Escherichia coli Bacteria Total Maximum Daily Load Evaluation for Beaver Creek segment 01 Lincoln County, South Dakota

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Division of Resource Conservation and Forestry

Watershed Protection Program

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List of Acronyms and Units of Measurement

ARSD	Administrative Rules of South Dakota
BMP	Best Management Practice
BSRP	Big Sioux River Implementation Project
CAFO	Concentrated Animal Feeding Operation
cfs	Cubic Feet Per Second
CFU	Colony Forming Unit
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
DANR	Department of Agriculture & Natural Resources (South Dakota)
DENR	Department of Environment & Natural Resources (South Dakota)
EDWDD	East Dakota Water Development District
EPA	Environmental Protection Agency (U.S.)
FC	Fecal Coliform
GM	Geometric Mean
HUC	Hydrologic Unit Code
IA DNR	Iowa Department of Natural Resources
IR	Integrated Report (South Dakota's Water Quality Integrated Report)
LA	Load Allocation
LDC	Load Duration Curve
µL	Microliter
mL	Milliliter
MOS	Margin of Safety
NASS	National Agricultural Statistic Survey
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point Source
NWS	National Weather Service
SSM	Single Sample Maximum
SRAM	Seasonal Riparian Area Management
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WISKI	Water Information Systems by KISTERS
WLA	Waste load Allocation
WPP	Watershed Protection Program (South Dakota)
WQM	Water Quality Monitoring

Beaver Creek segment 01 *E. coli* Total Maximum Daily Load Summary

Assessment Unit Identification (AUID):	SD-BS-R-BEAVER_01
Waterbody Type:	River/Stream
Location:	Big Sioux River to S9, T98N, R49W
County:	Lincoln County, SD
Initial Listing Date:	2020 South Dakota Integrated Report
TMDL Priority:	High
HUC 12 Codes:	101702031802, 101702031803, 101702031801
Size of Watershed:	81,389 Acres
303(d) Listing Parameter:	*Escherichia coli* bacteria
Listed Stream Miles:	8.78 miles
Designated Use of Concern:	Limited contact recreation, Immersion recreation
Analytical Approach:	Load Duration Curve
Target (Water Quality Criteria):	*E. coli* single sample maximum ≤235 cfu/100mL Geometric mean ≤126 cfu/100mL based on a minimum of 5 samples collected during separate 24-hour periods for any 30-day period (calendar month).

Immersion Recreation *E. coli* TMDL	Beaver Creek segment 01 Flow Zones Expressed as (CFU/day)				
	High Flows	Moist Conditions	Mid-Range Conditions	Dry Conditions	Low Flows
Flow Rate	>95.76	95.75 - 23.76	23.75 - 8.93	8.92 - 4.53	<4.52
WLA	0	0	0	0	0
LA	7.34E+12	4.41E+11	1.18E+11	4.49E+10	2.30E+10
10% Explicit MOS	8.16E+11	4.90E+10	1.31E+10	4.99E+09	2.56E+09
TMDL @235 cfu/100mL	8.16E+12	4.90E+11	1.31E+11	4.99E+10	2.56E+10
Current Load*	6.66E+14	1.51E+12	7.99E+11	1.43E+11	7.00E+10
Load Reduction	99%	68%	84%	65%	63%

** Current load is the 95th percentile single sample concentration times the 95th percentile flow in each flow zone*

1.0 Document Summary

The Environmental Protection Agency (EPA) delegates authority to the South Dakota Department of Agriculture and Natural Resources (SD DANR) to develop impaired waters lists and Total Maximum Daily Load (TMDL) reports in accordance with section 303(d) of the federal Clean Water Act (CWA). The intent of this document is to clearly identify the components of the TMDL, support adequate public participation and facilitate United States Environmental Protection Agency (EPA) review. This TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance provided by the EPA. This TMDL document addresses the *Escherichia coli* (*E. coli*) impairment for Beaver Creek (SD-BS-R-BEAVER_01) in Lincoln County, South Dakota. Beaver Creek segment 01 is supporting all other parameters associated with its designated beneficial uses.

SD-BS-R-BEAVER_01 was initially listed as impaired for *E. coli* and non-supporting the designated limited contact recreation use in the 2020 South Dakota Integrated Report for Surface Water Quality based on water quality data collected from 2014 to 2019 (SD DENR, 2020). It remained impaired for *E. coli* in the 2022 and 2024 South Dakota Integrated Reports, and in the most recent 2026 South Dakota Surface Water Quality Assessment based on water quality data collected from 2020 to 2025 (SD DANR, 2022) (SD DANR, 2024) (SD DANR, 2026). South Dakota criteria for determining support status states that if more than 10% of the samples collected within the 5-year data age range exceed the daily maximum criterion the waterbody is considered impaired (SD DANR, 2026).

1.1 *E. coli* Summary

Elevated concentrations of *E. coli* can put humans at risk for contracting water-borne illnesses. The presence of elevated *E. coli* concentrations in a waterway can also impair the waterbody's recreation beneficial uses. Water quality assessment methods are designed to evaluate the most sensitive use to ensure protection. Beaver Creek segment 01 is designated the limited contact recreation use. However, TMDLs must be protective of downstream uses and associated water quality criteria. This TMDL is written to the immersion recreation *E. coli* criteria because Beaver Creek segment 01 flows into segment 14 of the Big Sioux River (SD-BS-R-BIG_SIOUX_14) which is designated the beneficial use of immersion recreation. *E. coli* production in Beaver Creek segment 01 is attributable to both naturally occurring and human-caused sources. Human-caused sources include agricultural practices and failing or malfunctioning septic systems. Naturally occurring or background sources of *E. coli* are primarily from wildlife excrement. To comply with *E. coli* water quality standards, best management practices (BMPs) need to be implemented to reduce *E. coli* concentrations in the Beaver Creek segment 01 watershed.

2.0 Watershed Characteristics

The following sections provide a description of the Beaver Creek segment 01 watershed. Characteristics such as climate, land use, demographics, and hydrology will be covered in the following sections.

2.1 Location and Hydrology

SD-BS-R-BEAVER_01, as identified by the orange line in ***Figure 1***, is located in southeastern South Dakota. The majority of the watershed of Beaver Creek segment 01 is in Lincoln County with portions extending into Minnehaha and Turner counties. As identified in the National Hydrography Dataset, the headwaters of Beaver Creek segment 01 begin in southern Minnehaha County and extend 49 miles to its confluence with the Big Sioux River at the South Dakota/Iowa border. A total of 8.78 stream miles of Beaver Creek segment 01 is designated the beneficial use of limited contact recreation. SD-BS-R-BEAVER_01 is listed on the 303(d) list of impaired waters for not supporting the limited contact recreation use due to elevated levels of *E. coli*. Beaver Creek segment 01 drains approximately 81,389 acres of Minnehaha, Turner, and Lincoln counties in southeast South Dakota. Three hydrologic units make up the watershed of Beaver Creek: South Fork Beaver Creek (HUC12: 101702031802), Beaver Creek (101702031803), and Headwaters Beaver Creek (101702031801). There are two named tributaries of Beaver Creek segment 01 as identified in the NHD: Ditch number 14 and South Fork Beaver Creek. At this time monitoring has not been conducted on these tributaries and they are not assessed in the South Dakota IR. ArcGIS Pro was used to calculate the size of the Beaver Creek segment 01 watershed.

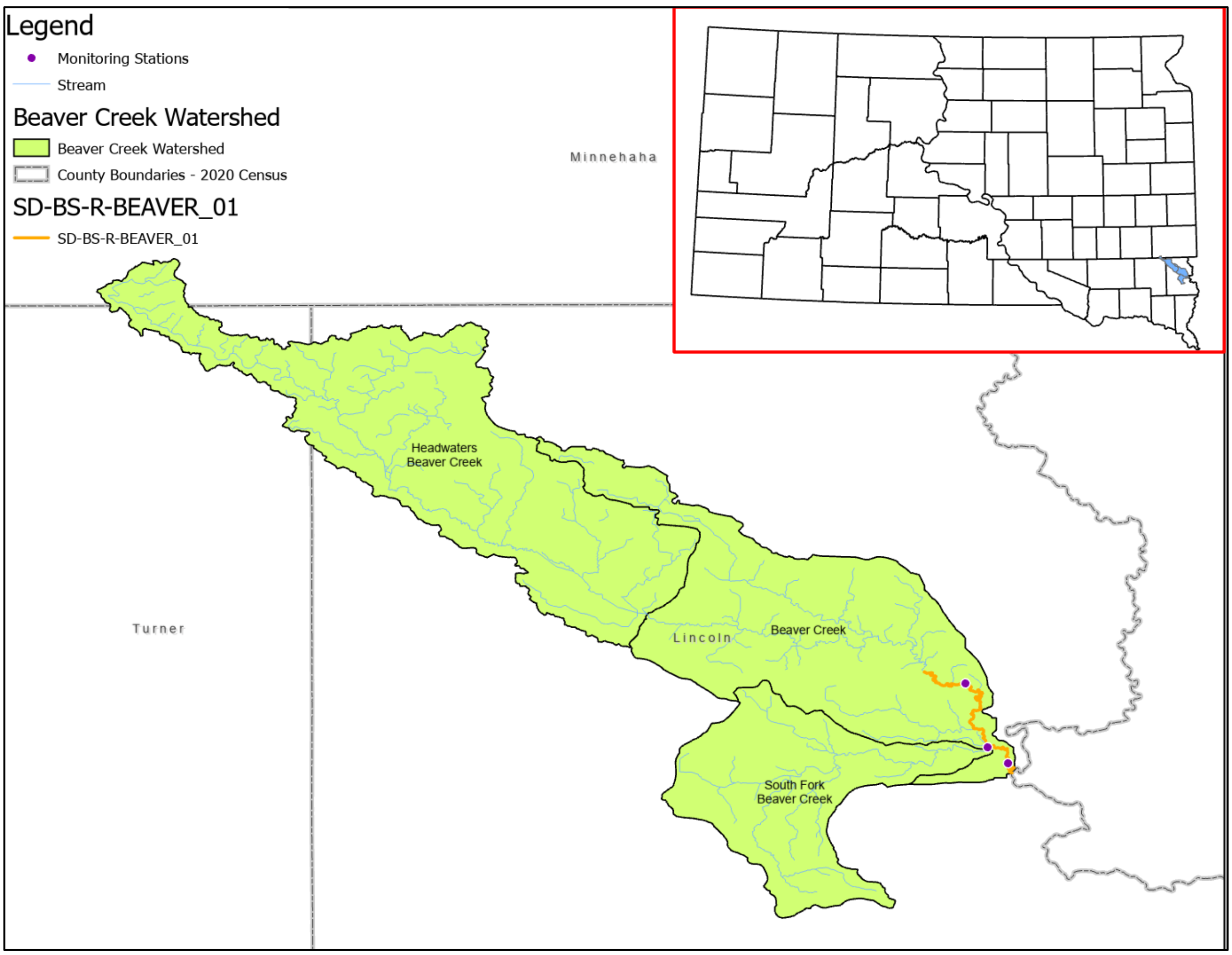

Figure 1. Map of Beaver creek segment 01 watershed location.

2.2 Demographics

The cities of Tea, Canton, and Worthing are located near the watershed of Beaver creek segment 01, although none are fully contained within the boundary (***Figure 2***). The total population of these three communities amounts to 9,831 people. Using the 2020 Census Blocks layer in ArcGIS Pro, the entire population within the watershed of Beaver Creek segment 01 was estimated to be 7,695, with 3,700 residents living outside of city limits.

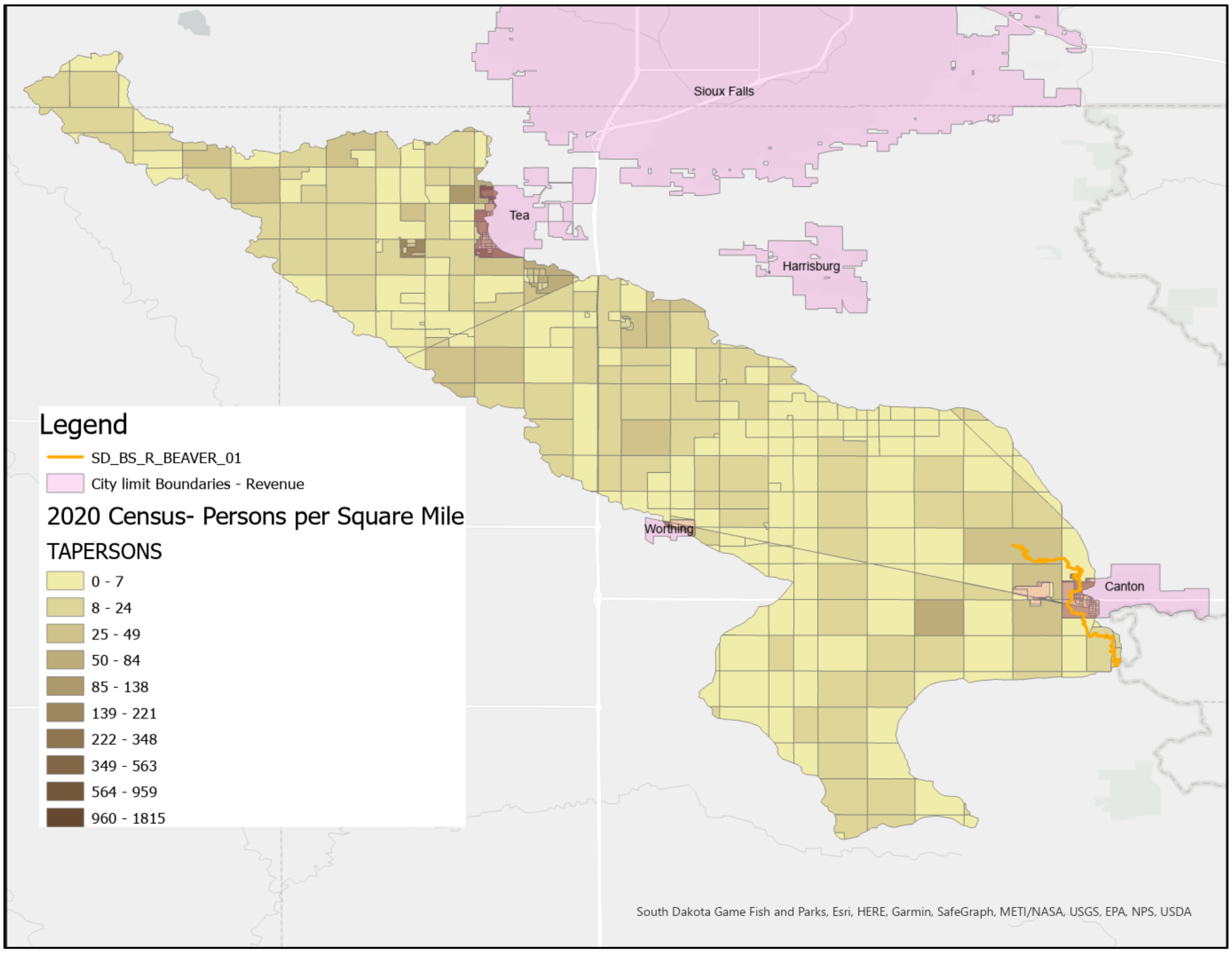

Figure 2. Map of population per square mile in Beaver Creek segment 01 watershed.

2.3 Climate

The Beaver Creek segment 01 watershed is located in the USDA Plant Hardiness Zone 4b, which is characterized by temperatures reaching lows of -25 °F to -20 °F (USDA- US Forest Service, 2012). Climate data was obtained from the nearest climatological data station at Foss Field near Sioux Falls. Over the past 10 years weather patterns in the area have shown an average yearly snowfall of 45 inches and an average yearly precipitation of 28 inches. Most of the precipitation falls during the warming period, and rainfall is usually heaviest late spring and in the summer months. Average summer temperatures are 69° F and winter temperatures average 33° F (NOAA, 2023). Yearly weather trends can be seen in ***Table 1***.

Table 1. Yearly and average temperature, precipitation, and snowfall.

Year	Average May-September Temperature (°F)	Average October - April Temperature (°F)	Yearly Snowfall (Inches)	Yearly Precipitation (Inches)
2022	70	32	31	25
2021	71	36	32	28
2020	70	34	43	16
2019	68	30	57	40
2018	69	30	71	39
2017	68	35	37	25
2016	69	36	49	32
2015	67	35	54	33
2014	66	29	39	29
2013	67	28	50	26
2012	70	37	29	17
Average	69	33	45	28

2.4 Land Use

Beaver Creek segment 01 is located in the level III ecoregion of The Northern Glaciated Plains and the level IV ecoregion of the James River Lowlands (46n). The Northern Glaciated Plains ecoregion is characterized by a flat to gently rolling landscape composed of glacial drift. Subhumid conditions support tall and shortgrass prairie with a high concentration of temporary and seasonal wetlands. The level IV ecoregion, (46n) James River Lowlands, has a mild climate with warmer temperatures favoring the growth of winter wheat, corn, and soybeans. Agricultural activity is also supported by the fertile mesic soils of the area (USGS, 1996). Land use in the Beaver Creek segment 01 watershed is predominately agricultural in nature. Developed land in the watershed accounts for only 5.38% of the land use and is distributed in or close by communities of Tea, Canton, and Worthing. Row crops, including corn, soybeans, sunflowers, and alfalfa, account for 80.69% of the land use in the watershed. 10.54% of the land is used for grassland/pasture. As seen in ***Figure 3*** grasslands and pastures are located near the banks of Beaver Creek segment 01 and its unnamed tributaries. Other land use types and their percentages are outlined in ***Table 2***.

Table 2. Land use percentages in the Beaver Creek segment 01 Watershed.

Land Use	Acres	Percentage
Row Crops	65,669	80.69%
Grassland/Pasture	8,581	10.54%
Developed	4,380	5.38%
Wetlands	1,431	1.76%
Forest and Shrubland	598	0.73%
Barren/Fallow Land	391	0.48%
Small Grain	219	0.27%
Water	113	0.14%
Sod	6	0.01%

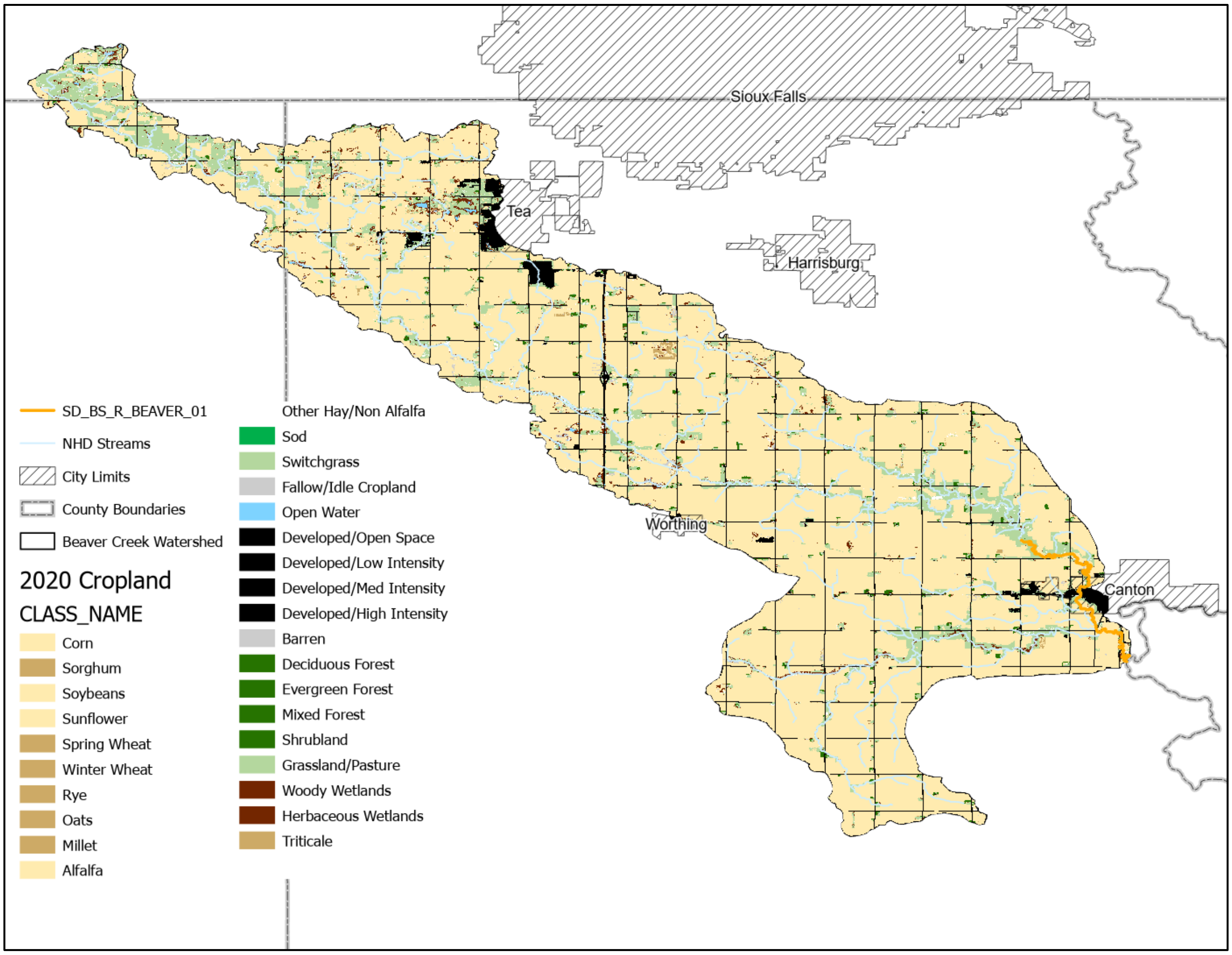

Figure 3. Map of land use in the Beaver Creek segment 01 watershed.

3.0 South Dakota Water Quality Standards

Water quality standards are defined in the Administrative Rules of South Dakota (ARSD) Chapter 74:51:01 and in the Federal Clean Water Act (33 U.S.C. §1251 et seq.). Standards are comprised of three main parts:

1. Beneficial uses: Functions or activities that reflect Waterbody management goals
2. Criteria: Numeric concentrations or narrative statements that represent the level of water quality required to support beneficial uses
3. Antidegradation: Additional policies that protect high quality waters

3.1 Beneficial Uses

All waterbodies in South Dakota are assigned one or more of the following beneficial uses as defined in South Dakota Administrative Rule 74:51:

(1) Domestic water supply
(2) Coldwater permanent fish life propagation

(3) Coldwater marginal fish life propagation
(4) Warmwater permanent fish life propagation
(5) Warmwater semipermanent fish life propagation
(6) Warmwater marginal fish life propagation
(7) Immersion recreation
(8) Limited contact recreation
(9) Fish, wildlife, propagation, recreation & stock watering
(10) Irrigation
(11) Commerce and industry

All streams in South Dakota are designated the beneficial use of (9) Fish, wildlife, propagation, recreation & stock watering and (10) irrigation, unless otherwise stated in the Administrative Rules of South Dakota (ARSD). Additional uses are designated by the state based on a waterbody specific use attainability assessment (SD Legislative Research Council, 2023).

SD-BS-R-BEAVER_01 is designated the beneficial uses of (6) Warmwater marginal fish life propagation, (8) Limited contact recreation, (9) Fish, wildlife, propagation, recreation & stock watering, and (10) Irrigation (SD DANR, 2026). Beaver Creek segment 01 flows into segment 14 of the Big Sioux River, which is designated the beneficial use of (7) immersion recreation.

3.2 Water Quality Criteria

The water quality criteria that must be met to protect all beneficial uses of SD-BS-R-BEAVER_01 can be found in ***Table 3.*** When multiple criteria exist for a certain parameter, the most stringent criterion is used.

Table 3. South Dakota Water Quality Criteria for SD-BS-R-BEAVER_01.

Parameter	Criteria	Unit of Measure	Beneficial Use
Alkalinity ($CaCO_3$)	≤750 30-day average ≤1,313 daily maximum	mg/L	Fish, wildlife, propagation, recreation, & stock watering
Escherichia coli Bacteria (May 1st-September 30th)	≤630 geometric mean ≤1,178 daily maximum	*E. coli*/100 mL	Limited contact recreation
Microcystin (May 1st-September 30th)	≤8	µg/L	Limited contact recreation
Cylindrospermopsin (May 1st-September 30th)	≤15	µg/L	Limited contact recreation
Conductivity	≤4,000 30-day average 7,000 daily maximum	umhos/cm @ 25°C	Fish, wildlife, propagation, recreation, & stock watering

Parameter	Criteria	Unit of Measure	Beneficial Use
Hydrogen Sulfide, undissociated	≤0.002 daily maximum	mg/L	Warmwater marginal fish life propagation
Nitrogen, total ammonia as N	30-day average: Equal to or less than the result from Equation 3 in Appendix A Daily maximum: Equal to or less than the result from Equation 2 in Appendix A	mg/L	Warmwater marginal fish life propagation
Nitrogen, nitrates as N	≤50 30-day average ≤88 daily maximum	mg/L	Fish, wildlife, propagation, recreation, & stock watering
Oxygen dissolved	≥4.0 October 1st- April 30th daily maximum ≥5.0 May 1st- September 30th daily maximum	mg/L	Warmwater marginal fish life propagation
pH	≥6.0 - ≤9.0	standard units	Warmwater marginal fish life propagation; Fish, wildlife, propagation, recreation, & stock watering; Commerce and industry
Sodium Adsorption Ratio	≤10	mg/L	Irrigation
Total suspended solids	≤150 30-day average ≤263 daily maximum	mg/L	Warmwater marginal fish life propagation
Total dissolved solids	≤2,500 30-day average ≤4,375 daily maximum	mg/L	Fish, wildlife, propagation, recreation, & stock watering
Temperature	≤90	°F	Warmwater marginal fish life propagation
Total Petroleum Hydrocarbons	≤10	mg/L	Fish, wildlife, propagation, recreation, & stock watering
Oli and Grease	≤10	mg/L	Fish, wildlife, propagation, recreation, & stock watering

3.2.1 *E. coli* Water Quality Standards

South Dakota has adopted numeric *E. coli* criteria for the protection of the immersion (7) and limited contact (8) recreation beneficial uses. Immersion recreation waters are to be maintained suitable for activities such as swimming, bathing, waterskiing and other activities with a high degree of water contact that make exposure and ingestion more likely. Limited contact waters must be maintained suitable for boating, fishing, and other water related recreation that does not involve immersion.

Through the 1970's and 1980's EPA epidemiological studies identified *E. coli* as a good predictor of gastrointestinal illnesses in fresh waters (US EPA, 1986). *E. coli* is a class of bacteria naturally found in the intestinal tract of humans and warm-blooded animals. The presence and concentration of *E. coli* in surface waters, typically measured in colony forming units (cfu) or counts (#) per 100ml, is used to identify fecal contamination and as an indicator for the likely presence of other pathogenic microorganisms. *E. coli* bacteria standards in South Dakota are expressed as a count/100mL. Laboratory results for *E. coli* were expressed as Most Probable Number (MPN) and Colony Forming Units (CFU), respectively. Both units are considered equivalent and representative of the number or count of bacteria/100mL. In 1986 EPA recommended states adopt *E. coli* criteria for immersion recreation based on a rate of 8 illnesses per 1,000 swimmers (US EPA, 1986). While it is generally understood that limited contact recreation is associated with a reduced illnesses risk and different routes of exposure, it is difficult to directly relate an illness rate to these activities from epidemiological studies based on immersion recreation. Therefore, to protect downstream uses and establish effluent limitations for limited contact recreation waters, EPA has suggested numeric criteria five times the immersion recreation values (US EPA, 2002). Because of the reduced risk, the multiplier was considered protective of the limited contact recreation use through the EPA and SD DANR water quality standards review and approval process.

The South Dakota *E. coli* criteria for the immersion recreation beneficial use requires that 1) no single sample exceed 235 cfu/100 ml and 2) during a 30-day period, the geometric mean of a minimum of 5 samples collected during separate 24-hr periods must not exceed 126 cfu/100 ml (ARSD 74:51:01:50). The *E. coli* criteria for the limited contact recreation beneficial use requires that 1) no single sample exceeds 1,178 cfu/100 ml and 2) during a 30-day period, the geometric mean of a minimum of 5 samples collected during separate 24-hour periods must not exceed 630 cfu/100 ml (ARSD 74:51:01:51). As noted, these limited contact criteria are five times the corresponding immersion criteria. *E. coli* criteria apply from May 1 through September 30, which is considered the recreation season. The numeric *E. coli* criteria applicable to Beaver Creek segment 01 (SD-BS-R-BEAVER_01) are the limited contact recreation values listed in ***Table 3***.

TMDLs must be protective of downstream uses and associated water quality criteria. Beaver Creek segment 01 flows into Big Sioux River segment 14 (SD-BS-R-BIG_SIOUX_14) which is designated the beneficial uses of both limited contact recreation and immersion recreation. To protect downstream water quality standards, the Beaver Creek segment 01 *E. coli* TMDL will be written to the immersion recreation beneficial use single sample maximum of 235 cfu/100mL. The criteria for immersion recreation is stricter than the criteria for limited contact recreation. Big Sioux River segment 14 is currently non-supporting of its *E. coli* water quality criteria for limited contact recreation and immersion recreation (SD DANR, 2026). Big Sioux River segment 14 runs along the border of South Dakota and Iowa. In the 2026 Iowa Integrated Report, the corresponding segments, IA 06-BSR-1524 and 06-BSR-1525, are both non-supporting of their *E. coli* water quality criteria for recreation: primary contact (IA DNR, 2026). 06-BSR-1524 is located from the confluence with Rock River (S1 T95N R48W Sioux County) to the confluence with Beaver Creek near Canton, SD, in S36 T98N R49W Lyon County and IA 06-BSR-1525 is located from the confluence with Beaver Creek near Canton, SD, (S36 T98N R49W Lyon County) to the confluence with Ninemile Creek in S25 T100N R49W Lyon County. These segments of the Big Sioux River are included in the 2008 Total Maximum Daily Loads for Pathogen Indicators: Big Sioux River, Iowa and South Dakota (USEPA Region 7, IA DNR, & SD DENR, 2008). This TMDL was approved by EPA Regions 7 and 8, and adopted by both Iowa and South Dakota. For South Dakota waters, this TMDL was written for fecal coliform; therefore, an updated TMDL to South Dakota's *E. coli* criteria is needed. Waterbodies listed as impaired for *E. coli* and in need of a TMDL are in priority group 1 in South Dakota's Vision 2 TMDL Prioritization Framework, which outlines plans for TMDL development for the period 2022-2032 (SD DANR, Watershed Protection Program, 2024).

3.3 Antidegradation

This TMDL document is consistent with South Dakota antidegradation policies (ARSD 74:51:01:34) because it provides recommendations and establishes pollutant limits at water quality levels necessary to meet criteria and fully support existing beneficial uses.

4.0 Numeric TMDL Targets

TMDLs are required to identify a numeric target to measure whether the applicable water quality standard is attained. A maximum allowable load, or TMDL, is ultimately calculated by multiplying this target with a flow value and a unit conversion factor. Generally, the pollutant causing the impairment and the parameter expressed as a numeric water quality criterion are the same. In these cases, selecting a TMDL target is as simple as applying the numeric criteria. Occasionally, an impairment is caused by narrative water quality criteria violation or by parameters that cannot be easily expressed as a load. When this occurs, the narrative criteria must be translated into a numeric TMDL target (e.g., nuisance aquatic life translated into a total phosphorus target) or a surrogate target established (e.g., a pH cause addressed through a total nitrogen target) and a demonstration should show how the chosen target is protective of water quality standards.

There are two numeric *E. coli* criteria for TMDL target consideration. When multiple numeric criteria exist for a single parameter, the most stringent criterion is selected as the TMDL target. To judge whether one is more protective of the beneficial use, it is necessary to further evaluate how the criteria were derived (***Appendix B***). Criteria development revealed that the geometric mean (GM) and single sample maximum (SSM) criterion are equally protective of the beneficial use because they are based on the same illness rate and only differ simply from different statistical values and sampling timeframes (US EPA, 2012 (B)). Because assessment data was insufficient to calculate a monthly GM, the SSM *E. coli* criterion of 235 cfu/100mL was selected as the numeric TMDL target for Beaver Creek segment 01, which is protective of downstream uses. In addition to the daily load, the geometric mean criteria must be attained on a longer (i.e., monthly) basis.

5.0 Impairment Assessment Methods

Assessment methods document the decision-making process used to define whether water quality standards are met. SD DANR evaluates monitoring data following these established procedures to determine if: 1) one or more beneficial use is not supported, 2) the waterbody is impaired, and 3) it should be placed on the next 303(d) list. Waterbodies impaired by pollutants require TMDLs and these assessment methods are commonly used again in the process sometime after TMDLs have been established and restoration efforts have been implemented. In select cases, attainment is judged instead by comparing current conditions to TMDL loading limits. For example, when certain characteristics of the pollutant (e.g., bioaccumulative) or waterbody (e.g., a reservoir filling with sediment) prioritize loading concerns. South Dakota's assessment method for *E. coli* bacteria describes what constitutes a minimum sample size and how an impairment decision is made is presented in ***Table 4***.

Table 4. Assessment methods for determining support status for Section 303(d) (SD DANR, 2024).

Integrated Report Assessment Methods		
Description	**Minimum Sample Size**	**Impairment Determination Approach**
FOR CONVENTIONAL PARAMETERS: • TSS • *E. coli* • pH • Temperature • Dissolved Oxygen	STREAMS: Minimum of 20 samples (collected on separate days) for any one parameter are required within a waterbody reach. Minimum of 10 chronic (calculated) results are required for chronic criteria (30-day averages and geomeans). LAKES: Reference the lake listing methodology.	STREAMS: >10% exceedance for daily maximum criteria (acute or >10% exceedance for 30-day average criteria OR when overwhelming evidence suggests nonsupport/support LAKES: Reference the lake listing methodology.

The assessment method mentions chronic and acute criteria. Although these terms do not directly relate to *E. coli* bacteria criteria as discussed in ***Appendix B***, the assessment method is organized together with other conventional parameters in the Integrated Report to show that a consistent approach is applied to many pollutants. In this limited definition, chronic refers to the GM and acute refers to the SSM *E. coli* bacteria criteria. Different assessment methods have been established for toxic parameters and mercury in fish tissue.

6.0 Source Assessment and Allocations

E. coli production in the Beaver Creek segment 01 watershed originates from point and nonpoint sources. All point sources with a National Pollutant Discharge Elimination Systems (NPDES) or state general permit are identified. Watershed scale nonpoint sources were also identified, and bacteria production is quantified using a population per area formula.

6.1 Point Sources

Section 502(14) of the federal Clean Water Act defines point source pollution as "any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture" (US EPA, 2022). Point sources are often wastewater treatment plants or industrial facilities that discharge effluent directly into waterbodies. Potential point sources of *E. coli* bacteria are documented here to provide a watershed scale account of the systems operational characteristics (discharge permits etc.), potential impact and Waste Load Allocation (WLA) consideration for TMDL development.

6.1.1 Non-Stormwater Point Sources

This section provides an *E. coli* source assessment for the Beaver Creek segment 01 watershed. All point sources with a NPDES permit are identified.

Adams Thermal Systems (SDPG00007) was the only permitted non-stormwater NPDES facility within the Beaver Creek segment 01 watershed. According to the General Pretreatment Industrial User Permit for Metal Finishing Industries, Adams Thermal Systems discharged to the City of Canton's sanitary sewer system, which was then discharged to the Big Sioux River. Discharges covered by SDPG00007 are primarily from industrial processes such as electroplating, anodizing, electroless plating, and related activities. The facility was covered under SDPG00007 from October 1st 2020 to September 30th 3025. This facility did not contribute *E. coli* loads to Beaver Creek segment 01. As a result, it was not given a WLA in the TMDL (US EPA, 2024). More information on NPDES permitted facilities can be found through the SD DANR Water Quality Program Surface water Discharge Database and the US EPA Enforcement and Compliance History Online (ECHO) (US EPA, 2024) (SD DANR Water Quality Program, n.d.).

As discussed in section 2.0, the cities of Canton, Worthing, and Tea are not entirely contained within the watershed boundary of Beaver Creek segment 01 but have some area within the watershed. The cities of Sioux Falls, Harrisburg, and Lennox are nearby but outside of the watershed boundary. All of these cities maintain their own wastewater treatment facilities and distribution systems. There is also rural water systems located in the area surrounding the watershed. The wastewater treatment facilities and distribution systems in these cities and rural areas all have coverage under either an individual Surface Water Discharge Permit (denoted with the prefix SD00xxxxx) or a General Surface Water Discharge Permit (denoted with the prefix SDGxxxxxx) (SD DANR Water Quality Program, n.d.). The outfalls for these facilities are not located within the Beaver Creek segment 01 watershed and therefore are not anticipated to contribute any *E. coli* and are not assigned WLAs.

6.1.2 Municipal Separate Storm Sewer Systems (MS4)

The City of Sioux Falls is the largest city located near the Beaver Creek segment 01 watershed. Because Sioux Falls has a population over 100,000, its storm sewer system must be covered under a Phase I Municipal Separate Storm Sewer System Permit (MS4). MS4 permit number SDS-000001 authorizes the City of Sioux Falls and the South Dakota Department of Transportation to discharge to the Big Sioux River, Skunk Creek, Spring Creek, Covell Lake, unnamed tributaries of the Big Sioux River, unnamed tributaries of Skunk Creek, unnamed tributaries of Covell Lake, and wetlands (SD DENR, 1999). Storm water being discharged from the City of Sioux Falls is not anticipated to contribute any *E. coli* to the Beaver Creek segment 01 watershed; therefore, no WLA is assigned.

Phase II MS4s, or Small MS4s, must be obtained for entities with populations over 10,000. SD DANR has issued the General Permit for Stormwater Discharges from Small MS4s. This general permit covers cities or other entities including military bases, large hospital or prison complexes, and highways and other thoroughfares that meet the conditions of the general permit. At this point in time, there are no entities in or around the Beaver Creek segment 01 watershed that require coverage under the General Permit and there are no anticipated *E. coli* contributions from Small MS4 facilities.

6.1.3 Construction Storm Water Permits

There are multiple active construction sites in the Beaver Creek segment 01 watershed. The status of these construction projects is considered to be active by DANR until the permitted party opts to close the permit. Construction activities have the potential to produce pollutants that may contaminate stormwater runoff. Stormwater construction activities must have coverage and comply with South Dakota's General Permit Authorizing Stormwater Discharges Associated with Construction Activities ensuring that discharges are minimal. Construction stormwater permits are denoted by the prefix SDR10xxxx. The permits also stipulate that they do not contribute to violations of surface water quality criteria. A Stormwater Pollution Protection Plan (SWPPP) is required for all permitted construction and Industrial stormwater sites. The SWPPP is a written document that outlines how contractors will ensure stormwater runoff leaving the site will not become contaminated with pollutants (SD DANR Water Quality Program, 2023). A WLA is not assigned since these permits are not expected to be a source of *E. coli.* Information on active Construction Stormwater Permits can be found through the US EPA ECHO database and the SD DANR Water Quality Program Stormwater Permit Database (US EPA, 2024) (SD DANR Water Quality Program, n.d.).

6.1.4 Concentrated Animal Feeding Operations

There is one permitted Concentrated Animal Feeding Operation (CAFO) in the Beaver Creek segment 01 watershed. Hurley Farms, South Dakota General Permit #SDG-0100249 operates a beef cattle (open lot) feeding operation. Permit coverage falls under the 2003 General Water Pollution Control Permits for CAFOs as denoted by the SDG-01* permit number. Under the 2003 General Water Pollution Control Permit for Concentrated Animal Feeding Operations housed lots are required to have no discharge of solid or liquid manure to waters of the state. Exceptions are made only in the event that "chronic or catastrophic storm events occur; this permit allows an overflow or discharge from certain manure management systems provided the producer meets the terms and conditions of this permit." Chronic or catastrophic storm events are defined as a single precipitation event, or a series of rainfall events in a short period of time, that totals or exceeds the volume of a 25-year, 24-hour storm event or a 100- year, 24-hour storm event. The event includes tornadoes, or other catastrophic conditions. The event would directly result in, or cause, an overflow from the containment structure or lagoon that receives and contains runoff from an open lot (SD DENR, 2003). The general permit ensures that all CAFOs in South Dakota have permit coverage regardless of if they meet conditions for coverage under an NDPES permit. A new general permit was put in effect on April 15, 2017. All CAFO's with coverage under the 2003 general permit have a deadline to apply for coverage under the 2017 general permit or apply for a NDPES permit.

The 2003 General Permit has requirements for annual reporting, availability of reports, inspections, duty to provide information, and proper operation and maintenance. As stated previously, under the 2003 General Permit Hurley Farms, #SDG-0100249, is not allowed to discharge to waters of the state unless there is a chronic or catastrophic storm event (SD DENR, 2003). Additional information of CAFO permitting requirements in South Dakota can be found by contacting the SD DANR Livestock Services Program. As long as this facility complies with the general CAFO permit requirements ensuring its discharges are unlikely and indirect loading events, the TMDL assumes the *E. coli* contribution is minimal, and unless found otherwise, no additional permit conditions are required by this TMDL.

Under Hurley Farms' South Dakota General Permit #SDG-0100249, the facility is not permitted to discharge to waters of the state. As a result, *E. coli* contribution to the Beaver Creek segment 01watershed from Hurley Farms is not expected and no WLA is included in this TMDL.

6.2 Nonpoint Sources

As defined by the U.S. Environmental Protection Agency (US EPA) non-point source refers to any sources of water pollution that does not meet the legal definition of point source in section 502(14) of the Clean Water Act. Non-point source (NPS) pollution results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification. NPS pollution comes from many sources and is transported by rain or snowmelt. As runoff moves across land, it picks up and carries away natural and manmade pollutants, eventually depositing them into lakes, rivers, wetlands, coastal waters, and ground waters (US EPA, 2022).

Nonpoint sources of *E. coli* originate primarily from wildlife (i.e., natural background), agriculture and humans. Due to a lack of literature values for *E. coli* for many livestock, human and wildlife species, source calculations were based on fecal coliform. This is an acceptable surrogate to source characterization because *E. coli* is a bacterium within the fecal coliform group. Further, fecal coliform source contributions are considered synonymous with *E. coli* based on the close statewide paired bacteria data relationship documented in *Escherichia coli* Total Maximum Daily Load Conversion with Existing Fecal Coliform TMDLs for Impaired Streams Designated Recreation Uses in South Dakota (Paul Lorenzen, 2022).

Estimates for nonpoint source bacteria inputs in the Beaver Creek segment 01 watershed were calculated for livestock, wildlife, and failing septic tanks using population data and reference values for bacteria production per day. Livestock and wildlife population counts within the Beaver Creek segment 01 watershed were obtained from the National Agricultural Statistic Survey (NASS) 2022 Census of Agriculture and the 2002 South Dakota County Wildlife Assessments for livestock and wildlife, respectively (USDA, 2024) (Huxoll, 2002). The number of septic tanks in the watershed was estimated using the 2025 USGS dataset of estimated residential septic density (Peterson, et al., 2025). Reference values for bacteria produced per day by each type of livestock and wildlife animal and failing septic tanks were obtained from the US EPA Protocol for Developing Pathogen TMDLs and the US EPA Bacterial Indicator Tool (US EPA, Office of Water, 2001) (US EPA, 2000). Methods detailed in the aforementioned documents were used for guidance to calculate the total bacteria produced per day in each category. Methods will be detailed in the following sections for livestock, wildlife, and septic.

Total bacteria production in the Beaver Creek segment 01 watershed was estimated at 8.84×10^{14} bacteria per day. Livestock contribute an estimated 99.04% of the total bacteria production in the

Beaver Creek segment 01 watershed. ***Table 5*** outlines sources and contributions. Further details are provided in the following sections.

Table 5. Bacteria sources in the Beaver Creek Watershed.

Source	Bacteria/Day	Percent
Livestock	8.76E+14	99.04%
Wildlife	6.12E+12	0.69%
Septic	2.33E+12	0.26%
Total	**8.84E+14**	

6.2.1 Livestock

Nonpoint sources of bacteria in the Beaver Creek segment 01 watershed come primarily from agricultural sources. Livestock contribute approximately 8.76 x 10^{14}per day. Manure from livestock is a potential source of bacteria. Among all livestock, cattle contributed the most bacteria. ***Table 6*** details the bacteria contributed from each livestock animal population in the watershed. Livestock populations for Turner, Lincoln, and Minnehaha counties were multiplied by the percentage of the watershed within each county to adjust county populations to the population within the Beaver Creek segment 01 watershed. The total bacteria produced/animal population/day was calculated by multiplying the watershed population of each livestock animal by the reference value for bacteria produced by each animal each day.

Table 6. Bacteria per day attributed to livestock.

Livestock				
Animal	**Bacteria/Animal/Day (Reference Value)**	**Number of Animal in Watershed**	**Bacteria Produced/Animal Population/Day**	**Percent**
Cattle (includes beef cows, dairy cows, calves, and other cattle)	1.04E+11	7143	7.43E+14	84.84%
Hog	1.08E+10	11953	1.29E+14	14.74%
Sheep	1.20E+10	202	2.42E+12	0.28%
Goat[2]	1.20E+10	92	1.10E+12	0.13%
Chicken	1.36E+08	819	1.11E+11	0.01%
Horse	4.20E+08	141	5.91E+10	0.01%
Turkey	9.30E+07	7	6.93E+08	0.0001%
		Total	**8.76E+14**	
[2] Assumed Value based on most similar animal				

6.2.2 Wildlife and Natural Background Sources

Natural background sources of bacteria are accounted for in the following wildlife estimates. Wildlife animals contribute 6.12 x 10^{12} bacteria per day to the Beaver Creek segment 01 watershed, with Nest Canada Geese contributing 43.93% of that total. Wildlife animal populations for Turner, Lincoln, and Minnehaha counties were multiplied by the percentage of the watershed within each county to adjust county populations to the population within the Beaver Creek segment 01 watershed. The total bacteria produced/animal population/day was calculated by multiplying the watershed population of each livestock animal by the reference value for bacteria produced by each animal each day. Specific reference values for Bacteria CFU produced by each animal per day were used when available, but some estimates are based on best professional judgment or using the reference value from the most similar animal. Counts for bacteria per day by each wildlife animal population in the Beaver Creek segment 01 watershed are outlined in ***Table 7***.

Table 7. Bacteria per day attributed to wildlife .

Wildlife				
Animal	**Bacteria/Animal/Day (Reference Value)**	**Number of Animal in Watershed**	**Bacteria Produced/Animal Population/Day**	**Percent**
Nest Canada Geese	4.90E+10	55	2.69E+12	43.93%
Fox[2]	5.00E+09	258	1.29E+12	21.05%
Coyote[2]	5.00E+09	232	1.16E+12	18.92%
Squirrel[2]	1.25E+08	1564	1.95E+11	3.19%
Cottontail Rabbit[2]	1.25E+08	1538	1.92E+11	3.14%
Whitetail Deer[1]	5.00E+08	262	1.31E+11	2.14%
Beaver[1]	2.50E+08	416	1.04E+11	1.70%
Raccoon[1]	1.25E+08	690	8.62E+10	1.41%
Partridge[2]	1.36E+08	518	7.04E+10	1.15%
Skunk[2]	1.25E+08	433	5.41E+10	0.88%
Mink[2]	1.25E+08	361	4.51E+10	0.74%
Muskrat[2]	1.25E+08	244	3.05E+10	0.50%
Opossum[2]	1.25E+08	225	2.81E+10	0.46%
Badger[2]	1.25E+08	171	2.14E+10	0.35%
Jackrabbit[2]	1.25E+08	130	1.62E+10	0.26%
Turkey	9.30E+07	90	8.40E+09	0.14%
Bobwhite Quail[2]	1.36E+08	15	2.09E+09	0.03%
Mule Deer[1]	5.00E+08	1	2.87E+08	0.005%
Sharp tail Grouse[2]	1.36E+08	1	1.08E+08	0.002%
		Total	**6.12E+12**	

[1] Best professional judgement

[2] Assumed Value based on most similar animal

6.2.3 Human Sources

Human sources of nonpoint source bacteria in the Beaver Creek segment 01 watershed come from failing septic tanks. Failing septic tanks contribute an estimated 2.33×10^{12} bacteria per day to the watershed. Septic tank counts in each HUC 12 in the Beaver Creek segment 01 watershed were obtained from the HUC12 dataset of the USGS Estimated Densities of Residential Septic Tanks across the

Conterminous United States National Hydrography Dataset (Peterson, et al., 2025). A septic tank failure rate of 15% was assumed based off two studies discussed in the US EPA Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems. One study found that over half of existing septic systems in the United States are over 30 years old and that 10 percent of these older systems will fail each year. Another study showed that at least 20 percent of all septic systems in the United States are malfunctioning to some degree (US EPA, Office of Water, 2003). The US EPA Bacterial Indicator tool uses a daily average discharge rate of 70 gallons of septic overflow per person from leaking septic tanks (US EPA, 2000). On average, there are 2.96 people per household in South Dakota (US Census Bureau, 2020). The bacteria contributed to the watershed per day was calculated by multiplying the values for failing septic tanks, average people per household, gallons of septic overflow per person per day, and the reference value for human bacteria produced per day from septic overflow. These values and the resulting total bacteria contributed to the Beaver Creek segment 01 watershed each day are outlined in ***Table 8***.

Table 8. Bacteria per day from human sources.

Human		
HUC12	**# of Septics**	**# of Failing Septics**
Headwaters Beaver Creek	1119	167.85
South Fork Beaver Creek	101	15.15
Beaver Creek	761	114.15
Total	**1981**	**297.15**
Average persons per household in SD		*2.96*
Estimated Gallons/person/day Septic Overflow		*70*
Human bacteria/day from Septic Overflow		*1.0E+6/100mL*
mL to gallon conversion		*3785.2*
297.15 x 2.96 x 70 x 1.0E+6 x 3785.2 =		
Total Bacteria from failing septic/day		**2.33E+12**

7.0 Data Collection

7.1 Water Quality Data and Discharge Information

All measured flow and water quality data acquired for development of this TMDL can be found in ***Appendix A***. *E. coli* data was obtained from projects and ambient water quality monitoring conducted by the South Dakota Department of Agriculture and Natural Resources (SD DANR) and from water quality sampling conducted by East Dakota Water Development District (EDWDD) through the Rotating Basins Project. SD DANR and EDWDD collect water samples following methods outlined in the South Dakota Standard Operating Procedures for Field Samplers. Samples were analyzed by the State Health Laboratory in Pierre, South Dakota. To ensure data quality, samplers also collect blank and replicate samples as outlined in the Watershed Protection Quality Assurance Project Plan. More information on these documents can be found at danr.sd.gov.

The Beaver Creek segment 01 Water Quality Monitoring (WQM) site was established in 2016 at the bridge on West 5^{th} Street/Highway 18 (43.286571, -96.598322) in Canton, SD. Flow measurements were taken at this location from 2018 to present. *E. coli* data was collected at 3 stations: 460183, LOWERBSLBST04, and LOWERBSLBST06 from 2002 to present.

7.1.1 Flow Information and Data

Flow information was obtained through the Watershed Protection Program's Statewide Streamflow Monitoring Network. A long-term continuous stream stage recorder was installed at WQM 183 in 2018. This electronic stage recorder measures stream height from a fixed position on the bridge deck to the water surface. The stage recorder was calibrated with a fixed wire weight gage tied to bridge deck elevation at mean sea level. The recorder is programmed to log stream stage at 15-minute intervals. Field staff from WPP and EDWDD measured stream discharge periodically at varying stages of the hydrograph during the period of record (6/25/18 to 11/03/22).

The hydrologic modeling program Water Information Systems (WISKI) (version 7.4.13 SR7) developed by Kisters Inc., (https://www.kisters.net/NA/) was used to generate a stage-discharge rating curve (relationship) for the period of record. Using WISKI three equations were generated to best estimate flow for a given stage at different height intervals:

Table 9. Discharge estimate equations across various stage radar levels.

Stage Radar	Discharge(Stage-Radar) Formula
73.60 - 75.88	$= 114624.9104 - 3120.868978 * \text{Stage-Radar}^1 + 21.2425946 * \text{Stage-Radar}^2$ [ft^3/s]
74.38 - 78	$= 117596.5656 - 3213.447142 * \text{Stage-Radar}^1 + 21.94931592 * \text{Stage-Radar}^2$ [ft^3/s]
77.34 - 82.85	$= 454423.465 - 11917.00194 * \text{Stage-Radar}^1 + 78.17356786 * \text{Stage-Radar}^2$ [ft^3/s]

Equation based flows generated from the continuous stage data were used to develop a mean daily flow record (in cubic feet per second [cfs or ft^3/s]). The mean daily flows were used to develop a flow frequency curve with the paired *E. coli* data from 2018 to 2022. The flow frequency curve was used to develop the Load Duration Curve (LDC) based TMDL.

7.1.2 *E. coli* Water Quality

E. coli samples were collected at three locations on Beaver Creek segment 01: 460183, LOWERBSLBST04, and LOWERBSLBST06. Sampling locations are shown in **Figure 4**. Sampling at stations LOWERBSLBST04 and LOWERBSLBST06 was conducted through the Lower Big Sioux River Watershed TMDL Assessment Project from 2002 to 2004.

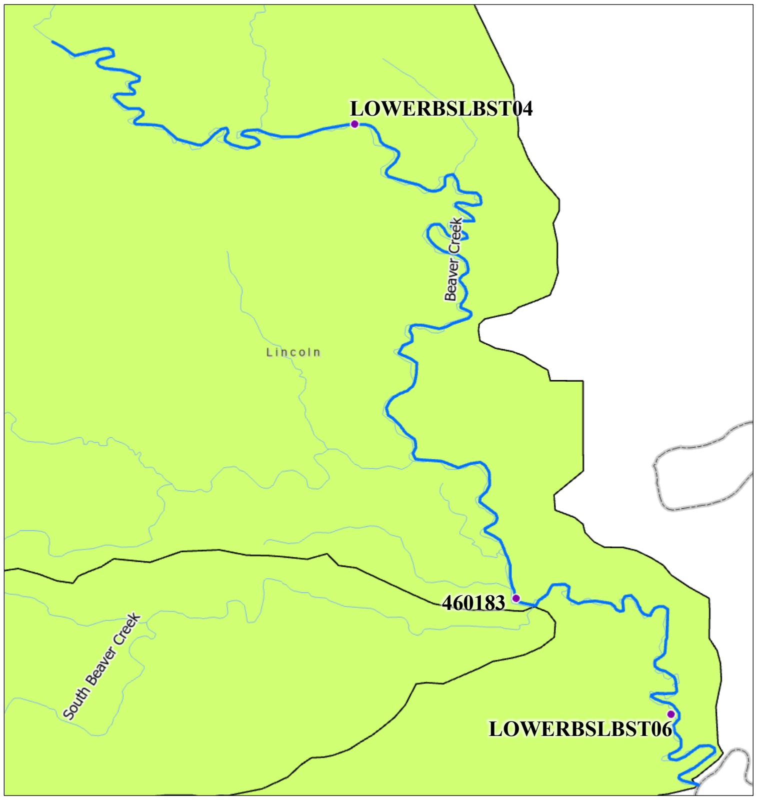

Figure 4. Sampling locations on Beaver Creek segment 01.

Station 460183 was established in 2016 as part of the Ambient Surface Water Quality Monitoring Network. Routine monitoring is conducted at this station through the Ambient Surface Water Quality Monitoring Network. The Ambient Surface Water Quality Monitoring Network collects data at 154 locations. This data is used to identify problems, document improvements, and demonstrate overall trends in water quality in South Dakota (SD DANR, Water Quality Program, n.d.).

Sampling was also conducted though the Big Sioux River Rotation of the Rotating Basins Project in 2020 and 2021. The Rotating Basins project was developed to supplement data collected through the Ambient Surface Water Quality Monitoring Network to ensure that there is enough water quality data to properly assess every AUID in the state. East Dakota Water Development District (EDWDD) collected *E. coli* samples in 2019 and 2020 for their own monitoring projects. **Figure 5** shows all *E. coli* results for samples collected from 2002-2022.

40% of all *E. coli* samples collected on Beaver Creek segment 01 from the years 2002-2022 exceed the SSM criterion. Most of these samples were collected at station 460183. *E. coli* minimums, maximums, mean, median, and exceedance rates by project and station can be found in ***Table 10.***

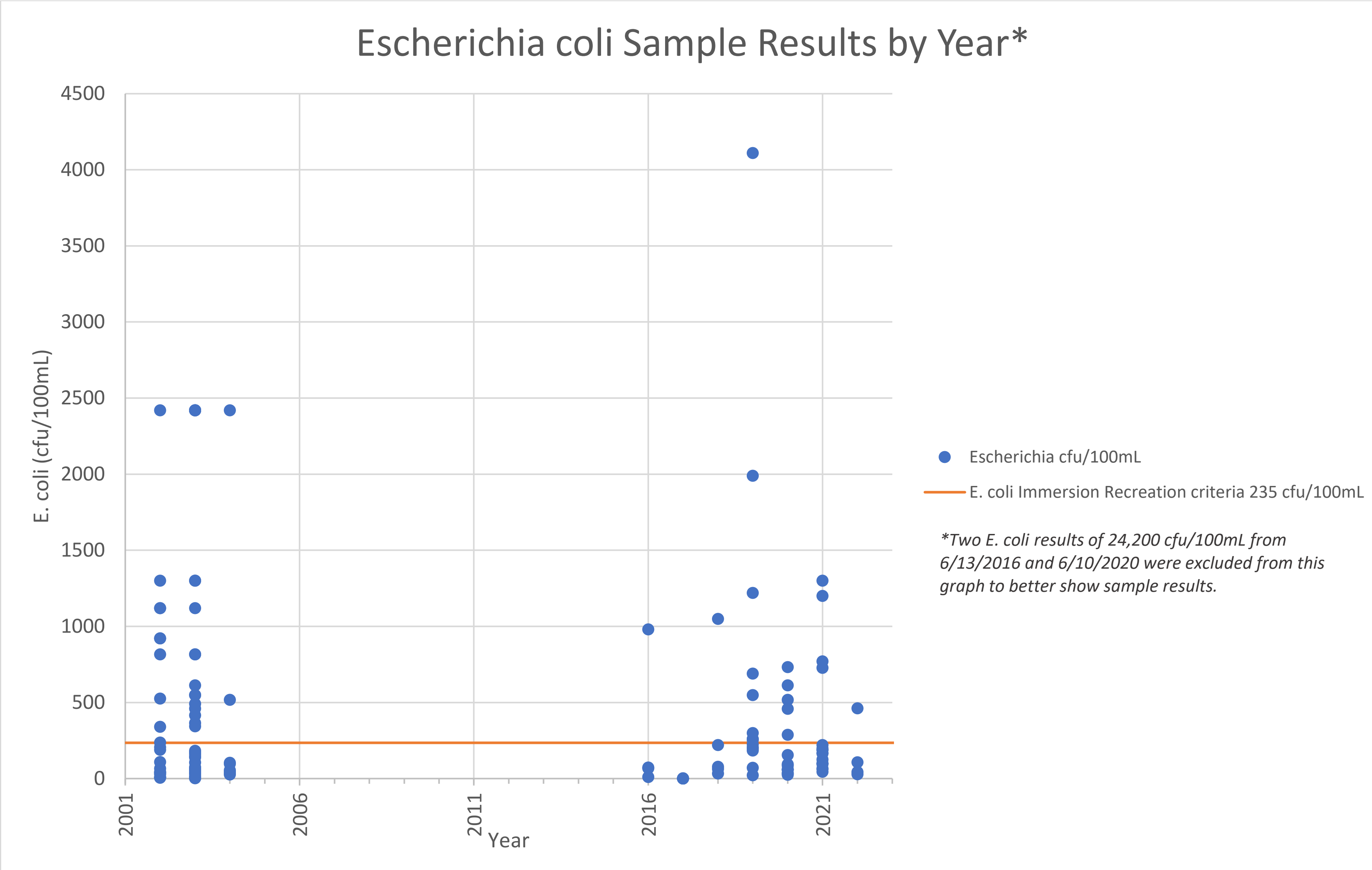

Figure 5. E. coli results 2002-2022.

Station	Project	Number of Samples	Date Range	*E. coli* maximum	*E. coli* minimum	*E. coli* mean	*E. coli* median	Percent Exceedance @ 235 cfu/100 mL
460183	AMBIENT SURFACE WATER QUALITY MONITORING	34	2016-2022	24200	1	928	72	21%
460183	ROTATING BASIN - RIVERS AND STREAMS	20	2020-2021	24200	32	1540	194	40%
460183	EAST DAKOTA WATER QUALITY SAMPLES	12	2019-2020	4110	25.7	728	280	67%
LOWERBSLBST06	LOWER BIG SIOUX RIVER WATERSHED TMDL ASSESSMENT PROJECT	45	2002-2003	2420	2	566	104	36%
LOWERBSLBST04	LOWER BIG SIOUX RIVER WATERSHED TMDL ASSESSMENT PROJECT	28	2002-2004	2420	6.3	566	355	57%
All stations	**All Projects**	**139**	**2002-2022**	**24200**	**1**	**809**	**166**	**40%**

Table 10. E. coli (cfu/100 mL) exceedances by project and station.

Although the sampling record on Beaver Creek segment 01 started in 2002, only *E. coli* data collected during the recreation season (May 1st to September 30th) from the years 2018 to 2022 was used to develop the load duration curve. This date range aligns with the flow record for this location. Of the 139 total *E. coli* samples 54 were collected during the same date range as the flow record. A record of paired flow and *E. coli* samples can be found in ***Appendix A*.** Three samples were collected outside of the recreation season and were not used for TMDL development. Nineteen of the 51 samples used in TMDL development were over the immersion recreation criteria of 235 cfu/100mL, for an exceedance rate of 37%. In the dataset used for TMDL development sample results ranged from 21.8 to 24,200 CFU/100mL with an average of 845 CFU/100mL. From 2018 to 2022, station 460183 was sampled at least once a month and at most 3 times a month. *E. coli* samples were not collected at a frequency required to calculate a geometric mean (GM).

8.0 TMDL Loading Analysis

The TMDL for Beaver Creek segment 01 was developed using a Load Duration Curve (LDC) approach. A LDC model is a representation of the allowable loading capacity of a pollutant based on the relevant water quality criterion. The LDC considers the entire flow regime, thus, making it an appropriate method for determining flow-variable *E. coli* loading for Beaver Creek segment 01. The LDC is separated into five flow zones (***Figure 6***); high flows (0 -10 percent), moist conditions (10-40 percent), mid-range conditions (40-70 percent), dry conditions (70-90 percent) and low flows (90-100 percent) in accordance with EPA guidance (USEPA, 2007).

In ***Section 4.0***, it was discussed why the immersion recreation SSM of 235 cfu/100mL for *E. coli* was selected as the numeric TMDL target for Beaver Creek segment 01. The LDC was calculated by multiplying the SSM criterion (235 cfu/100mL) by the average daily flow and then multiplying that by a unit conversion factor (24,465,888 mL*s / ft3*day). The LDC represents the TMDL across the entire flow regime.

$$\frac{235cfu}{100mL} * \frac{Daily\ Flow\ ft^3}{s} * \frac{86{,}400\ s}{1\ day} * \frac{283.17\ 100mL}{1\ ft^3} = \frac{cfu}{day}$$

When the individual sample observations are plotted on the LDC, characteristics of the water quality impairment are shown. Observations that are plotted above the curve are exceeding the TMDL, while those below the curve are in compliance. *E. coli* samples collected from Beaver Creek segment 01 exceed the TMDL across all flow zones (***Figure 6***). Exceedances in the high flow zone can typically indicate nonpoint source contributions from runoff conditions. Exceedances in low flow zones typically indicate point sources or in-stream load contributions (US EPA, 2007).

9.0 TMDL Allocations

Contributing factors of pollution are split between point and nonpoint sources. Waste load allocations (WLAs) are the allocated loads for point sources including all sources subject to regulation under the NPDES program. Therefore, load allocations are the allocated loads of nonpoint sources as well as natural background sources. The TMDL (or loading capacity) is the sum of waste load allocations, load allocations, and a margin of safety (MOS).

A TMDL is expressed by the equation: TMDL = ΣWLA + ΣLA + MOS, where:

ΣWLA is the sum of the waste load allocation(s) (point sources)
ΣLA is the sum of the load allocation(s) (nonpoint sources)
MOS = margin of safety (10%)

9.1 Margin of Safety (MOS)

TMDLs are required to include a MOS to for uncertainty in data analyses. A margin of safety is established (1) by using conservative assumptions in the calculation of the loading capacity of the waterbody and (2) by establishing allocations that in total are lower than the defined loading capacity. In the case of Beaver Creek segment 01, the latter approach was used to establish a safety margin for this TMDL.

An explicit MOS of 10% of the TMDL was calculated within the duration curve framework because the allocations are a direct function of flow, accounting for potential flow variability (***Table 11***). Once the MOS was calculated for each flow zone, the remaining assimilative capacity was allocated to nonpoint sources (LA).

9.2 Waste Load Allocation (WLA)

There is one permitted NPDES Facility, Adams Thermal Systems, within the watershed of Beaver Creek segment 01. As discussed in ***Section 6.1*** this facility does not contribute *E. coli* to the watershed of Beaver Creek segment 01 and was not given a waste load allocation in this TMDL.

One permitted Concentrated Animal Feeding Operation (CAFO), Hurley Farms, is in the watershed boundary. As discussed in S***ection 6.1*** if the facility abides by all the terms in the permit, which does not allow discharge to waters of the state, it can be assumed that Hurley Farms is not contributing *E. coli* to the Beaver Creek segment 01 watershed. There was not a waste load assigned to Hurley Farms in this TMDL. The WLA was set at zero in all five flow zones.

9.3 Load Allocation (LA)

EPA regulations require that a TMDL include load allocations (LA), which identify the loading capacity from nonpoint sources and sources of natural background. Most of the bacteria production was associated with agricultural sources. A list of bacteria producers and their daily bacteria production per acre can be found in ***Table 5*** through ***Table 8***. The LA was calculated by subtracting the 10 percent explicit MOS from the TMDL load at the standard for each flow zone (seen in the equation below).

LA = TMDL (-) MOS

Current load was calculated based off the 95th percentile flow and *E. coli* concentrations for all flow zones. Current loads above the LDC require a load reduction to reach the TMDL. Reductions are required across all flow zones (***Figure 6)***. Current loads below the LDC implies they are within TMDL attainment. Load reduction percentages for each flow zone were calculated using the following equation:

$$Percent\ Reduction = \left(\frac{current\ load - allowable\ load}{current\ load}\right) \times 100$$

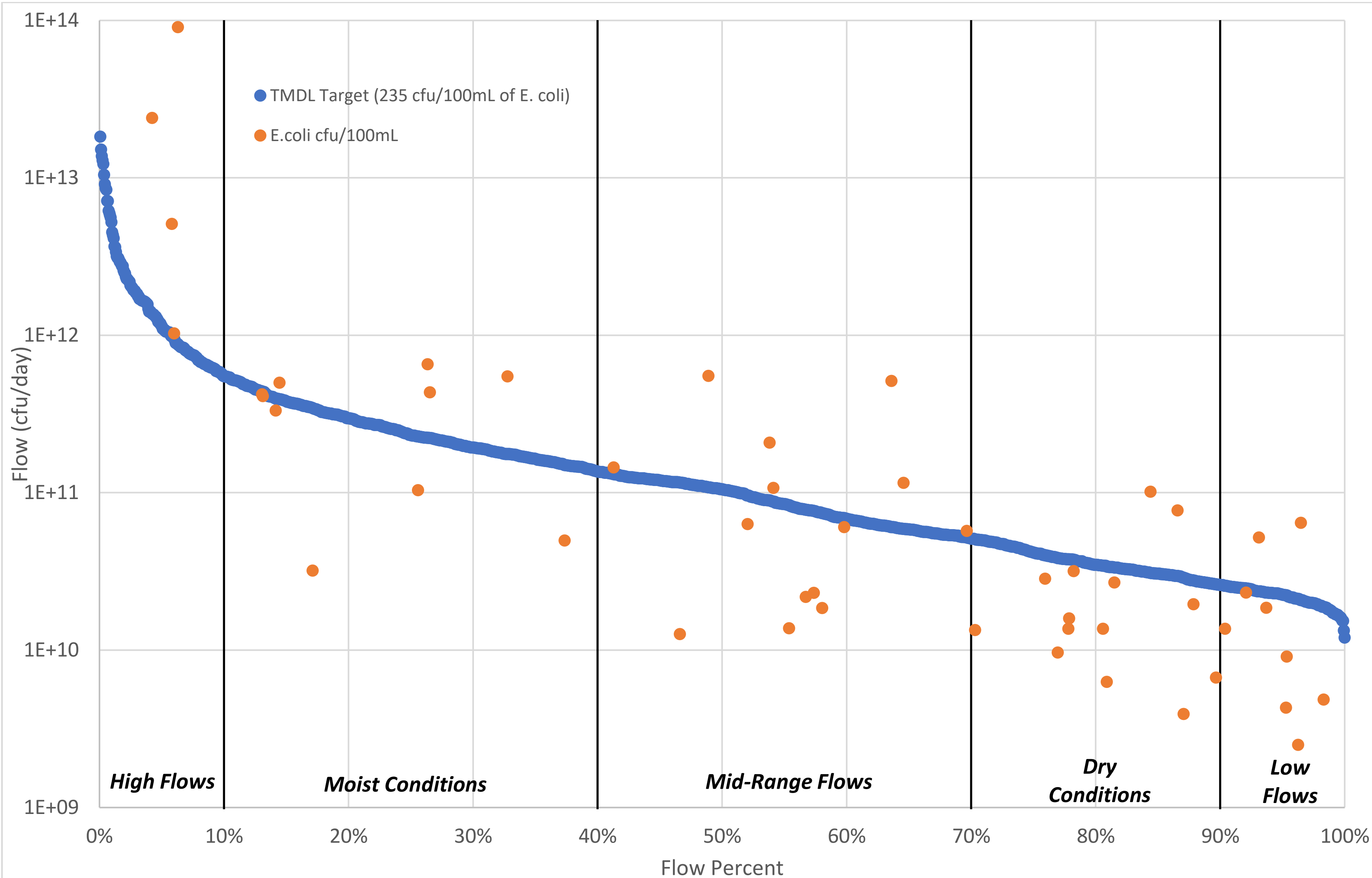

Figure 6. Load duration curve (LDC) for Beaver creek segment 01.

10.0 Numeric TMDL and Flow Zones

TMDL, allocations, and necessary load reductions for each flow zone are presented in ***Table 11***. The TMDL is calculated by multiplying the *E. coli* SSM criterion for immersion recreation (235 cfu/100mL) with the 95th percentile flow value and a conversion factor to present the load in *E. coli* CFU/day. The entire TMDL is allocated to LA or nonpoint sources of *E. coli*. To meet the TMDL, reductions in *E. coli* from nonpoint sources need to be achieved in all flow zones.

Table 11. E. coli TMDL and flow allocations.

Immersion Recreation *E. coli* TMDL	Beaver Creek segment 01 Flow Zones Expressed as (CFU/day)				
	High Flows	Moist Conditions	Mid-Range Conditions	Dry Conditions	Low Flows
Flow Rate	>95.76	95.75 - 23.76	23.75 - 8.93	8.92 - 4.53	<4.52
WLA	0	0	0	0	0
LA	7.34E+12	4.41E+11	1.18E+11	4.49E+10	2.30E+10
10% Explicit MOS	8.16E+11	4.90E+10	1.31E+10	4.99E+09	2.56E+09
TMDL @235 cfu/100mL	8.16E+12	4.90E+11	1.31E+11	4.99E+10	2.56E+10
Current Load*	6.66E+14	1.51E+12	7.99E+11	1.43E+11	7.00E+10
Load Reduction	99%	68%	84%	65%	63%
** Current load is the 95th percentile single sample concentration times the 95th percentile flow in each flow zone*					

10.1 High Flows

The high flow zone represents flows that were greater or equal to 95.76 cfs, or the highest 10% of all flows. Flows in this zone are infrequent and are typically the result of significant run-off events such as spring snowmelt or high-volume rain events. Flows of this velocity typically only last a few days at a time, except during flood years where they were observed for up to 2 weeks at a time. For example, flows of this level persisted in 2019 and 2018. As seen in ***Table 1***, 2018 and 2019 were flood years where the area received large amounts of precipitation and snow. High flows early in the spring of 2019 were influenced by snow accumulation late in the season as a historic storm moved across southeastern South Dakota on March 12th to 14th (NWS, 2019). Runoff events contributing to these high flows transport bacteria from farther distances across the watershed from a range of different sources. The least number of samples were collected in this flow zone. All 4 *E. coli* samples collected in this range exceeded the immersion recreation SSM criterion. A 99% reduction is needed in the high flow zone to meet the SSM criterion. In addition to the daily load, the geometric mean criteria must be attained on a longer (i.e., monthly basis).

TMDL

235 CFU/100mL *(TMDL target)* * 1418.806 cfs *(95th percentile flow)* * 24,465,888 *(Conversion factor)* = 8.16E+12

10.2 Moist Conditions

Moist conditions represent flows ranging from 95.75 cfs to 23.76 cfs. Moist conditions result from moderate precipitation events and moderate snowmelt. Prolonged flows of this level are common in flood years, and sporadic in normal to dry years. Bacteria transported by runoff events at this flow level most likely come from sources closer to the stream bank. Out of 10 samples collected in this range, 4 exceeded the immersion recreation threshold. A 68% reduction is needed in the moist condition flow range to meet the SSM criterion for immersion recreation. In addition to the daily load, the geometric mean criteria must be attained on a longer (i.e., monthly basis).

TMDL

235 CFU/100mL *(TMDL target)* * 85.145 cfs *(95th percentile flow)* * 24,465,888 *(Conversion factor)* = 4.90E+11

10.3 Mid-Range Conditions

Mid-range flows are represented by flows ranging from 23.75 cfs to 8.93 cfs. Mid-range flows are likely to occur in mid to late summer when stream bank vegetation has matured. Flows of this level are sustained between precipitation events. Bacteria sources in this flow zone likely originate in or near the stream channel with occasional runoff events. Seven of fifteen samples collected in this range exceeded the immersion recreation threshold. A load reduction of 84% is necessary in the mid-range flow zone to meet the SSM criterion for immersion recreation. In addition to the daily load, the geometric mean criteria must be attained on a longer (i.e., monthly basis).

TMDL

235 CFU/100mL *(TMDL target)* * 22.738 cfs *(95th percentile flow)* * 24,465,888 *(Conversion factor)* = 1.31E+11

10.4 Dry Conditions

Dry conditions are represented by flows ranging from 8.92 cfs to 4.52 cfs. Dry conditions are representative of below base flow conditions resulting from a lack of precipitation or input from groundwater sources. Prolonged dry conditions were observed in 2020 to 2022. Out of 13 total samples collected in the dry condition flow zone, 2 exceeded the immersion recreation contact threshold. A 65% load reduction is needed in the dry flow zone to meet the SSM criterion for immersion recreation. In addition to the daily load, the geometric mean criteria must be attained on a longer (i.e., monthly basis).

TMDL

235 CFU/100mL *(TMDL target)* * 8.675 cfs *(95th percentile flow)* * 24,465,888 *(Conversion factor)* = 4.99E+10

10.5 Low Flows

The low flow zone is represented by flows below 4.52 cfs. Low flows result from prolonged dry events. Flows in this range only occurred in 2020, 2021, and 2022. Two of the 9 samples collected in the low flow zone exceeded the immersion recreation threshold. An *E. coli* reduction of 63% is needed in the low flow zone to meet the SSM criterion for immersion recreation. In addition to the daily load, the geometric mean criteria must be attained on a longer (i.e., monthly basis).

TMDL

235 CFU/100mL *(TMDL target)* * 4.448 cfs *(95th percentile flow)* * 24,465,888 *(Conversion factor)* = 2.56E+10

11.0 Seasonality

The Clean Water Act §303(d) states that the TMDL load should be established at a level necessary to implement the applicable water quality standards with seasonal variation (US EPA, 2021). Flows taken at WQM 183 exhibited seasonal trends across the 5 years of flow data available (***Figure 6)***. Although high flows were observed each year in March due to snowmelt, the recreation season for which *E. coli* criteria applies is May 1st through September 30th. Because of this, seasonality in flows will be considered over the recreation season. On average Beaver Creek segment 01 sees its highest flows early in the season in May and June (***Figure 7***). Flows increase at the end of the recreation season in September but are not as high as flows seen earlier in the season.

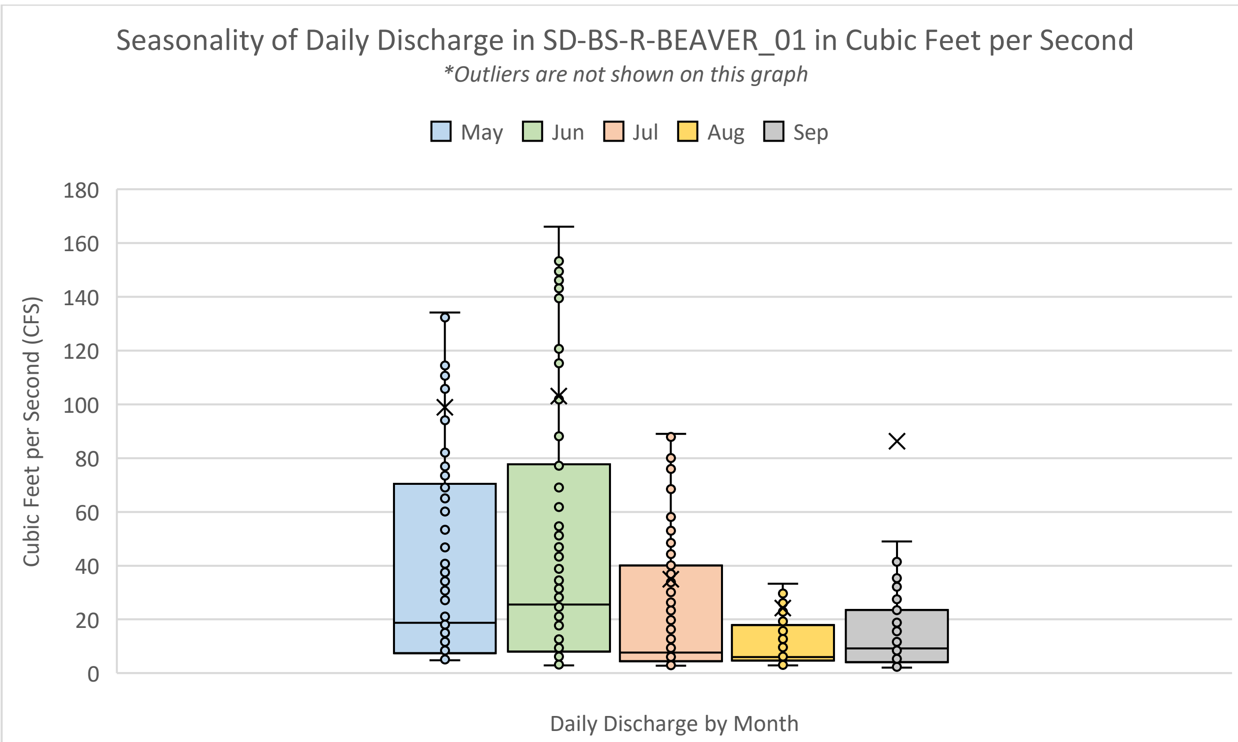

Figure 7. Daily discharge in Beaver Creek segment 01 May to September 2018-2022.

Average precipitation per month over the flow record (2018-2022) shows the same level of seasonality. On average rainfall peaks in July and August (***Figure 8)***. High volume precipitation events are observed early in the season in May and June and decrease in frequency by September. Larger amounts of rainfall correlating with lower flows in July and August can be attributed to mature vegetation in the riparian zone. As the amount of vegetation increases throughout the recreation season it collects more runoff, limiting high flow conditions.

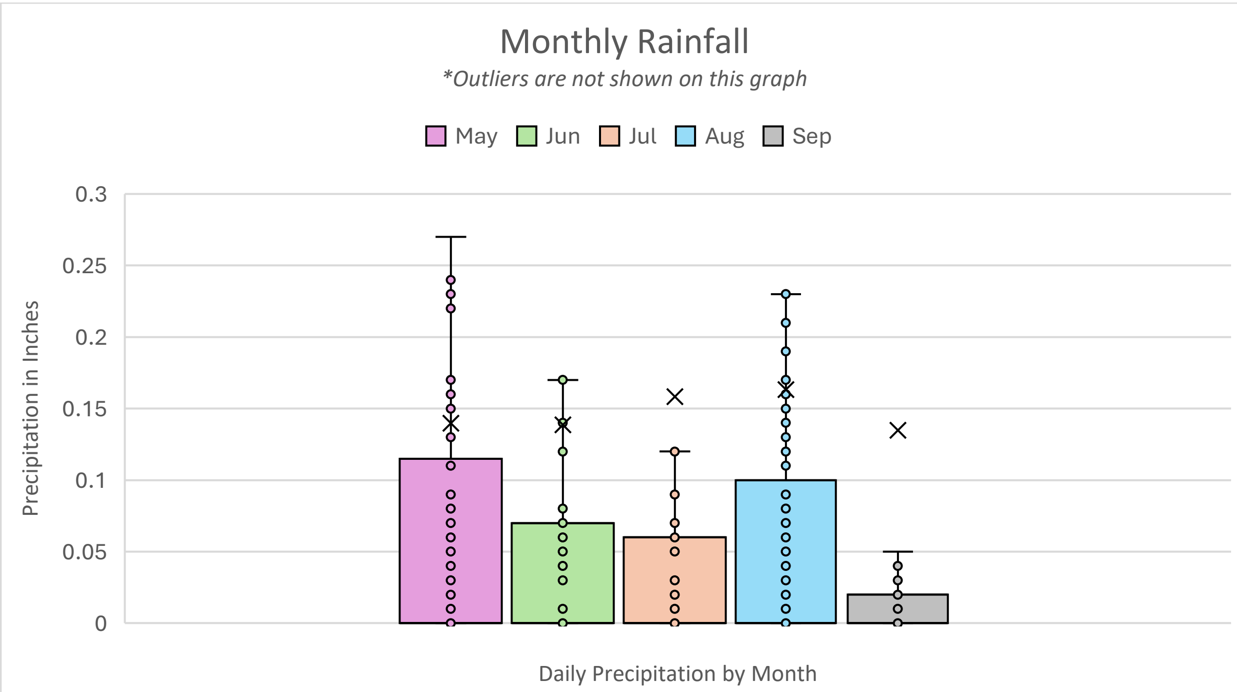

Figure 8. Monthly rainfall data from Foss Field weather station.

Seasonal variation is a component of the load duration curve framework that examines the seasonal exceedance pattern of individual *E. coli* bacteria loads. Sample data was collected May through September when the recreational standards apply for the immersion recreation beneficial use.

Daily bacteria loads exceed the single sample maximum TMDL threshold consistently through all flow regimes. The implications of this pattern suggest bacteria sources are consistently located near Beaver Creek segment 01 year-round. Identifying bacteria sources close to the creek is warranted to achieve TMDL attainment goals of the immersion recreation beneficial use.

12.0 Critical Conditions

Critical condition refers to trends indicated by the LDC where *E. coli* criteria are frequently exceeded. If *E. coli* criterion is met under these critical conditions, it is more likely that the TMDL will be met overall (EPA, 2007). In the case of Beaver Creek segment 01, the immersion recreation threshold is exceeded across all flow zones. Although a load reduction ranging from 63% to 99% is required across the flow regime, *E. coli* exceedances are more common in mid-range to high flow conditions. Every sample collected in the high flow zone exceeded the SSM criterion for immersion recreation (235 cfu/100mL) and a load reduction of 99% is necessary in this zone. A load reduction of 84% is necessary in the mid-range flow zone. If the TMDL can be met in these two conditions, it is likely that the TMDL will be met across all other flow zones. Implementing watershed-scale best management practices designed to reduce manure transport during runoff events is essential to meet reduction goals. Other priority implementation practices would be to reduce livestock access to the stream corridor and channel. Developing alternative water sources away from stream riparian areas would decrease risk of direct bacteria loadings.

Table 12. Percent exceedance and load reduction across different flow zones.

Flow Zone	Percent Exceedance	Load Reduction
High Flows	100%	99%
Moist Conditions	40%	68%
Mid-Range	47%	84%
Dry Conditions	15%	65%
Low Flows	22%	63%

13.0 Water Quality Improvement Plan and Monitoring Strategy

E. coli sources in the Beaver Creek segment 01 watershed are primarily nonpoint source, originating from livestock and wildlife. During precipitation events, runoff moves across the land collecting and carrying *E. coli* bacteria from these sources and eventually depositing it into Beaver Creek segment 01. Best management practices will need to be implemented to reduce *E. coli* loading from these sources to meet the TMDL. Additional monitoring and evaluation efforts will need to be conducted to assess the efficacy of the implemented BMPs.

13.1 Monitoring Strategy

To assure effectiveness of BMPs, continual monitoring will need to be conducted on Beaver Creek segment 01. Streamflow monitoring will be conducted at WQM 183 by the Watershed Protection Program through the Statewide Streamflow Monitoring Network. Ambient water quality monitoring data will be collected by the Watershed Protection Program and the Water Quality Program. Monitoring will also be collected through the Rotating Basins Project. In the past, sampling for Rotating Basins was conducted by staff at The East Dakota Water Development District (EDWDD). Future sampling for the Rotating Basins Project may be conducted by WPP staff and/or EDWDD staff.

Beaver Creek segment 01 is located in the watershed area of the Big Sioux River Project (BSRP). This project focuses on implementing best management practices on land adjacent or nearby the Big Sioux River and is funded in part by section 319 funds. Beaver Creek segment 01 is identified as a tributary of the Big Sioux River in the 2020 final report. Sampling on Beaver Creek segment 01 is not currently conducted through this project but might be in the future (Berg, 2020).

13.2 Implementation

Watershed-scale implementation projects can be accomplished by using financial and technical assistance through SD DANR. Financial support is administered to implementation projects aiming to protect and improve the water quality in South Dakota. Funding provided by DANR include the Consolidated Water Facilities Construction program, Clean Water State Revolving Fund (CWSRF) program, and the Section 319 Nonpoint Sources Management Program.

SD DANR recommends several best management practices (BMPs) to manage bacteria sources and reduce runoff in the Beaver Creek segment 01 watershed. Seasonal Riparian Area Management (SRAM) is a BMP that is now eligible in the focus area to landowners who meet the requirements for approval. Riparian Buffer Initiative (RBI) is another program that aims to increase the area of riparian buffers to reduce nonpoint source pollution. More information on RBI can be found at danr.sd.gov. The following additional practices are recommended to reduce the bacteria runoff from livestock contributors:

- Relocate livestock feeding, water sources, and grazing areas away from streams
- Protect riparian corridors to establish permanent vegetation for streambank stabilization and erosion control
- Control and contain manure from animal feeding areas

13.3 Adaptive Management

The Department (or EPA) may adjust the load and/or waste load allocations in this TMDL to account for new information or circumstances that develop during the implementation of the TMDL and a review of the new information or circumstances indicate that such adjustments are appropriate. Adjustment of the load and waste load allocation will only be made following an opportunity for public participation. New information generated during TMDL implementation may include, among other things, monitoring data, BMP effectiveness information and land use information. The Department will propose adjustments only in the event that any adjusted LA or WLA will not result in a change to the loading capacity; the adjusted TMDL, including its WLAs and LAs, will be set at a level necessary to implement the applicable water quality standards and any adjusted WLA will be supported by a demonstration that load allocations are practicable. The Department will follow EPA guidance for revising or withdrawing TMDLs in accordance with considerations documented in EPA's 2012 draft memo before taking action (US EPA, 2012 (A)).

13.4 Public Participation

State Agencies:
South Dakota Department of Agriculture and Natural Resources (SD DANR) was the primary state agency involved in the completion of this TMDL assessment. SD DANR's water quality monitoring (WQM) network provided much of the data used in this TMDL. SD DANR also provided technical support and other resources throughout the course of the Rotating Basins Project.

Federal Agencies:
Environmental Protection Agency (EPA) provided most of the funding through the 319(h), 106, and 604(b) sections of the Clean Water Act for approved nonpoint source management projects.

Local Government, Industry, Environmental, and other groups, and public at large:
East Dakota Water Development District (EDWDD) was the lead project sponsor of the Rotating Basins-Big Sioux River Assessment Project (2020-2021). The district held monthly informational meetings for

the general public and governmental entities. Meetings discussed information on the progress and effectiveness of implementation projects (EDWDD, 2021).

A 30-day public comment period was issued for the draft TMDL. A public notice letter was published in the ********. The draft TMDL document and ability to comment was made available on the SD DANR Public Notice Page. The public comment period began MM/DD/YYYY and ended MM/DD/YYYY. # public comments were received during the 30-day comment period or public comments were addressed in ***Appendix C***.

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Appendix A – Measured Discharge and *E. coli* Data at WQM 183 2018 – 2022

Sample Date	Sample Time	Station ID	Project ID	Escherichia coli cfu/100mL	Mean Daily Discharge (cfs)
07/18/2018	13:40	460183	AMBIENT	221	76.21
08/06/2018	15:30	460183	AMBIENT	78	26.09
09/17/2018	15:00	460183	AMBIENT	62.2	8.82
05/07/2019	16:00	460183	AMBIENT	21.8	60.17
05/22/2019	13:00	460183	EDWQSPZ1	4110	239.18
06/03/2019	15:20	460183	AMBIENT	253	166.15
06/06/2019	12:35	460183	EDWQSPZ1	197	69.08
06/24/2019	12:55	460183	EDWQSPZ1	689	38.92
07/08/2019	12:25	460183	EDWQSPZ1	299	68.44
07/18/2019	12:35	460183	EDWQSPZ1	1220	171.05
07/22/2019	14:55	460183	AMBIENT	226	76.4
08/01/2019	09:30	460183	EDWQSPZ1	260	22.81
08/12/2019	16:20	460183	AMBIENT	71	13.32
08/15/2019	09:18	460183	EDWQSPZ1	206	12.02
09/05/2019	09:45	460183	EDWQSPZ1	259	9.04
09/09/2019	15:45	460183	AMBIENT	1990	10.54
09/30/2019	09:40	460183	EDWQSPZ1	548	15.56
05/04/2020	16:30	460183	AMBIENT	58.6	12.91
05/07/2020	09:40	460183	EDWQSPZ1	25.7	20.17
05/28/2020	09:15	460183	EDWQSPZ1	733	30.67
06/01/2020	14:55	460183	AMBIENT	38.8	14.53
06/25/2020	10:40	460183	RTBNRIST	459	38.78
07/06/2020	14:50	460183	AMBIENT	155	16.72
07/08/2020	09:40	460183	RTBNRIST	288	15.26
07/23/2020	09:20	460183	RTBNRIST	85	6.58
08/06/2020	09:40	460183	RTBNRIST	93.3	5.99
08/10/2020	16:20	460183	AMBIENT	59.2	6.67
08/20/2020	09:40	460183	RTBNRIST	613	5.15
09/01/2020	14:10	460183	AMBIENT	60.1	4.56
09/03/2020	08:15	460183	RTBNRIST	517	4.11
09/24/2020	08:40	460183	RTBNRIST	32	5.02
05/03/2021	17:20	460183	AMBIENT	98.8	6.58
05/06/2021	09:10	460183	RTBNRIST	199	6.53
05/27/2021	09:30	460183	RTBNRIST	770	5.39
06/01/2021	13:45	460183	AMBIENT	125	4.47
06/10/2021	10:10	460183	RTBNRIST	221	4.3
06/24/2021	09:50	460183	RTBNRIST	45.4	3.89

Sample Date	Sample Time	Station ID	Project ID	Escherichia coli cfu/100mL	Mean Daily Discharge (cfs)
07/06/2021	18:45	460183	AMBIENT	727	3.62
07/08/2021	09:20	460183	RTBNRIST	188	4.04
07/22/2021	10:20	460183	RTBNRIST	60.8	3.27
08/03/2021	18:00	460183	AMBIENT	95.9	3.88
08/05/2021	09:15	460183	RTBNRIST	166	4.82
08/26/2021	09:15	460183	RTBNRIST	189	5.83
09/09/2021	09:30	460183	RTBNRIST	65.7	13.57
09/15/2021	16:00	460183	AMBIENT	167	6.97
09/23/2021	08:45	460183	RTBNRIST	1200	18.84
05/11/2022	09:20	460183	AMBIENT	107	39.68
06/21/2022	14:00	460183	AMBIENT	461	10.26
07/07/2022	14:00	460183	AMBIENT	43.4	5.92
08/03/2022	14:40	460183	AMBIENT	27.8	3.68

Appendix B – TMDL Numeric Target Selection Rationale

South Dakota's *E. coli* criteria are based on EPA recommendations originally published in 1986 (US EPA, 1986). EPA issued slightly modified recommendations in 2012 that did not substantially change the underlying analysis or criteria values in South Dakota (US EPA, 2012 (B)). As recommended, SD DANR adopted *E. coli* criteria that contain two components: a geometric mean (GM) and a single sample maximum (SSM). The GM was established from epidemiological studies by comparing average summer exposure to an illness rate of 8:1,000. The SSM component was computed using the GM value and the corresponding variance observed in the epidemiological study dataset (i.e., log-standard deviation of 0.4). EPA provided four different SSM values corresponding to the 75th, 82nd, 90th, and 95th percentiles of the expected water quality sampling distribution around the GM to account for different recreational use intensities (**Figure 9**). South Dakota adopted the most stringent recommendation, the 75th percentile, into state water quality standard regulations as the SSM protective of designated beaches.

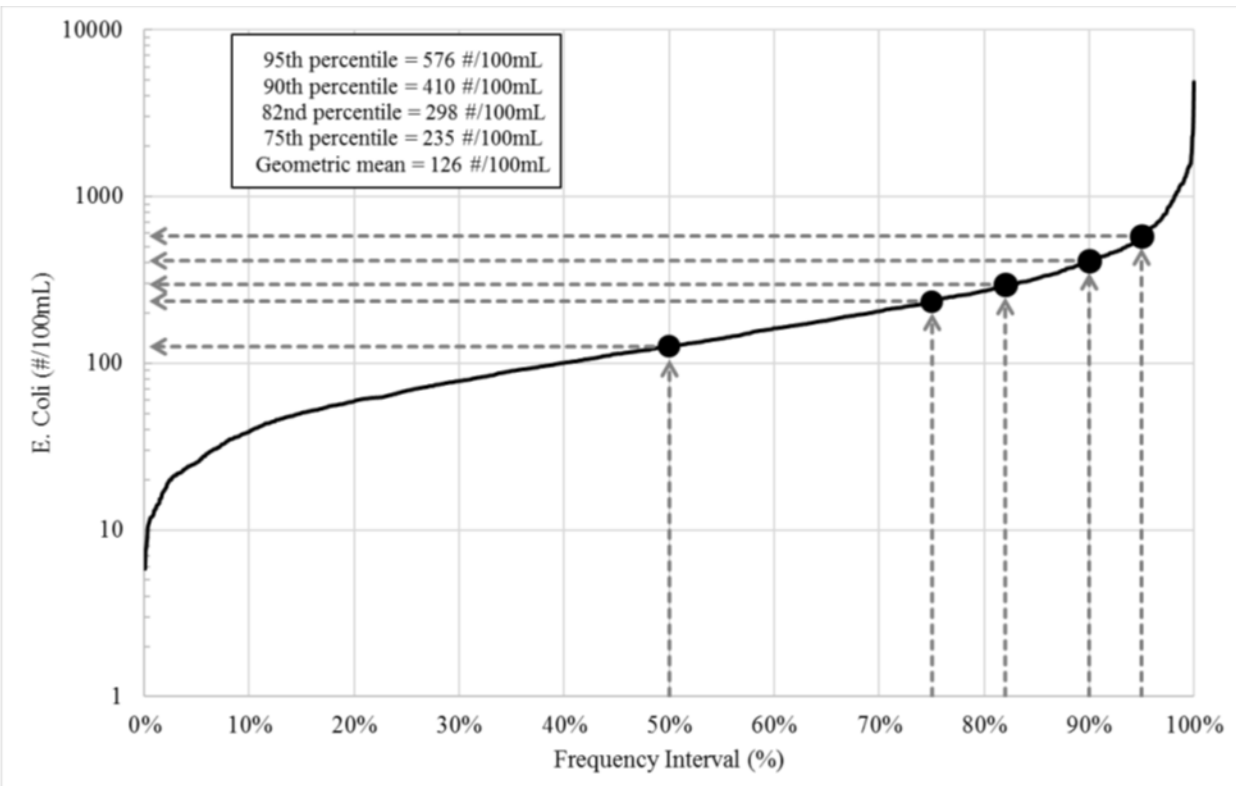

Figure 9. Log- Normal Frequency Distribution used to establish South Dakota's Immersion Recreation E. coli Criteria of 126 (GM) and 235 (SSM) #/100mL (EPA, 1986).

Dual criteria were established to balance the inherent variability of bacteria data and provide flexibility for handling different sampling routines. Together, the GM and SSM describe a water quality distribution expected to be protective of immersion contact recreation. The GM and SSM are equally protective of the beneficial use because they are based on the same illness rate and differ simply representing different statistical values and sampling timeframes. While this investigation has revealed the GM and SSM *E. coli* criteria to be equally protective of the immersion recreation use, a likewise conclusion can be made for the GM and SSM criteria associated with the limited contact recreation use since those values were simply derived as five times the immersion values.

As described in EPA's *Protocol for Developing Pathogen TMDLs*, the availability of data may dictate which criterion should be used as the TMDL target (EPA, 2001). When a geometric mean of the sampling dataset can be calculated as defined by South Dakota Administrative Rules (i.e., at least five samples separated by a minimum of 24-hours over a 30-day period) and compared to the GM criterion, SD DANR uses the GM criterion as the TMDL target. This establishes a smaller overall loading capacity and is considered a conservative approach to setting the TMDL.

When a proper GM cannot be calculated, as in this case for Beaver Creek (SD-BS-R-BEAVER_01), SD DANR uses the SSM as the TMDL target. This is permissible because the SSM is equally protective of the beneficial use as discussed above. Although this target selection leads to the establishment of a larger allowable load, in some respects it is more appropriate because timeframes align better (i.e., the SSM is associated with a single day and TMDLs establish daily loads, versus the 30-day GM). Additionally, certain aspects of SD DANR's *E. coli* assessment method, when combined with a SSM TMDL target, result in an expected dataset GM more protective than the GM criterion. SD DANR uses assessment methods to define how to interpret and apply water quality standards to 303(d) impairment decisions.

Returning to the original distribution used to establish South Dakota's Immersion Recreation *E. coli* criteria in Figure **9**, remember that SD DANR chose to adopt a SSM concentration based on the most stringent recommendation (75th percentile). According to assessment methods in South Dakota, however, the SSM concentration is treated as a 90th percentile (i.e., 10% exceedance frequency). Step #1 in Figure **10** shows how doing so effectively moves the SSM point to the right. If the original log-normal frequency distribution with a log-standard deviation of 0.4 is subsequently re-fitted to this new 90th percentile point at 235 #/100mL (red dotted line), the corresponding 50th percentile (GM) is 72 #/100mL as shown in Step #2 of ***Figure 10***.

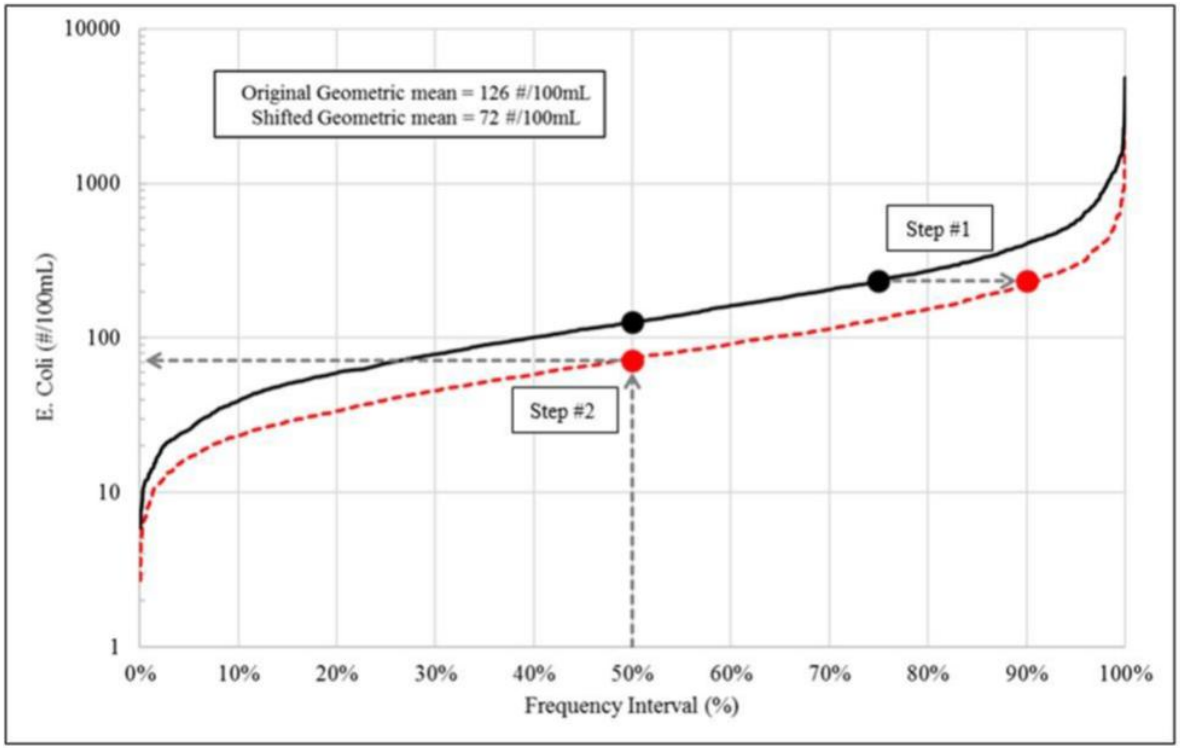

Figure 10. The effective impact of South Dakota's E. coli Assessment method on the criteria's original Log-normal frequency distribution (Black line = original; Red line = shifted)

The GM associated with this shifted distribution is more stringent than the GM of the original distribution (#/100mL), thus this demonstrates that attaining a maximum daily SSM target in a TMDL will also achieve the 30-day GM criterion when following South Dakota's assessment method. A similar conclusion was determined by EPA in An Approach for Using Load Duration Curves in the Development of TMDLs (US EPA, 2007) using Michigan criteria as an example.

Finally, while the SSM is associated with a single day of sampling and the GM is associated with 30 days of sampling, it is not technically appropriate to refer to them as "acute" and "chronic" criteria. Those terms distinguish timeframes over which harm-to-use impacts develop, not the sampling or averaging timeframe as with the SSM and GM. Acute refers to an effect that comes about rapidly over short periods of time. Chronic refers to an effect that can build up over longer periods, sometimes as long as the lifetime of a subject. In the case of *E. coli*, gastrointestinal illness develops within a matter of hours to days. Both the SSM and GM are derived from this same timeframe and based on the same underlying illness rate, thus treating the SSM as an acute criterion and assuming it to be less stringent is incorrect. EPA recommends states use the GM and SSM together, rather than just the GM or just the SSM, to judge whether water quality is protective of recreational uses. SD DANR follows these guidelines and only relies on one criterion when forced by data availability.

Appendix C – EPA Approval Letter and Decision Rationale