# Thief River Watershed Restoration and Protection Strategy Report

*March 2019*

RMB Environmental Laboratories, Inc.

MINNESOTA POLLUTION CONTROL AGENCY

Red Lake Watershed District • Dedicated to Water Management •

CLEAN WATER LAND & LEGACY AMENDMENT

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## Project Partners

Red Lake Watershed District

Minnesota Department of Natural Resources

Minnesota Pollution Control Agency

RMB Environmental Laboratories

Marshall County Water Planner

Marshall County Soil and Water Conservation District

Emmons and Olivier Resources, Inc.

Pennington County Soil and Water Conservation District

Beltrami County Soil and Water Conservation District

Minnesota Board of Soil and Water Resources

## Cover Photo

In the photo, Red Lake Watershed District and Minnesota Department of Natural Resources staff are surveying longitudinal profiles of the Thief River (upstream of the 05076000 USGS gaging station) for the fluvial geomorphology study of the watershed. The picture was taken by Red Lake Watershed District staff.

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## Key Terms

**Assessment Unit Identifier (AUID):** The unique water body identifier for each river reach comprised of the USGS eight-digit HUC plus a three-character code unique within each HUC.

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

**Aquatic recreation impairment:** Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus, chlorophyll-a, or Secchi disc depth standards are not met.

**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 Pomme de Terre River Watershed is assigned a HUC-8 of 07020002.

**Impairment:** Water bodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, 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).

**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).

**Stressor (or Biological Stressor):** This is a broad term that includes both pollutant sources and non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely affect aquatic life.

**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.

## Executive Summary

The Thief River Watershed (U.S. Geological Survey (USGS) Hydrologic Unit Code (HUC) 09020304) is in northwest Minnesota and is a tributary of the Red Lake River (USGS HUC 09020303) in the Red River of the North Basin (USGS HUC 090203). Most of the watershed area lies within Marshall, Pennington, and Beltrami Counties. The Thief River itself runs along the western side of the watershed and is joined along the way by tributaries that include the Moose River (Judicial Ditch 21), Mud River (Judicial Ditch 11), Branch 200 of Judicial Ditch 11, Marshall County Ditch 20, and Judicial Ditch 30. There are more than 30 impoundments and reservoirs in the watershed, including the Moose River Impoundment, Lost River Pool, Farmes Pool, the pools of Agassiz National Wildlife Refuge (NWR), and the Thief River Falls Reservoir. Agassiz NWR lies in the center of the watershed. Agassiz Pool, the main pool of the refuge, receives water from the Mud River from the east, Thief River from the north, and some smaller ditches. It discharges to the Thief River to the south.

The Thief River Watershed has been intensively studied by multiple organizations through multiple studies. A large amount of detailed data has been collected in the watershed. This has allowed for a confident understanding of the current conditions in the watershed and the causes of water quality problems.

The number of impairments on the 2014, U.S. Environmental Protection Agency's (EPA's) 303(d) list of impaired waters has been reduced to four, after multiple reaches were recommended for delisting during the 2013 assessment and another reach was recommended for delisting after additional data collection. The Moose River and the Mud River remain impaired by low dissolved oxygen (DO). The Thief River downstream of Agassiz Pool is listed as impaired by high turbidity. The Mud River is impaired by high concentrations of
*E. coli* bacteria. The state's new 30 mg/l Central Nutrient Region total suspended solids (TSS) standard was used to develop a Total Maximum Daily Load (TMDL) to address the turbidity impairment. The analysis of data revealed that the absence of sufficient flow in the Moose River and Mud River had a greater influence upon the ability of the streams to meet the 5 mg/l DO standard than any of the pollutants that have been monitored in those rivers. So, no TMDLs were developed for these two DO impairments, but strategies to address them are included in this report. The Mud River meets the *E. coli* standard at the furthest downstream crossing, but exceeds the standard within the city of Grygla. A TMDL was developed for the impaired section of the river.

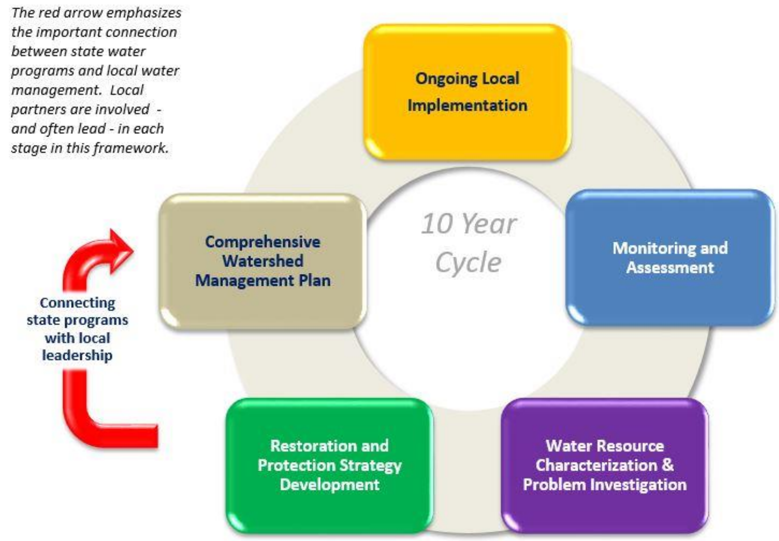
The findings of the Thief River Watershed Restoration and Protection Strategy (WRAPS) and other studies completed in the watershed will be used to guide the development of local water plans. Key strategies identified for improving water quality include:

- Reduce erosion and sedimentation by improving stream buffers, stabilizing streambanks, install windbreaks, install side inlet and grade control structures, and minimize the effects of Agassiz Pool drawdowns,
- Improve DO concentrations by improving nutrient and soil health management, improve base flows in the Mud and Moose Rivers, restore stream meanders, and increase vegetative cover, and

- Reduce *E. coli* bacteria concentrations by increasing conservation practices in critical areas, improve Subsurface Sewage Treatment System (SSTS) compliance, and improve grazing management and feedlot compliance.

This WRAPS Report, the concurrently developed TMDL Report, and other technical reports referenced in this document are publicly available on the Minnesota Pollution Control Agency (MPCA) website for the Thief River Watershed: https://www.pca.state.mn.us/water/watersheds/thief-river. These and other documents can also be found on watershed-based web pages created for the Thief River: http://www.rlwdwatersheds.org/wraps-info.

# What is the WRAPS Report?




Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota watershed approach incorporates **water quality assessment, watershed analysis, public participation, planning**, **implementation**, and **measurement of results** into a 10-year cycle that addresses both restoration and protection.

As part of the watershed approach, the MPCA developed a process to identify and develop strategies to address threats to water quality in each of these major watersheds. This process is called Watershed Restoration and Protection Strategy (WRAPS) development. WRAPS reports have two parts: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and TMDL studies are developed for them. TMDLs are incorporated into WRAPS. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves as the basis for addressing the EPA Nine Minimum Elements of watershed plans, to help qualify applicants for eligibility for Clean Water Act Section 319 implementation funds.

| | |
|---|---|
| Purpose | •Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning<br>•Summarize Watershed Approach work done to date including the following reports:<br>•*Thief River Watershed Monitoring and Assessment Report*<br>•*Thief River Watershed Total Maximum Daily Load Report*<br>•*Thief River Watershed Sediment Investigation Report* |
| Scope | •Impacts to aquatic recreation and impacts to aquatic life in streams<br>•Create strategies for restoration and protection of watershed resources |
| Audience | •Local working groups (watershed districts, SWCDs, watershed management groups, etc.)<br>•State agencies (MPCA, DNR, BWSR, etc.) |

The watershed-based strategy recognizes the connectivity of the watershed better than the past reach-by-reach system, since an impairment may extend over multiple assessment units, and impairments for different parameters may be linked by common stressors and/or pollutants. The stakeholder process is also helped through this strategy. Not only is there an increased emphasis on civic engagement, but the process also avoids the redundancy that could occur when addressing TMDLs with a reach-by-reach strategy. It also reduces the complexity of incorporating TMDL results into watershed management plans.

The Thief River WRAPS Report will provide information that will be needed for the creation of a "One Watershed One Plan" local comprehensive water management plan for the Thief River Watershed. The majority of the content of the Thief River WRAPS report is organized within four sections.

1. Watershed Background and Description

As the title implies, this section provides a description of the watershed to familiarize the reader with watershed features and issues. It also contains some information about the history of the watershed and findings of previous water quality studies.

2. Watershed Conditions

This section includes water quality assessment results from the 2013 assessment (2003 through 2012 data) and updated results generated from analysis of more recent data. Water quality trends were also calculated and revealed some strong trends. The current impaired waters are identified and TMDL summaries are included in this section. This section provides guidance for addressing stressors and sources of pollutant sources for all subwatersheds, regardless of impairment status. The results of investigative monitoring efforts are also described.

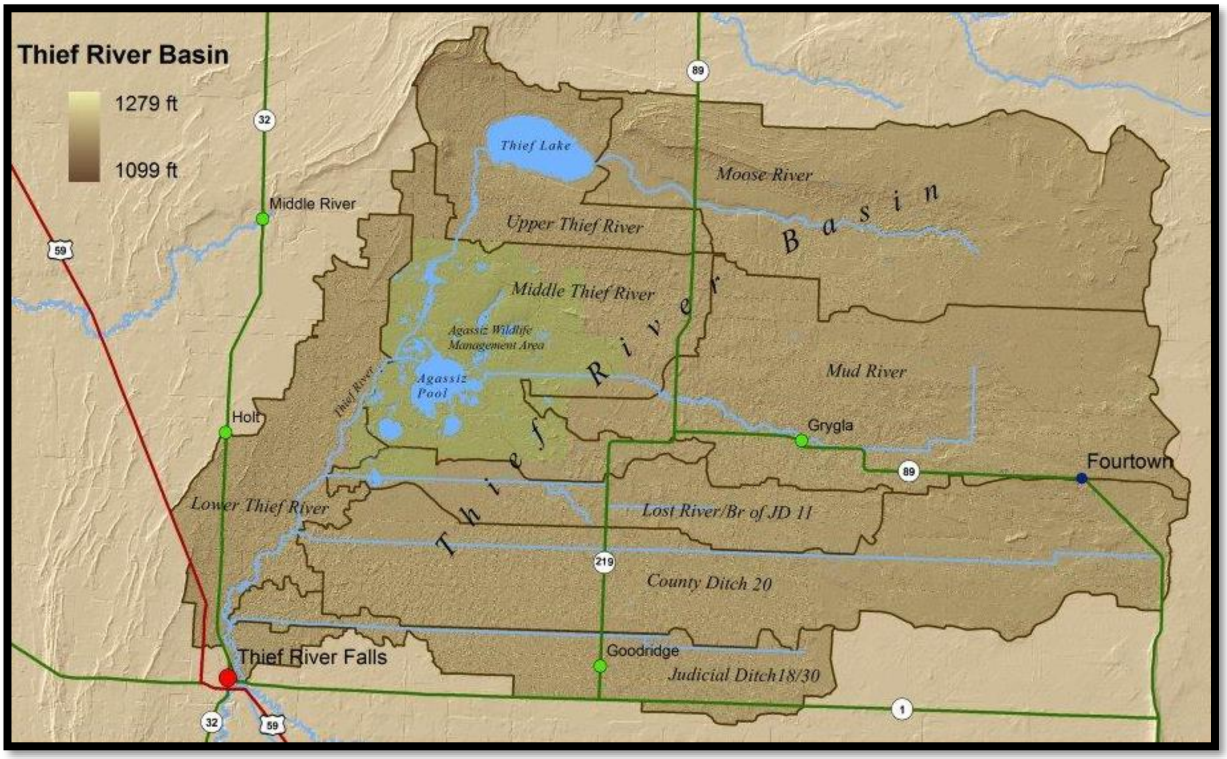
3. Prioritizing and Implementing Restoration and Protection

In recent years, multiple water quality models have been used to identify the areas of the watershed that are contributing the most significant quantities of pollutants. Stream Power Index (SPI) and Minnesota Department of Natural Resources (DNR) Stressor Identification (SID) analysis pinpointed locations that are need of repair or protection. A geomorphological assessment of the watershed made recommendations for implementation efforts throughout much of the watershed. State and local staff collaborated to compile lists of potential projects that could be completed to address water quality restoration and protection needs. The lists of projects are organized into tables for the entire watershed and for each HUC10 subwatershed.

4. Monitoring Plan

This section provides a detailed summary of monitoring site locations (flow and water quality). It also provides a description of data collection goals.

# 1. Watershed Background & Description




The Thief River Watershed (HUC 09020304) is located in northwest Minnesota and is a tributary of the Red Lake River in the Red River of the North Basin. Most of the watershed area lies within Marshall, Pennington, and Beltrami Counties. The watershed also lies within the Northern Minnesota Wetlands and Red River Valley ecoregions. Most of the soils in the Thief River Watershed are poorly drained. The Thief River runs along the western side of the watershed, and is fed along the way by tributaries that include the Moose River/Judicial Ditch 21 (JD21), Mud River/Judicial Ditch 11 (JD11), Branch 200 of JD11, Marshall County Ditch 20 (CD20), and Judicial Ditch 30 (JD30). Agassiz NWR lies in the center of the watershed. The refuge boundary encompasses a network of pools. The largest of those pools, Agassiz Pool, receives water from the Mud River, Thief River, and some smaller ditches. The pool discharges to the Thief River. The Thief River flows to the Red Lake River, which is a drinking water source for the cities of Thief River Falls, and East Grand Forks. Pool discharges most directly affects the Thief River Falls Reservoir and water supply. The Minnesota Department of Health has developed source water protection plans for Thief River Falls and East Grand Forks. One of the proposed changes from the 2013 MPCA Triennial Standards Review is to change the classification of the Thief River upstream of Thief River Falls from Class 2B (warm water fishery) to Class 1 (drinking water source).

Because it is home to Agassiz NWR and Thief Lake Wildlife Management Area (WMA), the area is productive and important for waterfowl, shorebirds, and migrating birds. The watershed also features productive farmland that is important to the local economy. The watershed is heavily managed with many miles of channelized streams and man-made ditches. More than 30 impoundments have been constructed in the watershed, including the Moose River Impoundment, Lost River Pool, Farmes Pool, and the pools of Agassiz NWR. Some of the impoundments were built to address flooding concerns and some are operated primarily for wildlife habitat management. The drainage-related hydrologic modification made farming possible within this area. Headlines in a 1909 edition of the Minneapolis

Journal proclaim “Net-Work of Ditches and Laterals Reclaims Vast Area in Thief River Valley” (sic) and “THIEF RIVER BOTTOMS TO BECOME A GARDEN.”

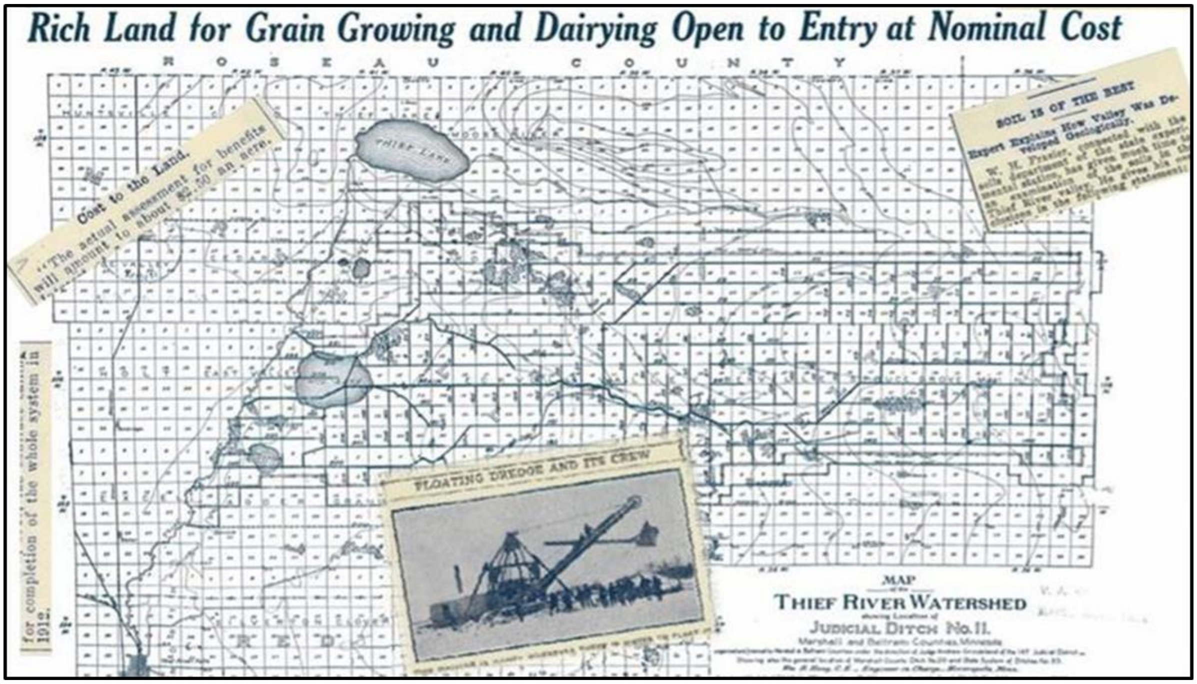


Figure 1-1. Historical map and newspaper clippings about the dredging that occurred in the early 1900s.

Additional information about the Thief River Watershed can be found on webpages dedicated to the Thief River on the http://www.rlwdwatersheds.org website. This website contains links to a multitude of reports related to the Thief River and water quality.

The Red Lake Watershed District (RLWD), Marshall County, Pennington County Soil and Water Conservation District (SWCD), and the Grygla River Watch condition monitoring programs have collected a large amount of data within the Thief River Watershed. Intensive monitoring was conducted throughout the watershed during the Thief River Watershed Sediment Investigation and the coinciding Agassiz NWR Water Quality Study. The watershed was again studied intensively during the Thief River WRAPS and Surface Water Assessment Grant (SWAG) projects.

The Thief River Watershed (8-digit HUC 09020304) is divided into eight 10-digit HUC subwatersheds.

401. Moose River (090203040401)
402. Upper Thief River (090203040402)
403. Mud River (090203040403)
404. Middle Thief River (090203040404) *(Agassiz NWR)*
405. Lost River (090203040405) *(Branch 200 of JD11)*
406. Marshall County Ditch 20 (090203040406)
407. Judicial Ditch 18 (090203040407)
408. Lower Thief River (090203040408)

Impairments addressed within this report have been identified in the 10-digit HUCs of the:

401. Moose River (090203040401)
403. Mud River (090203040403)
408. Lower Thief River (090203040408)

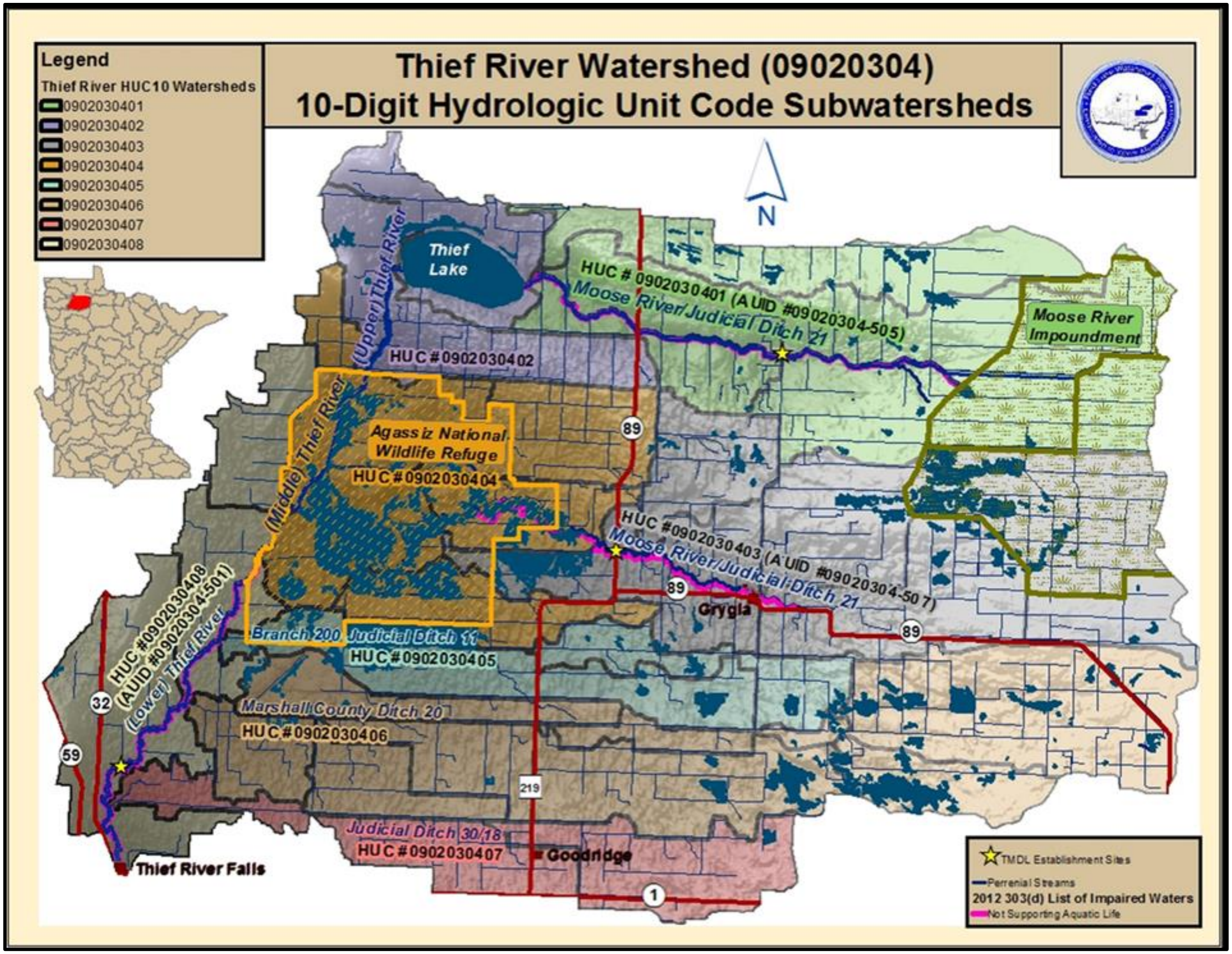



**Figure 1-2. 10-digit hydrologic units within the Thief River Watershed**

## 1.1. Land Use

The exact acreages and percentages vary by data source and watershed delineation method, but all land use data for the watershed show that the dominant land uses/covers in the Thief River Watershed are cultivated crops, wetlands, and forest. Large areas of natural wetlands, grasslands, and forests are protected on public lands such as refuges, state forests, and WMAs. Table 1-1 presents land use statistics from three different years. Figure 1-3 is a map that demonstrates the dominance of wetlands, cultivated crops, and forests as land uses in the watershed.

Table 1-1. Summary of 2001, 2006, and 2011 National Land Cover Database Categories

| Thief River Watershed Land Use Summary | | | |
|---|---|---|---|
| **National Land Cover Database Category** | **Percent of Watershed 2001** | **Percent of Watershed 2006** | **Percent of Watershed 2011** |
| Developed, Open Space | 2.57% | 2.53% | 2.57% |
| Developed, Low Intensity | 0.23% | 0.23% | 0.28% |
| Developed, Medium Intensity | 0.01% | 0.01% | 0.05% |
| Developed, High Intensity | 0.00% | 0.00% | 0.00% |
| Barren Land | 0.05% | 0.06% | 0.06% |
| Shrub/Scrub | 0.25% | 0.25% | 0.26% |
| Grassland/Herbaceous | 0.72% | 0.72% | 0.00% |
| **Deciduous Forest** | **19.11%** | **5.90%** | **5.97%** |
| Evergreen Forest | 0.55% | 0.46% | 0.47% |
| Mixed Forest | 0.00% | 0.00% | 0.00% |
| Pasture/Hay | 7.22% | 7.10% | 6.87% |
| **Cultivated Crops** | **37.01%** | **35.94%** | **36.35%** |
| Woody Wetlands | 3.91% | 17.09% | 17.06% |
| **Emergent Herbaceous Wetlands** | **26.73%** | **28.00%** | **28.36%** |
| Open Water | 1.63% | 1.69% | 1.69% |

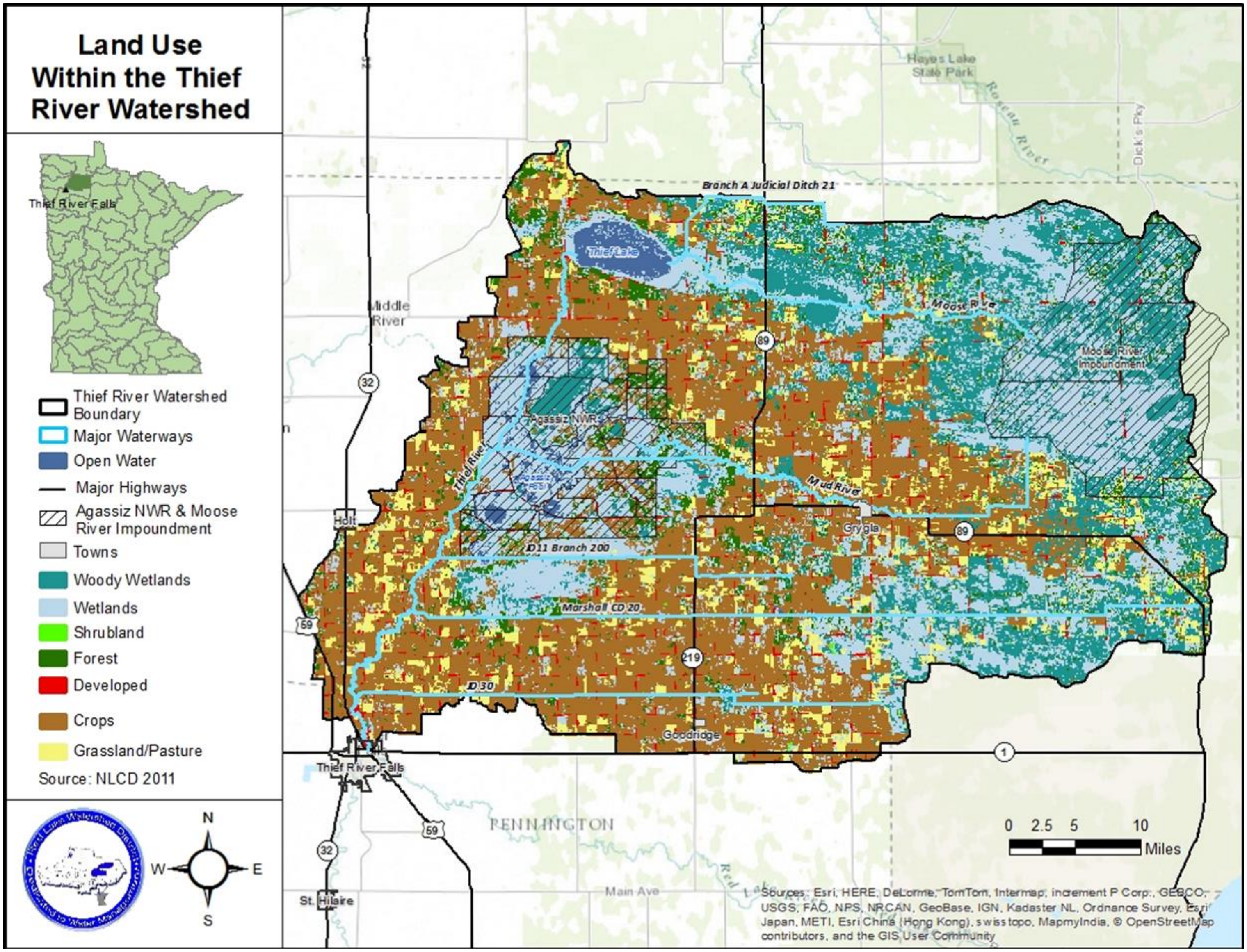


**Figure 1-3. Thief River Land Use (2011 National Land Cover Database)**

## 1.2. Previous Study Summary: Total Suspended Sediment Loadings: Red Lake, Thief, Mud, and Moose Rivers study (2003)

The *Total Suspended Sediment Loadings: Red Lake, Thief, Mud, and Moose Rivers* Study (2003) was completed by Houston Engineering on June 6, 2003, for the Pennington SWCD. Principal findings of the report are summarized below. The report is available in PDF format from the RLWD website at: http://www.redlakewatershed.org/projects/TSS%202003.pdf.

- The large reservoirs of Thief Lake and Agassiz NWR are discharging a significant amount of sediment, although Agassiz NWR Pools appear to be retaining about 2/3 of the sediment inflow.
- The load estimates and average TSS concentration data for Thief Lake indicate that more sediment is flowing out of Thief Lake than is flowing in. This seems contrary to "common sense" and may be a result of assumptions made to compute discharge.

## 1.3. Previous Study Summary: Erosion Sedimentation and Sediment Yield Report for the Thief and Red Lake Rivers Basin (April 1996)

The *Erosion, Sedimentation, Sediment Yield Report: Thief and Red Lake Rivers Basin, Minnesota* was completed by the USDA Natural Resources Conservation Service in cooperation with the Marshall-Beltrami SWCD, Pennington SWCD, and other local, state, and federal agencies in April of 1996. This was the first extensive effort that was made to understand the sources of sediment in the Thief River Watershed. The study created a sediment budget to help local agencies find solutions to sedimentation problems within public wildlife areas and the Thief River Falls Reservoir. Sediment sources were identified and quantified. The relative contributions from different types of erosion differ from the findings of a later study that focused on Agassiz Pool. This report determined that most of the sediment delivered to the Thief River Falls Reservoir came from stream or ditch bank erosion. A more recent study of the origin of sediment in Agassiz Pool determined that most of that sediment came from overland erosion. The conclusions of the studies are not mutually exclusive. Although overland erosion has been the most significant source of sediment deposition in Agassiz Pool, it is still plausible that the prevalent eroding streambanks downstream of Agassiz Pool are a very significant source of sediment delivered to the Thief River Falls Reservoir. Streambank erosion is prevalent along the Thief River downstream of Agassiz Pool. Principal findings and conclusions of the report are summarized below. The report is available online: http://www.redlakewatershed.org/projects/Erosion%20Sedimentation%20Sediment%20Yield%20Report.pdf.

- The Thief River and Red Lake River Watersheds were split into eight subbasins for evaluation. The watershed area that drains to the Thief River from the west was the "evaluation unit" with the highest gross erosion per square mile.
- About 9,500 tons of sediment are yielded annually to the pools of the public wildlife areas within the basin and about 98% is deposited in them.
- The Thief River Falls reservoir receives about 19,800 tons of sediment annually, of which about 27% is deposited in it.

- 65% (24 river miles) of the streambanks are eroding along the Thief River. Over 60% of this erosion is considered severe.
- Only 15% (nine miles) of the streambanks along the Red Lake River are eroding.
- The more extensive streambank erosion on the Thief River may be explained in part by greater water level fluctuations. The channel is not as wide as the Red Lake River, yet it has a larger uncontrolled drainage area than the Red Lake River.
- Of the total annual gross erosion of approximately 2.8 million tons, only about 53,900 tons of sediment is yielded to the ditches and streams annually. The rest is deposited on land.
- Of the 53,900 tons of sediment yielded to streams:
    - 58% (31,200 tons) is from streambank erosion
    - 22% (11,700 tons) is from sheet and rill erosion
    - 14% (7,900 tons) is from wind erosion
    - 5% (2,700 tons) is from ditch bank erosion
    - 1% (400 tons) is from classic gully erosion
- The average annual rate of deposition in the Thief River Falls reservoir was estimated at 5,330 tons in the years 1966 through 1990.
- Future options for reduced sedimentation:
    - Do nothing.
        - Water quality conditions would gradually become worse.
    - Land treatment.
    - Return cropland to permanent grass cover.
    - Accelerate the application of conservation tillage, crop residue use, field shelterbelts, and filter strips.
    - Accelerate the installation of grade stabilization structures and side-water inlets.
    - Adequately revegetate legal drains after their cleanout.
    - Structural measures.
    - Streambank stabilization measures.
    - Trap sediment before it is yielded to the reservoir.
    - Dredging.
        - Cost estimated at over 1 million dollars (in 1996 – it would be much more today).
        - 25-year project life.

    - Combine dredging with periodic drawdown.
    - Combine dredging and land treatment measures.
- Conclusions of the Erosion Sedimentation and Sediment Yield Report:
    1. Even though 98% of the gross erosion (total mass of erosion from the soil surface) occurs on cropland, this kind of erosion accounts for only 37% of the sediment yielded (net erosion) to ditches, streams, and the reservoir (only a fraction of eroded sediment is deposited into a waterbody). Soil erosion on cropland causes more damage on-site by reducing soil productivity, damaging growing crops, losing fertilizers and chemicals, and reducing net income.
    2. Wind erosion accounts for 94% of the gross erosion but only 14% of the sediment yield to streams, ditches, and the reservoir.
    3. The major source of sediment yielded to streams and ditches is from streambank and ditch bank erosion (63%).
    4. Current sediment deposited in the reservoir accounts for about 18% of the total volume. Annual deposition over the past 24 years amounts to 5,330 tons (RLWD data). Future depositions are expected to be less, unless current sediment accumulations are removed and CRP acreage is returned to crop production.
    5. Even though sediment yield values are considerably lower than in other parts of the state and nation, considerable local interest exists, especially among the recreationalists and city officials in Thief River Falls, for reducing the sediment yield to the reservoir. Similar interest also exists for the WMAs.
    6. Opportunities exist for using the sediment budget to determine impacts of various treatment scenarios.

## 1.4. Previous Study Summary: Thief River Watershed Sediment Investigation (2010)

The Thief River Watershed Sediment Investigation project was completed in 2010, with the help of funding from a Clean Water grant from the MPCA. The study was initiated because of growing concern about water quality issues in the Thief River Watershed, and a lack of detailed information about the severity or causes of those problems. Principal findings and conclusions of the report are summarized below.

- A large amount of sampling, continuous water quality, and flow data was collected.
- Soil and Water Assessment Tool (SWAT) modeling was conducted by Houston Engineering. The model identified the sub-basins in the watershed that are contributing the most sediment and nutrients. The model was used to simulate the implementation of best management practices like buffers and side water inlets.
    - The full SWAT Modeling Report is found here: http://www.redlakewatershed.org/waterquality/TRW_Report.pdf

- A windshield survey of tile outlet locations was conducted to aid the SWAT model calibration.
- Additional data needs were identified and have been addressed by the WRAPS project.
- Problem areas and pollutions sources were identified. Projects were recommended to address the problems that were found. Several of those projects have already been completed since the completion of the report with financial assistance from BWSR Clean Water Fund grants.
    - Grade Stabilization for Sediment Reduction in the Thief River (grade stabilization and side water inlets along CD20)
    - Erickson Group Streambank Stabilization Project
    - Halvorson Streambank Stabilization Project
    - Thief River Golf Club Breen #5 Streambank Stabilization Project
    - Thief River Cut-Off Project (stabilization of a developing meander cut-off to prevent further erosion)
- The Thief River Watershed Sediment investigation Final Report can be read here: http://www.redlakewatershed.org/waterquality/Thief%20River%20Watershed%20Sediment%20Investigation%20Final%20Report.pdf.

## 1.5. Previous Study Summary: Thief River Watershed Fluvial Geomorphology (2015)

Erosion and sedimentation are problems in the Thief River Watershed. Truly understanding these problems requires an understanding of how these processes are being affected by stream channel morphology within the watershed. The knowledge gained from geomorphic assessment will guide future strategies for reducing erosion and sedimentation. Initial geomorphologic field assessments were conducted in 2011. In 2012, follow-up geomorphology surveying, measurements, Bank Erosion Hazard Index (BEHI) ratings, and Pfankuch ratings were conducted at most of the Thief River geomorphology sites by DNR and RLWD staff. A final report was completed in 2015 that included Bank Assessment for Nonpoint source Consequences of Sediment (BANCS) modeling results, findings, discussion, and recommendations for six of the significant subbasins of the Thief River Watershed. Erosion estimates from the geomorphology report can be found in Section 2.3 of this report. Recommendations from the geomorphology report can be found in Section 3.1.5 and in the restoration and protection strategy tables in Section 3.3 of this report. The report can be downloaded at the following link: http://redlakewatershed.org/waterquality/Thief%20R%20Geomorphology%20Report%20Nov2015.pdf

## 1.6. Previous Study Summary: Assessment of Nutrients and Suspended Sediment Conditions in and near the Agassiz National Wildlife Refuge, Northwest Minnesota, 2008-2010 (2012)

In response to concerns about water-quality impairments that may affect habitat degradation in Agassiz NWR, the U.S. Geological Survey, in cooperation with the U.S. Fish and Wildlife Service, collected streamflow data, discrete nutrient and suspended- sediment samples, and continuous water-quality data from 2008 to 2010. Loads were estimated for nutrients and suspended sediment using sample data and streamflow data. In addition, a potential water-quality and streamflow monitoring program design was developed for the Refuge. Results from this study can be used by resource managers to address identified impairments, protect wildlife habitat, protect public water supplies, and contribute toward developing more effective water-management plans for Agassiz NWR. Findings of the study include:

- Outflow sites had greater suspended-sediment concentrations than inflow sites.
- There were small differences in suspended-sediment concentration among inflow sites.
- A recent (2011) radioisotope study indicated that Agassiz Pool has been experiencing a net gain of sediment (more inflow load than outflow load) in the last 68 years. Approximately 1.3 million tons of inorganic sediment have been deposited and trapped in Agassiz Pool from 1940 to 2008. During the three-year period of this study (2008 to 2010), however, a net loss of sediment from Agassiz Pool was measured. The amount of net loss of sediment from Agassiz Pool ranged from 650 tons/yr in 2008 to 25,300 tons/yr in 2010. The recent net loss was likely related to a combination of several atypical water-management activities that occurred at the two outflow sites including:
    - The first year of operation of the water control structure at the smaller outflow site in 2008
    - Construction downstream from the primary outflow site in 2008 and 2009 likely affected outflow loads that were measured at the CSAH 7 crossing of the Thief River (S002-088)
    - Scheduled drawdown of Agassiz Pool in fall 2009 through 2010, which occurs only once every 10 years.
- Large loads at the primary outflow site in 2010, particularly for sediment, likely resulted from the combination of greater flows in 2010 and scheduled drawdown of Agassiz Pool. Suspended solids concentrations increased during the drawdown.
- For all sites monitored for the study in 2010 (inflow and outflow), spikes in turbidity occurred related to rainfall, with as little as 2% of the values exceeding the 25 nephelometric turbidity units (NTU) water-quality standard and at most 38% of the values exceeding the standard.
- Continuous water-quality monitoring data from 2010 indicated instances when water quality standards for DO, pH, and turbidity were not met.
- It is likely that the primary sources of nutrients to rivers and ditches in the Thief River Watershed are from nonpoint sources in the form of agricultural runoff, and may include some nutrient inputs from wildlife. Within Agassiz NWR, processes such as mineralization, denitrification, and plant uptake all affect nutrient concentrations. Downstream of Thief Lake and Agassiz Pool, the seasonal patterns of most mean monthly nutrient loads and mean monthly flow-weighted nutrient concentrations were affected by releases from these water bodies and the vegetative growing season.

- Orthophosphorus (OP) and total phosphorus (TP) concentrations were significantly greater at inflow site A1 (Branch 1 of Ditch 11 that flows into the Mud River Pool on the northeast portion of the refuge) than any other site. This site accounted for 31, 27, and 13% of the inflow load for nitrate plus nitrite, OP, and TP, respectively, in 2010 despite accounting for only 3% of the total streamflow from inflow sites.
- A future water quality monitoring program for Agassiz NWR could include data collection at two indicator sites (one inflow and one outflow site) with a total of seven discrete samples and seven streamflow measurements consisting of the following: five samples, along with a streamflow measurement, collected during the same week each month in April, May, June, July, and October, combined with two supplementary samples and streamflow measurements during periods of storm runoff. In addition to the discrete samples, continuous water-quality monitors could be deployed at each site. Future water quality monitoring in Agassiz NWR would provide information that can be used to assess the changes in water quality with time, changes in management conditions, effects of upstream mitigation practices (for example, buffer strips or side-channel inlets) within the Thief River Watershed, as well as other variables.
- The report can be downloaded at the following link: http://pubs.usgs.gov/sir/2012/5112/sir2012-5112.pdf

# 2. Watershed Conditions

It is important for local agencies to be cognizant of current water quality conditions relative to current water quality standards to be able target critical areas, prioritize water quality improvement project ideas, and measure the success of projects. This section describes the waterbody impairments in the watershed and gives a summary of the loading capacities, allocations, and necessary reductions to address these impairments. Current water quality data is compared to the regional sediment and nutrient water quality standards that were adopted in 2015. The number of impairments in the Thief River Watershed is relatively low compared to neighboring watersheds. The chart in Figure 2-1 tracks the number of impaired waterbodies and impairments in the watershed over time.

Local water quality improvement efforts should not be limited to impaired waters. The Thief River was one of the last watersheds to be assessed by the State of Minnesota before the adoption of Tiered Aquatic Life Use (TALU) aquatic life standards and regionalized sediment and nutrient standards. During the 2013 assessment, aquatic life impairments on channelized reaches were deferred until the next water quality assessment, when the appropriate TALU standards will be applied. Water quality protection efforts are important and should be ongoing for waters with deferred impairments, un-impaired waters, waters that are in danger of becoming impaired, as well as high quality waters.

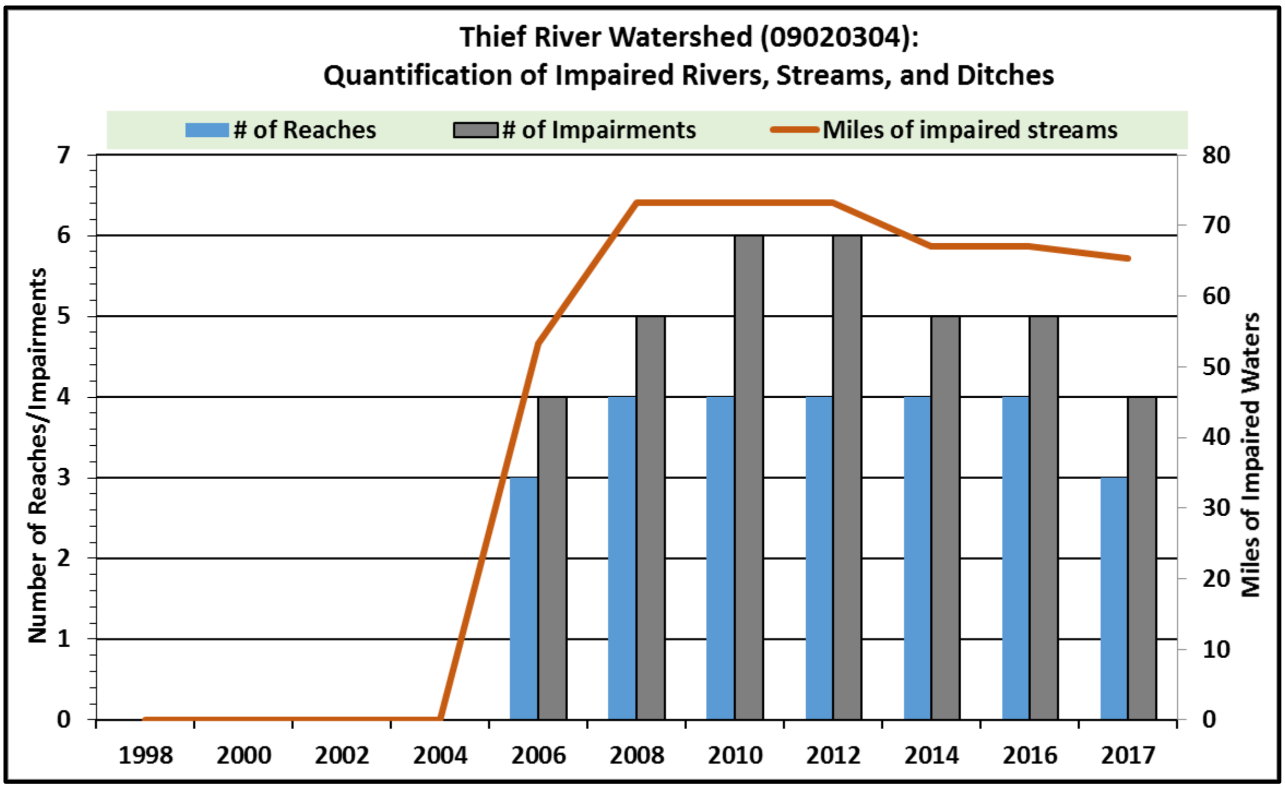



Figure 2-1. Historical record of the number of impaired waters in the Thief River Watershed.

## 2.1 Condition Status

The results of the most recent MPCA water quality assessment (2013) are shown in Table 2-1. All of the watershed's assessment units with sufficient data were assessed, but aquatic life impairments on channelized reaches were deferred until TALU water quality standards are in place. The TALU water quality standards were adopted in 2015 and will be used during the Thief River Watershed's next assessment cycle (2023).

Some of the waterbodies in the Thief River Watershed are impaired by mercury; however, this report does not cover toxic pollutants. For more information on mercury impairments see the statewide mercury TMDL 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](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).

**Table 2-1. Impairment listings and delistings that resulted from the 2013 water quality assessment**

| Name | Reach | HUC/AUID Code | Impairment (2013 Assessments) |
|---|---|---|---|
| Thief River | Agassiz Pool to Red Lake River | 09020304-501 | Aquatic Life – Turbidity |
| Thief River | Agassiz Pool to Red Lake River | 09020304-501 | Aquatic Life – Low Dissolved Oxygen **(DELISTED)** |
| Thief River | Thief Lake to Agassiz Pool | 09020304-504 | Aquatic Life – Unionized Ammonia **(DELISTED)** |
| Thief River | Thief Lake to Agassiz Pool | 09020304-504 | Aquatic Recreation – *E. coli* **(DELISTED)** |
| Moose River | Headwaters to Thief Lake | 09020304-505 | Aquatic Life – Low Dissolved Oxygen |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | Aquatic Life – Low Dissolved Oxygen |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | Aquatic Recreation – *E. coli* |
| Branch A of JD21 | Unnamed ditch to Moose River | 09020304-555 | Aquatic Recreation – *E. coli* **(DELISTED)** |

### 2.1.1 Streams

The RLWD has been collecting water samples in the Thief River Watershed since 1980. The Pennington SWCD and the International Water Institute (via a grant from the MPCA) also regularly collect samples in the watershed. The RLWD and the USGS completed concurrent intensive studies of the watershed and Agassiz NWR in 2009. Continuous water quality monitoring was conducted using multi-parameter sondes during the Thief River Watershed Sediment Investigation, Thief River WRAPS, and the Agassiz NWR water quality study.

**Table 2-2. Stream Mile Statistics for the 2013 MPCA Water Quality Assessment Summary**

| Impairment Assessment | Stream Length (Miles) | | Stream Length (%) | | Stream AUIDs (#) | |
|---|---|---|---|---|---|---|
| | Aquatic Life | Aquatic Recreation | Aquatic Life | Aquatic Recreation | Aquatic Life | Aquatic Recreation |
| Fully Supporting (FS) | 0.0 | 59.2 | 0% | 23% | 0 | 5 |
| Not Supporting (NS) | 65.3 | 21.7 | 25% | 8% | 3 | 2 |
| Insufficient Information (IF) | 36.7 | 0.0 | 14% | 0% | 8 | 0 |
| Not Assessed (NA) | 159.0 | 180.1 | 61% | 69% | 47 | 51 |
| **Total** | **261.0** | **261.0** | **100%** | **100%** | **58** | **58** |

Extensive data collection had been conducted in the watershed. A total of 2,350 sets of discrete daily values were available, 235 sets per year. However, only 35% of the 260.99 miles of stream channels in the watershed were officially assessed for either aquatic life or recreation as shown in Table 2-2 (including Branch A of JD21, which was listed for an *E. coli* impairment, but not officially assessed for aquatic life). Table 2-3 displays a list of the assessment units without monitoring data.

**Table 2-3. Established assessment units within the Thief River watershed that have not been monitored.**

| Thief River Watershed Assessment Units with No Data | | | |
|---|---|---|---|
| **River/Stream/Ditch Name** | **AUID** | **Reach Description** | **Miles** |
| Thief River | 09020304-502 | Agassiz Pool below Mud R | 3.26 |
| Thief River (Agassiz Pool) | 09020304-503 | Agassiz Pool above Mud R | 5.96 |
| Mud River (Agassiz Pool) | 09020304-508 | Agassiz Pool portion | 10.66 |
| County Ditch 20 | 09020304-514 | Unnamed ditch along CSAH 54 to CD 32 | 0.49 |
| County Ditch 20 | 09020304-516 | CD 31 to Unnamed ditch | 2 |
| County Ditch 22 | 09020304-518 | Unnamed ditch to Unnamed ditch | 3.51 |
| Unnamed Ditch (Moose R Impoundment) | 09020304-520 | Unnamed ditch to unnamed ditch | 1.01 |
| Judicial Ditch 11 | 09020304-523 | Unnamed ditch to Unnamed ditch (Carmel Rd) | 0.99 |
| Judicial Ditch 11 | 09020304-524 | Unnamed ditch to Unnamed ditch (Carmel Rd to Outpost Rd) | 1.96 |
| Unnamed Ditch (Br55 JD11, Hwy 54 Road Ditch) | 09020304-528 | Unnamed ditch (Br 95 JD11, 330th St NE) to unnamed ditch (Br 51 JD11, 340th St | 0.8 |
| Unnamed Ditch | 09020304-529 | Unnamed ditch to unnamed ditch | 2 |
| Unnamed Ditch | 09020304-530 | Unnamed ditch to Mud R | 1.54 |
| Unnamed Ditch | 09020304-531 | Unnamed ditch to Lost R | 0.84 |
| Unnamed Ditch | 09020304-532 | Lost R to Unnamed ditch | 2.67 |
| Unnamed Ditch | 09020304-533 | Unnamed ditch to Unnamed ditch | 2.47 |
| Judicial Ditch 11 (Lost River Pool) | 09020304-535 | Unnamed ditch (Mud River) to unnamed ditch (Br 194 JD11) | 4 |
| Judicial Ditch 13 | 09020304-538 | Unnamed ditch (195th St NE) to Unnamed ditch (200th St NE) | 0.5 |
| Judicial Ditch 13 | 09020304-539 | Unnamed ditch to T154 R40W S15, west | 1.01 |
| Unnamed Ditch (Mud River Pool) | 09020304-542 | Unnamed ditch to Mud R (Agassiz Pool) | 2.33 |
| Webster Creek | 09020304-544 | Unnamed ditch to Agassiz Pool | 4.47 |
| Webster Creek (Agassiz Pool) | 09020304-545 | Agassiz Pool portion to Mud R | 2.24 |
| County Ditch 21 | 09020304-547 | Unnamed ditch to Unnamed ditch | 0.48 |
| Unnamed ditch (Br 1 CD20) | 09020304-553 | CD 27 to CD 20 | 1.43 |
| **Totals:** | | **23 Reaches** | **56.62** |

The low percentage of assessed stream miles is due to the following factors:

- Aquatic life assessments of channelized reaches were deferred until after the adoption of TALU standards. Assessment statistics were compiled for conventional water chemistry parameters using existing standards. Water quality problems (DO, *E. coli*, and turbidity) and low index of biotic integrity (IBI) scores were identified in some of the reaches and will help prioritize protection efforts.

- Approximately 24 miles of stream assessment units in the Thief River Watershed lie wholly within pools and impoundments.
- Monitoring efforts have been focused on sites located near pour points of 10-digit HUCs. Upstream Assessment Unit Identifier (AUIDs) are typically not sampled unless problems are found at the pour point or water quality problems are suspected in the upstream reaches.
- Several ditch systems were split into numerous assessment units. Monitoring results from primary monitoring sites were only applied to relatively small assessment units in some cases (particularly Marshall CD 20, JD11, and the JD30/18/13 drainage system).
- Some of the assessment units are county road ditches that have not been of interest to local, long-term monitoring programs.

Water chemistry data was assessed for this report in 2015 by applying existing (*E. coli*, pH, DO, un-ionized ammonia) and proposed (TSS, TP, BOD, DO Flux) state water quality standards to data collected during the years of 2005 through 2014. The full results of this assessment are summarized in Tables 2-5 and 2-6.

**Table 2-4. Impaired Waterways of the Thief River Watershed on the 2014303(d) List of Impaired Waters**

| Name | Reach | HUC/AUID Code | Impairment | Listed | Addressed in the TMDL? |
|---|---|---|---|---|---|
| Thief River | Agassiz Pool to Red Lake River | 09020304-501 | Aquatic Life – Turbidity | 2006 | Yes |
| ~~Thief River~~ | ~~Agassiz Pool to Red Lake River~~ | ~~09020304-501~~ | ~~Aquatic Life – Low Dissolved Oxygen~~ | ~~2006~~ | No** |
| ~~Thief River~~ | ~~Thief Lake to Agassiz Pool~~ | ~~09020304-504~~ | ~~Aquatic Life – Unionized Ammonia~~ | ~~2006~~ | No** |
| ~~Thief River~~ | ~~Thief Lake to Agassiz Pool~~ | ~~09020304-504~~ | ~~Aquatic Recreation – *Escherichia coli*~~ | ~~2006~~ | No** |
| Moose River | Headwaters to Thief Lake | 09020304-505 | Aquatic Life – Low Dissolved Oxygen | 2006 | No* |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | Aquatic Life – Low Dissolved Oxygen | 2008 | No* |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | Aquatic Recreation - *Escherichia coli* | 2014 | Yes |
| ~~Branch A of JD21~~ | ~~Unnamed ditch to Moose River~~ | ~~09020304-555~~ | ~~Aquatic Recreation - *Escherichia coli*~~ | ~~2014~~ | No** |
| *A lack of flow was determined to be the primary cause of this dissolved oxygen impairment instead of a pollutant. No TMDLs were established for this particular impairment. | | | | | |
| ** Recent data shows that this reach is no longer violating the water quality standard for which it was listed. The reach has been recommended for delisting. | | | | | |

Data collected in the years 2003 through 2012 was analyzed for the 2013 assessment and the 2014 303(d) List of Impaired Waters. Recent monitoring data shows that four of the water quality impairments within the Thief River Watershed on the 2014 EPA 303(d) List of Impaired Waters continue to violate water quality standards. The number of official water quality impairments in the Thief River

Watershed has been reduced after several reaches were recommended for delisting (Table 2-4) using recent data.

Figure 2-3 displays the locations of the current impairments. The Moose River remains impaired by low DO. The Mud River remains impaired by low DO and high *E. coli* concentrations. An *E. coli* TMDL for the Mud River was developed. The Thief River downstream of Agassiz Pool is listed as impaired by high turbidity. The MPCA's new TSS standard (30 mg/l for the Central Nutrient Region) was used to develop a TMDL to address the turbidity impairment. Data analysis revealed that sufficient base flow is needed in the Moose River to maintain acceptable DO levels. Data indicates this to be the case for the Mud River DO levels as well. Therefore, no TMDLs will be developed for these two low DO impairments.

*E. coli* concentrations in in Branch A of JD21 (09020304-555) has shown enough improvement to meet the Minnesota water quality standards for the protection of aquatic recreation, after the addition of sampling data that was collected in 2013, 2014, and 2015. The June geometric mean of *E. coli* data collected from this reach through 2012 was 188.4 MPN/100ml, which triggered the impairment. The June geometric mean decreased to 128 MPN/100 ml after 2014 sampling and decreased further to 102.6 MPN/100 ml after 2015 sampling. After 2016 sampling, the June geomean dropped further, to 99.5 MPN/100ml.

The Thief River between Agassiz Pool and the Red Lake River (09020304-501) was listed as impaired by low DO on the 2006 303(d) List of Impaired Waters. It was delisted during the 2013 assessment due to satisfactory assessment of discrete monitoring data, along with fish and macroinvertebrate data that indicated that the reach was sufficiently supporting aquatic life (Figure 2-2). Data from DO loggers suggests that the overall frequency of low DO concentrations in the Thief River is higher than what discrete data suggests. DO loggers captured more violations of the standard than regular discrete sampling because they record the true daily minimum DO levels that occur during the early morning, prior to work hours. The continuous DO record is significantly influenced by a high rate of low DO concentrations measured during the 2012 monitoring season when flows were unusually low. The high quality direct measurements of fish and macroinvertebrate biotic integrity override the contradictory DO record by proving that the river is supporting aquatic life.

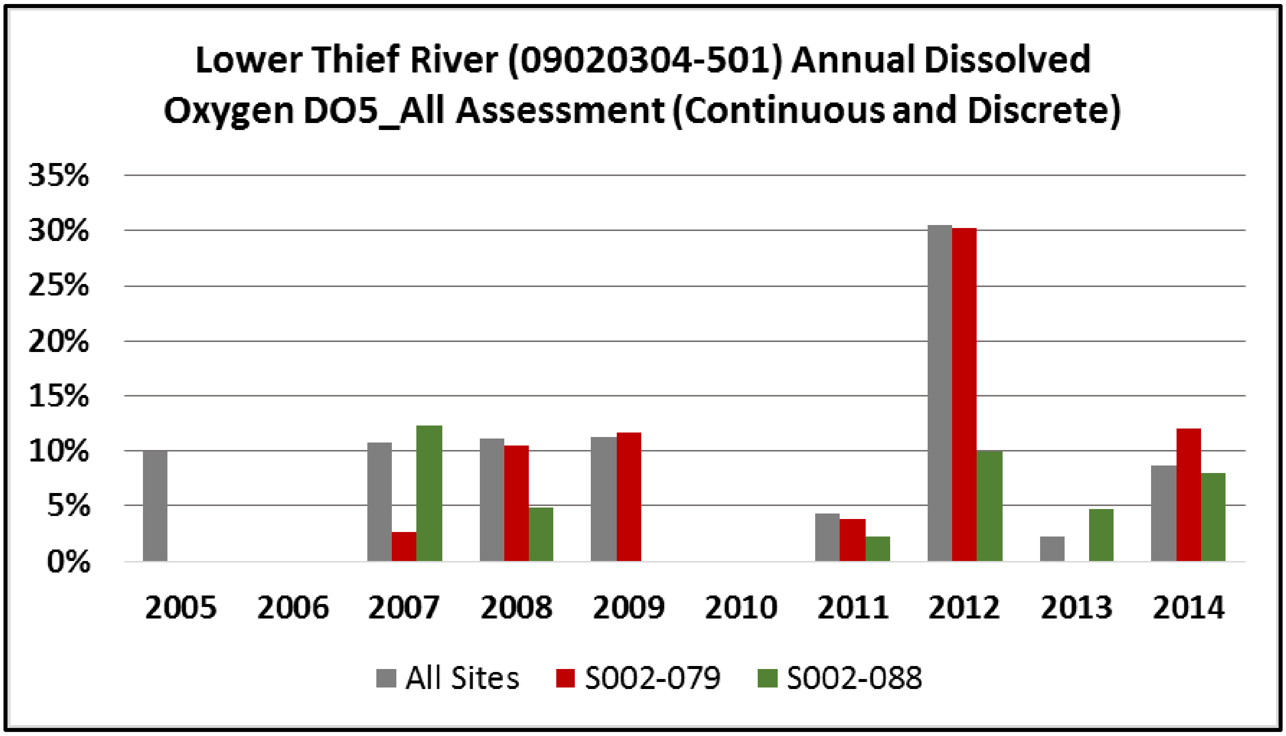


Figure 2-2. Yearly rates at which the DO standard is violated in the lower Thief River (09020304-501)

Section 2.5, Protection Considerations, includes information about which reaches are closest to being restored and which reaches are most in danger of becoming impaired.

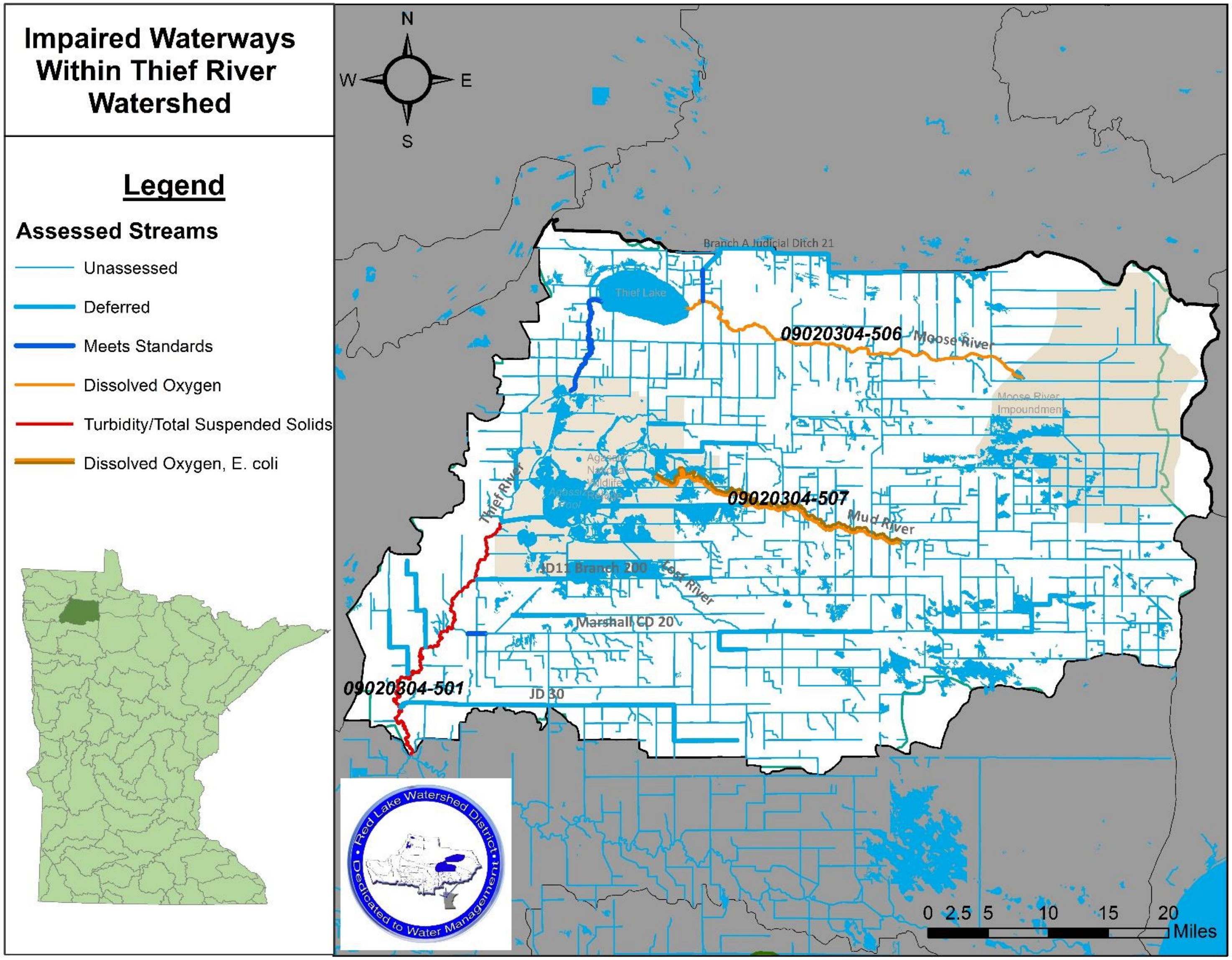


Figure 2-3. Impaired waters in the Thief River Watershed (after Branch A of JD21 *E. coli* delisting)

**Table 2-5. Results of an assessment of 2007-2016 Water Quality Data (Part 1)**

| River/ Stream/ Ditch | AUID (Last 3 Digits) | Reach Description | Miles | Days With Data | Fish IBI | Macro-invertebrate IBI | Total Suspended Solids | Eutrophication (TP & Chl-a, DO Flux, BOD, or pH) | Un-ionized Ammonia | Dissolved Oxygen | E. coli Bacteria | Better Since the 2013 Assessment | Worse Since the 2013 Assessment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thief River | 501 | Agassiz Pool to Red Lake R | 21.96 | 1309 | Sup | PI | Imp | Sup | Sup | PI | Sup | E. coli, DO5_All | DO12, DO7 |
| Thief River | 504 | Thief Lk to Agassiz Pool | 7.9 | 612 | Sup | Sup | Sup | Sup | Sup | Sup | Sup | E. coli | |
| Moose River | 505 | Headwaters to Thief Lk | 23.35 | 341 | PI | Sup | Sup | Sup | Sup | Imp | Sup | | DO, TSS |
| Mud River | 507 | Headwaters to Agassiz Pool | 20.01 | 817 | Sup | PI | PI | PI | Sup | Imp | Imp | E. coli | |
| Unnamed Ditch (Judicial Ditch ~~18~~ 30) | 509 | T154 R42W S14, east line (JD30) to Thief R | 8.45 | 244 | PI | IF | Sup | Sup | Sup | PI | Sup | | DO |
| County Ditch 20 | 510 | Unnamed ditch to Thief River | 0.95 | 2 | IF | IF | IF | IF | IF | IF | IF conc | | |
| Unnamed Ditch (Ditch 200) | 511 | Unnamed ditch to unnamed ditch | 5 | 299 | PI | PI | Sup | Sup | Sup | PI | Sup | DO | |
| Unnamed Ditch (Ditch 200) | 512 | Unnamed ditch (Upstream of 180th Ave NE) to Thief River | 0.11 | 0 | IF | IF | IF | IF | IF | IF | IF | | |
| County Ditch 20 | 513 | Unnamed ditch to CD 32 | 8.4 | 31 | Sup | Sup | IF | IF | IF | PI | IF concern | | DO |
| County Ditch 20 | 515 | CD 32 to CD 31 | 2 | 1 | IF | IF | IF | IF | IF | IF | IF concern | | E. coli |
| County Ditch 21 | 517 | Unnamed ditch to Unnamed ditch | 4.98 | 1 | IF | IF | IF | IF | IF | IF | IF concern | | E. coli |
| County Ditch 20 | 519 | Unnamed ditch (Branch A CD 30) to Unnamed ditch (Branch D CD 20) | 1 | 655 | Sup | Sup | Sup | Sup | Sup | Sup | Sup | TSS, DO | |
| Judicial Ditch 11 | 521 | Unnamed ditch (Moose R Impoundment South Pool Outlet) to unnamed ditch (Benville Rd) | 0.98 | 32 | IF | IF | IF | IF | IF | IF | IF | | |
| Judicial Ditch 11 | 522 | Unnamed ditch (Benville Rd) to Unnamed ditch | 1.51 | 2 | IF | IF | IF | IF | IF | IF | IF | | |
| Judicial Ditch 11 | 525 | Unnamed ditch to JD 11 (Outpost Rd to Gunpowder Rd) | 0.52 | 1 | IF | IF | IF | IF | IF | IF | IF | | |
| Judicial Ditch 11 | 526 | Unnamed ditch to Mud R | 4.39 | 2 | IF | IF | IF | IF | IF | IF | IF | | |
| Unnamed Ditch | 527 | Unnamed ditch to unnamed ditch | 7.9 | 0 | Sup | IF | IF | IF | IF | IF | IF | | |
| Unnamed Ditch | 534 | Unnamed ditch to unnamed ditch | 2 | 103 | IF | IF | Sup | IF | IF | PI | IF | | |
| JD11 (Lost R Pool) | 535 | Mud R to Br 194 JD 11 | 4.03 | 104 | IF | IF | IF | IF | IF | Sup | IF | | |
| Judicial Ditch 11 | 536 | Unnamed ditch (Branch 194 of JD11) to Thief River | 9.7 | 84 | Sup | Sup | IF | IF | IF | IF | IF | | |
| Unnamed ditch | 537 | Unnamed ditch to JD 13 | 3.4 | 0 | PI | PI | IF | IF | IF | IF | IF | | |
| Judicial Ditch 13 | 540 | T154 R40W S16, east line to JD 18 | 3.01 | 0 | PI | Sup | IF | IF | IF | IF | IF | | |
| Judicial Ditch 18 | 541 | T154 R40W S27, midpoint to T154 R42W S | 12.5 | 0 | Sup | IF | IF | IF | IF | IF | IF | | |

| | |
|---|---|
| IF | Insufficient data. Either there is no data, or the data doesn't meet minimum requirements for an assessment. |
| Imp | Impaired. The reach is officially listed as impaired for this parameter and 2005-2014 data supports that listing. |
| PI | Potentially impaired reach in need of Protection efforts. 2005-2014 data provides evidence that the reach is too frequently violating the standard for this specific parameter, but the reach is not currently listed as impaired. It may have been deferred until TALU standard adoption, the standard may have been newly adopted in 2015, water quality conditions may have changed, or good IBI scores may override poor water chemistry data. |
| Sup | Supporting. Current data indicates that the reach is meeting the standard for this parameter and supports the respective designated use. |

**Table 2-6. Results of an assessment of 2007-2016 Water Quality Data (Part 2)**

| River/ Stream/ Ditch | AUID (Last 3 Digits) | Reach Description | Miles | Days With Data | Fish IBI | Macro-invertebrate IBI | Total Suspended Solids | Eutrophication (TP & Chl-a, DO Flux, BOD, or pH) | Un-ionized Ammonia | Dissolved Oxygen | E. coli Bacteria | Better Since the 2013 Assessment | Worse Since the 2013 Assessment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unnamed Ditch (Br1 of JD11) | 543 | Unnamed ditch (Br15 JD11) to unnamed ditch (Br 7 JD11) | 1.98 | 0 | Sup | IF | IF | IF | Sup | IF | IF | | |
| County Ditch 20 | 546 | Unnamed ditch to Unnamed ditch | 3.02 | 0 | IF | IF | IF | IF concern | IF | IF | IF concern | | |
| County Ditch 20 | 548 | Unnamed ditch to unnamed ditch | 5.4 | 0 | PI | Sup | IF | IF | IF | IF | IF concern | | |
| Unnamed Ditch (Jelle Rd Ditch) | 549 | Unnamed ditch to CD 30 | 4 | 0 | Sup | IF | IF | IF | IF | IF | IF concern | | |
| Unnamed Ditch (Lat 1, JD23) | 550 | Headwaters to Thief R | 5.8 | 209 | PI | PI | IF | IF | IF | IF | IF | | |
| Unnamed Ditch (Main JD23) | 551 | Unnamed ditch to Thief River | 4.6 | 1 | PI | PI | IF | IF | IF | IF | IF | | |
| County Ditch 27 | 552 | Unnamed ditch to unnamed ditch | 4 | 1 | PI | Sup | IF | IF | IF | IF | IF | | |
| County Ditch 32 | 554 | Unnamed ditch to CD 20 | 2.5 | 1 | PI | PI | IF | IF | IF | IF | IF | | |
| Unnamed Ditch (Branch A of JD21) | 555 | Unnamed ditch to Moose R | 1.7 | 12 | Sup | Sup | Sup | Sup | Sup | Sup | Sup | E. coli | |
| Unnamed Ditch (Branch A of JD21) | 556 | Unnamed ditch to Unnamed ditch | 5.72 | 0 | IF | IF | IF | IF | IF | IF | IF | | |
| Unnamed Ditch | 557 | Unnamed ditch to unnamed ditch | 7 | 0 | Sup | Sup | IF | IF | IF | IF | IF | | |
| Unnamed Ditch (Marshall CD 35) | 558 | Unnamed ditch to Thief River | 2.33 | 0 | PI | IF | IF | IF | IF | IF | IF | | |
| Unnamed Ditch (Br 2 JD11) | 559 | Headwaters to Mud Lk | 6.3 | 0 | Sup | PI | IF | IF | IF | IF | IF | | |

| | |
|---|---|
| IF | Insufficient data. Either there is no data, or the data doesn't meet minimum requirements for an assessment. |
| IF concern | Insufficient data to assess the reach, but some of values collected fail to meet the water quality standard. Target this reach for additional monitoring. |
| PI | 2007-2016 data indicates that the reach is not meeting the standard for this parameter, but it the reach is not officially listed as impaired. |
| Imp | The reach is officially listed as impaired for this parameter. |
| Sup | Current data indicates that the reach is meeting the standard for this parameter. |

## 2.1.2 Lakes

**Table 2-7 Assessment status of Thief Lake**

| HUC-10 Subwatershed | Lake ID | Lake | Aquatic Life | Aquatic Recreation |
|---|---|---|---|---|
| Thief River 0902030402 | 45-0001-00 | Thief Lake | Insufficient Information | Insufficient Information |

Thief Lake is the only lake in the Thief River Watershed that has been addressed by an MPCA water quality assessment (Table 2-7). The lake drains land from the Northern Minnesota Wetland and Red River Valley ecoregions, and neither has dedicated standards for lakes. However, standards from the North Central Hardwood Forests are most commonly applied to lakes and reservoirs in the Red River Valley. Land use in the lake's immediate watershed (all land and water area that drains to the Thief Lake outlet) is 76% water/wetland, 9% forest, and 10% agricultural. Thief Lake is a shallow lake with a maximum depth of 7.4 feet. Access to the lake is available through a variety of accesses. However, much of the lake is restricted access for hunting and waterfowl nesting because the lake lies entirely within the Thief Lake WMA. In any year, aquatic recreation is limited by the shallow depths of the lake, severe water level fluctuations, and limited access to the lake due to hunting and waterfowl nesting. The 2012 drought severely affected water levels. Wildlife viewing and hunting are the primary activities for this basin. It is not used for recreational swimming. A landowner at one of the stakeholder meetings stated that the lake supported a fishery at one time – before it was originally drained by JD21.

In the 2012 Clean Water Act Reporting Cycle Stream Assessment Transparency Documentation, the MPCA staff provided the following comments about the status of Thief Lake:

- State agencies have collected data in Thief Lake in 2007, 2011, and 2012. (Two of the 2012 data points (August and September) were taken from the Moose River where it enters Thief Lake because low water levels prevented sampling of the lake. Those data points should be excluded from data that is used to assess the lake.)
- All the Secchi depths in 2011 and 2012 were limited by the depth of the lake (less than 1.2 meters). In other words, the water was clean enough and shallow enough to see the bottom of the lake during all the Secchi disk measurements.
- Monitoring data compares favorably to the deep and shallow North Central Hardwood Forests standards. The assessment concluded that the available data shows that the lake meets aquatic recreation use standards.
- No chloride concentrations exceeded 3.8 mg/l and several concentrations were below the lab's detection limit. Aquatic life is not threatened by high chloride levels in this lake.
- No biological data was available to determine if the lake was supporting aquatic life use.

## 2.2 Water Quality Trends

The direct measurement of water quality trends and other statistical improvements can be very challenging due to variables such as annual weather patterns, the timing of sample collection, and the quantity of data that is available. Stating a specific amount of change (%) for an individual parameter for a particular season/month overstates the precision of a monitoring data set, and is subject to change with every new sample that is collected. Therefore, this report will refrain from listing specific rates of change and, instead, simply display the direction of existing trends that exceed a statistical threshold with a specified level of confidence. The relative strength of trends is indicated by the Mann-Kendall Statistics in Tables 2-8 through 2-16.

Mann-Kendall trend analysis was applied to those monitoring sites within the Thief River Watershed with at least 10 years of sampling data, the locations of which are shown in Figure 2-4. The method was applied on an annual and a seasonal basis to identify trends. Some of the stronger trends were also plotted within time series charts with trends shown with a regression trendline. To determine that a trend exists in a set of data, a threshold Z (absolute) value of 1.282 (90% confidence for a standard normal distribution) was used. Z values greater than 1.282 indicated a significant upward trend with some confidence. Z values lower than -1.282 indicated a significant downward trend. All data available in EQuIS as of early 2015 was included in the analysis. Monthly/seasonal/annual averages were calculated for each year of data using a pivot table. Those averages were then used for the trend analysis. Summaries of this analysis are shown in Tables 2-8 through 2-16. Some trends are displayed visually in Figures 2-5 through 2-10.

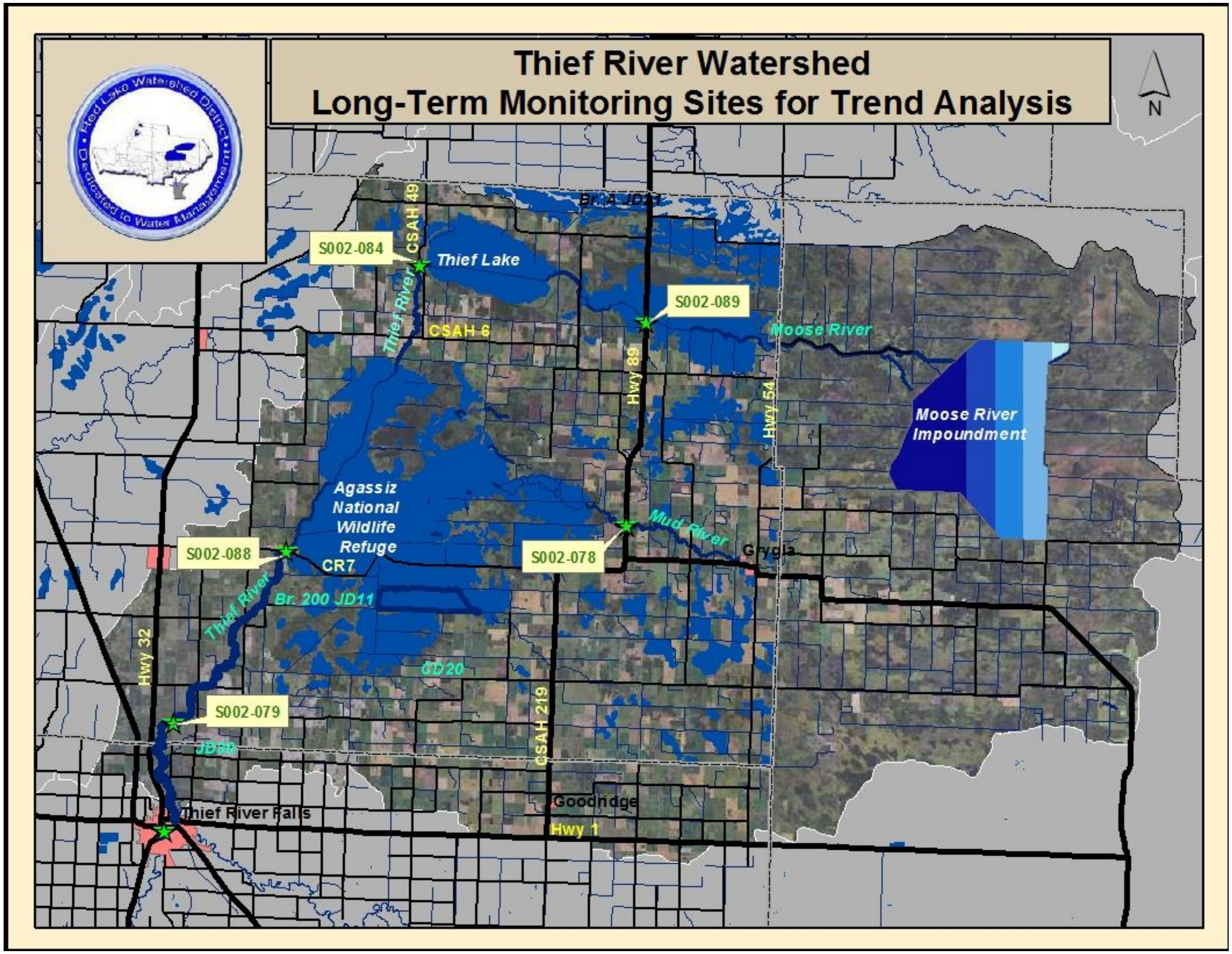



Figure 2-4. Long-term monitoring sites used for trend analysis

Table 2-8. Total suspended solids annual trend statistics

| Trend Analysis of April - September Annual Average Total Suspended Solids Data | | | | | | |
|---|---|---|---|---|---|---|
| River | Site # | Road Crossing | Period | Mann-Kendall Statistic | Confidence Factor | Trend Description |
| Thief River | S002-079 | 140th Ave NE | 1994-2014 | 7 | 57.2% | No Trend |
| Thief River | S002-088 | CSAH 7 | 1994-2014 | 88 | 99.6% | Increasing |
| Thief River | S002-084 | CSAH 49 | 1994-2014 | -57 | 95.6% | Decreasing |
| Mud River | S002-078 | Hwy 89 | 1994-2014 | -16 | 67.5% | Stable |
| Moose River | S002-089 | Hwy 89 | 1998-2014 | -56 | 99.0% | Decreasing |

Table 2-9. *E. coli* bacteria annual trend statistics

| Trend Analysis of April - October Annual Average E. coli Bacteria Data | | | | | | |
|---|---|---|---|---|---|---|
| River | Site # | Road Crossing | Period | Mann-Kendall Statistic | Confidence Factor | Trend Description |
| Thief River | S002-079 | 140th Ave NE | 1994-2014 | 1 | 50.0% | No Trend |
| Thief River | S002-088 | CSAH 7 | 1994-2014 | 7 | 70.4% | No Trend |
| Thief River | S002-084 | CSAH 49 | 1994-2014 | -19 | 94.6% | Probably Decreasing |
| Mud River | S002-078 | Hwy 89 | 1994-2014 | 1 | 50.0% | No trend |
| Moose River | S002-089 | Hwy 89 | 1998-2014 | -23 | 97.5% | Decreasing |

Table 2-10. Dissolved oxygen annual trend statistics

| Trend Analysis of April - October Annual Average Dissolved Oxygen Data | | | | | | |
|---|---|---|---|---|---|---|
| River | Site # | Road Crossing | Period | Mann-Kendall Statistic | Confidence Factor | Trend Description |
| Thief River | S002-079 | 140th Ave NE | 1994-2014 | 15 | 64.4% | No Trend |
| Thief River | S002-088 | CSAH 7 | 1994-2014 | 66 | 94.7% | Probably Increasing |
| Thief River | S002-084 | CSAH 49 | 1994-2014 | 101 | 99.4% | Increasing |
| Mud River | S002-078 | Hwy 89 | 1994-2014 | -4 | 53.0% | Stable |
| Moose River | S002-089 | Hwy 89 | 1998-2014 | 131 | 99.9% | Increasing |

Table 2-11. Total phosphorus annual trend statistics

| Trend Analysis of April - October Annual Average Total Phosphorus Data | | | | | | |
|---|---|---|---|---|---|---|
| River | Site # | Road Crossing | Period | Mann-Kendall Statistic | Confidence Factor | Trend Description |
| Thief River | S002-079 | 140th Ave NE | 1994-2014 | 29 | 77.0% | No Trend |
| Thief River | S002-088 | CSAH 7 | 1994-2014 | -21 | 35.3% | Stable |
| Thief River | S002-084 | CSAH 49 | 1994-2014 | -56 | 88.8% | Stable |
| Mud River | S002-078 | Hwy 89 | 1994-2014 | -96 | 96.3% | Decreasing |
| Moose River | S002-089 | Hwy 89 | 1998-2014 | -194 | 100.0% | Decreasing |

**Thief River**

The strongest trend identified in the Thief River downstream of Agassiz NWR was an increasing trend in TSS concentrations during the month of August that occurred at both sites (S002-079 and S002-088) that were analyzed (Table 2-12). Compared to the 1.282 Z-value threshold, the August Z value for average August TSS concentrations at S002-079 was 1.642. The Z value increases to 2.737 (more than twice as high as the threshold) if yearly August maximum TSS concentrations are analyzed. Drawdowns of Agassiz Pool have been occurring regularly in the month of August in recent years. The scouring and flushing of sediment from Agassiz Pool has also contributed to increased TSS concentrations.

Table 2-12. Water quality trends in the Thief River at 140th Avenue Northeast (S002-079)

| Trends of Seasonal Averages Using Seasonal Mann-Kendall Analysis | | | | |
|---|---|---|---|---|
| **Thief River<br>140th Ave NE Crossing<br>Site S002-079/05076000** | **Total Suspended Solids** | **Dissolved Oxygen** | **Total Phosphorus** | **E. coli** |
| Years | 1994-2014 | 1992-2014 | 1992-2014 | 2005-2014 |
| Annual Average | X | X | X | X |
| April | ↓ (green) | X | ↓ (green) | ↑ (red) |
| May | X | X | X | X |
| June | X | X | X | X |
| July | X | X | X | X |
| August | ↑ + (red) | X | X | X |
| September | X | ↑ (green) | X | X |
| October | X | ↓ (red) | X | X |
| November - March | X | X | X | No data |

| | |
|---|---|
| X | = No Trend |
| ↑ (green) | = Upward Trend (Getting Better) |
| ↓ (red) | = Downward Trend (Getting Worse) |
| ↑ + (red) | = Strong Upward Trend (Getting Significantly Worse) |
| ↑ (red) | = Upward Trend (Getting Worse) |
| ↓ (green) | = Downward Trend (Improvement) |

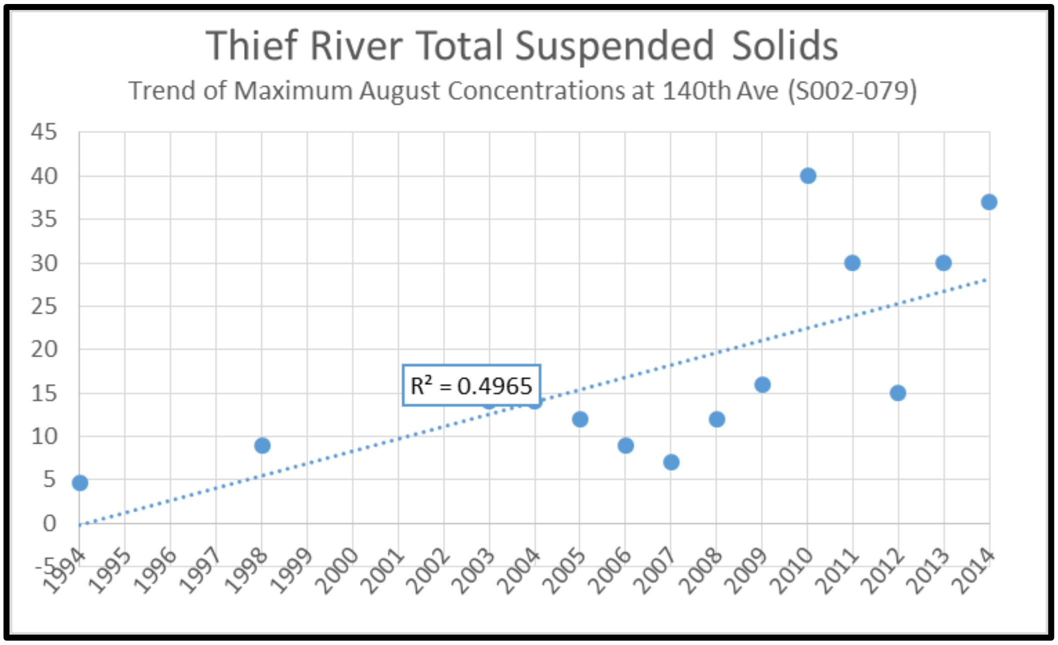



**Figure 2-5. Time series plot and regression analysis of maximum August TSS concentrations in the Thief River at 140th Avenue Northeast**

**Table 2-13. Water quality trends in the Thief River at CSAH 7 (S002-088)**

| Trends of Seasonal Averages Using Seasonal Mann-Kendall Analysis | | | | |
|---|---|---|---|---|
| **Thief River CSAH 7 Crossing Site S002-088** | **Total Suspended Solids** | **Dissolved Oxygen** | **Total Phosphorus** | **E. coli** |
| Years | 1998-2014 | 1984-2014 | 1984-2014 | 2005-2014 |
| Annual Average | Strong Upward Trend (Getting Significantly Worse) | Upward Trend (Getting Better) | X | X |
| April | X | X | X | Upward Trend (Getting Worse) |
| May | X | X | Downward Trend (Improvement) | X |
| June | Upward Trend (Getting Worse) | X | X | X |
| July | X | X | X | X |
| August | Strong Upward Trend (Getting Significantly Worse) | X | X | X |
| September | Upward Trend (Getting Worse) | Upward Trend (Getting Better) | Upward Trend (Getting Worse) | X |
| October | X | X | X | X |
| November - March | X | X | Upward Trend (Getting Worse) | No data |

X = No Trend

= Upward Trend (Getting Better)

= Downward Trend (Getting Worse)

= Upward Trend (Getting Worse)

= Downward Trend (Improvement)

= Strong Upward Trend (Getting Significantly Worse)

= Strong Downward Trend (Significant Improvement)

There is a long-term monitoring site on the Thief River near the Thief Lake outlet. The water quality improvements at this site have been impressive. Two impairments (*E. coli* and un-ionized ammonia) were removed from the 303(d) List of Impaired Waters during the 2013 assessment process. The trends that were identifiable (Table 2-14) all presented good news about water quality in the Thief River downstream of Thief Lake, including reductions in TSS, increased DO, decreased TP, and decreased *E. coli*.

**Table 2-14. Water quality trends in the Thief River at CSAH 49 (S002-084)**

| **Trends of Seasonal Averages Using Seasonal Mann-Kendall Analysis** | | | | |
|---|---|---|---|---|
| **Thief River CSAH 49 Crossing Site S002-084** | **Total Suspended Solids** | **Dissolved Oxygen** | **Total Phosphorus** | **E. coli** |
| Years | 1994-2014 | 1984-2014 | 1984-2014 | 2005-2014 |
| Annual Average | ↓ | ↑ + | ↓ - | ↓ |
| April | X | ↑ + | ↓ | X |
| May | X | ↑ + | ↓ | X |
| June | X | X | X | X |
| July | ↓ - | X | X | X |
| August | ↓ | ↑ | X | ↓ |
| September | X | ↑ + | X | X |
| October | ↓ - | X | X | X |
| November - March | X | X | X | No data |

| | |
|---|---|
| X | = No Trend |
| ↑ (green) | = Upward Trend (Getting Better) |
| ↓ (red) | = Downward Trend (Getting Worse) |
| ↑ (red) | = Upward Trend (Getting Worse) |
| ↓ (green) | = Downward Trend (Improvement) |
| ↑ + (green) | = Strong Upward Trend (Getting Significantly Better) |
| ↑ + (red) | = Strong Upward Trend (Getting Significantly Worse) |
| ↓ - (green) | = Strong Downward Trend (Significant Improvement) |

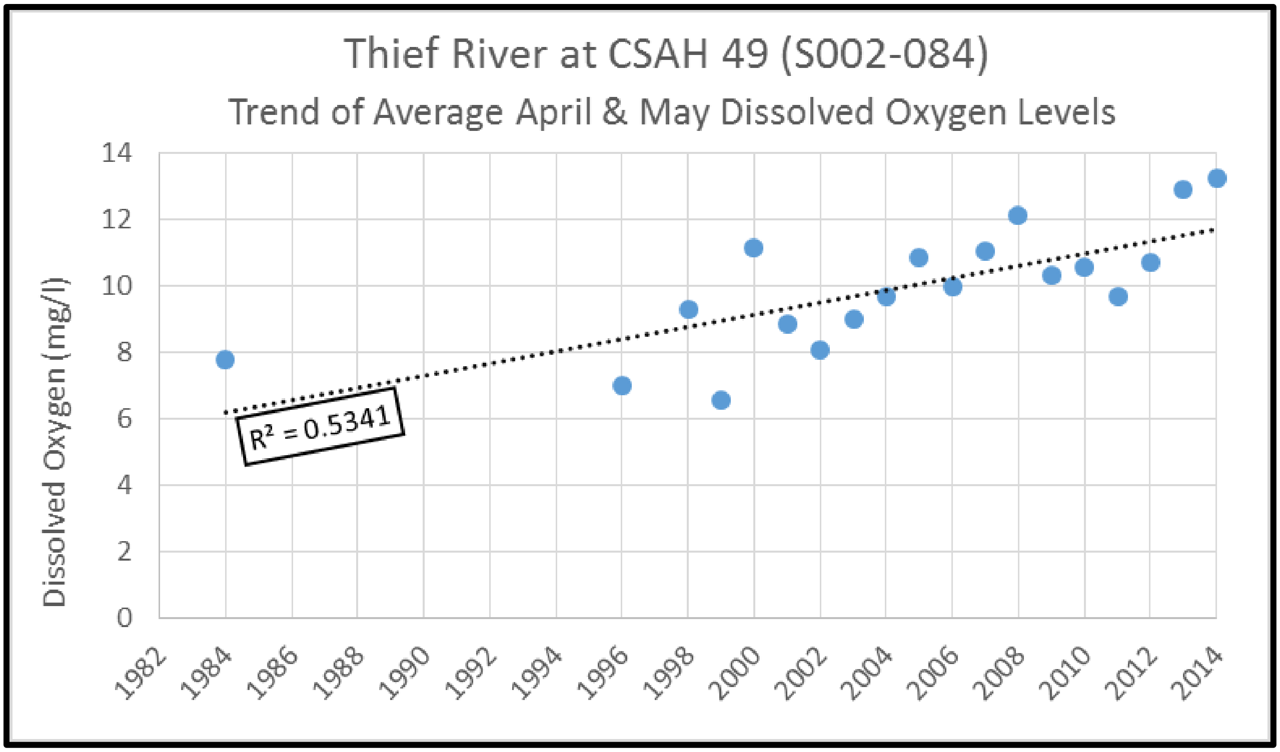



**Figure 2-6. Time series plot and regression analysis of annual average dissolved oxygen concentrations in the Thief River at CSAH 49**

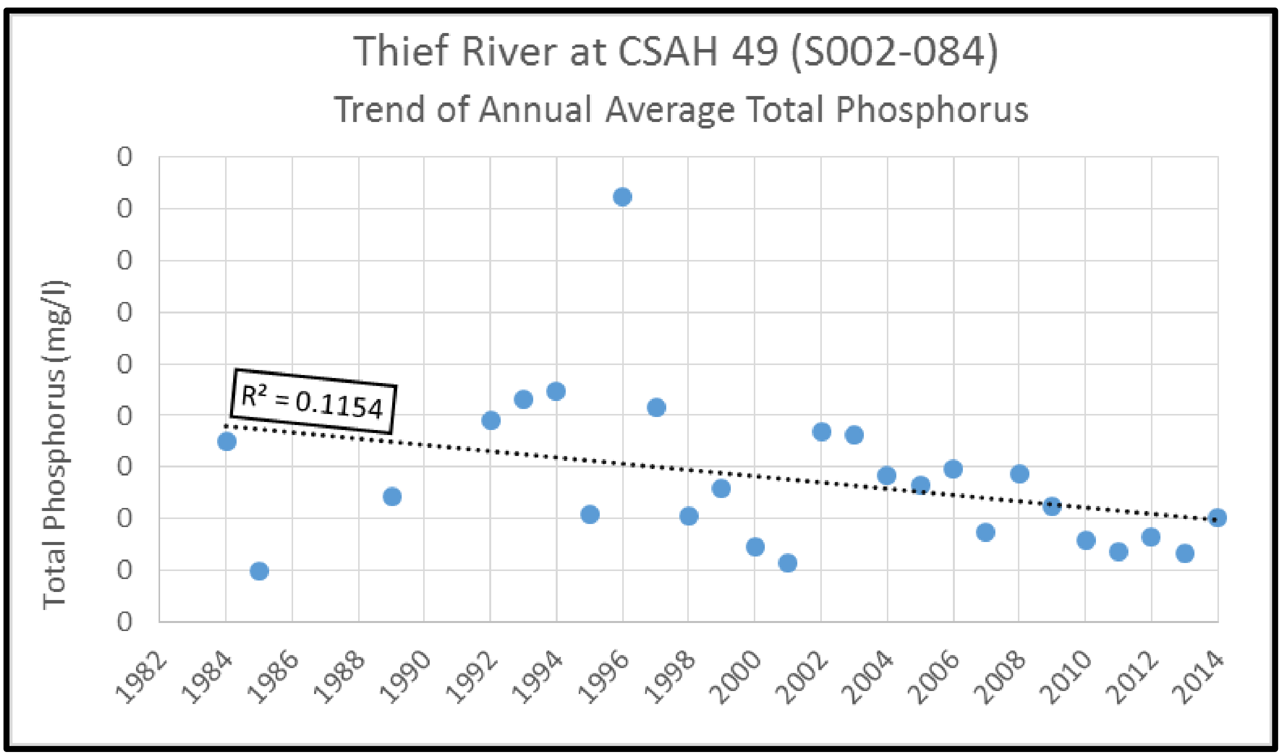



**Figure 2-7. Time series plot and regression analysis of annual average total phosphorus concentrations in the Thief River at CSAH 49**

**Moose River**

Water quality conditions within the Moose River appear to be improving in multiple ways (Table 2-15). TP, *E. coli*, and TSS pollutant concentrations appear to be decreasing during many months of the year. DO readings, on average, have improved over the last 30 years.

**Table 2-15. Water quality trends in the Moose River at Highway 89 (S002-089)**

| Trends of Seasonal Averages Using Seasonal Mann-Kendall Analysis | | | | |
|---|---|---|---|---|
| **Moose River Highway 89 Crossing Site S002-089** | **Total Suspended Solids** | **Dissolved Oxygen** | **Total Phosphorus** | **E. coli** |
| Years | 1998-2014 | 1984-2014 | 1984-2014 | 2005-2014 |
| Annual Average | ↓ | ↑ + | ↓ | ↓ |
| April | X | X | ↓ | X |
| May | X | X | ↓ | X |
| June | ↓ - | ↑ | X | X |
| July | ↓ - | ↑ | ↓ | X |
| August | ↓ | ↑ | X | X |
| September | X | X | ↓ | X |
| October | ↓ - | X | ↓ | ↓ |
| November - March | X | X | X | No data |
| X = No Trend | | | | |
| ↑ (green) = Upward Trend (Getting Better) | | | | |
| ↓ (red) = Downward Trend (Getting Worse) | | | | |
| ↑ (red) = Upward Trend (Getting Worse) | | | | |
| ↓ (green) = Downward Trend (Improvement) | | | | |
| ↑ + = Strong Upward Trend (Getting Significantly Better) | | | | |
| ↓ - = Strong Downward Trend (Significant Improvement) | | | | |

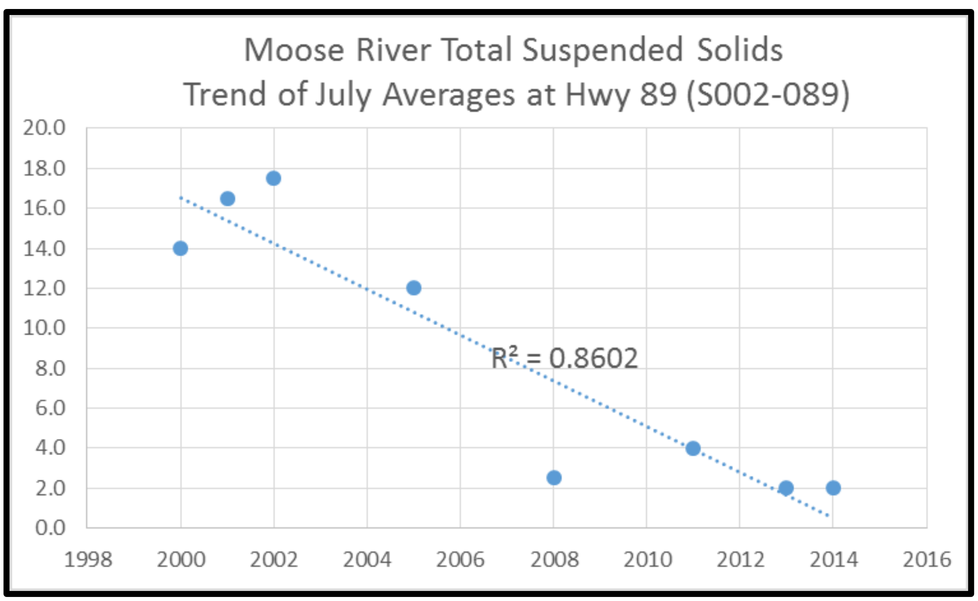



**Figure 2-8. Time series plots and regression analysis of yearly average total suspended solids in the Moose River**

**Mud River**

Water quality within the Mud River appears to be improving. Despite its name, the Mud River meets the North Region 30 mg/l TSS standard. Water quality in the Mud River has been good enough to meet the more protective 15 mg/L standard in recent years. The 15 mg/L standard provides a good "yardstick" against for showing changes in sediment concentrations over time (Figure 2-18). The decreasing trends in TSS in July and August TSS concentrations indicate progress toward reducing sedimentation within Agassiz Pool. A goal for the next 10 years would be to improve conditions enough to achieve a decreasing trend for the spring and early summer months when flows and loads are more significant.

Although the Mud River remains impaired upstream, near Grygla, this specific site (S002-078) has shown improvement and now appears to be meeting the *E. coli* water quality standard. Mann-Kendall analysis indicates that there is a downward trend in September and October, but regression analysis shows that the decrease is not gradual and that the trend is heavily influenced by two years with extraordinarily high concentrations. Table 2-17 shows how monthly geometric mean *E. col* concentrations in the Mud River have changed over time.

If it was not for the 2012 continuous monitoring data collected during a period of very low flow, the reach may have been recommended for a delisting of the DO impairment.

Table 2-16. Water quality trends in the Mud River at the Highway 89 crossing (S002-078)

| Trends of Seasonal Averages Using Seasonal Mann-Kendall Analysis | | | | |
|---|---|---|---|---|
| **Mud River Highway 89 Crossing Site S002-078** | **Total Suspended Solids** | **Dissolved Oxygen** | **Total Phosphorus** | **E. coli** |
| Years | 1994-2014 | 1984-2014 | 1984-2014 | 2005-2014 |
| Annual Average | X | X | ↓ | X |
| April | X | X | X | X |
| May | X | X | X | X |
| June | X | X | X | X |
| July | ↓ | X | X | X |
| August | ↓ | X | ↓ | X |
| September | X | X | X | ↓ |
| October | X | X | X | ↓ |
| November - March | X | X | X | No data |
| X = No Trend | | | | |
| ↑ = Upward Trend (Getting Better) | | | | |
| ↓ = Downward Trend (Getting Worse) | | | | |
| ↑ = Upward Trend (Getting Worse) | | | | |
| ↓ = Downward Trend (Improvement) | | | | |

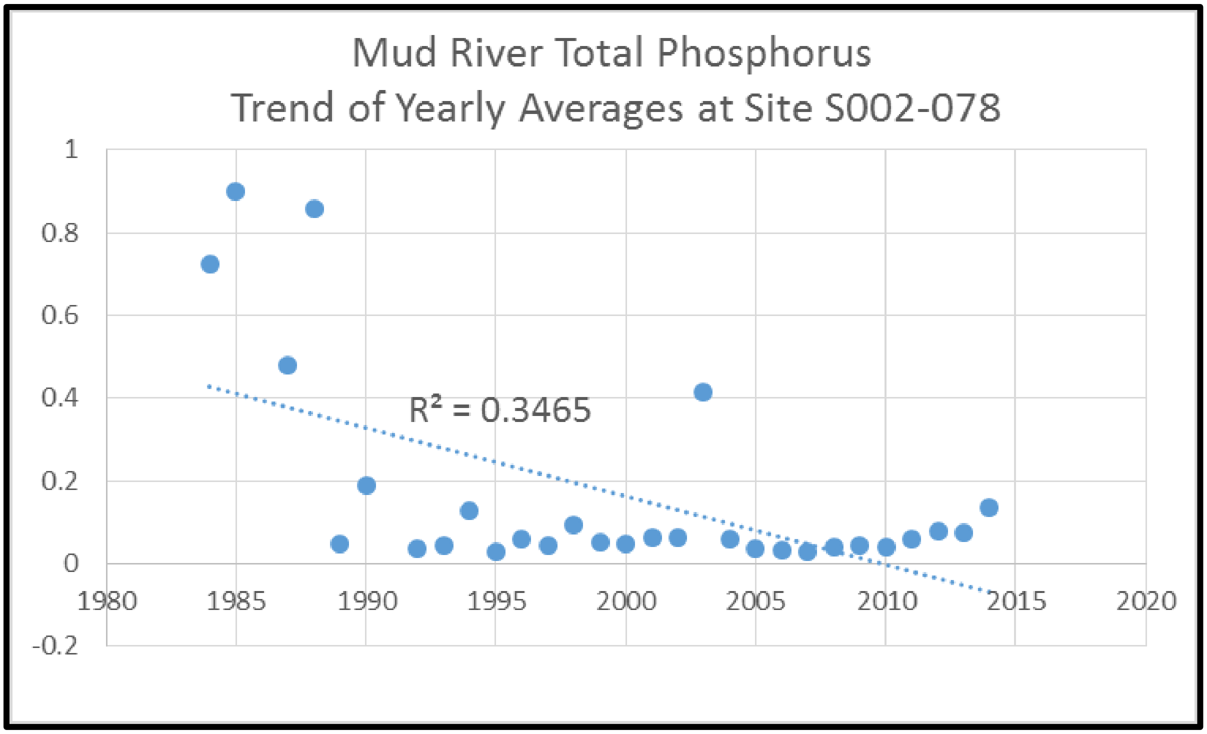



**Figure 2-9. Time series plots and regression analysis of average total phosphorus concentrations in the Mud River**

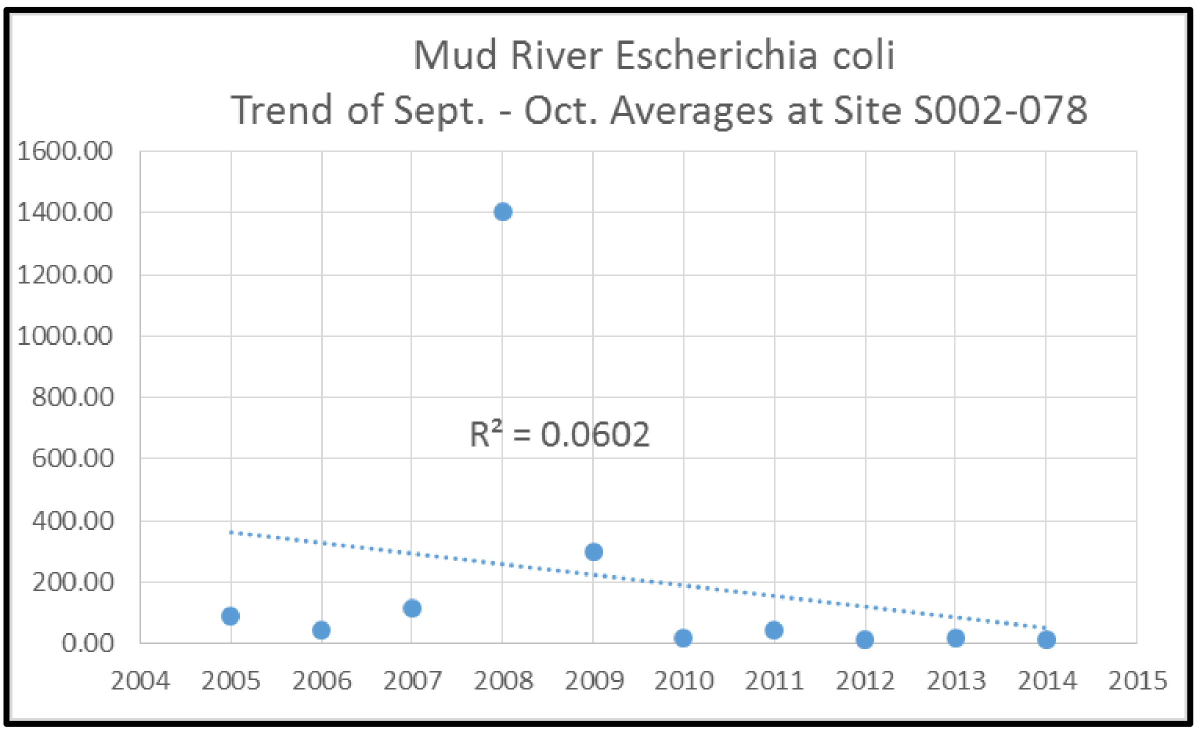



**Figure 2-10. Time series plots and regression analysis of average *E. coli* concentrations in the Mud River**

Table 2-17. History of reach-wide assessment statistics of the Mud River AUID 09020304-507. Formal assessments were conducted in 2007, 2009, and 2013.

| History of Mud River *E. coli* Monthly Geometric Means | | | | | | | |
|---|---|---|---|---|---|---|---|
| Monthly E. coli Geomean 2007-16 Data | Monthly E. coli Geomean 2006-15 Data | Monthly E. coli Geomean 2005-14 Data | Monthly E. coli Geomean 2005-13 Data | Monthly E. coli Geomean 2005-12 Data | Monthly E. coli Geomean 2005-11 Data | Monthly E. coli Geomean 2005-10 Data | Monthly E. coli Geomean 2005-09 Data |
| 14.6 | 14.6 | 16.9 | 16.9 | 16.9 | 17.5 | 14.3 | |
| 29.1 | 27.1 | 27.7 | 27.7 | 25.4 | 24.0 | 29.2 | 29.2 |
| 86.0 | 86.6 | 91.7 | 91.6 | 91.6 | 100.9 | 86.5 | 82.9 |
| **115.39** | **115.37** | **116.4** | **125.6** | **128.7** | **167.8** | 102.8 | 102.8 |
| 101.5 | 87.1 | 78.3 | 78.3 | 82.8 | 109.9 | 101.7 | 105.2 |
| 67.0 | 64.9 | 42.6 | 42.6 | 40.6 | 40.6 | 38.8 | 38.8 |
| **93.8** | **86.7** | **101.3** | **101.3** | **126.2** | **179.0** | **239.9** | **394.7** |

## 2.3 Stressors and Sources

To develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources affecting or threatening them must be identified and evaluated. Biological SID is done for streams with either fish or macroinvertebrate biota impairments, and encompasses both evaluation of pollutants and non-pollutant-related factors as potential stressors (e.g. altered hydrology, fish passage, habitat). Pollutant source assessments are done where a biological SID process identifies a pollutant as a stressor as well as for the typical pollutant impairment listings. Section 3 of this report and Section VI of the Thief River Watershed Monitoring and Assessment Report provide further detail on stressors and pollutant sources.

### 2.3.1 Stressors of Aquatic Life in the Thief River Watershed

None of the water quality impairments identified within the Thief River Watershed were due to poor fish and/or macroinvertebrate communities. However, the reason for the lack of biological impairments was not only that every stream met the requirements for full support of aquatic life. Rather, during the 2013 assessment process, impairment decisions on most waterways in the watershed were deferred until the adoption of TALU standards, to ensure that appropriate standards were applied and proper assessments were performed. Twenty stream/ditch segments were not assessed due to insufficient data, modified channel condition, or their status as limited resource waters.

A full SID Report was not written for the Thief River at this time because there were no formal aquatic life impairments listed during this assessment period. Despite the lack of official biological impairments, there are parts of this watershed in which stressors are known to be affecting aquatic life. Loss of waterbody connectivity, flow regime alteration, lack of in-stream habitat, excess suspended sediment, low DO, elevated ammonia, and pesticide toxicity are potential stressors that were identified in the 2014 Thief River Watershed Monitoring and Assessment Report. Excess suspended sediment can lead to sedimentation and bed loads of sediment that can negatively affect aquatic habitat. Monitoring data shows that three of the reaches fail to meet the water quality standard for DO.

Although they were not used to conduct formal biota assessments, fish and macroinvertebrate indices of biotic integrity (IBI) were calculated and summarized in the 2014 Thief River Watershed Monitoring and Assessment Report. Proactive solutions to potential/probable aquatic life deficiencies can be identified based on those sampling results and observations made during the intensive examination of the watershed that has been conducted over the last decade. Local, state, and federal agencies should continue to identify and address problems until formal water quality assessments are completed.

A lack of connectivity can negatively affect fish IBI ratings. The fish IBI score in the lower Thief River was good, but fish IBI scores appear to be negatively affected upstream of the dams that create the pools in Agassiz NWR and Thief Lake.

Extensive drainage and channelization also affect the quality of in-stream habitat. Extensive drainage can result in flashy flows during runoff events. Storage in impoundments helps moderate flows during runoff events, but the management of flood reduction impoundments can cut off base flows once target water level elevations within the pools are reached. The flashy, high flows that result from the practice of releasing water from impoundments as fast as possible to reach target elevations can increase in-channel erosion rates. Based upon conversations with water management staff, water from spring runoff is discharged from impoundments at high rates because of the importance of quickly reaching summer pool elevations and resetting flood storage capacities. However, the operating plans of impoundments should be examined to identify ways in which the goal of regaining flood storage capacity can be accomplished without causing negative downstream impacts. The water stored between the summer and winter pool elevations could be used to augment late summer flows if it is gradually discharged over the late summer and fall months rather than waiting until October to discharge at a high rate of flow.

**Information on Specific Waterbodies**

The Moose River (0902030401) had either fair or good fish and macroinvertebrate IBI scores with the exception of the 310th Avenue Northeast crossing where IBI scores were poor and stagnant water has resulted in frequent low DO levels. Branch A of JD21 produced satisfactory IBI scores. IBI scores were good at the CSAH 48 crossing of Branch A of JD21. Habitat needs improvement throughout the Moose River Subwatershed. Minnesota Stream Habitat Assessment (MSHA) scores were poor at more than half of the sites in the Moose River Subwatershed and only fair in the other sites.

The upper reach of the Thief River (0902030402) between Thief Lake and Agassiz NWR received a good macroinvertebrate score from the 2011 sampling, which is an indication that in-stream conditions are favorable to aquatic life. However, the fish IBI score was only fair. This is likely due to the absence of connectivity with the downstream reach of the Thief River. Small northern pike were seen during geomorphology work and landowners mentioned catching larger northern pike from the river. So, there is potential for healthy aquatic life in this reach if connectivity can be restored. The riparian and in-stream habitat have room for improvement because the MPCA only gave a "fair" rating to the conditions at the sampling station on this reach.

The Mud River (0902030403) received fair-to-good fish IBI ratings at sites that were sampled by the MPCA in 2011. However, macroinvertebrate results only received fair or poor rating. Geomorphology work found that riparian and in-stream conditions are better downstream of Grygla than they are upstream. This observation was supported by the fish and macroinvertebrate results that improved significantly from the sampling site upstream of Grygla to the downstream sampling site at Highway 89. A lack of riparian cover and buffer is a significant stressor in the upper reaches of the Mud River. The

MSHA results indicate that the quality of habitat overall needs to be improved along the entire Mud River, which received only fair or worse habitat ratings at all the main-channel sites.

The water control structures that created the system of pools within Agassiz NWR (0902030404) greatly contribute to the lack of connectivity within the watershed. The structures were constructed to restore pools that were drained in an unsuccessful attempt to farm the Mud Lake area. The fishery in the lower Thief River (0902030408) is separated from the upper reach of the Thief River (0902030402), the Mud River (0902030403), and the Moose River (0902030401) by multiple water control structures.

Agassiz Pool receives water from two significant rivers. Rivers naturally carry sediment. When a river (like the Mud River) reaches a pool, the velocity plummets and sediment falls out of suspension. When the water loses velocity, it loses the ability to carry sediment bed load. Sedimentation within a pool of this design is inevitable, but agricultural practices and human-made drainage have significantly increased the rate of sedimentation. The Thief River and Mud River both meet water quality standards for TSS. However, the Thief and Mud Rivers and their tributaries have been significantly altered (dredged and straightened) to create legal public drainage systems to accelerate drainage to land in the upper watershed, causing faster flows and significant erosion and sediment load in the ditches and streams over the last century. The deposition of that sediment has been threatening the quality of habitat for all wetland flora and fauna species within Agassiz Pool. Portions of the old JD11 channel within Agassiz Pool acted as a sediment trap and are now filled with sediment.

Branch 200 of JD11 (0902030405) was sampled on August 24, 2011, while there was no flow in the channel. Fish IBI results at the time of this sampling were poor, but northern pike and walleye have been observed by monitoring staff and landowners when water levels are higher. The macroinvertebrate IBI score was fair. Habitat ratings for this ditch system were poor. A lack of late summer flow is the primary driver of low DO levels and poor fish IBI scores in this reach. The lack of habitat is a consequence of a channel design that is meant to provide drainage and not habitat. It has “little to no depth variability, no channel development, low channel stability, and low flows” (*Thief River Watershed Monitoring and Assessment Report*, 49).

The sites along the lower portion of the main channel of CD20 (0902030406), downstream of County Road 28, had fair to good fish and macroinvertebrate IBI ratings. Poor fish IBI scores in upstream reaches could have been related to a lack of flow. Sampling occurred while there was no flow in CD20. The poor fish score in CD27, a tributary of CD20, may have been affected by a lack of connectivity. Habitat ratings were fair to poor. Improved riparian buffers would be a first step toward improving habitat along this channel.

The drainage system that contributes to JD 30 (0902030407) produced mostly poor IBI and habitat scores. One site on JD 13 had a good macroinvertebrate score. One site on JD 18 had a fair fish IBI score. Sampling occurred during low water levels – when there was no flow in JD 30. Water chemistry has shown no cause for concern on this reach, so habitat and base flow should be the focus for improvements to this waterway.

The Lower Thief River (0902030408), the only reach that was formally assessed for aquatic life in 2013, met fish and macroinvertebrate IBI standards. MPCA biological monitoring staff gave the habitat a good rating. The quality of aquatic life within that reach could be improved by reducing the impact of stressors like excess suspended sediment, excess sedimentation, and an altered flow regime. Ditches flowing into the Thief River were sampled by the MPCA in 2011. Not surprisingly, the IBI scores at those sites were poor.

### 2.3.2 Point Sources

**Table 2-18. Point Sources in the Thief River Watershed.**

| HUC-10 Subwatershed | Point Source | | | Pollutant reduction needed beyond current permit conditions/limits? |
|---|---|---|---|---|
| | Name | Permit # | Type | |
| 0902030403 | Grygla Wastewater Treatment Facility | MNG580139-SD-1 | Municipal wastewater | Not Required |

Table 2-18 describes the Grygla Wastewater Treatment Facility (WWTF). The facility discharges downstream of the portion of the Mud River that remains impaired by high *E. coli* and is not factored into the *E. coli* TMDL, but discharges from its stabilization pond system are of some concern from the perspective of protecting water quality. The WWTF could affect a large portion of the 09020304-507 AUID that includes water quality station S008-138 and other stations that are downstream of that location. However, discharges from this facility usually only occur twice per year, during permitted discharge windows (March 1 through June 30 and September 1 through December 31) when flows are highest; in most years (June and October). There have occasionally been three discharges in a year; however, the third discharge is usually less than one million gallons. The TSS and BOD discharge concentrations reported since 2010 have been well below the discharge limits except for one instance. Discharges are only allowed from the secondary pond cell and only six inches of water may be discharged per day.

Due to the discovery of human fecal DNA markers in the Mud River at Grygla, failing septic systems are a suspected source of *E. coli* bacteria. Septic system inspections within the Mud River Subwatershed is recommended.

There are few feedlots remaining in the Thief River Watershed. Feedlots in the Mud River Subwatershed are shown in Figure 2-11. There are some livestock operations that aren't represented by points on the map. Most of the drainage area of S002-977 is located within Beltrami County and that county does not have an official county feedlot officer. Feedlot Program staff at the Detroit Lakes MPCA office regulate feedlots in the area.

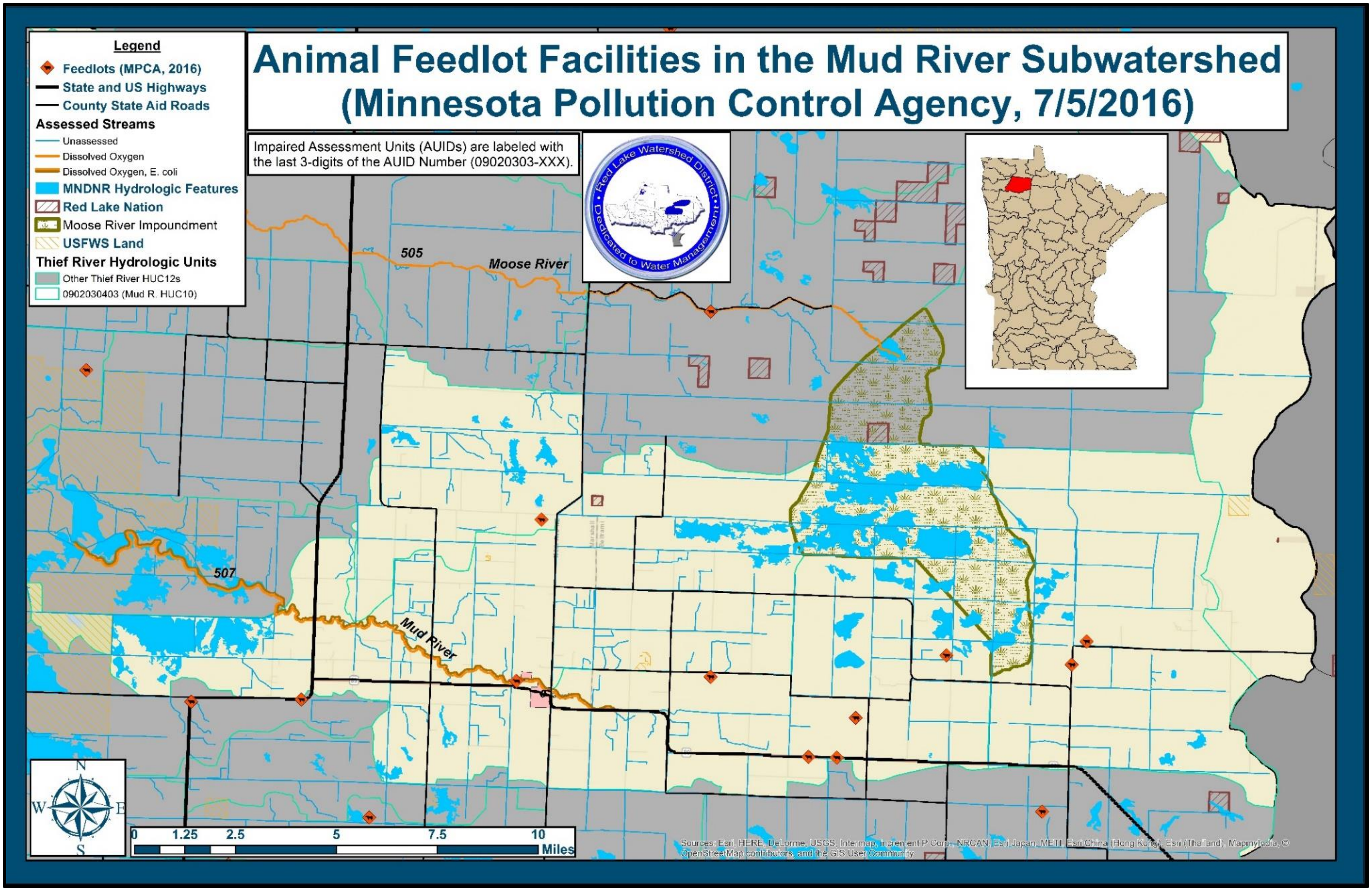



Figure 2-11. Registered feedlots in the Mud River Subwatershed

### 2.3.3 Nonpoint Sources

Suspended sediment, TP, and *E. coli* bacteria are the primary pollutants of concern within the Thief River Watershed. Sources of phosphorus are similar to sources of TSS. Sections 2.3.4, 2.3.5, and 2.3.6 describe known and suspected sources of nonpoint source pollutants in the Thief River Watershed. Tables 2-19 and 2-20 provide a summary of the significance of known pollutant sources.

The length of discussion of any specific pollutant source in this section is not indicative of the relative impact of that source. Some pollutant sources are easy to see and understand. Others require more explanation.

**Table 2-19. Nonpoint Sources in the Thief River Watershed for impaired waters. Relative magnitudes of contributing sources are indicated.**

| HUC-10 Subwatershed | Stream/Reach (AUID) or Lake (ID) | Pollutant | Pollutant Sources | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fertilizer & manure run-off | Livestock overgrazing in riparian | Failing septic systems | Wildlife | Poor riparian vegetation cover | Upland soil erosion | Stagnant Water and Lack of Flow | In-Channel Erosion | Impoundment Discharge | Wastewater |
| Thief River 0902030408 | Agassiz Pool to Red Lake R (501) | Bacteria | ○ | ○ | ○ | ● | | | | | ● | |
| | | TSS | | | | | ◎ | ● | | ● | ● | |
| | | TP | ○ | | ○ | ◎ | | ◎ | | ○ | | |
| | | Low DO | | | | | ○ | | | | | |
| Mud River and Judicial Ditch 11 0902030403 | *South Pool Outlet of Moose River Impoundment to Agassiz Pool (507, 521, 522, 523, 524, 525, 526)* | TSS | | | | | ◎ | ● | | ◎ | ○ | ○ |
| | | Low DO | | | | | ○ | | ● | | | ○ |
| | | *E. coli* | | ◎ | ● | ◎ | | | | | | |
| | | TP | ○ | | | | ○ | | ◎ | | | ● |
| Moose River 0902030401 | *Headwaters to Thief Lake (505)* | TSS | | | | | | ● | | ● | ○ | |
| | | TP | | | | | | ◎ | ○ | ○ | ○ | |
| | | Low DO | | | | | | | ● | | ○ | |
| | Branch A JD21 (555, 556) | *E. coli* | ○ | | | ● | | | | | | |
| Upper Thief River 0902030402 | Thief Lake to Agassiz Pool (504) | E.coli | | | | ● | | | | | ○ | |
| | | TSS | | | | | ○ | ● | | ◎ | ○ | |
| | | TP | | | | | | ● | | ○ | ○ | |
| Middle Thief River 0902030404 | Agassiz Pool (502, 503, 508, 536, 542) | E.coli | | ○ | | ● | | | | | | |
| | | TSS | | | | | | ● | | ● | ○ | ○ |
| | | TP | | ○ | | ○ | | ● | | | | |

**Key:** ● = High ◎ = Moderate ○ = Low

**Table 2-20. Nonpoint Sources in the Thief River Watershed for impaired waters. Relative magnitudes of contributing sources are indicated.**

| HUC-10 Subwater-shed | Stream/Reach (AUID) or Lake (ID) | Pollutant | Pollutant Sources | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fertilizer & manure run-off | Livestock overgrazing in Riparian Areas | Failing septic systems | Wildlife | Poor riparian vegetation cover | Upland soil erosion | Stagnant Water and Lack of Flow | In-Channel Erosion | Impoundment Discharge | Wastewater |
| Branch 200 of JD11 0902030405 | Headwaters to the Thief River (511, 512) | E.coli | | | | ○ | | | | | | |
| | | TSS | | | | | **O** | ● | | ○ | | |
| | | TP | ○ | | | | ○ | | | | | |
| Marshall County Ditch 20 0902030406 | Headwaters to the Thief River (510, 513,514, 515, 516, 517, 518, 519, 546, 548) | E.coli | | **O** | | **O** | | | | | | |
| | | TSS | | | | | **O** | ● | | ● | | |
| | | TP | ○ | ○ | | | ○ | **O** | | | | |
| Judicial Ditch 30/18/13 0902030407 | Headwaters to the Thief River (509, 538, 539, 540, 541) | *E. coli* | | | | ○ | | | | | | |
| | | TSS | | | | | **O** | ● | | **O** | | |
| | | TP | ○ | | | | ○ | **O** | | | | |
| **Key:** ● = High **O** = Moderate ○ = Low | | | | | | | | | | | | |

## 2.3.4 Nonpoint Sources of Sediment

**Thief River**

Sediment is a pollutant of concern along the reach of the Thief River that is impaired by high turbidity. Excess TSS can be harmful to aquatic life (fish and macroinvertebrates). The excess sediment in rivers, streams, and ditches has also caused sedimentation problems throughout the watershed. There are reaches and pools in which the reduction of sedimentation will be important for the protection of aquatic life, wetlands, and infrastructure.

The viability of Agassiz Pool for waterfowl production is being threatened by sedimentation within the pool. Agassiz Pool, Agassiz NWR's largest wetland, has accumulated so much sediment from upstream agricultural drainage practices that it has become dominated by hybrid cattail. The ability of the refuge staff to control water levels in the Agassiz Pool has been substantially reduced (Post van der Berg, 1). Research conducted by Houston Engineering and the Pennington SWCD indicates that two-thirds of the sediment flowing into the Refuge's main pool is deposited there, indicating significant erosion is occurring upstream of the refuge. The St. Croix Watershed Research Station estimated in their 2001 study that 1,840,000 metric tons of sediment have been deposited within Agassiz Pool since 1940.

Even within rivers that are meeting TSS standards, moving water still moves sediment. The lower Mud River (downstream of Grygla) is fairly stable. However, the Thief River Watershed Fluvial Geomorphology Report discovered that the Mud River moves a large amount of sand bedload in the downstream portion of the Mud River that likely comes from poorly buffered areas in the upstream portion of the subwatershed. Bedload consists of sediment particles that, although not suspended, are transported along the bed of the river. There is a poorly buffered section of the Mud River west of Highway 89 that is contributing sediment to that bedload. Bedload would not be represented by TSS sampling of the water column, but could still be contributing to the sedimentation within Agassiz Pool. The Mud River upstream of Grygla is channelized (Main JD 11) and there is a lack of buffers and higher erosion rates (239 tons/year/mile) in this reach.

Reduction of sediment inputs to the Thief River will benefit more than just aquatic life. Sedimentation within the Thief River Falls Reservoir and the effect of pollutants upon the quality of the city's drinking water are significant concerns. Sedimentation within the State Ditch 83 portion of the Thief River leads to clean-out projects that remove sediment deposited in the channel, but also results in the removal of vegetation (especially trees and shrubs) from the banks of the river that is important for stream and ditch bank stability.

Greater erosion results in darker colored water, more adsorption of solar energy, and increased temperature. Reduced shading allows for more solar energy to reach the river and results in increased temperature. Increased temperatures results in a decrease in the capacity of the water to hold DO. Increased temperatures can also lead to increased microbial activity, decomposition of organic matter, and oxygen consumption. Increased turbidity can reduce photosynthetic activity, also reducing oxygen production and levels.

Sources of sediment and causes of high TSS concentrations in the Thief River Watershed have been identified through extensive reconnaissance, data collection, research, and computer models.

A 1996 study by the NRCS that investigated sources of sedimentation within the Thief River Falls reservoir, found that the majority (63%) of sediment loading was coming from stream and ditch bank erosion. The extensive agricultural drainage in the watershed and impoundment drawdowns can create flashy, high flows that exacerbate stream and ditch bank erosion.

A 2011 study by the St. Croix Watershed Research Station, through the analysis of radioisotopes in core samples, found that most of the sediment deposited in Agassiz Pool had come from upland sources. The study provided evidence that the Mud River has transported a significant amount of sediment into Agassiz Pool. This study and the 1996 NRCS study taken together indicate that the impact of certain sediment sources may differ in different parts of the watershed. Upland sources of sediment in the Mud River Watershed may more impactful upstream of Agassiz NWR, and more in-channel erosion may be occurring throughout the lower part of the watershed between Agassiz NWR and Thief River Falls.

There are areas in the Thief River Watershed where trees, shrubs, and vegetation have been removed along river, stream, and ditch channels for agriculture and ditch maintenance purposes. The removal of woody vegetation makes stream banks more vulnerable to erosion. Insufficient buffers and unstable ditch outlets also increase the amount of sediment that enters rivers from overland erosion. The photo in Figure 2-12 shows a portion of the Mud River (JD11), 2.5 miles east of Grygla, that is being farmed up to and into the edge of the ditch bank. There are also good examples (Figure 2-13) throughout the watershed of how trees and their roots (especially willows) are doing a lot to protect the streambanks by holding soil in place, despite being subjected to great erosive force during high flows. Fine roots from shrubs, willows, native plants are especially effective at holding soil in place, because their root systems have greater surface area. Traveling along the rivers, streams, and ditches in the watershed provides an opportunity to observe the importance of riparian buffers for channel stability and reduction of pollutant transport from agricultural fields. Often, stretches of well-buffered and vegetated streambank are followed by stretches that have been farmed to their edge and are severely failing. A distinct contrast in stream bank stability can be observed when comparing a bank that is well buffered and vegetated with a nearby bank that has had its riparian forest buffer removed. (Figures 2-14 and 2-15) are examples of channels that are in violation of the Buffer Law and should be a priority areas for the establishment of buffer strips. Much discussion about riparian buffers focuses on their ability to filter overland runoff, but their importance for also maintaining streambank stability should not be overlooked.

**Figure 2-12. Example of a portion of the Mud River that needs a better buffer.**

Figure 2-13. Roots protecting a stream bank along the Thief River

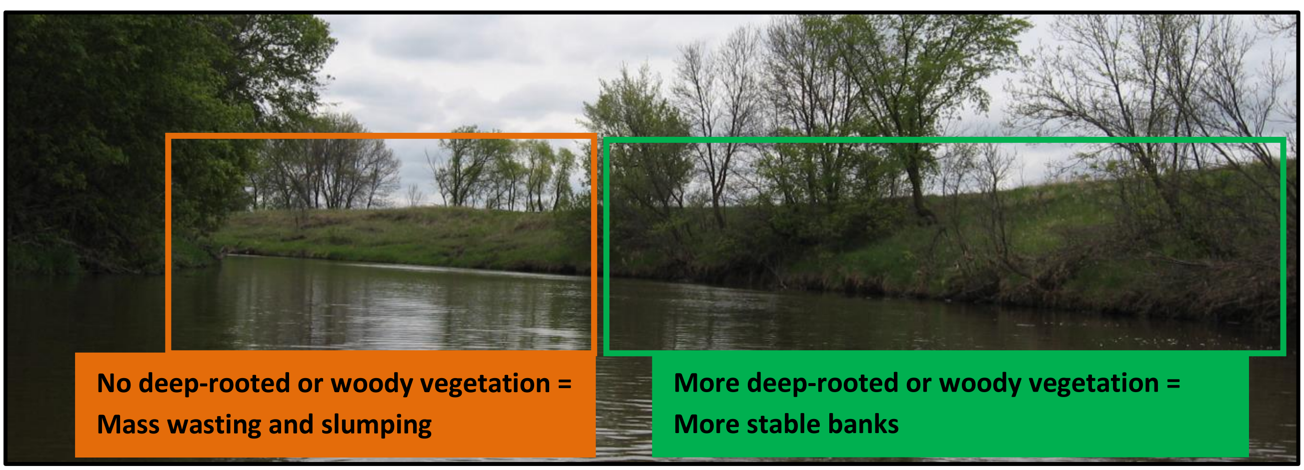



Figure 2-14. Neighboring stretches of streambank along the Thief River that demonstrate the difference between banks with and banks without deep rooted vegetation


**Figure 2-15. Examples of streambanks along the lower Thief River (top two photos) and the Mud River (bottom photo) that were badly eroding due to a lack of a buffer and a lack of deep-rooted vegetation**

Discharge from impoundments can abruptly and significantly raise flow rates within receiving channels When decisions are made to release water from a pool, it has been historically released with the goal of getting the pool down to the target elevation as quickly as possible. Releasing water at a rate that is higher than necessary increases the erosive power of downstream waters significantly. Stream stage elevations at downstream gauging stations are sometimes used to monitor and limit the rate of discharge. Those elevations should be reviewed with the knowledge gained by the Thief River Watershed Fluvial Geomorphology Study and with input from DNR geomorphology staff.

DNR staff used the BEHI and Near Bank Stress (NBS) data that were collected during the Thief River Watershed Geomorphic Assessment to estimate stream bank erosion rates using a Bank Assessment for Nonpoint Source Consequences of Sediment (BANCS) Model. The BANCS model is a quantitative method of estimating stream bank erosion rates. The analysis was conducted at the geomorphology study stations on the Thief River, Moose River, Mud River, and CD 20. The BANCS modeling results predicting erosion in tons per year per mile of stream for the Thief River Watershed are shown in Figure 2-16.

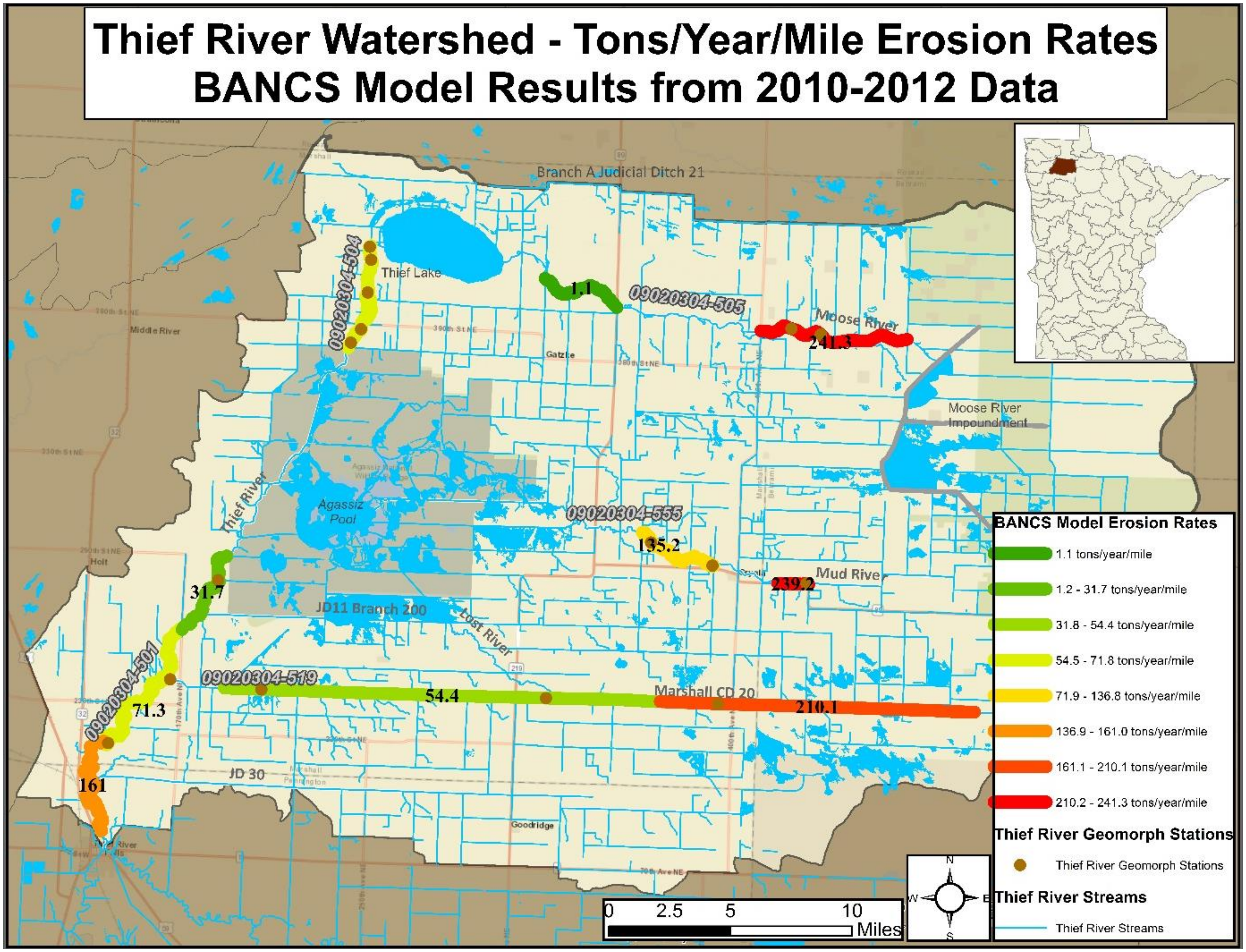



**Figure 2-16. BANCS Model stream bank erosion predictions from the Thief River Watershed Fluvial Geomorphology Report. The circles and ovals encompass the reaches that were evaluated.**

There are unstable ditch outlets within the watershed that are contributing to TSS loads and concentrations. Side water inlets and grade stabilization projects (such as the one completed on CD20) are effective strategies for minimizing headcutting and gully erosion.

Studies have also raised alarm about the rate at which Agassiz Pool has been filling-in with sediment. The most challenging and controversial obstacle to addressing the TSS impairment in the Thief River is the identification of a solution to the Agassiz Pool sediment problem that does not exacerbate TSS problems downstream.

**Agassiz Pool**

Agassiz Pool is one of the most prominent waterbodies in the Thief River Watershed and functions as a water flow "hub" of the watershed. It receives all the drainage from the Mud River, Upper Thief River, and Moose River watersheds and discharges to the Lower Thief River. Water quality sampling revealed a unique situation in and around Agassiz Pool. Typically, lakes and impoundments will absorb pollutants and discharge cleaner water. The outlets of Thief Lake and the Moose River Impoundment have consistently exhibited low TSS concentrations and good water clarity. The quality of water leaving Agassiz NWR, however, has been worse than the quality of water flowing into the refuge. A considerable amount of work has gone into gaining a better understanding of how and why water quality conditions are worse downstream of an impoundment than they are upstream. This section provides a lengthy description of those efforts and what was learned from them. The length of the discussion is representative of the degree of the challenge in understanding the situation and how sediment and nutrients are moved into and out of Agassiz Pool. Also, Agassiz Pool is not necessarily a source of the sediment that it is discharging. The sediment has been deposited within the pool over many years by the rivers and ditches that flow into the pool. The movement of that sediment out of the pool; however, has resulted in some downstream water quality problems. The following discussion describes the findings that led to the examination of sediment management in the refuge and the practices/processes that lead to high concentrations of sediment downstream of the pool.

Site-specific analysis of long-term monitoring data (Figure 2-16) shows that the Thief River is impaired at the downstream end of AUID 501 (S002-079) and at the upstream end of the reach where the river exits Agassiz NWR (S002-088). The quantity of data from other sites is much less, but the CSAH 12 (S004-052) and Golf Course Bridge (S003-945) sites appear to meet the 30 mg/L TSS standard. The Thief River and Mud River are the primary streams that flow into the pool. The assessment results for both the Mud River and the Thief River are much better upstream of Agassiz Pool than the results found in the Thief River downstream of Agassiz Pool. Only 4.9% of samples from the Mud River (AUID 09020304-507) have exceeded 30 mg/L TSS in 2007 through 2016 data. As for the Thief River upstream of Agassiz NWR (09020304-504), only one of the 127 daily average TSS concentrations (1994-2016) found in the EQuIS database exceeded the 30 mg/L standard. The maximum daily average TSS concentration within 09020304-504 was 45 mg/L, which was found at S004-055 on 4/28/2014.

Discharges from Agassiz Pool have been shown, at times, to negatively influence water quality for the system. Assessment of long-term monitoring data (Sites with >20 TSS samples) reveals that the Thief River exceeds the 30 mg/L TSS standard far more frequently downstream of Agassiz Pool (S002-088) than either the Thief River or Mud River violate the standard upstream (S004-055 and S002-78) of the pool (Figure 2-17). The USGS, USFWS, and RLWD cooperated to study sediment loads flowing into and out of Agassiz NWR. The sediment loading results (shown in Figure 2-18) at the radial gate outlet were much higher than the loading rate at any inlet. The combined sediment loading at the two Agassiz Pools was more than 4.7 times higher than the combined loading rate from the three inlets that were monitored. A 2009-2010 drawdown of Agassiz Pool, the first in over 10 years, contributed to the elevated sediment loads at the outlets.

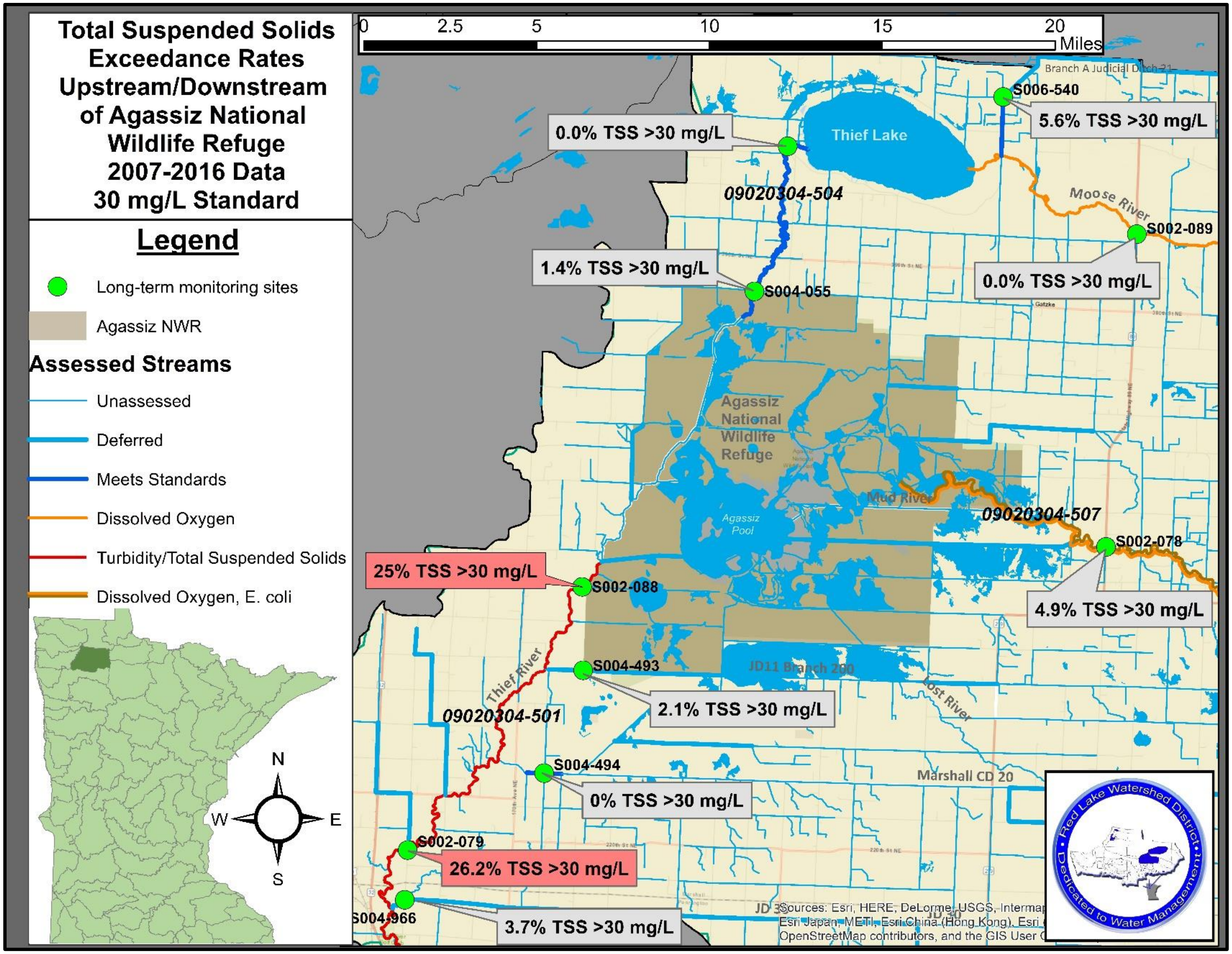


Figure 2-17. Rates at which the TSS standard is violated at monitoring sites near Agassiz NWR in 2007-2016 April-September data

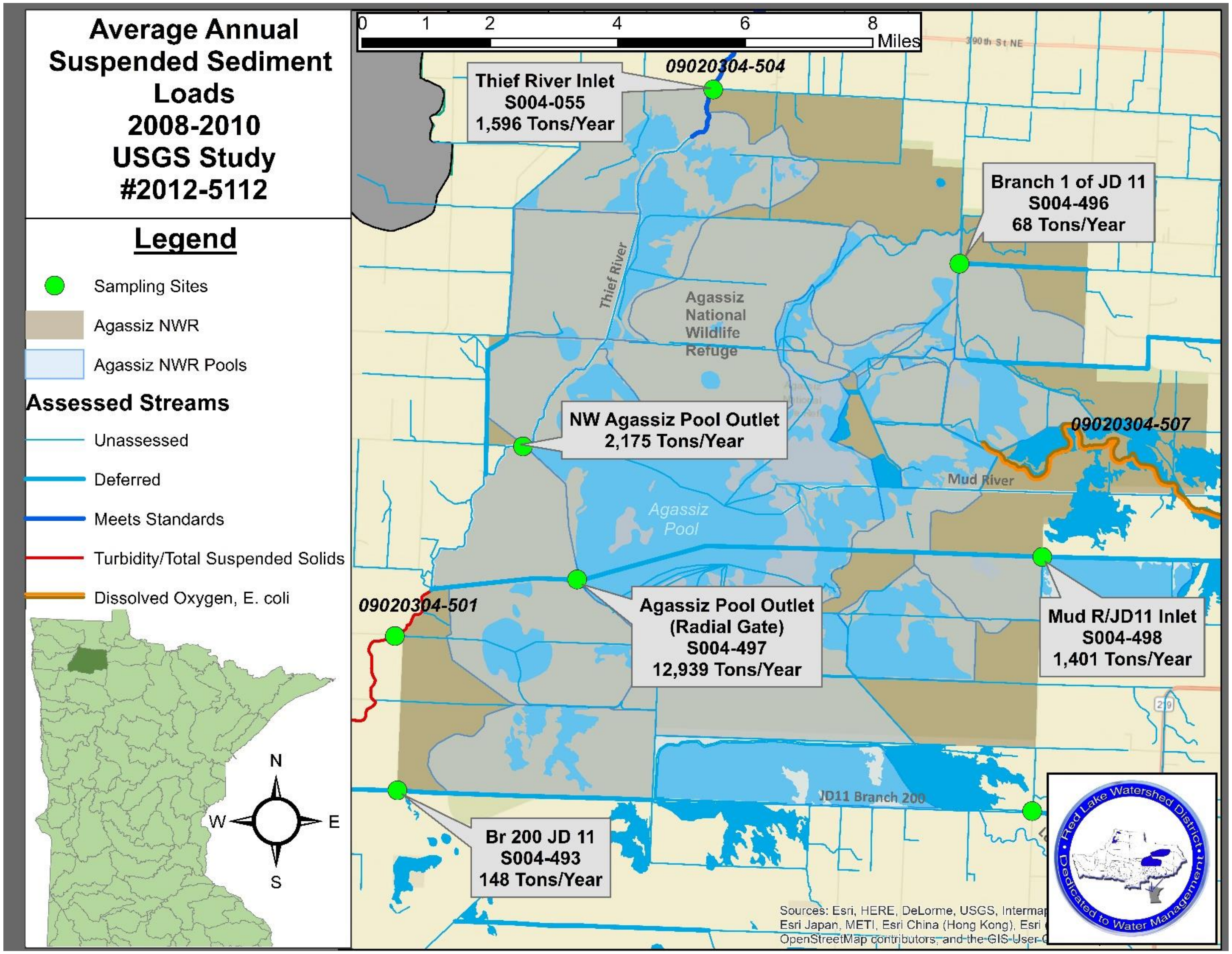



**Figure 2-18. Average annual sediment loads (2008-2010 Tons/Year) from the *USGS Assessment of Nutrients and Suspended Sediment Conditions in and near the Agassiz National Wildlife Refuge, Northwest Minnesota, 2008-2010* study.**

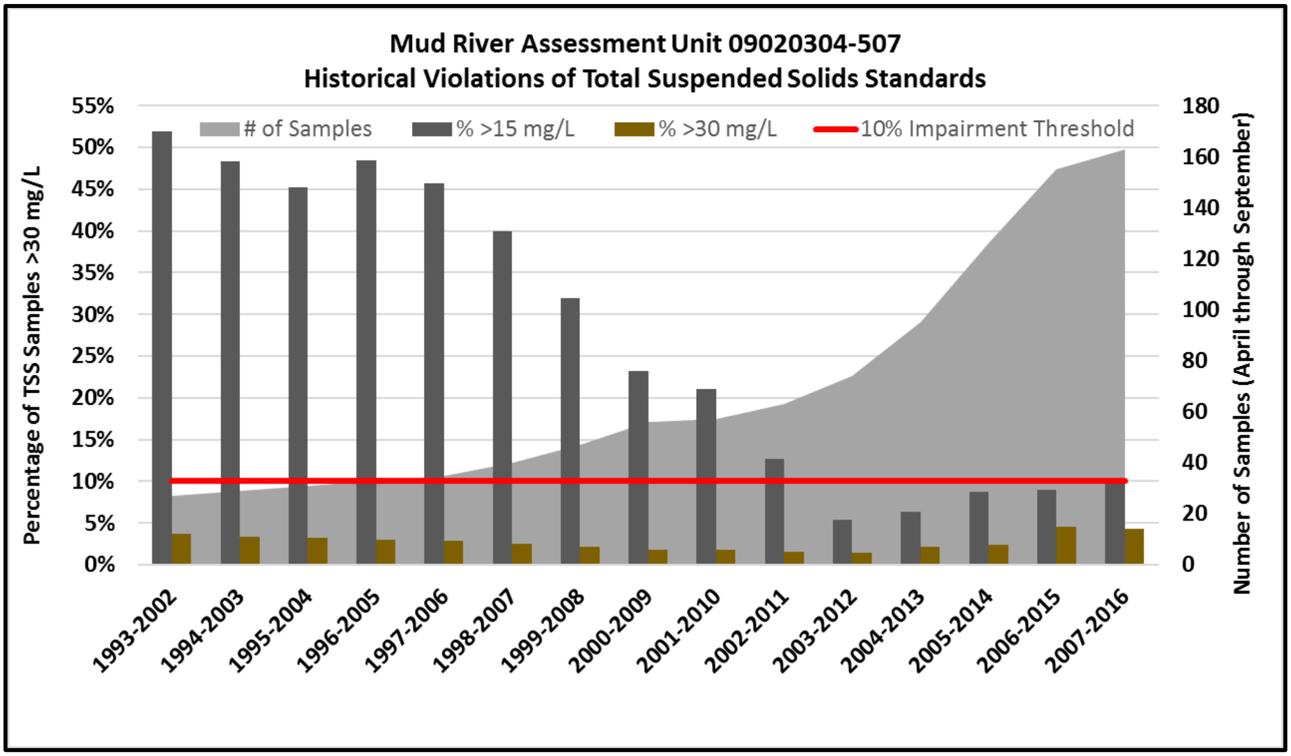



Figure 2-19. History of TSS concentrations and assessment statistics for the Mud River

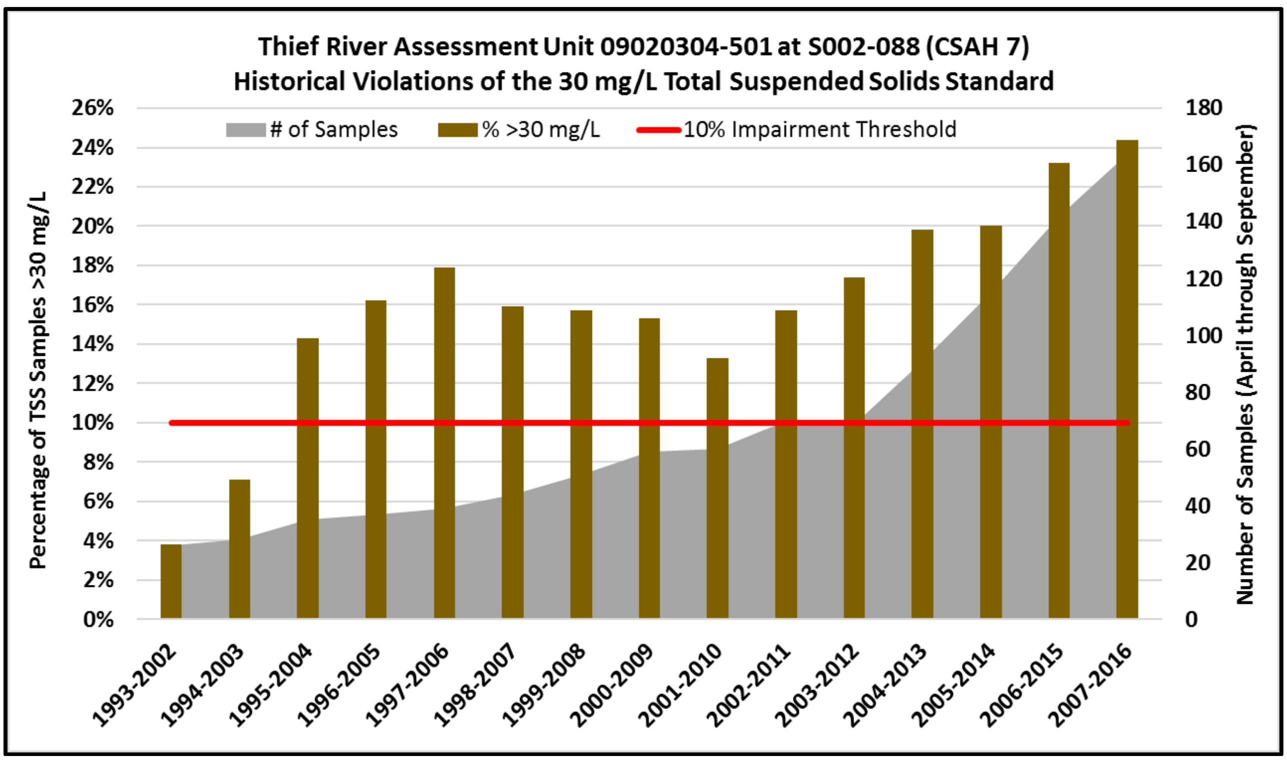



Figure 2-20. History of TSS concentrations and assessment statistic for the Thief River at CSAH 7 (S002-088).

Results of a USGS study (Nustad 2012) found that sediment loads in 2008 through 2010 were greater at the northwest outlet than at the Thief River inlet. The northwest outlet of Agassiz Pool is a four bay stoplog structure. That increase indicates that there may be some scouring where a portion of the flow from the Thief River bypasses the main pool by flowing along the inside of the northwestern dike of Agassiz Pool to the northwest outlet. The 579-ton increase in sediment loading along the northwest side of Agassiz Pool (shown in Figure 2-18) was much less than the 11,538-ton increase from the JD 11 inlet to the radial gate outlet along the old JD 11 channel.

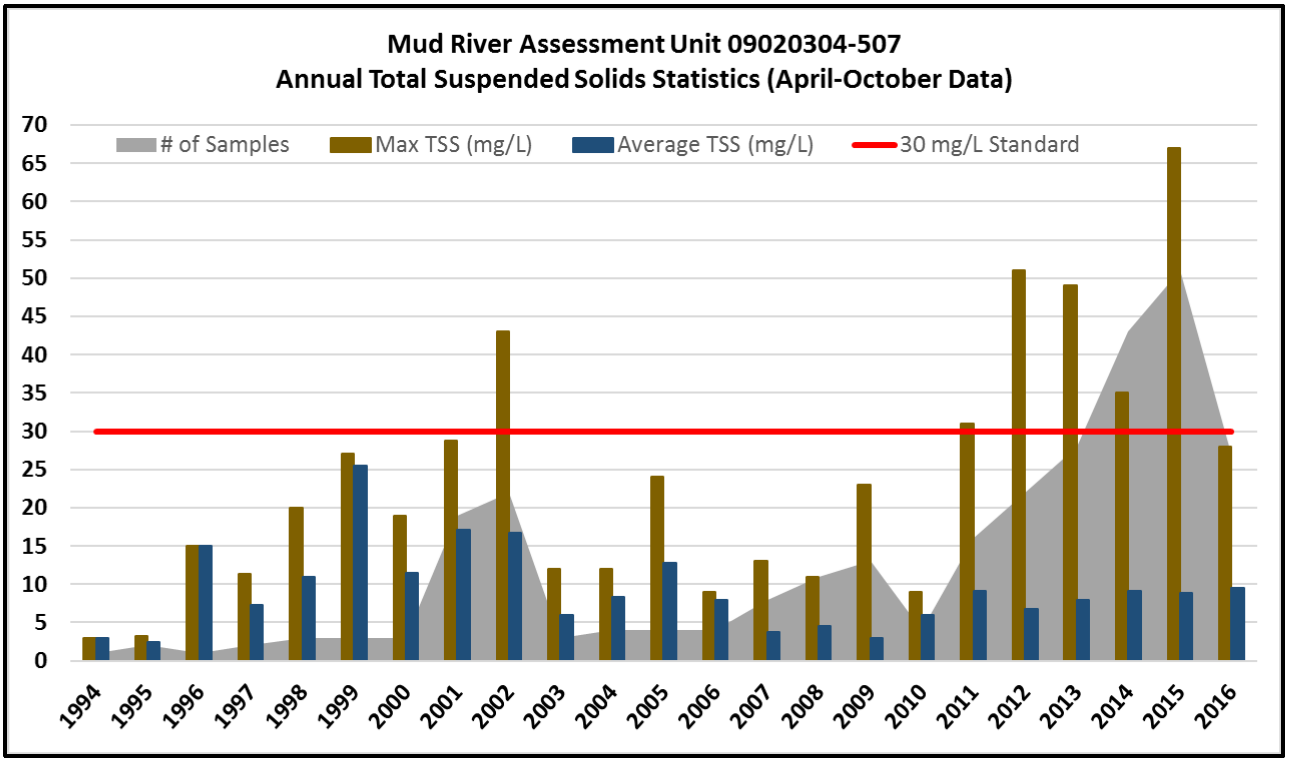



Figure 2-21. Annual (April through October Data) TSS statistics for the Mud River (09020304-507) - maximums and averages

The *Sediment Loading and Sources to Agassiz NWR* study describes the large quantity of sediment that has been deposited in Agassiz Pool by the Mud River throughout the history of the pool. Monitoring data suggests that sediment concentrations in the Mud River may have been worse in the 1990s and early 2000s than they currently are. The river flows through the north (15 mg/L TSS standard) and central (30 mg/L TSS standard) river nutrient regions. There hasn't been much change in the rate at which AUID 507 of the Mud River exceeds the 30 mg/L standard, but there is a more apparent change in water quality conditions in the river if they are compared to the 15 mg/L standard. The MPCA is currently planning to apply the 30 mg/L standard to the Mud River. Figure 2-19 shows changes in assessment statistics (10-year groups of data collected during the months of April through September) for both standards. The data shown in Figure 2-18 are limited to periods of time in which 20 or more data points were available. The sediment concentrations in the Mud River exceeded standards more frequently prior to 2002 than they have in recent years. The Mud River slightly exceeds the 15 mg/l TSS standard (2007 through 2016 data) but has met the standard very recently (2006 through 2015 data). Historical data suggests that TSS concentration in the Thief River downstream of Agassiz NWR met the 30 mg/L standard prior to 2004 (Figure 2-20). Although the frequency of high TSS levels in the Mud River seems to have decreased, high maximum concentrations have been discovered in recent years due to more intensive sampling and a change in management practices within Agassiz Pool (Figure 2-21).

Increased sampling frequency appears to increase the probability of recording high TSS concentrations, particularly if there are sampling efforts that target runoff events.

The water coming out of other impoundments and lakes, within and around the Thief River Watershed, is typically low in sediment (Moose River Impoundment, Thief Lake, Brandt Impoundment, Euclid impoundment, Thief River Falls reservoir, and Farmes Pool). However, the volume of water released can have significant erosive power. Impoundment operation plans typically involve drawdowns to reach seasonal pool elevation goals or, in some cases, involve complete drawdowns for habitat management or increased flood damage reduction storage capacity. The rate at which impoundments discharge during those drawdowns can affect the amount of stream bank erosion that occurs downstream during drawdown periods. Agassiz Pool, however, has also discharged water that is already sediment-laden during drawdown periods. Research indicates that two-thirds of the sediment flowing into the Refuge's main pool is deposited there as the water enters and loses velocity in the pools, but drawdowns flush a portion of that deposited sediment out of the pool. The amount of sediment leaving this impoundment is greater than typical impoundments due to:

- A radial gate outlet (opens from the bottom of the channel)
- Remnants of JD11 that concentrate flow
- Full drawdowns
- Maintenance and cleaning of the old JD11 channel by the USFWS that moves sediment downstream.

The radial gate outlet of Agassiz Pool opens from the channel bottom. This allows movement of water within the lower channels, gullies, and highly erodible soil/muck within the pool. The old JD 11 channel that was dug to drain the Agassiz NWR area is still present within Agassiz Pool. The lower portions of the ditch that have not filled with sediment facilitate the erosive processes that occur during the latter stages of a drawdown.

Scheduled drawdowns of Agassiz Pool are prescribed in the Agassiz NWR Comprehensive Conservation Plan. The plan states that impoundment drawdowns aid with the maintenance of bulrush plant communities and cattail management. Drawdowns have resulted in the discharge of large sediment loads to the downstream reach of the Thief River. In the late fall of 2009, for example, the USFWS opened the radial gate outlet of Agassiz for an extended drawdown period and the turbidity was very high in the Thief River downstream of Agassiz Pool for an extended period. There was extensive gully formation, sloughing, and erosion within Agassiz Pool along the old JD 11 channel. A thick layer of organic sediment was deposited downstream. The increased sediment loads were likely not an intended consequence when the drawdowns were first planned. Much has been learned about the in-pool impacts of drawdowns after the 2009/2010 and 2012 drawdowns. The *Assessment of Water Quality Conditions: Agassiz NWR, 2012* study by the USFWS provided some detail about the results of a 2012 Agassiz Pool drawdown. "Water monitoring data, aerial imagery and on-site inspections coordinated with the drawdown of Agassiz Pool in 2012 indicate extensive sheet flow, vegetation disturbance and discrete periods of channel formation and sediment scour within Agassiz Pool."

Due to the significant amount of sediment deposition in Agassiz NWR pools causing difficulties in managing the refuge for waterfowl, refuge staff initiated new maintenance practices in 2012. The USFWS has recently adopted a strategy that removes sediment from Agassiz Pool through flushing and scouring that is facilitated by incremental cleanup of the old JD 11 channel within Agassiz Pool, breaches in the ditch berm, and multiple drawdowns during the course of several years. The goal of that strategy was to make management of water levels easier for waterfowl production and hybrid cattail management. However, recent data has shown that these recently implemented maintenance practices within Agassiz Pool are increasing downstream water quality problems. Recent excavation by the USFWS within the old JD11 channel has exacerbated high sediment concentrations exiting Agassiz Pool. As sediment has been excavated from the water-filled, old JD11 channel to the berms, uncontrolled sediment has flushed downstream. Additionally, headcutting of the channel has occurred during drawdowns. That headcutting has sent additional sediment downstream. Trend analysis shows strong upward trends in TSS concentrations. Recent increases in TSS concentrations have occurred since the USFWS initiated the maintenance excavation of the old JD11 channel in 2012. Multiple specific instances in which discharge from Agassiz Pool has negatively affected downstream water quality have been documented with observations and monitoring data. Each data collection incrementally improved the understanding how and why discharge from Agassiz Pool is affecting downstream water quality.

Sediment Deposition along the Thief River

In August of 2012, Agassiz NWR began drawing down Agassiz Pool by releasing water through their water control structures at a rate of up to 1,200 CFS. This greatly increased turbidity in the river and affected the quality of drinking water in Thief River Falls. The RLWD and the MPCA both received complaints about the taste and odor of the drinking water in the city of Thief River Falls during the Agassiz Pool drawdown. During the drawdown, there was a very strong chlorine-like taste that made the water virtually undrinkable. Increases in organic pollutants require the city to use more chemicals to treat the water. Shortly after the drawdown was over, the city's tap water improved dramatically. The daily mean discharge in the Thief River near Thief River Falls increased from 64 CFS to 629 CFS on August 2$^{nd}$, near the beginning of the drawdown. On August 6, 2012, the daily mean discharge at the USGS gauge (05076000) had decreased to 241 CFS. Monitoring on August 6, 2012, found that the turbidity at the County Road 7 Bridge near Agassiz NWR was 25.1 NTRU, which is almost equal to the former 25 NTU turbidity standard. The data from the 2012 drawdown seemed to suggest that moderation of flows during pool discharge (keeping flows at or below the 241 CFS observed on August 6, 2012) would help reduce sediment concentrations, turbidity levels, and sedimentation in the Thief River. The assumption at the time was that higher flow rates caused higher TSS concentrations due to greater erosive force of higher rates of flow. The in-pool processes of Agassiz Pool, however, were not fully understood by outside agencies at the time. Subsequent sampling revealed that simply moderating flows may not be enough to keep TSS at acceptable levels. A 2012 study by the USFWS also provided insight into why there is a lack of a correlation between flow and TSS at S002-088.

Longitudinal samples were collected along the lower reach of the Thief River from CSAH 7 to Long's Bridge during a storm event on May 20, 2013 (Figure 2-22). This sampling revealed that, although erosion occurs along the Thief River and its tributaries during a runoff event, sediment can be discharged from Agassiz Pool at an extremely high rate. Concentrations of TSS gradually increased from upstream to downstream within the free-flowing portions of the Thief River with one exception. The TSS reading at the CSAH 7 Bridge (Station S002-088, closest crossing to the outlet of Agassiz Pool) was 293 mg/L at 3:00 pm. The TSS concentration at the next crossing downstream, CSAH 12 (S004-052), was 20 mg/L. It seemed unusual to see TSS (and turbidity) decrease that greatly from an upstream site to a downstream site during a runoff event. This indicated that a large amount sediment was being discharged from the Agassiz Pool outlet(s). According to USFWS staff, the radial gate outlet was opened on May 20, 2013, which likely created a "flush" of sediment from the pool. Multiple samples with high TSS were recorded that day, so the flush of sediment was not brief. Relatively large, dark-colored particles were visible in the CSAH 7 sample, but not in samples from other sites. The duration of that high concentration and the downstream extent of the heavily sediment-laden water are unknown. Another organization had collected a sample at CSAH 7 for a different sampling program 30 minutes earlier on May 20, 2013 (2:30 pm), and recorded a TSS concentration of 392 mg/L. The larger particles of rapidly-settling sediment found in the CSAH 7 samples likely contributed to the sedimentation problems that have been observed along the Thief River between the CSAH 7 and CSAH 12. Additionally, the TSS concentration in CD20 (30 mg/L) was higher than the concentration in the Thief River at either crossing upstream (20 mg/L at CSAH 12) or downstream (24 mg/L at CSAH 44) of its confluence. Concentrations of TSS began to decrease within the influence of the decreased flow velocity within the Thief River Falls reservoir at the Golf Course Bridge (S003-945) and Long's Bridge (S008-131).

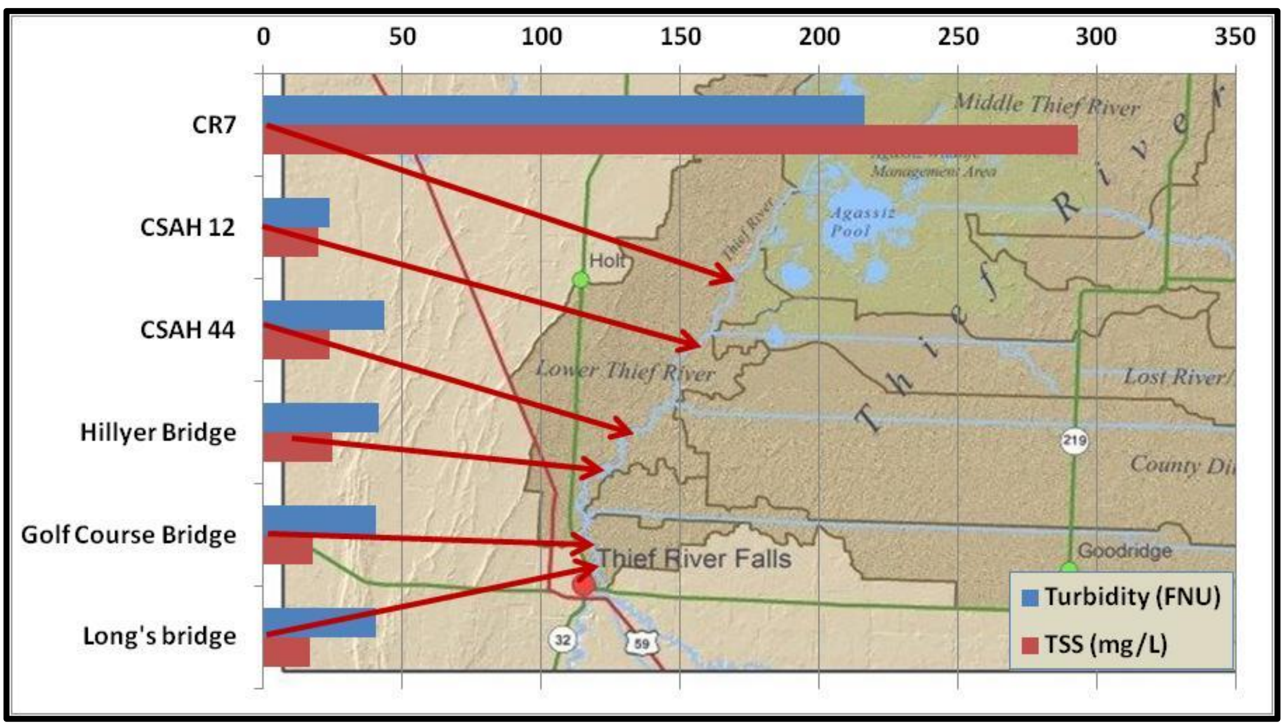



Figure 2-22. Longitudinal turbidity and TSS levels during a May 20, 2013 runoff event

Water quality in the Thief River was monitored during the Agassiz Pool drawdown in August of 2013. Water quality was satisfactory when it was tested slightly after the peak flow level during the discharge period. On August 19, 2013, a caller complained to the RLWD that the Thief River looked like a "flowing mud pie" near Agassiz NWR. RLWD staff investigated and found a turbidity level of 398.8 FNU and a transparency of only 2.5 cm at CSAH 7 (S002-088). Contrary to expectations, turbidity levels increased to record highs as water levels receded and flows decreased. Conditions were worsening on the receding limb of the hydrograph (Figure 2-23). This possible negative correlation between flow and TSS concentrations was the opposite of what is normally seen in rivers where TSS normally increases with flow due to increased overland and streambank erosion. A more intensive sampling effort was still needed.

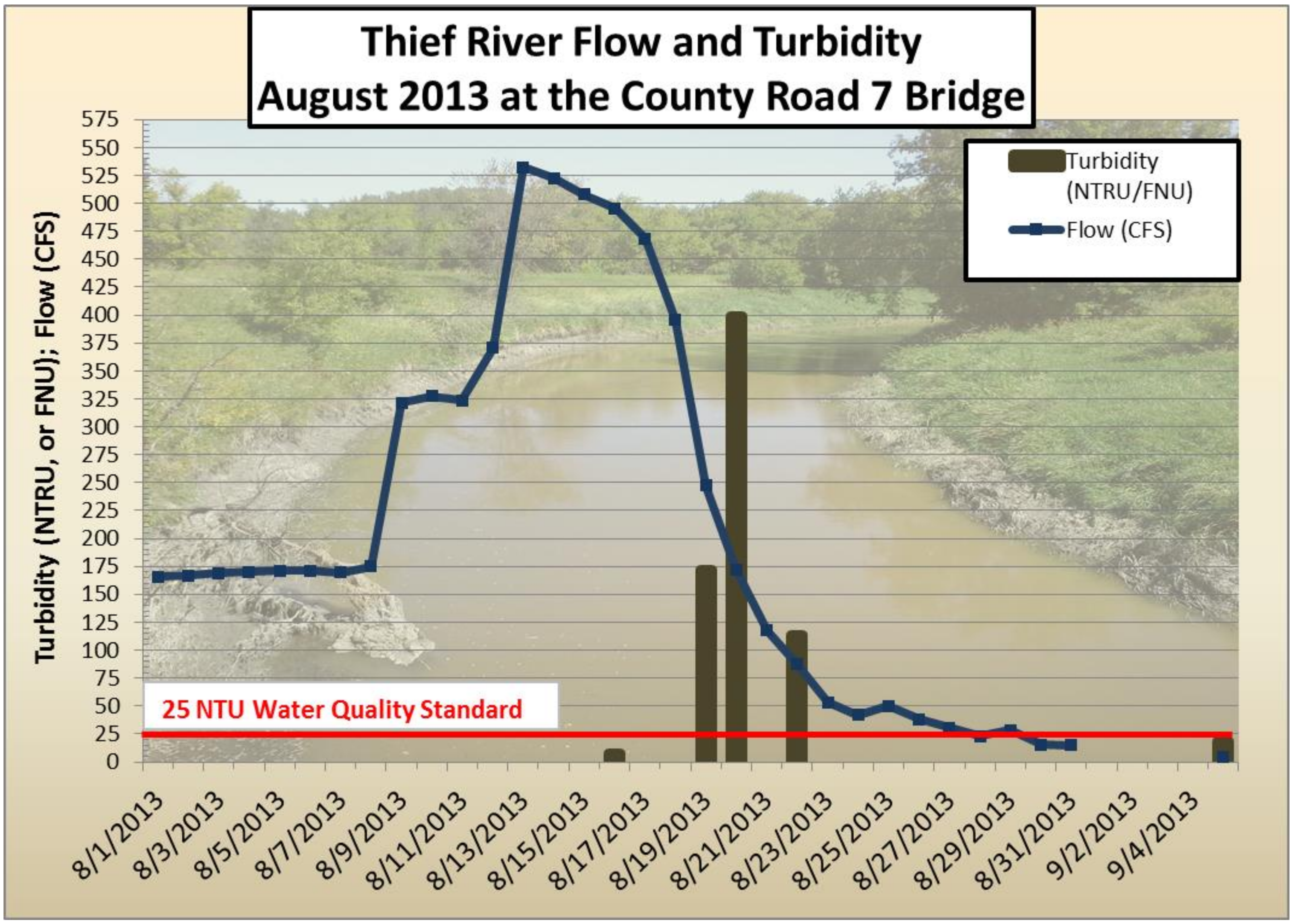



**Figure 2-23. 2013 intensive sampling of the lower Thief River**

The pattern observed in the 2013 sampling was also observed when the Thief River was intensively sampled during the 2015 late-summer drawdown of Agassiz Pool. TSS concentrations spiked during the receding limb of the hydrograph once again (Figure 2-24). The river was sampled at two sites: S002-079 near the downstream end of the 09020304-501 reach and S002-088 near the upstream end of the reach. Flows peaked in late August, as shown in Figure 2-14. High TSS concentrations (>30 mg/l) were found at the CSAH 7 crossing of the Thief River on six days during this effort (every sample collected from August 31, 2015 through September 10, 2015). When the river was sampled on August 31 and in early September, flows had decreased, but turbidity and TSS levels increased (Figure 2-24). Turbidity levels in the Thief River at CSAH 7 (S002-088) rose to 100 NTRU and DO levels fell below 5 mg/l. As flows decreased during the latter stages of the drawdown, concentrations of pollutants increased. Receding water levels revealed deep, freshly deposited sediment along the banks of the river (Figure 2-25, lower right). The dark, mucky sediment was over 2.5 feet deep in some places. The 2015 intensive sampling monitoring effort was successful in providing information about how the drawdown of Agassiz Pool affects downstream water quality.

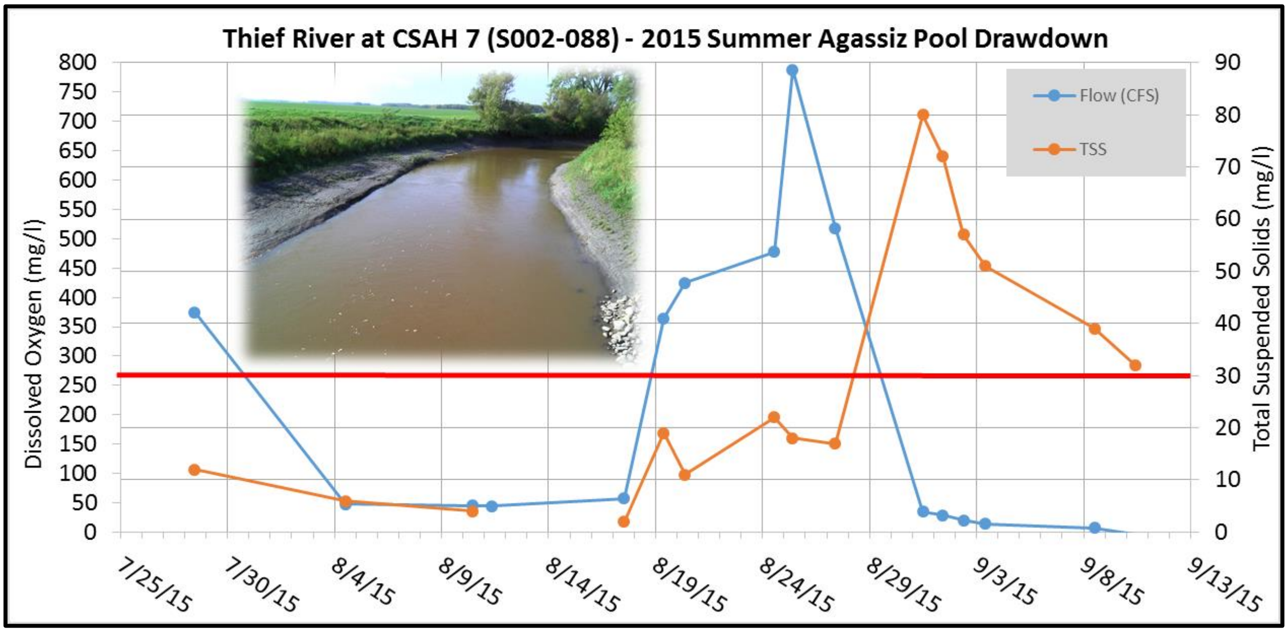



Figure 2-24. 2015 intensive sampling on the Thief River during the Agassiz Pool Drawdown. The red line represents the 30 mg/L TSS standard.


Figure 2-25. Photos of the Thief River during the late-summer 2015 drawdown of Agassiz Pool

Often, the water leaving natural outlets of large bodies of water is relatively clean. In many cases, surface water needs to flow over something to leave a pool, pond, or lake. For example, Clearwater Lake (Figure 2-26, left) happens to be a lake in which water levels are maintained by a dam. Pollutants from the Clearwater River are deposited into the lake at the inlet and consistently clean water from the surface of the lake leaves the lake through the Clearwater Lake Dam (S002-119). The outlet of Agassiz Pool along JD11 (Figure 2-26, right) is different because it uses a radial gate outlet that is positioned so that it opens at the bottom of the channel. This allows more movement of water along the bottom of the pond and the remains of JD11. The dam in Thief River Falls (Figure 2-27) also has radial gates, but they are positioned above a concrete dam. The top of the concrete dam in Thief River Falls is 2.75 feet above the upstream river bottom (according to plans shown in the 1992 Thief River Falls Reservoir Study.

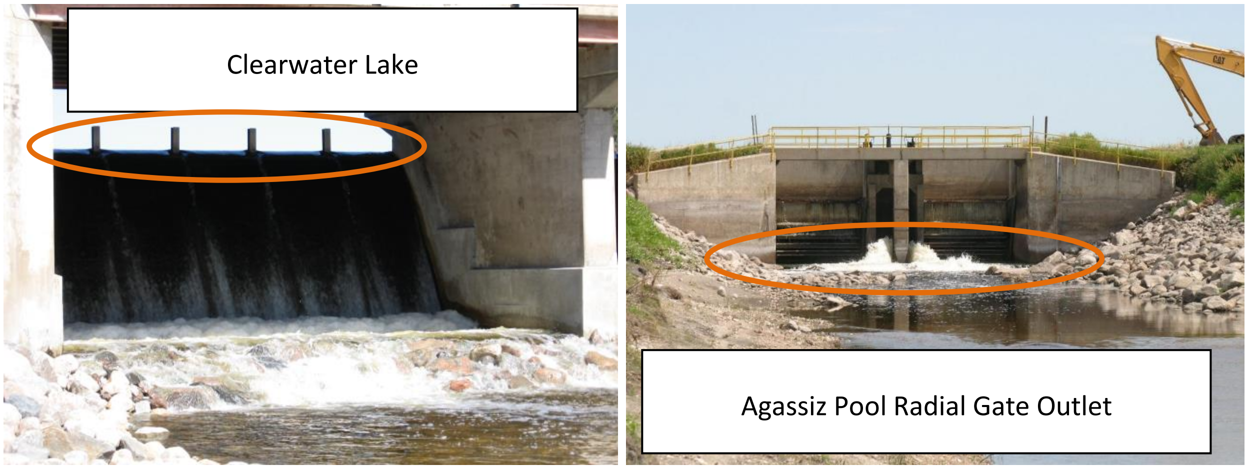



**Figure 2-26. Photos showing the differences between a concrete and stop-log dam on a reservoir and the Tainter radial gates at the primary outlet of Agassiz Pool.**

**Figure 2-27. Thief River Falls Dam on the Red Lake River**

Sediment concentrations can increase as flows decrease during the latter stages of a drawdown of Agassiz Pool. As the water levels drop in the pool, the movement of water becomes more concentrated within the channels and gullies within the pool (Figures 2-28 and 2-29). There will be less dilution from ponded water. There is an ample supply of loose sediment within the channels that has been deposited throughout the summer. More of the moving water will be concentrated in channels and gullies, giving it more erosive power within the pool.

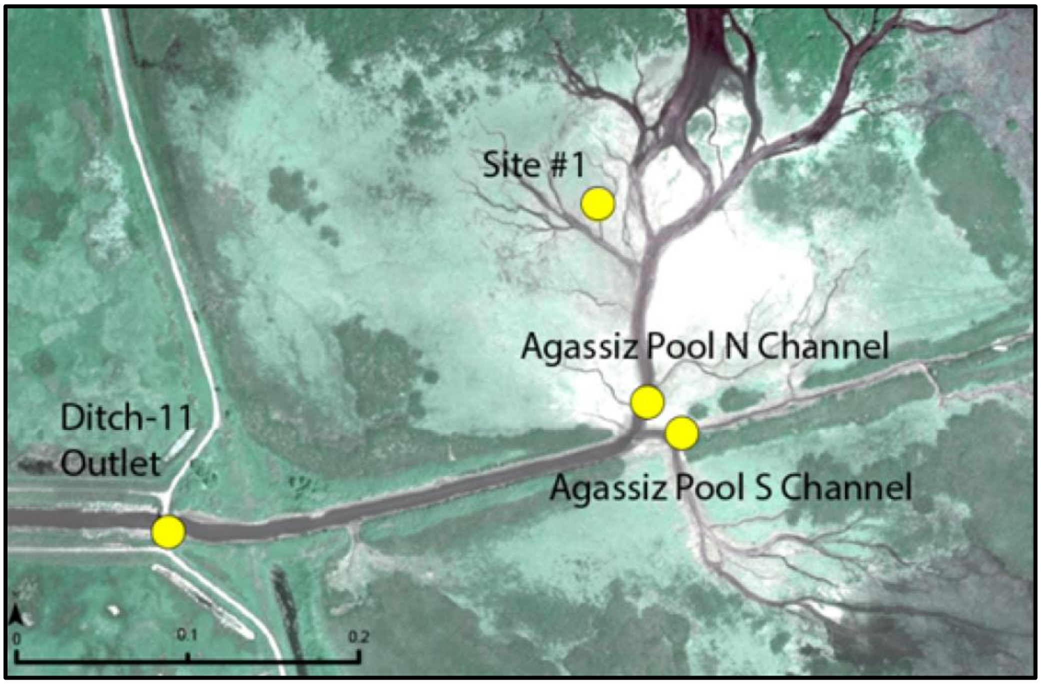



Figure 2-28. Scouring of sediment and gully formation within Agassiz Pool (Eash 2012)

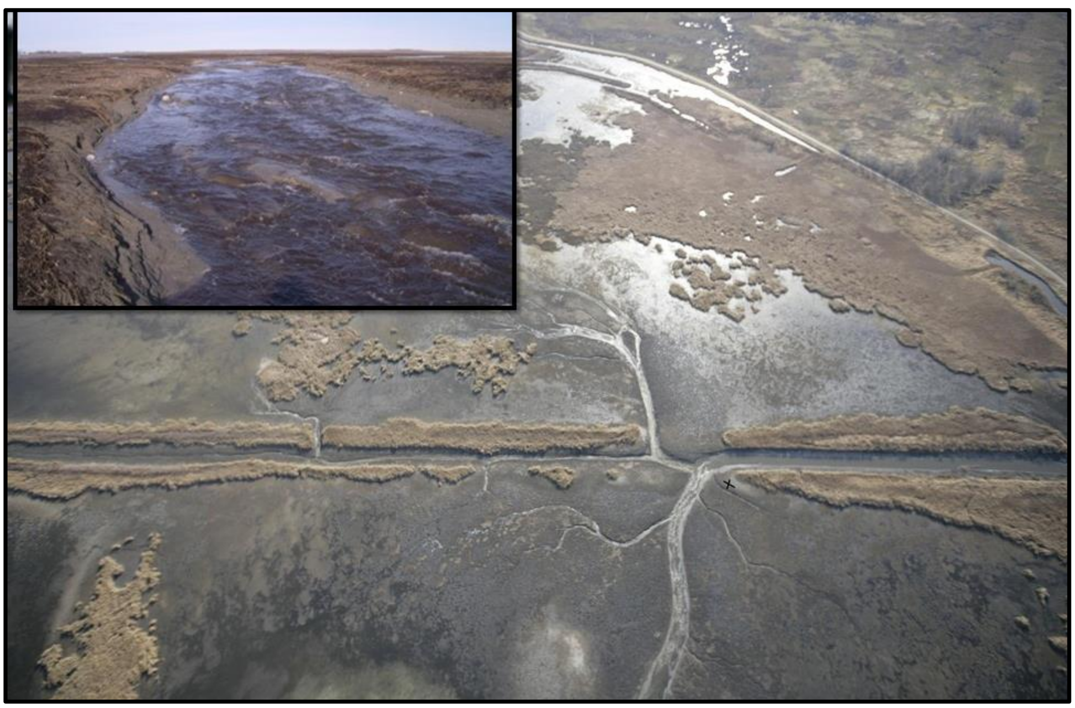


Figure 2-29. Photos of Agassiz Pool during a drawdown

The in-pool processes and downstream sediment concentrations during Agassiz Pool drawdowns seem similar, though on a much larger scale, to the drawdown of surface-drained wild rice paddies that were observed in the *Red Lake River Farm to Stream Tile Drainage Water Quality Study.* Sediment concentrations would be relatively low at the beginning of the drawdown when most of the water leaving the paddy is the water that was ponded above the "ground level" in the paddy. Sediment concentrations increased significantly as a greater percentage of water began flowing within the internal surface drainage ditches. TSS concentrations peaked at extremely high levels (>1,000 mg/l) at some paddy outlets. The loose sediment that had been deposited within the ditches by wave action and other processes throughout the summer was being flushed out of the pool with a diminishing amount of dilution from water that was pooled above the "ground level" within the paddy. In the case of Agassiz Pool, this includes sediment deposited by the Mud River and Thief River, decaying vegetation, waterfowl waste, organic soil, and disturbed sediment from excavation activities. The concentrations in both cases eventually decrease toward the end of the drawdown. The decrease may occur because of lower flow velocities, a depleted supply of easily moveable sediment, the pool goes dry, or a combination of those factors.

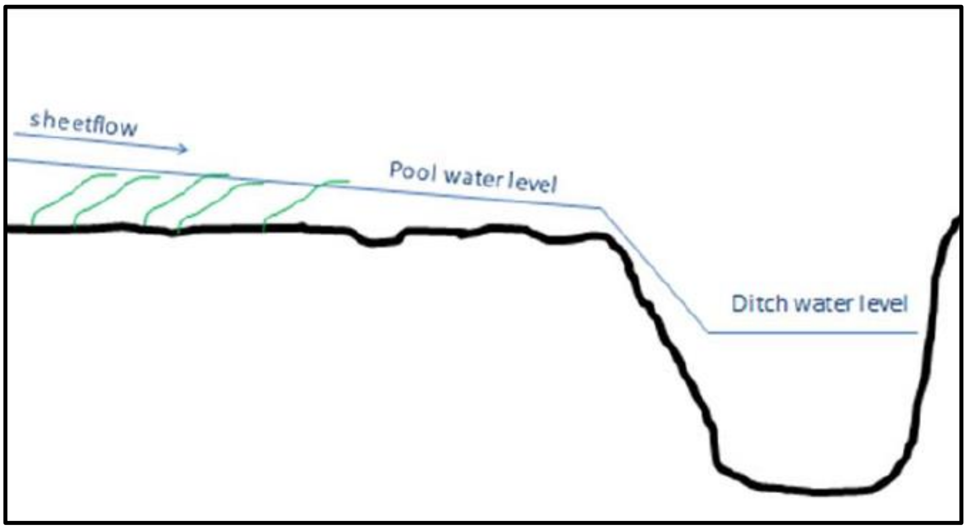



Figure 2-30. Diagram of hypothetical water surface profile within Agassiz Pool during periods of sheet flow (Eash 2012).

The 2012 report from the USFWS describes the scouring process that occurs within Agassiz Pool during drawdowns. The report provides information that explains why TSS concentrations increase as flow rates flow rates decrease. Large gullies formed within Agassiz Pool as water flowed to the open portion of the JD11 channel during the 2012 drawdown. "The drawdown within the pool caused significant disturbance to emergent wetland vegetation and substrate in the immediate vicinity of the Ditch 11 Outlet. The head differential created between water surface elevations in the main ditch system extending upstream of the Ditch 11 Outlet and water surface elevations within Agassiz Pool appear to have created velocities sufficient to flatten vegetation and scour multiple networks of channels." High velocity sheetflow occurred as "water levels in the ditch began to drop lower than the surrounding pool water level. The sheetflow had velocities sufficient to flatten large areas of vegetation and undoubtedly transport large volumes of unconsolidated organic substrate from these areas of the pool." Excavation and head cutting will open up more of the old JD11 channel within Agassiz Pool. The sediment scoured from the channel will not be the only sediment that travels downstream. As more of the JD11 channel is excavated, the head differential (Figure 2-31) that occurs during sheetflow would be occurring along a longer reach of open channel. The scouring within the pool described in the *Assessment of Water Quality Conditions: Agassiz NWR, 2012* report could increase as that open channel is lengthened.

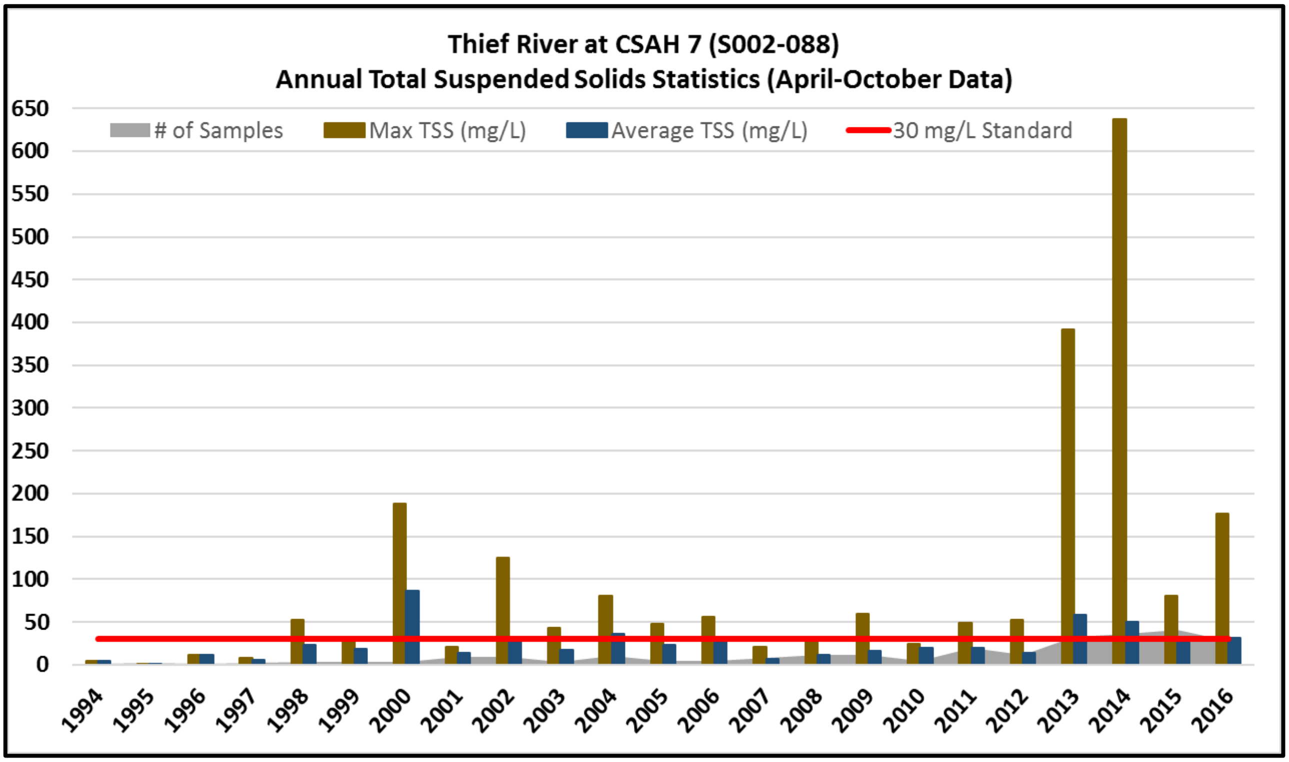



Figure 2-31. Historical annual maximum and average total suspended solids concentrations at CSAH 7 (S002-088)

Prior to the adoption of a new strategy for managing sediment within Agassiz Pool, monitoring data indicated that moderation of flows would be desirable for minimizing spikes in turbidity and TSS in the Thief River during Agassiz Pool drawdowns. Flashy flows in river channels can increase erosion rates. The cleaning of JD 11 for the purpose of flushing and the increased frequency of full drawdowns is the most likely cause of extreme turbidity and TSS levels in the Thief River in 2013 and 2014 (Figure 2-30) due to the disturbance of sediment in the pool and the in-pool erosive process that can occur during a drawdown. Flows through Agassiz Pool during spring runoff also result in exceptionally high TSS concentrations. Erosion from bare fields and unstable stream/ditch banks can also contribute to high TSS concentrations, but the

The sediment inputs from the Thief River may have been partially reduced by the northwest outlet structure that was installed in 2007 and allows a portion of the flow from the river to bypass the pool. This outlet reduced the amount of water that needs to flow through the radial gate outlet. USGS loading estimates and comments from USFWS staff indicate that the new outlet may be facilitating the removal of sediment. Sediment had been accumulating for decades in the northwest portion of Agassiz Pool and within the ditch channel along the pool's northwest dike.

Reducing the effects of sediment erosion upon all the waterways in the Thief River Watershed will be beneficial for accomplishing the goals of this TMDL. The amount of sediment coming into Agassiz Pool, for example, influences the amount of sediment available to be scoured out of Agassiz Pool and moved downstream. The pool receives water from the Thief River, Mud River, and some other smaller drainage systems. Both the Thief River and the Mud River meet their respective TSS water quality standards.

Although much discussion above is dedicated to discussion of the processes within Agassiz Pool, it is important to note that the origin of most of the sediment in the Thief River and its tributaries are stream bank erosion and overland erosion.

### 2.3.5 Nonpoint Sources of Nutrients

Any of the sources of sediment that were described in the previous section would also contribute nutrients. Local agencies test water quality samples for TP, OP, total Kjeldahl nitrogen (TKN, the sum of organic nitrogen, ammonia, and ammonium), nitrates plus nitrites, and ammonia. Of these, phosphorus is the nutrient of primary concern. Nitrates is another parameter that is often discussed due to high concentrations. The state of Minnesota has established eutrophication standards for rivers that establish summer (June through September) average concentration thresholds for phosphorus. The threshold for the central nutrient region is 100 µg/l, (0.100 mg/l). Intensive monitoring and data analysis has revealed a strong inverse correlation between levels of phosphorus and DO in the Thief River downstream of Agassiz Pool.

High concentrations of nitrates have been recorded at the outlets of tile drains in the Thief River Watershed. Concentrations in waterways have not been high enough to cause concern. Controlled drainage and technological advancements (e.g. bioreactors, saturated buffers, etc.) could lead to reduced nitrogen losses from tiled fields.

Sulfates and TP have been identified as quantifiable parameters that inversely correlate relatively well with daily minimum DO concentrations in the Thief River downstream of Agassiz Pool. Regression analysis of long-term monitoring data found an inverse correlation between sulfates and DO levels. Daily minimum DO concentrations appeared to decrease as sulfate concentrations increase. The lowest concentration of sulfates at which a sub-5 mg/l concentration of DO is recorded is 116 mg/l of sulfate. Sulfate; however, is more of a symptom of the low DO problem than it is a source of the problem. Sulfates, like depressed DO levels, are a product of oxidation of organic pollutants. More than just long-term data was needed to identify a statistical connection between depressed DO concentrations and a specific pollutant. An examination of individual occurrences of low DO levels indicated that some occurred during drawdowns of Agassiz Pool. In the late summer of 2015, the RLWD conducted an intensive monitoring effort during the August drawdown of Agassiz Pool to characterize the effect of drawdowns upon water quality and to identify a pollutant that has a negative correlation with DO levels.

RLWD water quality staff collected frequent early morning DO data and samples from the lower Thief River (downstream of Agassiz NWR) before and during the 2015 late-summer drawdown of Agassiz Pool. Samples were analyzed for TSS, TP, OP, TKN, ammonia nitrogen, nitrates + nitrites, *E. coli* bacteria, sulfates, total organic carbon, and chlorophyll-a. The river was sampled at two sites: S002-079 near the downstream end of the 09020304-501 reach and S002-088 near the upstream end of the reach. As flows decreased during the latter stages of the drawdown, concentrations of pollutants increased.

High TP concentrations (>0.1 mg/l) were found at CSAH 7 (S002-088) on 5 days (every sample in September) and 140th Avenue Northeast (S002-079, on three days) crossings of the Thief River during the 2015 drawdown. Low DO levels (<5 mg/l) were found at the CSAH 7 crossing of the Thief River on two days and another day was only 5.48 mg/l at 9:45 A.M., so it is reasonable to assume that the true daily minimum was less than 5mg/l early in the morning.

The 2015 intensive sampling effort successfully discovered negative correlations between pollutants and DO levels. The way that the correlations differed at the upstream end of the reach versus the downstream end of the reach also shed light upon what happens to nutrients and other pollutants as they travel downstream.

The data from this intensive monitoring effort show that the nutrients in the Thief River seem to have relatively strong correlations with DO concentrations, while river flows are dominated by discharge from Agassiz Pool. The strength of the correlation between daily minimum DO levels and parameters like sulfates, TP, OP, and ammonia nitrogen increase greatly from CSAH 7 to 140th Avenue The correlation between DO and sulfates (Figure 2-32) is very strong at the lower end of the reach (site S002-079). The correlation increases from an $R^2$ of 0.33 at CSAH 7 to an $R^2$ of 0.84 at 140th Avenue. A possible explanation for why this change occurs is that decomposition/oxidation of organic pollutants occurs along the reach. In other words, the decomposition and oxidation processes have had more time to consume DO and reduce DO concentrations by the time the water reaches the downstream monitoring site.

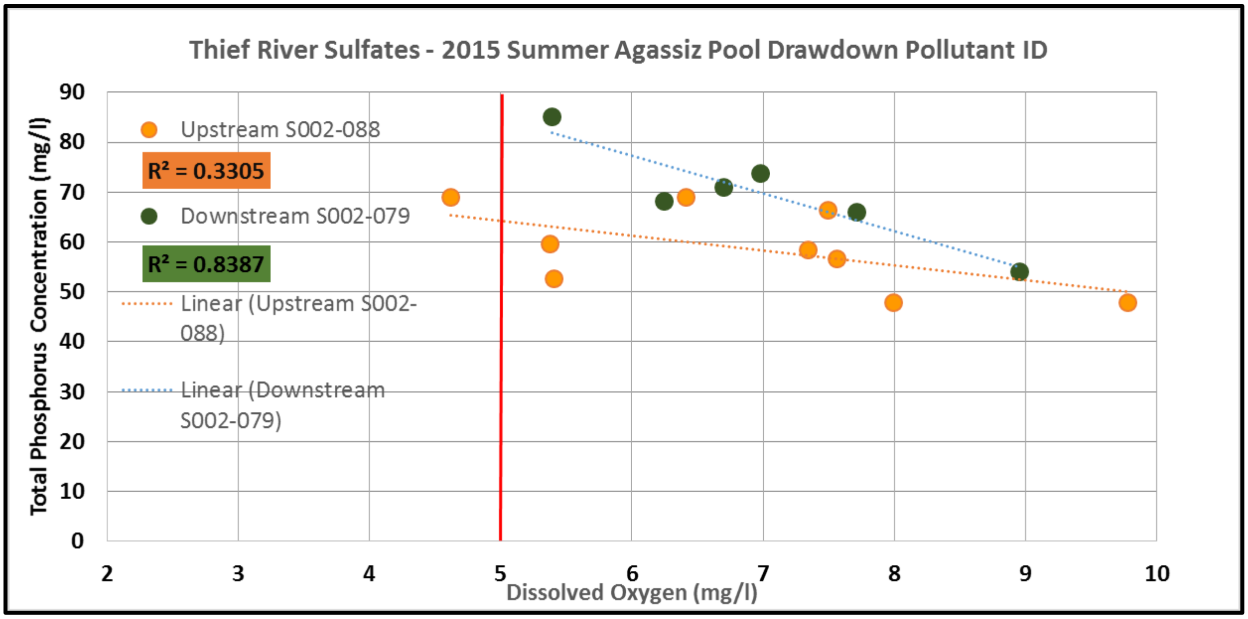



**Figure 2-32. The strength of the correlation ($R^2$) between dissolved oxygen and total sulfates increases from the upstream end of the reach to the downstream end of the 09020304-501 reach of the Thief River.**

Of the pollutants with inverse correlations with DO during this sampling effort, TP was the pollutant that had an existing eutrophication-related water quality standard. This sampling effort provided evidence that regular condition monitoring failed to provide regarding the relationship between phosphorus and DO levels (Figure 2-33). A time-series chart of the data shows that DO levels decrease when TP levels increase and vice-versa (Figure 2-34). The threshold for TP for the Central Nutrient Region established by state eutrophication water quality standards is 100 µg/l, which equals 0.100 mg/l (stream sample analysis is reported in mg/l). A time series of TP and DO levels during the 2015 intensive sampling showed that .100 mg/l of TP would be a reasonable numerical target for the limiting of pollution that is negatively affecting DO concentrations. During the 2015 sampling, DO levels decreased as TP concentrations increased. The TP concentration was greater than 0.100 mg/l when DO levels fell below 5 mg/l.

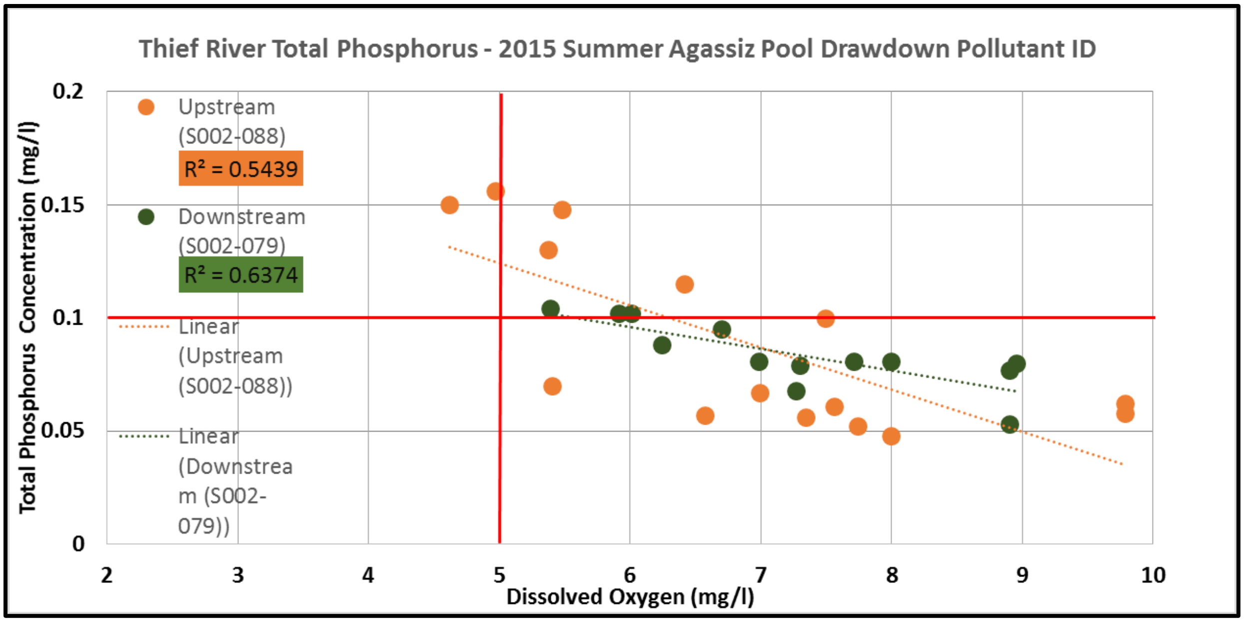



**Figure 2-33. The strength of the correlation ($R^2$) between dissolved oxygen and total phosphorus increases from the upstream end of the reach to the downstream end of the 09020304-501 reach of the Thief River.**

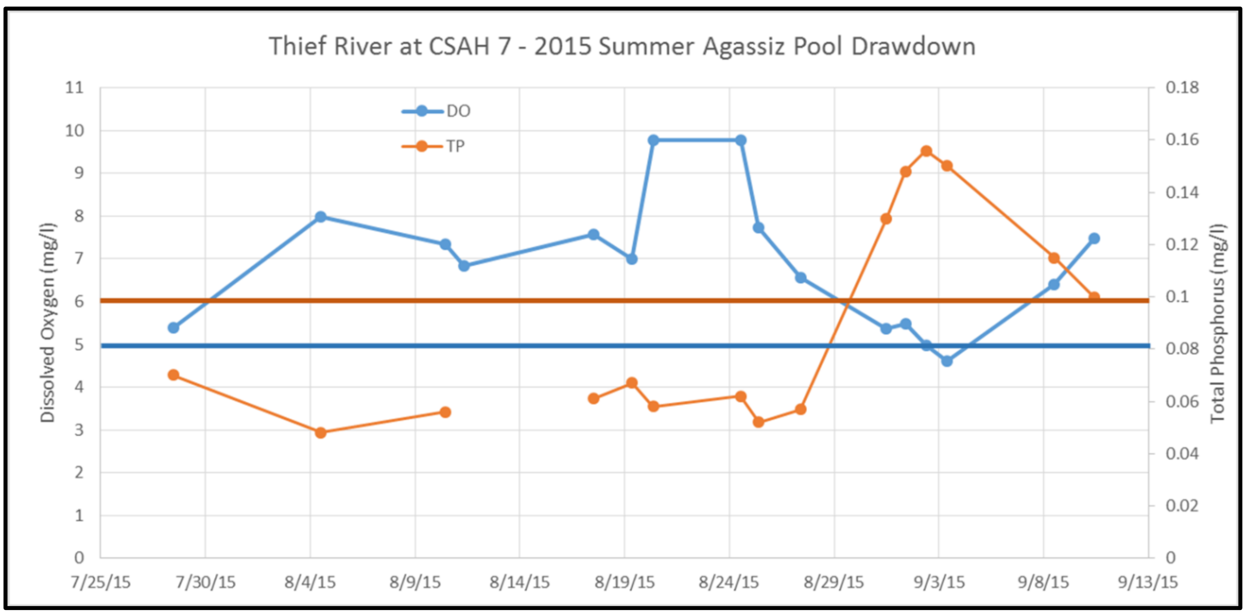



**Figure 2-34. Dissolved oxygen and total phosphorus concentrations mirrored each other during the late summer 2015 drawdown of Agassiz Pool.**

### 2.3.6 Nonpoint Sources of E.coli

In addition to failing septic systems, livestock and birds (cliff swallow colonies under bridges and within box culverts) have been identified as potential sources of *E. coli* in the Mud River. Natural background sources also contribute, minimally, to the *E. coli* concentrations found in the river.

Aerial photos show that there are some livestock operations along the Mud River upstream of Highway 54. Kayak stream reconnaissance identified sites where livestock are accessing the river downstream of Grygla.

Although some have been delisted, multiple reaches have been listed in the past as impaired by high concentrations of *E. coli* bacteria. There are two river reaches within the watershed (09020304-501 of the Thief River and 09020304-507 of the Mud River) that barely meet the *E. coli* standard when assessed as combined units, but have small segments or individual sites that exceed the chronic water quality standard for *E. coli* bacteria. On the Thief River, the CSAH 7 crossing (S002-088) exceeds the *E. coli* standard. The Mud River is failing to meet the standard at sites near the town of Grygla. A TMDL was calculated for the impaired portion of the Mud River.

The sites along the channelized portion of the Thief River (SD83) will likely be assessed separately from the sites on the lower, natural portion of the reach during the 2023 assessment. The data available for the SD 83 portion of the river will be dominated by the data collected at the CSAH 7 Bridge, where water quality sampling data shows a significant violation of the *E. coli* standard during the month of September (443.6 MPN/100ml). Concentrations improve at sites near the downstream end of the reach. Until the next official water quality assessment, knowledge of the bacteria sources that create an exceedance of the water quality standard is important for protecting recreational safety in the rest of the reach. Fecal DNA analysis has shown that waterfowl is a major contributor to *E. coli* concentrations at S002-088.

Branch A of JD 21 failed to meet the *E. coli* standard during the month of June in the 2011-2012 data that was used for the 2013 assessment. The assessment results were influenced by high concentrations recorded during June of 2011. Conditions have improved so that the reach is no longer impaired. The source of the impairment is unclear. Bird fecal DNA markers were found, but only in trace amounts. Cliff swallows inside culverts could have been contributing. Longitudinal sampling that was conducted during a rainfall event on June 5, 2014, failed to discover any high concentrations of *E. coli*. Concentrations were lower than 25 MPN/100mL throughout most of the watershed. The most significant increase was from 12 MPN/100mL to 49.5 MPN/100mL between 450$^{th}$ Street and CSAH 48 (downstream end of the drainage system).

The Thief River Reach 09020304-504 was formerly impaired by fecal coliform, but was delisted. *E. coli* data shows that the reach is meeting standards. The reach last failed to meet standards with a 137.8 MPN/100mL September geometric mean in 2005 through 2009 data (*E. coli* sampling began in 2005). In every subsequent incremental assessment (2001 through 2010, 2002 through 2011, 2007 through 2016), the reach has met *E. coli* standards. The high concentrations were discovered near the outlet of Thief Lake and fall bird baiting/banding along the outlet channel was one of the suspected sources. Birds would have been concentrated along the channel and there would have been little flow for dilution of *E. coli* "inputs" in the late summer or fall. Birds (pelicans and waterfowl) often congregate on the downstream side of the Thief Lake Dam – a natural source of *E. coli*.

### 2.3.7 Fecal DNA Analysis

Microbial source tracking (MST) is a method for identifying the type of animal that is the source of fecal coliform and *E. coli* pollution. MST samples were collected within the Thief River Watershed at sites that have failed to meet the 126 MPN/100ml standard in past assessments or had existing impairments at the time of sampling. Source Molecular, a laboratory in Florida that specializes in fecal DNA analysis testing, analyzed the samples. The lab conducts individual tests for each type of animal that may be contributing fecal bacteria. The numbers of sites, samples, and tests are limited by the cost of the analysis and shipping samples overnight to Miami. Therefore, MST samples were only collected at sites and reaches that have failed to meet *E. coli* standards. Past sampling results were used as a guide for the timing of samples. Sampling was scheduled for times of the years and flow levels at which high *E. coli* concentrations have been recorded in the past. *E. coli* samples were also collected and sent to RMB Environmental Laboratories in Detroit Lakes to document the concentration of *E. coli* bacteria at the time of sampling. In the Thief River Watershed, birds, waterfowl, ruminants (livestock), and humans (septic systems) were the sources for which the tests returned positive results. Dense populations of cliff swallows under bridges and within large culverts contribute to *E. coli* concentrations. High *E. coli* concentrations at the CSAH 7 crossing of the Thief River are most likely caused by waterfowl waste from the bottom of Agassiz Pool that is flushed out of the radial gate outlet. The results of fecal DNA sampling and analysis in the Thief River Watershed are summarized in Table 2-21.

**Table 2-21. Microbial Source Tracking Fecal DNA sampling results from the Thief River Watershed**

| Date | Site Name | S-Code | E. coli (CFU/100ml) | Analysis Requested | Quantification | DNA Analytical Results | Contribution to Fecal Pollution |
|---|---|---|---|---|---|---|---|
| 6/18/2014 | Mud R. @ Hwy. 89 | S002-078 | 95.9 | Bird Fecal ID | <LOQ | Positive (Trace) | Potential Contributor |
| 6/18/2014 | Mud R. @ Hwy. 89 | S002-078 | 95.9 | Cow Bacteroidetes ID | | Absent | |
| 6/18/2014 | Mud R. @ Hwy. 89 | S002-078 | 95.9 | Goose Bacteroidetes ID | | Absent | |
| 6/18/2014 | Mud R. @ Hwy. 89 | S002-078 | 95.9 | Human Bacteroidetes ID 1 | | Absent | |
| 6/18/2014 | Mud R. @ Hwy. 89 | S002-078 | 95.9 | Human Bacteroidetes ID 2 | | Absent | |
| 6/24/2014 | Mud R. @ Hwy. 89 | S002-078 | 920.8 | Bird Fecal ID | <LOQ | Present (Trace) | Potential Contributor |
| 6/24/2014 | Mud R. @ Hwy. 89 | S002-078 | 920.8 | Cow Bacteroidetes ID | | Absent | |
| 6/24/2014 | Mud R. @ Hwy. 89 | S002-078 | 920.8 | Goose Bacteroidetes ID | | Absent | |
| 6/24/2014 | Mud R. @ Hwy. 89 | S002-078 | 920.8 | Human Bacteroidetes ID 1 | | Absent | |
| 6/24/2014 | Mud R. @ Hwy. 89 | S002-078 | 920.8 | Human Bacteroidetes ID 2 | | Absent | |
| 8/26/2014 | Thief R. CSAH 7 | S002-088 | 114.5 | Bird Fecal ID | 2.00E+05 | Present | Major Contributor |
| 8/26/2014 | Thief R. CSAH 7 | S002-088 | 114.5 | Goose Bacteroidetes ID | | Absent | |
| 8/26/2014 | Thief R. CSAH 7 | S002-088 | 114.5 | Human Bacteroidetes ID 1 | Non-detect | Absent | Negative |
| 8/26/2014 | Thief R. CSAH 7 | S002-088 | 114.5 | Human Bacteroidetes ID 2 | Non-detect | Absent | Negative |
| 8/26/2014 | Thief R. CSAH 7 | S002-088 | 114.5 | Ruminant Fecal ID | | Absent | |
| 9/16/2014 | Thief R. CSAH 7 | S002-088 | 128.1 | Bird Fecal ID | 5.36E+04 | Present | Major Contributor |
| 9/16/2014 | Thief R. CSAH 7 | S002-088 | 128.1 | Goose Bacteroidetes ID | <LOQ | Present (Trace) | Potential Contributor |
| 9/16/2014 | Thief R. CSAH 7 | S002-088 | 128.1 | Human Bacteroidetes ID 1 | | Absent | |
| 9/16/2014 | Thief R. CSAH 7 | S002-088 | 128.1 | Human Bacteroidetes ID 2 | | Absent | |
| 9/16/2014 | Thief R. CSAH 7 | S002-088 | 128.1 | Ruminant Fecal ID | | Absent | |
| 6/18/2014 | Branch A JD21 | S006-540 | 26.2 | Bird Fecal ID | <LOQ | Positive (Trace) | Potential Contributor |
| 6/18/2014 | Branch A JD21 | S006-540 | 26.2 | Cow Bacteroidetes ID | | Absent | |
| 6/18/2014 | Branch A JD21 | S006-540 | 26.2 | Goose Bacteroidetes ID | | Absent | |
| 6/18/2014 | Branch A JD21 | S006-540 | 26.2 | Human Bacteroidetes ID 1 | | Absent | |
| 6/18/2014 | Branch A JD21 | S006-540 | 26.2 | Human Bacteroidetes ID 2 | | Absent | |
| 6/24/2014 | Branch A JD21 | S006-540 | 410.6 | Beaver Fecal ID | | Absent | |
| 6/24/2014 | Branch A JD21 | S006-540 | 410.6 | Bird Fecal ID | <LOQ | Present (Trace) | Potential Contributor |
| 6/24/2014 | Branch A JD21 | S006-540 | 410.6 | Cow Bacteroidetes ID | | Absent | |
| 6/24/2014 | Branch A JD21 | S006-540 | 410.6 | Human Bacteroidetes ID 1 | | Absent | |
| 6/24/2014 | Branch A JD21 | S006-540 | 410.6 | Human Bacteroidetes ID 2 | | Absent | |
| 7/18/2017 | Mud R. @ Grygla | S008-122 | 62 | Bird Fecal ID | | Not Detected | |
| 7/18/2017 | Mud R. @ Grygla | S008-122 | 62 | Ruminant Bacteroidetes ID | Low, Not Quantified | Detected | Potential Contributor |
| 7/18/2017 | Mud R. @ Grygla | S008-122 | 62 | Beaver Fecal ID | | Not Detected | |
| 7/18/2017 | Mud R. @ Grygla | S008-122 | 62 | Goose Bacteroidetes ID | | Not Detected | |
| 7/18/2017 | Mud R. @ Grygla | S008-122 | 62 | Human Bacteroidetes ID 1 | 1.76E+02 | Detected | Contributes at low levels |
| 7/18/2017 | Mud R. @ Grygla | S008-122 | 62 | Human Bacteroidetes ID 2 | | Not Detected | |

## 2.4 TMDL Summary

Table 2-22. Completed TMDLs in the Thief River Watershed

| Total Maximum Daily Load | Impaired AUIDs | Online Access (Link) |
|---|---|---|
| Thief River Watershed Total Maximum Daily Load | Thief River (09020304-501), TSS<br>Mud River (09020304-507), *E. coli* | https://www.pca.state.mn.us/water/watersheds/thief-river |

Table 2-23. Allocation summary for TMDLs, and for addressing Mud River and Moose River low DO, in the Thief River Watershed

| Stream (AUID) | Location (Site ID) | Pollutant | Units | Season or Flow Conditions | Current Load | Allocations: Wasteload Allocation | Allocations: Load Allocation | Allocations: Margin of Safety | Allocations: Reserve Capacity | Percent Reduction |
|---|---|---|---|---|---|---|---|---|---|---|
| **Thief River Watershed Total Maximum Daily Load** | | | | | | | | | | |
| Thief River | S002-079 | Total Suspended Solids (30 mg/l) | Tons/Day | Very High | 142.39 | 0.00 | 83.74 | 9.30 | 0.00 | 41.2% |
| Thief River | S002-079 | Total Suspended Solids (30 mg/l) | Tons/Day | High | 14.33 | 0.00 | 11.00 | 1.22 | 0.00 | 23.3% |
| Thief River | S002-079 | Total Suspended Solids (30 mg/l) | Tons/Day | Mid-Range | 0.21 | 0.00 | 0.95 | 0.11 | 0.00 | 0.0% |
| Thief River | S002-079 | Total Suspended Solids (30 mg/l) | Tons/Day | Low | 0.01 | 0.00 | 0.07 | 0.01 | 0.00 | 0.0% |
| Thief River | S002-079 | Total Suspended Solids (30 mg/l) | Tons/Day | Very Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0% |
| Mud River | S002-977 | *E. coli* (126 MPN/100mL) | Tons/Day | Very High | 53.00 | 0.00 | 484.43 | 53.83 | 0.00 | 0.0% |
| Mud River | S002-977 | E. coli (126 MPN/100mL) | Tons/Day | High | 229.80 | 0.00 | 140.25 | 15.58 | 0.00 | 39.0% |
| Mud River | S002-977 | E. coli (126 MPN/100mL) | Tons/Day | Mid-Range | 157.97 | 0.00 | 37.54 | 4.17 | 0.00 | 76.2% |
| Mud River | S002-977 | E. coli (126 MPN/100mL) | Tons/Day | Low | 203.49 | 0.00 | 5.35 | 0.59 | 0.00 | 97.4% |
| Mud River | S002-977 | E. coli (126 MPN/100mL) | Tons/Day | Very Low | No Data | 0.00 | 0.43 | 0.05 | 0.00 | 0.0% |
| Mud River | S002-078 | Flow (for DO) | Cubic feet per second | All | Maintain a rate of flow greater than 5 CFS at the Highway 89 crossing using water stored within the Moose River Impoundment. | | | | | |
| Moose Rive | S002-078 | Flow (for DO) | Cubic feet per second | All | Maintain a rate of flow greater than 0 CFS at the CSAH 54 crossing using water stored within the Moose River Impoundment. | | | | | |

The Thief River Watershed TMDL (Table 2-22) is the only TMDL report that has been completed for the Thief River Watershed. Its development was a part of the Thief River WRAPS project. It addresses one *E. coli* impairment and one TSS impairment. Sediment reductions will be required for the Thief River, between Agassiz Pool and the Red Lake River, to meet the 30 mg/l TSS standard. The low DO impairments on the Moose River and the Mud River were found to be the result of low flows rather than high nutrient concentrations. Analysis revealed that maintenance of minimal levels of flow would allow both of those rivers to meet the 5 mg/l DO standard. A summary of pollutant load allocations, pollutant load reduction goals, and base flow maintenance goals developed for the TMDL are shown in Table 2-23.

## 2.5 Protection Considerations

This section provides information that will help prioritize waterways in all subwatersheds of the Thief River Watershed for protection efforts.

To highlight and prioritize waters that are in most need of protection for each of the major parameters (TSS, *E. coli*, TP, DO), assessment statistics (exceedance rate, growing season average) are compared to impairment thresholds. Waterways are ranked according to the proximity of their current condition to the impairment threshold. Rivers, streams, and ditches that have exceedance rates in the high single-digits, for example, need protection efforts so that they don't exceed the 10% impairment threshold exceedance rate in future assessments. A reach that is exceeding the TSS standard in 8.1% of samples is within two percentage points of becoming impaired. That reach would likely be a high priority for protection efforts.

**TSS**

The threshold rate of exceedance of the TSS standard is 10%. As shown in Table 2-24, only one reach of the Thief River is failing to meet the standard (09020304-501). That reach will be targeted for restoration efforts aimed at erosion control. Protection consideration should be given to reaches that have rates of exceedance that are near the threshold. Efforts should be made to ensure that these reaches do not become impaired in the future. Those reaches include the Mud River upstream of Agassiz NWR (09020304-507) and JD11 at the outlet of Agassiz Pool (09020304-536). The Mud and Moose Rivers are currently assigned to the Central River Nutrient Region with a 30 mg/L standard. There is evidence that suggests that the 15 mg/L standard may be more appropriate for those rivers. Both standards are represented in Table 2-24. Both streams can meet the 15 mg/L standard. Multiple studies have found that the Mud River is carrying excess sediment, which has caused degradation of habitat within Agassiz Pool. Although the Mud and Moose River were not assessed in 2013 due to channelization, there were biological sampling results in both rivers that failed to meet expectations. Excess sediment would be a potential stressor of aquatic life in the Mud River, along with low DO and altered hydrology. The MPCA river nutrient region maps (prior to adaptation for TSS) have shown that the North River Nutrient Region (15 mg/L standard) encompassed the Moose River. Data shows that much degradation would be necessary for the Moose River to exceed the 15 mg/L standard.

Table 2-24. Proximity to the Total Suspended Solids Impairment Threshold

| River | Reach | AUID | TSS Std Exceedance Rate | Proximity to Std | TSS Standard | TSS Years |
|---|---|---|---|---|---|---|
| Thief River | Agassiz Pool to Red Lake R | 09020304-501 | 22.0% | 12.0% | 30 | 2007-2016 |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | 10.3% | 0.3% | 15 | 2007-2016 |
| Unnamed Ditch (Branch A of JD21) | Unnamed ditch to Moose R | 09020304-555 | 5.6% | 4.4% | 30 | 2011-2016 |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | 4.0% | 6.0% | 30 | 2007-2016 |
| Unnamed Ditch (Judicial Ditch ~~18~~ 30) | T154 R42W S14, east line (JD30) to Thief R | 09020304-509 | 3.7% | 6.3% | 30 | 2008-2016 |
| Moose River | Headwaters to Thief Lk | 09020304-505 | 2.7% | 7.3% | 15 | 2007-2016 |
| Moose River | Headwaters to Thief Lk | 09020304-505 | 0.0% | 10.0% | 30 | 2007-2016 |
| Thief River | Thief Lk to Agassiz Pool | 09020304-504 | 0.0% | >10% | 30 | 2007-2016 |
| Unnamed Ditch (Ditch 200) | Unnamed ditch to unnamed ditch | 09020304-511 | 0.0% | >10% | 30 | 2007-2012 |
| County Ditch 20 | Unnamed ditch (Branch A CD 30) to Unnamed ditch (Branch D CD 20) | 09020304-519 | 0.0% | >10% | 30 | 2007-2016 |
| Unnamed Ditch | Unnamed ditch to unnamed ditch | 09020304-534 | 0.0% | >10% | 30 | 2008-2009 |
| Impaired reach in need of restoration | | Not impaired, but close. Needs protection | | | | |

**TP**

TP is one of the most commonly collected of the parameters that are used for an assessment of river eutrophication. Instead of the exceedance rate that is used for other parameters, a growing season mean (June 1 through September 30) is used to determine if phosphorus is exceeding the river eutrophication standard. Standards were applied to the reaches in the Table 2-25 based upon the most recently available Red River Basin River Nutrient and Stream Assignment map. There are streams in the northeastern portion of the watershed that could be assigned to either the North River Nutrient Region or the Central River Nutrient Region. Due to uncertainty about the applicable standard, both standards are represented on the table for the benefit of local planning efforts.

Table 2-25. Ranking of reaches for protection and restoration activities related to total phosphorus nutrient inputs.

| River | Reach | AUID | TP Std (mg/l) | Summer Avg TP | Proximity to Standard |
|---|---|---|---|---|---|
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | 0.050 | 0.06 | 0.01 |
| Moose River | Headwaters to Thief Lk | 09020304-505 | 0.050 | 0.05 | 0.00 |
| Thief River | Agassiz Pool to Red Lake R | 09020304-501 | 0.100 | 0.07 | -0.03 |
| Unnamed Ditch (Judicial Ditch ~~18~~ 30) | T154 R42W S14, east line (JD30) to Thief R | 09020304-509 | 0.100 | 0.07 | -0.03 |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | 0.100 | 0.06 | -0.04 |
| Moose River | Headwaters to Thief Lk | 09020304-505 | 0.100 | 0.05 | -0.05 |
| County Ditch 20 | Unnamed ditch (Branch A CD 30) to Unnamed ditch (Branch D CD 20) | 09020304-519 | 0.100 | 0.06 | -0.05 |
| Unnamed Ditch (Ditch 200) | Unnamed ditch to unnamed ditch | 09020304-511 | 0.100 | 0.05 | -0.05 |
| Thief River | Thief Lk to Agassiz Pool | 09020304-504 | 0.100 | 0.04 | -0.06 |
| Unnamed Ditch (Branch A of JD21) | Unnamed ditch to Moose R | 09020304-555 | 0.100 | 0.03 | -0.07 |
| Impaired reach (potential, not official) in need of restoration | | Not impaired, but close. Needs protection | | | |

The Moose River and Mud River need protection efforts to meet the North River Nutrient Region standard and avoid future impairments. The Mud River and Moose River appear to be high priority areas for nutrient runoff reduction efforts. The reaches are not officially listed as impaired at this time. Eutrophication standards were not officially adopted and approved by the EPA until January 23, 2015, after the 2013 assessment process was completed. To designate an eutrophication impairment, the reach would also have to violate one of the state's BOD, chlorophyll-a, or DO flux standards. Data indicates that the Mud River (507) is currently failing to meet multiple eutrophication standards (TP, BOD, DO flux).

Of the reaches that appear to be meeting the TP standard, the Thief River downstream of Agassiz NWR also appears to be in danger of becoming impaired in the future, and needs protection efforts aimed at reducing nutrient runoff and reducing the amount of sediment and nutrients. Data analysis determined that reducing TP concentrations could improve DO concentrations.

**Table 2-26. Ranking of reaches for protection and restoration strategies focused upon reducing *E. coli* pollution.**

| River/Ditch Name | Reach Description | AUID | May E. coli | June E. coli | July E. coli | Aug. E. coli | Sept. E. coli | Max. Geo-Mean | Proximity to Std | E. coli Years |
|---|---|---|---|---|---|---|---|---|---|---|
| Thief River | Agassiz Pool to Red Lake R | 09020304-501 | 11.4 | 47.8 | 92.7 | 74.5 | 124.2 | 124.2 | 1.8 | 2005-2014 |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | 27.7 | 93.7 | 116.4 | 75.4 | 41.1 | 116.4 | 9.6 | 2005-2014 |
| Unnamed Ditch (Branch A of JD21) | Unnamed ditch to Moose R | 09020304-555 | 17.7 | 99.5 | 34.6 | 41.6 | 63.3 | 99.5 | 26.5 | 2011-2015 |
| County Ditch 20 | Unnamed ditch (Branch A CD 30) to Unnamed ditch | 09020304-519 | 13.3 | 43.5 | 70.6 | 52.0 | 39.4 | 70.6 | 55.4 | 2007-2014 |
| Thief River | Thief Lk to Agassiz Pool | 09020304-504 | 4.6 | 24.9 | 31.2 | 45.8 | 66.4 | 66.4 | 59.6 | 2005-2014 |
| Unnamed Ditch (Judicial Ditch ~~18~~30) | T154 R42W S14, east line (JD30) to Thief R | 09020304-509 | 16.2 | 51.1 | 45.8 | 42.1 | 43.9 | 51.1 | 74.9 | 2008-2014 |
| Unnamed Ditch (Ditch 200) | Unnamed ditch to unnamed ditch | 09020304-511 | 9.7 | 19.9 | 46.0 | 25.8 | 21.8 | 46.0 | 80.0 | 2007-2012 |
| Moose River | Headwaters to Thief Lk | 09020304-505 | 10.1 | 35.1 | 44.5 | 30.9 | 45.4 | 45.4 | 80.6 | 2005-2014 |
| Impaired reach in need of restoration | | | Not impaired, but close. Needs protection | | | | | | | |

### *E. coli*

Currently, only the Mud River (09020304-507) in the Thief River Watershed is officially impaired by *E. coli* bacteria (Table 2-26). Although the aggregated data for the entire reach look okay, site-specific analysis prevented this portion of the reach from being delisted. The reach is impaired at sites near the city of Grygla (S002-977 and S008-122). Table 2-26 shows that all other monthly geometric means are currently less than 126 MPN/100ml. Impairments have existed on several other reaches in the past, but have improved enough to be delisted. Most recently, the addition of more data in 2015 reduced the geometric mean *E. coli* concentration in Branch A of JD21 below the impairment threshold of 126 MPN/100ml. Because of recent impairments, Branch A of JD21 (09020304-555), and the Thief River upstream of Agassiz Pool (09020304-504) are two of the highest priority areas for protection efforts that will reduce the amount *E. coli* bacteria entering streams and prevent future returns to the 303(d) List of Impaired Waters.

The issues along the Lower Thief River (09020304-501), the other high-priority reach, have been described earlier in this document. The portions of the reach that do not meet the standard are balanced-out by the portions of the reach that do meet the standard. The statistics that blend the sampling results from throughout the 22-mile reach will not protect users of the excessive *E. coli* levels in the upper portion of this reach. Examination of strategies for reducing *E. coli* concentrations in the upper reaches of the Thief River are still important as protection strategies, even though restoration strategies are not currently required. During the next assessment using TALU protocols, assessment unit 09020304-501 may be split at the downstream end of the dredging for State Ditch 83. Stations S004-495, S004-723, S004-052, and S002-088 are the currently established monitoring stations along the channelized portion of AUID 09020304-501. The combined September geometric mean for those sites exceeds the chronic *E. coli* water quality standard with a concentration of 307.5 MPN/100ml (2007-2016 EQuIS data).

Table 2-27. Ranking of dissolved oxygen assessment results and identification of reaches in need of protection.

| River/Ditch Name | Reach Description | AUID | Percentage of values <5 mg/l DO12_All (EQuIS) | DO5_All (EQuIS) | DO5_9am |
|---|---|---|---|---|---|
| Unnamed Ditch (Branch 200 of JD11) | Unnamed ditch to unnamed ditch (Hwy 219 to 290th Ave NE) | 09020304-534 | 18.2% | 21.6% | 57.1% |
| Unnamed Ditch (Ditch 200) | Unnamed ditch to unnamed ditch | 09020304-511 | 8.8% | 12.4% | IF, 100% |
| Moose River | Headwaters to Thief Lk | 09020304-505 | 9.7% | 11.7% | IF, 65% |
| County Ditch 20 | Unnamed ditch to CD 32 | 09020304-513 | 6.5% | 8.7% | 40.0% |
| Unnamed Ditch (Br1 of JD11) | Unnamed ditch (Br15 JD11) to unnamed ditch (Br 7 JD11) | 09020304-543 | 2.6% | 5.4% | No data |
| County Ditch 20 | Unnamed ditch (Branch A CD 30) to | 09020304-519 | 2.2% | 2.9% | 42.9% |
| Thief River | Agassiz Pool to Red Lake R | 09020304-501 | 5.9% | 2.9% | 0.0% |
| Unnamed Ditch (Branch A of JD21) | Unnamed ditch to Moose R | 09020304-555 | 1.7% | 1.9% | IF, 0% |
| Mud River | Headwaters to Agassiz Pool | 09020304-507 | 1.3% | 1.7% | 16.0% |
| Judicial Ditch 11 | Unnamed ditch (Branch 194 of JD11) to Thief River | 09020304-536 | 0.0% | 1.6% | No data |
| Unnamed Ditch (Judicial Ditch 30) | T154 R42W S14, east line (JD30) to Thief R | 09020304-509 | 1.0% | 1.2% | 3.3% |
| Judicial Ditch 11 | Unnamed ditch (Moose R Impoundment South Pool Outlet) to unnamed ditch (Benville Rd) | 09020304-521 | 0.0% | 0.0% | IF, 0% |
| Thief River | Thief Lk to Agassiz Pool | 09020304-504 | 0.0% | 0.0% | IF, 0% |
| Judicial Ditch 11 (Lost River Pool) | Unnamed ditch (Mud River) to unnamed ditch (Br 194 JD11) | 09020304-535 | 0.0% | 0.0% | IF, 0% |
| Impaired reach in need of restoration | | Not officially impaired, but needs protection | | | |

**DO**

The Lower Thief River (09020304-501) was delisted during the 2013 assessment, but continuous DO data collected with deployed sondes (exacerbated by data collected during 2012 low flows) still raises concern about how well the reach meets the DO standard. The increased frequencies at which deployed sondes can capture violations of the DO standard, compared to daytime spot measurements, can be seen in Table 2-27.

The Mud River is within reach of a delisting of the DO impairment and should have a high priority for projects and BMPs that reduce nutrient runoff, maintain base flows, and/or improve DO levels. Discrete DO data from the Mud River looks good, but the reach is still impaired according to data from deployed DO loggers. The DO impairment in the Mud River is caused by a lack of base flow. Water became stagnant during exceptionally dry conditions in 2012 and increased the overall rate of true daily minimum low DO readings from deployed DO loggers enough to keep the river on the 303(d) List of Impaired Waters.

There are several reaches in need of protection. There are impairments on two ditches that were identifiable from discrete monitoring data, but were deferred due to channelization and the anticipated adoption of TALU water quality standards. Continuous data confirms that those reaches are not meeting the 5 mg/l standard often enough. Branch 200 of JD11 is primarily monitored at 190th Avenue Northeast. The site is downstream of an impoundment and water can become stagnant during periods of low flow. The 09020304-534 reach of Branch 200 was monitored at 290th Avenue Northeast for the Agassiz NWR water quality study and also had stagnant water during periods of low flow.

JD 30 would have passed an assessment of discrete data, but still needs some improvement to have DO levels that are sufficient to fully support aquatic life. Stagnant flow would likely be the cause of the low DO readings in JD30. The problem is not as bad as other reaches that were monitored with DO loggers in 2012.

A greater effort to collect pre-9 a.m. measurements or to collect new continuous DO data will be needed throughout the watershed, but especially in the reaches that currently have no pre-9 a.m. (DO5_9 a.m.) data.

### 2.5.1 0902030401 Moose River

Improving base flow conditions is essential for the maintenance of acceptable DO concentrations in the Moose River. Without flow in the Moose River, DO concentrations drop below the 5 mg/l threshold that has been set by state water quality standards for the protection of aquatic life. The operating plan of Moose River impoundment, operated by RLWD, needs to be adjusted to allow the stored water, between the summer and winter pool target elevations, to be metered out of the impoundment for maintaining base flow in the channel at the CSAH 54 flow monitoring site (S004-211). There is a staff gage at the CSAH 54 monitoring site for high flows, but it won't be readable at the minimum suggested flow. Tape-down measurements are made from the upstream end of the south culvert. According to the flow rating curve for this site, shown in Figure 2-35, a tape down of 6.7 feet or less would equal a flow of 5 CFS or more. Stage monitoring equipment with telemetry could be added to the site to aid in the maintenance of flow there. According to the most up-to-date version of the flow rating curve at CSAH 54:

6.7 ft. tape down from upstream end of S culvert = 1166.03 ft. NADV29 elevation on staff gauge

1166.03 ft. NADV29 elevation on staff gauge = 1167.32 ft. NADV88 elevation

1167.32 ft. NADV88 elevation = 5.56 CFS of flow

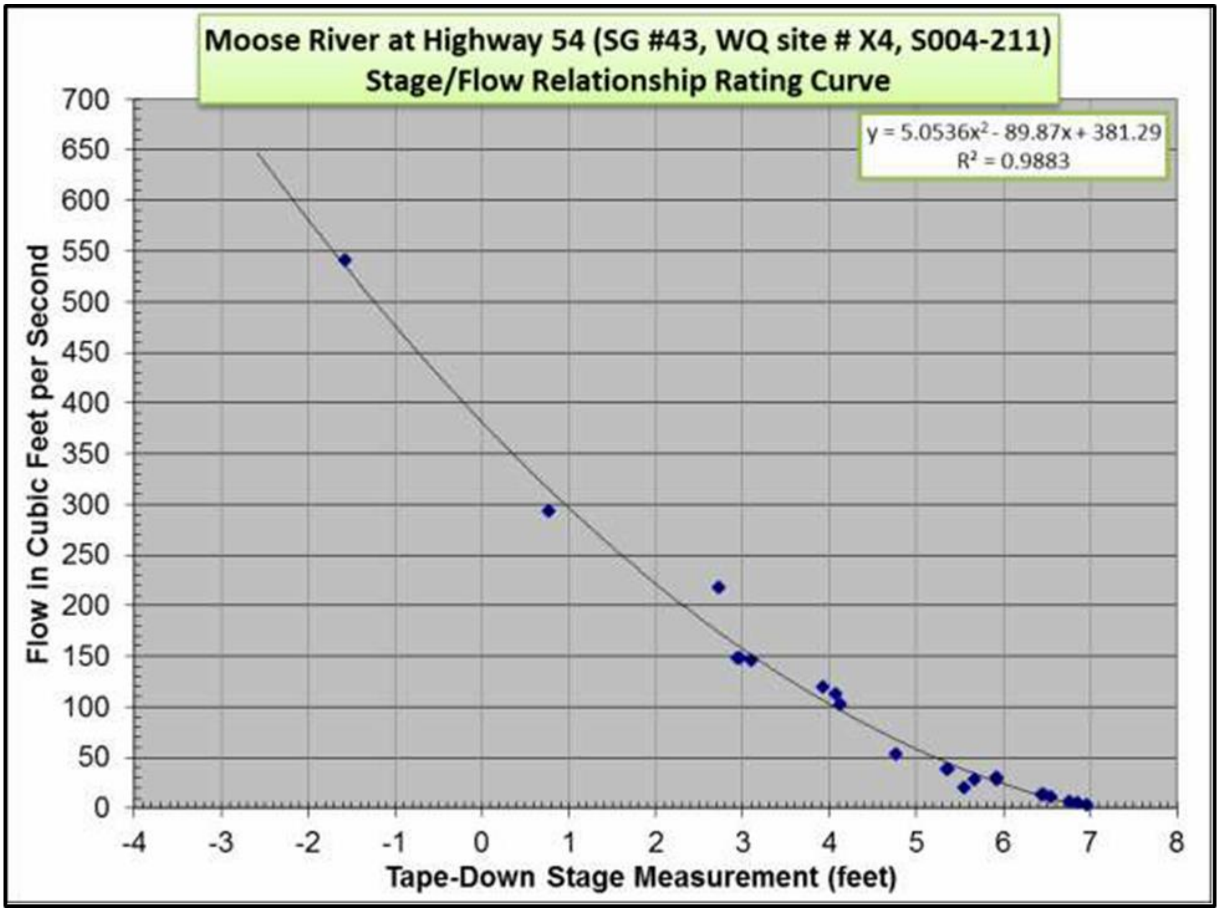



Figure 2-35. Moose River at Highway 54 (S004-211) Flow Rating Curve

Low DO levels in the Moose River are found in the summer months of June through September and under the ice in winter months (Figure 2-36).

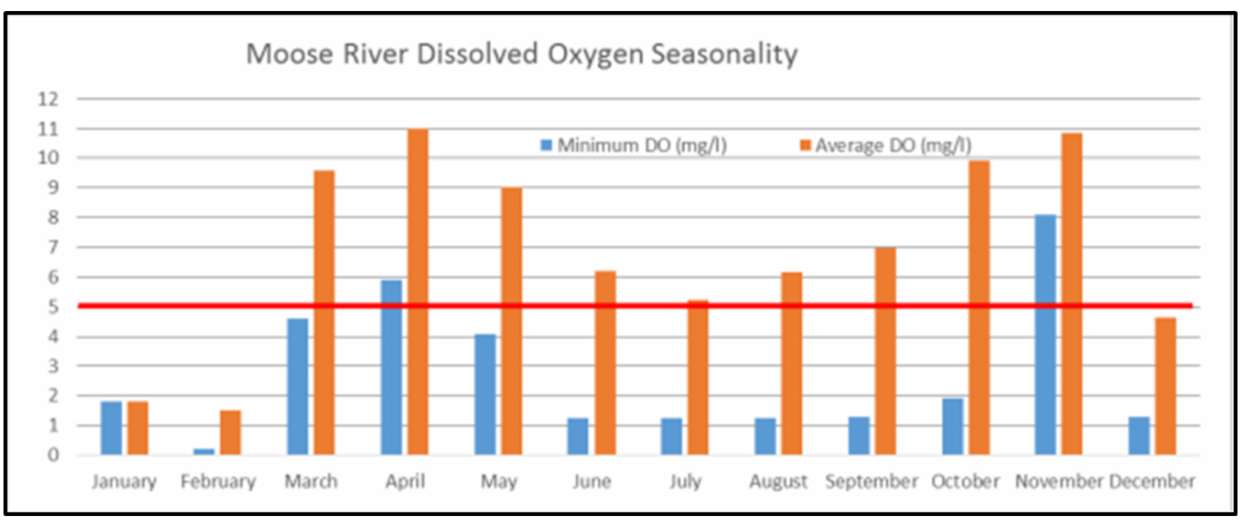



Figure 2-36. Monthly average and minimum dissolved oxygen concentrations in the Moose River – all historical data.

The rate at which low DO levels are recorded in the Moose River increases during the summer months and peaks in August (Figure 2-37). Flows in the Moose River are also low in August, and temperatures are high (Figure 2-38).

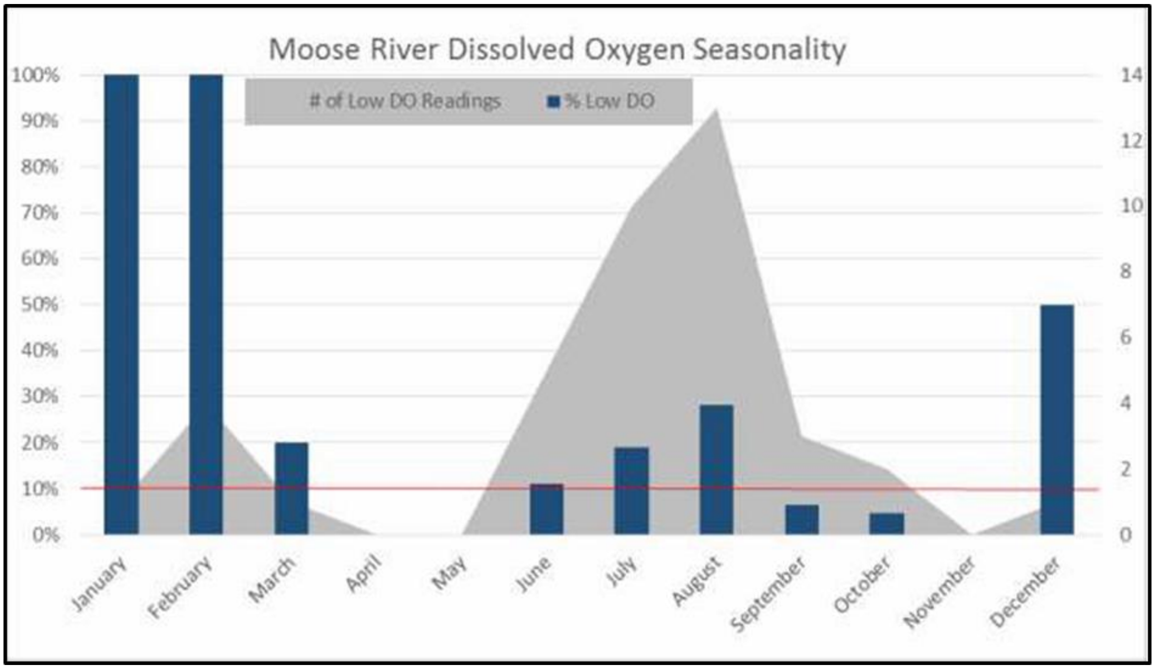



Figure 2-37. Monthly percentages of daily minimum discrete dissolved oxygen measurements below the 5 mg/l standard and the number of samples collected in the Moose River – all sites.

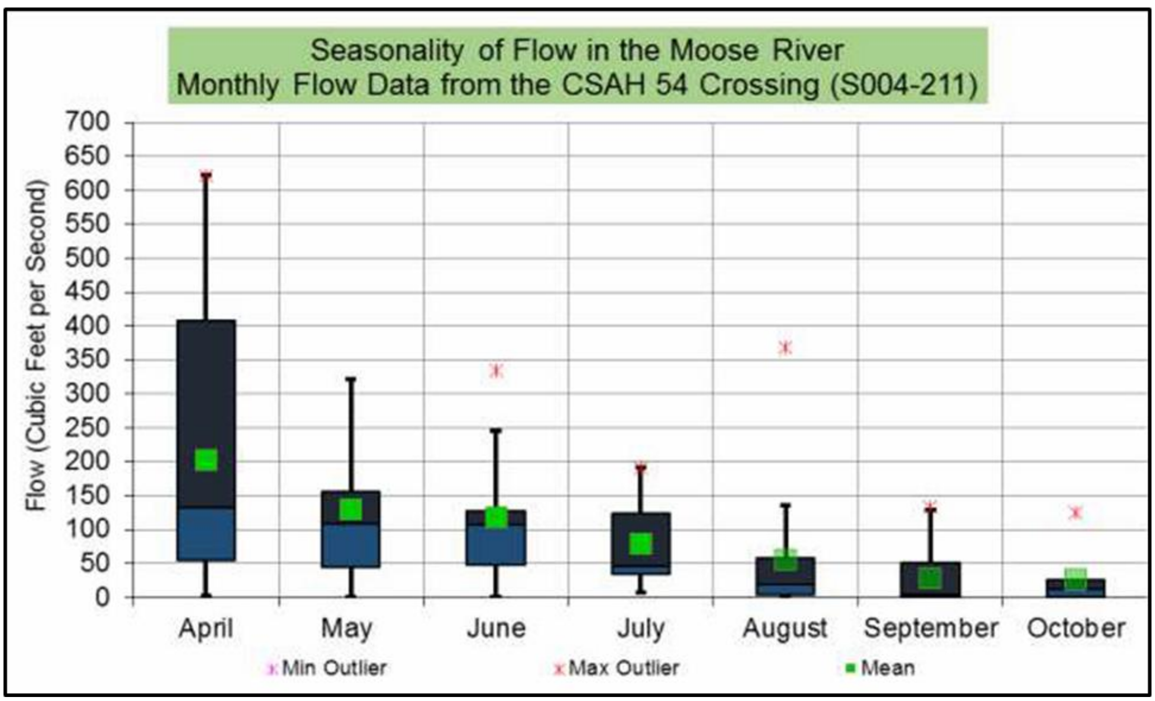



Figure 2-38. Seasonality of flow in the Moose River - an analysis of monthly flow data from the CSAH 54 (S004-211) monitoring site.

Low DO readings occur at a much greater frequency (in EQuIS data) where the Moose River is influenced by backwater from Thief Lake (Figure 2-39). The percentage of DO values that violate the standard exceeds the 10% impairment threshold at the two sites that are influenced by Thief Lake backwater (S006-539 and S002-089), but not at the free-flowing site at CSAH 54 (S004-211). Within the most recent 10 years, DO levels have been acceptable in the spring when water temperatures are cool and there is plenty of flow. Low DO values are found in the warmer summer months and occasionally in the fall.

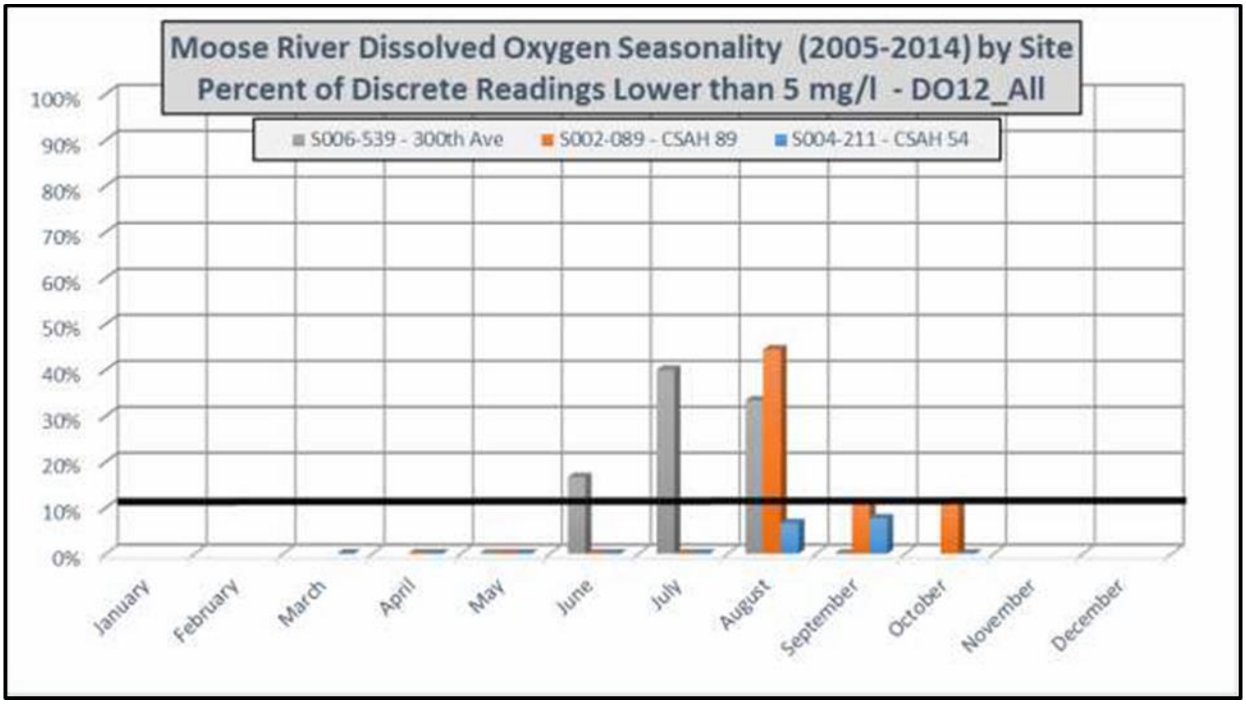


Figure 2-39. Site-specific seasonality of dissolved oxygen along the Moose River.

The focus of water quality protection and restoration activities to reduce pollutant yields along the Moose River should focus upon the area from Moose River Impoundment (including impoundment operations) and CSAH 54. Channel restoration and improvement of buffers along the Moose River upstream of CSAH 54 are needed to improve channel stability and habitat quality. Upland sources of sediment need to be targeted to lessen the contribution of excessive sediment to the river channel and to lessen sedimentation within Thief Lake (Figure 2-40). Although the Moose River is encompassed by the boundary of the North River Nutrient Region, it was assigned to the central nutrient region 30 mg/L when the nutrient regions were adapted for application of the TSS standard. Data shows that the 15 mg/L TSS standard would be a more appropriate standard for guiding local water quality protection goals and strategies. There has been only one exceedance of the 15 mg/L standard recorded in the years 2007 through 2016 at within the 09020304-505 AUID.

Most of the riparian area along the Moose River west of CSAH 54 is undeveloped and natural land that falls within the protective confines of the Thief Lake WMA. Accessibility to the reach between CSAH 54 and Highway 89 is very limited. There is little to be done to improve this portion of the river. The goal for this reach is to maintain its current condition, by supporting projects and management practices that reduce flashiness of flows and enhance base flows.


Figure 2-40. Some sedimentation within the main pool of Thief Lake has been noted with aerial photography.

During flooding events, velocities along the lower reaches of the Moose River could be decreased by creating "holes" in the spoil piles along the dredged channel. This would allow flood water to flow out onto the wetland complexes as surface water, and reduce velocities within the stream channel during flooding.

The quality of aquatic life in the Moose River is likely affected by a loss of connectivity. The Moose River is separated from the Red River of the North by dams on the Red Lake River in Thief River Falls, Thief River in Agassiz Pool, and at the Thief Lake outlet.

### 2.5.2 0902030402 Upper Thief River

The Thief River, from its beginning at the Thief Lake outlet to where it enters Agassiz NWR, was once listed as impaired by high un-ionized ammonia nitrogen and for high *E. coli* bacteria. The reach has been delisted for these impairments because recent data indicates these water quality standards are being met. Protection of water quality in the reach so that it doesn't exceed the standards for those parameters again will be an important goal for the future.

Waterfowl banding activity along the outlet channel of Thief Lake has been identified as a potential source of the *E. coli* impairment that was at one time attached to the Thief Lake to Agassiz Pool reach of the Thief River.

The quality of aquatic life in the Upper Thief River is affected by a loss of connectivity. The Upper Thief River is separated from the Red River of the North by dams on the Red Lake River in Thief River Falls and the Thief River in Agassiz Pool. It is separated from upstream waters by the dam at the outlet of Thief Lake.

Though this reach meets water quality standards, TSS concentrations are still a concern where the river enters Agassiz NWR. Water quality is usually quite good at the Thief Lake outlet. At the CSAH 49 crossing

(S002-084), the river has not exceeded the 30 mg/l TSS standard for the Central River Nutrient Region and even meets the 15 mg/l TSS standard for the North River Nutrient Region (only exceeds 15 mg/l in 3.9% of samples). However, water quality has been found to be at least slightly degraded by the time it enters Agassiz NWR at times. At the lower end of the reach, at the 380th Street Northeast crossing (S004-055), there has been one exceedance of the 30 mg/l TSS standard, but the 15 mg/l standard (for reference purposes only – not officially applicable to this reach) was exceeded in 15.9% of the samples in 2007 through2016.

The channelization of the Thief River for State Ditch 83 between CSAH 6 and Agassiz NWR has degraded the stability of the streambanks. The merits of a channel restoration project have been discussed at stakeholder meetings.

### 2.5.3 Middle Thief River (Agassiz National Wildlife Refuge)

Sedimentation within Agassiz Pool is the most significant problem in this subwatershed. Reduction of sediment entering the refuge is the goal for the reduction of sedimentation within the pool, and a reduction in the supply of sediment available to be flushed downstream during drawdowns. SWAT modeling revealed that buffer strips could have a significant impact on reduction of sediment yields. Future implementation efforts may seek to utilize the provisions of the new buffer bill to enforce 16.5' and 50' buffers in this subwatershed.

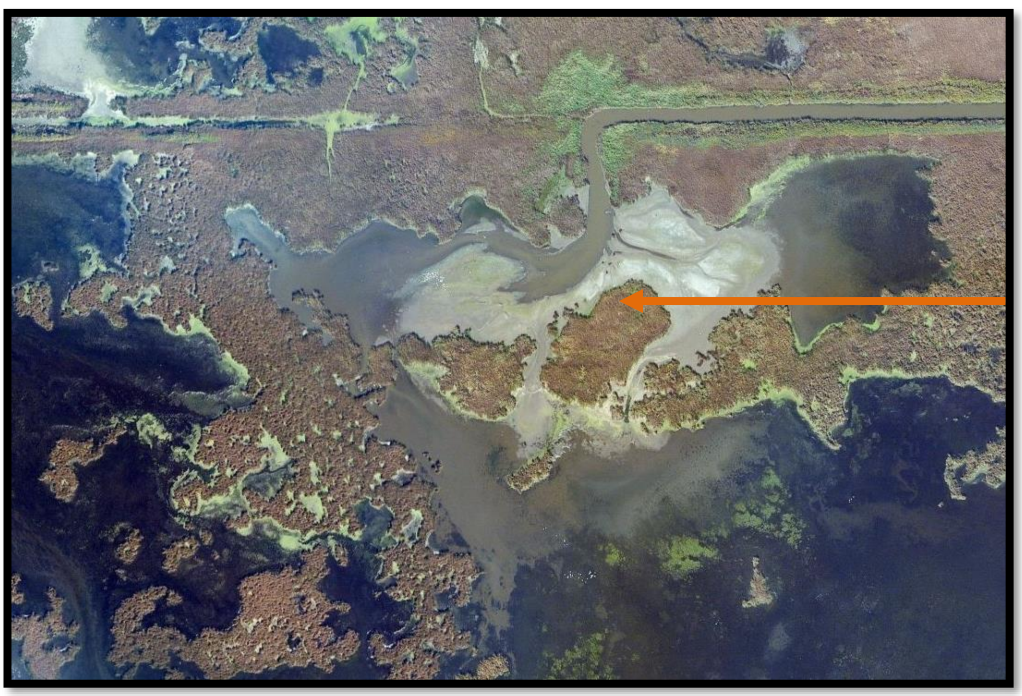


Figure 2-41. Judicial Ditch 11 delta within Agassiz Pool (via Bing Maps 2015)

Sediment plumes from the Mud River (Figure 2-41) and the Thief River (Figure 2-42) are visible in aerial photos. Sedimentation has resulted in shallower depths, expanded cattail growth and degraded nesting habitat in portions of Agassiz Pool. Local agencies have made efforts to reduce sediment contributions from agricultural runoff and stream bank erosion along the Mud River and the Thief River upstream of Agassiz NWR. The new outlet on the west side of Agassiz Pool may help reduce the amount of sediment deposition within the pool. A portion of the flow from the Thief River can bypass the pool by flowing along the western dike of the pool and return to the Thief River (SD 83) channel.

Figure 2-42. Thief River delta in Agassiz Pool and partial bypass flow along the west dike (via Bing Maps, 2015)

In response to the amount of sedimentation within the Agassiz Pool and the old JD11 channel, refuge staff have adopted a new maintenance strategy for removing sediment from the pool, ultimately for better water level control for waterfowl production, by excavating and flushing of sediment from the JD11 channel. The excavation and flushing of the old JD11 channel within Agassiz Pool sediment downstream has had an unintended, but negative effect on water quality downstream of the pool outlet. The organic sediment flushed out of Agassiz Pool not only has negative effects upon aquatic life and recreation in the river, but also has human health consequences of elevated trihalomethane concentrations in the city of Thief River Falls drinking water. Thief River Falls drinking water is withdrawn from the Red Lake River, one mile downstream of the confluence of the Thief River and the Red Lake River. Trihalomethanes are potentially carcinogenic disinfection byproducts. Concentrations of potentially harmful disinfection byproducts increase when there are increased concentrations of pollutants in source water, particularly organic carbon.

**Table 2-28. Thief River Falls source water organic carbon and historical trihalomethanes values above the maximum contaminant level.**

| Sample Date DBPs | Sample Location | Sample Date TOC - Nearest | TOC Raw Water | TTHM µg/L |
|---|---|---|---|---|
| 6/17/2004 | Distribution - Land O'Lakes Ctr | 6/7/2004 | 20 | 121.70 |
| 9/21/2004 | Distribution | 9/13/2004 | 18 | 93.90 |
| 7/24/2007 | Distribution - Bridgeman Distrib Center | 7/9/2007 | 20 | 105.10 |
| 8/24/2010 | Distribution - Bridgeman Distrib Center | 9/1/2010 | 13 | 84.40 |
| 8/15/2011 | Distribution - Deans Distrib Center | 8/2/2011 | 16 | 115.10 |
| 7/24/2013 | Distrbution - Chamber of Commerce | 8/7/2013 | 18 | 134.00 |

The Minnesota Department of Health (MDH) provided comments on the results of the assessment of the Thief River Watershed. The letter from the MDH noted exceedances of disinfection byproducts caused by high levels of organic material that is in the source water for the city of Thief River Falls. The letter included documentation (Table 2-28) of 6 instances over the last 10 years in which the total trihalomethanes in the city's drinking water exceeded the maximum contaminant level (MCL) of 80 µg/L. Trihalomethanes "form through reactions between organic compounds and chlorine disinfectants during drinking water treatment and distribution." "People who drink water containing trihalomethanes in excess of the MCL over many years may experience problems with their liver, kidneys, or central nervous system, and may have an increased risk of getting cancer." The letter also suggests "consideration of improvements in water detention, turbidity, and organics" in the watershed to improve the quality of the city's drinking water.

### 2.5.4 0902030405 Branch 200 of Judicial Ditch 11

Low DO levels have been recorded frequently within Branch 200 of JD11, between the outlet of Farmes Pool, an impoundment within Agassiz NWR and Elm Lake WMA, and the Thief River. Stagnant water from low flow could be one of the causes. Augmented but moderate flows could prevent some channel erosion and improve DO levels in receiving waters if late summer flows are not completely shut off by the upstream water control structure.

Walleyes and northern pike have been observed in the ditch when there has been sufficient flow.

Enforcement of the provisions of the 2015 Buffer Initiative Bill will be beneficial to overall water quality in this reach.

### 2.5.5 0902030403 Mud River

In addition to the restoration work that is necessary to reduce *E. coli* concentrations in the Mud River, excess sediment, overland runoff, poor buffers, poor aquatic biology sampling results and a lack of base flow are all concerns that need to be addressed in the Mud River Subwatershed.

Upland sources of sediment need to be targeted and addressed to reduce sedimentation in the channel and downstream pools in Agassiz NWR. Sedimentation in Agassiz Pool (0902030404) from the Mud River Watershed is one of the primary protection-related concerns for the Mud River Watershed. The Mud River has relatively low suspended solids concentrations for a river of its size. It also meets the most stringent standard for TSS, or 15 mg/l. However, erosion in the upper reaches of the Mud River contributes to a high sandy bed load that moves along the channel bottom further downstream. Regular water quality sampling efforts are aimed at the water quality of the water column and don't provide any information about how much sediment is being moved along the bottom of the channel. Even the cleanest of rivers will move sediment and deposit sediment into downstream reservoirs. The sand that is moving along the channel bottom is likely exacerbating the sedimentation problems in Agassiz Pool. Upland erosion was identified as the leading source of sediment entering Agassiz Pool. Finding ways to further minimize this erosion is important for prolonging the viability of those pools for raising waterfowl. Sedimentation has been observed within one of the culverts at the State Highway 89 crossing. A ditch entering the river from the south on the western side of the crossing appears to have deposited a large amount of sediment into the channel. Sand has also accumulated on the channel bottom upstream of the crossing.

Support for projects and management practices, particularly at the Moose River Impoundment, that reduce flashiness of flows and enhance base flows will further improve water quality.

A reach of the Mud River just downstream of the town of Grygla from 390$^{th}$ Avenue Northeast to 360$^{th}$ Avenue Northeast was examined for the geomorphologic study. The reach was found to be relatively stable due to a diverse vegetated riparian corridor (Figure 2-43). This corridor should be protected. This reach is part of the JD11 legal ditch system. Portions of the Mud River and JD11 channel are lacking proper buffers upstream of Grygla. Buffers along the Mud River should, at minimum, be maintained and improved.

The reach of the Mud River between Highway 89 and Agassiz NWR needs improved buffers and side water inlets to reduce erosion from cultivated fields adjacent to the channel. The low-quality riparian buffer along that portion of the river is contributing to stream bank instability and ultimately, sedimentation within the pools at Agassiz NWR.

Figure 2-43. Kayaking on a willow-lined reach of the Mud River

The main channel of the Mud River/JD11 drainage system is less stable upstream of Grygla and there are reaches that are lacking a riparian buffer. The 2016 Amended Buffer Law will require at least a 16.5-foot buffer, which will be an improvement in some areas along this channel.

The quality of aquatic life in the Mud River is affected by a lack of connectivity. The Mud River is separated from the Red River of the North by dams on the Red Lake River in Thief River Falls and the dam at the outlet of Agassiz Pool. The lack of connectivity, excess sediment (and sedimentation), low DO, and altered hydrology would be candidate stressors if any reach of this drainage system was found to have impaired aquatic biology during future assessments. The connectivity issue is not likely to be addressed in the next 10 years, but the other issues could be addressed.

WMAs should be kept undisturbed to maintain the excellent water quality within the ditches that flow out of those areas. Site S004-059, for example, was a site that had excellent water quality when it was tested as part of a 2005-2006 study.

### 2.5.6 0902030406 Marshall County Ditch 20

Water quality within Marshall CD20 is relatively good, for a ditch system. Even if CD20 had been assessed in the 2013 water quality assessment, it still would have met all water quality standards. Discussions with residents and landowners have revealed that walleyes can sometimes be found in the ditch. Northern pike and suckers have frequently been observed during water quality monitoring activities. Accounts from local water management staff reveal that during the 1997 flood, there was more flow in CD 20 than there was in the Thief River.

Reducing erosion along the CD20 channel and its tributary ditches can help reduce the amount of sedimentation in the Thief River that is coming from CD20. High flows have been observed during the recent water quality studies. These high flows generate the force necessary to move sediment. When the water hits the main channel of the Thief River (lower velocity), the larger particles drop out of suspension and are deposited near the confluence. Large sediment bars had formed in the main channel of the Thief River and were periodically cleaned out of the channel as part of State Ditch 83 maintenance. Headcutting at the lower end of the ditch was addressed with grade stabilization structures. Recommendations for CD20 include the enforcement of any requirements of the 2016 Amended Buffer Law and reduction of erosion in the upper reaches of the CD20 subwatershed. Better buffers in the upper/eastern portions of the channel will help reduce sediment loads. Sources of sediment in the upper portion of the subwatershed should be investigated.

Maintaining a diverse vegetated cover within the riparian zone will maintain and/or improve the stability of CD20, especially where soils are sandy (DNR 2015). If any clean-out projects are proposed, geomorphological evidence suggests that the narrow width-to-depth ratio should be maintained, but additional capacity should be created within the floodplain.

Water storage in the upper portion of the watershed would be designed to reduce peak flows, which would reduce the erosive power of flows in the ditch, thus reducing sediment loads.

Additional data collection is recommended for the CSAH 12 crossing of CD20.

CD20 meets the TP portion of the river eutrophication standards. Of the assessment units that meet the standard, CD20 (AUID 09020304-519 in particular) is the closest to exceeding the standard. It is the highest-ranking reach in need of protection from phosphorus nutrient inputs to prevent future impairment.

### 2.5.7 0902030407 Judicial Ditch 30/18/13

The 14,080-acre watershed of JD 30 and JD 18 drains to the Thief River four miles upstream of Thief River Falls. Concentrations of pollutants safely meet water quality standards. The most significant concern may be DO levels. A combined analysis of May through September pre-9 a.m. discrete measurements and measurements from deployed loggers found that 12.4% of daily minimums fell below 5 mg/l. The continuous DO record was collected in the dry year of 2012, so stagnant water may have been the reason for some of the low readings.

The ditch is in relatively good condition in terms of side water inlet installations and buffer maintenance. A ditch inventory currently being conducted by Pennington SWCD will identify areas along this ditch system where side water inlets, buffers, and grade stabilization are necessary. The results of the SWCD's inventory will be used to target BMP implementation. There is a large sediment bar where this ditch outlets into the Thief River. That sediment deposition indicates that reducing erosion and sediment loads (including bed loads) will reduce sedimentation within the Thief River.

### 2.5.8 0902030408 Lower Thief River

The city of Thief River Falls draws its drinking water from the Red Lake River at a point downstream of the Thief River confluence. Therefore, the Thief River contributes to the city's drinking water. Water quality in the Thief River tends to be of much worse quality than water in the Red Lake River

(Figure 2-44), particularly during Agassiz pool drawdowns and runoff events. Poor water quality in source water costs the city significantly more money to treat. It can also cause violations of the disinfection byproduct standards for drinking water. This causes regulatory issues and potential health concerns. During late-summer drawdowns of Agassiz Pool, the water becomes nearly undrinkable due to the amount of treatment that is needed to address the turbid water entering the reservoir from the Thief River. Reducing total organic carbon levels, in addition to the sediment and phosphorus recommendations made by the TMDL, will be beneficial to drinking water in the city of Thief River Falls. Sediment and nutrient sources are described in Sections 2.3.4 and 2.3.5, respectively. Because the lower reach of the Thief River is impaired at its furthest upstream monitoring station, water quality in this reach is heavily influenced by upstream subwatersheds (Upper Thief River, Middle Thief River, and Mud River in particular). Reducing sediment export from those watersheds will be a necessary part of improving water quality within the Lower Thief River.

**Figure 2-44. Sediment plumes from the Thief River at its confluence with the Red Lake River in Thief River Falls**

The lower reach of the Thief River was not listed as impaired by *E. coli*, but attention should be given to reduction of *E. coli* concentrations from a protection standpoint. When daily data summaries for the AUID are conducted using a geometric mean (one value for all of the samples collected along the entire, aggregated, 22-mile reach of the river for each calendar day), the monthly geometric means meet the standard. However, *E. coli* is still a parameter of concern along portions of this reach and should be addressed through on-the-ground projects. At least two of the sites, when assessed on their own, indicate an *E. coli* impairment exists. The worst site in this reach is actually the CSAH 7 crossing, at the upstream end of the reach near Agassiz NWR.

An analysis of discharge data in the Thief River Watershed Fluvial Geomorphology Report found that the bankfull discharge in the Thief River has been exceeded far more often than the 1.5-year recurrence interval, and the percentage of days that exceed the bankfull discharge of 1006 CFS has been increasing. Increased flows are partly due to increased precipitation, but additional variables seem to be affecting streamflow as well. On the other end of the flow spectrum, a lack of perennial storage is indicated by a steep drop in the flow duration curve at lower flows. The geomorphology report also includes a BANCS model result that indicate that the natural channel portion of the Lower Thief River is eroding at a greater rate than the channelized portion of the river (SD83).

The primary recommendation of the Thief River Fluvial Geomorphology Report for this reach is to maintain the existing condition of the channel and riparian zones. Prior to initiating a cleanout, it would be beneficial to assess whether the river is currently in a stable form. If the channel is unstable due to excessive sedimentation, the source of the sediment should be identified and alleviated. The Thief River in its stable form should be able to efficiently move both the water and sediment supplied from upstream, while at the same time maintaining depositional point bars. Creating building setbacks within the riparian zone will minimize future problems with the Thief River encroaching on development.

Despite a delisting of the DO impairment on this reach, low levels are periodically recorded with discrete measurements. In addition, more than 17% of the record of daily minimums that has been collected with DO loggers failed to meet the 5 mg/l standard.

# 3. Prioritizing and Implementing Restoration and Protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, and identify point sources and nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires the inclusion of an implementation table of strategies and actions that are capable of cumulatively achieving needed pollutant load reductions for point and nonpoint sources.

This section of the report provides the results of such prioritization and strategy development. Because much 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 best management practices. Thus, effective and ongoing public participation should be an important part of watershed management efforts.

Many sources of information have contributed to this section of the report. Multiple efforts have been made to prioritize and target areas for implementation projects within the watershed, including a SWAT model, an HSPF model, SPI development, stream reconnaissance, stakeholder meetings, and windshield surveys. The project ideas and plans are the product of the cooperative effort of local, state, and federal organizations.

## 3.1 Targeting of Geographic Areas

Specific strategies have been identified throughout the WRAPS and other studies of the Thief River Watershed, including:

Restoration efforts should be directed toward reducing sediment erosion upstream and downstream of Agassiz NWR in the Thief River, and in the Mud River upstream of the refuge. *E. coli* sources (septic systems and livestock) need to be addressed in the Mud River Subwatershed upstream of Grygla. Base flows need to be improved in the Mud and Moose Rivers to prevent low DO concentrations.

Implementation of the provisions of the state of Minnesota’s 2016 Amended Buffer Law will be very beneficial to water quality conditions throughout the watershed. Modeling results indicate that improved buffers will significantly improve water quality. The most severe erosion problems (slumping banks) occur where there is no buffer of perennial vegetation. The next step would be to improve the quality of vegetation along buffers (more woody and native vegetation).

In the Thief River Watershed, there are some conflicts with strategies for accomplishing management goals for waterfowl, drainage, and aquatic life. Historically, the interests of waterfowl management and flood damage reduction have been relatively balanced. However, increased scientific knowledge about the conditions and concerns for aquatic life in the watershed has been a relatively recent development. More work is needed to incorporate the needs of aquatic life (and recreation) into the water management activities of the watershed. Concerns include:

- Potential flood storage can be limited in some pools to provide water for nesting waterfowl.
- Rapid discharge from impoundments can erode streambanks.

- Impoundments often limit base flow in downstream waters during the late summer months, which negatively affect DO levels. Review of impoundment plans to find a way to improve late summer base flows in downstream waters is needed.
- The practice of excavating sediment from the old JD11 ditch channel within Agassiz Pool and subsequent drawdown has anecdotally improved waterfowl habitat, but monitoring data indicates that the negative downstream effects have been significant.
- Cleaning sediment from the Thief River as a ditch management practice reduces stream bank stability by removing vegetation that is necessary for stabilizing streambanks. The practice does not treat the source of the sediment, only the symptom or consequence of excess sediment from upstream sources.
- The water control structures of on-channel impoundments, pools, and reservoirs are fish passage barriers.

There are several ways that agricultural, flood damage reduction, waterfowl, and aquatic life interests can be satisfied through mutually beneficial projects.

- Side water inlets help reduce peak flows, prevent damage to fields from gully erosion, prevent nutrient loss, reduce pollutant loads, and deposition of sediment downstream.
- Off-channel storage projects for flood damage reduction can reduce peak flows and erosion.
- Reducing sediment loads in the Thief River, Mud River and other ditches will benefit water quality within Agassiz NWR, help preserve waterfowl habitat, and reduce the supply of sediment that is available to be moved out of Agassiz Pool to the Thief River.
- A proposed re-meandering of the Mud River within Agassiz NWR would have mutual benefits for aquatic life in the Mud River and for reducing the amount of sediment delivered to Agassiz Pool by allowing a portion to be deposited in the floodplain of the river.

There are several tools available that can, and have been used to rank and identify the areas of the Thief River Watershed that need projects to reduce nonpoint source pollution.

- SWAT model
- Hydrological Simulation Program – Fortran (HSPF) Watershed model and the associated Scenario Application Manager (SAM) tool
- Utilize LiDAR-based SPI GIS information to target points on the landscape that need protection from erosion.
- Develop Prioritize, Target, and Measure Application (PTMApp) for the Thief River to help local government units prioritize areas for BMP implementation. The cost/benefit ratings that the tool provides will give insight that is not available from previous modeling efforts. The PTMApp will also assess the watershed at a much finer scale than previous modeling effort. As of the end of 2017, funding had been acquired, much progress has been made, and the model will begin running in early 2018.

### 3.1.1 SWAT Modeling Results

A SWAT modeling report was completed by Houston Engineering in May 2010 as part of the Thief River Watershed Sediment Investigation study. Although the watershed has been modeled more recently with a HSPF model, the SWAT model was used for several years to help prioritize and plan implementation projects. Figures 3-1 and 3-2 are maps that have been used to plan targeted implementation of BMPs. Modeling results for base conditions, 50-foot buffer strip installation, 100-foot buffer strip installation, perennial cover, and side-water inlet controls are presented in the Thief River SWAT modeling report that can be downloaded at:

http://www.redlakewatershed.org/waterquality/TRW_Report.pdf

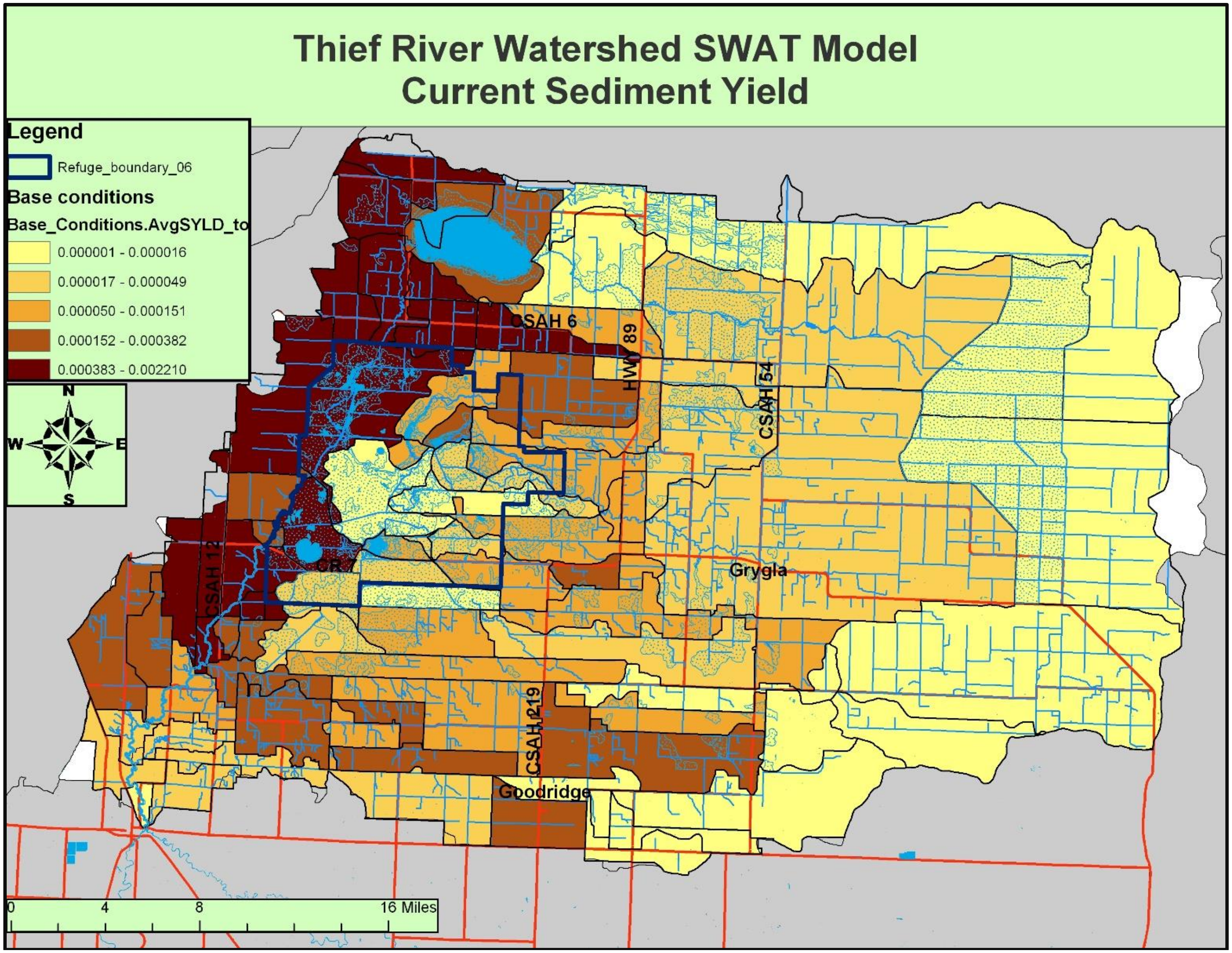


Figure 3-1. Thief River Watershed SWAT-Modeled Sediment Yields.

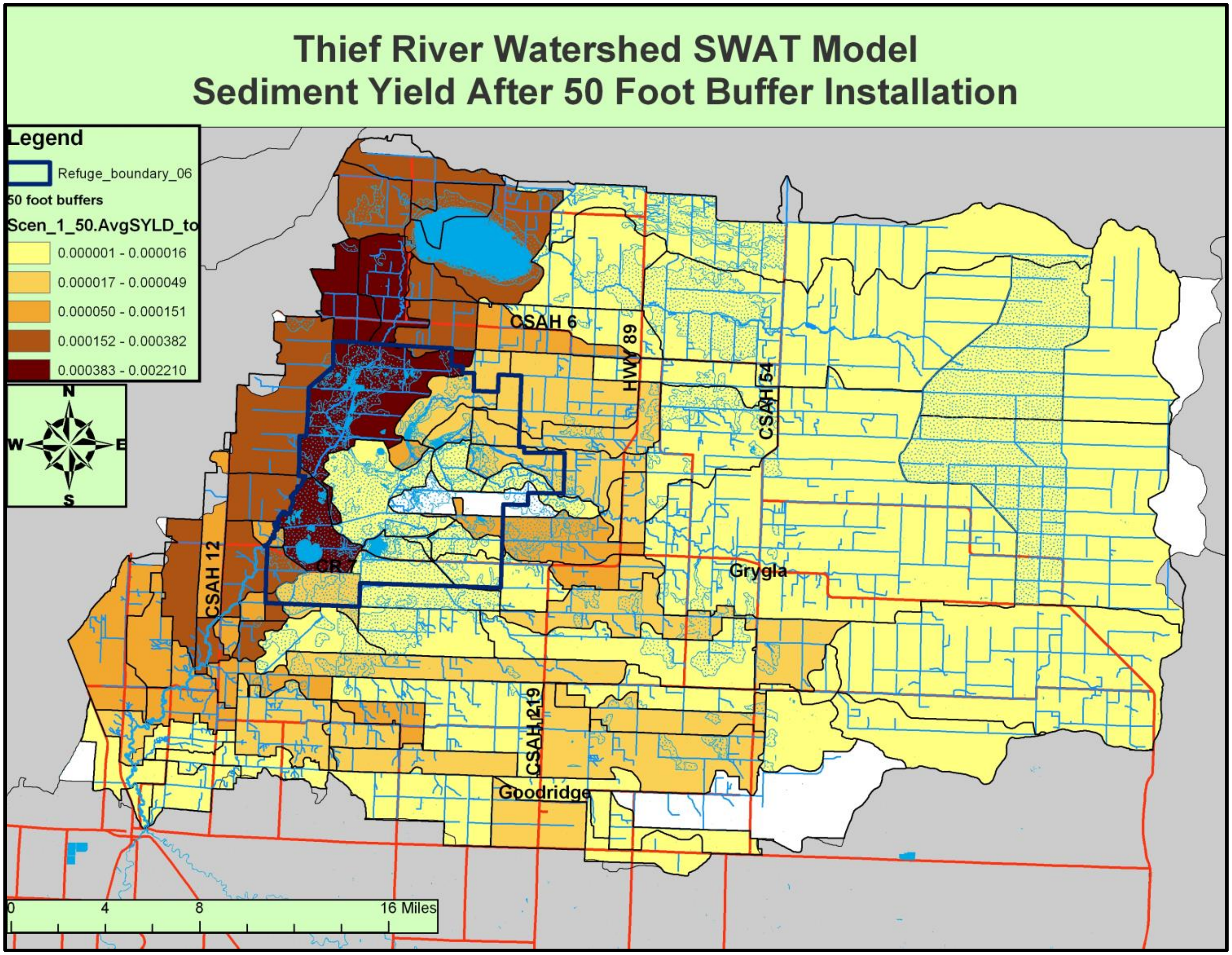


Figure 3-2. Thief River SWAT - Sediment Yield After 50-Foot Buffer Implementation

### 3.1.2 HSPF Modeling Results

HSPF is a computer model used for the simulation of hydrology and water quality for natural and manmade water systems. The model incorporates nonpoint and point source flows and water quality loading by simulating the processes on pervious and impervious land surfaces and in streams or impoundments. HSPF is a continuous model using an hourly time-step and typically outputting information on a daily time-step. Meteorological, point source, and other data, as well as outputs, are stored as time series in a binary Watershed Data Management (WDM) file. HSPF is part of the EPA's Better Assessment Science Integrating point and Nonpoint Sources (BASINS) suite of tools and is utilized using WinHSPF.

The following maps in Figures 3-3, 3-4, and 3-17 are derived from HSPF model results and highlight the areas that are most in need of projects and practices to reduce sediment and nutrient yields. The SAM tool is available for the HSPF model for the Thief River Watershed and is useful in determining subwatersheds where projects and practices will be the most effective.

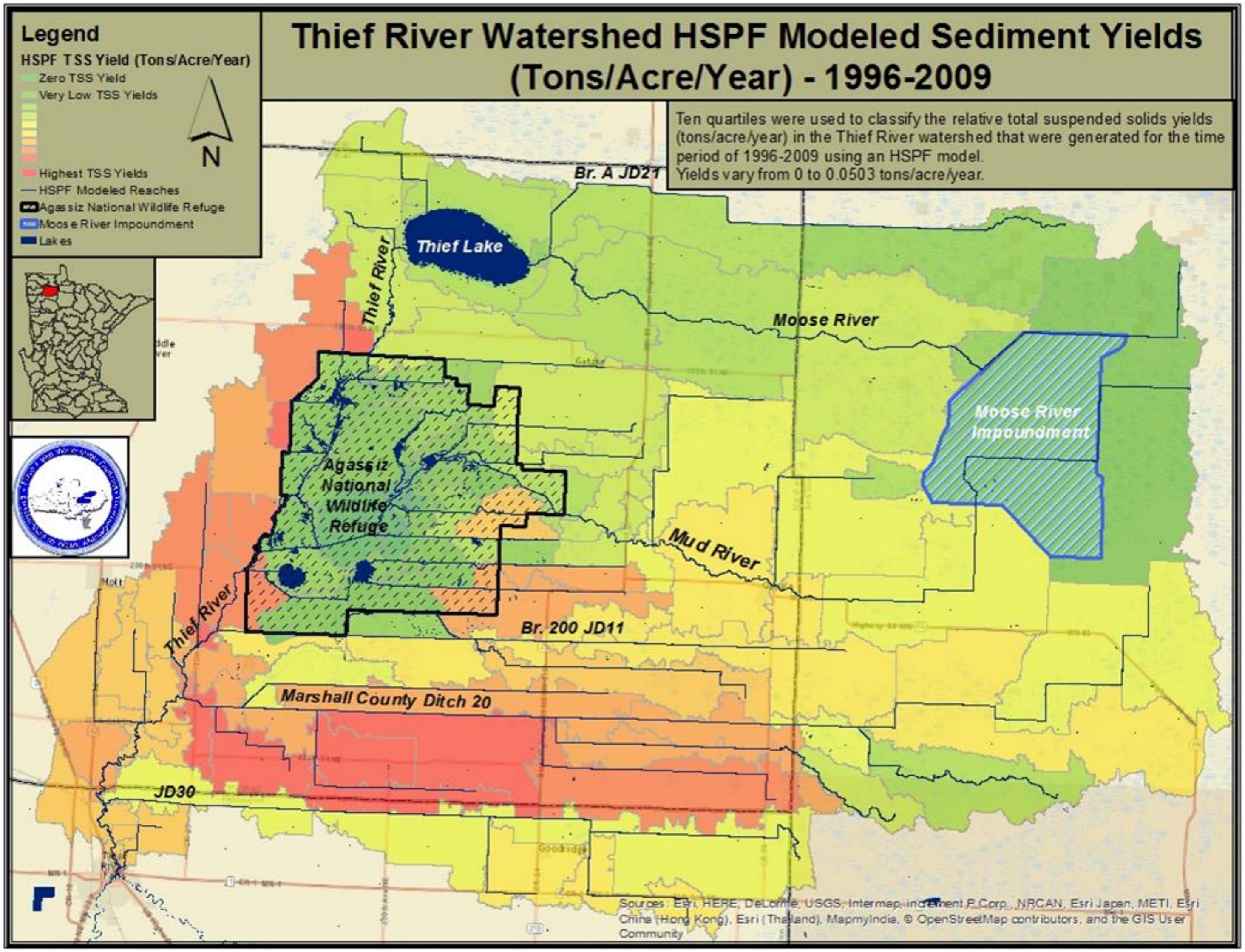



**Figure 3-3. Thief River Watershed HSPF-Modeled Total Suspended Solids Yields (Tons/Acre/Year)**

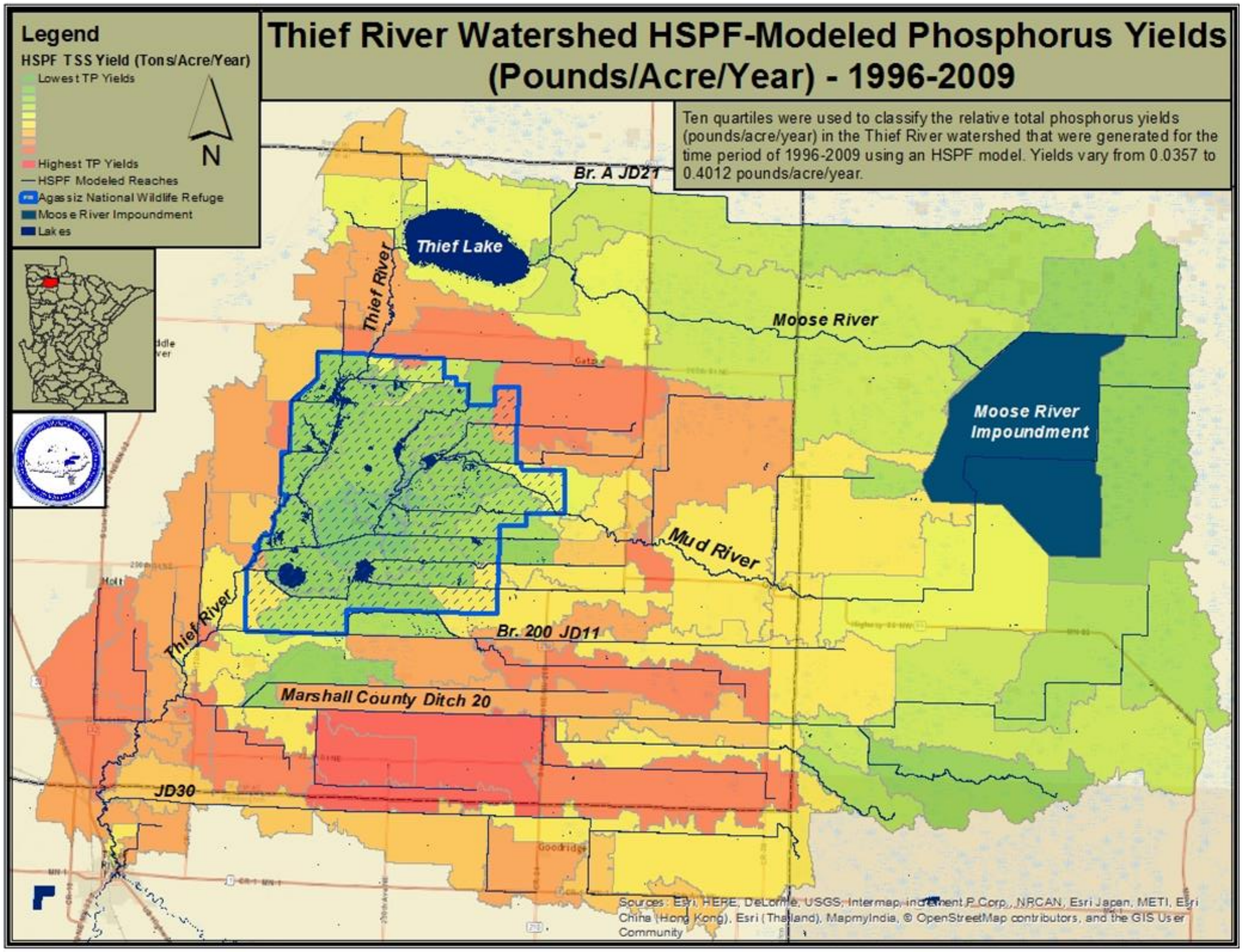



Figure 3-4. Thief River Watershed HSPF-Modeled Total Phosphorus Yields (Pounds/Acre/Year)

### 3.1.3 Stream Power Index

SPI maps show points on the landscape at which the power of simulated overland flow has the greatest erosive power. This information is very detailed and can be used to plan BMP implementation at the field scale. The high level of detail is made possible by Light Detection and Ranging (LiDAR) data that provides a 3-meter digital elevation model (DEM) grid. The SPI analysis was a component of the Thief River WRAPS Project.

In conducting this analysis, first, LiDAR-generated DEM surfaces needed to be hydro-corrected. Flow paths need to be added where bridges and culverts act as digital dams (LiDAR does not penetrate bridges or roads). As a part of this effort, an intensive culvert location inventory was completed for the Thief River Watershed. Line features were placed along real world culvert locations and stored as shapefiles. These linear features serve as guides along which flow paths are numerically “burned” to breach the digital dams in a raw surface due to the inherent inability of a LiDAR scan to detect culverts. Similarly, stream lines are aligned with aerial photos and raw DEMs to create guides along which stream flow paths are numerically “burned” into the output DEM.

Lake surfaces were delineated consistent with high resolution aerial images and assigned a single elevation value. The Arc Hydro ‘Level’ tool produced an output grid surface in which the lake surfaces were rendered at a uniform elevation. Non-contributing areas (NCAs) are regions, such as gravel pits or potholes within a watershed or basin in which surface drainage goes to a pit or sink, rather than to the downstream pour point. These areas were defined by first defining the soil permeability for all points on the surface, and then calculating the runoff volume at each point according to a set of hydrological formulas for a five-year rainfall. The well-drained Thief River Basin was found to have very few NCAs. Once the NCAs were determined, the final GRID output was a hydrologically conditioned DEM that can be used as a data source for many purposes, including power SPI analysis, flow accumulation lines, and drainage area delineations.

The SPI is a function of flow accumulation and terrain slope at any given data point. A higher SPI value represents a greater potential energy at that point and therefore a higher probability of erosion. Actual risk will depend on vegetative cover, land use, and surrounding drainage patterns. High SPI rankings have proven to be a reliable predictor for erosion, scouring, and slipping. The SPI raster (pixelated/points) patterns were shown to be more legible and compact after conversion into polyline vectors.

GIS layers for the top 2% of SPI values in the Thief River Watershed are available on the RLWD website: http://www.redlakewatershed.org/downloads. The results of the SPI analysis are displayed on a broad scale in Figures 3-5 through 3-10. The GIS files are sufficiently detailed to plan projects, such as side water inlets and grade control, at the field scale.

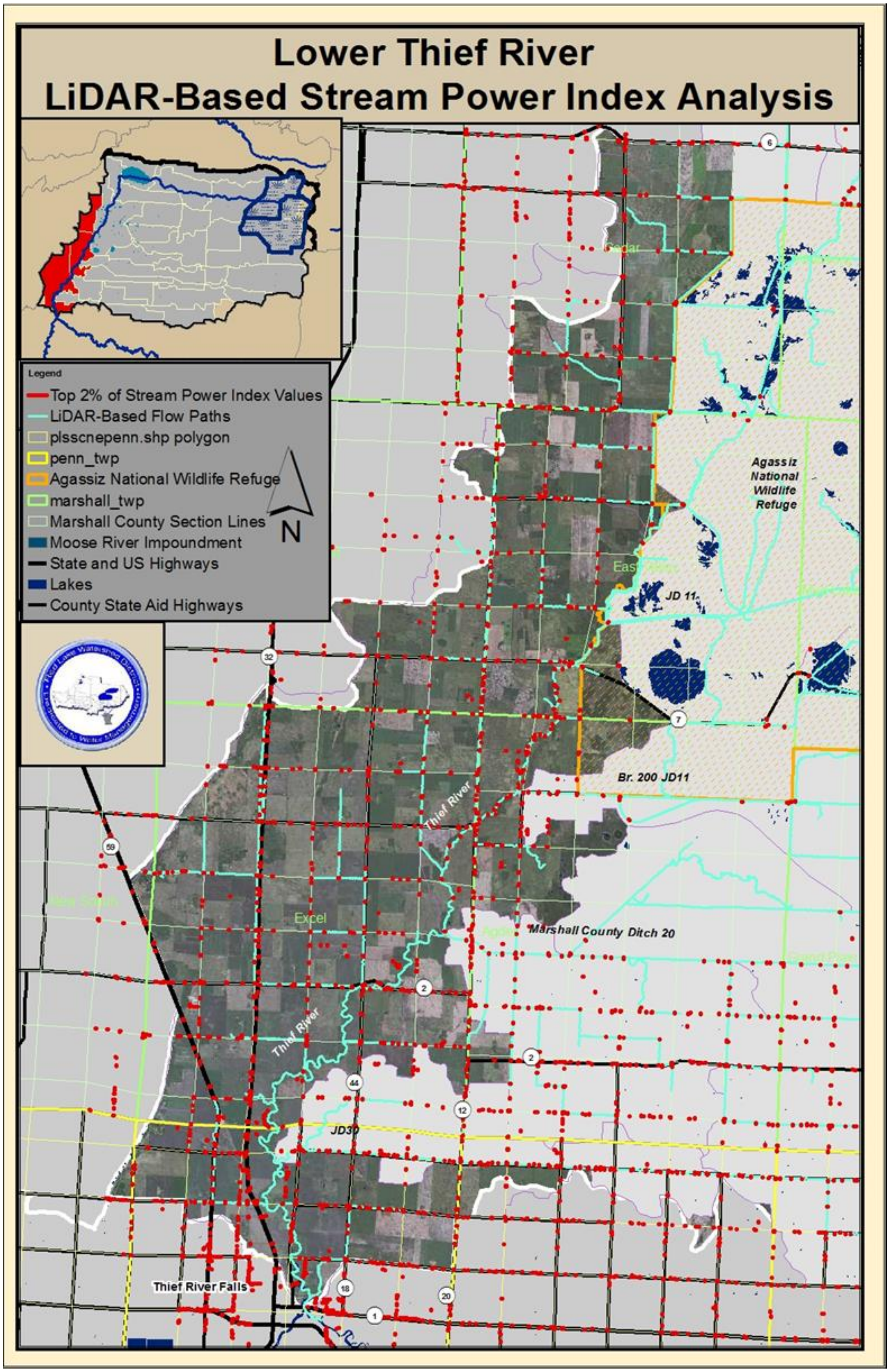



Figure 3-5. Lower Thief River Watershed high erosion potential based upon the top 2% of stream power index values.

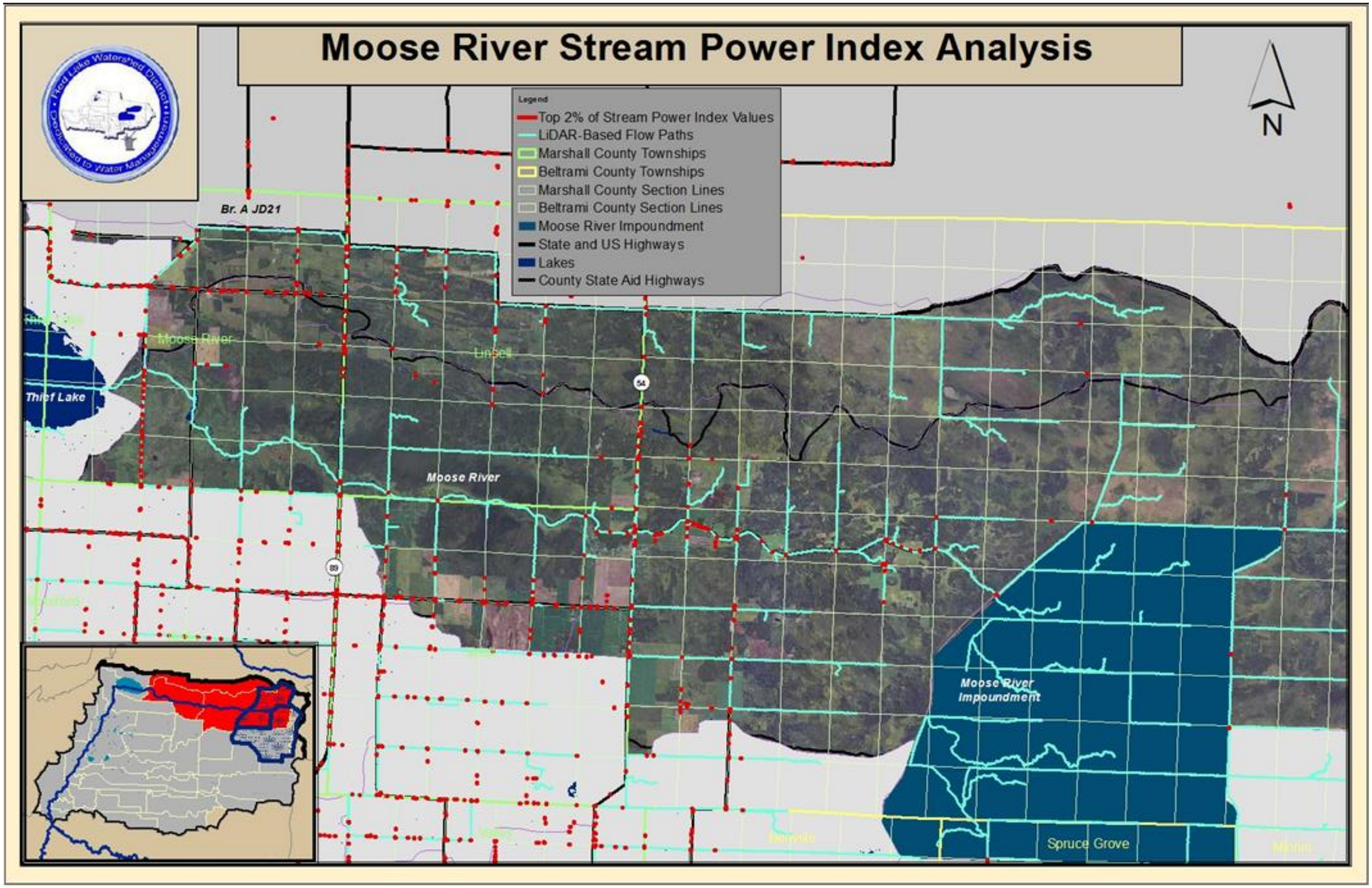



Figure 3-6. Moose River Watershed high erosion potential based upon the top 2% of stream power index values.

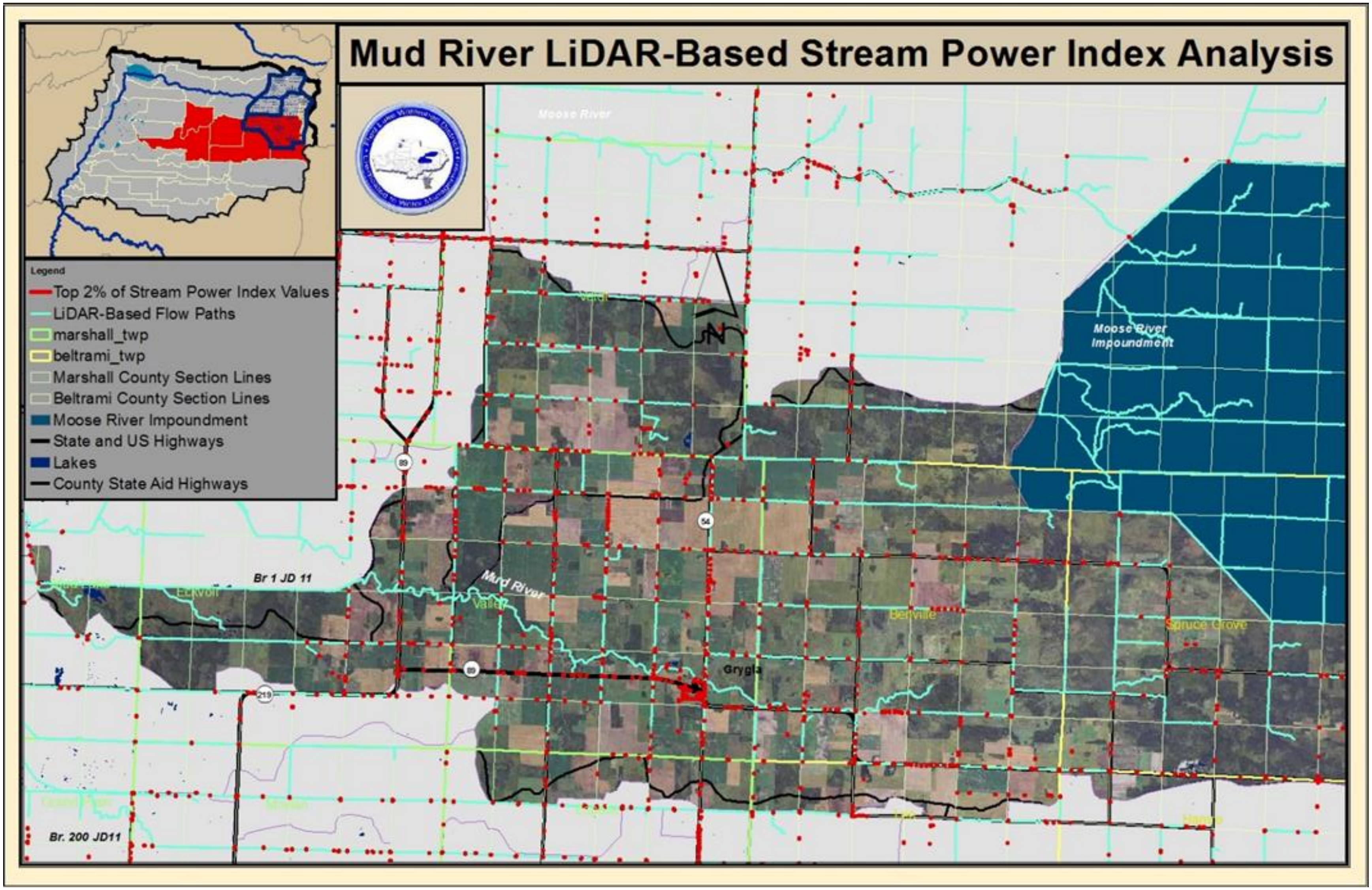



Figure 3-7. Mud River Watershed high erosion potential based upon the top 2% of stream power index values.

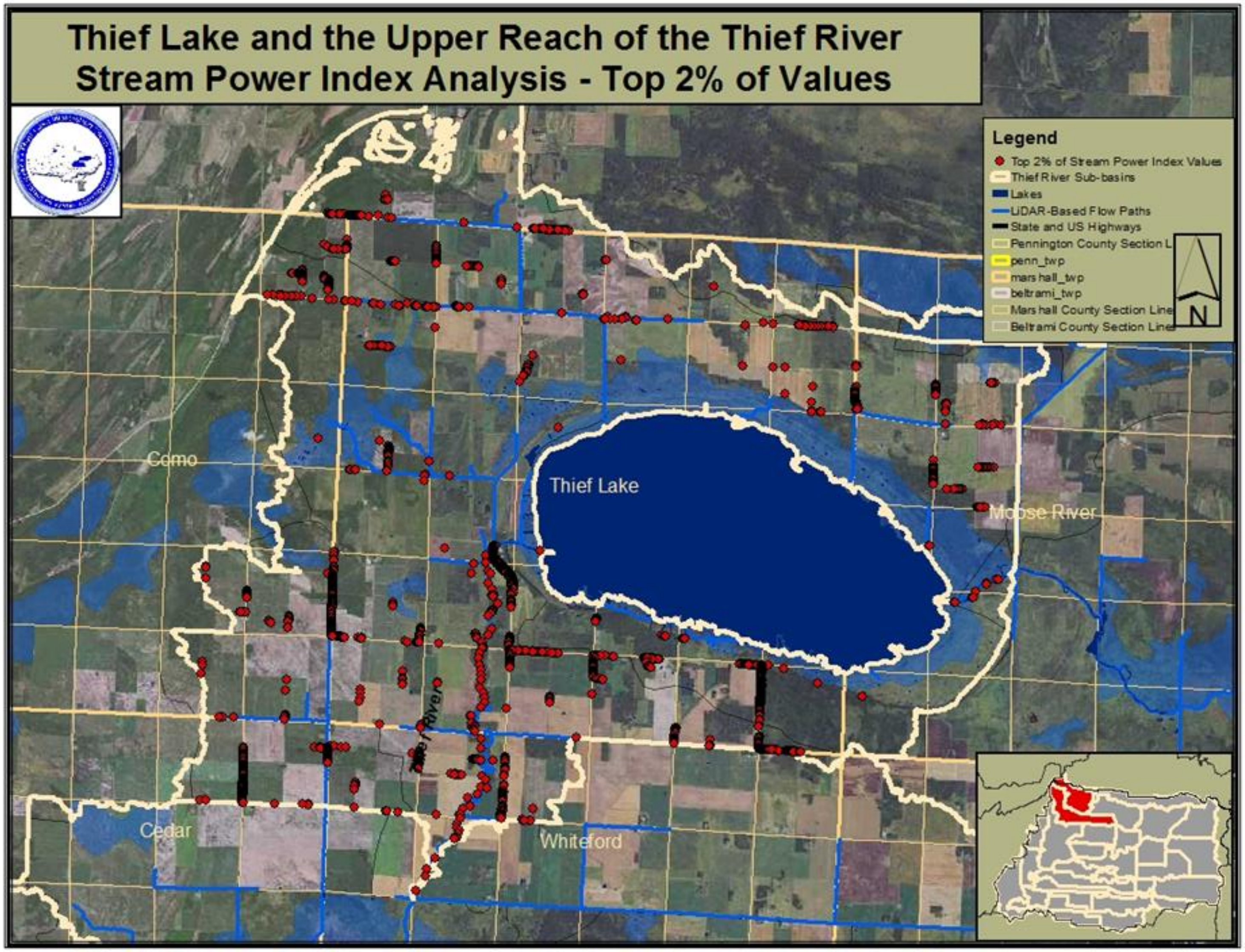



Figure 3-8. Thief Lake and upper Thief River Watershed high erosion potential based upon the top 2% of stream power index values.

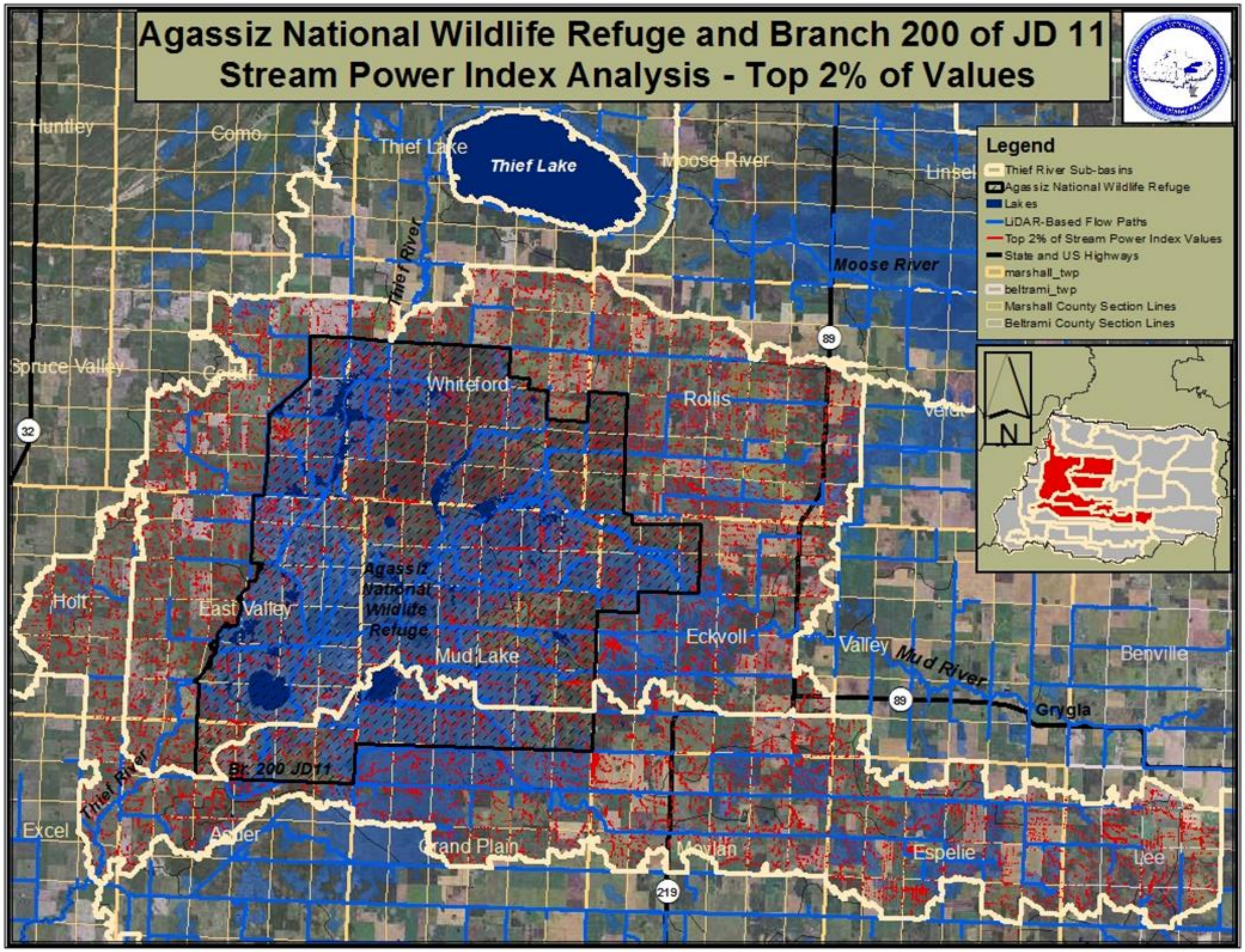



Figure 3-9. Agassiz National Wildlife Refuge area and Branch 200 of Judicial Ditch 11 Watershed high erosion potential based upon the top 2% of stream power index values.

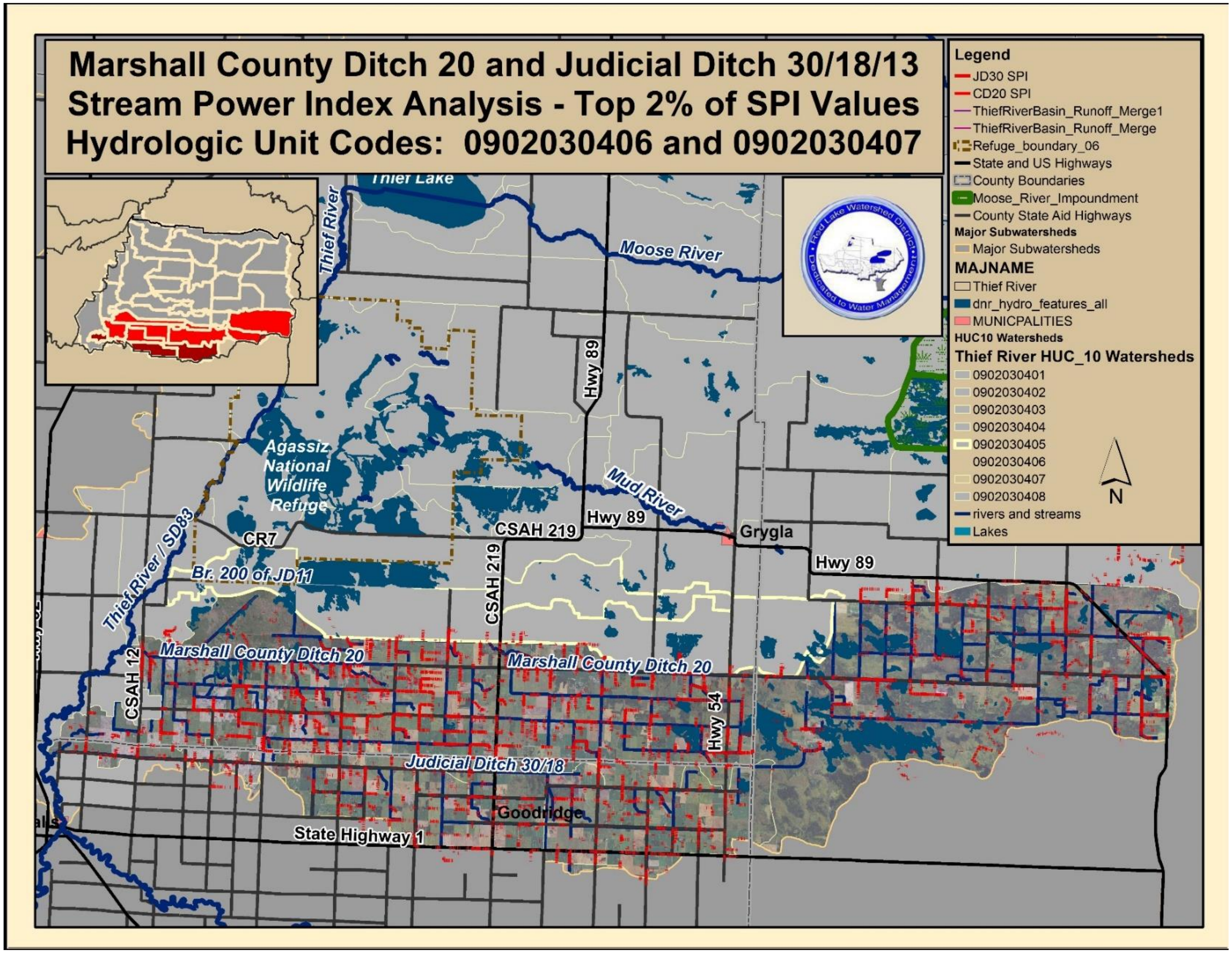



Figure 3-10. Marshall County Ditch 20 and JD30/18/13 Watersheds - high erosion potential based upon the top 2% of SPI values.

### 3.1.4 Longitudinal and Investigative Sampling

A method for directly measuring how water quality changes in a river as it flows past potential pollutant sources is the collection of longitudinal samples, especially during runoff events. This has been done on several occasions within the Thief River Watershed.

Multiple longitudinal surveys of *E. coli* concentrations were collected along the Mud River. These dates represented different flow levels. The August 20, 2009, sampling followed a recent rainstorm and had relatively high flow for that time of the year.

- June 4, 2009 (152.3 CFS of flow at S002-078)
- August 4, 2009 (9.7 CFS of flow at S002-078)
- August 20, 2009 (39.8 CFS of flow at S002-078)
- June 3, 2014 (325 CFS of flow at S002-078)
- July 17, 2017 (9.5 CFS of flow at S002-078)

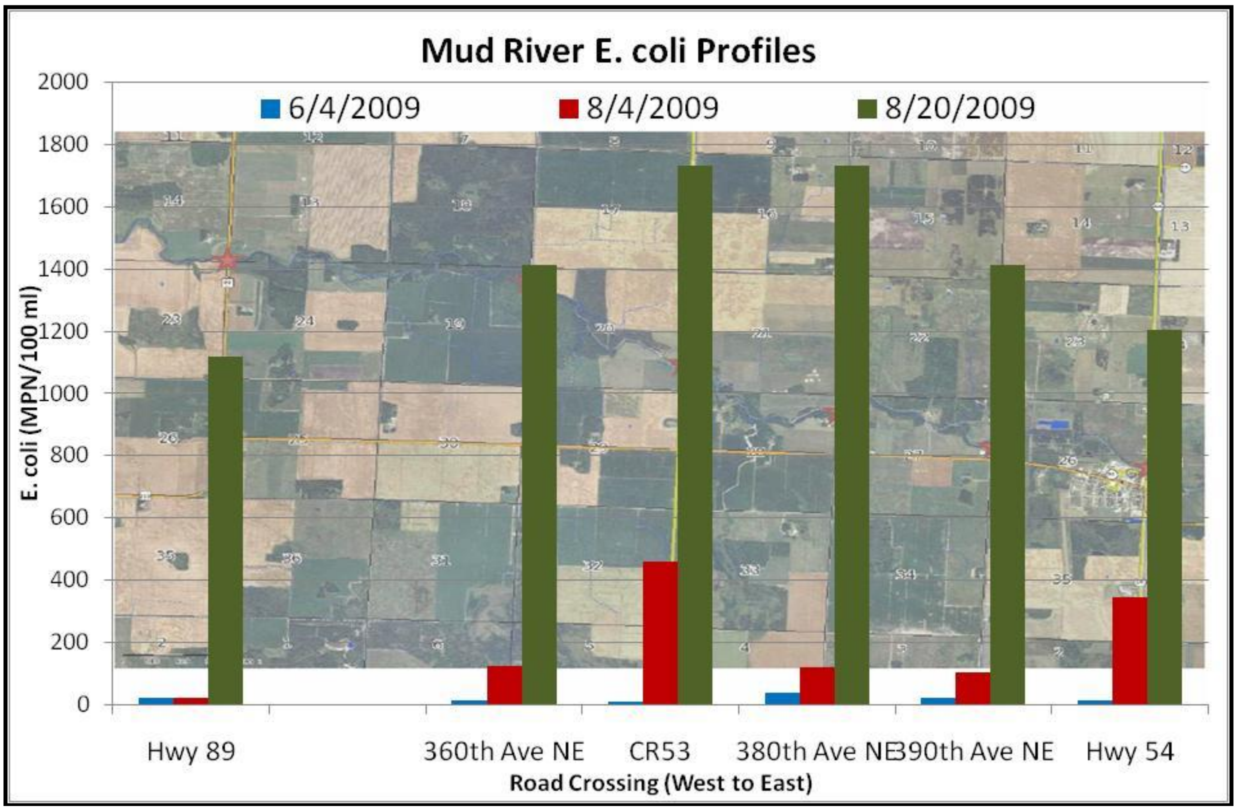



**Figure 3-11. 2009 Longitudinal *E. coli* Sampling along the Mud River.**

The June 2009 sampling results were all low and ranged from 9.8 to 37.9 MPN/100mL. So, that sampling effort did not reveal any potential sources of *E. coli.* In the August 2009 set of longitudinal samples (Figure 3-11), the *E. coli* concentrations were high on the east (upstream) side of Grygla, so that indicates the presence of *E. coli* sources upstream of CSAH 54. At the time of the 2009 longitudinal samples, a livestock operation was still in operation downstream of 370$^{th}$ Avenue Northeast (CSAH 53) that likely contributed to high *E. coli* concentrations during runoff events. In addition to contributing to

*E. coli* concentrations, cattle access to the river had caused stream bank instability. The operation and cattle access to the river appears to have continued through 2011 (at least), based upon aerial photos. In spring 2013 aerial photos, the operation no longer appeared to be active. The most recent, 2015 aerial photos indicated the presence of livestock near buildings, but there was no evidence of livestock access to the river. The banks of the river have revegetated where they had been bare and eroding. The recently lessened impact from the livestock operation near CSAH 53 coincides with the recent decrease in *E. coli* concentrations at the lower end of the subwatershed. The livestock in Section 28 of Valley Township also appeared to negatively affect *E. coli* concentrations.

Longitudinal *E. coli* samples were collected along the Mud River near Grygla in September 2013 after high concentrations of *E. coli* near the Grygla lagoons were reported. The results did not reveal high *E. coli* concentrations downstream of the lagoons. Rather, the highest concentration was at the CSAH 54 crossing (S002-977) on the east (upstream) side of town. This is the third set of longitudinal samples that suggested the presence of significant *E. coli* sources upstream of Grygla.

The June 3, 2014, longitudinal sampling event (Figure 3-12) followed a runoff event. Despite the recent rain, runoff, and relatively high flows, *E. coli* concentrations were all below the chronic standard of 126 CFU/100ml. *E. coli* concentrations did increase from upstream to downstream, though, and there were some points where there were relatively significant increases in *E. coli*. The lowest bacteria levels were found where JD 11 (headwaters of the Mud River) leaves Moose River impoundment (which was discharging at the time). This indicates that the impoundment is not a likely source of the high *E. coli* readings that are sometimes found in the river.

On July 17, 2017, longitudinal samples (Figure 3-13) were collected between the outlet of the Moose River Impoundment and the Grygla City Park. The *E. coli* concentration leaving the impoundment was very low (9.8 MPN/100ml). A common finding among longitudinal sampling upstream of Grygla is that the origin of the impairment is not the Moose River Impoundment because concentrations have been low at the outlet of the impoundment. Concentrations rose above the 126 MPN/100ml at the Flintlock Road crossing and peaked at the Dylan Road crossing. The concentration at CSAH 54 was 166.4 MPN/100ml. There was a decrease between CSAH 54 and the Grygla City Park. The high *E. coli* concentrations at the Highway 54 crossing of the Mud River in Grygla indicate that there are sources upstream of there that need to be addressed.

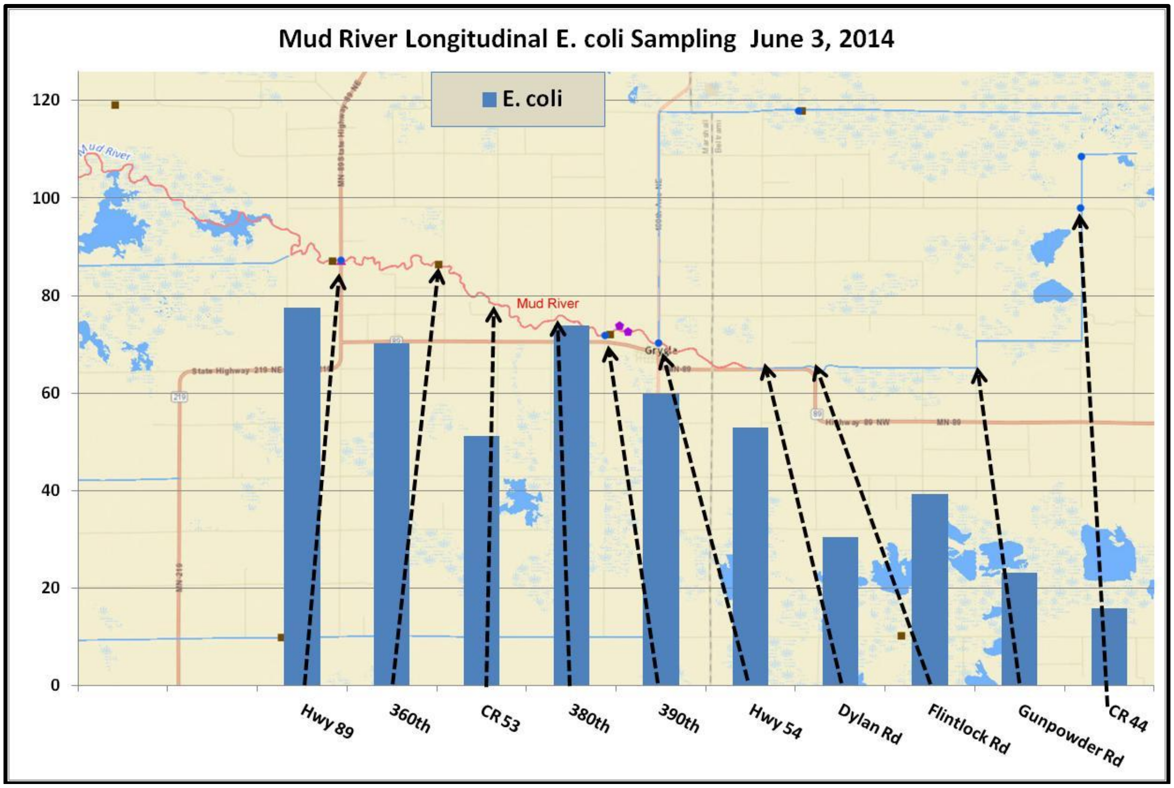



Figure 3-12. June 3, 2014 longitudinal *E. coli* sampling results along the Mud River

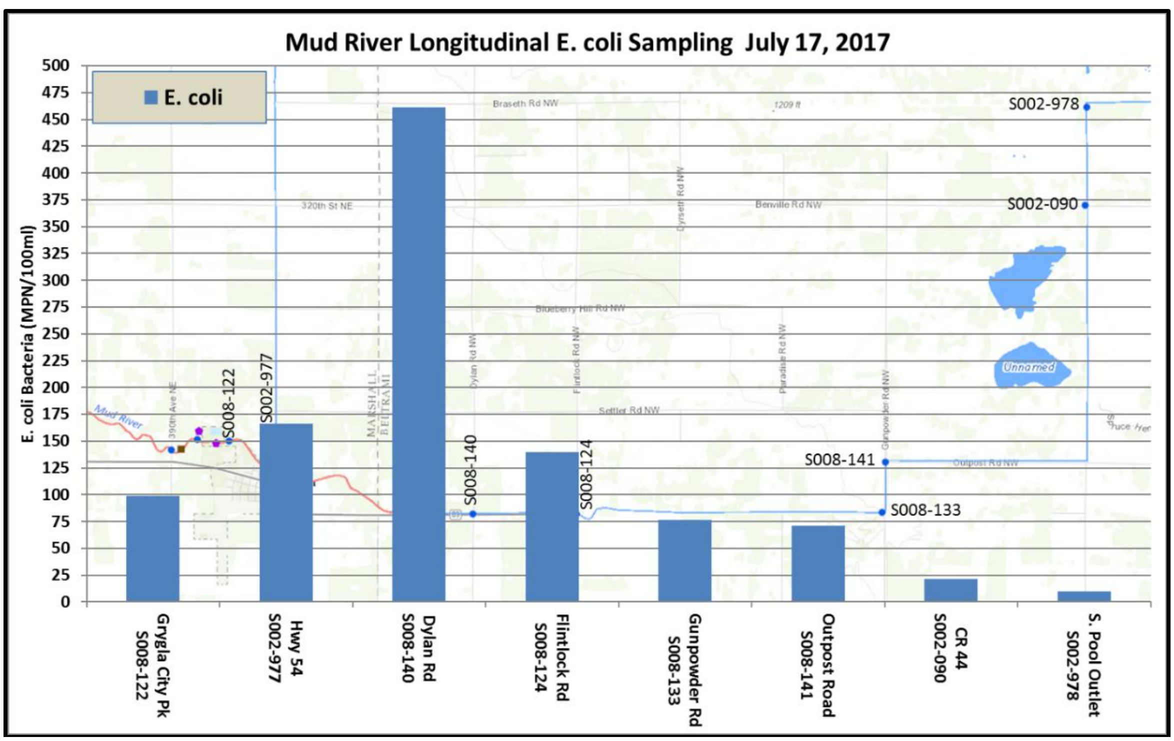



Figure 3-13. July 17, 2017 longitudinal *E. coli* sampling results along the Mud River upstream of Grygla.

Longitudinal samples were collected along the lower reach of the Thief River from CSAH 7 to Long's Bridge (142 Avenue Northeast) during a storm event on May 20, 2013. Turbidity gradually increased from upstream to downstream throughout much of the reach with one exception. The turbidity reading at the CSAH 7 Bridge (closest crossing to the outlet of Agassiz Pool) was 216.2 FNU. The turbidity at the next crossing downstream, CSAH 12 (Rangeline Road) was 24.0. It was unusual to see turbidity decrease that much from an upstream site to a downstream site. It indicates that there is a lot of sediment is being discharged from the Agassiz Pool outlet(s) and much of that sediment is being deposited along the Thief River between the two crossings. Relatively large, dark-colored particles were visible in the CSAH 7 sample, but not in samples from other sites. These larger particles would fall out of suspension rather quickly. The magnitude of the decrease in TSS and turbidity between the two crossings is demonstrated in Figure 3-14.

The photo to the right shows May 20, 2013, runoff and a plume of sediment entering the Thief River from a field near the 150 Avenue Northeast crossing.

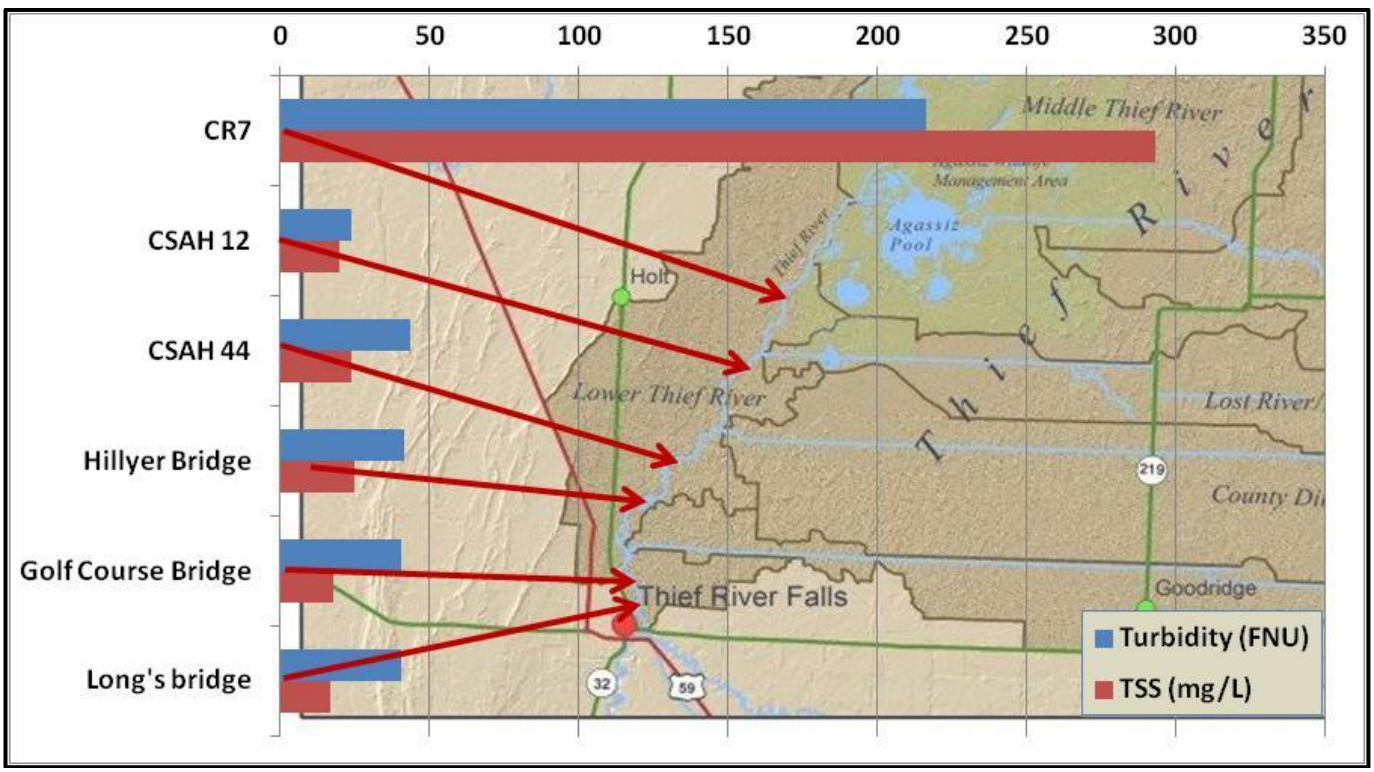



Figure 3-14. May 20, 2013 longitudinal sampling along the Thief River during a runoff event

Longitudinal sampling along Marshall CD 20 (Figure 2-38) revealed potential sources of *E. coli* bacteria along the upper reaches of the watershed. The samples were collected along CD 20 on June 12, 2014, after a June 11, 2014, rainfall event. Longitudinal measurements of temperature, DO, pH, specific conductivity, stage, and turbidity were also collected at each road crossing. Samples were analyzed for chemical oxygen demand, ammonia nitrogen, total Kjeldahl nitrogen, TP, TSS, and *E. coli*. Some of the highest *E. coli* readings were on the upstream end of the reach that was sampled (Figure 3-15). There is a lot of undeveloped land east of CSAH 219, so those results were surprising. There are a few livestock operations in that area that have bare soil and could be potential *E. coli* sources. There could also be natural sources in this area too. Turbidity and TSS were consistent throughout the reach with a slight increase over the last two crossings. TP was consistently in the .07-.09 mg/L range throughout the reach until an increase to .127 mg/l at the CSAH 12 crossing. All of the DO measurements were above the 5 mg/L standard. Total Kjeldahl nitrogen did not vary much throughout the reach and the average concentration was 1.96 mg/l.

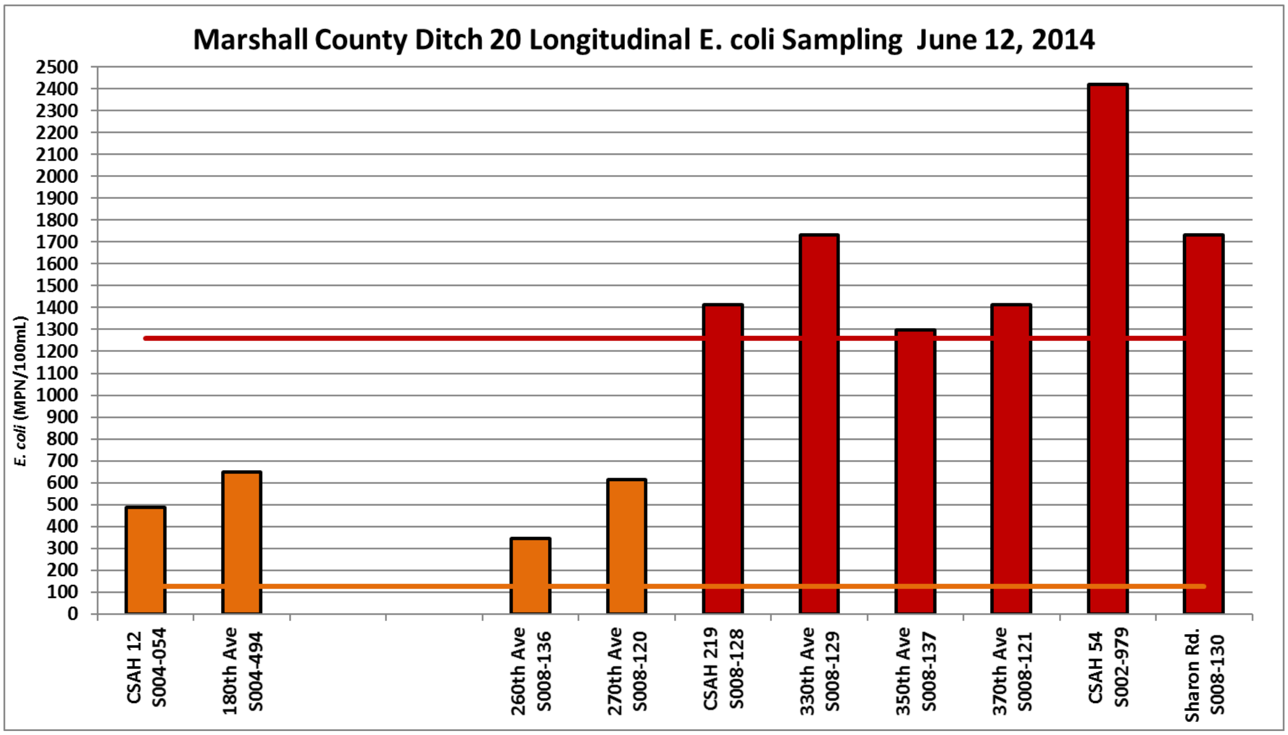



**Figure 3-15. June 12, 2014 longitudinal *E. coli* sampling along Marshall CD 20**

### 3.1.5 Stream Channel Stability Assessment (Geomorphology)

A reconnaissance of the Thief River Watershed was conducted by road and kayak to estimate BEHI scores throughout the watershed, identify station locations for stream bank stability assessments, identify problem areas, and identify potential projects. Intensive geomorphological assessments were performed at stations along the Thief River and major tributaries. Ideas generated during and after the reconnaissance include:

- Restore meanders in the Thief River between CSAH 6 and the 380$^{th}$ Street crossing at the north boundary of Agassiz NWR.
- Livestock had access to the Mud River in a few locations. One of the sites is particularly bad – the trampling of the banks has caused stream instability and channel widening. That farm is no longer in operation, so the river may get a chance to heal at that location.

- The Mud River upstream of Grygla is very poorly buffered. Some fields are plowed into the ditch slope. This area is most likely a significant source of sediment in the Mud River Watershed. Upland sources of sediment need to be targeted to lessen the contribution of excessive sediment to the river channel.
- Near the golf course in Thief River Falls, there was erosion along the outside bend of the river, gully erosion that has nearly cut off the meander, and erosion threatening a house just downstream. Since the reconnaissance, projects have been implemented by the Pennington SWCD to address all three of those problems.
- During the May 2010 stream reconnaissance, significant sedimentation was observed along the Thief River between CR7 (Agassiz Headquarters road) and CSAH 12 (Rangeline Road). The sedimentation between those two crossings has been documented during the aforementioned longitudinal sampling and during the 2015 intensive monitoring. It was also notable at the intensive geomorphology station along that stretch of the river. The muck along portions of the river bank was too deep to be safe for walking without getting stuck.
- Multiple areas along the straightened portion of the Moose River may allow for the restoration of meanders without disruption of agricultural operations.

Inadequate buffers allow upland sediment to enter the channels. Confined stream channels keep higher velocity stream flows within the channel, creating excessive bank erosion. Maintaining the natural equilibrium of the Thief, Moose, Mud, and other altered natural watercourses will not be successful through a patchwork of fixes on outside eroding banks or excavation of deposited sediment from the river channel. The correct strategy is to focus on addressing the driving forces behind channel instability. Address/prevent instability through the following actions:

- Establish and maintain perennial vegetation with robust and dense root mass adjacent to the stream.
- Vegetative plantings need to have sufficient width to function as a buffer.
- Watercourses must have access to a floodplain at the bankfull elevation.
- Artificial and altered natural watercourses should be designed and maintained with an appropriate base flow channel with floodplain access.

Additional recommendations from the geomorphological assessment and an intensive analysis of the watershed (like the Pfankuch and BANCS Model analysis shown in Figures 3-16 and 3-17) can be found in the 2015 Thief River Fluvial Geomorphology Report, in the protection considerations of Section 2.5, and in the restoration and protection strategy tables of Section 3.3. Download the full geomorphology report here:
http://redlakewatershed.org/waterquality/Thief%20R%20Geomorphology%20Report%20Nov2015.pdf

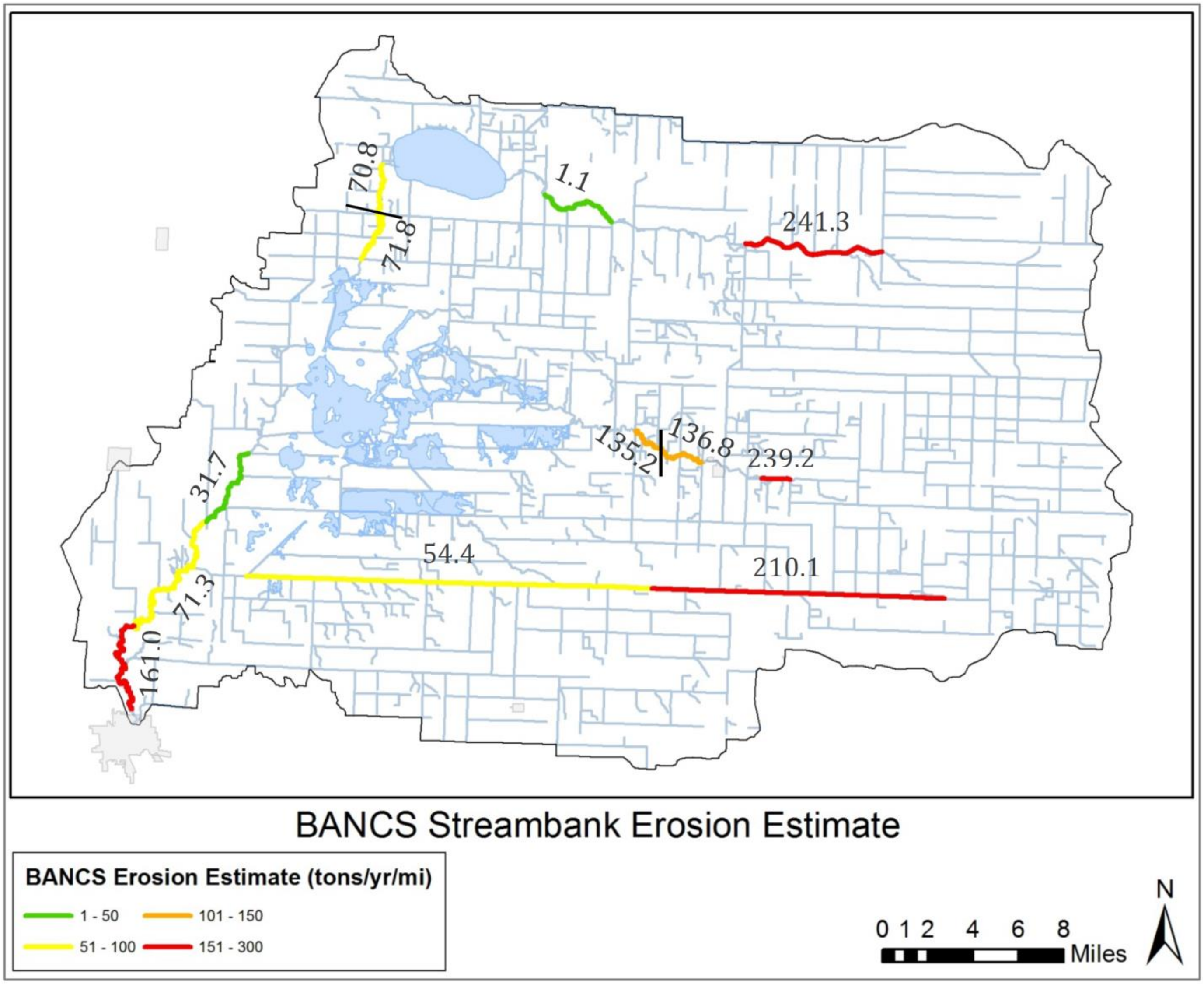



Figure 3-16. Stream bank erosion predictions from the BANCS model

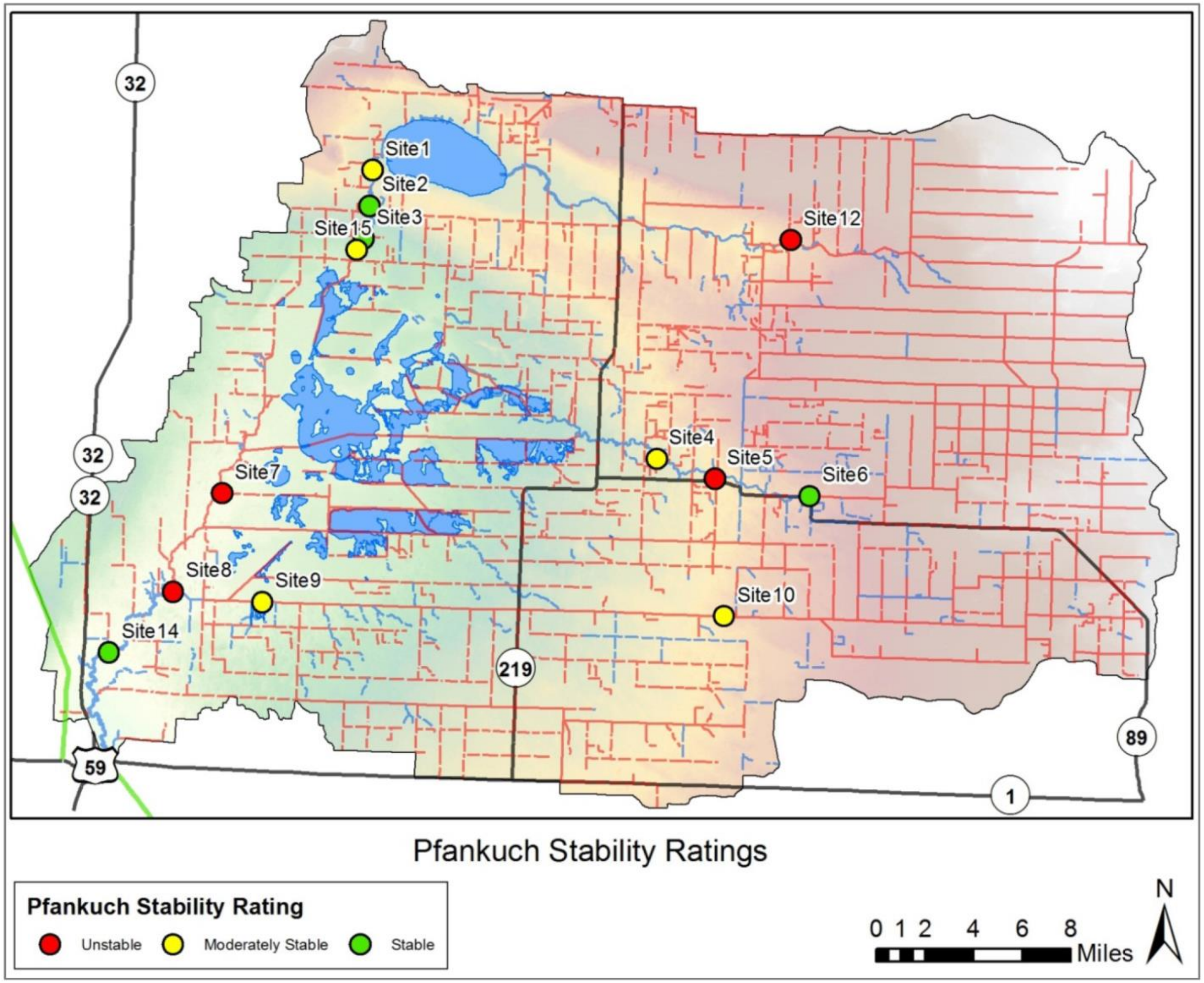



Figure 3-17. Pfankuch Stability Ratings at geomorphology study sites.

## 3.2 Civic Engagement

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement. This is distinguished from the broader term 'public participation' in that civic engagement encompasses a higher, more interactive level of involvement. The MPCA has coordinated with the University of Minnesota Extension Service for years on developing and implementing civic engagement approaches and efforts for the watershed approach. The University of Minnesota Extension's definition of civic engagement is "Making 'resourceFULL' decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration." Extension defines a resourceFULL decision as one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on civic engagement is available at: http://www.extension.umn.edu/community/civic-engagement/

### 3.2.1 Civic Engagement Accomplishments of the Thief River WRAPS Project


Multiple public and technical advisory meetings were held in conjunction with the Thief River WRAPS project.

- A town hall meeting was held at the Whiteford Town Hall on April 6, 2011, to encourage the installation of buffer strips in the Thief River Watershed, particularly in the area between Thief Lake and Agassiz NWR where the SWAT model identified high sediment loading.
- RMB Environmental Laboratories, Inc. (RMB Labs) staff and the MPCA staff gave a presentation at the Marshall County Water Resources Advisory Committee meeting in Newfolden on November 2nd, 2011. RMB staff also presented at the January 10, 2012, Pennington County WRAC meeting.

A public Stakeholders' Project Kick-Off meeting was held on January 13, 2012. More information and notes from the meeting are available in the January 2012 RLWD Water Quality Report:

- (http://www.redlakewatershed.org/waterquality/MonthlyWQReport/2012%201%20January%20Water%20Quality%20Report.pdf)
- Online informational resources were developed to distribute information about the RLWD projects and water quality/quantity related news specific to certain watersheds.
    - A Facebook page was created for the RLWD which serves as a means for quickly and easily sharing photos, links to reports, and other news.
    - A blog was created specifically for the Thief River Watershed at https://thiefriver.wordpress.com/.
    - Watershed-specific websites were created for the watersheds within the RLWD. Watershed-specific websites include links to existing documents and reports that relate to the watershed, photo galleries, descriptions of the watersheds, maps, meeting minutes, contacts, and more. At http://www.rlwdwatersheds.org/, users can click on the Thief River (or other watershed of their choice) to view general information about the watershed (http://www.rlwdwatersheds.org/tr-watershed-info) or learn more about the WRAPS process (http://www.rlwdwatersheds.org/wraps-info).
- Social networks within the watershed were mapped by RMB Environmental Laboratories staff.
- RMB staff also attended a RLWD Board meeting to talk about upcoming civic engagement events and get feedback from the Board.
- A "World Café" event was held for the Thief River Watershed at the Black Cat Bar and Grill in Thief River Falls in January of 2013.
- A second Thief River WRAPS Stakeholders' Update meeting was held on February 20th, 2013, at the Ralph Engelstad Arena Imperial Room in Thief River Falls. In conjunction with this meeting, 2300 Brochures were mailed to residents of the watershed that provided information about the project and let people know how they could get involved.
- The RLWD set up a booth at the Thief River Falls Community Expo at the Ralph Engelstad Arena on April 25th, 2013, in Thief River Falls. Technical Advisory Group meetings were held on June 12th, 2013, at the Detroit Lakes MPCA office and August 27th, 2014, at the RLWD Office.

- An open house event was held at the Grygla Community Center on June 17th, 2013, as part of the ongoing Thief River Watershed Restoration and Protection Project civic engagement efforts.
- The RLWD provided the Thief River Falls Parks and Recreation program with "River of Dreams" small cedar canoes that kids can decorate, launch, and track online.


The RLWD and the MPCA worked with an independent contractor to create professional videos that inform the public about DO, turbidity, and *E. coli* bacteria water quality issues. The video creation process involved script development, collection of video clips, and professional voiceover work. The videos were posted to YouTube and have over 8,200 views (including all three versions of the DO video), combined as of June 4, 2018.

- DO in Lakes and Rivers: https://youtu.be/ryIadGeJ7O8
- Turbidity: https://youtu.be/EkH3jZvADTk
- Bacteria in Lakes and Rivers: https://youtu.be/vkYUiJXyqLI

### 3.2.2 Future Plans

The RLWD and other local government units need to continue conducting the public outreach efforts that were initiated during the WRAPS process. Monthly water quality reports will be made available to the public on the RLWD website and their availability will be announced through Facebook posts, blog posts, and direct email. Local government units may continue to host open house style events that will facilitate one-on-one discussions with residents and other stakeholders. Booths at county fairs and community events (Thief River Falls Expo) are another way to connect with the public.

The RLWD Water Quality Coordinator writes monthly water quality reports that originated as reports to the RLWD Board of Managers, and represent a means of documenting project progress throughout the year (making annual report writing easier). The reports are available on the RLWD website (www.redlakewatershed.org), shared on social media, and shared with a large list of email contacts.

A Thief River Watershed Public Participation Strategy document was completed by RMB Labs in February 2013. This document presented the following civic engagement goals for the Thief River Watershed:

1. Increase volunteer participation in natural resource monitoring.
2. Increase the number of watershed residents participating in water quality discussions.

3. Find effective ways to engage citizens in a meaningful way.
4. Increase the resources utilized to communicate water quality activities within the watershed.
5. Create a document with contact information for local resources, specific to certain water quality concerns or funding sources.

The public can be kept informed of water related news, water quality problems, solutions to water issues, and opportunities for involvement in water-related programs through several different means.

- Websites of local government units
    - RLWD
        - www.redlakewatershed.org
        - www.rlwdwatersheds.org
    - Pennington County SWCD
        - http://www.penningtonswcd.org/
    - Marshall SWCD
        - http://marshallcounty-swcd.org/
    - MPCA
        - http://www.pca.state.mn.us/
        - http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/thief-river.html
- Mailings to individual landowners
- Radio interviews
- Informational brochures and displays
- Press releases and advertisements with local media contacts
- SWCD newsletters
- Organization of events to bring attention to the resource
- Presentations for local civic groups

Local government can gain insight on water issues by consulting the public. The public can provide useful feedback on analysis, alternatives, and/or decisions. Working directly with the public throughout the process helps ensure that public concerns and aspirations are consistently understood and considered.

- Public meetings
- Thief River blog: www.thiefriver.wordpress.com
- Social Media (RLWD and Marshall SWCD Facebook pages)

- Public Comment period on final draft reports
- Open houses
- World Café discussions

All of this public participation activity is predicated on the principle that if the strategies in the WRAPS plan have been developed with input from local land managers, the likelihood of implementation may increase. In addition, implementation activities will be streamlined due to the collaboration between landowners, local agencies, and funding sources.

### Public notice for comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from June 25, 2018 through July 25, 2018.

## 3.3 Restoration & Protection Strategies

Members of the Thief River WRAPS Technical Advisory Committee (TAC) worked together to create a list of strategies that can be used to restore impaired waters and provide protection where water quality is good. After a meeting was held to discuss the strategies, individuals from the DNR, MPCA, Pennington SWCD, and the RLWD reviewed the list of strategies and suggested changes. The strategies are presented in Tables 3-1 through 3-9 for practices that can be applied to the entire 8-digit HUC watershed and separate tables for practices that are more specifically applicable to each 10-digit HUC subwatershed. The areas of interest for each table are shown in the maps of Figure 3-18 through 3-26. This is done in accordance with Minn. Stat. 114D.26, subd. 1, which states that WRAPS shall "contain an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources, including:

1. Water quality parameters of concern
2. Current water quality conditions
3. Water quality goals and targets by parameter of concern
4. Strategies and actions by parameter of concern and the scale of adoptions needed for each
5. A timeline for achievement of water quality targets
6. The governmental units with primary responsibility for implementing each watershed restoration or protection strategy
7. A timeline and interim milestones for achievement of watershed restoration or protection implementation actions within 10 years of strategy adoption.

<u>Additional explanation of specific columns in table:</u>

***Water Quality – Current Conditions: "***Current" condition is interpreted as the baseline condition over some evaluation period for the pollutant or non-pollutant stressor identified in the previous column. This should be a numeric descriptor and unit of measurement. This can be a current load (from TMDL or from the load monitoring program if pursuing a downstream goal and not a local goal), a pollutant concentration (e.g., *E. coli* geometric mean) or a score (e.g., IBI or MSHA score).

***Water Quality – Goals / Targets:*** This should be expressed in the same terms as applied in the previous column (Current Conditions) and will generally be a load target (could be percent reduction or a load value) or a water quality concentration target. For some parameters (e.g. phosphorus reduction in a lake watershed) it may be best to use a load target. For others (e.g., *E. coli*) a concentration may be easier to both express (avoiding strings of scientific notation) and understand. For protection, specify a numeric goal/target if available.

***Water Quality – Current Conditions, Goals / Targets pertaining to downstream considerations:*** The WRAPS (and subsequent planning work) should be developed to not only address the goal of protecting and restoring water resources within a given Minnesota major watershed, but to also contribute to pollutant load reductions needed for downstream waters (Red Lake River, Red River, Lake Winnipeg). To describe a "current condition" relating to a downstream goal, consider citing the load monitoring program data (e.g., "current phosphorus load is XXXX kg/year); this will in most cases be an appropriate resolution and will fit well with a load reduction goal that can be included in the goals/targets column (e.g., 45% load reduction per Nutrient Reduction Strategy).

***Strategies:*** This column is intended to provide the high-level strategies to be used. 'High-level' generally means a category-type of action rather than a specific BMP or a specific project (e.g., 'Improve upland/field surface runoff controls' rather than 'Vegetated buffers'). The strategies should be briefly stated and then further described in

***Strategy Type and Estimated Scale of Adoption Needed to Meet Final Water Quality Target:*** This column ties to the Strategies column and provides the basic outcome of a modeling scenario (or similar analysis) that generally describes the collective magnitude of effort (over however many years or decades) that it will take to achieve the water quality target. This estimate is meant to describe approximately "what needs to happen" but does not need to detail precisely "how" goal attainment will be achieved (the latter is left to subsequent planning steps). As such, it is acknowledged that this is an approximation only and subject to adaptive management. Detail regarding degree of implementation of various BMPs may be added per stakeholder design/support, as long as it is recognized that there are often many permutations of BMP implementation that constitute a goal attainment scenario. This column can reference example scenarios.

***Interim 10-yr Milestones:*** This column ties to the Estimated Scale of Adoption column and should describe progress to be made toward implementing the strategy in the first 10 years. This may be provided in the form of a percentage, amount, or narrative descriptor.

***Governmental Units with Primary Responsibility:*** Identify the governmental unit with primary responsibility at a minimum, with option to identify secondary responsibilities (using a different symbol).

***Estimated Year to Achieve Water Quality Targets:*** This applies to the waterbody, specifically the year it is reasonably estimated that applicable water quality targets will be achieved. Explanatory information may be added either as a footnote or in the preceding narrative providing any assumptions used in the estimate.

**Red Rows:** Impaired waters requiring restoration

**Green Rows:** Unimpaired waters requiring protection

### 3.3.1. 09020304 Watershed-Wide Strategies

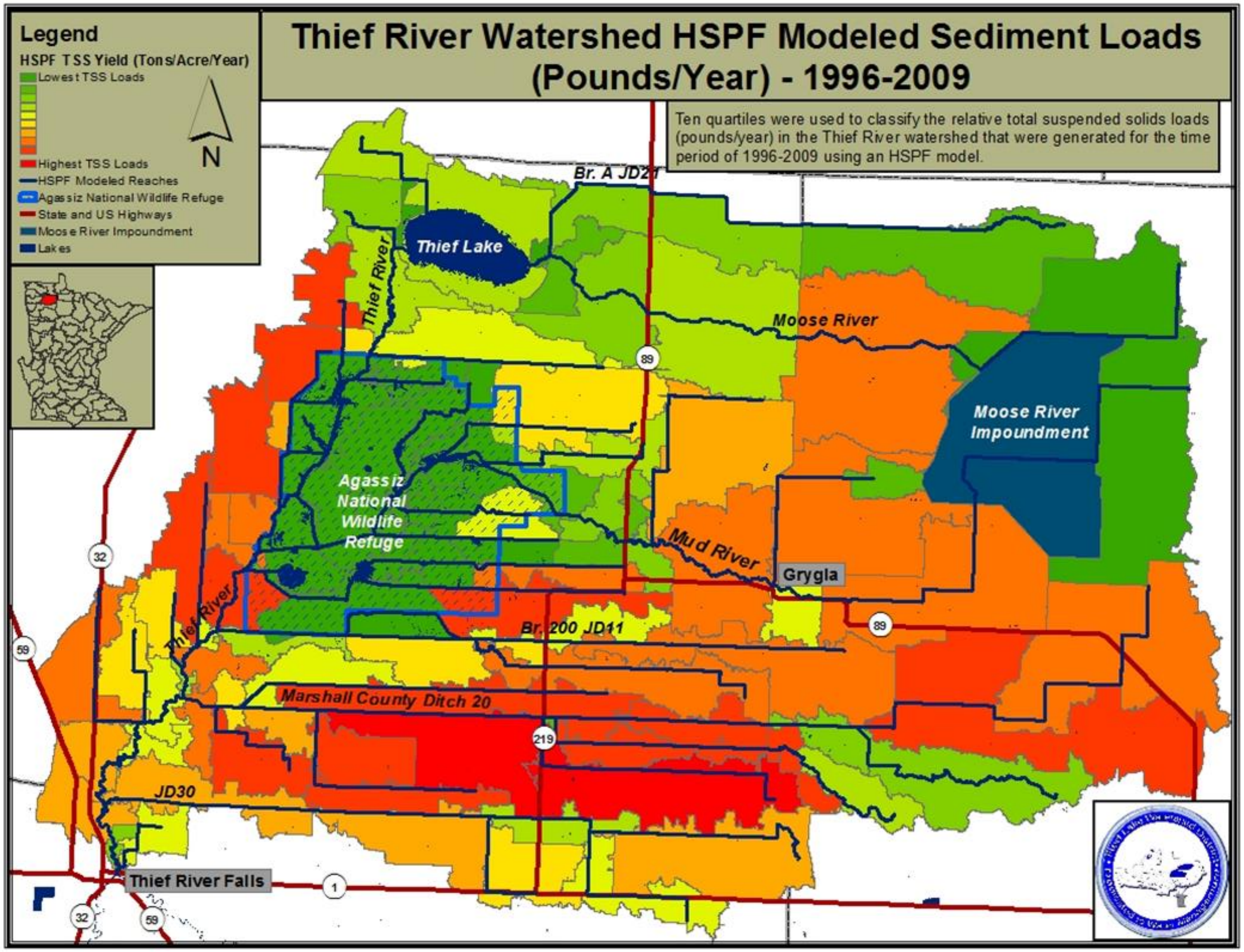



Figure 3-18. Thief River Watershed HSPF-Modeled Annual TSS Loads

**Table 3-1. Strategies and actions proposed for the Watershed-wide activities within the Thief River Watershed (09020304).**

| HUC-10 Subwatershed | Waterbody and Location | | Parameter | Water Quality | | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | | Current Conditions | Water Quality Target | | | | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | |
| Watershed-wide | All | All | Total Suspended Solids | Varies | < 30 mg/l (official MPCA standard)<br><br>< 15 mg/l recommended for local goal-setting for Moose R and Mud R | River Watch | Continued support of the Grygla River Watch Program. Revive the River Watch program in Thief River Falls. | Both schools are collecting monthly measurements during open water months. | ● | | | | | | | | | | | | ● | | ● | 2025 |
| | | | | | | Establish buffers or alternative practices along channels | This practice will now be required by state law along public perennial waterways and identified ditches in the state. | The implementation of Minnesota's Buffer Bill resulted in an increase in the miles of streams and ditches that are protected by buffers or alternative practices. | ● | ● | ● | ● | | | | | | | ● | | | | ● | 2018 |
| | | | | | | Utilize models, tools, site visits & inventories targeted best management (including but not limited to side water inlets, alternative side water inlets, cover crops, and crop residue management) practices to control upland erosion. | Concentrate upon tilled lands throughout the watershed. | Seek grant funding for accelerated implementation in critical areas identified.<br>Prioritize small watersheds for intensive sediment source inventory.<br>Use GIS tools and field verification to identify sediment sources.<br>GIS data is used to conduct an assessment of buffer quality. | ● | ● | ● | ● | ● | ● | | ● | | | ● | | | | | 2026 |
| | | | | | | Crop residue management & Conservation Tillage (no-till)<br>Cover Crops | Watershed-wide | Show a net increase in the percentage of tilled acres that utilize on-field BMPs to reduce soil loss. | | ● | ● | ● | | | | ● | | | | | | | ● | Ongoing |

| HUC-10 Subwatershed | Waterbody and Location | | Parameter | Water Quality | | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | | Current Conditions | Water Quality Target | | | | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | |
| Watershed-wide | All | All | Total Suspended Solids | Varies | < 30 mg/l (official MPCA standard)<br><br>< 15 mg/l recommended for local goal-setting for Moose R and Mud R | Installation and renovation of field windbreaks to reduce wind erosion | Watershed-wide | Installation of windbreaks and shelterbelts and the renovation of existing ones. | | ● | ● | ● | | | | ● | | | | | | | ● | Ongoing |
| | | | | | | Installation and renovation of field windbreaks to reduce wind erosion | Watershed-wide | Installation of windbreaks and shelterbelts and the renovation of existing ones. | | ● | ● | ● | | | | ● | | | | | | | ● | Ongoing |
| | | | | | | Floodplain access maintenance and improvement along ditches | Watershed-wide | Maintenance of floodplain access is considered when ditches are cleaned or improved.<br>Improved floodplain access on portions of ditches or watercourses that are severely incised.<br>Review pre-construction and as-built ditch plans to ensure that the project is not deepening the systems or to ensure that floodplain access is available.<br>Pursue opportunities to provide/acquire the additional funding needed to incorporate two-stage ditch designs into ditch improvement projects. | ● | ● | ● | ● | ● | | | | | | | ● | | ● | ● | Ongoing |
| | | | | | | Revegetation of disturbed areas (e.g. ditch cleanouts) | Watershed-wide | Revegetation of ditch cleanouts becomes a requirement during the permitting process.<br>The most recently updated guidance on ditch cleanouts is utilized. | ● | ● | ● | ● | ● | | | | | | ● | ● | | ● | | Ongoing |
| | | | *E. coli* Bacteria | Varies | < 126 MPN/100 ml monthly geomean | Use of Conservation Programs (i.e. CRP, EQIP & RIM) to encourage conservation practices in critical areas | Watershed-wide | Outreach to landowners with expiring contracts to help prevent CRP losses.<br>CRP losses are offset with perennial grasslands or alternative crops.<br>Grant funding is acquired to provide financial assistance to | | ● | ● | ● | | | | ● | | | | | | | ● | Ongoing |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | landowners that implement these projects.<br>Work with landowners to implement rotational grazing systems on expiring acres. | | | | | | | | | | | | | | | | |
| | | | | | | Septic system compliance | Watershed-wide | Conduct septic system inventories to identify non-compliant septic systems.<br>Out-of-compliance systems are brought into compliance in a timely manner.<br>Update County ordinances to include point of sale septic inspections.<br>Help homeowners get low interest loans for septic system updates. | | ● | ● | ● | | ● | | | | | | ● | | | ● | 2026 |
| | | | | | | Grazing Management and Feedlot Ordinance Compliance | Watershed-wide | Existing *E. coli* impairments are delisted.<br>Delisted *E. coli* impairments continue to meet standards.<br>One (1) livestock exclusion project is implemented.<br>Ensure that all feedlots are up-to-date and comply with regulations. Feedlots that are not meeting the regulations, local agencies will work with the landowner to get into compliance. | | ● | ● | ● | | ● | | | | | | ● | | | ● | Ongoing |

| HUC-10 Subwatershed | Waterbody and Location | | Parameter | Water Quality | | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | | Current Conditions | Water Quality Target | | | | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | |
| Watershed-wide | All | All | Index of Biological Integrity (IBI) | Varies (most not assessed due to channelization) | Fully support aquatic life | Improve connectivity with properly sized and placed culverts on road crossings | Watershed-wide | Complete culvert inventory that also assesses crossing for potential fish barriers. Ensure that proper culvert size and placements are being used when road work and repairs are being completed. Follow MESBOAC designs for all culvert installations. | ● | | | | ● | | | | | | | ● | | ● | | 2026 |
| | | | | | | Improve connectivity with the Thief and Red Lake Rivers through dam modification | Thief Lake Dam and the Agassiz Pool water control structures | The feasibility of adding fish passage or modifying structures is explored. If changes are not feasible, evidence is provided to explain why that is the case. The history and future plans for the dams are documented. | | | | | ● | | ● | | | | | | | | | 2036 |
| | | | | | | Reducing sedimentation within channels and pools by addressing overland and streambank erosion | Watershed-wide | No new Total Suspended Solids impairments Improve trends in Total Suspended Solids concentrations | ● | ● | ● | ● | ● | | | ● | | | | | | | ● | 2026 |
| | | | | | | Reduce runoff and leaching of pesticides | Watershed-wide | The Minnesota Department of Agriculture does not find violations of pesticides during its pesticide monitoring program during the 10 years. | | ● | ● | ● | | | | ● | ● | ● | | | | | ● | Ongoing |
| | | | Dissolved Oxygen | Varies (most not assessed due to channelization) | >90% of daily minimums are > 5 mg/l | Nutrient and Soil Health Management | Watershed-wide | Build relationships between agency staff and crop advisors | | ● | ● | ● | | | | ● | | | | | | | ● | 2046 |

## 3.3.2. 0902030401 Moose River

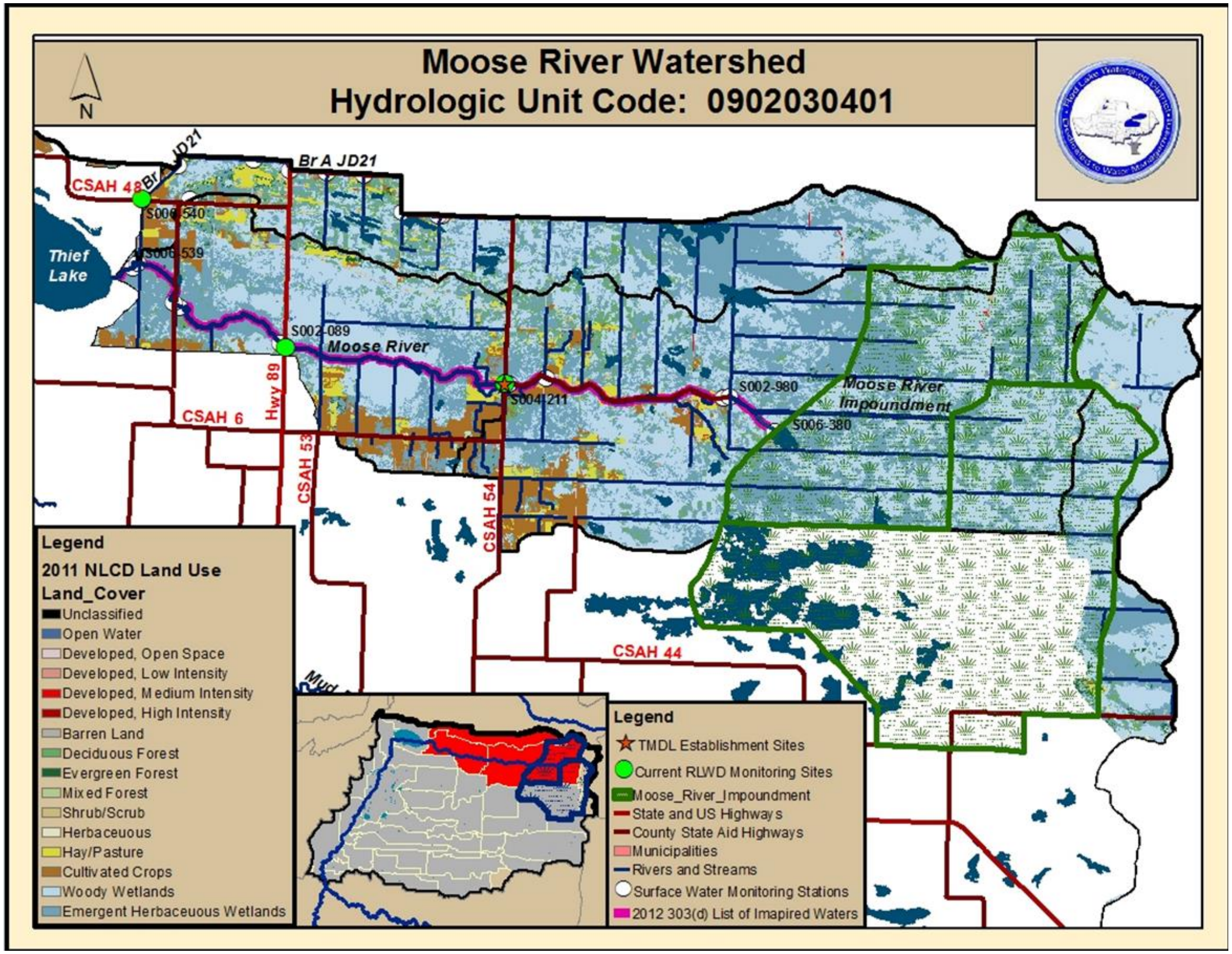



Figure 3-19. Moose River HUC10 0902030401

**Table 3-2. Strategies and actions proposed within the Moose River Watershed (0902030401).**

| | Waterbody and Location | | | Water Quality | | | | | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | Parameter | Current Conditions | Water Quality Target | Strategies | Estimated Scale of Adoption Needed | HUC-10 Subwatershed | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
| Moose River (0902030401) | Moose River | Beltrami and Marshall Counties | Dissolved Oxygen | Low DO DO5_All= 11.7%; DO5_9am= 57.9% | > 5 mg/l DO daily min. | Improve base flow in the Moose River | The rate of discharge from the Moose River impoundment in the late summer impacts the flashiness of the river. Flow can be metered out at a slower rate when drawing down to summer levels. | The operating plan for the Moose River impoundment has been reviewed and feasible changes have been made | ● | | | | ● | | | | | | | | | | | 2021 |
| | | | | | | Continued water quality monitoring | Collect samples and field measurements from sites S002-089 and S004-211 at least four times each year | At least three summer months of continuous DO monitoring prior to the 2023 State water quality assessment. | ● | | | | | | | | | | | | ● | | ● | Ongoing |
| | | | | | | | Continue to conduct stage and flow monitoring at the CSAH 54 crossing (S004-211). Consider making the site a real-time gauge. | Sufficient data, including pre-9am data, for a water quality assessment. Continued flow monitoring to facilitate load calculations. | ● | | | | | | | | | | | | ● | | ● | Ongoing |
| | | | | | | Establish riparian trees, brush, and herbaceous vegetation | Upstream of CSAH 54 | Establish a buffer or alternative practice along watercourses as required by law. Willow and native grass plantings along at least 1 mile of the channel. | ● | ● | | ● | | | | ● | | | | | | | ● | 2030 |
| | | | | | | Restore natural stream meander and complexity | | One project has been completed or at least planned. | ● | ● | | ● | ● | | | ● | | | | | | | ● | 2046 |
| | Moose River | Beltrami and Marshall Counties | Total Suspended Solids | Meets the 30 mg/L and 15 mg/l standards. Just 1.4% of sampling results from AUID 09020304-505 have been greater than 15 mg/l during the most recent 10 years of monitoring (2007-2016) | <30 mg/L (official MPCA standard) < 15 mg/l (to maintain/ improve water quality) | Continued water quality monitoring | Collect samples and field measurements from sites S002-089 and S004-211 at least four times a year. | Sufficient data for the 2023 water quality assessment. Continued flow monitoring to facilitate load calculations. | ● | | | | | | | | | | | | ● | | ● | Ongoing |
| | | | | | | | Continue to conduct stage and flow monitoring at the CSAH 54 crossing (S004-211). Consider making the site a real-time gauge. | | ● | | | | | | | | | | | | ● | | ● | |
| | | | | | | Riparian buffer improvement | River and ditch channels outside of the Thief Lake WMA | One project involving the planting of deep-rooted vegetation has been completed. | ● | | | ● | | | | | | | | | | | ● | 2046 |
| | | | | | | Restore natural stream meander and complexity | Upstream of CSAH 54 | One project has been completed or at least planned. | ● | ● | | ● | ● | | | | | | | | | | ● | 2046 |

| | Waterbody and Location | | | Water Quality | | | | | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | Parameter | Current Conditions | Water Quality Target | Strategies | Estimated Scale of Adoption Needed | HUC-10 Subwatershed | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
| Moose River (0902030401 | Moose River | Beltrami and Marshall Counties | Total Suspended Solids | Meets the 30 mg/L and 15 mg/l standards. Just 1.4% of sampling results from AUID 09020304-505 have been greater than 15 mg/l during the most recent 10 years of monitoring (2007-2016) | <30 mg/L (official MPCA standard)<br>< 15 mg/l (to maintain/ improve water quality) | Streambank stabilization | Upstream of CSAH 54 | One streambank stabilization project completed. | ● | ● | | | ● | | | | | | | | | | ● | Ongoing |
| | | | | | | Maintain current riparian corridor conditions | CSAH 54 to Thief Lake | West of CSAH 54, the riparian corridor along the Moose River remains intact. | | | | ● | ● | | | | | | | | | | ● | Ongoing |
| | | | | | | Side-inlet control structures (a.k.a. side water inlets or SWIs) | Agricultural lands east of Agassiz National Wildlife Refuge | Installation of side water inlet structures<br>Use models, tools, GIS layers, and inventories to ID the number that are needed. | ● | ● | | ● | | | | ● | | | ● | | | ● | | 2026 |
| | | | | | | Grade control structures | Upstream of CSAH 54 | A longitudinal survey is completed to identify locations where grade control structures could be beneficial to reduce channel degradation.<br>Using the result of the longitudinal survey, at least one grade control structure installed where headcutting is evident or in coordination with a channel restoration project. | ● | ● | | ● | | ● | | ● | | | | | | | | 2046 |
| | | | *E. coli* bacteria | All monthly geomeans < 126 MPN/100ml 41.3 MPN/100ml max. monthly geomean | All monthly geomeans < 126 MPN/100ml | Water Quality Monitoring | Collect samples and field measurements at sites S002-089 and S004-211 at least four times a year. | Sufficient data for the 2023 water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | ● | | ● | Ongoing |
| | | | Index of Biological Integrity (IBI) | Not assessed due to channelization | Fully support aquatic life | Moderation of flows (reduce peak flows, improve base flows) | Moose River Impoundment Outlet and the Moose River | Allow for continued discharge from the pool throughout the late summer and early fall to maintain flow >0 CFS in the Moose River | ● | | | | ● | | ● | | | | | | | | | 2016 |
| | | | | | | Restore natural stream meander and complexity | Upstream of CSAH 54 | One project has been completed or at least planned. | ● | ● | | ● | ● | | | ● | | | | | | | ● | 2046 |

### 3.3.3. 0902030402 Upper Thief River

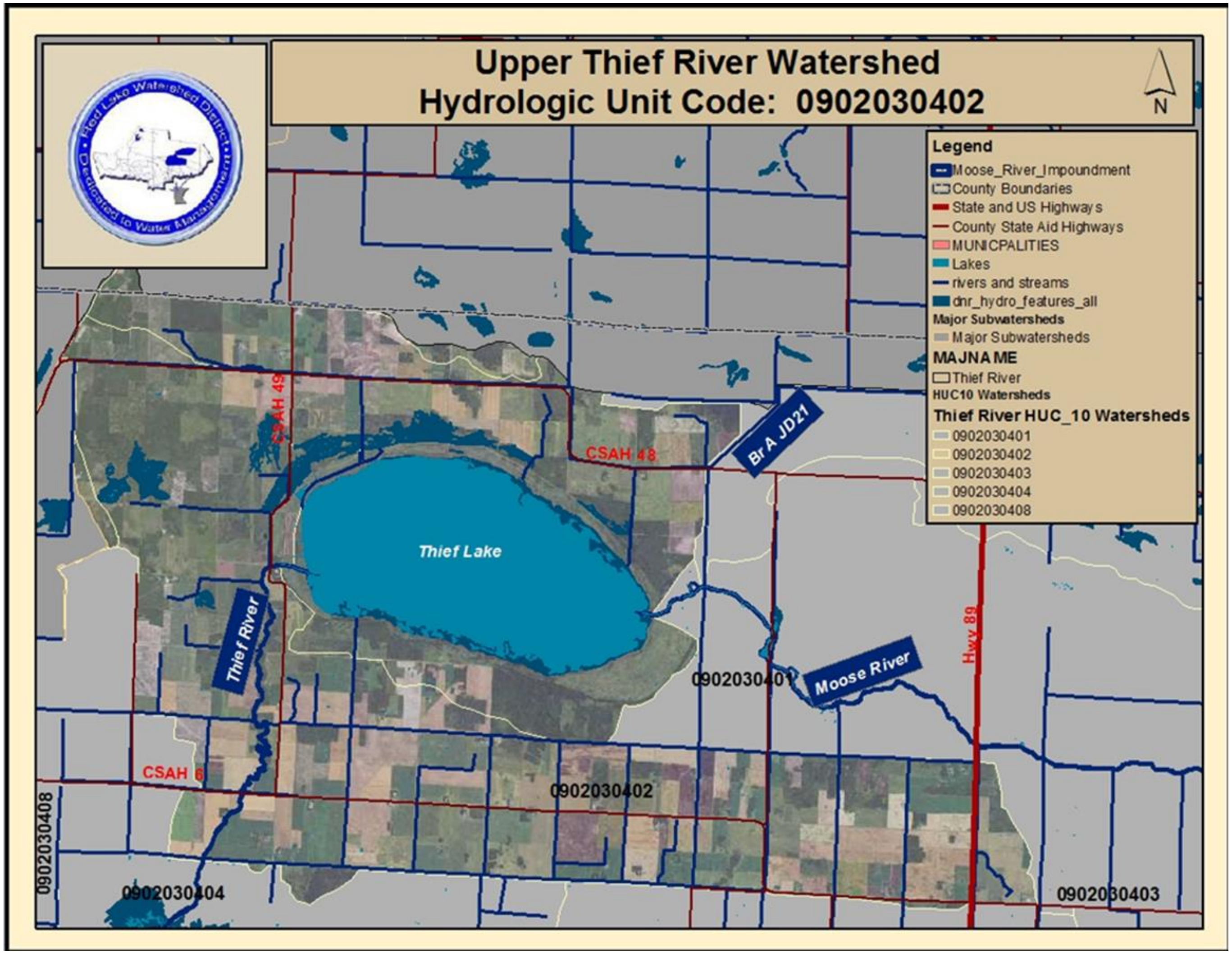



Figure 3-20. Upper Thief River Watershed HUC10 0902030402

Table 3-3. Strategies and actions proposed within the Upper Thief River Watershed (0902030402).

| HUC-10 Subwatershed | Waterbody and Location | | Parameter | Water Quality | | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | | Current Conditions | Water Quality Target | | | | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | |
| Upper Thief River (0902030402) | Thief River | Marshall County | Total Suspended Solids | All results < 30 mg/l<br>9.5% <15 mg/L | < 30 mg/L | Spoil piles from historical channelization should be pulled back to the outside edge of the 300-ft. wide riparian zone. | Between the CSAH 48 and 400th St. NE crossings | Investigate opportunities for a floodplain restoration project along a portion of the reach, without increasing the risk of flooding for homes and cropland along the river. | ● | | | ● | ● | | | | | | | | | ● | | 2026 |
| | | | | | | Rejuvenate riparian zone plant vigor and rooting depth | Throughout the reach, especially between CSAH 48 and 400th St. NE | Establish a 50-foot buffer or alternative practices on both sides of the watercourse to comply with new buffer standards. Establish native vegetation to promote plant vigor and rooting depth throughout the channel reach. | ● | | | ● | ● | | | | | | | | | | ● | 2036 |
| | | | | | | Continued Water Quality Monitoring | Collect samples and field measurements at sites S002-084 and S004-055 at least four times a year. | Sufficient data for the 2023 water quality assessment. | ● | | | ● | | | | | | | | | | | | Ongoing |
| | | | | | | Maintain floodplain access, connectivity, and riparian buffer condition. | Mid-reach (400th St. NE to CSAH 6) | No clearing of the riparian area has occurred. | ● | | | ● | | | | | | | | | | ● | ● | 2026 |
| | | | | | | Restoration of meanders to the river, with setback levees to protect farms from flooding | North of 380th St. NE | Examine the feasibility of a project. | ● | | | ● | ● | | | ● | | | ● | | | | ● | 2036 |
| | | | | | | Side-inlet control structures (a.k.a. side water inlets or SWIs) | Agricultural lands outside of the Thief Lake WMA | Installation of side water inlet structures<br>Use models, tools, GIS layers and inventories to identify the number that are needed. Aim for a portion of that number. | ● | | | ● | | | | ● | | | ● | | | ● | | 2026 |
| | | | *E. coli* bacteria | All monthly geomeans < 126 MPN/100ml | All monthly geomeans < 126 MPN/100mL (maintain or improve water quality) | Minimize the amount of baiting and banding that occurs along the Thief Lake outlet channel | Thief Lake outlet channel | Other banding areas are used instead of the one along the north side of the Thief Lake outlet channel.<br>Longitudinal sampling is conducted to determine the impact of banding activities on downstream *E. coli* concentrations compared to other potential sources. | ● | | | | | ● | | | | | | | | | | 2020 |
| | | | | | | Continued water quality monitoring | Collect samples and field measurements at sites S002-084 and S004-055 at least four times each year. | Sufficient data for the 2023 water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | Ongoing |

| HUC-10 Subwatershed | Waterbody and Location | | Parameter | Water Quality | | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | | Current Conditions | Water Quality Target | | | | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | |
| Upper Thief River (0902030402) | Thief River | Marshall County | Dissolved Oxygen | Fully supporting Only 1% of DO5_9am measurements are < 5 mg/l | >5 mg/l (maintain or improve water quality conditions) | Continued water quality monitoring | S004-055-Thief River at 380th St. NE (North Boundary of Agassiz NWR) and S002-084-Thief River at CR 49 | Collect sufficient data to conduct a successful water quality assessment.<br>Collect a minimum of 3 months of continuous DO data from at least one monitoring sites in one of the years 2013-2022.<br>Continued flow monitoring to facilitate load calculations. | ● | | | | | | | | | | | | | | | Ongoing |
| | | | Index of Biological Integrity (IBI) | Not assessed due to channelization | Full support of aquatic life | Moderation of flows (reduce peak flows, improve base flows) | Thief River between Thief Lake and Agassiz NWR | Educate the public/landowners about aquatic life and habitat and how to reduce peak flows on their lands.<br>Develop a strategy for the augmentation of low flows to protect aquatic life. | ● | | | | ● | | ● | | | | | | | | | 2023 |

### 3.3.4. 0902030403 Mud River

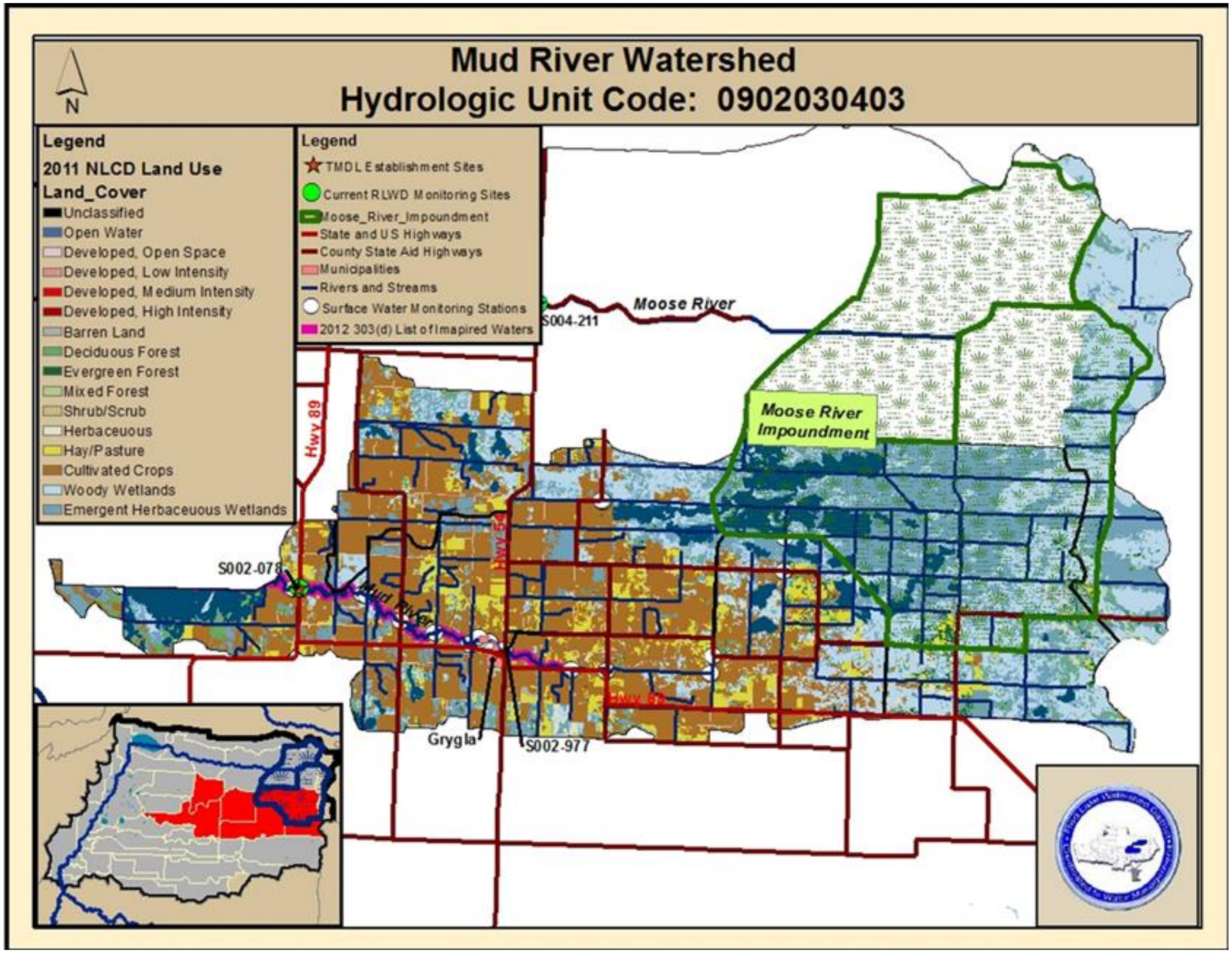



Figure 3-21. Mud River HUC10 Watershed 0902030403

**Table 3-4. Strategies and actions proposed within the Mud River Watershed (0902030403).**

| HUC-10 Subwatershed | Waterbody and Location | | Parameter | Water Quality | | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | | Current Conditions | Water Quality Target | | | | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | |
| Mud River (0902030403) | Mud River | Beltrami and Marshall County | Total Suspended Solids | 4% of April-Sept. samples are > 30 mg/l (2007-2016)<br><br>10.3% of April-Sept. samples are > 15 mg/l (2007-2016) | > 90% of April-Sept. samples are <15 mg/l | Stabilization of eroding stream banks | Documented sites with an extraordinary amount of preventable erosion. Between Highway 89 and Agassiz NWR<br>Throughout the reach, particularly in areas in which homes, infrastructure, or broad scale river stability area threatened. | At least one project has been completed. | ● | ● | | ● | ● | | | | | | | ● | | | | ● | 2026 |
| | | | | | | Restore natural stream meanders and complexity<br>Restore meanders in JD11 upstream of Agassiz Pool to allow for floodplain sediment deposition prior to Agassiz Pool | Throughout the reach, primarily downstream of Highway 89 and upstream of CSAH 54 | One project has been completed or at least planned, starting with the portion of the Mud River downstream of Highway 89. | ● | | | ● | ● | | ● | | | | | | | | ● | ● | 2046 |
| | | | | | | Side-inlet control structures (a.k.a. side water inlets or SWIs) | Agricultural lands east of Agassiz NWR | Installation of 100 side water inlet structures<br>Use models, tools, GIS layers and inventories to identify the number that are needed. Aim for a portion of that number. | ● | ● | | ● | | | | ● | | | | ● | | | ● | ● | 2026 |
| | | | | | | Continued water quality monitoring | Throughout the reach, particularly sites S002-078 | Sufficient data for the 2023 water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | ● | | | ● | | | | | ● | | ● | Ongoing |
| | | | | | | Stormwater runoff reduction | City of Thief River Falls | Creation of at least one rain garden.<br>Rain barrel building workshop in the area. | ● | | ● | | | ● | | | | | | | | | | | 2036 |
| | | | *E. coli* bacteria | 09020304-507 meets the standard as a combine unit. Sites near Grygla exceed the standard. | All monthly geomeans < 126 MPN/100ml | Continued water quality monitoring | Throughout the reach, particularly site S002-078 | Sufficient data for the 2023 water quality assessment. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | | | | Compliance and upgrade of substandard and failing SSTS. | Throughout the reach | Identification and repair of failing SSTS | | | | | | | | | | | | | ● | | | | Ongoing |
| | | | | | | Maintain compliance of the Grygla Wastewater Treatment Facility | Grygla WWTF site | No violations of leaks from 2015-2025 | | | | | | ● | | | | | | | | ● | | | Ongoing |

| | Waterbody and Location | | | Water Quality | | | | | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HUC-10 Subwatershed | Waterbody (ID) | **Location** and Upstream Influence Counties | Parameter | Current Conditions | Water Quality Target | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
| Mud River (0902030403 | Mud River | Beltrami and Marshall County | Dissolved Oxygen | DO5_9am 16% of daily minimums are < 5 mg/l | > 5 mg/l | Maintain or improve base flows to avoid low DO levels and conditions that lead to blue-green algae blooms | South pool of the Moose River Impoundment | Late-summer intensive sampling efforts identify the conditions in which blue-green algae blooms occur. Water management goals are adjusted to help avoid those conditions. | ● | | | | | | | | | | | | | | ● | | 2020 |
| | | | | | | Establish riparian trees, brush and herbaceous vegetation | Upstream of CSAH 54 | Establish a buffer or alternative practice along watercourses as required by law. Willow and native grass plantings along at least 2,000 additional feet of the channel. | ● | ● | | ● | | | | ● | | | | | | | | ● | 2036 |
| | | | | | | Restore natural stream meander and complexity | Throughout the reach, primarily downstream of Highway 89 and upstream of CSAH 54 | One project has been completed or at least planned, starting with the portion of the Mud River downstream of Highway 89 | ● | ● | | ● | ● | | | ● | | | | | | | | ● | 2046 |
| | | | | | | Continued water quality monitoring | Throughout the reach, particularly site S002-078 | Sufficient data for the 2023 water quality assessment.<br>Collect a minimum of 3 months of continuous DO data from at least one monitoring site in one of the years from 2013-2022.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | Index of Biological Integrity (IBI) | Not assessed due to channelization. Unofficial results were at or below the northern streams thresholds. | Full support of aquatic life | Moderation of flows (reduce peak flows, improve base flows) | Moose River Impoundment, South pool outlet | Water quality concerns are included in the impoundment operation review process. | ● | | | | ● | ● | ● | | | | | | | | | | 2026 |
| | | | | | | Restore natural stream meander and complexity | Throughout the reach, primarily downstream of Highway 89 and upstream of CSAH 54 | One project has been completed or at least planned, starting with the portion of the Mud River downstream of Highway 89 | ● | | | ● | ● | | | ● | | | | | | | | ● | 2046 |

### 3.3.5. 0902030404 Middle Thief River (Agassiz National Wildlife Refuge)

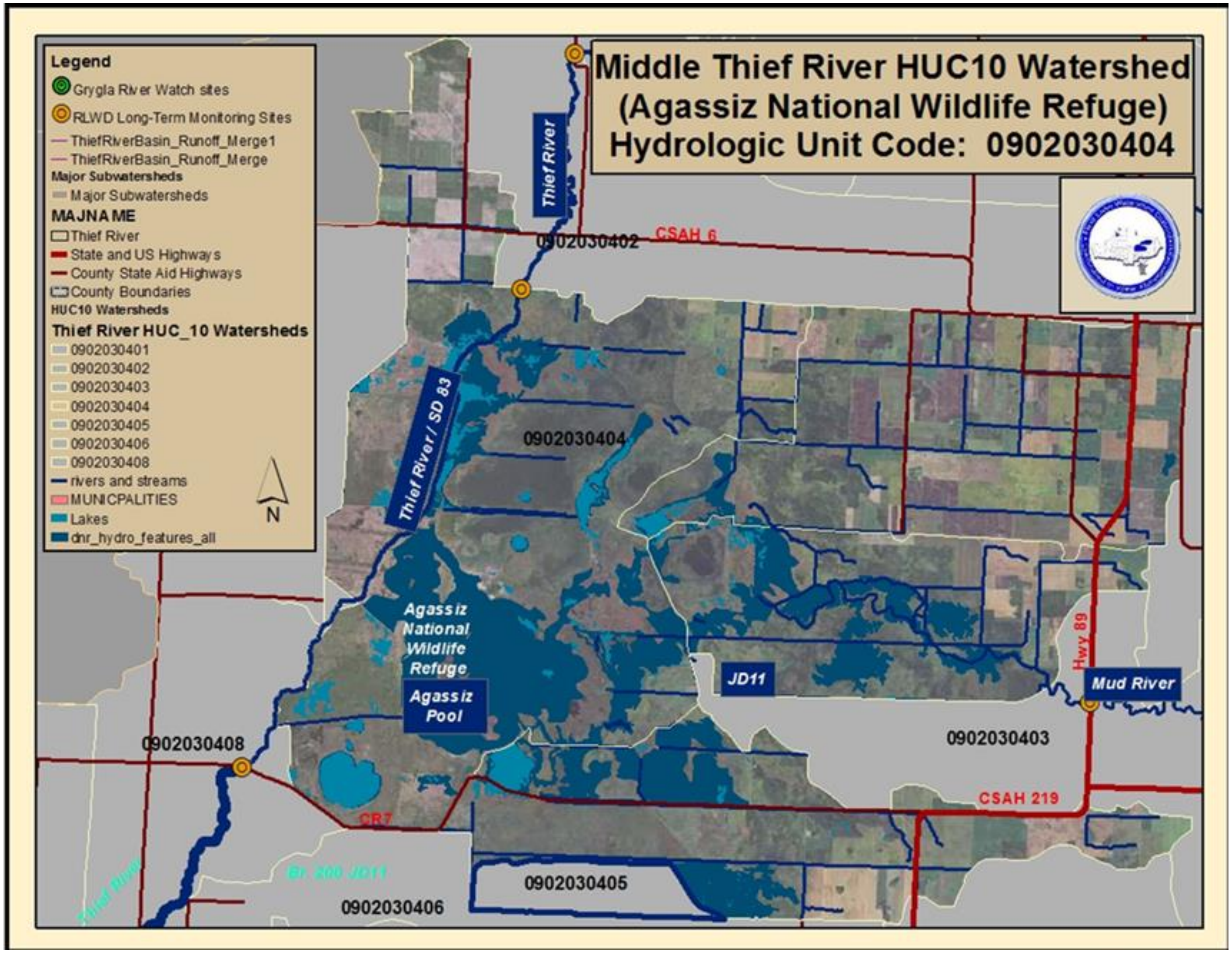



Figure 3-22. Middle Thief River HUC10 Watershed 0902030404

**Table 3-5. Strategies and actions proposed within Middle Thief River (Agassiz Pool, Portions of JD11) Watershed (0902030404).**

| | Waterbody and Location | | | Water Quality | | | | | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HUC-10 Subwatershed | Waterbody (ID) | **Location** and Upstream Influence Counties | Parameter | Current Conditions | Water Quality Target | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency/EPA | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute/ Red | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
| Middle Thief River (Agassiz Pool, Portions of JD11) (0902030404) | Thief River | Beltrami and Marshall County | Total Suspended Solids | Not assessed due to channelization and insufficient data | < 30 mg/l | Improved water quality monitoring data collection | S004-497 (Agassiz Pool radial gates outlet)<br>S004-496 (Branch 1 of JD 11) | Sufficient data for the 2023 water quality assessment.<br>Data collected by federal agencies is available for use in the assessment. | ● | | | | | | ● | | | | | | | | | | 2013-2022 |
| | | | | | | Reduce the amount of sediment that deposits within Agassiz Pool | Entirety of the contributing watershed | Reconsider alternatives to the "flushing and scouring" strategy for dealing with sediment in Agassiz Pool.<br>Plan and acquire funding for the projects that reduce sediment inputs, whether from bank or off-channel sources, from rivers and ditches upstream of Agassiz Pool. | ● | ● | | ● | ● | | ● | | | | | ● | | | ● | | 2036 |
| | | | | | | Minimize the effect of Agassiz Pool drawdowns | Agassiz Pool | Bring together a group of stakeholders to re-examine alternatives.<br>Water quality data is used to prove that recent changes in the operation of the impoundment have been detrimental to downstream resources.<br>Funding is sought for alternatives to the strategy of excavating the old JD11 channel and flushing sediment downstream.<br>Expectations for the management of Agassiz Pool are revised due to the reality of sedimentation within the pool.<br>The methodology and feasibility of changing Agassiz Pool into an off-channel impoundment is further explored. | ● | | | | ● | ● | ● | | ● | | | | | | | | 2026 |
| | | | | | | Explore ways to reduce the transport of sediment from the Mud River into Agassiz Pool | Thief River and Mud River | Re-meander the channelized reach of the Mud River | ● | | | ● | ● | | ● | | | | | ● | | | | | 2036 |
| | | | | | | Side inlet control structure (a.k.a. side water inlets or SWIs) | Agricultural land east of Agassiz NWR | Installation of 50 side water inlet structures<br>Use models, tools, GIS layers and inventories to identify the number that are needed. Aim for a portion of that number. | ● | ● | | ● | | | | | ● | | | ● | | | ● | | 2026 |
| | | | *E. coli* bacteria | Insufficient data | All monthly geomeans < 126 MPN/100ml (maintain or improve water quality) | Water quality monitoring | AUID #09020304-536 | Sufficient data for 2023 water quality assessment | | | | | | | ● | | | | | | | | | | 2022 |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | **Location** and Upstream Influence Counties | Parameter | Water Quality: Current Conditions | Water Quality Target | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility: Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency/EPA | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute/ Red | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Middle Thief River (Agassiz Pool, Portions of JD11) (0902030404) | Thief River | Beltrami and Marshall County | Dissolved Oxygen | Insufficient data | > 5 mg/l on > 90% of days | Minimize the effect of Agassiz Pool drawdowns | Agassiz Pool | Water quality data is used to prove that recent changes in the operation of the impoundment have been detrimental to downstream resources.<br>Funding is sought for alternatives to the strategy of excavating the old JD11 channel and flushing sediment downstream.<br>Expectations for the management of Agassiz Pool are revised due to the reality of sedimentation within the pool. | ● | | | | | ● | ● | | ● | | | | | | | | 2026 |
| | | | | | | Continued water quality monitoring | AUID #09020304-536 | Sufficient data for the 2023 water quality assessment.<br>Pre-9am and continuous DO data are collected. | | | | | | | ● | | | | | | | | | | 2022 |
| | | | Index of Biological Integrity (IBI) | Varies by location, not assessed due to channelization | Full support of aquatic life | Moderation of flows (reduced peak flows, improved base flows) | Impoundment outlets | Water quality concerns are included in the impoundment operation review process.<br>At least one wetland restoration project is completed. | ● | | | | ● | ● | ● | | | | | | | | | | 2026 |
| | | | | | | Support alternative methods of cattail and nutrient removal from impoundments | Impoundments | The Cattail Management for Wetland Wildlife and Bioenergy Potential study is completed.<br>Continued experimentation with and assessment of the grazing of dry impoundments. | ● | | | | ● | ● | ● | | | ● | | | | ● | | | 2026 |

### 3.3.6. 0902030405 Branch 200 of Judicial Ditch 11

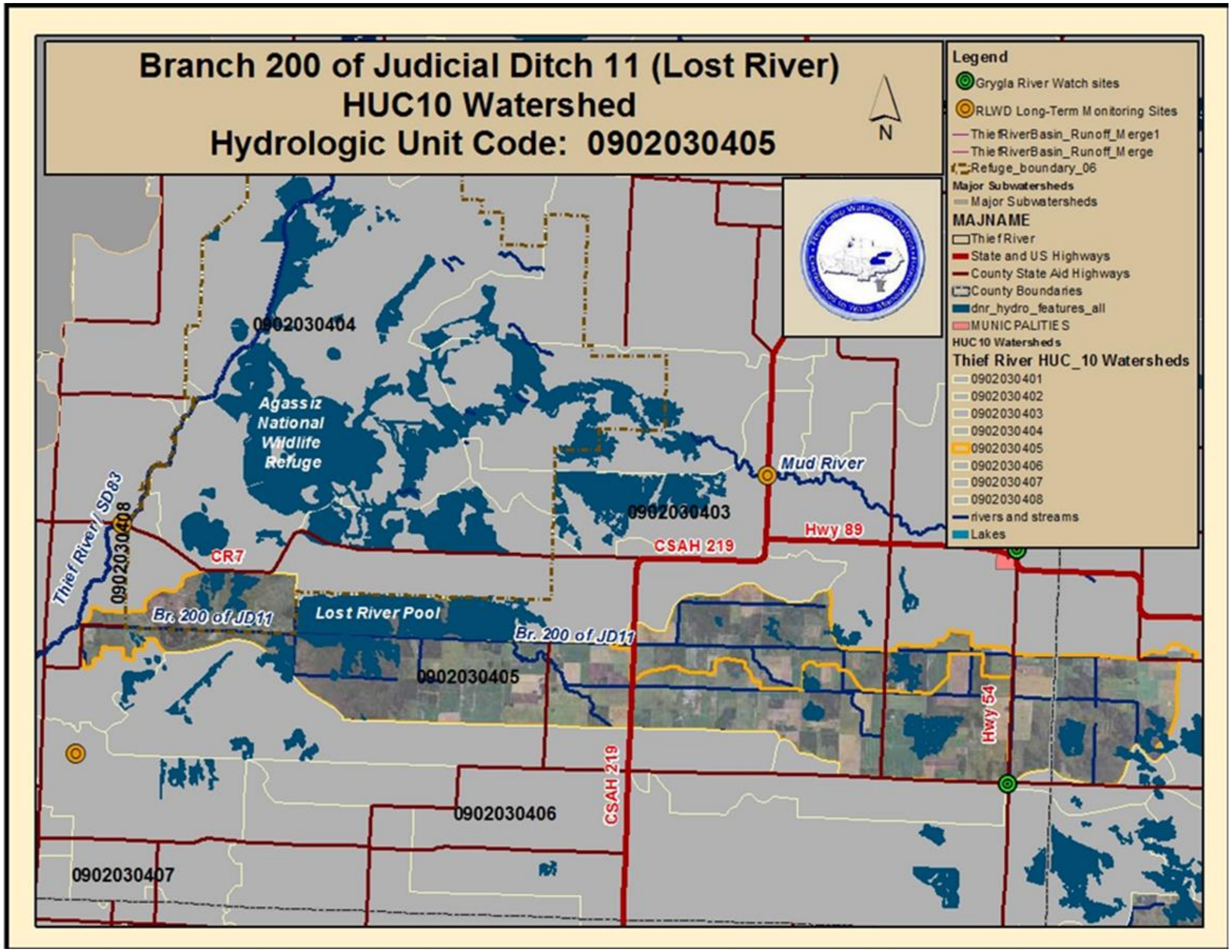



Figure 3-23. Branch 200 of Judicial Ditch 11 HUC10 Watershed 0902030405

Table 3-6. Strategies and actions proposed within Branch 200 of Judicial Ditch 11 Watershed (0902030405).

| | Waterbody and Location | | | Water Quality | | | | | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HUC-10 Subwatershed | Waterbody (ID) | **Location** and Upstream Influence Counties | Parameter | Current Conditions | Water Quality Target | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency/EPA | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute/ Red | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
| Branch 200 of JD11 (0902030405) | Branch 200 of JD11 | Beltrami and Marshall County | Total Suspended Solids | Not assessed but current data shows full support of the 30 mg/L TSS standard | < 30 mg/l | Continued water quality monitoring | Throughout the reach, particularly site S004-493 | Sufficient data for the 2023 water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | | | | Side inlet control structure (a.k.a. side water inlets or SWIs) | Agricultural land east of Agassiz NWR | Installation of 50 side water inlet structures<br>Use models, tools, GIS layers and inventories to identify the number that are needed. Aim for a portion of that number. | ● | ● | | ● | | | | ● | | | | ● | | | ● | | 2026 |
| | | | *E. coli* bacteria | All monthly geomeans < 126 MPN/100 ml in 09020304-511 | All monthly geomeans <126 MPN/100 ml | Water quality monitoring | Throughout the reach, particularly site S004-493 | Sufficient data for the 2023 water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | Dissolved Oxygen | Not assessed due to channelization<br>57.1% of DO5_9am < 5 mg/l in Reach 534<br>50.3% of DO5_9am < 5 mg/l in Reach 511 | > 5 mg/l | Water quality monitoring | Throughout the reach, particularly site S004-493 | Sufficient data for the 2023 water quality assessment.<br>Collect a minimum of 3 months of continuous DO data for at least one monitoring site in one of the years from 2013-2022.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | | | | Maintain stream flow | Downstream of Farmes Pool | Water quality concerns are included in the impoundment operation review process. | ● | | | | ● | | ● | | | | | | | | ● | | 2036 |
| | | | | | | Establish riparian trees, brush, and herbaceous vegetation | State Ditch 83, outside of Agassiz Pool | Establish a buffer or alternative practice along the channel as required by law. Willow and native grass plantings along at least 1 mile of the channel. | ● | ● | | ● | | | | ● | | | | | | | | ● | 2036 |

### 3.3.7. 0902030406 Marshall County Ditch 20

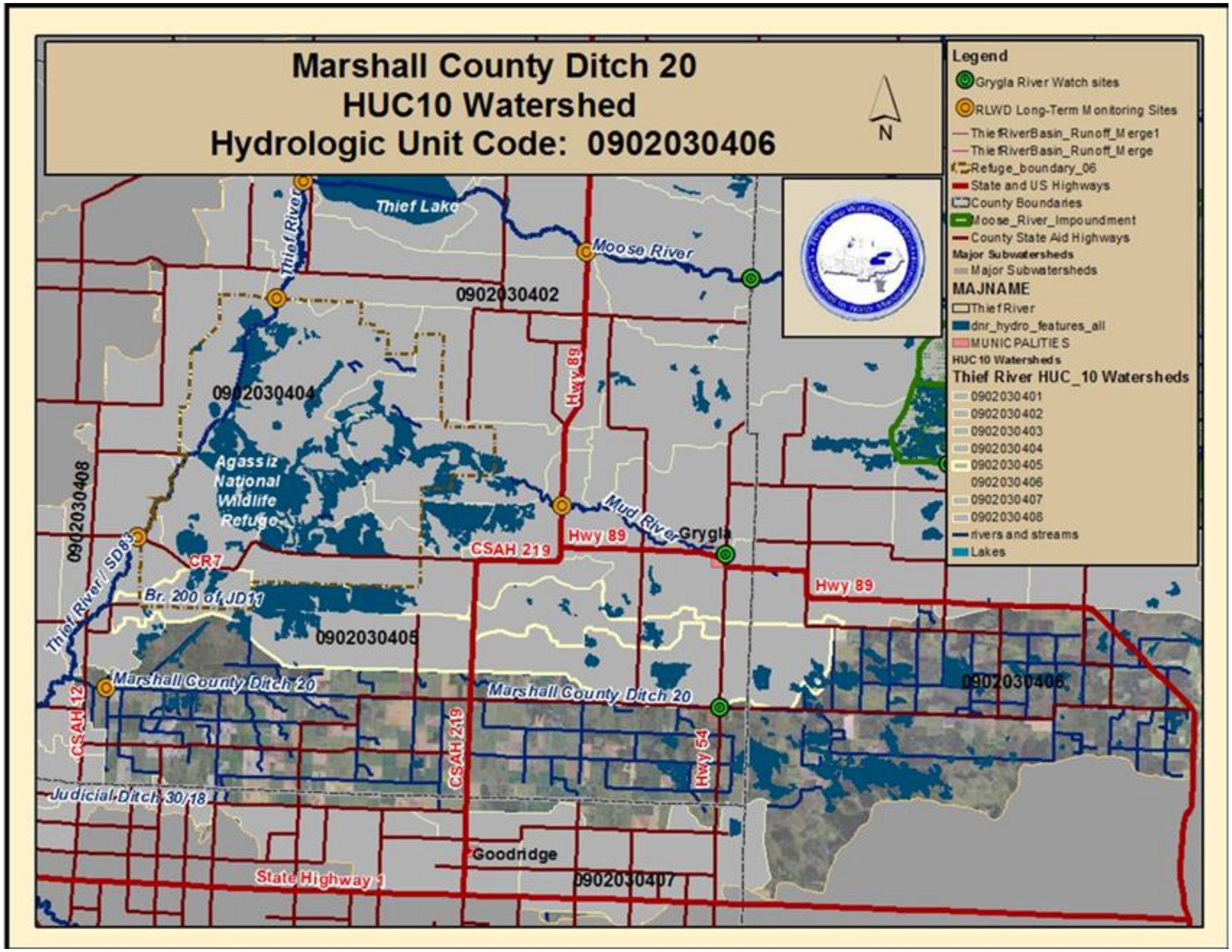



Figure 3-24. Marshall County Ditch 20 HUC10 Watershed 0902030406

Table 3-7. Strategies and actions proposed within Marshall County 20 Watershed (0902030406).

| HUC-10 Subwatershed | Waterbody and Location | | Parameter | Water Quality | | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | | Current Conditions | Water Quality Target | | | | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency/EPA | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute/ Red | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | |
| Marshall County 20 (0902030406) | Marshall County 20 | Beltrami and Marshall County | Total Suspended Solids | All samples <30 mg/l and only 1 sample <15 mg/L in 09020304-519 | < 30 mg/l | Establish a diverse riparian corridor buffer to increase the roughness of the streambank and reduce near bank velocities and the likelihood of bank cutting | Between 200th Ave. NE and 400th Ave. NE | Establish a buffer or alternative practice along the channel as required by law. Willow and native grass plantings along at least 2 miles of the channel. | ● | ● | | ● | | | | ● | | | | | | | | ● | 2036 |
| | | | | | | Maintain narrow width-to-depth ratios, but create additional capacity within the floodplain. | Throughout | No ditch cleanouts have been conducted. | ● | ● | | ● | ● | | | | | | | | ● | | ● | | 2056 |
| | | | | | | Side inlet control structure (a.k.a. side water inlets or SWIs) | Agricultural land east of Agassiz NWR | Installation of 50 side water inlet structures<br>Use models, tools, GIS layers and inventories to identify the number that are needed. Aim for a portion of that number. | ● | ● | | ● | | | | ● | | | | ● | | | ● | | 2026 |
| | | | | | | Water quality monitoring | Throughout the reach, particularly sites S004-494 and S002-979 | Sufficient data for the 2023 water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | *E. coli* bacteria | All monthly geomeans < 74.5 MPN/100ml | All monthly geomeans <126 MPN/100 ml | Water quality monitoring | Throughout the reach, particularly sites S004-494 and S002-979 | Sufficient data for the 2023 water quality assessment.<br>Investigation of sources in upper reaches.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | Dissolved Oxygen | Supports aquatic life 3.8% of DO5_9am values were < 5 mg/l | > 5 mg/l | Water quality monitoring | Throughout the reach, particularly sites S004-494 and S002-979 | Sufficient data for the 2023 water quality assessment.<br>Collect a minimum of 3 months of continuous DO data from at least one monitoring site in one of the years from 2013-2022.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | | | | Establish a diverse riparian corridor buffer of riparian trees, brush, and herbaceous vegetation to increase the roughness of the streambank | State Ditch 83, outside of Agassiz Pool | Establish a 16.5 or 50-foot buffer or alternative practices along channels as required by law by 2018. Willow and native grass plantings along 1 mile of the channel. | ● | ● | | ● | | | | ● | | | | | | | | ● | 2036 |
| | | | Index of Biological Integrity (IBI) | Not assessed due to channelization | Full support of aquatic life | Moderation of flows (reduce peak flows, improved base flows) | Throughout the subwatershed | The opportunity for storage in the watershed is reexamined. | ● | ● | | ● | ● | | ● | | | | | | | | | ● | 2036 |

### 3.3.8. 0902030407 Judicial Ditch 30/18/13

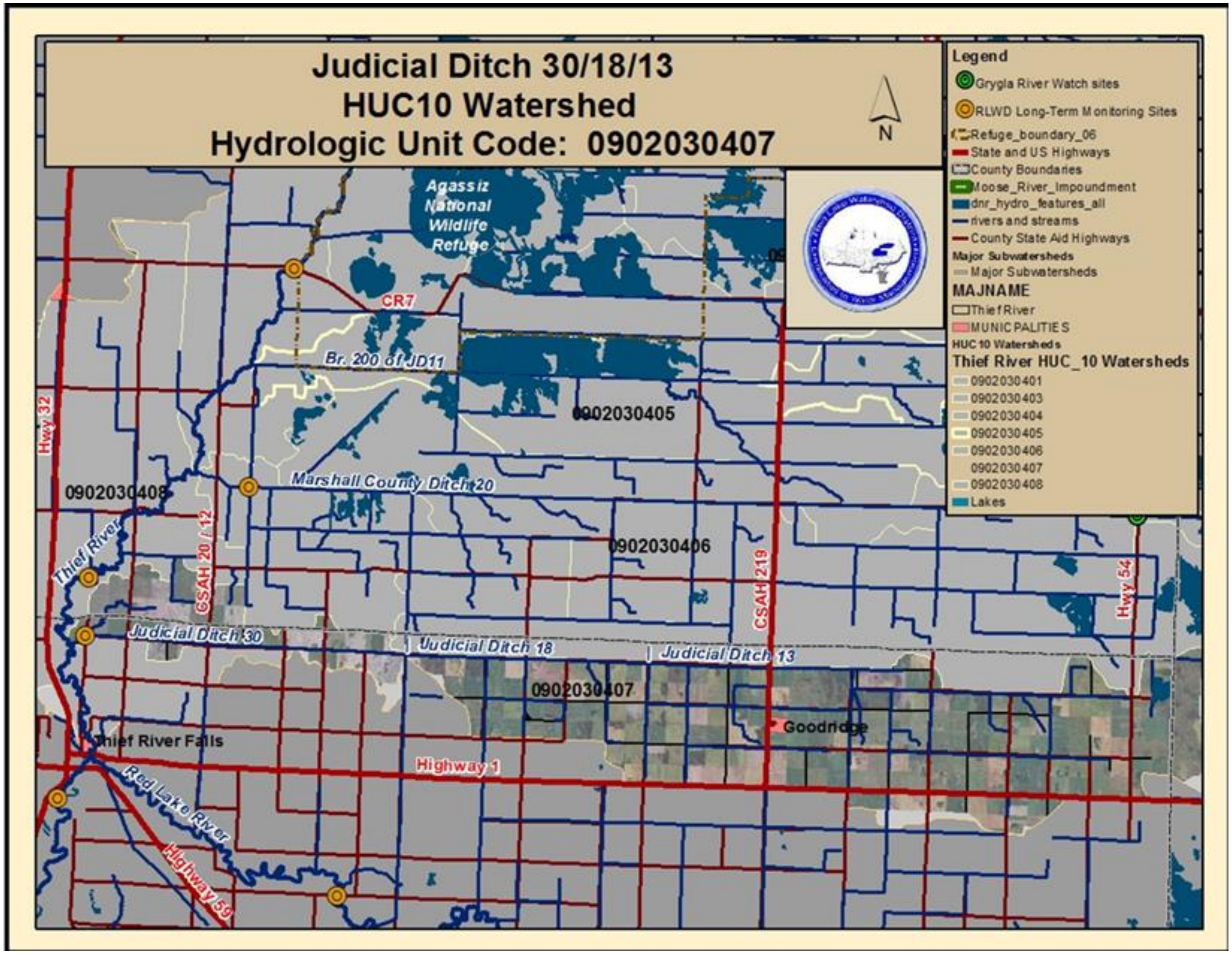



Figure 3-25. HUC10 Watershed of Judicial Ditch 30, 18, and 13 (0902030407)

**Table 3-8. Strategies and actions proposed within Judicial Ditch 30/18/13 Drainage System Watershed (0902030407).**

| HUC-10 Subwatershed | Waterbody and Location | | Parameter | Water Quality | | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility | | | | | | | | | | | | | | | | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Waterbody (ID) | **Location** and Upstream Influence Counties | | Current Conditions | Water Quality Target | | | | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency/EPA | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute/ Red | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | |
| JD30/18/13 (0902030407) | JD30/18/13 | Beltrami and Marshall County | Total Suspended Solids | Not assessed in 2013 due to channelization Meets the 30 mg/l TSS Standard.<br>2.1% of Apr-Sept. samplers in AUID 09020304-509 were > 30 mg/l. 5.6% were <15 mg/L | < 30 mg/l | Continued Monitoring | Sites S004-966 at 140th Ave. NE | Sufficient data for the 2023 water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | ● | | | | | | | | | | | | | | Ongoing |
| | | | | | | Grade Stabilization | Downstream of 140th Ave. NE and other locations identified by Penn. County staff. | Acquire funding for a grade stabilization project. | ● | | ● | | ● | | | | | | | ● | | | | | 2026 |
| | | | | | | Side inlet control structure (a.k.a. side water inlets or SWIs) | Agricultural land east of Agassiz NWR | Findings of the Pennington County Ditch Inventory.<br>Acquire funding and complete a side water inlet project.<br>Installation of 50 side water inlet structures<br>Use models, tools, GIS layers and inventories to identify the number that are needed. Aim for a portion of that number. | ● | ● | | ● | | | | ● | | | | ● | | | ● | | 2026 |
| | | | | | | Water quality monitoring | Throughout the reach, particularly sites S004-494 and S002-979 | Sufficient data for the 2023 water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | | ● | | | | | | | | | | | | | Ongoing |
| | | | Dissolved Oxygen | 11.3% of DO5_9am readings (discrete and continuous combined) are < 5 mg/l<br><br>Not assessed in 2013 due to channelization | > 5 mg/l | Continued monitoring | Site S004-966 at 140th Ave. NE | Sufficient data for the 2023 water quality assessment.<br>At least three summer months of continuous DO monitoring prior to the 2023 State water quality assessment.<br>Continued flow monitoring to facilitate load calculations. | ● | | ● | | | | | | | | | | | | | | Ongoing |
| | | | | | | Establish a diverse riparian corridor buffer of riparian trees, brush and herbaceous vegetation to increase the streambank roughness | State Ditch 83, outside of Agassiz Pool | Establish a buffer or alternative practice along channel as required by law by 2018.<br>New deep-rooted vegetation established along at least 2 miles of the channel. | ● | ● | | ● | | | | ● | | | | | | | | ● | 2036 |
| | | | *E. coli* bacteria | All monthly means <51.1 MPN/100ml | All monthly geomeans <126 org/100ml | Water Quality Sampling | Throughout the reach, particularly site S004-966 | • Sufficient data for the 2023 water quality assessment.<br>• Investigation of sources in upper reaches.<br>• Continued flow monitoring to facilitate load calculations. | ● | | ● | | | | | | | | | | | | | | Ongoing |
| | | | Index of Biological Integrity (IBI) | Not assessed due to channelization | Full support of aquatic life | Reconstruct the lower 4 miles of the ditch using a two-stage ditch design | The lower 4 miles of the ditch | Preliminary investigation, surveying, and planning has been completed.<br>Funding has been acquired for the additional costs associated with the two-stage ditch design in advance of the project start date. | ● | | | ● | ● | | ● | | | | | | ● | | | ● | 2036 |

### 3.3.9. 0902030408 Lower Thief River

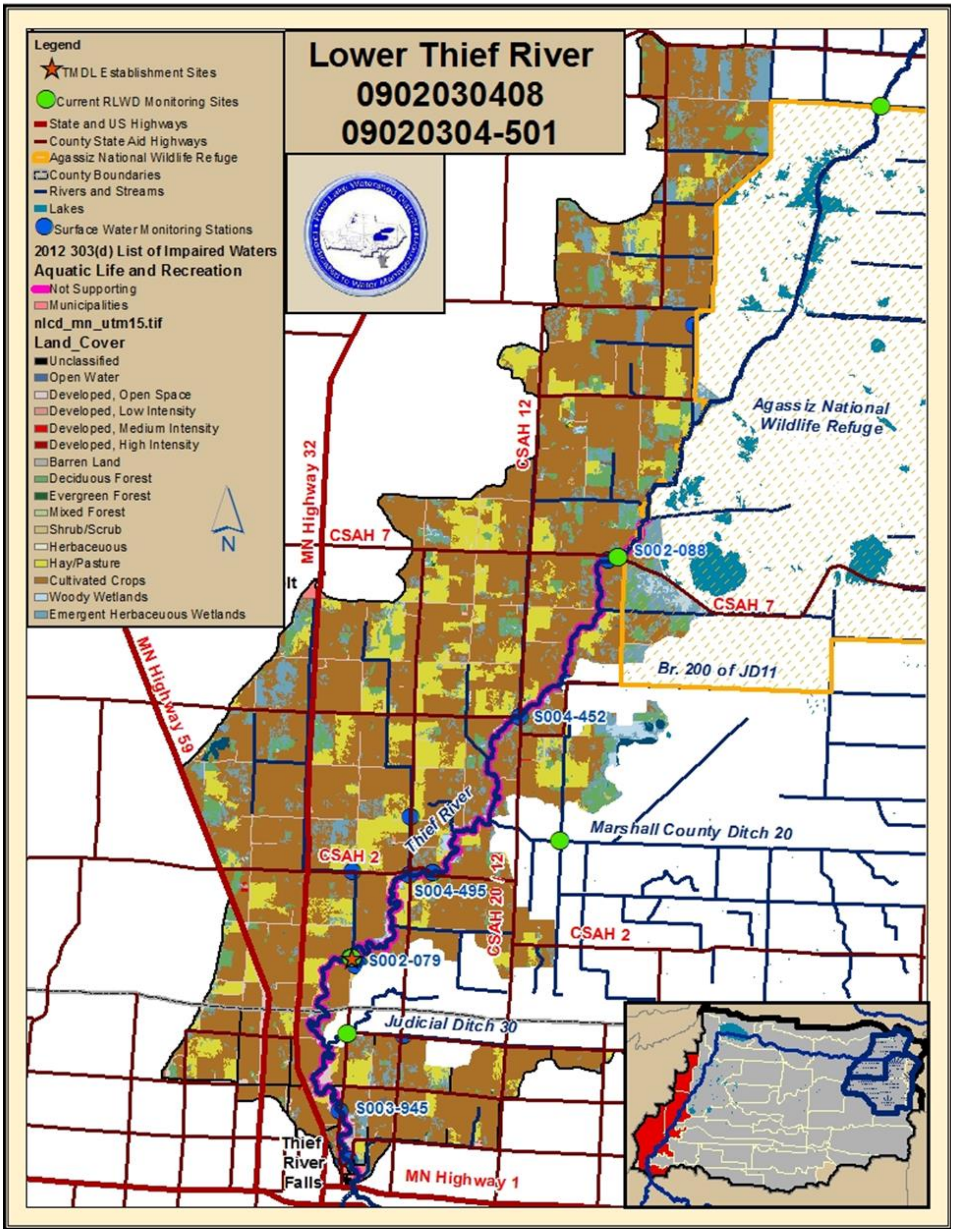



Figure 3-26. Lower Thief River HUC10 Watershed 0902030408

**Table 3-9. Strategies and actions proposed within the Lower Thief River (Agassiz Pool to the Red Lake River) Watershed (0902030408).**

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: **Location** and Upstream Influence Counties | Parameter | Water Quality: Current Conditions | Water Quality: Water Quality Target | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency/EPA | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute/ Red | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower Thief River (Agassiz Pool to Red Lake River) (0902030408) | Thief River | Marshall and Pennington Counties | Total Suspended Solids | Impaired by turbidity (>10% of readings are > 25 NTU)<br><br>Also impaired by high TSS (22% of April-Sept. readings from 2005-2015 are > 30 mg/l | >90% of TSS samples are < 30 mg/l | Consider alternatives to the purposeful flushing of sediment from Agassiz Pool to the Thief River | Agassiz Pool | Reconsider alternatives to the “excavation and drawdown” strategy (Strategy 6) for dealing with sediment in Agassiz Pool.<br>Plan and acquire funding for projects that reduce the amount of sediment that is transported into Agassiz Pool from upstream river and ditches.<br>Drawdown methods are examined to find methods that do not cause harm downstream. | ● | ● | | ● | ● | | ● | | | | | | | | ● | | 2036 |
| | | | | | | Reduce the flashiness of flows related to impoundment discharges by limiting non-emergency peak discharges | Watershed-wide, Agassiz Pool outlets, Farmes Pool outlet | Water quality concerns are included in the impoundment operation review process. | ● | | | | ● | ● | ● | | | | | | | | | | 2036 |
| | | | | | | Improve/maintain the existing condition of the channel and quality of riparian buffers | CSAH 12 to the Red Lake River | Establish a buffer or alternative practice along the channel as required by law by 2018.<br>New deep-rooted vegetation established along at least 2 miles of the channel.<br>Administer local shoreland and floodplain ordinances to ensure proper structure setbacks, buffer, and floodplain requirements are met. | ● | | ● | ● | ● | | | ● | | | | | ● | | | | 2036 |
| | | | | | | Prevent increases in slope and head cutting by preventing meander cutoffs along the main channel. | Eroding cut off channel discovered near the Thief River Falls Golf Club | The meander cut off discovered near the Thief River Falls Golf Club is stabilized. | ● | | ● | | | | | | | | | | | | | | 2017 |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Location and Upstream Influence Counties | Parameter | Water Quality: Current Conditions | Water Quality Target | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Governmental Units with Primary Responsibility: Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency/EPA | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute/ Red | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower Thief River (Agassiz Pool to Red Lake River) (0902030408) | Thief River | Marshall and Pennington Counties | Dissolved Oxygen | 14.9% of DO5_9am values (discrete and continuous combined) are < 5 mg/l | 90% of daily minimums > 5 mg/l<br>Reduce TP loads by 22,029 lbs/yr | Prevent head cutting along tributary ditches through outlet and grade stabilization | Along the whole channel | An inventory/inspection has been completed and documented in a shareable manner in order to identify public and private ditch outlets that are in need of stabilization. | ● | | | ● | | | | | | | | | | | ● | | 2030 |
| | | | | | | Reassess ditch maintenance activities | State Ditch 83 | A meeting is organized to bring together DNR geomorphology staff, county engineers, and ditch inspectors | ● | | ● | ● | ● | | | | | | | ● | | | ● | | 2020 |
| | | | | | | Streambank stabilization | Throughout the reach, particularly in areas in which homes, infrastructure, or broad scale river stability are threatened | Reconnaissance of the reach is conducted once every 5 years to look for erosion problems. | ● | | ● | ● | ● | | | | | | | ● | | | | ● | Ongoing |
| | | | | | | Side inlet control structures (a.k.a. side water inlets or SWIs) | Agricultural land throughout the subwatershed | Installation of 50 side water inlet structures<br>Use models, tools, GIS layers and inventories to identify the number that are needed. Aim for a portion of that number. | ● | ● | ● | ● | | | | ● | | | | ● | | | ● | | 2026 |
| | | | | | | Continued water quality monitoring | Focus upon AUID 09020304-501, particularly at sites S002-089 and S004-211 | Sufficient data for the 2023 water quality assessment.<br>Collect samples and field measurements at sites S002-089 and S004-211 at least 4 times each year.<br>Continue to conduct stage and flow monitoring at sites S002-089 and S004-211.<br>Continued flow monitoring to facilitate load calculations. | ● | | ● | | | | | | | | | | | ● | | ● | Ongoing |
| | | | | | | Storm water runoff retention | City of Thief River Falls | Creation of at least one rain garden<br>Rain barrel building workshop | ● | | ● | | ● | ● | | | | | | | | | | ● | 2036 |
| | | | | | | Continued water quality monitoring | Focus upon AUID 09020304-501, particularly at sites S002-089 and S004-211 | Sufficient data for the 2023 water quality assessment.<br>At least three summer months of continuous DO monitoring prior to the 2023 State water quality assessment.<br>Collect samples and field measurements at sites S002-089 and S004-211 at least 4 times each year.<br>Continued flow monitoring to facilitate load calculations. | ● | | ● | | | | | | | | | | | ● | | ● | Ongoing |
| | | | | | | Establish riparian trees, brush and herbaceous vegetation | Focus upon AUID 09020304-501 | Establish a buffer or alternative practice along channel as required by law.<br>New deep-rooted vegetation established along at least 1 miles of the channel. | ● | ● | | ● | | | | ● | | | | | | | | ● | 2036 |

| HUC-10 Subwatershed | Waterbody and Location: Waterbody (ID) | Waterbody and Location: **Location** and Upstream Influence Counties | Parameter | Water Quality: Current Conditions | Water Quality: Water Quality Target | Strategies | Estimated Scale of Adoption Needed | Interim 10-yr Milestones | Red Lake Watershed District | Beltrami SWCD | Pennington SWCD | Marshall SWCD | Department of Natural Resources | MN Pollution Control Agency/EPA | US Fish and Wildlife Service | NRCS | US Geological Survey | University of Minnesota Extension | Minnesota Department of Ag. | Board of Soil and Water Resources | Counties/Townships | International Water Institute/ Red | County Ditch Authorities/Engineers | Citizens/Landowners/Volunteers | Timeline for Achievement of Water Quality Goals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower Thief River (Agassiz Pool to Red Lake River) (0902030408) | Thief River | Marshall and Pennington Counties | *E. coli* bacteria | All monthly geomeans < 126 MPN/100ml when the AUID is assessed as a complete unit.<br>Site S002-088 exceeds the 126 MPN/100ml monthly geomean standard. | All monthly geomeans < 126 MPN/100ml | Continued water quality monitoring | Focus upon AUID 09020304-501, particularly at sites S002-088, S002-079 and S003-945 | Sufficient data for the 2023 water quality assessment.<br>Site S002-079 continues to be used as a load monitoring site.<br>The RLWD will collect samples and field measurements at sites S002-088 and S002-079 at least 4 times each year.<br>The Pennington SWCD will continue to collect monthly samples at site S003-945.<br>Continue to conduct stage and flow monitoring at sites S002-079 (USGS) and S002-088 (MPCA/DNR Co-op gauge).<br>Collect sufficient data for the identification of water quality trends. | ● | | ● | | ● | ● | | | ● | | | | | ● | | | Ongoing |
| | | | Index of Biological Integrity (IBI) | Fully supports aquatic life | Fully supports aquatic life | Moderation of flows (reduce peak flows, improve base flows) | Watershed-wide, Agassiz Pool outlets, Farmes Pool outlet | Water quality concerns are included in the impoundment operation review process.<br>A private-land wetland restoration project has been completed. | ● | | | | ● | ● | ● | | | | | | | | | ● | 2036 |
| | | | | | | Reduce sediment inputs in order to maintain fully supporting status (so that habitat is maintained and not overwhelmed by "fines" | Watershed-wide | No new Total Suspended Solids Impairments<br>Improved trends in Total Suspended Solids concentrations.<br>Improved stability scores in future geomorphologic assessments.<br>Improved fish and macroinvertebrate IBI scores. | ● | ● | ● | ● | ● | | | ● | | | | | | | | | 2026 |

## 3.4 Monitoring Plan

The RLWD has been collecting water samples in the Thief River Watershed since 1980. Some of the new sites that were monitored for the Thief River Watershed Sediment Investigation were added to the RLWD long-term monitoring program. The monitoring program collects data from the significant waterways within the watershed, including multiple reaches of the Thief River, the Mud River, Moose River, CD20, and JD30. Current monitoring sites are mapped in Figure 3-27. Field measurements of DO, temperature, turbidity, specific conductivity, pH, and stage are collected during each site visit (if there is water). Four rounds of samples are also collected and analyzed for TP, OP, TSS, total dissolved solids, TKN, ammonia nitrogen, nitrates + nitrites, and *E. coli* at most of the sites. For the past few years, biochemical oxygen demand (BOD) analysis has been added for the sites that are located on reaches that have had low DO levels. BOD was replaced with chemical oxygen demand analysis in 2014 because too many BOD levels were too low to be measured. Sampling months are alternated each year with the goal of collecting at least five samples per calendar month within a 10-year period.

The Pennington SWCD collects monthly samples from the Thief River at the "Golf Course Bridge" monitoring site (S003-945).

The Thief River Monitoring site (S002-079) that is co-located with the USGS gauging station, the Thief River site near Agassiz NWR (S002-088), and the Mud River site at Highway 89 (S002-078) have been intensively monitored for other projects, including the MPCA's Watershed Pollutant Load Monitoring Network (Figure 3-28). Frequent sampling may continue for the Pollutant Load Monitoring program. The International Water Institute has worked with the MPCA to conduct that sampling.

Flow monitoring is conducted by the MPCA/DNR, USGS, USFWS, and RLWD throughout the watershed (Figure 3-29). The Thief River has two real time gauges. One is the USGS Gauge 05076000 at the 140th Avenue Northeast crossing of the Thief River, north of the city of Thief River Falls. The other is located at CSAH 7, near Agassiz Refuge, and is monitored by a MPCA and DNR cooperative gauge at site S002-088. The Mud River is also monitored by a MPCA/DNR cooperative gauging system at the Highway 89 crossing of that river (S002-078), west of Grygla. Other significant reaches of the watershed are monitored with HOBO water level loggers by the RLWD.

River Watch is a volunteer monitoring program that gives high school students the opportunity to collect water quality data. This data is collected using the same methods that are used by professionals, and is stored in EQuIS along with all other data that is collected within the watershed. Grygla High School has an active River Watch program. The Thief River Falls River Watch program is active periodically, but is currently inactive. Reviving this program and keeping it active is a recommended goal. The Grygla River Watch team samples at the following sites (as of 2016):

1. S002-979 – CD20 at CSAH 54
2. S002-977 – Mud River at CSAH 54
3. S002-978 – Mud River at the Moose River Impoundment (S Pool) outlet to JD11
4. S002-980 – Moose River at Moose River Forest Road
5. S006-380 – Moose River at the Moose River Impoundment (N Pool) outlet to JD21

6. S005-783 – Moose River at 310th Av NE
7. S004-211 – Moose River at CSAH 54
8. S002-078 – Mud River at CSAH 89

The RLWD has conducted multiple intensive watershed monitoring projects in recent years that have involved continuous water quality monitoring. Several projects that were funded by grants and contracts have left the RLWD very well equipped for continuous DO monitoring.

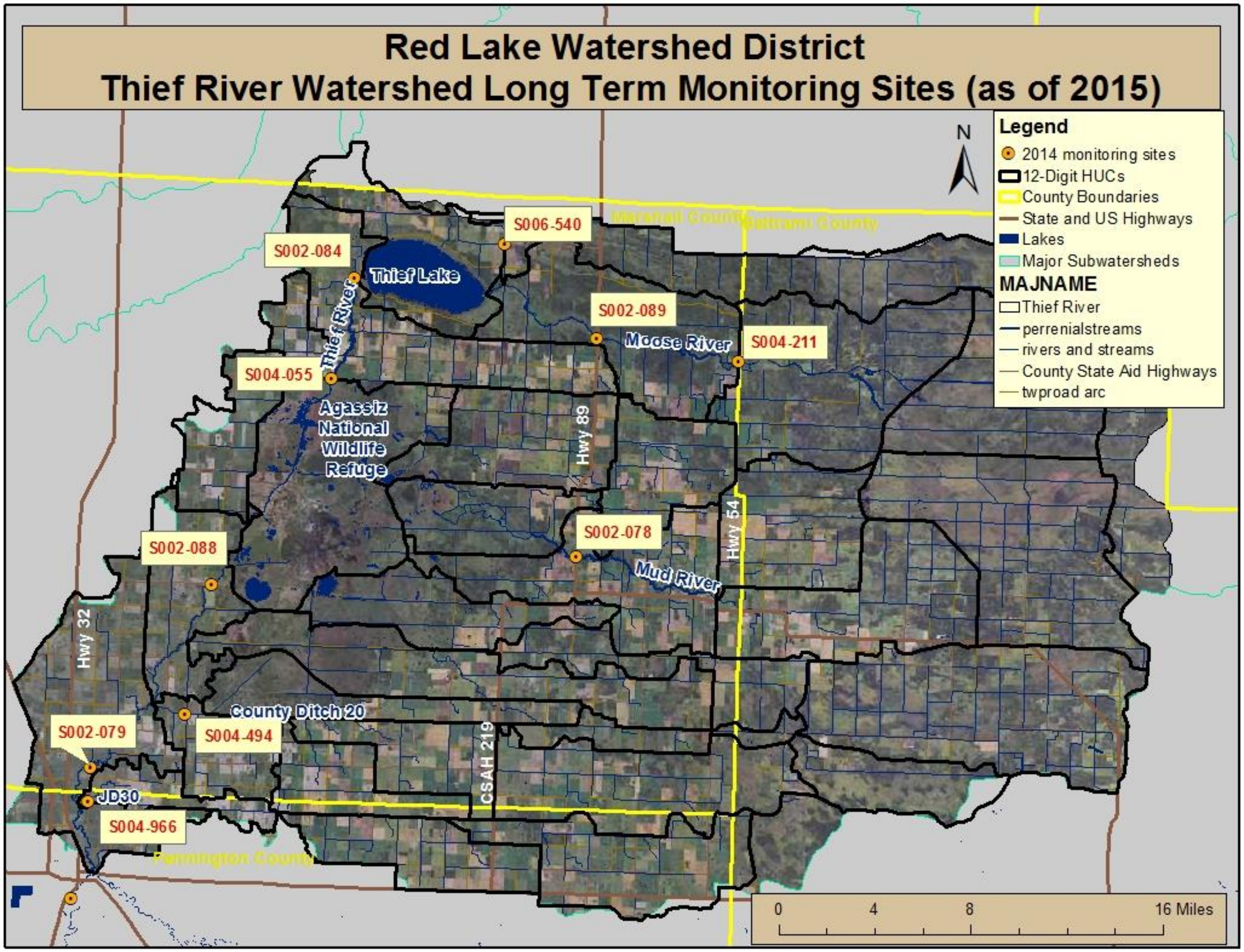



Figure 3-27. Long term monitoring sites within the Thief River Watershed

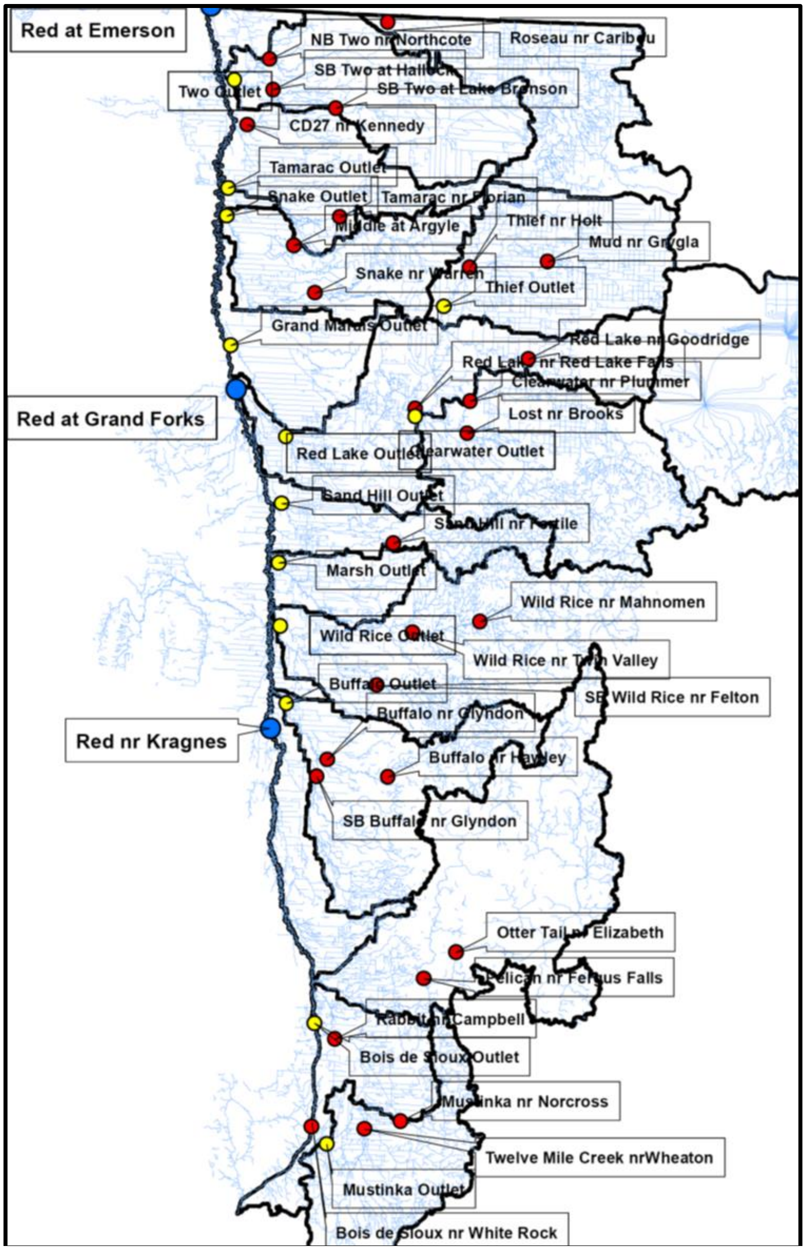


Figure 3-28. MPCA Pollutant Load Monitoring Sites in the Red River Basin

The following are recommendations for possible future monitoring, contingent on availability and prioritization of resources.

The DO impairment on the Mud River should be monitored to see if conditions on the river improve. The continuous DO record is the reason this reach was not removed from the 303(d) List of Impaired Waters. The MPCA was initially considering a delisting for this reach during the 2013 water quality assessment. More pre-9 a.m. data was needed and provided in the form of the continuous monitoring record that was collected in 2007, 2008, 2009, and 2012. Prior to 2012, which was a dry year, the Mud River DO impairment looked like a candidate for delisting. There were enough days with low DO levels in 2012; however, to bring the overall frequency of low DO readings back up over the impairment threshold. Despite the bad year in 2012, the river is still close to meeting the water quality standard, which makes it a good candidate for targeted project implementation and more intensive monitoring to assess the effectiveness of water quality improvement efforts. Longitudinal continuous DO monitoring along the Mud River could effectively characterize the origins of low DO problems within the river. Characterize DO concentrations and how they change as water is discharged from the south pool of the Moose River Impoundment, flows through the ditches upstream of Grygla, and then flows between Grygla and Highway 89.

Potential aquatic life impairments on channelized reaches of the Thief River were deferred during the 2013 assessment. Now that TALU standards have been adopted by the state of Minnesota, these reaches will be assessed during the 2023 assessment process. Basic water quality data and biologic data will likely be collected in 2021 and 2022. Branch 200 of JD11 will likely be listed as impaired by low DO during the 2023 water quality assessment. Additional data collection and analysis can help improve the understanding of the extent of the problem and true causes of the problem.

June is an important month for monitoring *E. coli* in Branch A of JD21. Additional investigation of the watershed may help with further identifying the sources of *E. coli* along the ditch and to watch for signs of regression back to an impaired condition. Additional *E. coli* data should also be collected from the upper reaches of CD20 to investigate the high *E. coli* concentrations that were found there during longitudinal sampling.

Additional TP data should be collected from JD 18 and Branch 1 of JD11.

Additional intensive sampling during runoff events and Agassiz Pool drawdowns will help shed light upon the causes of water quality problems in the watershed. Ditch systems on the east side of Agassiz NWR should be sampled during runoff events (Marshall County Ditch 35, Branch B of Marshall County Ditch 28).

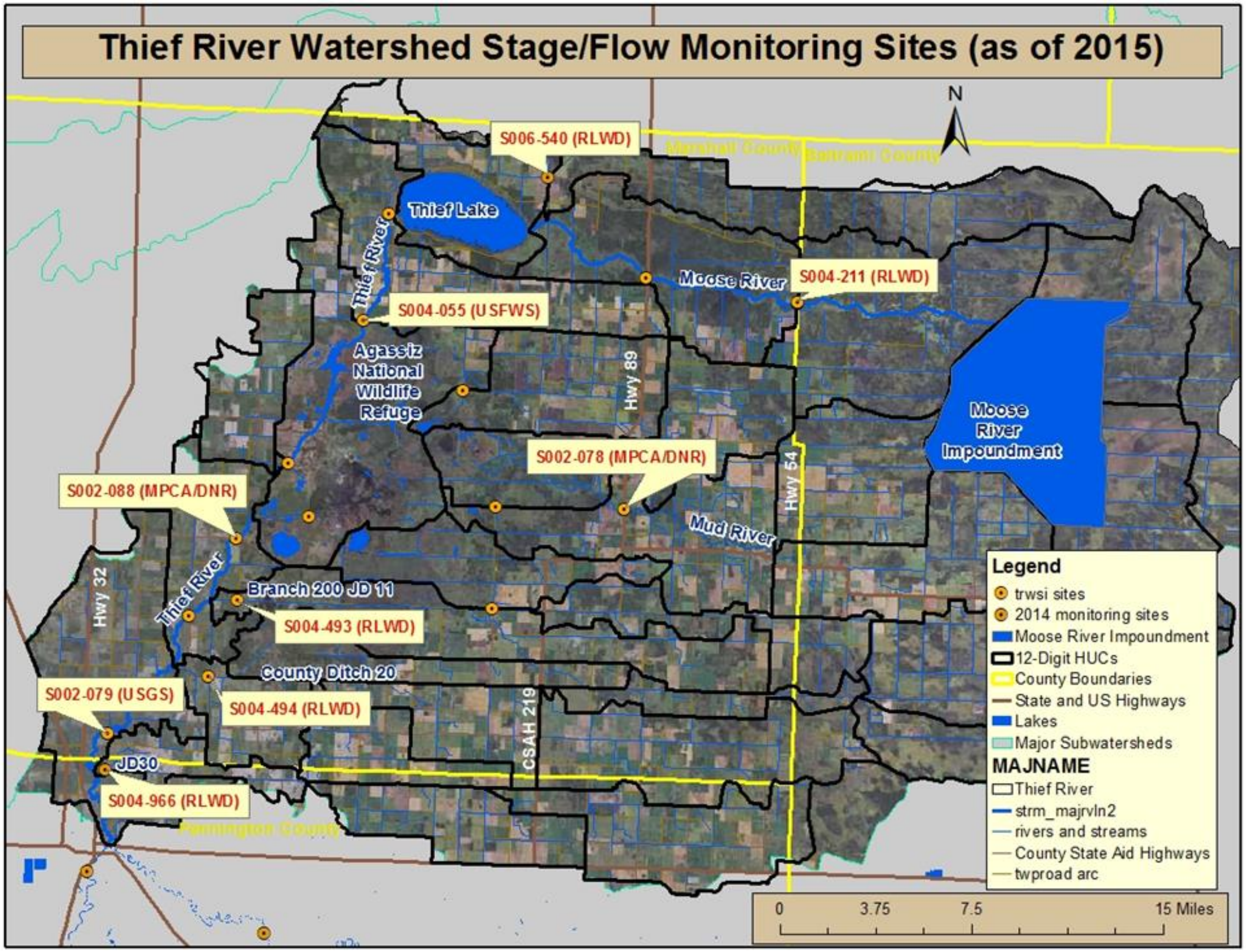



Figure 3-29. Stage and flow monitoring sites in the Thief River Watershed

# 4. References and Further Information

Resources and links that pertain to the Thief River Watershed can be found on a website dedicated to the Thief River (http://www.rlwdwatersheds.org/tr-docs).

References used for the Thief River TMDL and WRAPS documents include: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# Appendix A. Thief River Watershed Stream TMDL/Load Allocation Tables

| Monitoring Site Flow record used to develop flow zones and loading capacities: S002-079 (EQuIS), 05076000 (USGS Gauge) | | Loading Capacity and Load Allocations for Total Suspended Solids in the Thief River at Marshall County Road 77 (S002-079, USGS #05076000) | | | | |
|---|---|---|---|---|---|---|
| Drainage Area (square miles): | 985 | Duration Curve Zone | | | | |
| %MS4 Urban: | 0.00 | | | | | |
| Total WWTF Design Flow (mgd): | 0.00 | **Very High** | **High** | **Mid** | **Low** | **Very Low (No Flow)** |
| TMDL Component | | Values expressed as Tons per Day of Sediment | | | | |
| Flow Duration Interval of Median Flow | | 5% | 25% | 50% | 71.60% | 91.60% |
| **TOTAL DAILY LOADING CAPACITY** | | 93.04 | 12.22 | 1.05 | 0.07 | 0.00 |
| **Wasteload Allocation** | | | | | | |
| Permitted Wastewater Treatment Facilities | | 0 | 0 | 0 | 0 | 0 |
| Communities Subject to MS4 NPDES Requirements | | 0 | 0 | 0 | 0 | 0 |
| Livestock Facilities Requiring NPDES Permits | | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | | 0 | 0 | 0 | 0 | 0 |
| **Reserve Capacity** | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Daily Load Allocation (Nonpoint and Natural Background)** | | 83.74 | 11.00 | 0.95 | 0.07 | 0.00 |
| **Daily Margin of Safety** | | 9.30 | 1.22 | 0.11 | 0.01 | 0.00 |
| | | | | | | |
| | | Values expressed as Tons per Day of Sediment | | | | |
| **TOTAL MONTHLY LOADING CAPACITY** | | 93.04 | 12.22 | 1.05 | 0.07 | 0.00 |
| **Wasteload Allocation** | | | | | | |
| Permitted Wastewater Treatment Facilities | | 0% | 0% | 0% | 0% | 0% |
| Communities Subject to MS4 NPDES Requirements | | 0% | 0% | 0% | 0% | 0% |
| Livestock Facilities Requiring NPDES Permits | | 0% | 0% | 0% | 0% | 0% |
| "Straight Pipe" Septic Systems | | 0% | 0% | 0% | 0% | 0% |
| **Reserve Capacity** | | 0% | 0% | 0% | 0% | 0% |
| **Load Allocation (Nonpoint and Natural Background Sources)** | | 90% | 90% | 90% | 90% | 90% |
| **Margin of Safety** | | 10% | 10% | 10% | 10% | 10% |

| Lower Thief River (09020304-501) Total Suspended Solids Load Reductions S002-079 Thief River at CR 77 | Very High Flows | High Flow | Mid-Range Flows | Low Flows | Very Low (No) Flow | Total |
|---|---|---|---|---|---|---|
| Current Daily Load (tons/day) | 142.39 | 14.33 | 0.21 | 0.01 | 0.00 | -- |
| Load Allocation (tons/day) | 83.74 | 11.00 | 0.95 | 0.07 | 0 | -- |
| Load reduction (tons/day) | 58.66 | 3.34 | 0.00 | 0.00 | 0 | -- |
| % of Flows Represented | 10% | 30% | 20% | 23.2% | 16.8% | 100% |
| # of Days Represented | 36.5 | 109.5 | 73.0 | 84.7 | 61.3 | 365 |
| Annual Load Reduction (tons/year) | 2140.9 | 365.2 | 0.0 | 0.0 | 0.0 | **2506.2** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Drainage Area (square miles): 133.81 | **AUID 09020304-507** | | | | | |
| Monitoring Site Flow record used to develop flow zones and loading capacities: S002-977 (EQuIS) | **Mud River at CSAH 54 (S002-977)** | | | | | |
| | **Loading Capacity and Load Allocations for *E. coli*** | | | | | |
| *E. coli* Standard: 126 MPN/100ml | **Duration Curve Zone** | | | | | |
| %MS4 Urban: 0.00 | | | | | | |
| Total WWTF Design Flow (mgd): 0.00 | **Very High** | **High** | **Mid-Range** | **Low** | **Very Low** | |
| TMDL Component | Values expressed as Billions of Organisms per Day | | | | | |
| MEDIAN FLOW | 174.61 | 50.55 | 13.53 | 1.93 | 0.15 | |
| MEDIAN OF FLOW DURATION ZONE | 5% | 25% | 50% | 75.0% | 91.5% | |
| **TOTAL DAILY LOADING CAPACITY** | 538.25 | 155.83 | 41.71 | 5.94 | 0.47 | |
| **Wasteload Allocation** | | | | | | |
| Permitted Wastewater Treatment Facilities | 0 | 0 | 0 | 0 | 0 | |
| Communities Subject to MS4 NPDES Requirements | 0 | 0 | 0 | 0 | 0 | |
| Livestock Facilities Requiring NPDES Permits | 0 | 0 | 0 | 0 | 0 | |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 | |
| **Reserve Capacity** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| **Daily Load Allocation** | 484.43 | 140.25 | 37.54 | 5.35 | 0.43 | |
| **Daily Margin of Safety** | 53.83 | 15.58 | 4.17 | 0.59 | 0.05 | |
| | | | | | | |
| | Values expressed as Billions of Organisms per Day | | | | | |
| **TOTAL MONTHLY LOADING CAPACITY** | 538.25 | 155.83 | 41.71 | 5.94 | 0.47 | |
| **Wasteload Allocation** | | | | | | |
| Permitted Wastewater Treatment Facilities | 0% | 0% | 0% | 0% | 0% | |
| Communities Subject to MS4 NPDES Requirements | 0% | 0% | 0% | 0% | 0% | |
| Livestock Facilities Requiring NPDES Permits | 0% | 0% | 0% | 0% | 0% | |
| "Straight Pipe" Septic Systems | 0% | 0% | 0% | 0% | 0% | |
| **Reserve Capacity** | 0% | 0% | 0% | 0% | 0% | |
| **Load Allocation** | 90% | 90% | 90% | 90% | 90% | |
| **Margin of Safety** | 10% | 10% | 10% | 10% | 10% | |

| Mud River (09020304-507) at CSAH 54 Annual E. coli Load Reductions at S002-977 | Very High Flows | High Flows | Mid-Range Flows | Low Flows | Very Low Flows | Total |
|---|---|---|---|---|---|---|
| **Current Daily Load ($10^9$orgs/day)** | 53.00 | 229.80 | 157.97 | 203.49 | No Data | |
| **Load Allocation ($10^9$orgs/day)** | 484.43 | 140.25 | 37.54 | 5.35 | 0.43 | |
| **Load reduction ($10^9$orgs/day)** | - | 89.55 | 120.42 | 198.14 | - | |
| **% of Flows Represented** | 10% | 30% | 20% | 30.0% | 3.0% | 93% |
| **# of Days Represented** | 36.5 | 109.5 | 73.0 | 109.5 | 11.1 | 339.60 |
| **Annual Load Reduction ($10^9$orgs/year)** | - | 9,805.98 | 8,790.93 | 21,696.74 | - | **40,293.64** |
| **Total Current Load** | 1,934.50 | 25,163.30 | 11,531.48 | 22,282.46 | 0 | 60,911.74 |
| **Percent Reduction** | 0.0% | **39.0%** | **76.2%** | **97.4%** | 0.0% | **66.2%** |