume during high flow events that can result in bank erosion and an increase in sediment load. Bank erosion can lead to loss of riparian habitat and vegetation, further exacerbating the bank erosion. The resulting excess sediment load fills the interstitial spaces of the coarse substrate that is utilized by sensitive gravel spawning fish and macroinvertebrates. During periods of low flow, crucial habitat may not be available to aquatic animals, and DO and stream temperature may undergo severe fluctuations.

Elevated concentrations of phosphorus were found in many of the stream reaches throughout the watershed, often leading to excessive primary productivity of algae in the streams and wide fluctuations in DO concentrations. A significant effort will be required to reduce overland runoff in the watershed to prevent the loss of excess phosphorus and sediment from the landscape. Increasing the volume of surface water storage on the landscape will reduce the altered hydrologic conditions and could lead to decreased streambank instability, channel incision, and the associated issues.

Re-establishment of the riparian zones and use of BMPs for cultivated lands within the Lac qui Parle River Watershed could greatly reduce upland soil loss, leading to declines in suspended sediment and phosphorus concentration within the streams of the watershed. Additionally, detention/retention of water over the landscape would especially help with flow regime instability. Augmenting (increasing) baseflow by holding water on the landscape for longer could also help to maintain sustainable DO concentrations by preventing extreme low flow or stagnation conditions in streams.

In addition to the AqL impairments, 17 stream reaches in the Lac qui Parle River Watershed are listed as impaired for AqR for excessive bacteria. Reducing bacteria concentrations within the waterbodies of the Lac qui Parle River Watershed will require livestock are kept away from waterbodies, appropriate manure management (proper storage and application methods), and replacement or maintenance of noncompliant SSTSs.

Watershed managers within the portion of the Lac qui Parle River Watershed that lies within Minnesota will need to work collaboratively with watershed managers in South Dakota as more than 340 square miles of the contributing watershed lies to the west of the Minnesota border.

Restoration Strategies

The DNR compiled a list of restoration practices that could be utilized in the Lac qui Parle River Watershed (DNR 2019). Their recommendations are based on a tiered approach: preserving native communities, restoration and enhancement to create larger habitat networks, and incorporating BMPs into the agricultural landscape. All three tiers can be implemented at the same time and focusing on these three levels of restoration and protection strategies maximizes conservation benefits. Remaining clusters of rare or sensitive natural features are indicative of good habitat quality, whereas scarcity elsewhere in the watershed signals the need for restoration or adaptive management. Furthermore, maintaining and restoring native biological diversity, abundance, and resiliency is a component of integrated watershed health. The restoration practices are grouped by upland and in-channel/near-channel restoration strategies.

Upland Restoration Strategies

Since the leading cause of many of the stream instability issues in the Lac qui Parle River Watershed result from a change in land use, hydrologic pathways, and climate, restoration of watershed health must begin with upland components. Future climate and rainfall trends are unknown and uncontrollable, so it is essential that land use practices adapt to changing climate. Water retention projects prepare the landscape for both wet and dry conditions and can reduce flood events that are the main drivers of river instability in this watershed. The following list provides examples of projects that help store water on the landscape and reduce downstream flood impacts (DNR 2019):

- Increase water storage, both temporary and long-term. This can include restoring historical wetlands, floodplain connectivity, and sinuosity in channelized natural streams. This can also include installing drainage management practices and storm water retention practices.
- Increase perennial vegetation, such as buffer strips along all waterways and grassed waterways in areas of cropland with concentrated flow.
- Increase soil organic matter.
- Utilize tillage practices that minimize carbon dioxide loss in soils (e.g. no-till and strip-till) and promote the use of cover crops.
- Treat and prevent nutrient (i.e. nitrogen and phosphorus) runoff into streams, using BMPs such as appropriately sized bioreactors, increased crop residue, and planting cover crops and grassed waterways.

In-Channel and Near-Channel Restoration Strategies

Restoration of river and stream channels can be a challenging task in the Lac qui Parle River Watershed, as many streams have shown some degree of incision. Proper restoration of a channel must reduce the degree of incision, reconnect the stream to the floodplain, develop a meander pattern, and restore channel slope to a degree that is reflective of a stable channel with the same stream type and valley type in a similar geographical area. Successful stream restorations require broad objectives to address all watershed health components. Addressing hydrology or sediment alone can result in a project that does not restore ecological function.

One of the most important practices to implement are buffer strips consisting of perennial vegetation along both banks of the river. Riparian vegetation is necessary to help stabilize riverbanks in nearly all stream types, but in many cases is not the only solution.

There are some practices that can be used in-channel to help stabilize streams with local stressors (e.g., excessive bank erosion, longitudinal barriers, and undersized culverts). Along the western reaches of the Lac qui Parle River Watershed, channel instability is the result of over-grazing or previous channelization. These areas could be relieved of stress by restoring the straightened reaches to a naturally meandering channel or changing grazing strategies to allow vegetation growth and protection of the stream banks. The following list provides examples of in- and near-channel stabilization practices:

- Stabilize banks that endanger infrastructure. This includes planting perennial vegetation, placing practices on the outside bend, and using grade-control structures. See the DNR River Ecology Unit's Fact Sheets (DNR2021b) for more information.
- Re-size bridges and culverts to allow flood flows' access to the floodplain, when applicable. This is most feasible after a bridge or culvert failure or when crossings are scheduled for replacement. The correct size allows for sediment transport and flood flows (see Zytkovicz and Murtada, 2013). Recess channel culverts into the stream bed to allow for low-flow fish passage. Locations with very wide floodplains could have multiple relief culverts along the floodplain.
- Reconnect areas with longitudinal barriers to fish passage. This includes removing or retrofitting dams and replacing perched culverts.

While in-channel restoration practices may often be implemented, many of them are short-term fixes. Practices addressing the cause of instability (e.g. altered hydrology, historic channelization) should be prioritized over the symptom (e.g. eroding bank). Installing in-stream structures are not usually recommended unless the bank is an anomaly to the system, if infrastructure is in jeopardy, or if an opportunity arises to re-meander a historically channelized stream.

Protection Strategies

Although multiple impairments have been identified throughout the watershed, Del Clark Lake is a dramatic exception to the overall trend of degraded water quality seen throughout the watershed. Del Clark Lake fully supports AqR and offers a wonderful resource for the residents of the communities in the area. Maintaining water quality within Del Clark Lake should be a priority as it is the only assessed waterbody in the watershed that meets AqR standards.

The actions implemented to restore impaired waters can also be implemented in areas with unimpaired waters in an effort to keep the unimpaired waters from becoming impaired or to prevent water quality from declining within unassessed waterbodies.

Depending on local conditions, strategies may be implemented to protect a waterbody from becoming impaired or degrading to nearly impaired. There are multiple areas within the watershed that are not considered impaired and should be protected from future harm. Many areas within the watershed have intact riparian corridors, and it is important that these areas remain unaltered and stream channels continue to meander. The following list provides examples of areas of protection within the watershed (DNR 2019):

- Since water retention is a major driver to hydrologic stability, existing lakes, wetlands, and wet marshes should be protected.
- Areas of significant groundwater-surface water interaction.
- Areas that are already enrolled in conservation programs or other BMPs. Land that was taken out of production and put in short-term conservation programs should remain in conservation programs.
- Areas that have been shown to remain stable over time, by identifying, documenting, and protecting stable stream reaches and their watersheds.
- Rare natural features and native plant communities should be protected and enhanced. This will help with watershed health and stream stability.

Strategy Tables

Table 33 and **Table 34** contain a more complete list of the strategies to restore impaired streams and protect streams of the Lac qui Parle River Watershed that are not impaired. Included in the tables are water quality goals for restoration, suggested implementation strategies to achieve those goals, estimated necessary adoption rates, units/metrics to track progress towards goals, and the timeline to achieve those goals. All other waters (lakes included) in the watershed are assumed to be unimpaired and, therefore, subject to protection strategies. Given the homogeneity of the watershed, protection strategies are identified on a watershed-wide basis and generalized for all unimpaired streams and lakes. **Table 35** contains examples of BMPs to implement for the listed strategies for each pollutant.

Interim 10-year milestones are identified in **Table 33** so that incremental progress is measured and achieved. Ongoing water quality monitoring data will be collected in future iterations of the WRAPS process to judge the effectiveness of the proposed strategies and inform adaptive implementation toward meeting the identified long-term goals.

Table 33. Strategies and actions proposed for the Lac qui Parle River Watershed.

Parameter	Aggregated HUC-12 Names	Aggregated HUC-12s[1]	Impaired Waterbody (AUID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goal for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		Restoration and Protection Strategies Estimated Rate of Adoption: All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10%	Estimated years to reach goal from 2020
								Land Use	Pathway		
Sediment	County Ditch 5	0702000303-02		- / - / -	90% of stream concentrations are below 65 mg/L (class 2B and 3C). Aquatic life populations are not stressed by sediment.	Protect	Protect	Streams Stream banks Crop Agriculture (not tiled) Crop Agriculture (tiled)	In stream erosion Bank erosion Surface runoff Surface runoff, Open tile intakes	**Most** fields use surface sediment controls to prevent sediment mobilization and transport including conservation tillage, cover crops, removing open tile intakes, or strategic implementation of sediment reducing BMPs. **Many** fields increase runoff filtration or detention to trap/settle eroded sediment (e.g. grassed waterways or water and sediment control basins). **Most** pastures are managed to prevent overgrazing and direct stream access by livestock. **All** waterbodies have adequate and well-maintained riparian vegetation (native vegetation). **Some** larger streambank stabilization/buffer enhancements - in areas to provide the **most** benefit to threatened, high value property. Incorporate the principles of natural channel design. Address altered hydrology in contributing areas utilizing strategies discussed below under 'Hydrology.'	40
	Lost Creek	0702000303-03		- / 1 / 2		Protect	Protect				
	Upper West Branch Lac qui Parle River	0702000303-01	-516	1 / 1 / -		0% Reduction[3]	Protect				
	Tributary to West Branch Lac qui Parle River	0702000305-02		- / - / -		Protect	Protect				
	Florida Creek	0702000304-01	-521, -583*	2 / - / 1		83% Reduction during high flow	10% Reduction				
	Lower West Branch Lac qui Parle River	0702000305-01		- / 2 / 2		Protect	Protect				
	Tributary to Lac qui Parle River	0702000301-02	-530, -569*	2 / - / -		55% Reduction (-530)	10% Reduction				
	Upper Lac qui Parle River	0702000301-01	-505	1 / - / -		72% Reduction	10% Reduction				
	County Ditch 4	0702000307-02		- / 1 / 2		Protect	Protect				
	Tenmile Creek	0702000306-01		- / 1 / 5		Protect	Protect				
	Lower Lac qui Parle River	0702000307-01	-501, -506,	2 / - / 3		75% Reduction	10% Reduction				
	Lazarus Creek	0702000302-01	-508, -509*	2 / - / 4		34% Reduction	10% Reduction				
Hydrology	County Ditch 5	0702000303-02		- / - / -	Aquatic life populations are not stressed by altered hydrology (too high or too low river flow). Hydrology is not accelerating other parameters (sediment, etc.). Decrease intermediate flood peaks (2-yr to 10 yr Events)	Increase storage by 0.39 inch across watershed (20,986 acre-ft.)	Increase storage by 0.1 inch across watershed (3,329 acre-ft.)	Crop Agriculture (not tiled) Crop Agriculture (tiled) All other land use	Excess surface runoff, lack of groundwater recharge Subsurface tile drainage, lack of groundwater recharge Excess surface runoff, lack of groundwater recharge	**Many** fields - increase runoff filtration or detention to attenuate peak flows and augment baseflow by retaining water on the landscape (e.g. grassed waterways or water and sediment control basins). **Most** fields - improve vegetative cover by using cover crops, buffers, grassed waterways, etc. **Many** fields - increase soil water holding capacity by increasing soil organic matter through the use of conservation/no tillage, increased vegetation, etc. **Most** fields - incorporate conservation drainage principles and/or direct drainage to ponds, wetlands, etc. that allow for infiltration. **Many** drainage and ditch projects - designed to attenuate peak flows and augment baseflow by retaining water on the landscape where possible. **Most** drainage and ditch projects - incorporate multiple benefits including maintaining vegetation and natural stream features. Some nonag land use areas - add wetlands, perennial vegetation, and urban/ residential stormwater management. **Some** stream channel restoration projects - return channelized streams to a more natural condition using natural channel design principles. Reconnect streams to floodplains where possible, starting in headwaters.	50
	Lost Creek	0702000303-03		- / 3 / -							
	Upper West Branch Lac qui Parle River	0702000303-01		- / 2 / -							
	Tributary to West Branch Lac qui Parle River	0702000305-02	-580*	1 / - / -							
	Florida Creek	0702000304-01	-521*, -583*	2 / - / -							
	Lower West Branch Lac qui Parle River	0702000305-01		- / - / 2							
	Tributary to Lac qui Parle River	0702000301-02		- / 1 / 1							
	Upper Lac qui Parle River	0702000301-01	-505*	1 / - / -							
	County Ditch 4	0702000307-02	-575*, -582*	2 / - / -							
	Tenmile Creek	0702000306-01	-526*, -570*, -571*, -577*, -578*	5 / - / -							
	Lower Lac qui Parle River	0702000307-01	-534*, -588*	2 / 1 / -							
	Lazarus Creek	0702000302-01	-508*, -509*, -	4 / - / -							

Parameter	Aggregated HUC-12 Names	Aggregated HUC-12s[1]	Impaired Waterbody (AUID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goal for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		Restoration and Protection Strategies Estimated Rate of Adoption: All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10%	Estimated years to reach goal from 2020
								Land Use	Pathway		
			557*, -586*								
Nitrogen	County Ditch 5	0702000303-02		- / 1 / -	Aquatic life not stressed by nitrate. Protect groundwater and drinking water throughout the watershed. Meet Minnesota's nitrogen reduction goal for watershed.	45% Reduction to support regional goals and downstream water quality.	25% Reduction to support regional goals and downstream water quality.	Crop agriculture (tiled and nontiled)	Surface runoff, tile drainage, and groundwater infiltration	**All** fields incorporate nutrient management principles for fertilizer and manure use. Hydrology practices as discussed above are implemented, including design parameters for nitrogen removal. Sediment practices as discussed above are implemented, including design parameters for nitrogen removal.	25
	Lost Creek	0702000303-03		- / 1 / 2							
	Upper West Branch Lac qui Parle River	0702000303-01		- / 2 / -							
	Tributary to West Branch Lac qui Parle River	0702000305-02		- / - / -							
	Florida Creek	0702000304-01		- / 1 / 1							
	Lower West Branch Lac qui Parle River	0702000305-01		- / 3 / 2							
	Tributary to Lac qui Parle River	0702000301-02		- / 1 / 1							
	Upper Lac qui Parle River	0702000301-01		- / 1 / -							
	County Ditch 4	0702000307-02		- / 1 / 2							
	Tenmile Creek	0702000306-01	-526*, -570*, -571*,-577*	4 / 1 / -							
	Lower Lac qui Parle River	0702000307-01		- / 3 / 3							
	Lazarus Creek	0702000302-01		- / 1 / 4							
Phosphorus	County Ditch 5	0702000303-02		- / - / - - / - / 1	Summer average phosphorus concentrations below 150 ug/L. Aquatic life not stressed by phosphorus. Meet Minnesota's phosphorus reduction goals for watershed to support statewide and downstream goals.	35% Reduction in streams to support regional goals and downstream water quality. 50% reduction for Lake Hendricks, protect lakes not assessed as impaired	10% Reduction to support regional goals and downstream water quality.	Crop Agriculture (tiled and nontiled) Pasture (overgrazed) Developed	Surface runoff, subsurface tile drainage, and groundwater runoff Surface runoff Sanitation (WWTPs and SSTS) and Surface runoff	**All** fields are to incorporate nutrient management principles for fertilizer and manure use. **Some** ditches/streams should be naturally treated via stream/ditch vegetative improvements. **All** failing SSTSs are to be fixed.	25
	Lost Creek	0702000303-03	-517*, -520*, -567*	3 / - / - - / - / -							
	Upper West Branch Lac qui Parle River	0702000303-01		- / 1 / 1 - / - / -							
	Tributary to West Branch Lac qui Parle River	0702000305-02		- / - / - - / - / 2							
	Florida Creek	0702000304-01	-521*, -583*	2 / - / - - / - / -							
	Lower West Branch Lac qui Parle River	0702000305-01		- / - / 4 - / - / 2							
	Tributary to Lac qui Parle River	0702000301-02	-530*, -569*	2 / - / - - / - / 2							
	Upper Lac qui Parle River	0702000301-01	-505* 41-0110-00	1 / - / - 1 / - / 3							
	County Ditch 4	0702000307-02	-575*	1 / 1 / 1 - / - / 1							
	Tenmile Creek	0702000306-01	-526*, -570*, -571*, -	5 / - / 1 - / - / 2							

Parameter	Aggregated HUC-12 Names	Aggregated HUC-12s[1]	Impaired Waterbody (AUID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goal for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		Restoration and Protection Strategies Estimated Rate of Adoption: All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10%	Estimated years to reach goal from 2020
								Land Use	Pathway		
			-577*, -578*								
	Lower Lac qui Parle River	0702000307-01	-501*, --534*, -588*	3 / - / 2 - / - / 2							
	Lazarus Creek	0702000302-01	-508*	1 / - / 4 - / 1 / 2							
Bacteria	County Ditch 5	0702000303-02	-523	1 / - / -	Monthly geomean of stream samples is below 126 org/100mL or 630 for class 7 streams.	44% Reduction	10% Reduction	Crop agriculture (with manure application) Pasture (overgrazed) Developed	Surface and feedlot runoff Pasture runoff Sanitation (failing SSTS and WWTPs)	**All** manured fields - incorporate best manure management practices. **Many** manured fields - incorporate infield and edge of field vegetative practices to capture manure runoff including cover crops, buffer strips, etc. **Much** of the pastureland is to be managed to reduce surface manure runoff. **Most** manure feed lot pile runoff is to be controlled. **All** failing SSTSs are to be fixed.	40
	Lost Creek	0702000303-03	-517	1 / - / -		21% Reduction					
	Upper West Branch Lac qui Parle River	0702000303-01	-516, -519	2 / - / -		86% Reduction (-519)					
	Tributary to West Branch Lac qui Parle River	0702000305-02	-580	1 / - / -		38% Reduction					
	Florida Creek	0702000304-01	-521	1 / - / -		69% Reduction					
	Lower West Branch Lac qui Parle River	0702000305-01	-512, -513	2 / - / -		64% Reduction (-513)					
	Tributary to Lac qui Parle River	0702000301-02	-530	1 / - / -		85% Reduction					
	Upper Lac qui Parle River	0702000301-01	-505	1 / - / -		56% Reduction					
	County Ditch 4	0702000307-02	-581	1 / - / -		61% Reduction					
	Tenmile Creek	0702000306-01	-577, -578	2 / - / -		42% Reduction (-577)					
	Lower Lac qui Parle River	0702000307-01	-501, -502, -506	3 / - / -		39% Reduction (-502)					
	Lazarus Creek	0702000302-01	-508	1 / - / -		64% Reduction during mid-range flows					
Habitat	County Ditch 5	0702000303-02		- / - / -	Increase in average MSHA scores. Aquatic life not stressed by poor habitat.	54% increase in the average MSHA score to 66	15% increase in MSHA score	Crop agriculture (tiled and nontiled)	Degraded riparian corridor, altered hydrology	**Many** streams - provide adequate buffer size and vegetation to meet shading, woody debris, geomorphology, and other habitat needs. Address altered hydrology and excess sediment in contributing areas using strategies discussed above under "Hydrology" and "Sediment" respectively.	30
	Lost Creek	0702000303-03	-517*, -520*, -567*	3 / - / -							
	Upper West Branch Lac qui Parle River	0702000303-01	-516*, -519*	2 / - / -							
	Tributary to West Branch Lac qui Parle River	0702000305-02	-580*	1 / - / -							
	Florida Creek	0702000304-01	-521*, -583*	2 / - / -							
	Lower West Branch Lac qui Parle River	0702000305-01	-515*	1 / - / 1							
	Tributary to Lac qui Parle River	0702000301-02	-569*	1 / - / 1							
	Upper Lac qui Parle River	0702000301-01	-505*	1 / - / -							
	County Ditch 4	0702000307-02	-575*, -582*	2 / - / -							

Parameter	Aggregated HUC-12 Names	Aggregated HUC-12s[1]	Impaired Waterbody (AUID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goal for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		Restoration and Protection Strategies Estimated Rate of Adoption: All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10%	Estimated years to reach goal from 2020
								Land Use	Pathway		
	Tenmile Creek	0702000306-01	-526*, -570*, -571*, -577*,	4 / - / 1							
	Lower Lac qui Parle River	0702000307-01	-501*, -534*	2 / - / 1							
	Lazarus Creek	0702000302-01	-508*, -509*, -586*	3 / - / 1							
DO	County Ditch 5	0702000303-02		- / - / 1	Minimum concentrations of 5 mg/L in all streams. Aquatic life not stressed by low DO.	Meet eutrophication standard, reduce effect of altered hydrology, improve riparian and aquatic habitat	Meet phosphorus, hydrology, and habitat goals	All	Land use stressors (phosphorus, altered hydrology, degraded riparian corridor)	**Most** streams - collect additional eutrophication related data (e.g. phosphorus, chlorophyll-a, DO flux) from affected stream reaches to determine relationship to DO concentration Address "Hydrology", "Phosphorus", and "Habitat" practices as discussed above.	25
	Lost Creek	0702000303-03	-517	1 / - / 2							
	Upper West Branch Lac qui Parle River	0702000303-01		- / - / 2							
	Tributary to West Branch Lac qui Parle River	0702000305-02	-580*	1 / - / -							
	Florida Creek	0702000304-01		- / - / 2							
	Lower West Branch Lac qui Parle River	0702000305-01		- / - / 4							
	Tributary to Lac qui Parle River	0702000301-02	-569*	1 / - / 1							
	Upper Lac qui Parle River	0702000301-01		- / 1 / -							
	County Ditch 4	0702000307-02	-575*	1 / - / 2							
	Tenmile Creek	0702000306-01	-570*, -571*, -577*	3 / 1 / 1							
	Lower Lac qui Parle River	0702000307-01	-501, -534*	2 / - / 4							
	Lazarus Creek	0702000302-01		- / - / 5							
Connectivity	County Ditch 5	0702000303-02		- / - / -	Aquatic life populations not stressed by human-caused barriers.	Address identified barriers	Address identified barriers	Streams Road crossings	Loss of longitudinal connectivity	**Many** streams - remove or alter dams or culverts to allow for passage of aquatic organisms to upstream/headwaters region. **Some** culverts - evaluate culvert size for potential to act as velocity barriers to fish passage (i.e. locate undersized culverts).	45
	Lost Creek	0702000303-03		- / 3 / -							
	Upper West Branch Lac qui Parle River	0702000303-01		- / 2 / -							
	Tributary to West Branch Lac qui Parle River	0702000305-02		- / 1 / -							
	Florida Creek	0702000304-01		- / 2 / -							
	Lower West Branch Lac qui Parle River	0702000305-01	-515*	1 / 1 / -							
	Tributary to Lac qui Parle River	0702000301-02	-569*	1 / 1 / -							
	Upper Lac qui Parle River	0702000301-01	-505*	1 / - / -							
	County Ditch 4	0702000307-02		- / 2 /							
	Tenmile Creek	0702000306-01		- / 5 / -							
	Lower Lac qui Parle River	0702000307-01	-588*	1 / 2 / -							

Parameter	Aggregated HUC-12 Names	Aggregated HUC-12s[1]	Impaired Waterbody (AUID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goal for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		Restoration and Protection Strategies Estimated Rate of Adoption: All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10%	Estimated years to reach goal from 2020
								Land Use	Pathway		
	Lazarus Creek	0702000302-01	-557*, -586*	2 / 2 / -							

Key: ## / ## / ## = Number of waterbodies where parameter is: impairing water quality / supporting water quality / sampled, but insufficient data to classify. Top line in phosphorus is streams and bottom line is lakes.

*Reaches are not impairing, but are a stressor for the given parameter.

[1]Aggregated HUC12s follow the Monitoring and Assessment (MPCA 2018) report.

[2]Individual reduction goals that are different from watershed-wide goals are the needed TMDL load reductions (see Table 26).

[3]Reach -516 impairment for turbidity was barely impaired when listed in 2010. The 2017 assessment dataset was not conclusive in showing that the stream was meeting conditions for full support and thus the listing remained. This reach should be monitored and reevaluated in cycle 2.

Table 34. Strategies that can be implemented to help meet water quality goals in the Lac qui Parle River Watershed. Practice efficacy by BMP mode of action are prioritized.

Land use	Restoration and Protection Strategies[1]	Adoption Rate		BMP Mode of Action[2]							
				By pollutant or Stressor							
	Common management practices by land use	% of Watershed Area	Watershed Acres	Sediment	Hydrology	Nitrogen	Phosphorus	Bacteria	Habitat	Dissolved Oxygen	Connectivity
Cultivated Crops	Improved fertilizer management	50%	351,000	-	-	x	x	-		X	
	Grassed waterway*	5%	35,000	X	-	X	-	-		-	
	Conservation tillage	15%	105,000	X	-	-	X			-	
	Crop rotation (including small grain)	Alternative crop management practices				X	-			-	
	Critical area planting			X			-		-	-	
	Improved manure field application			-	-	X	-	-		X	
	Cover crops*	25%	176,000	X	-	-	X	-		-	
	WASCOBS, terraces, flow-through basins*	16%	112,000	X	X	-	X	-		-	
	Buffers, border filter strips*	Alternative practices, sufficient application as alternative to other similar practices			-	X	-	X	X	X	
	Contour strip cropping (50% crop in grass)			X	X	X	X	X	-	-	
	Wind Breaks*			-			-			-	
	Conservation cover (replacing marginal farmed areas) *			X	X	X	X	X	-	-	
	In/near ditch retention/treatment			-	-	-	-	-		-	
	Alternative tile intakes*	9%	63000	X			X	-		-	
	Treatment wetland (for tile drainage system)	3%	21,000		-	X	-				
	Controlled drainage, drainage design*	5%	35,000		X	X	-			-	
	Saturated buffers	3%	21,000		-	X	-			-	
	Wood chip bioreactor	5%	35,000			X	-			-	
	Wetland Restoration	5%	35,000	X	X	X	X	X	X	-	
	Retention Ponds*	Alternative to tile line practices		X	X	X	X	X	-	-	
	Mitigate agricultural drainage projects	All new projects		X	X	X	X	X	-	-	
	Maintenance and new enrollment of BMPs, CRP, RIM, etc.	All current BMPs		X	X	X	X	X	-	-	
Pastures	Rotational grazing/improved pasture vegetation management	As needed to protect shoreland		X			X	X	X	-	
	Livestock stream exclusion and watering facilities			X			X	X	X	-	

Land use	Restoration and Protection Strategies[1] Common management practices by land use	Adoption Rate % of Watershed Area	Adoption Rate Watershed Acres	BMP Mode of Action[2] (By pollutant or Stressor) Sediment	Hydrology	Nitrogen	Phosphorus	Bacteria	Habitat	Dissolved Oxygen	Connectivity
Cities & yards	Nutrient/fertilizer and lawn mgt.	Sufficient to reduce current contributions by 20%		-	-	-	-	-		-	
	Infiltration/retention ponds, wetlands			-	-	X	-			-	
	Rain gardens, rain barrels				-						
	Street sweeping & storm sewer mgt.			-							
	Trees/native plants			-			-			-	
	Snow pile management				-						
	Permeable pavement for new construction			-	-						
	Construction site erosion control			X	X	-	X		-	-	
SSTS	Maintenance and replacement/upgrades*					X	X	X		-	
Feedlots	Feedlot runoff controls including buffer strips, clean water diversions, etc. on feedlots with runoff*					X	X	X		-	
Streams, ditches, & ravines	Protect and restore buffers, natural features	Buffers per law; no natural feature loss		X	X	X			X		
	Reduce or eliminate ditch clean-outs	All ditches		X		X			X		
	Bridge/culvert design	All new projects		X	X						X
	Dam design	All new projects									X
	Streambank stabilization*	As needed to protect property or excessive/extreme erosion		X		X	X		-	-	
	Ravine/stream (grade) stabilization*			X		X	X			-	
	Stream channel restoration and floodplain reconnection	5% of needed areas		X		X	X		X	-	
Lakes & Wetlands	Near-water vegetation protection and restoration	Assess and address shoreland and in-lake management where needed		X		X	X		X	-	
	In-water management and species control					X	-		X	-	
Grassland & Forest	Protect and restore areas in these land uses, increase native species populations*	All forests and prairies		X	-	X	X		X	-	

<table>
<tr><th rowspan="3">Land use</th><th>Restoration and Protection Strategies[1]</th><th colspan="2" rowspan="2">Adoption Rate</th><th colspan="8">BMP Mode of Action[2]</th></tr>
<tr><th rowspan="2">Common management practices by land use</th><th colspan="8">By pollutant or Stressor</th></tr>
<tr><th>% of Watershed Area</th><th>Watershed Acres</th><th>Sediment</th><th>Hydrology</th><th>Nitrogen</th><th>Phosphorus</th><th>Bacteria</th><th>Habitat</th><th>Dissolved Oxygen</th><th>Connectivity</th></tr>
<tr><td rowspan="8">Social Strategies</td><td>Networking, education, and demonstrations including programing on: soil health, altered hydrology, residential stormwater, septic system, and manure management</td><td colspan="2" rowspan="8">Sufficient to address barriers to adopting all other strategies at specified adoption rates</td><td colspan="8" rowspan="8">No direct impacts to pollutants and stressors. however, these strategies are critical to get the physical practices adopted</td></tr>
<tr><td>Encourage and support farmer/citizen-led or other movements with overlapping goals</td></tr>
<tr><td>Dialog and relationship-building between ag producers and conservation professionals to identify additional strategies</td></tr>
<tr><td>Program changes (Farm Bill, crop insurance, etc.): ensure income and eliminate obstacles for farmers to implement sustainable practices; support alternative crops, small farms, perennials, rural communities; remove incentives that result in unintended environmental damage</td></tr>
<tr><td>Develop markets for small grains and perennials</td></tr>
<tr><td>New ordinances/ordinance review (e.g. septic compliance upon property transfer, well head protection)</td></tr>
<tr><td>Existing ordinance compliance/enforcement (e.g. manure application, shoreland)</td></tr>
<tr><td>Permit compliance for regulated sources</td></tr>
</table>

1. Blue shaded practices are preferred practice (see **Table 32**).
2. "X" – strong benefit to water quality improvement as related to the specified parameter, "x" --moderate benefit to water quality as related to the specified parameter, "-" – low benefit to water quality as related to the specified parameter, blank – little benefit to water quality as related to the specified parameter
* Previously installed/implemented practice within the Lac qui Parle River Watershed.

Table 35. Additional information for restoration and protection strategies.

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
Total Suspended Solids (TSS)	**Improve upland/field surface runoff controls:** Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland.	Cover crops
		Water and sediment basins, terraces
		Rotations including perennials
		Conservation cover easements
		Grassed waterways
		Strategies to reduce flow – some of flow reduction strategies should be targeted to ravine subwatersheds
		Residue management – conservation tillage
		Forage and biomass planting
		Open tile inlet controls – riser pipes, french drains
		Contour farming
		Field edge buffers, borders, windbreaks and/or filter strips
		Stripcropping
	Protect/stabilize banks/bluffs: Reduce collapse of bluffs and erosion of streambank by reducing peak river flows and using vegetation to stabilize these areas.	Strategies for altered hydrology (reducing peak flow)
		Streambank stabilization
		Riparian forest buffer
		Livestock exclusion – controlled stream crossings
	Stabilize ravines: Reduce erosion of ravines by dispersing and infiltrating field runoff and increasing vegetative cover near ravines. Also may include earthwork/regrading and revegetation of ravine.	Field edge buffers, borders, windbreaks and/or filter strips
		Contour farming and contour buffer strips
		Diversions
		Water and sediment control basin
		Terrace
		Conservation crop rotation
		Cover crop
		Residue management – conservation tillage
		Addressing road crossings (direct erosion) and floodplain cut-offs

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
	Stream channel restoration.	Clear water discharge: urban areas, ag tiling etc. – direct energy dissipation
		Two-stage ditches
		Large-scale restoration – channel dimensions match current hydrology and sediment loads, connect the floodplain, stable pattern, (natural channel design principals)
		Stream channel restoration using vertical energy dissipation: step pool morphology
	Improve forestry management.	Proper water crossings and road construction
		Forest roads - cross-drainage
		Maintaining and aligning active forest roads
		Closure of inactive roads and post-harvest
		Location and sizing of landings
		Riparian Management Zone Widths and/or filter strips
	Improve urban stormwater management [to reduce sediment and flow].	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
Nitrogen (TN) or Nitrate	**Increase fertilizer and manure efficiency:** Manage fertilizer and manure application to maximize crop uptake while minimizing leaching losses to waters.	Nitrogen rates at maximum return to nitrogen (U of MN rec's)
		Timing of application closer to crop use (spring or split applications)
		Nitrification inhibitors
		Manure application based on nutrient testing, calibrated equipment, recommended rates, etc.
	Store and treat tile drainage waters: Manage tile drainage waters so nitrate can be denitrified or water volumes and loads from tile drains are reduced.	Saturated buffers
		Restored or constructed wetlands
		Controlled drainage
		Woodchip bioreactors
		Two-stage ditch
	Increase vegetative cover/root duration: Plant crops and vegetation that maximize vegetative cover and capture of soil nitrate by roots during the spring, summer and fall.	Conservation cover (easements/buffers of native grass and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials

Parameter (include nonpollutant stressors)	Strategy key	
	Description	Example BMPs/actions
		Crop conversion to low nutrient-demanding crops (e.g., hay).
Phosphorus (TP)	**Improve upland/field surface runoff controls:** Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland.	Strategies to reduce sediment from fields (see above - upland field surface runoff)
		Constructed wetlands
		Pasture management
	Reduce bank/bluff/ravine erosion.	Strategies to reduce TSS from banks/bluffs/ravines (see above for sediment)
	Increase vegetative cover/root duration: Plant crops and vegetation that maximize vegetative cover and minimize erosion and soil losses to waters, especially during the spring and fall.	Conservation cover (easements/buffers of native grass and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
	Preventing feedlot runoff: Use manure storage, water diversions, reduced lot sizes and vegetative filter strips to reduce open lot phosphorus losses.	Open lot runoff management to meet Minn. R. 7020 rules
		Manure storage in ways that prevent runoff
	Improve fertilizer and manure application management: Apply phosphorus fertilizer and manure onto soils where it is most needed using techniques that limit exposure of phosphorus to rainfall and runoff.	Soil P testing and applying nutrients on fields needing phosphorus
		Incorporating/injecting nutrients below the soil
		Manure application meeting all 7020 rule setback requirements
	Address failing septic systems: Fix septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Sewering around lakes
		Eliminating straight pipes, surface seepages
	Reduce in-water loading: Minimize the internal release of phosphorus within lakes	Rough fish management
		Curly-leaf pondweed management
		Alum treatment
		Lake drawdown
		Hypolimnetic withdrawal
	Improve forestry management	See forest strategies for sediment control
	Reduce Industrial/Municipal wastewater TP	Municipal and industrial treatment of wastewater P

Parameter (include nonpollutant stressors)	Strategy key	
	Description	Example BMPs/actions
		Upgrades/expansion, address inflow/infiltration
	Treat tile drainage waters: Treat tile drainage waters to reduce phosphorus entering water by running water through a medium which captures phosphorus.	Phosphorus-removing treatment systems, including bioreactors
	Improve urban stormwater management.	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
E. coli	**Reduce livestock sourced bacteria in surface runoff:** Prevent manure from entering streams by keeping it in storage or below the soil surface and by limiting access of animals to waters.	Strategies to reduce field TSS (applied to manured fields, see above)
		Improved field manure (nutrient) management
		Adhere/increase application setbacks
		Improve feedlot runoff control
		Animal mortality facility
		Manure spreading setbacks and incorporation near wells and sinkholes
		Rotational grazing and livestock exclusion (pasture management)
	Reduce urban bacteria: Limit exposure of pet or waterfowl waste to rainfall	Pet waste management
		Filter strips and buffers
		See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Address failing septic systems: Fix septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Replace failing septic (SSTS) systems
		Maintain septic (SSTS) systems
	Reduce industrial/municipal wastewater bacteria	Reduce straight pipe (untreated) residential discharges
		Reduce WWTP untreated (emergency) releases
Dissolved Oxygen	Reduce phosphorus	See strategies above for reducing phosphorus
	Increase river flow during low flow years	See strategies above for altered hydrology
	In-channel restoration: Actions to address altered portions of streams.	Goal of channel stability: transporting the water and sediment of a watershed without aggrading or degrading.
		Restore riffle substrate

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	**Increase living cover:** Plant crops and vegetation that maximize vegetative cover and ET especially during the high flow spring months.	Grassed waterways
		Cover crops
		Conservation cover (easements and buffers of native grass and trees, pollinator habitat)
		Rotations including perennials
	Improve drainage management: Manage drainage waters to store tile drainage waters in fields or at constructed collection points and release stored waters after peak flow periods.	Treatment wetlands
		Restored wetlands
	Reduce rural runoff by increasing infiltration: Decrease surface runoff contributions to peak flow through soil and water conservation practices.	Conservation tillage (no-till or strip till w/ high residue)
		Water and sediment basins, terraces
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve irrigation water management: Increase groundwater contributions to surface waters by withdrawing less water for irrigation or other purposes.	Groundwater pumping reductions and irrigation management
Poor habitat (Fish/Macroinvertebrate IBI)	**Improve riparian vegetation:** Plant and improve perennial vegetation in riparian areas to stabilize soil, filter pollutants and increase biodiversity.	50' vegetated buffer on waterways
		One rod ditch buffers
		Lake shoreland buffers
		Increase conservation cover: in/near water bodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shoreline protection/stabilization
		Wetland restoration
		Accurately size bridges and culverts to improve stream stability
		Retrofit dams with multi-level intakes
		Restore riffle substrate

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
	Restore/enhance channel: Various restoration efforts largely aimed at providing substrate and natural stream morphology.	Two-stage ditch
		Dam operation to mimic natural conditions
		Restore natural meander and complexity
Water temperature	Urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve riparian vegetation: Actions primarily to increase shading, but also some infiltration of surface runoff.	Riparian vegetative buffers
		Tree planting to increase shading
Connectivity (Fish IBI)	**Remove fish passage barriers:** Identify and address barriers.	Remove impoundments
		Properly size and place culverts for flow and fish passage
		Construct by-pass
All [protection-related]	**Implement volume control/limited-impact development:** This is aimed at development of undeveloped land to provide no net increase in volume and pollutants.	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php

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Lac qui Parle River Watershed Reports

All Lac qui Parle River Watershed reports referenced in this watershed report are available at the Lac qui Parle River Watershed webpage: https://www.pca.state.mn.us/water/watersheds/lac-qui-parle-river]

5. Appendix

Appendix 5.1 TMDL Tables

Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low Dissolved Oxygen TMDL Assessment Report

Fecal TMDLs

Table 2.15 – *E. coli* Loading Capacities and Allocations – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	279.05	82.94	22.91	4.40	0.03
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	251.14	74.65	20.62	3.96	0.03
MOS	27.91	8.29	2.29	0.44	0.00

Table 2.19 – *E. coli* Loading Capacities and Allocations – Lazarus Creek: Canby Creek to Lac qui Parle River (AUID 07020003-508)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	314.80	82.88	32.34	8.12	0.93
Σ WLA					
NPDES Permitted Treatment Facilities	12.40	12.40	12.40	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	270.92	62.19	16.71	*	*
MOS	31.48	8.29	3.23	na	na

Table 2.24 – *E. coli* Loading Capacities and Allocations – West Branch Lac qui Parle River, Unnamed ditch to Unnamed creek (AUID 07020003-512)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	883.04	262.45	72.49	13.94	0.10
Σ WLA					
NPDES Permitted Treatment Facilities	3.84	3.84	3.84	3.84	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	790.90	232.36	61.40	8.71	*
MOS	88.30	26.25	7.25	1.39	na

Table 2.28 – *E. coli* Loading Capacities and Allocations – West Branch Lac qui Parle River, Lost Creek to Florida Creek (AUID 07020003-516)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	343.23	102.01	28.18	5.42	0.04
Σ WLA					
NPDES Permitted Treatment Facilities	1.60	1.60	1.60	1.60	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	307.31	90.21	23.76	3.28	*
MOS	34.32	10.20	2.82	0.54	na

Table 2.33 – *E. coli* Loading Capacities and Allocations – Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	265.79	69.98	27.30	6.85	0.78
Σ WLA					
NPDES Permitted Treatment Facilities	11.21	11.21	11.21	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	228.00	51.77	13.36	*	*
MOS	26.58	7.00	2.73	na	na

Table 2.37 – *E. coli* Loading Capacities and Allocations – Lac qui Parle River, Lazarus Creek to W. Branch Lac qui Parle River (AUID 07020003-506)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	777.45	204.68	79.86	20.05	2.28
Σ WLA					
NPDES Permitted Treatment Facilities	23.61	23.61	23.61	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	676.09	160.60	48.26	*	*
MOS	77.75	20.47	7.99	na	na

Table 2.42 – *E. coli* Loading Capacities and Allocations – Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	1600.68	401.20	152.48	60.29	17.69
Σ WLA					
NPDES Permitted Treatment Facilities	41.38	41.38	41.38	41.38	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	1399.23	319.70	95.85	12.88	*
MOS	160.07	40.12	15.25	6.03	na

Table 2.46 – *E. coli* Loading Capacities and Allocations – Ten Mile Creek, Headwaters to Lac qui Parle River (AUID 07020003-511)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	308.51	77.33	29.39	11.62	3.41
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	277.66	69.60	26.45	10.46	3.07
MOS	30.85	7.73	2.94	1.16	0.34

Turbidity TMDLs

Table 3.14 – TSS Loading Capacities and Allocations – Florida Creek: South Dakota border to W. Branch Lac qui Parle River (AUID 07020003-521)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	10.74	1.52	0.41	0.13	0.01
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	<0.01	<0.01
Industrial Stormwater	0.01	<0.01	<0.01	<0.01	<0.01
Σ LA	9.65	1.37	0.37	0.12	0.01
MOS	1.07	0.15	0.04	0.01	0.00

Table 3.18 – TSS Loading Capacities and Allocations – Lazarus Creek: Canby Creek to Lac qui Parle River (AUID 07020003-508)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	11.07	2.05	0.58	0.19	0.03
Σ WLA					
NPDES Permitted Treatment Facilities	0.44	0.44	0.44	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	*	*
Industrial Stormwater	0.01	<0.01	<0.01	*	*
Σ LA	9.50	1.40	0.08	*	*
MOS	1.11	0.21	0.06	na	na

Table 3.22 – TSS Loading Capacities and Allocations – West Branch Lac qui Parle River-Lost Creek to Florida Creek (AUID 07020003-516)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	13.21	1.88	0.51	0.16	0.01
Σ WLA					
NPDES Permitted Treatment Facilities	0.06	0.06	0.06	0.06	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	<0.01	*
Industrial Stormwater	0.01	<0.01	<0.01	<0.01	*
Σ LA	11.81	1.63	0.40	0.08	*
MOS	1.32	0.19	0.05	0.02	na

Table 3.27 – TSS Loading Capacities and Allocations – Lac qui Parle River, Headwaters to Lazarus Creek (AUID 07020003-505)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	9.35	1.73	0.49	0.16	0.03
Σ WLA					
NPDES Permitted Treatment Facilities	0.40	0.40	0.40	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	*	*
Industrial Stormwater	0.01	<0.01	<0.01	*	*
Σ LA	7.99	1.16	0.04	*	*
MOS	0.94	0.17	0.05	na	na

Table 3.31 – TSS Loading Capacities and Allocations – Lac qui Parle River, Lazarus Creek to West Branch Lac qui Parle (AUID 07020003-506)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	27.34	5.06	1.45	0.48	0.07
Σ WLA					
NPDES Permitted Treatment Facilities	0.84	0.84	0.84	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.02	<0.01	<0.01	*	*
Industrial Stormwater	0.02	<0.01	<0.01	*	*
Σ LA	23.73	3.71	0.46	*	*
MOS	2.73	0.51	0.15	na	na

Table 3.36 – TSS Loading Capacities and Allocations – Lac qui Parle River, West Branch Lac qui Parle River to Ten Mile Creek (AUID 07020003-501)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	59.61	10.39	3.33	1.48	0.28
Σ WLA					
NPDES Permitted Treatment Facilities	1.54	1.54	1.54	*	*
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.05	0.01	<0.01	<0.01	*
Industrial Stormwater	0.05	0.01	<0.01	<0.01	*
Σ LA	52.02	7.80	1.47	*	*
MOS	5.96	1.04	0.33	na	na

Lac qui Parle River (AUID 07020003-501) DO TMDL

Table 4.10 – TMDL allocations represented in pounds per day.

	TMDL CBOD (*pounds O_2 per day*)	TMDL NBOD (*pounds O_2 per day*)	TMDL SOD (*pounds O_2 per day*)	TMDL Total Oxygen Demand (*pounds O_2 per day*)
TMDL Allocation = Σ WLA + Σ LA + MOS	5,322.9	961.3	8,013.9	14,298.1
Σ WLA				
NPDES Permitted Treatment Facilities	--	--	--	--
Feedlots Requiring NPDES Permits	--	--	--	--
Noncompliant Septic Systems	--	--	--	--
Construction Stormwater	5.0	1.0	--	6.0
Industrial Stormwater	5.0	1.0	--	6.0
Σ LA				
Sources of Sediment Flux	--	--	6,998.9	6,998.9
Diffuse Sources	3,267.1	144.7	--	3,411.8
Boundary Condition: West Branch Lac qui Parle River (1.50 river miles)	459.4	233.4	237.4	930.2
Boundary Condition: South Branch Lac qui Parle River	105.0	131.2	--	236.2
Boundary Condition: County Ditch 27	963.3	250.6	--	1,213.9
Boundary Condition: County Ditch 4	154.0	199.4	--	353.4
MOS	364.1	--	777.7	1,141.8

Lac qui Parle River Watershed Total Maximum Daily Load

Escherichia coli

Lac qui Parle River, Tenmile Cr to Minnesota R (07020003-502)

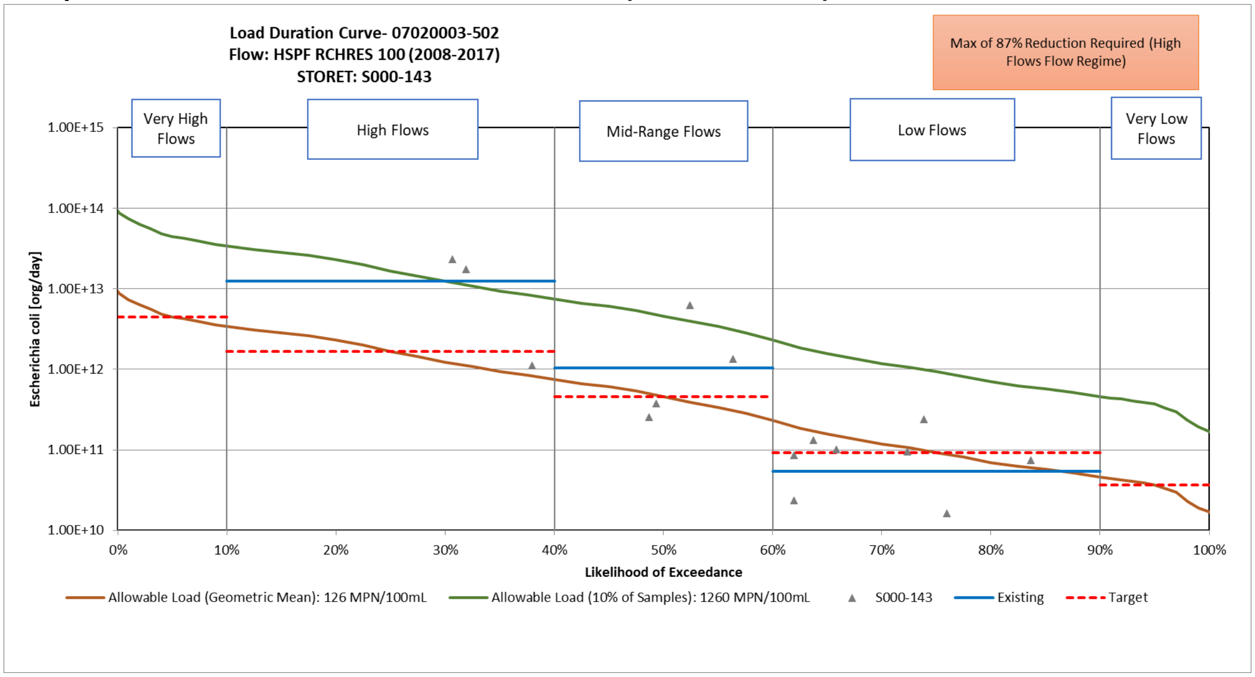

Figure 1. Lac qui Parle River, Tenmile Cr to Minnesota R (07020003-502).

Table 1. *E. coli* allocations for Lac qui Parle River, Tenmile Cr to Minnesota R (07020003-502).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billions organisms/day]				
Loading Capacity	**Total**	**4,440**	**1,660**	**454**	**93**	**37**
	Minnesota[1]	**3,205**	**1,199**	**328**	**67**	**27**
Wasteload Allocation	*Canby WWTP*	12	12	12	12	12
	Dawson WWTP	2.2	2.2	2.2	2.2	2.2
	Hendricks WWTP	12	12	12	12	12
	Madison WWTP	2.3	2.3	2.3	2.3	2.3
	Marietta WWTP	1.6	1.6	1.6	1.6	1.6
	PURIS Proteins LLC	12	12	12	12	12
	Total WLA	**42**	**42**	**42**	**42**	**###**
Load Allocation	**Total LA**	**2,842**	**1,037**	**253**	**18**	**###**
Margin of Safety (MOS)		**321**	**120**	**33**	**6.7**	**2.7**
Average existing monthly geometric mean		**202.7 org/100 mL**				
Overall estimated percent reduction[2]		**39%**				

= The permitted design flows exceed the streamflow in the indicated flow zone. The allocations are expressed as an equation rather than an absolute number: (flow contribution from source) X (126 org/100 mg/L) X conversion factors. See Section 4.3.3 for details.

[1]Based of 72.2% of existing load coming from Minnesota.

[2]The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard

Lac qui Parle River, West Branch, Unnamed ditch to Lac Qui Parle R (07020003-513)

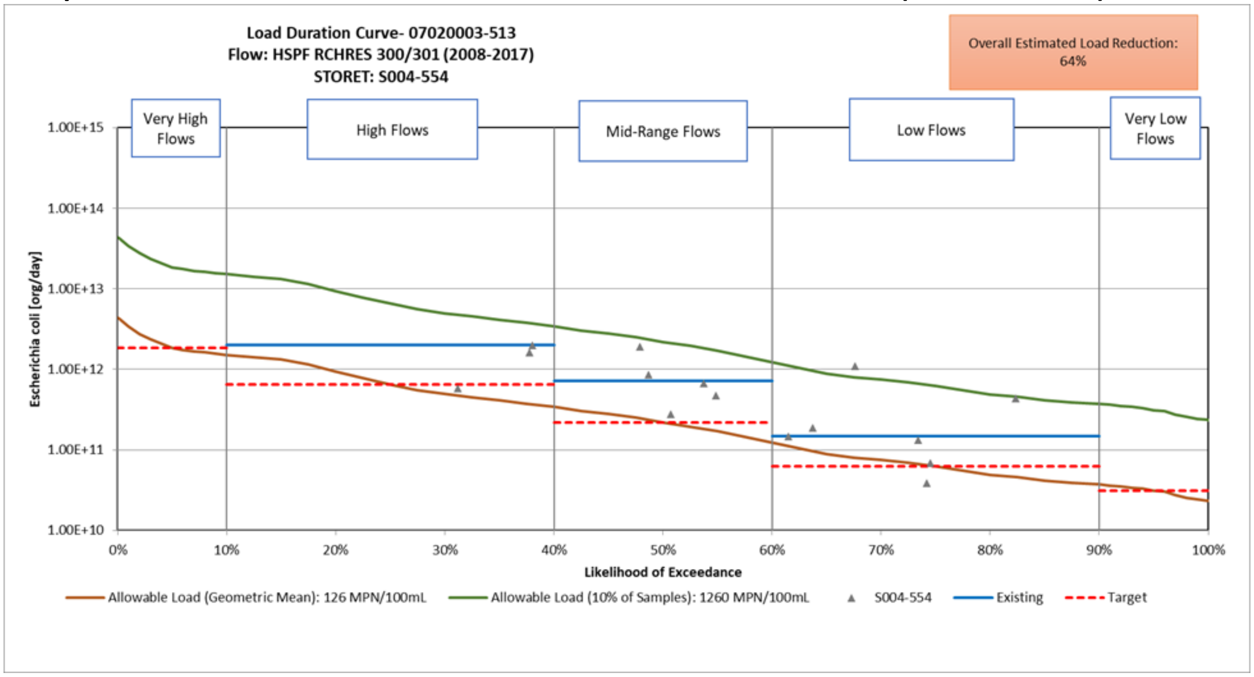

Figure 2. Lac qui Parle River, West Branch, Unnamed ditch to Lac Qui Parle R (07020003-513) *E. coli* LDC.

Table 2. *E. coli* allocations for Lac qui Parle River, West Branch, Unnamed ditch to Lac Qui Parle R (07020003-513).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billions organisms/day]				
Loading Capacity	**Total**	**1,834**	**653**	**220**	**62**	**31**
	Minnesota[1]	**978**	**348**	**117**	**33**	**17**
Wasteload Allocation	*Dawson WWTP*	2.2	2.2	2.2	2.2	2.2
	Marietta WWTP	1.6	1.6	1.6	1.6	1.6
	Total WLA	**3.8**	**3.8**	**3.8**	**3.8**	**3.8**
Load Allocation	**Total LA**	**876**	**310**	**102**	**26**	**11**
Margin of Safety (MOS)		**98**	**35**	**12**	**3.3**	**1.7**
Average existing monthly geometric mean		**352.5 org/100 mL**				
Overall estimated percent reduction[2]		**64%**				

[1]Based of 53.3% of existing load coming from Minnesota.

[2]The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard

Lost Creek, Crow Timber Cr to W Br Lac Qui Parle R (07020003-517)

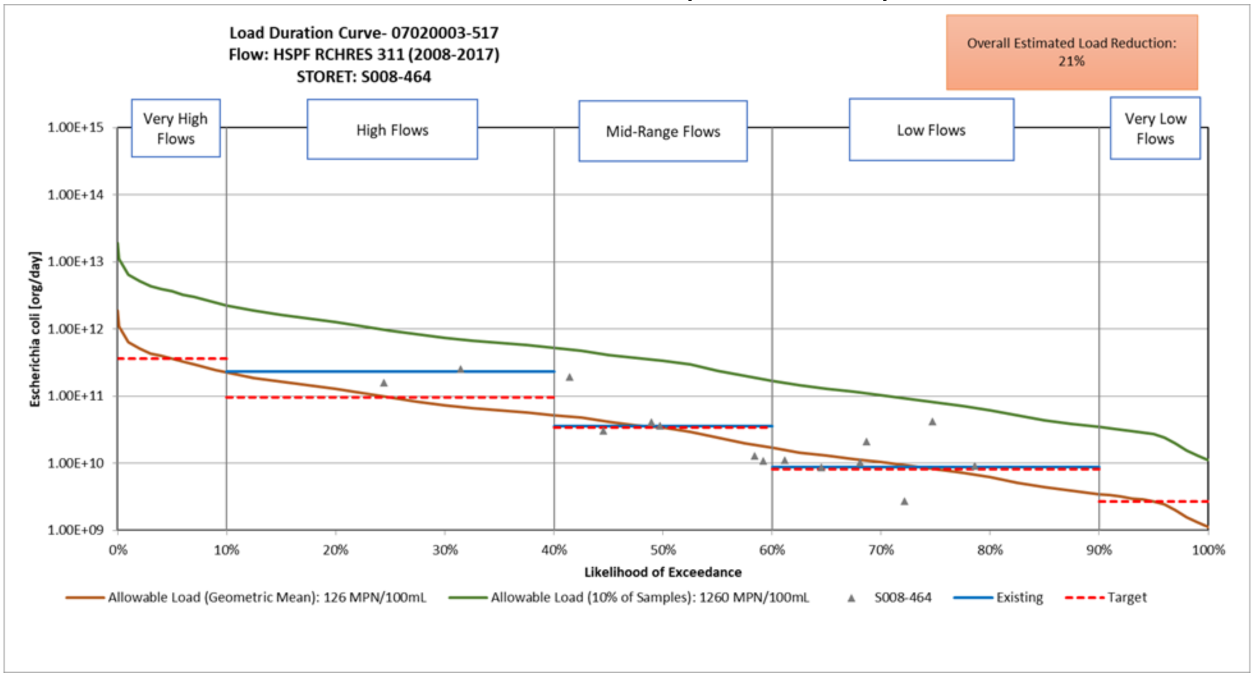

Figure 3. Lost Creek, Crow Timber Cr to W Br Lac Qui Parle R (07020003-517) *E. coli* LDC.

Table 3. *E. coli* allocations for Lost Creek, Crow Timber Cr to W Br Lac Qui Parle R (07020003-517).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billions organisms/day]				
Loading Capacity	Total	363	95	34	8.2	2.7
	Minnesota[1]	66	17	6.2	1.5	0.49
Wasteload Allocation		0	0	0	0	0
Load Allocation		59	16	5.5	1.3	0.44
Margin of Safety (MOS)		6.6	1.7	0.62	0.15	0.049
Average existing monthly geometric mean		154.4 org/100 mL				
Overall estimated percent reduction[2]		21%				

[1]Based of 18.2% of existing load coming from Minnesota.

[2] The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard.

Lac qui Parle River, West Branch, MN/SD border to Lost Cr (07020003-519)

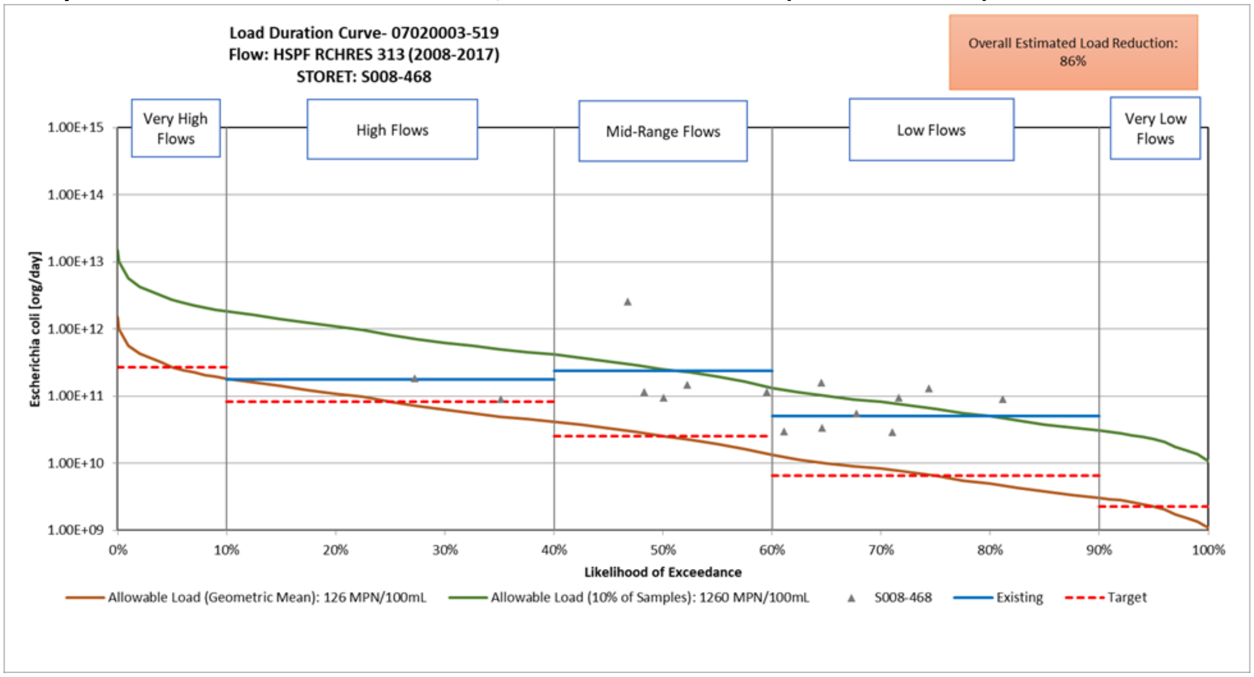

Figure 4. Lac qui Parle River, West Branch, MN/SD border to Lost Cr (07020003-519) *E. coli* LDC.

Table 4. *E. coli* allocations for Lac qui Parle River, West Branch, MN/SD border to Lost Cr (07020003-519).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billions organisms/day]				
Loading Capacity	Total	273	82	25	6.5	2.3
	Minnesota[1]	43	13	4.0	1.0	0.36
Wasteload Allocation		0	0	0	0	0
Load Allocation		39	12	3.6	0.93	0.32
Margin of Safety (MOS)		4.3	1.3	0.40	0.10	0.036
Average existing monthly geometric mean		914.9 org/100 mL				
Overall estimated percent reduction[2]		86%				

[1]Based of 15.9% of existing load coming from Minnesota.

[2] The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard.

County Ditch 5, T118 R46W S23, north line to W Br Lac Qui Parle R (07020003-523)

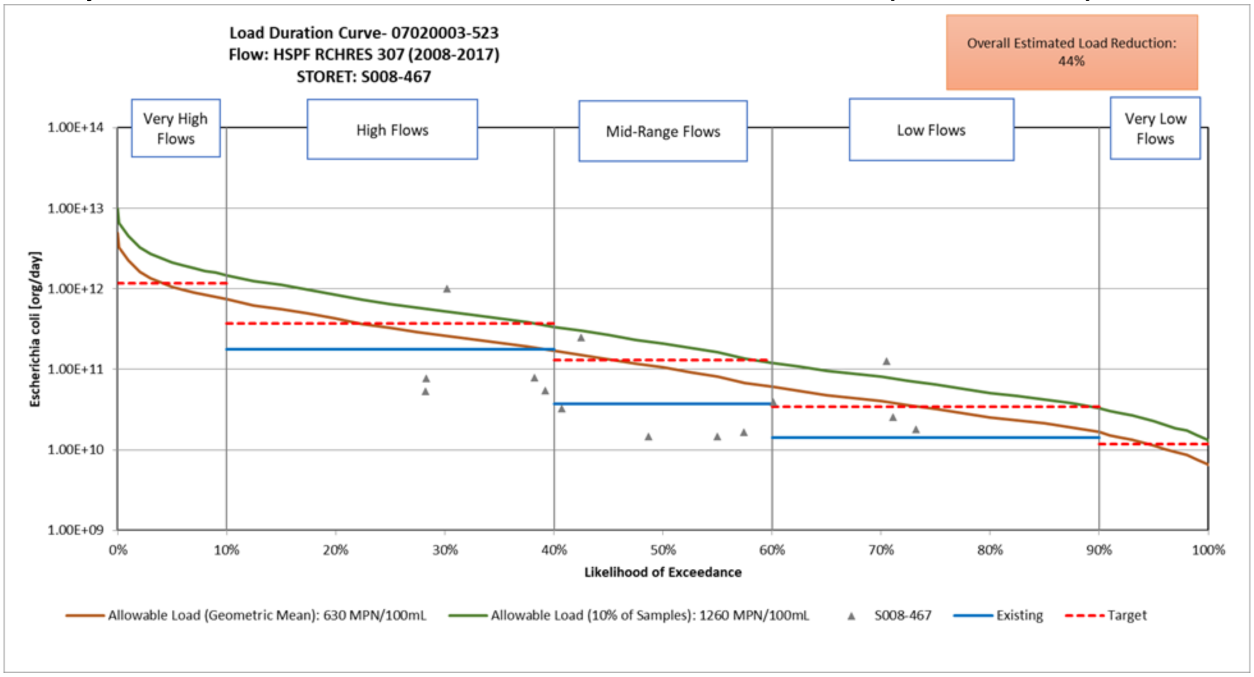

Figure 5. County Ditch 5, T118 R46W S23, north line to W Br Lac Qui Parle R (07020003-523) *E. coli* LDC.

Table 5. *E. coli* allocations for County Ditch 5, T118 R46W S23, north line to W Br Lac Qui Parle R (07020003-523).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billions organisms/day]				
Loading Capacity	**Total**	**1,177**	**368**	**130**	**34.3**	**11.9**
	Minnesota[1]	**554**	**173**	**61**	**16**	**5.6**
Wasteload Allocation	*Marietta WWTP*	1.6	1.6	1.6	1.6	1.6
	Total WLA	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**
Load Allocation	**Total LA**	**497**	**154**	**53.5**	**13**	**3.4**
Margin of Safety (MOS)		**55.4**	**17.3**	**6.12**	**1.62**	**0.559**
Average existing monthly geometric mean		**301.9 org/100 mL**				
Maximum monthly 90th percentile		**2,246 org/100 mL**				
Overall estimated percent reduction[2]		**44%**				

[1]Based of 47.1% of existing load coming from Minnesota.

[2]The overall estimated percent reduction is the reduction in the maximum monthly 90th percentile to meet the 1,260 org/100 mL standard.

Unnamed creek, Unnamed cr to Lac Qui Parle R (07020003-530)

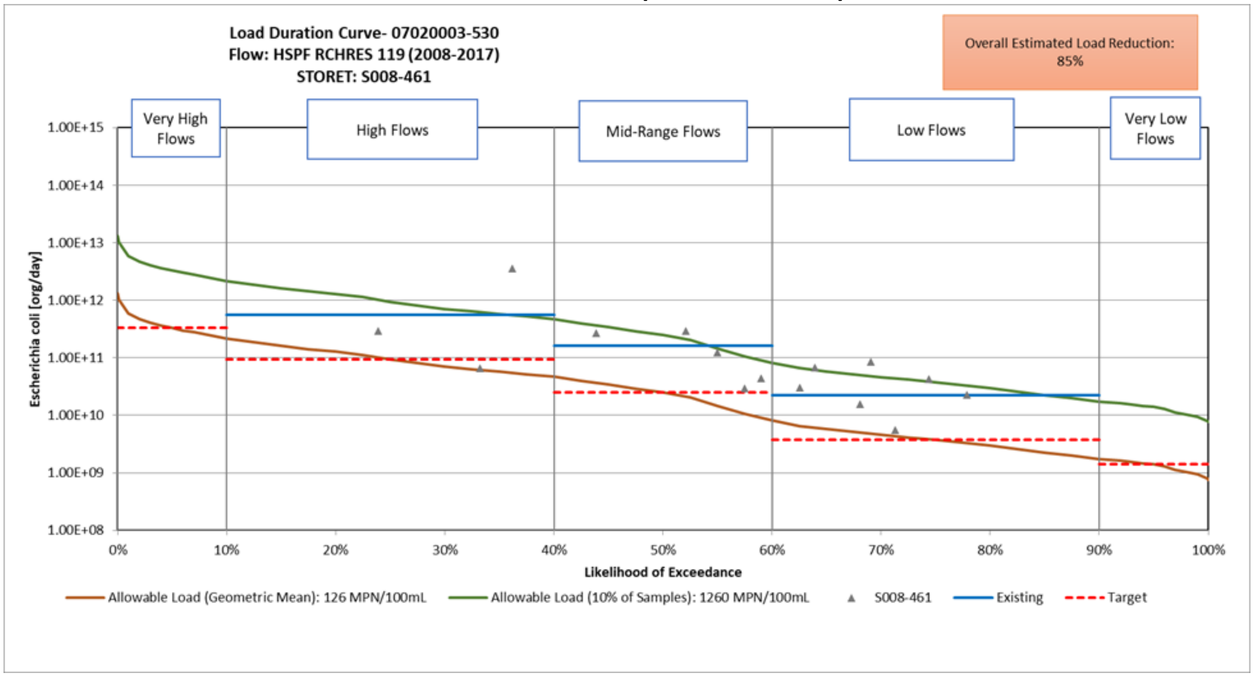

Figure 6. Unnamed creek, Unnamed cr to Lac Qui Parle R (07020003-530) *E. coli* LDC.

Table 6. *E. coli* allocations for Unnamed creek, Unnamed cr to Lac Qui Parle R (07020003-530).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billions organisms/day]				
Loading Capacity	Total	328	94	25	3.7	1.4
	Minnesota[1]	130	37	9.9	1.5	0.56
Wasteload Allocation		0	0	0	0	0
Load Allocation		117	34	8.9	1.3	0.50
Margin of Safety (MOS)		13.0	3.7	0.99	0.15	0.056
Average existing monthly geometric mean		798.6 org/100 mL				
Overall estimated percent reduction[2]		85%				

[1]Based of 39.7% of existing load coming from Minnesota.

[2] The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard.

Unnamed creek, -96.1517, 44.9533 to W Br Lac Qui Parle R (07020003-580)

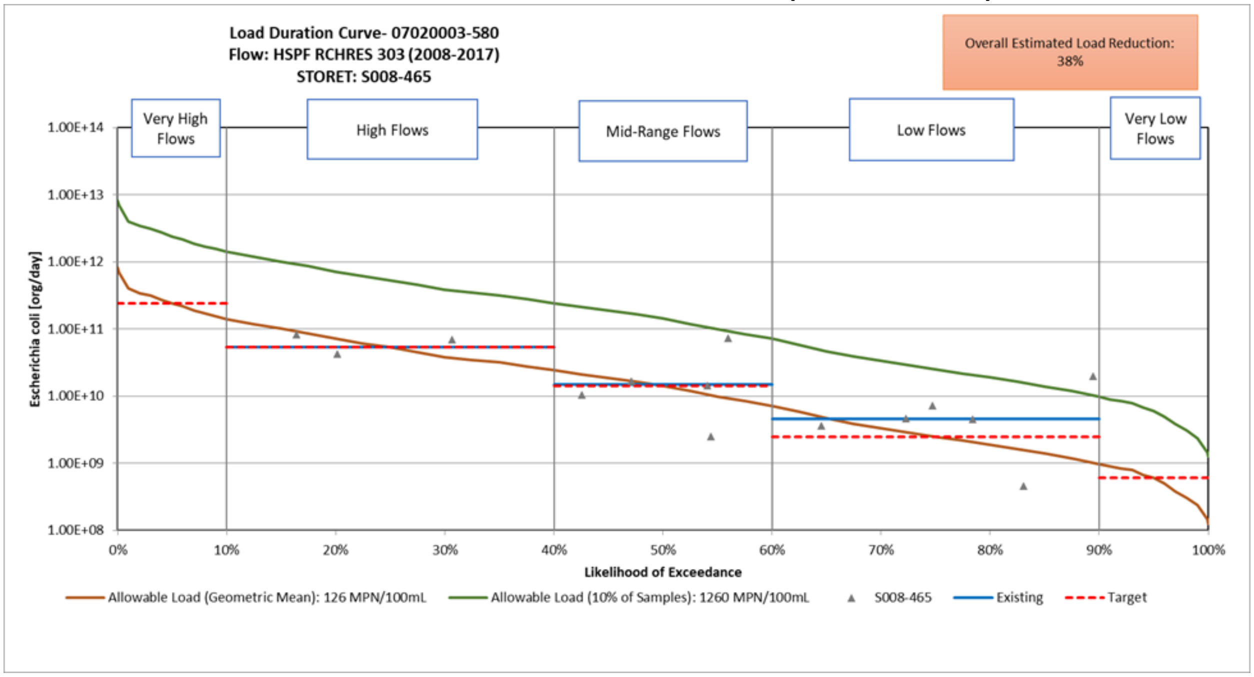

Figure 7. Unnamed creek, -96.1517, 44.9533 to W Br Lac Qui Parle R (07020003-580) *E. coli* LDC.

Table 7. *E. coli* allocations for Unnamed creek, -96.1517, 44.9533 to W Br Lac Qui Parle R (07020003-580).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billions organisms/day]				
Loading Capacity	239	53	14	2.5	1.4
Wasteload Allocation	0	0	0	0	0
Load Allocation	215	48	13	2.3	1.3
Margin of Safety (MOS)	24	5.3	1.4	0.2	0.1
Average existing monthly geometric mean	215.7 org/100 mL				
Overall estimated percent reduction[1]	38%				

[1] The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard.

Unnamed ditch (County Ditch 4), Unnamed ditch to CSAH 20 (07020003-581)

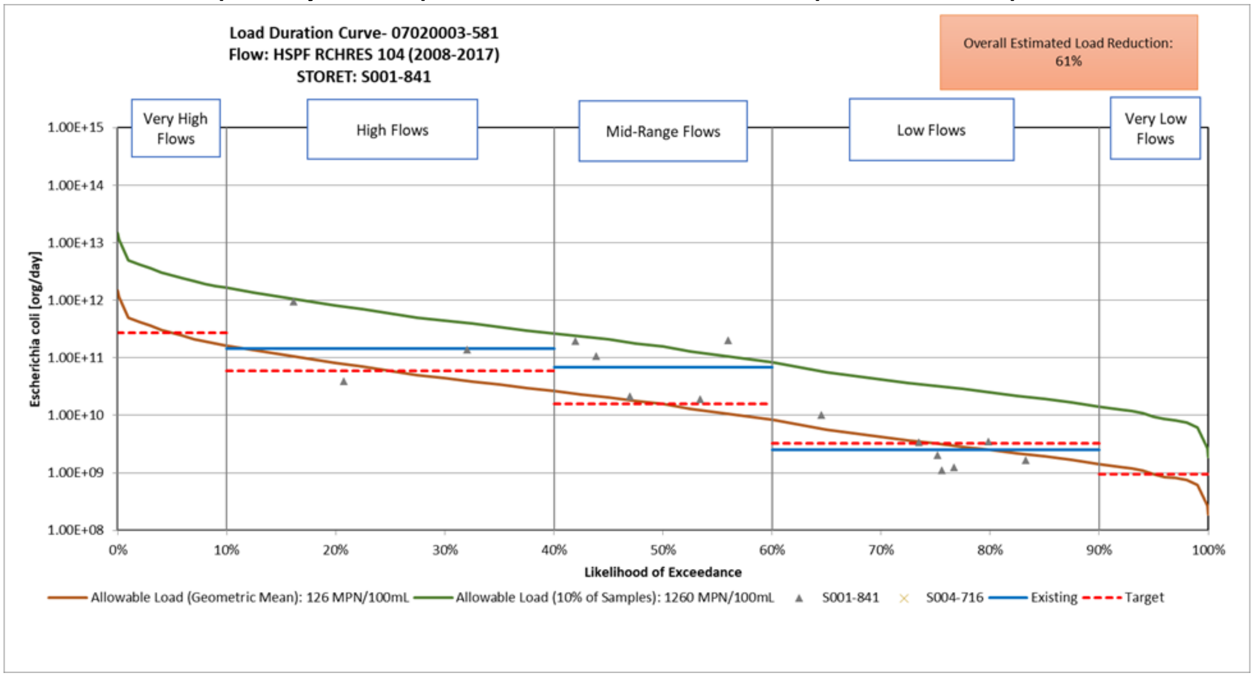

Figure 8. Unnamed ditch (County Ditch 4), Unnamed ditch to CSAH 20 (07020003-581) *E. coli* LDC.

Table 8. *E. coli* allocations for Unnamed ditch (County Ditch 4), Unnamed ditch to CSAH 20 (07020003-581).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billions organisms/day]				
Loading Capacity	274	59	16	3.2	0.94
Wasteload Allocation	0	0	0	0	0
Load Allocation	247	53	14	2.9	0.85
Margin of Safety (MOS)	27	5.9	1.6	0.32	0.09
Average existing monthly geometric mean	292.8 org/100 mL				
Overall estimated percent reduction[1]	61%				

[1] The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard.

Total Suspended Solids

Unnamed creek, Unnamed cr to Lac Qui Parle R (07020003-530)

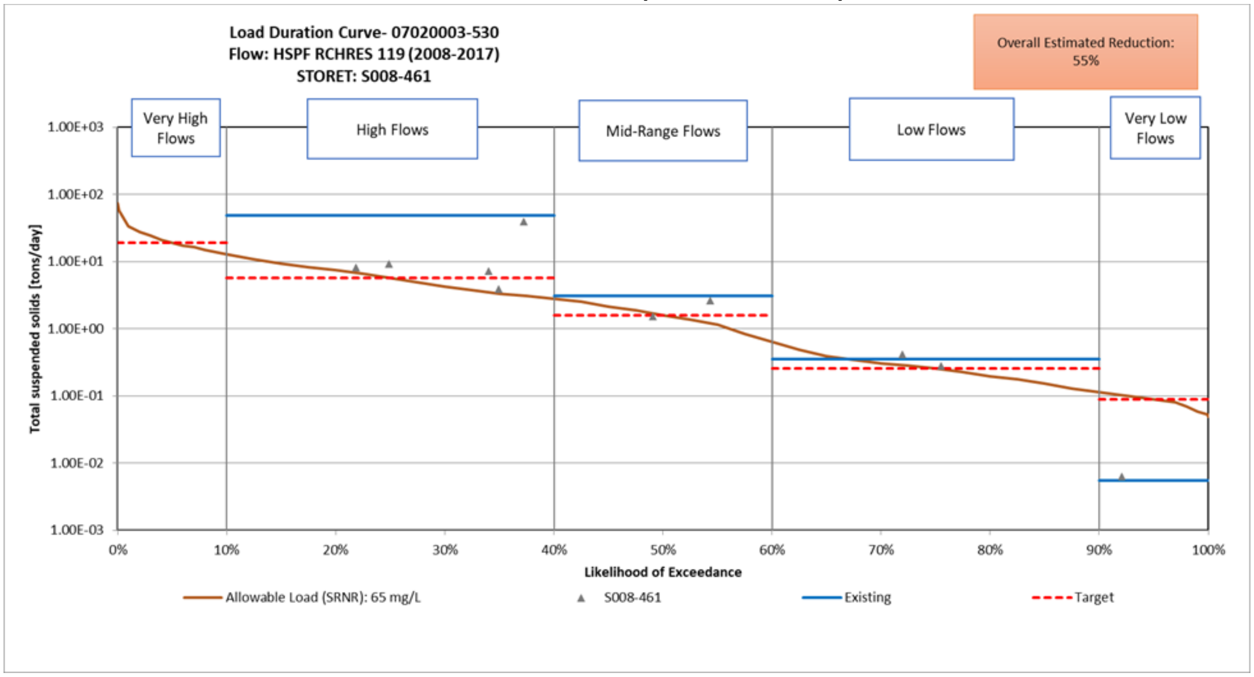

Figure 9. Unnamed creek, Unnamed cr to Lac Qui Parle R (07020003-530) TSS LDC.

Table 9. TSS allocations for Unnamed creek, Unnamed cr to Lac Qui Parle R (07020003-530).

Total Suspended Solids		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[tons/day]				
Loading Capacity	Total	19	5.7	1.6	0.3	0.09
	Minnesota[1]	12	3.7	1.0	0.17	0.058
Wasteload Allocation	*Construction/Industrial Stormwater*	0.012	0.004	0.001	0.0002	0.0001
	Total WLA	0.01	0.004	0.001	0.0002	0.0001
Load Allocation	Total LA	11	3.3	0.90	0.15	0.05
Margin of Safety (MOS)		1.2	0.37	0.10	0.017	0.006
90th Percentile Concentration		143.1 mg/L				
Overall estimated percent reduction		55%				

[1]Based on 64.4% of existing load coming from Minnesota.

Appendix 5.2 Altered Hydrology Analysis

Introduction

One of the stressors commonly referenced as a reason for AqL impairments is "altered hydrology." Altered hydrology is commonly thought to be characterized by increases in peak discharge and runoff volume for a range of precipitation events, as compared to some historic or benchmark condition. Numerous studies have suggested that this hydrologic alteration is a result of some combination of climatic variation, land use/land cover changes, or other landscape scale changes. Aquatic habitat loss, increased streambank erosion and bank failure, and increased sediment levels are some of the suggested consequences of altered hydrology. Individually and collectively these are believed to lead to the impairment of AqL, exhibited by lower ecological diversity.

This appendix describes a framework used to define and quantify altered hydrology using records from the USGS's long-term, continuous flow gaging network. In addition, this describes methods to estimate storage goals based on changes of altered hydrology metrics that can be used to develop management plans to help mitigate the impacts of alteration.

A Need to Assess Altered Hydrology

Although a general sense of the characteristics of altered hydrology exists, a substantive challenge remains. A challenge associated with addressing altered hydrology is the lack of a common definition, including agreement on a set of science-based metrics to establish the desired (i.e., benchmark) condition, and assess whether altered hydrology has indeed occurred. Figure 1 provides an example of hydrologic data which could be used to illustrate altered hydrology. Figure 1 shows a flow duration curve for a streamflow gage in the Lac qui Parle River Watershed. Two 26-year time periods are shown on the graph; i.e., 1992 through 2018 (orange line, top) and 1965 through 1991 (blue line, bottom). The graph represents the likelihood of exceeding a specific daily mean discharge. The graph indicates an increase in the daily mean discharge through most of the flow range, because for the same likelihood of exceedance the daily mean discharge is greater for the more recent time periods. This suggests "altered hydrology" meaning that flow conditions in the watershed differ between the two time periods. The example illustrates one possible visual metric, which could be used to describe altered hydrology.

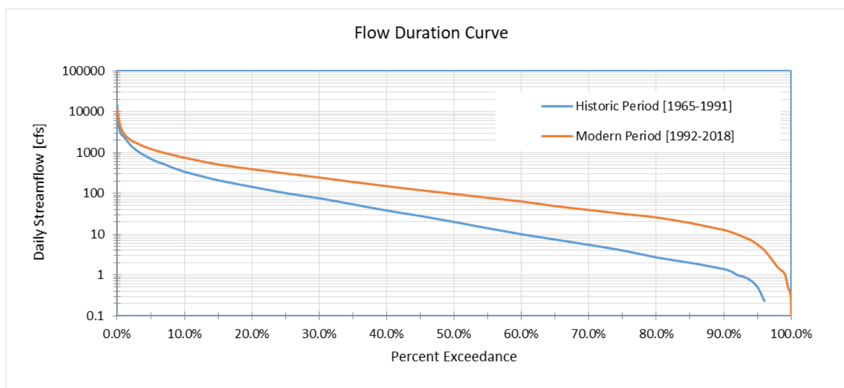

Figure 1. Flow duration curve for the Lac qui Parle River near Lac qui Parle, Minnesota. The orange line (top) shows an increase in daily mean discharge for the 1992 – 2018 period, compared to the early 1965 – 1991 period.

Agreement on a set of science-based metrics to assess the extent of hydrologic alteration and the desired (i.e., benchmark) condition is needed in order to quantitatively assess changes in the hydrology of a watershed. A definition is needed to rigorously assess whether hydrology has indeed changed through time, establish goals for altered hydrology, and assess and evaluate various means, methods and projects to mitigate the adverse effects of altered hydrology.

Considerable research and technical information relative to describing altered hydrology has been completed. The report "Technical Report: Protecting Aquatic Life from Effects of Hydrologic Alteration" (Novak et al. 2015) is one example. The report presents metrics, which can be used to describe altered hydrology. However, causal information about how the change in hydrology results in the alteration or loss of ecological function is lacking within the report.

For the hydrology of a watershed to be altered there must be some deviation from a preferred or desired hydrologic condition; i.e., a "benchmark" condition. The benchmark for altered hydrology could be the "natural hydrologic regime" or some other condition. The natural hydrologic regime (Poff et al 1997; Arthington et al 2006; Bunn and Arthington 2002; Sparks 1995) is the characteristic pattern of water quantity, timing, and variability in a natural water body. A river's hydrologic or flow regime consists of environmental flow components (Mathews and Richter 2007; The Nature Conservancy 2009), each of which can be described in terms of the magnitude, frequency, duration, timing, and rate of change in discharge. The integrity of an aquatic system presumably depends on the natural dynamic character of these flow components to thereby drive ecological processes.

Defining altered hydrology and the benchmark condition, identifying the metrics to describe altered hydrology, and translating the information into goals to mitigate the adverse consequences is technically challenging. The approach used to evaluate whether a watershed exhibits altered hydrology is presented within this document. A definition of altered hydrology is presented. Specific quantitative metrics to assess the extent of hydrologic change and the desired (i.e., benchmark) condition are also presented. No effort is made to describe the causal relationship between hydrology and the ecological, geomorphological or water quality effects. Rather, the assumption is made that the desired condition is achieved by obtaining the benchmark condition. These results are intended to be a beginning point in addressing the topic of altered hydrology in a more rigorous manner, which no doubt will evolve through time.

A Methodology to Define Altered Hydrology

A Brief History of Changing Hydrology

Streamflows in Minnesota (Novotny & Stefan 2007) and across the contiguous United States (Lins and Slack 1999 McCabe and Wolock 2002) have been changing during the past century, with flows in the period starting from the 1970s to the beginning of the 21st Century tending to be higher than during the early to mid-1900s (Ryberg et al. 2014). Numerous studies have been conducted to quantify magnitude of impact and pinpoint relative importance of potential causes of these changes, but scientific consensus has currently not been achieved. The science is not at a point where specific causes can be attributed to altered hydrology with any significant certainty and public discussion about specific causes usually leads to barriers to implementation.

In general, the leading candidate causes of altered hydrology can be categorized into two primary groups: climatic changes and landscape changes. Examples of climatic changes include changes in annual precipitation volumes, surface air temperature, timing of the spring snowmelt, annual distribution of precipitation, and rainfall characteristics (timing, duration, and intensity). Examples of landscape changes include changes in land use/land cover, increased imperviousness (urbanization), tile drainage and drainage ditching, wetland removal/restoration, groundwater pumpage, flow retention and regulation, and increased storage (both in-channel and upland storage). Although it is important to water resource management to understand the mechanics behind the changes in hydrology, the focus of this analysis is developing a definition for altered hydrology, a method for assessing whether it has occurred within a watershed and establishing a goal for addressing altered hydrology. No assumption of causation is made or needed to use this framework.

Altered Hydrology Defined

Altered hydrology is defined as a *discernable* change in specific metrics derived from stream discharge, occurring through an entire annual hydrologic cycle, which exceeds the measurement error, compared to a benchmark condition. For this framework, *discernable* has been used as a proxy for statistical comparisons. The metrics are typically some type of hydrologic statistic derived from the annual discharge record across a long period of time, usually a minimum of 20-years (Gan et al. 1991). The amount of baseflow, the hydrograph shape, peak discharge, and runoff volume for a range of precipitation event magnitudes, intensities, and durations are specific components of or derived from the annual hydrograph.

Establishing Benchmark Condition

A reference or “benchmark” condition is needed to complete an assessment of whether hydrology is altered. A minimum of a 20-year time-periods reasonably ensures stable estimates of streamflow predictably (Gan et al. 1991; Olden & Poff 2003), sufficient duration to capture climate variability and the interdecadal oscillation typically found in climate (McCabe et al. 2004, Novotny and Stefan 2007), and is the standard timespan used for establishing “normal” climate statistics in the United States. Where the extent data allows it, the analysis is performed for two 35-year time periods (i.e., a benchmark period called “historic” and an “altered” state or called “modern”). The benchmark period used to establish benchmark conditions represents the period before shifts in hydrology are commonly thought to have begun within Minnesota as a result of land use/land cover changes, or increases in the depth, intensity, and duration of precipitation.

To illustrate an example of a change in streamflow and the validity in the breakpoint period, cumulative streamflow (using annual depth values) is plotted across time (Figure 2) for the USGS gage at Crow River at Rockford, Minnesota (USGS ID: 05280000). Cumulative streamflow was used instead of straight annual streamflow because (1) it linearizes streamflow relationship where the slope of a trendline would be the average annual streamflow, (2) no assumptions about multi-year dependencies (e.g. changes in storage) or autocorrelation is necessary, and (3) changes in slope can be visualized, showing an altered state of hydrology.

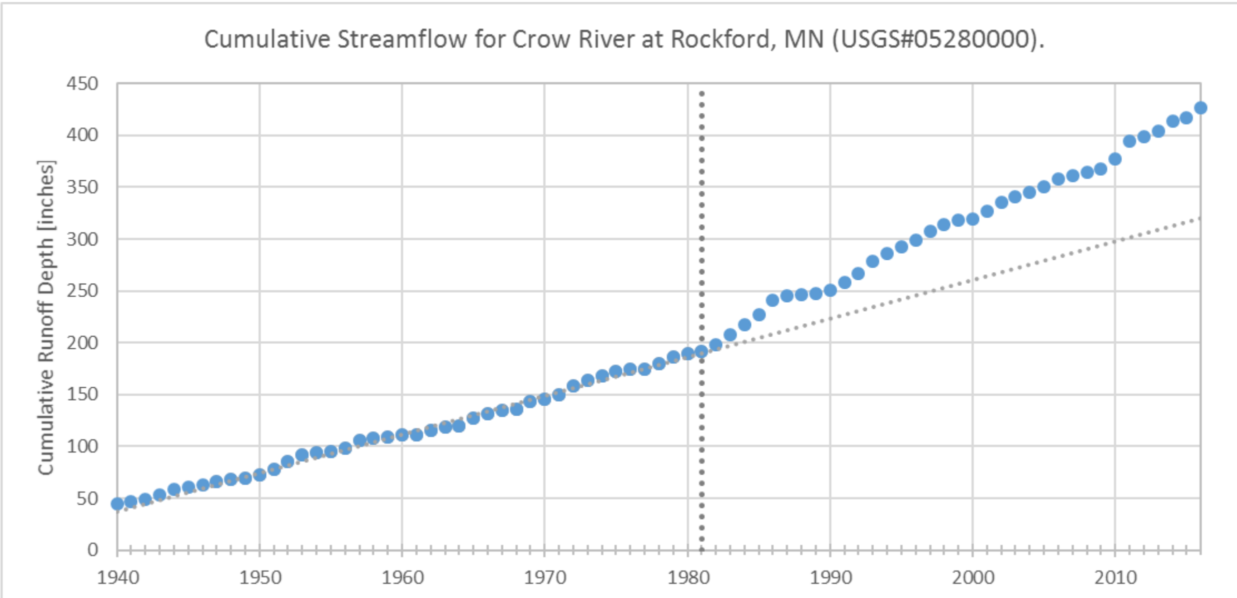

Figure 2. Cumulative streamflow for the Crow River at Rockford, MN (USGS Station 05280000).

Results from analysis shown in the example (**Figure 2**) determine the break point and define the benchmark and modern conditions.

Metrics Used to Assess Altered Hydrology

Many potential metrics can be used to describe a measurable change in the annual hydrograph. For example, the indicators of hydrologic alteration software developed by the Nature Conservancy (https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofHydrologicAlteration/Pages/indicators-hydrologic-alt.aspx) uses 67 different statistics derived from mean daily discharge to describe altered hydrology. Ideally, each indicator or metric could be causally linked to an ecological or geomorphological consequence, although this is technically challenging. Use of such a large number of indictors can be problematic as many of the metrics can be correlated and are therefore interdependent or lack ecological or geomorphological meaning.

The structure and therefore function of ecological systems are often “driven” by “nonnormal” events; e.g., low flows associated with drought, higher flows which inundate the floodplain. Metrics used to complete this analysis were preferentially selected to reflect the variability in specific characteristics of the annual hydrograph, and include peak discharges, runoff volumes and hydrograph shape. Each metric was specifically selected to represent a flow condition believed to be of ecological or geomorphological importance, in the absence of causal information. **Table 1** shows the specific metrics used to complete the analysis. The use of these metrics is intended to identify: 1) whether the hydrology within a watershed is indeed altered: and 2) which resources may be at risk because of the alteration.

Table 1. Metrics used to define and assess whether hydrology is “altered” for a specific watershed.

Relevance	Hydrograph Feature	Frequency of Occurrence	Duration	Metric	Ecological or Geomorphic Endpoint
Condition of Aquatic Habitat	Baseflow	10-year	30 day	The minimum change between time periods is the accuracy of measuring streamflow discharge and estimating daily mean discharge. A discharge measurement accurate within 10% of the true value is considered excellent by the United States Geological Survey (USGS). Some additional error is induced through the conversion of these data to discharge. Therefore, a minimum change of 15% is needed between “historic” and ”modern” period for this metric to classified as “altered.”	Discharge needed to maintain winter flow for fish and aquatic life.
		Annual	30-day median (November)		
Aquatic Organism Life Cycle	Shape	Mean	Monthly average of daily means	Use the ”historic” period of record to define “normal variability.” Develop a histograms of daily mean discharges for each month within the period of record for the “historic” and “modern” time periods. Compare the histograms of the monthly average of daily means using an appropriate statistical test. Assume the histograms are from the same statistical population and text for significance at an appropriate significance level.	Shape of the annual hydrograph and timing of discharges associated with ecological cues.
	Timing	Julian day of minimum	1-day		
		Julian day of maximum			
Riparian Floodplain (Lateral) Connectivity	Peak discharge	10-year	24-hour and 10-day	The minimum change between time periods is the accuracy of measuring streamflow discharge and estimating daily mean discharge. A discharge measurement accurate within 10% of the true value is considered excellent by the United States Geological Survey (USGS). Some additional error is induced through the conversion of these data to discharge. Therefore, a minimum change of 15% is needed between “historic” period and “modern” period for this metric to classified as “altered.”	Represents the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water – groundwater interactions
		50-year			
		100-year			
	Volume	10-year	Total runoff volume for those days with a daily mean discharge exceeding the 24-hour discharge		
		50-year			
		100-year			
Geomorphic Stability and Capacity to Transport Sediment	Peak Discharge	1.5 year	24 - hour	The minimum change between time periods is the accuracy of measuring streamflow discharge and estimating daily mean discharge. A discharge measurement accurate within 10% of the true value is considered excellent by the United States Geological Survey (USGS). Some additional error is induced through the conversion of these data to discharge. Therefore, a minimum change of 15% is needed between “historic” period and “modern” period for this metric to classified as “altered.”	Channel forming discharge. An increase is interpreted as an increased risk of stream channel susceptibility to erosion.
	Volume	1.5 year	Cumulative daily volume exceeding channel forming discharge		
		Average daily	30-year flow duration curve		

Determination of Altered Hydrology

A simple weight of evidence approach is used to decide whether the hydrology of a watershed is "altered" between two time periods. A "+" is assigned to each metric if it has a discernable increase from the benchmark as defined by the metric, between the historic and modern time periods. A "-" is assigned to each metric if it has a discernable decrease from the benchmark as defined by the metric, between the historic and modern time periods. An "o" is assigned to each metric if it lacks a discernable increase or decrease from the benchmark as defined by the metric, between the historic and modern time periods. If the number of "+" values exceeds the number of "-" values, an increase in the watershed response to precipitation is implied and the hydrology is considered altered between the two time periods. If the number of "-" values exceeds the number of "+" values, the a decrease in the watershed response to precipitation is implied and the hydrology is considered altered between the two time periods. The hydrologic response of the watershed is considered "altered" if the percentage of + and – signs exceeds 50% in any group of metrics.

Establishing Altered Hydrology Goals

There are two types of goals; i.e., a qualitative and a quantitative goal. The qualitative goal is to return the hydrology to the benchmark condition. The qualitative goal is evaluated using a weight of evidence approach. The goal is simply to achieve the conditions for the historic period as defined by the metrics with **Table 1**. It is presumed the historic period is "better" from an ecological and geomorphological perspective.

The second type of goal is a quantitative storage goal. Several of the metrics within **Table 1** can be used to establish storage goals, which may be accomplished by a variety of types of projects. These project types include not only traditional storage but increasing the organic matter content of soils. These goals are the change in volume between the historic and modern time periods. The volume needs to be described by the effective volume, which is the amount of storage required on the landscape.

Methods for Evaluating Altered Hydrology Mitigation Strategies

Several methods can be used to develop strategies to mitigate the effects of altered hydrology. These methods include the use of continuous simulation hydrology models (like the HSPF) and the event-based hydrology approaches (like those within the Prioritize, Target and Measure Application).

Altered Hydrology in the Lac qui Parle River

The following are summaries of results from the altered hydrology analysis conducted on the long-term gaging station in the Lac qui Parle River Watershed.

Lac qui Parle River near Lac qui Parle, Minnesota(USGS# 05300000)

The USGS long-term, continuous flow gaging station in the Lac qui Parle River near Lac qui Parle, Minnesota (USGS# 05300000) records flow from approximately 960 square miles. The data record starts in 1910 and runs to 1915, then restarts in 1931 and runs through 2019 (present day). The flow record was downloaded on 09/04/2019. The site includes both daily average streamflow records and peak flow measurements. **Figure 3** shows the cumulative streamflow (in inches per year) for the gaging site. Cumulative streamflow is used to determine a breakpoint between the benchmark condition and the altered condition (see **Section 2.3**).

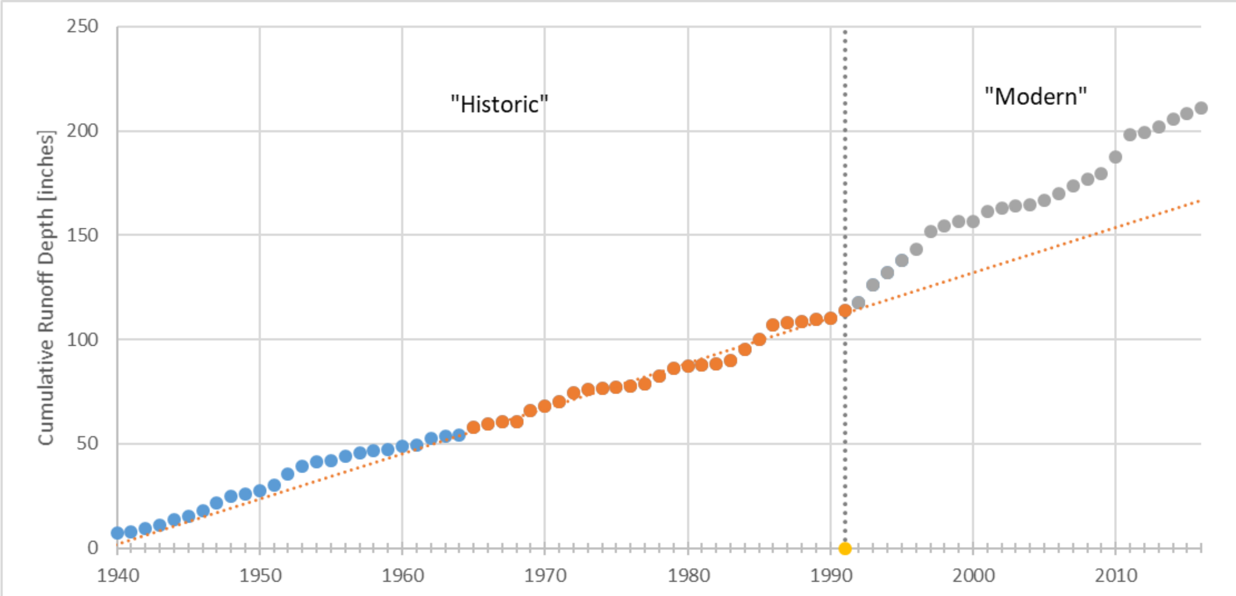

Figure 3. Cumulative streamflow for Lac qui Parle River near Lac qui Parle, MN. (USGS# 05300000).

According to the cumulative streamflow analysis, a breakpoint exists around 1991-1992. Therefore, the benchmark ("historic") conditions will include data from 1965-1991 and the altered ("modern") will include data form 1992 through 2018.

A summary of the results from the altered hydrology analysis is provided in **Table 2.** A more detailed description of the results is provided below. A summary of the storage goals based on the altered hydrology analysis are provided in **Section 4**.

Table 2: Altered Hydrology Summary for Lac qui Parle River near Lac qui Parle, MN. (USGS# 05300000).

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	>1000%	+	Yes, Increasing
	10-year, Annual Minimum 7-day Mean Daily Discharge	>1000%	+	
	Median November (Winter Base) Flow	412%	+	
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	31% -to->341%	+	Yes, Increasing
	Distribution of Monthly Runoff Volumes	-31% -to- 129%	+	
	Timing of Annual Peak Discharge	10%	o	
	Timing of Annual Minimum Discharge	-15%	-	
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	-0.25%	o	No, possible decreasing
	50-year Peak Discharge Rate	-14%	o	
	100-year Peak Discharge Rate	-19%	-	

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
	Average Cumulative Volume above the Historic 10-year Peak Discharge	100%	+	
	Average Cumulative Volume above the Historic 50-year Peak Discharge	NA	NA	
	Average Cumulative Volume above the Historic 100-year Peak Discharge	NA	NA	
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	34%	+	Yes, Increasing
	2-year Peak Discharge Rate	25%	+	
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	43%	+	
	Average Cumulative Volume above the Historic 2-year Peak Discharge	44%	+	
	Duration above the Historic 1.5-year Peak Discharge	65%	+	
	Duration above the Historic 2-year Peak Discharge	28%	+	
	Flow Duration Curve	20% -to- 815%	+	

Storage Goals

Goals for addressing the change in hydrology were estimated using four methods. Each method is based on different assumptions and altered the metrics for a specific "altered hydrology" group. The first method is focused on two groups (**Figure 2**), the aquatic habitat and the geomorphic stability and capacity to transport sediment, and uses the change in the cumulative volume for mean daily discharges, exceeding the 1.5-year return period event. The cumulative total volume when the daily average discharge exceeds the 1.5-year peak discharge includes all flows above the 1.5-year peak (i.e. can include storms with much larger return periods). This method is based on the changes in the observed data and since it includes all flows above the 1.5-year flow relies on the two periods to have a similar distribution of flows. The second method is based on the changes in hydrology across the entire annual hydrograph and integrates the differences in return period discharges between the modern and historic period and finding a probability-weighted representative change in flow rate. A volume is found by assuming a flow period equal to the change in flow period for the 1.5-year flow (i.e. the change in the number of days above the 1.5-year flow). This method assumes a constant flow over a representative duration to estimate the storage goal. Since a hydrograph typically changes over time, this method may over-estimate the storage goal. The third method is also based on addressing the effects through the entire flow range and is a revision to Method 2. Method 3 considers the observed change in the timing of the peak discharge for each return period event. This method uses the probability-weighted representative change in flow rate and multiplies the flow rates by the change in the number of days exceeding the return period flow for each return period. Method 4 estimates a storage goal based on changes in the flow duration curve (FDC) (see **Figure A.6**). Method 4 integrates the changes in the FDC between two periods and applies the probability of each flow to occur.

This analysis presents a preliminary framework for defining altered hydrology, applying a method to determine whether altered hydrology has occurred, and establishing a goal for relating to proposed projects. The storage goals are provided in **Table 3** for each of the four methods. For planning purposes, we recommend a preliminary goal equal to a representative goal, taken as the average of the 4 methods, across the watershed, realizing that the altered hydrology goals should ideally be established at the 12-digit HUC scale. The average, representative storage goal is **0.39 inches** across the watershed, or **20,094 acre-feet**. The actual amount of mitigation needed may exceed the estimated range, as the methods used to achieve the goal are not expected to be 100% effective in removing volume from the peak of the hydrograph. The means to achieve the estimated mitigation goal may include the use of structural practices and management practices and should be specifically evaluated through completion of a hydrologic study or the use of appropriate tools and models.

Table 3: Storage goals for rivers in the Lac qui Parle River.

Stream	USGS ID	Storage Targets			
		Method 1	Method 2	Method 3	Method 4
Lac qui Parle River, near Lac qui Parle, MN	05300000	0.34 in.	0.22 in.	0.14 in.	0.45 in.

Details on calculations of the storage goals can be found below.

Metrics of Altered Hydrology for the Lac qui Parle River near Lac qui Parle, Minnesota (USGS #05300000).

The following are the summary statistics used to determine the altered hydrology metrics in detail and develop the storage goals. A summary of these statistic is shown in **Table 2** in **Section 3.1.1**.

Condition of Aquatic Habitat

The condition of aquatic habitat includes a group of metrics that primarily reflect the flow characteristics of the annual hydrograph, needed to maintain adequate habitat for fish and AqL. The 7-day low flow, the 30-day low flow, and the median November mean daily discharge are metrics used to represent changes in the availability of flow for aquatic habitat.

Annual minimum 30-day mean daily discharge

The annual minimum 30-day mean daily discharge is the minimum of the 30-day moving mean daily discharge within a year (an annual minimum series). **Figure 4** shows the annual minimum 30-day mean daily discharge for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table 4** summarizes the data shown in **Figure 4**.

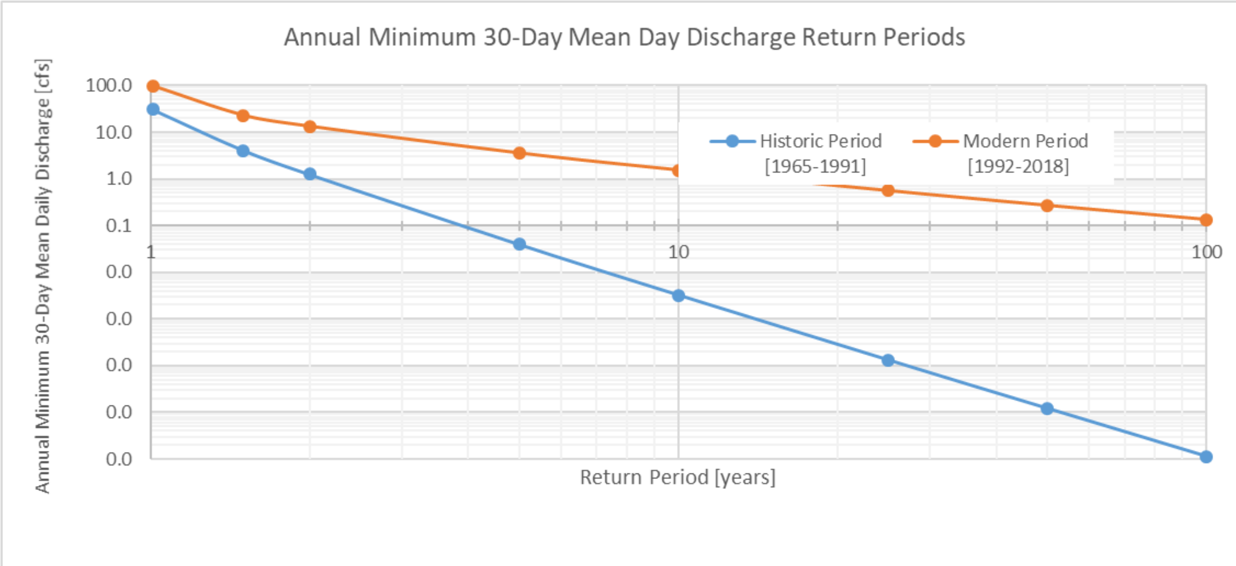

Figure 4. Historical (1965-1991) versus modern (1992-2018) annual minimum 30-day mean daily discharge versus return period for Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Table 4: Summary of annual minimum 30-day mean daily discharge by return periods for the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.01	30.8	97.4	216.6%	+
1.5	4.1	22.8	458.6%	+
2	1.2	13.3	965.6%	+
5	0.0	3.6	9006.6%	+
10	0.0	1.5	47343.2%	+
25	0.0	0.6	426557.5%	+
50	0.0	0.3	2262639.3%	+
100	0.0	0.1	12049977.7%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Annual Minimum 7-Day Mean Daily Discharge

Like the annual minimum 30-day mean daily discharge, the annual minimum 7-day mean daily discharge is the minimum of the 7-day moving average flow in the year. **Figure 5** shows the annual minimum 7-day mean daily discharges for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table 5** summarizes the data shown in **Figure 5**.

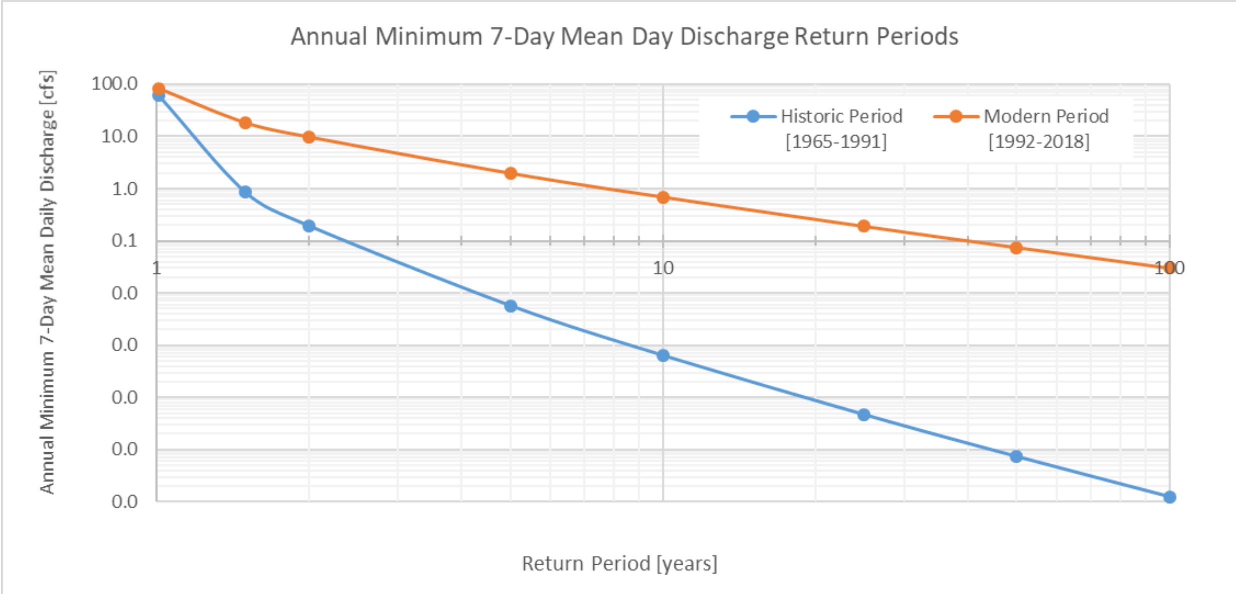

Figure 5. Historical (1965-1991) versus modern (1992-2018) annual minimum 7-day mean daily discharge return periods for Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Table 5: Summary of annual minimum 7-day mean daily discharge return periods for the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.0101	62.1	83.2	34.1%	+
1.5	0.9	18.3	2046.1%	+
2	0.2	9.8	4948.9%	+
5	0.0	2.0	34516.8%	+
10	0.0	0.7	108551.7%	+
25	0.0	0.2	409488.5%	+
50	0.0	0.1	1024975.1%	+
100	0.0	0.0	2437343.8%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

November Median Daily Discharge

The median daily mean discharge for November is another indicator of baseflow. This metric is intended to represent baseflow condition during the winter months. **Table 6** provides the median November flow for each period.

Table 6: Historical (1965-1991) and modern (1992-2018) median November flow for the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
Period median November flow [cfs]	16.0	82.0	412.5%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Aquatic Organism Life Cycle

The shape of the annual hydrograph and timing of discharges are associated with ecological cues. Metrics related to the aquatic organism life cycle include the shape of the annual hydrographs, timing of the annual minimum flow, and timing of the annual peak flow.

Annual Distribution of Discharges

The annual distribution of runoff is shown two ways: as average monthly runoff volume in acre-feet per month (**Figure 6**) and as a percentage of average annual runoff volume (**Figure 7**). **Table 7** summarized the data used to generate **Figures 6** and **7**.

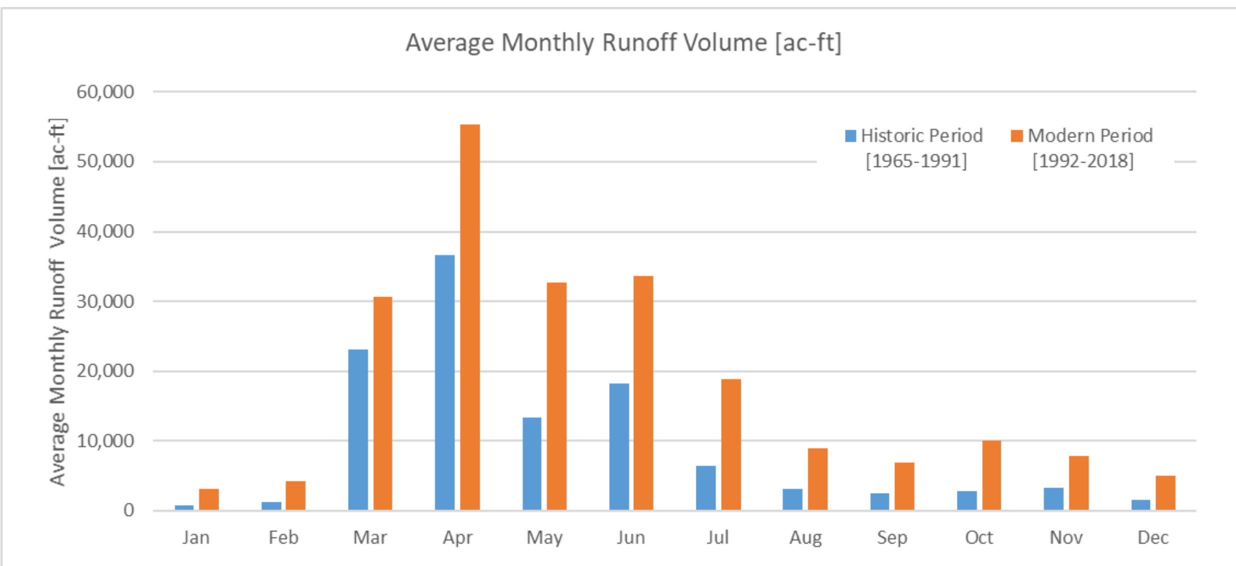

Figure 6. Average monthly runoff volume [ac-ft] in the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

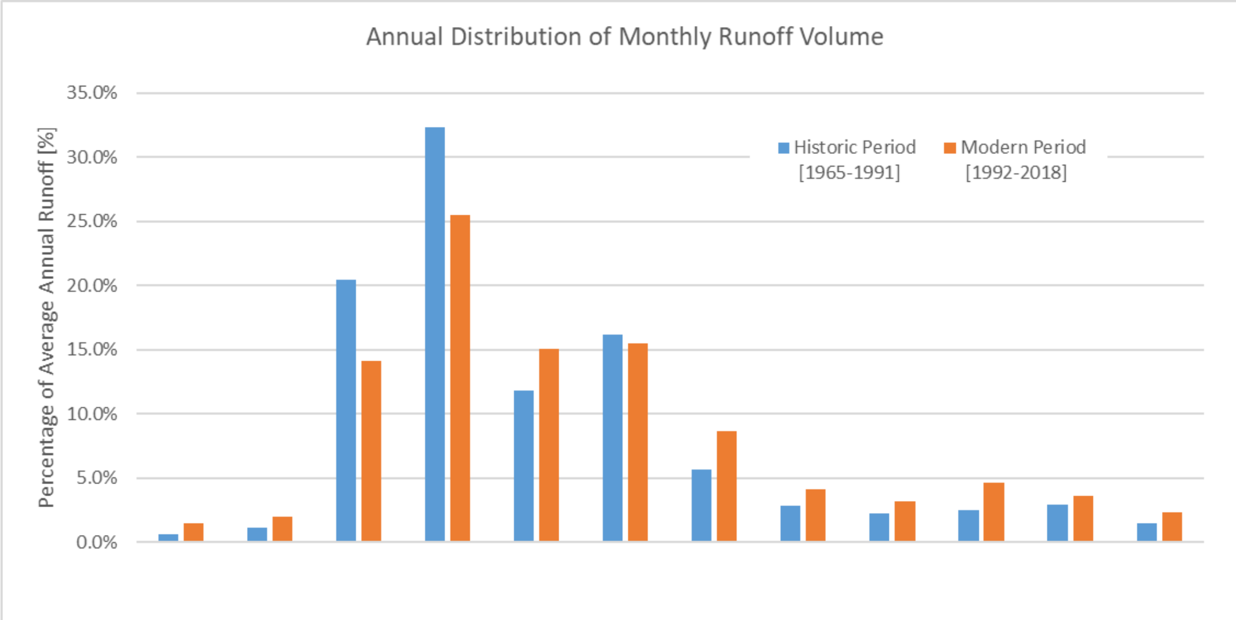

Figure 7. Annual distribution of average monthly runoff volume as a percentage of annual total volume in the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Table 7. Average monthly runoff volume and annual distribution of monthly runoff volumes in Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Month	Average Monthly Volumes [ac-ft]				Distribution of Annual Volume			
	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Jan	703	3,099	340.7%	+	0.6%	1.4%	129.3%	+
Feb	1,220	4,240	247.7%	+	1.1%	2.0%	80.9%	+
Mar	23,061	30,692	33.1%	+	20.4%	14.1%	-30.7%	-
Apr	36,564	55,285	51.2%	+	32.4%	25.5%	-21.3%	-
May	13,364	32,666	144.4%	+	11.8%	15.1%	27.2%	+
Jun	18,259	33,604	84.0%	+	16.2%	15.5%	-4.2%	o
Jul	6,370	18,815	195.4%	+	5.6%	8.7%	53.7%	+
Aug	3,181	8,928	180.6%	+	2.8%	4.1%	46.0%	+
Sep	2,513	6,837	172.1%	+	2.2%	3.2%	41.6%	+
Oct	2,795	9,991	257.4%	+	2.5%	4.6%	86.0%	+
Nov	3,288	7,869	139.3%	+	2.9%	3.6%	24.5%	+
Dec	1,608	5,004	211.2%	+	1.4%	2.3%	61.9%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

Timing of Annual Maximum and Minimum Flows

The timing of the annual maximum daily discharge and annual minimum daily discharge are important metrics of the annual distribution of flows. The timing of the annual maximum typically occurs during the spring flood and the timing of the annual minimum usually occurs during the winter months. **Table 8** provides statistics on the Julian day of the annual maximum flow and **Table 9** provides the Julian day for the annual minimum flow. The statistics include the average, the median, and the standard deviation of the Julian days when the maximum or minimum flow occur.

Table 8. Julian Day of annual maximum in the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	26-Apr	8-May	10.33%	+
Median	9-Apr	10-May	31.31%	+
Standard Deviation	43 days	44 days	2.62%	o

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

Table 9. Julian Day of annual minimum flow in the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	117	129	10.33%	+
Median	99	130	31.31%	+
Standard Deviation	43	44	2.62%	o

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

Riparian Floodplain (Lateral) Connectivity (Peak Flows)

The riparian floodplain connectivity metrics represent the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water – groundwater interactions. The riparian floodplain connectivity metrics include the discharge rates for the 10-year, the 25-year, the 50-year, and the 100-year peak discharges. The annual peak discharge rates for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and 200-year) are shown in **Figure 8**.

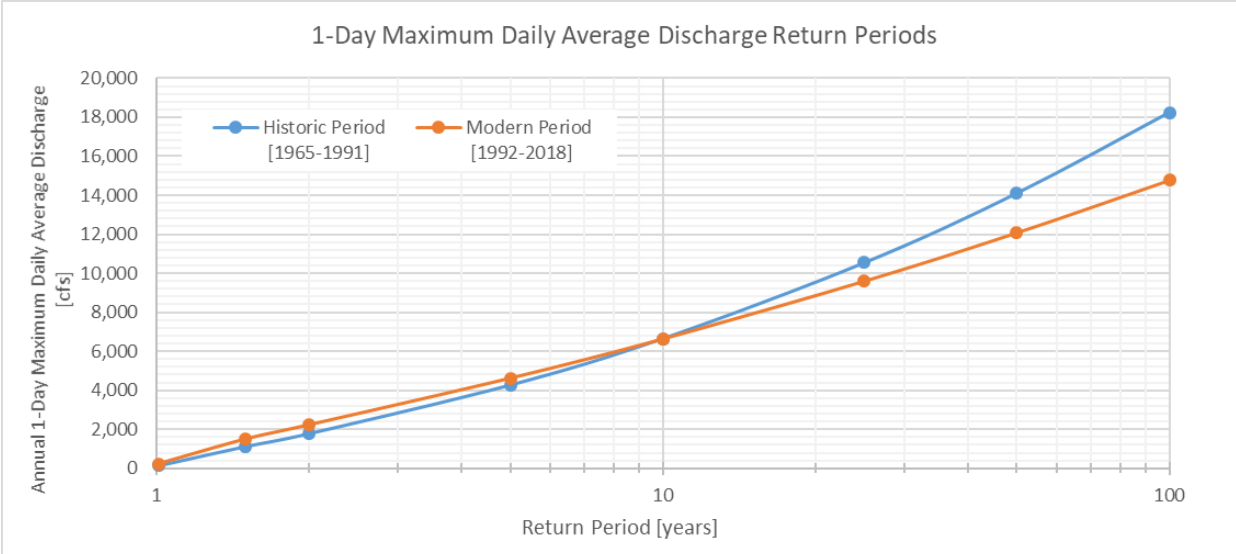

Figure 8. Historical (1965-1991) versus modern (1992-2018) peak discharge return periods for Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Geomorphic Stability and Capacity to Transport Sediment

The geomorphic stability and capacity to transport sediment metrics are related to the channel forming discharge. An increase in these metrics would be interpreted as an increase in the risk of the stream channel susceptibility to erosion. These metrics include changes to the FDCs, the 1.5-year peak flow, the 2-year peak flow. The 1.5-year to 2-year peak flows are generally considered the range of channel forming flow. In addition, the number of years within a period exceeding the historic peak flows, the average number of days above the historic peak flow rates, and the average volume of flow above the historic peak flows are provided (**Table 10**). **Figure 9** shows the FDCs for the historic and modern periods and **Table 10** provides a summary of flows for select percent exceedances. Both show that discharges across the flow spectrum have increased substantially, with the exception of the very high flows.

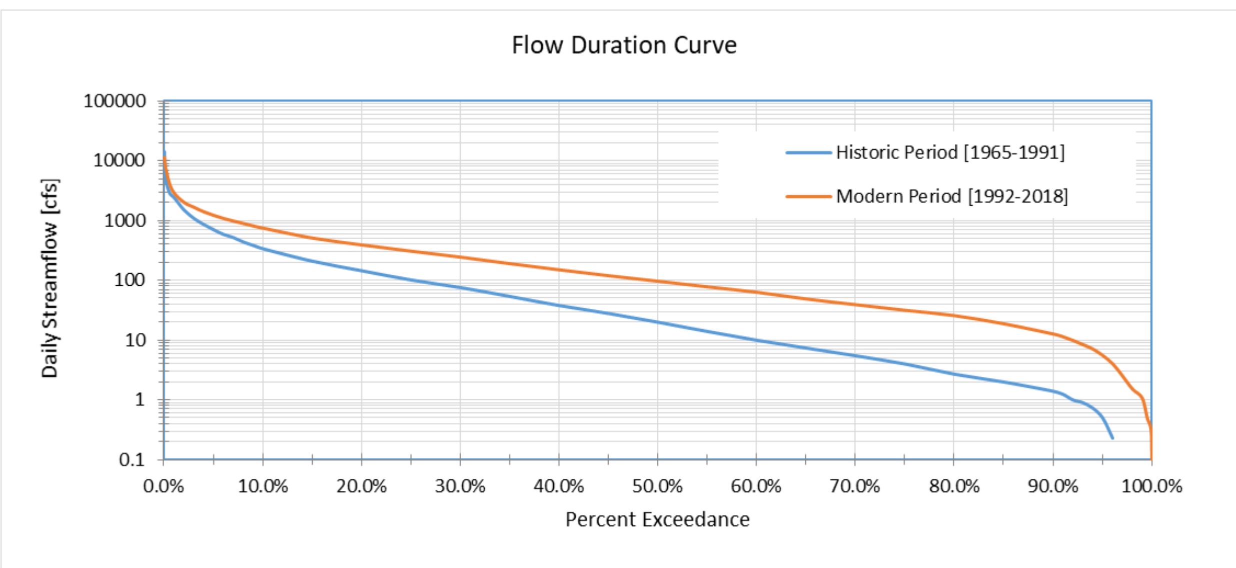

Figure 9. Historical (1965-1991) versus modern (1992-2018) flow duration for Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Table 10. Select summary of the flow duration curves for the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Percent Exceedance	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
0.10%	5,628	8,317	47.8%	+
1.0%	2,420	2,910	20.2%	+
10.0%	339	757	123.3%	+
25.0%	102	312	205.9%	+
50.0%	20	98	390.0%	+
75.0%	6	40	621.8%	+
90.0%	1	13	815.0%	+
99.0%	0.0	1.1		o
99.9%	0.00	0.3		o

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Table 11 provides the 1.5-year and 2-year annual peak flows and flow statistics, including peak discharge, number of years with flow rates above the historic return period flow, average number of days per year above the historic return period flow, and average volume above the historic return period flow.

Table 11. Geomorphic stability and capacity to transport sediment metrics for the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
1.5-Year Peak Discharge, Q(1.5) [cfs]	1,114	1,492	34.0%	+
Number of years with Discharge (Q) > Q_H (1.5)	18	20	11.1%	+
Average number of days per year Q > Q_H (1.5)	16	26	65.1%	+
Average annual cumulative volume > Q_H (1.5) [ac-ft]	40,006	57,235	43.1%	+
2-Year Peak Discharge, Q(2) [cfs]	1,774	2,219	25.1%	+
Number of years with Discharge (Q) > Q_H (2)	13	14	7.7%	o
Average number of days per year Q > Q_H (2)	13	16	27.9%	+
Average annual cumulative volume > Q_H (2) [ac-ft]	33,834	48,781	44.2%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Setting Goals

A summary of the storage goals is provided in **Table 7.** The following are the methods used to develop those goals. Goals for addressing the change in hydrology were estimated using four methods. Each method is based on different assumptions and altered the metrics for a specific "altered hydrology" group (see Table 11). The first method is focused on the aquatic habitat and geomorphic and ability to transport sediment metric group and uses the change in the cumulative volume for mean daily discharges, exceeding the 1.5-year return period event. The cumulative total volume when the daily average discharge exceeds the 1.5-year peak discharge includes all flows above the 1.5-year peak, i.e. can include storms with much larger return periods. The change in average annual cumulative volume above the 1.5-year peak flow (see **Table 11**). This method is based on the changes in the observed data and since it includes all flows above the 1.5-year flow relies on the two periods to have a similar distribution of flows. The storage goal based on observed flows is **17,230 AF or 0.0.34 inches** across the watershed.

The second method is based on the changes in hydrology across the entire annual hydrograph and integrates the differences in return period discharges between the modern and historic period (see **Table 12**) and finding a probability-weighted representative change in flow rate. A volume is then found by assuming a flow period equal to the change in flow period for the 1.5-year flow (i.e. the change in the number of days above the 1.5-year flow; see **Table 11**).

Table 12. Estimated goal for the drainage area of the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000) using method 2.

Return Period	Historic Period Discharges (cfs)	Modern Period Discharges (cfs)	Difference (cfs)	Probability of Occurrence	Difference*Probability (cfs)
1.5	1,114	1,492	379	0.67	252.4
2	1,774	2,219	446	0.50	222.8
5	4,270	4,621	351	0.20	70.2
10	6,650	6,634	-16	0.10	0.0
25	10,541	9,601	-940	0.04	0.0
50	14,103	12,086	-2017	0.02	0.0
100	18,244	14,781	-3463	0.01	0.0
				Sum (cfs):	545
				Sum (ac-ft/day):	1,082
		Number of days:	10	Total Volume Goal:	11,115 AF (0.22 in.)

The third method is also based on addressing the effects through the entire flow range and is a revision to Method 2. Method 3 considers incorporates the observed change in the timing of the peak discharge for each return period event. This method uses the probability-weighted representative change in flow rate and multiples the flow rates by the change in the number of days exceeding the return period flow for each return period (see **Table 13**).

Table 13. Estimated goal for the drainage area of the Lac qui Parle River near Lac qui Parle River, MN. (USGS# 05300000) using method 3.

Return Period	Change in Flow (Q_m-Q_h) [cfs]	Probability of Occurrence	Probability Weighted Flow [AF/day]	Change in number of days above flow (days)	Storage Volume
1.5	379	0.67	500.8	10	5,145
2	446	0.50	442.0	4	1,583
5	351	0.20	139.3	4	492
10	-16	0.10	0.0	5	0

Return Period	Change in Flow (Q_m-Q_h) [cfs]	Probability of Occurrence	Probability Weighted Flow [AF/day]	Change in number of days above flow (days)	Storage Volume
25	-940	0.04	0.0	1	0
50	-2,017	0.02	0.0	0	0
100	-3,463	0.01	0.0	0	0
				Total Volume Goal:	7,220 AF (0.14 in.)

The fourth method integrates the changes in the FDC (**Figure 9**) and the probability of occurrence of each flow (**Table 14**). The trapezoid rule was applied to integrate the change in FDCs. The fourth method estimated a storage goal of **22,958 AF, or 0.45 inches,** across the watershed.

Table 14. Calculations for integration of the probability weighted change in FDCs for storage goal 2.

Probability of Exceedance	Historic Period [1965-1991] Flow [cfs]	Modern Period [1992-2018] Flow [cfs]	Change in flow between periods [cfs]	Change in Probability	Change in flow per increment (cfs)	Probability weighted flow per increment [cfs]	Probability weighted Volume per increment [acre-ft]
0.0001	14,225	11,628	-2,597	0.0001	-0.130	-1.3E-05	-0.01
0.001	5,628	8,317	2,689	0.0009	1.215	1.1E-03	0.79
0.005	2,980	4,350	1,370	0.004	4.769	1.9E-02	13.8
0.01	2,420	2,910	490	0.005	5.875	2.9E-02	21.3
0.02	1,508	2,040	532	0.01	7.768	7.8E-02	56.2
0.03	1,090	1,690	600	0.01	14.318	1.4E-01	104
0.04	861	1,420	559	0.01	20.180	2.0E-01	146
0.05	704	1,240	536	0.01	24.580	2.5E-01	178
0.06	589	1,100	511	0.01	28.730	2.9E-01	208
0.07	522	996	474	0.01	31.927	3.2E-01	231
0.08	440	908	468	0.01	35.305	3.5E-01	256
0.09	386	824	438	0.01	38.415	3.8E-01	278
0.1	339	757	418	0.01	40.601	4.1E-01	294
0.15	210	517	307	0.05	43.920	2.2E+00	1,590
0.2	145	397	252	0.05	48.205	2.4E+00	1,745
0.25	102	312	210	0.05	51.430	2.6E+00	1,862
0.3	76	248	172	0.05	52.005	2.6E+00	1,882
0.35	54	193	139	0.05	50.080	2.5E+00	1,813
0.4	38	152	114	0.05	47.125	2.4E+00	1,706
0.45	28	121	93	0.05	43.725	2.2E+00	1,583
0.5	20	98	78	0.05	40.425	2.0E+00	1,463
0.55	14	79	65	0.05	37.348	1.9E+00	1,352
0.6	10	64	54	0.05	34.048	1.7E+00	1,232
0.65	7.4	49	42	0.05	29.850	1.5E+00	1,081
0.7	5.5	40	34	0.05	25.620	1.3E+00	927
0.75	4	32	28	0.05	22.470	1.1E+00	813

Probability of Exceedance	Historic Period [1965-1991] Flow [cfs]	Modern Period [1992-2018] Flow [cfs]	Change in flow between periods [cfs]	Change in Probability	Change in flow per increment (cfs)	Probability weighted flow per increment [cfs]	Probability weighted Volume per increment [acre-ft]
0.8	2.7	26	23	0.05	19.820	9.9E-01	717
0.85	2	19	17	0.05	16.545	8.3E-01	599
0.9	1.4	13	11	0.05	12.360	6.2E-01	447
0.91	1.24	12	10	0.01	9.803	9.8E-02	71
0.92	1	10	9.0	0.01	8.808	8.8E-02	64
0.93	0.9	8.5	7.6	0.01	7.683	7.7E-02	56
0.94	0.73	7.2	6.5	0.01	6.575	6.6E-02	48
0.95	0.5	5.6	5.1	0.01	5.454	5.5E-02	39
0.96	0.23	4.1	3.8	0.01	4.266	4.3E-02	31
0.97	0.1	2.6	2.5	0.01	3.032	3.0E-02	22
0.98	0	1.5	1.5	0.01	1.943	1.9E-02	14
0.99	0	1.1	1.1	0.01	1.289	1.3E-02	9.3
0.995	0	0.50	0.5	0.005	0.783	3.9E-03	2.8
0.999	0	0.31	0.31	0.004	0.40311	1.6E-03	1.2
0.9999	0	0.04	0.04	0.0009	0.174009	1.6E-04	0.1
Total							22,958

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Appendix 5.3. HSPF-SAM Scenarios

The goal of each scenario was to determine the necessary BMPs to be implemented in order to reach a pollutant reduction goal. Scenarios were created for reach pollutant at different watershed scales. The BMPs selected for each scenario were based on the results from the public participation meetings with landowners, elected officials, and local water resource managers. All scenarios are for subwatersheds in Minnesota, except when explicitly stated otherwise.

The scenarios listed below are titled with the name of the stream reach, pollutant, and the reduction goal. Multiple scenarios were run for TSS watershed wide. The difference between these four scenarios are types of BMPs included. The resulting reductions are found in **Section 3.1.2.**

Unnamed Creek (-530) TSS 10

BMP	Acres
BMP1 - Riparian Buffers, 16 ft wide (replacing row crops)	1,445
BMP2 - Corn & Soybeans with Cover Crop	8,748
BMP3 - Water and Sediment Control Basin (Cropland)	5,610
BMP4 - Reduced Tillage (30%+ residue cover)	5,612

Unnamed Creek (-530) TSS 10 optimized

BMP	Acres
BMP1 - Riparian Buffers, 16 ft wide (replacing row crops)	1,445
BMP2 - Reduced Tillage (30%+ residue cover)	4,265

Unnamed Creek (-530) TSS 55 optimized

BMP	Acres
BMP1 - Corn & Soybeans with Cover Crop	8,748
BMP2 - Water and Sediment Control Basin (Cropland)	5,610
BMP3 - Reduced Tillage (30%+ residue cover)	5,612
BMP4 - Riparian Buffers, 50 ft wide (replacing row crops)	2,098
BMP5 - Filter Strips, 50 ft wide (Cropland field edge)	2,098
BMP6 - Conservation Crop Rotation	9,369
BMP7 - Conservation Cover Perennials	9,369
BMP8 - Corn & Soybeans to Rotational Grazing	9,021
BMP9 - Constructed Wetland	0

Unnamed Creek (-530) TSS 55

BMP	Acres
BMP 1 - Corn & Soybeans with Cover Crop	8,748
BMP 2 - Water and Sediment Control Basin (Cropland)	5,610
BMP 3 - Reduced Tillage (30%+ residue cover)	5,612
BMP 4 - Riparian Buffers, 50 ft wide (replacing row crops)	2,098
BMP 5 - Controlled Tile Drainage	0
BMP 6 - Filter Strips, 50 ft wide (Cropland field edge)	2,098
BMP 7 - Conservation Crop Rotation	9,369
BMP 8 - Conservation Cover Perennials	9,369

BMP 9 - Corn & Soybeans to Rotational Grazing	9,021
BMP10 - Constructed Wetland	0
BMP11 - Alternative Tile Intakes	0

LqP River (-502) TP 25

BMP	Acres
BMP1 - Nutrient Management	188,689
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	69,679
BMP3 - Corn & Soybeans with Cover Crop	215,037
BMP4 - Reduced Tillage (30%+ residue cover)	104,131
BMP5 - Alternative Tile Intakes	71,600
BMP6 - Corn & Soybeans with Cover Crop	1,161

LqP River (-502) TP 45

BMP	Acres
BMP1 - Nutrient Management	384,844
BMP2 - Riparian Buffers, 50 ft wide (replacing row crops)	100,403
BMP3 - Corn & Soybeans with Cover Crop	381,380
BMP4 - Reduced Tillage (no-till)	109,649
BMP5 - Alternative Tile Intakes	92,694
BMP6 - Restore Tiled Wetlands (Cropland)	82,504
BMP7 - Controlled Tile Drainage	69,795
BMP8 - Constructed Stormwater Pond	1,466
BMP9 - Bioretention/Biofiltration	1,466

LqP River (-502) TN 25

BMP	Acres
BMP1 - Nutrient Management	382,718
BMP2 - Tile Line Bioreactors	81,802
BMP3 - Riparian Buffers, 16 ft wide (replacing row crops)	69,001
BMP4 - Corn & Soybeans with Cover Crop	181,067
BMP5 - Alternative Tile Intakes	71,706
BMP6 - Corn & Soybeans with Cover Crop	4,060

LqP River (-502) TN 45

BMP	Acres
BMP 1 - Nutrient Management	382,718
BMP 2 - Tile Line Bioreactors	81,802
BMP 3 - Riparian Buffers, 16 ft wide (replacing row crops)	69,001
BMP 4 - Corn & Soybeans with Cover Crop	135,144
BMP 5 - Alternative Tile Intakes	64,900
BMP 6 - Restore Tiled Wetlands (Cropland)	80,434
BMP 7 - Controlled Tile Drainage	64,774
BMP 8 - Water and Sediment Control Basin (Cropland)	114,452
BMP 9 - Reduced Tillage (30%+ residue cover)	106,302
BMP10 - Corn & Soybeans with Cover Crop	18,070

LqP River (-502) TSS 10

BMP	Acres
BMP1 - Riparian Buffers, 16 ft wide (replacing row crops)	66,540
BMP2 - Water and Sediment Control Basin (Cropland)	1,039
BMP3 - Reduced Tillage (30%+ residue cover)	107,474
BMP4 - Corn & Soybeans with Cover Crop	379,112

LqP River (-502) TSS-1

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	82,504
BMP2 - Riparian Buffers, 50 ft wide (replacing row crops)	100,403
BMP3 - Corn & Soybeans with Cover Crop	381,380
BMP4 - Water and Sediment Control Basin (Cropland)	117,877
BMP5 - Alternative Tile Intakes	92,694
BMP6 - Reduced Tillage (no-till)	109,649
BMP7 - Conservation Crop Rotation	399,614

LqP River (-502) TSS-2

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	82,504
BMP2 - Riparian Buffers, 50 ft wide (replacing row crops)	100,403
BMP3 - Corn & Soybeans with Cover Crop	381,380
BMP4 - Reduced Tillage (30%+ residue cover)	109,649
BMP5 - Alternative Tile Intakes	92,694
BMP6 - Water and Sediment Control Basin (Cropland)	117,877
BMP7 - Filter Strips, 50 ft wide (Cropland field edge)	100,385
BMP8 - Constructed Stormwater Pond	1,466

LqP River (-502) TSS-3

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	82,504
BMP2 - Riparian Buffers, 50 ft wide (replacing row crops)	100,403
BMP3 - Filter Strips, 50 ft wide (Cropland field edge)	100,385
BMP4 - Conservation Crop Rotation	399,614
BMP5 - Corn & Soybeans with Cover Crop	381,380
BMP6 - Reduced Tillage (no-till)	109,649
BMP7 - Water and Sediment Control Basin (Cropland)	117,877
BMP8 - Corn & Soybeans to Rotational Grazing	381,670
BMP9 - Alternative Tile Intakes	92,694

LqP River (-502) TSS-4 including South Dakota

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	84,476
BMP2 - Riparian Buffers, 50 ft wide (replacing row crops)	104,109

BMP3 - Filter Strips, 50 ft wide (Cropland field edge)	104,091
BMP4 - Conservation Crop Rotation	410,904
BMP5 - Corn & Soybeans with Cover Crop	392,425
BMP6 - Reduced Tillage (no-till)	114,005
BMP7 - Water and Sediment Control Basin (Cropland)	122,270
BMP8 - Corn & Soybeans to Rotational Grazing	392,725
BMP9 - Alternative Tile Intakes	95,127

Appendix 5.4. Existing BMPs

State funded Conservation Practices and BMPs installed/implemented within the Lac qui Parle River Watershed.

NRCS Practice Code	Practice Name	Number of Installed Practices*
351	Well Decommissioning	276
380	Windbreak/Shelterbelt Establishment	100
393	Filter Strip	67
638	Water and Sediment Control Basin	60
126M	Septic System Improvement	48
170M	Alternative Tile Intake - Dense Pattern Tiling	35
325M	Walk-In Access	22
600	Terrace	21
172M	Alternative Tile Intake - Gravel Inlet	11
642	Water Well	11
412	Grassed Waterway and Swales	7
362	Diversion	5
340	Cover Crop	4
580	Streambank and Shoreline Protection	4
410	Grade Stabilization Structure	3
587	Structure for Water Control	3
712M	Bioretention Basin	3
327M	Conservation Easement	2
313	Waste Storage Facility	1
554	Drainage Water Management	1
558	Roof Runoff Management	1
639M	Water and sediment control basin maintenance	1
643	Restoration and Management of Declining Habitats	1

* As of October 2019

Appendix 5.5. Public Participation

Lac qui Parle River Watershed Survey

The Lac qui Parle-Yellow Bank Watershed District invites you to participate in this survey. This survey will collect baseline information on perceptions about the Lac qui Parle River and tributaries and will take less than 5 minutes to complete. There will be additional surveys in the future as we collect and assess water quality data throughout the watershed.

1. Please check all that apply.

City resident Rural resident Business Owner Ag Producer

Lac qui Parle Lincoln Yellow Medicine Other_____________

Age group 16-30 31-50 51-70 71 and older

	Count	County	Count	Age	Count
City resident	1	Lac qui Parle	14	16-30	2
Rural resident	25	Lincoln	2	31-50	6
Business Owner	3	Yellow Medicine	7	51-70	21
Ag Producer	11	Other	0	71 and older	1
Government Employee	5				

2. Please rate these water resources in order of importance, in your opinion.
   1 being most important and 4 being least important

_____Lakes ______Streams ______Wetlands ______Groundwater

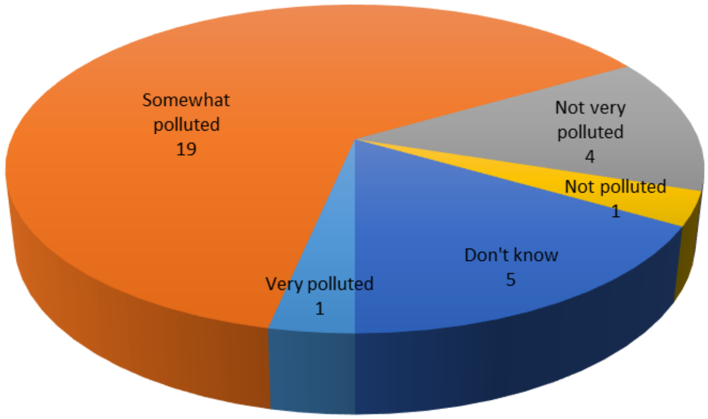
Comments

	1	2	3	4
Lakes	2	12	8	8
Streams	2	12	14	2
Wetlands	4	4	3	19
Groundwater	24	2	3	1

3. In your opinion, how polluted is the Lac qui Parle River and its tributaries.

Very polluted Somewhat polluted Not very polluted
Not polluted Don't know

Comments



4. Who is responsible for water quality? Check all that apply.

Landowners State Government Federal Government
Industry Individuals Local Government Other________

Comments

	Count
Landowners	23
State Government	13
Federal Government	11
Industry	13
Individuals	21
Local Government	11
Other	5

5. Water quality in the Lac qui Parle and its tributaries is most influenced by which of the following?

Land-use practices adjacent to the river Mother Nature
Agricultural practices South Dakota
City Activities Industrial Activities
All of the above Not sure
Comments

	Count
Land-use practices adjacent to the river	5
Agricultural practices	8
City activities	4
Mother nature	4
South Dakota	1
Industrial Activities	1
All of the above	21
Not sure	0

6. How concerned are you about the Lac qui Parle River and its tributaries?
   Very Concerned   Somewhat concerned   Not very concerned
   Not at all concerned   Don't know
   Comment

	Count
Very concerned	10
Somewhat concerned	16
Not very concerned	1
Not at all concerned	2
Don't know	2

7. Do you think something should be done to clean up the Lac qui Parle River and tributaries?   Yes   No

	Count
Yes	24
No	4

8. Who do think should be most responsible for making decision about clean up the Lac qui Parle River and its tributaries?

   Local residents
   Local Government
   State Government
   Federal Government
   Other Please specify______________________________
   Comments

	Count
Local residents	23
Local Government	16
State Government	3
Federal Government	1
Other: specify	3

9. Are you aware of efforts to improve water quality in the Lac qui Parle River and its tributaries? Yes No Not sure
Comments

	Count
Yes	26
No	1
Not sure	1

10. If you are interested in receiving electronic updates about the Lac qui Parle River and its tributaries, please fill out your contact information below. Thank you.
Name_______________________________________
Email_______________________________________

Appendix 5.6. ET Rate Data & Calculation

The presented ET rates are from the following sources/methodologies:

ET rate	Formula/specifics	Reference	Applicable Data
Wetland	$ET_W = 0.9 * ET_{pan}$	Wallace, Nivala, and Parkin (2005)	Waseca station pan ET 1989-2008 average
Lake	$ET_L = 0.7 * ET_{pan}$	Dadaser-Celik and Heinz (2008)	
Crops	Crop ET, Climate II	NRCS (1977)	Table from source

The NRCS crop ET source, despite the source age, was selected because it provided the highest estimates of crop ET. To illustrate this point, the seasonal corn ET rates, as determined from several sources, are presented below:

Methodology, data	Source	May-Sept Corn ET
1. Irrigation table	NRCS (1977)	64 cm
2. SWAT modeling in the Lake Pepin Full Cost Accounting	Dalzell et al. (2012)	54 cm
3. MN Irrigation Scheduling Checkbook, Waseca station temp	NDSU (2012)	42 cm
4. MN Crop Coefficient Curve for Pan ET, Waseca station pan ET	Seeley and Spoden (1982)	39 cm

Using the highest crop ET rates for comparison was desired for multiple reasons: 1) pan coefficients were developed using older data sets and it is likely that corn, with higher crop densities and larger plant sizes, uses more water today than it did when the coefficients were determined, 2) using lower crop ET rates may appear to exaggerate the difference between crop and noncrop ET rates, and 3) error associated with pan ET rates could result in exaggerated differences between estimated wetland/lake ET and crop ET.

Appendix 5.7. Prioritization and Restoration Classification Table

AUID	DO	*E coli*	NO23	TP	TSS
07020003-501	HRE	HRE	AAQ	HRE	HRE
07020003-502	PIR	HRE	AAQ	HRE	HRE
07020003-505	PIR	HRE	AAQ	HRE	HRE
07020003-506	PIR	HRE	AAQ	HRE	HRE
07020003-508	PIR	HRE	AAQ	TIR	HRE
07020003-509	AAQ		AAQ	AAQ	AAQ
07020003-512	PIR	HRE	AAQ	LRE	HRE
07020003-513	PIR	HRE	AAQ	LRE	AAQ
07020003-515	TIR		AAQ	TIR	AAQ
07020003-516	AAQ	HRE	AAQ	PIR	PIR
07020003-517	HRE	HRE	AAQ	PIR	AAQ
07020003-519	AAQ	HRE	AAQ	LRE	AAQ
07020003-520	LRE		AAQ	LRE	AAQ
07020003-521	PIR	HRE	AAQ	TIR	LRE
07020003-523	AAQ	HRE	AAQ	AAQ	AAQ
07020003-530	AAQ	HRE	AAQ	HRE	HRE
07020003-534	LRE		AAQ	HRE	AAQ
07020003-557	PIR		AAQ	AAQ	HRE
07020003-563	PIR	HRE	PIR	PIR	AAQ
07020003-569	TIR		AAQ	TIR	HRE
07020003-570	LRE				
07020003-571	HRE				
07020003-575	PIR				
07020003-577	AAQ	HRE	AAQ	PIR	AAQ
07020003-578	AAQ	HRE	AAQ	PIR	LRE
07020003-580	HRE	HRE	AAQ	HRE	AAQ
07020003-581	PIR	HRE	AAQ	PIR	AAQ
07020003-583	AAQ				
07020003-586	AAQ		AAQ	AAQ	AAQ
07020003-588	AAQ				

AAQ: Above Average Quality
PIR: Potential Impairment Risk
TIR: Threatened Impairment Risk
LRE: Low Restoration Effort
HRE: High Restoration Effort
Blank: Not analyzed