Watershed

December 2020

Final Roseau River Watershed Total Maximum Daily Load Study

A sediment and bacteria TMDL assessment for the Roseau River Watershed, focused on the Hay Creek Subwatershed

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

Authors

Dr. Nicholas Thomas and Mr. Michael Ryan
HDR, Inc.
701 Xenia Ave S, #600
Golden Valley, MN 55416

Mr. Cory Foreman
HDR, Inc.
703 Main St, #200
Rapid City, SD 57701

Cary Hernandez
Minnesota Pollution Control Agency
714 Lake Ave, Ste 220
Detroit Lakes, Minnesota 56501

Contributors/acknowledgements

Tracy Halstensgard
Roseau River Watershed District
714 6th St SW
Roseau, MN 56751

Nathan Dalager
HDR, Inc.
213 Labree Ave N, #203
Thief River Falls, MN 56701

Cover photo credit:
Roseau River Watershed District

The MPCA is reducing printing and mailing costs by using the Internet to distribute reports and information to wider audience. Visit our website for more information.

The MPCA reports are printed on 100% post-consumer recycled content paper manufactured without chlorine or chlorine derivatives.

Document Number: wq-iw5-18e

Contents

List of tables

List of figures

Acronyms

AUID	Assessment Unit ID
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
DNR	Minnesota Department of Natural Resources
EDA	Environmental Data Access
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program-Fortran
ITPH	Imminent Threat to Public Health
LA	load allocation
lb	pound
lb/day	pounds per day
lb/yr	pounds per year
m	meter
mg/L	milligrams per liter
mL	milliliter
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NPDES	National Pollutant Discharge Elimination System
RR	release rate
SDS	State Disposal System
SID	stressor identification
SRO	surface runoff
SSTS	Subsurface Sewage Treatment Systems
TDLC	total daily loading capacity
TMDL	total maximum daily load
TSS	total suspended solids
USGS	United States Geological Survey

WLA	wasteload allocation
WRAPS	Watershed Restoration and Protection Strategy
WWTP	wastewater treatment plant

Executive summary

The Clean Water Act, Section 303(d) requires that total maximum daily loads (TMDLs) be established for surface waters that do not meet water quality standards (Minn. R. 7050.022) to support their designated uses. A TMDL determines the amount of a pollutant a receiving waterbody can allow, while meeting water quality standards. Through the TMDL, pollutant loads are allocated to nonpoint and point sources within the upstream watershed discharging to impaired waterbodies. This TMDL assessment addresses one total suspended solids (TSS) and one bacteria (as *Escherichia coli* [*E. coli*]) impairment in the Roseau River Watershed (RRW). Both impairments occur on Hay Creek, a tributary to the Roseau River.

The RRW Hydrologic Unit Code (HUC) 09020314, is located in northern Minnesota along the Canadian Border. The Minnesota portion of the RRW has a drainage area of 1,062 square miles, which spans portions of the following counties: Roseau, Lake of the Woods, Beltrami, Kittson, and Marshall. The city of Roseau is the only incorporated community located within the Minnesota portion of the RRW. Water from the RRW flows into Canada, proceeding to the Red River of the North. Land use in the watershed is primarily agriculture and wetlands.

Information from multiple sources was used to evaluate the potential sources of pollutants and health of Hay Creek, including: available water quality data from the TMDL assessment period (2005 through 2014), RRW Hydrologic Simulation Program – FORTRAN (HSPF) modeling, stressor identification (SID) studies, watershed monitoring and assessments, stakeholder input, and Geographic Information Systems (GIS) data sources. This assessment evaluated a number of pollutant sources to Hay Creek including: watershed runoff, point sources, feedlots, septic systems, wildlife, and other natural sources. The load duration curve (LDC) approach was used to evaluate each impairment and to determine the pollutant reduction needed to meet the current water quality standards.

Findings from this TMDL assessment aided in developing scientifically supported implementation strategies for the Roseau River Watershed Restoration and Protection Strategy (WRAPS) Report. The purpose of the WRAPS process is to support development of local water watershed management plans. The implementation strategies are intended to meet the goals outlined in this TMDL study. Following the completion of the WRAPS process, the Roseau River WRAPS Report will be publically available at the MPCA RRW website: https://www.pca.state.mn.us/water/watersheds/roseau-river.

1. Project overview

1.1 Purpose

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

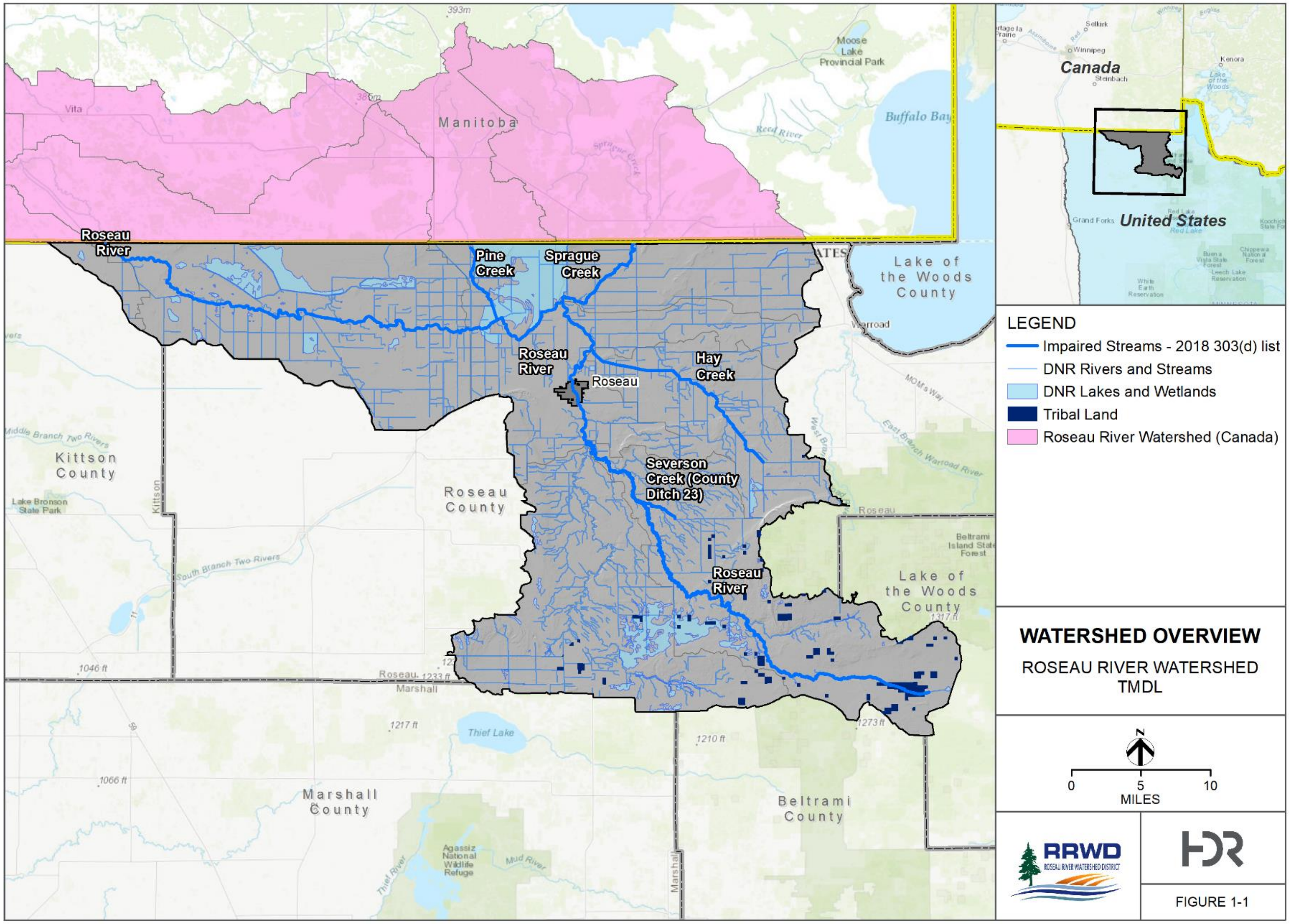
The RRW is situated in northwest Minnesota and southern Manitoba, within the Red River of the North major drainage basin (Figure 1-1). The Minnesota portion of the RRW has a drainage area of 1,062 square miles, which spans portions of the following counties: Roseau, Lake of the Woods, Beltrami, Kittson, and Marshall. The city of Roseau is the only incorporated community located within the Minnesota portion of the RRW. The watershed spans two ecoregions, the Northern Minnesota Wetlands (NMW) to the north and east, and the Lake Agassiz Plain (LAP) centrally located. The predominant land use aligns with the ecoregions, where wetlands occupy the NMW area and cultivated crops concentrate in the LAP ecoregion.

The 2018 federal 303(d) Impaired Waters list identifies eight of the RRW's streams as having impaired water quality (i.e., not meeting water quality standards) (Table 1-1). These streams contain a total of 11 impairment listings: 1 for excessive turbidity, 1 for high levels of TSS, 1 for high levels of *E. coli*, 3 for aquatic macroinvertebrate bioassessment, 2 for fish bioassessment, and 3 for mercury in fish tissue. The three streams listed as impaired for mercury in fish tissue (Assessment Unit IDs [AUID] -501, -502, and -504) are not addressed by this TMDL study. The stream impaired due to elevated turbidity (AUID 508) is expected to be delisted during the 2020 impaired waters review and is not addressed in this TMDL study. The three streams listed as impaired due to macroinvertebrate bioassessment (AUIDs -505, -516, and -541) were determined to be the result of flow regime instability and insufficient physical habitat rather than because of a pollutant, and therefore cannot be addressed by TMDLs. The two streams listed as impaired due to fish bioassessments (AUIDs -505 and -542) were determined to be the result of flow regime instability and insufficient physical habitat rather than because of a pollutant, and therefore cannot be addressed by TMDLs. The *E. coli* and TSS impairments on AUID -505 will be addressed in this TMDL study.

A TMDL is defined as the maximum quantity of a pollutant that a waterbody can receive while still meeting the (numeric) water quality standards for beneficial uses. The TMDL study apportions the maximum load between point sources (i.e., a wasteload allocation [WLA]) that 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. Hay Creek (AUID -505) is the only waterbody within the RRW requiring a TMDL. The designated uses on Hay Creek affected by these impairments are for aquatic life (TSS) and recreation (*E. coli*).

In 2006, Minnesota passed the Clean Water Legacy Act (CWLA) to protect, restore, and preserve the quality of Minnesota's surface waters. As a result, the MPCA established a watershed approach for monitoring, assessment, and the development of TMDLs. Other components of this larger effort include the RRW Monitoring and Assessment Report (MPCA 2018b), the Roseau River SID Report (MPCA 2018a), the Roseau River Model development (RESPEC 2016b), and the Hydrology and Water Quality Calibration of the Roseau River HSPF Watershed Model Application (RESPEC 2016a). One component of the watershed approach is to complete TMDLs for the impaired waterbodies within each watershed and develop a watershed-wide TMDL study. This TMDL study is intended to fulfill the TMDL requirement of the defined watershed approach. The watershed approach also includes the concurrent creation of a WRAPS report that ultimately recommends a list of strategies for restoring impaired reaches and protecting waterbodies that are currently meeting water quality standards. WRAPS are used to inform local watershed planning and implementation.

Figure 1-1: Roseau River Watershed Overview



1.2 Identification of waterbodies

This TMDL study addresses two impairments in the RRW (Table 1-1, Figure 1-2); both TMDLs are on the same reach of Hay Creek (AUID -505). Hay Creek has been listed as impaired for aquatic life use due to high TSS levels and impaired for aquatic recreation use due to high *E. coli* levels. Because all TMDLs occur on Hay Creek, the remainder of this TMDL study will focus on Hay Creek and the associated drainage area. Discussion of the greater RRW can be found in the RRW Monitoring and Assessment Report (MPCA 2018b) and the Roseau River Model Development technical memorandum (RESPEC 2016b).

The aquatic life impairment, due to high turbidity, assessed on Sprague Creek (-508) in 2008 was re-evaluated using TSS data and determined to be meeting the standard for TSS. As a result of the re-evaluation, the -508 aquatic life impairment has been approved for delisting during the 2020 federal 303(d) list cycle.

The aquatic consumption impairments, due to mercury in fish tissue, assessed on the Roseau River reaches -501, -502, and -504 in 1998 are not addressed in this TMDL study. In 2007, the MPCA completed a statewide mercury TMDL that determined that human-caused, air-deposited mercury from state, federal, and global sources must be reduced by 93% from 1990 levels to reduce mercury concentrations in fish tissue to safe levels, and the fish consumption advisories could then be removed.

The aquatic life impairments, resulting from low index of biological integrity (IBI) scores, are not explicitly addressed in this TMDL study since their identified stressors (MPCA 2018a) do not include conventional pollutants with numeric standards. The stressors identified as causing or contributing to the low IBI scores are connectivity, altered hydrology, and habitat. Non-pollutant stressors are not subject to load quantification and, therefore, do not require TMDLs. If a non-pollutant stressor is linked to a pollutant (e.g., habitat issues driven by TSS or low dissolved oxygen (DO) caused by excess phosphorus) a TMDL study is required. However, in many cases habitat stressors are not linked to pollutants. Note that all aquatic life use impairments – not just those with associated TMDLs – are addressed in the WRAPS report.

Table 1-1 summarizes RRW impairments, and those addressed by TMDLs in this document.

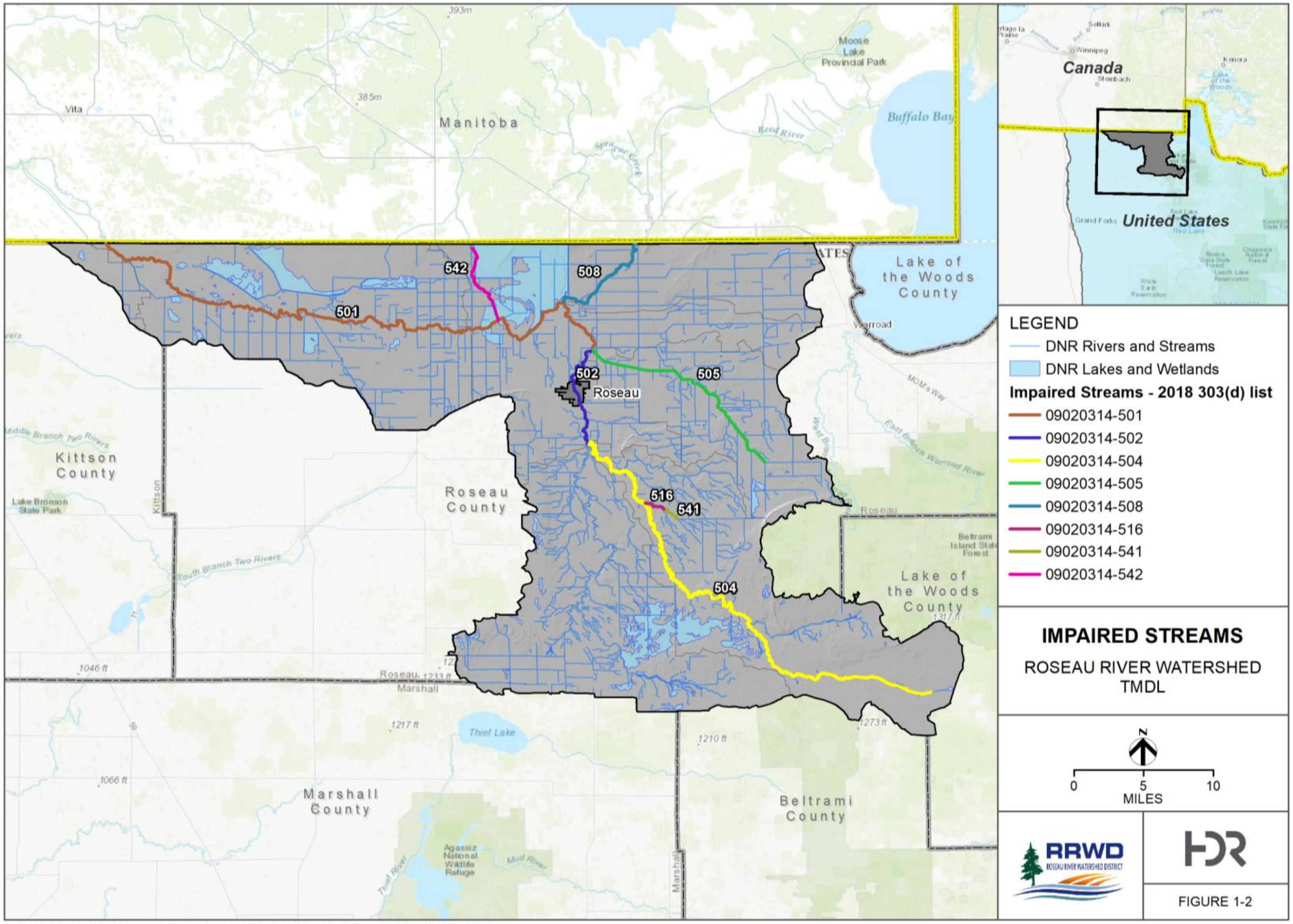
Table 1-1: RRW impairments addressed in this TMDL study

AUID 09020314 -	Waterbody	Impairment/Parameter	Beneficial Use	Year Listed	Addressed in this TMDL?
501	Roseau River	Mercury in Fish Tissue	Aquatic Consumption	1998	No
502	Roseau River	Mercury in Fish Tissue	Aquatic Consumption	1998	No
504	Roseau River[1]	Mercury in Fish Tissue	Aquatic Consumption	1998	No
505	Hay Creek	TSS	Aquatic Life	2018	Yes
		E. coli	Aquatic Recreation	2018	Yes
		Macroinvertebrate Bioassessments	Aquatic Life	2018	No
		Fish Bioassessments	Aquatic Life	2018	No
508	Sprague Creek	Turbidity[2]	Aquatic Life	2008	No
516	Severson Creek (Co. Ditch 23)	Macroinvertebrate Bioassessments	Aquatic Life	2018	No
541	Severson Creek (Co. Ditch 23)	Macroinvertebrate Bioassessments	Aquatic Life	2018	No
542	Pine Creek	Fish Bioassessments	Aquatic Life	2018	No

[1]Delisted for turbidity in 2018

[2]Approved for delisting of turbidity impairment – will be finalized during 2020 cycle.

Figure 1-2: Impaired Streams in the Roseau River Watershed



PATH: X:\RRWD\10077098\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FORMAT_RRW_IMPAIRMENTS.MXD - USER: NTHOMAS - DATE: 9/24/2019

1.3 Priority ranking

The MPCA's schedule for TMDL study completions, as indicated on Minnesota's Section 303(d) Impaired Waters list, reflects Minnesota's priority ranking of this TMDL study. The MPCA has aligned TMDL priorities with the watershed approach and the WRAPS cycle. The MPCA developed a state plan, Minnesota's TMDL Priority Framework Report, to meet the needs of the EPA 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, the MPCA identified water quality impaired segments that will be addressed by TMDL studies by 2022. The RRW waters addressed by this TMDL study are part of the MPCA prioritization plan to meet EPA's national measure.

Hydrological Simulation Program - FORTRAN (HSPF) Modeling

An HSPF model was developed for the RRW to simulate the hydrology and water quality conditions throughout the watershed on an hourly basis from 1995 to 2014. The HSPF model incorporates a watershed-scale agricultural runoff model and non-point source models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. The model enables the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the water quality and quantity at the outlet of each subwatershed. The HSPF model outputs were used in the evaluation of impairment sources, and in developing TMDL calculations. Development of the RRW HSPF model and calibration and validation of the HSPF model can be found in RESPEC (2016a) and RESPEC (2016b) documents.

2. Applicable water quality standards and numeric water quality targets

Water quality standards are developed to protect water resources for uses such as fishing, swimming, other recreation, and to sustain fish, bugs, plants, and other aquatic life. Numeric water quality standards are a measure to identify polluted or healthy waters in need of protection or restoration. One impaired reach within the RRW, Hay Creek, failed to meet the water quality standards for TSS and *E. coli*. The state of Minnesota's water quality standards for those parameters pertinent to Hay Creek are described in Sections 2.1 and 2.2, and summarized in Table 2-1.

Generally, waters within the RRW are classified as class 2 waters, indicating they are protected for aquatic life and aquatic recreation. Protection, in accordance with Minnesota State Statute 7050.0150, is defined by the Minnesota Narrative standard below:

> *"For all class 2 waters, 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 aquatic biota 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 aquatic biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters."*

The impaired waters in Hay Creek have been assigned 2Bg (MPCA 2017), aquatic life and recreation – general warm water habitat, use classification. The narrative water quality standards associated with a 2Bg classification from Minnesota State Statute 7050.0222:

> *"'General cool and warm water aquatic life and habitat' or 'class 2Bg' is a beneficial use that means waters capable of supporting and maintaining a balanced, integrated, adaptive community of warm or cool water aquatic organisms having a species composition, diversity, and functional organization comparable to the median of biological condition gradient level 4 as established in Calibration of the Biological Condition Gradient for Streams of Minnesota, Gerritsen et al. (2012)."*

Table 2-1: Applicable water quality standards in the Roseau River Watershed

Parameter	Water Quality Standard	Criteria	Applicable Time Period
Total Suspended Solids – Central Nutrient Region	Not to Exceed 30 mg/L; TSS standards for Class 2B may be exceeded no more than 10% of the time	≤ 30 mg/L	April 1 – September 30
E. coli	Not to exceed 126 organisms per 100 milliliters (org/100 mL) as a geometric mean within a calendar month	≤ 126 org/100 mL (*geometric mean*)	April 1 – October 31
	Not to exceed 1,260 organisms per 100 milliliters (org/100 mL) for more than 10 % of samples during a calendar month	≤ 1260 org/100 mL (*10% of Samples*)	April 1 – October 31

2.1 *Escherichia coli*

E. coli bacteria is used as an indicator species of potential water pathogens, and exceedances of the *E. coli* standard indicates that a water body does not meet the aquatic recreation designated use. There are *two E. coli* standards. Table 2-1 describes each standard in detail. In 2008, Minnesota changed from a fecal coliform standard to an *E. coli* standard for bacteria. Below is the current water quality standard from Minn. Stat. 7050.0220:

> *"Escherichia (E.) coli bacteria shall not 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."*

The geometric mean is a method of determining central tendency of a group of values, similar to the arithmetic mean. However, the geometric mean aides in reducing the effects of outliers (extremely high or low values). Surface water quality standards are based on *E. coli*, wastewater dischargers and previous surface water quality standards were based on fecal coliform (another indicator bacteria species). A conversion factor of 200 fecal coliform per 100 milliliters to 126 *E. coli* organisms per 100 milliliters is used and describer further in Section 4.1.

2.2 Total Suspended Solids

A TSS standard is intended to protect aquatic life as designated by use classifications. TSS occur naturally in water bodies, where background or natural concentrations are essential to their ecological function. In excessive amounts, TSS can limit light penetration through the water column, and deposit on the stream bed. These effects act to limit photosynthesis (thus proliferation of natural vegetation), bed habitat, fish spawning, and can smother invertebrates through deposition.

Minnesota recently replaced the turbidity standards, with the TSS standards as described in MPCA (2019). The new TSS standards divide the state into nutrient regions, noting the variability of watershed and stream response based on regional characteristics, and generally follow the existing ecoregion boundaries. The RRW lies within the Central Nutrient Region, with a TMDL concentration target of 30 milligrams/Liter (mg/L). Table 2-1 summarizes the applicable TSS standard, and below is the current water quality narrative standard from Minn. Stat. 7050:

> *"TSS standards for the class 2B North, Central, and South River Nutrient Regions and the Red River mainstem may be exceeded for no more than ten percent of the time. This standard applies April 1 through September 30."*

3. Watershed and waterbody characterization

The Roseau River 8-digit HUC Watershed (RRW) is located in the northeastern area of the Red River of the North Basin. The Roseau River follows a general northwesterly course over its entire length of approximately 180 miles. It crosses the international border near Caribou, Minnesota and enters the Red River approximately 50 miles downstream from the border.

The RRW Monitoring and Assessment Report (MPCA 2018) and the Roseau River Model Development Technical Memorandum (RESPEC 2016) provide a description of the RRW and Hay Creek Subwatershed, which includes discussion of current and historical land cover, surface hydrology, precipitation, and groundwater. Figure 3-1 shows the EPA Ecoregions (2013), which provide a further description of pre-development land use and human modifications in the Glacial Lake Agassiz and the NMW Ecoregions, as described here:

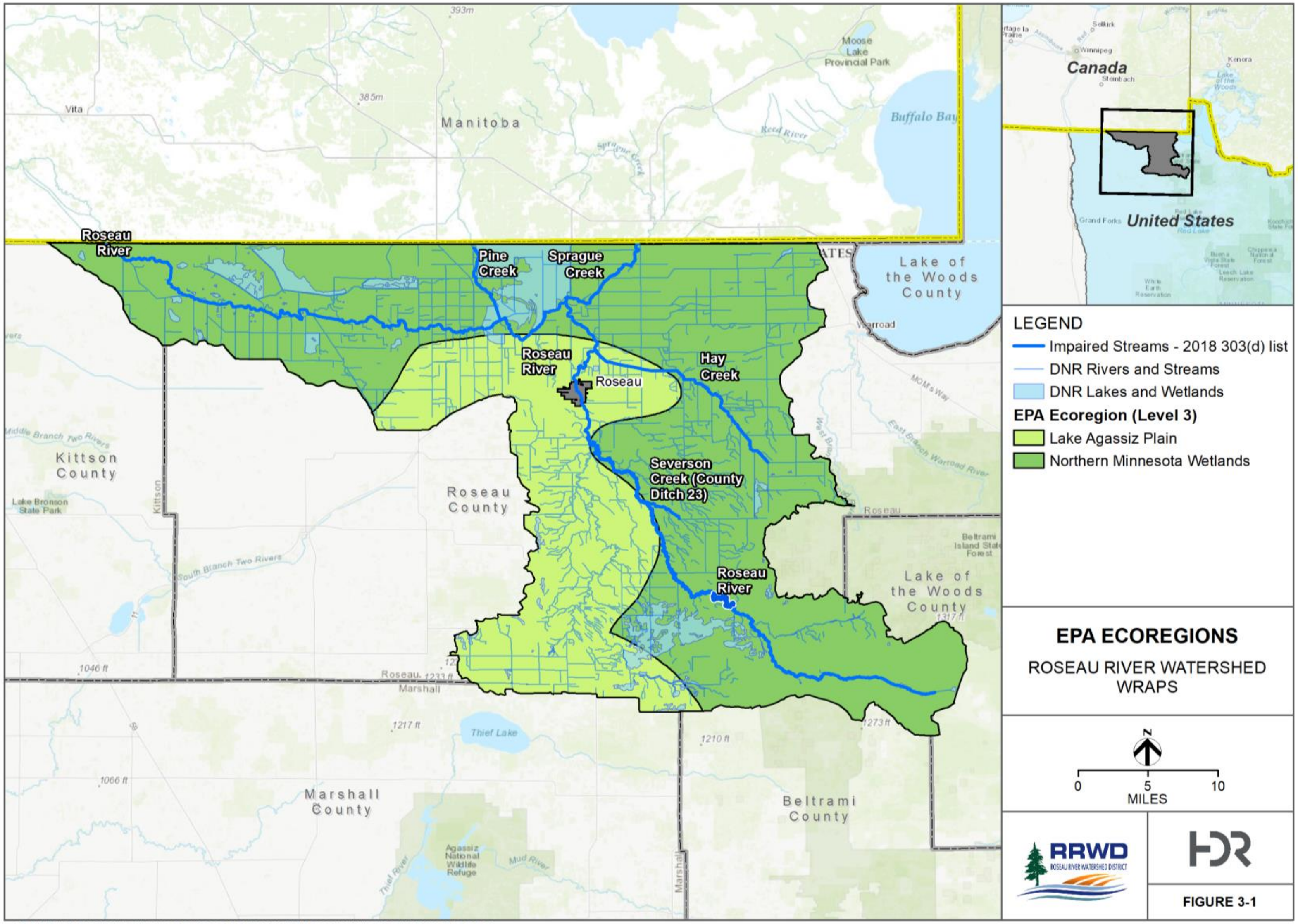
> *"Glacial Lake Agassiz was the last in a series of proglacial lakes to fill the Red River valley in the three million years since the beginning of the Pleistocene. Thick beds of lake sediments on top of glacial till create the extremely flat floor of the Lake Agassiz Plain. The historic tallgrass prairie 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 Northern Minnesota Wetlands 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."*

Tribal Lands in the Roseau River Watershed

Tribal lands associated with the Red Lake Band of Chippewa Ojibwe are located within the RRW. Figure 1-1 shows that the Red Lake Band of Chippewa Ojibwe land is located primarily in the southeast portion of the watershed and is not impacted by this TMDL study. The state does not have authority to assess or list impairments for waters within Tribally-owned lands.

Figure 3-1: Roseau River Watershed Ecoregions



3.1 Lakes

No lakes within the RRW were listed as impaired and, therefore, no lake TMDL calculations are required.

3.2 Streams

The total contributing drainage area for Hay Creek, the impaired stream addressed in this TMDL study, is 62,007 acres (97 sq. mi.) as summarized in Table 3-1. The watershed area listed in Table 3-1 includes all of the drainage area to the impairment assessment unit. The direct drainage areas were delineated from the RRW HSPF model subwatersheds (RESPEC 2016b).

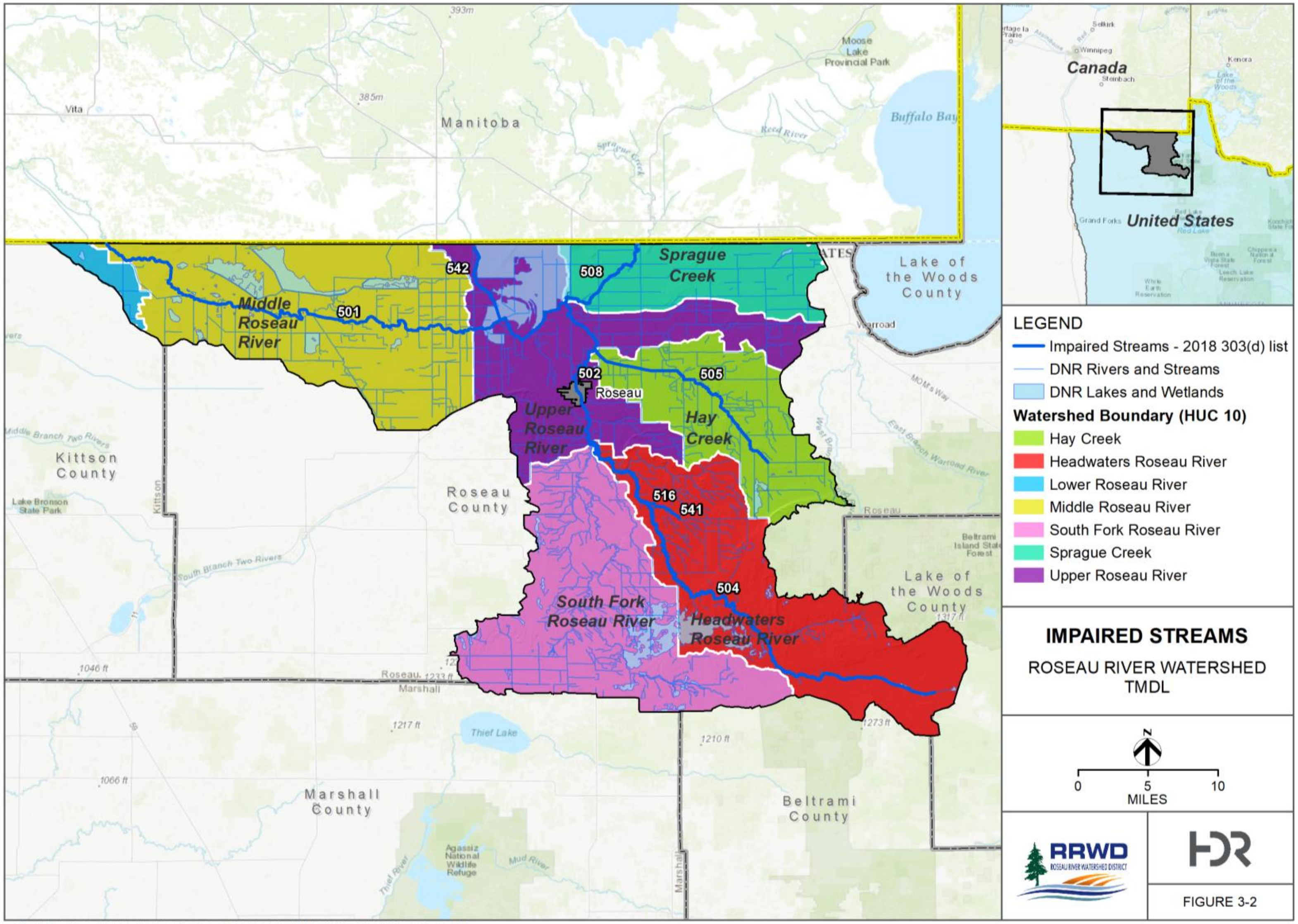
Table 3-1: Watershed areas of impaired streams addressed in this study

AUID 09020314 -	Stream Name	Watershed Area (ac)
505	Hay Creek	62,007

3.3 Subwatersheds

The RRW was divided into seven 10-digit HUC subwatersheds (Figure 3-2), which are used to organize the components of this TMDL study. Hay Creek (0902031403) is the only HUC-10 subwatershed containing an impaired reach. Only the Hay Creek Subwatershed will be discussed further, as it is the focus of this TMDL study on impaired waterbodies.

Figure 3-2: Roseau River Watershed 10-digit HUC subwatersheds



3.3.1 Hay Creek

The Hay Creek Subwatershed is located in the eastern portion of the RRW. Local drainage ditches combine to form Hay Creek at 530th Avenue crossing, in the southeastern portion of the subwatershed. Hay Creek flows to the north and west, discharging into the Roseau River north of Roseau, Minnesota. The entire length of Hay Creek and many of the other streams in the Hay Creek Subwatershed (68%) have been physically altered, channelized, ditched, or impounded (MPCA 2013a). The southeastern third of the Hay Creek Subwatershed is dominated by wetlands, while cultivated row crop agriculture dominates the central and northwestern areas of the subwatershed.

The Hay Creek 10-digit HUC Subwatershed contains one impaired reach: Hay Creek (AUID 09030214-505). Hay Creek is impaired for its aquatic recreation designated beneficial use due to elevated levels of *E. coli* and its aquatic life designated beneficial use due to elevated levels of TSS. The total drainage area of the impaired reach and associated land uses are shown in Figure 3-4.

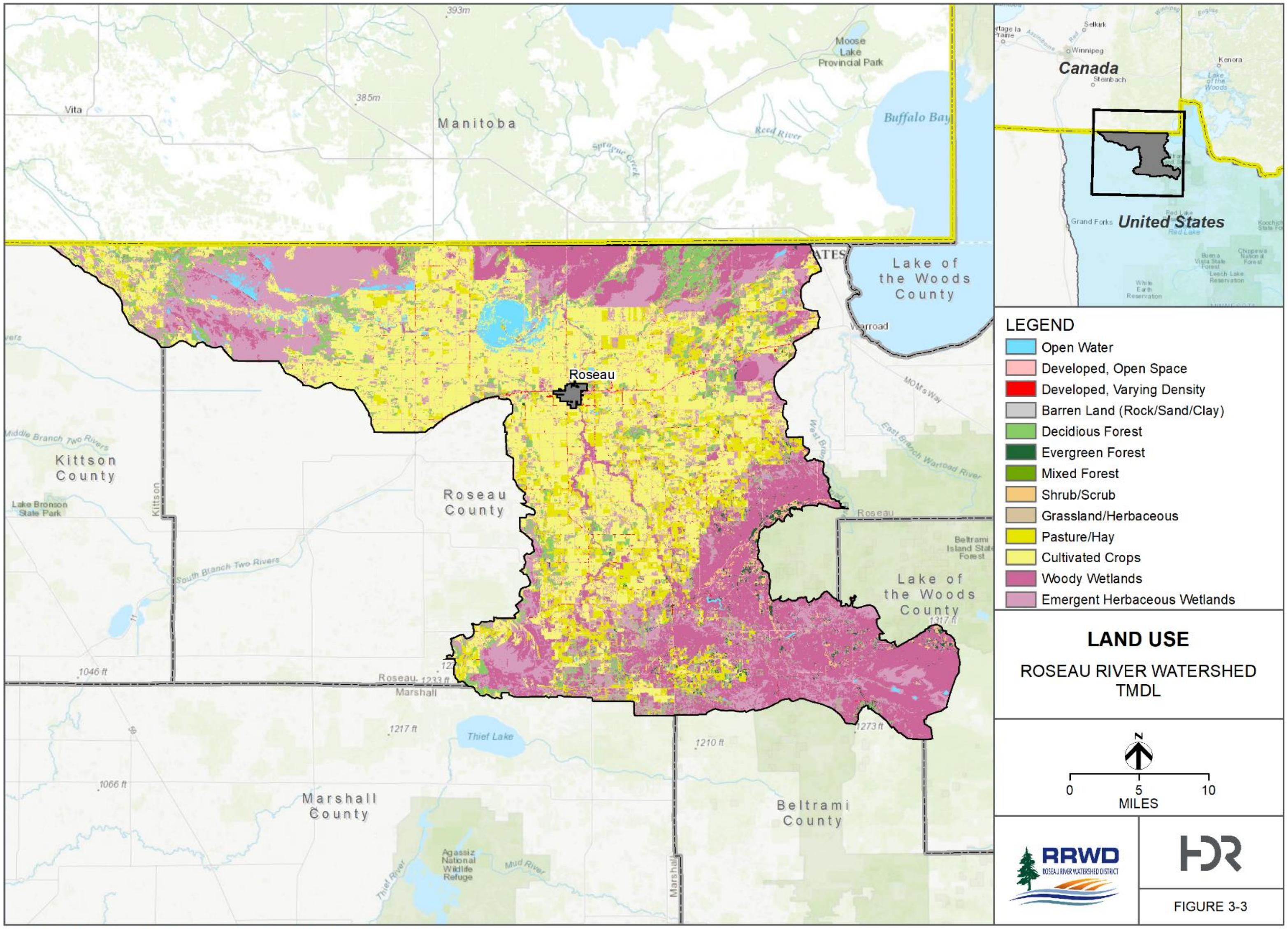
Table 3-2: Land uses as a percent of the total drainage area for the Roseau River Watershed and the TMDL assessed reach of Hay Creek. Land Use statistics were based on NLCD (2011).

Watershed/AUID	Open Water	Urban	Barren	Forest/ Shrub	Pasture/Hay/ Grassland	Cropland	Wetland
Entire Watershed	1.8%	3.3%	0.0%	9.7%	9.1%	31.7%	44.4%
Hay Creek (0902031403)							
09020314-505	0.2%	4.6%	0.0%	8.9%	14.5%	38.4%	33.4%

3.4 Land use

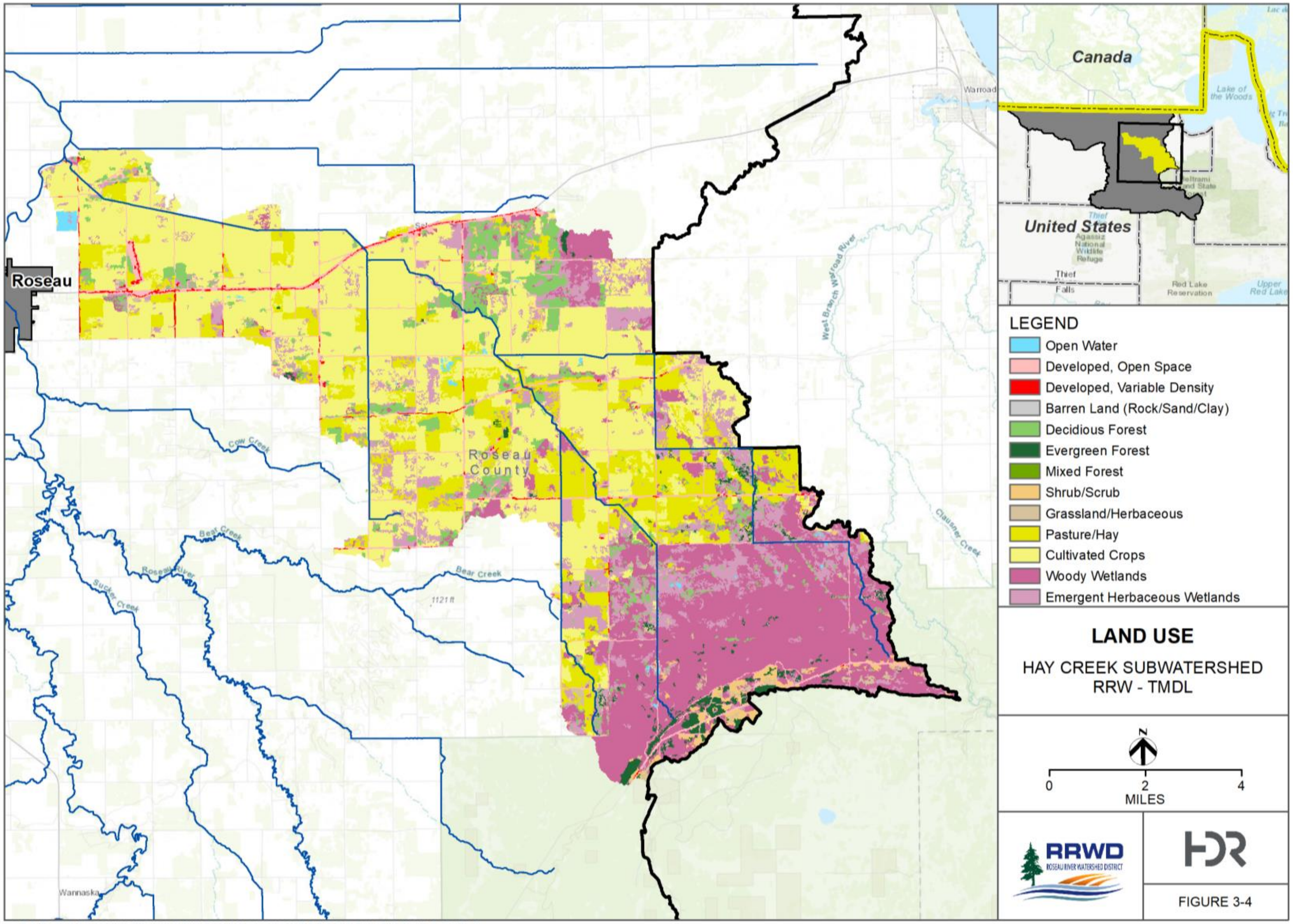
Land use within the RRW and Hay Creek Subwatershed can be described by the Multi-Resolution Land Characteristic Consortium Dataset (NLCD 2011). Agriculture and wetland areas are the primary land uses in both the RRW and the Hay Creek Subwatershed, as shown in Table 3-2. The division between the dominant land use classifications generally falls along the ecoregion boundary, with agriculture dominating the Glacial Lake Agassiz Ecoregion, and wetlands encompassing most of the NMW Ecoregion (Figure 3-1). Figure 3-3 and Figure 3-4 show graphical representations of land use in the RRW and Hay Creek Subwatershed, respectively.

Figure 3-3: Land Use within the Roseau River Watershed based on NLCD 2011



PATH: X:\RRWD\10077098\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\FORMAT_RRW_LANDUSE.MXD - USER: NTHOMAS - DATE: 2/19/2019

Figure 3-4: Land use for Hay Creek Subwatershed from Roseau River to the headwaters (AUID 09020314-505)



3.5 Current/historical water quality

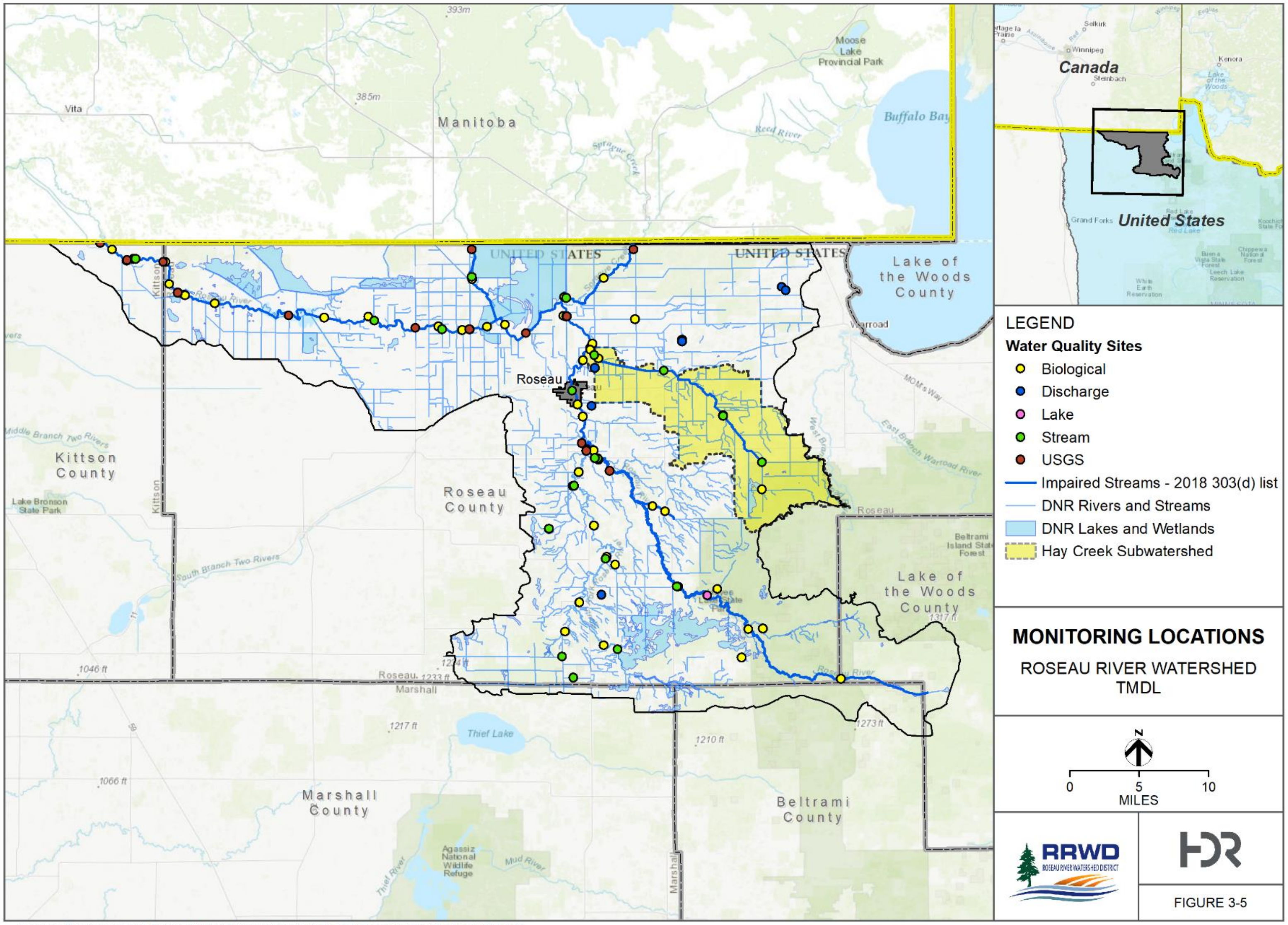
The existing RRW water quality conditions were determined using data downloaded from the MPCA's Environmental Quality Information System (EQuIS) database (MPCA 2018). All water quality sampling data used for assessments, modeling, and data analysis, for this study and reference reports, are stored in this database and are accessible through the MPCA's Environmental Data Access (EDA) website (MPCA 2018).

There are 56 biological monitoring sites, 7 discharge monitoring sites, 1 lake water quality monitoring site, 25 stream water quality monitoring sites, and 14 United States Geological Survey (USGS) gauging stations located in the RRW (Figure 3-5). Not all sites were used in the RRW's TMDL assessments. Sites were excluded for various reasons including: their period of record being outside of the assessment period (2005 through 2014); the sites were not located in impaired stream reaches or lakes; or a site did not have relevant observed data.

The MPCA conducts 2 years of intensive watershed monitoring in all 80 watersheds in Minnesota on a 10-year cycle (i.e., every major watershed is sampled for 2 years, once every 10 years). The RRW intensive watershed monitoring occurred in 2015 and 2016. The TMDL studies required paired flow and pollutant concentration data to compute loading. Flow data from the HSPF modeling or other sources is unavailable beyond 2014. Data from the 2015 to 2016 intensive monitoring period was compared to historical data, to ensure no recent shifts in water quality were evident. Upon reviewing recent data, it was determined that the historical data was comparable to recent data; therefore, the historical data were used as the basis for these assessments.

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

Figure 3-5: Monitoring Stations in the Roseau River Watershed



3.5.1 Hay Creek current/historical water quality data

Hay Creek is the only impaired water body within the RRW which requires a TMDL study. Figure 3-6 shows that within the Hay Creek HUC-10 Subwatershed there are three biological monitoring sites, four stream monitoring sites, and one discharge monitoring site. Hay Creek does not have an active or historical USGS stream gauge.

Bacteria

Hay Creek has been listed as impaired for aquatic recreational use due to elevated *E. coli.* Based on the Roseau River Monitoring Report, the impairment may be restricted to the northern portion of the stream. The *E. coli* criteria for impairment requires more than 10% of samples for a calendar month to exceed 1,260 organisms (org)/milliliter (mL) or the geometric mean concentration to exceed 126 organisms/mL. These criteria require not less than five samples within a calendar month.

Table 3-3 provides a summary of bacteria measurements (*E. coli* and fecal coliform converted to *E. coli*) during the assessment period (2005 through 2014) for the months of April through October. The *E. coli* measurements within the assessment period are limited to one sampling location (S004-135 in Figure 3-6) and 22 total samples. The *E. coli* and fecal coliform standards are both used as indicators for waterborne pathogens. Due to limited number of *E. coli* samples, fecal coliform were converted to *E. coli* to expand the number of samples. Fecal coliform concentrations were converted to *E. coli* based on 200 fecal coliform organisms to 126 *E. coli* organisms per 100 mL. The conversion of fecal coliform is based on a relation between permitted standards for wastewater treatment plants (WWTP) of 200 org/100mL fecal coliform, and a recently updated water quality criteria of (126 org/100mL) *E. coli*. Fecal coliform and *E. coli* were sampled at the same location with fecal coliform samples dating prior to 2009 and *E. coli* samples dating after 2009. Including fecal coliform added 18 samples to the existing 22 *E. coli* samples during the evaluation period.

Figure 3-7 shows the range of *E. coli* measurements aggregated by month. Measured concentrations in Hay Creek were found to be the highest in June through September following higher temperatures and optimal growth conditions (Wang et al., 2018). Table 3-3 summarizes the *E. coli* samples in tabular form. The highest geometric mean concentration and highest single sample occurred in July. In each month, June through September, at least one sample exceeded the 126 organisms per 100 mL criteria, additional discussion related to the *E. coli* exceedance follows in section 4.3. The *E. coli* samples from the intensive watershed monitoring period (2015 through 2016) were not included in this analysis, but summarized for reference in Appendix B. Recent bacteria sampling from 2015 and 2016 shows similar geometric means, and seasonal patterns to the data within the assessment period.

TSS

Hay Creek has also been listed as impaired for aquatic life due to high concentrations of TSS. Hay Creek falls within the Central Nutrient Region. Per Minn. R. ch. 7050, TSS standards for the class 2B waters within the Central Nutrient Region are limited to TSS concentrations of up to 30 mg/L. This standard is applicable April 1 through September 30 and if exceeded for more than 10% of the time, the waterbody is listed as impaired.

Table 3-4 provides a summary of TSS measurements taken during the assessment period for the months of April through September. The TSS measurements within the assessment period were limited to two sampling locations (S002-105 and S002-106 in Figure 3-6), and a total of 45 samples. Turbidity was previously used to determine suspended sediment impairments in Minnesota. In 2015, the previous turbidity criteria was abandoned and a TSS criteria was adopted. Turbidity data were available during this time period; however, there was not enough paired TSS and turbidity data along this reach to create a relationship to convert turbidity to TSS.

Sampled TSS data are summarized in Table 3-4 and monthly aggregation of data is shown for S002-105 and S002-106 in Figure 3-8 and Figure 3-9, respectively. The highest TSS concentrations and the most variability occur in the spring and early summer months. Spring snow melt and rainfall on bare agricultural fields likely increase the TSS concentrations along Hay Creek. The TSS sampling from the intensive watershed monitoring period (2015 – 2016) were not included in this analysis, but summarized for reference in Appendix B. Recent sediment sampling from 2015 and 2016 shows similar geometric means and seasonal patterns to the data within the assessment period.

Modeled data

Limited measured data (*E. coli*, TSS, and flow) are available for the assessment period. To account for limited TSS data during the assessment period, and the lack of flow data along Hay Creek, HSPF modeling (REPSEC 2016a, b) was used to supplement the existing information. The model simulates flow, TSS, and other water quality constituents for the period of 1995 to 2014. Simulated water quantity and quality data were available through the Scenario Application Manager (SAM) at daily increments for each of the 104 reaches within the model. The SAM provides a graphical interface to access and visualize modeling results, and to develop Best Management Practices (BMP) implementation scenarios within a calibrated and validated HSPF model. The TMDL study's LA calculations, outlined in Section 4.0 TMDL Development, use modeled flow and TSS results to determine needed reductions in impaired reaches. The *E. coli* data were unable to be supplemented with HSPF modeling results, as bacteria was not included in the modeling effort (RESPEC 2016a, b).

Figure 3-6: Water quality monitoring stations in Hay Creek Subwatershed

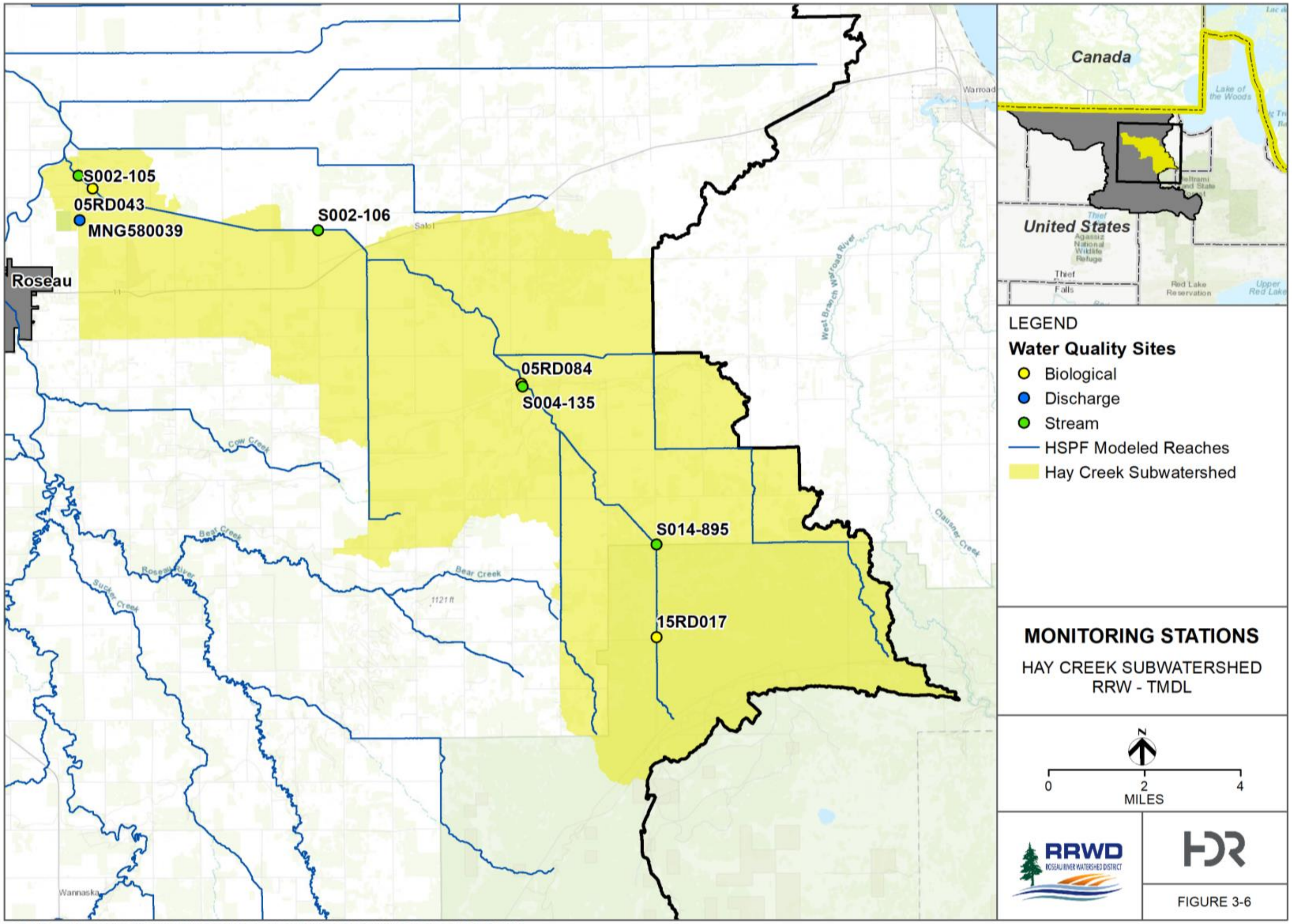


Table 3-3: Summary of *E. coli* sampling in Hay Creek, note 18 samples were fecal coliform converted to *E. coli* equivalents.

AUID		09020314-505
Site ID		S004-135
Sampling Years		2005-2012
April	# of Samples	1
	Geo-Mean (org/100 mL)	2.5
	Range (org/100 mL)	-
	# of Samples > 1,260 (org/100 mL)	0
May	# of Samples	5
	Geo-Mean (org/100 mL)	5.0
	Range (org/100 mL)	1 - 35
	# of Samples > 1,260 (org/100 mL)	0
June	# of Samples	10
	Geo-Mean (org/100 mL)	110.7
	Range (org/100 mL)	21 - 1,414
	# of Samples > 1,260 (org/100 mL)	1
July	# of Samples	7
	Geo-Mean (org/100 mL)	266.0
	Range (org/100 mL)	128 - 2420
	# of Samples > 1,260 (org/100 mL)	1
August	# of Samples	7
	Geo-Mean (org/100 mL)	155.5
	Range (org/100 mL)	42 - 723
	# of Samples > 1,260 (org/100 mL)	0
September	# of Samples	7
	Geo-Mean (org/100 mL)	200.1
	Range (org/100 mL)	32 - 1,206
	# of Samples > 1,260 (org/100 mL)	0
October	# of Samples	3
	Geo-Mean (org/100 mL)	9.1
	Range (org/100 mL)	4 - 20
	# of Samples > 1,260 (org/100 mL)	0
Total April - Oct.	# of Samples	40
	Geo-Mean (org/100 mL)	77.7
	Range (org/100 mL)	1 - 2,420
	# of Samples > 1,260 (org/100 mL)	2

Figure 3-7: *E. coli* sampling aggregated by month on Hay Creek at the monitoring station S004-135. The dashed line denotes the stream water quality standard (126 org/100mL).

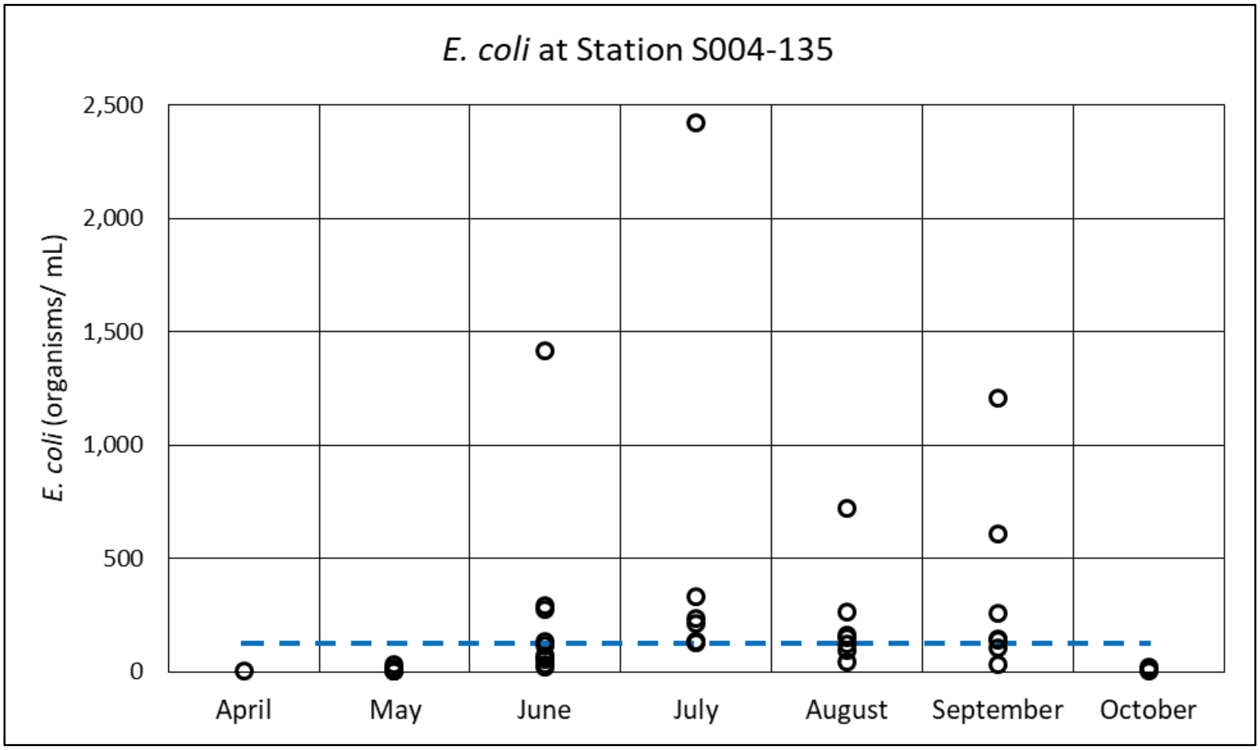


Table 3-4: Summary of TSS sampling in Hay Creek

AUID		09020314-505	
Site ID		S002-106	S002-105
Sampling Years		2006-2013	2006-2013
April	# of Samples	4	4
	Geo-Mean (mg/L)	17.5	52.8
	Range (mg/L)	2 - 95	7 - 168
	# of Samples > 30 (mg/L)	2	3
May	# of Samples	5	5
	Geo-Mean (mg/L)	31.2	17.2
	Range (mg/L)	13 - 227	2 - 390
	# of Samples > 30 (mg/L)	1	1
June	# of Samples	4	4
	Geo-Mean (mg/L)	18.4	20.8
	Range (mg/L)	5 - 76	4 - 100
	# of Samples > 30 (mg/L)	1	2
July	# of Samples	4	4
	Geo-Mean (mg/L)	30.8	21.9
	Range (mg/L)	13 - 159	13 - 37
	# of Samples > 30 (mg/L)	1	2
August	# of Samples	2	3
	Geo-Mean (mg/L)	5.9	22.0
	Range (mg/L)	5 - 7	17 - 25
	# of Samples > 30 (mg/L)	0	0
September	# of Samples	3	3
	Geo-Mean (mg/L)	6.0	7.4
	Range (mg/L)	3 - 18	5 - 9
	# of Samples > 30 (mg/L)	0	0
Total April - Sept.	# of Samples	22	23
	Geo-Mean (mg/L)	17.5	20.8
	Range (mg/L)	2 - 227	2 - 390
	# of Samples > 30 (mg/L)	5	8

Figure 3-8: TSS sampling aggregated by month on Hay Creek at the monitoring station S002-105. The dashed line denotes the stream water quality standard (30 mg/L).

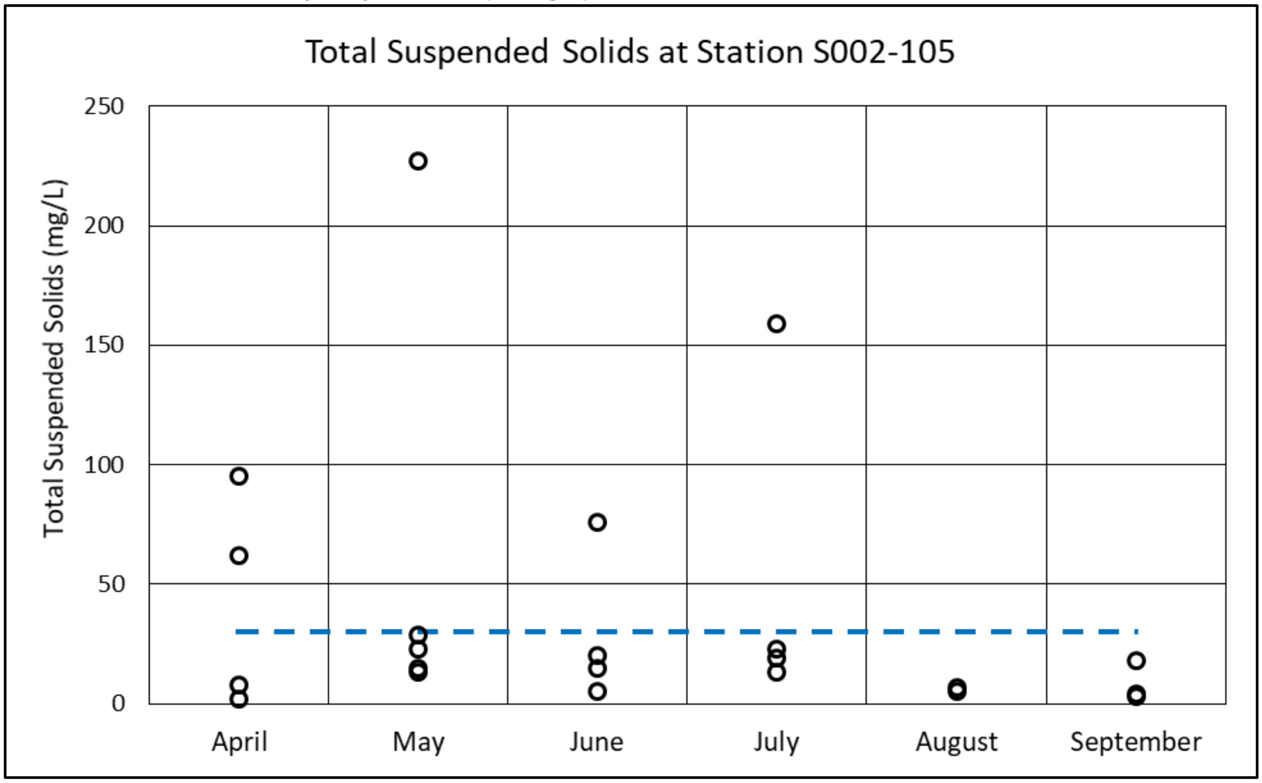
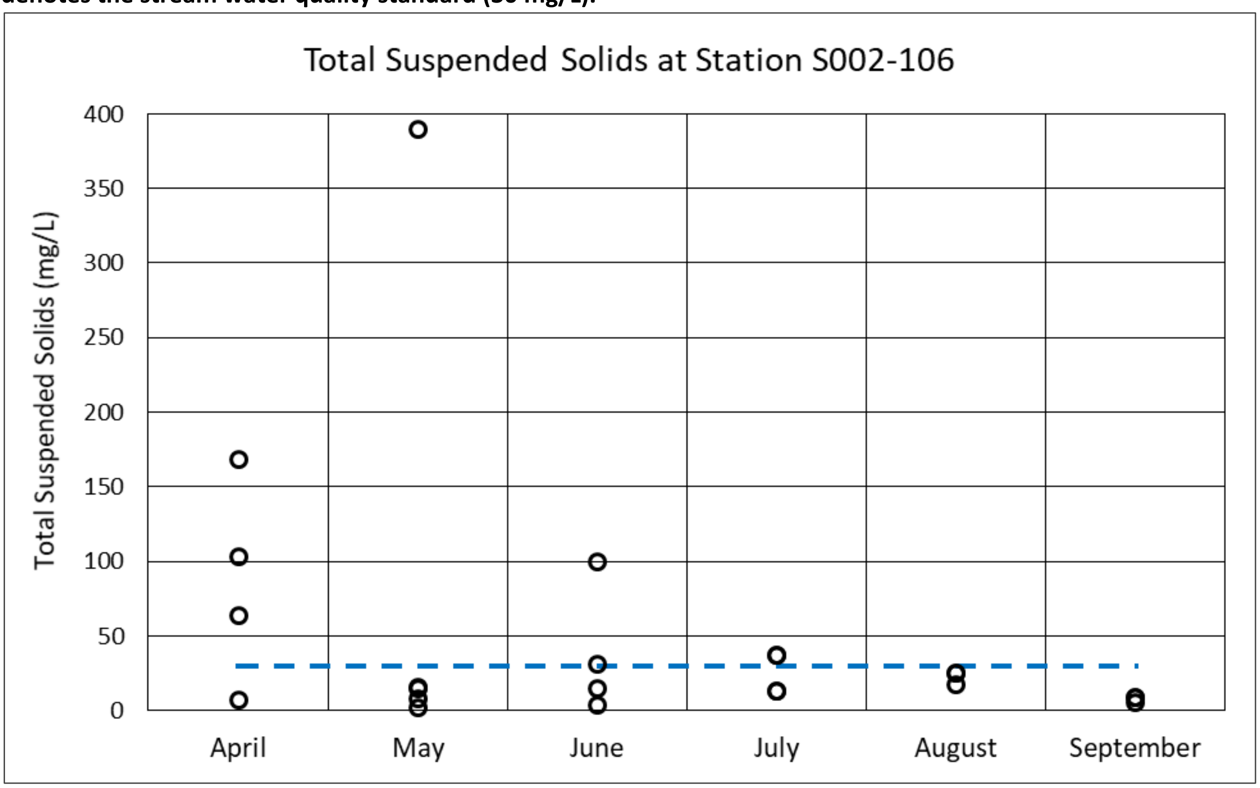


Figure 3-9: TSS sampling aggregated by month on Hay Creek at the monitoring station S002-106. The dashed line denotes the stream water quality standard (30 mg/L).



3.6 Pollutant source summary

Developing an understanding of the sources contributing to impairments is an important component in developing a TMDL study. The Hay Creek Subwatershed exhibits contrasting land use, soils, topography, and drainage patterns from the southeast to the northwest. This diversity results in stressors which vary across the system. This section provides a description of the sources, by pollutant, in the subwatershed that could contribute to the documented impairments. The RRW SID Report (MPCA 2018a) provides a discussion on biological stressors and pollutant sources.

3.6.1 Total Suspended Solids

TSS in the stream channel originate from numerous sources, outlined in the RRW SID Report (MPCA 2018a). Generally, in the Hay Creek Subwatershed, sediment originates through rainfall and runoff processes acting to dislodge and mobilize upland sediment, in-stream bank and bed erosion and deposition, and to a lesser extent through permitted discharges (construction, industrial facilities, and WWTPs). The next sections describe potential sources of TSS in more detail.

3.6.1.1 Permitted sources

The regulated sources of TSS within the RRW and the impaired streams addressed in this TMDL study include: WWTP effluent, National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) permitted feedlots (permitted to be zero-discharge), construction stormwater, and industrial stormwater.

Construction activities exposing bare ground can be a large source of TSS to streams. The larger and longer an area of bare soil is exposed, the more likely soil is to erode from the landscape and enter nearby waterbodies. Industrial operations vary widely, and discharge criteria of TSS is regulated based on the specific industrial activity. Construction and industrial stormwater activities in the RRW are not of a high magnitude, and do not have enough data to support identification of site specific loading; as such, compliance with TMDLs occur under NPDES/SDS general permits for each activity. Section 4.2 discusses how these sources are included in the TMDL study's LAs.

The RRW contains one WWTP, discharging to an impaired stream (Table 3-5). The Roseau WWTP is a stabilization pond system containing primary and secondary treatment ponds. The WWTP is permitted to discharge March 1 through June 30 and September 1 through December 31. Applicable permitted discharge limits for the Roseau WWTP are described in Section 4.2. This TMDL study will not result in a change to the Roseau WWTP's existing TSS limit.

Table 3-5: RRW WWTP permitted discharger

Facility	Permit Number	HUC-10 Subwatershed Name	System Type	Secondary Pond Size (ac)
Roseau WWTP	MNG580039	Hay Creek	Pond	31.0

3.6.1.2 Non-permitted sources

In the Hay Creek Subwatershed, TSS loading is comprised primarily of upland field erosion and in-channel stream bank erosion. Erosion is a natural process whereby soil and/or rock is transported from one location to another by water and/or wind. Acceleration of erosion, resulting from human influences, degrades habitat and biological productivity, and changes the stream's function and shape.

Upland field erosion occurs when sediment is dislodged by rainfall impact, or is entrained into water running over the landscape. These processes can occur on any land use, but become accelerated when vegetation is limited or non-existent. With vegetation in place, leaves and limbs absorb rainfall and reduce the impact on the ground. Flow of water over the ground is slowed by vegetation, allowing it to infiltrate. Cultivated land comprises 38.4% of the Hay Creek Subwatershed. These areas do not have a crop canopy for eight to nine months out of the year and, therefore, are without sufficient protection, so these areas can become primary sources of upland sediment.

In-stream channel and bank erosion can be accelerated by changes to the landscape such as channelization of waterways, drainage, modification to riparian vegetation, increases in impervious surfaces or precipitation causing more runoff, and livestock access to streams. According to the MPCA (2013), 68% of the watercourses in the Hay Creek Subwatershed have been physically altered, though channelization, or ditching. This includes the entire length of Hay Creek itself, as shown in Figure 3-10. Channels were often straightened and widened in an effort to alleviate flooding. Each modification results in increases in slope, stream velocity, and channel erosion.

The RRW SID Report (MPCA 2018a) highlighted a number of potential sources of increased sediment to Hay Creek. Past channelization and ditch maintenance have increased the velocity and strength of water flow, and acted to disconnect or remove the floodplain during high flow conditions. Channel modifications are likely a primary contributor to the altered hydrology of the reach, as stated in the repot: “the reach is prone to extreme peak flows, as well as periods of minimal flow.” These items act to increase stream flow velocities and intensify erosion. The erosion results in deposition along flatter sloped reaches of the stream. In lesser channelized locations, the Stressor ID report indicated signs of cattle grazing in the channel, linking these activities with increased erosion.

The HSPF modeling was set up to account for the varying landscapes of the watershed, including upland and in-stream erosion. The TSS loading data for the 2005 to 2014 period were extracted from the model using SAM. Figure 3-11 shows that 56% of the TSS load at the outlet of Hay Creek originates from in-stream and bank erosion processes, while approximately 33% of the TSS results from upland agricultural sources. Figure 3-12 and Figure 3-13 describe spatially where the sediment originates. The HSPF modeling shows that 31% of the TSS comes from reach A247, and over 75% of the sediment originates in the downstream half of the subwatershed. Increased sediment sources in the downstream portion of Hay Creek are consistent with the Glacial Lake Agassiz Basin ecoregion, and the highly cultivated areas. The results shown in Figure 3-13 can also be used for prioritization of protection strategies based on the relative magnitude of sediment yield.

Figure 3-10: Waterways in Hay Creek Subwatershed denoted by the DNR Rivers and Streams database as ditches or streams

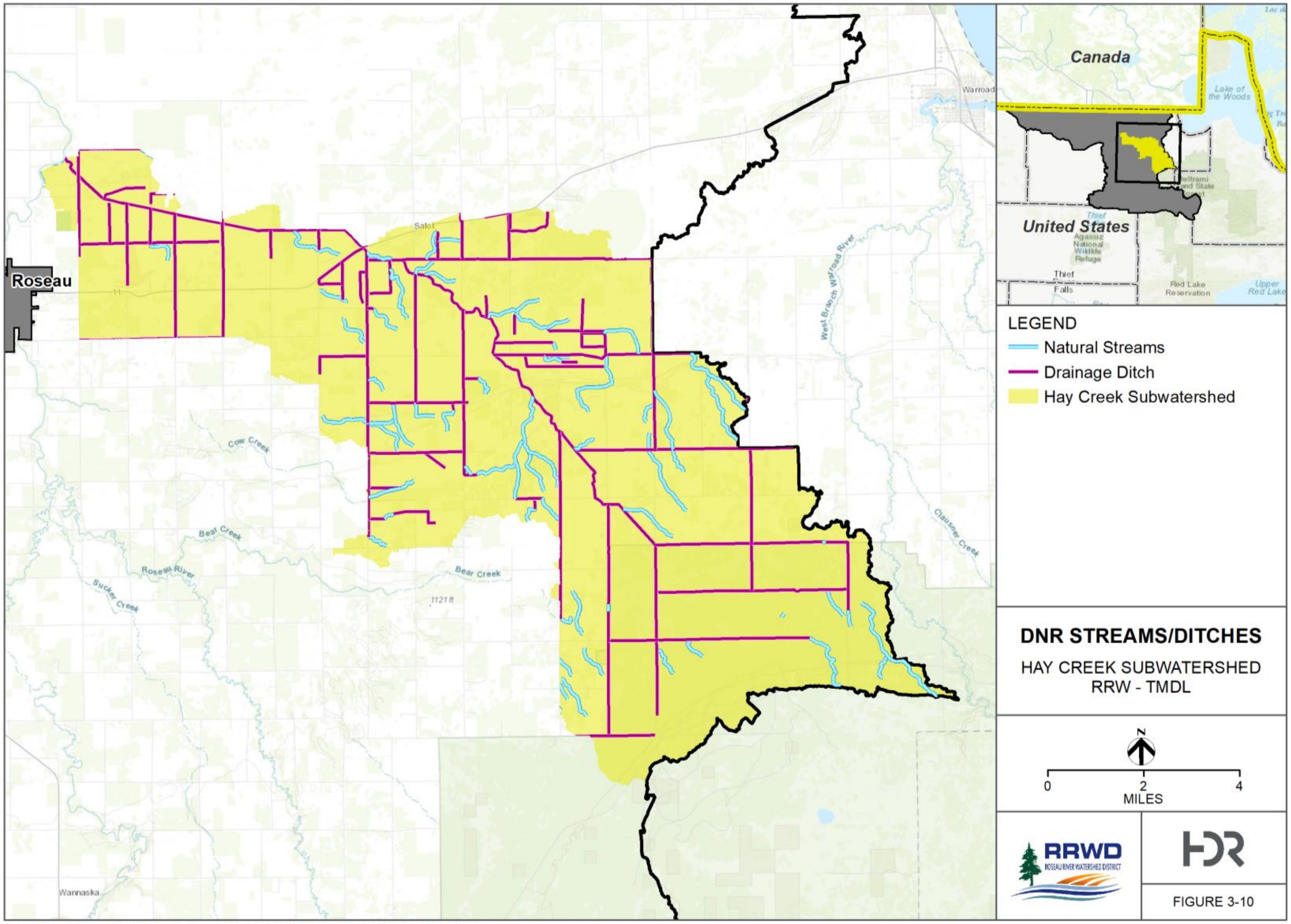
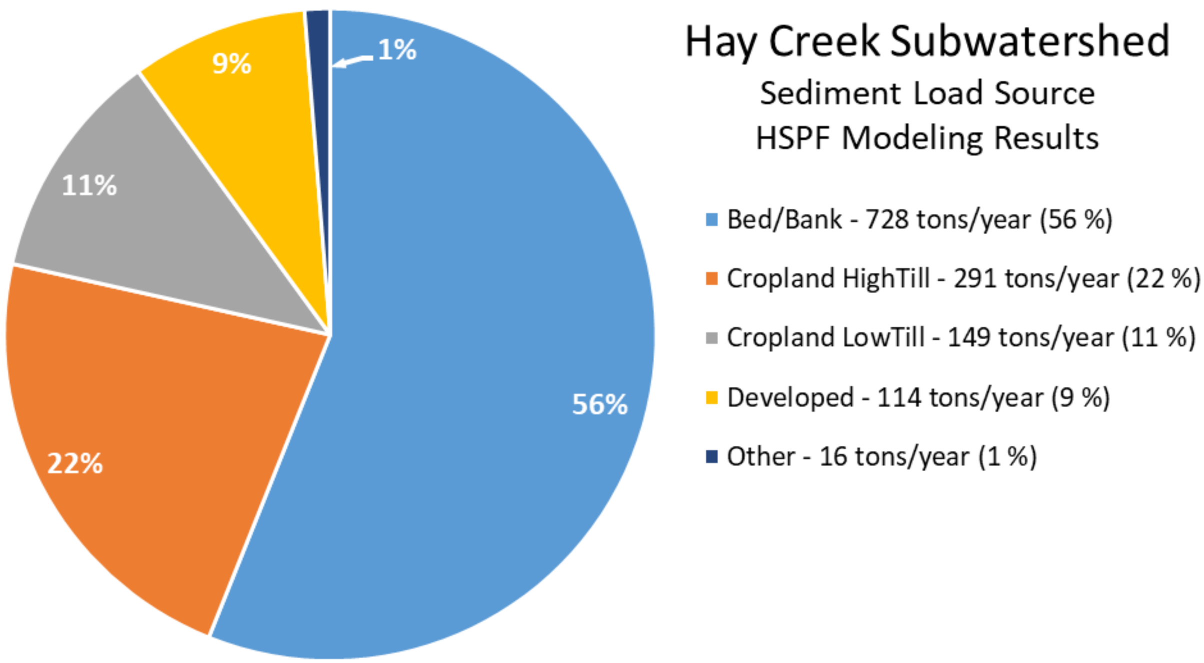


Figure 3-11: Hay Creek Subwatershed sediment source loading summary by source type. HSPF modeling results over the analysis period (2005 to 2014).



*Other Sediment Source Loads in descending order include: Developed Effective Impervious Area (EIA), Roseau WWTP, Woody Wetlands, Pasture, Deciduous Forest, Coniferous Forest, Grassland, and Herbaceous Wetlands.

Figure 3-12: Hay Creek Subwatershed sediment source loading summary, by source location. HSPF modeling results over the analysis period (2005 to 2014).

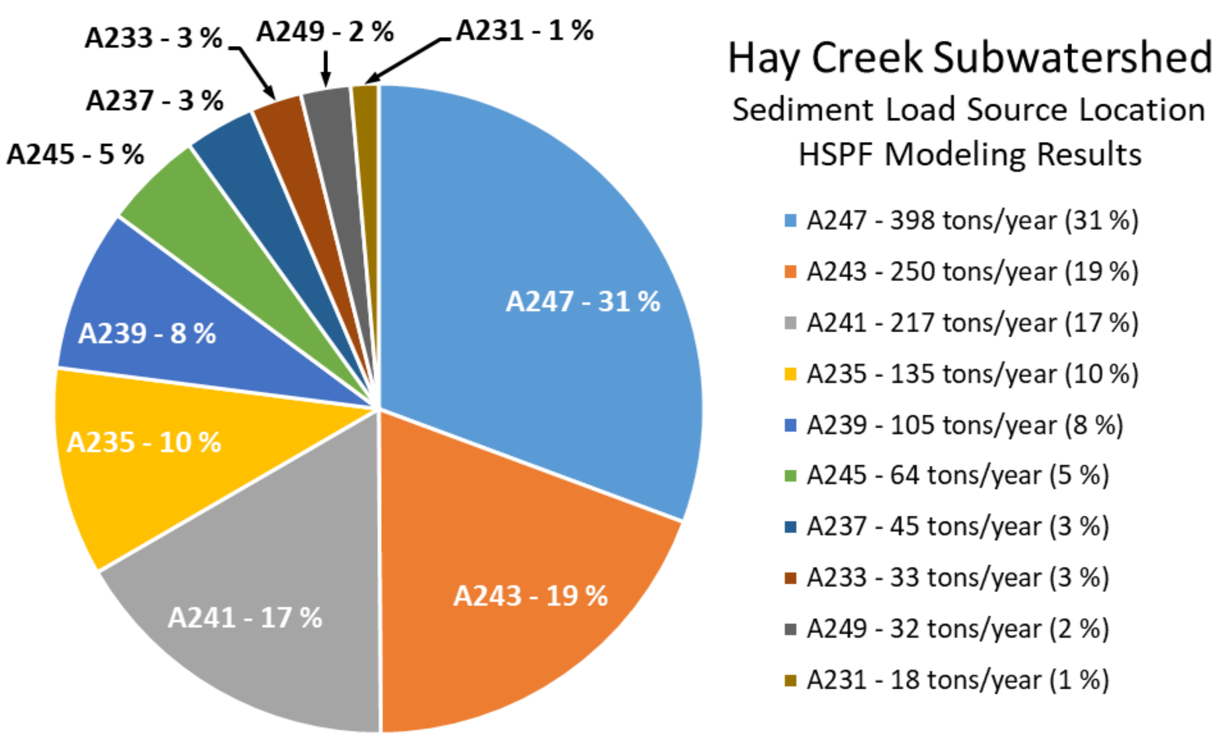
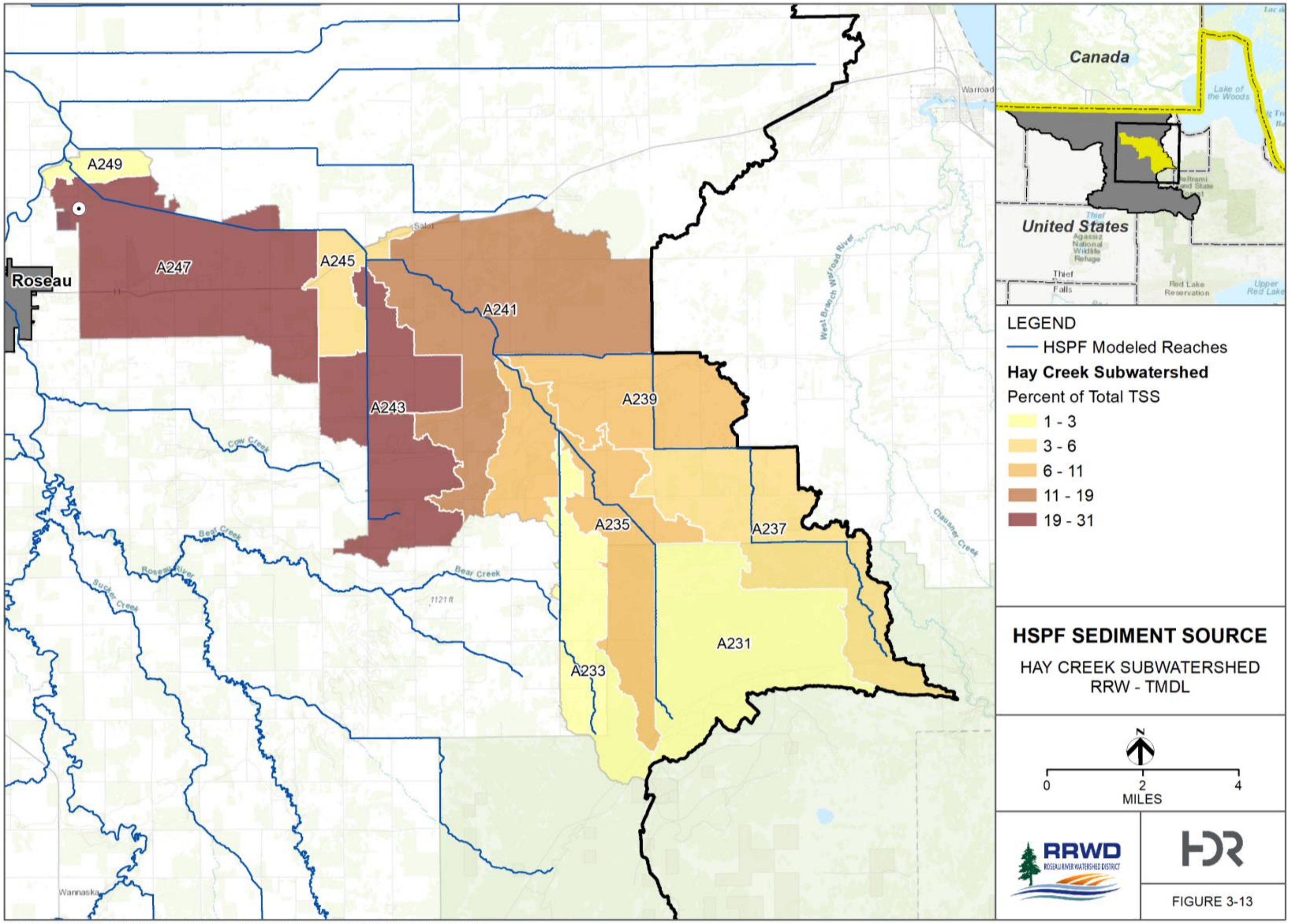


Figure 3-13: Hay Creek Subwatershed sediment source loading summary map. The figure is colored by the percent of total load each sub-basin contributes to the end of the impaired reach (Hay Creek). Darker color denotes higher contribution. HSPF modeling results over the analysis period (2005 to 2014)



3.6.2 *Escherichia coli*

Bacteria is naturally occurring in the environment; however, bacteria concentrations can be increased through a number of sources including humans, companion animals, and livestock. Many factors contribute to the complex relationship between bacteria sources and in-stream bacteria concentrations including livestock management practices, wildlife activities, land use practices, stream flow, temperature, resuspension, and other environmental factors. The following section discusses sources of bacteria in the environment and delivery mechanisms to the stream.

Investigation of the potential sources of bacteria delivered to Hay Creek was based on population production estimates, and potential delivery mechanisms to the stream. Identification and quantification of the bacteria sources to the stream were completed through the following steps:

1. Identify and quantify the magnitude of potential bacteria sources which could contribute *E. coli* to Hay Creek. Potential sources include: permitted sources (WWTPs, industrial facilities, municipal stormwater discharge, and confined animal feeding operations), and non-permitted sources (subsurface sewage treatment systems [SSTS], companion animals, livestock, and wildlife);
2. Assign a bacteria production rate to each identified source based on literature values; and
3. Summarize the relative loading from each identified source of bacteria. Bacteria production rates are applied to the potential sources and magnitudes estimated. This information was aggregated to describe the relative impact of each source.

3.6.2.1 Potential Bacteria Sources

Point (Permitted) Sources

The NPDES/SDS Program regulates discharge of pollutants from point sources into waters of the United States. Regulations include limits of discharge, monitoring and reporting requirements, and other provisions to limit impacts on public health and water quality. Point sources can include municipal wastewater, industrial wastewater, and animal feeding operations (which are permitted to be zero-discharge).

In the Hay Creek Subwatershed, there is only one point source discharger, the Roseau WWTP. A WWTP operating under an NPDES/SDS permit is required to reduce fecal coliform concentrations to 200 org/100mL (*E. coli* - 126 org/100mL) or less. The function of this limit is to ensure the wastewater effluent has been adequately disinfected, and no longer poses a risk to human health through recreational activities. The Roseau WWTP is a stabilization pond system with primary and secondary cells. This WWTP discharges treated effluent to the surface water in the spring (March through June) and again in the fall (September through December). Table 3-6 provides the permitted discharge volume and bacteria load of Roseau WWTP. This TMDL study will not result in a change to the Roseau WWTP's existing *E. coli* limit.

Table 3-6: WWTP permitted flows and bacteria loads in Hay Creek

Facility	Permit Number	HUC-10 Subwater-shed Name	System Type	Secondary Pond Size (acres)	Discharge Volume (MGD)	Bacteria Load as *E. coli* (billion organisms/day)[1]
Roseau WWTP	MNG580039	Hay Creek	Pond	31.0	5.05	24.1

[1] Bacteria loading is based on the *E. coli* limit of 126 org/100mL

Nonpoint Sources

Humans – Subsurface Sewage Treatment Systems (SSTS)

Rural communities or residential lots often rely on SSTS, often referred to as septic systems, to treat wastewater. Non-compliant SSTSs can become an important source of bacterial contamination to surface waters, especially during dry periods when stream flows are low and SSTSs continue to discharge. An SSTS discharging untreated wastewater to the ground surface, road ditches, tile lines, or directly into streams is considered an Imminent Threat to Public Health (ITPH).

The MPCA (2011) reports failing SSTSs by county from 2000 to 2009. The Hay Creek Subwatershed lies completely within Roseau County, which has an estimated 4% ITPH septic systems. The rural population in Hay Creek Subwatershed was estimated based on the 2010 census data, and multiplied by the rate of failing SSTSs to obtain an estimated loading rate. Therefore, of the rural pollution in the Hay Creek Subwatershed, an estimated 4% or 30 residents have failing SSTSs. This is a small source category.

Companion Animals

Human companion animal (pet) waste can be a significant source of pathogen contamination to water resources. If companion animal waste is not disposed of properly, runoff from streets and green space transports pet waste to stormwater conveyance systems and into the stream. According to the American Veterinary Medical Association's data (AVMA 2007), 34.2% of households in Minnesota own dogs and each of these households has 1.4 dogs. Furthermore, 38% of dog waste is not collected by owners and is capable of contributing to surface waters (TBEP 2012). Bacteria loading from dogs was estimated based on total households in the Hay Creek Subwatershed (U.S Census Bureau 2010a and 2010b).

Waste from domestic cats, even those spending time outside is typically collected indoors, and was not considered a source of bacteria for this TMDL assessment. Feral cats may supply a significant bacteria load. However, feral cat populations are unknown and not included in this assessment.

This is a small source category.

Livestock

Livestock have the potential to contribute bacteria to surface water through grazing and runoff, direct stream input, and improper management and storage of manure. The United States Department of Agriculture (USDA) National Agricultural Statistic Service (NASS) provides livestock populations by county. The most recent USDA census of agriculture occurred in 2012; livestock numbers for Roseau County are tabulated in Table 3-7. Livestock populations are assumed to be distributed evenly across the county. Hay Creek Subwatershed makes up 5.7% of Roseau County, so it is assumed 5.7% of the livestock population is located in Hay Creek Subwatershed. Roseau County has a large turkey population. However, there are no permitted turkey feedlots in Hay Creek Subwatershed, so it was assumed turkeys do not contribute to the Hay Creek Subwatershed bacteria loading. This (livestock) is the dominant source category.

Table 3-7: Livestock population estimates in Roseau County and Hay Creek Subwatershed (USDA 2013)

Animal		Livestock Estimates*	
		Roseau County	Hay Creek
Cattle	All	16,701	965
	Beef	6,884	398
	Dairy	1,469	85
	Cattle on Feed	8,348	482
Hogs	-	8,529	493
Sheep	-	1,027	60
Goats	-	237	14
Horses	-	837	49
Poultry	Layers	727	42
	Pullets	64	4
	Boilers	236	14

*Based on 2012 USDA agricultural census data

Wildlife

Wildlife living in waterbodies, wetlands or fields adjacent to waterbodies, and areas of congregation can contribute significant bacteria loading to streams and lakes. Ducks, geese, and beavers live and defecate into waterbodies, directly contributing to the bacteria loading. Deer and other small animals (raccoons, coyote, foxes, squirrels, etc.) commonly live and congregate in areas adjacent to waterbodies, where rainfall and runoff processes deliver bacteria into streams. Potential areas of congregation and contribution of bacteria loading from wildlife include DNR designated wildlife management areas, state parks, national parks, national wildlife refuges, golf courses, state forests, and other conservation areas. In addition, private land managed for wildlife such as food plotting or other feeding can concentrate wildlife and provide an additional source or higher delivery of bacteria to waterbodies.

Hay Creek Subwatershed partially lies in the NMW Ecoregion, offering numerous places for wildlife to congregate, live, and provide a source of bacteria to the impaired reach of Hay Creek. In this assessment, the wildlife considered as potential sources of bacteria include deer, geese, and ducks. Other animals, which could live in the watershed including beaver, raccoons, coyotes, foxes, and squirrels, were not explicitly reported in Table 3-10. It is assumed that the bacteria loading of these animals is lower than the wildlife reported. However, the bacteria loading contributed by these animal groups is accounted for in the observed bacteria data, which is used to develop the LDCs and the estimated load reductions needed for bacteria. This is a minor source category.

Table 3-8: Wildlife population estimate data sources

Bacteria Source	Population Estimate Source and Assumptions
Deer	The DNR report "Status of Wildlife Populations, Fall 2014" (DNR 2014) includes numerous studies which estimate wildlife populations of various species. Pre-fawn deer densities were reported by permit area. Permit area 105 covers all of Hay Creek Subwatershed, densities were attributed to all NLCD 2011 land uses except open water. An average of the 2009 to 2014 densities was used.
Geese	The DNR report "Status of Wildlife Populations, Fall 2014" (DNR 2014) includes numerous studies which estimate wildlife populations of various species. Geese counts were reported annually by ecoregion. Counts from 2005 to 2014, were averaged and used to calculate a population density. An area-weighted estimate was used to determine geese population density, and applied to the Hay Creek Subwatershed.
Ducks	Duck pair density population estimates from the USFW service commonly called the "Thunderstorm Maps" provided input duck populations (MPCA 2011).

Natural/Background Occurrence

In addition to human or animal induced sources, literature has shown that *E. coli* bacteria could occur naturally, or may endure long bouts without animal inputs. Research in the last 15 years has found the persistence of *E. coli* in soil, beach sand, and sediments throughout the year in the north central United States without the continuous presence of sewage or mammalian sources. An Alaskan study (Adhikari et al. 2007) found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions. A study of cold water streams in southeastern Minnesota completed by the MPCA staff found the resuspension of *E. coli* in the stream water column due to stream sediment disturbance. A recent study near Duluth, Minnesota (Ishii et al., 2010) found that *E. coli* were able to grow in agricultural field soil. A study by Chandrasekaran et al. (2015) of ditch sediment in the Seven Mile Creek Watershed in southern Minnesota found that strains of *E. coli* had become naturalized to the water−sediment ecosystem. Survival and growth of fecal coliform has been documented in storm sewer sediment in Michigan (Marino and Gannon 1991). This is a small source category.

3.6.2.2 Bacteria Production Rate

The EPA's document *Protocol for Developing Pathogen TMDLs* (EPA 2001) provides a summary of source-specific pathogen and fecal indicator concentrations. Productions rates described in the EPA document were provided in fecal coliform, and converted to *E. coli* equivalents (200 org/100mL fecal coliform to 126 org/100mL *E. coli*). Fecal coliform rates, *E. coli* rates, and references for production rates are included in Table 3-9.

Table 3-9: Bacteria production rates

Source Category	Producer	Production Rate (billion org/day-head)		Literature Source
		Fecal Coliform	*E. coli*	
Humans	Humans	2	1.3	Metcalf and Eddy (1991)
	Companion Animals	5	3.2	Horsley and Witten (1996)
Livestock	Cattle	100	63	ASAE (1998)
	Hogs	10	6.3	ASAE (1998)
	Sheep and Goats	12	7.6	ASAE (1998)
	Horses	0.42	0.26	ASAE (1998)

Source Category	Producer	Production Rate (billion org/day-head)		Literature Source
		Fecal Coliform	*E. coli*	
	Chickens	0.14	0.09	ASAE (1998)
Wildlife	Deer	0.36	0.23	Zeckoski et al (2005)
	Geese	49	31	LIRPB (1978)
	Ducks	2.5	1.6	ASAE (1998)

E. coli Source Summary

Estimates of bacteria production were completed at the watershed scale, and are meant to inform stakeholders of the relative magnitude of bacteria produced from varying sources across the watershed. This bacteria source assessment is a valuable tool for planning and management of impaired waterbodies. Table 3-10 shows the results of the bacteria source assessment, with livestock as the largest source of bacteria in Hay Creek Subwatershed (92%).

Table 3-10: Summary of *E. coli* production estimates

Source Category	Producer	*E. coli* Source – Hay Creek	
		E. coli (billion org/day)	% of total
Humans	**All**	**260**	**0%**
	WWTP	23	0%
	SSTS	38	0%
	Companion Animals	198	0%
Livestock	**All**	**64,479**	**92%**
	Cattle	60,795	87%
	Hogs	3,106	4%
	Sheep and Goats	559	1%
	Horses	13	0%
	Poultry	5	0%
Wildlife	**All**	**5,484**	**8%**
	Deer	205	0%
	Geese	4,507	6%
	Ducks	772	1%
Total		**70,222**	

The bacteria evaluation was completed through a GIS desktop analysis, using generalized bacteria production rates. Population estimates were based on county, state, and regional scale data. These were formulated to be the most relevant for Hay Creek Subwatershed. Uncertainty can be attributed to a lack of knowledge of the spatial distribution of the data. Only the source and magnitude of bacteria were estimated in this assessment, omitting the fate and transport of bacteria. Bacteria die off, travel time, and transport mechanisms impact how much of the bacteria source is transported to the stream. The species *E. coli* represents a single strain of bacteria and is used as an indicator for other pathogens. Further evaluation would include spatial distribution of sources, incorporation of manure into soil, BMPs to reduce or eliminate concentrated sources, and time and travel distance to impaired waters.

4. TMDL development

4.1 Loading allocation methodology/Natural background

This section presents the approach to estimate components on the TMDL study. Pollutants were identified and estimated through the source assessment and HSPF modeling investigation. The loading capacity (LC) is estimated based on HSPF modeling results at the downstream end of an impaired reach. A TMDL for a waterbody with excessive loading of a particular constituent is described by

Equation 0-1: TMDL equation

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

Where:

LC = loading capacity: the greatest pollutant load a waterbody can receive without violating water quality standards;

WLA = wasteload allocation: the pollutant load that is allocated to permitted point sources. These sources include all current or future NPDES/SDS permitted pollutant dischargers (e.g., including WWTPs, regulated construction stormwater, and regulated industrial).

LA = load allocation: the pollutant load that is allocated to sources not from permitted point sources (e.g., non-regulated stormwater runoff, atmospheric deposition, and internal loading).

MOS = margin of safety: the portion of the LC allocated to account for uncertainty associated with attaining the water quality standard.

RC = reserve capacity: the portion of the LC attributed to growth of existing or future load sources.

4.1.1 Natural background consideration

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

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

(Reference found on the MPCA website: Little Rock Creek TMDL Court of Appeals Decision; Filed November 28, 2016.)

4.2 Total Suspended Solids

4.2.1 Loading capacity

The TMDL loading calculations use HSPF-modeled results to determine needed reductions in impaired reaches. Section 0 Hydrological Simulation Program - FORTRAN (HSPF) Modeling briefly discusses background information related to the model development, calibration, and validation, and provides sources of additional information.

Sediment capacity and current sediment load were computed using a LDC approach. The TSS criteria for this reach are only applicable between April 1 and September 30. For this reason, only simulated data within the specified period were used for the LDC analysis. The most recent 10 years of modeled results were used as the evaluation period (2005 to 2014). A Flow Duration Curve (FDC) was created for this period, by ranking the modeled daily average flows and assigning a percent exceedance value to each flow. Each flow exceedance pair represents the frequency for which the flow rate is exceeded (the maximum flow is exceeded 0% of the time, while the minimum flow is exceeded 100% of the time).

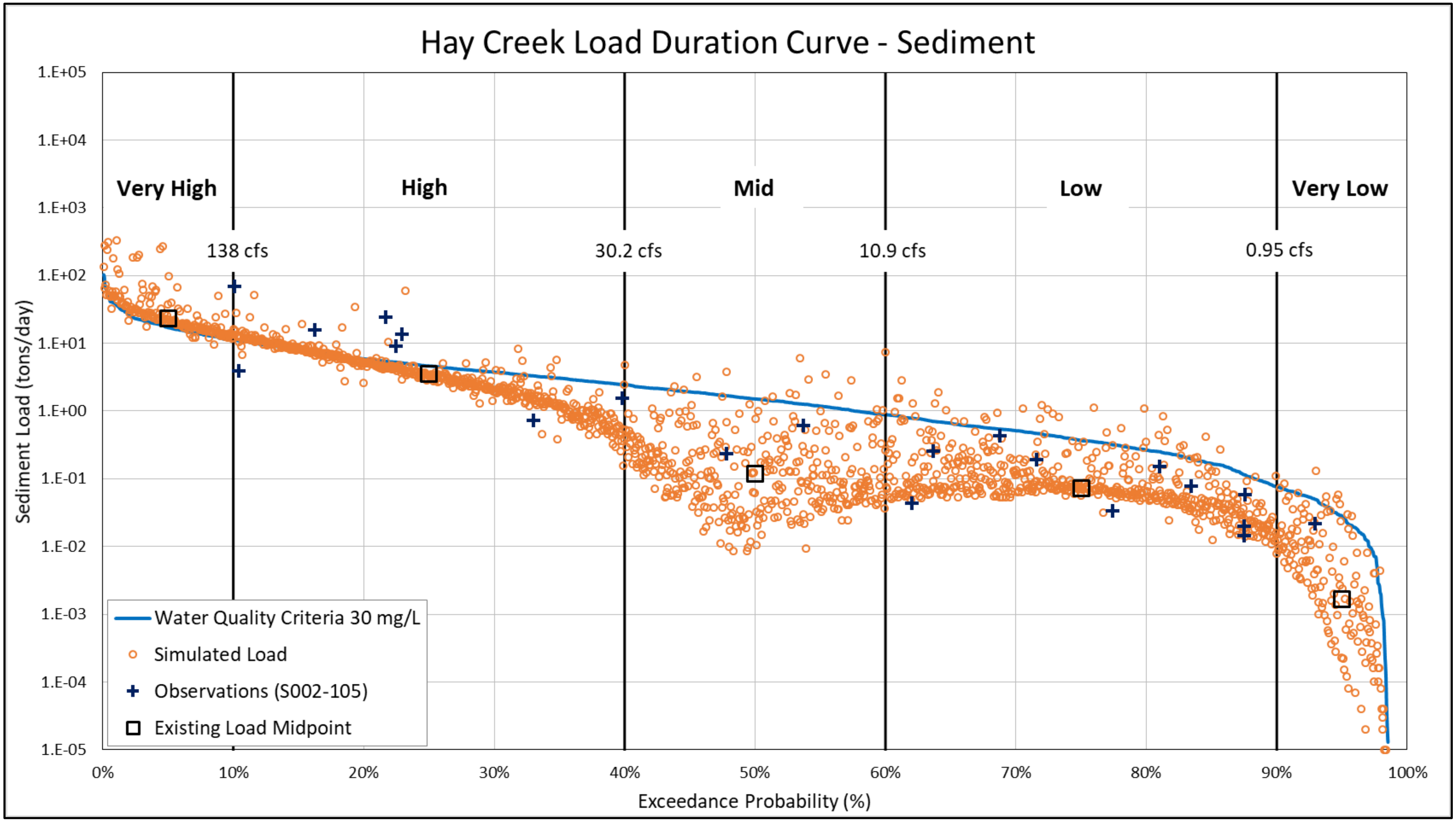
Figure 4-1 shows the LDC in blue, which was created by multiplying the FDC by the TSS criteria of 30 mg/L. The LDC shown in blue represents the LC of the system, since the line is based on the water quality criteria. Water quality under the LDC (blue line) is below the criteria, while anything above the LDC is exceeding the numeric criteria. The TSS water quality criteria allows for exceedance of the 30 mg/L threshold up to 10% of the time, as described in section 2.2. The LDC shown in blue represents the 30 mg/L standard, which does not take into account the 10% exceedance. This does not modify the approach to compute the TMDL, but creates an implicit MOS in the TMDL calculations.

Simulated daily average TSS loads for the analysis period were plotted with the associated daily flow exceedance for the analysis period. Orange points in Figure 4-1 represent a single daily load; daily loads exceeding the TSS nutrient criteria are located above the blue LDC line.

Figure 4-1 also shows observed TSS loading along Hay Creek (**+**). Observed loading was calculated using the measured TSS concentration and the HSPF average stream flow for the sampled day. The HSPF simulated loading (orange points) fit the limited observed data (**+**) well. The goodness of fit, or the extent to which the observed data matches the expected values, provides confidence in simulated results, and the corresponding LAs calculated based on the simulation results.

The LDC was divided into five different flow regimes to better describe loading for a range of events. The flow regimes were identified per EPA guidance as Very High (0% to 10%), High (10% to 40%), Mid (40% to 60%), Low (60% to 90%), and Very Low (10% to 0%). Existing loading was calculated as the median (50%) of the daily modeled loading results in each flow regime.

Figure 4-1: TSS Load Duration Curve for Hay Creek (AUIC 09020314-505)



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 summary table of this study (Table 4-3), 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 it is what the EPA ultimately approves.

4.2.2 Load allocation methodology

The LA represents the portion of the LC that is designated for non-point sources of TSS. The LA is the remainder of the LC once the WLA, MOS, and RC have been allocated. Section 3.6.2 discusses the non-point sources of sediment along Hay Creek in more detail.

4.2.3 Wasteload allocation methodology

The WLA represents the portion of the LC that is regulated by NPDES/SDS permits. These typically include construction stormwater, industrial stormwater, Municipal Separate Storm Sewer System (MS4) permitted areas, NPDES/SDS permitted feedlots, and WWTPs. The only regulated sources of TSS in the Hay Creek Subwatershed are construction and industrial stormwater dischargers, and a WWTP. There are no NPDES/SDS permitted feedlots or MS4s in the drainage area.

4.2.3.1 Construction Stormwater

Construction stormwater is regulated by NPDES/SDS permits for any construction activity which disturbs more than one acre of soil, or poses a risk to water resources. The MPCA provides guidance for setting WLAs for construction stormwater to 0.05% to 0.15% of the overall TMDL, minus the MOS (MPCA 2011). WLAs for construction stormwater activities were assigned a categorical allocation of 0.1% of the TMDL minus the MOS. A review of the construction stormwater permits in Hay Creek Subwatershed during the analysis period (2005 to 2014) showed the value of 0.1% to be a reasonable approximation of the average annual fraction of the watershed to be under construction activities.

4.2.3.2 Industrial Stormwater

Industrial stormwater is regulated by NPDES/SDS permits if the industrial activity has the potential for significant materials and activities to be exposed to stormwater discharges. The WLAs for industrial stormwater activities were assigned a categorical allocation equal to the construction stormwater WLAs, as industrial activities make up a small fraction of the watershed area.

4.2.3.3 Municipal Wastewater Treatment Systems

The proposed TSS water quality standard, applicable April through September, is intended to protect aquatic life and aquatic habitats from the negative effects of excess inorganic nonvolatile suspended solids (NVSS). The TSS loads in most Minnesota rivers and streams are largely composed of inorganic NVSS (Rott 2011). The TSS from municipal WWTPs consist primarily of volatile suspended sediments (VSS) sources, falling outside of the water quality criteria. The VSS relate primarily to nutrient and eutrophication, currently being addressed through river eutrophication criteria.

The Roseau WWTP (MNG580039) is the only municipal WWTP discharging to the Hay Creek Subwatershed. Discharge from this WWTP is limited to one secondary treatment cell. The NPDES/SDS permit allows for two discharge windows: between March 1 and June 30 and between September 1 and

December 31, with no discharge to ice covered waters. A WWTP is allowed to discharge up to 6 inches of volume from the secondary treatment pond in a 24-hour period. The WLAs were computed for TSS based on the permitted discharge volume, and an NPDES/SDS average monthly discharge limit of 45 mg/L (converted to tons/day) (Table 4-1). The TSS WLA for the Roseau WWTP is consistent with their current permitted limit; therefore, this TMDL study will not result in a change to the WWTP's TSS limit.

Table 4-1: WWTP design flows and permitted TSS loads

Facility	Permit Number	HUC-10 Subwatershed Name	System Type	Secondary Pond Size (acres)	Discharge Volume (MGD)	TSS Limit - Daily (mg/L)	TSS WLA - Daily (ton/day)
Roseau WWTP	MNG580039	Hay Creek	Pond	31.0	5.05	45	0.95

4.2.4 Margin of safety

The MOS accounts for uncertainty in estimating and attaining water quality standards and observations. An explicit MOS of 10% of the LC was applied to each flow regime for the LDC developed for this TMDL study. The LDC approach applied in this TMDL study did not directly take into account an allowable exceedance of the 30 mg/L threshold up to 10% of the time, creating an additional implicit MOS in these TMDL study calculations. Uncertainty in this TMDL study is primarily associated with HSPF simulated flow and TSS results, which are the basis for the LDC and TMDL development. Variability in the allocations and loading capacities, which vary from high- to low-flows, is accounted for using the five flow regimes and the LDCs.

Calibration results indicate that the HSPF model is a valid representation of hydrologic and water quality conditions in the watershed (RESPEC 2016a). Additionally, the MPCA and USGS estimate that the recorded/reported data should be within 10% of the actual value for any given measurement. Since the HSPF model is calibrated to measured field data, the MPCA determined that a 10% MOS is suitable because the explicit MOS accounts for uncertainty of the measured data and the calibrated HSPF-modeled flow and water quality results.

4.2.5 Seasonal variation

The TSS water quality criteria applies from April through September, during periods of open water and increased biological activity. Generally, high TSS concentrations and loading occur during these periods. The TSS loading varies with season and flow regime. The TSS from the primary sources is driven in the spring by snowmelt and rain on bare soils, in the summer by low flows interspersed with large convective rainstorms, and fall with a changing cultivated landscape and rapid cooling. Investigation of the Hay Creek LDC (Figure 4-1) shows the very high-flow regime to be susceptible to high TSS concentrations, requiring a load reduction of 27% (Table 4-2).

Table 4-2: Maximum required TSS loading reductions for Hay Creek

Impaired Water (AUID 09020314-XXX)	Total Suspended Solids	
	Maximum Load Reduction (%)	Critical Flow Regime
Hay Creek (505)	27%	Very High

4.2.6 TMDL summary

Table 4-3 shows the computed LC and allocations for Hay Creek for TSS. LAs were calculated for each flow regime, which divide the LC described by the central region nutrient criteria into a WLA, MOS, and LA following Equation 0-1. The TSS load capacity and current load were computed with a LDC approach, which uses 10 years of HSPF-simulated flow and sediment loading as described in Sections 4.2.1 and 4.2.2. Required load reduction was calculated as the LC minus the current load, if the current load is less than the LC a needed reduction is not needed. Along Hay Creek, a load reduction is only required in the very high-flow regime of 6.13 tons/day (27%), as seen in Table 4-3.

The LDC method uses the full range of simulated flows at the end of the impaired reach of Hay Creek over a 10-year period. However, Table 4-3 only shows five points, the midpoint of each designated flow regime. Ultimately, the entire curve shown in Figure 4-1 represents the TMDL, and the entire curve is what EPA approves.

Table 4-3: Hay Creek (09030314-505) TSS TMDL summary

- **303(d) listing year: 2018**
- **Baseline year(s): 2005-2014**

Hay Creek - Total Suspended Solids		**Flow Condition***				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		Tons per day				
Loading Capacity		**17.0**	**4.62**	**1.51**	**0.37**	**0.028**
Wasteload Allocations	**Total WLA**	**0.99**	**0.96**	**0.95**	**	**
	Roseau WWTP (MNG580039)	0.95	0.95	0.95	**	**
	Construction Stormwater (MNR100001)	0.02	0.005	0.002	**	**
	Industrial Stormwater (MNR500000)	0.02	0.005	0.002	**	**
Load Allocations	**Total LA**	**14.29**	**3.20**	**0.41**	**	**
Margin of Safety - MOS (10%)		1.70	0.46	0.15	**	**
Existing Load		**23.10**	**3.48**	**0.12**	**0.07**	**0.002**
Estimated Load Reduction		**6.10**				
Percent Reduction		**27%**				

*HSPF simulated flow and TSS loading were used to develop the flow zones and loading capacities for this reach.

**The WLA for the permitted wastewater discharger is based on a facility design flow. The WLA exceeded the very low-flow and low-flow zone total daily LC (minus the MOS). For these flow zones, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (TSS concentration limit or standard).

4.3 *Escherichia coli*

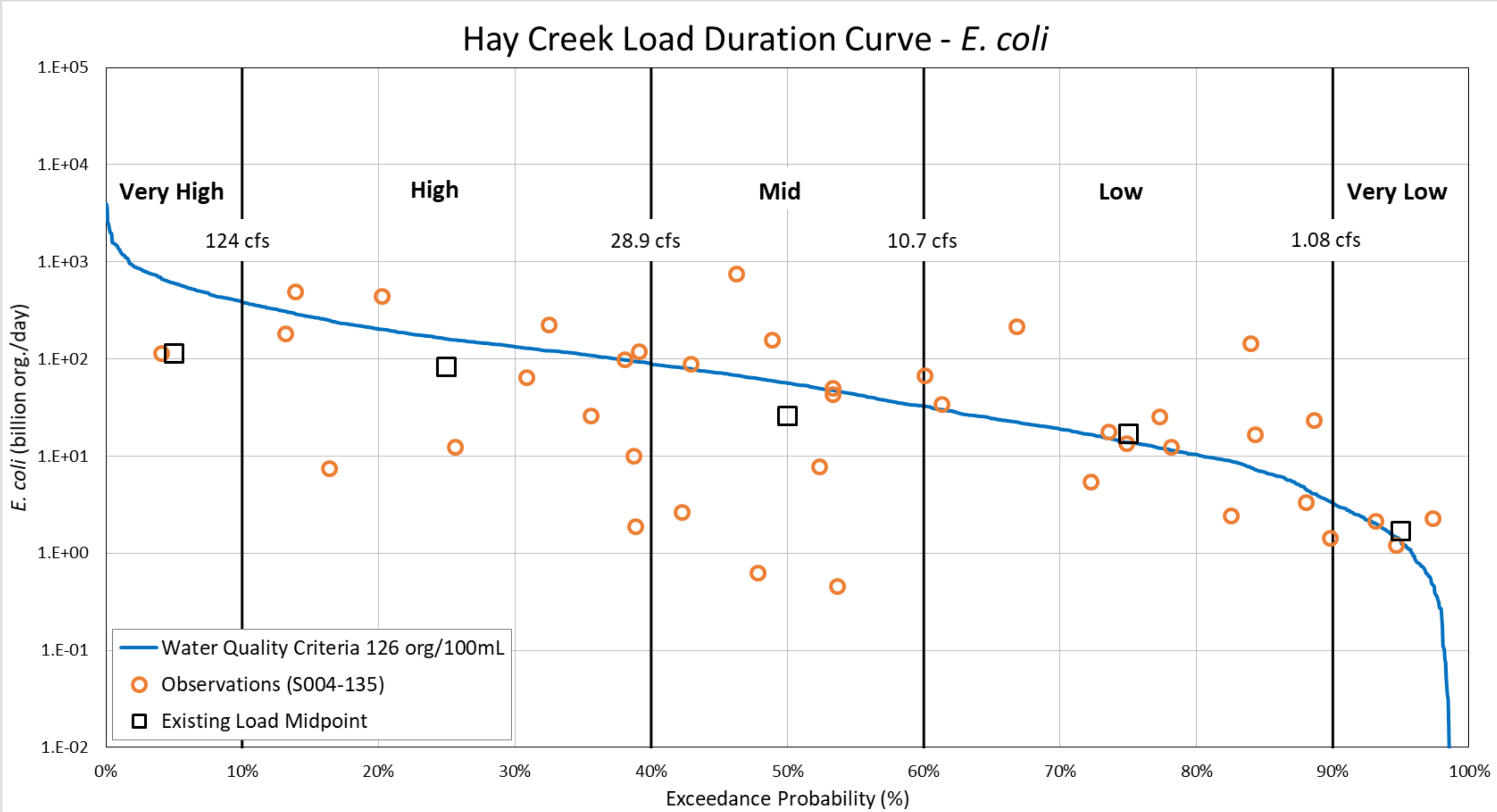
4.3.1 Loading capacity methodology

The *E. coli* load reductions were computed using the LDC approach discussed in Section 4.2. The *E. coli* criteria for this reach are only applicable between April 1 and October 31. For this reason only simulated flow results within the specified period were used for the creation of the LDC. The most recent 10 years of model results were used as the evaluation period (2005 to 2014). Figure 4-2 shows the LDC in blue, which was created by multiplying the FDC by the *E. coli* criteria of 126 org/100 mL. The LDC shown in blue represents the LC of the system, since the line is based on the water quality criteria. Water quality under the line is below the criteria, while the anything above the line is exceeding the numeric criteria.

Figure 4-2 shows observed *E .coli* loading along Hay Creek. Observed loading was calculated using the measured *E. coli* concentration and the HSPF average stream flow for the sampled day. Due to a limited number of sampling points (40) during the evaluation period, each point is assumed to represent the geometric mean concentration between samples. The previous assumption makes the water quality criteria of 126 org/100 mL applicable to the bacteria loading shown in Figure 4-2.

The LDC was divided into five different flow regimes to better describe loading for a range of events. The flow regimes were identified per EPA guidance as Very High (0% to 10%), High (10% to 40%), Mid (40% to 60%), Low (60% to 90%), and Very Low (10% to 0%). Existing loading was calculated as the median (50%) of the daily modeled loading results in each flow regime.

Figure 4-2: *E. coli* Load Duration Curve for Hay Creek (AUID 09020314-505)



4.3.2 Load allocation methodology

The LA represents the portion of the LC that is designated for non-point sources of *E. coli*. The LA is the remainder of the LC once the WLA, MOS, and RC have been allocated. Section 3.6.2 discusses the sources of bacteria along Hay Creek in more detail.

4.3.3 Wasteload allocation methodology

The WLA represents the portion of the LC that is regulated by NPDES/SDS permits, these typically include construction stormwater, industrial stormwater, MS4 permitted areas, NPDES/SDS permitted feedlots, and WWTPs. Construction stormwater is not regulated for bacteria, but is regulated for sediment. Stormwater controls for sediment also reduce bacteria loading, and are assumed to limit bacteria input from construction stormwater to the streams. Industrial stormwater is not regulated for bacteria and industrial stormwater is generally not considered to contribute to bacteria impairments and should not receive a WLA, except in special circumstances (MPCA 2009). Special circumstances include industrial dischargers operating under individual permits that monitor bacteria indicators. Such circumstances are not applicable to industrial dischargers in the RRW. As such, the only regulated sources of *E. coli* in the Hay Creek Subwatershed is the Roseau WWTP. There are no NPDES/SDS permitted Concentrated Animal Feeding Operation (CAFOs) or MS4s in the drainage area.

4.3.3.1 Municipal Wastewater Treatment Systems

The Roseau WWTP (MNG580039) is the only municipal WWTP discharging to the Hay Creek Subwatershed. Discharge from this WWTP is limited to one secondary treatment cell. The NPDES/SDS permit allows for two discharge windows: between March 1 and June 30 and between September 1 and December 31, with no discharge to ice covered waters. A WWTP is allowed to discharge up to 6 inches of volume from the secondary treatment pond in a 24-hour period. The WLAs were computed for *E. coli* based on the permitted discharge volume, and an NPDES/SDS discharge limit of 200 org/100 mL fecal coliform. Fecal coliform loading was converted to *E. coli* by using the ratio of 126 org/100 mL *E. coli* to 200 org/100 mL fecal coliform. Table 4-4 shows the WLA calculated for the Roseau WWTP discharging into Hay Creek. The *E. coli* WLA for the Roseau WWTP is consistent with their current permitted limit; therefore, this TMDL study will not result in a change to the WWTP's *E. coli* limit.

Table 4-4: *E. coli* WLA for Hay Creek WWTPs

Facility	Permit Number	HUC-10 Subwatershed Name	System Type	Secondary Pond Size (acres)	Discharge Volume (MGD)	Bacteria Load as *E. coli* (billion organisms/day)
Roseau WWTP	MNG580039	Hay Creek	Pond	31.0	5.05	24.1

4.3.4 Margin of safety

The MOS accounts for uncertainty in estimating and attaining water quality standards and observations. An explicit MOS of 10% of the LC was applied to each flow regime for the LDC developed for this TMDL study. Uncertainty in this TMDL is primarily associated with HSPF-simulated flow and limited measured *E. coli* data, which are the basis for the LDC and TMDL development. Variability in the allocations and loading capacities, which vary from high- to low-flows, is accounted for using the five flow regimes and the LDCs.

Calibration results indicate that the HSPF model is a valid representation of hydrologic conditions in the watershed (RESPEC 2016a). Furthermore the MPCA and USGS estimate that the recorded/reported data should be within 10% of the actual value, for any given measurement. Since the HSPF model is calibrated to observed data, the MPCA determined that a 10% MOS is suitable because the explicit MOS accounts for uncertainty of the measured *E. coli* data and the calibrated HSPF-simulated flow.

4.3.5 Seasonal variation

The *E. coli* water quality criteria applies from April through October, during periods of open water and increased biological activity. The *E. coli* loading varies with season and flow regime. The *E. coli* transport is driven in the spring by snowmelt and rain on bare soils, in the summer by low flows interspersed with large convective rainstorms, and fall with a changing cultivated landscape and rapid cooling. Summer months typically have the highest *E. coli* concentrations. Investigation of the Hay Creek LDC (Figure 4-2) shows, during the low- and very low-flow regimes to be susceptible to high *E. coli* loading, requiring loading reductions described in Table 4-4.

Table 4-5: Maximum required *E. coli* loading reductions for Hay Creek

Impaired Water (AUID 09020314-XXX)	*E. coli*	
	Maximum Load Reduction (%)	Critical Flow Regime
Hay Creek (505)	18%	Low
Hay Creek (505)	21%	Very Low

4.3.6 TMDL summary

Table 4-6 shows the computed LC and allocations for Hay Creek, the only stream in the RRW impaired for *E. coli*. LAs were calculated for each flow regime, which divide the LC into WLA, MOS, and LA following Equation 0-1. The *E. coli* load capacity and current load were computed with a LDC approach, which uses 10 years of HSPF-simulated flow and sediment loading as described in Sections 4.3.1 and 4.3.2. Required load reductions were calculated as the LC minus the current load. If the current load is less than the LC, a load reduction is not needed.

Table 4-6 shows a needed load reduction in the low- and very low-flow regimes of 3.06 billion org/day (18%) and 0.35 billion org/day (21%), respectively. Reductions in *E. coli* loading could be needed in the high- and very high-flow regimes. Due to limitations in the quantity of bacteria measurements, this TMDL assessment was unable to find conclusive evidence of needed reductions in runoff driven flow regimes (high and very high). Mobilization of sediment, nutrients, and bacteria typically occur in response to runoff events causing increased loads to the stream. These events were not captured as part of the monitoring data.

The LDC method uses the full range of simulated flows at the end of the impaired reach of Hay Creek over a 10-year period. However, Table 4-6 only shows five points, the midpoint of each designated flow regime. Ultimately, the entire curve shown in Figure 4-2 represents the TMDL, and the entire curve is what EPA approves.

Table 4-6: Hay Creek (09020314-505) *E. coli* TMDL summary

- **303(d) listing year: 2018**
- **Baseline year(s): 2005-2014**

Hay Creek - *E. coli*		Flow Condition				
		Very High	High	Mid	Low	Very Low
		Billion Organisms per day				
Loading Capacity		**602**	**161**	**56.5**	**13.8**	**1.3**
Wasteload Allocations	**Total WLA**	**24.1**	**24.1**	**24.1**	**	**
	Roseau WWTP (MNG580039)	24.1	24.1	24.1	**	**
Load Allocations	**Total LA**	**518**	**120**	**26.8**	**	**
Margin of Safety - MOS (10%)		60.2	16.1	5.6	**	**
Existing Load		**114**	**81.9**	**25.6**	**16.8**	**1.68**
Estimated Load Reduction					**3.06**	**0.35**
Percent Reduction					**18%**	**21%**

*HSPF-simulated flow was used to develop the flow zones and loading capacities for this reach.
**The WLA for the permitted wastewater discharger is based on a facility design flow. The WLA exceeded the very low-flow and low-flow zones total daily LC (minus the MOS). For these flow zones, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (*E. coli* concentration limit or standard).

5. Future growth considerations

Agriculture, farming and livestock operations, and industrial manufacturing drive the economy in the RRW. The primary land uses within the watershed are agricultural and wetland/forested areas. The uses of the land in RRW are not expected to change significantly in the future, as they have not changed significantly in the past.

Based on data from the United States Census Bureau, estimates from 1990 and 2010 show that in two counties (Roseau -4%, Beltrami -23%) populations are decreasing and in three counties (Kittson +27%, Lake of the Woods +1%, Marshall +16%) populations are increasing.

The impact of changes to the landscape of population on pollutants, as well as the implication on TMDL study allocations are discussed below.

5.1 New or expanding permitted MS4 WLA transfer process

At the time of completion of this TMDL study, there were no MS4 permitted areas located in the RRW. The following information is included as guidance in the event that parts of the RRW become MS4 permitted areas.

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

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an urban area at the time the TMDL study 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 an NPDES/SDS permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL study. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

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 2012). This procedure will be used to update WLAs in approved TMDL studies for new or expanding wastewater dischargers whose permitted effluent limits are at or below the in-stream 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 study's WLA(s) will be made.

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

6. Reasonable assurance

Reasonable assurance of the load reductions and strategies developed under this TMDL assessment comes from multiple sources. Point sources contributing water with pollutants can be assured through issuing NPDES/SDS permits and adequately regulating dischargers. The LA and reductions originating from various nonpoint sources described in Section 4 can be assured through historical and ongoing collaborations and investments in the RRW. Strong partnerships between Roseau River Watershed District (RRWD), counties, and soil and water conservation districts (SWCDs) have led to implementation of numerous conservation practices in the past. These collaborations have goals pertaining to pollutant reduction and flood mitigation, with plans of additional implementation in the future.

The RRW WRAPS (HDR 2020 Draft), details a number of tools that identify sources of pollutant loading in the RRW and potential strategies to address them. Although the WRAPS goes beyond addressing just the impairments within the RRW, it does show that bacteria and sediment impairments in Hay Creek can be resolved through a number of practices. Improved upland and field surface runoff controls, protecting and stabilizing channel banks, and restoring stream channels were found to be cost-effective practices to reduce TSS loading to surface waters. Restricting livestock access to streams was identified as a cost-effective practice well suited to address bacteria impairments. The practices described are only a few of the many viable options which would address sediment and bacteria loading in Hay Creek. These options, along with the continued collaborations and ability to gain grant funding provides reasonable assurance the impairments can be addressed.

In summary, significant time and resources have been devoted to identifying the best BMPs, providing means of focusing them in the RRW, and supporting their implementation via state initiatives and dedicated funding. The RRW WRAPS and TMDLs process engaged partners to arrive at reasonable examples of BMP combinations that attain pollutant reduction goals. Minnesota is a leader in watershed planning as well as monitoring and tracking progress toward water quality goals and pollutant load reductions. Finally, examples cited herein confirm that BMPs and restoration projects have proven to be effective over time and as stated by the State of Minnesota Court of Appeals in A15-1622 MCEA vs MPCA and MCES:

> "*We conclude that substantial evidence exists to conclude that voluntary reductions from nonpoint sources have occurred in the past and can be reasonably expected to occur in the future. The Nutrient Reduction Strategy (NRS) provides substantial evidence of existing state programs designed to achieve reductions in nonpoint source pollution as evidence that reductions in nonpoint pollution have been achieved and can reasonably be expected to continue to occur.*"

6.1 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 available for nonpoint pollutant reduction work. Examples of other funding sources include, but are not limited to, Clean Water Act Section 319 grants, Board of Water and Soil Resources (BWSR) state Clean Water Fund implementation funding, state Clean Water Partnership loans, and National Resources Conservation Service (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.

7. Monitoring plan

Stream monitoring in the RRW will continue with efforts from numerous entities, including: MPCA, RRWD, county SWCDs, and citizen monitoring.

As an overview, the Roseau County SWCD has monitored creek sites within the county since 2001. The SWCD collects turbidity, DO, conductivity, temperature, pH, nitrate, phosphorus, fecal coliform, and *E. coli* data in an effort to provide a baseline study of Roseau County. In addition to baseline analysis by the SWCD, project-related monitoring data are routinely posted to the EPA STORET site for broader application. River Watch, a program where public high school students work with the Red River Watershed Management Board and local watershed districts, has been active in collecting data since the early 2000s. The MPCA also supports a Watershed Pollutant Load Monitoring Network (WPLMN) where data is collected at the outlet of the RRW 25 to 35 times a year.

The MPCA completes a systematic assessment of the water quality in each HUC-8 size watershed in Minnesota on a 10-year cycle. During 2015 and 2016, the MPCA conducted intensive water quality monitoring and reporting in the RRW, preceding the SID, TMDL study, and WRAPS report development. The MPCA is scheduled to begin its Cycle II intensive water quality monitoring effort in the RRW in 2025.

The MPCA also coordinates two programs aimed at encouraging long-term citizen surface water monitoring: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Involvement within the RRW has been limited within these Citizen-led programs, but these collaborative relationships can help track water quality changes in years where intensive monitoring by the MPCA is not occurring.

8. Implementation strategy summary

8.1 Permitted sources

8.1.1 Construction stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre expected to be active in the watershed 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 Minnesota'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 the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL study. Construction activity must also meet all local government construction stormwater requirements.

8.1.2 Industrial stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES/SDS Industrial Stormwater Permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in Minnesota's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000), or NPDES/SDS General Permit for Construction Sand and 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 industrial stormwater discharges would be expected to be consistent with the WLA in this TMDL study. Industrial activity must also meet all local government construction stormwater requirements.

8.1.3 Municipal Separate Storm Sewer Systems

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

8.1.4 Wastewater

Requirements set forth by the NPDES/SDS permit for the existing WWTP in the RRW are currently consistent with the WLAs assigned in this TMDL and are sufficient for achieving the pollutant load targets needed for the impaired stream in the RRW. Any new WWTPs in the RRW applying for, obtaining, and abiding by NPDES/SDS wastewater permitting requirements are expect to be consistent with this TMDL study.

8.2 Non-permitted sources

A variety of BMPs to restore and protect the lakes and streams with the RRW have been outlined and prioritized in the WRAPS report. Refer to the WRAPS report (HDR 2019) for information regarding implementation of BMPs.

8.3 Cost

The Clean Water Legacy Act (Minn. Stat. 2007, §114D.25) requires that a TMDL assessment provide a range of implementation costs to address the TMDL study.

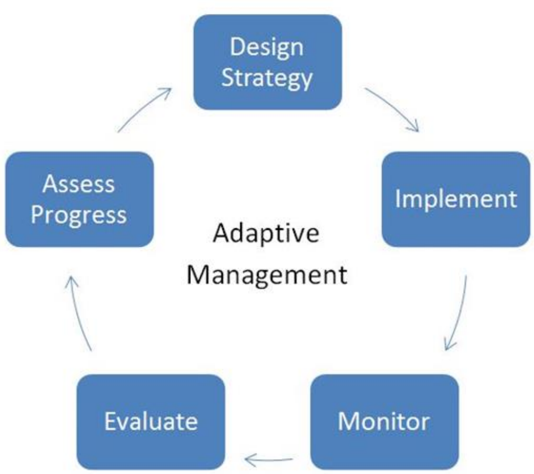
8.3.1 TSS

Estimated public funding costs to incentivize BMP adoption were estimated using the SAM tool and detailed in the RRW WRAPS report (HDR 2019). Based on the BMP implementation outlined that report, the estimated cost to address the TSS impairment in Hay Creek is approximately $300,000 per year. An interagency work group (BWSR, USDA, MPCA, MASWCD, MAWD, and NRCS) estimated restoration costs for TSS impaired streams to be $117,000 per square mile. The Hay Creek Subwatershed is roughly 116 square miles and would require $13.6 million over 10 years (or $1.4 million per year) using this approach to estimate costs. The BMPs could include regional water retention, riparian vegetative buffers, sediment control basins, pasture management, conservation tillage, vegetative practices, wetland restorations, etc.

8.3.2 *E. coli*

The cost estimate for bacteria load reduction is based on unit costs for livestock manure management and runoff, which was identified as the major source of bacteria in the watershed. The unit costs to supply adequate manure management and feedlot runoff controls is roughly $350 per animal unit (AU). These values are based on USDA EQUIP payments for implementation, including water diversion structures, buffers, manure management plans, waste storage structures, and livestock access control. Providing this level of BMP implementation for the 1,379 AUs in Hay Creek would cost an estimated $500,000.

Figure 8-1: Adaptive management



8.4 Adaptive management

This list of implementation elements and the more detailed WRAPS report, which was prepared concurrently with this TMDL report, are based on the principle of adaptive management (Figure 8-1). Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL report. Management activities will be changed or refined as appropriate over time to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water bodies.

9. Public participation

Public involvement during this process was led by the RRWD. The TMDL assessment involves numerous local partners involved at varying levels through the process. Technical committee meetings and more widely-open public comments were included at numerous stages through the project duration. The technical committee includes members of the RRWD, SWCDs, DNR, MPCA, and counties within the watershed. Table 9-1 summarizes the outreach meetings held as part of this TMDL assessment.

Table 9-1: Summary of RRW TMDL meetings

Date	Location	Meeting Focus
February 25, 2016	Roseau River Watershed District Office, Roseau, MN	TMDL study and WRAPS report process, timeline, and the importance of water quality.
March 13, 2018		Preliminary results of the Watershed Monitoring and Assessment and Stressor Identification reports.
September 19, 2019		Draft TMDL study and WRAPS report findings and next steps.

Public notice

An opportunity for public comment on the draft TMDL study was provided via a public notice in the State Register from September 21, 2020, through October 21, 2020. There were no comment letters received during the public comment period.

10. Literature cited

American Society of Agricultural Engineers (ASAE). “ASAE Standards”, 45th Edition. Standards, Engineering Practices, Data. 1998.

Adhikari, Hrishikesh, David L. Barnes, Silke Schiewer, and Daniel M. White. “Total Coliform Survival Characteristics in Frozen Soils.” Journal of Environmental Engineering, Vol. 133, No. 12, pp: 1098–1105, December 2007.

American Veterinary Medical Association (AVMA). “US Pet Ownership & Demographics Sourcebook.” Schaumburg, IL: American Veterinary Medical Association. 2007.

Chandrasekaran, Ramyavardhanee, Matthew J. Hamilton, Ping Wanga, Christopher Staley, Scott Matteson, Adam Birr, and Michael J. Sadowsky. “Geographic Isolation of *Escherichia coli* Genotypes in Sediments and Water of the Seven Mile Creek — A Constructed Riverine Watershed.” Science of the Total Environment 538:78–85, 2015.

Environmental Protection Agency (EPA). “Protocol for developing pathogen TMDLs”. EPA 841-R00-002. U.S. Environmental Protection Agency, Washington D.C. 2001.

Environmental Protections Agency (EPA). “Primary Distinguishing Characteristics of Level III Ecoregions of the Continental United States.” https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states. September 2013.

Horsley and Witten, Inc. “Identification and evaluation of nutrient and bacterial loadings to Maquoit Bay, New Brunswick and Freeport, Maine.” Final Report. 1996

Ishii, Satoshi, Tao Yan, Hung Vu, Dennis L. Hansen, Randall E. Hicks, and Michael J. Sadowsky. “Factors Controlling Long-Term Survival and Growth of Naturalized *Escherichia coli* Populations in Temperate Field Soils.” Microbes and Environments, Vol. 25, No. 1, pp. 8−14, 2010.

Long Island Regional Planning Board (LIRPB). “The Long Island Comprehensive Waste Treatment Management Plan: Volume II: Summary Documentation.” Nassau-Suffolk regional Planning Board. Hauppauge, NY. 1978.

Marino, Robert P, and John J. Gannon. “Survival of Fecal Coliforms and Fecal Streptococci in Storm Drain Sediments.” Water Research, Vol. 25 No. 9, pp. 1089–1098, 1991.

Metcalf and Eddy. “Wastewater Engineering: Treatment, Disposal, Reuse.” 3rd ed. McGraw-Hill, Inc., New York. 1991.

Minnesota Department of Natural Resources (MnDNR). “Status of Wildlife Populations, Fall 2014.” St. Paul, MN. December 2014.

Minnesota Pollution Control Agency (MPCA). “Bacteria TMDL Protocols and Submittal Requirements.” Revised March 2009.

Minnesota Pollution Control Agency (MPCA). “Guidance for Setting Wasteload Allocations for Regulated Stormwater.” September 2011.

Minnesota Pollution Control Agency (MPCA). “Recommendations and Planning for Statewide Inventories, Inspections of Subsurface Sewage Treatment Systems.” Report to the Minnesota Legislature. January 2011.

Minnesota Pollution Control Agency (MPCA). “3rd Generation Thunderstorm Map”. Presentation. 2011.

Beneficial Use Designations for Stream Reaches: Roseau River Watershed (09020314).” May 2017.

Minnesota Pollution Control Agency (MPCA). “Beneficial Use Designations for Stream Reaches: Roseau River Watershed (09020314).” May 2017.

Minnesota Pollution Control Agency (MPCA). “Roseau River Stressor Identification Report.” June 2018a.

Minnesota Pollution Control Agency (MPCA). “Roseau River Watershed Monitoring and Assessment Report.” July 2018b.

Minnesota Pollution Control Agency (MPCA). “Regionalization of Minnesota’s Rivers for Application of the River Nutrient Criteria.” January 2019a.

Minnesota Pollution Control Agency (MPCA). EQUIS: Environmental Quality Information System (EQuIS) Database: Accessed November 28, 2018.

RESPEC. “Hydrology and Water Quality Calibration of the Roseau River HSPF Watershed Model Application.” Technical Memorandum prepared for Michael Vavricka (MPCA), January 2016a.

RESPEC. “Roseau River Model Development.” Technical Memorandum prepared for Michael Vavricka (MPCA), February 2016b.

TBEP (Tampa Bay Estuary Program). “Get the scoop on (dog) poop!” 2011.

United States Census Bureau (USCB). 2010 Census Data Minnesota. Prepared by the US Census Bureau. 2011.

United States Department of Agriculture (USDA). 2012 Agricultural Census Data Minnesota Prepared by the US Department of Agriculture, 2013.

Wang, C., Schneider, R.L., Parlange, J-Y. “Explaining and modeling the concentration and loading of *Escherichia coli* in a stream-A case study.” Science of the Total Environment 635:1426–1435, 2018.

Zeckoski, R. W., Benham, B. L., Shah, S. B., Wolfe, M. L., Brannan, K. M., Al-Smadi, M., Dillaha, T. A., Mostaghimi, S., & Heatwole. C. D. “BSLC: A tool for bacteria source characterization for watershed management.” Appl. Eng. Agricul. Vol. 21(5):879-889. 2005.

Appendix A

Aquatic Life Impairment Listings Not Addressed in this TMDL Study

HUC-10 Subwatershed Name	Reach Name	AUID (09020314-XXX)	Designated Use	Basis for Aquatic Life Listing: MIBI Exceed Criteria?	Basis for Aquatic Life Listing: FIBI Exceed Criteria?	Basis for Aquatic Life Listing: Based on Turbidity Only?	New Data Confirm Use not Impaired	Non-pollutant Stressor(s)?	Insufficient Information to Link Stressor to a Pollutant	No Water Quality Standard for Identified Stressor(s)	Proposed Category[1]	Notes
Headwaters Roseau River	Severson Creek (County Ditch 23)	541	AQL	Yes				Habitat & flow alteration			**4C[2]**	
	Severson Creek (County Ditch 23)	516	AQL	Yes				Habitat & flow alteration			**4C[2]**	
Hay Creek	Hay Creek	505	AQL	Yes	Yes			Habitat & flow alteration			**4C[2]**	
Sprague Creek	Sprague Creek	508	AQL			Yes	Yes				**Proposed for delisting in 2020**	Impairment based on turbidity; TSS TMDL is not required, as described in Appendix C
Upper Roseau River	Pine Creek	542	AQL		Yes			Habitat & flow alteration and connectivity			**4C[2]**	

[1]The proposed impairment category indicates the proposed category upon approval of this TMDL report. Recategorizations will not be final until they are approved by USEPA as part of Minnesota's list of impaired water bodies. All waters in the watershed are currently classified as Category 5 in the 2018 impaired waters list. Category 5 indicates an impaired status and a TMDL plan has not been completed. Proposed categories are provided for those listings that have been further assessed and are proposed for recategorization as either 4A or 4C.

[2]Category 4C: A water is placed in Category 4C when the state demonstrates that the failure to meet an applicable water quality standard is not caused by a pollutant, but instead is caused by other types of pollution. Segments placed in Category 4C do not require the development of a TMDL.

Appendix B

Monitored Data outside the Assessment Period

Table B-1: Summary of TSS sampling in Hay Creek during the intensive watershed monitoring period (2015-2016). Data not included in the TMDL analysis.

AUID		09020314-505
Site ID		S002-105
Sampling Years		2015
April	# of Samples	0
	Geo-Mean (mg/L)	-
	Range (mg/L)	-
	# of Samples > 30 (mg/L)	-
May	# of Samples	2
	Geo-Mean (mg/L)	16.8
	Range (mg/L)	6 - 47
	# of Samples > 30 (mg/L)	1
June	# of Samples	2
	Geo-Mean (mg/L)	10.6
	Range (mg/L)	8 - 14
	# of Samples > 30 (mg/L)	0
July	# of Samples	2
	Geo-Mean (mg/L)	8.1
	Range (mg/L)	4 - 12
	# of Samples > 30 (mg/L)	0
August	# of Samples	2
	Geo-Mean (mg/L)	2.0
	Range (mg/L)	2 - 2
	# of Samples > 30 (mg/L)	0
September	# of Samples	2
	Geo-Mean (mg/L)	2.0
	Range (mg/L)	2 - 2
	# of Samples > 30 (mg/L)	0
Total April - Sept.	# of Samples	11
	Geo-Mean (mg/L)	5.8
	Range (mg/L)	2 - 47
	# of Samples > 30 (mg/L)	1

Figure B-1: TSS sampling aggregated by month on Hay Creek at the monitoring station S002-105. The dashed line denotes the stream water quality standard (30 mg/L). Data originates from intensive watershed monitoring period (2015-2016). Data not included in the TMDL analysis.

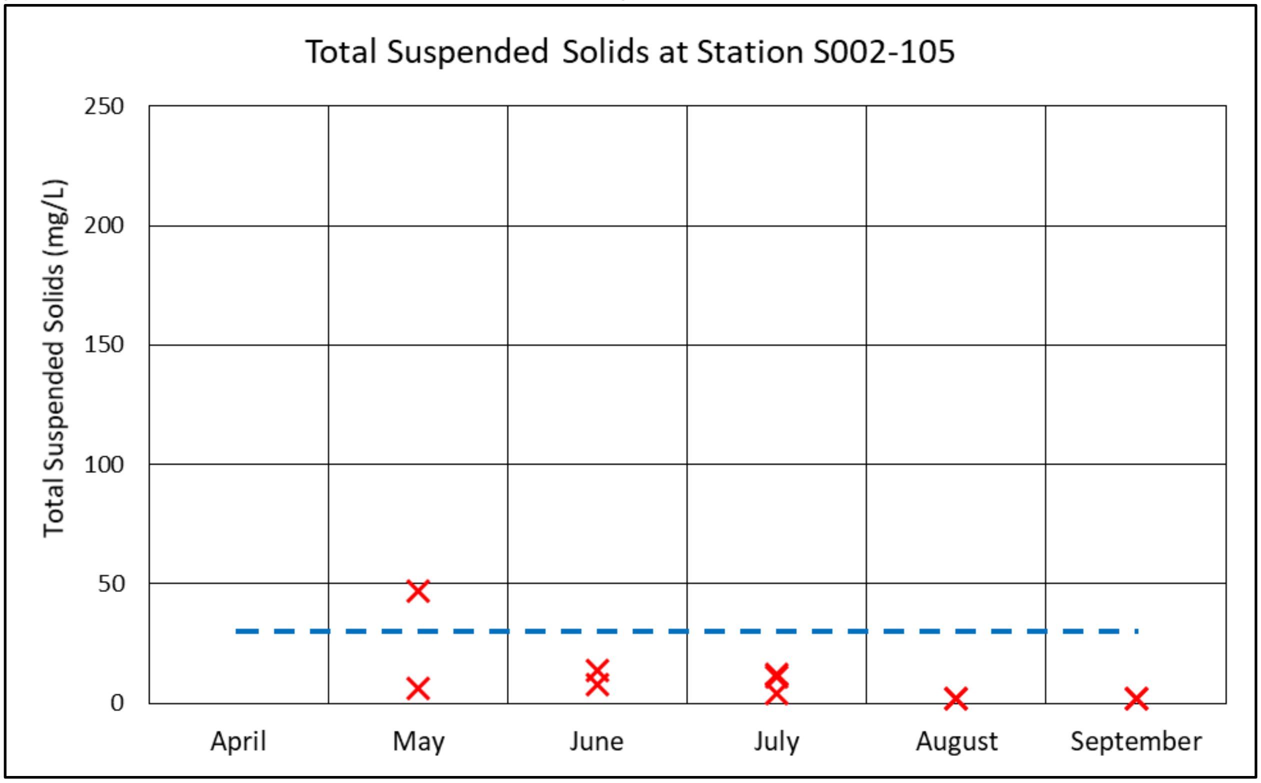
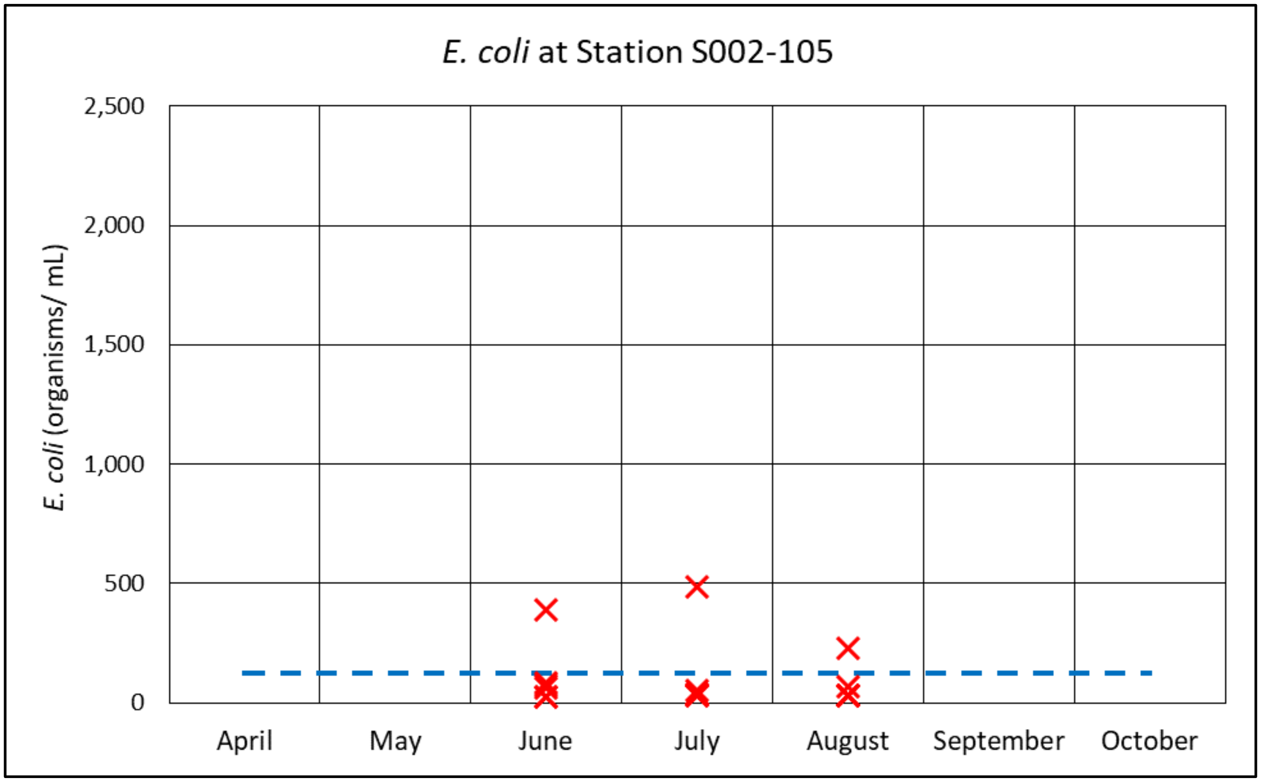


Table B-2: Summary of *E. coli* sampling in Hay Creek during the intensive watershed monitoring period (2015-2016). Data not included in the TMDL analysis.

AUID		09020314-505
Site ID		S002-105
Sampling Years		2015-2016
April	# of Samples	0
	Geo-Mean (org/100 mL)	-
	Range (org/100 mL)	-
	# of Samples > 1,260 (org/100 mL)	0
May	# of Samples	0
	Geo-Mean (org/100 mL)	-
	Range (org/100 mL)	-
	# of Samples > 1,260 (org/100 mL)	0
June	# of Samples	5
	Geo-Mean (org/100 mL)	80.5
	Range (org/100 mL)	23 - 387
	# of Samples > 1,260 (org/100 mL)	0
July	# of Samples	6
	Geo-Mean (org/100 mL)	54.7
	Range (org/100 mL)	28 - 488
	# of Samples > 1,260 (org/100 mL)	0
August	# of Samples	5
	Geo-Mean (org/100 mL)	54.6
	Range (org/100 mL)	29 - 228
	# of Samples > 1,260 (org/100 mL)	0
September	# of Samples	0
	Geo-Mean (org/100 mL)	-
	Range (org/100 mL)	-
	# of Samples > 1,260 (org/100 mL)	0
October	# of Samples	0
	Geo-Mean (org/100 mL)	-
	Range (org/100 mL)	-
	# of Samples > 1,260 (org/100 mL)	0
Total April - Oct.	# of Samples	16
	Geo-Mean (org/100 mL)	61.7
	Range (org/100 mL)	23 - 488
	# of Samples > 1,260 (org/100 mL)	0

Figure B-2: ***E. coli*** **sampling, during the period of 2015 to 2016, aggregated by month on Hay Creek at the monitoring station S002-105. The dashed line denotes the stream water quality standard (126 org/100mL).**



Appendix C

Sprague Creek TSS/Turbidity Impairment Listing

Sprague Creek (AUID 09020314-508) is located within the RRW northeast of the city of Roseau. Sprague Creek drains a total of 286 square miles, of which 70% lies within Canada. The Sprague Creek Subwatershed predominantly consists of forest and wetlands, with small areas of agriculture. The United States portion falls mostly within the Lost River State Forest. Sprague Creek flows eight miles south from the Canadian border to combine with the Roseau River. Figure C-1 shows the location, land use, and general orientation of the Sprague Creek Subwatershed.

The 2008 federal Impaired Waters 303(d) list identified Sprague Creek as impaired for aquatic life use due to elevated turbidity levels, requiring a TMDL study. In 2015, the state of Minnesota changed the standard for sediment from turbidity to TSS. Sprague Creek is located within the Central Nutrient Region (as adapted for application of the TSS standard), and has a TSS standard of 30 milligrams per liter (mg/L). In 2018, the MPCA re-assessed the Sprague Creek turbidity-related impairment against the new TSS standard of 30 mg/L.

Figure C-1 shows that two biological sampling sites, two water chemistry sampling sites, and a USGS stream gage are located along Sprague Creek. Monitoring data were downloaded from the MPCA's EQuIS. Table C-1 summarizes the available observed information as it relates to sediment. Reoccurring TSS observations were available at one of the chemical monitoring locations (S00-097), and single samples were available at each of the biological monitoring locations, totaling 18 data points. The TSS data were available at observation location S00-097 in only two years: 2002 and 2015. Turbidity data was available during this time period; however, there was not enough paired TSS and turbidity data along this Sprague Creek to establish a relationship to convert turbidity results to TSS.

A HSPF hydrologic and water quality model was developed and calibrated to observed data for the RRW (RESPEC 2016). The model simulates flow, TSS, and other water quality constituents for the period of 1995 to 2014. Simulated water quantity and quality results were available through the SAM at daily increments for each of the 104 reaches within the model. The TMDL load calculations were developed using modeled results to determine the potential reductions needed in impaired reaches, as described in the following sections.

Figure C-1: Sprague Creek land use and monitoring locations

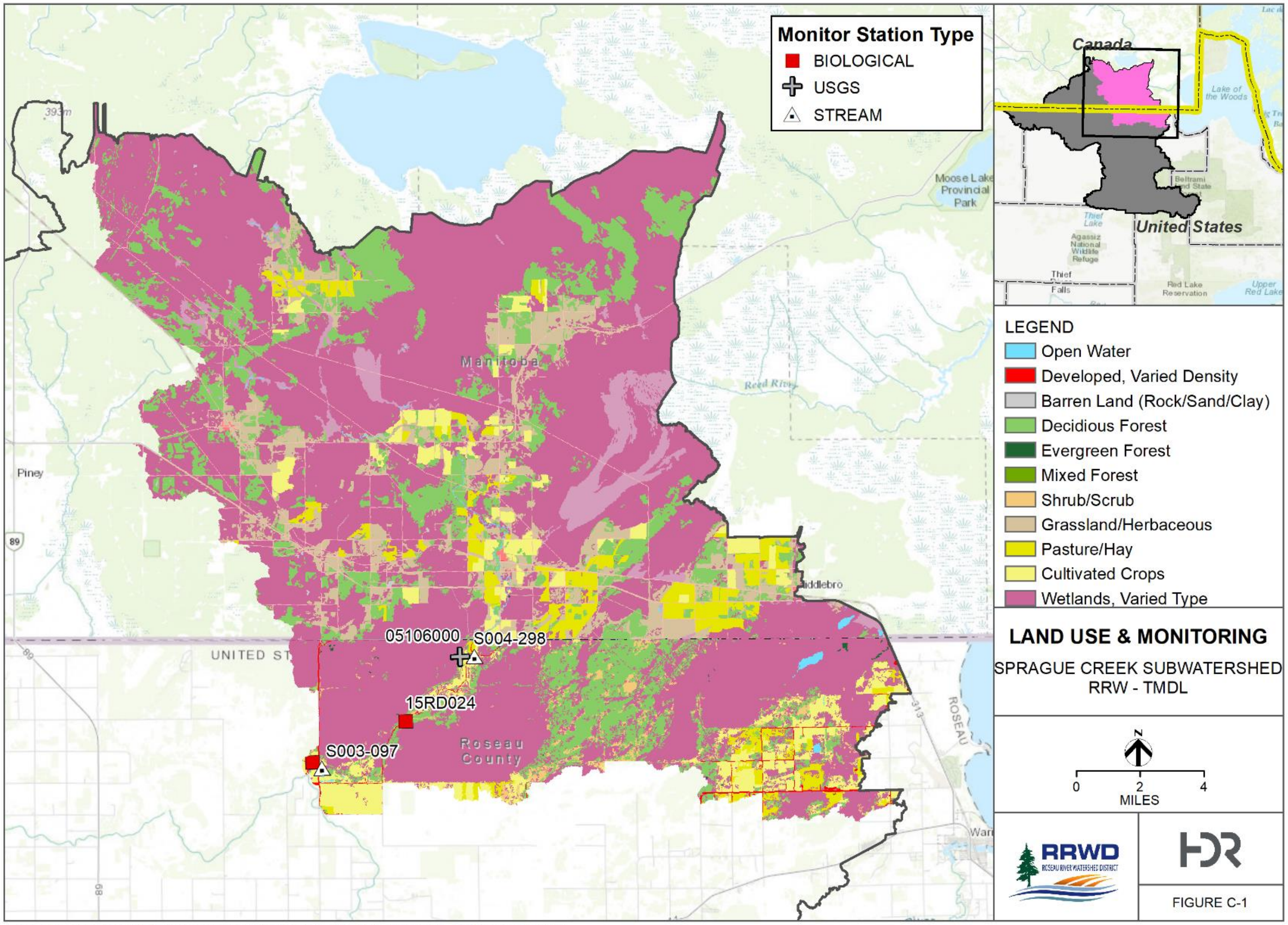


Table C-1: Sprague Creek available TSS data

Station ID	Type	Sampling Period	TSS Sampled	Number of TSS Samples
S003-097	Chemical	2001 to 2017	Yes	16
S004-098	Chemical	2003 to 2012	No	0
15RD004	Biological	2015	Yes	1
15RD024	Biological	2015	Yes	1
05106000	USGS Stream Gage	1928 to 2019	No	0

Load Calculations

Sprague Creek falls within the Central Nutrient Region (as adapted for application of the TSS standard). Per Minn. R. ch. 7050, TSS standards for the Class 2B waters within the Central Nutrient Region are limited to TSS concentrations of up to 30 mg/L. This criteria is applicable April 1 through September 30 and if exceeded for more than 10% of the time, the waterbody is listed as impaired for aquatic life.

Sediment capacity and the current sediment load were computed using a LDC approach with HSPF simulated results. The TSS criteria for this reach are only applicable between April 1 and September 30, for this reason, only simulated results within the specified period were used for the LDC analysis. The most recent 10 years of modeled data were used as the evaluation period (2005 to 2014). A FDC was created for this period, by ranking the modeled daily average flows and assigning a percent exceedance value to each flow. Each flow exceedance pair represents the frequency for which the flow rate is exceeded, the maximum flow is exceeded 0% of the time, while the minimum flow is exceeded 100% of the time. Figure C-2 shows the LDC in blue, which was created by multiplying the FDC by the TSS standard of 30 mg/L. The LDC shown in blue represents the LC of the system, since the line is based on the water quality criteria. Water quality results underneath the line are below the numeric criteria, while any results above the line are in exceedance of the numeric criteria.

Simulated daily average TSS loads for the analysis period were plotted with the associated daily flow exceedance for the analysis period. Orange points in Figure C-2 represent a single daily load. Daily loads exceeding the TSS nutrient criteria are located above the blue LDC.

Figure C-2 shows observed TSS loading (**+**) along Sprague Creek. Observed loading was calculated using the measured TSS concentration and the USGS average stream flow for the sampled day. The TSS loads are likely larger than displayed in Figure C-2, because the USGS flow observations are collected upstream of the sampling sites, near the Canadian border. The USGS observations account for 70% of the area draining to each sampling location. Adjustment of the flow would shift observed loading up and left in Figure C-2. HSPF simulated loading (orange points) fit the limited observed data (**+**) well. The goodness of fit, or the extent to which the observed data matches the expected values, provides confidence in simulated results, and the corresponding LAs calculated which are based on the simulation results.

The LDC was divided into five different flow regimes to better describe loading for a range of events. The flow regimes were identified per United States EPA guidance as Very High (0% to 10%), High (10% to 40%), Mid (40% to 60%), Low (60% to 90%), and Very Low (10% to 0%).

LAs were calculated for each flow regime, which divide the LC described by the central region nutrient criteria into WL), MOS, and LA. The WLA represents the regulated portion of the LC, requiring a NPDES/SDS permit. The MOS accounts for uncertainty in estimating and attaining water quality standards and observations. The LA consists of the remaining capacity after the WLA and MOS have been determined. The current load represents the modeled reach loading. If the current load is greater than the LC, then a reduction in the water quality parameter is needed.

Table C-2 shows the results of the LA calculations. LC was calculated as the median (50%) nutrient loading criteria for each flow regime. Warroad WWTP is the only permitted discharger in the Sprague Creek Subwatershed. The WLA was calculated using the preferred (or design) flow and the permitted maximum monthly average TSS for the Warroad WWTP. The MOS was explicitly set to 10% of the LC in each flow regime. Existing loading was calculated as the median (50%) of the daily modeled loading data in each flow regime.

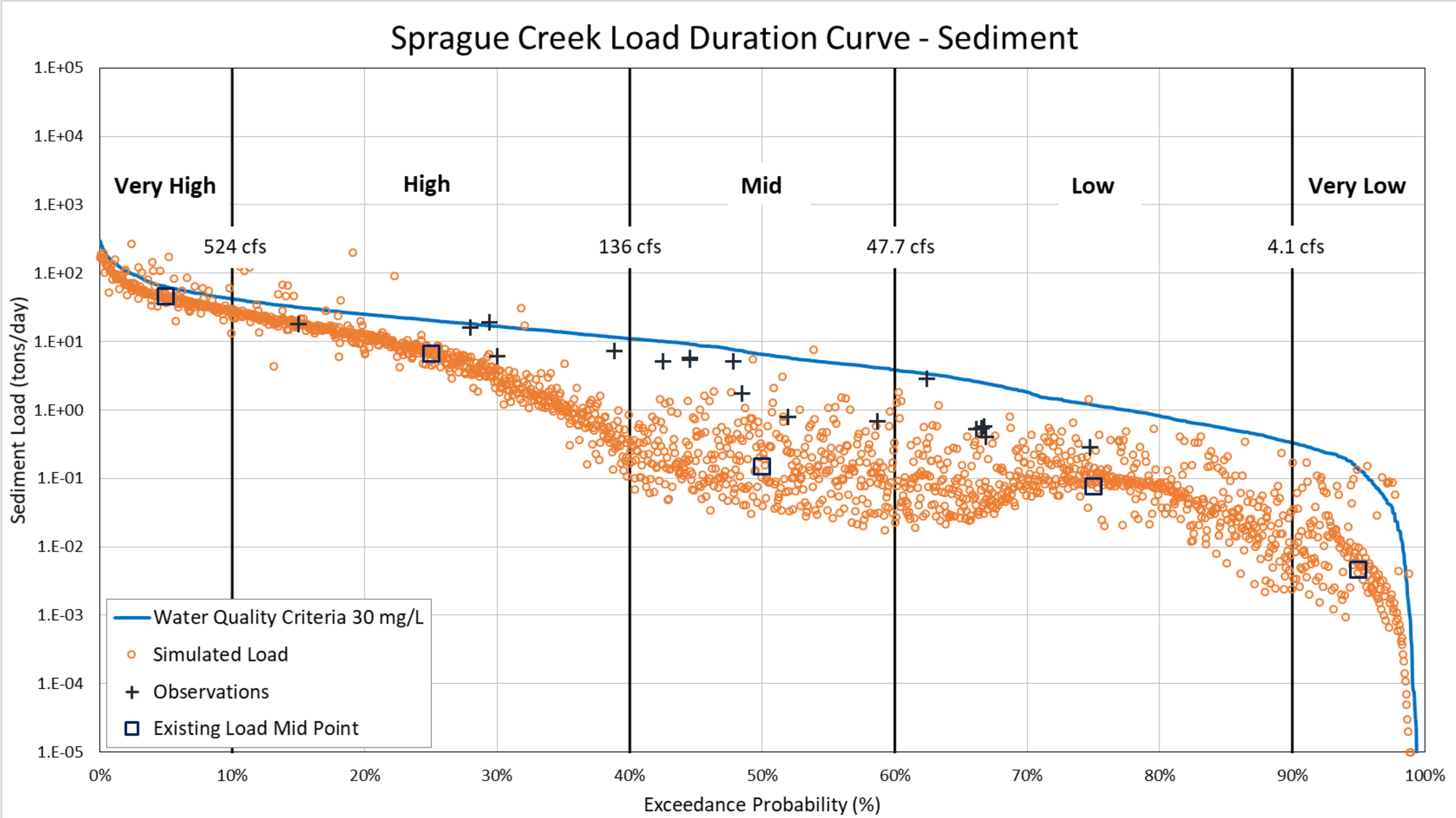
The needed reduction is calculated as the LC minus the current load; however, because the current load is less than the LC for all flow regimes, there is no needed load reduction. Because a reduction in current load is not needed, a value is not displayed in Table C-2. Figure C-2 similarly shows that the majority of simulated daily loads and observed loads fall below the water quality criteria LDC.

Summary

Sprague Creek (AUID 09020314-508) is currently listed as impaired for aquatic life use based on elevated turbidity levels. An evaluation of HSPF modeling and observed data shows no reduction needed for TSS along this reach of Sprague Creek. Findings of this evaluation are consistent with the Roseau River Monitoring and Assessment Report (2018), “An existing aquatic life impairment for turbidity will be re-evaluated once sufficient data has been collected; a limited dataset suggests that current conditions may meet the TSS standard.” Without a needed reduction in sediment loading, a TMDL for TSS will not be developed for Sprague Creek.

Sprague Creek is currently scheduled to be delisted as impaired for aquatic life use due to elevated turbidity levels during the 2020 impaired waters review cycle.

Figure C-2: Sprague Creek (AUID - 508) TSS load duration curve



[1]All observed data are outside of the evaluation period (2005 to 2014)

Table C-2: Sprague Creek (AUID -508) TSS load allocations

- **303(d) listing year or proposed year: 2008**
- **Baseline year(s): 2005-2014**

Sprague Creek - Total Suspended Solids		**Flow Condition***				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		Tons per day				
Loading Capacity		**63.1**	**20.4**	**6.57**	**1.20**	**0.14**
Wasteload Allocations	**Total WLA**	**0.65**	**0.56**	**0.54**	**0.52**	**
	Warroad WWTP (MNG580033)	0.52	0.52	0.52	0.52	**
	Construction Stormwater (MNR100001)	0.060	0.020	0.007	0.001	**
	Industrial Stormwater (MNR500000)	0.060	0.020	0.007	0.001	**
Load Allocations	**Total LA**	**56.2**	**17.8**	**5.4**	**0.60**	**
Margin of Safety - MOS (10%)		6.31	2.04	0.66	0.12	**
Existing Load		**46.1**	**6.63**	**0.15**	**0.076**	**0.005**
Estimated Load Reduction						
Percent Reduction						

*HSPF simulated flow and TSS loading were used to develop the flow zones and loading capacities for this reach.

**The WLA for the permitted wastewater discharger is based on a facility design flow. The WLA exceeded the very low-flow and low-flow zone total daily LC (minus the MOS). For these flow zones, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (TSS concentration limit or standard).