Final Lake of the Woods Watershed Total Maximum Daily Load Study

Minnesota Pollution Control Agency

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Table of Contents

List of Tables

List of Figures

Acronyms

1W1P	One Watershed One Plan
AF	Anoxic factor
AUID	Assessment Unit ID
BMP	best management practice
BWSR	Board of Water and Soil Resources
CLMP	Citizen Lake Monitoring Program
CSMP	Citizen Stream Monitoring Program
CWLA	Clean Water Legacy Act
DEM	digital elevation models
DNR	Minnesota Department of Natural Resources
DO	Dissolved Oxygen
EDA	Environmental Data Access
EPA	United States Environmental Protection Agency
EQuIS	Environmental Quality Information System
E. coli	*Escherichia coli*
HSPF	Hydrologic Simulation Program-Fortran
HUC	Hydrologic Unit Code
IBI	Index of Biological Integrity
in/yr	inches per year
LA	load allocation
Lb	pound
LDC	Load Duration Curves
LiDAR	Light Detection and Ranging
LOWW	Lake of the Woods Watershed
m	meter
mg/L	milligrams per liter
mL	milliliter
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NLCD	National Land Cover Dataset
NMW	Northern Minnesota Wetlands Ecoregion
NPDES	National Pollutant Discharge Elimination System
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation Districts
TMDL	Total Maximum Daily Load
TSS	total suspended solids
USGS	United States Geological Survey
WLA	wasteload allocation
WMP	Watershed Management Plan
WRAPS	Watershed Restoration and Protection Strategy
WWTF	wastewater treatment facilities

Executive Summary

The federal Clean Water Act (1972) requires that each state assess their waterbodies, and develop a plan to restore any waterbody that is not meeting the state's water quality standards and is deemed impaired. A Total Maximum Daily Load (TMDL) study is the study required by the federal Clean Water Act, Section 303(d) and U.S. Environmental Protection Agency (EPA) to address impaired waters. A TMDL study identifies the pollutant sources causing the impairment and estimates how much pollutant the waterbody can receive and still meet the water quality standards. In Minnesota, the Minnesota Pollution Control Agency (MPCA) is tasked with assessing and listing waterbodies that do not meet water quality standards and developing TMDLs (Minn. R. 7050.022).

The greater Lake of the Woods Watershed (LOWW) falls on the U.S. and Canadian border. This study will focus on the Minnesota portion of the LOWW (Hydrologic Unit Code [HUC] 09030009) draining 734,783 acres in the northernmost Minnesota counties of Lake of the Woods and Roseau. The LOWW's namesake, the Lake of the Woods, takes up approximately 42% of the total LOWW area in Minnesota, with approximately 70% of the remaining watershed area in wetlands and another 20% of land use in agriculture, found mainly along the southern lake shore of the Lake of the Woods (MPCA 2016a).

For purposes of this TMDL study, the LOWW is divided into four 10-digit HUC subwatersheds used to organize TMDL components throughout the study. These subwatersheds include Bostick Creek (0903000901), Zippel Creek (0903000902), Warroad River (0903000903) and Muskeg Bay (0903000904) HUC-10 Subwatersheds (Figure 4). There are impaired waters located in the Zippel Creek, Warroad River, and Muskeg Bay Subwatersheds. Overall, three TMDLs were developed to address the impairments within the three subwatersheds. There are no impaired waters located in the Bostic Creek Subwatershed; therefore, it is not included in this study.

The 2018 federal Impaired Waters 303(d) list identifies seven LOWW streams as having impaired water quality (i.e., not meeting water quality standards) and requiring TMDL studies. These streams contain a total of 15 impairment listings: 3 for impaired aquatic life caused by low dissolved oxygen (DO) levels, 1 for impaired aquatic recreation caused by high *Escherichia coli (E. coli) levels*, 4 for impaired aquatic life determined by fish bioassessments (F-IBI), 5 for impaired aquatic life determined by macroinvertebrate bioassessments (M-IBI), and 2 for impaired aquatic life due to high total suspended solids (TSS) levels. The 3 TMDLs completed in this study address 6 of the 15 impairments, the 2 TSS impairments and 4 of the bioassessment-related impairments where TSS was identified as a contributing stressor. Due to insufficient data, the *E. coli* and DO impairments are expected to be addressed in a future TMDL study.

The 2018 federal Impaired Waters 303(d) list also identifies two lakes in the LOWW as being impaired for aquatic recreation and requiring TMDL studies. The lakes, Lake of the Woods (main) and Lake of the Woods 4-mile Bay, both have impaired aquatic recreation due to nutrient/eutrophication biological indicators. These lake impairments are being addressed in a separate TMDL study and will not be addressed in this TMDL report.

Information from multiple sources was used to evaluate the potential sources of pollutants and ultimate health of each waterbody, including (but not limited to): stressor identification (SID) studies, Hydrologic Simulation Program – FORTRAN (HSPF) modeling, analysis of the available water quality data for the last 10 years, and GIS analysis. The following pollutant sources were evaluated for each waterbody: watershed runoff, loading from upstream sources, point sources, feedlots, septic systems, wildlife and other natural sources, and hydrologic alterations. Load duration curves (LDCs) for each impaired stream reach were used to determine the pollutant reduction needed to meet current water quality standards.

The findings in this TMDL study were used to guide the development of implementation strategies as part of the Lake of the Woods Watershed Restoration and Protection Strategies (WRAPS) process. The purpose of the WRAPS report is to support local working groups in jointly developing scientifically-supported restoration and protection strategies. These implementation strategies are intended to meet the TMDL goals outlined in this document. The WRAPS report, as well as numerous other technical reports referenced in this document, are publicly available on the MPCA LOWW website: https://www.pca.state.mn.us/water/watersheds/lake-woods.

1. Project Overview

1.1 Purpose

In 2006, Minnesota passed the Clean Water Legacy Act (CWLA) to protect, restore, and preserve the quality of Minnesota's waters. As a result, the MPCA established a watershed approach to restore and protect Minnesota's waters. One component of that work is to complete TMDL studies for the impaired waterbodies within each watershed and develop a watershed-wide TMDL study. This study is a watershed-wide TMDL study that aligns with the MPCA's watershed approach to implementing the requirements under the CWLA.

A TMDL is defined as the maximum quantity of a pollutant that a water body can receive while still meeting the (numeric) water quality standards for its designated beneficial uses. The TMDL study apportions the maximum load between point sources (i.e., a wasteload allocation [WLA] to sources, which are authorized by a National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permit under the Clean Water Act), nonpoint sources (i.e., load allocation [LA]), and a margin of safety (MOS). The MOS is a portion of the maximum load reserved to account for uncertainty.

This TMDL study focuses on the Minnesota portion of the LOWW (HUC 09030009), covering 734,783 acres in the northernmost Minnesota counties of Lake of the Woods and Roseau (Figure 1). Due to remoteness and dominance of wetlands, the Northwest Angle Inlet Subwatershed, (HUC 0903000905) located in the northernmost portion of the watershed, will be excluded from this TMDL study (north of the area shown in Figure 1; not shown). The LOWW is the northwestern-most watershed in the Rainy River Basin, located entirely within the Northern Minnesota Wetlands Ecoregion (NMW). The body of the Lake of the Woods covers 41.2% of the watershed, with 25.3% U.S. government (county, state, or federal land), 9.5% Tribal and approximately 24% privately owned land. Municipalities within the LOWW include the cities of Williams, Roosevelt, and Warroad.

Some of the land in LOWW is tribal land (see Figure 2). This includes various areas of the Red Lake Reservation in the southern portion of the watershed owned by the Red Lake Band of Chippewa. These areas are not under the state's jurisdiction and TMDLs in this study do not apply to any tribal lands and/or tribal waters within the watershed.

In 2015, Minnesota transitioned from a turbidity standard, used to represent sediment transport, to a TSS standard. The TSS TMDLs were developed to address the turbidity impairments. Further discussion is provided in Section 2. Bacteria (*E. coli)* because *E. coli* is identified as a stressor causing an aquatic recreation impairment within the LOWW; however, the *E. coli* impairment is being deferred to a future TMDL study due to lack of observed and simulated flow data during the years when *E. coli* exceeded standards. Fish and macroinvertebrate bioassessments are not conventional pollutants for which a numerical TMDL can be calculated. A TMDL has been developed for fish and macroinvertebrate bioassessments where a conventional pollutant (e.g., elevated turbidity or excessive sediment) has been identified as a contributing stressor. High suspended solids are identified as a stressor contributing to seven of the macroinvertebrate and fish bioassessment impairments within the LOWW and four of the seven are assessed in this TMDL study. Other (non-conventional pollutants) stressors have been identified in the SID Report, but are not addressed in this TMDL study. Additional discussion on the stressors and impairments is provided in Section 2**.**

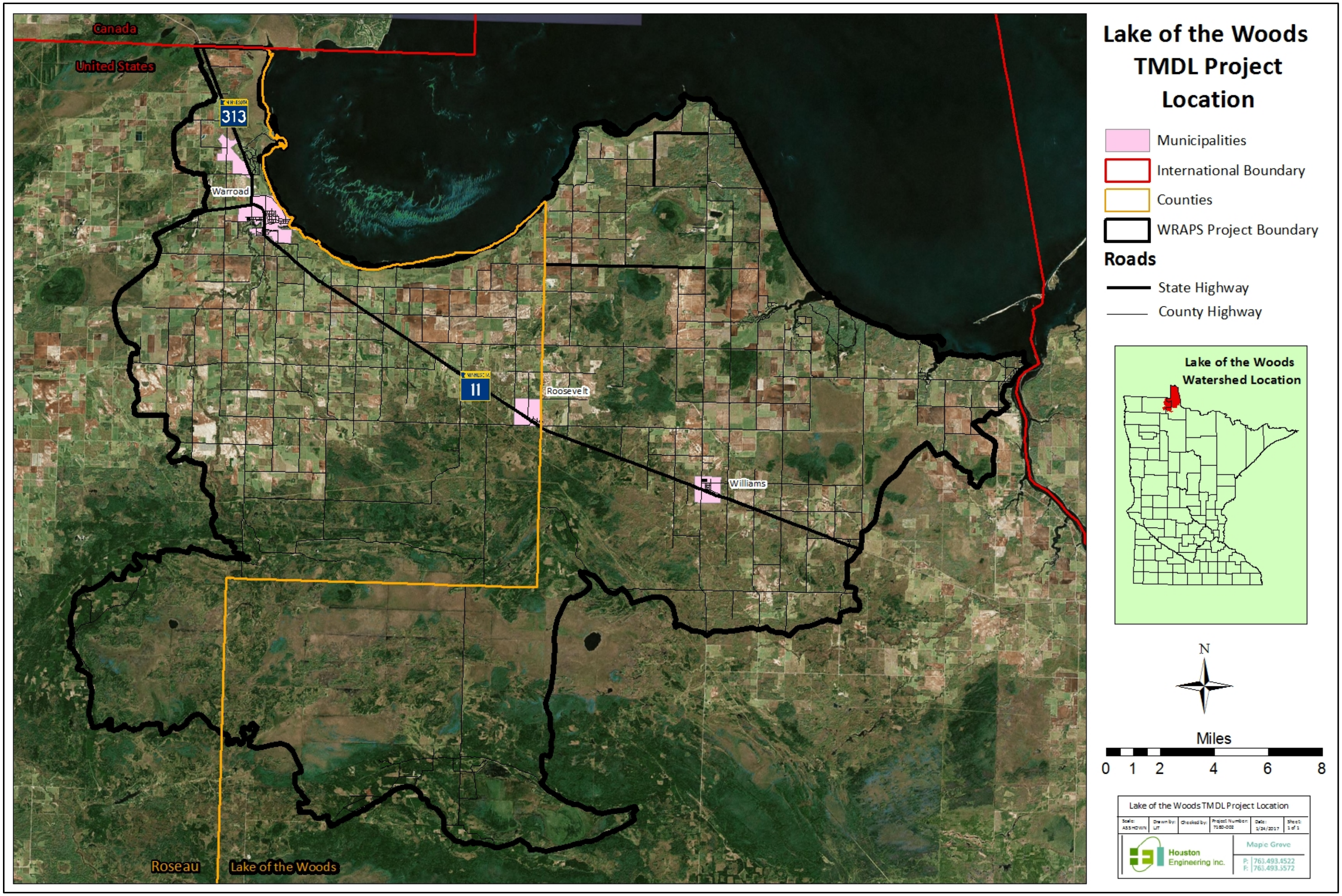


Figure 1: Lake of the Woods Watershed TMDL/WRAPS Study Project Location.

1.2 Identification of Waterbodies

For purposes of this TMDL study, the LOWW is divided into four 10-digit HUC subwatersheds used to organize TMDL components throughout the study. These subwatersheds include Bostick Creek (0903000901), Zippel Creek (0903000902), Warroad River (0903000903) and Muskeg Bay (0903000904) HUC-10 subwatersheds (Figure 4). There are impaired waters located in the Zippel Creek, Warroad River, and Muskeg Bay subwatersheds. There are no impaired waters located in the Bostic Creek Subwatershed; therefore, it is not included in the descriptions below.

The 2018 federal Impaired Waters 303(d) list identifies seven LOWW streams as having impaired water quality (i.e., not supporting their designated beneficial use) and requiring TMDL studies. These streams contain a total of 15 impairment listings: 3 for aquatic life caused by low DO levels; 1 for aquatic recreation caused by high *E. coli* levels; 4 for aquatic life determined by fish bioassessments (F-IBI); 5 for aquatic life determined by macroinvertebrate bioassessments (M-IBI); and 2 for aquatic life due to high TSS levels (Table 1, Figure 2). The TMDLs were completed on 6 of the 15 impairments, the 2 TSS impairments and 4 of the bioassessment-related impairments where TSS was identified as a contributing stressor. Due to insufficient data, the *E. coli* and DO impairments are expected to be addressed in a future TMDL study.

Of the nine bioassessment-related impairments, two (Williams Creek F-IBI [Zippel Creek Subwatershed] and Zippel Creek F-IBI) had low DO levels and low base-flow identified as their probable stressors. The remaining seven bioassessment-related impairments all had TSS identified as a contributing stressor. The TSS TMDLs performed to address the Warroad River M-IBI, Willow Creek F-IBI (Zippel Creek Subwatershed), and County Ditch 20 M-IBI (Muskeg Bay Subwatershed) resulted in no reduction needed at any flow regime; therefore, these TMDLs cannot be included in this study. The remaining four bioassessment-related impairments (Williams Creek M-IBI [Zippel Creek Subwatershed], Zippel Creek M-IBI, and Unnamed Ditch F-IBI and M-IBI [Muskeg Bay Subwatershed]) are addressed by TSS TMDLs in this study. The impairments included in the three TSS TMDLs are identified in Table 1 below.

Table 1: Lake of the Woods Watershed impairments.

Assessment Unit ID	Waterbody	Impairment/Parameter	Beneficial Use	Listing Year	Addressed in this TMDL?
09030009-501	Williams Creek, Headwaters to Zippel Creek	Fish Bioassessment	Aquatic Life	2016	No
		Dissolved Oxygen	Aquatic Life	2016	No†
		Macroinvertebrate Bioassessment	Aquatic Life	2016	Yes (TSS*)
		Total Suspended Solids	Aquatic Life	2016	Yes
09030009-503	Warroad River, West Branch, Headwaters to Warroad River	*Escherichia coli*	Aquatic Recreation	2016	No†
09030009-504	Warroad River, East Branch, Headwaters to Warroad River	Macroinvertebrate Bioassessment	Aquatic Life	2016	No
09030009-505	Willow Creek, Headwaters to Lake of the Woods	Dissolved Oxygen	Aquatic Life	2010	No†
		Fish Bioassessment	Aquatic Life	2016	No
09030009-515		Dissolved Oxygen	Aquatic Life	2016	No†

Assessment Unit ID	Waterbody	Impairment/Parameter	Beneficial Use	Listing Year	Addressed in this TMDL?
	Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (Lake of the Woods)	Fish Bioassessment	Aquatic Life	2016	No
		Macroinvertebrate Bioassessment	Aquatic Life	2016	Yes (TSS*)
		Total Suspended Solids	Aquatic Life	2016	Yes
09030009-523	Unnamed ditch, Unnamed ditch to Unnamed ditch	Macroinvertebrate Bioassessment	Aquatic Life	2016	Yes (TSS*)
		Fish Bioassessment	Aquatic Life	2016	Yes (TSS*)
09030009-560	County Ditch 20, Headwaters to Lake of the Woods	Macroinvertebrate Bioassessment	Aquatic Life	2016	No

*TSS was identified as a potential stressor and a TSS TMDL was calculated to partially address the bioassessment impairment. See Section 2.2 for more details.

†Deferred to a future TMDL study when additional data will be available

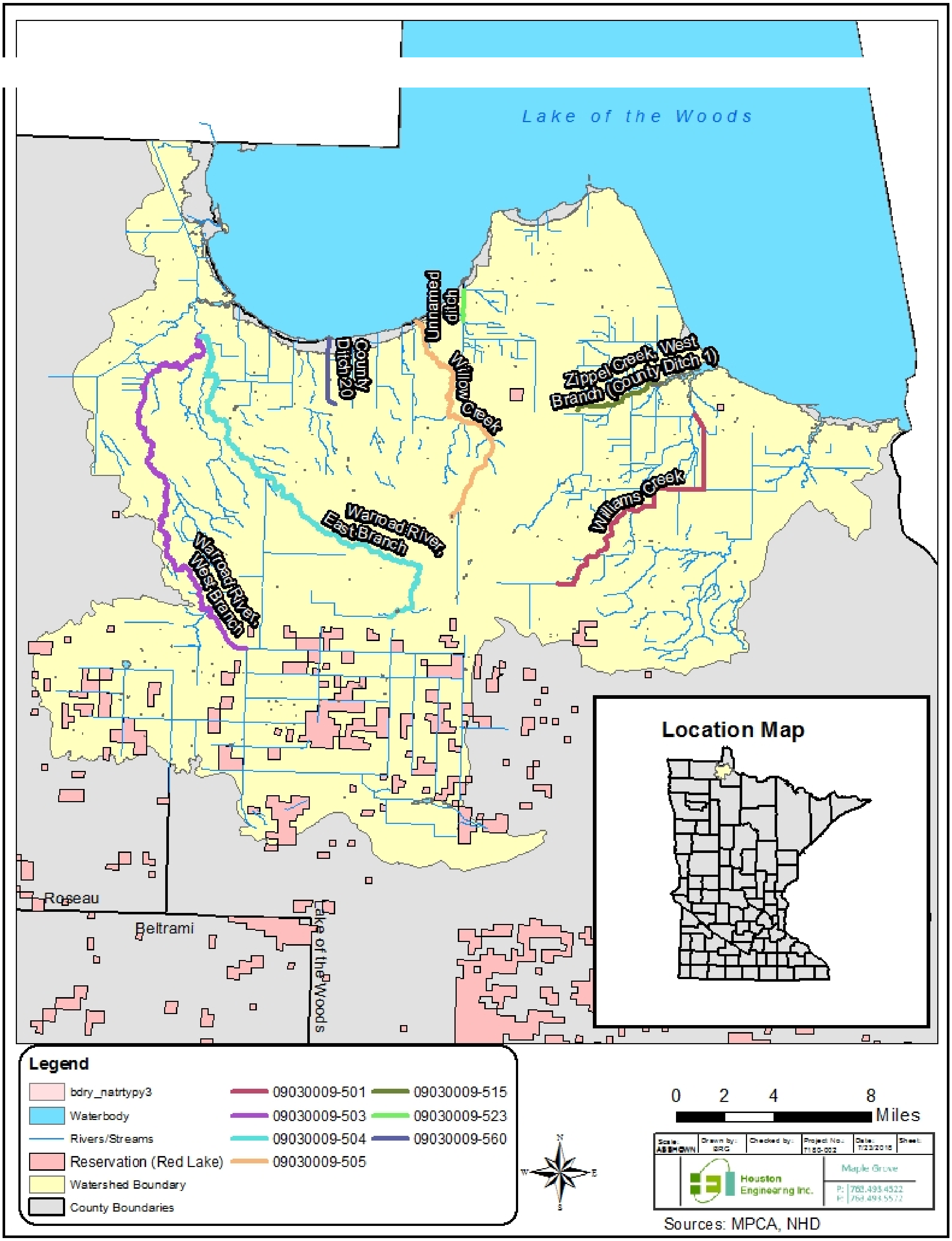


Figure 2: Impaired Streams in the Lake of the Woods Watershed.

1.3 Priority Ranking

The MPCA's schedule for TMDL study completions, as indicated on the federal Section 303(d) Impaired Waters list, reflects Minnesota's priority ranking of this TMDL study. The MPCA has aligned its TMDL study priorities with the watershed approach and WRAPS cycle. The schedule for TMDL study completion corresponds to the WRAPS report completion on the 10-year cycle. The MPCA developed a state plan called Minnesota's TMDL Priority Framework Report to meet the needs of EPA's national measure (WQ-27) under EPA's Long-Term Vision for Assessment, Restoration, and Protection under the federal Clean Water Act Section 303(d) Program. As part of these efforts, the MPCA identified water quality impaired segments that will be addressed in TMDL studies by 2022. The LOWW waters addressed by this TMDL study are part of that MPCA prioritization plan to meet EPA's national measure.

The MPCA is required to list and prioritize TMDL study development for impaired stream reaches and lakes. Schedules are estimates and indicate when a TMDL study may be completed, not when a waterbody will meet its water quality standard.

2. Applicable Water Quality Standards and Numeric Water Quality Targets

Water quality standards are the fundamental benchmarks by which the quality of surface waters are measured and used to determine impairment. Use attainment status describes whether or not a waterbody is supporting its designated beneficial use, as evaluated by the comparison of monitoring data to criteria specified in the *Minnesota Water Quality Standards* (Minn. R. ch. 7050 2008[1]). These standards can be numeric or narrative in nature, and define the concentrations or conditions of surface waters that allow them to meet their designated beneficial uses, such as for fishing (aquatic life), swimming (aquatic recreation) or human consumption (aquatic consumption). All impaired waters addressed in this TMDL study are classified as Class 2Bd waters (MPCA 2016a).

> ***Class 2Bd waters -*** The quality of Class 2Bd surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water (Minn. R. 7050.0222, subp. 3).

2.1 Lakes

Two lake assessment unit identifications (AUID) are present within the LOWW. These include Lake of the Woods Main (HUC 39000201) and Lake of the Woods 4 Mile Bay (HUC 39000202); both are present on the EPA 2018 303(d) list of impaired waters for nutrient/eutrophication biological indicators. These two lake nutrient/eutrophication biological indicator impairments are being addressed in another ongoing

[1] https://www.revisor.leg.state.mn.us/rules/?id=7050

TMDL study, the Lake of the Woods Excess Nutrient (Lake) TMDL. There will be no further discussion regarding lakes in this TMDL study.

2.2 Streams

The Minnesota narrative water quality standard for all Class 2 waters (Minn. R. 7050.0150, subp. 3) states that:

> *The aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments, and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters*.

Applicable water quality standards for the LOWW stream impairments addressed in this TMDL study are shown in Table 2, while Table 1 shows the specific water bodies affected.

Table 2: Surface Water quality standards for LOWW stream reaches addressed in this report.

Parameter	Water Quality Standard	Units	Criteria	Period of Time Standard Applies
Total suspended solids (TSS)- Northern Nutrient Region	Not to exceed 15	mg/L	Upper 10^{th} percentile	April 1 – September 30

TSS is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water. The recently approved Minnesota TSS water quality standards are based upon nutrient regions, which are loosely based on ecoregions. The LOWW is located in the Northern Nutrient Region. The TSS water quality standard for this region is 15 milligrams per liter (mg/L) (MPCA 2016a).

In addition to TSS, there are two types of biological impairments (fish and macroinvertebrate bioassessments) based on Index of Biological Integrity (IBI) scores. The IBI scores assess the health of fish (F-IBI) and macroinvertebrate (M-IBI) communities. Unlike conventional pollutants, TMDLs for biological impairment listings cannot be directly calculated. However, a TMDL to address a biological impairment can be computed if a stressor causing the impairment can be quantified (e.g., conventional pollutant such as TSS). The primary stressors investigated for biological impairments in the LOWW include loss of longitudinal connectivity, insufficient base flow, insufficient physical habitat, high suspended sediment, and low DO (MPCA 2016b). A list of the stressors for the biological impairments is provided in Table 3. The stressors listed in Table 3 are scaled on the level of support identifying the stressor as a cause of the biological impairment, ranging from no support (blank) to high support.

Table 3: Primary stressors to aquatic life in biologically impaired reaches in the LOWW.

AUID	Stream	Biological Impairment	Primary Stressor*			
			Low Dissolved Oxygen	High Suspended Sediment	Insufficient Base Flow	Insufficient Physical Habitat
09030009-501	Williams Creek, Headwaters to Zippel Creek	Fish	○		◉	
		Macroinvertebrate	◉	◉	◉	○
09030009-504	Warroad River, East Branch, Headwaters to Warroad River	Macroinvertebrate	○	○	○	○
09030009-505	Willow Creek, Headwaters to Lake of the Woods	Fish	◉	○	◉	◉
09030009-515	Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (Lake of the Woods)	Fish	◉		○	
		Macroinvertebrate	●	◉	◉	○
09030009-523	Unnamed ditch, Unnamed ditch to Unnamed ditch,	Fish	○	○	◉	◉
		Macroinvertebrate	◉	○	◉	◉
09030009-560	County Ditch 20, Headwaters to Lake of the Woods	Macroinvertebrate	◉	○	◉	◉

*● = high support, ◉ = medium support, ○ = low support; based on Table 23 in Stressor Identification Report (MPCA 2016b)

3. Watershed and Waterbody Characterization

The LOWW (HUC 09030009) borders the United States and Canada covering approximately 734,783 acres within Minnesota. The LOWW is heavily influenced by former glacial lakes that were once abundant across the landscape. The glacial lake influence is now found in vast amounts of flat wetlands. This area is also rich in boreal forest vegetation. Approximately 42% of the watershed is covered by the Lake of the Woods (AUID 39000202), with dominant land use characterized as wetlands comprising 42% and cropland comprising 2%. Municipalities within the watershed include the cities of Williams, Roosevelt, and Warroad.

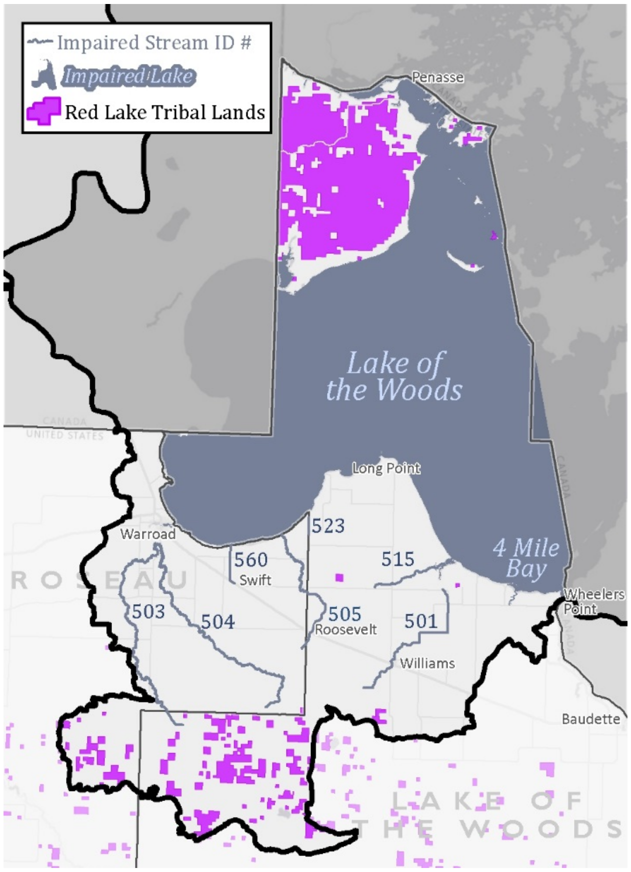
The LOWW contains a high ratio of modified streams with 60% of the watercourses being hydrologically altered. The highly altered landscape and stream channel characteristics have resulted in impaired conditions as measured with a broad suite of aquatic community, water chemistry, and stream habitat indicators.

More information about the physical characteristics of the LOWW can be found in the LOWW Biotic SID (MPCA 2016b) Report, the LOWW Monitoring and Assessment Report (MPCA 2016a), and/or the LOWW Conditions Report (HEI 2012).

Tribal Lands in the Lake of the Woods Watershed

The Red Lake Nation has tribal lands located within the boundary of the LOWW (Figure 3). None of the impaired waterbodies are within the boundaries of the Red Lake Nation's tribal lands. Therefore, no tribal lands are impacted by the LOWW TMDL Study.

Figure 3: Red Lake Tribal Lands.



3.1 Streams

Total drainage areas, direct drainage areas, noncontributing areas, and any upstream waterbodies for impaired AUID stream reaches in the LOWW are listed in Table 4. The direct drainage areas include only the areas draining to the impaired AUID, or the total drainage areas minus the noncontributing area. Direct drainages and total contributing drainage areas were delineated using hydrologically-conditioned 3-meter digital elevation models (DEM) derived from the states airborne Light Detection and Ranging (LiDAR) technology. The noncontributing areas are based on a 10-year, 24-hour event.

Table 4: Impaired stream reach total and noncontributing drainage areas.

AUID (09030009-XXX)	Name	HUC 10 Subwatershed	Total Drainage Area (acres)	Direct Drainage Area (acres)	Noncontributing Area (acres)	Upstream Waterbody
501	Williams Creek, Headwaters to Zippel Creek	Zippel Creek	25,061	24,483	578	Unnamed ditch (09030009-544)
503	Warroad River, West Branch, Headwaters to Warroad River	Warroad River	155,907	155,888	19	Bulldog Run, Clausner Creek (09030009-535, 534)
504	Warroad River, East Branch, Headwaters to Warroad River	Warroad River	62,772	62,748	24	Unnamed Ditches (09030009-526, 536)

AUID (09030009-XXX)	Name	HUC 10 Subwatershed	Total Drainage Area (acres)	Direct Drainage Area (acres)	Noncontributing Area (acres)	Upstream Waterbody
505	Willow Creek, Headwaters to Lake of the Woods	Muskeg Bay	17,693	16,008	1,685	N/A
515	Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (Lake of the Woods)	Zippel Creek	29,638	29,375	263	Unnamed ditch, Unnamed Creek (09030009-527, 529)
523	Unnamed ditch, Unnamed ditch to Unnamed ditch	Muskeg Bay	11,437	11,283	154	Unnamed Ditch (09030009-522)
560	County Ditch 20, Headwaters to Lake of the Woods	Muskeg Bay	6,107	6,079	28	N/A

3.2 Subwatersheds

For purposes of this TMDL study, the LOWW is divided into four 10-digit HUC subwatersheds used to organize TMDL components throughout the study. These subwatersheds include Bostick Creek (0903000901), Zippel Creek (0903000902), Warroad River (0903000903) and Muskeg Bay (0903000904) HUC-10 subwatersheds (Figure 4). There are impaired waters located in the Zippel Creek, Warroad River, and Muskeg Bay subwatersheds. There are no impaired waters located in the Bostic Creek Subwatershed; therefore, it is not included in the descriptions below.

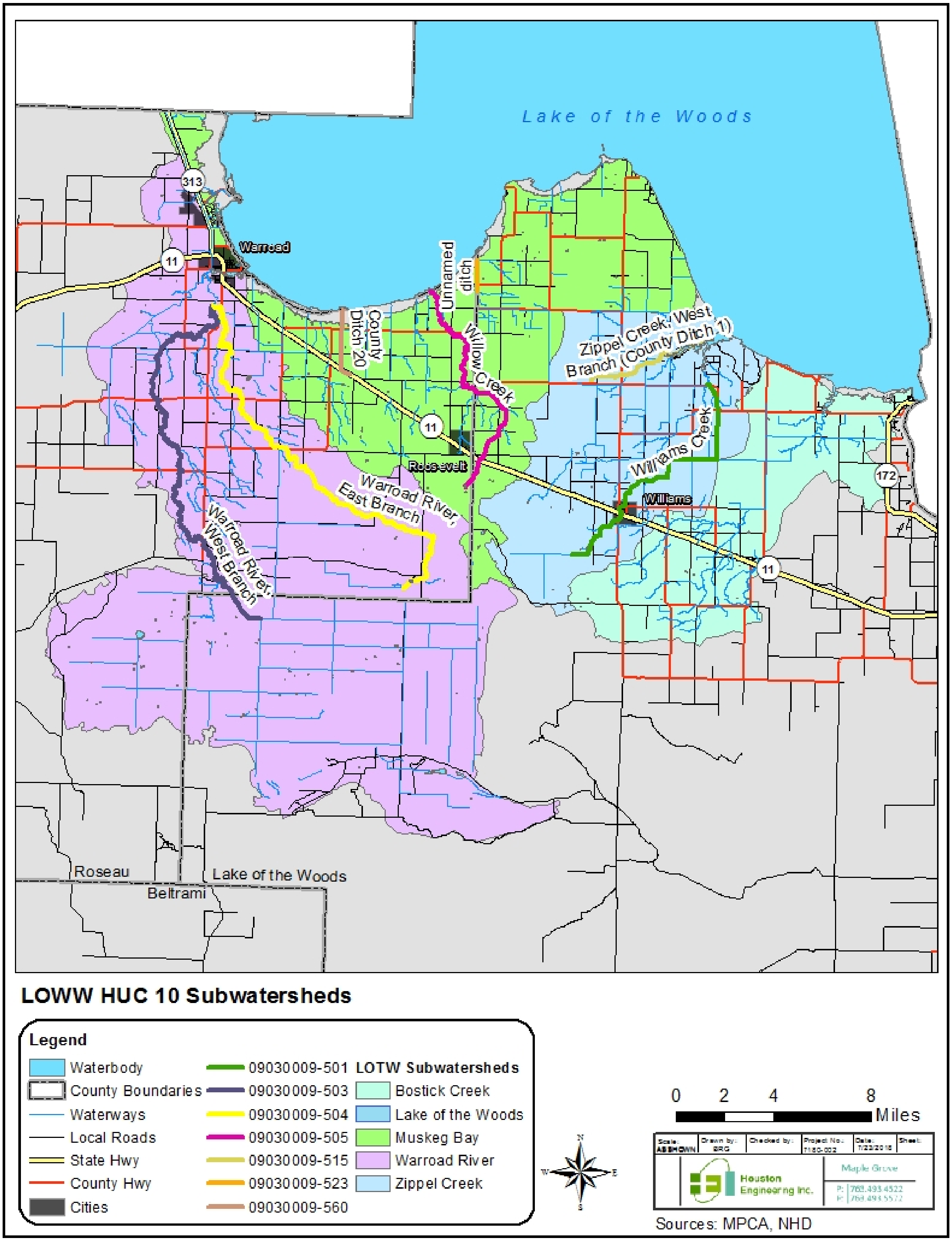


Figure 4: Lake of the Woods Watershed's HUC-10 Subwatersheds.

3.2.1 The Zippel Creek Subwatershed (HUC 0903000902)

The Zippel Creek Subwatershed is located in the eastern portion of central LOWW. It is located entirely within the NMW Ecoregion. Dominant land cover is wetland (63%), with approximately 20% cropland cover. The city of Williams is located within the Zippel Creek Subwatershed. Remaining land area is unorganized territory containing portions of Lake of the Woods and Beltrami State Forests. The Zippel Creek Subwatershed contains two impaired stream reaches, AUID 09030009-501 and AUID 09030009-515, and both are impaired due to high TSS levels and low DO levels, and both have impaired fish and macroinvertebrate bioassessments (Table 5). No conventional parameters were identified as stressors for the two F-IBI impairments; therefore, no TMDLs were calculated to address those impairments. Due to insufficient data, both of the DO impairments are being deferred to a future TMDL study. Both of the TSS impairments and both of the M-IBI impairments are addressed by the respective TSS TMDLs calculated for this study.

The Zippel Creek HUC-10 Subwatershed is shown in Figure 5. The drainage areas for each individual impaired reach are shown in Figure 6 and Figure 7. Each figure includes the total drainage area, noncontributing drainage areas, any feedlots within the total drainage areas, water quality sites, 2011 National Land Cover Dataset (NLCD) land uses, and any point sources (e.g., WWTF) located in the total drainage areas.

Table 5. Impaired Stream Reaches in the Zippel Creek HUC-10 Subwatershed.

AUID	Description	Impairment/Parameter	Addressed in this TMDL study?
-501	Williams Creek, Headwaters to Zippel Creek	F-IBI	No†
		DO	No◊
		M-IBI	Yes (TSS)*
		TSS	Yes
-515	Zippel Creek, West Branch (CD 1), Headwaters to Zippel Bay	F-IBI	No†
		DO	No◊
		M-IBI	Yes (TSS)*
		TSS	Yes

† No conventional parameters were identified as stressors.
◊ Insufficient data to perform a TMDL
* TSS was identified as a potential stressor and a TSS TMDL was calculated to address the M-IBI impairment

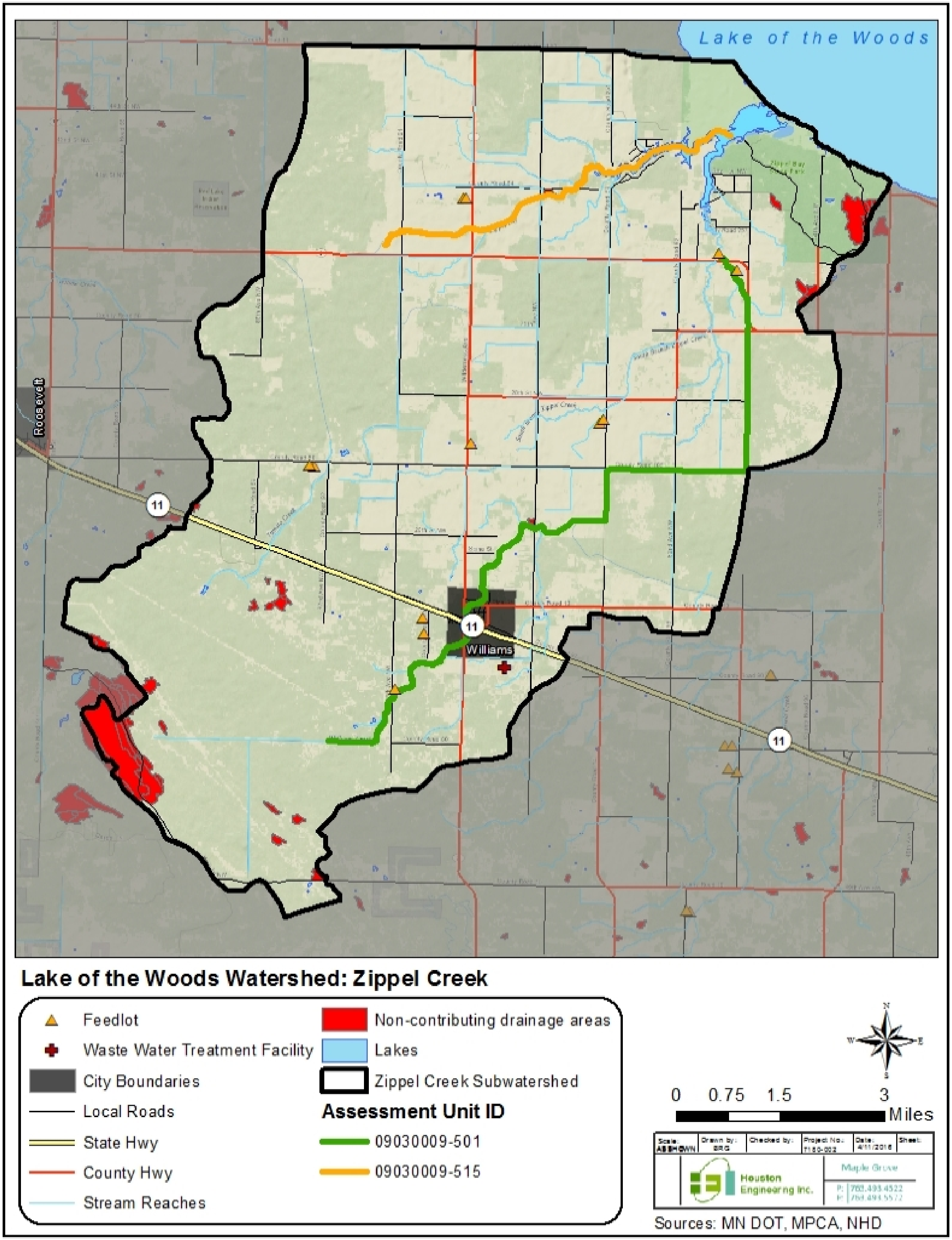


Figure 5: Drainage Area for Zippel Creek Subwatershed (HUC 090300902) in the Lake of the Woods Watershed.

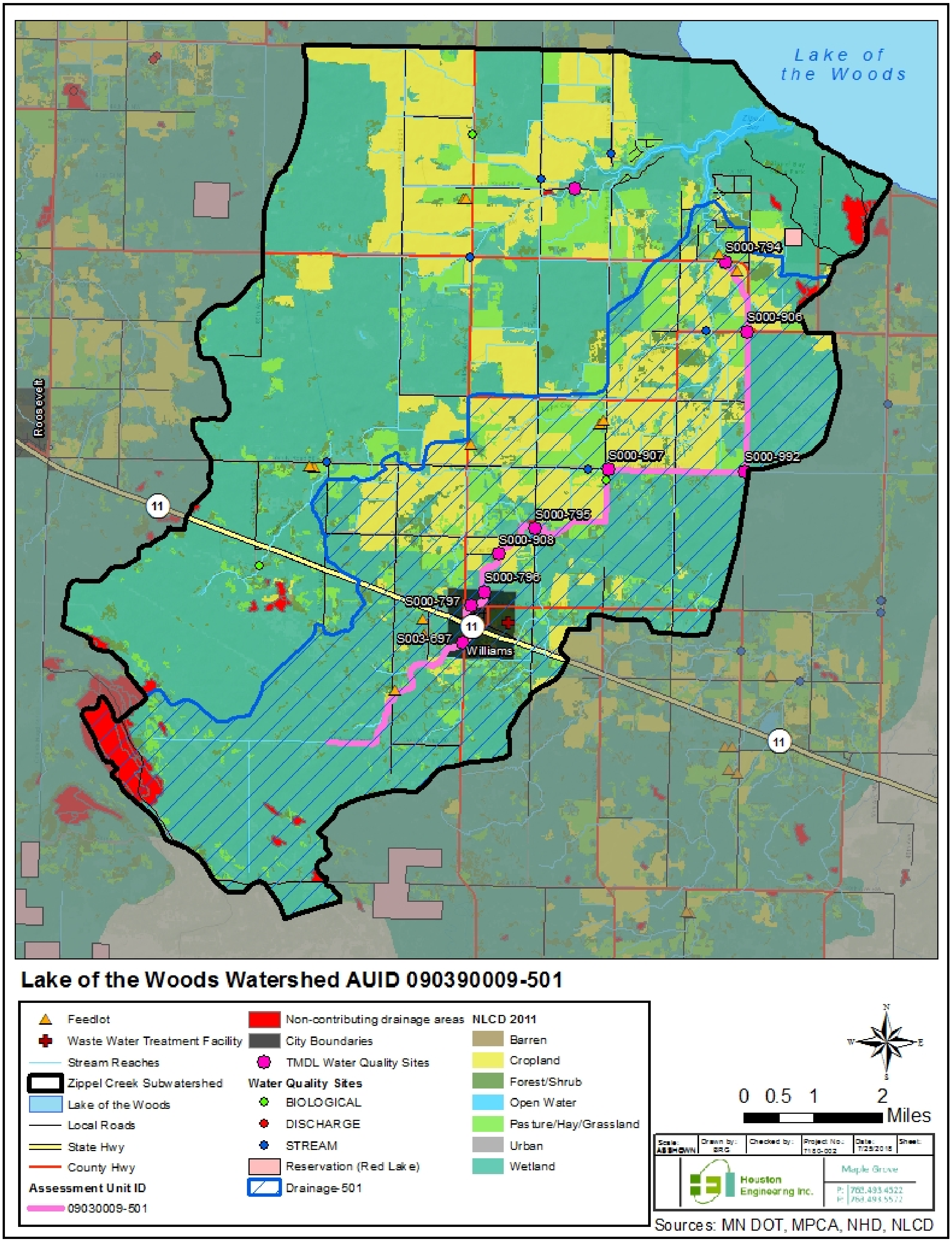


Figure 6: Drainage Area for the Williams Creek, Headwaters to Zippel Creek (AUID 09030009-501).

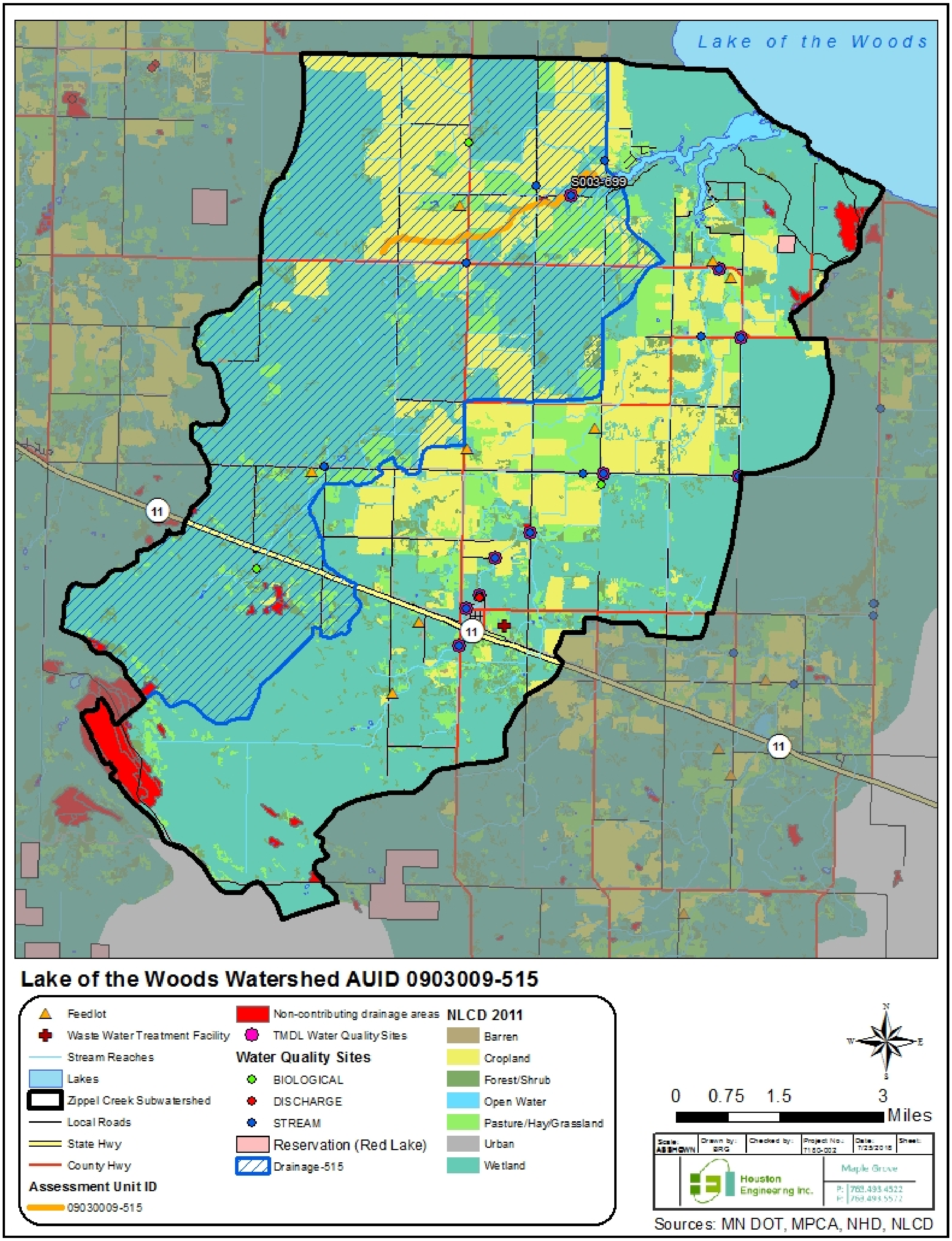


Figure 7: Drainage Area for Zippel Creek, West Branch (County Ditch 1) Headwaters to Zippel Bay (Lake of the Woods) (AUID 09030009-515).

3.2.2 The Warroad River Subwatershed (HUC 0903000903)

The Warroad River Subwatershed is located on the far western edge of the LOWW. It is located entirely within the NMW Ecoregion. Dominant land cover is wetland (73%) with approximately 10% cover of both pasture/hay/grassland and cropland. Portions of the city of Warroad and the townships of Cedarbend, Lake, Laona, and Moranville fall within the Warroad River Subwatershed, in addition to areas of unorganized territory and portions of Beltrami Island State Forest. The Warroad River Subwatershed contains two impaired stream reaches; AUID 0903009-503 is impaired by *E. coli* and AUID 09030009-504 has an impaired macroinvertebrate bioassessment (Table 6). Due to insufficient data, the *E. coli* impairment is being deferred to a future TMDL study. While TSS was identified as a potential stressor for the M-IBI impairment, the TMDL indicated that no reductions were needed at any of the flow regimes; therefore, the TMDL was not included in this study.

The Warroad River HUC-10 Subwatershed is shown in Figure 8. The drainage areas for each individual impaired reach are shown in Figure 9 and Figure 10. Each figure includes the total drainage area, noncontributing drainage areas, any feedlots within the total drainage areas, water quality sites, 2011 NLCD land uses, and any point sources (e.g., WWTF) located in the total drainage areas.

Table 6: Impaired Reaches in the Warroad River HUC-10 Subwatershed.

AUID	Description	Impairment/Parameter	Addressed in this TMDL study?
-503	Warroad River, West Branch, Headwaters to Warroad River	*E. coli*	No◊
-504	Warroad River, East Branch, Headwaters to Warroad River	M-IBI	No*

◊ Insufficient data to perform a TMDL

* TSS was identified as a potential stressor and a TSS TMDL was calculated to address the M-IBI impairment; however, the TMDL indicated that no reductions were needed at any of the examined flow regimes

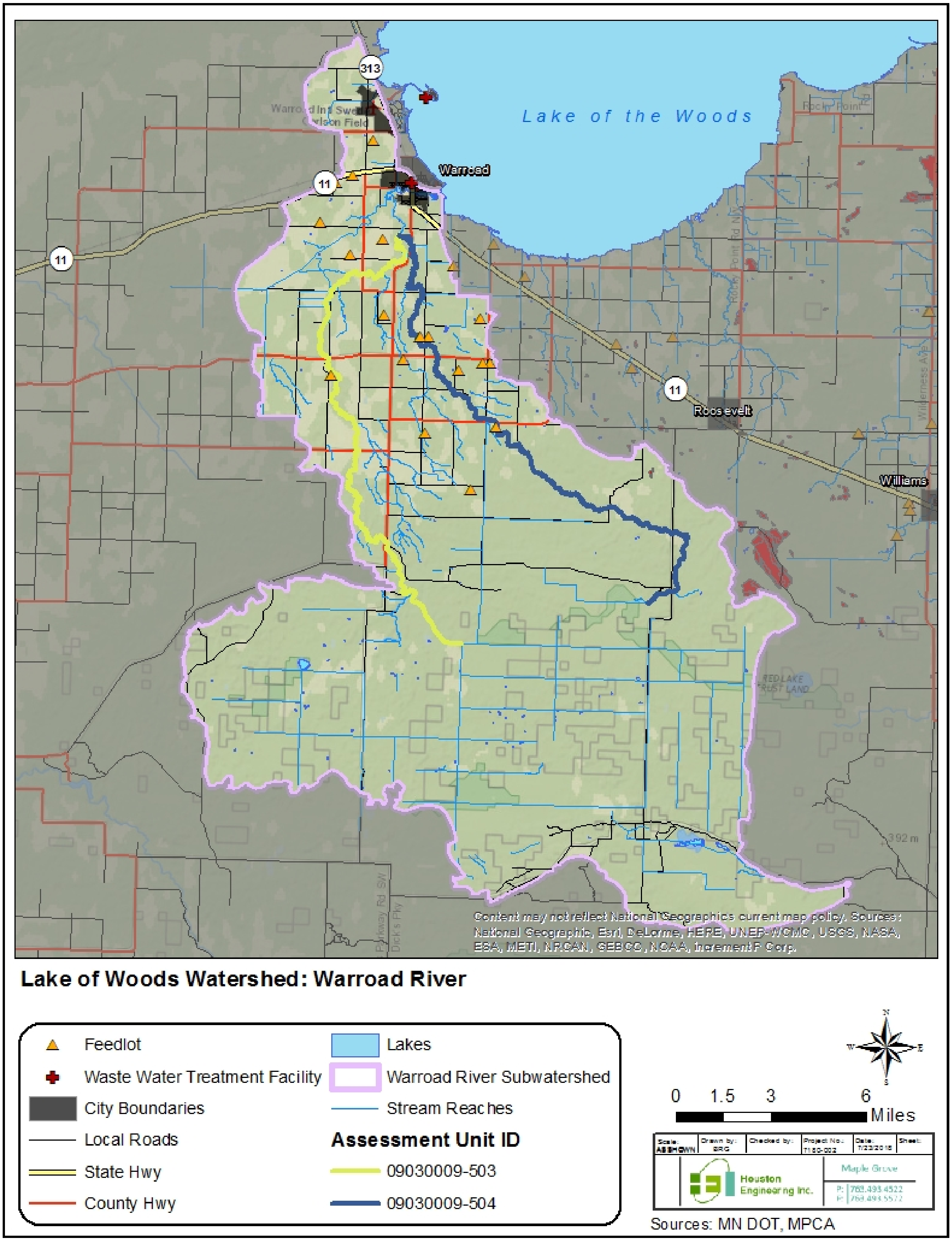


Figure 8: Drainage Area for the Warroad River Subwatershed (HUC 090300903) in the Lake of the Woods Watershed.

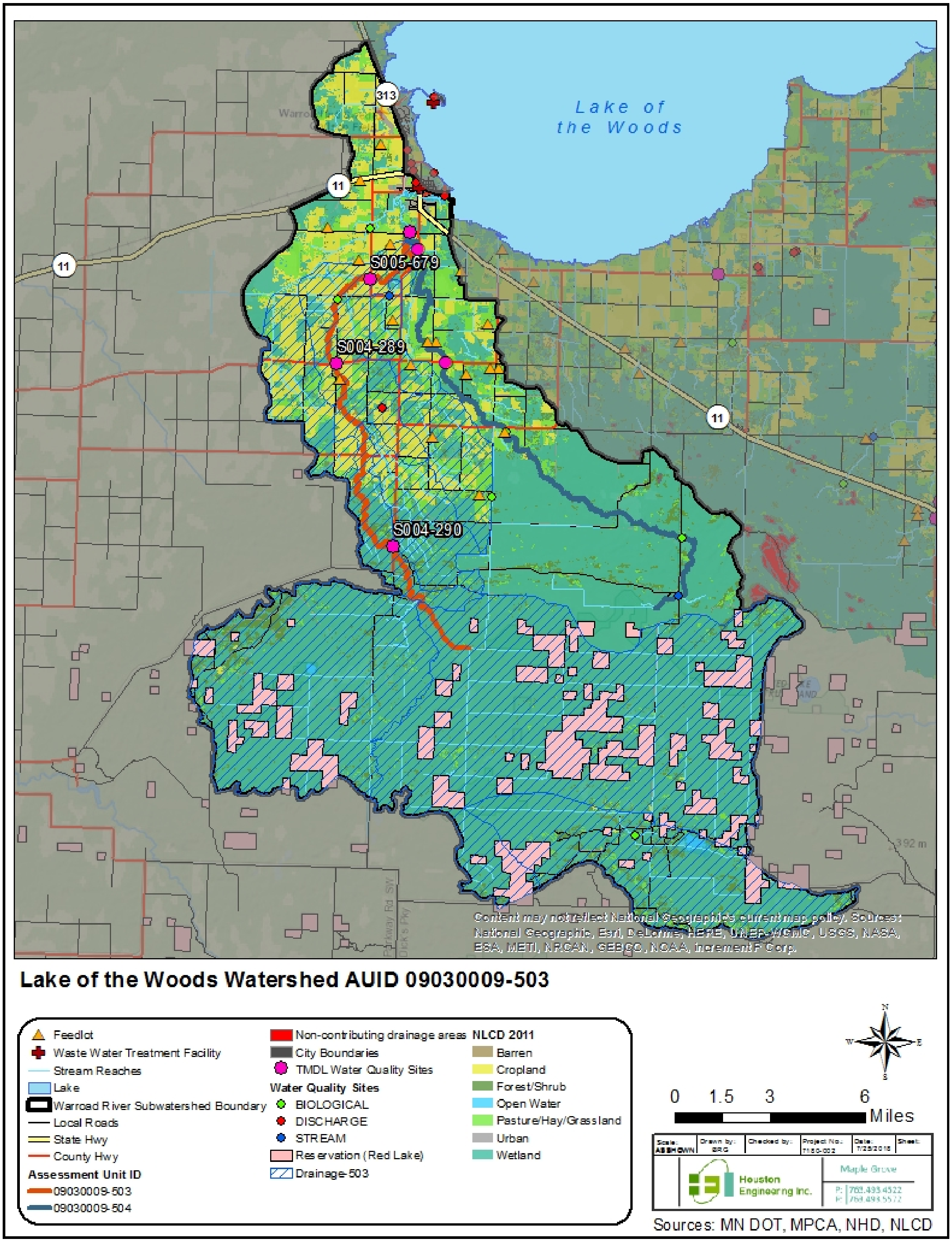


Figure 9: Drainage area for the Warroad River West Branch, Headwaters to Warroad River (AUID 09030009-503).

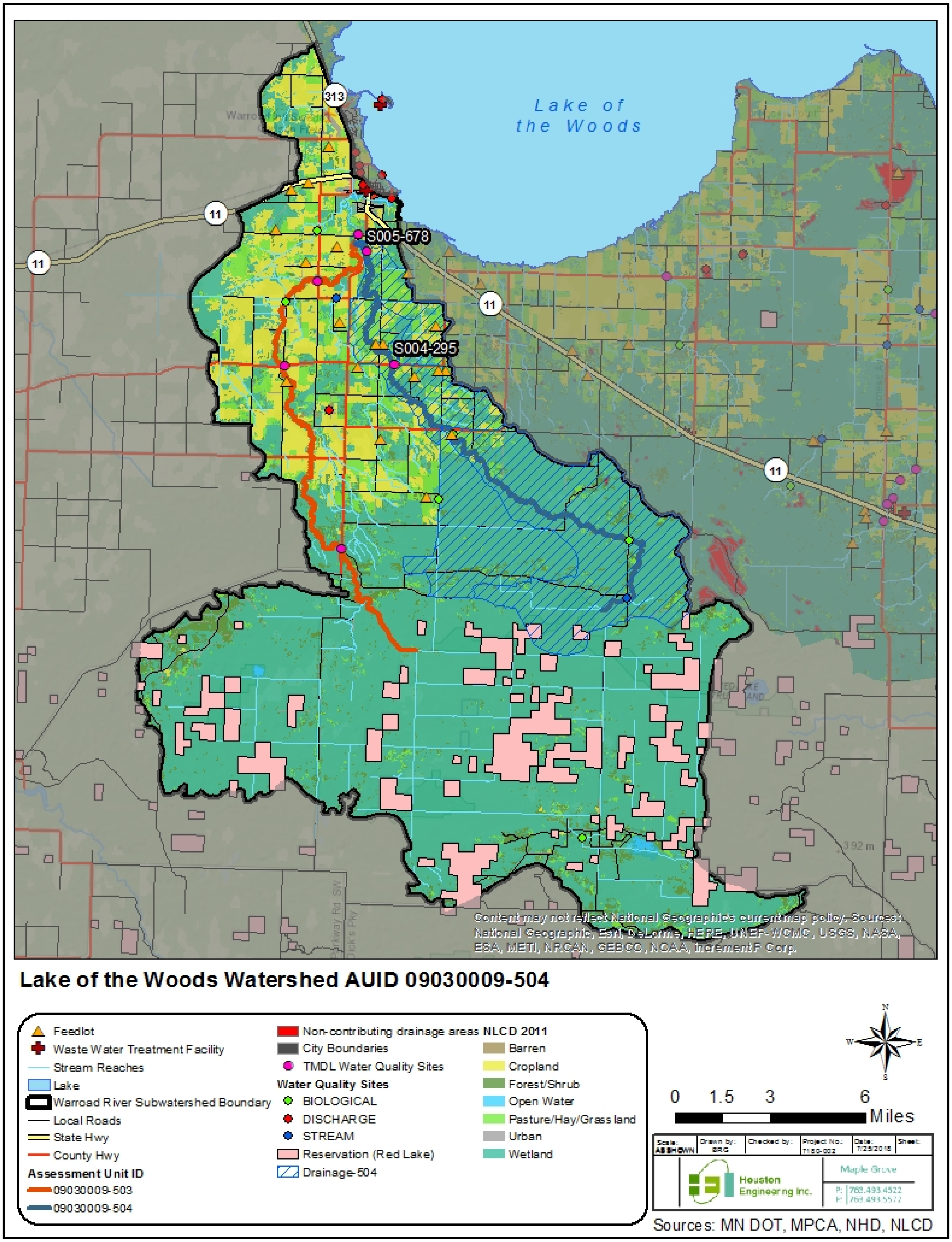


Figure 10: Drainage area for the Warroad River East Branch, Headwaters to Warroad River (AUID 09030009-504).

3.2.3 The Muskeg Bay Subwatershed (HUC 0903000904)

The Muskeg Bay Subwatershed is located in the western portion of central LOWW. It is located entirely within the NMW Ecoregion. Dominant land cover is wetland (53%) with approximately 20% cover of both pasture/hay/grassland and cropland. The city of Roosevelt and portions of the city of Warroad fall within the Muskeg Bay Subwatershed, in addition to the Lake, Laona, and Moranville townships. Remaining land area is unorganized territory and portions of Beltrami Island State Forest. The Muskeg Bay Subwatershed contains three impaired stream reaches, AUID 09030009-505 is impaired due to low DO levels and has an impaired fish bioassessment, AUID 09030009-523 has impaired fish and macroinvertebrate bioassessments, and AUID 09030009-560 has an impaired macroinvertebrate bioassessment (Table 7). Due to insufficient data, the DO impairment is being deferred to a future TMDL study. The SID report identified TSS as a potential stressor for the F-IBI in reach -505 and the M-IBI in reach -560. The TSS TMDLs calculated to address the -505 F-IBI and -560 M-IBI impairments indicated that no reductions were needed at any of the examined flow regimes; therefore, those TMDLs are not included in this study. The SID report identified TSS as a potential stressor for the M-IBI and F-IBI impairments in reach -523. The TSS TMDL calculated to address the reach -523 impairments indicated that a reduction was needed at the highest flow regime; therefore, this TMDL is included in this study.

The Muskeg Bay HUC-10 Subwatershed is shown in Figure 11. The drainage areas for the impaired reaches are shown in Figure 12, Figure 13, and Figure 14. The figure includes the total drainage area, noncontributing drainage area, any feedlots within the total drainage area, water quality sites, 2011 NLCD land uses, and any point sources (e.g., WWTF) located in the total drainage area.

Table 7: Impaired Reaches in the Muskeg Bay HUC-10 Subwatershed.

AUID	Description	Impairment/Parameter	Addressed in this TMDL study?
-505	Willow Creek, Headwaters to Lake of the Woods	DO	No◊
		F-IBI	No*
-523	Unnamed ditch, Unnamed ditch to Unnamed ditch	M-IBI	Yes (TSS)†
		F-IBI	Yes (TSS)†
-560	CD 20, Headwaters to Lake of the Woods	M-IBI	No*

◊ Insufficient data to perform a TMDL

* TSS was identified as a potential stressor and a TSS TMDL was calculated to address the F-IBI and M-IBI impairments; however, the TMDL indicated that no reductions were needed at any of the examined flow regimes.

† TSS was identified as a potential stressor and a TSS TMDL was calculated to address the F-IBI and M-IBI impairments

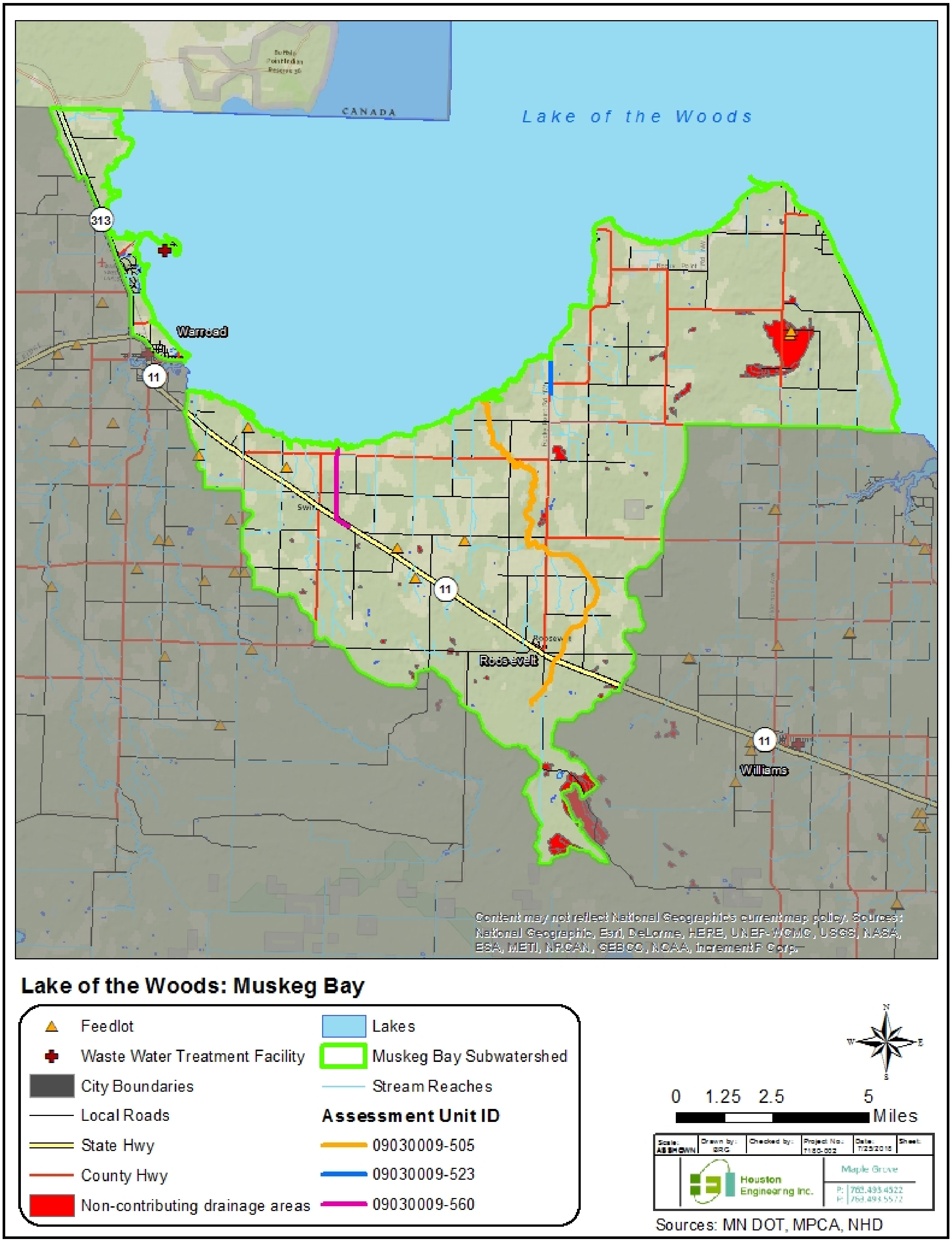


Figure 11: Drainage Area for the Muskeg Bay Subwatershed (HUC 0903009004) in Lake of the Woods Watershed.

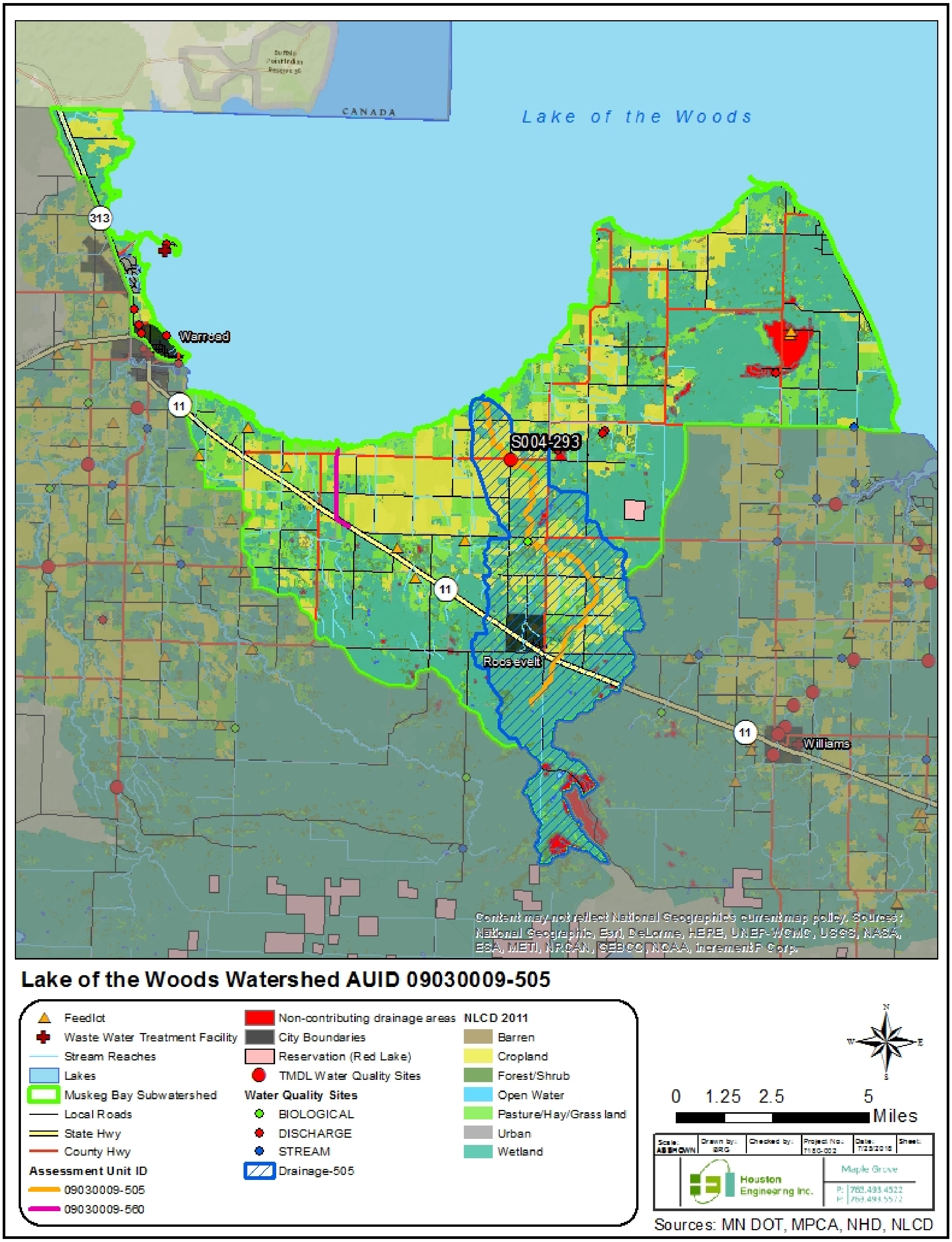


Figure 12: Drainage Area for Willow Creek, Headwaters to Lake of the Woods (AUID 09030009-505).

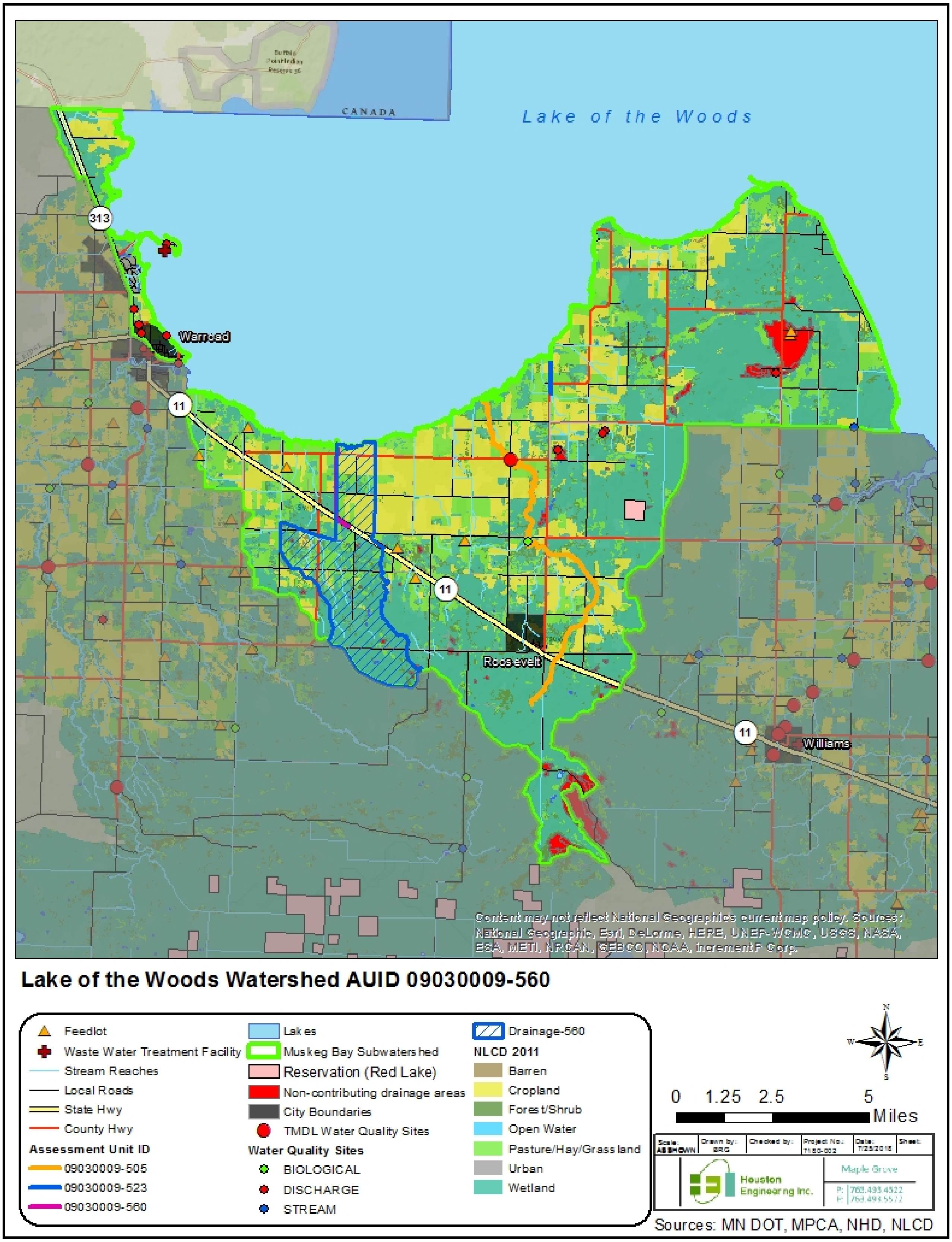


Figure 13: Drainage Area for County Ditch 20, Headwaters to Lake of the Woods (AUID 09030009-560).

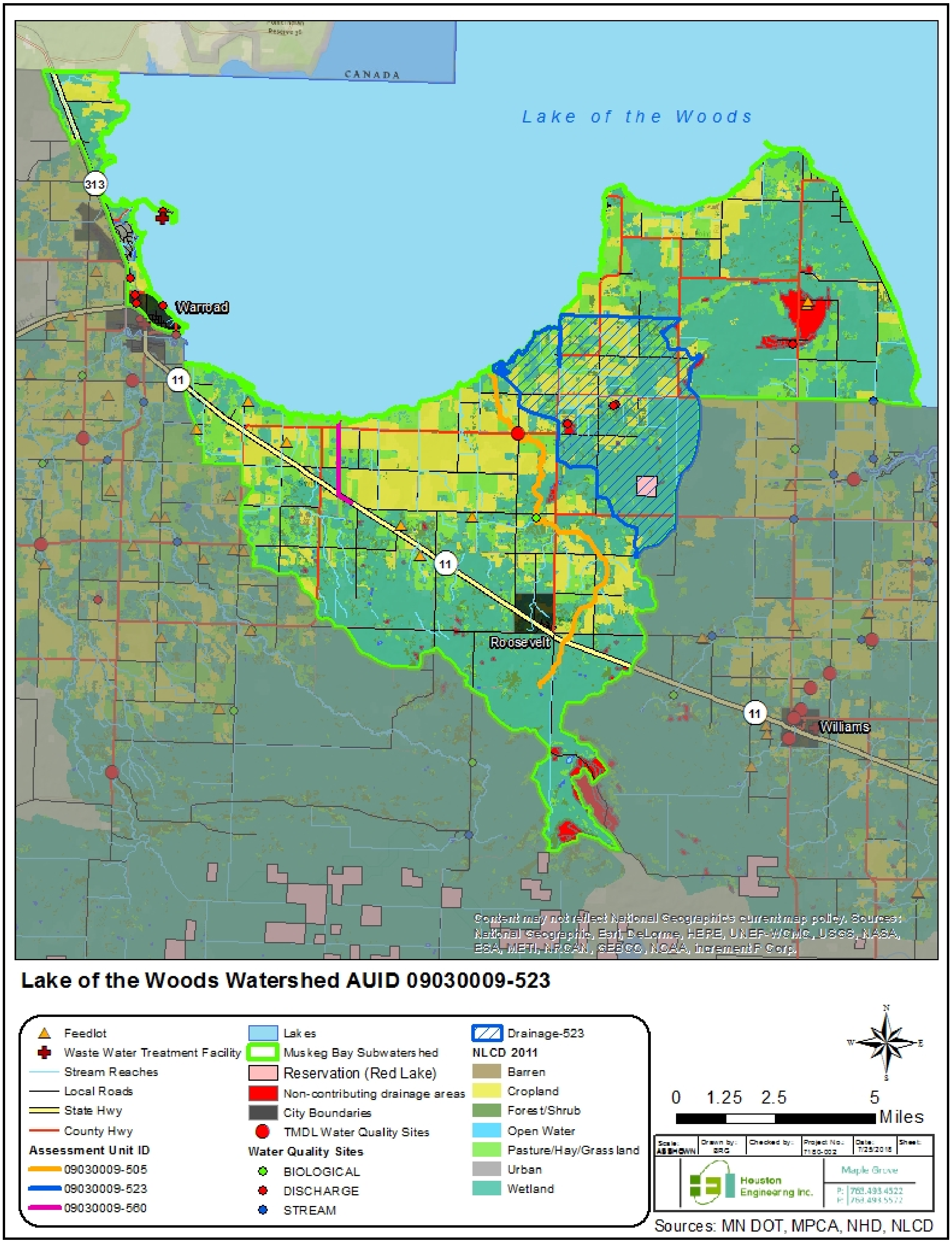


Figure 14: Drainage Area for Unnamed ditch, Unnamed ditch to Unnamed ditch (AUID 09030009-523).

3.3 Land Use

Land use within the LOWW can be described using the Multi-Resolution Land Characteristic Consortium 2011 NLCD (Figure 15). Table 8 contains a summary of land uses, in the LOWW, for the entire watershed as well as for each impaired water by direct drainage area. The land use statistics were generated from the 2011 NLCD. Land use in the LOWW is primarily wetland and open water.

Table 8: Land use percentages in the LOWW by AUID direct drainage area (NLCD 2011).

Watershed/Immediate Drainage Area	Open Water	Urban	Barren	Forest/ Shrub	Pasture/Hay/ Grassland	Cropland	Wetland
Entire Watershed	41.6%	1.6%	0.0%	2.7%	5.1%	6.6%	42.3%
Zippel Creek Subwatershed							
09030009-501	0.0%	3.8%	0.0%	5.8%	11.7%	20.3%	58.5%
09030009-515	1.1%	2.3%	0.0%	3.3%	7.9%	18.6%	66.7%
Warroad River Subwatershed							
09030009-503	0.2%	1.8%	0.0%	6.0%	7.2%	7.9%	76.8%
09030009-504	0.04%	2.1%	0.03%	5.7%	11.7%	4.6%	75.8%
Muskeg Bay Subwatershed							
09030009-505	0.1%	3.9%	0.0%	8.1%	11.2%	19.7%	57.0%
09030009-523	0.08%	2.9%	0.19%	4.1%	17.7%	22.5%	52.6%
09030009-560	0.05%	4.3%	0.60%	6.5%	19.6%	15.1%	53.8%

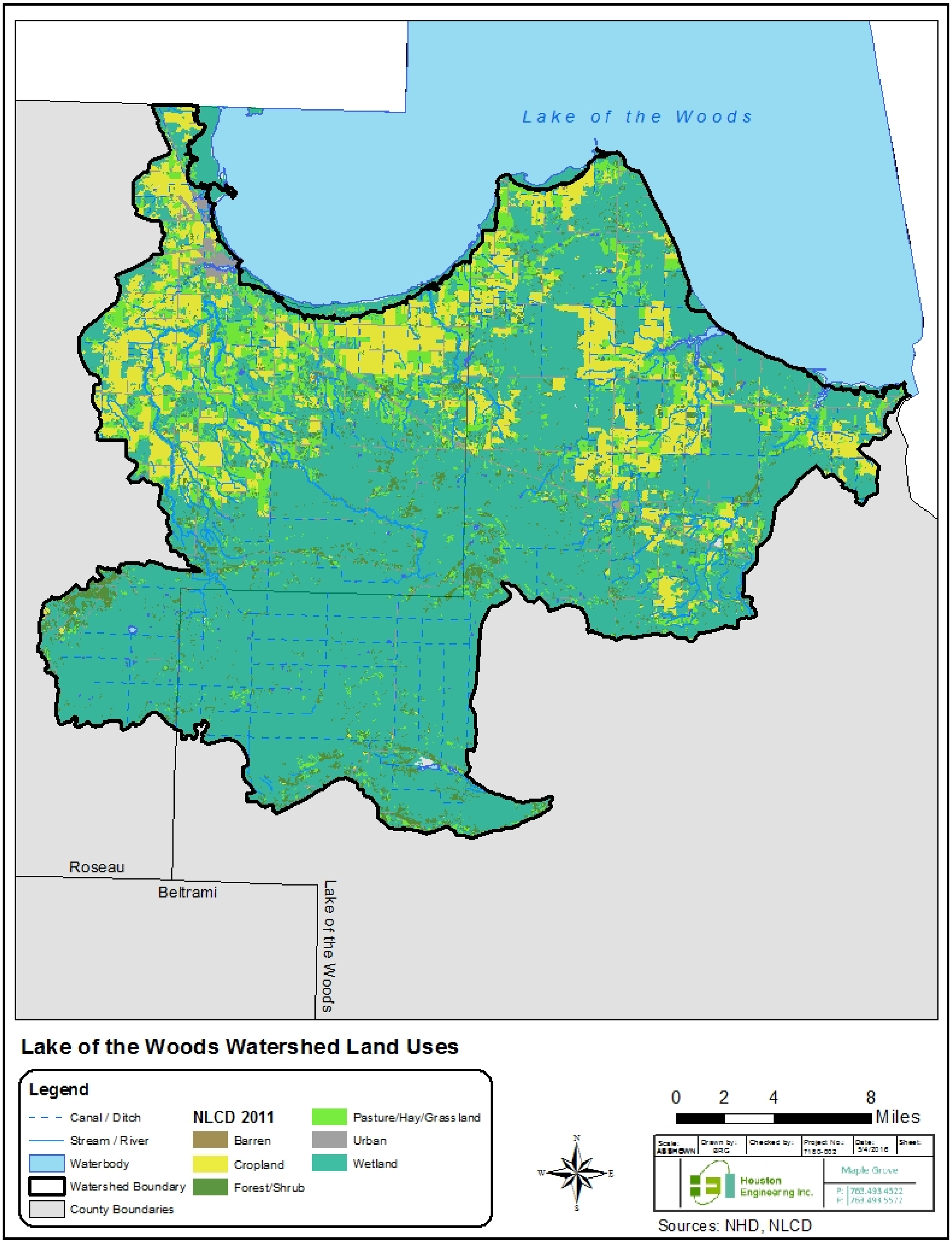


Figure 15: Land use and land cover in the Lake of the Woods Watershed.

3.4 Current/Historical Water Quality

The existing water quality conditions were described using data downloaded from the MPCA's Environmental Quality Information System (EQuIS) database accessible through the MPCA's Environmental Data Access (EDA) website. The EQuIS database stores water quality data from more than 17,000 sampling locations across the state, containing information from Minnesota streams and lakes dating back to 1926.

According to EQuIS and the MPCA's spatial datasets, there are 11 biological monitoring sites, 21 lake water quality monitoring sites, 36 stream water quality monitoring sites, 5 United States Geological Survey (USGS) sites, and 15 discharge sites located in the LOWW (Figure 16). Of the flow sites, all sites were excluded for various reasons including: (1) the period of record being outside of the assessment period (2005 through 2014); (2) the sites were not located in impaired stream reaches or lakes; or (3) a site did not have relevant observed data. Of the five USGS sites, two are lake level sites located in the Lake of the Woods and three are stream sites with data only available for prior to 2005. All of the 15 identified discharge sites are NPDES/SDS sites that may or may not discharge to a stream. The water quality sites used to develop the LDCs and TMDLs are provided in Table 9.

Table 9: Water quality stations and data ranges used to develop TMDLs.

AUID	Water Quality Monitoring Locations	TSS Data
09030009-501	S000-906	2006-2013
09030009-503	S004-289, S004-290	NA
09030009-515	S003-699	2006-2013
09030009-523	None	NA

The MPCA conducts intensive watershed monitoring for two years in all 80 watersheds in Minnesota on a 10-year cycle (i.e., every major watershed is sampled for 2 years, once every 10 years). The LOWW's intensive watershed monitoring occurred in 2012 and 2013. To supplement data collection between intensive monitoring years, the MPCA coordinates two programs aimed at encouraging citizen surface water monitoring (i.e., the Citizen Lake Monitoring Program [CLMP] and the Citizen Stream Monitoring Program [CSMP]). Sustained citizen monitoring can provide the long-term picture needed to help evaluate current water quality status and trends. The advanced identification of lake and stream sites that will be sampled by agency staff provides an opportunity to actively recruit volunteers to monitor those sites, so that water quality data collected by volunteers are available for the years before and after the intensive monitoring effort by MPCA staff (HEI 2012).

Available data from the current 10-year assessment period (2012 through 2022), that were consistent with the months where the water quality standard applies, were used for development of this TMDL study. As 2013 is the last year with available MPCA EQuIS data, the assessment period of 2004 through 2013 was used for development of this TMDL study. For TSS, data collected only during the months of April through September were used.

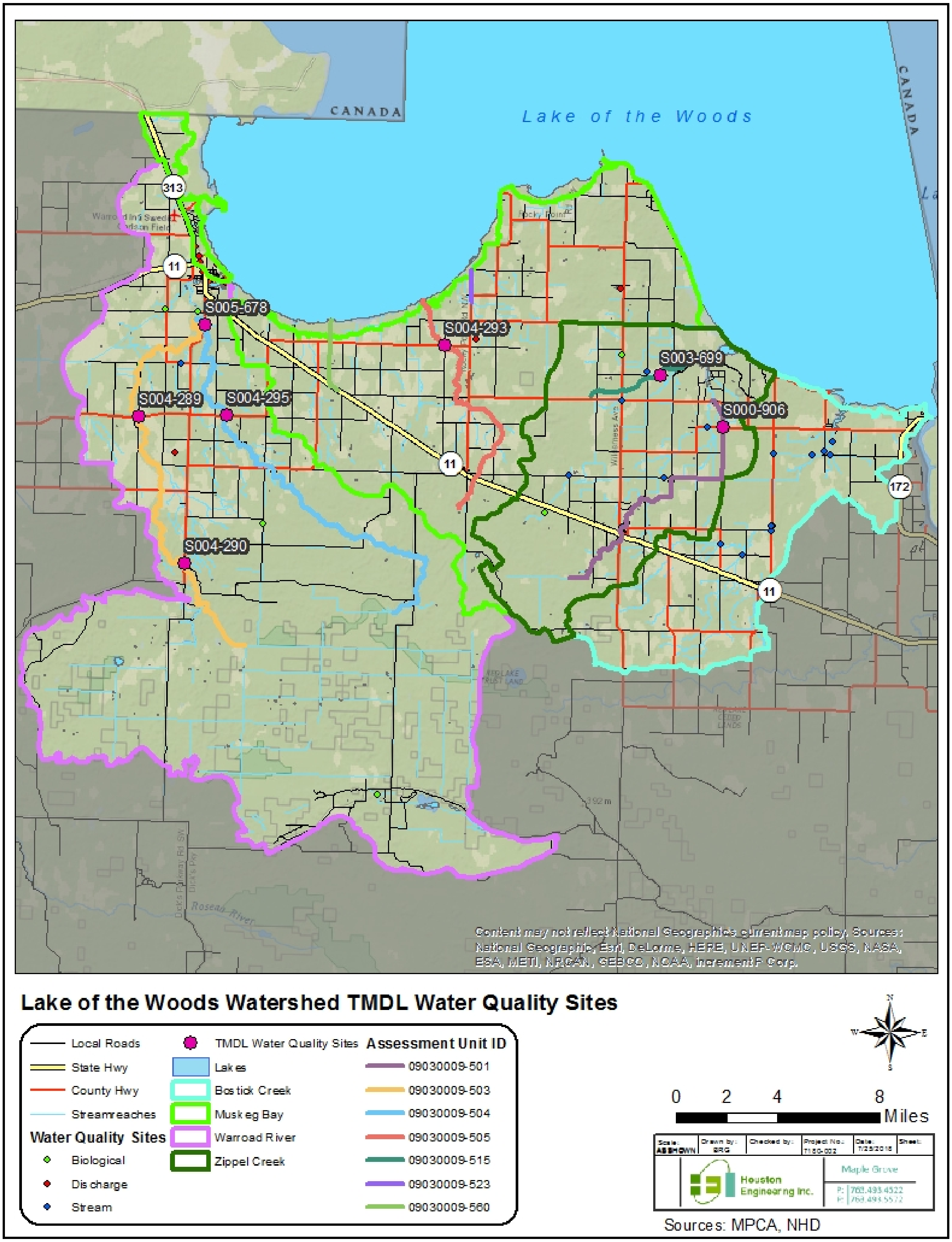


Figure 16: Water quality sites used to develop TMDLs.

In instances where this TMDL study references "Natural Background Conditions", natural background conditions are considered the landscape condition that occurs outside of human influence. Minn. R. 7050.0150, subp. 4, defines the term "natural causes" as the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence.

3.4.1 Total Suspended Solids

The TSS is a direct measurement of all suspended solids, organic and inorganic, in a water quality sample. In January of 2015, the EPA issued an approval of the adopted amendments to the Minnesota State Water Quality Standards, replacing the historically-used turbidity standard with TSS standards. The TSS TMDLs now replace the turbidity TMDLs.

The recently approved Minnesota State TSS standards are based upon nutrient regions, which are loosely based on ecoregions. The LOWW is located in the Northern Nutrient Region. Therefore, the applicable TSS standard is 15 mg/L (MPCA 2016b). Table 10 lists all water quality sites within impaired reaches in the LOWW with turbidity and/or TSS observations during the assessment period.

Table 10: Summary of sites with total suspended solids observations for the assessment period 2004-2013 (n=sample size).

AUID	Site ID	Total Suspended Solids			
		Sampling Years	Sample Size (n)	90th % [mg/L]	# of Exceed.
09030009-501	S000-906	2006-13	41	18	6
09030009-504	S004-295	2012	10	5	0
09030009-504	S005-678	2009	1	6	0
09030009-505	S004-293	2012	10	8.1	0
09030009-515	S003-699	2006-13	29	24.8	5

3.5 Pollutant Source Summary

A key component for developing a TMDL study is understanding the sources contributing to the impairment(s). The LOWW contains a high ratio of modified streams, with 64% of the watercourses being hydrologically altered. The highly-altered landscape and stream channel characteristics have resulted in impaired conditions as measured with a broad suite of aquatic community, water chemistry, and stream habitat indicators. Several stressors in the LOWW play a role in influencing water quality in the system and limiting the health of these aquatic communities (HEI 2012).

This section provides a brief description of the potential sources by pollutant in the LOWW contributing to the listed impairments. A more in-depth discussion of the biological stressors, pollutant sources, and causal pathways can be found in the Lake of the Woods Biotic SID Report (MPCA 2016b). More discussion on the current conditions in the LOWW can be found in the LOWW Monitoring and Assessment Report (MPCA 2016a).

Natural Background Conditions

Natural background conditions refer to inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment. Therefore, natural background is accounted for and addressed through the MPCA's waterbody assessment process. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, WWTFs, failing subsurface sewage treatment systems (SSTS) and other anthropogenic sources.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence or data at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the waterbodies' ability to meet state water quality standards. For all impairments addressed in this TMDL study, natural background sources are implicitly included in the LA portion of the TMDL study allocation tables, and TMDL study reductions should focus on the major anthropogenic sources identified in the source assessment.

3.5.1 Total Suspended Solids

The LOWW Biotic SID Report (MPCA 2016b) describes the sources and causal pathways for TSS. Flow alteration in the form of channelization, ditching, and impoundments is a contributing factor to a flashy flow regime, leading to unstable stream channels and high delivery of sediment within the LOWW. Upland erosion from pasture and cropland land uses, in addition to removal of riparian buffers within the watershed, are also contributing factors in some impaired stream reaches (HEI 2015b). It is worth noting that sources of sediment from channel erosion were not measured as part of this investigation. Subsequent studies should investigate the role of channel erosion in TSS impairments.

3.5.1.1 Permitted Sources

The LOWW contains one WWTF (Williams WWTF, NPDES/SDS Permit Number: MN0021679) that contributes to one reach impaired by TSS (09030009-501). The WWTF is a pond-type wastewater treatment plant containing a discharge monitoring station and a 3-cell stabilization pond system (Table 11). General operations for WWTFs such as this are to discharge their treated wastewater into the surface water in the spring/early summer and again in the late fall of each year. The permitted windows for discharges are March through June and September through December. This TMDL study assumes that a portion of the discharge will contain suspended solids from the treatment ponds; therefore, a portion of the WLA is assigned to the WWTF. Table 11 identifies the permitted WWTF in the LOWW that contributes to the TSS impaired reach, and the permitted daily discharge flow. The TSS TMDL for 09030009-501 does not require any change to Williams WWTF's permitted TSS limit.

Table 11: Relevant WWTF permit in the Lake of the Woods Watershed.

Facility	Secondary Pond Size (acres)	Average Wet Weather Design Flow (gpd)[1] /Permitted Max Daily Discharge (gpd)[1] (A*0.163*106)	Liters per Gallon	Permitted Max Daily Discharge (liters/day)[1] (B*C)	Average # of Days Discharging per Year	Permitted TSS Conc. (mg/L)	WLA-TSS (kg/day) (D*F/106)	Kg per Ton	WLA-TSS (tons/ day)	WLA-TSS (tons/yr)
Williams (SD003)	3.4	553,947	3.785	2,096,919	16	45	94.2	907.2	0.1	1.6

3.5.1.2 Non-permitted Sources

There are several major causes of elevated nonpoint sediment that contribute to the TSS impairments within the LOWW. Hydrologic modification within the LOWW is a major source of TSS. Per the Minnesota Statewide Altered Watercourse Project dataset, 64% of the watercourses in the LOWW have been channelized, ditched, or impounded leading to increased channel instability and creation of unstable substrates. This degree of hydrologic alteration results in higher volume and velocity peak flows, creating a "flashy" or unstable flow regime and unstable stream channels. Streams managed for drainage also tend to contribute significant sediment loads downstream (MPCA 2016a; HEI 2016a). Moreover, climatic variation may also impact channel stability within the LOWW (i.e., larger, more frequent storm events).

HSPF is a watershed-scale model that simulates hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. It addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/transformation of chemical constituents in-stream reaches. The output from the HSPF model is used to identify those locations where yields are greatest on average at the subwatershed outlet. Figure 17 displays LOWW HSPF subwatershed priority using Total Sediment. Figure 18 shows the average annual sediment yields (tons/acre/year) by land segments in the LOWW. More information on the LOWW HSPF model's development and calibration can be found in the modeling report (HEI 2015a).

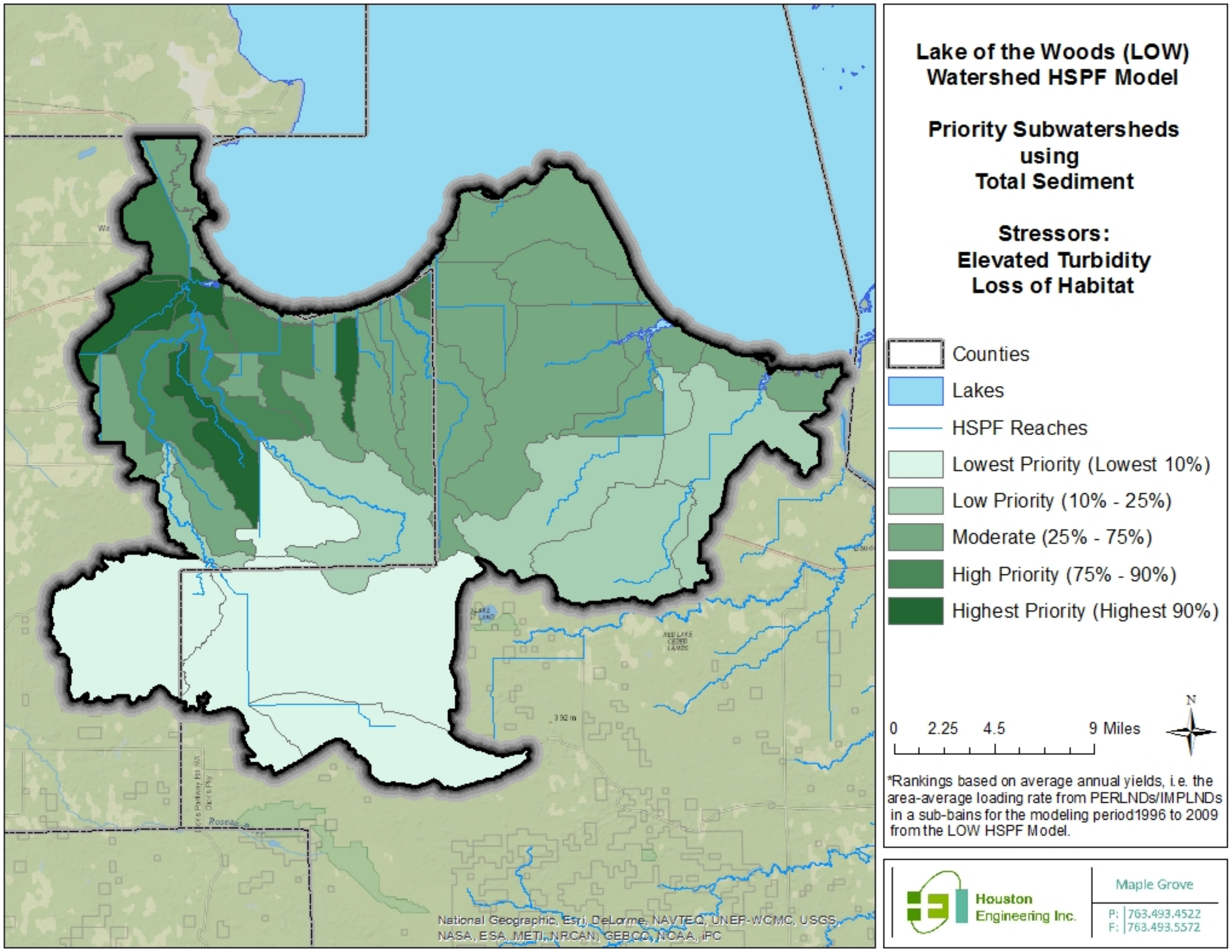


Figure 17: Tributary scale subwatershed priority for implementation for the stressors elevated turbidity and loss of habitat for LOWW using average (1996-2009) annual total sediment yields.

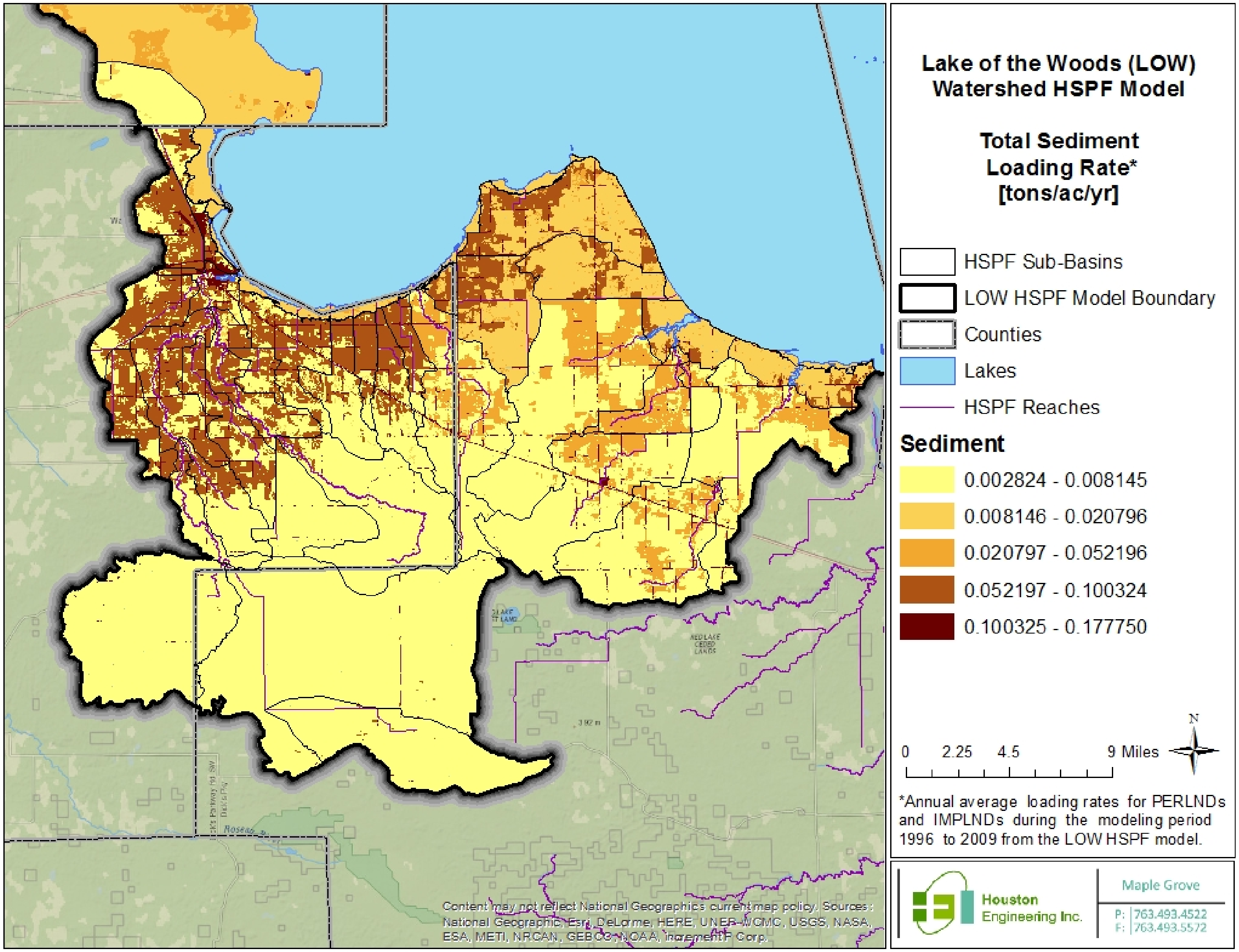


Figure 18: Average annual sediment yield (1996-2009) by land use segment for LOWW from the LOWW HSPF Model.

4. TMDL Development

The TMDLs are developed based on the following equation:

$$\textbf{TMDL = LC = } \sum \textbf{WLA + } \sum \textbf{LA + MOS + RC}$$

Where:

LC = loading capacity, or the greatest amount of a pollutant a waterbody can receive and still meet water quality standards (see Section 4.1.1);

WLA = Wasteload allocation, or the portion of the loading capacity allocated to existing or future permitted point sources (see Section 3.2);

LA = load allocation, or the portion of the loading capacity allocated for existing or future nonpoint sources (see Section 3.3);

MOS = margin of safety, or accounting for any uncertainty associated with attaining the water quality standard. The MOS may be explicitly stated as an added, separate quantity in the TMDL calculation or maybe implicit, as in a conservative assumption (EPA 2007) (see Section 3.4);

RC = reserve capacity, or the portion of the TMDL that accommodates for future loads;

The following sections discuss each component of the LOWW TMDLs in greater detail.

4.1 Total Suspended Solids

4.1.1 Loading Capacity Methodology

The LDC approach was used to compute needed sediment load reductions in the LOWW. To adequately capture different types of flow events and pollutant loading during these events, five flow regimes were identified per EPA guidance: High flow (0% to 10%), Moist Conditions (10% to 40%), Mid-range Flows (40% to 60%), Dry Conditions (60% to 90%), and Low Flow (90% to 100%). Development of the LDCs is discussed in Appendix A.

This TMDL study developed LDCs for three AUIDs (Table 1212 and Figure 19) in the LOWW. No observed, continuous daily streamflow data or USGS gauging stations were available in the LDC reaches. Therefore, simulated daily mean flows from the LOWW HSPF model (RESPEC 2013) were used to create the LDCs. The HSPF model simulates flows from 1995 through 2014. To capture the most recent assessment period, the period 2005 through 2014 was used to develop the LDCs and captures the most recent water quality data in the LOWW.

Table 12: Water quality sites used to develop load duration curves by AUID.

AUID (09030009-XXX)	Water Quality Monitoring Locations	Turbidity/ TSS Data
501	S000-795, S000-906, S003-697	2004-2013
515	S003-699	2004-2013
523	No Water Quality Sites Available (HSPF Model Data)	2005-2014

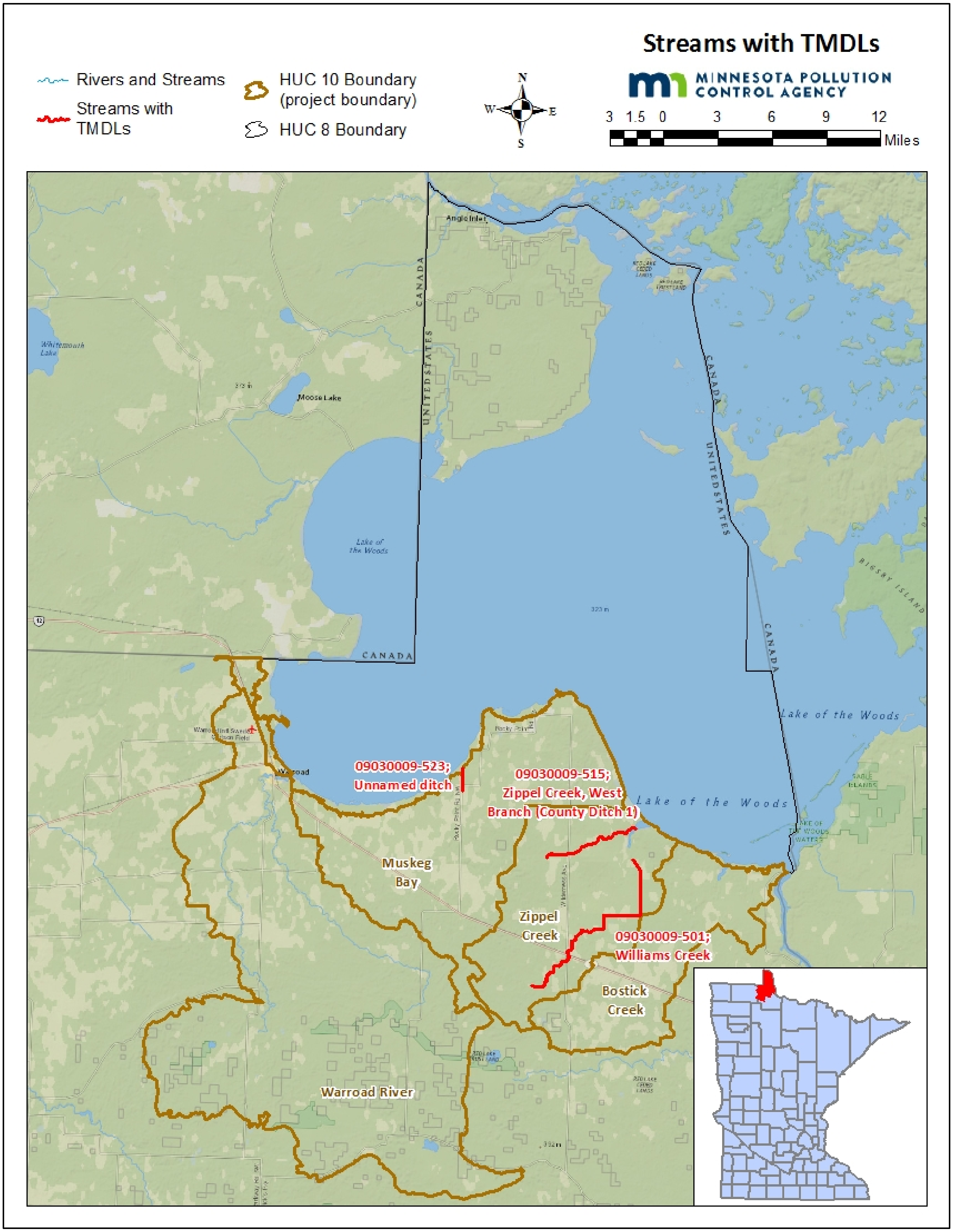


Figure 19: Lake of the Woods Watershed Streams with TMDLs.

There are no water quality chemistry sites located in AUID 09030009-523; therefore, no observed TSS data were available. The HSPF model's sediment load data is used as a surrogate for observed TSS data in that reach.

The TSS LDCs were created using the Northern Region TSS standard of 15 mg/L. The TSS LDCs were calculated using the TSS data collected during the assessment period, April through September. Individual loading estimates were calculated by combining the observed TSS concentration and simulated mean daily flow value on each sampling date. The load estimates were separated by station, mainly for purposes of display on the curve. "Allowable" loading curves were created for the TSS criteria by multiplying each "allowable" concentration (15 mg/L) by the simulated mean daily flow values and ranking the flows. A 10% MOS was applied to each of the "allowable" loading curves. Conversion factors for this work are shown in Table 13**.** Water quality sites used to develop TSS LDCs were shown previously in Table 10**.**

Table 13: Converting flow and concentration to sediment load.

Load (tons/day) = TSS standard (mg/L) * Flow (cfs) * Conversion Factor			
For each flow regime			
Multiply **flow** (cfs) by **28.31** (L/ft^3) and **86,400** (sec/day) to convert	cfs	→	L/day
Multiply **TSS standard** (65 mg/L) by **L/day** to convert	L/day	→	mg/day
Divide **mg/day** by **907,184,740** (mg/ton) to convert	mg/day	→	tons/day

4.1.2 Load Allocation Methodology

The LA represent the portion of the loading capacity designated for nonpoint sources of TSS. The LA is the remaining load once the WLA, reserve capacity, and MOS are determined and subtracted from the loading capacity. The LA includes all sources of TSS that do not require NPDES/SDS permit coverage, including unregulated watershed runoff, internal loading, groundwater, and atmospheric deposition and a consideration for "natural background" conditions. "Natural background" can be described as physical, chemical, or biological conditions that would exist in a waterbody that are not a result of human activity. Nonpoint sources of TSS in the LOWW were previously discussed in Section 3.5.2.

4.1.3 Wasteload Allocation Methodology

The WLA represents the regulated portion of the loading capacity, requiring a NPDES/SDS permit. Regulated sources may include construction stormwater, industrial stormwater, Municipal Separate Storm Sewer Systems (MS4) permitted areas, NPDES/SDS permitted feedlots, and wastewater treatment facilities (WWTF). The regulated TSS contributing sources with WLAs in the LOWW impaired stream reaches are the Williams WWTF and possible construction stormwater and industrial stormwater sources. There are no MS4s or NPDES/SDS permitted feedlots.

Construction and industrial stormwater discharges expected to contribute TSS in the drainage basins of any impaired stream reach were accounted for as 0.1% of the LA. It is expected that in any given year, about 0.1% of the area in a watershed is covered by construction and/or industrial activities. Therefore, it is assumed that 0.1% of the load capacity is contributed to construction and/or industrial activities covered under the state's general construction and industrial stormwater permits.

The Williams WWTF (NPDES/SDS Permit Number: MN0021679) is the only WWTF located in the drainage area of an impaired reach, Williams Creek (AUID 09030009-501). The Williams WWTF is limited to discharging from a secondary treatment cell. The general operation of these facilities is to discharge their treated wastewater into the surface water system in the spring/early summer and again in the late fall of each year. The permitted windows for discharges are in March through June and September through December.

The maximum daily permitted WLA was calculated for the WWTF discharging to a HUC-10 with a TSS impaired reach based on a maximum discharge of six inches per day, per MPCA guidance. The WLA was computed for TSS based on the maximum permitted daily flow rate from the WWTF. The maximum permitted daily and annual TSS WLAs for the WWTF contributing to the TSS impairments are shown in Table 14. The Williams Creek TSS TMDL will not require any change to the WWTF's permitted TSS limit.

Table 14: Annual and daily TSS WLAs for LOWW WWTFs contributing to TSS impaired reaches.

Facility	Secondary Pond Size (acres)	Average Wet Weather Design Flow (gpd)[1] /Permitted Max Daily Discharge (gpd)[1] (A*0.163*106)	Liters per Gallon	Permitted Max Daily Discharge (liters/day)[1] (B*C)	Average # of Days Discharging per Year	Permitted TSS Conc. (mg/L)	WLA-TSS (kg/day) (D*F/106)	Kg per Ton	WLA-TSS (tons/ day) [G/H]	WLA-TSS (tons/yr)
Williams (SD003)	3.4	553,947	3.785	2,096,919	16	45	94.2	907.2	0.1	1.66

4.1.4 Margin of Safety

The purpose of the MOS is to account for any uncertainty with attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, and modeling error. An explicit 10% of the loading capacity MOS was applied to each flow regime for all LDCs developed for this TMDL study. The explicit 10% MOS accounts for:

- Uncertainty in the observed daily flow record;
- Uncertainty in the observed water quality data, including uncertainty associated with the transformation of turbidity data to a TSS surrogate; and
- Allocations and loading capacities are based on flow, which varies from high to low. This variability is accounted for using the five flow regimes and the LDCs.

A 10% MOS is deemed suitable since both the MPCA and USGS estimate that at any given time the record/reported data should be within 10% of the actual value. Therefore, it was assumed that the uncertainty in the observed data is 10% and a 10% MOS is suitable for this TMDL study.

4.1.5 Seasonal Variation

A summary of the TSS load reduction results can be found in Table 15. Results are summarized by indicating the maximum required percent load reduction for each curve and the flow regime and water quality criteria under which this maximum reduction occurred (i.e., the critical flow regime and criteria). The most common critical condition for the TSS standard is high flows.

Table 15: Maximum required TSS load reductions for the Lake of the Woods Watershed.

AUID (09030009-XXX)	TSS Standard	
	Max. % Load Reduction	Critical Flow Regime
501	63%	High Flows
515	77%	High Flows
523	40%	High Flows

4.1.6 Reserve Capacity

No additional reserve capacity was included for the point sources in the LOWW, given the nature of assumptions used to create the WLAs. Similarly, no reserve capacity was included for nonpoint sources in the watershed (LAs), given that the land use in the LOWW is remote and dominated by open water and wetland and is unlikely to substantially change in the future. For more information on future growth and reserve capacity, see Section 5.

4.1.7 TMDL Summary

Table 16, Table 17, and Table 18 show the computed loading capacities and allocations for LOWW streams currently impaired by turbidity/TSS, using the TSS standard. The various components of these allocations were developed as described in Sections 4.2.1 to 4.2.4. The LDCs used to develop the loading capacities and allocations are provided in Figure 20, Figure 21, Figure 22, and Appendix A. It should be noted that the sum of some of the TMDL calculations may not equal the loading capacity of the AUID, due to rounding errors.

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation table of this study, only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is what is ultimately approved by the EPA. The LDCs used to develop the loading capacities and allocations are provided in Figure 20, Figure 21, and Figure 22 (HEI 2016a). It is important to note that all load reduction estimates are based upon HSPF modeling results and may differ from current water quality conditions measured during the Intensive Watershed Monitoring process.

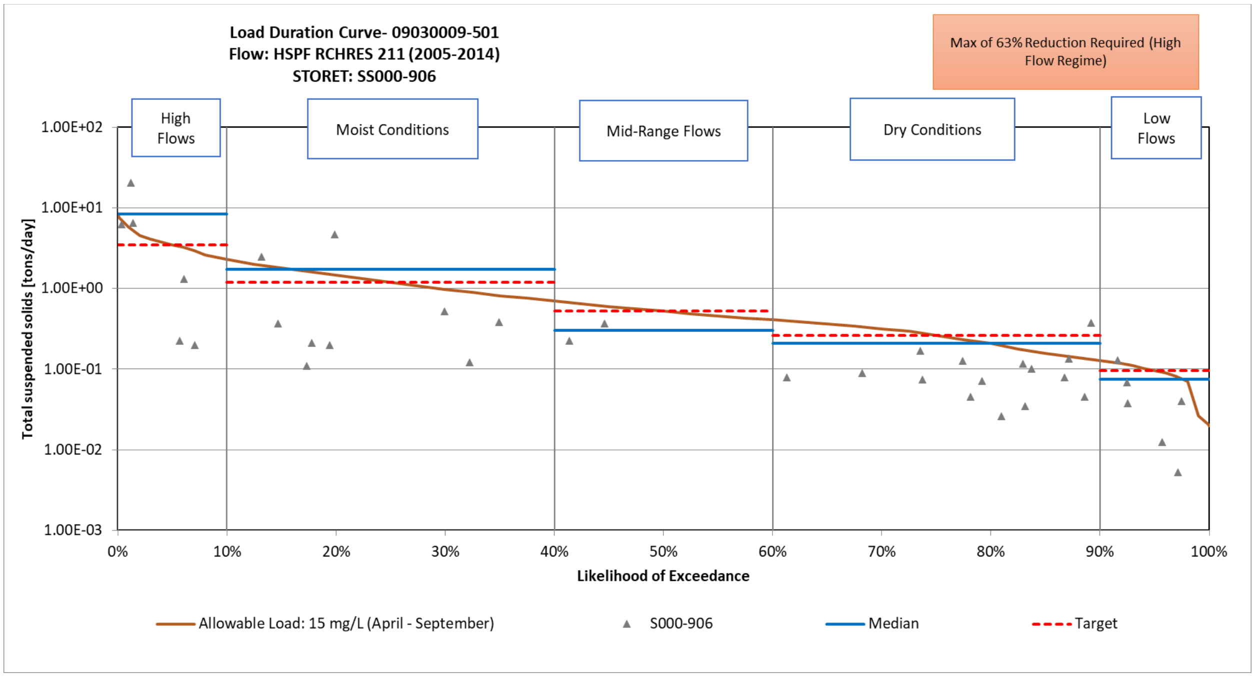


Figure 20: Total Suspended Solids LDC for Williams Creek, Headwaters to Zippel Cr (AUID 09030009-501).

Table 16: Total Suspended Solids loading capacities and allocations for Williams Creek, Headwaters to Zippel Cr (AUID 09030009-501).

Total Suspended Solids		Flow Condition				
		High	Moist Conditions	Mid-Range	Dry Conditions	Low
		[tons/day]				
Loading Capacity		**3.48**	**1.19**	**0.52**	**0.27**	**0.20**
Wasteload Allocation	**Total WLA**	**0.10**	**0.10**	**0.10**	**0.10**	**0.1**
	Williams WWTF	0.1	0.1	0.1	0.1	0.1
	Construction/Industrial Stormwater	0.0035	0.0012	0.0005	0.0003	0.0001
Load Allocation	**Total LA**	**3.03**	**0.97**	**0.37**	**0.14**	**0.09**
Margin of Safety (MOS)		**0.35**	**0.12**	**0.05**	**0.03**	**0.01**
Existing Load		**8.36**	**1.74**	**0.30**	**0.21**	**0.08**
Unallocated Load		**0.00**	**0.00**	**0.22**	**0.06**	**0.12**
Estimated Load Reduction		**58%**	**32%**	**0%**	**0%**	**0%**

Loading capacity, WLA, LA, and MOS are part of the TMDL equation (Section 4) The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity minus the MOS; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

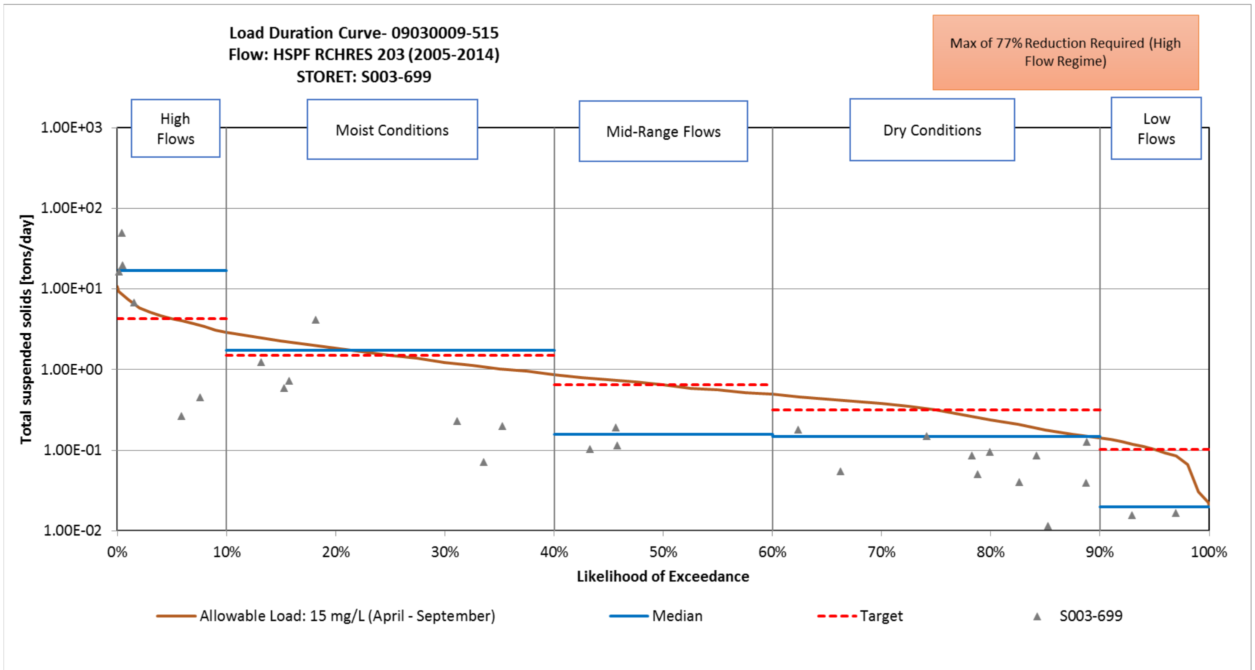


Figure 21: Total Suspended Solids LDC for Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (Lake of the Woods) (AUID 09030009-515).

Table 17: TSS loading capacities and allocations for Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (Lake of the Woods) (AUID 09030009-515).

Total Suspended Solids		Flow Condition				
		High	Moist Conditions	Mid-Range	Dry Conditions	Low
		[tons/day]				
Loading Capacity		**4.31**	**1.50**	**0.64**	**0.32**	**0.10**
Wasteload Allocation	**Total WLA**	**0.0043**	**0.0015**	**0.0006**	**0.0003**	**0.0001**
	Construction/Industrial Stormwater	*0.0043*	*0.0015*	*0.0006*	*0.0003*	*0.0001*
Load Allocation	**Total LA**	**3.87**	**1.35**	**0.58**	**0.28**	**0.09**
Margin of Safety (MOS)		**0.43**	**0.15**	**0.06**	**0.03**	**0.01**
Existing Load		**17.0**	**1.74**	**0.16**	**0.15**	**0.02**
Unallocated Load		**0.0**	**0.0**	**0.49**	**0.17**	**0.08**
Estimated Load Reduction		**75%**	**13%**	**0%**	**0%**	**0%**

Loading capacity, WLA, LA, and MOS are part of the TMDL equation (Section 4) The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity minus the MOS; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

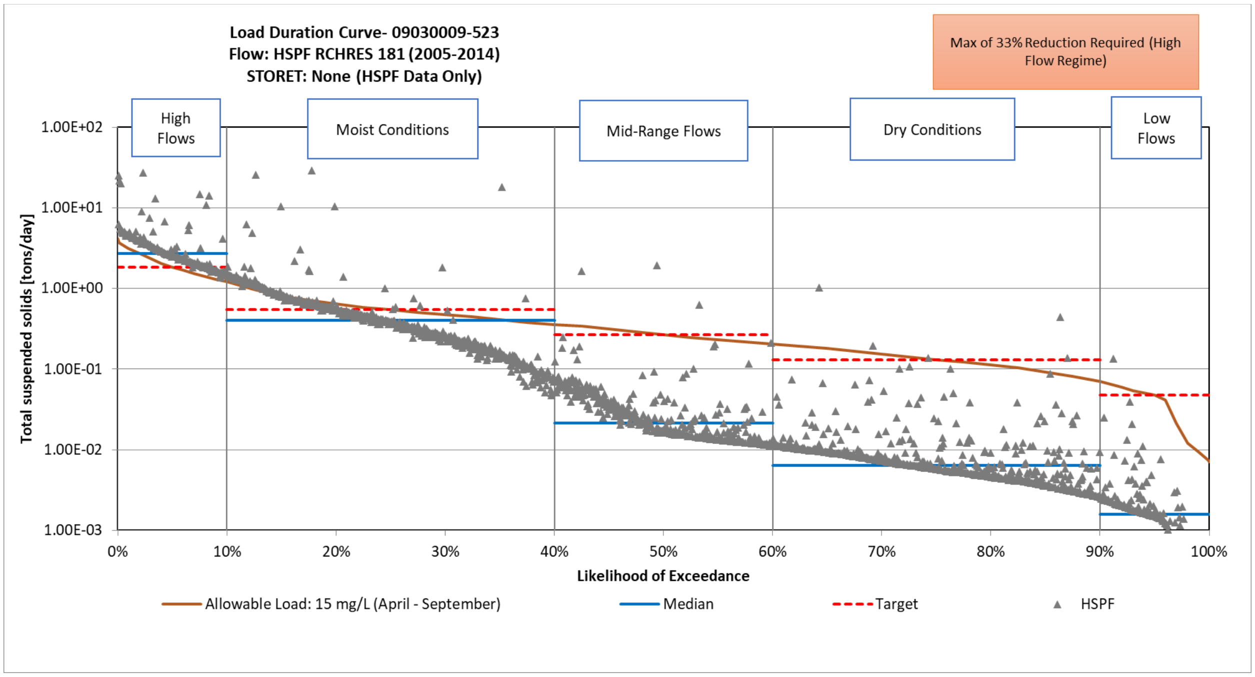


Figure 22: Total Suspended Solids LDC for Unnamed ditch, Unnamed ditch to Unnamed ditch (AUID 09030009-523).

Table 18: TSS loading capacities and allocations for Unnamed ditch, Unnamed ditch to Unnamed ditch (AUID 09030009-523).

Total Suspended Solids		Flow Condition				
		High	Moist Conditions	Mid-Range	Dry Conditions	Low
		[tons/day]				
Loading Capacity		**1.83**	**0.54**	**0.27**	**0.13**	**0.05**
Wasteload Allocation	**Total WLA**	**0.0018**	**0.0005**	**0.0003**	**0.0001**	**0.00005**
	Construction/Industrial Stormwater	*0.0018*	*0.0005*	*0.0003*	*0.0001*	*0.00005*
Load Allocation	**Total LA**	**1.65**	**0.49**	**0.24**	**0.117**	**0.04**
Margin of Safety (MOS)		**0.18**	**0.05**	**0.03**	**0.013**	**0.005**
Existing Load		**2.7**	**0.40**	**0.02**	**0.01**	**0.002**
Unallocated Load		**0.0**	**0.1**	**0.25**	**0.12**	**0.046**
Estimated Load Reduction		**32%**	**0%**	**0%**	**0%**	**0%**

Loading capacity, WLA, LA, and MOS are part of the TMDL equation (Section 4) The existing load is based on available water quality data; the unallocated load is the load, if any, that remains if the existing load is below the load capacity minus the MOS; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

5. Future Growth Considerations

Primary economic forces within the LOWW include agriculture, industry, forestry, and tourism. As the LOWW is predominately open water and wetland, little change in land use is expected in future years. Like much of the Rainy River Basin, land use has changed very little in recent years. Analysis of the 2006 and 2011 NLCD dataset show less than 1% change in land uses in the LOWW between those years. Very minor increases (less than 0.3%) were observed in developed land.

Population within the LOWW experienced a steady increase from the 1970s to the 1990s. The LOWW experienced a period of rapid growth in the 15-year period from 1980 to 1995, with a leveling off since that time. Growth in industry and tourism contributed to this population growth period. Population statistics show a 5% to 15% population increase from 1990 to 2000 within Roseau and Lake of the Woods Counties.

5.1 New or Expanding Permitted MS4 WLA Transfer Process

Future transfer of watershed runoff loads in this TMDL study may be necessary if any of the following scenarios occur within the project watershed boundaries:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. For example: an existing state highway that was outside an urban area at the time the TMDL study was completed, but is now inside a newly expanded urban area, would require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES/SDS permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL study. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment. It is important to note that the LOWW currently does not contain any MS4 permits.

5.2 New or Expanding Wastewater

The MPCA, in coordination with the EPA Region 5, has developed a streamlined process for setting or revising WLAs for new or expanding wastewater discharges to waterbodies with an EPA approved TMDL (MPCA 2012). This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target and will ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying any and all WLAs will be handled by the MPCA, with input and involvement by the EPA, once a permit request or reissuance is submitted. The overall process will use the permitting public notice process to allow for the public and EPA to comment on the permit changes based on the proposed WLA modification(s). Once any comments or concerns are addressed, and the MPCA determines that the new or expanded wastewater discharge is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made.

For more information on the overall process visit the MPCA's TMDL Policy and Guidance webpage.

6. Reasonable Assurance

Reasonable assurance of the load reductions and strategies developed under this TMDL study comes from multiple sources. The WLAs are assured through the issuance and regulation of NPDES/SDS permits. The LAs and their associated nonpoint source implementation strategies are reasonably assured by historical and ongoing collaborations in the LOWW. Several agencies and local governmental units have been and continue to work toward the goal of reducing pollutant loads in the LOWW. Strong partnerships between the Warroad River Watershed District, counties, and Soil and Water Conservation Districts (SWCD) have led to the implementation of conservation practices in the past and will continue to do so into the future. Upon approval of the TMDL study by the EPA, the Lake of the Woods Soil and Water Conservation District (LOW SWCD) and the Roseau SWCD will incorporate the various implementation activities described by this TMDL study (see Section 8) and the LOW WRAPS Report into their Watershed Management Plan (WMP) or their One Watershed One Plan (1W1P), currently under development. The LOW SWCD and the Roseau SWCD are committed to taking lead roles during the implementation of this TMDL study and have the ability to generate revenue and receive grants to finance the implementation items.

In addition to commitment from local agencies, the state of Minnesota has also made a commitment to protect and restore the quality of its waters. In 2008, Minnesota voters approved the Clean Water, Land, and Legacy Amendment to increase the state sales tax to fund water quality improvements. The interagency Minnesota Water Quality Framework (Figure 23) illustrates the cycle of assessment, watershed planning, and implementation to which the state is committed. Funding to support implementation activities under this framework is made available through Minnesota's Board of Water and Soil Resources (BWSR), an agency that the LOW SWCD and Roseau SWCD have received grants from in the past.

The LOW SWCD and Roseau SWCS have the ability to provide funding for projects consistent with those identified within the WMP and/or the 1W1P. The WMP and the 1W1P are required to be updated following a 10-year cycle and future revisions will include projects and methods to make progress toward implementing the goals identified in the TMDL study.

Figure 23: Minnesota Water Quality Framework.

7. Monitoring Plan

The LOW SWCD with support from the Lake of the Woods County Water Plan Committee will continue monitoring priority streams in the county as outlined in the Lake of the Woods County Water Quality Monitoring Plan. This plan also supports a River Watch Program for the Rainy River. Data collected are utilized to prioritize projects and priority areas within the county (LOW SWCD 2015). The Roseau SWCD will also continue water quality monitoring efforts for baseline study on the Warroad River and Willow Creek (Roseau SWCD 2009). The Warroad River Watershed District is working to develop a water quality monitoring plan to help identify baseline conditions (WWWD 2007). As outlined in the Rainy-Lake of the Woods State of the Basin Report, the Lake of the Woods Water Sustainability Foundation (WSF) will continue coordination with appropriate stakeholders, agencies, and organizations to conduct and expand basin-wide monitoring (LOWWSF 2014).

In addition to the stream monitoring sponsored by the Lake of the Woods and Roseau SWCDs, the Warroad River Watershed District, and the Lake of the Woods WSF, the MPCA also has on-going monitoring in the LOWW. The MPCA's major watershed outlet monitoring will continue to provide a long-term on-going record of water quality at the LOW outlet. The MPCA will return to the LOWW under their Intensive Watershed Monitoring program in 2022 through 2024. On-going stream flow monitoring has also been undertaken by the USGS at one site within the LOWW.

8. Implementation Strategy Summary

8.1 Permitted Sources

8.1.1 Construction Stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre expected to be active in the LOWW at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the state's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs, and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL study. All local construction stormwater requirements must also be met.

8.1.2 Industrial Stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the LOWW for which NPDES/SDS industrial stormwater permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the state's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs, and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL study. All local stormwater management requirements must also be met.

8.1.3 MS4

There are no MS4s in the LOWW. Therefore, no implementation strategies were developed for MS4s in the LOWW.

8.1.4 Wastewater

The current requirements of a WWTF's NPDES/SDS permit are sufficient implementation strategies for WWTFs in the LOWW. This TMDL study will not result in any new requirements or reductions for WWTFs in the LOWW. The Wastewater methods and TMDL summary for TSS are summarized in Section 4.2.3 and 4.2.7, respectively.

8.2 Non-Permitted Sources

Water quality restoration and implementation strategies within the LOWW were identified through collaboration with state and local partners. Due to the homogeneous nature of the LOWW, most of the suggested strategies are applicable throughout the LOWW.

The identified implementation strategies and priorities are discussed in the Lake of the Woods WRAPS Report (HEI 2016b) and the LOWW Biotic SID Report (MPCA 2016b). Below is a summary of the suggested strategies needed to achieve restoration goals in the LOWW:

- Prevent or mitigate activities that will further alter the hydrology of the LOWW;
- Improve storage capacity within the LOWW through storage projects;
- Implement water and sediment control basins;
- Pursue opportunities and options to reduce peak flows and augment base flows in streams throughout the LOWW;
- Re-establish natural functioning stream channels wherever possible using natural channel design principles;
- Increase the quantity and quality of instream habitat throughout the LOWW;
- Establish and/or protect riparian corridors along all waterways, including ditches, using native vegetation whenever possible;
- Increase the amount of continuous living cover throughout the LOWW;
- Implement agricultural BMPs to reduce soil erosion from fields;
- Implement agricultural BMPs to reduce delivery of sediment to surface waters (i.e., grass filter strips);
- Limit or exclude the access of livestock to waterways.

The Lake of the Woods and Roseau SWCDs and the Warroad River Watershed District have a long history of water quality protection and improvement. All three have been actively seeking grants to improve local water quality since the passage of the Clean Water, Land, and Legacy Amendment and before.

Five main priority concerns were identified within the Lake of the Woods County 2010 through 2020 Local Water Management Plan, 2015 Amendment including, erosion and sedimentation, land use management, sewage treatment systems and other potential sources of water contamination, water quality, and education. Objectives of these priority concerns addressed within this study include river systems, ditch systems, buffers and riparian corridors, surface water, and sewage treatment systems and other pollution risks.

Between 2010 and 2016, the Lake of the Woods SWCD installed six shoreline stabilization and protection projects, each approximately 100 linear feet, utilizing State Cost Share Program and other funds at approximately $80 per linear foot. In addition, 640 acres of wetland surrounding Graceton Wildlife Management Area were preserved through a wetland banking program. Completion of the Bostic and Zippel Creeks Watershed Assessment also occurred in 2013. The Low Income Septic Upgrade

Grant Program provided by the Lake of the Woods SWCD upgraded over a dozen septic systems over the past five years at a cost of $5,000 to $10,000 per system.

The Lake of the Woods SWCD completed several projects between 2010 and 2016, targeted at reducing pollutant loading from ditch systems. These projects include the installation of side-water inlets, gully stabilization, and modifying ditches to improve water quality. In 2009, a Judicial Ditch was reconstructed using a two stage ditch design at a project expense of $150,000. $61,000 from a Clean Water Fund Grant was used to replace 10 side-water inlets on Zippel Creek. Lastly, the LOW SWCD partnered with the LOW County Highway Department on rock chutes installation concurrent with a county road widening project on County Road 17. Funding was provided utilizing EQIP to accomplish 14 rock chute projects for approximately $4,500 each on Willow Creek and unnamed ditch sections.

The LOW SWCD has identified several river system implementation actions planned for the years 2016 through 2020. These include the implementation of shoreline stabilization projects and education, workshops, and cost-share program assistance to landowners. Additionally, the shoreline erosion program will use inventories and assessments to prioritize and implement solutions to address watershed erosion and sedimentation problems identified in the 2013 Bostic and Zippel Creeks Watershed Assessment (NRCS 2013). Actions targeted for the years 2018 through 2020, are to plan restoration projects on Bostic, Zippel, Warroad Bays, and Pine Creek once upstream erosion has been adequately addressed. Cost and timeline estimates for these restoration projects have not yet been identified. In addition to these future actions, the LOW SWCD will continue to participate in local work groups to address identified erosion and sedimentation issues through priority implementation, targeted education, and technical assistance.

Examples of ongoing planning efforts to reduce pollutant loading from ditch systems by the LOW SWCD are: continue to update the 2010 culvert inventory; educate landowners and agriculture producers on the existence and extents of right-of-ways to assist in drainage infrastructure management; and prevent public infrastructure damage by maintaining funding for local beaver control. Actions targeted between the years of 2016 and 2020 include continued partnerships with the Lake of the Woods and Roseau County Highway Departments on road and ditch projects to implement BMPs with private landowners at the same time as construction of public road and ditch infrastructure. Cost and timeline estimates for these restoration projects have not yet been identified.

In 2014, the LOW SWCD received a Clean Water Fund Grant through BWSR to install an additional 10 side water inlet replacements in the Zippel Subwatershed at a cost of approximately $61,000. Additional projects with unidentified costs and timelines include updating and implementing a drainage management plan and policy for Lake of the Woods County utilizing the drainage committee, and educating and encouraging landowners, county drainage committee, and government officials on BMPs for maintenance of ditches and conservation practices that can be used along ditches, watercourses, and wetlands. Reduction of erosion and sedimentation in the Bostic and Zippel Watersheds by executing the recommendations from the Bostic and Zippel Watershed Assessment Project developed by the NRCS Water Resource Staff and WRAPS process is also planned for implementation, in addition to completion of a drainage record digital inventory (NRCS 2013).

The LOW SWCD has several ongoing efforts targeting the improvement of buffers and riparian corridors on public and private lands, including an inventory of all areas eligible for filter strips, field borders, or riparian buffers. The LOW SWCD will use GIS and the WRAPS process outputs to prioritize sites for erosion control, water quality improvement, and public use value. The LOW SWCD will work with landowners to identify alternative buffer strip options and develop a local buffer strip cost share program. As of 2019, the LOWW has achieved 95% compliance with the DNR Public Waters Buffer Law. The LOW SWCD will continue to encourage qualifying landowners to use buffers, filter strips, and field-border installations.

Actions targeted by the LOW SWCD between the years of 2016 and 2020 for water quality improvements include: ditch abandonments throughout the watershed to restore hydrologic regimes; ditch reconstruction with implementation of BMPs and/or two-stage design; wetland restorations; and assisting all landowners in establishing buffers on their property. Cost and timeline estimates for these implementation actions have not yet been identified.

The LOW SWCD has ongoing efforts to protect and improve surface water quality. These efforts include: ensuring hazard risk management plans are up to date; adequately addressing transportation of hazardous materials; ensuring companies have adequate procedures, equipment, staff, and trainings for local fire departments to be able to address a spill as safely and quickly as possible; reducing feedlot runoff by implementing the Delegated Feedlot Program; providing feedlot owners technical and financial assistance; and coordinating with Canadian agencies to address binational water quality concerns. Cost and timeline estimates for these implementation actions have not yet been identified.

Ongoing efforts identified by the LOW SWCD to manage Sewage Treatment Systems and other potential sources of water contamination include: identifying areas of the county potentially in need of community and cluster sewer systems and holding informational meetings after areas are identified; promoting utilization of community and cluster systems where a surface or ground water pollution potential exists; researching feasibility of performance septic systems; and educating contractors and realtors on ordinance updates and new rules. In addition, the LOW SWCD will complete and maintain an inventory of non-compliant on-site sewage systems, support efforts of the Wheeler's Point Sanitary District for installation and expansion, and work with the county to develop low interest loan programs for septic system upgrades. Information regarding the MPCA's Clean Water Partnership Loan Program for implementing nonpoint-source BMPs can be found here: https://www.pca.state.mn.us/water/cwp-loans. Cost and timeline estimates for these implementation actions have not yet been identified.

Implementation Strategies identified within the 2010 through 2019 Roseau County Local Water Plan include, but are not limited to, the following actions targeted at erosion and sedimentation of surface waters, stormwater runoff, and wetlands: flood control and flood damage reduction; surface water protection and improvement; management of ditch systems; and groundwater protection and quality (Roseau SWCD 2009).

To reduce erosion and sedimentation, the Roseau SWCD will enhance and improve quality of surface waters and wetlands through conservation practices, BMPs, restorations, and structures (including future projects in inventoried sites for side-water inlets). The Roseau SWCD will also provide cost share opportunities to landowners for side-water inlets plus rock weir, rock dams, or rip-rap projects. Cost for these actions will be determined by SWCD staff. Future projects for flood control and damage reduction include: the removal of beavers and beaver dams; raingarden implementation in strategic areas; and the expansion or improvement of gauges in Geenbush, Pelan, and SD#72. Cost estimate for flood control projects is approximately $200,000.

$8,550 plus Roseau SWCD staff time will be used for projects that promote and support the restoration of Warroad River, $85,000 plus Roseau SWCD staff time for proper ditch system care, and maintenance and $14,475 plus Roseau SWCD staff time for the establishment of a cost-share program for septic system protection, quality analysis, and implementation of ordinances.

8.3 Cost

The CWLA requires that a TMDL study include an overall approximation of implementation costs (Minn. Stat. 2007, § 114D.25). Based on cost estimates from current, planned, and proposed work as outlined in the Lake of the Woods and Roseau County Water Management Plans, a reasonable estimate to continue efforts for reducing sediment loading in the impaired reaches, addressed in this study, would be $2.5 to $3 million prior to 2020 (LOW SWCD 2015; Roseau SWCD 2009). Provided cost estimates are in addition to staff time. Funding will be spent primarily on practices such as retention projects, side-water inlets, grassed water ways/filter strips, sediment control basins, cover crops, saturated buffers, and perennial plantings.

8.4 Adaptive Management

Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities (Figure 24). It is an ongoing process of evaluating and adjusting the strategies and activities that will be developed to achieve the goals of the TMDL study. The implementation of practicable controls should take place even while additional data collection and analysis are conducted to guide future implementation actions. Adaptive management does not include changes to water quality standards or loading capacity. Any changes to water quality standards or loading capacity must be preceded by appropriate administrative processes; including public notice and an opportunity for public review and comment.

Findings and recommended strategies from this TMDL study and the WRAPS report were used to inform the implementation components of the comprehensive local water plan developed through the 1W1P process. Implementation of TMDL-related activities can take many years, and water quality benefits associated with these activities can also take many years. As the pollutant source dynamics within the LOWW are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the goals of the TMDL study and lay the groundwork for de-listing the impaired reaches. The follow-up water monitoring program outlined in Section 7 will be integral to the adaptive management approach, providing assurance that implementation measures are succeeding in attaining water quality standards.

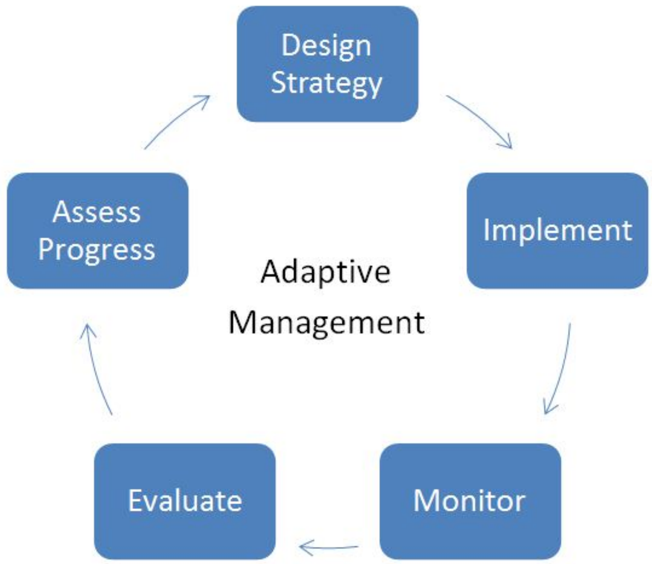


Figure 24: Adaptive management.

9. Public Participation

Public participation during this TMDL study process was a coordinated effort led by the Lake of the Woods SWCD. A TMDL study stakeholder group was identified early in the TMDL study process and kept up to date of actions as the project proceeded. Members of the group included area landowners, representatives from the area SWCDs, counties and townships, and representatives from state agencies (MPCA, DNR, and BWSR). The TMDL study updates were presented through five public meetings in the LOWW during the months of March 2012, October 2012, November 2012, April 2013, and June 2016. In addition, the LOW SWCD developed a project webpage where updates and select reports are be posted. The MPCA also developed a project webpage to keep the public informed of progress.

Since water quality is among the ongoing priorities of the Lake of the Woods and Roseau SCWDs and the Warroad River Watershed District, management activities and future public participation will continue to be led by these three organizations. The watershed district and SWCDs will update, educate, and engage stakeholders on water quality issues through the normal communications, including plan update events and on the LOW SWCD website.

An opportunity for public comment on the draft TMDL study was provided via a public notice in the State Register from November 12, 2019, through December 12, 2019. The MPCA did not receive any comment letters resulting from the public notice.

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Appendix A. Lake of the Woods Watershed Load Duration Curve Development

INTRODUCTION

Appendix A summarizes the methods used and results for creating LDC for impaired stream segments (delineated by AUID numbers) in the LOWW. An LDC was calculated for each of the segments impaired for aquatic life due to TSS standard or high TSS as a stressor for a macroinvertebrate/fish bioassessments impairments. Preparation of the LDCs includes computing the existing loads, the load capacities, and necessary load reductions within each flow regime of the curve, which will be used to develop TMDLs for each of the impaired reaches. A list of the AUIDs addressed by TMDLs is included in Table A-1. Also included, is an indication of the impairments that LDCs will be used to address, a list of water quality monitoring stations located within each AUID and the associated HSPF model subbasin, which was used to represent flows for creating the curves.

Table A-1: AUIDs associated with LDCs, stressors, and data used.

AUID (09030009-XXX)	Reach Name	Stressors	Water Quality Stations	USGS Site or HSPF Flow RCHRES ID
501	Williams Creek, Headwaters to Zippel Cr	Total Suspended Solids, Macroinvertebrate Bioassessment (TSS)[1]	S000-795, S000-906, S003-697	RCHRES 211
515	Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (Lake of the Woods)	Total Suspended Solids, Macroinvertebrate Bioassessment (TSS)[1]	S003-699	RCHRES 203
523	Unnamed ditch, Unnamed ditch to Unnamed ditch	Fish and Macroinvertebrate Bioassessment (TSS)[1]	None	RCHRES 181

[1]TSS LDC developed since TSS identified as a potential stressor.

METHODOLOGY

LDCs were developed for each AUID listed in Table A-1. Each LDC was developed by combining the (simulated or observed) river/stream flow at the downstream end of the AUID with the measured concentrations available within the segment. Methods detailed in the EPA document *An Approach for Using* LDCs *in the Development of TMDLs* were used in creating the curves (EPA 2007). A summary of this methodology, as applied in the LOWW, is provided below. Full details on LDC methods can be found in the EPA guidance (EPA 2007).

Data

Observed daily flow data are very limited within the LOWW and no observed, continuous daily streamflow data or USGS gauging stations were available in the watershed. Therefore, simulated daily mean flows from the LOWW HSPF model (RESPEC 2013) were used to create the LDCs for all the AUIDs. The HSPF model simulates flows from 1995 through 2014. In order to best capture the flow regimes and the most recent assessment period of each AUID, the period 2005 through 2014 was used in development of the LDCs.

The water quality data used in this work were obtained from the MPCA through their EQuIS database. Table A-2 summarizes the water quality sites and data ranges used to develop the LOWW LDCs by AUID. Water quality data from the period 2005 through 2014 were used to develop the LDCs to capture the assessment period used to determine the impairments in the LOWW.

Table A-2: Water quality data used for each LDC.

AUID (09030009-XXX)	Water Quality Monitoring Locations	Turbidity/ TSS Data
501	S000-906	2006-2013
515	S003-699	2006-2013
523	None	NA

Total Suspended Solids LDCs

The TSS LDCs were created using the Northern Region TSS standard of 15 milligrams per liter (mg/L). The TSS LDCs were calculated using the TSS data collected during the assessment period, April through September. Individual loading estimates were calculated by combining the observed TSS concentration and simulated mean daily flow value on each sampling date. The load estimates were separated by station, mainly for purposes of display on the curve. “Allowable” loading curves were created for the TSS criteria by multiplying each “allowable” concentration (15 mg/L) by the simulated mean daily flow values and ranking the flows. A 10% MOS was applied to each of the “allowable” loading curves. In AUIDs 09030009-523, no observed TSS data were available. Therefore, daily sediment concentrations from the HSPF model were used to determine the existing conditions in the reach.

Flow Regimes and LDCs

A system’s water quality often varies based on flow regime, with elevated pollutant loadings sometimes occurring more frequently under one regime or another. Loading dynamics during certain flow conditions can be indicative of the type of pollutant source causing an exceedance (e.g., point sources contributing more loading under low flow conditions). The LDC approach identifies these flow regimes and presents the observed and “allowable” loading within each regime, to compute necessary load reductions. To represent different types of flow events, and pollutant loading during these events, five flow regimes were identified in the LOWW LDCs based on percent exceedance: High Flows (0% to 10%), Moist Conditions (10% to 40%), Mid-range Flows (40% to 60%), Dry Conditions (60% to 90%), and Low Flows (90% to 100%). An example TSS LDC (for AUID 09030009-501) is shown in Figure A-1, identifying the flow regimes.

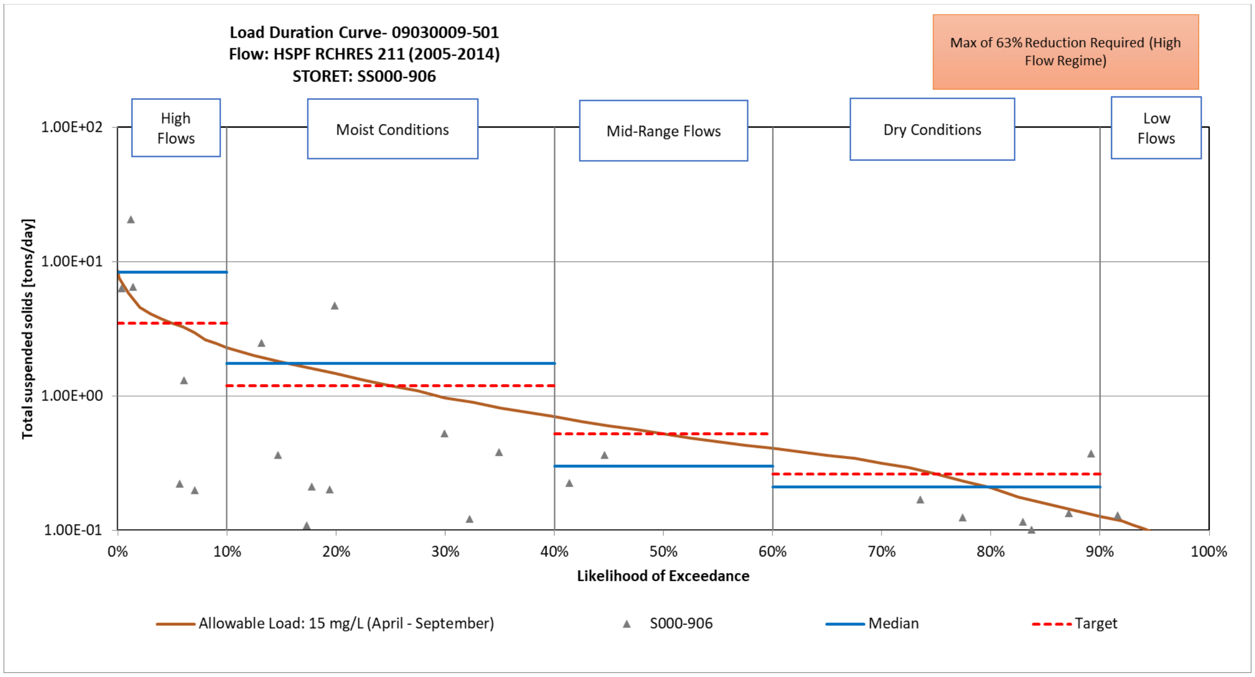

Figure A-1: Example TSS LDC (AUID 09030009-501) showing flow regimes.

The example LDC in Figure A-1 was created with flow and water quality data from April through September. The percent likelihood of flow exceedance is shown on the x-axis, while the computed TSS loading is shown on the y-axis. “Allowable” loadings under each flow condition, based on the water quality standards, is shown with a red line. Observed loads are also shown, indicated by points on the plot. Observed loads are broken out by station, allowing for a detailed examination of when and where loading exceedances have occurred.

RESULTS

Total Suspended Sediment

Total suspended sediment LDCs were developed for all TSS impairments and in biologically impaired reaches were high suspended sediment was identified as a potential stressor. The TSS impaired reaches include AUIDs 09030009-501 and 09030009-515. AUID 09030009-523 is impaired for fish and/or macroinvertebrate bioassessments and high suspended sediment was identified as a potential stressor.

Williams Creek, AUID 09030009-501

A TSS LDC was generated for Williams Creek, Headwaters to Zippel Creek (AUID 09030009-501) and is shown in Figure A-2. The allowable load for the northern nutrient region TSS standard of 15 mg/L is shown as a red dashed line in Figure A-2. AUID 09030009-501 is listed on the federal 303(d) list for low dissolved oxygen (DO), turbidity, fish bioassessment, and macroinvertebrate bioassessment. The LDC was generated to address the turbidity impairment. Table A-3 shows the observed loads, allowable loads, and load reductions for the five flow regimes. As shown in Table A-3, a maximum of 58% reduction during the high flows regime is needed to meet the TSS numeric water quality standard.

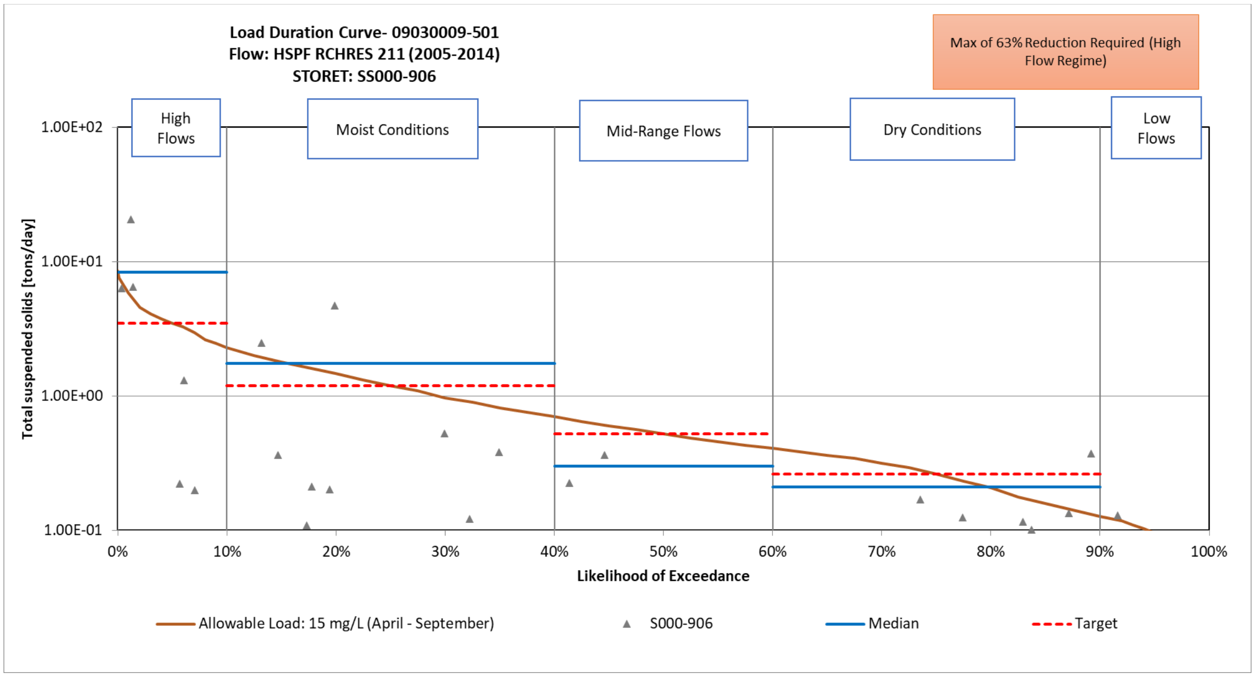

Figure A-2: Williams Creek, Headwaters to Zippel Cr (AUID 09030009-501) TSS LDC.

Table A-3: Williams Creek, Headwaters to Zippel Cr (AUID 09030009-501) TSS Load Reductions.

Flow Regime	Median Flow [cfs]	Observed Concentration [mg/L]	Observed Load [tons/day]	Target Load [tons/day]	Load minus MOS [tons/day]	Load Reduction [tons/day]	Percent Load Reduction
0%-10%	86.1	36.0	8.36	3.5	3.1	5.22	58%
10%-40%	29.5	21.9	1.74	1.2	1.1	0.67	32%
40%-60%	13.0	8.6	0.30	0.5	0.5	-0.17	-57%
60%-90%	6.5	12.0	0.21	0.3	0.2	-0.03	-13%
90%-100%	2.37	11.8	0.08	0.2	0.1	-0.01	-14%

Zippel Creek, AUID 09030009-515

A TSS LDC was generated for Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (AUID 090030009-515) and is shown in Figure A-3. The allowable load for the northern nutrient region TSS standard of 15 mg/L is shown as a red dashed line in Figure A-3. AUID 09030009-515 is listed on the federal 303(d) list for TSS, fish bioassessment, macroinvertebrate bioassessment, and low DO. The LDC was generated to address the TSS TMDL. Table A-4 shows the observed loads, allowable loads, and load reductions for the five flow regimes. As shown in Table A-4, a maximum load reduction of 75% load reduction during high flow conditions is required to meet the TSS numeric water quality standard.

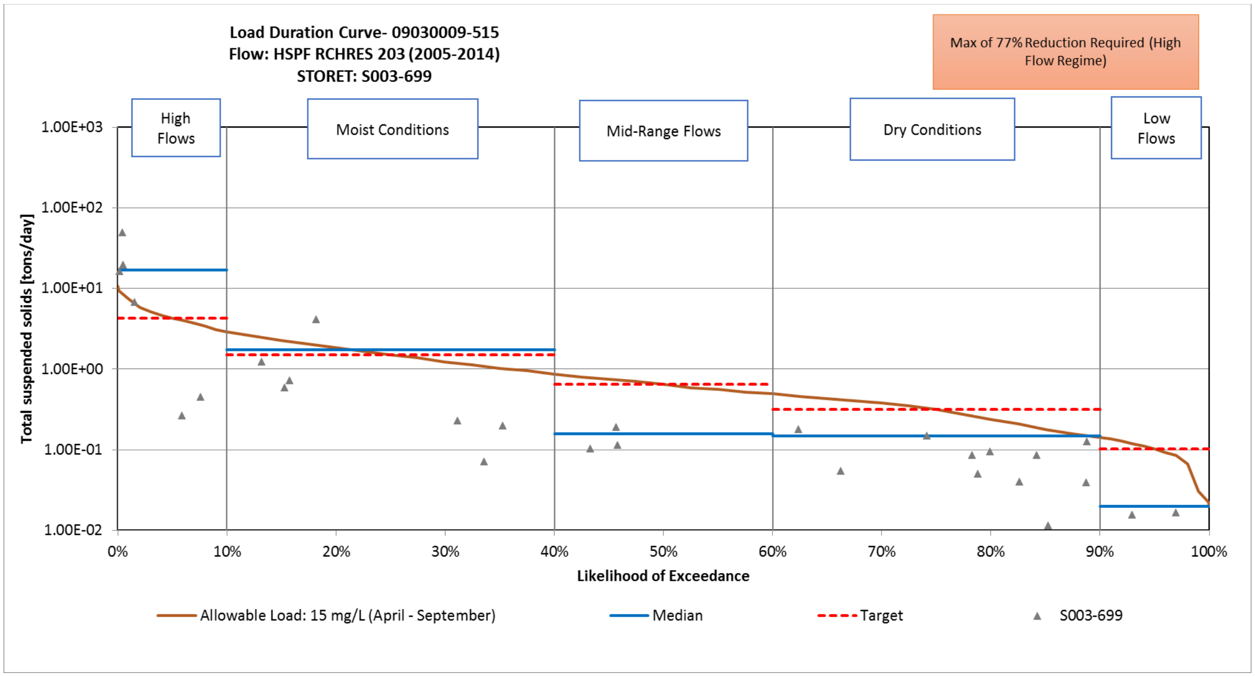

Figure A-3: Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (AUID 090030009-515) TSS LDC.

Table A-4: Zippel Creek, West Branch (County Ditch 1), Headwaters to Zippel Bay (AUID 090030009-515 TSS Load Reductions.

Flow Regime	Median Flow [cfs]	Observed Concentration [mg/L]	Observed Load [tons/day]	Target Load [tons/day]	Load minus MOS [tons/day]	Load Reduction [tons/day]	Percent Load Reduction
0%-10%	106.5	59.0	16.95	4.3	3.9	13.07	75%
10%-40%	37.2	17.4	1.74	1.5	1.4	0.39	13%
40%-60%	15.9	3.7	0.16	0.6	0.6	-0.42	-267%
60%-90%	7.8	7.0	0.15	0.3	0.3	-0.14	-93%
90%-100%	2.53	2.9	0.02	0.1	0.1	-0.07	-366%

Unnamed Ditch, AUID 09030009-523

A TSS LDC was generated for Unnamed ditch, Unnamed ditch to Unnamed ditch (AUID 09030009-523) and is shown in Figure A-4. The allowable load for the northern nutrient region TSS standard of 15 mg/L is shown as a red dashed line in Figure A-4. AUID 09030009-523 is listed on the federal 303(d) list for macroinvertebrate and fish bioassessments. The LDC was generated to address the portion of the biological impairment potentially caused by the high suspended sediment stressor. There are no observed TSS records in the reach; therefore, HSPF sediment data was used to estimate the existing loads. Table A-5 shows the observed loads, allowable loads, and load reductions for the five flow regimes. As shown in Table A-5, a maximum load reduction of 32% load reduction during high flow conditions is required to meet the TSS numeric water quality standard.

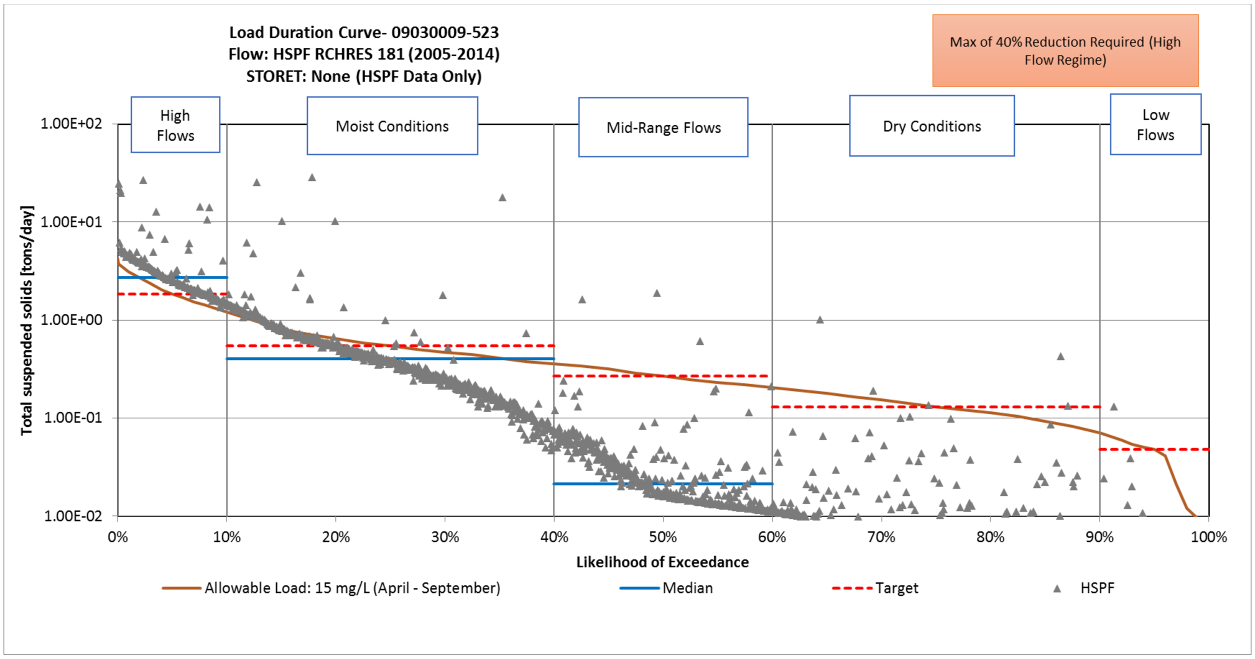

Figure A-4: Unnamed ditch, Unnamed ditch to Unnamed ditch (AUID 09030009-523) TSS LDC.

Table A-5: Unnamed ditch, Unnamed ditch to Unnamed ditch (AUID 09030009-523) TSS Load Reductions.

Flow Regime	Median Flow [cfs]	Observed Concentration [mg/L]	Observed Load [tons/day]	Target Load [tons/day]	Load minus MOS [tons/day]	Load Reduction [tons/day]	Percent Load Reduction
0%-10%	45.3	22.4	2.74	1.8	1.6	1.09	32%
10%-40%	13.4	11.1	0.40	0.5	0.5	-0.09	-22%
40%-60%	6.6	1.2	0.02	0.3	0.2	-0.22	-1027%
60%-90%	3.2	0.7	0.01	0.1	0.1	-0.11	-1738%
90%-100%	1.18	0.5	0.00	0.0	0.0	-0.04	-2593%

Critical Condition

A summary of the TSS standard load reduction results can be found in Table A-6. Results are summarized by indicating the maximum required percent load reduction for each curve and the flow regime and water quality criteria under which this maximum reduction occurred (i.e., the critical flow regime and criteria).

Table A-6: Maximum required TSS load reductions for the LOWW.

AUID (09020311-XXX)	Max. % Load Reduction	Critical Flow Regime
501	58%	High
515	75%	High
523	32%	High

CONCLUSION

Total Suspended Solid standard LDCs were developed for three AUIDs in the LOWW based on impairment or stressor status. The curves were developed following the methods in the EPA guidance document, *An Approach for Using* LDCs *in the Development of TMDLs* (EPA 2007). Existing loads, load capacities, and load reductions from the LDCs will be used to develop the TMDLs in the impaired reaches of the LOWW.

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