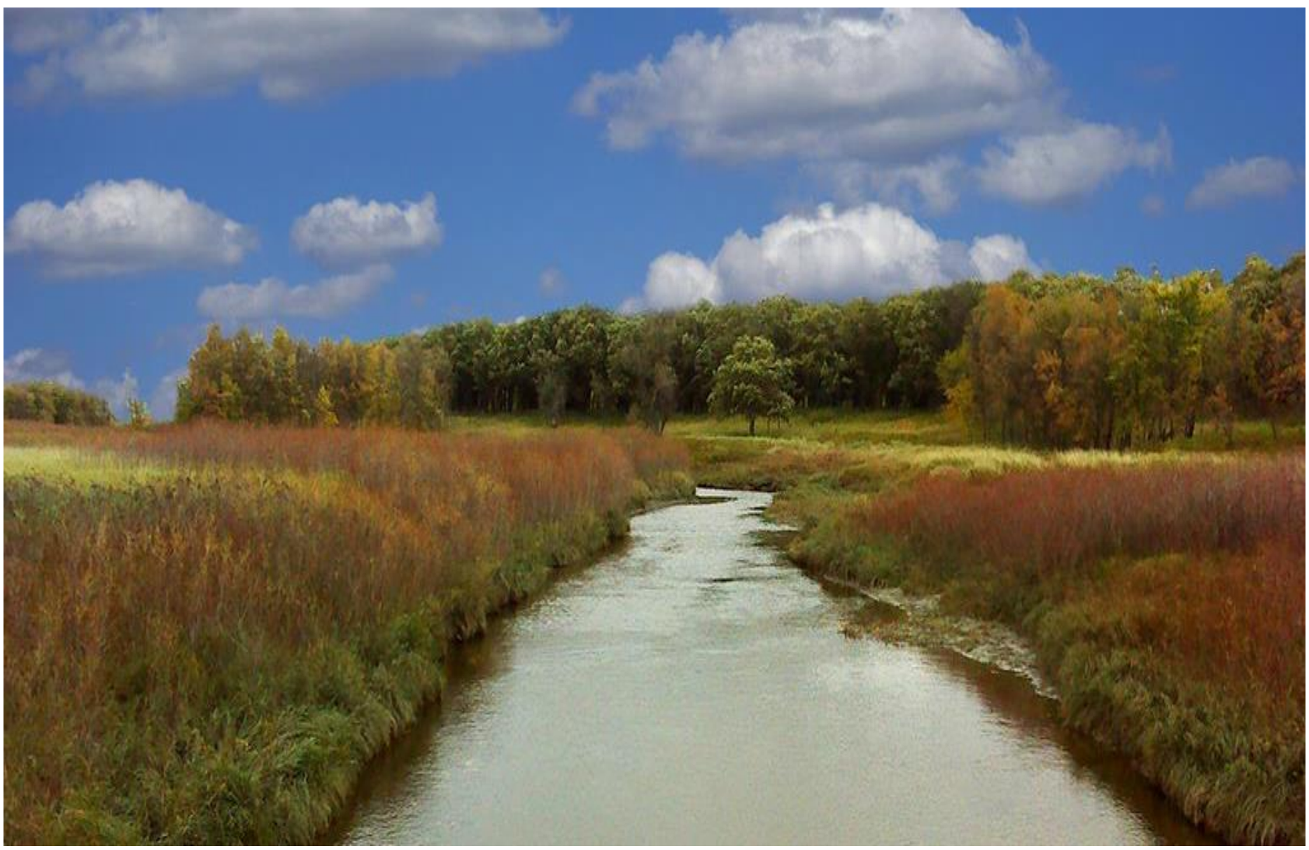
Watershed

June 2019

Two Rivers Watershed Total Maximum Daily Load Report



MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Acronyms

AU	animal unit
AUID	Assessment Unit ID
BMP	best management practice
BWSR	Minnesota Board of Water and Soil Resources
CAFO(s)	Concentrated Animal Feeding Operation(s)
DO	dissolved oxygen
DNR	Minnesota Department of Natural Resources
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
gpd	gallons per day
HSPF	Hydrological Simulation Program-FORTRAN
HUC	Hydrologic Unit Code
kg	kilogram
LA	load allocation
LC	loading capacity
LDC	load duration curve
LGU	Local Government Unit
mg/L	milligrams per liter
mgd	million gallons per day
mL	milliliter
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
org	organism
RC	reserve capacity
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation District

TMDL	total maximum daily load
TRW	Two Rivers Watershed
TRWD	Two Rivers Watershed District
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WRAPS	Watershed Restoration and Protection Strategy
WWTF	Wastewater Treatment Facility

Executive Summary

The Clean Water Act (1972) requires each state to identify any waterbody that is deemed impaired by state regulations, and to develop a Total Maximum Daily Load (TMDL) study for each waterbody impairment. In Minnesota, the Minnesota Pollution Control Agency (MPCA) is tasked with assessing and listing waterbodies that do not meet water quality standards (Minn. R. 7050.022). A TMDL identifies the pollutant sources causing the impairment, estimates how much pollutant can enter a waterbody and still allow it to meet the water quality standards, and allocates pollutant loads to sources.

The Two Rivers Watershed (TRW; Hydrologic Unit Code [HUC] 09020312), located in northwest Minnesota (**Figure 1-1**), comprises approximately 1,098 square miles and includes portions of Kittson, Roseau, and Marshall Counties. There are an additional 3.6 square miles of this watershed that extend into Canada, but TMDLs in this report do not apply within the jurisdiction of Canada, and meeting the goals of the TMDL is not dependent upon obtaining reductions from the portion of the watershed in Canada. The TRW consists of three branches of the Two Rivers, the North Branch, Middle Branch, and South Branch, all generally flowing east-to-west and joining to form the main stem (Two River), three miles east of its outlet into the Red River of the North near the Minnesota-North Dakota border; there are also many ditches and tributaries in the TRW that drain into the Two Rivers system. Land use within the TRW is predominantly agriculture.

The MPCA has 16 TRW stream reaches and 1 TRW lake listed on Minnesota's approved 2018 303(d) list as having impaired water quality (i.e., not meeting the standards that have been set for them) and needing a TMDL study. These streams and lake contain a total of 30 impairment listings: 2 for turbidity, 5 for *Escherichia coli* (*E. coli*), 13 for fishes bioassessment, 7 for aquatic macroinvertebrate bioassessment, 2 for dissolved oxygen (DO), and 1 for mercury in fish tissue (the only lake impairment). This TMDL report addresses seven of the existing impairments, two for turbidity and five for *E. coli*. TMDLs were not developed for the 20 biological (fish and aquatic macroinvertebrates) impairments, because they were either caused by stressors that are nonconventional pollutants (e.g., lack of habitat, altered hydrology); or they were caused by conventional pollutant stressors (total suspended solids [TSS] and/or DO), but the standards for those pollutants were either not exceeded or there was a lack of data. The 2 DO impairments are expected to be addressed with future TMDL studies; there are insufficient DO data to develop the TMDLs within this report. The mercury impairment will be addressed in the future as part of the Minnesota Statewide Mercury TMDL Study.

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 studies, Hydrological 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 stream: watershed runoff, loading from upstream sources, atmospheric deposition, 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 Two Rivers Watershed Restoration and Protection Strategy (WRAPS) process uses the findings from this TMDL report to guide the development of its implementation strategies. The purpose of the WRAPS process is to support local working groups and jointly develop scientifically-supported restoration and protection strategies. These implementation strategies are intended to meet the TMDL goals outlined in this document. Concurrently with this TMDL report, the WRAPS report, as well as numerous other technical reports referenced in this document, will be publicly available on the MPCA's Two Rivers Watershed website located at: https://www.pca.state.mn.us/water/watersheds/two-rivers.

1. Project Overview

1.1 Purpose

The Two Rivers Watershed (TRW) is located in northwest Minnesota and comprises approximately 1,098 square miles within Kittson, Roseau, and Marshall Counties (**Figure 1-1**). There are an additional 3.6 square miles of this watershed that extend into Canada, but TMDLs in this report do not apply within the jurisdiction of Canada and meeting the goals of the TMDL is not dependent upon obtaining reductions from the portion of the watershed in Canada. The TRW is located in the Red River of the North Basin and the boundary spans two Level III EPA Ecoregions: The Glacial Lake Agassiz Plains (LAP) and Northern Minnesota Wetlands (NMW) Ecoregions. Land cover is predominantly agricultural (64%) along with approximately 16% wetland cover, 10% forest, and the remaining 10% comprises several other land cover types. Municipalities located within the TRW include Badger, Greenbush, Hallock, Halma, Lake Bronson, Lancaster, and Strathcona.

In 2006, Minnesota passed the Clean Water Legacy Act (CWLA), in part, to protect, restore, and preserve the quality of Minnesota's surface waters. As a result, the MPCA established a watershed approach to restore and protect Minnesota's waters. One component of that approach is to complete TMDL studies for the impaired waterbodies within each watershed and develop a watershed-wide TMDL report. This TMDL report is intended to fulfill the TMDL requirement.

The MPCA has 16 TRW streams and 1 TRW lake on the approved 2018 303(d) list as having impaired water quality (i.e., not meeting water quality standards) and needing a TMDL study. These waterbodies contain a total of 30 impairment listings: 2 for DO, 5 for *E. coli*, 13 for fish bioassessment, 7 for macroinvertebrate bioassessment, 2 for turbidity, and 1 for mercury in fish tissue (the only lake impairment). TMDLs were developed to address the 5 *E. coli* and 2 turbidity impairments. A TMDL is defined as the maximum quantity of a pollutant that a waterbody can receive while meeting the (numeric) water quality standards for beneficial uses. The TMDL apportions the maximum load between point sources (i.e., a wasteload allocation [WLA] to sources, which are authorized by a 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.

TMDLs were not developed for the remaining 23 impairments. They were not developed for the 20 biological (fish and aquatic macroinvertebrates) impairments, because they were either caused by stressors that are nonconventional pollutants (e.g., lack of habitat, altered hydrology); or they were caused by conventional pollutant stressors (total suspended solids [TSS] and/or DO), but the standards for those pollutants were either not exceeded or there was a lack of data. The two DO impairments are expected to be addressed with future TMDL studies; there are insufficient DO data to develop the TMDLs within this report. The mercury impairment will be addressed in the future as part of the Minnesota Statewide Mercury TMDL Study.

In January 2015, EPA approved Minnesota's switch from a turbidity standard, to represent sediment in a waterbody, to a TSS standard. Although the turbidity standard is no longer used, at the time of publication, stream reaches in the TRW are still listed as having impaired aquatic life due to elevated turbidity on the MPCA's approved 2018 Impaired Waters List[1]. Therefore, for purposes of this TMDL report, the impairments will be listed as turbidity, but the TMDLs will be for TSS.

1.2 Identification of Waterbodies

There are currently 29 impairments in 16 stream reaches, and 1 impairment in 1 lake, on the approved 2018 303(d) impaired waterbodies list in the TRW. These include:

- 2 DO impairments, not supporting aquatic life use;
- 5 *E. coli* impairments, not supporting aquatic recreation use;
- 13 fish bioassessment impairments, not supporting aquatic life use;
- 7 macroinvertebrate bioassessment impairments, not supporting aquatic life use;
- 2 turbidity impairments, not supporting aquatic life use; and
- 1 mercury in fish tissue impairment, not supporting aquatic consumption use (the lake impairment).

Table 1-1 lists the impaired waterbodies by a numeric Assessment Unit Identifier (AUID). This TMDL report addresses 7 of the 30 impairments in the TRW (**Table 1-1**, **Figure 1-1**), including 6 AUIDs with 5 *E. coli* impairments and 2 turbidity impairments. The remaining impairments are not addressed for several reasons.

For the DO impairments, there is not sufficient water quality data to identify the causes of the impairments; therefore, these will be addressed in future TMDL studies when sufficient data becomes available.

The mercury in fish tissue impairment will be addressed as part of the Minnesota Statewide Mercury TMDL Study.

Of the 13 fish and 7 macroinvertebrate impairments in 13 AUIDs, the available evidence "somewhat supports" high suspended sediment as a candidate cause for 1 fish and 4 macroinvertebrate impairments in 5 AUIDs (MPCA 2016a). The available existing water quality data (see **Table 3-5**) for these five stream reaches show: (1) no exceedance of the TSS water quality standard, or (2) no/limited TSS data is available. Therefore, no TSS TMDLs were calculated for these stream reaches. Twelve fish and 5 macroinvertebrate impairments on 12 AUIDs have low DO listed as a stressor but no TMDL was developed because DO meets standards on one of the AUIDs and DO data is limited on the remaining 11 AUIDs. More data is needed to determine whether these remaining 11 biologically impaired AUIDs are impaired due to low DO, and, if any of them are, to identify the root cause of the low DO (a nonconventional cause such as low flow is very possible in this watershed). One fish and 1 macroinvertebrate bioassessment impairments have primary stressors that are not conventional pollutants (i.e., connectivity, altered hydrology, and habitat) and are not addressed in this TMDL report. Re-categorization to 4C for these two impairments will be pursued in 2019.

[1] https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list

Table 1-1: 2018 303(d) list information for impaired waterbodies in the TRW.

Affected Use: Pollutant/ Stressor	AUID/ Lake ID	Stream or Lake Name	Location/Reach Description	Designated Use Class	Listing Year	Target Completion Year
Aquatic Life: Dissolved Oxygen	09020312-504	Two River, North Branch	Headwaters to CD 22	2B, 3C	2010	2027[3]
	09020312-508	Two Rivers, North Branch	CD 22 to Two R	2B, 3C	2010	2027[3]
Aquatic Recreation: *Escherichia coli*	09020312-501	Two Rivers	M Br Two R to N Br Two R	2B, 3C	2010	2018
	09020312-503	Two River, Middle Branch	CD23 to S Br Two R	1C, 2Bd, 3C	2016	2018
	09020312-505	Two River, South Branch	Lateral Ditch 2 to Lk Bronson	1C, 2Bd, 3C	2016	2018
	09020312-506	Two River, South Branch	Unnamed ditch to Lateral Ditch 2 SD 95	1C, 2Bd, 3C	2016	2018
	09020312-535	County Ditch 13	Unnamed ditch to Badger Cr (disconnected portion)	2B, 3C	2016	2018
Aquatic Life: Fish Bioassessment	09020312-502	Two Rivers, South Branch	Lk Bronson to M Br Two R	1C, 2Bd, 3C	2016	2018[2]
	09020312-503	Two River, Middle Branch	CD23 to S Br Two R	1C, 2Bd, 3C	2002	2018[2]
	09020312-504	Two River, North Branch	Headwaters to CD 22	2B, 3C	2002	2018[2]
	09020312-505	Two River, South Branch	Lateral Ditch 2 to Lk Bronson	1C, 2Bd, 3C	2016	2018[2]
	09020312-506	Two River, South Branch	Unnamed ditch to Lateral Ditch 2 SD 95	1C, 2Bd, 3C	2002	2018[2]
	09020312-508	Two Rivers, North Branch	CD 22 to Two R	2B, 3C	2016	2018[1]
	09020312-514	State Ditch 84	Headwaters to N Br Two R	2B, 3C	2016	2018[2]
	09020312-521	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 95	2B, 3C	2016	2018[2]
	09020312-522	County Ditch 4	Unnamed ditch to Unnamed ditch	2B, 3C	2016	2018[2]
	09020312-531	State Ditch 72	JD 31 to State Ditch 85	2B, 3C	2016	2018[2]
	09020312-539	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 50	2B, 3C	2016	2018[2]

Affected Use: Pollutant/ Stressor	AUID/ Lake ID	Stream or Lake Name	Location/Reach Description	Designated Use Class	Listing Year	Target Completion Year
Aquatic Life: Fish Bioassessment (cont.)	09020312-544	State Ditch 49	Headwaters to S Br Two R	2B, 3C	2016	2018[2]
	09020312-549	Judicial Ditch 31	Unnamed cr to N BR Two R	2B, 3C	2016	2018[2]
Aquatic Life: Macro-invertebrate Bioassessment	09020312-502	Two Rivers, South Branch	Lk Bronson to M Br Two R	1C, 2Bd, 3C	2016	2018[2]
	09020312-503	Two River, Middle Branch	CD23 to S Br Two R	1C, 2Bd, 3C	2016	2018[1]
	09020312-505	Two River, South Branch	Lateral Ditch 2 to Lk Bronson	1C, 2Bd, 3C	2016	2018[1]
	09020312-506	Two River, South Branch	Unnamed ditch to Lateral Ditch 2 SD 95	1C, 2Bd, 3C	2016	2018[1]
	09020312-521	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 95	2B, 3C	2016	2018[2]
	09020312-531	State Ditch 72	JD 31 to State Ditch 85	2B, 3C	2016	2018[2]
	09020312-539	Lateral Ditch 1 of State Ditch 95	Unnamed ditch to State Ditch 50	2B, 3C	2016	2018[1]
Aquatic Life: Turbidity	09020312-501	Two Rivers	M Br Two R to N Br Two R	2B, 3C	2006	2018
	09020312-509	Two Rivers	N Br Two R to Red R	2B, 3C	2008	2018
Aquatic Consumption: Mercury in Fish Tissue	35-0003-00	Bronson	Lake or Reservoir	1C, 2Bd, 3C	2016	2029

[1]Elevated Turbidity/Excessive Suspended Sediment identified as a “somewhat supportive” stressor but existing water quality data (see Table 3-5) shows no exceedances of standard. Therefore, no TSS TMDL study will be performed for this AUID.

[2]No conventional pollutant identified as primary stressor, no TMDL study will be performed. TALU was used for the assessment process.

[3]No DO TMDL study will be performed due to lack of useful data.

☐ Addressed in this TRW TMDL Report.

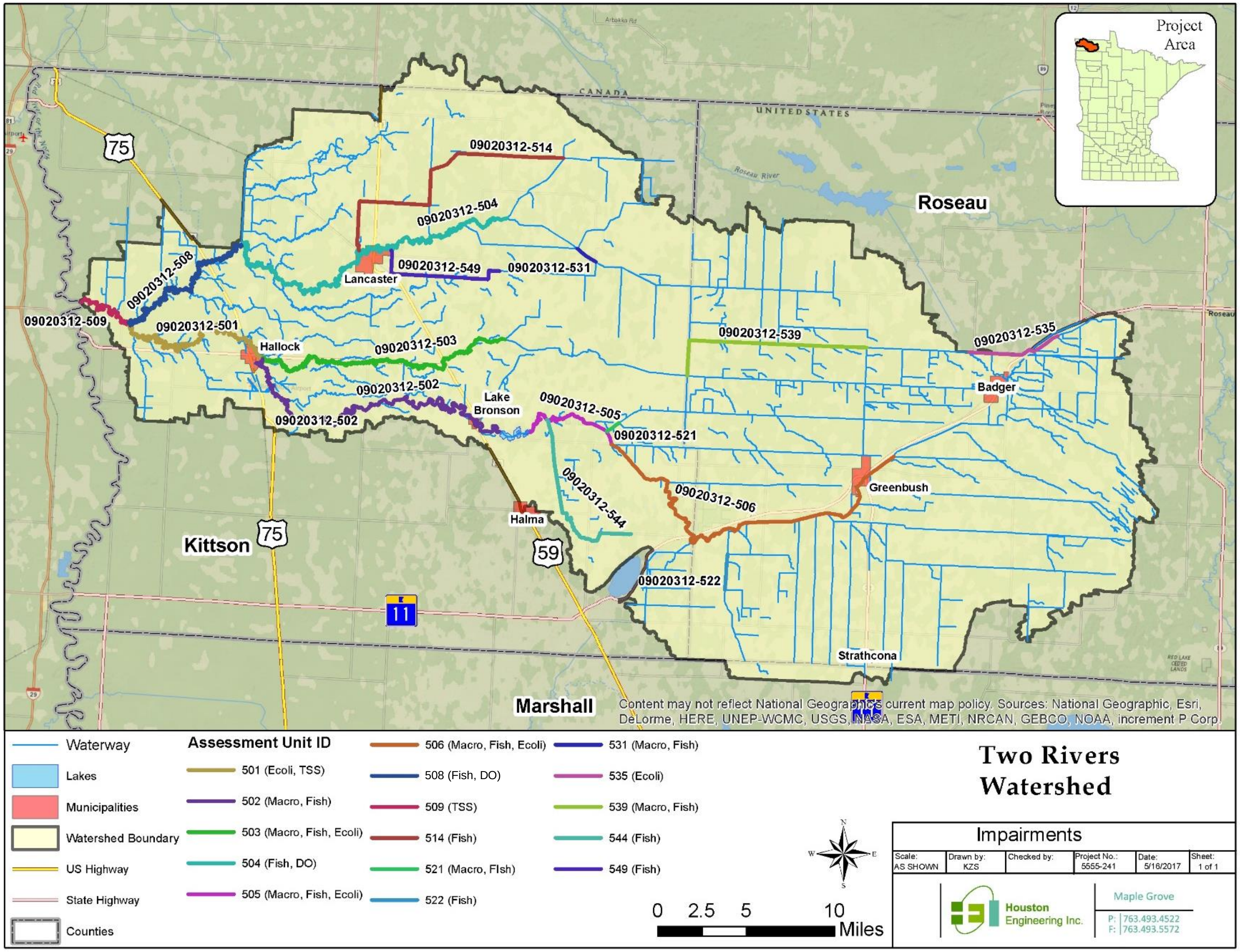

Figure 1-1: TRW stream impairments on the approved 2018 303(d) list.

1.3 Priority Ranking

The MPCA's schedule for TMDL completions, as indicated on the approved 2018 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. The MPCA has aligned TMDL priorities with the watershed approach and our WRAPS cycle. The schedule for TMDL completion corresponds to the WRAPS report completion on the 10-year cycle. The MPCA developed a state plan 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 Clean Water Act Section 303(d) Program. As part of these efforts, MPCA identified water quality impaired segments that will be addressed by TMDLs by 2022. TRW waters addressed by this TMDL are part of that the MPCA prioritization plan to meet the EPA's national measure.

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[2]). 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 report are classified as Class 2Bd, 2B, or 2C waters (MPCA 2016b).

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).

Class 2B waters - The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated 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 water is not protected as a source of drinking water (Minn. R. 7050.0222, subp. 4).

Class 2C waters - The quality of Class 2C surface waters shall be such as to permit the propagation and maintenance of a healthy community of indigenous fish and associated aquatic life, and their habitats. These waters shall be suitable for boating and other forms of aquatic recreation for which the waters may be usable (Minn. R. 7050.0222, subp. 5).

[2] https://www.revisor.mn.gov/rules/?id=7050

2.1 Lakes

Within the TRW, Lake Bronson (35-0003-00) is listed on the approved 2018 303(d) list as being impaired due to mercury in fish tissue (does not support aquatic consumption). However, this impairment will be addressed in the Minnesota Statewide Mercury 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 TRW stream impairments in this TMDL report are shown in **Table 2-1**, while **Table 1-1** shows the specific water bodies affected.

Table 2-1: Surface water quality standards for TRW stream reaches addressed in this TMDL report.

Parameter	Water Quality Standard	Units	Criteria	Period of Time Standard Applies
Escherichia coli (*E. coli*)	Not to exceed 126	org/100 mL	Monthly geometric mean	April 1-October 31
	Not to exceed 1,260	org/100 mL	Upper 10^{th} percentile	
Total suspended solids (TSS)-Southern Nutrient Region	Not to exceed 65	mg/L	Upper 10^{th} percentile	April 1 – September 30

Escherichia coli (*E. coli*)

In 2008, Minnesota changed from a fecal coliform standard to an *E. coli* standard for bacteria impairments. The bacteria standard change is supported by an EPA guidance document on bacteriological criteria (EPA 1986). As of 2018, Minn. R. 7050.0222 water quality standards for *E. coli* states:

> *Escherichia (E.) coli - Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.*

Although surface water quality standards are now based on *E. coli*, wastewater treatment facilities (WWTFs) are permitted based on fecal coliform (not *E. coli*) concentrations. A conversion factor of 126

E. coli organisms per 100 mL for every 200 fecal coliform per 100 mL is used and discussed in **Section 4.1**.

The *E. coli* standard is based on the geometric mean of water quality observations. Geometric mean is used in place of arithmetic mean in order to describe the central tendency of the data, dampening the effect that very high or very low values have on arithmetic means. The MPCA's *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List* provides details regarding how waters are assessed for conformance to the *E. coli* standard (MPCA 2016c).

Total Suspended Solids (TSS)

In January of 2015, the EPA issued an approval of the adopted amendments to the State Water Quality Standards, replacing the historically-used turbidity standard with TSS standards. The TSS TMDLs now replace the turbidity TMDLs. Therefore, this TMDL report will assume all previous turbidity impairments in the TRW will be treated as TSS impairments.

TSS is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water (MPCA 2016c). The recently approved Minnesota State TSS standards are based upon nutrient regions, which are loosely based on ecoregions. The TRW is located in the Southern Nutrient Region. The state TSS standard for this region is 65 milligrams per liter (mg/L) (MPCA 2016c).

3. Watershed and Waterbody Characterization

The TRW (HUC 09020312), located in northwest Minnesota, comprises approximately 1,098 square miles and includes portions of Kittson, Roseau, and Marshall Counties. There are an additional 3.6 square miles of this watershed that extend into Canada, but TMDLs in this report do not apply within the jurisdiction of Canada and meeting the goals of the TMDL is not dependent upon obtaining reductions from the portion of the watershed in Canada. The Two Rivers contains three branches, the Middle Branch, North Branch, and South Branch, which flow west toward their confluence three miles east of the outlet to the Red River near the Minnesota-North Dakota border. Land cover in the TRW during European settlement times (mid-late 1800s) consisted almost entirely of prairies in the western half of the watershed and a mix of mainly prairies and aspen-oak land in the eastern half (**Figure 3-12**). Currently, land use in the TRW is predominately agriculture (64%), with 16% of wetland cover and 10% forest (see **Figure** 3-13). Municipalities located within the TRW include Badger, Greenbush, Hallock, Halma, Lake Bronson, Lancaster, and Strathcona. No part of the TRW is located within the boundary of a Native American Reservation recognized by the federal government.

The TRW includes portions of two Level III ecoregions (**Figure 3-1**) as defined by the EPA: The Glacial LAP and NMW Ecoregions. The majority of the TRW is located in the LAP (greater than 80%). The EPA defines an ecoregion as a relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables. Since natural processes often vary by ecoregion, some water quality standards have taken these regions into account. Descriptions of the ecoregions in the TRW are given as follows (EPA 2013):

> "The LAP was formed by Glacial Lake Agassiz, the last in a series of proglacial lakes to fill the Red River Valley in the three million years since the beginning of the Pleistocene. Thick beds of lake sediments on top of glacial till create the extremely flat floor of the LAP. The historic tall grass prairie

> has been replaced by intensive row crop agriculture. The preferred crops in the northern half of the region are potatoes, beans, sugar beets, and wheat; soybeans, sugar beets, and corn predominate in the south."
>
> "Much of the NMW is a vast and nearly level marsh that is sparsely inhabited by humans and covered by swamp and boreal forest vegetation. Formerly occupied by broad glacial lakes, most of the flat terrain in this ecoregion is still covered by standing water."

Much of the LAP has been drained for agricultural use. The drainage network in place today in the Red River Basin "has thousands of miles of principal drains and probably tens of thousands of miles of small laterals and on-farm channels." (Carlyle 1984). The Red River Valley is among the world's largest artificially drained landscapes.

More information about the physical characteristics of the TRW can be found in the Two Rivers Watershed Stressor Identification Report (MPCA 2016a) and/or the Watershed Conditions Report (HEI 2014a).

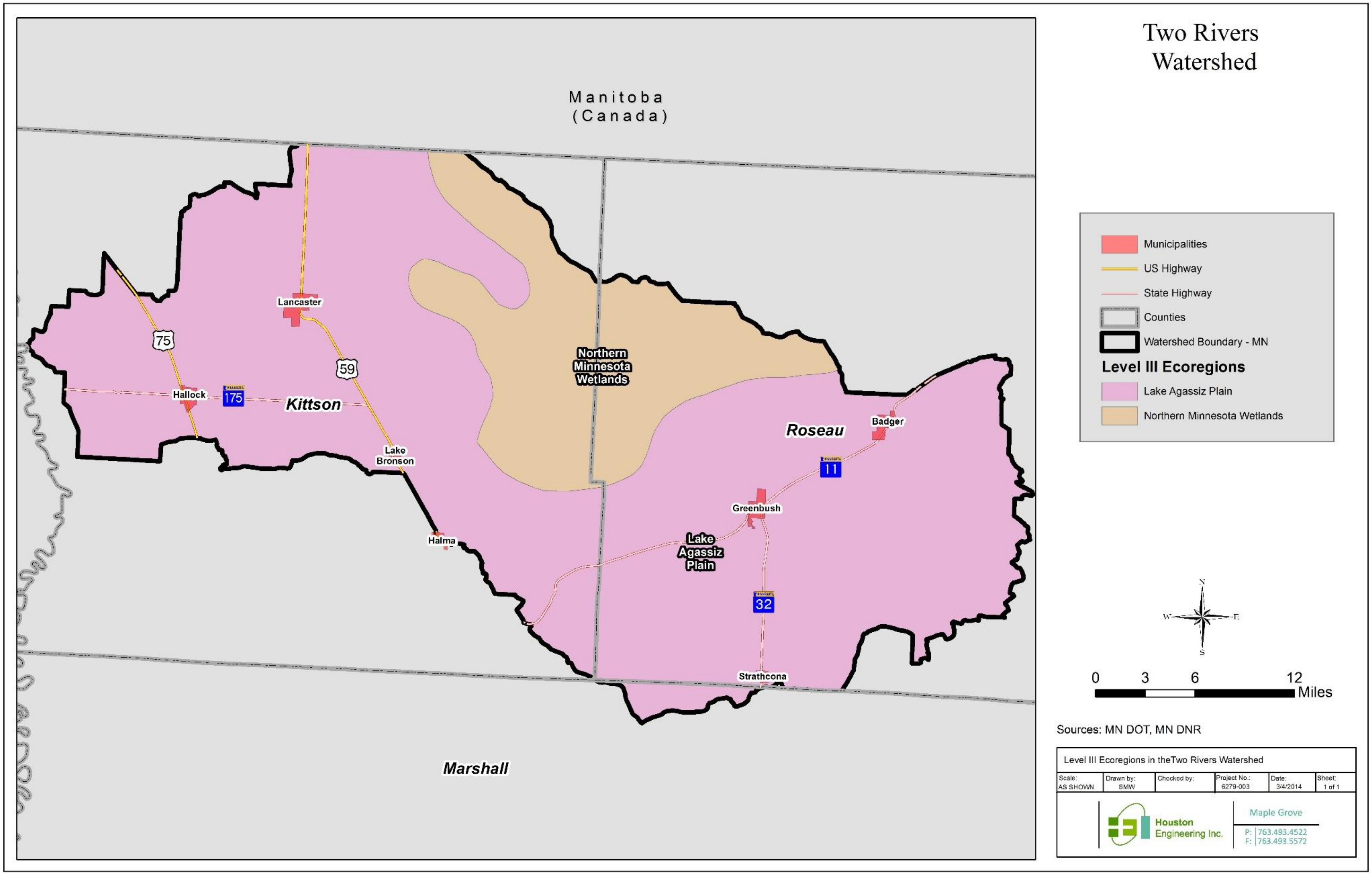

Figure 3-1: EPA Level III eco-regions in the TRW.

3.1 Streams

The total contributing drainage areas, any noncontributing areas, and any upstream waterbodies for impaired AUID stream reaches in the TRW are listed in **Table 3-1**. Total contributing drainage areas were delineated from the TRW HSPF model subwatersheds (RESPEC 2014). The noncontributing areas are based on whether runoff moves downstream for the 10-year, 24-hour event.

Table 3-1: Impaired stream reaches drainage areas.

HUC 10 Subwatershed	AUID (09020312-XXX)	Stream Name	Location/Reach Description	Total Drainage Area (acres)	Noncontributing Area (acres)[1]	Upstream Waterbody (AUID 09020312-XXX)
State Ditch No 95 (0902031202)	505	Two River, South Branch	Lateral Ditch 2 to Lk Bronson	50,555	3,336	506, 513, 521
	506	Two River, South Branch	Unnamed ditch to Lateral Ditch 2 SD 95	344,400	1,527	507, 516
	535	County Ditch 13	Unnamed ditch to Badger Cr (disconnected portion)	13,462	0	534, 541
Middle Branch Two Rivers (0902031203)	503	Two River, Middle Branch	CD23 to S Br Two R	36,787	35	518
South Branch Two Rivers (0902031207)	501	Two Rivers	M Br Two R to N Br Two R	49,071	4,569	502, 503, 512
	509	Two Rivers	N Br Two R to Red R	719,200	4,678	501

[1]Based on the 10-year, 24-hour rainfall event.

3.2 Subwatersheds

The TRW was divided into seven 10-digit HUC subwatersheds (**Figure 3-2**) used to organize components of this TMDL report. Three of these seven 10-digit HUC subwatersheds contain impaired reaches addressed in this TMDL report, including State Ditch Number 95 (902031202), Middle Branch Two Rivers (0902031203), and South Branch Two Rivers (0902031207). Only these three subwatersheds will be discussed further, because the focus of the TMDL report is impaired water bodies.

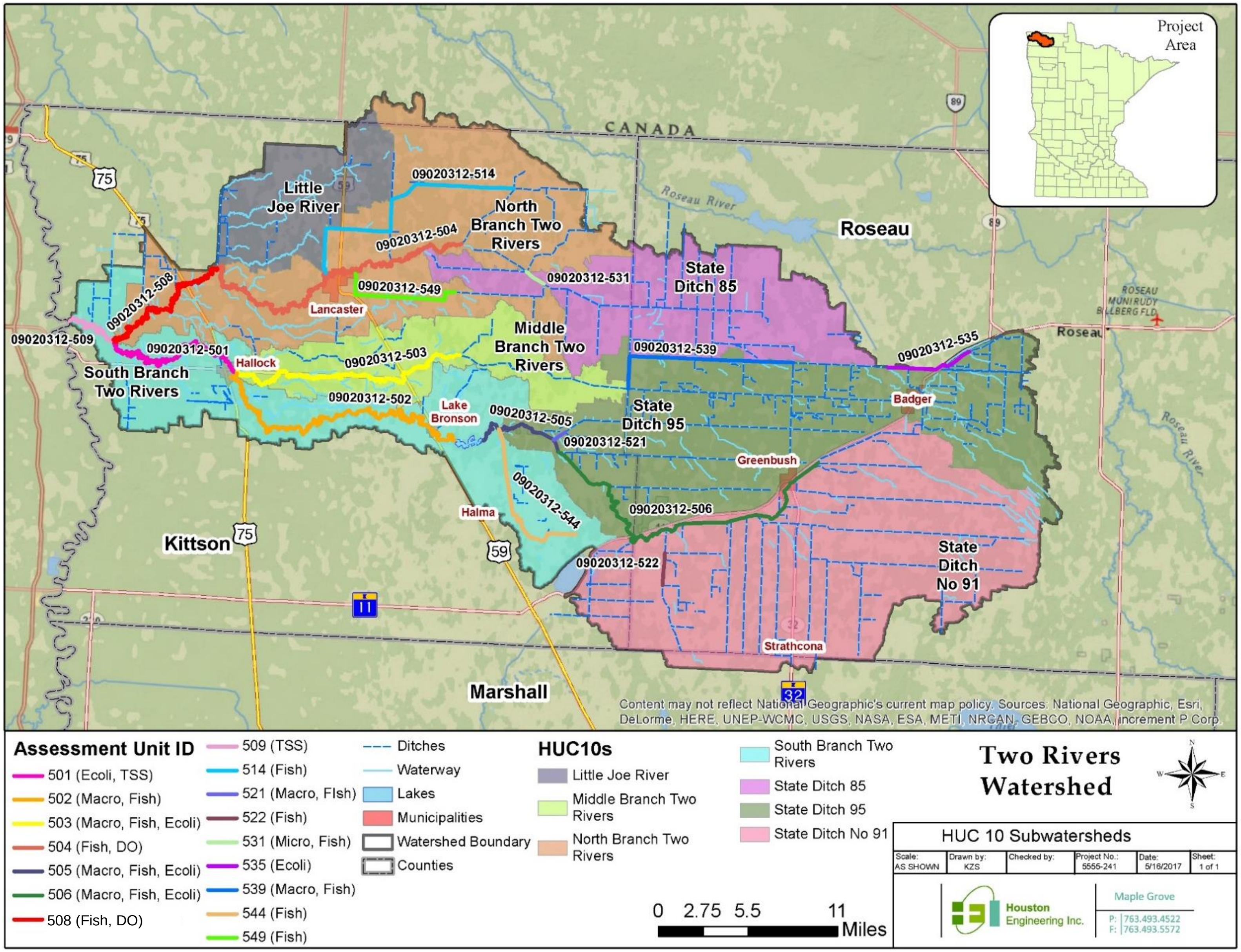

Figure 3-2: TRW 10-digit HUC subwatersheds.

3.2.1 State Ditch Number 95 Subwatershed (HUC 0902031202)

The State Ditch Number 95 Subwatershed drainage area, located in the east central portion of the TRW, contains the headwaters of the Two Rivers, North Branch (see **Figure** 3-3)**.** The State Ditch Number 95 Subwatershed is located mainly within the LAP ecoregion, with the northwestern portion located within the NMWs ecoregion, and is dominated by agricultural land use. This subwatershed contains five impaired stream reaches, three of which are addressed for *E. coli* in this TMDL report (AUIDs 09020312-505, 09020312-506, and 09020312-535).

The drainage area for the State Ditch Number 95 Subwatershed 10-digit HUC is shown in **Figure 3-13.** The total drainage areas for each of the three impaired reaches addressed in this report are shown in **Figure 3-4** through **Figure 3-6.** The figures include the total drainage areas, noncontributing drainage areas, any feedlots within the total drainage areas, water quality sites, National Land Cover Database 2011 (NLCD 2011: Homer et al. 2015) land uses, and any point sources (e.g., WWTF) located in the total drainage areas.

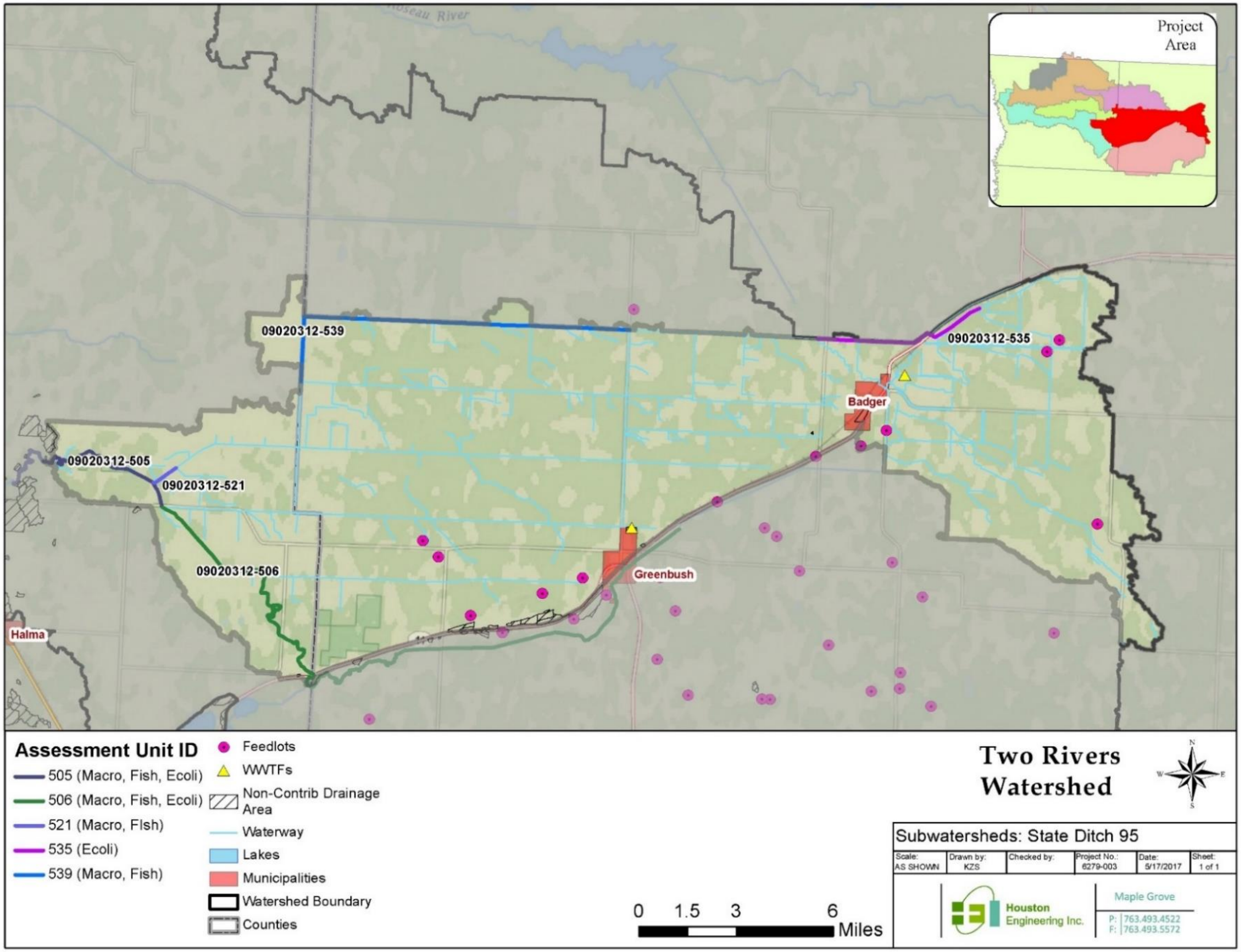

Figure 3-3: Drainage area for State Ditch Number 95 Subwatershed (HUC 0902031202).

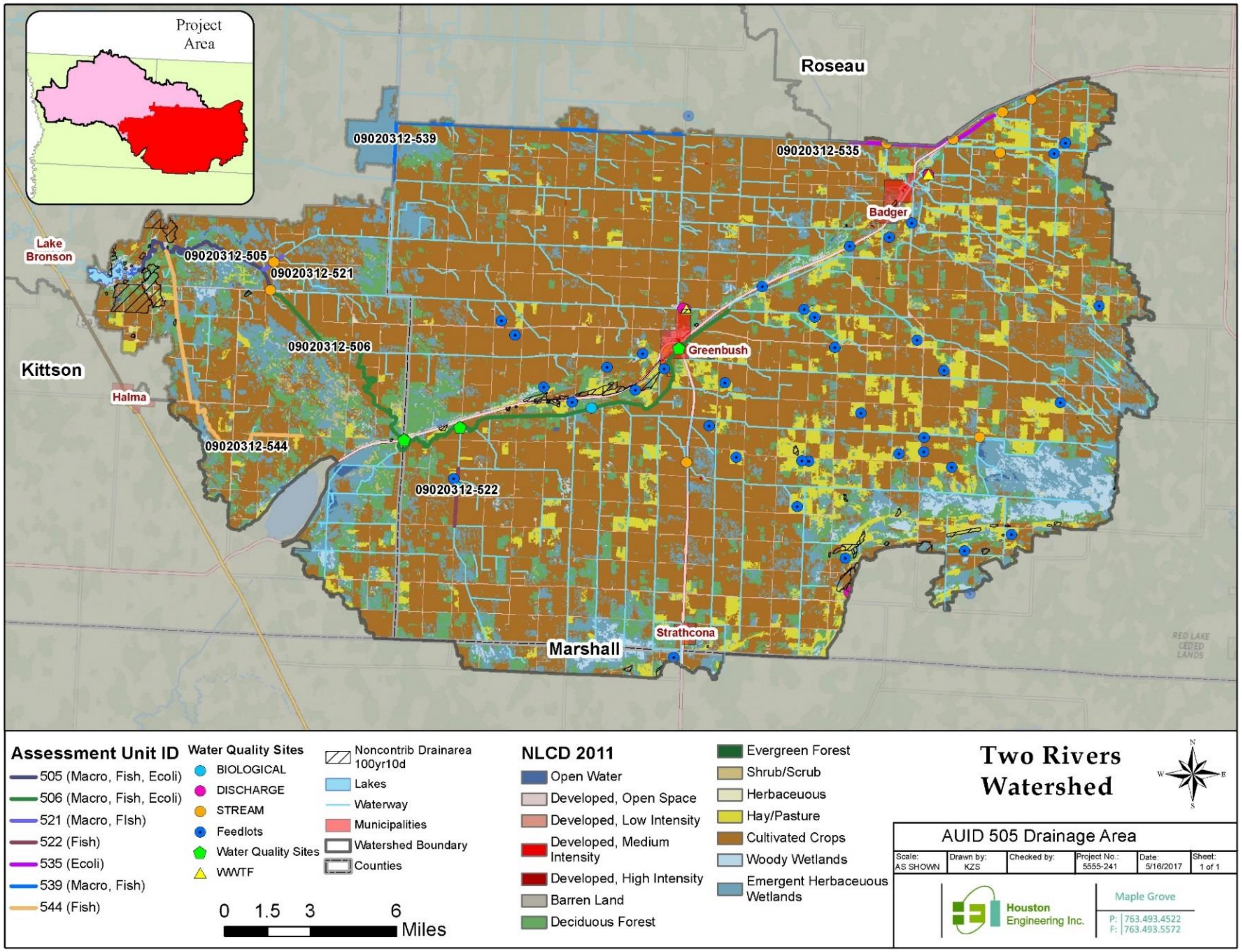

Figure 3-4: Drainage Area for South Branch Two Rivers, Lateral Ditch 2 to Lake Bronson (AUID 09020312-505).

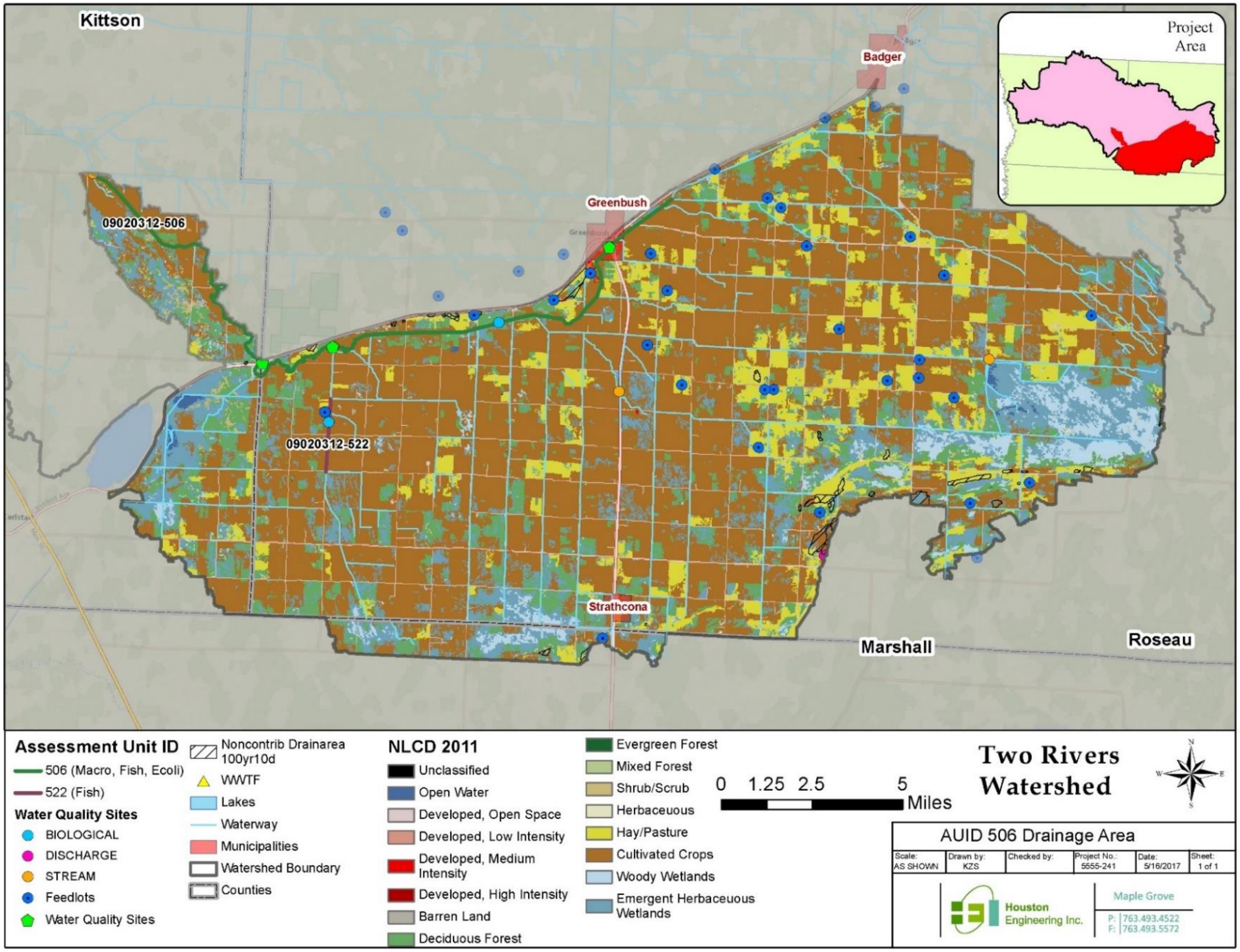

Figure 3-5: Drainage Area for South Branch Two Rivers, Unnamed ditch to Lateral Ditch 2 SD 95 (AUID 09020312-506).

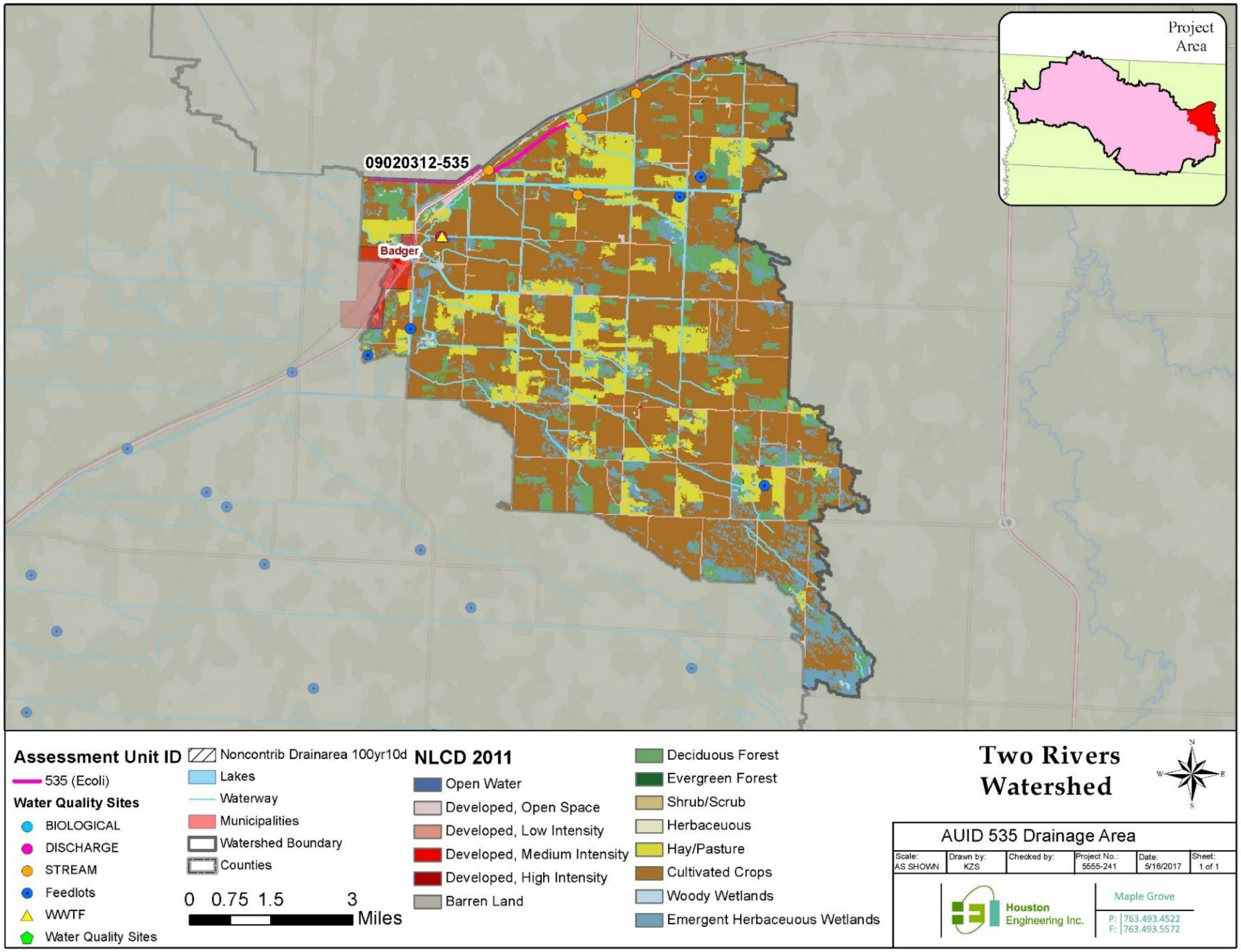

Figure 3-6: Drainage Area for County Ditch 13, Unnamed ditch to Badger Creek (disconnected portion) (AUID 09020312-535).

3.2.2 Middle Branch Two Rivers Subwatershed (HUC 0902031203)

The Middle Branch Two Rivers Subwatershed, located in the central portion of the TRW, contains the headwaters of the Two Rivers, Middle Branch (see **Figure 3-7**)**.** The Middle Branch Two Rivers Subwatershed is located mainly within the LAP ecoregion with the western portion located within the NMW ecoregion. The region is dominated by agricultural land use. The region contains one impaired stream reach (AUID 09020312-503) for which there is an *E. coli* TMDL in this report.

The drainage area of the Middle Branch Two Rivers Subwatershed 10-digit HUC is shown in **Figure 3-7.** The total drainage area for the impaired reach (AUID 09020312-503) is shown in **Figure 3-8.** The figure includes the total drainage area, noncontributing drainage areas, any feedlots within the drainage area, water quality monitoring sites, NLCD 2011 land uses, and any point sources (e.g., WWTF) located in the drainage area.

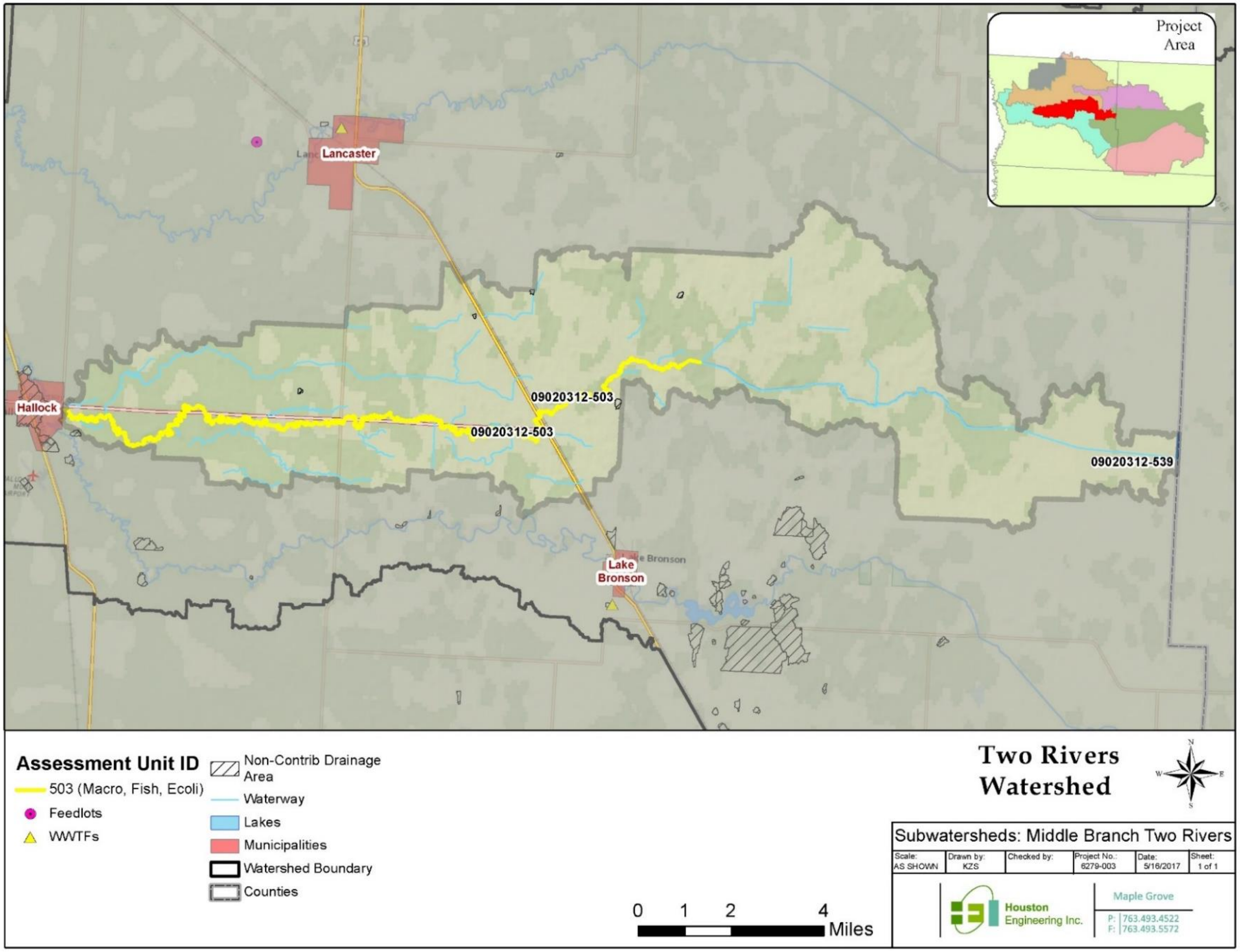

Figure 3-7: Middle Branch Two Rivers Subwatershed (HUC 0902031203).

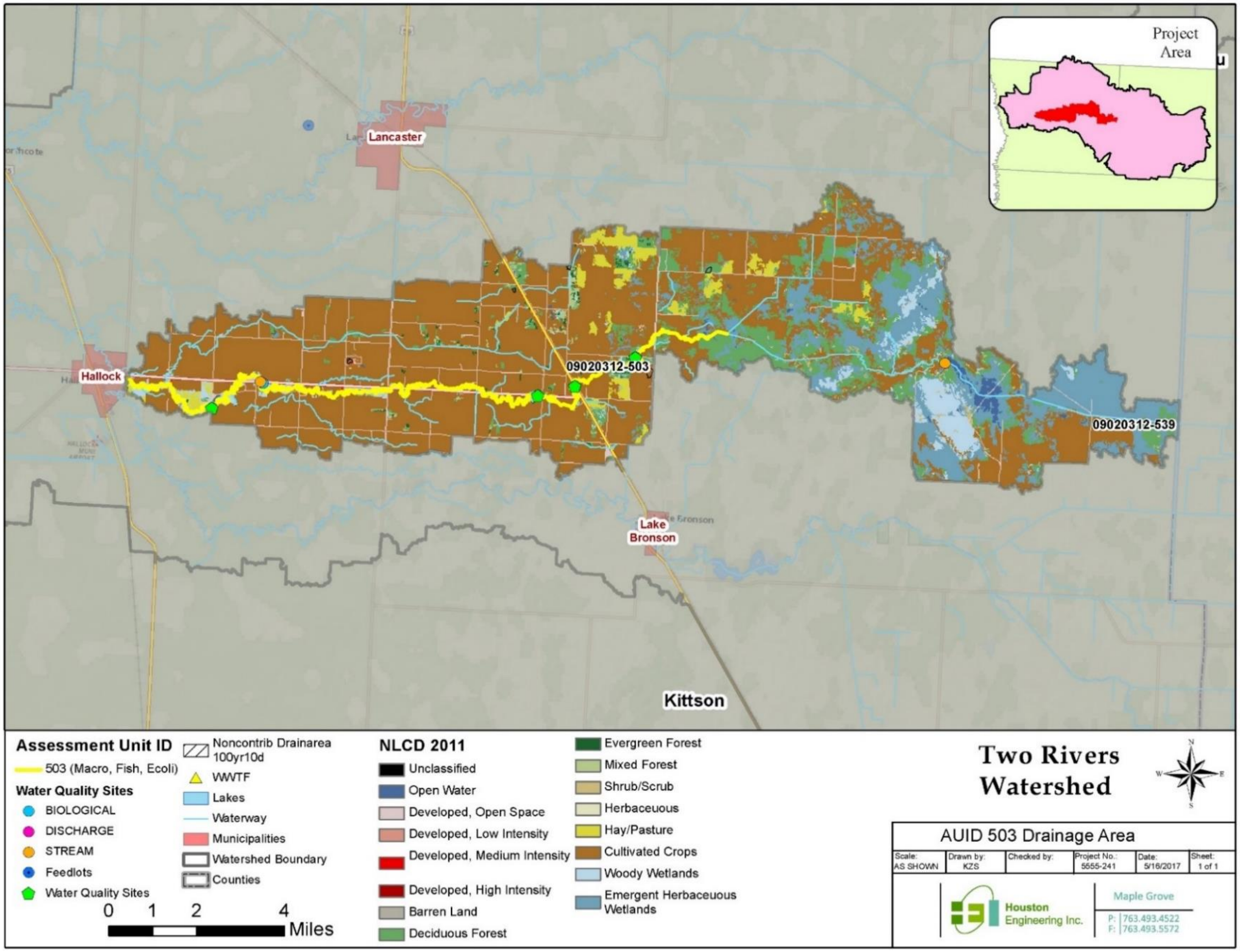

Figure 3-8: Drainage Area for Middle Branch Two Rivers, CD 23 to South Branch Two Rivers (AUID 09020312-503).

3.2.3 South Branch Two Rivers Subwatershed (HUC 0902031207)

The South Branch Two Rivers Subwatershed, located in the southwestern portion of the TRW, contains the headwaters of the Two River, South Branch (see **Figure 3-9).** The South Branch Two Rivers Subwatershed is located mainly within the LAP ecoregion with a minor portion located in the NMWs ecoregion. The region is dominated mainly by agricultural land use. This Subwatershed contains four impaired stream reaches, two of which are addressed for *E. coli* and /or TSS in this TMDL report (AUIDs 09020312-501 and 09020312-509).

The drainage area of the South Branch Two Rivers Subwatershed 10-digit HUC is shown in **Figure 3-9.** The total drainage areas for each of the two impaired reach addressed in this report are shown in **Figure 3-10** and **Figure 3-11.** The figures include the total drainage areas, noncontributing drainage areas, any feedlots within the total drainage areas, water quality sites, NLCD 2011 land uses, and any point sources (e.g., WWTF) located in the total drainage areas.

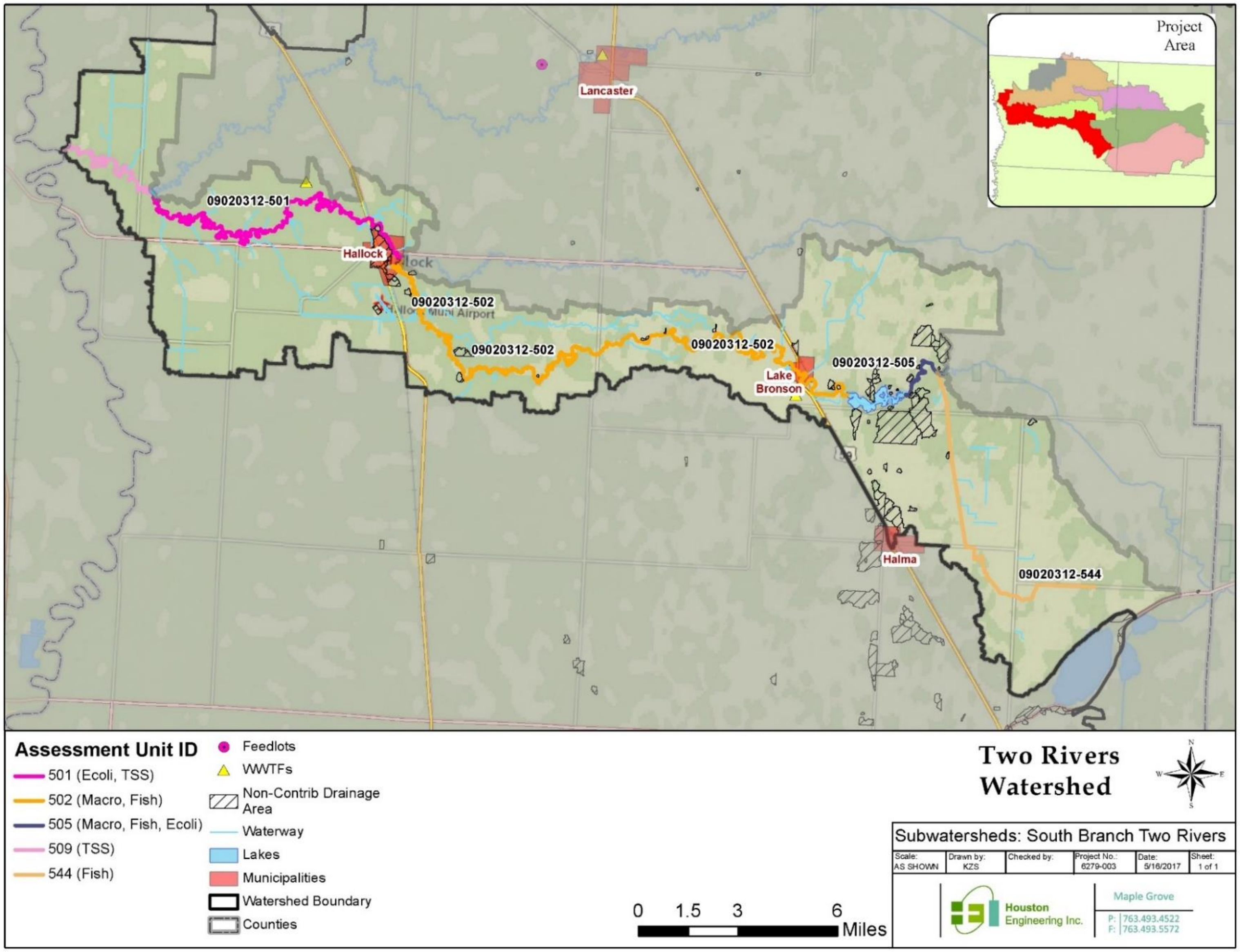

Figure 3-9: South Branch Two Rivers Subwatershed (HUC 0902031207).

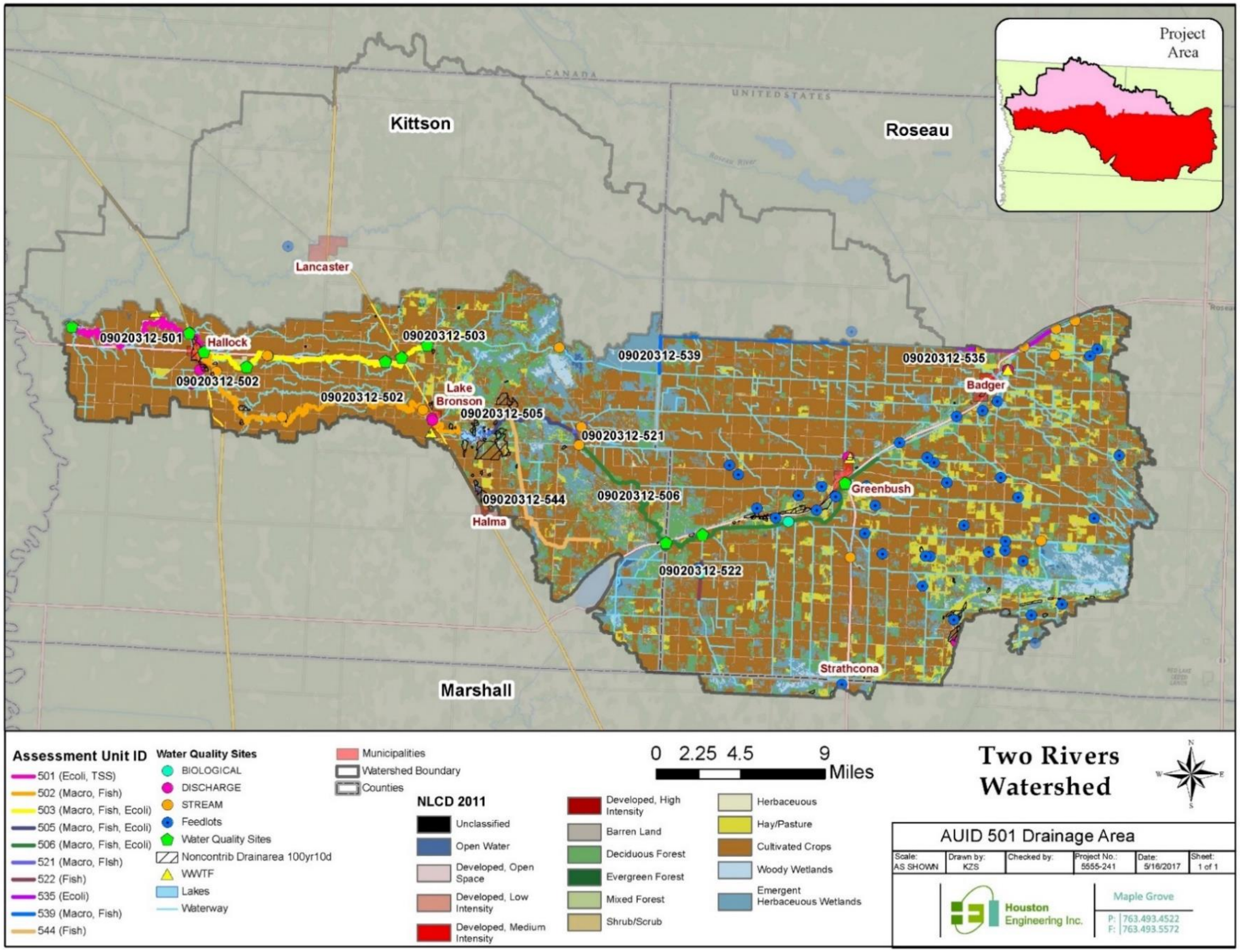

Figure 3-10: Drainage Area for Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501).

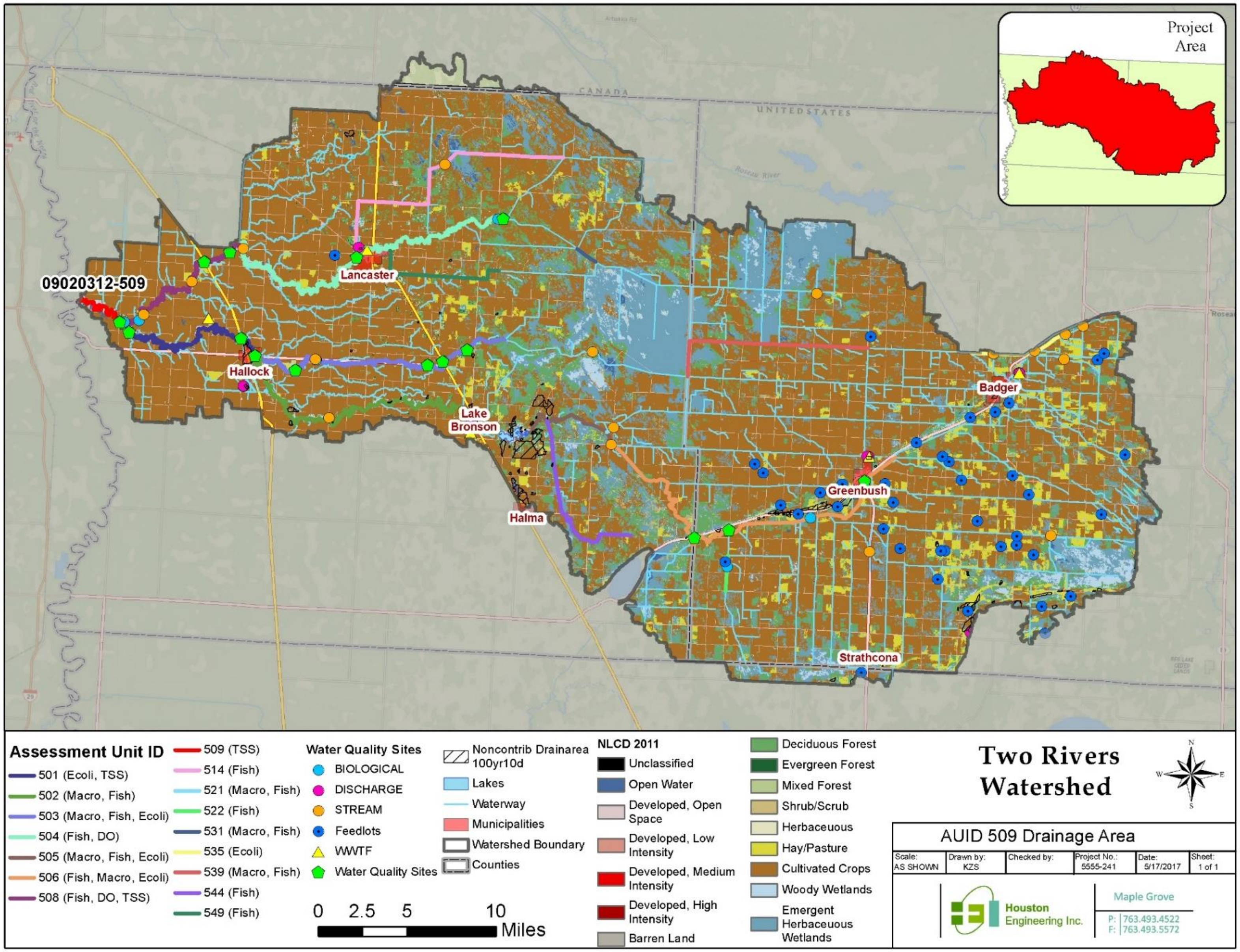

Figure 3-11: Drainage Area for Two Rivers, North Branch Two Rivers to Red River (AUID 09020312-509).

3.3 Land Use

Historically, land cover in the TRW during European settlement times (mid-late 1800s) consisted almost entirely of prairies in the western half of the watershed and a mix of mainly prairies and aspen-oak land in the eastern half (Figure **3-12**). More current land use within the TRW can be described using the Multi-Resolution Land Characteristic Consortium Dataset[3] (NLCD 2006: Fry et al. 2011). Agriculture is the primary land use in the TRW. **Table 3-2** contains a summary of land uses in the TRW, for the entire watershed as well as for each impaired water's drainage area. It should be noted that **Table 3-2** provides the NLCD 2006 distribution instead of the current NLCD 2011 data (at this date of publication) since it better represents the time period and conditions for which the TMDLs were developed; **Figure** 3-13, which is the graphical representation of land cover, uses the NLCD 2011 data. In addition, land use in the TRW has not seen significant changes in the last few generations of NLCDs (2001 [Homer et al. 2007], 2006, and 2011).

Table 3-2: Land use percentages for drainage areas of TMDL-addressed reaches in the TRW. Land use statistics are based on the National Land Cover Database 2006.

Watershed/AUID Drainage Area	Open Water	Urban	Barren	Forest/ Shrub	Pasture/ Hay/ Grassland	Cropland	Wetland
Entire Watershed	0.7	4.3	0	10.1	5.0	63.7	16.3
State Ditch No. 95 (0902031201)							
09020312-505	0.3	4.4	0	10.8	7.9	61.5	15.1
09020312-506	0.2	4.2	0	11.9	10.4	56.4	16.9
09020312-535	0.0	5.4	0	8.2	13.6	61.6	11.2
Middle Branch Two Rivers (0902031203)							
09020312-503	0.8	3.9	0	12.0	2.8	62.2	18.3
South Branch Two Rivers (0902031207)							
09020312-501	0.5	4.7	0	10.5	6.6	63.2	14.6
09020312-509	0.7	4.3	0	10.1	5.0	63.7	16.3

[3] http://www.mrlc.gov/

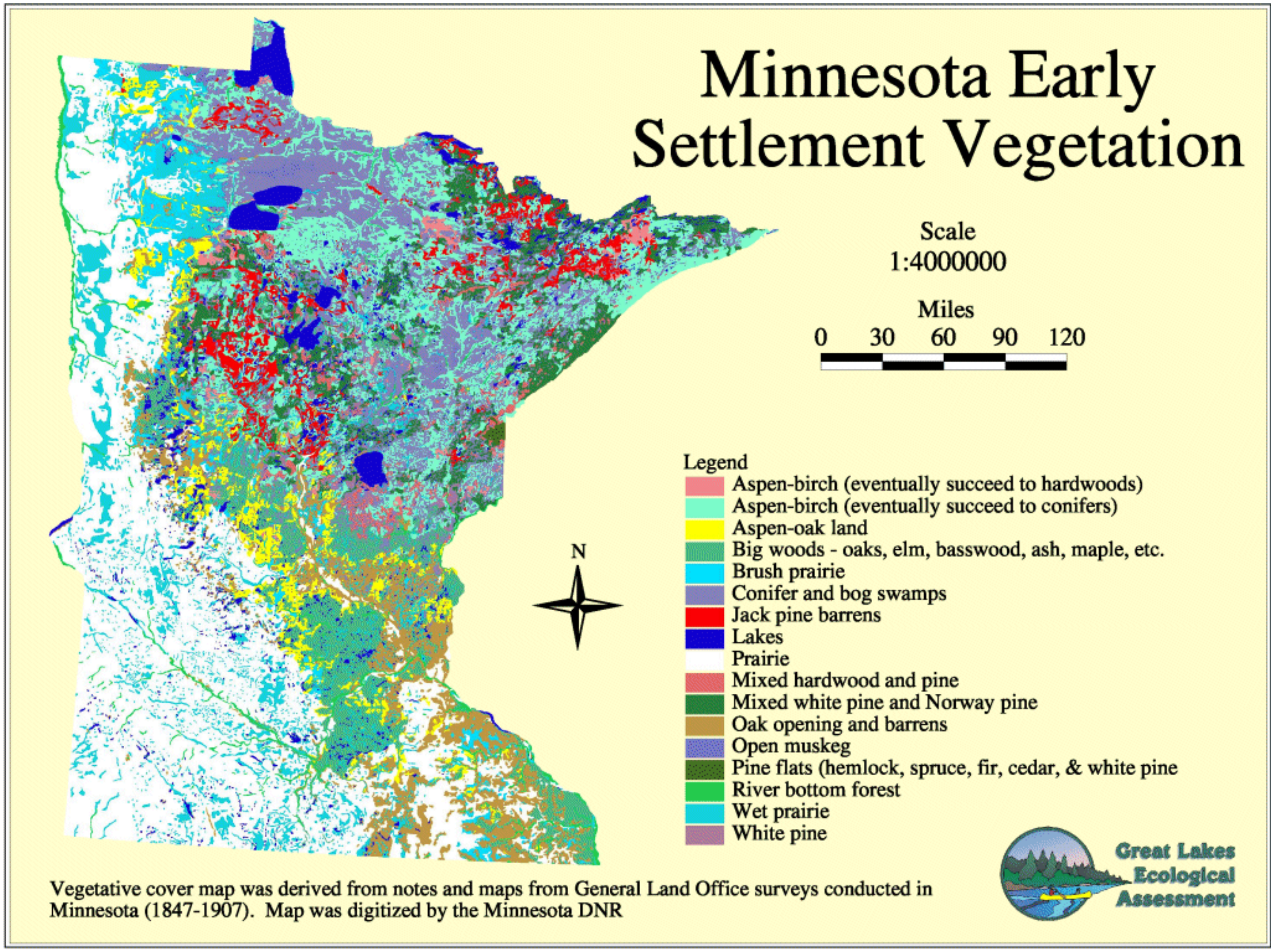

Figure 3-12: Historical map of land cover in Minnesota based on European settlement data. The original version is the "Marschner's Map", created by Francis J. Marschner in 1930.[4]

[4] http://www.mngeo.state.mn.us/chouse/land_use_historic.html

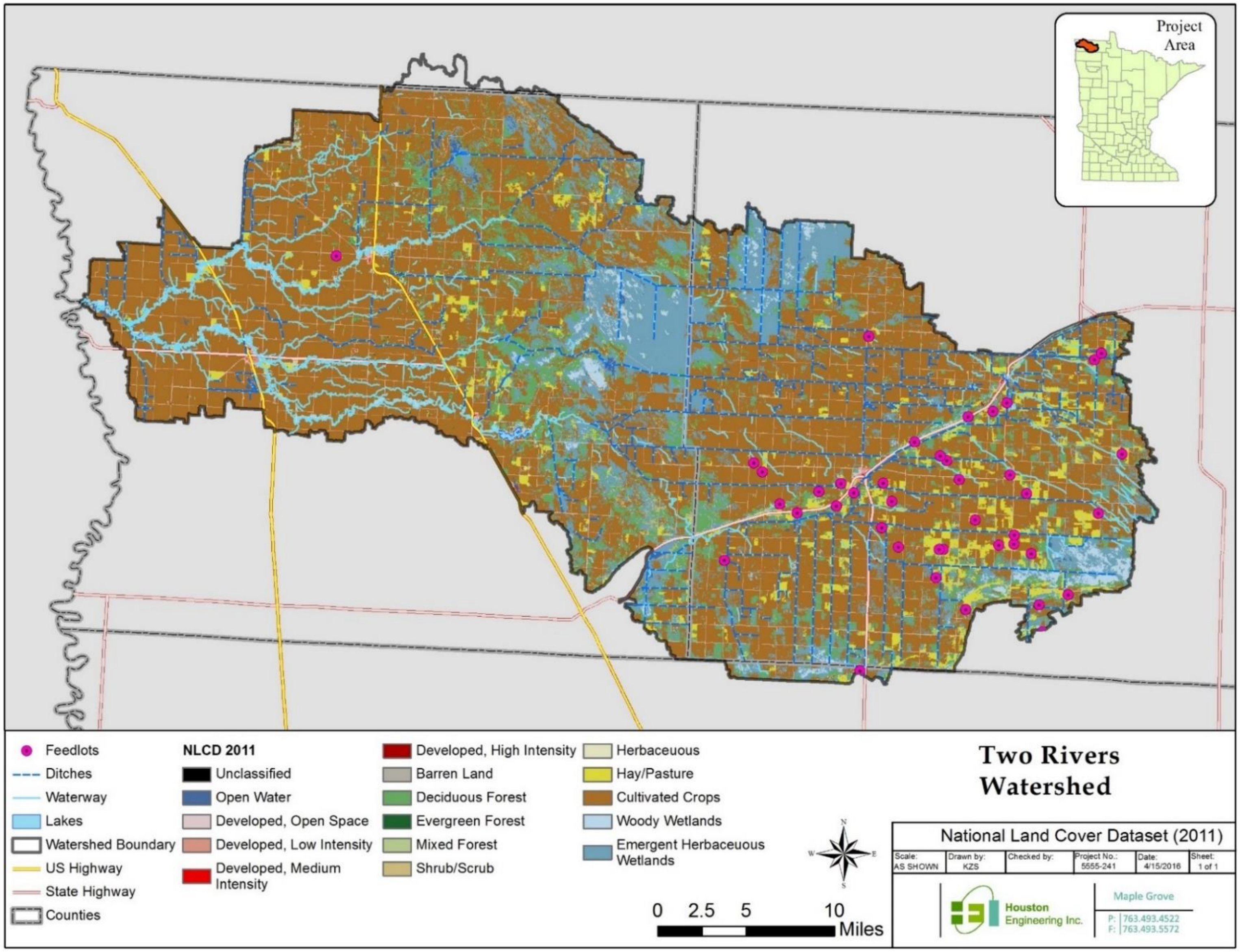

Figure 3-13: Land use within the TRW based on the NLCD 2011.

3.4 Registered Feedlots

The MPCA requires that feedlots with less than 1,000, but more than 50, animal units (AUs) (and outside of shoreland areas) be registered with the MPCA. Facilities with more than 10 AUs and inside shoreland areas are also required to register with the MPCA. These facilities are subject to state feedlot rules, which include provisions for registration, inspection, permitting, and upgrading. Shoreland is defined in Minn. Stat. § 103F.205 to include: land within 1,000 feet of the normal high-watermark of lakes, ponds, or flowages; land within 300 feet of a river or stream; and designated floodplains (MPCA 2010).

There are 53 registered feedlots in the TRW, 32 of which are required to be registered with the state due to having more than the minimum number of AUs (the other 21 feedlots are registered but are currently listed as having no AUs). Two of the feedlots are large enough to be Concentrated Animal Feeding Operations (CAFOs) and one of these requires an NPDES permit (see **Section 3.6.1.1**). According to the MPCA's feedlot data[5], there is a maximum of 179,294 agricultural animals (in registered facilities) in the TRW. The majority of these animals are birds (168,025), followed by bovine (11,219) and horses (50). **Table 3-3** contains a summary of the feedlot information for impaired stream reaches (by AUID) addressed in this TMDL report. **Figure 3-14** shows the locations of the facilities in TRW.

Table 3-3: Livestock population estimates for TRW, by AUID total drainage area.

AUID (09020312-XXX)	MPCA-Registered Feedlot Facilities[1]				
	Bovine	Birds	Goats/Sheep	Horses	Pigs
501	7422	168025	0	13	0
503	434	0	0	0	0
505	6143	168025	0	13	0
506	4752	132000	0	3	0
535	321	36025	0	2	0
509 (drainage area is the entire watershed)	11219	168025	0	50	0

[1] Facilities outside shoreland with >50 and <1,000 AUs or within shoreland and having >10 AUs.

[5] https://gisdata.mn.gov/dataset/env-feedlots

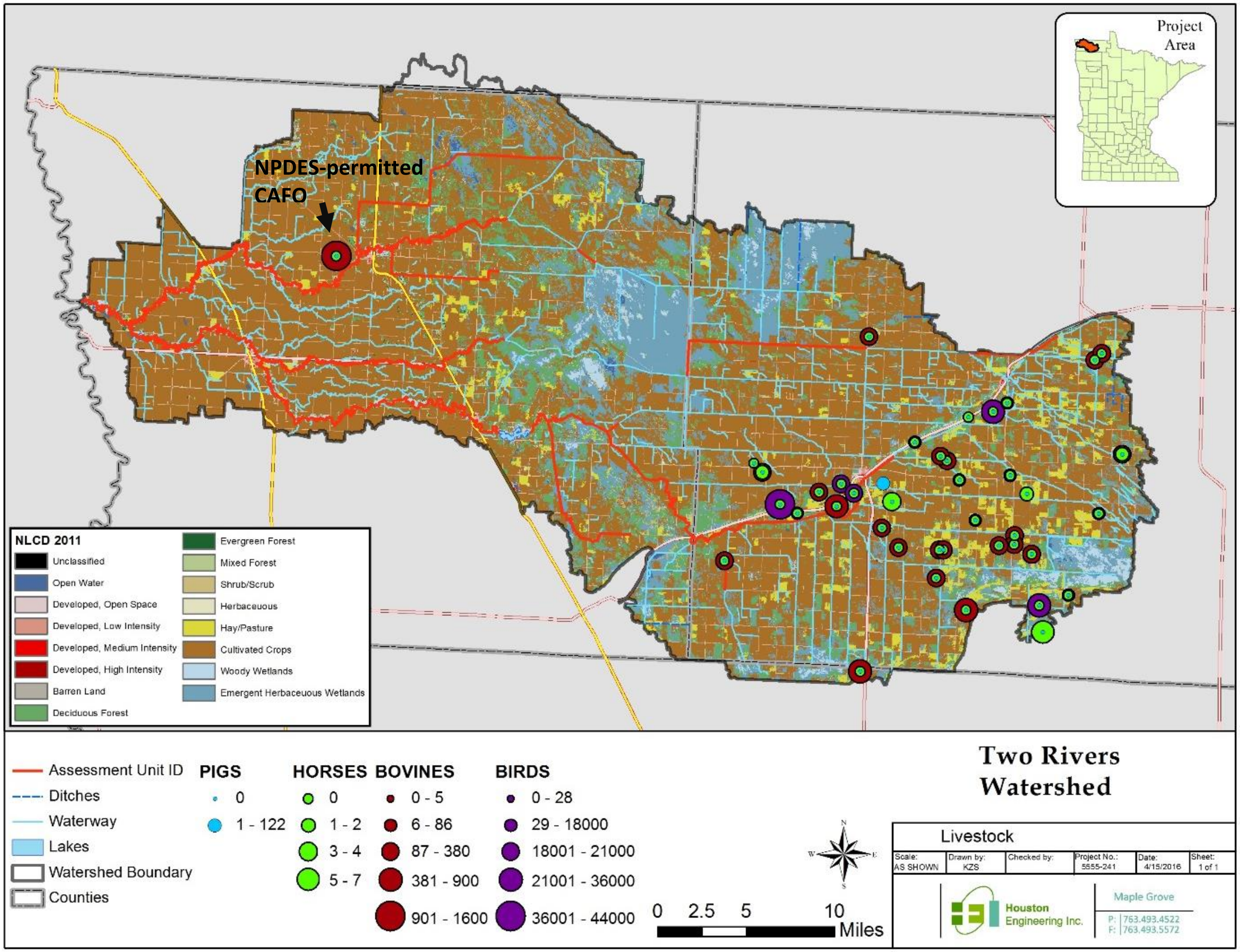

Figure 3-14: Location of registered feedlots and confined animal feedlot operations and permitted numbers of animals.

3.5 Current/Historical Water Quality

The existing TRW water quality conditions were described using data downloaded from the MPCA's Environmental Quality Information System (EQuIS) database[6]. EQuIS 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. EQuIS stores data collected by the MPCA, partner agencies, grantees, and citizen volunteers. All water quality sampling data utilized for assessments, modeling, and data analysis, for this report and reference reports, are stored in this database and are accessible through the MPCA's Environmental Data Access (EDA) website[6].

According to EQuIS and the MPCA spatial datasets[7], there are 7 biological monitoring sites, 5 lake water quality monitoring sites (in Lake Bronson), 32 stream water quality monitoring sites, 7 streamflow discharge sites (i.e., WWTF), and 3 United States Geological Survey (USGS) gauging stations located in the TRW (**Figure 3-15**). Not all sites were used in the development of the TRW TMDL report. Sites were excluded for various reasons including: (1) their period of record being outside of the assessment period (2006 through 2015); (2) the sites were not located in impaired stream reaches or lakes; or (3) a site did not have relevant observed data.

The MPCA conducts two years of intensive watershed monitoring in all 80 watersheds in Minnesota on a 10-year cycle (i.e., every major watershed is sample for two years, once every 10 years). The TRW intensive watershed monitoring occurred in 2014 and 2015.

Data from the current 10-year assessment period (2006 through 2015), consistent with the time period for the application of the water quality numeric standards, were used for development of this TMDL report. For *E. coli*, only data collected during the months of April through October were used. For the TSS standard, data collected from April through September were used.

[6] https://www.pca.state.mn.us/environmental-data

[7] https://www.pca.state.mn.us/data/spatial-data

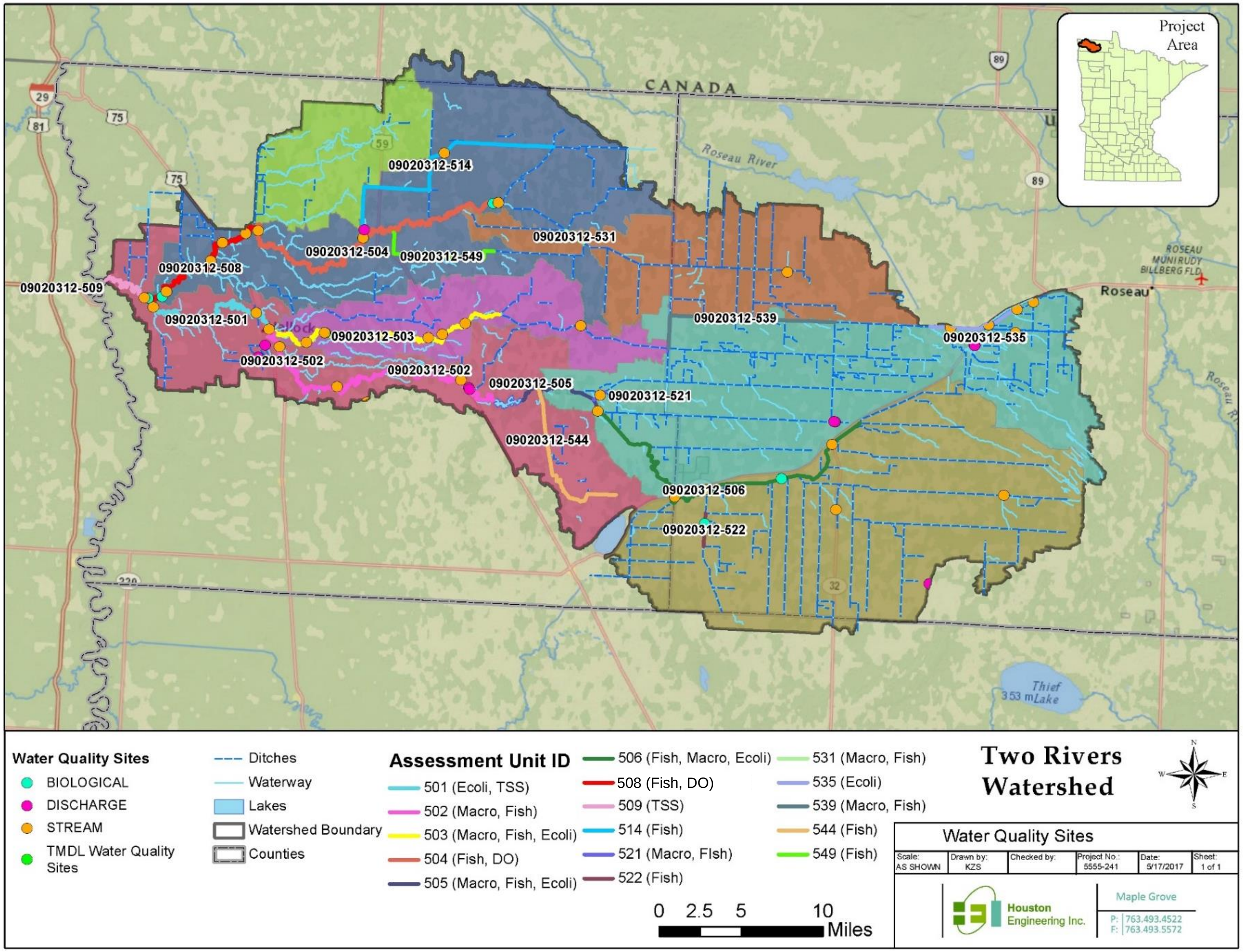

Figure 3-15: EQuIS water quality sites in the TRW.

3.5.1 Streams

3.5.1.1 *Escherichia coli*

A stream reach is listed as having impaired recreational use due to elevated *E. coli* if the geometric mean of the aggregated monthly *E. coli* concentrations for one or more months (with five or more samples) exceeds 126 organisms per 100 milliliters (mL), or if more than 10% of the individual samples within a month (with five or more samples) exceeds 1,260 organisms per 100 mL.

Table 3-4 shows the number of samples for each month, the monthly geometric mean, and the percent of samples in each month exceeding 1,260 organisms per 100 mL, for April 1 to October 31 for each water quality monitoring site in the 5 *E. coli*-impaired stream reaches in the TRW. The months where either standard is exceeded, and have at least five samples, are highlighted in orange. A few more months showed standard exceedances but did not have the minimum five samples required to qualify for a standard exceedance. In general, *E. coli* concentrations were highest in July for impaired AUIDs.

3.5.1.2 Total Suspended Solids

A stream reach is listed as having impaired aquatic life due to high TSS if more than 10% of samples taken on April 1 through September 30 are above the numeric standard of 65 mg/L for the Southern Nutrient Region. The TRW is considered to be part of the Southern Nutrient Region of Minnesota because of similar land use and topography. **Table 3-5** lists the available TSS data for impaired reaches in the TRW, including the AUIDs with TSS as a potential stressor for fish and macroinvertebrate bioassessments (AUIDs 503, 505, 506, 508, and 539). As shown in **Table 3-5**, the current conditions in AUIDs with biological impairments do not exceed the TSS numeric standard for the southern nutrient region of 65 mg/L. Therefore, it was determined that TSS TMDLs would not be needed for these reaches.

Table 3-4: Summary of *E. coli* in the TRW for the assessment period 2006-2015 (Geo = geometric mean [no. per 100 mL]; n=sample size).

AUID (09020312-XXX)		Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (-501)	Middle Branch Two Rivers, CD 23 to South Branch Two Rivers (-503)		South Branch Two Rivers, Lateral Ditch 2 to Lake Bronson (-505)	Unnamed ditch to Lateral Ditch 2 SD 95 (-506)	Unnamed ditch to Badger Creek (disconnected portion) (-535)
Month	Site ID	S000-186	S003-100	S007-441	S002-996	S002-373	S002-371
	Sampling Years	2006-08	2008-14	2013-14	2009-14	2009-11	2009-11
April	n	2	1	0	0	0	0
	Geo	14.4	8.4				
	% n>1260 org/100 mL	0%	0%				
May	n	5	3	0	0	0	0
	Geo	26.3	15.1				
	% n>1260 org/ 100mL	0%	0%				
June	n	6	5	5	10	5	5
	Geo	93.4	58.1	38.7	60.9	114.5	34.3
	% n>1260 org/100 mL	0%	0%	0%	10%	20%	0%
July	n	6	8	3	10	5	5
	Geo*	283.9	152.1	14.69	168.1	142.6	243.8
	% n>1260 org/100 mL	0%	0%	0%	0%	0%	20%
August	n	6	8	3	10	4	5
	Geo	113.8	104.3	214.00	51.6	49.9	90.8
	% n>1260 org/100 mL	0%	0%	0%	0%	0%	0%
September	n	4	2	0	0	0	0
	Geo	244.3	335.7				
	% n>1260 org/100 mL	0%	0%				
October	n	2	0	0	0	0	0
	Geo	62.4					
	% n>1260 org/100 mL	0%					

*Highlighted row represents the impairment listing data

Table 3-5: Summary of total suspended solids observations for impaired reaches in the TRW (n=sample size).

AUID Name (09020312-XXX)	Site ID	Total Suspended Solids			
		Sampling Years	n	90th % [mg/L]	# of Exceedances
Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (-501)	S000-186	2007-11	31	115	11
	S005-387	2014-14	25	118.6	8
South Branch Two Rivers, Lake Bronson to Middle Branch Two Rivers (-502)	S001-154	NA	0		
	S002-365	2008-14	36	12.5	0
Middle Branch Two Rivers, CD 23 to South Branch Two Rivers (-503)	S002-360	NA	0	--	--
	S002-999	NA	0	--	--
	S003-100	2008-10	20	17.5	0
	S007-441	2013-13	10	7.5	0
North Branch Two Rivers, Headwaters to CD 22 (-504)	S002-368	2008-11	14	17.7	0
	S002-369	NA	0		
South Branch Two Rivers, Lateral Ditch 2 to Lake Bronson (-505)	S002-996	2009-13	30	12.4	0
South Branch Two River, Unnamed ditch to Lateral Ditch 2 SD 95 (-506)	S002-364	NA	0		
	S002-373	2009-11	23	8.6	0
	S002-998	NA	0		
North Branch Two Rivers, CD 22 to Two Rivers (-508)	S002-370	2008-11	31	29	0
	S003-092	NA	0		
	S007-442	2013-14	9	63.2	1
Two Rivers, North Branch Two Rivers to Red River (-509)	S000-569	2006-14	165	228.4	77
Lateral Ditch 1 od State Ditch 95, Unnamed Ditch to State Ditch 95 (-521)	S002-997	2009-13	31	9	0
County Ditch 13, Unnamed ditch to Badger Creek (disconnected portion) (-535)	S002-371	2009-10	20	7.1	0
	S003-452	2006-13	22	10	0
Lateral Ditch 1 of State Ditch 95, Unnamed ditch to State Ditch 50 (-539)	--	NA	0	--	--
Judicial Ditch 31, Unnamed creek to North Branch Two Rivers (-549)	--	NA	0	--	--

3.6 Pollutant Source Summary

A key component for developing TMDL studies is understanding the sources contributing to the impairment(s). The TRW is a complex system with considerable diversity in land use, topography, soils, and drainage intensity. This diversity results in a variety of conditions that support a broad spectrum of fish and other aquatic life. Several stressors in the TRW play a role in influencing water quality in the system and limiting the health of these biological communities.

In instances where this TMDL report references “Natural Background Conditions” as a pollutant source, natural background conditions refer to inputs that would be expected under natural, undisturbed conditions that occur 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. 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, and therefore natural background is included in MPCA’s waterbody assessment process. Not enough data were available to evaluate natural background conditions explicitly. The position of the MPCA is that the source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, artificial drainage, WWTFs, failing SSTSs, and other anthropogenic sources. For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment.

This section provides a brief description, by pollutant, of the sources in the TRW that potentially contribute to the listed impairments. A more in-depth discussion of the biological stressors, pollutant sources, and causal pathways, excluding *E. coli*, can be found in the Two Rivers Watershed Stressor Identification Report (MPCA 2016a). More discussion on the current conditions in the TRW can be found in the Two Rivers Watershed Monitoring and Assessment Report (MPCA 2016b).

3.6.1 *Escherichia coli*

The relationship between bacterial sources and bacterial concentrations found in streams is complex, driven in part by the amount of precipitation and runoff, surface water temperature, the type of livestock management practices, wildlife population abundance and spatial distribution, bacterial survival rates, land use practices, and other environmental factors. These relationships were evaluated to determine the sources of bacteria. To evaluate the potential sources of bacteria delivered to waterbodies, a bacteria source investigation was conducted based on population production estimates and delivery mechanics. The bacteria source investigation included the following steps:

1. Identify and estimate magnitude (i.e., production rate) of potential bacteria sources that may contribute *E. coli* in the TRW. These sources include humans (subsurface sewage treatment systems [SSTS], WWTF), companion animals (cats and dogs), livestock (cows, chickens, goats, hogs, horses, sheep, and turkeys), and wildlife (deer, ducks, geese, and others). Once the population contributing bacteria have been identified, population estimates were obtained from the various sources provided in the following sections.
2. Each source is assigned a bacteria production rate (see **Table 3-6**), based on literature values. These bacteria yields are then applied to the relevant areas, described in the following sections.
3. Apply an empirical downstream delivery factor, representing die-off and based on water travel time, to the bacteria production rates across the TRW. This delivery factor accounts for the fate and transport of bacteria from the source to the impaired waterbody.

4. Finally, the total bacteria load was estimated by summing the bacteria production with the delivery factor applied to estimate the relative loads for each identified source. A ranking was applied based on percentage of total bacteria load.

Production Rates

The EPA's *Protocols for Developing Pathogen TMDLs* (EPA 2001) provides estimates for bacteria production rates for most animals shown in **Table 3-6**. Bacteria production rates were based on estimated bacteria content in feces and average excretion rates, expressed as units of colony forming units (cfu) per day per head (individual). Production rates are usually provided as fecal coliform; therefore, a conversion factor of 0.63 was used to convert fecal coliform to *E. coli*. The conversion factor is based on the ratio of the previous fecal coliform standard (200 org/100 mL) to the current *E. coli* standard (126 org/100 mL).

Table 3-6: Bacteria production rates by source.

Source	Producer	Fecal Coliform Production Rate [billion (10^9) org/day-head]	*E. coli* Production Rate [billion (10^9) org/day-head][1]	Reference[1]
Humans	Humans	2	1.3	Metcalf and Eddy 1991
	Domestic Animals	5	3.2	Horsley and Witten 1996
Livestock	Cattle	5.4	3.4	Metcalf and Eddy 1991
	Hogs	8.9	5.6	Metcalf and Eddy 1991
	Sheep and Goats	18	11.3	Metcalf and Eddy 1991
	Poultry	0.24	0.15	Metcalf and Eddy 1991
	Horses	4.2	2.6	ASAE 1998
Wildlife	Deer	0.36	0.2	Zeckoski et al. 2005
	Geese	4.9	3.1	LIRPB 1978
	Ducks	11	6.9	Metcalf and Eddy 1991
	Other (e.g. feral cats, raccoons, etc.)	5	3.2	Yagow 2001

[1]Literature rates are provided as fecal coliform, estimates for E. coli rates are based on fecal coliform estimates and conversion factor of 0.63, based on the conversion of the fecal coliform standard and E. coli standard.

3.6.1.1 Permitted

Wastewater Treatment Facilities

Permitted WWTFs in the State of Minnesota are required to monitor their effluent to ensure that concentrations of specific pollutants remain within levels specified in their National Pollutant Discharge Elimination System (NPDES) discharge permit. In Minnesota, WWTFs are permitted based on fecal coliform, not *E. coli*. Effluent limits require that fecal coliform concentrations remain below 200 organisms/100 mL (MPCA 2002). Based on the previous fecal standard and the current *E. coli* standard, a ratio of 200:126 (0.63) is used to convert fecal coliform to *E. coli*. Therefore, the effluent limit for *E. coli* concentrations remains below 126 organisms/100 mL.

The TRW contains five "minor" (as defined by the MPCA) WWTFs. These facilities are all pond-type treatment plants with primary and secondary treatment ponds. **Table 3-7** identifies the five permitted WWTFs in the TRW, and their permitted daily discharge flow and permitted daily bacteria load.

Table 3-7: Wastewater treatment facilities, permitted flows, and bacteria loads for minor facilities in the TRW.

Facility	Permit Number	Discharges to	City / Township	System Type	Permitted Daily Discharge Flow [mgd]	Equivalent Bacteria Load as *E. coli*: 126 org/100mL [billion org/day]
Badger	MNG580155	Unnamed ditch	Badger	Class D: 3-cell pond	0.37	1.79
Greenbush	MNG580156	Lateral Ditch #2	Greenbush	Class D: 2-cell pond	2.28	10.88
Hallock	MNG580147	Unnamed Ditch	Hallock	Class D: 3-cell pond	1.56	7.46
Lake Bronson	MNG580029	Two Rivers, South Branch	Lake Bronson	Class D:2-cell pond	0.44	2.10
Lancaster	MNG580066	Coulee Creek	Lancaster	Class D: 2-cell pond	0.41	1.94

NPDES Permitted Concentrated Animal Feeding Operation

The MPCA regulates the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation wastes (MPCA 2011). The MPCA currently uses the federal definition of a CAFO in its regulation of animal facilities. In Minnesota, the following types of livestock facilities are issued, and must operate under a NPDES Permit: (a) all federally defined (CAFOs); and (b) all CAFOs and non-CAFOs, which have 1,000 or more AUs (MPCA 2010). There is one permitted CAFO requiring an NPDES permit in the TRW. High Prairie Dairy has 2,240 AUs of dairy cows and holds NPDES Permit MNG440499. It is located in the North Branch Two Rivers Subwatershed (0902031206), which is within the drainage basin of one of the AUIDs that has an impairment addressed in this report (09020312-509). However, this is a zero discharge facility and therefore is not given a WLA in the TMDL. See **Figure 3-14** for the CAFO's location on a map.

3.6.1.2 Non-permitted

Humans

Subsurface Sewage Treatment Systems

Malfunctioning SSTSs can be an important source of fecal contamination to surface waters, especially during dry periods when these sources continue to discharge and surface water runoff is minimal. Malfunctioning SSTSs are commonly placed in two categories: Imminent Public Health Threat (IPHTs) or failing to protect groundwater (i.e., failing). IPHT indicates the system has a sewage discharge to surface water; sewage discharge to ground surface; sewage backup; or any other situation with the potential to immediately and adversely affect or threaten public health or safety. Failing to protect groundwater indicates the bottom of the system does not have the required separation to groundwater or bedrock.

Of the rural population in the TRW, an estimated 126 systems have inadequate treatment of household wastewater. This includes individual residences and any un-sewered communities. An MPCA document (MPCA 2011) reports numbers from 2000 through 2009 on the total number of SSTSs by county, along with the average estimated percent of SSTSs that are failing versus the percent that are considered IPHTs. The total numbers of SSTSs per county were multiplied by the estimated percent IPHT and percent failing within each area (MPCA 2011) to compute the number of potential IPHTs and potentially failing SSTSs per county and in the TRW overall. **Table 3-8** summarizes the results.

Table 3-8: SSTS compliance status in the TRW.

	Kittson	Roseau	Marshall
Identified # of SSTSs	538	1,165	14
# of potentially failing SSTSs	48	0	3
# of potential IPHTs	27	47	1

Companion Animals

Companion animals, such as dogs and cats, can contribute bacteria to a watershed when their waste is not disposed of properly. Dog waste can be a significant source of bacteria to water resources (Geldreich 1996) at a local level when in the immediate vicinity of a waterbody. It was estimated that 34.3% of households own dogs and each dog owning households has 1.4 dogs (AVMA 2007). Waste from domestic cats is usually collected by owners in the form of litter boxes. Therefore, it is assumed that domestic cats do not supply significant amounts of bacteria on the watershed scale. Feral cats may supply a significant source of bacteria and are accounted for under wildlife. Population estimates of domestic dogs were taken from the 2010 Census as a function of number of households per census block. Distribution of bacteria from companion animals is applied to all land uses in the NLCD land cover layer except open water. The bacteria sources, assumptions, and distribution used to estimate the potential source of bacteria related to humans are listed in **Table 3-9**.

Table 3-9: Data sources, assumptions, and distribution of bacteria attributed to humans.

Bacteria Source	Distribution
Unsewered Communities-Failing and IPHT SSTS Population in unsewered communities based on 2010 Census Block information. Number of failing and IPHT SSTS from County estimates (MPCA 2011).	The population of unsewered communities were estimated based on 2010 Census Block data. Production rates of 1.3×10^9 cfu/day/person was used. Total bacteria was applied to Developed land use classes in the NLCD 2011 dataset.
Companion Animals (Dogs only) 34.3% of households own dogs, 1.4 dogs in households with dogs. Populations of dogs was based on the 2010 Census Block data.	An estimated 38% of dog owners do not dispose of waste properly (TBEP 2011). Population distributions are based on 2010 Census Blocks. Production rates of 3.2×10^9 cfu/day/dog was used. Total bacteria was distributed among all land use classes in the NLCD 2011 dataset except open water.

Livestock

Populations

The United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) provides livestock numbers, by county. Estimated numbers are available for cattle, hogs, horses, sheep, goats, and poultry (chicken and turkey) through the U.S. Census of Agriculture. County livestock populations were distributed across the TRW in an area-weighted basis. Livestock waste is distributed throughout the TRW in four main categories: grazing animals, animal feedlots, land application of manure, and small operations. Discussion of each of these categories follows.

Livestock - Grazing

Grazing occurs on pastured areas where concentrations of animals allow grasses or other vegetative cover to be maintained during the growing season. The state of Minnesota does not require permitting or registration of grazing pastures. Grazing cattle were assumed to be the total cattle population from the Census of Agriculture (see *Livestock Populations*) minus the cattle of feed.

Livestock - Animal Feedlots

Animal feedlots with less than 1,000, but more than 50, AUs (and are outside of shoreland areas) are regulated by the MPCA under a registration program. Animal feedlots with more than 10 AUs and inside shoreland areas are also regulated under this program. Shoreland is defined in Minn. Stat. § 103F.205 to include: land within 1,000 feet of the normal high-watermark of lakes, ponds, or flowages; land within 300 feet of a river or stream; and designated floodplains (MPCA 2010). These smaller facilities are subject to state feedlot rules, which include provisions for registration, inspection, permitting, and upgrading.

Livestock - Land Application of Manure

Manure is often surface applied or incorporated into fields as a fertilizer and soil amendment. The land application of manure has the potential to be a substantial source of fecal bacteria, transported to waterbodies from surface runoff and drain tile intakes. Minn. R. ch. 7020 contains manure application setbacks based on research related to nutrient transport, but the effectiveness of these setbacks on bacteria transport to surface waters is unknown. A portion of the livestock population was assumed to supply manure for land application (see **Table 3-10**).

Livestock – Small Operations

Small-scale animal operations do not require registration and are not included in the MPCA's geographic feedlots database, but should be included in the Census of Agriculture (see *Livestock Populations*). All cattle, goats, horses, sheep, and poultry were treated as partially housed or open lot operations, and literature estimates were used to identify the number of animal feedlots without runoff controls (see **Table 3-10**). The geographic areas for stockpiling or spreading of manure from these small, partially housed or open lot operations is based on NLCD 2011 *Pasture/Hay* and *Grassland/Herbaceous* land covers.

Table 3-10: Data sources, assumptions, and watershed distribution of bacteria from livestock.

Bacteria Sources	Distribution
Grazing Grazing populations estimates for cattle, horses, goats, and sheep were based on NASS Quick Stats (http://www.nass.usda.gov/Quick_Stats/).	Bacteria from grazing animals was applied to grasslands and pasture classes in the NLCD 2011 dataset.

<table>
<tr><th colspan="2">Bacteria Sources</th><th>Distribution</th></tr>
<tr><td rowspan="2">Animal Feedlots
Animal feedlot populations for cattle, goats, hogs, horses, poultry, and sheep are based on NASS Quick Stats (http://www.nass.usda.gov/Quick_Stats/)</td><td>Partially Housed or Open Lot without Runoff Controls[8]
The proportion of feedlot animals that are partially housed or in open lots without runoff controls:
- Cattle 50%
- Poultry 8%
- Goats 42%
- Sheep 42%
- Hogs 15%</td><td>Bacteria from open lot animal feedlots was applied to barren, scrub/shrub, grassland, and pasture classes of the NLCD 2011 dataset.</td></tr>
<tr><td>Land Application of Manure
- Cattle 50%
- Poultry 92%
- Goats 58%
- Sheep 58%
- Hogs 85%</td><td>Land application of manure was distributed across the cropland class of the NLCD 2011 dataset.</td></tr>
</table>

Livestock populations were estimated for cattle, chickens, goats, horses, sheep, and turkeys for each county and are provided in **Table 3-11**. The MPCA's geographic feedlot database was developed for registered and NPDES-permitted animal feedlots; it provides the location and allowable populations of animals, but these populations are the maximum allowable populations under the permits and are not the actual populations at these sites. Therefore, the USDA census data was used to estimate livestock populations.

Table 3-11: Livestock population estimates (numbers) in the TRW.

Animal	Type	Kittson	Marshall	Roseau
Cattle	Beef	6,128	52	4,759
	Cattle on Feed	221	2	198
Other	Pigs	20	0	2,531
	Sheep and Goats	140	10	610
	Horses	125	3	242
Poultry	Layers	118	4	216
	Boilers	82	2	70
	Turkey	0	0	70,832
	Ducks and other	1	0	4

Wildlife

Wildlife, especially waterfowl, contribute bacteria to the watershed by directly defecating into waterbodies and through runoff from wetlands and fields adjacent to waterbodies, which are used as feeding grounds. In the TRW, land cover that could potentially attract wildlife includes: herbaceous wetlands and row crops adjacent to streams and lakes, wildlife management areas (WMA), and open water. Wildlife contribute bacteria to surface waters by living in waterbodies, living near conveyances to waterbodies, or when their waste is delivered to waterbodies during storm runoff events. Areas such as

[8] Estimates based on Mulla et al. (2001).

WMAs, state parks, national parks, national wildlife refuges, golf courses, state forest, and other conservation areas provide habitat for wildlife and are potential sources of bacteria due to high densities of animals. Additionally, private land managed for wildlife with practices such as food-plotting or supplemental feeding can concentrate wildlife and have the potential to be a source of bacteria from wildlife sources.

Fate and transport mechanisms differ between wildlife that live in/on surface waters (e.g., ducks, geese, cliff swallows, shorebirds, and beavers) where bacteria are directly delivered to waters and wildlife that live in upland areas (e.g., deer) where bacteria delivery is primarily driven by washoff and surface runoff. The wildlife considered as potential sources of bacteria include deer, ducks, geese, and others. Data sources and assumptions for wildlife populations are shown in **Table 3-12**. In addition, a category called "other wildlife" was added to the source summary. These other animals include all other wildlife that may dwell in the watershed, such as beaver, raccoons, coyote, foxes, squirrels, etc. It is possible that the "other wildlife" category may at times be a significant source of bacteria, which lacks the data needed to account for it in this assessment. An example might be cliff swallows nesting under bridges, which may be in close proximity to sampling sites. The lack of data needed for this source assessment is a limitation of this technique.

Table 3-12: Data sources and assumption for wildlife population and bacteria delivery.

Bacteria Source	Delivery
Deer The DNR report "Status of Wildlife populations, Fall 2009" includes a collection of studies that estimate wildlife populations of various species (Dexter 2009). Pre-fawn deer densities (in deer per square mile) were reported by DNR deer permit area.	Bacteria from deer were applied to all land use classes in the NLCD 2011 dataset except for open water and developed land use classes.
Ducks Populations of breeding ducks was taken from the U.S. Fish and Wildlife "Thunderstorm" Maps for the Prairie Pothole Region of Minnesota and Iowa	The USFW "Thunder Maps" are spatially distributed and were used once a bacteria production rate was applied.
Geese Population estimates were taken from the state-wide DNR's Minnesota Spring Canada Goose Survey, 2009 (Rave 2009). Counts were reported by Level I Ecoregion. An area-weighted estimate was taken from the state-wide data, resulting in an estimate of 1,568 geese in the TRW.	Bacteria from geese were distributed to areas within a 100 ft buffer of and including wetlands and open water classes in the NLCD 2011 dataset.
Other Wildlife Other wildlife in the TRW includes such animals as swallows, beaver, raccoons, coyote, foxes, and squirrels. Instead of estimating individual populations of each type of wildlife within the TRW. The bacteria production was assumed to be the same as the bacteria production from deer. Therefore, the bacteria production from deer was doubled to account for all other wildlife in the watershed that are not accounted for explicitly.	Same as deer.

Natural/Background Sources

Three Minnesota studies described the potential for the presence of "naturalized" or "indigenous" *E. coli* in watershed soils (Ishii et al. 2006) and ditch sediment and water (Sadowsky et al. 2010;

Chandrasekaran et al. 2015). Sadowsky et al. (2010) conducted DNA fingerprinting of *E. coli* in sediment and water samples from Seven Mile Creek, located in south-central Minnesota. They concluded that roughly 63.5% of the bacteria were represented by a single isolate, suggesting new or transient sources of *E. coli*. The remaining 36.5% of strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. The authors suggested that 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period, but results might not be transferable to other locations without further study. Although the result may not be transferable to other locations, they do suggest the presence of natural background *E. coli* and a fraction of *E. coli* may be present regardless of the control measures taken by traditional implementation strategies.

Fate and Delivery of Bacteria

A delivery factor was developed to account for the fate and transport of bacteria from the landscape to the impaired waterbody. The delivery factor accounts for factors such as proximity to surface waters, landscape slope, imperviousness, and the probable bacteria die-off rate (bacteria cannot survive outside of a warm-blooded host). Therefore, the die-off rate is known to follow an exponential (first-order) loss rate. The bacteria delivery factor assumed delivery to the waterbody is dependent on water travel time and a bacteria die-off rate.

The EPA's *Protocols for Developing Pathogen TMDLs* provides a methodology for estimating bacteria die-off and lists coefficients for die-off calculations (EPA 2001). The die-off equation was given as:

$$C = C_0 exp(-KT_t)$$

Where *C* is the concentration of bacteria (cfu/day), C_0 is the initial concentration of bacteria (cfu/day), *K* is the decay (die-off) coefficient (1/day), and T_t is travel time (days). The die-off coefficient for natural surface water used in the TRW was 0.202 $days^{-1}$ (essentially meaning about 20% per day). The die-off equation was applied to a water travel-time grid for the watershed as a whole and each impaired reach to estimate the delivery factor. An assumption is that the time of travel through the watershed by bacteria is the same as water.

The magnitude of the bacteria sources were placed into one of three categories: low, medium, and high. The rankings are based on the percentage of total bacteria load for each potential source. The sources were categorized into 10 groups. If all 10 potential sources contributed equally, they should each contribute 10% of the total load. As such, we ranked potential sources contributing 5% to 20% of the total load as a medium risk, or half to twice the expected value. If the source of bacteria was less than 5% of the total load, a rank of low was assigned and if greater than 20% a rank of high was assigned. The rankings for the TRW were all relative to the delivery of *E. coli* to the TRW outlet.

The magnitude of bacterial source delivery was also summarized by 12-digit HUC watersheds (hereafter HUC-12) within the TRW. The bacterial source loading to the outlet of the TRW was calculated for each HUC-12. The bacterial sources were aggregated to Human (STSS; Pets), Livestock (Grazing; Manure; Animal Feedlots), and Wildlife (Deer; Ducks; Gees; Other). WWTF were excluded from the HUC-12 rankings as they are currently a regulated point source. The magnitudes of the three sources were then ranked using a linear normalization relative to the total magnitude of all sources.

Table 3-13 shows the risk rankings of potential sources of bacteria in the TRW by impaired AUID. These ranks are relative to the potential sources within each subwatersheds (i.e., ranks cannot be compared between subwatersheds, only within). Livestock sources of bacteria consistently posed the greatest risk of contributing disproportionately larger quantities of bacteria to the outlet of the TRW. This information can be used to prioritize management efforts for the potential sources of bacteria that pose the greatest risk of impacting surface waters in the TRW. It should be noted that there are potential sources of *E. coli* that were not accounted for in this analysis due to a lack of data. For instance, Cliff Swallows often colonize under bridges along waterways in this area and would be a potentially high source of direct *E. coli* contributions to surface waters in the area.

Table 3-13: Relative sources of *E. coli* in the TRW.

Assessment Unit Identification	Humans				Livestock				Wildlife					Upstream Sources	
	All	WWTF Effluent	Septic Systems	Domestic Animals	All	Grazing	Manure	Feedlot Open Lots	All	Deer	Ducks	Geese	Other	Level	Estimated Percentage
501	○	○	○	○	●	●	●	●	○	○	○	○	○	●	87%
503	○	○	○	○	●	●	⭘	⭘	○	○	○	○	○		NA
505	○	○	○	○	●	●	●	●	○	○	○	○	○	●	90%
506	○	○	○	○	●	●	●	●	○	○	○	○	○		NA
535	○	○	○	○	●	●	●	●	○	○	○	○	○		NA

Key: ● = high risk, ⭘ = medium risk, ○ = low risk

3.6.2 Total Suspended Solids

The Two Rivers Watershed Stressor Identification Report (MPCA 2016a) describes the sources and believed causal pathways for turbidity and TSS. Each of the biologically impaired reaches is prone to high and quick peak flows and/or prolonged periods of low or no discharge. Historical changes in land cover (e.g., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) could be anthropogenic factors contributing to this flow regime instability. The habitats of several reaches have been degraded, presumably as a result of hydrologic alterations in the form of overland soil erosion and channel instability.

3.6.2.1 Permitted (Point) Sources

The TRW contains five “minor” (as defined by the MPCA) WWTFs that drain into impaired streams. These WWTFs are all pond-type plants with primary and secondary treatment ponds. Per their permits, these WWTFs are allowed to discharge only during certain time periods during the year: March 1 through June 30 and September 1 through December 31. The WWTFs are listed in **Table 3-14**.

Table 3-14: Relevant WWTF permits in the TRW.

			A				
Facility	**NPDES Permit Number**	**System Type**	**Secondary Pond Size (acres)**	**Operating Depth (ft)**	**Average Wet Weather Design Flow (gpd)**	**Permitted Max Daily Discharge (gpd)[1] (A*0.163*10^6)**	**Permitted Calendar Month Average[2,3] (kg/day)**
Badger	MNG580155	Class D: 3-cell pond	2.3	4	55,000	374,729	63.7
Greenbush	MNG580156	Class D: 2-cell pond	14	3	114,000	2,280,960	388
Hallock	MNG580147	Class D: 3-cell pond	9.6	4	200,000	1,564,087	266
Lake Bronson	MNG580029	Class D: 2-cell pond	2.7	4	35,000	439,899	74.9
Lancaster	MNG580066	Class D: 2-cell pond	2.5	3.5	55,000	407,314	69.3

[1] Computed based on the average surface area of the secondary treatment pond size and an assumed maximum daily discharge of six inches per day.
[2]Assumes twice annual maximum discharges to completely drain secondary pond (i.e. 2* 6 inches per day * operating depth*daily WLA)
[3]Calender Month Average load used per MPCA guidance.

3.6.2.2 Nonpoint Sources

The TRW is located within the Red River of the North Basin, a region with the highest median suspended sediment concentrations of any region in Minnesota, with the exception of the Western Corn Best Plains ecoregion (MPCA 2016a). Within the TRW, there are three major sources of nonpoint sediment that contribute to turbidity impairments; upland field erosion, wind erosion, and in-channel stream bank and bluff erosion.

Upland Field Erosion

Upland field erosion occurs primarily when the soil is unprotected (e.g., row crop agriculture, ditch maintenance/repair, mining, insufficiently vegetated pastures or livestock access to stream banks). Soil erosion from agricultural fields is believed to be a large source of sediment to streams in the basin, which contains 63.7% of land in agricultural use. Modified headwater (i.e., first and second order) streams convey much of this sediment to receiving waters. The majority of the annual suspended sediment load associated with the streams in the basin is discharged between the months of March and May, when agricultural fields are particularly vulnerable to erosion.

Wind Erosion

Wind erosion can play an important role in soil erosion. Wind erosion is primarily driven by three processes: (1) Creep - where medium to coarse sand roll along the ground surface; (2) Saltation - where fine to medium sand "hop" across the soil surface, potential impacting and loosening more particles as it bounces across the ground; and (3) Suspension - where fine sand, silt, and clay are lifted from the soil surface and deposited a distance away from the source. A wind erosion study is not available in the TRW, but a Wind Erosion Prediction System (WEPS) model (HEI 2016) was developed for the Lower Red

River Watershed (LRRW), and the results can transfer to the TRW because the land uses are similar and a large portion of the TRW borders the LRRW on the north, west, and southern boundaries of the watershed. The LRRW WEPS model found an average annual wind erosion rate of 4.12 tons/acre. This wind erosion rate is on par with the erosion rates in the HSPF model (**Figure 3-16**).

Bank and Bluff Erosion

Another potentially significant source of soil loss and high stream turbidity levels is sediment/soil eroded from the stream banks, bluffs, and stream bed. This can be caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, increases in impervious surfaces resulting in more runoff, increased precipitation, and livestock access to the stream channel. Hydrology in the TRW has changed through time, which influences how sediment is transported through the watershed. Increased drainage of the land leads to increased flows and stream power, resulting in increased bank and channel erosion.

Figure 3-16 shows the sediment yields (tons/acre) from the landscape as estimated by the HSPF model. The model suggests that the largest sources of sediment are typically found in areas dominated by agricultural land use.

To show the relative magnitude of field sources of sediment to in-stream sources, a field-stream index (FSI) was developed using results from the HSPF model (**Figure 3-17**). The FSI is an indicator based on the ratio of the total surface runoff sediment load (i.e., overland or field load) reaching a stream reach from the direct drainage area divided by the in-stream sediment flux (within a stream reach). The total surface runoff sediment is the sediment entering the channel in the specific subwatershed and represented in the HSPF model as entering the upstream end. The in-channel sediment load is taken as the flux of sediment in the sediment reach of the subwatershed, where positive FSI numbers equate to a sediment source (i.e. more sediment leaves the reach than comes in) and negative FSI numbers equates to a sediment sink (i.e. more sediment enters the reach than leaves). The FSI indicates dominant sediment process within a stream reach. If the FSI is between -1 and 1, in-stream processes as a source of are more dominant than surface runoff sources. If the FSI is less than -1 or greater than 1, surface runoff sources are larger in magnitude. For example, if a stream reach has an FSI of -2, the stream reach is a sink for sediment and surface runoff is two time larger than in channel sediment sources. The FSI highlights areas within the watershed, where in-stream processes are dominant and areas where field processes are more important and where implementation of in-channel practices might be more important than field practices, or vice versa. The FSI for sediment in the TRW is shown in **Figure 3-17**. Of the 90 HSPF subwatersheds in the TRW, only 16 are sediment sources (all with FSI values in excess of 10.0), and 74 are sediment sinks (68 of these have an FSI value lower than -10.0; the other 6 subwatersheds with FSI values between 0 to -10 are notably on the downstream end of the watershed).

Figure 3-18 shows priority ranking of subwatershed in the TRW, the darker grey-green colors represent subwatersheds with stream reaches that, on an annual average, supply the highest yield of sediment. The lighter grey-green colors represent subwatersheds where sediment yields are the lowest.

Figure 3-19 shows prioritization for TSS based on sediment yields from the TRW HSPF model for AUID 09020312-501. Since the drainage area for AUID 09020312-509 is equal to that of the whole TRW its TSS prioritization is shown in **Figure 3-18**. **Figure 3-18** and **Figure** 3-19 highlight the subwatersheds that contribute the highest yields of sediment within the drainage areas of the impaired AUIDs.

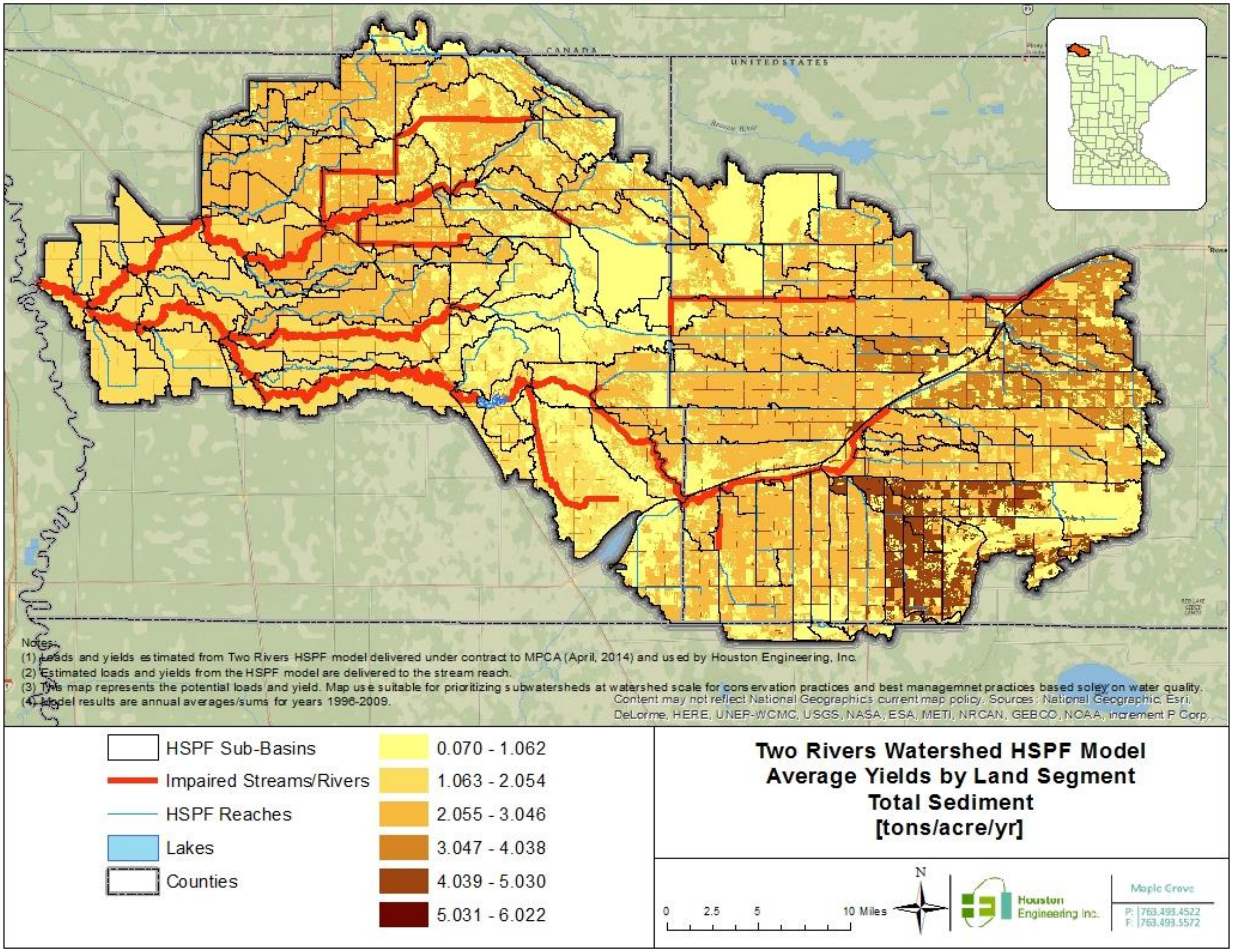

Figure 3-16: Total Sediment Yields from the landscape as estimated by the TRW HSPF model.

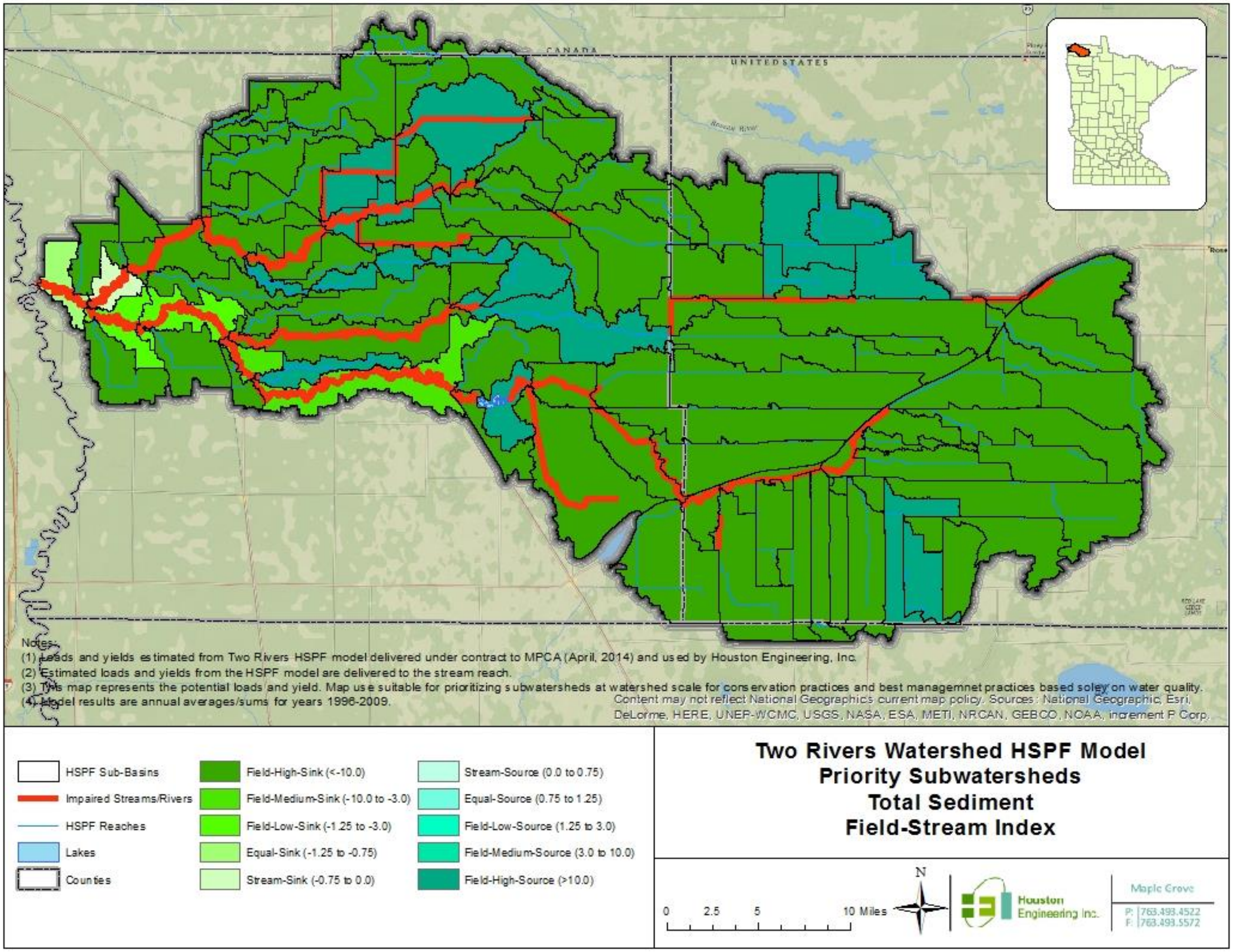

Figure 3-17: Total Sediment Field Stream Index using HSPF model results.

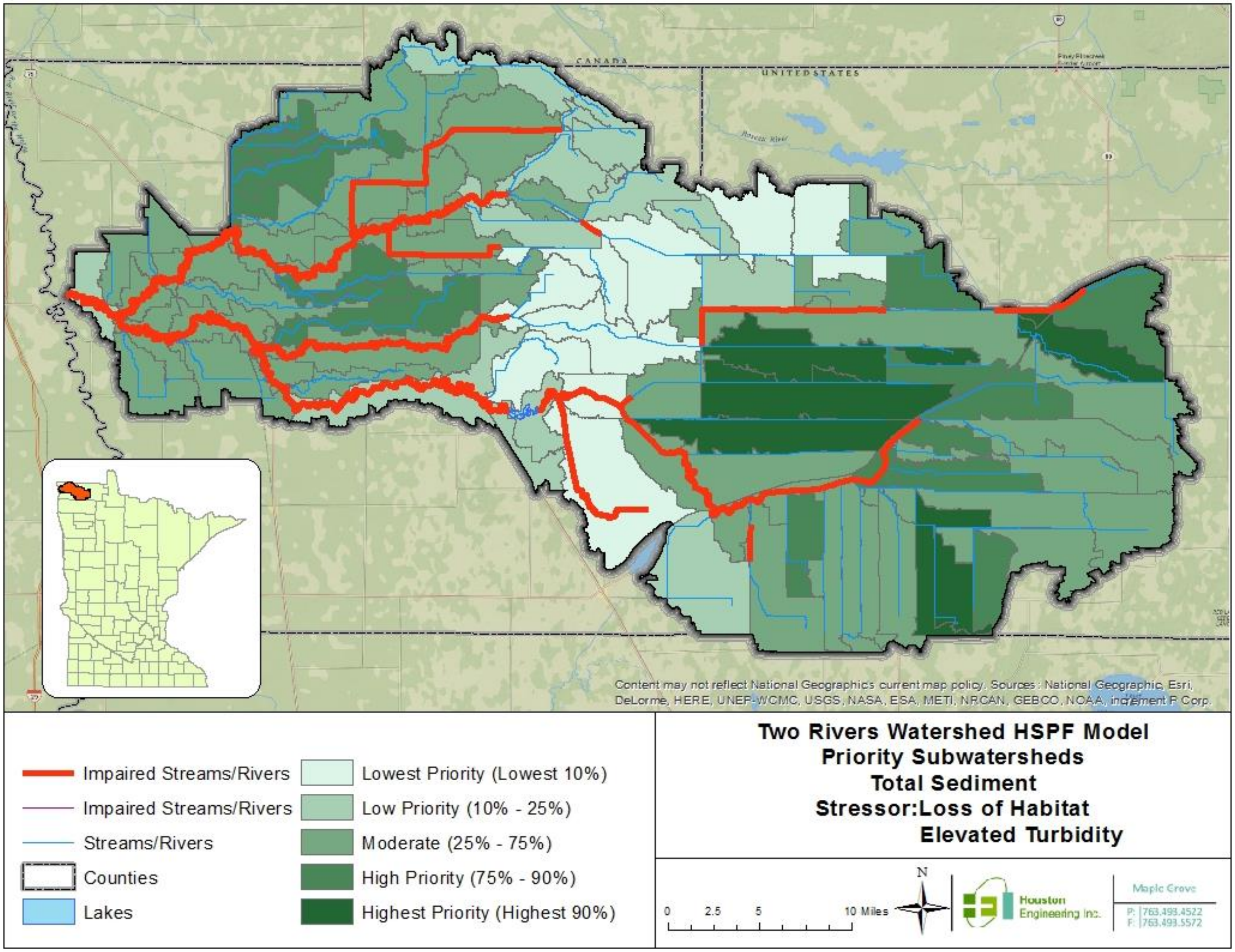

Figure 3-18: Subwatershed priority of TSS yields for subwatersheds in the TRW based on HSPF model results.

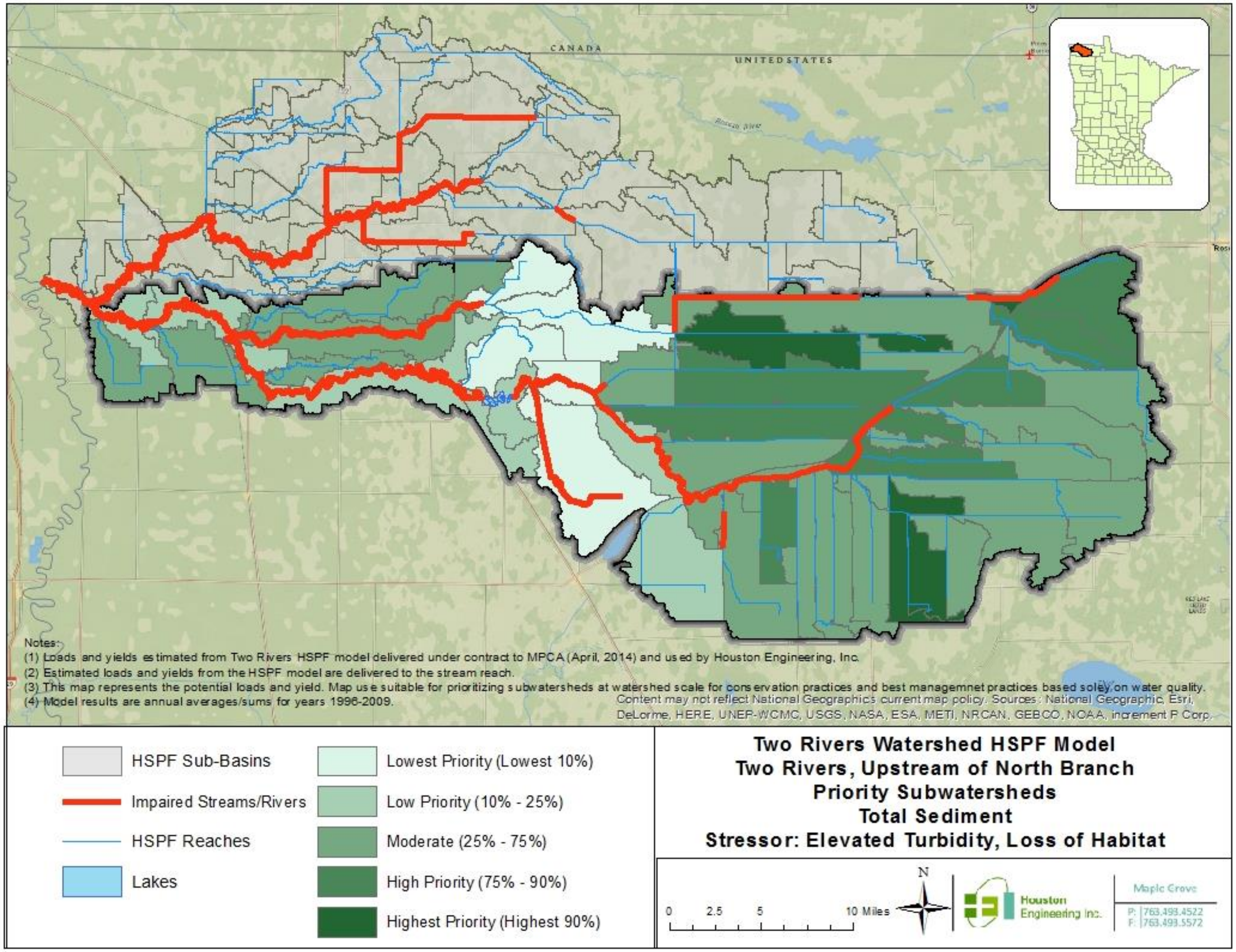

Figure 3-19: Subwatershed priority of TSS yields for Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501) drainage area based on HSPF model result.

4. TMDL Development

TMDLs are developed based on the following equation (**Equation 1**):

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

Equation 1: TMDL equation.

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** and **Section 4.2.1**);

WLA = Wasteload allocation, or the portion of the LC allocated to existing or future permitted point sources (see **Section 4.1.3** and **Section 4.2.3**);

LA = load allocation, or the portion of the LC allocated for existing or future nonpoint sources (see **Section 4.1.2** and **Section 4.2.2**);

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 4.1.4** and **Section 4.2.4**);

RC = reserve capacity, or the portion of the TMDL that accommodates for future loads (see **Section 4.1.6** and **Section 4.2.6**);

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

4.1 *Escherichia coli*

4.1.1 Loading Capacity Methodology

The LC for stream reaches with *E. coli* impairments and receiving a TMDL were determined using the LDC approach (**Appendix A**). An LDC is developed by applying a particular pollutant load standard or criteria to a stream's flow duration curve (FDC) and expressing it as a pollutant load per day. FDC analysis looks at the cumulative frequency of historical flows and plots flows over the exceedance probability scale. The probability of exceedance scale ranges from 0% to 100% with high flows near 0% and low flows being near 100% exceedance (e.g., the maximum flow during the time period will be near 0% exceedance). LDC analysis is the same but applies the water standard to the flows to obtain a load for a given flow frequency. Methods detailed in the EPA document *An Approach for Using Load Duration Curves in the Development of TMDLs* were used in creating the curves (EPA 2007).

To adequately capture different types of flow events and pollutant loading during these events, five flow regimes were identified per EPA guidance (EPA 2007; page 2): Very High Flow (0% to 10%), High Flow (10% to 40%), Mid Flows (40% to 60%), Low Flow (60% to 90%), and Very Low Flow (90% to 100%).

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 tables of this report (**Table 4-5** through **Table 4-9**), only five points on the entire LC curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is ultimately approved by the EPA.

Benefits of LDC analysis include: (1) the loading capacities are calculated for multiple flow regimes, not just a single point; (2) use of the method helps identify specific flow regimes and hydrologic processes/patterns where loading maybe a concern; and (3) ensuring that the applicable water quality standards are protective across all flow regimes. Some limitations with the LDC approach exist: (1) the approach is limited in the ability to track individual loadings or relative source contributions; and (2) is appropriate when a correlation between flow and water quality exists.

For *E. coli*, the LC was calculated using both the instantaneous standard of 1260 organisms/100 mL and the geometric mean (i.e., geomean) standard of 126 organisms/100 mL. Given that all bacteria impairments in the TRW occur under the geometric standard, the load reductions computed under the geometric scenario were used to set the TMDLs. Conversions for computing bacterial loads are shown in **Table 4-1**.

Table 4-1: Converting flow and concentration into bacterial load.

Load (org/day) = Concentration (organisms/100mL) * Flow (cfs) * Factor			
Multiply by **28.316** to convert	ft^3 per second	→	L/sec
Multiply by **1000** to convert	Liters per second	→	mL/sec
Divide by **100** to convert	Milliliters per second	→	organisms/sec
Multiply by **86,400** to convert	organisms per second	→	organisms/day

Observed daily flow data are limited within the TRW. No USGS station is located near the end of an *E. coli*-impaired AUID. Therefore, simulated daily mean flows from the TRW HSPF model (RESPEC 2014) were used to create the LDCs for the remaining AUIDs. The HSPF model simulates flows from 1995 through 2009. In order to best capture the flow regimes of each AUID, the period 1996 through 2009 was used in development of the LDCs. The year 1995 was used in the model as a warm-up period and simulated flows might not be valid (RESPEC 2014). In order to explain the timeframe of the LDCs and include more observed samples in the development of the LDC, the flow record was extended using relationships developed between the modeled HSPF flows and the observed, continuous flows for the USGS gaging station downstream of Lake Bronson (05094000) and two Minnesota Department of Natural Resources (DNR) gaging stations (70021001 in the North Branch Two Rivers near Northcote, CSAH4 and 70018001 in the South Branch Two Rivers at Hallock, Minnesota). More information on the extension of the flow record can be found in the TRW LDC memorandum (**Appendix A**).

The water quality data used to develop the LDCs were obtained from the MPCA through their EQuIS database (see **Section 3.5** for water quality sites). For the purposes of creating the LDCs, water quality data for 1996 through 2014 was used. It was assumed the distribution of flow conditions have not changed between the two time periods used to generate the LDCs (1996 through 2009 for flows and 1996 through 2014 for observed water quality data). **Table 4-2** provides a list of water quality stations used to develop the LDCs. To match the time period when the water quality standard is applicable, the bacterial LDCs were created using flow and *E. coli* water quality data from April through October only. Individual loading estimates were calculated by combining the observed *E. coli* concentration and simulated mean daily flow value on each sampling date. The load estimates were separated by month and by station, mainly for purposes of display on the curve. “Allowable” loading curves were created for both the instantaneous (1260 organisms/100mL) and monthly geometric mean (i.e., geomean, 126 organisms/100mL) criteria by multiplying each "allowable" concentration by the simulated mean daily flow values and ranking the flows.

Table 4-2: Water quality sites used to develop load duration curves by AUID.

AUID (09020312-XXX)	Water Quality Monitoring Site	*E. coli*	
		Sampling Period	# of Samples
501	S000-186	2000-2008	47
503	S003-100	2008-2014	25
	S007-441	2013-2014	13
505	S002-996	2009-2014	30
506	S002-373	2009-2011	14
535	S002-371	2009-2011	15

4.1.2 Load Allocation Methodology

LAs represent the portion of the LC designated for nonpoint sources of *E. coli*. The LA is the remaining load once the WLA, RC, and MOS are determined and subtracted from the LC. LAs are associated with loads that are not regulated by NPDES permits, including nonpoint sources of pollutants and "natural background" contributions. "Natural background" can be described as physical, chemical, or biological conditions that would exist in a waterbody and that are not a result of human activity. Nonpoint sources of *E. coli* in the TRW were previously discussed in **Section 3.6.1**.

4.1.3 Wasteload Allocation Methodology

All TRW WWTFs are limited to discharging from a single surface secondary treatment cell. All WWTFs are permitted to discharge only during specified discharge windows in the spring and fall. The discharge windows are March 1 through June 30 and September 1 through December 31, with no discharge to ice covered waters.

Maximum daily permitted WLAs were calculated for each WWTF based on a maximum discharge of six inches per day, per MPCA guidance. WLAs were computed for TSS and bacteria based on the maximum permitted daily flow rate from each WWTF.

The maximum daily permitted bacteria WLAs were converted to maximum annual loads by estimating the number of days to discharge the secondary pond at maximum discharge and multiplying that value by the allowable daily loads. Maximum permitted daily and annual bacteria WLAs for the TRW WWTFs are shown in **Table 4-3**. The WLAs for straight pipe septic systems remain at zero.

Table 4-3: Annual and daily *E. coli* wasteload allocations for WWTFs in the TRW.

	A	B	C	D	E	F	G
Facility	**Permitted Max Daily Discharge (liters/day)[1]**	**# of Days Discharging per Year at Maximum Discharge, Twice a year**	**Permitted Fecal Coliform Conc. (org/100 mL)**	**WLA-Fecal Coliform (10^9org/day) (A*C/10^6/100)**	***E. coli* Colonies per Fecal Coliform Colony[2]**	**Daily WLA-*E. coli* (10^9org/day) (D*E)**	**Annual WLA-*E. coli* (10^9/yr) (B*F)**
Badger	1,418,504	16	200	2.84	0.63	1.8	28.6
Greenbush	8,634,373	12	200	17.27	0.63	10.9	130.6
Hallock	5,920,713	16	200	11.84	0.63	7.5	119.4
Lake Bronson	1,665,201	16	200	3.33	0.63	2.1	33.6

[1] Computed based on the average surface area of the secondary treatment pond size and an assumed maximum daily discharge of six inches per day.

[2] Based on the MPCA recommended *E. coli* to fecal coliform ratio of 126:200

WLAs for regulated construction stormwater (Permit #MNR100001) were not developed, since *E. coli* is not a typical pollutant from construction sites. WLAs for regulated industrial stormwater were also not developed. Industrial stormwater must receive a WLA only if the pollutant is part of benchmark monitoring for an industrial site in the watershed of an impaired waterbody. There are no bacteria or *E. coli* benchmarks associated with any of the industrial stormwater permit (Permit #MNR050000). The NPDES-permitted CAFO is not located within the drainage areas of any of the AUIDs addressed with an *E. coli* TMDL.

4.1.4 Margin of Safety

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

- Uncertainty in the observed daily flow record;
- Uncertainty in the simulated flow data from the HSPF model;
- Uncertainty in the observed water quality data;
- Uncertainty with regrowth in the sediment, die-off, and natural background levels of *E. coli*; and
- Allocations and loading capacities are based on flow, which varies from very high to very low. This variability is accounted for using the five flow regimes and the LDCs.

The majority of the MOS is apportioned to uncertainty related to the HSPF model than with the other causes for uncertainty. There is no reason to believe that this number is inappropriate, as it is consistent with HSPF modeling errors and is similar to the MOS in TMDLs within the region and across the state.

4.1.5 Critical Condition and Seasonal Variation

The water quality standard for *E. coli* applies from April through October, coinciding with the time period when aquatic recreation occurs, including portions of or all of the spring, summer, and fall seasons. Spring is usually associated with the spring snow-melt and flood flows, the summer with low flows and rapid-rising flows from storm events, and fall with increases in precipitation and rapidly changing landscape, especially in agricultural landscapes. The summer months (especially July, see **Table 3-4**) tend to be the time when the water quality standards for *E. coli* are exceeded the most. This is partly due to the fact that five samples are required to be collected per month in order to assess a stream reach for an *E. coli* impairment and this requirement is most often met in summer months, when the build-up and washoff of bacteria is associated with summary hydrology and warmer water temperatures.

A summary of the bacteria load reduction results and critical flow regimes are found in **Table 4-4**. 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 critical flow regime for bacteria loading ranges from low flows to very high flows.

Table 4-4: Maximum required bacterial (*E. coli*) load reductions for the TRW.

AUID (09020312-XXX)	Bacteria		
	Max. % Load Reduction	Critical Flow Regime	Critical Criterion
501	40%	Very High	Geometric Mean
503[1]	33%	Low	Geometric Mean
505[1]	95%	Very High	Geometric Mean
506[1]	71%	Low	Geometric Mean
535[1]	74%	Low	Geometric Mean

[1] Observed data not available for all flow regimes (see paragraph below).

It should be noted for **Table 4-4**, not all flow regimes in all AUIDs have observed data available to estimate existing loads and, therefore, the critical conditions expressed in **Table 4-4** are for flow regimes where observed data exists. It is unknown if existing conditions during flow regimes without observed data require a significant load reduction or if they are the critical condition. Although the existing loads could be supplemented with modeling data, the LDCs are based on observed data and used to establish the TMDL, the LC, the WLA, and the LA. It is the opinion of the authors that the LDC method is a statistical method and using modeling data to supplement those portions of the flow regime with missing data means the use of two inconsistent data types, which we do not believe is technically defensible and adds unnecessary uncertainty to the estimates. This methodology is consistent with similar TMDLs in the region and across the state (e.g. Sand Hill River Watershed TMDL Study[9] or Mustinka River Watershed TMDL Study[10]).

[9] https://www.pca.state.mn.us/sites/default/files/wq-iw5-10e.pdf

[10] https://www.pca.state.mn.us/sites/default/files/wq-iw5-08e.pdf

4.1.6 Future Growth/Reserve Capacity

No additional RC was included for the point sources in the TRW, given the nature of the assumptions used to create the WLAs. Similarly, no RC was included for nonpoint sources in the watershed (LAs), given that the land use in the TRW is dominated by agriculture and is unlikely to substantially change in the future.

4.1.7 TMDL Summary

Table 4-5 through **Table 4-9** show the computed loading capacities and allocations for the stream *E. coli* impairments in the TRW. The various components of these allocations were developed as described in **Sections 4.1.1** through **4.1.5**. All *E. coli* TMDLs apply to the geometric mean standard. In addition to the TMDL study components, the existing load, the unallocated load (if applicable), and the estimated load reduction as a percentage are given for each flow regime. The existing load is based on existing water quality data, the unallocated load is the potential load available if the existing load is lower than the LC for a given flow regime (i.e., the LC minus the existing load). The existing load and unallocated load are only provided if water quality data are available in the stated flow regime. The TMDLs are based on the conditions for the period 1996 through 2009[11] and these conditions should be considered as the baseline years. In addition, an unallocated load is only provided if the existing load is lower than the LC. The estimated load reduction is the required load reduction, as a percentage of existing load, to meet the LC. A load reduction is only provided if the LC is less than the existing load.

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 tables of this report (**Table 4-5** through **Table 4-9**), only five points on the entire LC curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is ultimately approved by EPA. The LDCs used to develop the loading capacities and allocations are provided in **Appendix A**.

[11] The flows used to load duration curves are for 1996-2009. The observed data used to calculate the existing loads was extended (1996-2014) using seasonal data and derived relationships described in Appendix A. Continuous data was not available to extend the flow record (and therefore the load capacities) through 2014 and it was assumed the distribution of flow condition are similar between the two periods. This only impacts the existing loads and load reductions, not the TMDL components (Equation 1).

Table 4-5: *E. coli* TMDL summary for Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501).

Escherichia coli		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[Billions CFU/day]				
Loading Capacity		**5,737**	**1,304**	**398**	**122**	**25**
Wasteload Allocation	**Total WLA**	**22.2**	**22.2**	**22.2**	**22.2**	**22.2**
	Badger WWTF	1.8	1.8	1.8	1.8	1.8
	Greenbush WWTF	10.9	10.9	10.9	10.9	10.9
	Hallock WWTF	7.5	7.5	7.5	7.5	7.5
	Lake Bronson WWTF	2.1	2.1	2.1	2.1	2.1
Load Allocation	**Total LA**	**5,141**	**1,151**	**336**	**88**	**0.3**
Margin of Safety (MOS)		**574**	**130**	**40**	**12**	**2.5**
Existing Load		**9,562**	**409**	**197**	**119**	**20.0**
Unallocated Load		**0**	**894**	**201**	**3**	**5**
Estimated Load Reduction		**40%**	**0%**	**0%**	**0%**	**0%**

LC, WLA, LA, and MOS are part of the TMDL equation (**Equation 1**). 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; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

Table 4-6: *E. coli* TMDL summary for Middle Branch Two Rivers, CD 23 to South Branch Two Rivers (AUID 09020312-503).

Escherichia coli		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[Billions CFU/day]				
Loading Capacity		**474.1**	**90.9**	**26.8**	**7.4**	**0.90**
Wasteload Allocation	**Total WLA**	**1.8**	**1.8**	**1.8**	**1.8**	***
	Badger WWTF	1.8	1.8	1.8	1.8	***
Load Allocation	**Total LA**	**424.9**	**80.0**	**22.4**	**4.9**	**0.81**
Margin of Safety (MOS)		**47.4**	**9.1**	**2.7**	**0.7**	**0.09**
Existing Load		**112.7**	**45.6**	**18.1**	**11.0**	**ND[1]**
Unallocated Load		**361.4**	**45.3**	**8.7**	**0.0**	**Unk**
Estimated Load Reduction		**0%**	**0%**	**0%**	**33%**	**Unk**

LC, WLA, LA, and MOS are part of the TMDL equation (**Equation 1**). 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; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

***The outflow from the WWTF will be greater than the median flow under this condition. Since outflow is a portion of streamflow, loading under this condition is unlikely to occur. If outflow from this WWTF occurs during this flow condition, the WLA will be the permitted outflow concentration multiplied by the flow rate

[1]ND = No data. No observed data during this flow regime is available at the time of this TMDL. Therefore, existing load, unallocated load, and estimated load reductions are unknown (Unk).

Table 4-7: *E. coli* TMDL summary for South Branch Two Rivers, Lateral Ditch 2 to Lake Bronson (AUID 09020312-505).

Escherichia coli		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[Billions CFU/day]				
Loading Capacity		**4,595**	**1,000**	**303.8**	**99.3**	**19.7**
Wasteload Allocation	**Total WLA**	**10.9**	**10.9**	**10.9**	**10.9**	**10.9**
	Greenbush WWTF	10.9	10.9	10.9	10.9	10.9
Load Allocation	**Total LA**	**4,125**	**889**	**262.5**	**78.5**	**6.9**
Margin of Safety (MOS)		**459.5**	**100**	**30.4**	**9.9**	**2.0**
Existing Load		**88,242**	**631**	**190.9**	**24.2**	**ND[1]**
Unallocated Load		**0.0**	**369**	**112.9**	**75.1**	**Unk**
Estimated Load Reduction		**95%**	**0.0**	**0.0**	**0.0**	**Unk**

LC, WLA, LA, and MOS are part of the TMDL equation (**Equation 1**). 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; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

[1]ND = No data. No observed data during this flow regime is available at the time of this TMDL. Therefore, existing load, unallocated load, and estimated load reductions are unknown (Unk).

Table 4-8: *E. coli* TMDL summary for South Branch Two Rivers, Unnamed ditch to Lateral Ditch 2 SD 95 (AUID 09020312-506).

Escherichia coli		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[Billions CFU/day]				
Loading Capacity		**2,773.6**	**614.0**	**191.3**	**60.7**	**11.7**
Wasteload Allocation	**Total WLA**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Load Allocation	**Total LA**	**2,496**	**553**	**172**	**54.6**	**10.5**
Margin of Safety (MOS)		**277.4**	**61.4**	**19.1**	**6.1**	**1.2**
Existing Load		**ND[1]**	**567.7**	**63.8**	**209.5**	**ND[1]**
Unallocated Load		**Unk**	**46.3**	**127.5**	**0.0**	**Unk**
Estimated Load Reduction		**Unk**	**0%**	**0%**	**71%**	**Unk**

LC, WLA, LA, and MOS are part of the TMDL equation (**Equation 1**). 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; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

[1]ND = No data. No observed data during this flow regime is available at the time of this TMDL. Therefore, existing load, unallocated load, and estimated load reductions are unknown (Unk).

Table 4-9: *E. coli* TMDL summary for County Ditch 13, Unnamed ditch to Badger Creek (disconnected portion) (AUID 09020312-535).

Escherichia coli		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[Billions CFU/day]				
Loading Capacity		**201.7**	**41.3**	**11.38**	**3.21**	**0.58**
Wasteload Allocation	**Total WLA**	**1.8**	**1.8**	**1.8**	**1.8**	***
	Badger WWTF	1.8	1.8	1.8	1.8	***
Load Allocation	**Total LA**	**179.8**	**35.4**	**8.45**	**1.09**	**0.52**
Margin of Safety (MOS)		**20.2**	**4.1**	**1.1**	**0.32**	**0.06**
Existing Load		**ND[1]**	**10.3**	**10.4**	**12.4**	**ND[1]**
Unallocated Load		**Unk**	**31.0**	**1.0**	**0.0**	**Unk**
Estimated Load Reduction		**Unk**	**0%**	**0%**	**74%**	**Unk**

LC, WLA, LA, and MOS are part of the TMDL equation (**Equation 1**). 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; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

***The outflow from the WWTF will be greater than the median flow under this condition. Since outflow is a portion of streamflow, loading under this condition is unlikely to occur. If outflow from this WWTF occurs during this flow condition, the WLA will be the permitted outflow concentration multiplied by the flow rate

[1]ND = No data. No observed data during this flow regime is available at the time of this TMDL. Therefore, existing load, unallocated load, and estimated load reductions are unknown (Unk).

4.2 Total Suspended Solids

In January 2015, EPA approved Minnesota's transition from a turbidity standard to a TSS standard to represent sediment in a stream reach. Therefore, TSS TMDLs were developed for all turbidity impairments in the TRW.

4.2.1 Loading Capacity Methodology

Sediment load reductions were computed using the LDC approach. To adequately capture different types of flow events and pollutant loading during these events, five flow regimes were identified per EPA guidance: Very High Flow (0% to 10%), High Flow (10% to 40%), Mid Flow (40% to 60%), Low Flow (60% to 90%), and Very Low Flow (90% to 100%). Development of the LDCs is discussed in other sections (see **Section 4.1.1** and **Appendix A**).

The TSS standard-based LDCs were created using the Southern Region TSS standard of 65 mg/L. The TSS standard-based LDCs were calculated using a combination of TSS data and converted turbidity data collected during the assessment period (see **Section 4.1.1** for more information about the LDCs). The TSS standard only applies during the months of April through September. A 10% MOS was applied. Conversion factors for this work are shown in **Table 4-10**.

Table 4-10: 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 surrogate** (32 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

The water quality sites used to develop the TSS LDCs are provided in **Table 4-11**. It should be noted that only unique data points of turbidity and TSS were used to develop the LDCs; in other words, if both turbidity and TSS were sampled at the same time and at the same site, the TSS sample was used.

Table 4-11: Water quality sites used to develop TSS load duration curves.

AUID (09020301-XXX)	Water Quality Monitoring Site	Total Suspended Solids		Turbidity		Combined Turbidity/TSS	
		Sampling Period	# of Samples	Sampling Period	# of Samples	Sampling Period	# of Samples
501	S000-186	1996-2011	59	2000-2008	12	1996-2011	71
	S003-102	--	0	2000-2008	8	2000-2008	8
	S005-387	2014	25	--	0	2014	25
509	S000-569	1996-2014	229	2000-2010	6	1996-2014	232

4.2.2 Load Allocation Methodology

The LA is considered the remaining LC once WLAs, reserve capacities, and MOSs are determined. LAs are associated with loads that are not regulated by NPDES permits, including nonpoint sources of pollutants and "natural background" contributions. "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 pollution in the TRW were discussed previously and include overland erosion, channel degradation, natural background, and other sources.

4.2.3 Wasteload Allocation Methodology

The WLA represents the regulated portion of the LC, requiring a NPDES permit. Regulated sources may include construction stormwater, industrial stormwater, Municipal Separate Storm Sewer Systems (MS4) permitted areas, NPDES permitted feedlots, and WWTFs. The only regulated sources of TSS are construction and industrial stormwater discharges and WWTFs. There are no MS4s or NPDES permitted feedlots in the drainage basins of any impaired streams.

WLAs for construction and industrial stormwater discharges were combined and addressed through a categorical allocation. This TMDL report assumes that 0.1% of the TRW's land use contributes construction and/or industrial stormwater runoff at any given time. Historical permits and land use in the watershed support this assumption. Stormwater runoff from construction sites that disturb: (a) one acre of soil or more, (b) less than one acre of soil and are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but determined to pose a risk to water quality are regulated under the state's NPDES/State Disposal System (SDS) General Stormwater Permits for Construction Activity (MNR1000001). This permit requires and identifies BMPs to be implemented to protect water resources from mobilized sediment and other pollutants of concern. If the owner/operators of impacted construction sites, within the TRW, obtain and abide by the NPDES/SDS General Construction Stormwater Permit, the stormwater discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Similar to construction activities, industrial sites are regulated under general permits, in this case either the NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or the NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying, and Hot Mix Asphalt Production facilities (MNG490000). Like the NPDES/SDS General Construction Stormwater Permit, these permits identify BMPs to be implemented to protect water resources from pollutant discharges at the site. If the owner/operators of industrial sites within the TRW obtain and abide by the necessary NPDES/SDS General Stormwater Permits, the discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Due to the transient nature of construction and industrial activities, it is assumed that 0.1% of the drainage area is under construction and industrial activities at any given time. Therefore, to calculate the WLA for construction and industrial stormwater, this TMDL report assumes that 0.1% of the load capacity for the stream reach is assigned to construction/industrial stormwater WLA.

All TRW WWTFs are limited to discharging from a single surface secondary treatment cell. All WWTFs are permitted to discharge only during specified discharge windows in the spring and fall. The discharge windows are March 1 through June 30 and September 1 through December 31 with no discharge to ice covered waters.

Per MPCA guidance, the permitted WLAs were calculated for each WWTF based on the Calendar Month Average TSS and the maximum discharge of six inches per day. WLAs were computed for TSS based on the maximum permitted daily flow rate from each facility.

The maximum daily permitted TSS WLAs were converted to maximum annual loads by estimating the number of days to discharge the secondary pond at maximum discharge and multiplying that value by the allowable daily loads. Maximum permitted daily and annual TSS WLAs for the TRW WWTFs are shown in **Table 4-12**.

Table 4-12: Annual and daily TSS wasteload allocations for TRW WWTFs.

			A				B		
Facility	**NPDES Permit Number**	**System Type**	**Secondary Pond Size (acres)**	**Operating Depth (ft)**	**Average Wet Weather Design Flow (gpd)**	**Permitted Max Daily Discharge (gpd)[1] (A*0.163*10^6)**	**Calendar Month Average Load (kg/day)**	**Daily WLA-TSS (tons/ day) [B/907.2 (kg/ton)]**	**Annual WLA-TSS (tons/yr)[2]**
Badger	MNG580155	Class D: 3-cell pond	2.3	4	55,000	374,729	63.8	0.7	1.12
Greenbush	MNG580156	Class D: 2-cell pond	14	3	114,000	2,280,960	388.5	0.43	5.13
Hallock	MNG580147	Class D: 3-cell pond	9.6	4	200,000	1,564,087	266.4	0.29	4.69
Lake Bronson	MNG580029	Class D: 2-cell pond	2.7	4	35,000	439,899	74.9	0.08	1.32
Lancaster	MNG580066	Class D: 2-cell pond	2.5	3.5	55,000	407,314	69.3	0.08	1.07

[1] Computed based on the average surface area of the secondary treatment pond size and an assumed maximum daily discharge of six inches per day.

[2]Assumes twice annual maximum discharges to completely drain secondary pond (i.e. 2* 6 inches per day * operating depth*daily WLA).

The NPDES-permitted CAFO is located within the drainage area of AUID 09020312-509, which has a TSS TMDL in this report. This is a zero discharge facility and is given a WLA of zero. It should not impact water quality in the basin as a point source and thus is not listed as a point source in the TMDL summary table.

4.2.4 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, modeling error, and implementation activities. An explicit 10% of the LC MOS was applied to each flow regime for all LDCs developed for this TMDL report. The explicit 10% MOS accounts for:

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

The majority of the MOS is apportioned to uncertainty related to the HSPF model than with the other causes for uncertainty. There is no reason to believe that this number is inappropriate as it is consistent with HSPF modeling errors and is similar TMDLs in the region and across the state.

4.2.5 Critical Condition and Seasonal Variation

A summary of the TSS load reduction results can be found in **Table 4-13**. 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 critical flow regimes for TSS loading were very high flow for AUID 09020312-501 and high flow for AUID 09020312-509.

Table 4-13: Maximum required total suspended solids load reductions for the TRW.

AUID (09020312-XXX)	Total Suspended Solids	
	Max. % Load Reduction	Critical Flow Regime
Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (-501)	58%	Very High
Two Rivers, North Branch Two Rivers to Red River (-509)	78%	High

4.2.6 Reserve Capacity

No additional RC was included for the point sources in the TRW, given the nature of assumptions used to create the WLAs. Similarly, no RC was included for nonpoint sources in the watershed (LAs), given that the land use in the TRW is dominated by agriculture and is unlikely to substantially change in the future.

4.2.7 TMDL Summary

Table 4-14 and **Table 4-14** show the computed loading capacities and allocations for the TRW streams, which are currently listed for turbidity, using the TSS standard. The various components of these allocations were developed as described in **Sections 4.2.1** to **4.2.6**. The LDCs used to develop the loading capacities and allocations are provided in **Appendix A**. It should be noted that the sum of some of the TMDL calculations may not equal the LC of the AUID; this is due to rounding. The TMDLs are based on the conditions for the period 1996 through 2009[12], and these conditions should be considered as the baseline years.

In addition to the TMDL components, the existing load, the unallocated load (if applicable), and the estimated load reduction, as a percentage, are given for each flow regime. The existing load is based on existing water quality data, the unallocated load is the potential load available if the existing load is lower than the LC for a given flow regime (i.e., the LC minus the existing load). An unallocated load is only provided if the existing load is lower than the LC. The estimated load reduction is required load reduction, as a percentage of existing load, to meet the LC. A load reduction is only provided if the LC is less than the existing load.

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,

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[12] The flows used to load duration curves are for 1996-2009. The observed data used to calculate the existing loads was extended (1996-2014) using seasonal data and derived relationships described in Appendix A. Continuous data was not available to extend the flow record (and therefore the load capacities) through 2014 and it was assumed the distribution of flow condition are similar between the two periods. This only impacts the existing loads and load reductions, not the TMDL components (Equation 1).

virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report (**Table 4-14** and **LC,** WLA, LA, and MOS are part of the TMDL equation (Equation 1). 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; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

Table 4-15: Total suspended solids TMDL for Two Rivers, North Branch Two Rivers to Red River (AUID 09020312-509).), only five points on the entire LC curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is ultimately approved by the EPA. The LDCs used to develop the loading capacities and allocations are provided in **Appendix A**.

Table 4-14: Total suspended solids TMDL for Two Rivers, Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501).

Total Suspended Solids		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[tons/day]				
Loading Capacity		**347.9**	**87.8**	**28.81**	**9.20**	**1.64**
Wasteload Allocation	**Total WLA**	**1.22**	**0.96**	**0.90**	**0.88**	**0.87**
	Badger WWTF	0.07	0.07	0.07	0.07	0.07
	Greenbush WWTF	0.43	0.43	0.43	0.43	0.43
	Hallock WWTF	0.29	0.29	0.29	0.29	0.29
	Lake Bronson WWTF	0.08	0.08	0.08	0.08	0.08
	Construction/Industrial Stormwater	0.35	0.09	0.03	0.009	0.002
Load Allocation	**Total LA**	**311.9**	**78.0**	**25.0**	**7.40**	**0.60**
Margin of Safety (MOS)		**34.8**	**8.8**	**2.9**	**0.92**	**0.16**
Existing Load		**820.9**	**131.5**	**28.4**	**6.13**	**0.89**
Unallocated Load		**0.0**	**0.0**	**0.4**	**3.07**	**0.75**
Estimated Load Reduction		**58%**	**33%**	**0%**	**0%**	**0%**

LC, WLA, LA, and MOS are part of the TMDL equation (Equation 1). 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; and the estimated load reduction is the reduction, as a percentage, of the existing load to meet the numeric water quality standard.

Table 4-15: Total suspended solids TMDL for Two Rivers, North Branch Two Rivers to Red River (AUID 09020312-509).

Total Suspended Solids		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[tons/day]				
Loading Capacity		**520.7**	**130.3**	**45.0**	**14.4**	**2.79**
Wasteload Allocation	**Total WLA**	**1.47**	**1.08**	**0.99**	**0.96**	**0.95**
	Badger WWTF	0.07	0.07	0.07	0.07	0.07
	Greenbush WWTF	0.43	0.43	0.43	0.43	0.43

Total Suspended Solids		Flow Regime				
		Very High	High	Mid	Low	Very Low
		[tons/day]				
	Hallock WWTF	0.29	0.29	0.29	0.29	0.29
	Lake Bronson WWTF	0.08	0.08	0.08	0.08	0.08
	Lancaster WWTF	0.08	0.08	0.08	0.08	0.08
	Construction/Industrial Stormwater	0.52	0.13	0.04	0.014	0.003
Load Allocation	**Total LA**	**467.2**	**116.2**	**39.5**	**12.0**	**1.56**
Margin of Safety (MOS)		**52.1**	**13.0**	**4.5**	**1.44**	**0.28**
Existing Load		**1,509.3**	**579.5**	**154.0**	**26.6**	**2.2**
Unallocated Load		**0.0**	**0.0**	**0.0**	**0.0**	**0.59**
Estimated Load Reduction		**65%**	**78%**	**71%**	**46%**	**0%**

LC, WLA, LA, and MOS are part of the TMDL equation (**Equation 1**). 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; 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

The economy of the entire watershed area, including municipalities, is driven by agriculture. As such, little change in land use is expected in the future. Consistent with much of the Red River Valley, land use in the TRW has shown little change in recent years. Analysis of the NLCDs from 2006 and 2011 show nearly 0% change in land cover between the years.

In general, populations within the western portion of the TRW have experienced a steady decline since the 1950s and 1960s. The greater Red River Basin is characterized as low gradient with a poorly defined floodplain, which combined with extensive drainage, conversion of native prairie to farmland, and urban development create a highly flood prone area. Frequent flooding in addition to the expansion of large scale farm operations have contributed to this population decline. In contrast, business and industry expansion in the Roseau and Warroad areas, located just east of the TRW boundary have contributed to population growth within that area.

5.1 New or Expanding Permitted MS4 WLA Transfer Process

Future transfer of watershed runoff loads in this TMDL report 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. An example is existing state highways that were outside an Urban Area at the time the TMDL report was completed, but are now inside a newly expanded Urban Area. This will 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 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 report. 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.

5.2 New or Expanding Wastewater (TSS and *E. coli* TMDLs only)

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 2014). 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[13] webpage.

6. Reasonable Assurance

Reasonable assurance of point sources contributing water with pollutant levels below state standards are assured through the issuance and regulation of NPDES permits. No additional NPDES permit requirements are needed for TRW point sources to meet their WLAs. Reasonable assurance of load reductions and strategies developed under this TMDL report comes from multiple other sources. LAs and their associated nonpoint source implementation strategies are reasonably assured by historical and ongoing collaborations in the TRW. Several agencies and local governmental units have been and continue to work toward the goal of reducing pollutant loads in the TRW. Strong partnerships between the TRWD, counties, and soil and water conservation districts (SWCDs) have led to the implementation of conservation practices in the past and will continue to do so into the future. As discussed in the Monitoring Plan section (**Section 7**) and the Implementation Strategy Summary (**Section 8**), the TRWD has a long history of stream monitoring and implementing best management practices (BMPs). Since

[13] http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/project-resources/tmdl-policy-and-guidance.html

2003, The TRWD has been actively involved in volunteer water quality over the most recent MPCA 10-year assessment period.

TRWD in partnership with the Kittson and Roseau SWCDs has applied for and received several Clean Water Fund Grants to install numerous projects and structures in the TRW to improve water quality. The TRWD, Kittson SWCD, and Roseau SWCD plan to continue their partnerships to proactively seek funding and implement BMPs to address water quality issues within the TRW. Further discussion on the monitoring and implementation strategies can be found in **Section 7** and **Section 8**, respectively.

Upon approval of the TMDL report by the EPA, the TRWD will incorporate the various implementation activities described by this TMDL report and concurrently developed Two Rivers WRAPS Report (HEI 2019) into their Watershed Management Plan (WMP) and the 2018-awarded One Watershed, One Plan (1W1P). The TRWD is committed to taking a lead role during the implementation of this TMDL report and has 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, in part, to fund water quality improvements. The interagency Minnesota Water Quality Framework (**Figure 6-1**) 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 TRWD has received grants from in the past.

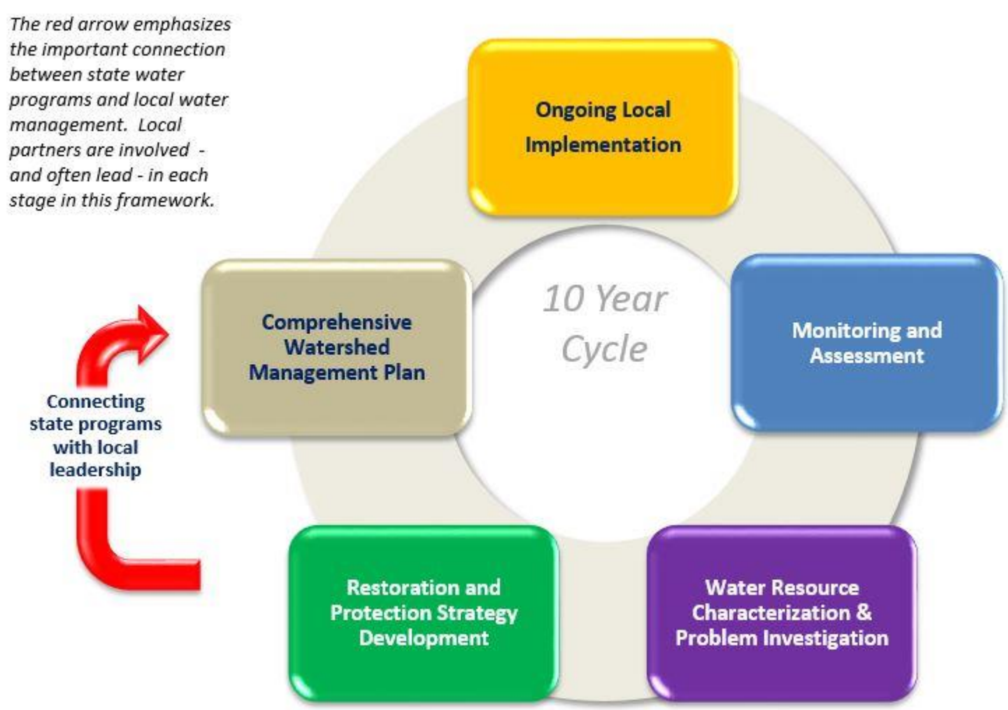

Figure 6-1: Minnesota Water Quality Framework.

The TRWD has the ability to provide funding for projects consistent with those identified within the WMP and/or 1W1P (when completed). The WMP and/or 1W1P (when completed) is required to be updated following a 10-year cycle and future revisions will include projects and methods to make progress toward implementing the TMDLs.

6.1 Regulatory

6.1.1 Construction Stormwater

State implementation of the TMDL will be through action on NPDES Permits for regulated construction stormwater. To meet the categorical WLA that includes construction stormwater, construction stormwater activities are required to meet the conditions of the Construction General Permit under the NPDES program, and properly select, install, and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

6.1.2 Industrial Stormwater

To meet the categorical WLA that includes industrial stormwater, industrial stormwater activities are required to meet the conditions of the industrial stormwater general permit or Nonmetallic Mining & Associated Activities general permit (MNG49) under the NPDES program, and properly select, install and maintain all BMPs required under the permit.

6.1.3 Municipal Separate Storm Sewer System (MS4) Permits

There are no MS4s present in the TRW.

6.1.4 Wastewater NPDES & SDS Permits

The MPCA issues permits for WWTFs or industrial facilities that discharge into waters of the state. The permits have site specific limits on bacteria or TSS that are based on water quality standards. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. In addition, NPDES and SDS Permits set limits and establish controls for land application of waste and byproducts. No additional requirements are needed beyond what is already in the permits in order for TRW point sources to meet their WLAs.

6.1.5 Subsurface Sewage Treatment Systems (SSTS) Program

SSTS, commonly known as septic systems, are regulated by Minn. Stat. §§ 115.55 and 115.56. Counties and other local government units (LGUs) that regulate SSTS must meet the requirements for local SSTS programs in Minn. R. ch. 7082. Counties and other LGUs must adopt and implement SSTS ordinances in compliance with Minn. R. chs. 7080, through 7083.

These regulations detail:

- Minimum technical standards for individual and mid-size SSTS;
- A framework for LGU to administer SSTS programs; and
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee.

Counties and other LGUs enforce Minn. R. chs. 7080, through 7083, through their local SSTS ordinance and issue permits for systems designed with flows up to 10,000 gallons per day. There are approximately 200 LGUs across Minnesota, and depending on the location, an LGU may be a county, city, township, or sewer district. LGUs SSTS ordinances vary across the state. Some require SSTS compliance inspections prior to property transfer, require permits for SSTS repair and septic tank maintenance, and may have other requirements, which are stricter than the state regulations.

Compliance inspections by counties and other LGU are required by Minn. R. for all new construction and for existing systems if the LGU issues a permit for the addition of a bedroom. In order to increase the number of compliance inspections, the MPCA has developed and administers several grants to LGUs for various ordinances and specific actions. Additional grant dollars are awarded to counties that have additional provisions in their ordinance above the minimum program requirements. The MPCA has worked with counties through the SSTS Implementation and Enforcement Task Force (SIETF) to identify the most beneficial way to use these funds to accelerate SSTS compliance statewide.

The MPCA staff keep a statewide database of known imminent threat to public health or safety (ITPHS) systems that include “straight pipe systems”. These straight pipe systems are reported to the counties or the MPCA by the public. Upon confirmation of a straight pipe system, the county sends out a notification of non-compliance, which starts a 10-month deadline to fix the system and bring it into compliance. From 2006 through 2017, 742 straight pipes have been tracked by the MPCA. Seven hundred and one of those were abandoned, fixed, or were found not to be a straight pipe system as defined in Minn. Stat. 115.55, subd. 1. There have been 17 Administrative Penalty Orders issued and docketed in court. The remaining straight pipe systems received a notification of non-compliance. Those that do not update within the timeframe are addressed through the process outlined in Minn. Stat. § 115.55, subd. 11, that states if the owner does not replace or discontinue the use of the straight-pipe system within 10 months after the notice was received, the owner of the straight-pipe system shall be subject to an administrative penalty of $500 per month of noncompliance beyond the 10-month period.

6.1.6 Feedlot Program

All feedlots in Minnesota are regulated by Minn. R. ch. 7020. The MPCA has regulatory authority of feedlots, but counties may choose to participate in a delegation of the feedlot regulatory authority to the local unit of government. Delegated counties are then able to enforce Minn. R. ch. 7020 (along with any other local rules and regulations) within their respective counties for facilities that are under the CAFO threshold. In the TRW, the counties of Kittson and Marshall are delegated the feedlot regulatory authority. The counties will continue to implement the feedlot program and work with producers on manure management plans.

The MPCA regulates the collection, transportation, storage, processing and disposal of animal manure and other livestock operation waste. The MPCA Feedlot Program implements rules governing these activities, and provides assistance to counties and the livestock industry. The feedlot rules apply to most aspects of livestock waste management including the location, design, construction, operation and management of feedlots, and manure handling facilities.

There are two primary concerns about feedlots in protecting water:

- Ensuring that manure on a feedlot or manure storage area does not run into water and
- Ensuring that manure is applied to cropland at a rate, time and method that prevents bacteria and other possible contaminants from entering streams, lakes, and ground water.

6.1.7 Nonpoint Source

For the seven TMDLs in this report, the vast majority of the pollutant load is attributed to nonpoint sources. Thus, for TMDLs that require reductions in pollutant loads, nonpoint sources are the only sources for reductions. The existing state statutes/rules pertaining to nonpoint sources include:

- 50-foot buffer required for the shore impact zone of streams classified as protected waters (Minn. Stat. § 103F.201) for agricultural land uses. November 1, 2017 was the deadline for compliance.
- 16.5-foot minimum width buffer required on public drainage ditches (Minn. Stat. § 103E.021). November 1, 2018 was the deadline for compliance.
    - In a mn.gov buffer compliance map, preliminary compliance estimates as of September 12, 2017 indicated that 37 of Minnesota's 87 counties were 95% to 100% in compliance with the buffer law. Compliance estimates for Kittson, Marshall, and Roseau Counties were 70% to 79%, <70%, and 95% to 100%, respectively.
    - In an updated mn.gov buffer compliance map, preliminary compliance estimates as of July 26, 2018, indicated the number of counties that were 95% to 100% in compliance with the buffer law increased to 45. Compliance estimates changed for only one of the counties of interest. Roseau County compliance estimate actually changed to 80% to 89%.
- Protecting highly erodible land within the 300-foot shoreland district (Minn. Stat. § 103F.201).
- Excessive soil loss statute (Minn. Stat. § 103F.415).
- Nuisance nonpoint source pollution (Minn. R. 7050.0210, subp. 2).
- Other measures that may be identified in the WRAPS report or the future 1W1P.

6.2 Non-regulatory

6.2.1 Pollutant Load Reduction

Reliable means of reducing nonpoint source pollutant loads are fully addressed in the Two Rivers WRAPS Report (HEI 2019), a document that is written to be a companion to this TMDL report. In order for the impaired waters to meet water quality standard, all of pollutant reductions in the TRW will need to come from nonpoint sources. The presence of naturally occurring fine silts and clays along with soil erosion and channel degradation are believed to be the primary sources of sediment in the TRW. In addition, changes to flow patterns has been identified as a primary driver of degraded habitat. Historical changes in land cover (e.g. native vegetation to cropland) and drainage patterns (e.g. ditching and channelization) are primary anthropogenic factors contributing to flow regime instability (MPCA 2016a). As described in the WRAPS report, the BMPs included there have all been demonstrated to be effective in reducing transport of pollutants to surface water. The combinations of BMPs discussed throughout the WRAPS report were derived from Minnesota's Nutrient Reduction Strategy (NRS) (MPCA 2015) and related tools. As such, they were vetted by a statewide engagement process prior to being applied in the TRW.

Selection of sites for BMPs will be led by LGUs, including SWCDs, watershed districts, and county planning and zoning, with support from state and federal agencies. These BMPs are supported by programs administered by the SWCDs and the Natural Resource Conservation Service (NRCS). Local resource managers are well-trained in promoting, placing, and installing these BMPs. State and local agencies will need to work with landowners to identify priority areas for BMPs and practices that will help reduce runoff, as well as streambank and overland erosion. Agencies, organizations, LGUs, and citizens alike need to recognize that resigning waters to an impaired condition is not acceptable. These BMPs reduce pollutant loads from runoff (i.e. phosphorus, sediment, and pathogens) and loads delivered through drainage tiles or groundwater flow (e.g. nitrates).

To help achieve nonpoint source reductions, the watershed's citizens and communities will need to voluntarily adopt the practices at the necessary scale and rates to achieve the 10-year targets presented in Table 19 of the Two Rivers WRAPS Report. These tables also present the allocations of the pollutant/stressor goals and targets to the primary sources and the estimated years to meet the goal. The strategies identified and relative adoption rates developed by the WRAPS Local Work Group were used to calculate the adoption rates needed to meet the pollutant/stressor 10-year targets. In addition to public participation, several government programs are in place to support a political and social infrastructure that aims to increase the adoption of strategies that will improve watershed conditions and reduce loading from nonpoint sources.

One example of a government program available is *The Minnesota Agricultural Water Quality Certification Program* (MAWQCP). The MAWQCP is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Those who implement and maintain approved farm management practices will be certified and in turn obtain regulatory certainty for a period of 10 years.

Through this program, certified producers receive:

- Regulatory certainty**:** certified producers are deemed to be in compliance with any new water quality rules or laws during the period of certification;
- Recognition**:** certified producers may use their status to promote their business as protective of water quality; and
- Priority for technical assistance**:** producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality.

6.2.2 Prioritization

The WRAPS details a number of tools that provide means for identifying priority pollutant sources and implementation work in the watershed. Further, LGUs in the TRW often employ their own local analysis for determining priorities for work. Priorities for implementation will be detailed in the 2018-selected One Watershed, One Plan process for the TRW.

6.2.3 Funding

On November 4, 2008, Minnesota voters approved the Clean Water, Land and Legacy Amendment to the constitution to:

- protect drinking water sources;
- protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat;
- preserve arts and cultural heritage;
- support parks and trails; and
- protect, enhance, and restore lakes, rivers, streams, and groundwater.

This is a secure funding mechanism with the explicit purpose of supporting water quality improvement projects.

Additionally, there are many other funding sources for nonpoint pollutant reduction work; they include but are not limited to Clean Water Act Section 319 grants, BWSR state Clean Water Fund implementation funding, state Clean Water Partnership loans, and NRCS incentive programs. Programs and activities are also occurring at the local government level, where county staff, commissioners, and residents work together to address water quality issues.

6.2.4 Planning and Implementation

The WRAPS, TMDLs, and all the supporting documents provide a foundation for planning and implementation. Subsequent planning, including imminent development of the 1W1P for the TRW, will draw on the goals, technical information, and tools to describe in detail strategies for implementation. For the purposes of reasonable assurance, the WRAPS document is sufficient in that it provides strategies for achieving pollutant reduction goals. In addition, the commitment and support from the local governmental units will ensure that this TMDL project is carried successfully into the One Watershed, One Plan process, and through implementation.

6.2.5 Tracking Progress

Water monitoring efforts within the TRW are diverse and constitute a sufficient means for tracking progress and supporting adaptive management (See **Section 8.4**).

7. Monitoring Plan

Monitoring within the TRW will continue primarily through the efforts of the TRWD. A summary of scheduled water quality sampling, in addition to recommendations for additional sampling needs, is outlined in the Two Rivers WRAPS Data Review and Sampling Plan (HEI 2014b). Ongoing and historical water quality monitoring actions taken by the TRWD are also outlined within the Overall Plan of the TRWD (TRWD 2004).

Three monitoring components are outlined within the Two Rivers Watershed's WRAPS Data Review and Sampling Plan (HEI 2014b), including water chemistry (quality) sampling, biological sampling, and flow monitoring. Ongoing water quality sampling occurs at 25 river/stream sites within the TRW that are sampled primarily between June 1 and September 30, with the majority of data available for DO, *E. coli*, eutrophication, pH, turbidity, and TSS. Minimum sample sizes for these parameters are determined by the data requirements for select water quality parameters in Minnesota's rivers and streams (MPCA 2014). Twelve citizen groups and LGU sponsored programs performed water chemistry sampling during the past 10-year assessment period and are anticipated to have continued involvement in water chemistry sample collection into the future.

Future biological assessment sampling within the TRW includes resampling of seven locations for fish and four locations for macroinvertebrates (Dingmann 2014). Five long-term flow monitoring stations will continue to operate as permanent long-term stations, which will be visited every 30 to 40 days with additional visits during high flows (HEI 2014b). Section 7 of the Overall Plan of the TRWD (TRWD 2004), outlines additional details of historical and ongoing TRWD water quality and flow monitoring program actions.

8. Implementation Strategy Summary

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

The identified implementation strategies and priorities are discussed in the Two Rivers WRAPS Report (HEI 2019) and the Two Rivers Watershed Stressor Identification Report (MPCA 2016a). The following sections are summaries of the suggested strategies needed to achieve restoration goals in the TRW. More detailed information can be found in the Two Rivers WRAPS Report (HEI 2019).

8.1 Permitted Sources

8.1.1 MS4

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

8.1.2 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 TRW at any one time, 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 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 report. All local construction stormwater requirements must also be met.

8.1.3 Industrial Stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the TRW for which NPDES 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 report. All local stormwater management requirements must also be met.

8.1.4 Wastewater

The current requirements of the WWTFs' NPDES permits should be sufficient implementation strategies for the WWTFs in the TRW. If a WWTF follows all requirements under the NPDES wastewater permit, the wastewater discharge would be expected to be consistent with the WLA in this TMDL report.

8.2 Non-Permitted Sources

8.2.1 Agriculture

The TRWD, along with Kittson, Marshall, and Roseau SWCDs, have a long history of improving water quality. They have been actively seeking grants to improve local water quality since the passage of the Clean Water, Land, and Legacy Amendment, and before.

The TRWD have set goals in their WMP (TRWD 2004) to improve and sustain surface water quality and to reduce erosion and sedimentation. This includes reducing erosion and sedimentation to waterways and wetlands, restoring a more natural hydrograph to waters in the watershed and reducing the "flashiness" of the hydrograph, restoring and rehabilitating unstable stream channels, continuing to monitor water quality, and completing this TMDL report. TRWD's strategies to achieve their goals include utilizing BMPs to install buffer strips along ditch systems adjacent to ag fields (in line with Minnesota's 2016 Buffer Law), identify susceptible areas via monitoring and this TMDL report, utilizing grass waterways, restoring and creating new wetlands, reducing field drainage and increasing temporary storage in fields designed to hold water for short periods, installation of shelter belts to reduce wind erosion, installation of streambank bio-engineering protections and riparian restorations to create sinuosity and pools and riffles along water courses, and promotion of fencing of cattle and other livestock along water course when practical and feasible. In addition, the TRWD plans to adopt strategies laid out in this TMDL report and the WRAPS document with coordination of local communities and utilizing local and state agencies, such as the NRCS, DNR, and MPCA.

As an example, in 2011 the Kittson SWCD partnered with the TRWD, Roseau SWCD, NRCS, and Farm Service Agency, to install grass filter strips to improve Lake Bronson. With their original $100,000 Clean Water Fund grant, Kittson SWCD was able to enroll 12 contracts for 104.1 acres of grass filter strips, reducing the sediment entering Lake Bronson by 3,077 tons per year and phosphorus by 3,021 pounds per year. The program was so successful that Kittson SWCD applied for and was awarded Clean Water Funds again in 2012 and 2013. From these two grants combined, they received another $300,000 to provide incentives to establish 300 additional acres of grass filter strips and also install side water inlets wherever they were needed in the subwatersheds contributing to Lake Bronson. Since 2014, Kittson SWCD has also been involved in streambank stabilization project on the South Branch Two Rivers through reshaping, mulching, grass seeding, and some rock riprap. The total project cost was $32,357. Since 2000, the Kittson SWCD has also been involved and active with well sealing.

Between 1998 and 2007, TRWD staff conducted a culvert inventory and worked to locate every culvert within the District. In addition to location, the size, type, direction of flow, flow line elevation, and condition of each culvert was recorded. The data collected is helping identify water flow patterns within the District and has been put into a computerized geographic information system to do long range planning and analysis. In addition to the culvert inventory, TRWD has a goal of conducting annual inspections of the legal ditch systems to identify general ditch conditions and specific problems, including any flow restrictions; conditions of outlets banks, and bed failures; and sedimentation, water quality, fish and wildlife, and any other issues that may exist in the ditch system. The annual inspections help identify problem areas and allow for the development of remediation plans.

The TRWD has installed numerous flood control structures and impoundments to address repeated overland flooding, erosion, and sedimentation taking place throughout the TRW and in the LRRW, also under the jurisdiction of the TRWD. Although the primary goal of these types of projects is flood protection, additional benefits of reduction in erosion and sedimentation also exist.

In the 1960s, the TRWD partnered with the Soil Conservation Service (now the NRCS), the Kittson SWCD, and the DNR to install 11.13 miles of channel improvements on two different legal ditch systems, two grade stabilization structures to provide erosion control, and one single purpose wildlife structure near Saint Joseph and Poppleton townships in the drainage of the North Branch of Two Rivers. In addition, 9.62 miles of channel improvements for flood protection and agricultural water management, and one mile of channel improvement for flood prevention only where installed in Hazelton and Thompson Townships in the drainage of the Middle Branch of Two Rivers. Both projects were funded under the Federal Public Law 566 Program.

In 2008, Roseau SWCD partnered with TRWD to complete a dry impoundment project in Ross Township. The project drainage area includes 18.2 square miles. Gated storage holds 2.55 inches of runoff and total storage holds 3.73 inches of runoff. The Roseau SWCD was instrumental on the Project Work Team, wetland delineation, and project planning, review, and approval.

The Marshall SWCD has a history of partnership with the USDA National Resources Conservations Service/Farm Service Agency to provide funded programs for conservation practice implementation, BMP implementation, and conservation easements. These programs have been delivered through the Environmental Quality Incentives Program (EQIP), the Wildlife Habitat Incentive Program (WHIP), the Conservation Stewardship Program (CSP), and the Conservation Reserve Program (CRP).

In 2016, the TRWD received a grant from the NRCS for $500,000 for planning, preliminary engineering, permitting, economic review, and prepare an environmental assessment for the proposed "Klondike Clean Water Retention Project" or KCWRP. The KCWRP is a floodwater impoundment and its purpose is to prevent flooding to agriculture lands and public infrastructure, provide an adequate outlet for various laterals of State Ditch 95, provide an outlet for water that overflows from State Ditch 72 and from the Roseau River, and provide water quality and environmental benefits. This will specifically reduce flooding on lateral 1 of State Ditch 95, reduce flooding on Red River, and reduce flooding on the North Branch, Middle Branch, and South Branches of the Two Rivers. Environmental benefits will be to protect and enhance a naturally occurring rich fen, provide feeding and resting areas for migratory waterfowl, and provide water quality benefits by reducing sediment and nutrients that enter Lake Bronson and the three branches of the Two Rivers. It is projected to store up to 37,000 acre-feet of water and will cost approximately $35 million to build. In addition, additional information can be found in the current 10-year Overall Plan for TRWD and yearly Annual Reports found at the TRWD website[14] show all past, current, and future planned projects.

8.3 Cost

The CWLA requires that a TMDL report include an overall approximation of implementation costs (Minn. Stat. 2007, § 114D.25). Based on cost estimates from current, planned, and proposed work (listed above) in the TRW and the level of effort required to address the water quality issues, a reasonable estimate to continue efforts for reducing sediment and phosphorus in the impaired reaches, addressed in this report, would be approximately $75 million dollars over 10 years, including $35 million for the KCWRP. These dollars would be spent primarily on practices such as regional water retention projects, riparian vegetative buffers, sediment BMPs (water and sediment control basins and side inlets), pasture management, conservation tillage, vegetative practices, wetland restorations, rain gardens, urban BMPs, and structural practices (e.g. feedlot upgrades and improvements, grade stabilizations, grass waterways, etc.).

Bacteria reductions are also needed to meet the targets of this TMDL report. Strategies that would aid in reducing bacteria include improving livestock and manure management and identifying and addressing IPHT septic systems. The unit cost for bringing AUs under manure management plans and feedlot runoff controls is $350/AU. This value is based on USDA EQIP payment history and includes buffers, livestock access control, manure management plans, waste storage structures, and clean water diversions. Repair or replacement of IPHT septic systems was estimated at $7,500/system. Multiplying the unit costs by an estimated 10,514 AU and 75 IPHT systems in the TRW provides a total cost of approximately $4,242,400. Many of the AUs may already have sufficient management, for example the 2240 AU at the CAFO, which is a zero discharge facility, thus reducing the cost.

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. Adaptive management is an ongoing process of evaluating and adjusting the strategies and activities that will be developed to implement the TMDL report. 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 LC. Any changes to water quality standards or LC must be preceded by appropriate administrative processes, including public notice and an opportunity for public review and comment.

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[14] http://www.tworiverswd.com/index.html

The Two Rivers WRAPS Report (HEI 2019) provides details of the management strategies and activities listed in **Section 7**. The WRAPS report focuses on adaptive management (**Figure 8-1**) to evaluate project progress, as well as to determine if the implementation plan should be amended. 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 watershed are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the TMDLs 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.

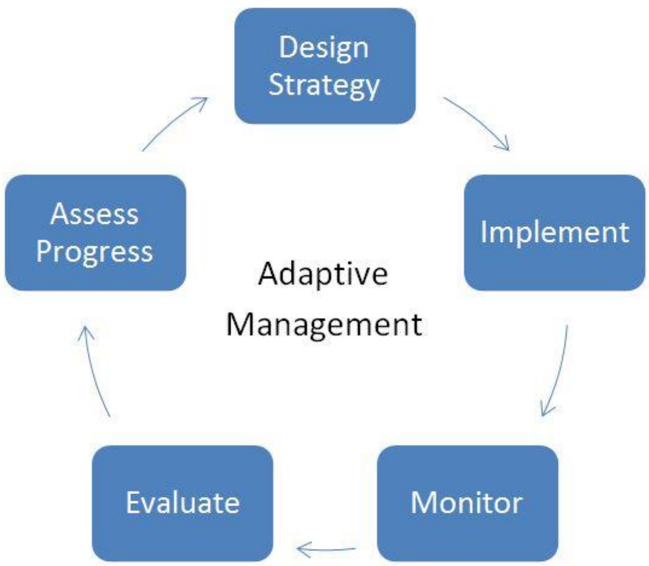

Figure 8-1: Adaptive Management Process.

9. Public Participation

Public participation (i.e., civic engagement) during this TMDL report process was a coordinated effort led by the TRWD, Kittson SWCD, and Roseau SWCD. A TMDL report stakeholder group was identified early in the TMDL report 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, representatives from state agencies (MPCA, DNR, and BWSR), and board members of the TRWD. TMDL report updates were regularly presented through open houses and public meetings in the watershed. In addition, the TRWD developed a webpage[15] where updates and select reports were posted. The MPCA also developed a project webpage[16] to keep the public informed of progress.

[15] http://www.tworiverswd.com/

[16] https://www.pca.state.mn.us/water/watersheds/two-rivers

Since water quality is among the ongoing priorities of the TRWD and SWCD management activities, future civic engagement will continue to go through these organizations. The Kittson and Roseau SWCDs will also continue with their civic engagement programs and activities. The TRWD and the SWCDs will update, educate, and engage stakeholders on water quality issues through the normal communications, including plan update events and on the TRWD website.

An opportunity for public comment on the draft Two Rivers Watershed TMDL Report was provided via a public notice in the State Register from December 24, 2018, through January 23, 2019. No comments pertaining to the draft TMDL report were received.

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Appendices

Appendix A

Two Rivers Watershed Load Duration Curve (LDC) Technical Memorandum

MEMO

(External Correspondence)

To:	Dan Money, TRWD	**From:**	Timothy Erickson, PE
	Tara Mercil, MPCA		Mark R. Deutschman, Ph.D., P.E.
Date:	April 28, 2017	**Subject:**	Two Rivers Watershed Load Duration Curves- Final

INTRODUCTION

This memorandum summarizes the methods used and results for creating load duration curves (LDCs) for impaired stream segments (delineated by assessment unit identification (AUID) numbers) in the Two Rivers Watershed (TRW). Each of the segments are impaired for aquatic recreation due to elevated *E. coli* levels, impaired relative to aquatic life due to total suspended solids (TSS) or the previous turbidity standards, or exhibit elevated turbidity/high TSS as a stressor for a macroinvertebrate/fish bioassessment impairment. 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 total maximum daily loads (TMDLs) for impaired reaches. A list of the AUIDs addressed in this memorandum is included in **Table 1**. Also included is an indication of the impairments that the LDCs will be used to address, a list of water quality monitoring stations located within each AUID used to develop the curves and the associated HSPF model subbasin or U.S. Geological Survey (USGS) gaging site which was used to represent flows for creating the curves. In addition, the AUIDs and monitoring locations are shown in **Figure 1**.

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

AUID (09020312-XXX)	Reach Name	Stressors	Water Quality Stations	USGS Site or HSPF Flow RCHRES ID
501	Two Rivers: M Br Two R to N Br Two R	*E. coli* / Turbidity	S000-186, S003-102, S005-387	RCHRES 290
503	Two Rivers, Middle Branch: CD23 to S Br Two R	*E. coli*	S002-360, S002-999, S003-100, S003-103, S007-441	RCHRES 257
505	Two Rivers, South Branch: Lateral Ditch 2 to Lk Bronson	*E. coli*	S002-368, S002-369	RCHRES 190
506	Two Rivers, South Branch: Unnamed ditch to Lateral Ditch 2 SD 95	*E. coli*	S002-364, S002-373, S002-998	RCHRES 130
509	Two Rivers, North Branch to Red R	Turbidity	S000-569	RCHRES 450
535	County Ditch 13: Unnamed ditch to Badger Cr (disconnected portion)	*E. coli*	S002-371, S003-452	RCHRES 133

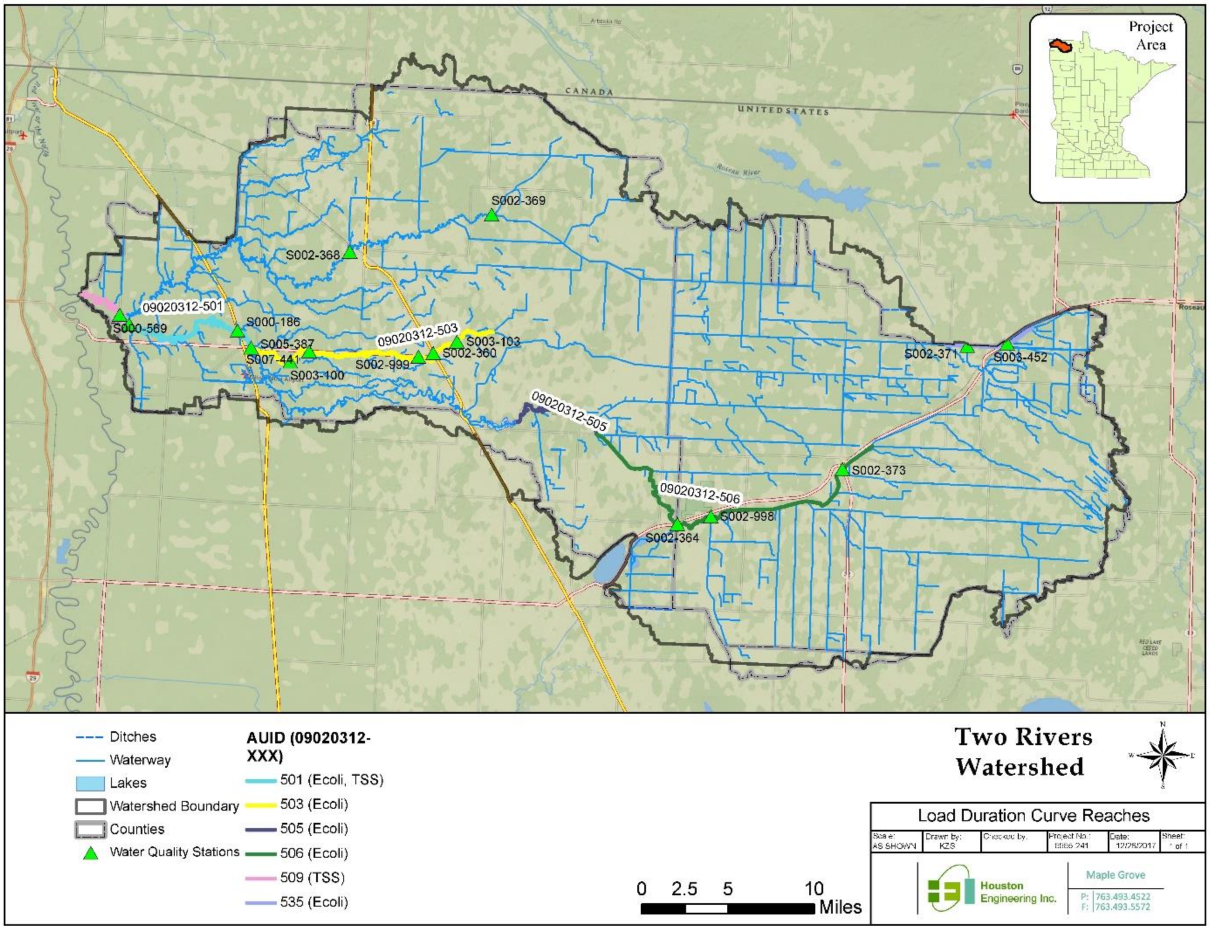

Figure 1. AUIDs, water quality monitoring locations used for LDCs in the Two Rivers Watershed.

METHODOLOGY

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

Data

Observed daily flow data is limited within the TRW and no USGS gauging stations were located near the downstream ends of the reaches with sufficient long-term data needed to develop the LDCs. Therefore, simulated daily mean flows from the TRW HSPF model (RESPEC 2014) were used to create the LDCs for all the AUIDs. The HSPF model simulates flows from 1995 through-2009. In order to best capture the flow regimes of each AUID, the period 1996 through 2009 was used in development of the LDCs, 1995 was used as a warm-up period for the model and simulated flows might not be valid (RESPEC 2014).

In order to expand the timeframe of the LDCs and include more observed samples in the development of the LDC, the flow record was extended using relationships developed between the modeled HSPF flows and the observed, continuous flows for the USGS gaging station downstream of Lake Bronson (05094000) and two DNR gaging stations (70021001 in the North Branch Two Rivers near Northcote, CSAH4 and 70018001 in the South Branch Two Rivers at Hallock, Minnesota). Flows were calculated for days with observed water quality to allow inclusion of those observation days outside of the modeling time period. **Table 2** provides a list of the flow gaging stations and the regression equation with respective R^2 used to extend the water quality data from each reach needing a LDC.

Table 2. Flow transfer summary.

AUID (09020312-XXX)	USGS/MNDNR Gage Transfer Site	Regression Equations	R^2
501	70018001	0.7907*Flow [cfs] + 76.122	0.79
503	70018001	0.0681*Flow [cfs] + 5.3255	0.68
505	05094000 / 70033001	0.7526*Flow [cfs] + 86.682	0.66
506	05094000 / 70033001	0.4524*Flow [cfs] + 54.826	0.63
509	70018001	1.1905*Flow [cfs] + 116.17	0.78
535	05094000 / 70033001	0.0315*Flow [cfs] + 3.8632	0.59

The regressions in **Table 2** were only used to estimate the flows on days with water quality data. To reduce the uncertainty in the allowable loads and ultimately the TMDL equation, the flow record period used to develop the allowable loads (i.e., the LC of a reach) was 1996 through 2009. Only the existing loads are impacted by extending the time period of the water quality data.

The water quality data used in this work was obtained from the MPCA through their EQuIS database. For the purposes of creating the curves (which will inform TMDL development) and including as much data as possible, water quality data during the simulation period (1996 through 2009) plus data after the modeling period (2010 through 2014) were used. Flows were estimated for observation days after the modeling period using methods described above. **Table 3** summarizes the water quality data used in the bacteria and TSS LDCs for each impaired AUID in the TRW.

Table 3. Water quality data used for each LDC.

AUID (09020312-XXX)	Water Quality Monitoring Locations	*E. coli* Data	Turbidity/ TSS Data
501	S000-186, S003-102, S005-387	2000-2008	1996-2014
503	S002-360, S002-999, S003-100, S003-103, S007-441	2008-2014	--
505	S002-996	2009-2014	--
506	S002-364, S002-373, S002-998	2009-2011	--
509	S000-569	--	1996-2014
535	S002-371, S003-452	2009-2011	--

Bacterial LDCs

To match the time period when the water quality standard is applicable, the bacterial LDCs were created using flow and *E. coli* water quality data from April through October only. Individual loading estimates were calculated by combining the observed *E. coli* 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 both the instantaneous (1260 organisms/100mL) and monthly geometric mean, i.e., geomean, (126 organisms/100mL) criteria by multiplying each "allowable" concentration by the simulated mean daily flow values and ranking the flows. A 10% margin of safety (MOS) was applied to each of the "allowable" loading curves.

Total Suspended Solids LDCs

The TSS LDCs were created using the Southern Region TSS standard of 65 mg/L. The TSS LDCs were calculated using the TSS data collected during the assessment period, April through September. In addition to TSS data, the useable dataset was expanded using converted turbidity data. The standard only applies during the months of April through September. Therefore, the proposed TSS standard LDCs were created using turbidity/TSS data and flow data from this period.

When available, TSS was used as the preferred value for calculating solids loading. However, since turbidity data may be prevalent in the historical record, turbidity was used to expand the TSS dataset. This is consistent with MPCA guidance (MPCA 2012). To convert turbidity to TSS, paired TSS and turbidity data were analyzed and a regression was applied to find a relationship (**Figure 2**). The resulting regression equation for converting turbidity values (in NTU/NTRU) in the TRW to TSS (in mg/L) is:

$$TSS = 1.0863 * Turbidity + 0.2043$$

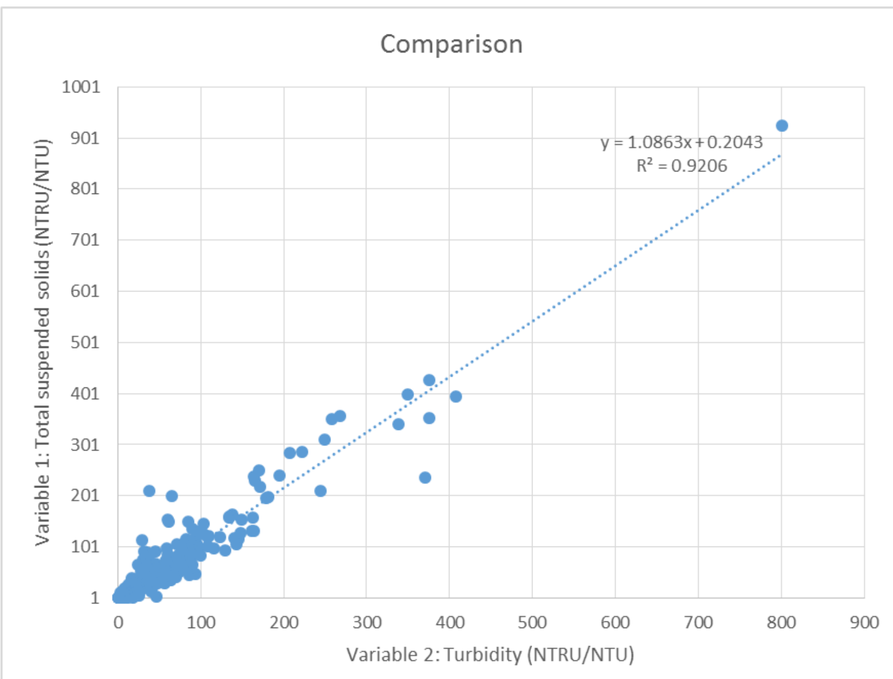

Figure 2. Relationship between Turbidity and Total Suspended Solids in the TRW.

Again, a 10% MOS was applied.

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 TRW LDCs based on percent exceedance: Very High (0% to 10%), High (10% to 40%), Mid (40% to 60%), Low (60% to 90%), and Very Low (90% to 100%) flow conditions. An example TSS LDC (for AUID 09020312-509) is shown in **Figure 3**, identifying the flow regimes.

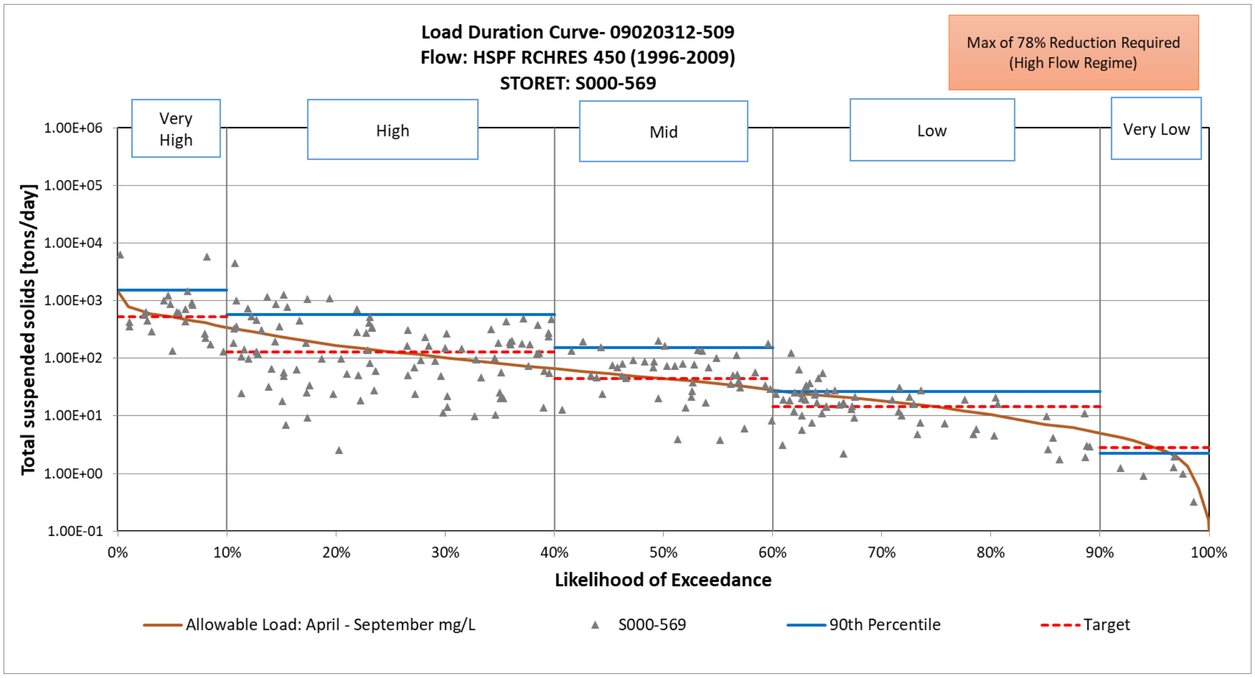

Figure 3. Example TSS LDC (AUID 09020312-509) showing flow regimes.

The example LDC in **Figure 3** 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. Observed loads are also shown, indicated by points on the plot. The median loads for each flow regime is shown as a red dashed line for median "allowable" load and a solid blue line for median existing loads under each flow condition. Observed loads are broken out by station, allowing for a detailed examination of when and where loading exceedances have occurred.

Load Duration Curves

Bacteria (*E. coli*)

Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501)

An *E. coli* LDC was generated for Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501) and is shown in **Figure 4**. *E. coli* has both a geometric mean standard of 126 organisms/100 mL and an instantaneous standard of 1,260 organisms/100 mL, represented as a red and black line, respectively, in **Figure 4**. **Tables 4** & **5** show the observed loads, allowable loads, and load reductions for the five flow regimes for the geometric mean and instantaneous standards, respectively.

As shown in **Table 4** and in text box in **Figure 4**, a maximum load reduction of 40% load reduction during very high flow conditions is required to meet the geometric mean water quality standard for *E. coli*.

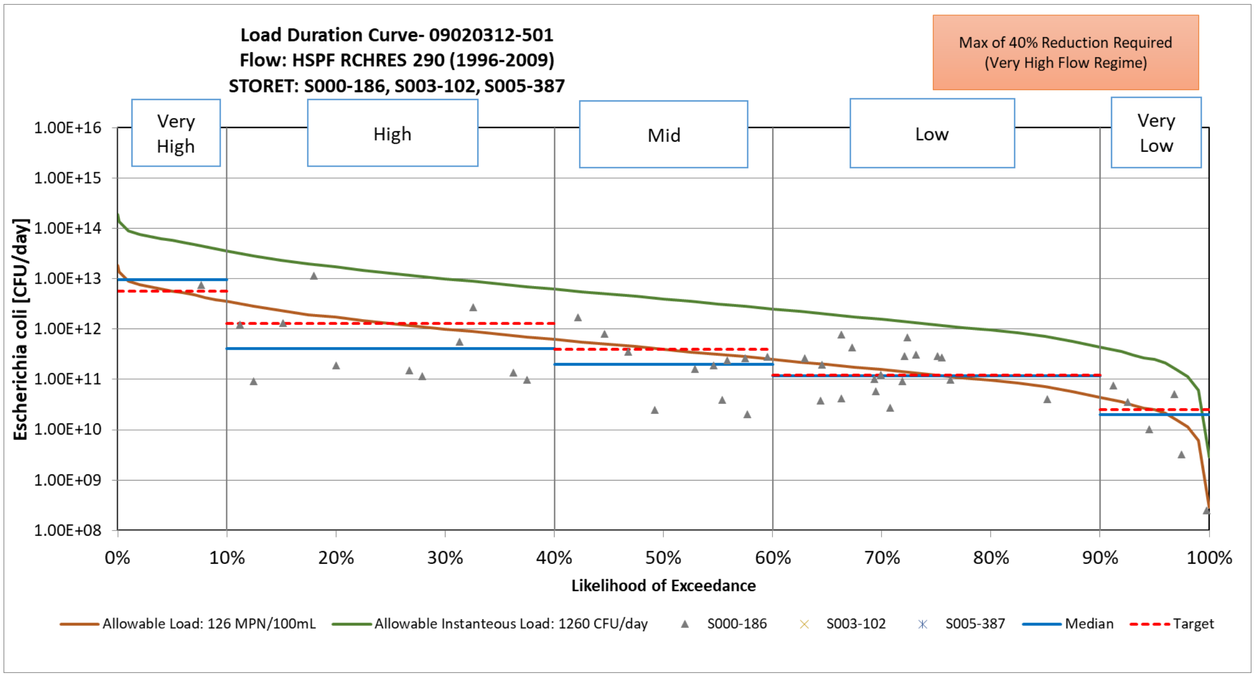

Figure 4. Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501) *E. coli* LDC.

Table 4. Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501) load reductions relative to geometric mean criteria for *E. coli.*

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	1861.1	210.0	9.56E+12	5.74E+12	5.16E+12	3.82E+12	40%
10%-40%	422.9	39.6	4.09E+11	1.30E+12	1.17E+12	-8.94E+11	-218%
40%-60%	129.0	62.3	1.97E+11	3.98E+11	3.58E+11	-2.01E+11	-102%
60%-90%	39.6	122.8	1.19E+11	1.22E+11	1.10E+11	-3.13E+09	-3%
90%-100%	8.12	100.7	2.00E+10	2.50E+10	2.25E+10	-5.04E+09	-25%

Table 5. Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501) load reductions relative to instantaneous criteria for *E. coli.*

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	1861.1	210	9.56E+12	5.74E+13	5.16E+13	-4.78E+13	-500%
10%-40%	422.9	390	4.04E+12	1.30E+13	1.17E+13	-9.00E+12	-223%
40%-60%	129.0	200	6.31E+11	3.98E+12	3.58E+12	-3.35E+12	-530%
60%-90%	39.6	372	3.60E+11	1.22E+12	1.10E+12	-8.59E+11	-239%
90%-100%	8.12	315	6.26E+10	2.50E+11	2.25E+11	-1.88E+11	-300%

Two Rivers, Middle Branch: CD 23 to South Branch Two Rivers (AUID 09020312-503)

An *E. coli* LDC was generated for Two Rivers, Middle Branch: CD 23 to South Branch Two Rivers (AUID 09020312-503) and is shown in **Figure 5**. *E. coli* has both a geometric mean standard of 126 organisms/100 mL and an instantaneous standard of 1,260 organisms/100 mL, represented as a red and black line, respectively, in **Figure 5**. **Tables 6** & **7** show the observed loads, allowable loads, and load reductions for the five flow regimes for the geometric mean and instantaneous standards, respectively. As shown in **Table 6** and in text box in **Figure 5**, a maximum load reduction of 33% load reduction during low flow conditions is required to meet the geometric mean water quality standard for *E. coli*. It should be noted that no observations occurred during in the Very Low flow regime and observed conditions could not be established during this flow regime.

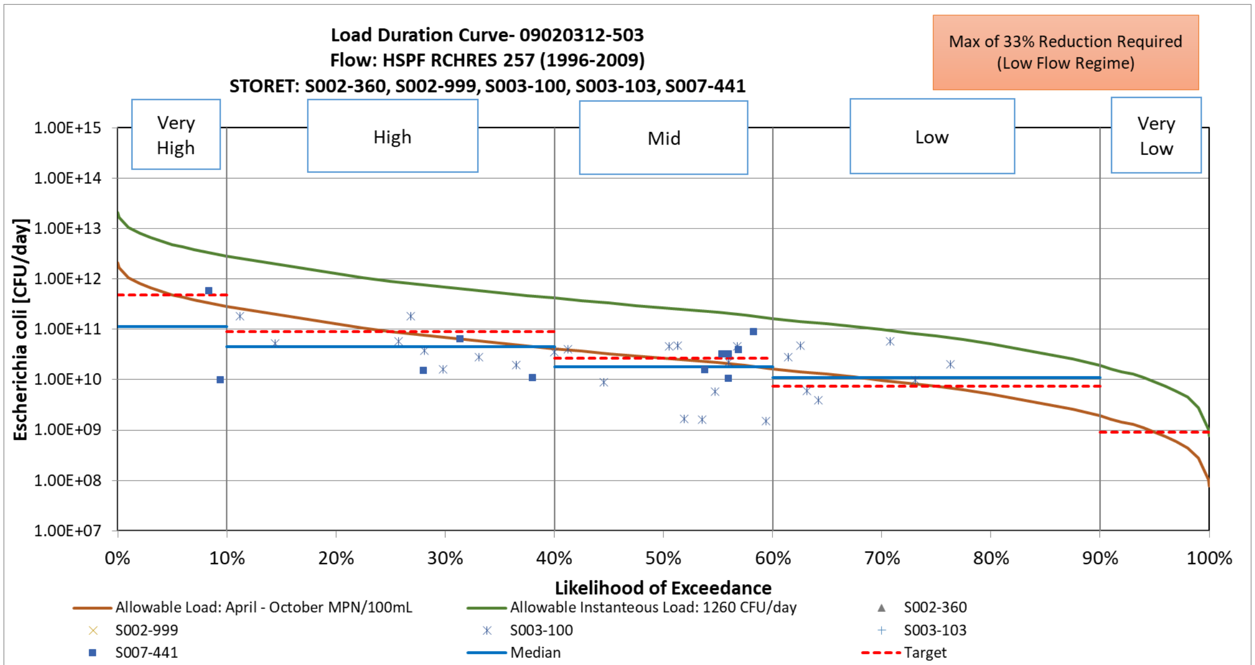

Figure 5. Two Rivers, Middle Branch: CD 23 to South Branch Two Rivers (AUID 09020312-503) *E. coli* LDC.

Table 6. Two Rivers, Middle Branch: CD 23 to South Branch Two Rivers (AUID 09020312-503) load reductions relative to geometric mean criteria for *E. coli.*

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	153.8	29.9	1.13E+11	4.74E+11	4.27E+11	-3.61E+11	-321%
10%-40%	29.5	63.1	4.56E+10	9.09E+10	8.18E+10	-4.53E+10	-100%
40%-60%	8.7	85.0	1.81E+10	2.68E+10	2.41E+10	-8.73E+09	-48%
60%-90%	2.4	188.1	1.10E+10	7.40E+09	6.66E+09	3.65E+09	33%
90%-100%	0.29	no data	no data	9.03E+08	8.13E+08	unknown	unknown

Table 7. Two Rivers, Middle Branch: CD 23 to South Branch Two Rivers (AUID 09020312-503) load reductions relative to instantaneous criteria for *E. coli.*

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	153.8	197.24	7.42E+11	4.74E+12	4.27E+12	-4.00E+12	-539%
10%-40%	29.5	126.24	9.11E+10	9.09E+11	8.18E+11	-8.18E+11	-898%
40%-60%	8.7	269.5	5.74E+10	2.68E+11	2.41E+11	-2.11E+11	-368%
60%-90%	2.4	554.4	3.26E+10	7.40E+10	6.66E+10	-4.14E+10	-127%
90%-100%	0.29	no data	no data	9.03E+09	8.13E+09	unknown	unknown

Two Rivers, South Branch: Lateral Ditch 2 to Lake Bronson (AUID 09020312-505)

An *E. coli* LDC was generated for Two Rivers, South Branch: Lateral Ditch 2 to Lake Bronson (AUID 09020312-505) and is shown in **Figure 6**. *E. coli* has both a geometric mean standard of 126 organisms/100 mL and an instantaneous standard of 1,260 organisms/100 mL, represented as a red and black line, respectively, in **Figure 6**. **Tables 8** & **9** show the observed loads, allowable loads, and load reductions for the five flow regimes for the geometric mean and instantaneous standards, respectively. As shown in **Table 8** and in text box in **Figure 6**, a maximum load reduction of 95% load reduction during very high flow conditions is required to meet the geometric mean water quality standard for *E. coli*. It should be noted that no observations occurred during in the Very Low flow regime and observed conditions could not be established during this flow regime.

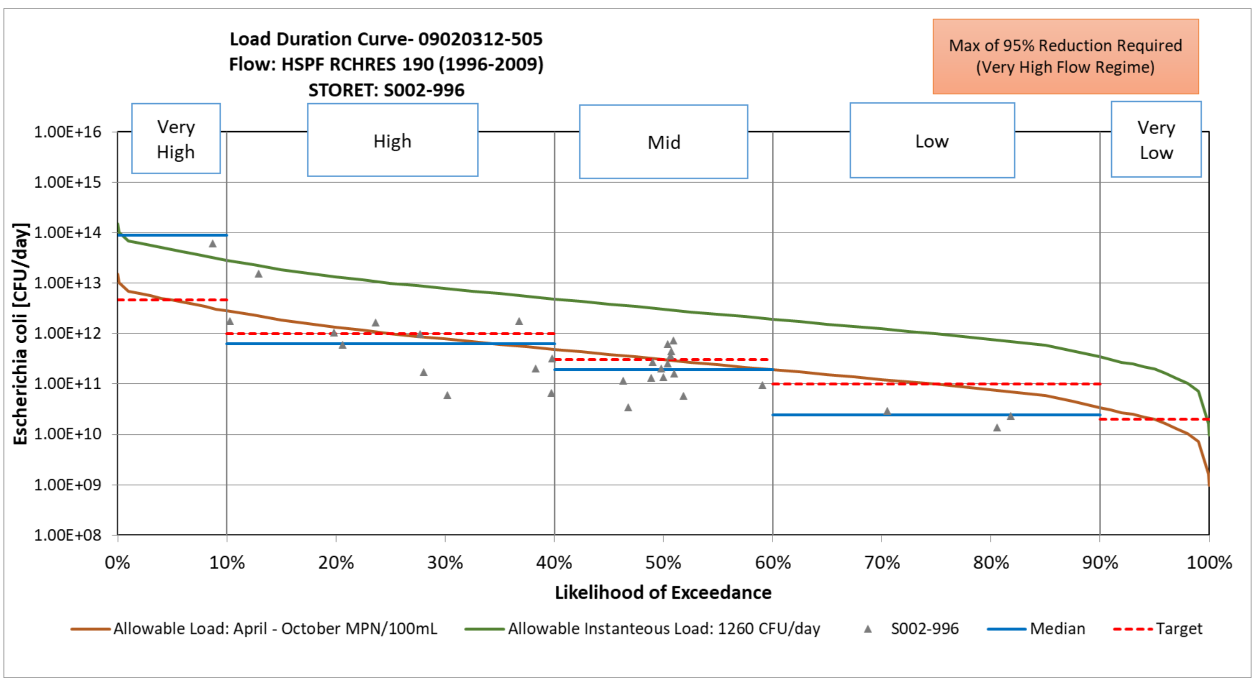

Figure 6. Two Rivers, South Branch: Lateral Ditch 2 to Lake Bronson (AUID 09020312-505) *E. coli* LDC.

Table 8. Two Rivers, South Branch: Lateral Ditch 2 to Lake Bronson (AUID 09020312-505) load reductions relative to geometric mean criteria for *E. coli.*

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	1490.7	2419.6	8.82E+13	4.60E+12	4.14E+12	8.36E+13	95%
10%-40%	324.4	79.5	6.31E+11	1.00E+12	9.00E+11	-3.69E+11	-58%
40%-60%	98.5	79.2	1.91E+11	3.04E+11	2.73E+11	-1.13E+11	-59%
60%-90%	32.2	30.7	2.42E+10	9.93E+10	8.93E+10	-7.51E+10	-311%
90%-100%	6.40	no data	no data	1.97E+10	1.78E+10	unknown	unknown

Table 9. Two Rivers, South Branch: Lateral Ditch 2 to Lake Bronson (AUID 09020312-505) load reductions relative to instantaneous criteria for *E. coli.*

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	1490.7	2419.6	8.82E+13	4.60E+13	4.14E+13	4.23E+13	48%
10%-40%	324.4	367.29	2.92E+12	1.00E+13	9.00E+12	-7.09E+12	-243%
40%-60%	98.5	240.45	5.80E+11	3.04E+12	2.73E+12	-2.46E+12	-424%
60%-90%	32.2	38.9	3.06E+10	9.93E+11	8.93E+11	-9.62E+11	-3139%
90%-100%	6.40	no data	no data	1.97E+11	1.78E+11	unknown	unknown

Two Rivers, South Branch: Unnamed Ditch to Lateral Ditch 2 SD 95 (AUID 09020312-506)

An *E. coli* LDC was generated for Two Rivers, South Branch: Unnamed Ditch to Lateral Ditch 2 SD 95 (AUID 09020312-506) and is shown in **Figure 7**. *E. coli* has both a geometric mean standard of 126 organisms/100 mL and an instantaneous standard of 1,260 organisms/100 mL, represented as a red and black line, respectively, in **Figure 7**. **Tables 10** & **11** show the observed loads, allowable loads, and load reductions for the five flow regimes for the geometric mean and instantaneous standards, respectively. As shown in **Table 10** and in text box in **Figure 7**, a maximum load reduction of 71% load reduction during low flow conditions is required to meet the geometric mean water quality standard for *E. coli*. It should be noted that no observations occurred during in the Very High and Very Low flow regimes and observed conditions could not be established during these flow regimes.

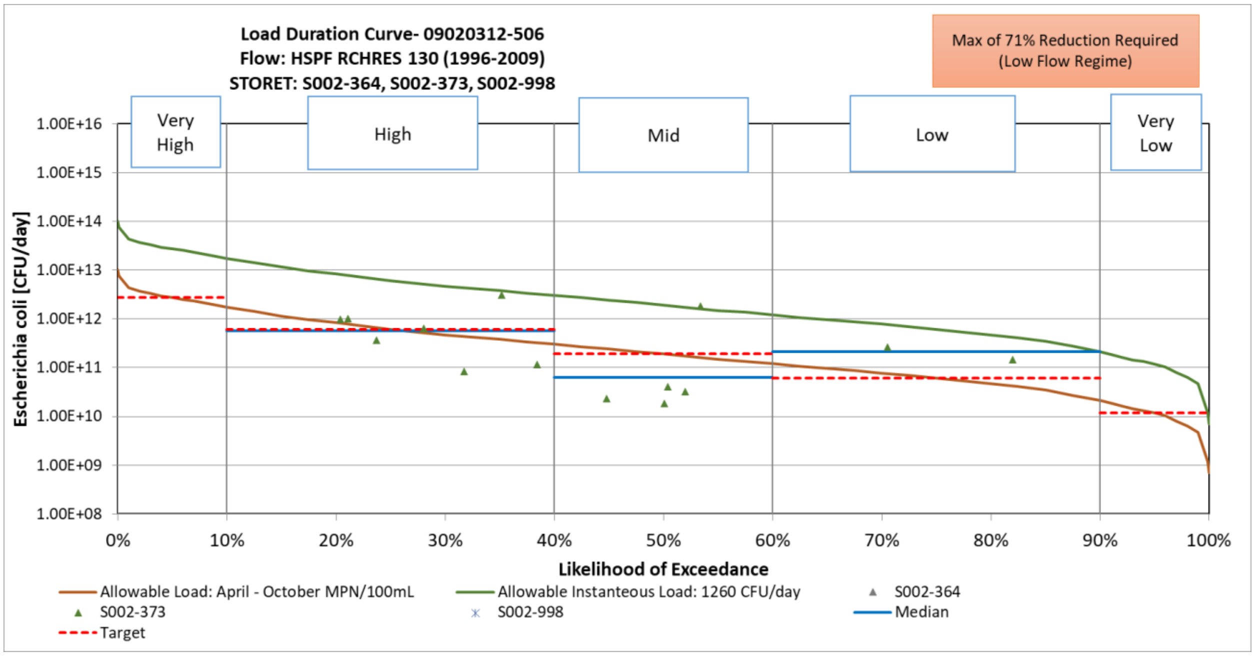

Figure 7. Two Rivers, South Branch: Unnamed Ditch to Lateral Ditch 2 SD 95 (AUID 09020312-506) *E. coli* LDC.

Table 10. Two Rivers, South Branch: Unnamed Ditch to Lateral Ditch 2 SD 95 (AUID 09020312-506) load reductions relative to geometric mean criteria for *E. coli*.

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	899.8	no data	no data	2.77E+12	2.50E+12	unknown	unknown
10%-40%	199.2	116.5	5.68E+11	6.14E+11	5.53E+11	-4.63E+10	-8%
40%-60%	62.1	42.0	6.38E+10	1.91E+11	1.72E+11	-1.28E+11	-200%
60%-90%	19.7	435.2	2.09E+11	6.07E+10	5.46E+10	1.49E+11	71%
90%-100%	3.80	no data	no data	1.17E+10	1.05E+10	unknown	unknown

Table 11. Two Rivers, South Branch: Unnamed Ditch to Lateral Ditch 2 SD 95 (AUID 09020312-506) load reductions relative to instantaneous criteria for *E. coli*.

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	899.8	no data	no data	2.77E+13	2.50E+13	unknown	unknown
10%-40%	199.2	517.96	2.52E+12	6.14E+12	5.53E+12	-3.62E+12	-143%
40%-60%	62.1	858.92	1.30E+12	1.91E+12	1.72E+12	-6.09E+11	-47%
60%-90%	19.7	435.2	2.09E+11	6.07E+11	5.46E+11	-3.97E+11	-190%
90%-100%	3.80	no data	no data	1.17E+11	1.05E+11	unknown	unknown

County Ditch 13: Unnamed Ditch to Badger Creek (disconnected portion) (AUID 09020312-535)

An *E. coli* LDC was generated for County Ditch 13: Unnamed Ditch to Badger Creek (disconnected portion) (AUID 09020312-535) and is shown in **Figure 8**. *E. coli* has both a geometric mean standard of

126 organisms/100 mL and an instantaneous standard of 1,260 organisms/100 mL, represented as a red and black line, respectively, in **Figure 8**. **Tables 12** and **13** show the observed loads, allowable loads, and load reductions for the five flow regimes for the geometric mean and instantaneous standards, respectively. As shown in **Table 12** and in text box in **Figure 8**, a maximum load reduction of 74% load reduction during low flow conditions is required to meet the geometric mean water quality standard for *E. coli*. It should be noted that no observations occurred during in the Very High and Very Low flow regimes and observed conditions could not be established during these flow regimes.

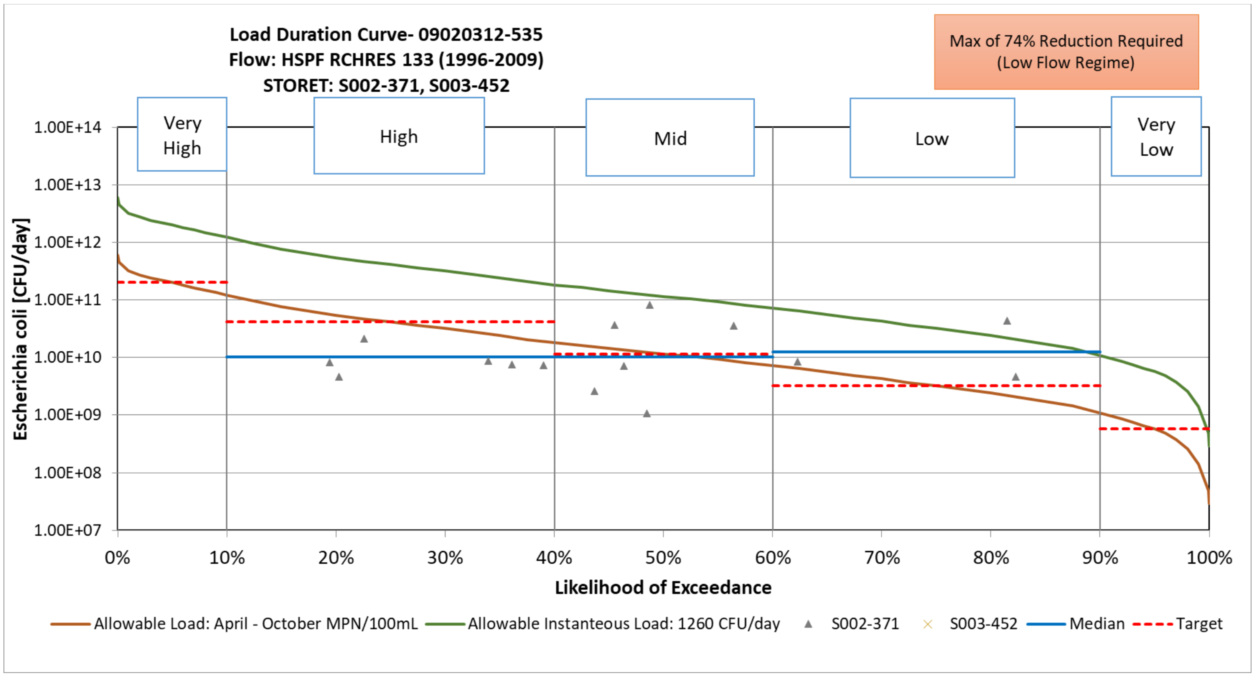

Figure 8. County Ditch 13: Unnamed Ditch to Badger Creek (disconnected portion) (AUID 09020312-535) *E. coli* LDC.

Table 12. County Ditch 13: Unnamed Ditch to Badger Creek (disconnected portion) (AUID 09020312-535) load reductions relative to geometric mean criteria for *E. coli.*

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	65.4	no data	no data	2.02E+11	1.82E+11	unknown	unknown
10%-40%	13.4	31.4	1.03E+10	4.13E+10	3.72E+10	-3.10E+10	-302%
40%-60%	3.7	114.8	1.04E+10	1.14E+10	1.02E+10	-1.01E+09	-10%
60%-90%	1.0	485.7	1.24E+10	3.21E+09	2.89E+09	9.16E+09	74%
90%-100%	0.19	no data	no data	5.78E+08	5.20E+08	unknown	unknown

Table 13. County Ditch 13: Unnamed Ditch to Badger Creek (disconnected portion) (AUID 09020312-535) load reductions relative to instantaneous criteria for *E. coli.*

Flow Regime	Median Flow [cfs]	Observed Concentration [org/100 mL]	Observed Load [CFU/day]	Target Load [CFU/day]	Load minus MOS [CFU/day]	Load Reduction [CFU/day]	Percent Load Reduction
0%-10%	65.4	no data	no data	2.02E+12	1.82E+12	unknown	unknown
10%-40%	13.4	52.7	1.73E+10	4.13E+11	3.72E+11	-3.96E+11	-2291%
40%-60%	3.7	691.8	6.25E+10	1.14E+11	1.02E+11	-5.13E+10	-82%
60%-90%	1.0	2055.1	5.23E+10	3.21E+10	2.89E+10	2.02E+10	39%
90%-100%	0.19	no data	no data	5.78E+09	5.20E+09	unknown	unknown

Total Suspended Solids (TSS)

Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501)

A TSS LDC was generated for Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501) and is shown in **Figure 10**. The allowable load for the southern nutrient region TSS standard of 65 mg/L is shown in red in **Figure 10**. **Table 15** shows the observed loads, allowable loads, and load reductions for the five flow regimes. As shown in **Table 15** and the text box in **Figure 10**, a maximum load reduction of 58% is needed during the Very High Flow regime to meet the TSS numeric water quality standard.

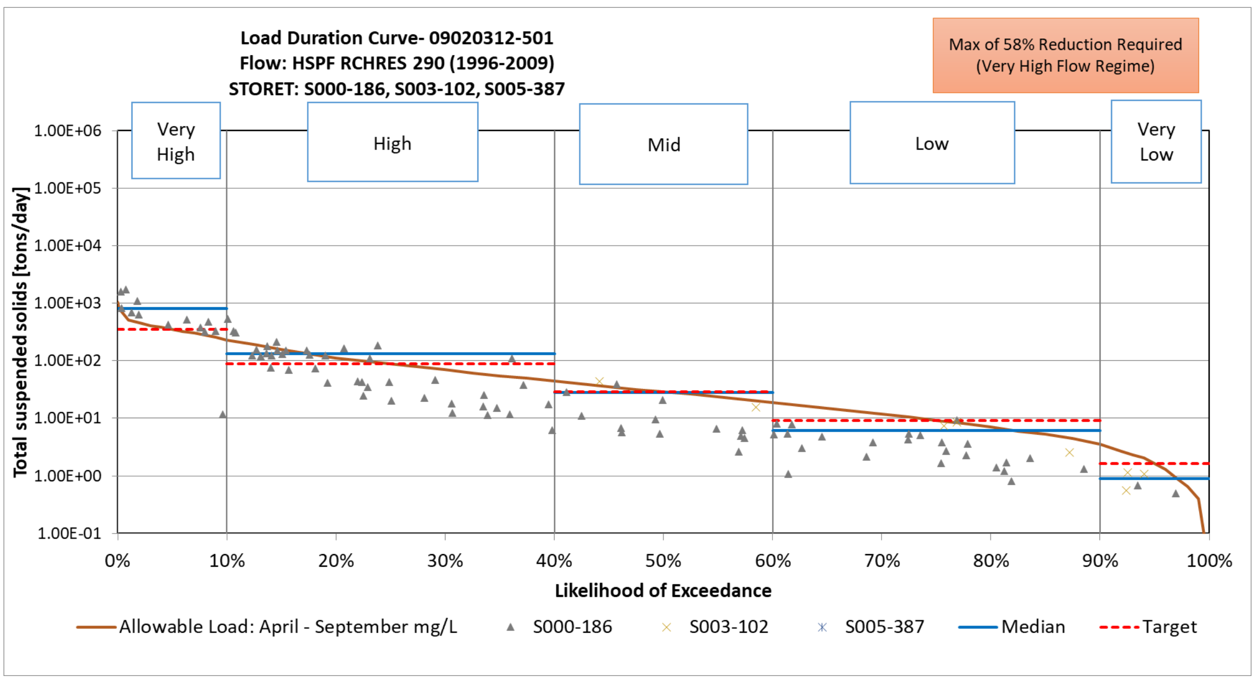

Figure 10. Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501) TSS LDC.

Table 15. Two Rivers: Middle Branch Two Rivers to North Branch Two Rivers (AUID 09020312-501) Load Reductions for TSS.

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%	1984.4	153.4	820.94	347.9	313.1	473.09	58%
10%-40%	500.6	97.4	131.50	87.8	79.0	43.74	33%
40%-60%	164.4	64.0	28.37	28.8	25.9	-0.44	-2%
60%-90%	52.5	43.3	6.13	9.2	8.3	-3.07	-50%
90%-100%	9.37	35.2	0.89	1.6	1.5	-0.75	-84%

Two Rivers, North Branch Two Rivers to Red River (AUID 09020312-509)

A TSS LDC was generated for Two Rivers, North Branch Two Rivers to Red River (AUID 09020312-509) and is shown in **Figure 9**. The allowable load for the southern nutrient region TSS standard of 65 mg/L is shown in red in **Figure 9**. **Table 14** shows the observed loads, allowable loads, and load reductions for the five flow regimes. As shown in **Table 14** and the text box in **Figure 9**, a maximum load reduction of 78% is needed during the High Flow regime to meet the TSS numeric water quality standard.

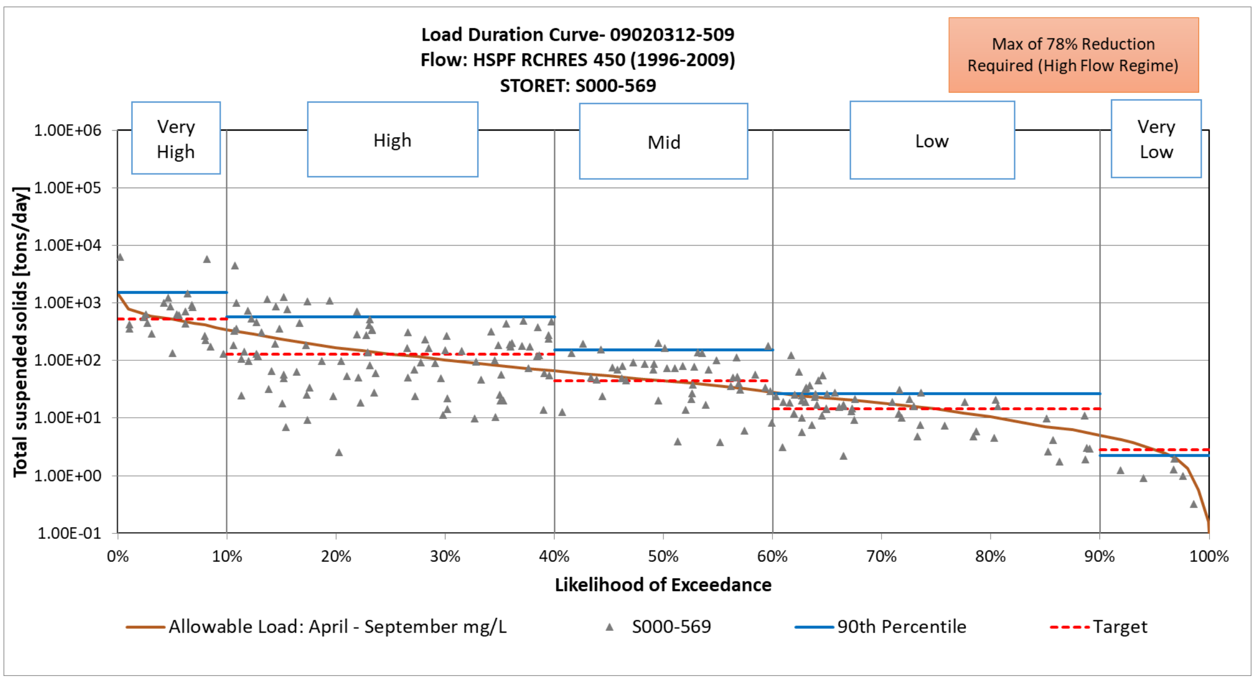

Figure 9. Two Rivers, North Branch Two Rivers to Red River (AUID 09020312-509) TSS LDC.

Table 14. Two Rivers, North Branch Two Rivers to Red River (AUID 09020312-509) Load Reductions for TSS.

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%	2970.5	188.4	1509.27	520.7	468.6	988.56	65%
10%-40%	743.1	289.2	579.54	130.3	117.2	449.29	78%
40%-60%	256.7	222.5	154.03	45.0	40.5	109.03	71%
60%-90%	82.2	120.0	26.60	14.4	13.0	12.19	46%
90%-100%	15.93	51.5	2.21	2.8	2.5	-0.58	-26%

Critical Condition

A summary of the *E. coli* and TSS standard load reduction results can be found in **Table 16**. 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 critical criterion for *E. coli* LDCs are the geometric mean criterion during very high flows or low flows. The critical condition for the TSS standard is very high and high flows.

Table 16. Maximum required *E coli* and sediment load reductions for the TRW.

AUID (09020311-XXX)	*E. coli*			TSS Standard	
	Max. % Load Reduction	Critical Flow Regime	Critical Standard	Max. % Load Reduction	Critical Flow Regime
501	40%	Very High Flow	Geometric mean	58%	Very High Flow
503	33%	Low Flow	Geometric mean	---	---
505	95%	Very High Flow	Geometric mean	---	---
506	71%	Low Flow	Geometric mean	---	---
509	---	---	---	78%	High
535	74%	Low Flow	Geometric mean	---	---

--- Not impaired (no LDC)

NRR No reduction required

CONCLUSION

E. coli and TSS standard LDCs were developed for four AUIDs in the TRW based on impairment or stressor status. The curves were developed following the methods in the EPA guidance document, *An Approach for Using Load Duration Curves 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 Two Rivers Watershed.

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