Watershed

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Snake-Middle Rivers Watershed Total Maximum Daily Load Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Abbreviations

AUID	Assessment Unit Identifier
BMP	Best management practice
CAFO	Concentrated Animal Feeding Operation
$CBOD_5$	five-day carbonaceous biochemical oxygen demand
Chl-*a*	Chlorophyll-*a*
CWA	Clean Water Act
CWLA	Clean Water Legacy Act
DMR	Discharge Monitoring Report
DNR	Minnesota Department of Natural Resources
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
HUC	Hydrologic Unit Code
HSG	Hydrologic Soil Groups
HSPF	Hydrological Simulation Program - FORTRAN
in/yr	inches per year
LA	Load allocation
LDC	Load duration curves
LID	Low-impact development
LGU	Local Units of Government
m	meter
mg/L	milligrams per liter
MIDS	Minimal Impact Design Standards
mL	milliliter
MnDOT	Minnesota Department of Transportation
MOS	Margin of safety
MPCA	Minnesota Pollution Control Agency
MRCC	Midwestern Regional Climate Center
MS4	Municipal Separate Storm Sewer Systems
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System

NRCS	Natural Resources Conservation Services
SDS	State Disposal System
SSTS	Subsurface sewage treatment systems
SWCD	Soil and water conservation districts
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
WLA	Wasteload allocations
WRAPS	Watershed Restoration and Protection Strategy
WWTF	Wastewater Treatment Facility

Executive summary

This Total Maximum Daily Load (TMDL) report was completed for impaired waterbodies of the Snake-Middle Rivers Watershed (Hydrologic Unit Code [HUC] 09020309), which enters the Red River of the North west of Argyle, Minnesota, and is part of the Lake Winnipeg Basin (HUC-09).

There are a total of 32 aquatic life use, aquatic recreation use, and aquatic consumption use impairments (3 caused by *Escherichia coli* [*E. coli*], 5 caused by turbidity, 7 caused by low dissolved oxygen [DO], 16 caused by poor biological communities, and 1 caused by mercury in the water column) included on Minnesota's U.S. Environmental Protection Agency (EPA)-approved 2018 303(d) list of impaired waters for the Snake-Middle Rivers Watershed. TMDLs were completed for this report to address 8 of the 31 aforementioned impairments. The TMDLs include three river/stream-reach aquatic recreation use impairments caused by *E. coli* and five river/stream-reach aquatic life use impairments caused by turbidity. The goal of these TMDLs is to quantify the pollutant reductions needed to meet the state water quality standards for *E. coli* and total suspended solids (TSS) for impaired streams. TMDLs were not completed for 24 of the 32 impairments. No impairments caused by poor fish or macroinvertebrate communities (*n*= 9 and 7, respectively) were addressed, because while all of them are linked to stressors with numeric criteria to some extent, the impairments are primarily linked to stressors without numeric criteria (e.g., flow regime instability and poor habitat) that cannot have TMDLs calculated. The seven DO impairments were not addressed for various reasons ranging from lack of information to lack of reasonable assurance that the reductions required to meet a TMDL could be met. This report does not cover toxic pollutants so the aquatic consumption use impairment caused by mercury in the water column is not addressed. Mercury concentrations are above the threshold values for this impairment to be addressed by the Minnesota Statewide Mercury TMDL, so it is scheduled to have a TMDL study completed at a later date. No other TMDLs have previously been developed for waters in the Snake-Middle Rivers Watershed.

TMDLs described herein were primarily derived from output of the HSPF model that was developed for the entire Snake-Middle Rivers Watershed. This model incorporated available flows and monitored water quality (1996 through 2015) [Burke 2017]. HSPF-estimated runoff and pollutant characterizations were employed to assess TMDLs for stream bacteria (*E. coli*) and TSS loads. HSPF-generated flows and outputs were used to establish load duration curves (LDCs) for three stream-reach impairments caused by bacteria and five stream-reach impairments caused by turbidity, with wasteload allocations (WLAs) and load allocations (LAs) established for five flow duration curve categories: very high, high, mid, low, and very low-flow conditions.

Reductions that are required to achieve *E. coli* standards range from 0% to 83%, depending on the stream and the TMDL load duration curve category. Sediment reductions that are required to achieve TSS standards range from 0% to 95%, depending on the stream and the TMDL load duration curve category. There are seven National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) permitted WWTFs located within the Snake-Middle Rivers Watershed. Three of the WWTFs were assigned an *E. coli* WLA and all seven were assigned a TSS WLA. All seven of the NPDES/SDS permits include permit limits that already comply with the assigned WLAs, so no additional reductions are required in this TMDL.

Water quality restoration will continue to be aided by the interdependent and cooperative efforts of the Snake-Middle Rivers Watershed communities, local soil and water conservation districts (SWCDs), local units of government (LGUs), counties, state, and federal partners via leveraged management actions phased over budgetary cycles to address the largest pollutant sources. Among the best management practices (BMPs) needed, widespread adoption of buffers and streambank stabilization should proceed as a high priority, which will assist in reducing bacteria and TSS. Dominant bacterial sources have been identified by impaired stream and flow patterns that will help prioritize and guide implementation.

Storm rainfall amounts for the typical 24-hour storm and multiday wet periods can be substantial, with potential wide-ranging negative impacts to communities and agricultural producers, as well as the receiving waterbodies and associated aquatic habitats. Collectively, this report's dry- and wet-cycle characterizations may aid in considering BMP design factors for wet periods, and augmenting storage and retention practices for dry periods to increase stream-base flows and reuse.

While the impaired waterbodies lie primarily in Marshall County, contributing portions of the impaired waterbody watersheds extend into Polk and Pennington Counties. Hence, future implementation strategies to improve and protect local waters and those downstream will require continued close cooperative efforts of all Snake-Middle Rivers Watershed counties and LGUs. The findings from this TMDL report were used to assist in selecting the implementation and monitoring activities as part of the Snake-Middle Rivers Watershed Restoration and Protection Strategy (WRAPS) process. The purpose of the WRAPS report is to support these local working groups and jointly develop scientifically supported restoration and protection strategies for subsequent implementation planning. The WRAPS report is publicly available on the Minnesota Pollution Control Agency (MPCA) website: https://www.pca.state.mn.us/water/watersheds/snake-river-red-river-basin.

1. Project Overview

1.1 Purpose

Section 303(d) of the Clean Water Act (CWA) and the EPA Water Quality Planning and Management Regulations (40 CFR 130) require states to develop TMDLs for waterbodies that do not meet applicable water quality standards or guidelines to protect designated uses under technology-based controls. TMDLs specify the maximum pollutant load that a waterbody can receive and still meet water quality standards. Based on a calculation of the total allowable load, TMDLs allocate pollutant loads to sources and incorporate a margin of safety (MOS). TMDL pollutant load reduction goals for significant sources provide a scientific basis for restoring surface water quality by linking the development and implementation of control actions to attaining and maintaining water quality standards and designated uses.

This TMDL report addresses three river/stream-reach aquatic recreation use impairments caused by *E. coli* bacteria and five river/stream-reach aquatic life use impairments caused by turbidity in the Snake-Middle Rivers Watershed[1] in the Red River of the North Basin. Impairments addressed in this TMDL report are listed in **Table 1-1**. Stream IDs from **Table 1-1** are discussed in this document by the last three digits of the stream ID (e.g., Reach 501). While the impaired waterbodies lie primarily in Marshall County, contributing portions of their watersheds extend into areas of Polk and Pennington Counties. No other TMDLs have previously been developed for waters in the Snake-Middle Rivers Watershed. The accompanying WRAPS process prioritizes and synchronizes restoration activities among the three Snake-Middle Rivers Watershed counties.

Table 1-1. Water quality impairments on the approved 2018 303(d) list that are addressed in this TMDL report.

Name	Stream ID	Description	Proposed Use Subclass	Year Added to List	TMDL Target Completion Year	Pollutants Addressed
Snake River	09020309-501	Middle R to Red R	2B, 3C	2002	2019	Turbidity
	09020309-502	CD 3 to Middle R	2B, 3C	2010	2019	Turbidity
	09020309-504	S Br Snake R to CD 7	2B, 3C	2008	2019	Turbidity
				2016		*E. coli*
	09020309-537	T154 R49W S17, east line to CD 3	2B, 3C	2016	2019	*E. coli*
	09020309-543	Unnamed Cr to S Br Snake R	2B, 3C	2016	2019	*E. coli*
Middle River	09020309-540	Co Rd 114 to T156 R49W S3, north line	2B, 3C	2008	2019	Turbidity
	09020309-541	T157 R49W S34, south line to Snake R	2B, 3C	2008	2019	Turbidity

The goal of this TMDL report is to quantify the pollutant reductions needed to meet the state water quality standards for bacteria and TSS for the addressed impaired stream reaches. This TMDL report is established in accordance with Section 303(d) of the CWA and defines WLAs, LAs, and pollutant reductions needed to achieve state water quality standards.

[1] Please note that while the MPCA's official name for the major watershed is the Snake River Watershed – Red River Basin, the locally preferred name is the Snake-Middle Rivers Watershed. The name Snake-Middle Rivers Watershed and corresponding acronym (SMRW) are used in this report wherever possible.

Developing TMDLs for the Snake-Middle Rivers Watershed will provide information and a framework for the Middle-Snake-Tamarac Rivers Watershed District (MSTRWD), MPCA, SWCDs, other state and federal agencies, and county watershed managers on which to base management decisions. This TMDL and WRAPS effort will inform the One Watershed One Plan process in this geographic planning area authorized in 2020. TMDLs will also provide reasonable assurance that impairments will be addressed by continued BMP implementation and that future impairments will be readily addressed with an in-place model and TMDL. Furthermore, outcomes from the TMDLs, such as increased implementation, will protect the designated uses and will not impair or threaten other designated uses assigned to these waterbodies.

Twenty-four impairments on the 2018 303(d) list are not addressed in this TMDL report for reasons explained in the proceeding paragraphs. Unaddressed impairments are listed in **Table 1-2**.

Seven impairments caused by DO were not addressed in this report. TMDL assessments were completed for impairments caused by low DO on Reaches 502, 540, and 541, but it was determined that there is not reasonable assurance that nutrient load reductions necessary to meet the DO standard could be achieved. Therefore, DO TMDLs are not included for Reaches 502, 540, and 541. DO impaired Snake River Reach 501 was not addressed because backwater from the Red River of the North can drive the low DO in this Reach. Snake River Reach 537 needs to be further assessed for DO impairment. Land cover in Middle River Reach 539 is dominated by two very large wetlands, and the possibility of naturally low DO in this reach needs to be evaluated. Snake River Reach 543 has a large impoundment that contributes to it, which will be evaluated before a TMDL to address low DO is completed. Any DO impairments remaining on the 303(d) list of impaired waters after further assessment, will be addressed during the next round of TMDL development.

This report does not cover toxic pollutants so the aquatic consumption use impairment caused by mercury in the water column in Assessment Unit Identifier (AUID) 501 is not addressed. Mercury concentrations are above the threshold values for this impairment to be addressed by the Minnesota Statewide Mercury TMDL, so it is scheduled to have a TMDL study completed at a later date.

Sixteen impairments indicated by poor biological communities were not fully addressed, because they are primarily linked to stressors that do not have numeric criteria with which to develop a TMDL, or the pollutant equivalents to the numeric stressors (e.g., turbidity and TSS are the pollutant equivalents to the high suspended sediment stressor) meet standards, or more information and evaluation is needed to develop TMDLs. However, Reaches 501, 502, 504, and 540 have a total of six biological impairments, all of which have high suspended sediment as one of the stressors and they also have turbidity-caused impairments that are addressed with TSS TMDLs in this report, so the sediment stressor is incidentally addressed with the TMDL studies. Although a more thorough analysis would be needed to fully conclude the following hypothesis, it is likely that achieving the applicable water quality standard for TSS would also help address the impaired fish and/or macroinvertebrate community impairments. Future intensive monitoring studies will assess if biota metrics have changed as a result of implementation efforts.

Table 1-2. Water quality impairments on the approved 2018 303(d) list that are not addressed in this TMDL report.

Name	Stream ID	Description	Proposed Use Subclass	Impairment Causes Not Addressed
Judicial Ditch 29	09020309-519	Headwaters to Snake R	2B, 3C	FIBI
Unnamed Ditch	09020309-529	Unnamed ditch to Middle R	2B, 3C	MIBI
Snake River, South Branch (old channel)	09020309-544	Unnamed ditch to Snake R	2B, 3C	FIBI, MIBI
Snake River, South Branch (new channel)	09020309-546	Headwaters to Snake R	2B, 3C	FIBI
Snake River	09020309-501	Middle R to Red R	2B, 3C	FIBI, DO, Mercury in water column
	09020309-502	CD 3 to Middle R	2B, 3C	FIBI, MIBI, DO
	09020309-504	S Br Snake R to CD 7	2B, 3C	FIBI, MIBI
	09020309-537	T154 R49W S17, east line to CD 3	2B, 3C	FIBI, MIBI, DO
	09020309-543	Unnamed Cr to S Br Snake R	2B, 3C	FIBI, MIBI, DO
Middle River	09020309-538	Headwaters to -96.171 48.4349	2B, 3C	FIBI
	09020309-539	–96.171 48.4349 to Co Rd 114 bridge	2B, 3C	DO
	09020309-540	Co Rd 114 to T156 R49W S3, north line	2B, 3C	MIBI, DO
	09020309-541	T157 R49W S34, south line to Snake R	2B, 3C	DO

1.2 Identifications of Waterbodies

The Snake-Middle Rivers Watershed is in northwestern Minnesota, as illustrated in **Figure 1-1**. The Snake-Middle Rivers Watershed contains 3 bacteria-impaired stream reaches (**Figure 1-2**), 5 turbidity-impaired reaches (**Figure 1-3**), 7 DO-impaired reaches, and 11 biologically-impaired reaches that are included on the approved 2018 303(d) list of impaired waters. This TMDL addresses the three *E. coli*-impaired stream reaches and the five turbidity-impaired stream reaches. The impairments addressed are described in **Table 1-1**. None of the drainage areas of impaired waterbodies addressed in this document contain tribal lands.

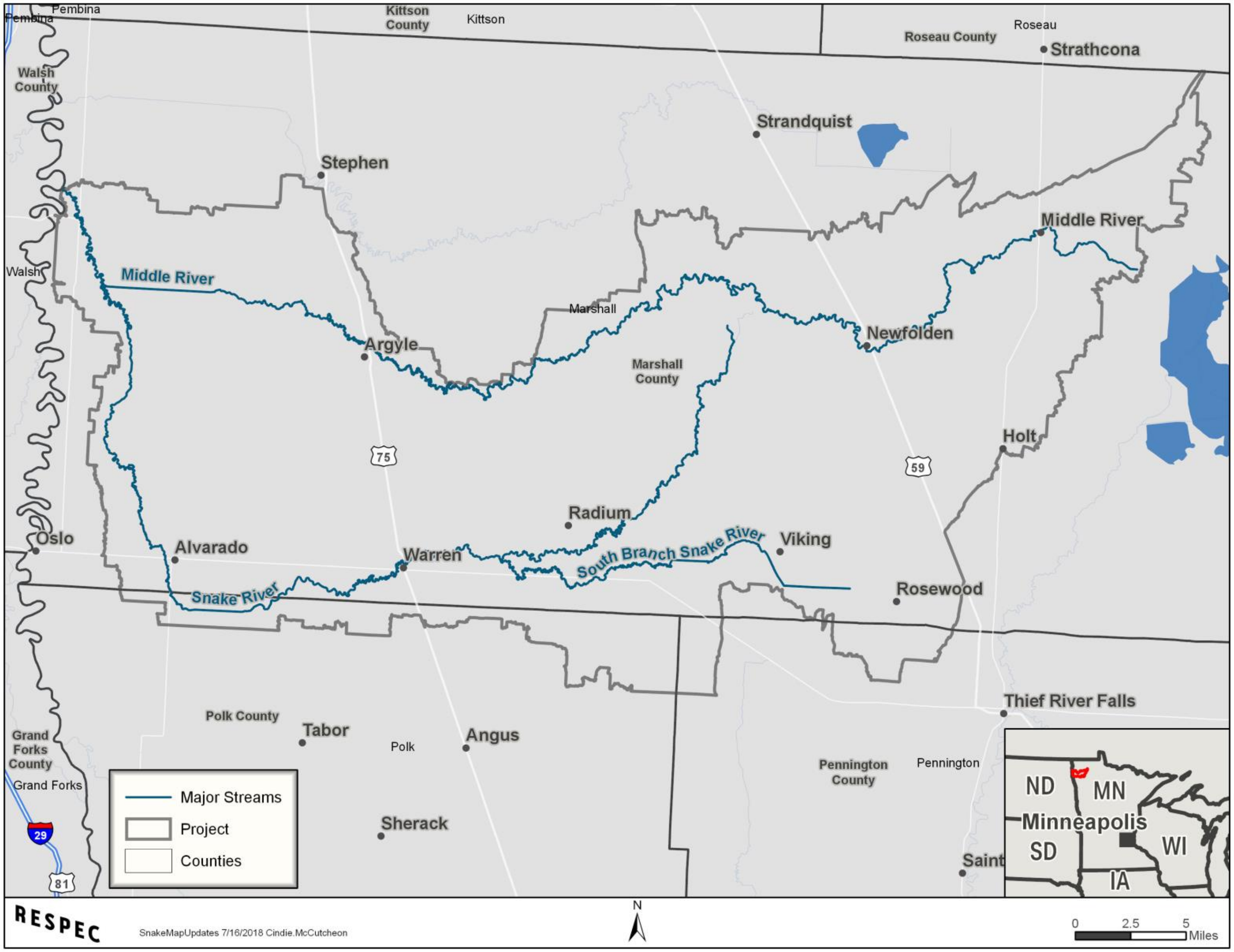

Figure 1-1. Snake-Middle Rivers Watershed.

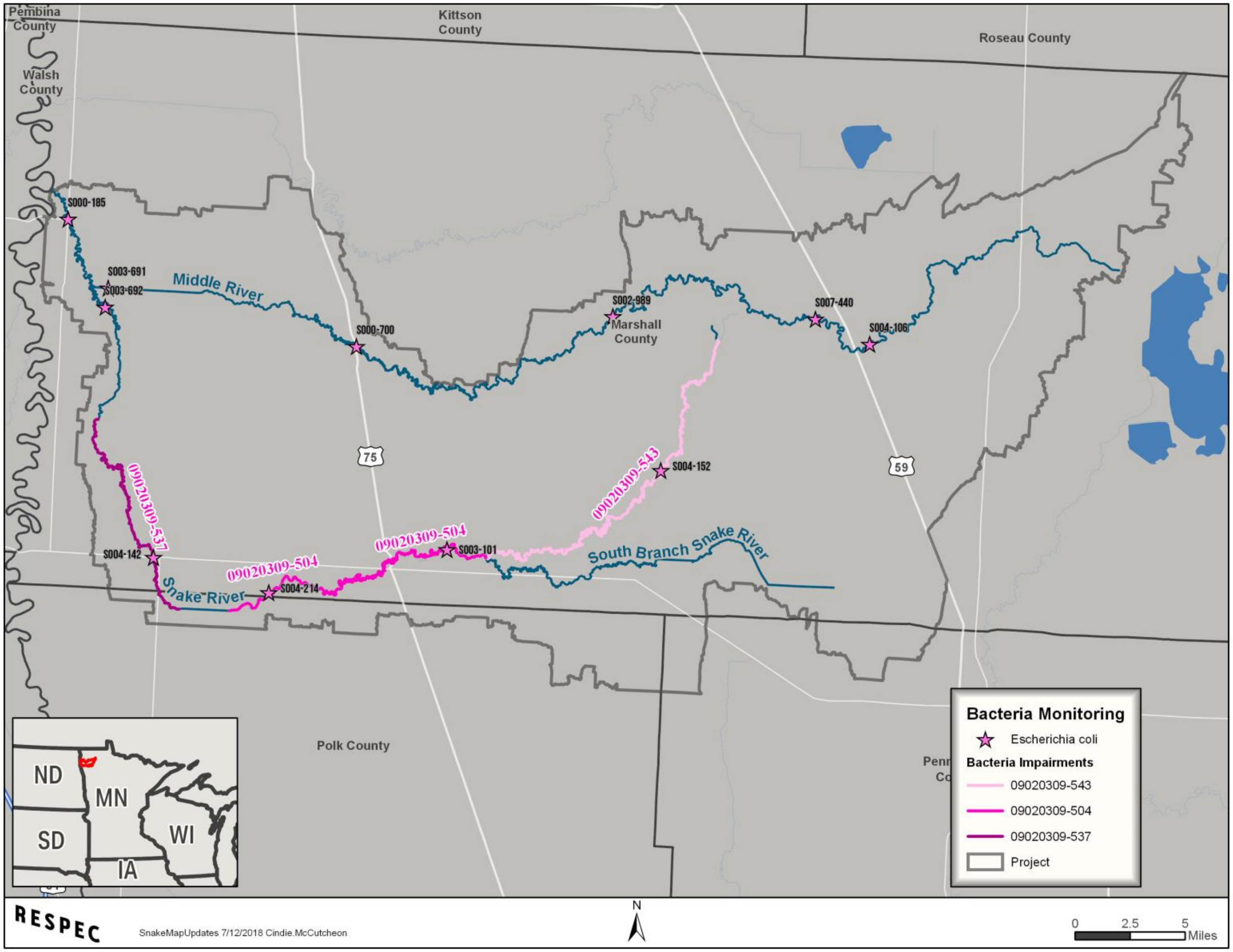

Figure 1-2. Impairments caused by bacteria, and monitoring locations.

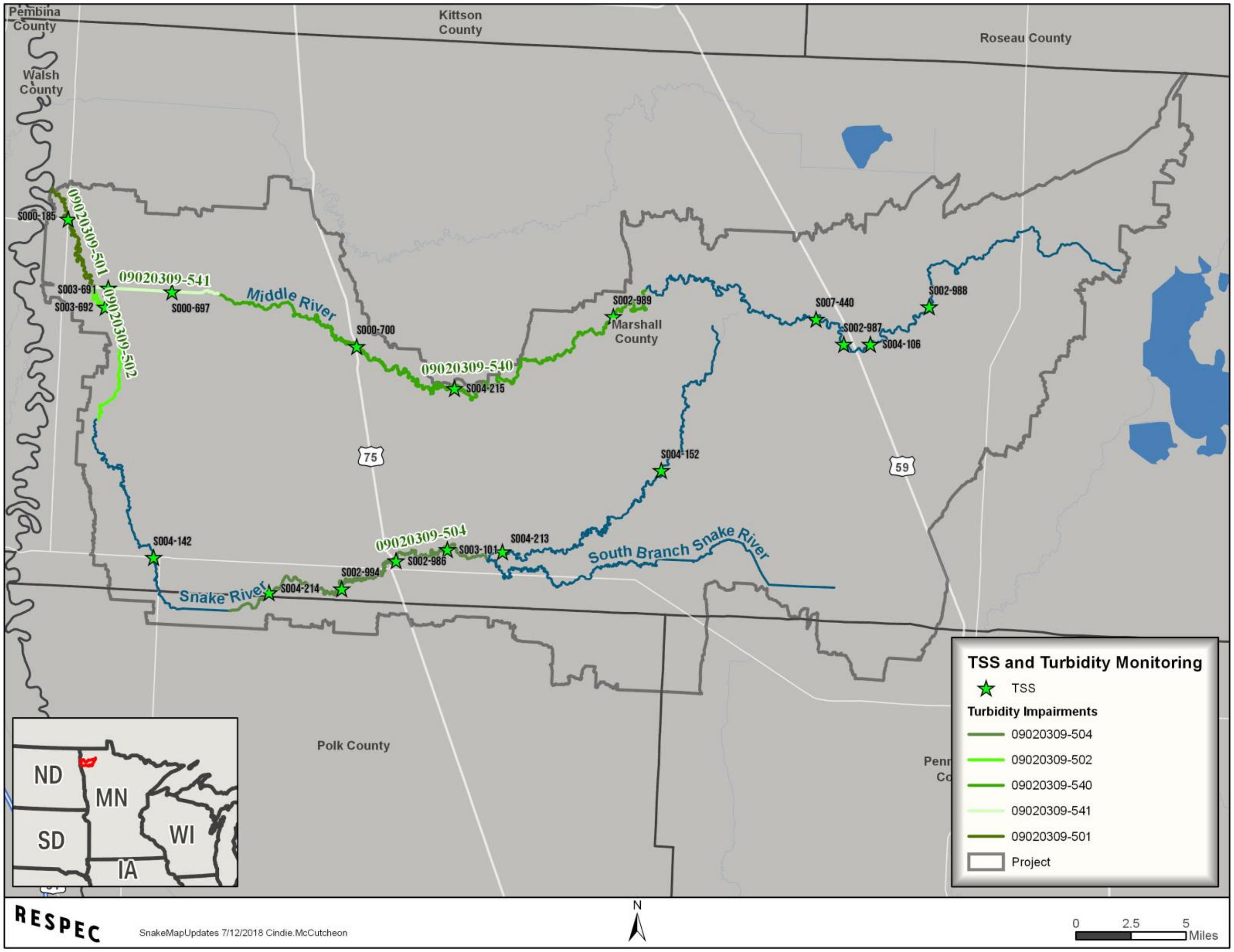

Figure 1-3. Impairments caused by turbidity, and monitoring locations.

The State of Minnesota classifies streams into categories, which are protected for specific designated uses. All impairments addressed in this TMDL are in Class 2B and Class 3C waters. The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool- or warm-water sport or commercial fish and associated aquatic life, as well as their habitats. These waters shall be suitable for all kinds of aquatic recreation, including bathing. This class of surface water is not protected as a source of drinking water. Applicable standards for Class 2B waters [Minnesota State Legislature 2008] are summarized in **Section 2**. Class 3C-related water quality standards (chlorides, hardness, and pH) are neither violated in the Snake-Middle Rivers Watershed nor addressed in this TMDL report.

1.3 Priority Ranking

The MPCA schedule for TMDL completions, as indicated on Minnesota's draft 303(d) list, reflects Minnesota's priority ranking of these TMDLs. The MPCA has aligned TMDL priorities with the watershed approach and WRAPS development. The schedule for TMDL completion corresponds to the WRAPS report completion schedule, with all WRAPS for the state's 80 watersheds due to be completed by mid-2023. WRAPS updates, including additional TMDLs, will be completed on an as-needed basis thereafter. The MPCA developed a state plan, *Prioritization Plan for Minnesota 303(d) Listings to Total Maximum Daily Loads* [MPCA 2015a], to meet the needs of the EPA's national measure (WQ-27) under EPA's *A Long-Term Vision for Assessment, Restoration and Protection under the CWA Section 303(d) Program* [EPA 2013]. As part of these efforts, the MPCA identified water quality-impaired segments that will be addressed by TMDLs by 2022. Prioritization of impaired segments listed after the state's prioritization plan [MPCA 2015a] was developed are reflected in the "TMDL target completion year" in the impaired waters list; the MPCA prioritizes impaired water bodies as they are added to the impaired waters list. Impaired waters in the Snake-Middle Rivers Watershed addressed in this TMDL report are part of the MPCA's prioritization plan to meet EPA's national measure.

2. Applicable Water Quality Standards and Numeric Water Quality Targets

The Snake-Middle Rivers Watershed is located within the Lake Agassiz Plain Level III ecoregion, which is characterized by flat topography resulting from the deposition of lake sediments over thousands of years. For the recently adopted river nutrient standards and TSS standards, the Snake-Middle Rivers Watershed is in the South River Nutrient Region. Water quality standards for class 2B streams can be found in Minn. R. 7050.0222 subp. 4.

2.1 *E. coli* Bacteria

The Minnesota water quality rules [Minnesota State Legislature 2008] state that "*E. coli* bacteria shall not exceed 126 organisms per 100 milliliters (mL) as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 mL. The standard applies only between April 1 and October 31."

2.2 Turbidity and Total Suspended Sediment

Turbidity is the measurement of cloudiness or haziness of water, which is the result of dissolved and suspended materials in the water such as sediment or phytoplankton. Excess turbidity can harm aquatic life, increase the cost of treatment for drinking water or food processing, and decrease the aesthetic qualities of a waterbody. Aquatic life is harmed by turbidity when it impacts their ability to find food, smothers spawning beds and habitat, and/or affects gill function.

Five reaches in the Snake-Middle Rivers Watershed are impaired by turbidity. The turbidity standard at the time of the impairment assessment for these reaches was 25 nephelometric turbidity units (NTUs). This standard protected the designated use for propagation/maintenance of healthy cold-water sport or commercial fish and the aquatic life associated with them and their habitat. This turbidity standard was replaced by a TSS standard in January 2015. Therefore, for the purposes of this TMDL report, the newly adopted TSS standard of 65 mg/L TSS for the Southern River Nutrient Region will be used in place of the turbidity standard. The assessment season for the TSS standard is April through September.

3. Watershed and Waterbody Characterization

3.1 Historical/Legacy Perspectives

The Snake River drains an area of 498,609 acres (or approximately 779 square miles) in northwestern Minnesota. Much of the watershed is in Marshall County (92%), with smaller portions located in Polk (6%) and Pennington (2%) Counties. Following the Civil War, European settlement of the region by various Scandinavian, English, Polish, and other immigrants followed expansion of private roads and stage coach lines. Transit vastly improved by the 1870s expansion of the railroads that allowed farmers access to Minneapolis grain mills. At the time, railroads owned vast land grants in the Red River Valley with lines extended to newly named communities such as Alvarado and Newfolden by the Minneapolis, St. Paul and Sault Ste. Marie Railroad (Soo Line), and Middle River and Stephen by the Great Northern Railway. Marshall County settlements and post offices were established, including Alvarado in 1879, Newfolden in 1904, Stephen in approximately 1883, and Strandquist in 1923. Since the late 1880s settlement period, the Snake-Middle Rivers Watershed has undergone dramatic land use modification for agricultural production via conversion of native prairies, harvesting its hardwood forests, draining its wetlands, and modifying its natural stream courses. Today, approximately 81% of its landscape is used for agricultural production. A map showing the historic vegetation is included in **Appendix A**.

3.2 Demographic Growth Projections

Demographic projections from 2015 and 2045 by the Minnesota State Demographic Center [Dayton 2014] indicate that the population will increase by approximately 3% in Marshall County, which makes up a majority of the Snake-Middle Rivers Watershed.

3.3 Climate

Basic climate data were reviewed to (1) define typical seasonal and annual cycles that affect runoff and water quality, (2) identify wet and dry patterns that affect pollutant loading dynamics, (3) assist in implementing design considerations, and (4) help inform future performance monitoring efforts. Included in this assessment are typical monthly temperature and precipitation information (normals), annual precipitation, frost-free season lengths, dry and wet periods, and average summer temperatures. Climate variability for the Snake-Middle Rivers Watershed was assessed by using available long-term data for sites from the Midwest Regional Climate Center, the Minnesota Department of Natural Resources (DNR) gridded precipitation, and National Oceanic and Atmospheric Administration's (NOAA) databases summarized for northwestern Minnesota (Climate Division 1). Few monitoring stations with long-term climate data exist across the Snake-Middle Rivers Watershed; hence, interpolated data from the DNR's gridded precipitation network and the NOAA's Climate Division data were evaluated. The monthly normals for Argyle, Minnesota (USC00210252) and Agassiz Refuge, Minnesota (USC00210050), are presented as monthly average precipitation as well as maximum, average, and minimum temperatures for the 1981through 2010 period in **Figure 3-1** and **Figure 3-2**, respectively. A NOAA plot of average growing-season temperatures, as depicted in **Figure 3-3**, shows a large increasing trend.

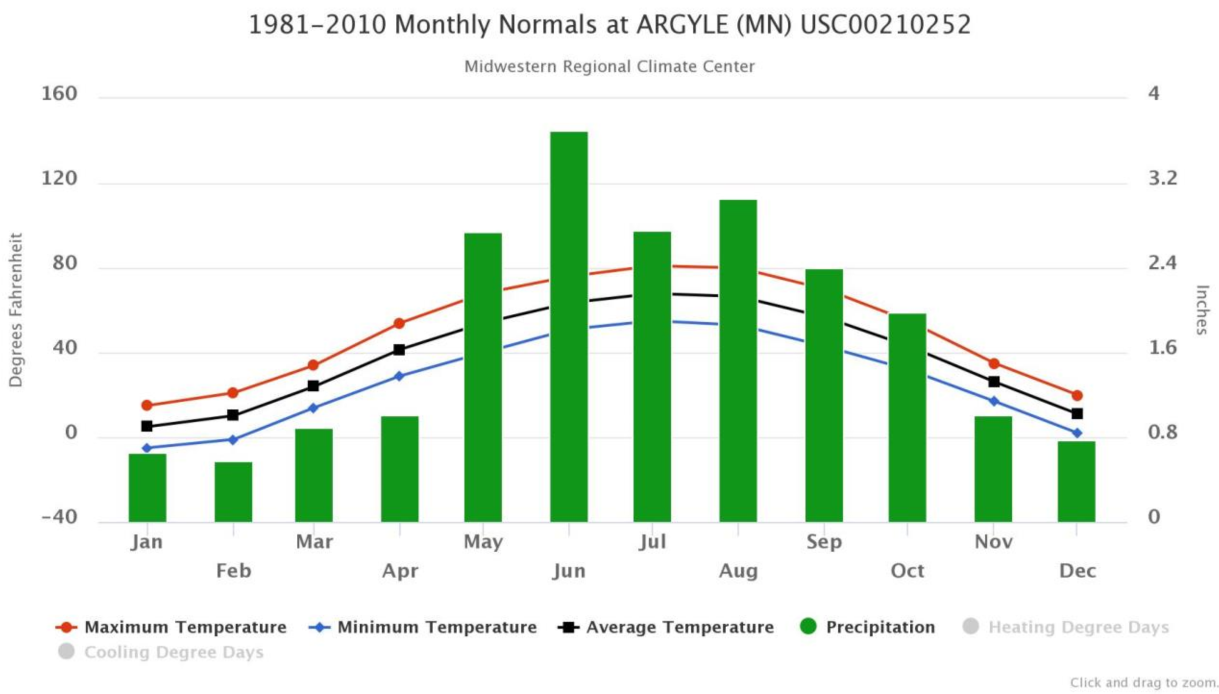

Figure 3-1. Observed monthly climate normals for Argyle, Minnesota (USC00210252), from 1981 to 2010 [Midwestern Regional Climate Center 2017].

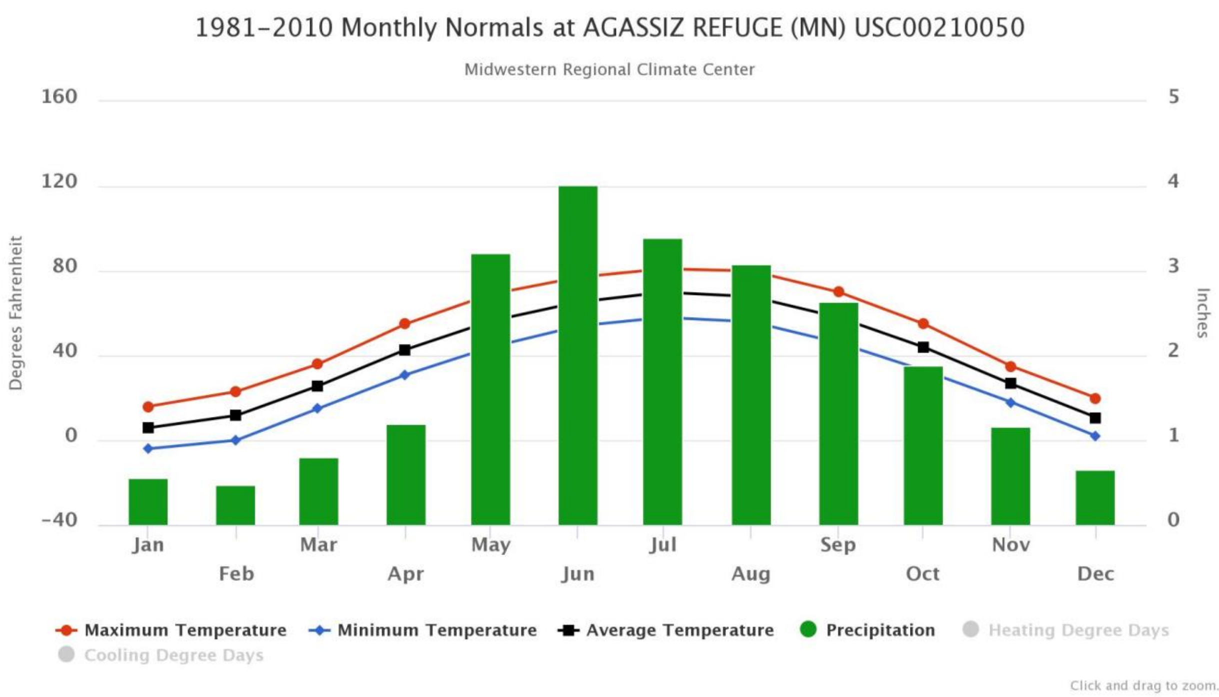

Figure 3-2. Observed monthly climate normals for Agassiz Refuge, Minnesota (USC00210050), from 1981 to 2010 [Midwestern Regional Climate Center 2017].

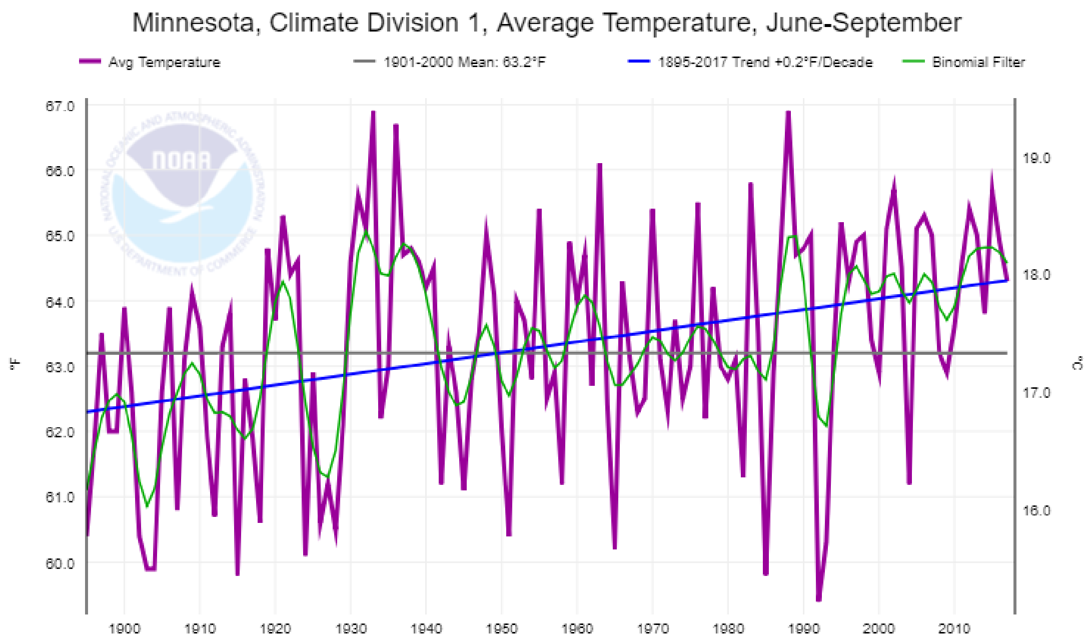

Figure 3-3. Growing-season (June through September) temperature for 1895–2017 From NOAA [2016a] for Minnesota Climate Division 1.

Via the DNR's gridded precipitation network, the variability of annual precipitation across the watershed was examined by using representative sites for the eastern portion of the watershed (Middle River) and the western portion of the watershed (Argyle), as shown in **Figure 3-4**. Annual precipitation has ranged from approximately 14 inches in Argyle in 1989 to nearly 32 inches in Middle River in 1999 across the watershed, with similar annual precipitation patterns for both locations with generally lower annual totals for Argyle. Over the TMDL study time period (2006 through 2015), the annual precipitation average for the two sites was approximately 21.9 inches. These generalized average values differ from the more intensive precipitation station data from 1995 to 2015 that were used in developing the HSPF model for the Snake-Middle Rivers Watershed.

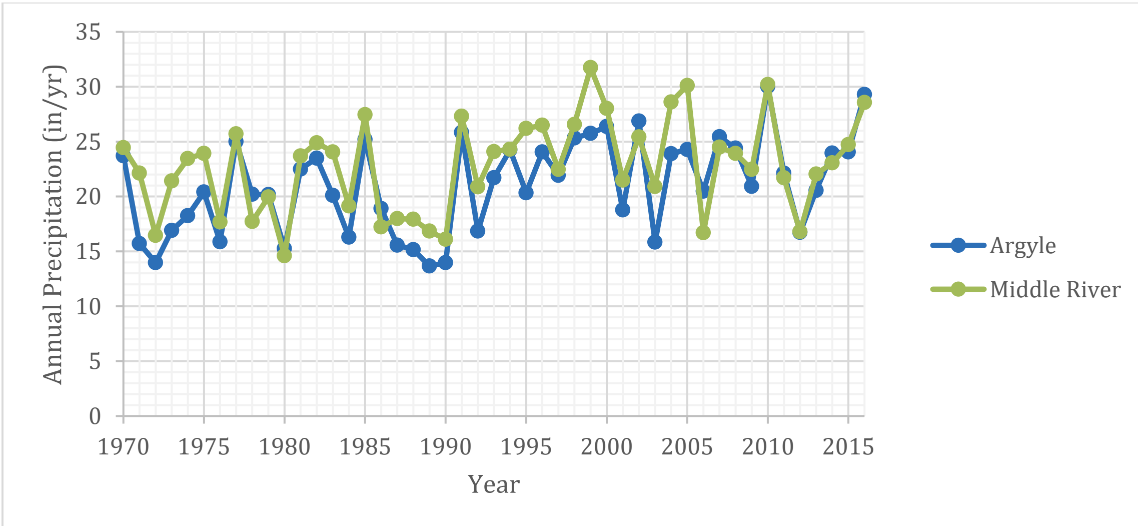

Figure 3-4. Comparison of annual precipitation (inches) for representative sites of the eastern (Middle River) and western (Argyle) portions of the Snake-Middle Rivers Watershed [DNR 2017a].

A long-term overview (1895 through 2017) of annual precipitation variation and trends for Climate Division 1 that covers northwestern Minnesota is depicted in **Figure 3-5** from NOAA's National Centers for Environmental Information [NOAA 2016a]. Using the smoothed time-series and rolling-averaged plots facilitates observation of longer periods of wet and dry precipitation patterns. From this data, considerable year-to-year variability in annual precipitation is evident with a rolling pattern of multiyear averages noted by the smoothed binomial filter represented by the red line. A variable but generally increasing pattern of annual precipitation was noted since approximately 1990, particularly for the most recent years that encompasses the TMDL report period (2006 through 2015).

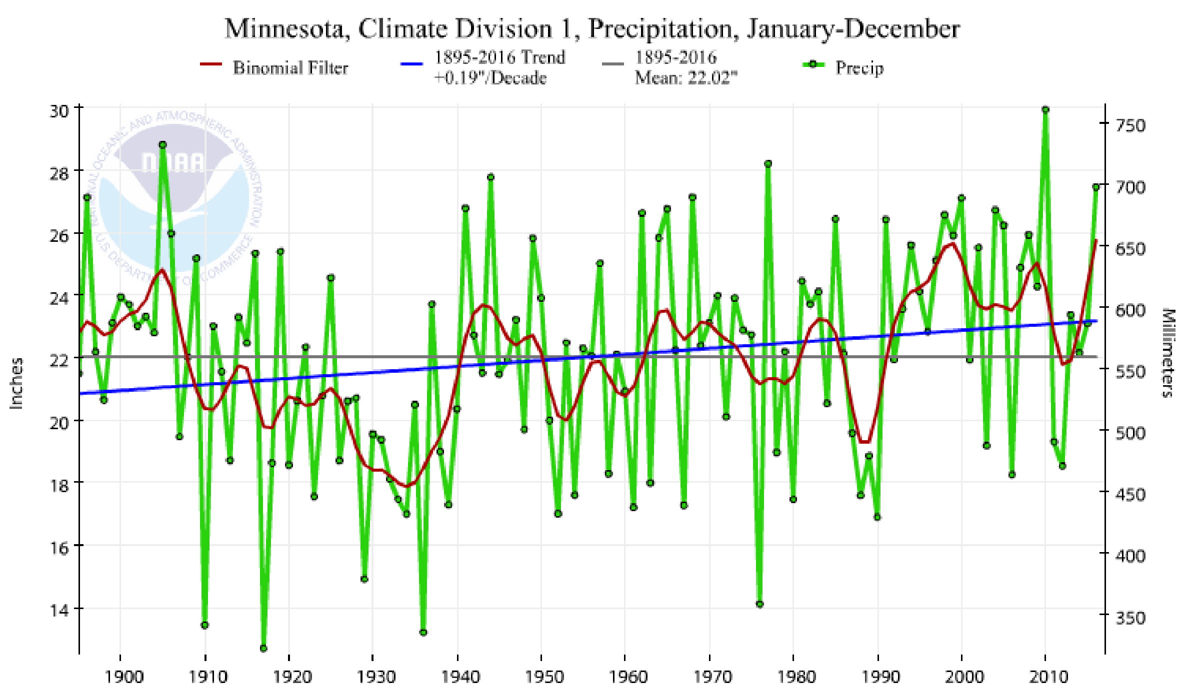

Figure 3-5. Annual precipitation for 1895–2017 from NOAA [2016a] for Minnesota Climate Division 1.

Focusing on summer precipitation patterns, a similar NOAA plot for June through September is again presented for Climate Division 1 (northwest Minnesota) in **Figure 3-6**. In this figure, a long-term increase in growing-season precipitation was evident, but more muted than noted for annual precipitation and also quite variable. Over the TMDL period (2006 through 2015), growing-season precipitation ranged from below 8 inches to above 18 inches with an average of approximately 12.41 inches.

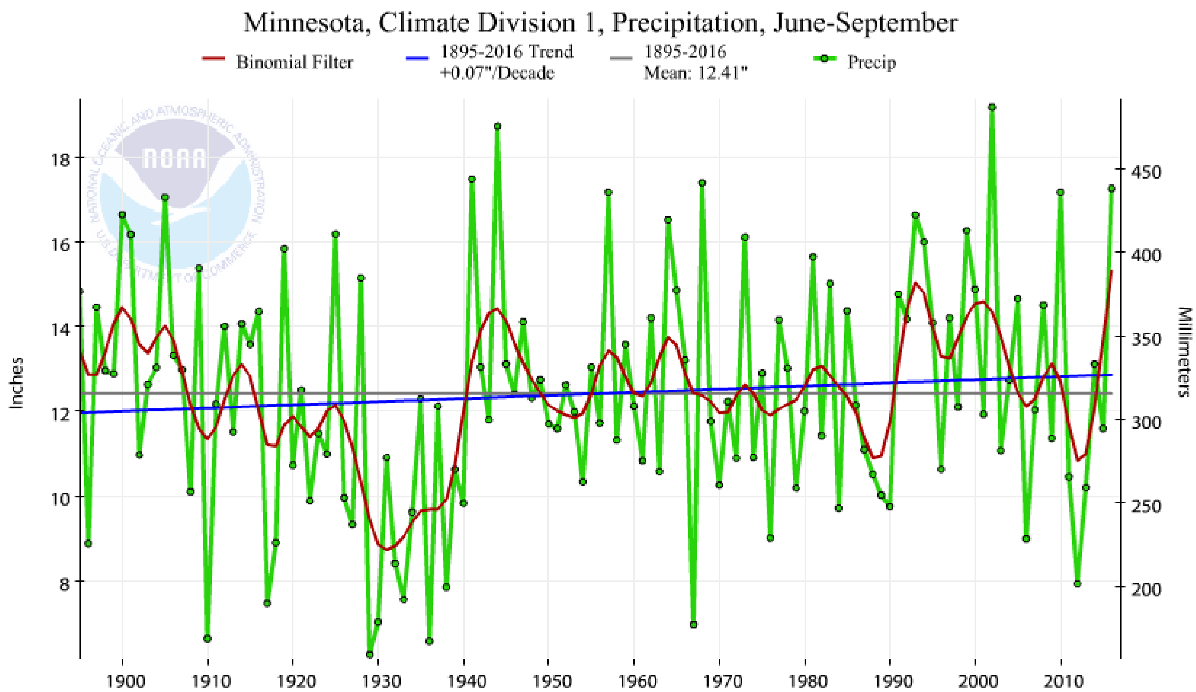

Figure 3-6. Growing-season (June–September) precipitation for 1895–2017 from NOAA [2016a] for Minnesota Climate Division 1.

3.3.1 Characterization of Storm Events

NOAA, in cooperation with the MPCA, DNR State Climatology Office, and the Minnesota Department of Transportation (MnDOT), updated precipitation intensity and duration records through December 2012 for the entire state, which are referred to as Atlas 14. Storm event totals, such as those reported in various media weather reports, are typically for 24-hour periods that have been summarized from data reported for stations representative of the western (Argyle) area and just east (Agassiz Refuge) of the Snake-Middle Rivers Watershed. A comparison of these 24-hour storm records that span the Snake-Middle Rivers Watershed is tabulated in **Table 3-2** with increases in storm amounts noted across all recurrence intervals (1/1 year to 1/1,000 year occurrence). An average recurrence interval of 1 year has a 100% chance of occurring every year, while an average recurrence interval of 1,000 years has a 0.1% chance of occurring every year. Back-to-back storms over several days often generate much larger totals associated with peak runoff events; therefore, frequencies of 10-day wet-period storms were summarized in **Table 3-2**. Ten-day wet period precipitation amounts were noted to range from approximately 3.42 inches (annually) to 13.3 inches (1,000 year), with higher storm amounts in the east. From a flooding perspective, wet periods can have large cumulative storm totals that affect watershed runoff, agricultural producers, public safety, and pollutant loading.

Table 3-1. Atlas 14 summaries of 24-hour precipitation amounts (inches) for 2 representative Snake-Middle Rivers Watershed locations [NOAA 2016b].

24-Hour Storms Depth (inches)	Average Recurrence Interval (years)	1	2	5	10	25	50	100	200	500	1,000
	Chance of Occurrence (%)	100%	50%	20%	10%	4%	2%	1%	0.5%	0.2%	0.1%
Location	Arygle	1.94	2.3	2.94	3.52	4.38	5.1	5.87	6.7	7.87	8.81
	Agassiz Refuge	2.09	2.46	3.13	3.75	4.69	5.5	6.37	7.31	8.67	9.77

Table 3-2. Atlas 14 summaries of 10-day wet-period precipitation amounts (inches) for two representative Snake-Middle Rivers Watershed locations [NOAA 2016b].

10-Day Wet Period Depth (inches)	Average Recurrence Interval (years)	1	2	5	10	25	50	100	200	500	1,000
	Chance of Occurrence (%)	100%	50%	20%	10%	4%	2%	1%	0.5%	0.2%	0.1%
Location	Arygle	3.42	3.89	4.69	5.39	6.41	7.24	8.1	9.02	10.3	11.3
	Agassiz Refuge	3.8	4.25	5.07	5.83	7	7.99	9.07	10.3	11.9	13.3

3.3.2 Precipitation Variability: Wet and Dry Periods

A closer examination of year-to-year and monthly precipitation variability was evaluated by using synthetic data from the *DNR's Monthly Precipitation Data From a Gridded Database* [DNR 2017a]. Data were summarized by month and year and are presented in **Table 3-3** for Middle River Township near Argyle in Marshall County, Minnesota. In this evaluation, the wet months (greater than 70th percentile months) were color-coded blue and dry months (less than 30th percentile months) were color-coded red. The in-between values (normal) are color-coded green. In the past 10 years, five "warm" seasons have been wet (e.g., precipitation greater than 70th percentile), three have been normal, and two have been dry (precipitation less than 30th percentile). Peak spring (April and May) and June precipitation events are of particular note for the potential to generate stormwater runoff from fertilized fields, growing crops with undeveloped canopies, and urban conveyance systems just before the peak growing season. The data from 2006 to 2015 also show many substantial rotations between wet (blue color) and dry (red) monthly precipitation amounts, particularly from June to September. Higher precipitation amounts that occur during July and August with established vegetative canopies and higher evaporative losses may not have peak runoff unless they are caused by extreme events and wet periods from back-to-back storm systems.

Table 3-3. Monthly precipitation by year (2006–2016) for Middle River Township, Marshall County, Minnesota [DNR 2017a].

	January	February	March	April	May	June	July	August	September	October	November	December	WARM
Period-of-Record Summary Statistics													
30%	0.35	0.27	0.48	0.79	1.50	2.28	2.06	1.77	1.19	0.69	0.42	0.36	11.92
70%	0.80	0.67	1.04	1.67	2.90	4.34	3.79	3.07	2.67	1.79	0.95	0.89	15.83
mean	0.64	0.53	0.83	1.39	2.39	3.42	3.07	2.74	2.23	1.43	0.82	0.66	13.87
1981 - 2010 Normals													
normal	0.66	0.56	0.87	0.99	2.86	3.74	2.81	3.08	2.33	1.94	1.00	0.78	14.81
Year-to-Year Data													
2016	0.30	0.62	0.74	1.59	3.55	5.09	5.98	3.30	4.01	1.15	1.01	1.95	21.93
2015	0.76	0.43	0.62	0.63	5.08	3.31	3.78	3.80	1.52	1.36	1.87	0.90	17.49
2014	1.03	0.34	0.69	3.49	2.71	6.69	3.26	2.61	1.93	0.65	0.18	0.37	17.20
2013	0.80	1.00	1.33	1.53	4.51	1.40	3.26	0.88	2.02	2.08	0.44	1.31	12.07
2012	0.46	0.82	1.33	1.36	1.48	2.96	1.28	1.62	0.18	4.08	0.84	0.32	7.52
2011	1.26	0.25	0.46	2.21	3.27	4.64	4.91	1.88	2.58	0.36	0.17	0.14	17.28
2010	0.71	0.71	1.04	1.18	5.59	4.94	2.87	2.45	6.27	2.89	0.79	0.58	22.12
2009	0.40	0.93	2.09	1.90	2.08	4.10	2.06	2.35	1.28	2.11	0.25	1.37	11.87
2008	0.21	0.75	0.60	0.72	0.99	3.92	2.06	4.30	2.87	3.47	2.69	1.82	14.14
2007	0.15	0.70	1.64	0.80	4.38	6.16	2.68	1.90	0.61	4.61	0.52	1.29	15.73
2006	0.99	0.83	1.78	0.61	2.77	0.94	0.87	6.77	1.93	1.45	0.49	1.05	13.28

Note: Warm Season = May through September. Retrieved August 24, 2017.

Blue values = wet (or greater than 70th percentile)

Green values = mid-range (30th–70th percentile)

Red values = dry (or less than 30th percentile)

3.3.3 Frost-Free Season Length

Along with patterns of average summer ambient temperatures, variations of the frost-free season length were examined. The frost-free season, as defined by the number of days between the last 32°F day of spring and the first 32°F day of autumn, were tabulated from Argyle, Minnesota (USC00210252), as shown in **Figure 3-7**. While the Argyle dataset was limited because of missing data, the long-term pattern generally indicates increasing frost-free periods. The dataset for the Agassiz Refuge (USC00210050) east of the Snake-Middle Rivers Watershed was also retrieved and plotted in **Figure 3-8**. The Agassiz Refuge data also indicate longer frost-free periods.

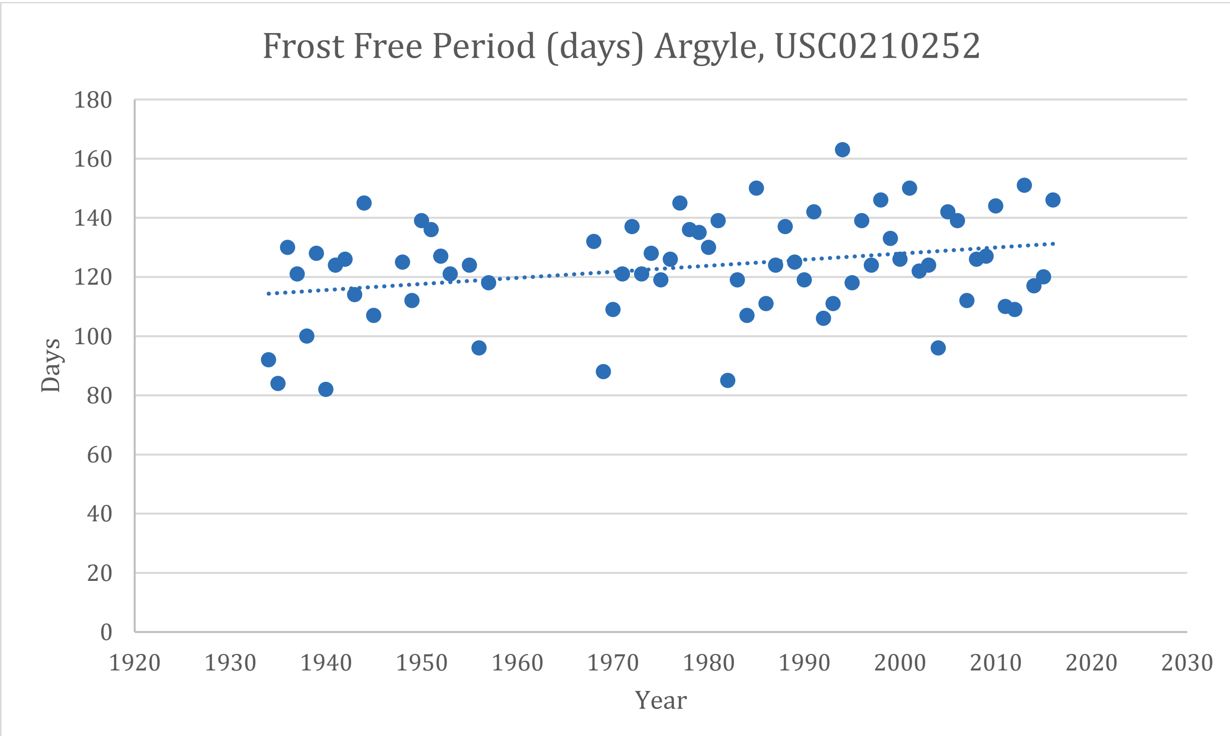

Figure 3-7. Frost-free period (days) for Argyle, Minnesota [Midwestern Regional Climate Center 2017].

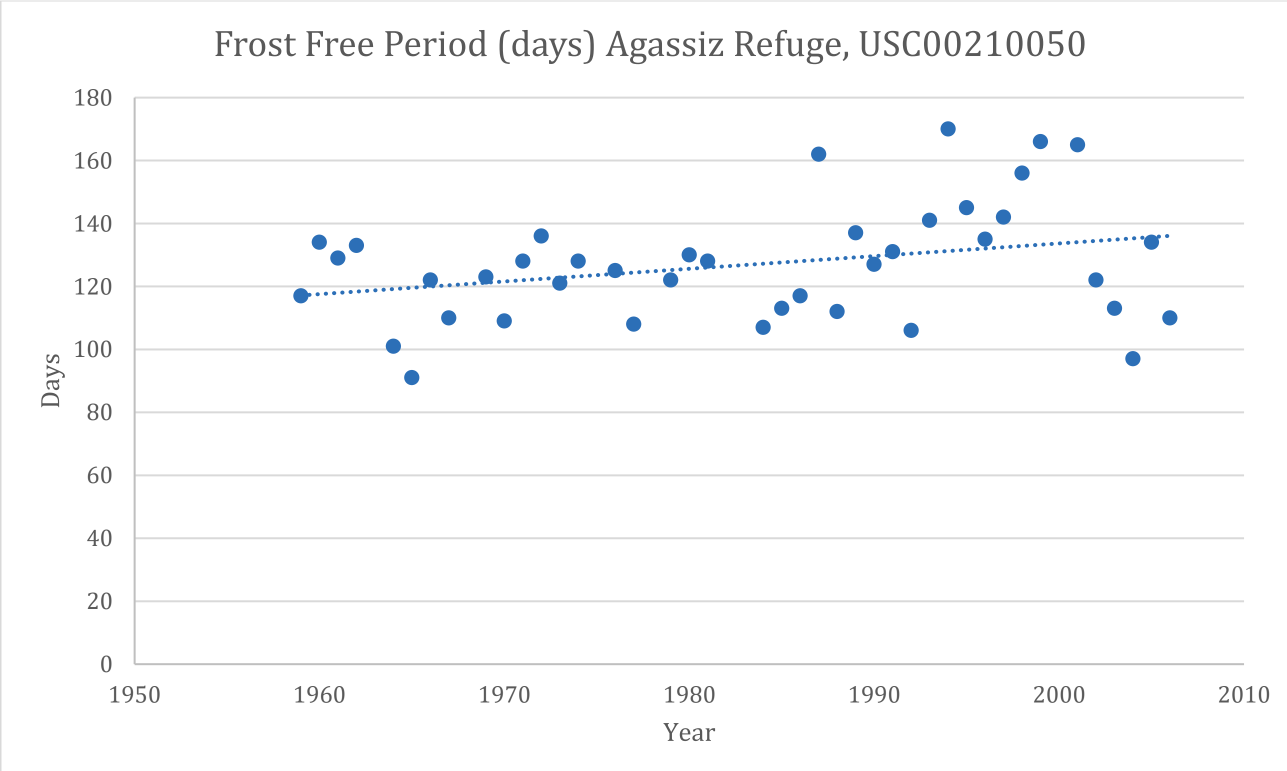

Figure 3-8. Frost-free period (days) for Agassiz Refuge [Midwestern Regional Climate Center 2017].

3.3.4 Evaporation

Free water surface evaporation is approximately 31 inches per year (in/yr) in the project area [Farnsworth and Thompson 1982].

3.3.5 Climate Summary

Subtle west to east gradients were noted across the Snake-Middle Rivers Watershed as defined by storm-precipitation intensities and durations, annual precipitation, evaporation, and frost-free periods, with higher levels in the eastern portion of the watershed. Growing-season runoff can be expected to be affected by wide variations of month-to-month rainfall amounts, increasing average temperatures, and storm intensities. Storm-precipitation intensities for the typical 24-hour storm and multiday wet periods can be substantial with potential wide-ranging impacts that affect communities, agricultural producers, streams, wetlands, and associated aquatic habitats. Collectively, these basic climate and hydrologic cycle components vary considerably between years and seasonally, which potentially results in wide ranges of watershed runoff and the associated runoff-pollutant dynamics that should be factored into future restoration/protection and monitoring program design considerations.

3.4 Watershed Characteristics

3.4.1 Subwatersheds

AUID, length, and drainage area are presented for the impaired reaches addressed in this TMDL in **Table 3-4**.

Table 3-4. Impaired reach lengths, locations, and watershed drainage areas.

Stream Name	Stream Reach AUID #	Reach Description	Pollutants Addressed	Reach Length (miles)	Drainage Area (acres)
Snake River	09020309-501	Middle R to Red R	Turbidity	10.35	492,660
	09020309-502	CD 3 to Middle R	Turbidity	11.16	268,916
	09020309-504	S Br Snake R to CD 7	Turbidity, *E. coli*	22.88	136,734
	09020309-537	T154 R49W S17, east line to CD 3	*E. coli*	14.91	211,279
	09020309-543	Unnamed Cr to S Br Snake R	*E. coli*	29.09	84,251
Middle River	09020309-540	Co Rd 114 to T156 R49W S3, north line	Turbidity	45.54	182,770
	09020309-541	T157 R49W S34, south line to Snake R	Turbidity	5.91	186,915

3.4.2 Land Cover

National Land Cover Database (NLCD) 2006 data were used to develop the Snake-Middle Rivers Watershed HSPF model and, for consistency, the TMDLs described herein. Land cover types, shown in **Figure 3-9**, for the Snake-Middle Rivers Watershed consist primarily of cultivated crops (78%), wetlands (7%), forest (6%), developed (5%), and pasture/hay (3%). Very little open water, grassland/herbaceous, shrub/scrub, and barren land exist in the Snake-Middle Rivers Watershed. NLCD 2006 land cover types by impaired drainage area are described in **Table 3-5**. A comparison between the NLCD 2006 and 2011 for the entire watershed showed very little change; for example, the greatest changes from the 2006 NLCD to the 2011 NLCD are that Emergent Herbaceous Wetlands increased by approximately 0.0262% and Pasture/Hay decreased by approximately 0.0435%.

Watershed soils and their distributions are important factors to consider, because soils can significantly affect runoff and its quality from particle sizes, nutrients, interflow, and infiltration/groundwater recharge. For this purpose, Hydrologic Soil Groups (HSGs), which are defined by the Natural Resource Center of the U.S. Department of Agriculture, were tabulated by four HSG soil groups (A, B, C, and D) and are summarized in **Table 3-6**. The project area consists of approximately 11% HSG A or A/D soils, 67% HSG B or B/D soils, 10% HSG C or C/D soils, and 12% HSG D soils (**Figure 3-10**), with most C/D soils occurring in the western portion of the watershed. Dual HSG classification soils (notably HSG A/D and B/D soils) behave as HSG D soils when undrained. The distribution of the different land covers, soil types, and aquatic ecoregions are foundational aspects that affect (1) runoff quantity and quality and (2) future implementation within the Snake-Middle Rivers Watershed.

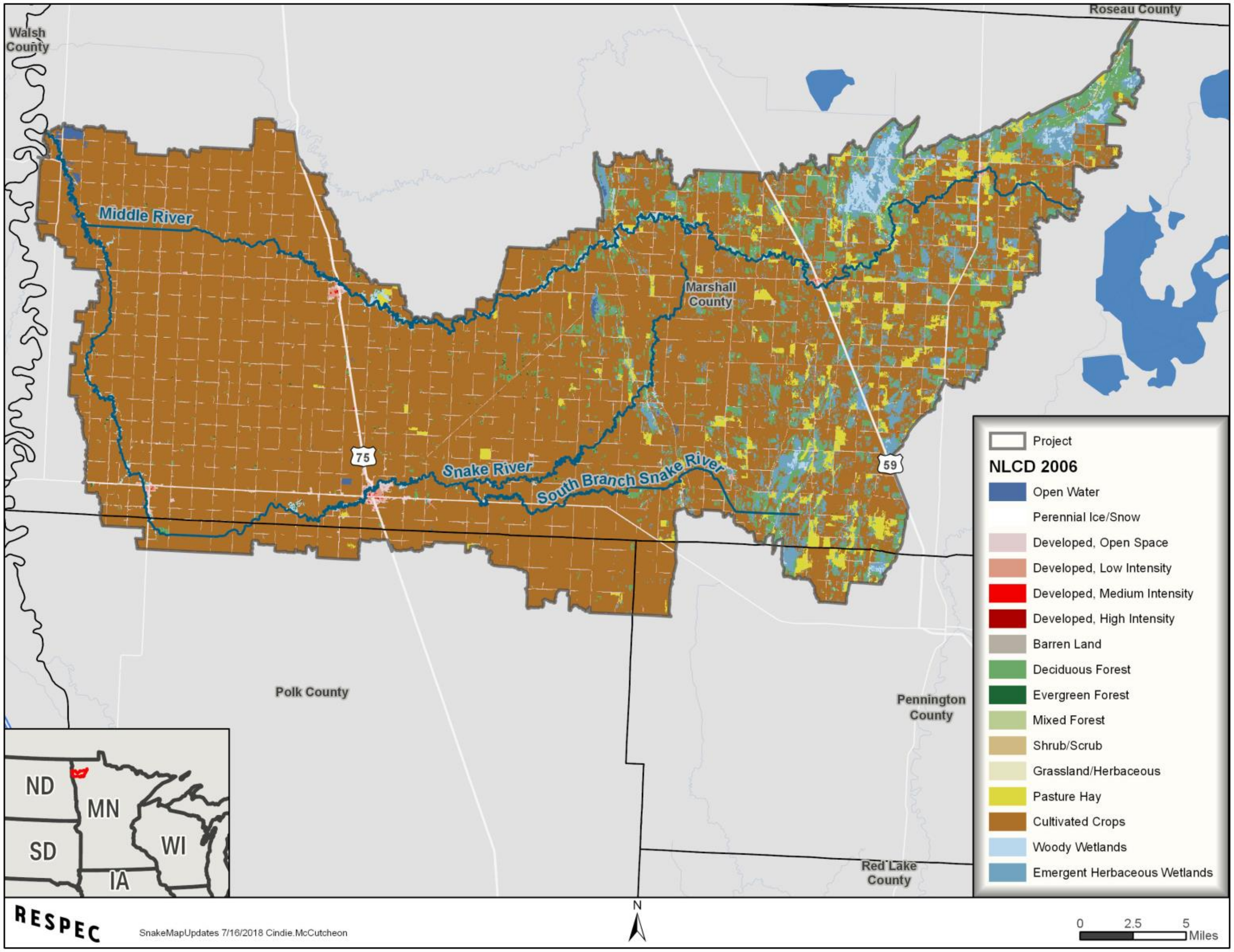

Figure 3-9. Land cover from the 2006 National Land Cover Database [Multi-Resolution Land Characteristics Consortium 2012].

Table 3-5. National Land Cover Dataset 2006 distribution by impaired stream.

Name	Lake/ Stream	Drainage Area (Sq. Miles)	Developed (%)	Forest (%)	Pasture/Hay (%)	Cultivated Crops (%)	Wetlands (%)	Other (%)
Snake River	Reach 501 (Entire Snake-Middle Rivers Watershed)	770	5	6	3	78	7	1
	Reach 502	420	5	3	2	86	3	1
	Reach 504	214	5	5	3	81	6	0
	Reach 537	330	5	3	2	85	4	1
	Reach 543	80	4	7	5	75	8	1
Middle River	Reach 540	286	5	10	5	64	15	1
	Reach 541	292	5	10	5	64	15	1

Table 3-6. General description of hydrologic soil groups [Natural Resources Conservation Service 2009].

Hydrologic Soil Group	Abbreviated Description
A Soils	Sand, sandy loams with high infiltration rates. Well-drained soils with high transmission.
B Soils	Silt loam or loam soils. Moderate infiltration, moderately drained.
C Soils	Sandy clay loams. Low infiltration rates, impedes water transmission.
D soils	Heavy soils, clay loams, silty, clay. Low infiltration rates that impedes water transmission.
Dual soils A/D, B/D, and C/D	Dual HSG classification soils (notably A/D, B/D, and C/D) behave as type D soils when undrained.

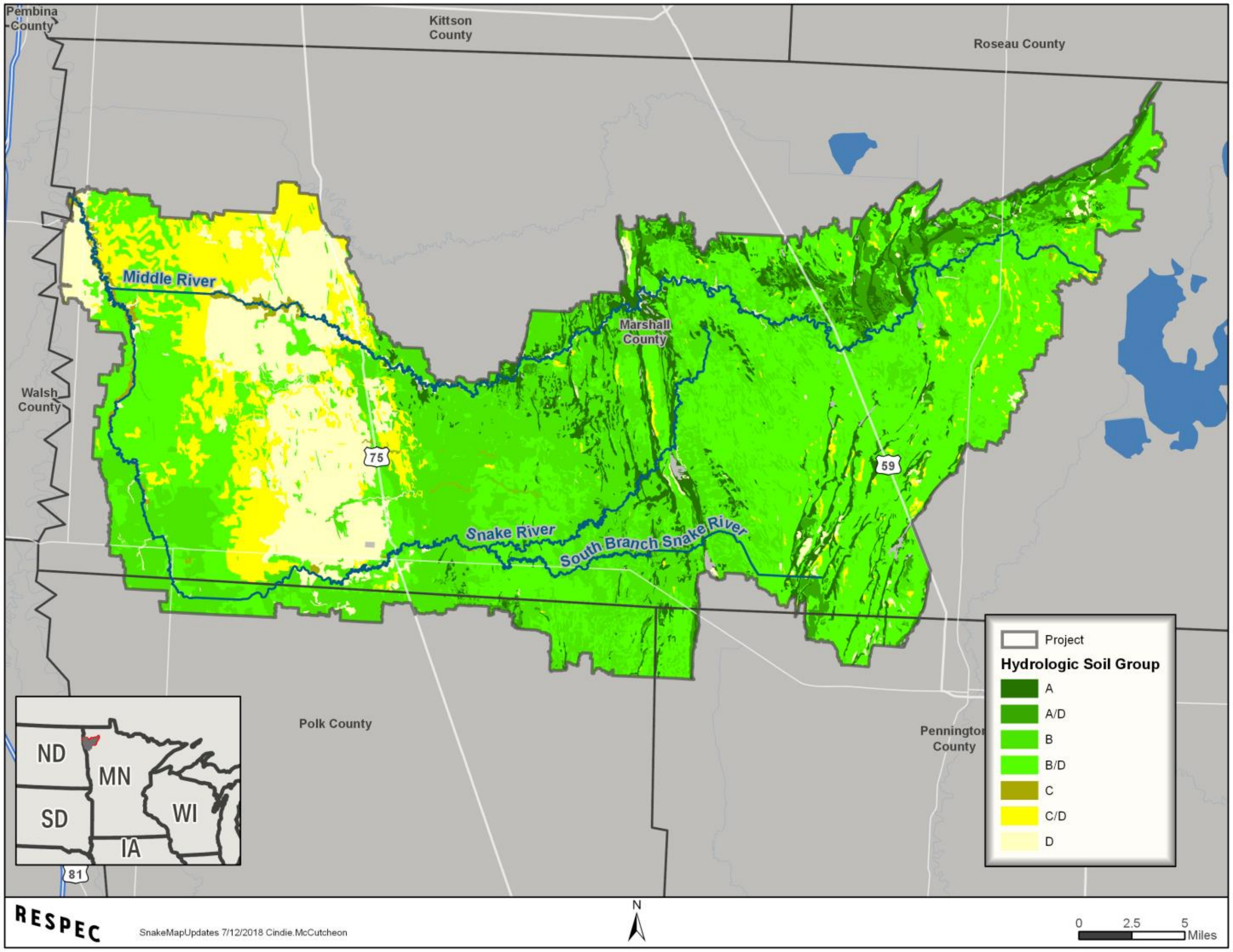

Figure 3-10. Hydrologic soil groups in the Snake-Middle Rivers Watershed.

3.5 Current/Historical Water Quality

3.5.1 Stream and Snake River Flows

Throughout the Snake-Middle Rivers Watershed, several county, regional, state, and federal entities have been actively involved in gathering and reporting stream and river discharge flow data for many years. Five stations throughout the Snake-Middle Rivers Watershed have discharge data available between 1995 and 2015. This dataset was used for calibrating the Snake-Middle Rivers Watershed hydrology model, which was the foundation of the TMDLs addressed in this report. **Table 3-7** summarizes available flow data by stream reach, years of data, and mean flows. A map of flow stations is included in **Appendix A**.

Table 3-7. Locations throughout the Snake-Middle Rivers Watershed with flow data available from 1996 to 2015.

Site	Description	First Year Available	Final Year Available	Number of Days With Flow	Mean Flow (cfs)
H68032002	Snake River near Radium, MN	2004	2008	1,006	18
H68031002	Snake River Above Warren, MN	2008	2015	2,605	52
H68006002	Snake River near Alvarado, MN	1996	1996	274	117
H68006001	Snake River at MN-1 Crossing in Alvarado	2004	2015	3,090	67
H68017001	Middle River at Argyle, MN	1996	2015	7,305	94

3.5.2 Water Quality

Water quality data were downloaded from the MPCA Environmental Quality Information System (EQuIS) database, and all analyses were based on the 10-year period from 2006 through 2015 in developing the stream TMDLs.

3.5.2.1 *E. coli*

E. coli data from 2006 through 2015 are summarized by stream reach in **Table 3-8**, which includes geometric mean concentrations by month for each impaired reach. Geometric means were above the 126 organisms per 100 milliliter (org/100 mL) standard for every reach during at least 1 month between April and October. Monthly samples are shown for *E. coli*-impaired Reaches 504, 537, and 543 of the Snake River in **Figure 3-11** through **Figure 3-13**, respectively. Monitoring sites for each impairment are shown in **Figure 1-2**.

Table 3-8. Observed monthly geometric mean *E. coli* data summary from 2006 through 2015 between April and October; months with 5 or more samples are shown in bold.

Impaired Reach (station IDs)	Description	Month	Number of Samples	Geometric Mean (org/100 mL)
504 (S003-101 and S004-214)	Snake River, S Br Snake R to CD 7	April	No Data	N/A
		May	3	73.3
		June	**10**	**69.0**
		July	**10**	**134.1**
		August	**9**	**92.9**
		September	1	517.2
		October	No Data	N/A
537 (S004-142)	Snake River, T154 R49W S17, east line to CD 3	April	No Data	N/A
		May	3	24.2
		June	**10**	**67.6**
		July	**10**	**115.7**
		August	**9**	**214.8**
		September	1	67.6
		October	No Data	N/A
543 (S004-152)	Snake River, Unnamed Cr to S Br Snake R	April	No Data	N/A
		May	3	9.7
		June	**5**	**51.7**
		July	**5**	**276.7**
		August	**5**	**173.6**
		September	1	44.1
		October	No Data	N/A

Geometric means shown in **bold** text have five or more samples during a month when the standard (126 org/100 mL) applies (April–October).

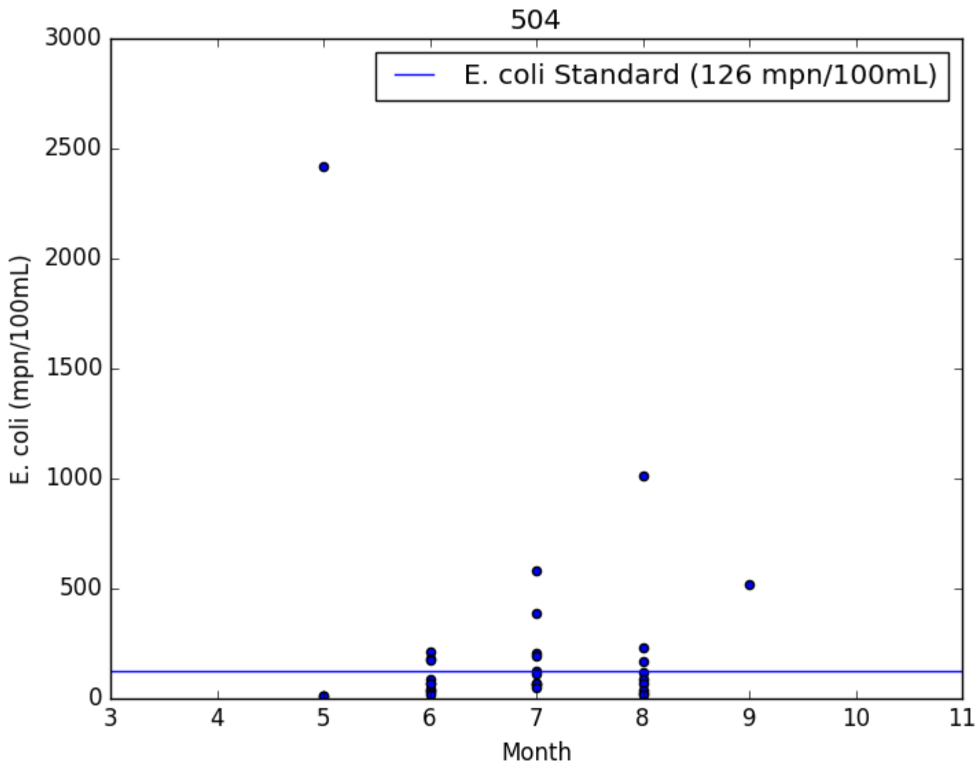

Figure 3-11. Single sample *E. coli* concentrations (*n*=33) by month in Reach 504 (stations S003-101 and S004-214) from 2006 through 2015.

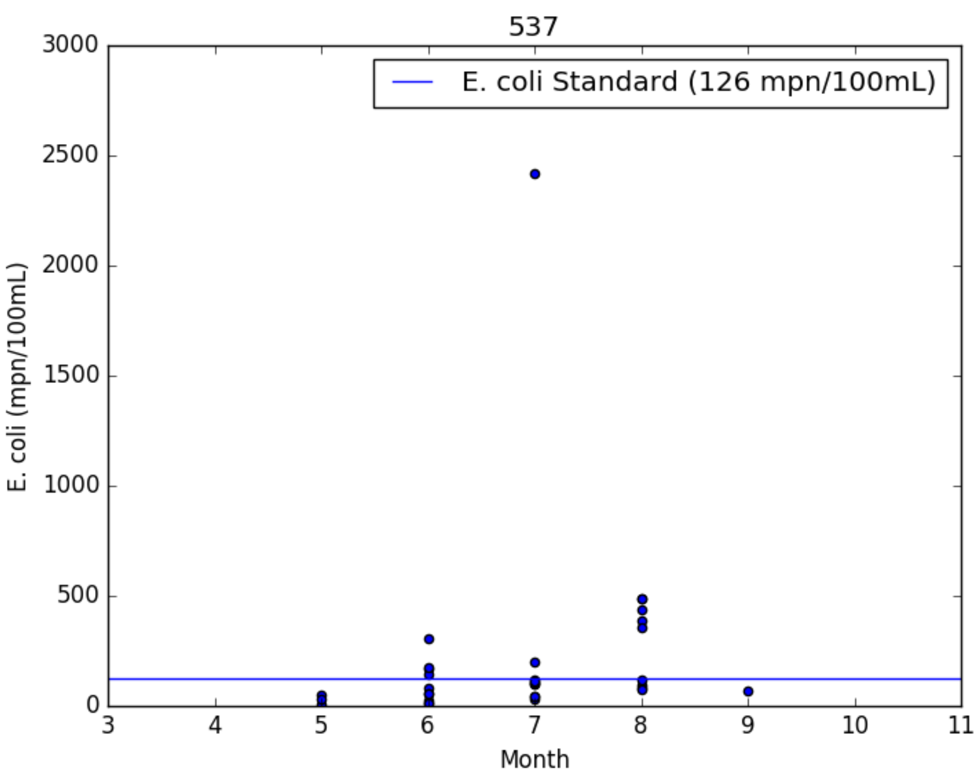

Figure 3-12. Single sample *E. coli* concentrations (*n*=33) month in Reach 537 (station S004-142) from 2006 through 2015.

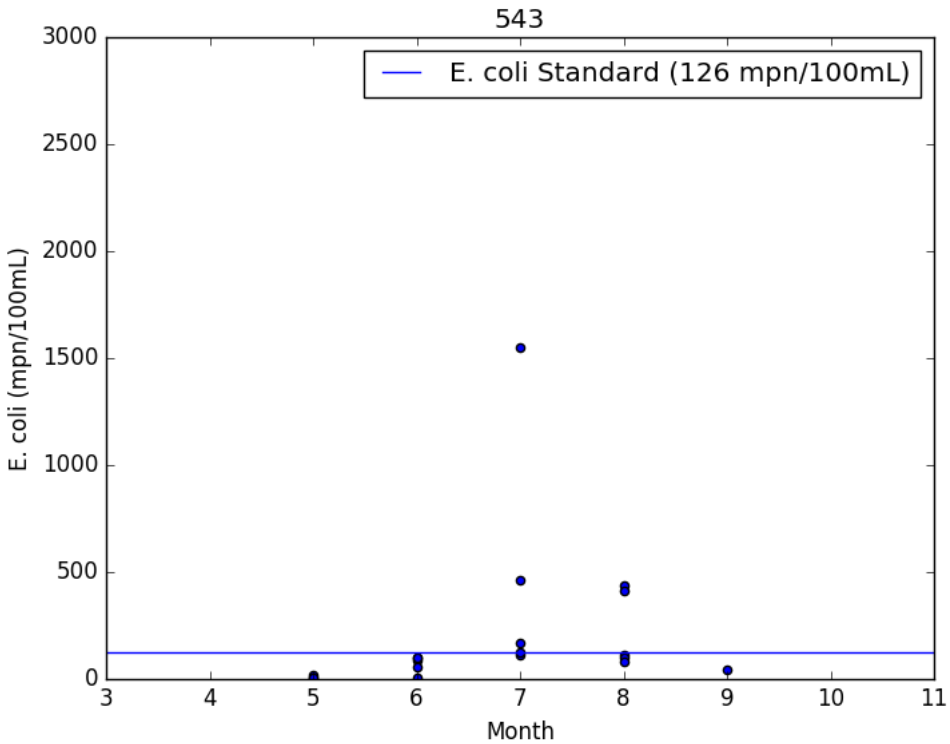

Figure 3-13. Single sample *E. coli* concentrations (*n*=19) by month in Reach 543 (station S004-152) from 2006 through 2015.

3.5.2.2 Total Suspended Solids

TSS data were summarized by site along each turbidity impairment by using April through September data from 2006 to 2015 (**Table 3-9**). **Figure 3-14** through **Figure 3-18** show the seasonal variation of TSS data at each TMDL reach. The locations of the reaches that are impaired by turbidity and the monitoring sites with TSS and/or turbidity data are shown in **Figure 1-3**.

Table 3-9. Observed TSS data summary from 2006 through 2015 between April and September.*

Impaired Reach (station IDs)	Description	Year	Count	Minimum TSS (mg/L)	Mean TSS (mg/L)	Maximum TSS (mg/L)
501 (S000-185)	Snake River, Middle R to Red R	2006	13	41	132.2	386
		2007	21	3.6	59.4	128
		2008	15	20	90.0	278
		2009	14	10	100.6	360
		2010	27	14	192.7	1750
		2011	11	8	64.2	276
		2012	7	34	49.6	76
		2013	30	11	88.1	352
		2014	24	7	133.0	768
		2015	26	14	291.2	868
502 (S003-692)	Snake River, CD 3 to Middle R	2006	10	43	93.7	206
		2013	10	9	28.7	59
504 (S002-994, S003-101, and S004-214)	Snake River, S Br Snake R to CD 7	2006	8	4	34.4	83
		2009	7	2	4.4	9
		2010	9	2	25.7	61
		2013	10	9	26.2	63
		2014	21	5	47.7	336
		2015	15	2	25.6	84
540 (S000-700 and S002-989)	Middle River, Co Rd 114 to T156 R49W S3, north line	2006	6	3	7.8	17
		2009	7	4	7.6	13
		2010	11	5	44.0	164
		2014	30	4	58.3	187
		2015	23	4	71.0	308
541 (S003-691)	Middle River, T157 R49W S34, south line to Snake R	2006	15	13	80.2	174
		2013	8	27	46.8	81
		2014	2	32	60.5	89

* Note that the TSS standard is 65 mg/L.

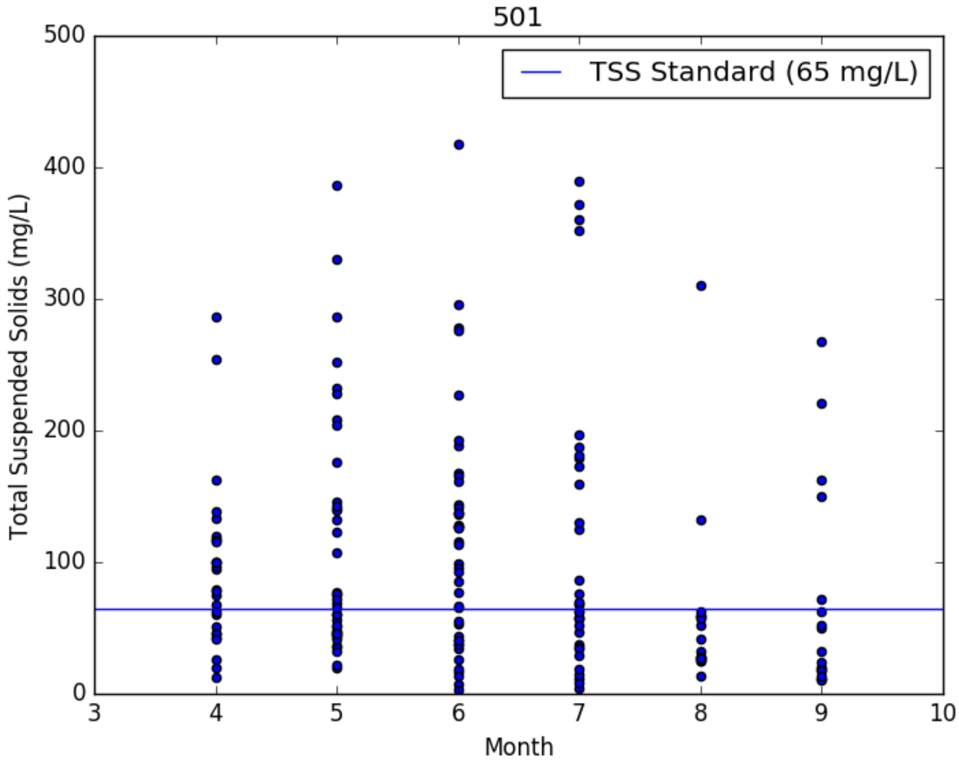

Figure 3-14. TSS results (*n*=188) by month in Reach 501 (station S000-185) from 2006 through 2015.

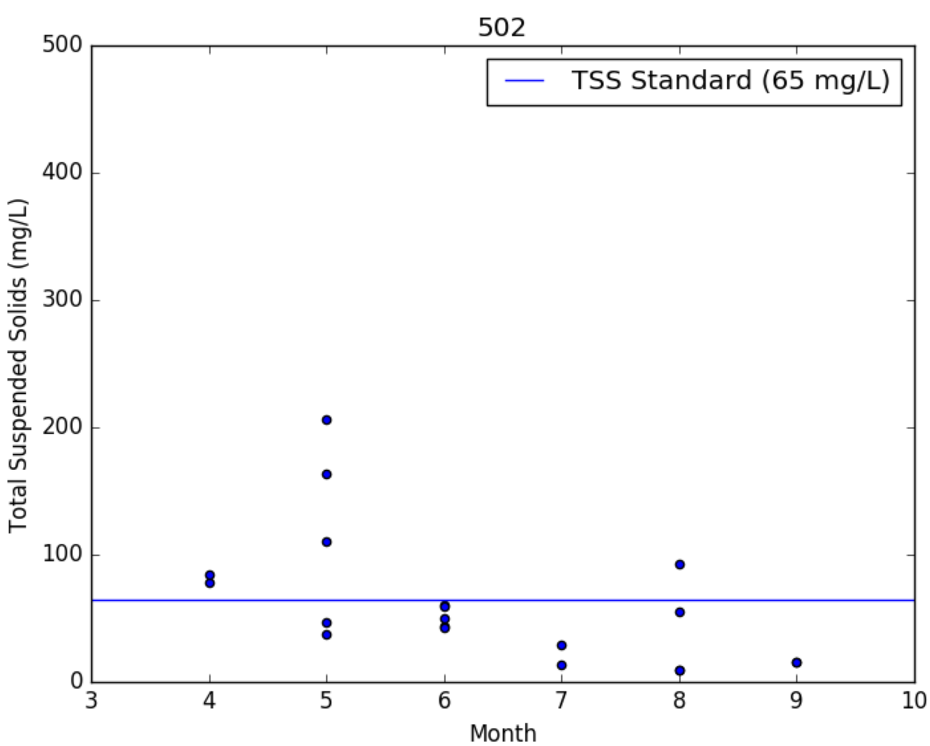

Figure 3-15. TSS results (*n*=20) by month in Reach 502 (station S003-692) from 2006 through 2015.

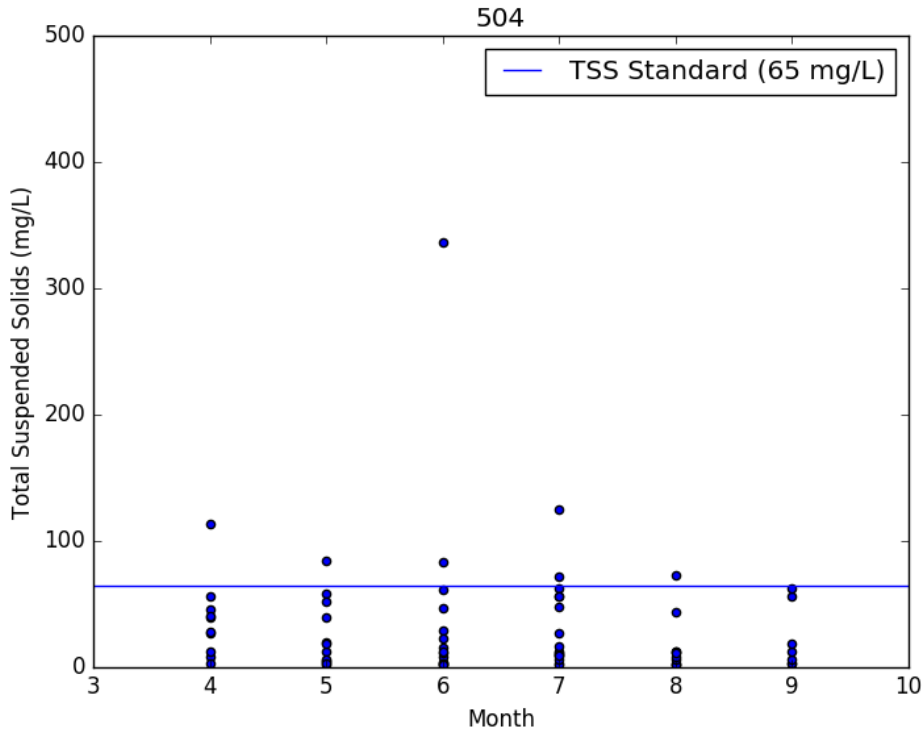

Figure 3-16. TSS results (*n*=70) by month in Reach 504 (stations S002-994, S003-101, S004-214) from 2006 through 2015.

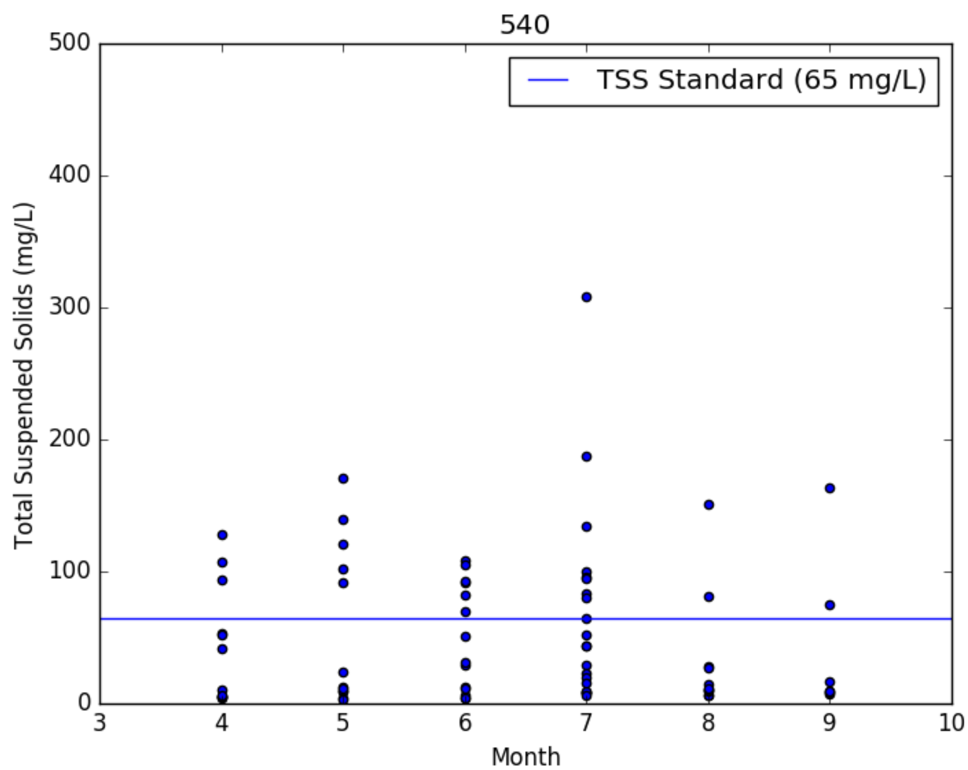

Figure 3-17. TSS results (*n*=77) by month in Reach 540 (stations S000-700, S002-989) from 2006 through 2015.

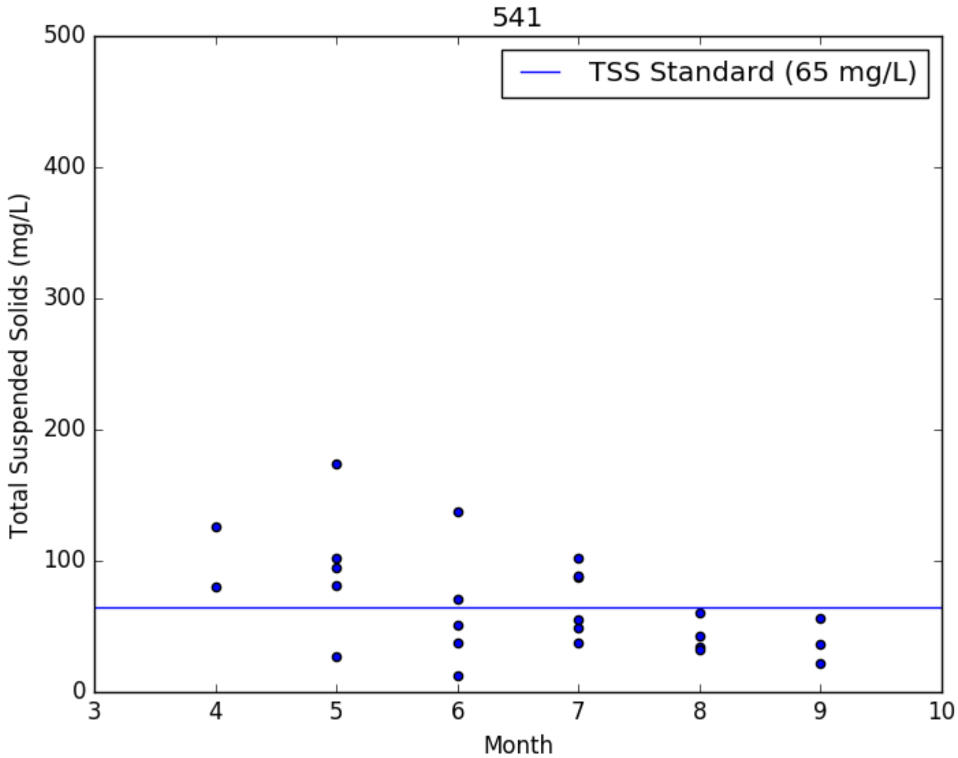

Figure 3-18. TSS results (*n*=25) by month in Reach 541 (station S003-691) from 2006 through 2015.

3.6 HSPF Model Methodology

HSPF is a comprehensive watershed computer model of hydrology and water quality, which includes modeling surface and subsurface hydrologic and water quality processes, which are linked and closely integrated with corresponding stream and reservoir processes. The framework can be used to determine the critical environmental conditions (e.g., certain flows or seasons) for the impaired segments by providing continuous flows and pollutant loads at any point within the system. HSPF simulates the fate and transport of modeled pollutants and can simulate subsurface concentrations in addition to surface concentrations (where appropriate). For this project, HSPF was used to assess sources and to determine the loading capacity and current loads of TSS. HSPF-generated flows were also used to generate flows for *E. coli*-loading capacities. The following sections provide more detail on the source-assessment approach as well as the quantitative results of the source load assessment.

The primary components of developing an HSPF model application include the following:

- Gathering and developing time-series data
- Characterizing and segmenting the watershed
- Calibrating and validating the model.

Each of these components is described in the following sections.

3.6.1 Gathering and Developing Time-Series Data

Data requirements for developing and calibrating an HSPF model application are both spatially and temporally extensive. The modeling period was from 1995 through 2015. Time-series data used in developing the model application included meteorological data, atmospheric deposition data, and point-source data. Precipitation, potential evapotranspiration, air temperature, wind speed, solar radiation, dew-point temperature, and cloud cover data are needed for HSPF to simulate hydrology (including snow-related processes).

3.6.2 Characterizing and Segmenting the Watershed

The Snake-Middle Rivers Watershed was delineated into 106 subwatersheds to capture hydrologic and water quality variability. The watershed was then segmented into individual land and channel pieces that are assumed to demonstrate relatively homogeneous hydrologic, hydraulic, and water quality characteristics. This segmentation provides the basis for assigning inputs and/or parameter values or functions to remaining portions of a land area or channel length contained in a model segment. The individual land and channel segments are linked together to represent the entire project area.

The land segmentation was defined by land cover. Land use and land cover affect the hydrologic and water quality response of a watershed through their impact on infiltration, surface runoff, and water losses from evapotranspiration. Water that moves through the system is affected by land cover. Land use (as estimated by land cover) affects the rate of the pollutant accumulation, because certain land uses often support different pollutant sources.

The NLCD 2006 land cover categories, which are summarized in **Table 3-10**, were combined into six groups with similar characteristics. The urban categories were divided into pervious and impervious areas based on an estimated percentage of effective impervious area. The term “effective” implies that the impervious region is directly connected to a local hydraulic conveyance system (e.g., open channel and river), and the resultant overland flow will not run onto pervious areas but will directly enter the reach network.

The channel segmentation considers river travel time, riverbed slope continuity, temporal and spatial cross section, morphologic changes or obstructions, the confluence of tributaries, impaired reaches, and locations of flow and water quality calibration and verification gages. After the reach network was segmented, the hydraulic characteristics of each reach were computed, and the areas of the land cover categories that drain to each reach were calculated. Reach hydraulics are specified by a reach function table (F-table), which is an expanded rating curve that contains the reach surface area, volume, and discharge as functions of depth. F-tables were developed for each reach segment by using channel cross-sectional data. Unsurveyed tributaries were assigned the geometry of hydraulically similar channels.

Table 3-10. Land cover category aggregation [Multi-Resolution Land Characteristics Consortium 2012].

NLCD Categories	Percent of Snake River Watershed (%)	Model Category	Percent of Snake-Middle Rivers Watershed (%)
Developed, Open Space	4.3	Developed	4.9
Developed, Low Intensity	0.6		
Developed, Medium Intensity	0.0		
Developed, High Intensity	0.0		
Barren Land	0.0	Grassland	0.2
Shrub/Scrub	0.1		
Grassland/Herbaceous	0.1		
Deciduous Forest	5.6	Forest	5.7
Evergreen Forest	0.1		
Mixed Forest	0.0		
Pasture/Hay	3.0	Pasture	3.0
Cultivated Crops	78.4	Cropland	78.4
Woody Wetlands	2.0	Wetland	7.8
Herbaceous Wetlands	5.4		
Open Water	0.4		

3.6.3 Calibrating and Validating the HSPF Model

Model calibration involved hydrologic and water quality calibration by using observed flow and water quality data to compare to simulated results. Because water quality simulations depend highly on watershed hydrology, the hydrology calibration was completed first, followed by the sediment calibration, the temperature calibration, and finally the nutrient/oxygen/Chlorophyll-*a* (Chl-*a*) calibration. The stream-discharge sites with time-series data were used for the calibration and validation. Data from all but the first year of the simulation period were used to calibrate the model. The initial year (1995) was simulated for the model to adjust to existing conditions. The 20-year simulation period included a range of dry and wet years. This range of precipitation improves the model calibration and validation, and provides a model application that can simulate hydrology and water quality during a broad range of climatic conditions.

Hydrologic calibration is an iterative process intended to match simulated flow to observed flow by methodically adjusting model parameters. HSPF hydrologic calibration is divided into the following four sequential phases of adjusting parameters to improve model performance:

- Annual runoff;
- Seasonal or monthly runoff;
- Low- and high-flow distribution; and
- Individual storm hydrographs.

By iteratively adjusting calibration parameters within accepted ranges, the simulation results are improved until an acceptable comparison of simulated results and measured data is achieved. The procedures and parameter adjustments involved in these phases are more completely described in Donigian et al. [1984] and Lumb et al. [1994].

The hydrology calibration was evaluated using a weight-of-evidence approach based on a variety of graphical comparisons and statistical tests. The performance criteria are described in more detail in Donigian [2002]. Graphical comparisons included monthly and average flow volume comparisons, daily time-series data comparisons, and flow duration plots. Statistical tests included annual and monthly runoff errors, low-flow and high-flow distribution errors, and storm volume and peak flow errors. The flow calibration time series from Snake River at MN-1 Crossing in Alvarado is shown in **Figure 3-19**.

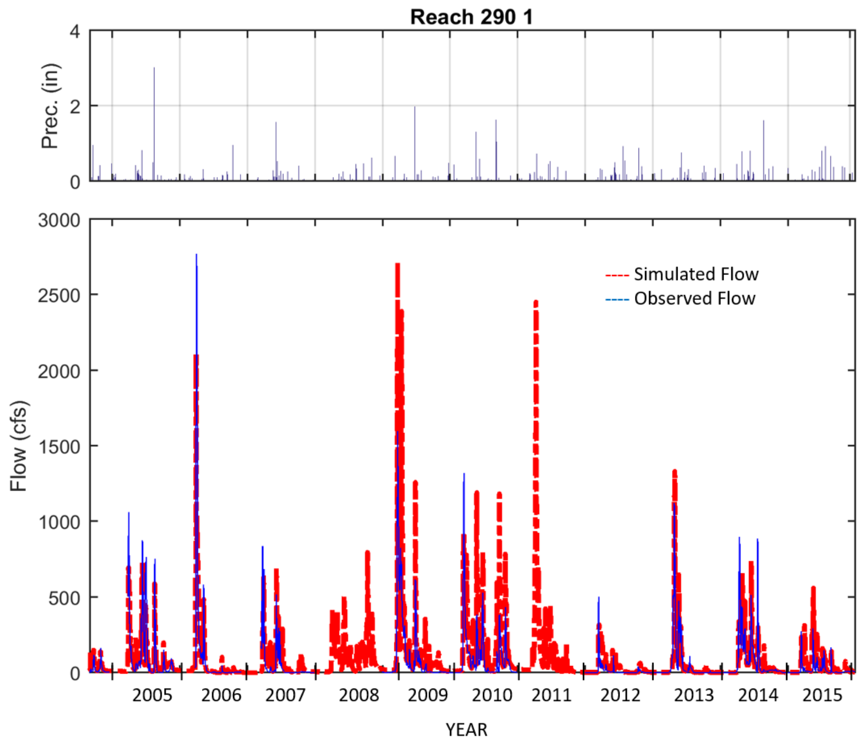

Figure 3-19. Flow time series at station H68006001.

The water quality calibration optimized alignment between the loads that are predicted to be transported throughout the system and the observed in-stream concentrations. Water quality data from monitoring sites were used to calibrate the model to observed conditions. Many parameters can be adjusted to calibrate water quality loads and concentrations. A TSS monthly concentration calibration plot from Snake River at MN-1 Crossing in Alvarado is shown in **Figure 3-20**. More detailed information on the HSPF model application and model calibration results (hydrology and water quality) can be found in the Snake-Middle Rivers Watershed project modeling memorandum [Burke 2017].

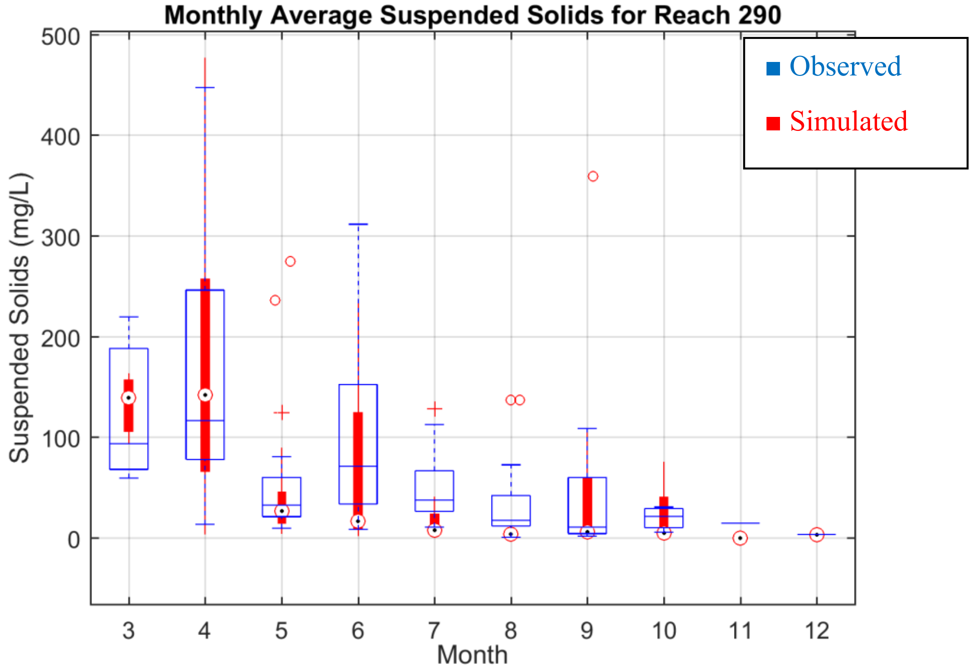

Figure 3-20. TSS monthly average plots at station H68006001.

3.7 Pollutant Source Summary

Pollutant sources are summarized for *E. coli* and TSS impairments in the following sections. *E. coli* that was produced in each impaired stream drainage area was estimated by source by using a GIS approach, while the sources of TSS were estimated by using the Snake River HSPF model application.

3.7.1 *E. coli*

Sources of bacteria-to-stream impairments can include livestock, wildlife, human, and pet sources. Bacteria from human and animal waste are naturally dispersed throughout the landscape, spread by humans, and/or treated in facilities. Once the bacteria are in the environment, their accumulation and delivery to the stream is affected by die-off and decay, surface imperviousness, detention time, ultraviolet exposure, and other mechanisms.

3.7.1.1 Permitted

Detailed information about specific permitted *E. coli* sources is included in **Section 4** of this TMDL report. There are three discharging NPDES/SDS permitted point sources located in the Snake-Middle Rivers Watershed that drain to an *E. coli*-impaired reach. Effluent from wastewater treatment facilities (WWTFs) is monitored and regulated, but contributes an allowable amount of *E. coli* to the stream. A map of point sources is included in **Appendix A**.

One concentrated animal feeding operation (CAFO) with turkeys is in the area that drains to the two downstream *E. coli* impaired reaches (Reaches 504 and 537). CAFOs are generally not allowed to discharge to surface water except in the event of chronic or catastrophic precipitation, but manure from liquid manure storage areas or dry manure stockpiles can be spread locally and can be washed off during precipitation events to contribute to impairments. A map of animal feedlots and the CAFO is included in **Appendix A**.

No Municipal Separate Storm Sewer Systems (MS4s) are located in the Snake-Middle Rivers Watershed.

Land application of biosolids from WWTFs was not included in these TMDLs as a source of bacteria, because all of the WWTFs in the watershed are stabilization pond systems, which do not normally remove and spread biosolids.

E. coli is not typically contributed from construction stormwater. Also, no benchmark monitoring of bacteria or *E. coli* are required with industrial permits, and *E. coli* is not typically contributed from industrial stormwater.

3.7.1.2 Nonpermitted

Manure from livestock is a potential nonpermitted source of bacteria to streams. Livestock directly contribute bacteria loads by defecating in the stream and indirectly by defecating on cropland or pastures where bacteria can be washed off during precipitation events, snowmelt, or irrigation. Spreading livestock manure on cropland or pasture also can contribute *E. coli* to waterbodies. Livestock in the project area mainly include cattle, poultry, hogs, horses, sheep, and goats. Livestock are grazed and/or confined in the areas that drain to *E. coli*-impaired waterbodies. Approximately 40 active animal feedlots are within the watersheds of impaired reaches.

Wildlife (including waterfowl and large-game species) also directly contribute bacteria loads by defecating while wading or swimming in the stream, and indirectly contribute by defecating on lands that produce stormwater runoff during precipitation events. According to the Clean Water Legacy Act (CWLA), natural background means characteristics of the waterbody that result from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the physical, chemical, or biological conditions in a waterbody, but does not include measurable and distinguishable pollution that is attributable to human activity or influence. Bacteria loads from wildlife are generally considered natural background. Some BMPs that reduce loads from livestock and other sources can also reduce loads from wildlife.

Human bacteria sources in urban settings can include cross connections between sanitary sewers and storm drain systems, leaks or overflows from sanitary sewer systems, and wet-weather discharges from centralized wastewater collection and treatment facilities. Outside of city domestic wastewater coverage areas, septic systems can be a potential human source of bacteria loads. Pet waste is another potential source of bacteria from nonregulated communities in a watershed.

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 stormsewer sediment in Michigan [Marino and Gannon 1991].

3.7.1.3 Sources Assessment

A GIS-based assessment was completed within each impaired drainage area to estimate populations of livestock, wildlife, humans, and pets. Animal populations were multiplied by average excretion rates obtained from the scientific literature. Reported literature values for fecal coliform excretion were converted to *E. coli* excretion by using a fecal coliform to *E. coli* ratio of 200:126 org/100 mL. Annual excretion estimates for livestock (excluding hogs) and wildlife were obtained from the *Bacteria Source Load Calculator: A Tool for Bacteria Source Characterization for Watershed Management* [Zeckoski et al. 2005], and bacterial estimates for humans and hogs were obtained from *Wastewater Engineering: Treatment, Disposal, Reuse* [Metcalf and Eddy 1991]. Annual excretion rates for dogs and cats were from *Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, New Brunswick and Freeport, Maine* [Horsley and Witten, Inc. 1996].

Domestic wastewater sewers within each *E. coli*-impaired drainage area were estimated by summing the 2010 population for all 2010 Census Block Centroid Population points that fall within urban areas that have a WWTF. Points located within the urban areas were assumed to be connected to the WWTFs in applicable impairment drainage areas.

The number of people who use septic systems was estimated by summing the 2010 population for all 2010 Census Block Centroid Population points that fall outside of urban areas that have a WWTF.

Pet populations were estimated by summing the households from the 2010 Census Block Centroid Population points within each applicable impairment drainage area and assuming 0.58 dogs (36.5% of households times 1.6 dogs per household) and 0.64 cats (30.4% of households times 2.1 cats per household) per household [American Veterinary Medical Association 2016].

The most recent MPCA feedlot data layer (downloaded June 22, 2017) at the time of the analysis with Animal Counts and Animal Units was obtained from the Minnesota Geospatial Commons. The layer was spatially joined to the drainage area of the impaired reaches, and the total number of birds, bovines, goats/sheep, horses, and pigs from active feedlots was calculated.

Deer were estimated by using average deer densities in deer-permit area boundaries. Boundaries and densities were provided from DNR [Norton 2017]. Ducks and geese were estimated from the DNR and US Fish and Wildlife Service *2016 Waterfowl Breeding Population Survey and Subwatershed Waterbody Densities*. The *2016 Waterfowl Breeding Population Survey* was downloaded from the DNR [2016]. Coots and swans were also estimated. Coots were included in the duck population, while swans were included in the geese population. Small mammals such as beaver, muskrat, and mink, as well as other birds such as swallows are difficult to estimate but also contribute to the wildlife bacteria.

Table 3-11 shows the total number (head) of each animal estimated for the purposes of this TMDL report, the amount of bacteria produced by each animal per day, and the literature source that was used to estimate the amount of bacteria produced by each animal per day. In some cases, such as sheep and goats, the number was an average of the amount produced by sheep and goats, because the number of each animal individually in the watershed is unknown.

Table 3- shows estimated bacteria produced within the drainage area of each impaired stream from each animal and the percent that it makes up.

The areas that drain to the most upstream *E. coli*-impaired reach (Reach 543) are included in the areas that drain to the middle *E. coli*-impaired reach (Reach 504). Both the areas that drain to the most upstream and the middle *E. coli*-impaired reaches are included in the total area that drains to the most downstream *E. coli*-impaired reach (Reach 537).

A majority of the bacteria that is produced in the drainage area of the most upstream Reach 543 (72%) is produced by cattle. Sheep/goats produce 17% of the bacteria that drain to Reach 543, and waterfowl produce 7% of the bacteria in the area that drains to Reach 543. The remainder of the bacteria produced in the area that drains to Reach 543 is produced by humans, dogs, cats, and deer.

In the drainage area of the middle *E. coli*-impaired Reach (504), slightly less of the bacteria produced is from cattle (54%), while 13% is produced by poultry, 15% is produced by humans and their pets, and 8% is produced by waterfowl. The remaining bacteria produced in the drainage area of Reach 504 is from sheep/goats, horses, and deer.

Approximately 52% of the bacteria produced in the drainage area of the most downstream *E. coli*-impaired drainage area is produced by cattle, 18% is produced by humans and their pets, 11% is produced by poultry, and 10% is produced by waterfowl.

The remaining bacteria produced in the watershed is from sheep/goats, deer, and horses. These estimates provide watershed managers with the relative magnitudes of total production by source and do not account for wash-off availability, delivery to the impaired reach or in-stream growth, or die-off dynamics.

Table 3-11. Total number of each animal producing bacteria in drainage area and bacteria production rates.

Impaired Reach	Total Humans		Total Pets		Total Livestock					Total Wildlife		
	Wastewater Treatment Plant	Subsurface Sewage Treatment Systems	Cats	Dogs	Cattle	Horses	Poultry	Sheep/ Goats	Hogs	Deer	Ducks	Geese
Snake River Reach 543, Unnamed Cr to S Br Snake R	0	241	60	55	740	0	0	279	10	1332	801	348
Snake River Reach 504, S Br Snake R to CD 7	1551	908	661	605	1,191	18	100,000	279	10	2894	2145	931
Snake River Reach 537, T154 R49W S17, east line to CD 3	2022	1263	866	793	1,306	18	100,000	279	10	3486	2996	1293
Bacteria Production Rate (org/day/head)	1.3E+09	1.3E+09	3.1E+09	3.2E+09	2.1E+10	2.6E+10	5.9E+07	1.3E+10	5.6E+09	2.2E+08	1.5E+09	5.0E+08
Source of Bacteria Production Rate	[Metcalf and Eddy 1991]		[Horsley and Witten, Inc. 1996]		[Zeckoski et al. 2005]				[Metcalf and Eddy 1991]	[Zeckoski et al. 2005]		

Table 3-12. Percent of bacteria produced in each impaired stream drainage area by source.

Impaired Reach		Total Humans		Total Pets		Total Livestock					Total Wildlife		
		Wastewater Treatment Facility	Subsurface Sewage Treatment Systems	Cats	Dogs	Cattle	Horses	Poultry	Sheep/ Goats	Hogs	Deer	Ducks	Geese
Snake River Reach 543, Unnamed Cr to S Br Snake R	Total Bacteria Produced (org/day)	0.0E+00	3.0E+11	1.9E+11	1.7E+11	1.5E+13	0.0E+00	0.0E+00	3.5E+12	5.6E+10	2.9E+11	1.2E+12	1.8E+11
Snake River Reach 504, S Br Snake R to CD 7		2.0E+12	1.1E+12	2.1E+12	1.9E+12	2.5E+13	4.8E+11	5.9E+12	3.5E+12	5.6E+10	6.4E+11	3.2E+12	4.7E+11
Snake River Reach 537, T154 R49W S17, east line to CD 3		2.5E+12	1.6E+12	2.7E+12	2.5E+12	2.7E+13	4.8E+11	5.9E+12	3.5E+12	5.6E+10	7.7E+11	4.5E+12	6.5E+11
Snake River Reach 543, Unnamed Cr to S Br Snake R	Percent of Total Bacteria Produced (%)	0	1	1	1	72	0	0	17	0	1	6	1
Snake River Reach 504, S Br Snake R to CD 7		4	2	5	4	54	1	13	8	0	1	7	1
Snake River Reach 537, T154 R49W S17, east line to CD 3		5	3	5	5	52	1	11	7	0	1	9	1

3.7.2 Total Suspended Solids

Sources of TSS to stream impairments can include overland flow during large storm events, in-stream bed/bank scour, and point sources.

3.7.2.1 Permitted

Detailed information about specific permitted TSS sources is included in **Section 4.3.2** of this TMDL. All of the seven discharging permitted point sources located in the Snake-Middle Rivers Watershed drain to a TSS-impaired reach. Effluent from WWTFs is monitored and regulated, but does contribute an allowable amount of TSS to the stream. A map of point sources in the Snake-Middle Rivers Watershed is included in **Appendix A**. One CAFO in the area drains to the turbidity-impaired Reaches 501, 502, and 504. CAFOs are generally not allowed to discharge to surface water except in the event of chronic or catastrophic precipitation. A map of animal feedlots and the CAFO is included in **Appendix A**. No MS4s are located in the Snake-Middle Rivers Watershed. Industrial and construction stormwater contribute a relatively small amount to TSS in watersheds through erosion and wash-off during rainfall events.

3.7.2.2 Nonpermitted

Nonpoint sources of sediment generally come from surface runoff, bed and bank erosion, cropland erosion, and erosion from small construction projects. Additionally, feedlots often have bare ground that could be prone to contribute sediment to impaired streams during rainfall events. Natural background sediment occurs from natural background runoff, especially when local soils are composed of very fine clays.

3.7.2.3 Potential Sources

The HSPF model was used to determine the contribution of TSS from identified sources to each sediment-impaired reach. Source-assessment modeling results were summarized by using the following categories: bed/bank, high-till cropland, low till cropland, developed land, pasture, grassland, forest, and point sources. The pie charts shown in **Figure 3-21** through **Figure 3-25** were produced at each of the five TMDL endpoints to show the land cover of the drainage area (pie charts on the left) and the relative contribution of each source from the HSPF model (pie charts on the right). All impaired reaches showed bed and bank to be the primary source of sediment, followed by conventional (high-till) cropland. Developed lands contributed 3% or less of sediment for all impaired reaches. Bed/bank sediment erosion can increase from practices that increase “flashiness” of the system such as straightening of channels (ditches), tile drainage, and runoff from impervious urban land.

According to the MSTRWD [2011], the Snake River has a “flashy” flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge. Groshens [2007] attributed the river’s flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. Straightened natural channels and ditching shorten the distance water must flow and thereby increase the slope of the stream and increase flow velocities. The extreme high-flow events are large contributors to bed and bank sediment throughout the watershed. **Figure 3-21** through **Figure 3-25** align with the results of the stressor ID report and the geomorphology assessment. Brief summaries of the stressor ID report and geomorphology assessment for each impaired reach are summarized below.

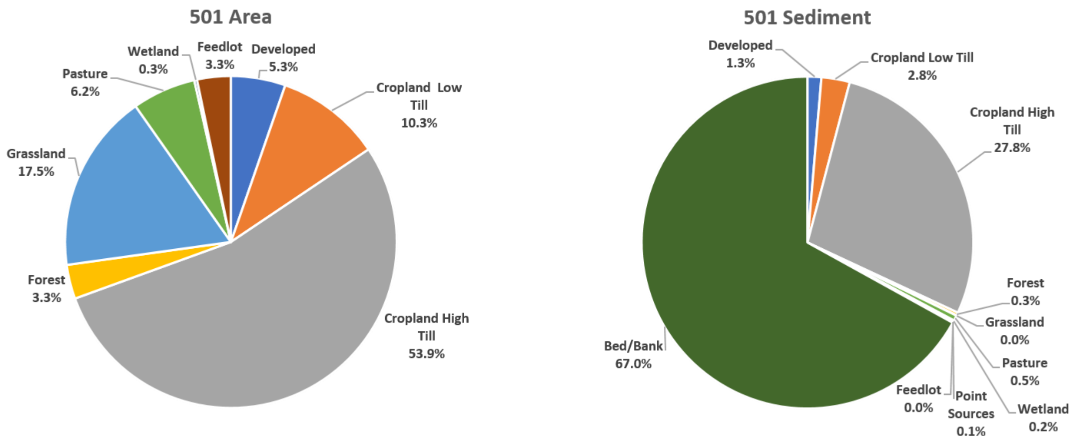

Figure 3-21. Land cover of drainage area (left) and TSS source-assessment modeling results (right) for impaired Reach 501.

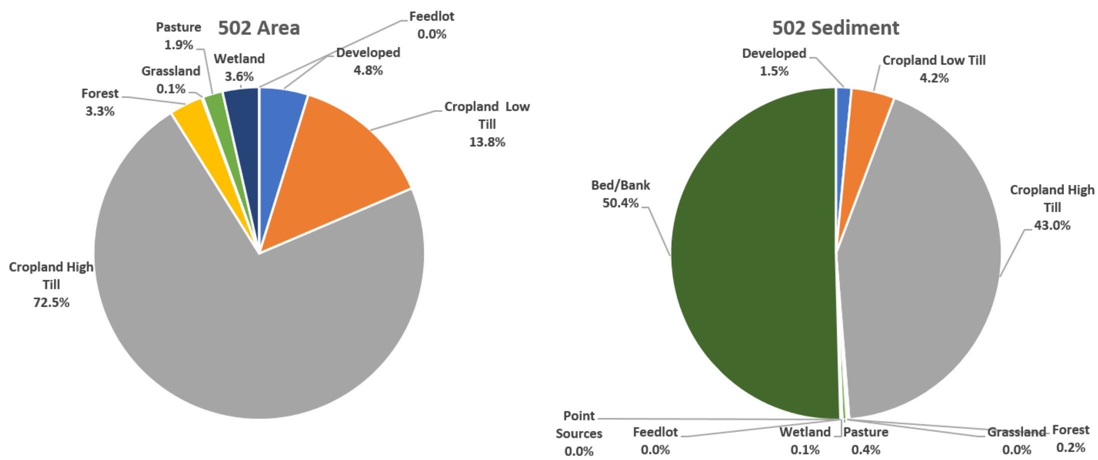

Figure 3-22. Land cover of drainage area (left) and TSS source-assessment modeling results (right) for impaired Reach 502.

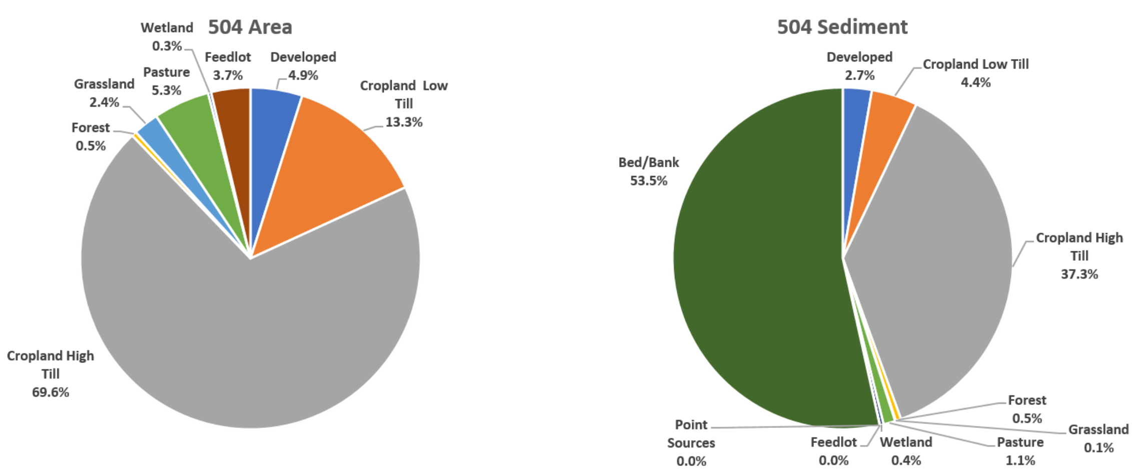

Figure 3-23. Land cover of drainage area (left) and TSS source-assessment modeling results (right) for impaired Reach 504.

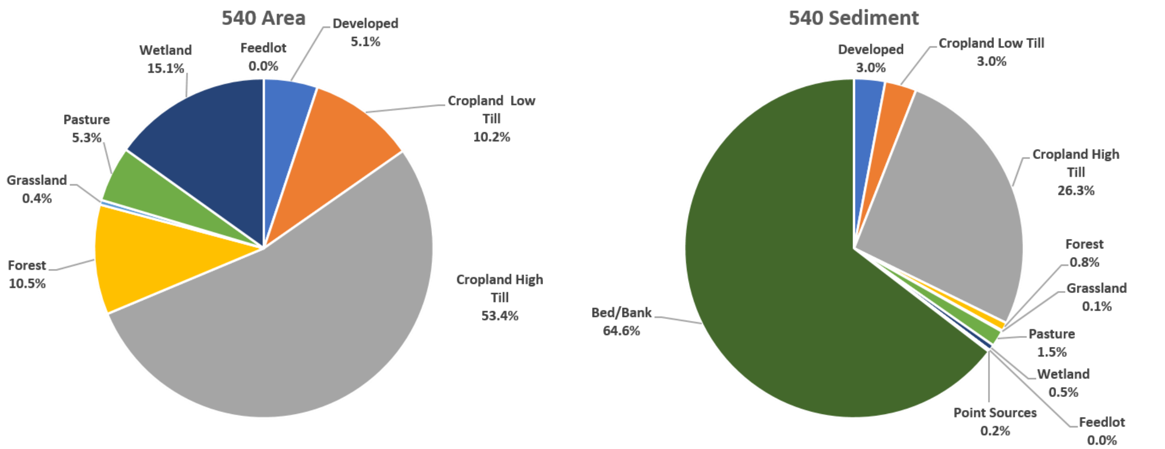

Figure 3-24. Land cover of drainage area (left) and TSS source-assessment modeling results (right) for impaired Reach 540.

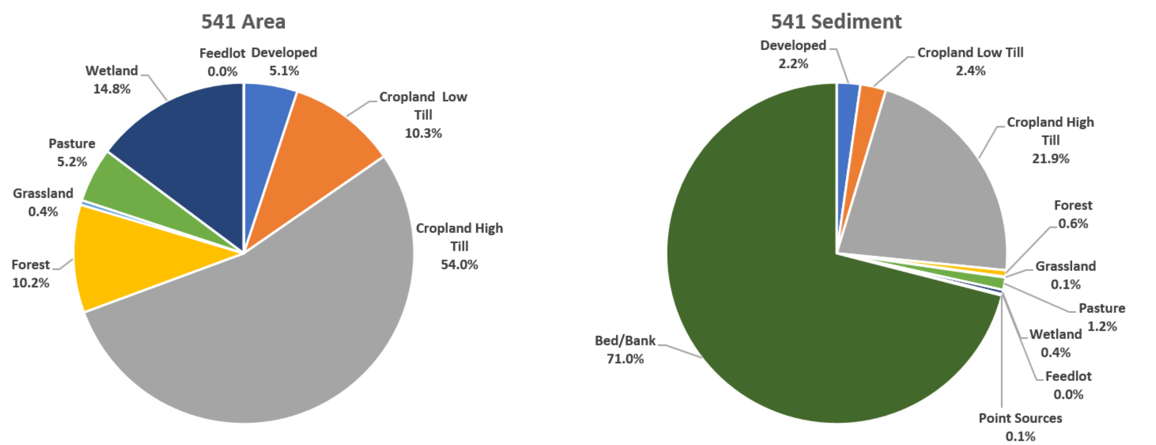

Figure 3-25. Land cover of drainage area (left) and TSS source-assessment modeling results (right) for impaired Reach 541.

Reach 501

According to the stressor ID report [MPCA 2017], Reach 501 is 10 miles long and has a drainage area of 779 square miles. The area that drains to Reach 501 has 352 miles of intermittent stream, 434 miles of intermittent drainage ditch, 185 miles of river, 32 miles of perennial drainage ditch, and 3 miles of perennial stream. According to the MPCA [2013], 52% of the watercourses in the drainage area have been hydrologically altered (i.e., channelized, ditched, or impounded). The stressor ID report noted a severe amount of bank erosion along the reach.

One geomorphology site was located along turbidity-impaired Reach 501. A stream survey was completed at this site. The site was located on glacial lake sediment and was narrow and deep. The bed material at the site was silt and clay; the banks were steep with mass erosion, cutting, and deposition; and the riparian zone had few species [DNR 2017b].

Reach 502

According to the stressor ID report [MPCA 2017], Reach 502 is 11 miles long and has a drainage area of 429 square miles. The area that drains to Reach 502 has 237 miles of intermittent stream, 227 miles of intermittent drainage ditch, 88 miles of river, 14 miles of perennial drainage ditch, and 2 miles of perennial stream. According to MPCA [2013], 49% of the watercourses in the drainage area have been hydrologically altered (i.e., channelized, ditched, or impounded), including 16% of the impaired reach itself. The stressor ID report noted substantial bank erosion along the reach.

Two geomorphology sites were located along turbidity-impaired Reach 502. These sites did not have stream surveys, but did have Pfankuch assessments completed. The Pfankuch assessments created channel stability ratings by evaluating the upper bank, lower bank, and channel bed using the Pfankuch Stability Index. They systemize measurements and evaluations of the resistive capacity to the detachment of bed and bank materials, and to provide information about the capacity of streams to adjust and recover from potential changes in flow or increases in sediment production [DNR 2017b]. Both sites were located on glacial lake sediment and were wide and shallow. The bed material at both sites was silt and clay, and the bottoms were soft and mucky. At the more upstream site along Reach 502, the upper and lower banks were in good condition. At the more downstream site along Reach 502, the upper banks and bank slope were in fair condition, and the lower banks were in excellent condition [DNR 2017b].

Reach 504

According to the stressor ID report [MPCA 2017], Reach 504 is 23 miles long and has a drainage area of 215 square miles. The area that drains to Reach 504 has 127 miles of intermittent stream, 113 miles of intermittent drainage ditch, 61 miles of river, 1 mile of perennial drainage ditch, and 1 mile of perennial stream. According to the MPCA [2013], 44% of the watercourses in the drainage area have been hydrologically altered (i.e., channelized, ditched, or impounded), including 15% of the impaired reach itself. The stressor ID report noted substantial bank erosion along the reach, and most of the stations had moderate to severe embeddedness.

Three geomorphology sites were located along turbidity-impaired Reach 504. A stream survey was completed on each of these sites. The most upstream site was located on lake-modified till with a moderate width-to-depth ratio. The bed material at the most upstream geomorphology site along Reach 504 was sandy; the banks were steep; and the riparian area consisted of trees, shrubs, and herbaceous plants. The center geomorphology site along Reach 504 was also located on modified lake till with a moderate width-to-depth ratio. The bed material at the center site was gravel, the banks were incised and entrenched, and the riparian holding cover was lacking. The most downstream geomorphology site along Reach 504 was located on glacial lake sediment and was narrow and deep. The bed material at the most downstream site was silt and clay, the banks were unstable and slightly entrenched with slumping and cutting, and the riparian area consisted of trees, shrubs, and herbaceous plants [DNR 2017b].

Reach 540

According to the stressor ID report [MPCA 2017], Reach 540 is 46 miles long and has a drainage area of 285 square miles. The area that drains to Reach 540 has 106 miles of intermittent stream, 162 miles of intermittent drainage ditch, 85 miles of river, and 14 miles of perennial drainage ditch. According to the MPCA [2013], 54% of the watercourses in the drainage area have been hydrologically altered (i.e., channelized, ditched, or impounded). The stressor ID report noted a severe amount of bank erosion along the reach.

Five geomorphology sites were located along turbidity-impaired Reach 540. Stream surveys were completed at three of these sites; although no stream surveys were completed at the other two sites, Pfankuch assessments were completed. The most upstream site was located on glacial lake beach ridges and was wide and shallow. The bed material at the most upstream site was sand and gravel; the banks were moderately unstable; and the riparian area consisted of trees, shrubs, and herbaceous plants. The second site was located on a shift from glacial lake beach ridges to lake-modified till. The bed material at the second site was mixed, the banks were moderately unstable, and the riparian area was rated fair. The third site was located on lake modified till and was wide and shallow. The bed material at the third site was loamy fine sands and very fine sand loams, and the banks were incised and entrenched. The fourth site was also located on lake-modified till. The bed material at the fourth site was sand and the banks were unstable, incised, and eroding. The most downstream site was located on glacial lake sediment with a moderate width-to-depth ratio. The bed material at the most downstream site was sand, the banks were entrenched, and the riparian area was rated fair. Overall, the reach was unstable, incised, and entrenched with mass erosion issues on the upper banks and cutting issues on the lower banks [DNR 2017b].

Reach 541

One geomorphology site was located along turbidity-impaired Reach 541. A stream survey was completed at this site. The site was located on glacial lake sediment and was narrow and deep. The bed material was silt and clay, the banks were slightly entrenched and unstable, and vegetation was established on the upper banks [DNR 2017b]. No stressor ID evaluation was completed within this reach.

4. TMDL Development: *E. coli* and Total Suspended Solids

4.1 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 and 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 report. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, WWTFs, failing subsurface sewage treatment systems (SSTSs), and other anthropogenic sources.

Based on the MPCA's waterbody assessment process and the TMDL 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 waterbodies' ability to meet state water quality standards. For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL allocation tables and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment.

4.2 *E. coli*

LDCs, which represent the allowable daily *E. coli* load under a wide range of flow conditions, were used to represent the *E. coli*-loading capacity and allocations of each impaired reach. This approach results in a flow-variable target that considers the entire flow regime within the time period of interest. Five flow intervals were developed for each reach, and the loading capacity and allocations were developed for each flow interval. The five flow intervals were very high (0% to 10%), high (10% to 40%), mid (40% to 60%), low (60% to 90%), and very low (90% to 100%) in adherence to guidance provided by the EPA [2007].

4.2.1 Loading Capacity

The TMDL is the loading capacity of a reach and is the sum of the LA, the WLA, and a MOS, shown in Equation 4-1.

$$TMDL = \sum(WLA) + \sum(LA) + MOS \qquad \textbf{Equation (4-1)}$$

LDCs were used to represent the loading capacity. The flow component of the loading capacity curve is the HSPF-simulated daily average flow at the outlet of each impaired reach, and the concentration component is geometric mean *E. coli* concentration criterion (126 org/100 mL). The loading capacities presented in the TMDL tables are the products of the median simulated flow in each flow interval, the applicable concentration criterion, and a unit conversion factor. The current load is based on the median flow and the geometric mean of all observed samples in each flow zone. An LDC and TMDL summary table are provided in **Section 4.2.5** for each *E. coli*-impaired reach.

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 curve. In the *E. coli* TMDL tables of this report, only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, the entire curve represents the TMDL and is what is ultimately approved by the EPA.

4.2.2 Wasteload Allocation Methodology

WLAs for TMDLs represent permitted WWTFs. The three permitted WWTFs that contribute to an *E. coli*-impaired reach are shown in **Table 4-1** along with the impairments to which each contributes. The WLAs were calculated as the product of the facility design flows or maximum permitted flow rates, the allowed effluent concentration, and a unit conversion factor. Loads from controlled municipal discharging WWTFs were calculated based on the maximum daily volume that may be discharged in a 24-hour period. Viking, Warren, and Alvarado WWTFs are all controlled facilities. The design flow, *E. coli* concentration limits used to calculate WLAs, and the WLAs are included in **Table 4-1**. The WWTFs have fecal coliform regulations instead of *E. coli*. The *E. coli* standard of 126 org/100 mL was used to calculate the WLAs instead of the fecal coliform permit limit of 200 org/100 mL. The WLAs do not vary based on flow. Occasionally, the portion of the WLA from permitted wastewater dischargers exceeded the low-flow regimes' total daily loading capacity (minus the MOS). In these flow regimes, the WLA and nonpoint-source LAs are denoted by a "*" and should be calculated as the product of the current flow, the *E. coli* concentration limit, and a conversion factor. If all NPDES/SDS permitted WWTFs meet their fecal coliform current permit limit, they will meet their assigned *E. coli* WLA, so no additional reductions are required beyond what is in the permits.

Table 4-1. Wastewater treatment facilities design flows and *E. coli* WLAs.

Impaired Reach	Facility	Permit	Maximum Daily Effluent Volume (mgd)	Permitted Concentration (org/100 mL)	*E. coli* WLA (org/day)	Impaired Reach Point-Source WLA (org/day)
504	Viking WWTF	MNG585370	0.244	126	1.17E+09	1.17E+09
537	Warren WWTF	MNG585073	4.790	126	2.28E+10	2.59E+10
	Alvarado WWTF	MNG585171	0.648	126	3.09E+09	

mgd = million gallons per day.
org/day – organisms per day.

E. coli is not typically contributed from construction stormwater; therefore, a construction stormwater WLA was not necessary. No benchmark monitoring of bacteria or *E. coli* are required with industrial permits, and *E. coli* is not typically contributed from industrial stormwater. Therefore, an industrial stormwater WLA was not necessary. Because the CAFO is not allowed to discharge except in the event of a chronic or catastrophic precipitation event, no WLA was assigned to the CAFO.

4.2.3 Margin of Safety

MOS is a portion of the TMDL that is set aside to account for the uncertainties associated with achieving water quality standards. MOS is usually expressed in terms of the percentage of the loading capacity. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit and expressed in the TMDL as a set-aside load. For *E. coli* TMDLs in the Snake-Middle Rivers Watershed, an explicit MOS was calculated for each impairment as 10% of the loading capacity. This percent was considered an appropriate MOS because the LDC approach minimizes the uncertainty associated with developing TMDLs. Additionally, 10% is appropriate because no rate of decay or die-off rate of pathogen species was used in calculating the TMDL or creating LDCs. As stated in the EPA's Protocol for Developing Pathogen TMDLs (EPA 841-R-00-002), many different factors affect the survival of pathogens, including the physical condition of the water. These factors include, but are not limited to, sunlight, temperature, salinity, and nutrient deficiencies. These factors vary depending on the environmental condition/circumstances of the water, and therefore asserting that the rate of decay caused by any given combination of these environmental variables was sufficient to meet the water quality standard of 126 org/100 mL would be difficult.

4.2.4 Load Allocation Methodology

The LA represents the load allowed from nonpoint sources or nonregulated sources of *E. coli*, as described in **Section 3.7.1.2**. The LA was calculated as the loading capacity minus the MOS and the WLA.

4.2.5 Total Maximum Daily Load Summaries

The LDCs and *E. coli* TMDL tables are shown for each impaired reach in **Figure 4-1** through **Figure 4-3** and **Table 4-2** through **Table 4-4**. The required loading capacities, current loads, and load reductions are shown in the TMDL tables and represent the loads for each reach minus any boundary conditions, whereas LDCs show the entire loading capacity at the outlet of the impaired reach. Based on the geometric mean of available data, Reach 504 reductions are needed in the high-flow zone; Reach 537 reductions are needed in the very high, low, and very low-flow zones; and Reach 543 reductions needed are zero in all flow zones with no data available in the very low-flow zone. The percent load reductions needed to meet the loading capacity in each flow interval were calculated to provide the overall magnitude of the required reductions. Reduction magnitudes also help focus future management actions; if higher reductions are needed in a certain flow interval, management practices should focus on the sources that most likely influence concentrations in those flow conditions. Exceedances of the *E. coli* target during high flows are typically caused by larger, area-induced, indirect pollutant sources that reach surface waters through watershed runoff. Low-flow exceedances are typically caused by direct pollutant loads or sources near the stream, such as direct defecation by wildlife or livestock in the stream channel or failing septic systems [EPA 2007]. The reduction required in each flow zone is shown in the bottom row of **Table 4-2** through **Table 4-4**.

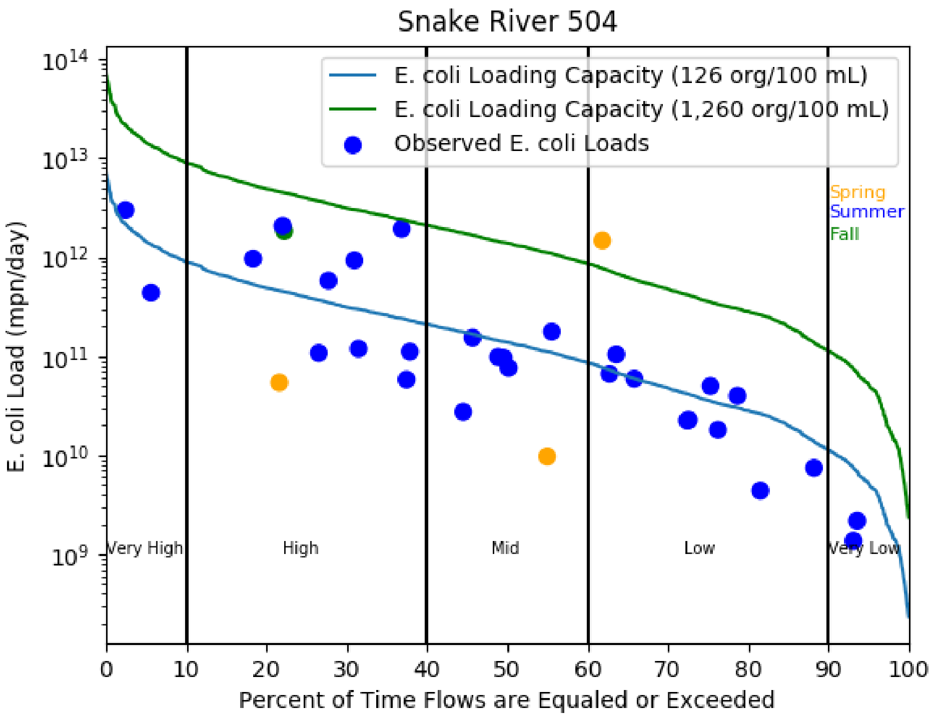

Figure 4-1. Snake River Reach 504 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from stations S003-101 and S004-214.

Table 4-2. Snake River Reach 504 *E. coli* TMDL summary.

09020309-504		Flow Zone				
***E. coli* TMDL Component (organisms/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Allowable Loading at Pour point		1.44E+12	3.96E+11	1.39E+11	3.57E+10	5.17E+09
Boundary Condition (BC) Allowable Loading (Reach 543)		9.75E+11	2.29E+11	5.94E+10	1.11E+10	1.13E+09
Total Daily Loading Capacity (Adjusted for BC)		4.61E+11	1.67E+11	7.93E+10	2.46E+10	4.04E+09
Margin of Safety		4.61E+10	1.67E+10	7.93E+09	2.46E+09	4.04E+08
Wasteload Allocations	Viking WWTF	1.17E+09	1.17E+09	1.17E+09	1.17E+09	1.17E+09
	Industrial and Construction Stormwater	–	–	–	–	–
Load Allocation		4.14E+11	1.49E+11	7.02E+10	2.10E+10	2.47E+09
Current Load at Pourpoint		9.56E+11	4.27E+11	6.56E+10	3.47E+10	1.26E+09
Current BC Load (Reach 543)		6.65E+11	1.57E+11	2.48E+10	1.01E+10	(a)
Current Load (Adjusted for BC)		2.91E+11	2.71E+11	4.08E+10	2.46E+10	(a)
Reduction Required		0%	38%	0%	0%	(a)

(a) No data available to calculate adjusted current load.

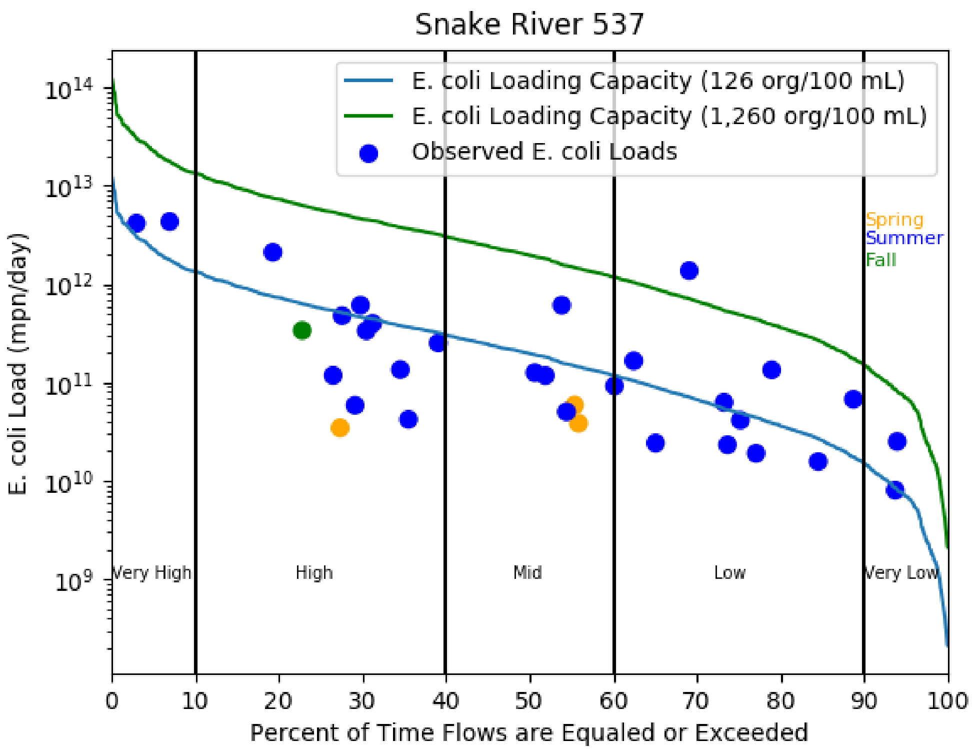

Figure 4-2. Snake River Reach 537 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from station S004-142.

Table 4-3. Snake River Reach 537 *E. coli* TMDL summary.

09020309-537		Flow Zone				
***E. coli* TMDL Component (organisms/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Allowable Loading at Pour point		2.28E+12	5.73E+11	1.96E+11	4.89E+10	6.92E+09
Boundary Condition (BC) Allowable Loading (Reach 504)		1.44E+12	3.96E+11	1.39E+11	3.57E+10	5.17E+09
Total Daily Loading Capacity (Adjusted for BC)		8.43E+11	1.78E+11	5.76E+10	1.32E+10	1.74E+09
Margin of Safety		8.43E+10	1.78E+10	5.76E+09	1.32E+09	1.74E+08
Wasteload Allocations	Permitted Wastewater Dischargers	2.59E+10	2.59E+10	2.59E+10	*	*
	Industrial and Construction Stormwater	–	–	–	–	–
Load Allocation		7.33E+11	1.34E+11	2.59E+10	1.19E+10	1.57E+09
Current Load at Pourpoint		4.16E+12	2.59E+11	1.22E+11	6.01E+10	1.18E+10
Current BC Load (Reach 504)		9.56E+11	4.27E+11	6.56E+10	3.47E+10	1.26E+09
Current Load (Adjusted for BC)		3.21E+12	0.00E+00	5.63E+10	2.54E+10	1.05E+10
Reduction Required		74%	0%	0%	48%	83%

Note: The WLA for the permitted wastewater dischargers are based on facility design flow. The WLA exceeded the low-flow regime total daily loading capacity and is denoted in the table by a “*”. For this flow regime, the WLA and nonpoint-source LA is determined by the following formula:

Allocation = (flow contribution from a given source) × (*E. coli* concentration limit or standard) × conversion factor.

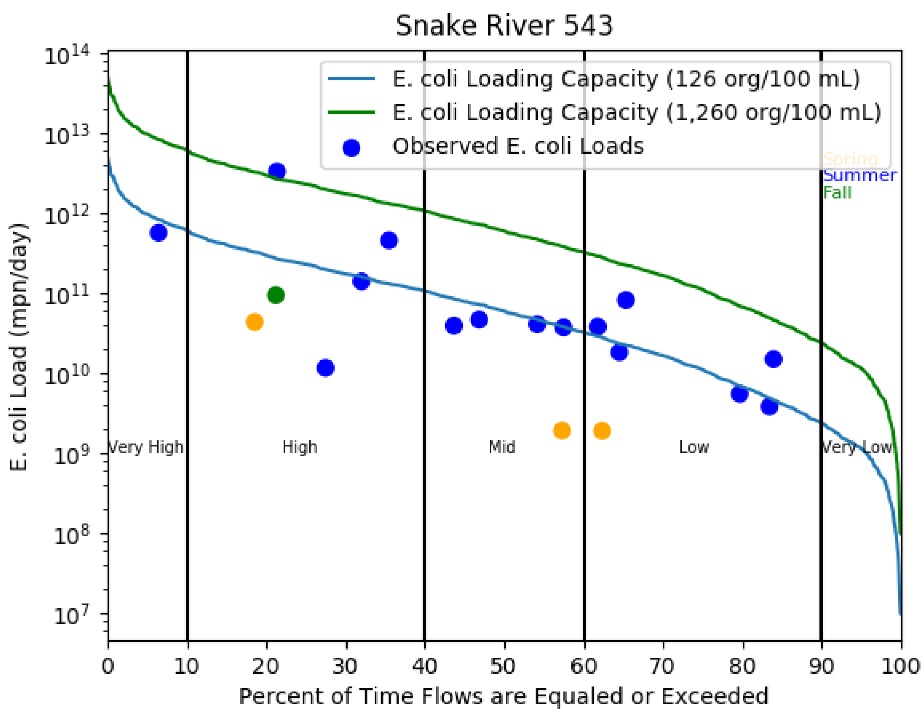

Figure 4-3. Snake River Reach 543 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from station S004-152.

Table 4-4. Snake River Reach 543 *E. coli* TMDL summary.

09020309-543		Flow Zone				
***E. coli* TMDL Component (organisms/day)**		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Total Daily Loading Capacity		9.75E+11	2.29E+11	5.94E+10	1.11E+10	1.13E+09
Margin of Safety		9.75E+10	2.29E+10	5.94E+09	1.11E+09	1.13E+08
Wasteload Allocations	Permitted Wastewater Dischargers	–	–	–	–	–
	Industrial and Construction Stormwater	–	–	–	–	–
Load Allocation		8.77E+11	2.06E+11	5.35E+10	9.99E+09	1.02E+09
Total Current Load		6.65E+11	1.57E+11	2.48E+10	1.01E+10	(a)
Reduction Required		0%	0%	0%	0%	(a)

(a) No data available to calculate current load.

4.3 Total Suspended Solids

LDCs, which represent the allowable daily TSS load under a wide range of flow conditions, were used to represent the TSS loading capacity and allocations of each impaired reach. This approach results in a flow-variable target that considers the entire flow regime within the time period of interest. Five flow intervals were developed for each reach, and the loading capacity and allocations were developed for each flow interval. The five flow intervals were very high (0% to 10%), high (10% to 40%), mid (40% to 60%), low (60% to 90%), and very low (90% to 100%) in adherence to guidance provided by the EPA [2007].

4.3.1 Loading Capacity

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 average flow, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL tables of this report only five points on the loading capacity curve are depicted (one for each flow zone). However, it should be understood that the entire curve represents the TMDL. The TMDL is the loading capacity of a reach and is the sum of the LA, the WLA, and a MOS, shown in Equation 4-2.

$$TMDL = \sum(WLA) + \sum(LA) + MOS \qquad \textbf{Equation (4-2)}$$

LDCs were used to represent the loading capacity. The flow component of the loading capacity curve is based on the HSPF-simulated daily average flows (2006 through 2015), and the concentration component is the TSS concentration criteria of 65 mg/L. The loading capacities presented in the TMDL tables are the products of the median simulated flow in each flow zone, the TSS concentration criterion, and a unit conversion factor.

4.3.2 Wasteload Allocation Methodology

Seven active regulated NPDES/SDS permitted wastewater dischargers in the Snake-Middle Rivers Watershed that drain to TSS-impaired reaches have been assigned TSS effluent limits. The WLAs for the permitted wastewater dischargers that contribute to the turbidity-impaired reaches are based on facility design flow. Facility TSS WLAs were provided by the MPCA and are the product of the TSS effluent limit and permitted facility design flow and a unit conversion factor, as shown in **Table 4-5**. Controlled municipal pond discharge WWTF WLAs were calculated based on the maximum daily volume that may be discharged in a 24-hour period. All WWTFs contributing to the TSS impairments addressed are controlled facilities, while the Hawkes Co. Inc. is mechanical. If all NPDES/SDS permitted WWTFs meet their TSS current permit limit, they will meet their assigned TSS WLA, so no additional reductions are required beyond what is in the permits.

Occasionally, the portion of the WLA from permitted wastewater dischargers exceeded the low-flow regimes' total daily loading capacity (minus the MOS). In these flow regimes, the WLA are denoted by a "*" and are calculated as the product of the current flow, the TSS concentration limit, and a conversion factor. MS4 allocations were not needed because the Snake-Middle Rivers Watershed has no MS4s. One facility (Hawkes Co. Inc.) is in the process of expanding and updating their permit. The increased updated design flow was used to develop the TMDL for Reach 540 [Strong 2018].

Table 4-5. Permitted TSS allocations for point sources in the Snake-Middle Rivers Watershed.

Impaired Reach	Facility	Permit	Effluent Design Flow (mgd)	Permitted Concentration (mg/L)	TSS WLA (tons/day)	Impaired Reach Point-Source WLA
502	Warren WWTF	MNG585073	4.790	45	0.8988	1.021
	Alvarado WWTF	MNG585171	0.6484	45	0.1217	
504	Viking WWTF	MNG585370	0.2444	45	0.0459	0.0459
540/541	Argyle WWTF	MNG585140	0.7381	45	0.1385	2.083
	Newfolden WWTF	MNG585145	0.3259	45	0.0611	

Impaired Reach	Facility	Permit	Effluent Design Flow (mgd)	Permitted Concentration (mg/L)	TSS WLA (tons/day)	Impaired Reach Point-Source WLA
	Middle River WWTF	MNG585163	0.2444	45	0.0459	
	Hawkes Co Inc	MN0062715	14.69	30	1.838	

Construction stormwater is regulated by NPDES/SDS permits for any construction activity that disturbs (1) one acre or more of soil; (2) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than 1 acre; or (3) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The WLA for stormwater discharges from sites with construction activities reflects the number of construction sites that have less than one acre that are expected to be active in the impaired reach subwatershed at any one time.

A categorical WLA was assigned to all construction activity in the watershed. The average annual acres under construction in each applicable county were available from 2009 through 2015 from MPCA Construction Stormwater Permit data. The percent of each county in the Snake-Middle Rivers Watershed was multiplied by the average annual construction acres for that county to determine the acres under construction in the Snake-Middle Rivers Watershed. Finally, the percent of area under construction was determined by dividing total construction acres over total watershed acres. This percentage was multiplied by the portion of the TMDL LA associated with direct drainage to determine the construction stormwater WLA. Average annual construction acres from 2006 through 2015 ranged from 0.014% of the area to 0.016% of different impairment areas. To add in a small MOS, 0.025% of the area in all impairments was assumed to be under construction.

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 number of acres regulated under 2015 industrial permits was available from MPCA Industrial Stormwater Permit data. The percent of each county in the Snake-Middle Rivers Watershed was multiplied by 2015 industrial permitted acres for that county to determine the acres under industrial permits in the Snake-Middle Rivers Watershed. Finally, the percent of area with industrial uses was determined by dividing total industrial acres over total watershed acres. Average annual industrial stormwater acres in 2015 ranged from 0.012% of the area to 0.038% of the area for different impairment areas. To add in a small MOS, 0.045% of the area in all impairments was assumed to be industrial.

To determine the load allowed from construction and industrial stormwater, the loading capacity in each flow zone (minus the MOS) was multiplied by 0.0007 to represent 0.025% from construction stormwater and 0.045% from industrial permits.

4.3.3 Margin of Safety

For TSS TMDLs in the Snake-Middle Rivers Watershed, an explicit MOS was calculated for each impairment as 10% of the loading capacity. The calculation of the loading capacity is the product of monitored flow and the TSS target concentration. Ten percent was considered an appropriate MOS because the LDC approach minimizes uncertainty associated with the development of TMDLs because the calculation of the loading capacity is the product of simulated flow and the TSS target concentration.

4.3.4 Load Allocation

The LA represents the load allowed from nonpoint sources or nonregulated sources of TSS as described in **Sections 3.7.2.2** and **3.7.2.3**. The LA was calculated as the loading capacity minus the MOS and the WLA.

4.3.5 Total Maximum Daily Load Summaries

The LDCs and TSS TMDL tables for each impaired reach are shown in **Figure 4-4** through **Figure 4-8** and **Table 4-6** through **Table 4-9**. The percent load reductions needed to meet the loading capacity in each flow interval were calculated to provide the magnitude of the required reductions at different flows. Reduction magnitudes by flow help focus future management actions; if higher reductions are needed in a certain flow interval, management practices should focus on the sources that most likely influence concentrations in those flow conditions. Exceedances of the TSS target during higher flows are typically caused by storm-related sediment wash-off or high-flow related in-stream/near-stream erosion and scour (bed and bank loads). Low-flow exceedances are more likely to be caused by direct pollutant loads or sources near the stream [EPA 2007].

The required loading capacities, current loads, and load reductions are shown in the TMDL tables and represent the loads for each reach minus any boundary conditions, whereas LDCs show the entire loading capacity at the outlet of the impaired reach. Based on the HSPF-simulated TSS loads, all of the turbidity-impaired reaches need reductions in the highest flow zone, and none need reductions in the lowest flow zone. An overall reduction for each impaired reach was calculated by using an overall loading capacity based on median flow and an overall current load based on the median flow and the 90^{th} percentile TSS concentration. The overall reduction required for each impaired reach is shown in the bottom row of **Table 4-6** through **Table 4-9**.

A TMDL table for Reaches 540 and 541 were combined into a single TSS TMDL at the outlet of Reach 541 (**Table 4-9**). The combination of the two reaches is based on the following: (1) the drainage area that contributes to the more upstream Reach 540 is approximately 286 square miles, and the drainage area between Reaches 540 and 541 is 6.5 square miles; (2) the percent of sediment from bed/bank increases from 64.6% in Reach 540 to 71% in Reach 541; (3) the project area is known for its extremely flashy flows, and the flows from the entire area drain to Reach 540 likely drive the large bed/bank contributions that occur in Reach 541. Also, at the lower end of Reach 540, the soils shift from more sandy soils to more clay-like soils, and the higher percentage of clay remains throughout Reach 541. The soil erodibility factor is higher in the soil that has a higher clay content in the Snake-Middle Rivers Watershed, and the clay-like soils are more easily suspended and transported than sandy material. If the individual TMDLs were assigned to Reaches 540 and 541 instead of the combined TMDL at the outlet of Reach 541, Reach 540 would need a 70% reduction and Reach 541 would need a 99.5% reduction when the Reach 540 boundary condition is considered. When the two reaches are combined into one at the outlet of Reach 541, an overall reduction of 76% is required. Implementing BMPs to decrease flashiness of flows throughout the entire area that drains to Reach 541 would likely have a greater impact than prioritizing implementation within the 6.5-square-mile area that drains to Reach 541 below Reach 540.

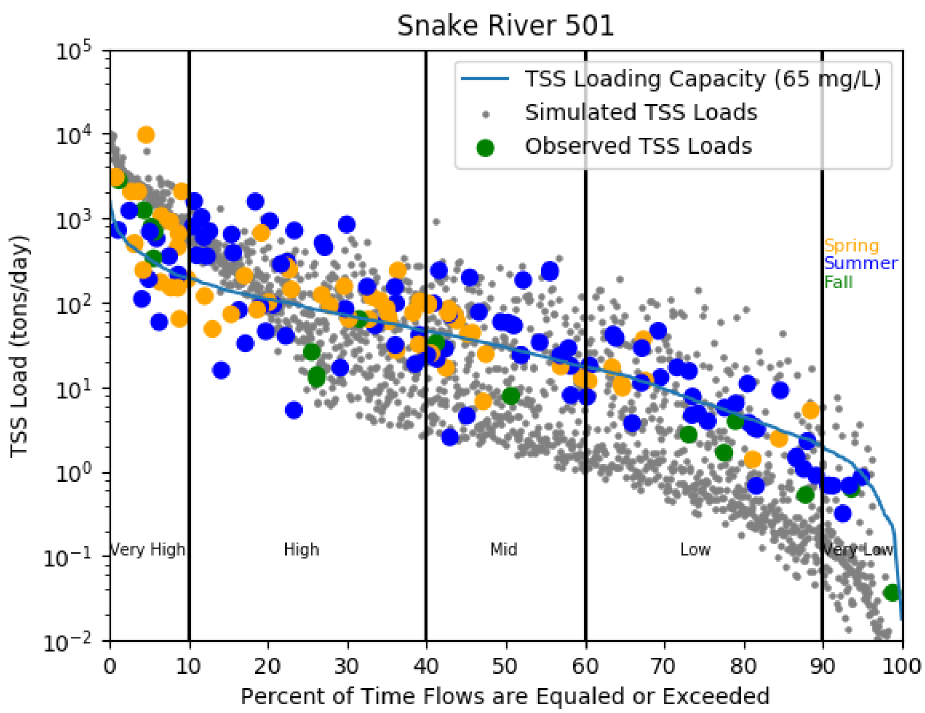

Figure 4-4. Snake River Reach 501 TSS LDC generated with simulated flow and TSS data from HSPF and observed TSS data from station S000-185.

Table 4-6. Snake River Reach 501 TSS TMDL summary.

09020309-501		Flow Zone				
TSS TMDL Component (tons/day)		Very High	High	Mid	Low	Very Low
Allowable Loading at Pour point		328.7	86.86	29.64	6.400	0.9300
Boundary Condition (BC) Allowable Loading (Reach 502)		176.3	45.60	16.14	3.560	0.4216
BC Allowable Loading (Reach 541)		138.4	35.24	10.42	2.103	0.3054
Total Daily Loading Capacity (Adjusted for BC)		14.03	6.017	3.080	0.7369	0.2013
Margin of Safety		1.403	0.6017	0.3080	0.0737	0.0201
Wasteload Allocations	Permitted Wastewater Dischargers	–	–	–	–	–
	Industrial/Construction Stormwater	0.0088	0.0038	0.0019	0.0005	0.0001
Load Allocation		12.62	5.411	2.770	0.6627	0.1811
Current Load at Pourpoint		2285	306.5	115.7	18.79	0.2364
Current BC Load (Reach 502)		981.9	156.0	67.21	11.07	0.0843
Current BC Load (Reach 541)		737.0	73.35	21.13	4.435	0.1511
Current Load (Adjusted for BC)		566.3	77.15	27.36	3.281	0.0010
Reduction Required		98%	92%	89%	78%	0%
Overall Reduction Required		93%				

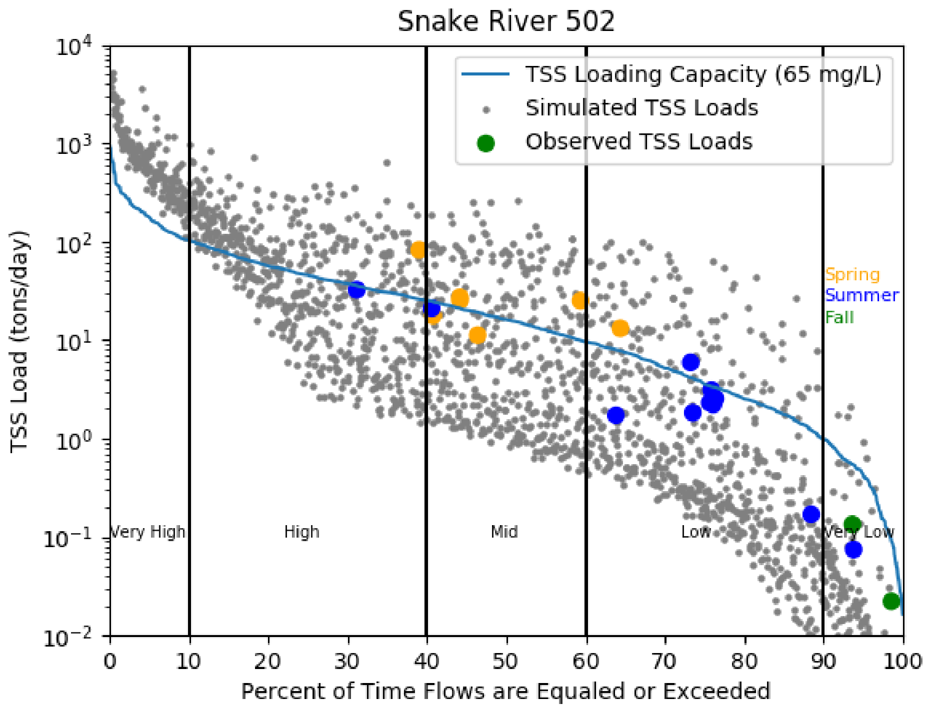

Figure 4-5. Snake River Reach 502 TSS LDC generated with simulated flow and TSS data from HSPF and observed TSS data from station S003-692.

Table 4-7. Snake River Reach 502 TSS TMDL summary.

09020309-502		Flow Zone				
TSS TMDL Component (tons/day)		Very High	High	Mid	Low	Very Low
Allowable Loading at Pour point		176.3	45.60	16.14	3.560	0.4216
Boundary Condition (BC) Allowable Loading (Reach 504)		86.49	25.00	8.935	2.217	0.2613
Total Daily Loading Capacity (Adjusted for BC)		89.81	20.60	7.205	1.343	0.1603
Margin of Safety		8.981	2.060	0.7205	0.1343	0.0160
Wasteload Allocations	Permitted Wastewater Dischargers	1.021	1.021	1.021	1.021	*
	Industrial/Construction Stormwater	0.0566	0.013	0.0045	0.0008	0.0001
Load Allocation		79.75	17.51	5.459	0.1869	0.1442
Current Load at Pourpoint		981.9	156.0	67.21	11.07	0.0843
Current BC Load (Reach 504)		349.9	32.39	14.74	1.969	0.0204
Current Load (Adjusted for BC)		632.0	123.6	52.47	9.101	0.0639
Reduction Required		86%	83%	86%	85%	0%
Overall Reduction Required		84%				

Note: The WLA for the permitted wastewater dischargers are based on facility design flow. The WLA exceeded the low-flow regime total daily loading capacity and is denoted in the table by a "*". For this flow regime, the WLA and nonpoint-source LA is determined by the following formula:

Allocation = (flow contribution from a given source) × (TSS concentration limit or standard) × conversion factor.

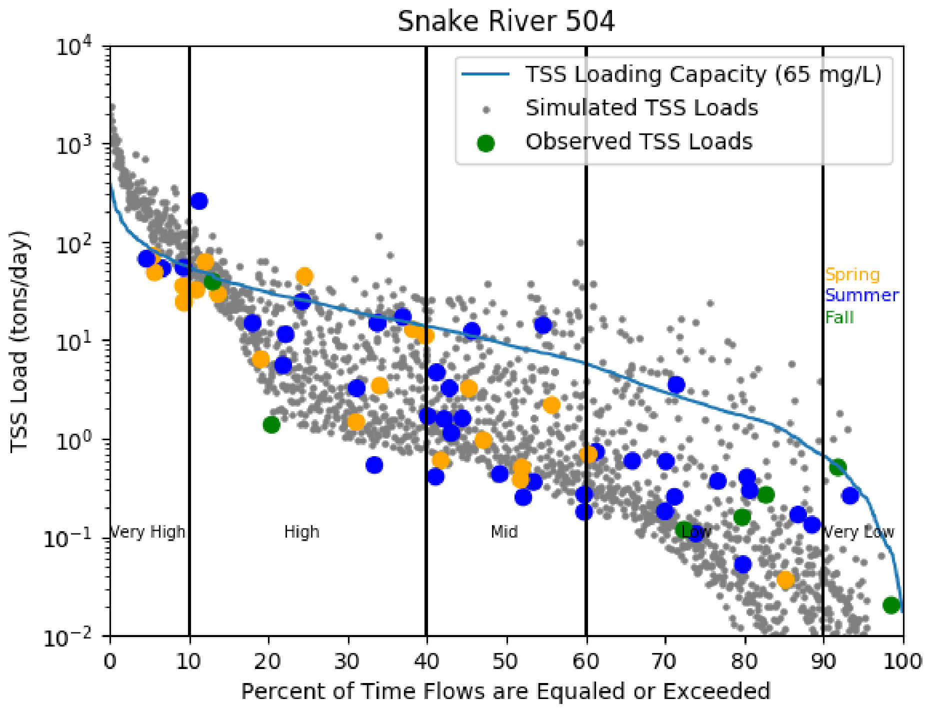

Figure 4-6. Snake River Reach 504 TSS LDC generated with simulated flow and TSS data from HSPF and observed TSS data from stations S002-994 (6%), S003-101 (80%), and S004-214 (14%).

Table 4-8. Snake River Reach 504 TSS TMDL summary.

09020309-504		Flow Zone				
TSS TMDL Component (tons/day)		Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity		86.49	25.00	8.935	2.217	0.2613
Margin of Safety		8.649	2.500	0.8935	0.2217	0.0261
Wasteload Allocations	Viking WWTF	0.0459	0.0459	0.0459	0.0459	0.0459
	Industrial/Construction Stormwater	0.0545	0.0158	0.0056	0.0014	0.0002
Load Allocation		77.74	22.44	7.990	1.948	0.1891
Total Current Load		349.9	32.39	14.74	1.969	0.0204
Reduction Required		75%	23%	39%	0%	0%
Overall Reduction Required		50%				

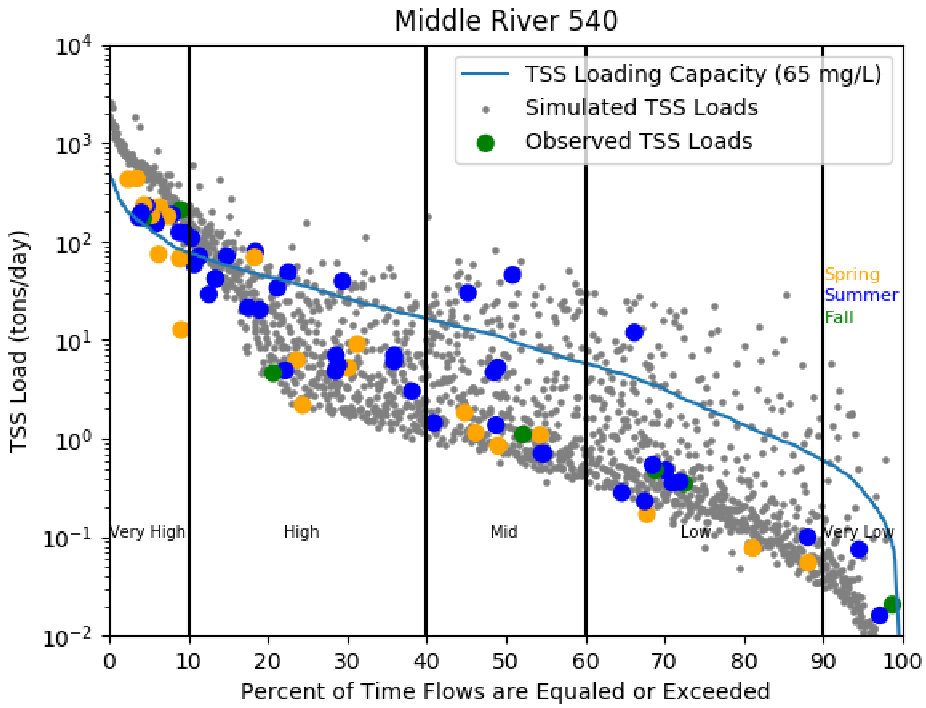

Figure 4-7. Middle River Reach 540 TSS LDC generated with simulated flow and TSS data from HSPF and observed TSS data from stations S000-700 (7%) and S002-989 (93%).

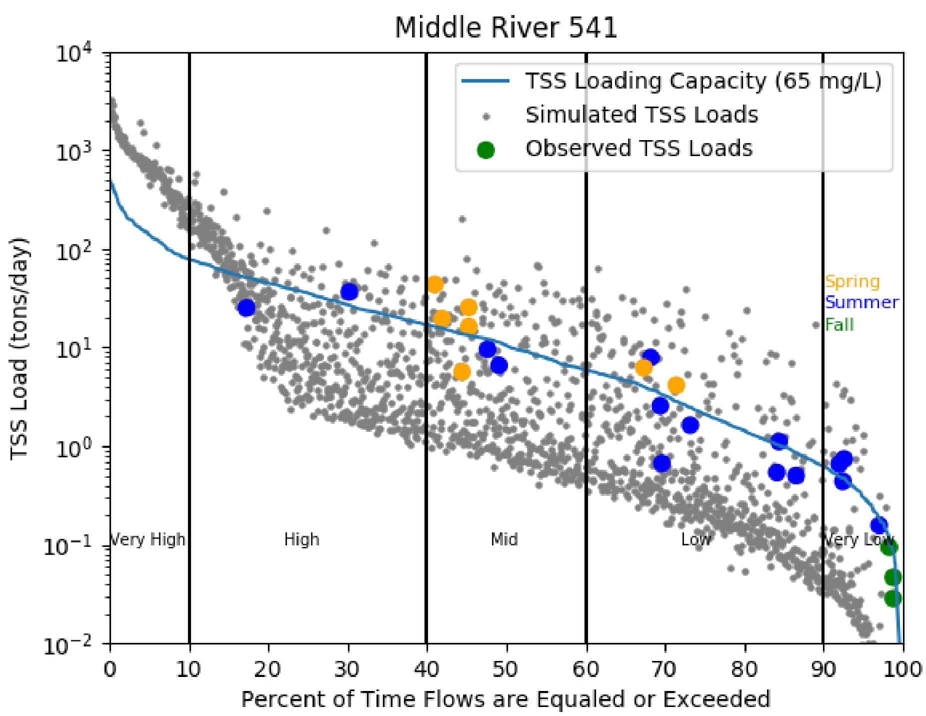

Figure 4-8. Middle River Reach 541 TSS LDC generated with simulated flow and TSS data from HSPF and observed TSS data from station S003-691.

Table 4-9. Middle River Reaches 540 and 541 Combined TSS TMDL summary.

09020309-540 and 541 Combined		Flow Zone				
TSS TMDL Component (tons/day)		Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity		138.4	35.24	10.42	2.103	0.3054
Margin of Safety		13.84	3.524	1.042	0.2103	0.0305
Wasteload Allocations	Permitted Wastewater Dischargers	2.083	2.083	2.083	*	*
	Industrial/Construction Stormwater	0.0872	0.0222	0.0066	0.0013	0.0002
Load Allocation		122.4	29.61	7.29	1.891	0.2747
Total Current Load		737.0	73.35	21.13	4.435	0.1511
Reduction Required		81%	52%	51%	53%	0%
Overall Reduction Required		76%				

Note: The WLA for the permitted wastewater dischargers are based on facility design flow. The WLA exceeded the low-flow regime total daily loading capacity and is denoted in the table by a “*”. For this flow regime, the WLA and nonpoint-source LA is determined by the following formula:

Allocation = (flow contribution from a given source) × (TSS concentration limit or standard) × conversion factor

5. Seasonal Variation

Monthly precipitation, flows, and pollutant concentrations vary seasonally. Average monthly precipitation in the project area is generally the highest in spring and summer (May through August), as shown in **Figure 3-1** and **Figure 3-2**. Short-duration, high-intensity rainstorms are common during the spring and summer months. These localized storms can cause significant runoff with the potential of increasing pollutant concentrations for a relatively short time period, particularly from spring and early-summer events. Occasionally, large events can occur during the drier summer months that have significant wash-off of pollutants while not significantly increasing stream flow.

Monthly average flows in the Snake-Middle Rivers Watershed were typically highest during the late-spring and early-summer months (April through July) and lowest during winter months (December through February), as shown in **Figure 5-1**.

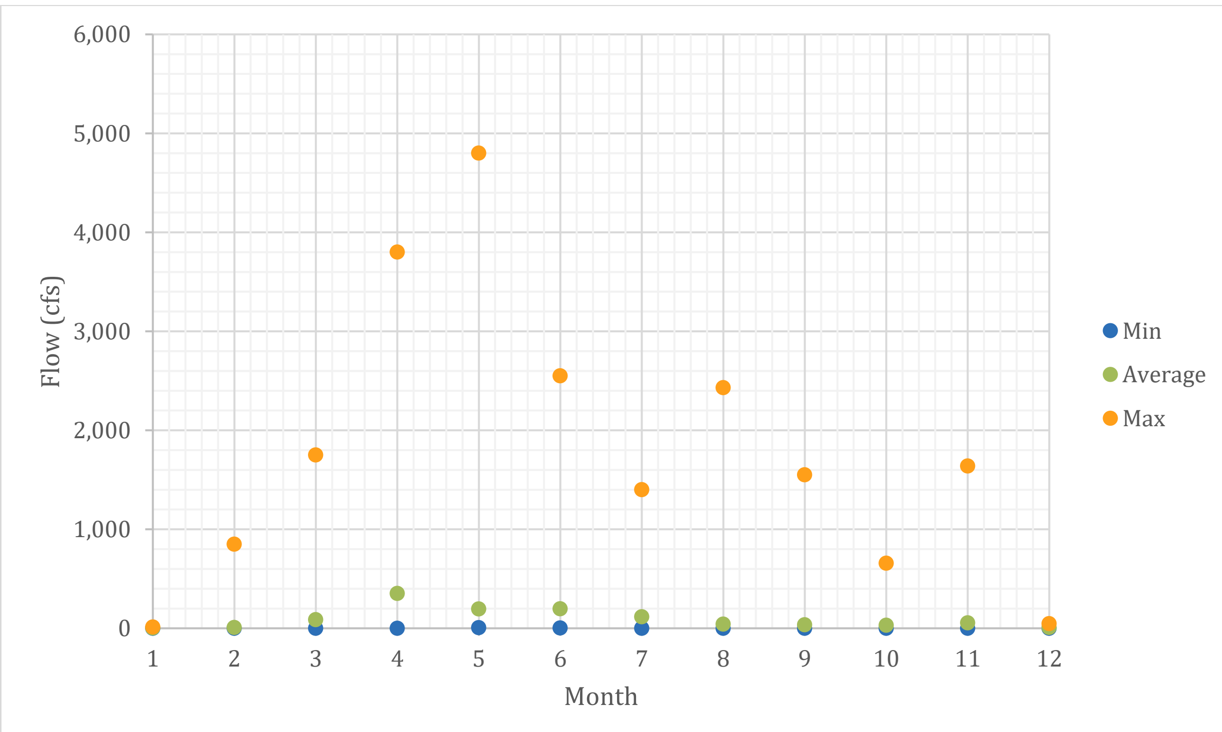

Figure 5-1. Monthly average annual flow (2006–2015) from Middle River at Argyle.

5.1 *E. coli*

The highest average and median *E. coli* concentrations in the Snake River impaired streams typically occurred in spring and summer months. The highest bacteria loads occur during summer months, as shown in the *E. coli* LDCs. Figures of bacteria concentrations in impaired reaches by month are shown in **Section 3.5.2.1**. Bacteria concentration geometric means were the highest during July and August at Reaches 537 and 534. In Reach 504, the geometric mean was highest in July and September. The LDC approach to develop the TMDL allocations for five flow zones accounts for the seasonal variability in flow and *E. coli* loads (e.g., the high-flow zone contains flows that primarily occur in the spring and summer). The *E. coli* TMDLs are also seasonal, because the *E. coli* criterion is active from April through October.

5.2 Total Suspended Solids

The highest average and median TSS concentrations in the Snake River impaired streams typically occurred in late-spring and early-summer months. The highest TSS loads also occurred during spring and summer months, as shown in the TSS LDCs. Figures of TSS in impaired reaches by month are shown in **Section 3.5.2.2**. The mean TSS concentration was the highest at Reaches 502 and 504 in June and Reaches 501, 540 and 541 in July. The LDC approach to develop the TMDL allocations for five flow zones accounts for the seasonal variability in flow and TSS loads (e.g., the high-flow zone contains flows that primarily occur in the spring and summer). The TSS TMDLs are seasonal in nature, because the TSS criterion applies from April through September.

6. Future Growth Considerations

6.1 New Permitted MS4 Waste Load Allocation Transfer Process

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

One or more nonregulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA to the WLA.

A U.S. Census Bureau Urban Area is expanded to encompass new regulated areas for existing permittees. An example of this scenario is existing state highways that were outside an urban area at the time that the TMDL was completed but are now inside a newly expanded urban area. A WLA-to-WLA transfer or an LA-to-WLA transfer is required.

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 that are consistent with those used in setting the allocations in this TMDL (a land-area basis). In cases where the WLA is transferred to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

6.2 New or Expanding Wastewater Treatment Facilities

The MPCA, in coordination with the EPA Region 5, has developed a streamlined process for setting or revising WLAs for new or expanding WWTFs to waterbodies with an EPA-approved TMDL [MPCA 2012]. This procedure will be used to update WLAs in approved TMDLs for new or expanding WWTFs 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 the public and EPA to comment on the permit changes based on the proposed WLA modification(s). Once any comments or concerns are addressed and the MPCA determines that the new or expanded wastewater discharge is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made. For more information on the overall process, visit the MPCA's TMDL Policy and Guidance webpage https://www.pca.state.mn.us/water/tmdl-policy-and-guidance.

6.2.1 Reserve Capacity

The reserve capacity (RC) is the portion of the loading capacity directed to growth of existing and new future load sources. Very slight demographic growth of the TMDL region is expected to result in slight shifts from agricultural to developed land classes. As such, there is no planned increase in wastewater facilities and MS4 development is not planned. Community attention to better stormwater management practices such as low-impact development (LID) and Minimal Impact Design Standards (MIDS) performance standards for new, redevelopment, and linear developments are helping developed areas decrease pollutant loads. Hence, RC allocations were not derived for the TMDLs defined herein.

7. Reasonable Assurance

An important part of the TMDL implementation strategy is to provide reasonable confidence or reasonable assurance that the TMDL allocations (1) were properly developed, documented, and calibrated and (2) will be implemented by local (SWCDs and LGUs), state, and federal entities. The TMDL allocations described herein have been based on the best and latest available information. The TMDL goals defined by this report are consistent with objectives defined in local water plans that have been further refined by MPCA's Snake-Middle Rivers WRAPS report [MPCA 2020]. The Snake-Middle Rivers Watershed local governmental units have been active participants in the TMDL planning and development process, and most have decades of water quality management experience. Stakeholder meetings have been conducted to provide comment/feedback and support, including local governmental units that receive TMDL allocations. Future water quality planning and restoration efforts will be led by the Snake-Middle Rivers Watershed local and county entities. Funding resources may be obtained from the following state and/or federal programs:

- Minnesota Clean Water, Land, and Legacy Funds
- EPA funding, such as CWA Section 319 grants
- State Clean Water Partnership Loan Program
- Natural Resources Conservation Services (NRCS) cost-share funds
- Local governmental funds and utility fees

7.1 Nonregulatory

At the local level, the Snake-Middle Rivers Watershed county (primarily Marshall County), SWCDs, and the MSTRWD have a long history of completing water quality improvement projects with well-developed infrastructure (i.e., technical assistance, administrative support, and fiscal oversight) in place. The implementation strategies described in **Section 9** have been demonstrated to be effective in reducing pollutant loads to Minnesota waters. Performance monitoring will continue to guide adaptive management, including evaluating progress-to-goals in achieving water quality standards and established beneficial uses.

Recent watershed projects include the Minnesota Prairie Recovery Project, Reinvest in Minnesota (RIM) easements, Native Prairie Bank (NPB) easements, and a Source Water Protection Competitive Grant. Additionally, Newfolden/Middle River Subwatershed Flood Reduction, Judicial Ditch #14 Project, and the Swift Coulee/Marshall County Ditch #3 Project are in the planning stages. The Legacy Amendment allocates 33% of its sales tax revenue to the Clean Water Fund, which is spent to protect, enhance, and restore water quality. Projects funded by the Clean Water Fund can be found online (https://www.legacy.mn.gov/projects?f%5B0%5D=project_facet_source%3A10). Minnesota has a buffer rule that establishes 50 foot perennial vegetation buffers on all lands that border public waters and 16.5 foot buffers on all lands that border a public drainage system that will help filter out phosphorus, nitrogen, and sediment. Additionally, multiple flood damage reduction projects have been completed throughout the watershed, such as the Agassiz project 6 miles east-southeast of Warren and the off channel storage about 10 miles east-northeast of Warren. More detailed information regarding nonregulatory reasonable assurance is included in the costs section.

7.1.1 Pollutant Load Reduction

Reliable means of reducing nonpoint source pollutant loads are addressed in the Snake-Middle Rivers WRAPS Report [MPCA 2020], a document that is written to be a companion to this TMDL report. In order for the impaired waters to meet water quality standards, the majority of pollutant reductions in the Snake-Middle Rivers Watershed will need to come from nonpoint sources. Additionally, channelization, inadequate riparian cover, and high levels of water discharge cause dramatic fluctuations of water levels, exacerbating sediment related problems [MPCA 2016b].The strategies and BMPs described in the WRAPS report have been demonstrated to be effective in reducing transport of pollutants to surface water. The combinations of BMPs discussed throughout the WRAPS process were derived from Minnesota's Nutrient Reduction Strategy (NRS) [MPCA 2015b] and related tools. As such, they have been vetted by a statewide engagement process.

Selection of sites for BMPs will be led by LGUs, including SWCDs, watershed districts, and county planning and zoning offices, with support from state and federal agencies including information provided in this TMDL report and the WRAPS report. These BMPs are supported by programs administered primarily by the SWCDs, BWSR, and the Natural Resource Conservation Service (NRCS). Local resource managers are well-trained in promoting, locating, and installing these BMPs. State and local agencies will need to work with landowners to identify priority areas for BMPs and practices that will help reduce runoff, as well as streambank and overland erosion. These BMPs reduce pollutant loads from runoff (i.e. phosphorus, sediment, and pathogens) and loads delivered through drainage tiles.

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

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

Through this program, certified producers receive:

- Regulatory certainty**:** certified producers are deemed to be in compliance with any new water quality rules or laws during the period of certification;

- Recognition: certified producers may use their status to promote their business as protective of water quality; and
- Priority for technical assistance: producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality.

In summary, significant time and resources have been, and will be, devoted to identifying the best BMPs, providing means of focusing them in the Snake-Middle Rivers Watershed, and supporting their implementation via state initiatives and dedicated funding. The Snake-Middle Rivers Watershed 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.

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 [MPCA 2015b] 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.

7.1.2 Prioritization

The WRAPS report details a number of tools such as SAM and PTMApp for local water planners that provide means for identifying priority pollutant sources and implementation work in the watershed. Further, LGUs in the Snake-Middle Rivers Watershed often employ their own local analysis for determining priorities for work.

7.1.3 Funding

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

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

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

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

7.1.4 Planning and Implementation

The WRAPS, TMDLs, and all the supporting documents provide a foundation for planning and implementation. Subsequent planning, including voluntary development of One Watershed, One Plan (1W1P)[2] for the Snake-Middle Rivers Watershed approved for funding in August 2020, will draw on the goals, technical information, and tools to describe in detail strategies and actions for implementation. For the purposes of reasonable assurance, the WRAPS document is sufficient in that it provides strategies for achieving pollutant reduction goals. In addition, the commitment and support from the local governmental units will ensure that this TMDL project is carried successfully through implementation.

7.1.5 Tracking Progress

Water monitoring efforts within the Snake-Middle Rivers Watershed are diverse and constitute a sufficient means for tracking progress and supporting adaptive management (See **Section 8**).

BMP tracking is reported on the MPCA's "Healthier Watersheds" webpage at https://www.pca.state.mn.us/water/healthier-watersheds.

7.2 Regulatory

7.2.1 Construction Stormwater

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

7.2.2 Industrial Stormwater

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

7.2.3 Municipal Separate Storm Sewer System (MS4) Permits

Phase II MS4 NPDES/SDS-permitted stormwater communities are required by permit (the General Permit Authorization to Discharge Stormwater Associated with Small MS4s Under the NPDES/SDS Permit [MNR040000]) to develop and implement a Stormwater Pollution Prevention Plan (SWPPP). However, no MS4s are currently located in the Snake-Middle Rivers Watershed.

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[2] http://www.bwsr.state.mn.us/planning/1W1P/index.html

7.2.4 Wastewater NPDES and SDS Permits

The MPCA issues NPDES/SDS permits for WWTFs or industrial facilities that discharge into waters of the state. The permits have site specific limits on pollutants such as *E. coli*, TSS, and five-day carbonaceous biochemical oxygen demand ($CBOD_5$) that are based on water quality standards. NPDES/SDS permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. In addition, NPDES/SDS Permits set limits and establish controls for land application of waste and byproducts. See **Section 9.1.5** for a summation of Discharge Monitoring Reports (DMRs) from WWTFs in the Snake-Middle Rivers Watershed.

7.2.5 Subsurface Sewage Treatment Systems (SSTS) Program

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

These regulations detail:

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

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

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

The MPCA staff keep a statewide database of known imminent threat to public health or safety (ITPHS) systems that include “straight pipe systems”. These straight pipe systems are reported to the counties or the MPCA by the public. Upon confirmation of a straight pipe system, the county sends out a notification of noncompliance, which starts a 10-month deadline to fix the system and bring it into compliance. From 2006 through 2017, 742 straight pipe systems have been tracked by the MPCA throughout the state. Seven hundred and one of those were abandoned, fixed, or were found not to be a straight pipe system as defined in Minn. Stat. 115.55, subd. 1. There have been 17 Administrative Penalty Orders issued and docketed in court. The remaining straight pipe systems received a notification of noncompliance.

7.2.6 Feedlot Program

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

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

There are two primary concerns about feedlots in protecting water:

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

7.2.7 Nonpoint Source

For the eight impairments addressed with seven TMDLs in this report, the vast majority of the pollutant loads are attributed to nonpoint sources. Thus, for TMDLs that require reductions in pollutant loads, nonpoint sources will become the main targets for reductions. The existing state statutes/rules pertaining to nonpoint sources include:

- Average of a 50-foot buffer (minimum of 30 feet) required for the shore impact zone of streams classified as protected waters (Minn. Stat. § 103F.201) for agricultural land uses [Minnesota State Legislature 2015]. November 1, 2017, was the deadline for compliance.
- 16.5-foot minimum width buffer required on public drainage ditches (Minn. Stat. § 103E.021). November 1, 2018, was the deadline for compliance.
- Protecting highly erodible land within the 300-foot shoreland district (Minn. Stat. § 103F.201).
- Excessive soil loss statute (Minn. Stat. § 103F.415).
- Nuisance nonpoint source pollution (Minn. R. 7050.0210, subp. 2).

Other measures may be identified in the WRAPS report or the future 1W1P.

8. Monitoring Plan

Tracking progress toward achieving the TMDL load reductions will primarily rely on monitoring each impaired watershed for (1) BMP implementation and (2) tracking attainment to water quality standards. The Snake-Middle Rivers Watershed SWCDs, the MSTRWD, and other LGU will track and report implementation projects annually within their jurisdictions. Therefore, existing tools, such as the pollutant reduction calculators, input into Minnesota Board of Soils and Water Resources' (BWSR) web-based eLINK tracking system [Minnesota BWSRs 2016], and other methods of tracking will be used to report on progress. BMP effectiveness may be estimated by BWSR and MPCA calculators based on BMP designs, construction, and operation and maintenance considerations. BMP tracking is reported on the MPCA's "Healthier Watersheds" webpage.

Water monitoring will be conducted by a combination of volunteer monitors and county/SWCD technicians. The monitoring level of effort will vary among the Snake-Middle Rivers Watershed entities as staffing and budgets vary. Annual reporting by the Snake-Middle Rivers Watershed partners will provide benchmarks for measuring progress of the implemented TMDLs and for adaptive management. Details of the monitoring approach were specified during the Snake-Middle Rivers WRAPS process. Some monitoring also occurs in the Snake-Middle Rivers Watershed at the local and state level independently of the WRAPS schedule; for example, MPCA's watershed pollutant load monitoring network[3] and DNR's cooperative stream gaging[4] both provide useful long-term water monitoring data. The next intensive watershed monitoring in the next iteration of the Snake-Middle Rivers WRAPS project is scheduled to start in 2024 with waterbody condition assessments in early 2026.

[3] https://www.pca.state.mn.us/wplmn/overview

[4] https://www.dnr.state.mn.us/waters/csg/index.html

9. Implementation Strategy Summary

Rehabilitation actions within the impaired river reach watersheds will require cooperative planning and implementation by nonregulated and regulated entities with: partnering counties; SWCDs; MSTRWD; regional, state, and federal agencies; and funding sources. Pollutant reductions can be achieved primarily by using BMPs, land use changes, benchmark assessments, and monitoring to identify critical areas.

9.1 Permitted Sources

9.1.1 Phase II Municipal Separate Storm Sewer Systems (MS4)

No permitted MS4s exist in the project area.

9.1.2 Concentrated Animal Feeding Operations

One CAFO is located in the Snake-Middle Rivers Watershed. However, CAFOs are not allowed to discharge to surface water (with permit-specified exceptions) and were not given a WLA.

9.1.3 Construction Stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than 1 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 Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report. Construction activity must also meet all local government construction stormwater requirements.

9.1.4 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 stormwater discharges would be expected to be consistent with the WLA in this TMDL report. Industrial activity must also meet all local government construction stormwater requirements.

9.1.5 Wastewater

DMR data for each facility in the impaired watersheds were downloaded from the MPCA database to assess effluent levels.

A bacteria effluent evaluation was completed for the facilities in the watersheds of bacteria-impaired reaches with monthly average DMR monitoring data. The current bacteria permit limit for these facilities is a fecal coliform limit of 200 organisms per 100 milliliters (org/100 mL). The monitoring data shows all facilities typically discharge at bacteria concentrations below 200 org/100 mL. In 2006, the Argyle WWTF had one exceedance. The Middle River WWTF had one exceedance in 2006, one in 2009, and one in 2011. The Viking WWTF had one exceedance in 2011, two in 2013, and three in 2014. No exceedances have occurred at any sites since 2014.

A TSS effluent evaluation was completed for the facilities with monthly average DMR monitoring data (January 2006 through March 2015) for sites in the watersheds of turbidity-impaired reaches. The monitoring data show that all facilities typically discharge at TSS concentrations below their permit limits. Argyle WWTF exceeded their permit limit of 45 mg/L once in each of the following years: 2006, 2007, 2009, 2010, 2011, 2013, and 2017. Middle River WWTF exceeded their permit limits of 45 mg/L three times in 2006, once in 2007, twice in 2008 and 2009, once in 2015, and once in 2017. Newfolden WWTF exceeded their permit limit of 45 mg/L once in 2016 and 2017. Warren WWTF exceeded their permit limit of 45 once in 2006, 2009, and 2014. The remainder of the TSS samples for facilities in the Snake-Middle Rivers Watershed were in compliance with the permit limits.

The point sources are performing very well the majority of the time. Currently, fecal coliform and TSS limits that are consistent with the assigned WLAs are included in the NPDES/SDS Permits issued to the WWTFs. No additional reductions are required at this time, but because some permit-limit exceedances have occurred, the point-source contributions in the Snake-Middle Rivers Watershed can be improved.

9.2 Nonregulated Sources

Nonregulated rehabilitation actions within the impaired river reach watersheds will require cooperative planning and implementation by: partnering counties; SWCDs; MSTRWD; and regional, state, and federal agencies.

9.2.1 *E. coli*

BMPs that are expected to reduce *E. coli* loads to impaired streams are identified below, with details provided by *The Agricultural BMP Handbook for Minnesota* [Miller et al. 2012] and *Minnesota Stormwater Manual* [MPCA 2016a]. Cost, targets, and other BMP information are further discussed in the Snake-Middle Rivers WRAPS Report [MPCA 2020].

- **Animal Access Control:** Off-stream watering and fencing will aid in restricting animal access to stream and sensitive stream bank areas and allow growth of riparian vegetation.

- **Buffers and Streambank Stabilization:** Riparian vegetation helps to filter pollutants and stabilize banks. On all lands that border public waters, 50 foot average (30 foot minimum) vegetation buffers are required, and on all lands that border a public drainage system, 16.5 foot vegetation buffers are required. The deadline to seed the buffers on public waters was November 1st, 2017, and the deadline to seed the buffers on county ditches was November 1st, 2018. The Clean Water Legacy Fund included $5 million to BWSR for local government implementation. The SWCD is identifying the priority for placing perennial vegetation buffers along small streams, headwater areas, and county ditches.
- **Manure Management:** Proper manure management will assist in reducing the amount of manure-related organic matter that is carried in runoff volumes. Manure management techniques include applying at recommended rates, controlling manure stockpile runoff, avoiding manure application near open inlets, and avoiding winter manure spreading.
- **Pasture Management:** Rotational grazing, off-stream watering, and maintenance of riparian vegetation will aid in keeping bacteria from entering stream systems.
- **Pet waste management**: Ensure that local ordinances are being followed by using public education and enforcement of pet waste regulations.
- **Channelization and Artificial Drainage:** Exporting organic substrates, nutrients, and bacteria to downstream segments of the flow network will increase as drainage increases. Targeted monitoring of potential critical areas or specific areas of concern should be considered in the WRAPS monitoring plan.
- **County SSTS (Septic System) Compliance and Inspection Programs:** County ordinances have been developed to protect human health and the environment and need the public's support. Upgrades of noncompliance systems may be required to obtain building permits and upon property sale. County support via the Snake-Middle Rivers WRAPS process may result in designating grants or loans to help in upgrading old and failing septic systems. Failing and noncompliant SSTSs adjacent to lakes, streams, and associated drainages should receive the highest priority.
- **Public Education, Public Outreach, and Civic Engagement:** Public education, public outreach, and civic engagement on the benefits of the above practices should continue within the Snake-Middle Rivers Watershed. SWCDs, LGUs, and partnering counties should provide core materials for reinforcing messages aimed at target audiences.

9.2.2 Total Suspended Solids

BMPs that are expected to reduce TSS loads to impaired reaches are summarized below, with greater detail provided by *The Agricultural BMP Handbook for Minnesota* [Miller et al. 2012] and the *Minnesota Stormwater Manual* [MPCA 2016a]. Cost, targets, and other BMP information will be further discussed in the Snake-Middle Rivers WRAPS Report [MPCA, 2020].

- **Buffers and Streambank Stabilization:** Riparian vegetation helps to filter pollutants and stabilize banks. On all lands that border public waters, 50-foot average (30 foot minimum) vegetation buffers are required and on all lands that border a public drainage system, 16.5 foot vegetation buffers are required. The deadline to seed the buffers on public waters was November 1st, 2017, and the deadline to seed the buffers on county ditches was November 1st, 2018. The Clean Water Legacy Fund included $5 million to BWSR for local government implementation. The SWCDs is identifying the priority for placing perennial vegetation buffers along small streams, headwater areas, and county ditches.

- **Agricultural BMPs:** Cropland BMPs such as conversion to pasture with rotational grazing, conversion to grassland/perennials, the use of no-till cropping systems, the use of cover crops, and many others help to filter out or reduce the sediment that moves into the stream system. Cropland BMPs also help to redirect overland flow into interflow and groundwater flow to reduce the flashiness of the system and, therefore, the sediment issues.
- **Restoration of Hydrology to Altered Watercourses and Wetland Complexes:** Wetland restoration, reduction of tile-drains, and restoration of the altered waterways would help to reduce the flashiness of the system and, therefore, the in-stream sediment issues related to high flows such as bed and bank scour. Hydrology restoration would also be expected to reduce sediment delivery to downstream segments of the flow network.
- **Tracking and Implementation of Agricultural BMPs:** Encouraging and tracking implementation of agricultural BMPs, as detailed by *The Agricultural BMP Manual for Minnesota*, will substantially reduce agricultural lands' sediment loadings. Proper site designs, construction, and maintenance are key components for effective performance of agricultural best practices.
- **Tracking and Implementation of Urban BMPs:** Encouraging and tracking implementation of urban BMPs, as detailed by the *Minnesota Stormwater Manual* and MIDS, will cover the spectrum of source, rate, and volume controls that will substantially reduce developed land's sediment loadings. Proper site designs, construction, and maintenance are key components for effective performance of urban BMPs.
- **Public Education:** The benefits of the above practices should continue with Snake-Middle Rivers Watershed partnering counties providing core materials for reinforcing messages aimed at targeted audiences.

9.3 Cost

The CWLA requires that a TMDL include an overall approximation of the cost to implement a TMDL [Minnesota State Legislature 2007]. Using HSPF, scenarios were run to evaluate a TMDL cost scenario. Other scenarios will be evaluated as a part of the WRAPS portion of the Snake-Middle Rivers project. The cost scenario included converting 30% of cropland to no till, 30% of cropland to rotational grazing, and 30% of cropland to perennials, and attaining a 75% reduction of bed and bank sediment from armoring and stabilization along sediment-impaired reaches throughout the entire Snake-Middle Rivers HUC-08.

Cropland conversion to perennials and to rotational grazing were both estimated to cost approximately $105 per acre, while conversion to no till was estimated to cost approximately $10 per acre. Thus, the total cost for the cropland BMPs would be approximately $25 million dollars. Cost estimates for cropland BMPs were based on the 2016 Minnesota NRCS EQIP cost-share docket for Minnesota [Kenner and Oswald 2017]. The bed and bank scenarios were estimated to be 50% rip-rap at approximately $188,000 per acre and 50% bank shaping and vegetation at approximately $3,500 per acre. With approximately 95 miles of impaired stream assuming a treated width of 50 ft (25 ft per side), approximately 580 acres are assumed to need treatment, and the total cost of bed and bank BMPs would be approximately $56 million. Costs for the bed and bank BMPs were based on the Minnesota *Agricultural BMP Handbook* [Miller et al. 2012]. The total cost estimate to meet sediment TMDLs would be approximately $81 million. This estimate is, by nature, a very general approximation with considerable uncertainties associated with design complexity, local regulatory requirements, unknown site constraints, and BMP choices with widely variable costs per water quality volume treated. This estimate is large-scale, and many other implementation strategies will likely be used in addition to or to replace general practices that are used in this estimate.

According to the Minnesota *Agricultural BMP Handbook*, both filter strips and field borders reduce pathogens by 60%. Because *E. coli* sources in the Snake-Middle Rivers Watershed are primarily agricultural in nature, and much of the agricultural manure in the watershed is spread on local cropland, the increase in vegetation and cover on the cropland from the three cropland BMPs is likely to have a large positive impact on pathogens, with an overall expected decrease from cropland sourced *E. coli* of more than 50%. Additional feedlot filter strips with shaping could be added to the estimated 12 feedlot acres that drain to the impaired reaches for a cost of $230 to $258 per acre (total cost of approximately $3,000). Off-stream watering (highly variable cost) and livestock exclusion (average cost of approximately $1.30/foot of fence) are also very effective practices to reduce pathogens in the stream [Miller et al. 2012]. The further scenarios will be run as a part of the WRAPS portion of the watershed planning process. Estimated costs available on a per-acre basis summarized in the above paragraphs are shown in **Table 9-1**.

Table 9-1. Estimated Costs Available on a Per-Acre Basis.

Practice	$/Acre	Acres	Total Cost	Source
Cropland Conversion to Perennials	$105	115,200	$12,096,000	2016 MN NRCS Equip Cost Share Docket
Rotational Grazing	$105	115,200	$12,096,000	2016 MN NRCS Equip Cost Share Docket
No-Till Conversion	$10	115,200	$1,152,000	2016 MN NRCS Equip Cost Share Docket
50% Rip-Rap	$188,000	290	$54,520,000	MN Ag BMP Handbook
50% Bank Shaping and Vegetation	$3,500	290	$1,015,000	MN Ag BMP Handbook
Feedlot Filter Strips with Shaping	$244	12	$2,928	MN Ag BMP Handbook

9.4 Adaptive Management

The list of implementation elements and the more detailed WRAPS report has been prepared following this TMDL assessment and focuses on adaptive management as illustrated in **Figure 9-1**. Continued monitoring and "course corrections" that respond to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDL and provide the groundwork for delisting the impaired waterbodies. Currently, the cycle depicted in **Figure 9-1** is repeated every 10 years. Ongoing monitoring and analysis of trend data and BMP implementation information will assist managers to make informed decisions on adapting management approaches.

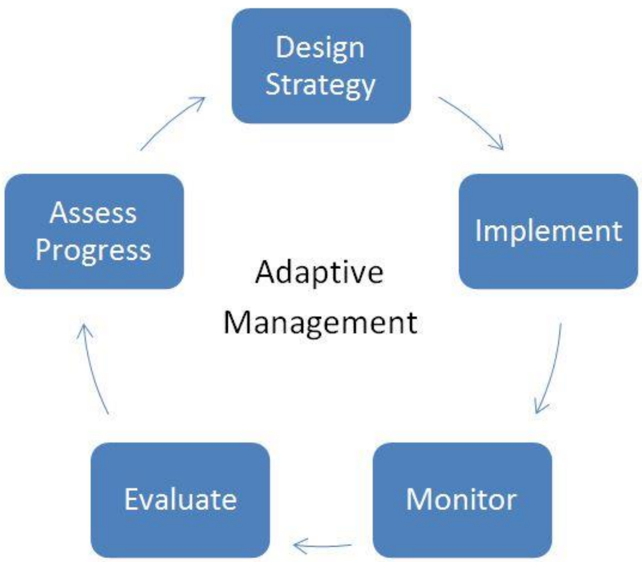

Figure 9-1. Adaptive management cycle.

10. Public Participation

Efforts to facilitate public education, review, and comment with developing the Snake-Middle Rivers TMDLs included meetings with local groups in the watershed on the assessment findings and a 30-day public notice period for public review and comment of the draft TMDL report. All input, comments, responses, and suggestions from public meetings and the public notice period were addressed or were taken into consideration in developing the TMDL report. The draft TMDL report was made available at https://www.pca.state.mn.us/public-notices. Regular updates regarding the TMDL process with the Snake-Middle Rivers Watershed WRAPS team included meetings to discuss TMDL processes and results. Public and team meetings are listed below:

- A project kickoff meeting was held with the project team on April 25, 2017.
- A project team meeting was held on June 1, 2017, to discuss the project timeline, methods, and TMDL segments to be addressed.
- An open house for the public was held at the community center in Argyle, Minnesota, on July 27, 2017, to introduce the public to the TMDLs and educate them on the watershed and watershed activities.
- Because of the COVID-19 pandemic, it was not possible to hold an in-person public meeting to present the draft TMDL and WRAPS reports. A two-page flyer was developed instead with information and web addresses to prerecorded, on-demand presentations available to the public with material that would normally be discussed at an in-person meeting. The MSTRWD mailed the flyer and a cover letter to 110 contacts and organizations (including township clerks, county commissioners, county engineers, city clerks, Minnesota Department of Transportation, SWCDs, National Resources Conservation Service, BWSR, etc) shortly after the beginning of public notice. The flyer also listed one contact person from each state and local organization that the public can contact with any feedback, concerns, or questions.
- An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from September 21, 2020 through October 21, 2020. One comment letter was received and responded to as a result of the public comment period.

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Appendix A – TMDL Maps

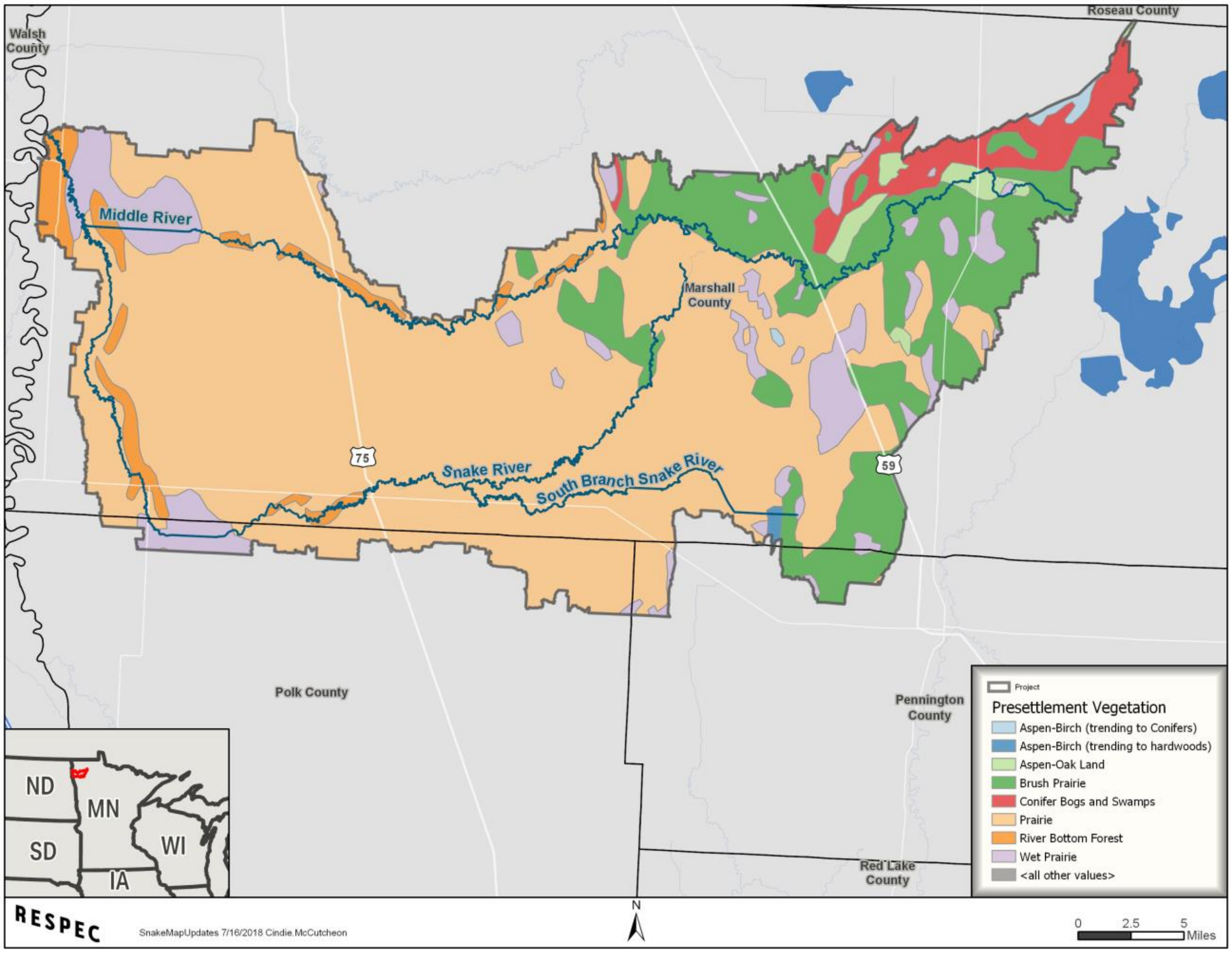

Figure A-1. Pre-settlement vegetation in the Snake-Middle Rivers Watershed.[5]

[5] The GIS layer was created by MN DNR and is based on the "Marschner's Map", created by Francis J. Marschner in 1930.

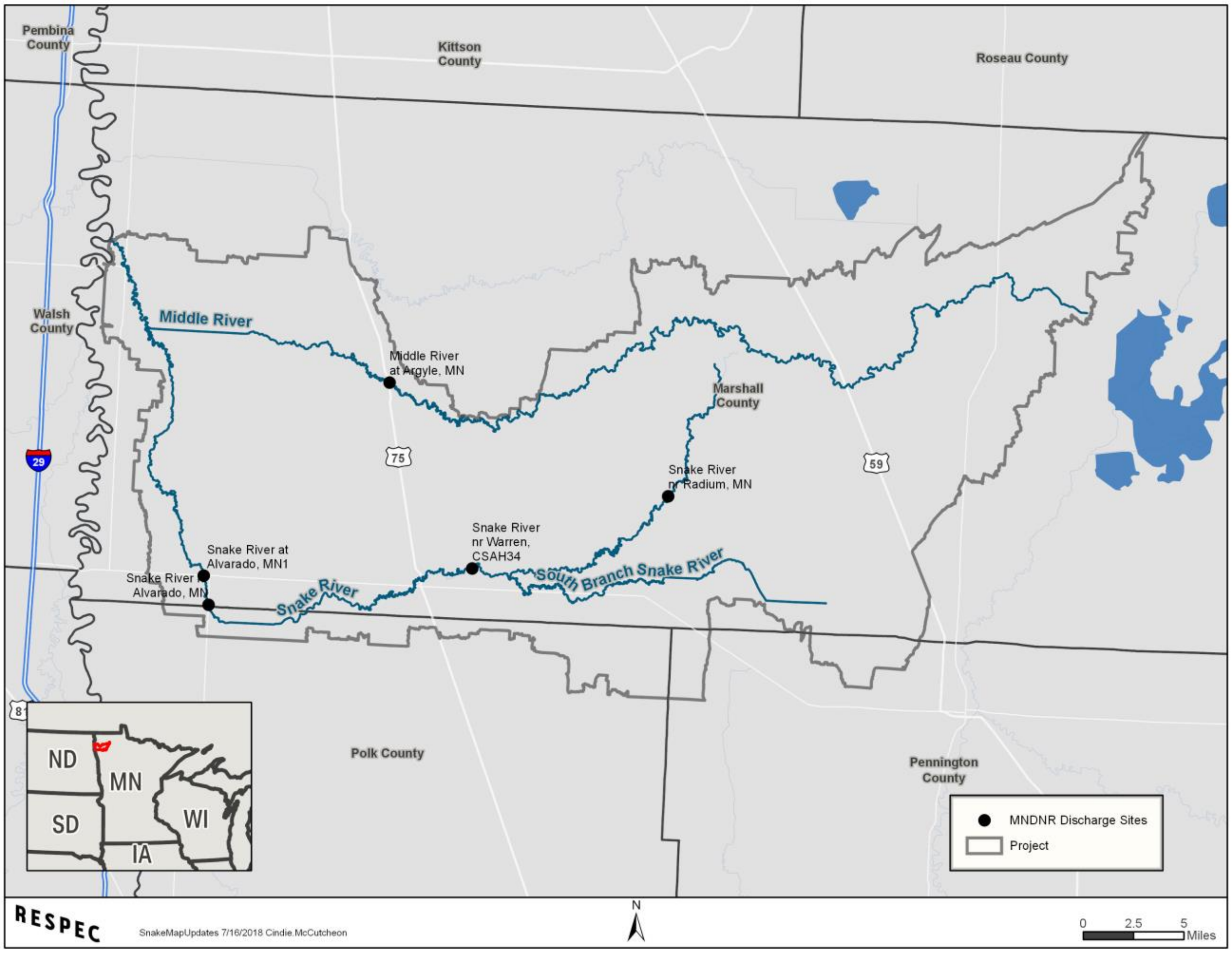

Figure A-2. Discharge monitoring locations in the Snake-Middle Rivers Watershed.

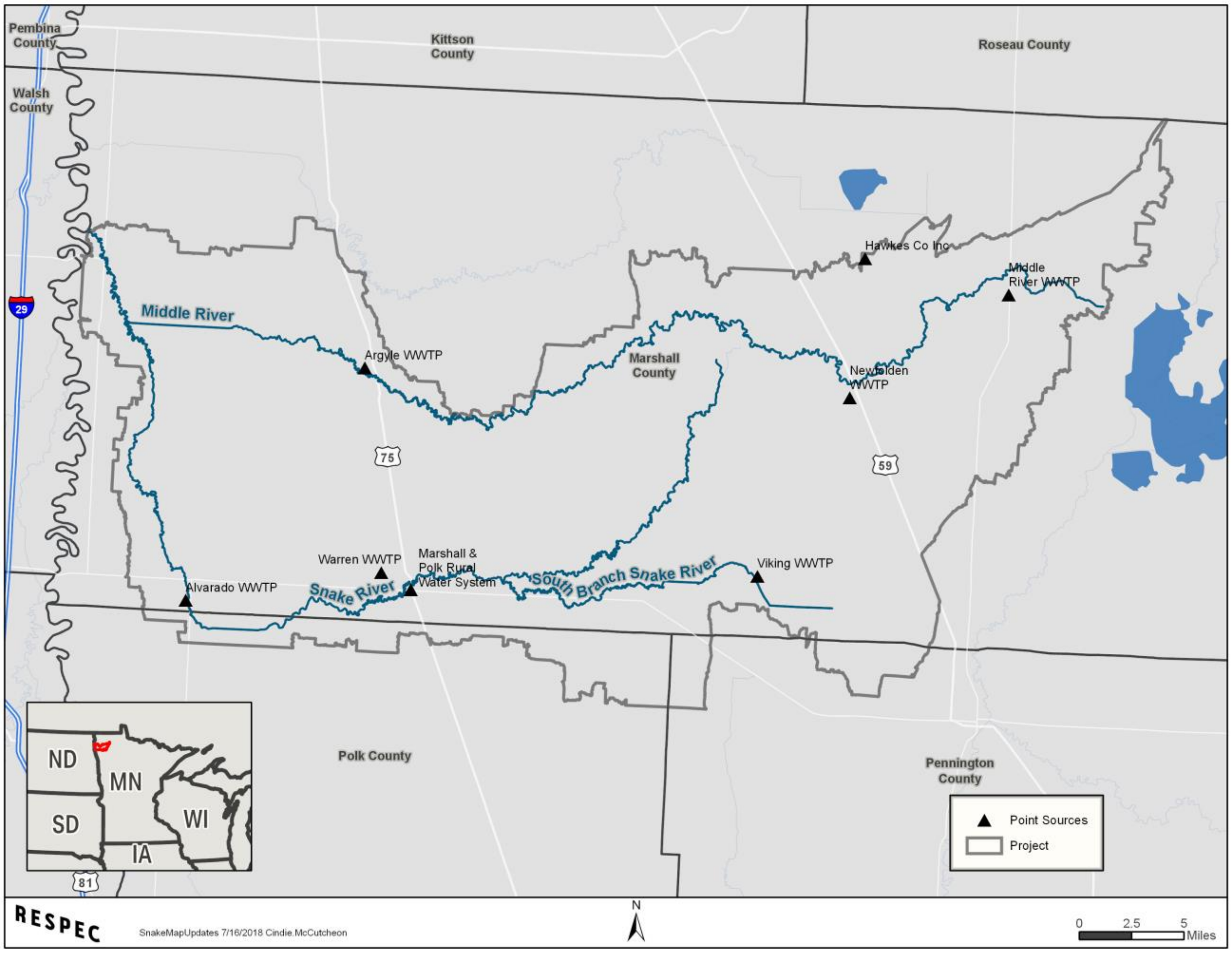

Figure A-3. Point sources in the Snake-Middle Rivers Watershed.

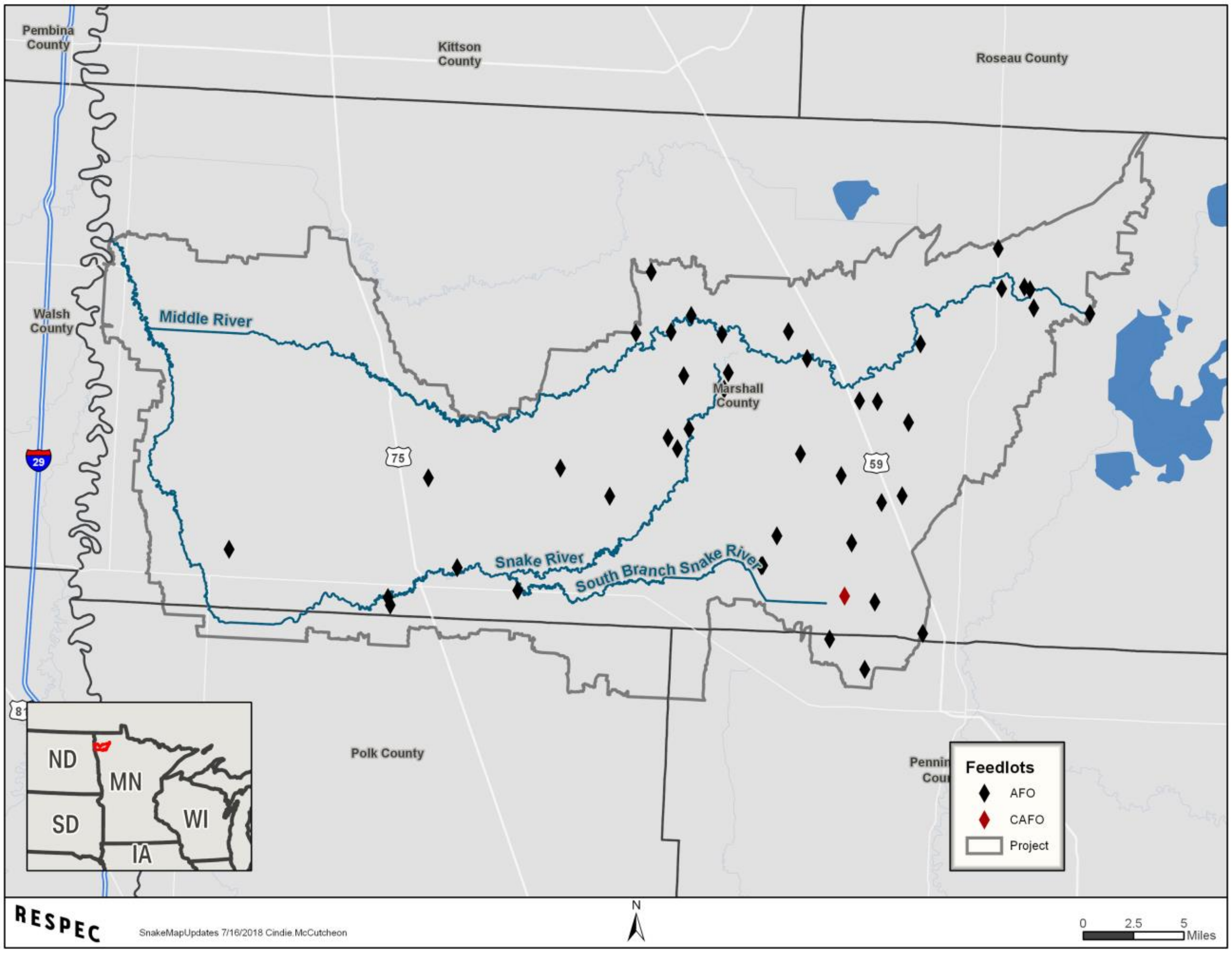

Figure A-4. Feedlots in the Snake-Middle Rivers Watershed.