UPDATE OF *E. COLI* TOTAL MAXIMUM DAILY LOAD FOR SEGMENTS OF THE BIG SIOUX RIVER, MINNEHAHA COUNTY, SOUTH DAKOTA

TOPICAL REPORT RSI-2805

PREPARED FOR

South Dakota Department of Environment
and Natural Resources
523 East Capitol
Joe Foss Building
Pierre, South Dakota 57501

JUNE 2019

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Project Number 3344

Total Maximum Daily Load Summary	
Waterbody Name/Description	Big Sioux River (S2, T104N, R49W to I-90)
Assessment Unit I.D.	SD-BS-R-BIG_SIOUX_08
Waterbody Type	River
Size of Impaired Waterbody	28.5 miles (45.8 kilometers)
Size of Watershed (Incremental)	79.0 square miles (204.7 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 101702030604, 101702030605, and 101702031201
Impaired Designated Use(s)	Immersion Recreation and Limited Contact Recreation
303(d) Listing Parameter	*E. coli* Bacteria
Cycle Most Recently Listed	2018 South Dakota Integrated Report
TMDL Priority Ranking	N/A
Total Maximum Daily Load Criteria Threshold Values	Indicator Name: *E. coli* Bacteria Threshold Values: Maximum daily concentration of ≤ 235 colony-forming units per 100 milliliters (most probable number[mpn]/100 mL) and a geometric mean of at least five samples over a 30-day period ≤ 126 mpn/100 mL. These criteria apply from May through September.
Analytical Approach	Load-duration curves and HSPF modeling
High-Flow Zone LA	3.79E + 12 mpn/day
High-Flow Zone PS WLA	1.68E + 11 mpn/day
High-Flow Zone MS4 WLA	0 mpn/day
High-Flow Zone MOS	4.40E + 11 mpn/day
High-Flow Zone TMDL	4.40E + 12 mpn/day

Total Maximum Daily Load Summary	
Waterbody Name/Description	Big Sioux River (I-90 to diversion return)
Assessment Unit I.D.	SD-BS-R-BIG_SIOUX_10
Waterbody Type	River
Size of Impaired Waterbody	15.8 miles (25.4 kilometers)
Size of Watershed (Incremental)	40.9 square miles (106.0 square kilometers)
Location	12-Digit Hydrologic Unit Code (HUC): 101702031203
Impaired Designated Use(s)	Immersion Recreation and Limited Contact Recreation
303(d) Listing Parameter	*E. coli* Bacteria
Cycle Most Recently Listed	2018 South Dakota Integrated Report
TMDL Priority Ranking	N/A
Total Maximum Daily Load Criteria Threshold Values	Indicator Name: *E. coli* Bacteria Threshold Values: Maximum daily concentration of ≤ 235 colony-forming units per 100 milliliters (mpn/100 mL) and a geometric mean of at least five samples over a 30-day period ≤ 126 mpn/100 mL. These criteria apply from May through September.
Analytical Approach	Load-duration curves and HSPF modeling
High-Flow Zone LA	1.14E +12 mpn/day
High-Flow Zone PS WLA	8.89E + 10 mpn/day
High-Flow Zone MS4 WLA	2.45E + 11 mpn/day
High-Flow Zone MOS	1.64 E + 11 mpn/day
High-Flow Zone TMDL	1.64E + 12 mpn/day

Total Maximum Daily Load Summary	
Waterbody Name/Description	Big Sioux River (Diversion return to Sioux Falls Wastewater Treatment Plant [WWTP])
Assessment Unit I.D.	SD-BS-R-BIG_SIOUX_11
Waterbody Type	River
Size of Impaired Waterbody	4.7 miles (7.5 kilometers)
Size of Watershed (Incremental)	49.0 square miles (127.0 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 101702031705
Impaired Designated Use(s)	Immersion Recreation and Limited Contact Recreation
303(d) Listing Parameter	*E. coli* Bacteria
Cycle Most Recently Listed	2018 South Dakota Integrated Report
TMDL Priority Ranking	N/A
Total Maximum Daily Load Criteria Threshold Values	Indicator Name: *E. coli* Bacteria Threshold Values: Maximum daily concentration of ≤ 235 colony-forming units per 100 milliliters (mpn/100 mL) and a geometric mean of at least five samples over a 30-day period ≤ 126 mpn/100 mL. These criteria apply from May through September.
Analytical Approach	Load-duration curves and HSPF modeling
High-Flow Zone LA	4.50E + 12 mpn/day
High-Flow Zone PS WLA	1.36E + 11 mpn/day
High-Flow Zone MS4 WLA	2.16E + 11 mpn/day
High-Flow Zone MOS	5.39E + 11 mpn/day
High-Flow Zone TMDL	5.39E + 12 mpn/day

Total Maximum Daily Load Summary	
Waterbody Name/Description	Big Sioux River (Sioux Falls Wastewater Treatment Plant [WWTP] to above Brandon)
Assessment Unit I.D.	SD-BS-R-BIG_SIOUX_12
Waterbody Type	River
Size of Impaired Waterbody	4.2 miles (6.8 kilometers)
Size of Watershed (Incremental)	45.3 square miles (117.4 square kilometers)
Location	12-digit Hydrologic Unit Code (HUC): 101702031705
Impaired Designated Use(s)	Immersion Recreation and Limited Contact Recreation
303(d) Listing Parameter	*E. coli* Bacteria
Cycle Most Recently Listed	2018 South Dakota Integrated Report
TMDL Priority Ranking	N/A
TMDL Criteria Threshold Values	Indicator Name: *E. coli* Bacteria Threshold Values: Maximum daily concentration of ≤ 235 colony-forming units per 100 milliliters (mpn/100 mL) and a geometric mean of at least five samples over a 30-day period ≤ 126 mpn/100 mL. These criteria apply from May through September.
Analytical Approach	Load-duration curves and HSPF modeling
High-Flow Zone LA	4.39E + 12 mpn/day
High-Flow Zone PS WLA	5.96E + 11 mpn/day
High-Flow Zone MS4 WLA	0 mpn/day
High-Flow Zone MOS	5.54E + 11 mpn/day
High-Flow Zone TMDL	5.54E + 12 mpn/day

EXECUTIVE SUMMARY

This Total Maximum Daily Load (TMDL) assessment was completed as an update to an existing TMDL assessment for Big Sioux River impaired waterbodies near the city of Sioux Falls. The assessment addresses *E. coli* impairments in four river and stream reaches. A second TMDL assessment and TMDL assessment update was completed in the same four river and stream reaches for total suspended solids impairments. The goal of these TMDL updates was to quantify the pollutant reductions needed to meet the state water quality standards for *E. coli* and TSS in more recent years (i.e., 2013–2017). Reserve capacity was also added to the point source portion of the wasteload allocations to accommodate inevitable growth within the city of Sioux Falls. Because the point sources currently contribute less than one percent of the overall *E.* coli and TSS load, the point-source concentrations must remain below the water quality standards, and the point-source allocations are generally less than the margin of safety; thereby, the increased point-source allocations are not a water quality concern.

TMDLs described herein were derived from output of an HSPF model and observed data collected from 2013–2017. This model was calibrated to available flows (2005–2017), monitored water quality, and the latest National Land Cover Database and City of Sioux Falls Parcel Data. HSPF-estimated runoff and pollutant characterizations were employed to assess TMDLs for stream *E. coli* and TSS. HSPF-generated flows and outputs were used to establish load-duration curves for the *E. coli* and TSS impairments with wasteload allocations and load allocations established for five flow duration curve categories: high, moist, mid, low, and dry conditions. Reductions required to achieve state bacteria standards range from 0 percent to 96 percent by TMDL duration curve category. The reductions that are required to achieve state TSS standards range from 0 percent to 63 percent by TMDL duration curve category.

Restoring water quality will continue to be aided by the interdependent and cooperative efforts of the local communities, counties, state, and federal partners via leveraged management actions phased over budgetary cycles regarding the largest pollutant sources. Of the best management practices (BMPs), widespread adoption of buffers and streambank stabilization should proceed as a high priority and will assist in reducing bacteria and TSS. Knowing dominant bacteria and TSS sources to each impaired stream will help prioritize and guide implementation with agricultural producers and municipal storm sewer system areas. The findings from this TMDL study will assist in selecting implementation and monitoring activities.

The high flow zone distribution of the *E. coli* and TSS TMDL allocations for each reach are illustrated in figures ES-1 and ES-2, respectively.

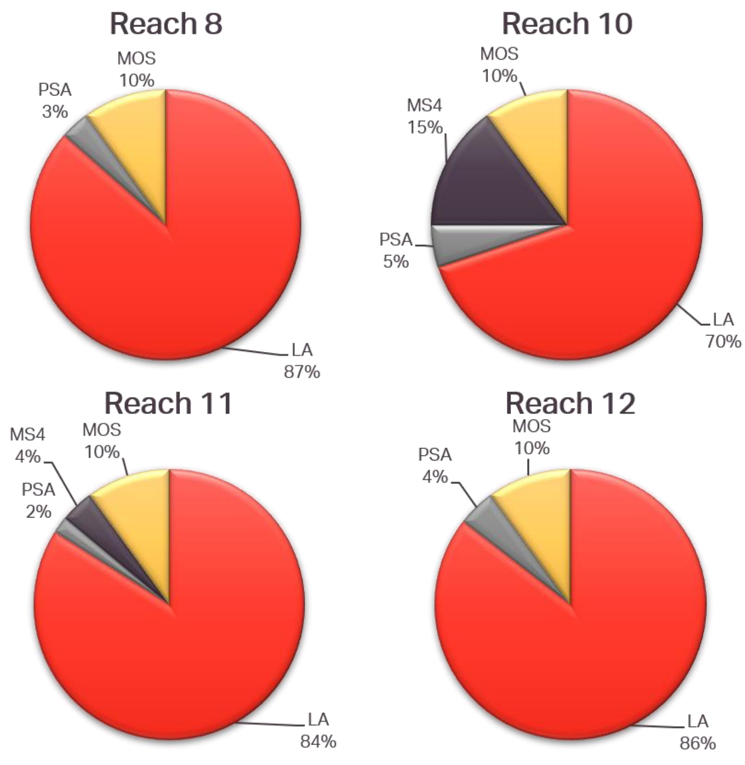

Figure ES-1. Total Suspended Solids High Flow Zone Total Maximum Daily Load Distribution.

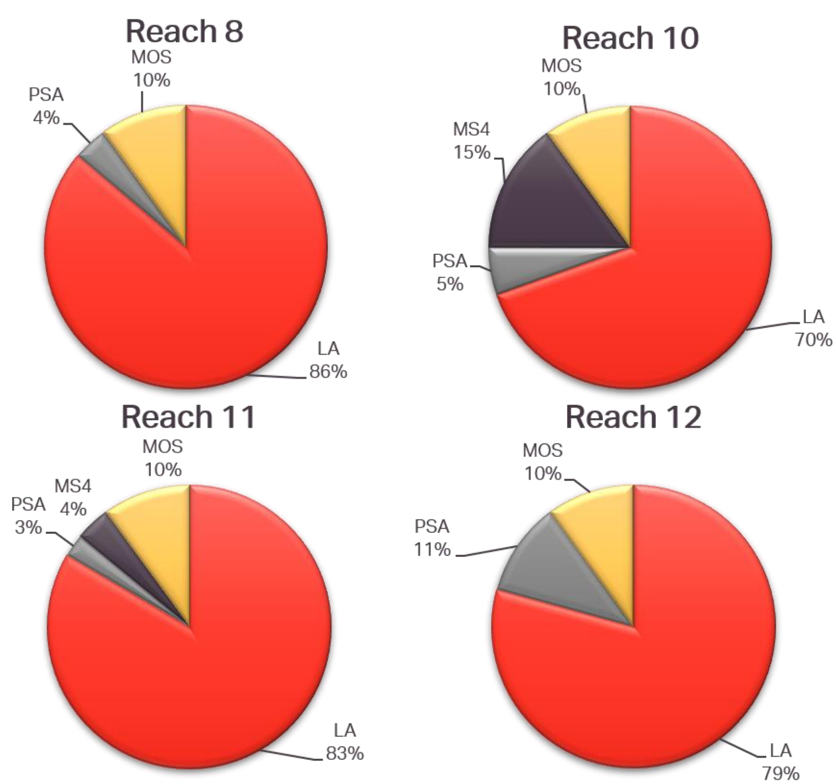

Figure ES-2. *E. coli* High Flow Zone Total Maximum Daily Load Distribution.

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1.0 INTRODUCTION

The intent of this document is to clearly identify the components of a set of Total Maximum Daily Loads (TMDLs), support adequate public participation, and facilitate the US Environmental Protection Agency (EPA) review. This document is an update to the TMDLs that were finalized in 2012, which have been developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by the EPA. This TMDL document addresses *E. coli* bacteria impairments on the Big Sioux River within the Lower Big Sioux River Watershed local to the city of Sioux Falls. A revision to the 2012 TMDLs was deemed necessary to account for the inevitable population and industrial growth occurring in and around the city of Sioux Falls, as Census data indicate that the population of Sioux Falls has increased nearly 15 percent since the previous TMDLs were written. Also, since the previous TMDLs were completed the fecal coliform standard has been changed to an E. *coli* bacteria standard. The revision utilized updated land cover datasets and newly collected ambient water quality data. The impaired reaches SD-BS-R-BIG_SIOUX_08 (Reach 8), SD-BS-R-BIG_SIOUX_10 (Reach 10), SD-BS-R-BIG_SIOUX_11 (Reach 11), and SD-BS-R-BIG_SIOUX_12 (Reach 12) were assigned to priority category 1 (high priority) in the 2010 impaired waterbodies list [South Dakota Department of Environment and Natural Resources, 2010], but were removed from priority category 1 when the TMDLs were approved by the EPA in 2012.

From 2008 to 2010, the South Dakota Department of Environment and Natural Resources (SD DENR) integrated SD-BS-R-BIG_SIOUX_09 (Reach 9) into the upstream and downstream reaches because of the differences in beneficial use designations and TMDL development [SD DENR, 2010]. Reaches listed as impaired in the 2008 impaired waterbodies list, which were slightly different from the 2010 reaches, included Reaches 8, 9, 10, 11, and 12 [SD DENR, 2008]. The 2018 integrated report lists the four reaches as impaired for *E. coli* bacteria in EPA category 4A (water impaired with an approved TMDL). Fecal coliform impairments were removed in the 2018 integrated report as *E. coli* TMDLs are expected to address fecal coliform.

1.1 WATERSHED CHARACTERISTICS

The Big Sioux River Watershed above the project area outlet is primarily located in eastern South Dakota and drains approximately 5,598 square miles in South Dakota, Minnesota, and Iowa. The Sioux Falls TMDL Assessment Project area lies within the Lower Big Sioux River Watershed, which includes the city of Sioux Falls (South Dakota's largest city). The project area drains approximately 216 square miles within the state of South Dakota.

Figure 1-1 shows the impaired (Section 303(d) listed) reaches on the Lower Big Sioux River located within the project area [SD DENR, 2018]. Reach 8 begins near Dell Rapids at the Moody/Minnehaha county line and ends at Interstate-90 (I-90). In the 2008 integrated report, Reach 8 was defined as extending from near Dell Rapids to below Baltic [SD DENR, 2008]. In the 2010 integrated report, Reach 8 was expanded to include the portion of Reach 9 above the diversion split or at I-29 [SD DENR, 2010]. The remainder of Reach 9 below the diversion to Skunk Creek was incorporated into Segment Reach 10 in the 2010 report [SD DENR, 2010]. Reach 10 now begins at I-90 and ends at the diversion return; Reach 11 begins at the diversion return and ends at the Sioux Falls Wastewater Treatment Plant (WWTP) and Reach 12 begins at the Sioux Falls WWTP and ends above Brandon, South Dakota [SD DENR, 2018]. These TMDLs represent the contiguous Reaches 8 through 12.

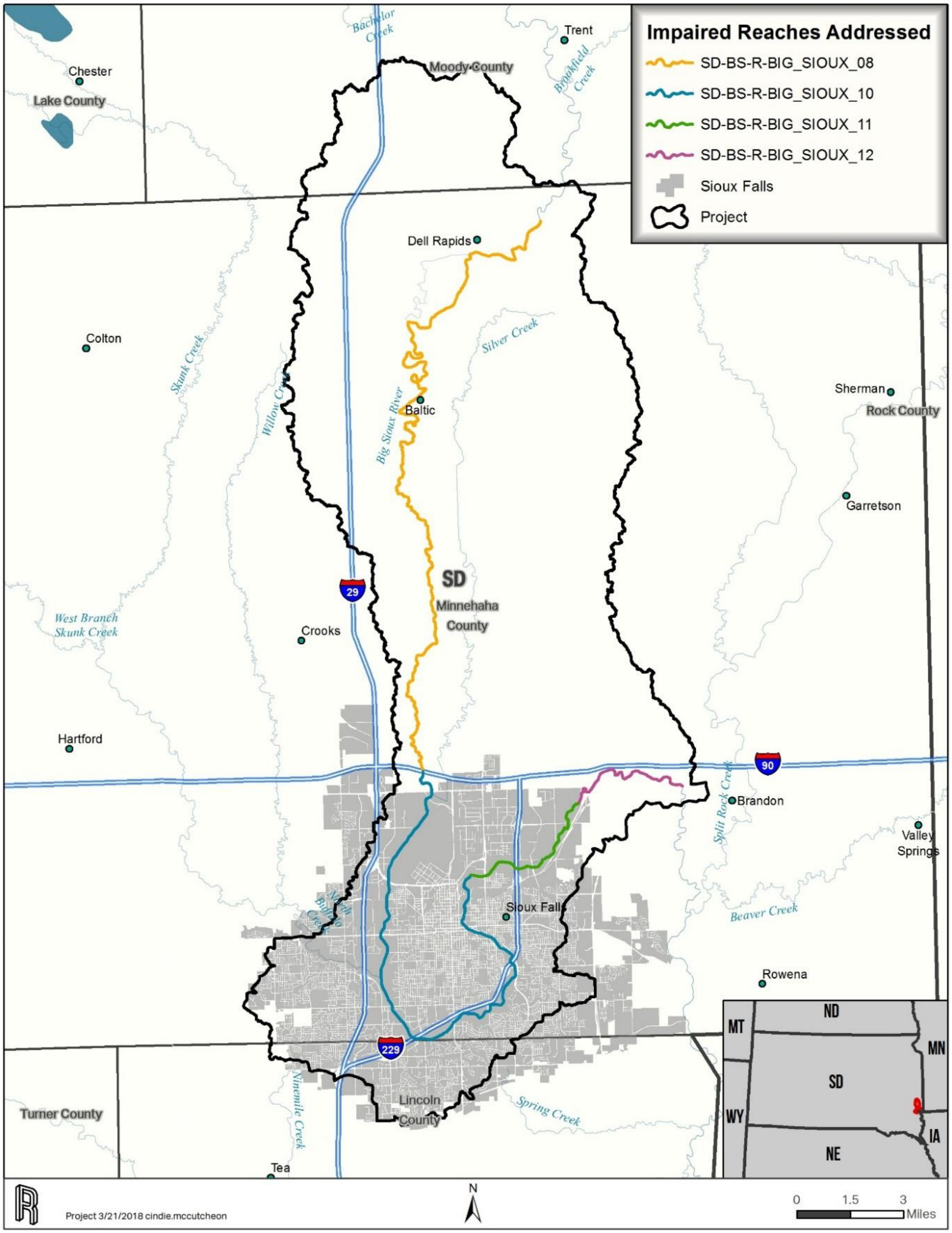

Figure 1-1. Project Area and Bacteria-Impaired Reaches.

The Big Sioux River, upstream of the project area, and Skunk Creek are both project area influences that had TMDLs completed in 2008. Both project area influences have the limited contact recreation beneficial use as opposed to the more stringent immersion recreation use of the project area.

The Sioux Falls TMDL project area receives 73 percent of its average annual precipitation (24.7 inches) during the growing season of April through September [South Dakota State University, 2008]. The average annual precipitation in the project area is shown in Figure 1-2. Local storms with short durations often produce heavy rainfall events. These storms can elevate to severe thunderstorms and occasionally produce tornadoes. The average seasonal snowfall is 41.1 inches per year [US Department of Commerce National Climatic Data Center, 2004]. Land use in the entire area draining to the impaired reaches is predominantly cropland and pasture. A complete list of watershed land uses and percent areas is shown in Table 1-1.

1.2 CLEAN WATER ACT SECTION 303(D) LISTING INFORMATION

Four Big Sioux River Reaches (8 through 12) within the project area are listed as impaired in the South Dakota 2018 303(d) list because of sample concentrations of *E. coli* bacteria that exceeded the criteria for the protection of the immersion recreation use and the limited contact recreation use. The immersion recreation use criteria are more stringent than the limited contact recreation use criteria.

Big Sioux River Reaches 10, 11, and 12 were listed as impaired because of fecal coliform bacteria in nearly every integrated report since 1998. Reach 8 was first listed as impaired in South Dakota's 2010 303(d) list [SD DENR, 2010]. However, the earlier version of this reach was listed with the other reaches in the 2004 303(d) list [SD DENR, 2004]. In 2008, the EPA approved a fecal coliform TMDL for Reach 8 that is defined as extending from near Dell Rapids to below Baltic. Because the boundaries for this segment have since expanded, the Reach 8 *E. coli* TMDL is not directly comparable to the 2008 fecal coliform TMDL. Reaches 8 through 12 are no longer listed for fecal coliform in the 2018 integrated report.

1.3 AVAILABLE WATER QUALITY AND WATER-QUANTITY DATA

Data have been collected throughout the project area by the SD DENR, the US Geological Survey (USGS), and by the City of Sioux Falls throughout the years. A summary of older water quality data, which included a specific summary of the baseflow samples versus the stormflow samples, is included in the previous version of this updated TMDL [McCutcheon et al., 2012]. Data summarized for this updated TMDL were collected between 2013 and 2017. Water quality data monitoring locations are shown in Figure 1-3 and listed in Table 1-2. Data were used to create boxplots (Figure 1-4), that show the range of *E. coli* concentrations [most probably number per 100 milliliters (mpn/100 mL)] at each site. Table 1-3 contains data summaries for each site from 2013 through 2017 including concentration ranges, percent exceedance of the daily maximum standard, and percent exceedance of the geometric mean standard.

The most downstream monitoring site in each reach was used for load-duration curve development. The most downstream monitoring sites include BSR020 in Reach 8, BSR070 in Reach 10, BSR090 in Reach 11, and BSR105 in Reach 12. In Reach 8, BSR020 is the first mainstem site below the diversion above Skunk Creek into the city. In Reach 10, BSR070 includes flows from much the city and Skunk Creek but does not include diversion flows. Approximately half-way down Reach 11, BSR090 includes

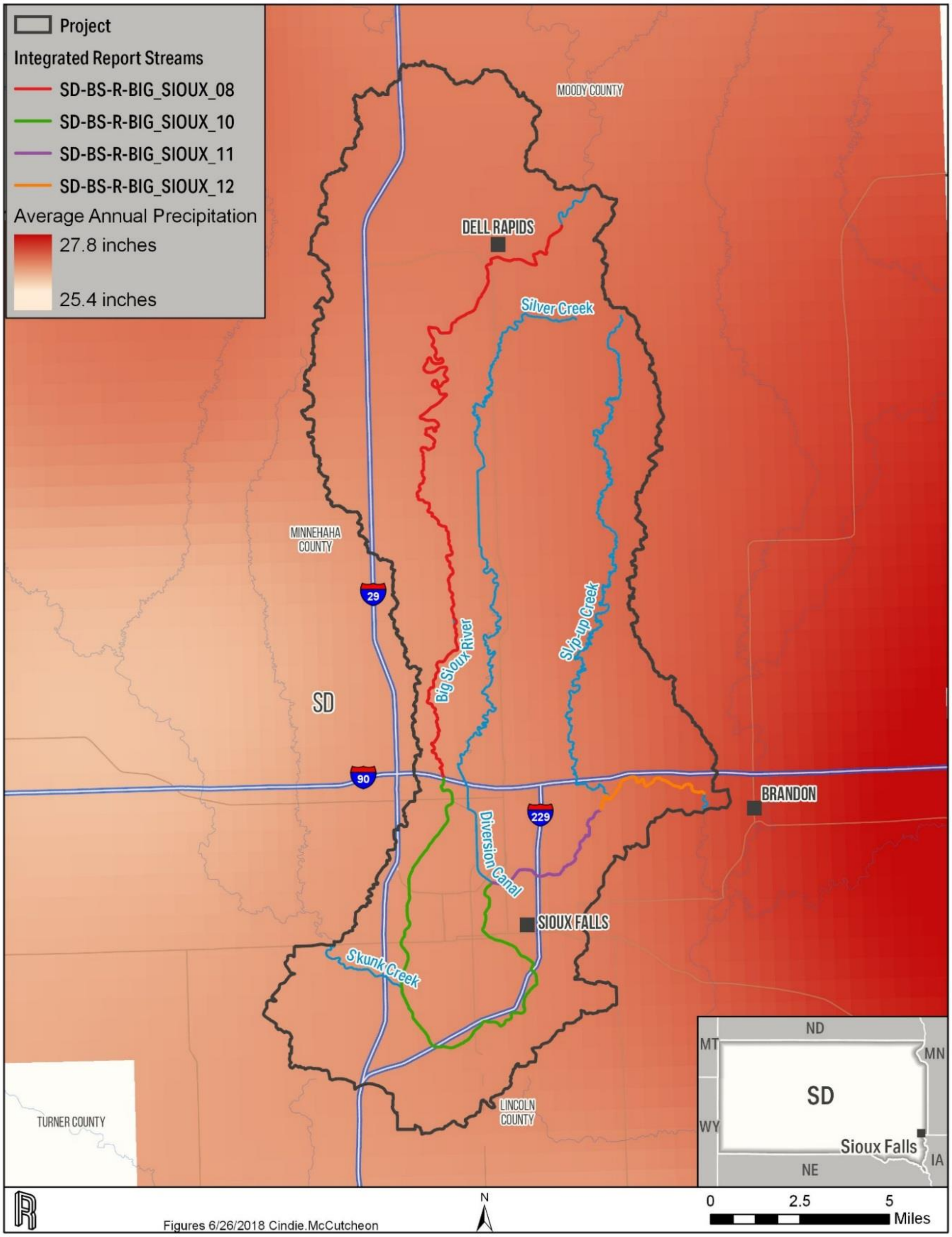

Figure 1-2. PRISM Average Annual Precipitation From 1981 to 2010.

Table 1-1. Land Use at Total Maximum Daily Load Reach Endpoints

Land Use	Reach 8 Land-Use Drainage Area (mi^2)	Percent at TMDL Reach 8 Endpoint[a]	Reach 10 Land-Use Drainage Area (mi^2)	Percent at TMDL Reach 10 Endpoint[a]	Reach 11 Land-Use Drainage Area (mi^2)	Percent at TMDL Reach 11 Endpoint[a]	Reach 12 Land-Use Drainage Area (mi^2)	Percent at TMDL Reach 12 Endpoint[a]
Cultivated Crops	2601.9	54	3002.2	55	3023.7	55	3052.2	55
Grassland/Herbaceous	930.7	19	967.7	18	969.6	17	972.5	17
Pasture/Hay	467.3	10	571.7	10	582.4	11	593.4	11
Open Water	457.3	9	483.3	9	483.6	9	483.9	9
Developed	229.1	5	297.9	5	309.5	6	318.9	6
Wetlands	126.6	3	137.9	3	138.2	2	138.6	2
Forest	26.3	1	31.1	1	32.4	1	33.1	1
Shrub/Scrub	2.3	0	2.4	0	2.5	0	2.5	0
Barren Land	2.0	0	2.5	0	2.7	0	2.7	0
Total Drainage Area (mi^2)	4,843.4		5,496.7		5,544.6		5,597.7	

(a) National Land Cover Data 2011 (Total Drainage Area = 5598 mi^2, Total Project Area = 216 mi^2).

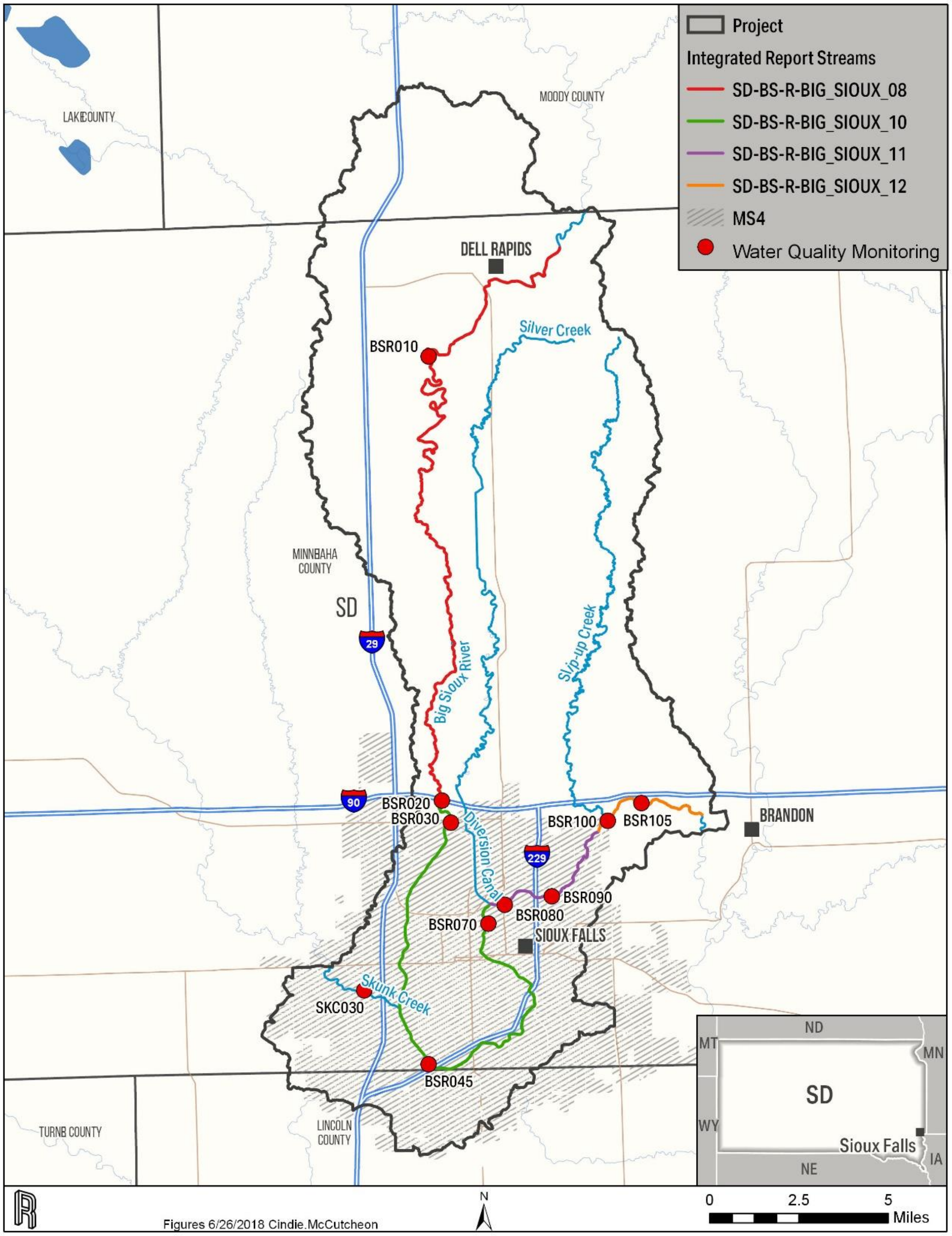

Figure 1-3. Monitoring Stations Within the Sioux Falls Study Area Along the Big Sioux River.

flows from the entire city, Skunk Creek, and the diversion, but not flows from Slip-up Creek. Approximately half-way down Reach 12, BSR105 includes flows from the entire city, Skunk Creek, the diversion, and Slip-up Creek. At all locations, exceedances of the geometric mean criteria were far more prevalent than exceedances of the daily maximum criteria; therefore, these TMDLs are developed using geometric mean concentrations and criteria.

Table 1-2. Data Available Between 2013 and 2017

Observed Monitoring Stations	Site I.D.	Reach	Number of Samples
Big Sioux River Minnehaha Co. Line to Below Baltic[(a)]	BSR010	SD-BS-R-BIG_SIOUX_08	60
Big Sioux River I-90 Bridge Upstream of Sioux Falls	**BSR020**	**SD-BS-R-BIG_SIOUX_08**	**222**
Big Sioux River at Silver Creek[(a)]	BSR030	SD-BS-R-BIG_SIOUX_10	8
Skunk Creek at Marion Road Bridge at Sioux Falls [(a)]	SKC030	NA	212
Big Sioux River at I-229 Bridge[(a)]	BSR045	SD-BS-R-BIG_SIOUX_10	46
Big Sioux River from Skunk Creek to diversion return	**BSR070**	**SD-BS-R-BIG_SIOUX_10**	**187**
Big Sioux River at North Cliff at Sioux Falls[(a)]	BSR080	SD-BS-R-BIG_SIOUX_11	10
Big Sioux River at Bahnson Ave. Bridge	**BSR090**	**SD-BS-R-BIG_SIOUX_11**	**217**
Big Sioux River at Bridge Downstream of Slip-up Creek[(a)]	BSR100	SD-BS-R-BIG_SIOUX_12	214
Big Sioux River (26B) at Hwy 21	**BSR105**	**SD-BS-R-BIG_SIOUX_12**	**171**

(a) Not used in the development of TMDL tables and load-duration curves (LDC).

Note: Sites shown in bold were used for load-duration curves and total maximum daily load tables.

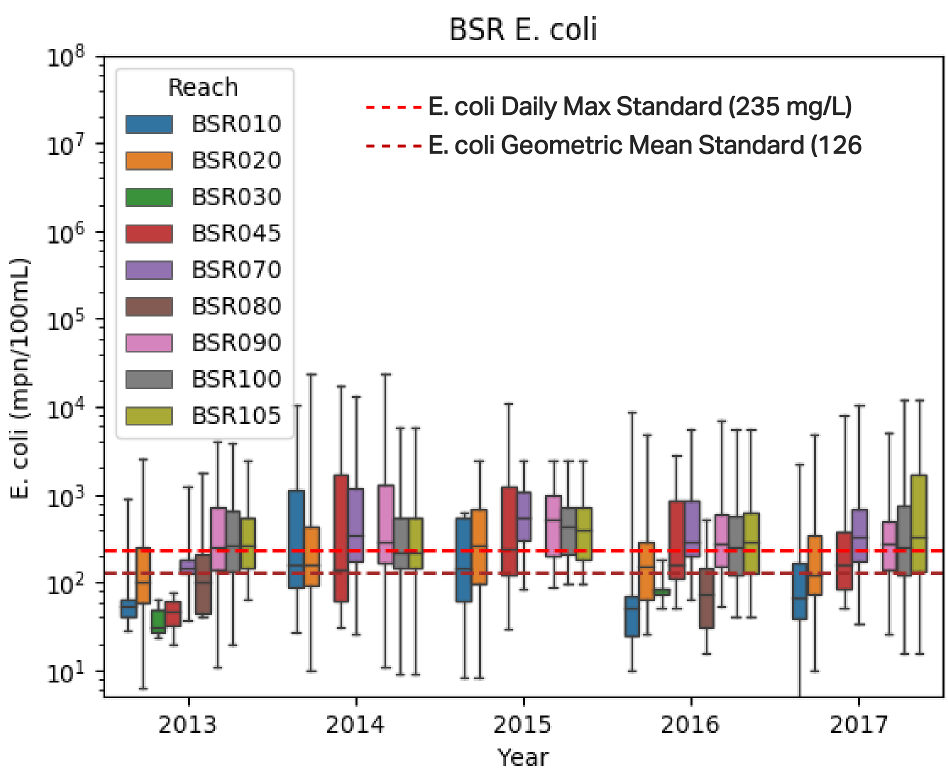

Figure 1-4. *E. coli* Boxplots for the Mainstem Sampling Sites With 2013–2017 Data.

Table 1-3. Percent Exceedance of *E. coli* Concentration Criteria and Ranges for Water Quality Monitoring Sites With Data Between 2013 and 2017 (Recreational Season)

Observed *E. coli* Monitoring Stations	Site I.D.	Total Number of Samples	Daily Maximum Exceedance	Daily Maximum Percent Exceedance	Daily Maximum Concentration Range (mpn/100 mL)[(a)]	Median Concentration (mpn/100mL)[(a)]	Geometric Mean[(b)] Values	Geometric Mean[(b)] Exceedance	Geometric Mean Percent Exceedance	Geometric Mean[(b)] Concentration Range (mpn/100 mL)[(a)]
Big Sioux River Minnehaha County Line to Below Baltic[(d)]	BSR010	60	16	27	4.1–10,500	70.5	N/A[(c)]	N/A[(c)]	N/A[(c)]	N/A[(c)]
Big Sioux River I-90 Bridge upstream of Sioux Falls	**BSR020**	**222**	**81**	**36**	**6.3–24,196**	**152.5**	**25**	**16**	**64**	**38.9–1,693.6**
Big Sioux River at Silver Creek[(d)]	BSR030	8	0	0	24.2 –183	69.5	N/A[(c)]	N/A[(c)]	N/A[(c)]	N/A[(c)]
Skunk Creek at Marion Road Bridge at Sioux Falls[(d)]	SKC030	212	134	63	10.2–24,196	345	25	23	92	73.6–2,459.6
Big Sioux River at I-229 Bridge[(d)]	BSR045	46	20	43	20–17,300	159.5	N/A[c)]	N/A[(c)]	N/A[(c)]	N/A[(c)]
Big Sioux River From Skunk Creek to Diversion Return	**BSR070**	**187**	**130**	**70**	**26–12,997**	**345**	**20**	**20**	**100**	**154.5–1,866.6**
Big Sioux River at North Cliff at Sioux Falls[(d)]	BSR080	10	2	20	16–1,790	88.65	N/A[c)]	N/A[(c)]	N/A[(c)]	N/A[(c)]
Big Sioux River at Bahnson Avenue Bridge	**BSR090**	**217**	**125**	**58**	**10.8–24,196**	**291**	**25**	**23**	**92**	**68.3–2,069.1**
Big Sioux River at Bridge Downstream of Slip-up Creek[(d)]	BSR100	214	119	56	9–12,033	280.5	25	24	96	72.8–1,367.8
Big Sioux River (26B) at Highway 21	**BSR105**	**171**	**99**	**58**	**9–12,033**	**291**	**20**	**19**	**95**	**72.8–1,367.8**

(a) mpn/100 mL = most probably number per 100 milliliters.

(b) The 30-day geometric mean concentration is calculated for each month in the recreational season. South Dakota criteria require at least five samples in a 30-day period to calculate a 30-day geometric mean. Therefore, months with less than five samples were not considered.

(c) 30-day geometric means based on at least five samples were not available.

(d) Sites Shown In Bold Were Used for Load-Duration Curves and Total Maximum Daily Load Tables)

At all locations, exceedances of the geometric mean criteria were far more prevalent than exceedances of the daily maximum criteria and therefore these TMDLs are written using geometric mean concentrations and criteria.

Monitoring was completed in 2009 on three key tributaries (Skunk Creek, Slip-up Creek, and Silver Creek); on the diversion canal, which sends flow around the Sioux Falls area; at multiple sites along the Big Sioux River; and throughout the city's storm drainage network. A detailed analysis of these sites is included in the previous version of this TMDL [McCutcheon et al., 2012]. This monitoring increased the understanding of the flows and associated *E. coli* concentrations throughout the watershed, as well as the flows being diverted around the city of Sioux Falls for the watershed model, which were ultimately used for the TMDLs.

Skunk Creek contributes a significant flow volume (40 to over 60 percent) to the Big Sioux River as illustrated in Figure 1-5. The significant flow contribution from Skunk Creek is related to the diversion of much of the Big Sioux River around the city of Sioux Falls through a diversion canal (see Figure 1-1 for the canal location). Because of the diversion, runoff from Sioux Falls (and flow from Skunk Creek) accounts for much of the Big Sioux River flow in Reach 10. The median concentration at Skunk Creek is over twice as high as that at BSR020.

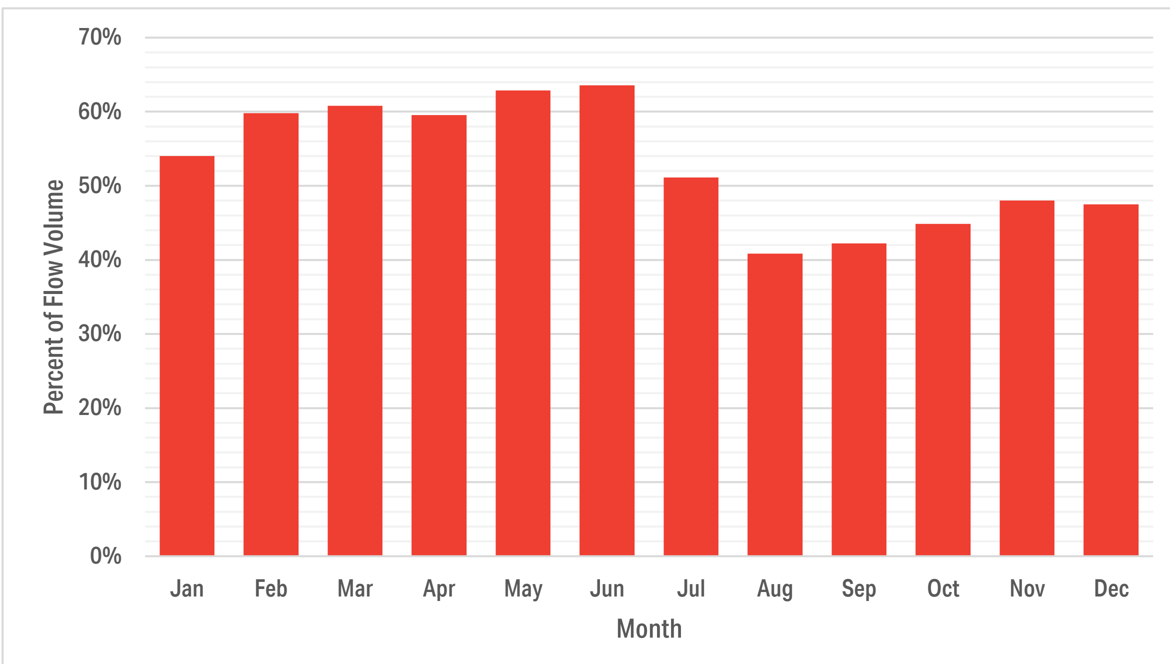

Figure 1-5. Skunk Creek Monthly Flow Volume Contribution Percentage to the Big Sioux River Directly Downstream of Skunk Creek (2013–2017).

The municipal separate storm sewer system (MS4) permit is a municipal stormwater discharge permit that authorizes the discharge of stormwater from the MS4. For the Sioux Falls TMDLs, the permit refers to stormwater runoff from the city of Sioux Falls into the Big Sioux River and its tributaries. The level of stormwater-quality control is defined by federal regulations in terms of maximum extent practicable (MEP). MEP considers the practicality and/or economics in treating low-frequency, very large events, and it recognizes that the majority of stormwater loadings are generated by the frequent, smaller events.

The 2009 stormwater portion of the monitoring showed the average median concentrations in stormwater sites from the city to range from 750 to 24,196 mpn/100 mL, which is far higher than the *E. coli* criteria in the project area. The 2009 monitoring also showed the existing best management practices (BMP) within the study area (e.g., detention ponds and constructed wetland channels and basins) did not appear to significantly decrease bacteria concentrations. Because of these high stormflow bacteria concentrations, future BMPs should also focus on reducing bacteria concentrations [McCutcheon et. al., 2012].

The USGS monitors long-term streamflow on the Big Sioux River at USGS 06481000 Big Sioux River near Dell Rapids, USGS 06482000 Big Sioux River at Sioux Falls, USGS 06482020 Big Sioux River at Cliff Avenue at Sioux Falls, and on Skunk Creek at USGS 06481500 Skunk Creek at Sioux Falls. These streamflow gages are illustrated in Figure 1-6. Two additional streamflow gages also existed but did not have continuous flow data (BSR020 at the I-90 Bridge upstream of Sioux Falls and BSR110 near Brandon). Additional flow data were collected as a part of the 2009 monitoring effort. All flow data from 2005 to 2017 were used to calibrate the hydrology portion of the watershed model.

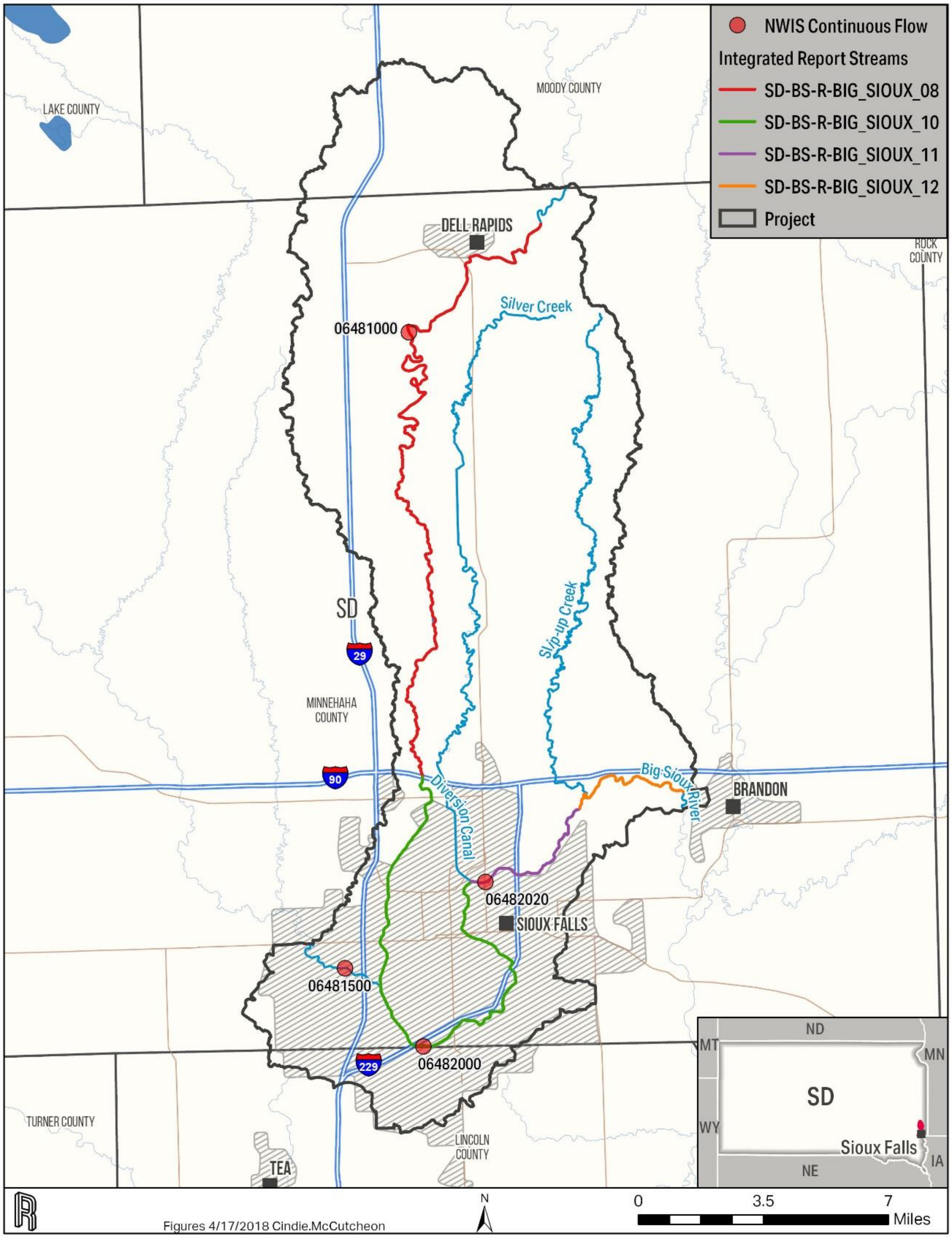

Figure 1-6. Long-Term US Geological Survey Stream Flow Gages on the Big Sioux River and Skunk Creek.

2.0 WATER QUALITY STANDARDS AND TOTAL MAXIMUM DAILY LOAD TARGETS

Each waterbody within South Dakota is assigned beneficial uses. All waters (both lakes and streams) are designated with the use of fish and wildlife propagation, recreation, and stock watering, and all streams are assigned the use of irrigation. Additional uses may be assigned by the state based on a beneficial use analysis of each waterbody. Water quality standards are defined in South Dakota state statutes in support of these uses (Administrative Rules of South Dakota [ARSD] 74:51:01–74:51:03), and these standards consist of suites of criteria that provide physical and chemical benchmarks for management decisions [ARSD, 2010].

Additional "narrative" standards that may apply can be found in ARSD Articles 74:51:01:05; 06; 08; 09; and 12 [ARSD, 2010]. These standards generally prohibit the presence of materials that cause pollutants to form, visible pollutants, nuisance aquatic life, and pollutants impacting biological integrity.

The Big Sioux River Reaches 8 and 10 were assigned the following beneficial uses: domestic water supply, fish and wildlife propagation, immersion recreation, irrigation waters, limited contact recreation, and warm-water semipermanent fish life. Big Sioux River Reaches 11 and 12 were assigned the same beneficial uses except for domestic water supply, which is not a beneficial use in these downstream reaches. Table 2-1 lists the *E. coli* water quality criteria that must be met to support the beneficial uses currently assigned to the Big Sioux River within the city of Sioux Falls. All listed reaches must meet the more stringent standards of immersion recreation because they are listed as impaired for both immersion and limited contact recreation. Greater than 10 percent of the samples must exceed water quality criteria for that parameter to be included as a cause of impairment on the 303(d) Impaired Waters List. For a parameter to be considered representative of actual conditions, at least 20 samples of the parameter are required; however, the sample threshold is reduced to ten samples if three or more samples exceed daily maximum water quality standards.

Table 2-1. State Bacteria Surface Water Quality Standards for the Big Sioux River in the City of Sioux Falls

Parameter	Criteria	Unit of Measure	Special Conditions
E. coli[a]	≤ 126	mpn /100 mL	Geometric mean[b] (May 1–Sep 30)
	≤ 235	mpn /100 mL	Daily maximum (May 1–Sep 30)

(a) Criteria for immersion recreation use.

(b) Geometric mean must be based on a minimum of five samples obtained during separate 24-hour periods for any 30-day period.

Current *E. coli* criteria for the immersion and limited contact recreation use require; that no sample exceeds 235 mpn/100 mL and 1,178 mpn/100 mL, respectively and the geometric mean of a minimum of five samples collected during separate 24-hour periods for any 30-day period must not exceed 126 mpn/100 mL and 630 mpn/100 mL, respectively. The geometric mean, as defined in ARSD Article 74:51:01:01, is the *n* root of a product of *n* factors. The *E. coli* criteria are applicable from May 1 through September 30.

According to ARSD Article 74:51:01:04, pollutants may not cause the more stringent criterion to be exceeded if they are discharged into a segment and the criteria for that segment's designated beneficial use are not exceeded, but the waters flow into another segment whose designated beneficial use requires a more stringent parameter criterion. Skunk Creek and the Big Sioux River Reach SD-BS-R-BIG_SIOUX_07 (Reach 7) are currently assigned a limited contact recreation beneficial use, which has less-stringent *E. coli* criteria (geometric mean criteria of 630 mpn/100 mL and daily maximum criteria of 1,178 mpn/ 100 mL) than the Big Sioux River project area's immersion recreation beneficial use (geometric mean criteria of 126 mpn/100 mL and daily maximum criteria of 235 mpn/100 mL). Because Skunk Creek and Reach 7 are relatively large contributors of flow to the Big Sioux River, the discrepancy in water quality standards is a concern. *E. coli* concentrations in these waterbodies at their current water quality standards have the potential to cause water quality standard exceedances in the Big Sioux River within the project area without any urban load contribution from the city of Sioux Falls. This potential for exceedance could make it very difficult for the Big Sioux River to support its assigned beneficial use within the project area. The Skunk Creek Watershed and Reach 7 are not part of the current TMDL assessment for the Big Sioux River through the city of Sioux Falls.

3.0 SIGNIFICANT SOURCES

3.1 POINT SOURCES

Multiple permitted point-source discharges are in the project area and are listed in Table 3-1. These permitted point sources, illustrated in Figure 3-1, include L.G. Everest in Reach 8, the Dell Rapids WWTP (wastewater treatment plant) in Reach 8, the Baltic WWTP in Reach 8, the Sioux Falls MS4 permit in Reaches 10 and 11, Smithfield Foods in Reach 11, and the Sioux Falls WWTP in Reach 12. Because L.G. Everest is not a wastewater facility, it is not expected to contribute to the *E. coli* impairments and was not given a waste load allocation (WLA). The Baltic and Dell Rapids WWTPs are lagoons. According to the discharge monitoring report data, the Baltic WWTP has not discharged in over 10 years, and the Dell Rapids WWTP typically discharges in May and December each year. When the previous version of this TMDL document was written, Smithfield Foods was John Morrell. The permit area covered by the MS4 includes "all areas within the corporate boundary of the city of Sioux Falls served by, or otherwise contributing to, discharges to state waters from municipal separate storm sewers owned or operated by the city of Sioux Falls and interstate highways operated by South Dakota Department of Transportation" [SD DENR, 1999]. Multiple concentrated animal feeding operations (CAFOs) are located in Minnehaha County. Note, however, that all of these permitted CAFOs have zero discharge except in the rare case of a precipitation event that produces a volume of water greater than the facility's design capacity. In this case, the permittee is required to notify the SD DENR and develop a plan of action to remediate the problem. CAFOs were therefore not given WLAs.

Table 3-1. Point Sources Within the Sioux Falls Project Area

Point Sources	Permit Number	Reach	Flow (mgd)[a]	*E. coli* Limit (mpn/100 mL)	*E. coli* WLA (mpn/day)
L. G. Everest	SD-0000051	08	5.08	NA	NA
Dell Rapids WWTP	SD-0022101	08	4.38	235	3.90×10^{10}
Baltic WWTP	SD-0022284	08	4.56	235	4.06×10^{10}
Sioux Falls NPDES MS4	SDS-000001	10, 11	N/A	N/A	NA
Smithfield Foods[a]	SD-0000078	11	5.25	235	4.67×10^{10}
Sioux Falls WWTP	SD-0022128	12	57	235	5.07×10^{11}
Future Industrial Growth Reserve Capacity	NA	NA	10	235	8.89×10^{10}

3.2 NONPOINT SOURCES

Based on a review of available information and communication with state and local authorities, the primary nonpoint sources of bacteria within the project area include livestock operations, agricultural runoff, wildlife, pets, and septic systems. Bacterial loadings for the model were estimated using the simulated hydrologic response of each modeled land use and the corresponding event mean concentrations (EMCs) for each land use that were derived from 2009 sample data based on representative land use draining to particular sampling sites. For example, one sampling site was predominantly residential, so the concentrations observed from that site were used as the EMC for all residential land. The multiple sampling sites each had a targeted representative land use. To account

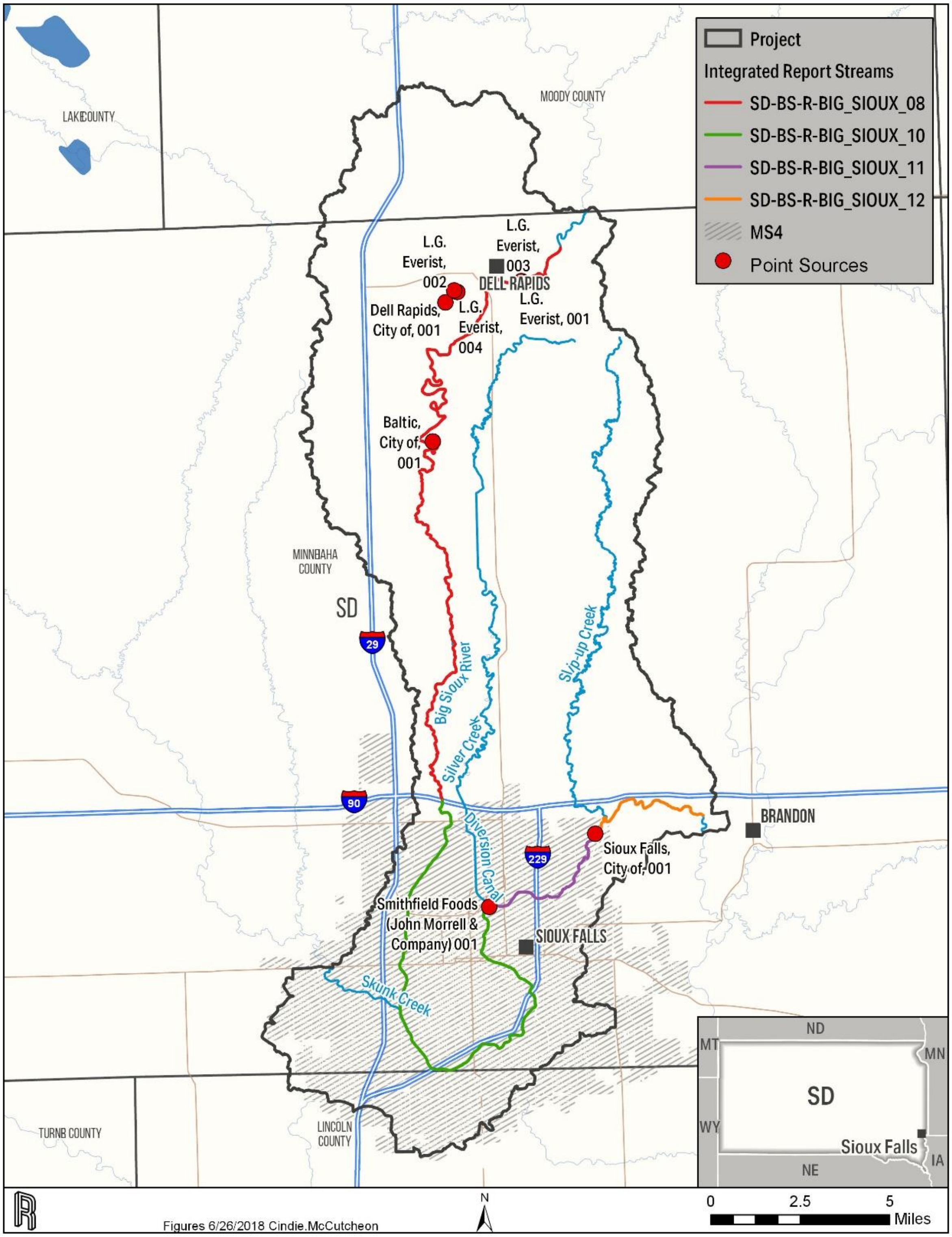

Figure 3-1. Point Sources Including the Municipal Separate Storm Sewer Systems.

for spatial variability in the watershed and to align with downstream sampling measurements, the EMCs in some cases were adjusted through the calibration process within the range of concentrations that were observed for the land use.

Bacteria sources within the study area are provided in Table 3-2. Because these were not the primary source of information for the TMDL modeling, they were not fully updated from the previous TMDL version. Pets (dogs and cats) were added to this summary based on the number of household units located in the project area from the 2010 census (63,704 household units) assuming 0.58 dogs (36.5 percent of households times 1.6 dogs per household) and 0.64 cats (30.4 percent of households times 2.1 cats per household) per household [American Veterinary Medical Association, 2016]. For the previous TMDL version, livestock numbers were estimated based on 2007 US Department of Agriculture(USDA) Census information [USDA, 2009]. Wildlife numbers were estimated from the 2002 South Dakota Game Report [Huxoll, 2003]. Septic system numbers were based on information provided in the 2010 Census.

Table 3-2. Estimated Count of Bacteria Sources in the Project Area

Bacteria Source	Number
Livestock	
Cattle	4,951
Horses	359
Sheep	913
Hogs	6,628
Poultry	226
Wildlife	
Deer	756
Beaver	169
Muskrats	986
Raccoons	753
Skunks	763
Nesting Canadian Geese	313
Rabbits	6,315
Wild Turkeys	125
Humans	
Septic	1,585
Pets	
Dogs	36,948
Cats	41,025

3.2.1 HUMAN
Human bacterial sources in urban settings can generally include cross connections between sanitary sewers and storm drain systems, overflows from sanitary sewer systems, and wet weather discharges from centralized wastewater collection and treatment facilities. The City of Sioux Falls has investigated and removed any existing cross connections. Outside city limits, septic systems are a potential human source of bacteria loads because much of the land is rural.

3.2.2 DOMESTIC ANIMALS
Pet waste is a contributor to the bacteria in the Big Sioux River. A recreational trail exists along the Big Sioux River throughout Sioux Falls which can accumulate pet waste. Additionally, pet waste may not be properly disposed of on private property along the river or within the stormwater drainage network, and it may be washed off during precipitation events.

3.2.3 AGRICULTURE
Manure from livestock is a potential source of bacteria to the stream. Livestock in the basin are predominantly beef cattle. Other livestock in the basin include dairy cattle, chickens, swine, sheep, and horses. Livestock contribute bacteria loads to the Big Sioux River directly by defecating while wading in the stream and indirectly by defecating on pastures or cropland that can be washed off during precipitation events.

3.2.4 NATURAL BACKGROUND/WILDLIFE
Wildlife within the watershed is a natural background source of bacteria. Similar to livestock, wildlife (including waterfowl and large game species) contribute bacteria loads to the Big Sioux River directly by defecating while wading in the stream and indirectly by defecating on lands that are washed off during precipitation events.

3.2.5 PETS
Dogs and cats within the watershed are large potential source of bacteria. Pets distribute bacteria in approximately one-third of the yards in the project area, and pet waste is not always removed promptly. It is then washed off into the river during precipitation events.

3.3 BACTERIAL SOURCE TRACKING
As a part of the 2009 monitoring efforts, RESPEC collected a fecal coliform source tracking event sample from eight stormwater sites draining into the Big Sioux River in Sioux Falls to aid in locating sources of impairment and prioritizing BMP implementation. Figure 3-2 shows the locations of the bacterial source tracking sites. One sample was taken during a storm event at each site. STW040 had a second, duplicate sample collected for quality assurance and quality control purposes. These samples were analyzed for the presence of the human *Enterococcus faecium* gene biomarker. The biomarker was detected at four of the sites, provided in Table 3-3, and indicates that human fecal contamination was present. No quantification analysis was performed on these samples. Results of *E. coli* concentration samples taken concurrently with bacterial source tracking samples are also provided in Table 3-3. Although these source tracking tests suggest the presence of human sources, further quantification is required to verify these human sources. Additionally, in 2015 a study was completed in the Skunk Creek Watershed which showed that dogs were a major contributor to bacteria in the lower watershed during storm events. Although it is not known with certainty whether this is the

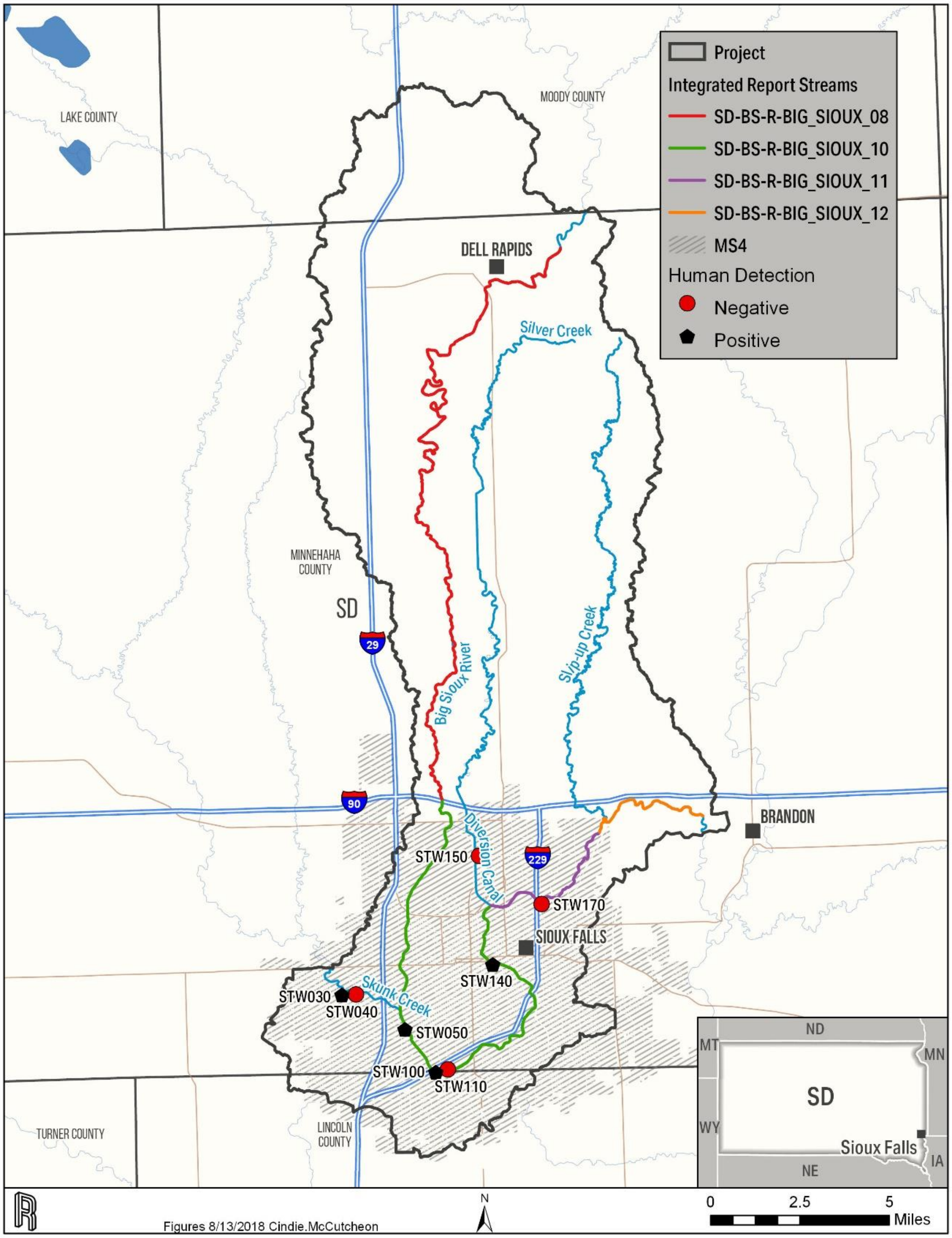

Figure 3-2. Bacterial Source Tracking Stations From the 2009 Monitoring Effort.

case throughout the project area, it can be expected that some similarities do occur in similar residential watersheds. This study also showed positive human detection at STW030 [Oswald and Rausch, 2015].

Table 3-3. Results of 2009 Presence/Absence Analysis of *Human Enterococcus Faecium* Gene Biomarker at Eight Urban Stormwater Outfalls

Project I.D.	Location	Human Enterococcus Biomarker Detection	Result (MPN/ 100 mL)[a]
STW030	Urban Stream Channel near S. Dunham Circle	**Positive**	9,210
STW040	Stormwater Channel near W. Silver Valley Drive	Negative	14,680
STW050	Storm Drain near PetSmart	**Positive**	6,490
STW100	Urban Stream Channel near 57th Street	**Positive**	9,800
STW110	Storm Drain in Yankton Trail Park	Negative	12,030
STW140	Storm Drain along Beadle Greenway	**Positive**	14,130
STW150	Stormwater Channel near E. Benson Road	Negative	12,030
STW170	Urban Stream Channel Near E. Rice Street	Negative	2,990

(a) MPN/100 mL = most probable number per 100 milliliters.

3.4 SOURCE ASSESSMENT MODELING RESULTS

The watershed modeling package selected for this assessment was the EPA HSPF model. HSPF is a comprehensive watershed model of hydrology and water quality that includes modeling both land surface and subsurface hydrologic and water quality processes and is linked and closely integrated with corresponding stream and reservoir processes. HSPF is considered a premier, high-level model among those currently available for comprehensive watershed assessments.

The HSPF model was used to determine the contribution of *E. coli* bacteria from identified sources in the project area and evaluate the implementation of BMPs to control these sources. The Big Sioux River drainage basin was represented in the model using twenty-four subwatersheds and two boundary conditions that represent Skunk Creek and the Big Sioux River at Dell Rapids. Nonpoint-source bacterial loadings for HSPF were estimated using the EMCs for each land use, which were derived from sample data based on representative land uses draining to particular sampling sites. For example, one sampling site was predominantly residential so the concentrations from that site were used as the EMCs for all residential land. EMCs were applied throughout the watershed, and the buildup and washoff of *E. coli* were simulated based on the EMC values and precipitation. Point-source data provided by SD DENR for facilities discharging below the Big Sioux River boundary condition were represented in the model at the time step provided (30-day average).

Source assessment modeling results were summarized using the following categories: nonpoint sources and local and upstream MS4s. Big Sioux River boundary conditions, Skunk Creek, and Slip-up Creek. A diagram of sources is included in Figure 3-3. The nonpoint-source category includes all areas north of the Sioux Falls MS4 except the Slip-Up Watershed (local Big Sioux River in Reach 8) and Silver Creek. A time series of average daily loads by source occurring on each date from 2013 through 2017 was created. Pie charts, shown in Figure 3-4 through 3-7, were produced for each of the four TMDL

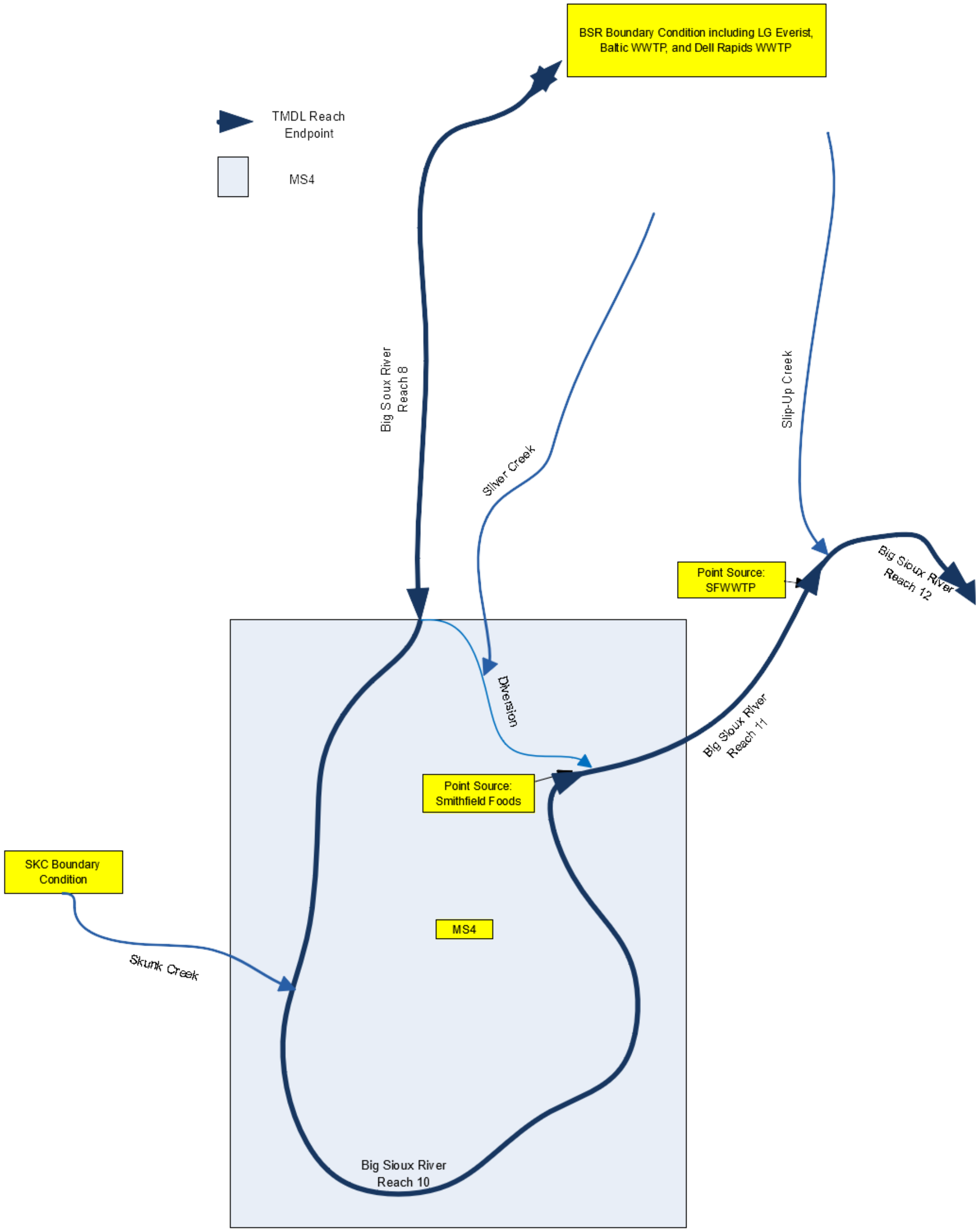

Figure 3-3. Diagram of Sources Used in Source Assessment Pie Charts.

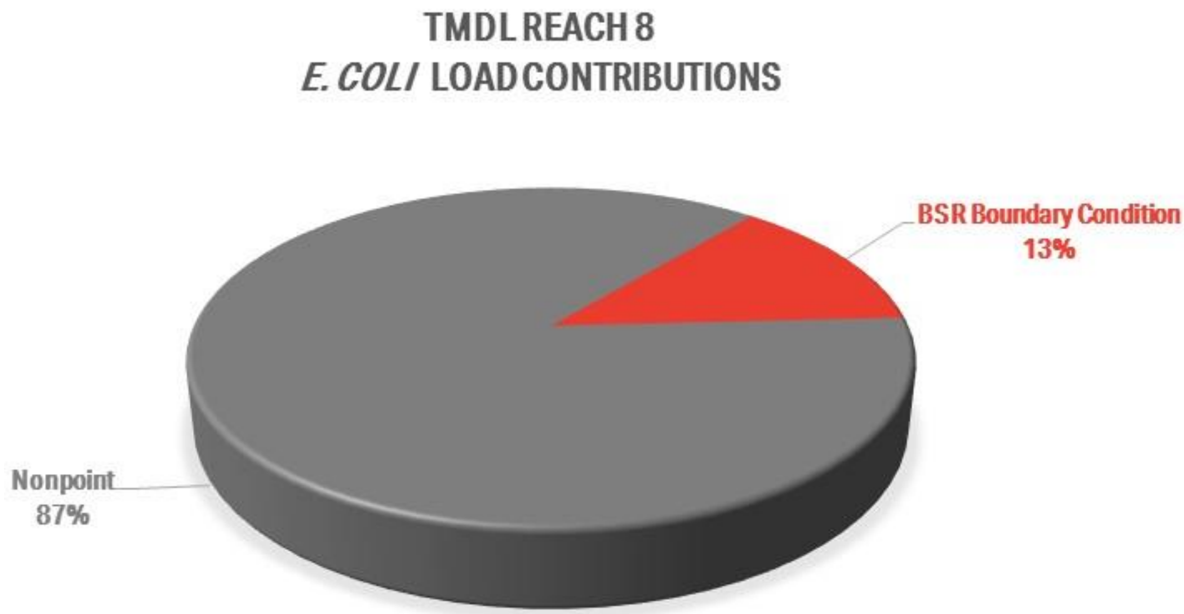

Figure 3-4. Source Assessment Modeling Results for the Endpoint of Reach 8.

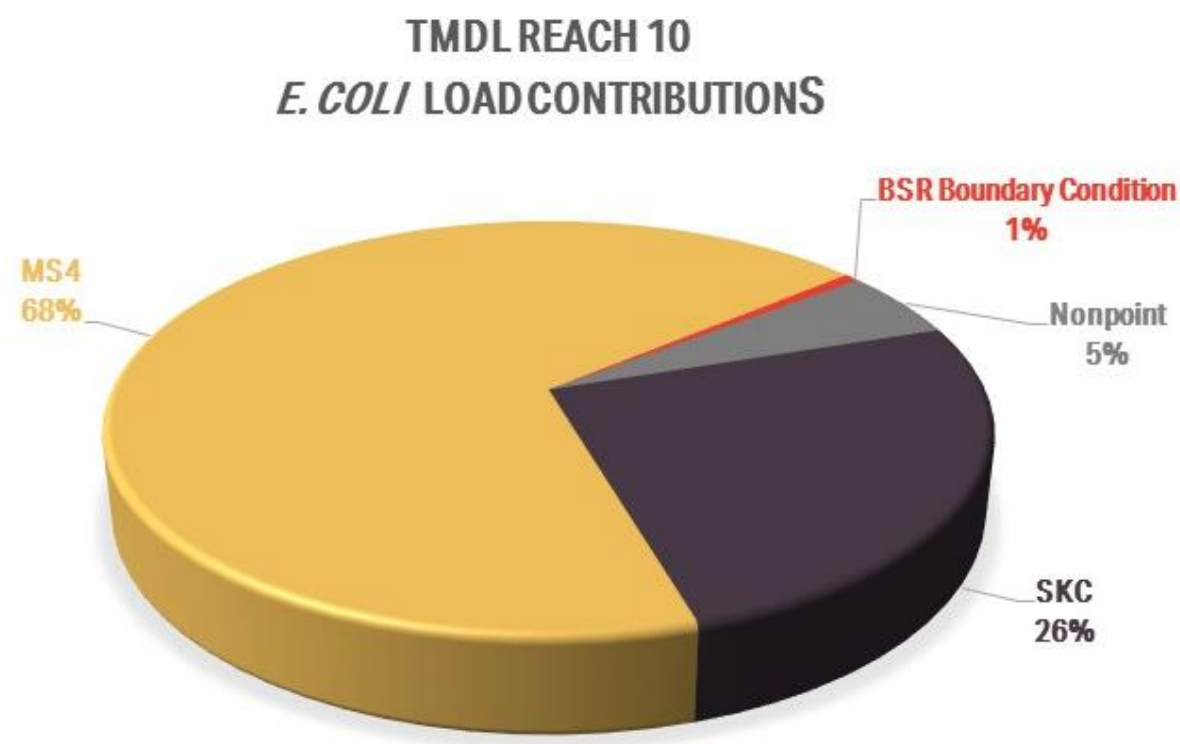

Figure 3-5. Source Assessment Modeling Results for the Endpoint of Reach 10.

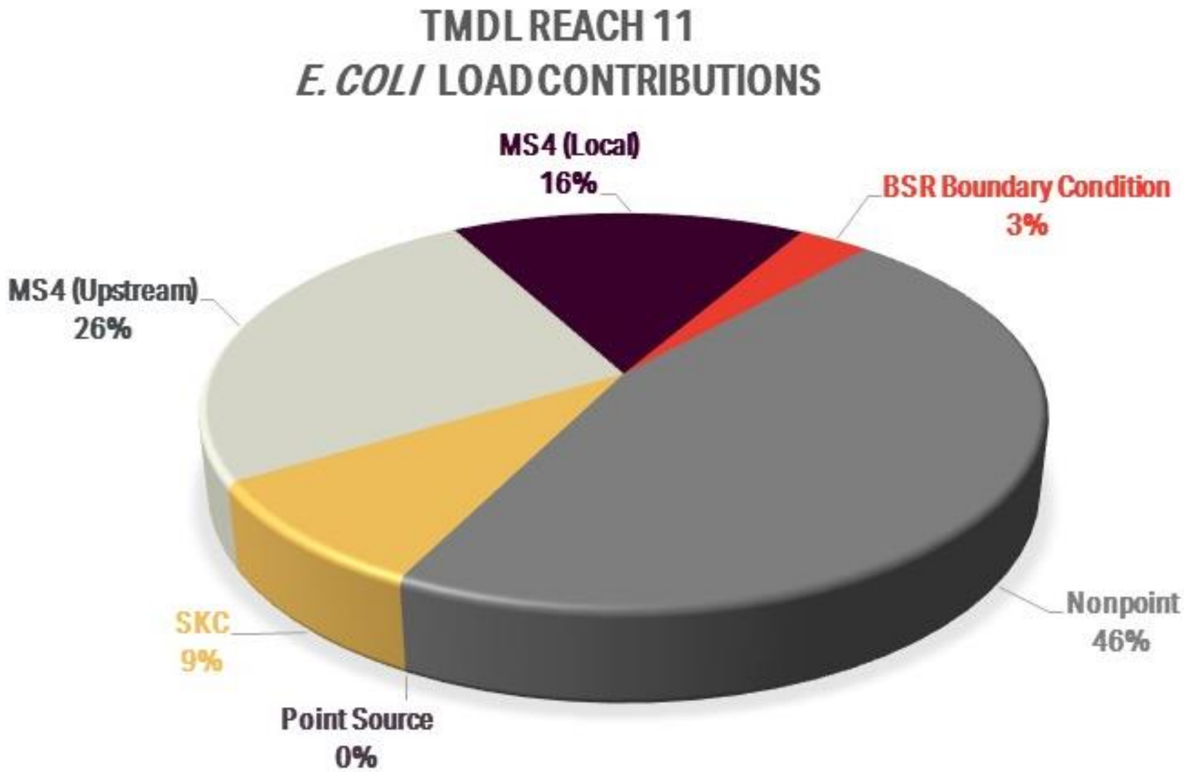

Figure 3-6. Source Assessment Modeling Results for the Endpoint of Reach 11.

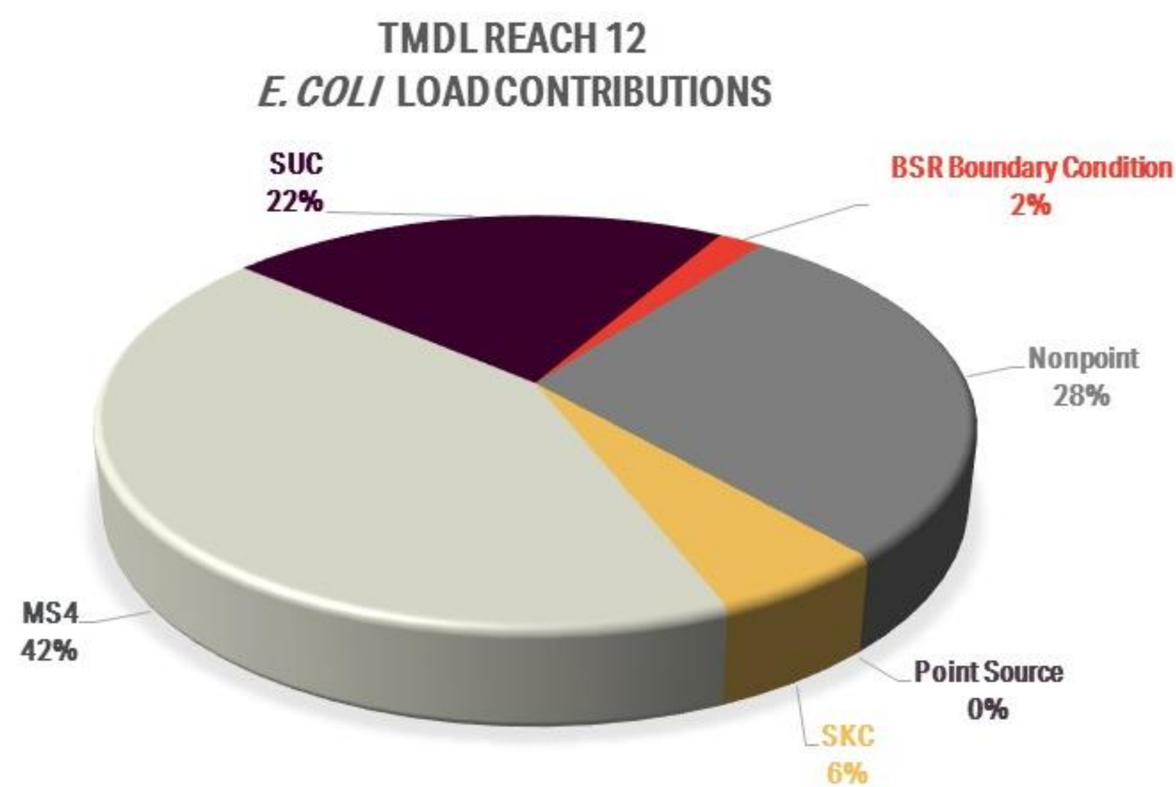

Figure 3-7. Source Assessment Modeling Results for the Endpoint of Reach 12.

endpoints for each source throughout the recreational season. Point sources contributing to the Big Sioux River above the boundary condition at the USGS flow gage (L.G. Everist, Dell Rapids WWTP, and Baltic WWTP) were not explicitly modeled and are included in the boundary condition. Source contributions to Reach 8 were from the Big Sioux River upstream of the boundary conditions and nonpoint sources. Reach10 loads were primarily from the MS4 and Skunk Creek because most of the Big Sioux River water is diverted around the city. Small percentages of the Reach 10 loads were from the Big Sioux River boundary conditions and nonpoint sources. Reach 11 loads were a combination of the nonpoint sources, the upstream MS4, the local MS4, Skunk Creek, and the Big Sioux River boundary condition. Reach 12 loads were attributed to the upstream MS4, nonpoint sources, Slip-up Creek, Skunk Creek, and the Big Sioux River boundary condition.

Table 3-4 shows percent of average reach flow from each source and the percent contribution on an *E. coli* load basis from each source based on model application predictions (percent of reach load). In each reach, the boundary conditions tend to make up a large percentage of the flow but a smaller percentage of the load. The load tends to be contributed from the more local sources such as local nonpoint sources and the MS4. This load partially occurs because of die-off and decay, but also occurs because of the large concentrations being delivered from the local sources.

Table 3-4. Flow and Load Sources

TMDL Reach	Sources	Average Flow (cfs)	Percent of Reach Flow (%)	Average Load (10^6 mpn/day)	Percent of Reach Load (%)
8	Nonpoint – Local Big Sioux River Reach 8	30	4	1.67×10^7	87
	BSR BC	670	96	2.51×10^6	13
10	MS4	34	15	1.60×10^7	68
	SKC	115	51	5.97×10^6	26
	Nonpoint– Local Big Sioux River Reach 8	6	3	1.25×10^6	5
	BSR BC	70	31	1.47×10^5	1
11	MS4 Upstream	34	4	1.60×10^7	26
	MS4 Local	13	2	1.01×10^7	16
	SKC	115	13	5.57×10^6	9
	Nonpoint– Local Big Sioux River Reach 8 and Silver Creek	42	5	2.84×10^7	46
	BSR BC	669	76	2.01×10^6	3
12	SUC	13	1	2.15×10^7	22
	MS4	50	5	4.12×10^7	42
	SKC	115	12	5.36×10^6	5
	Nonpoint– Local Big Sioux River Reach 8 and Silver Creek	42	5	2.75×10^7	28
	BSR BC	670	73	1.92×10^6	2

Annual loadographs of the MS4 loads for Reaches 10 and 11 developed from 2013 through 2017 predictions are illustrated in Figure 3-8 and Figure 3-9, respectively. The modeled MS4 loads (maroon) are the product of the modeled MS4 flows and the EMCs; the ideal loads (blue) are the product of the modeled MS4 flows and the Big Sioux River daily maximum *E. coli* criteria of 235 mpn/100 mL.

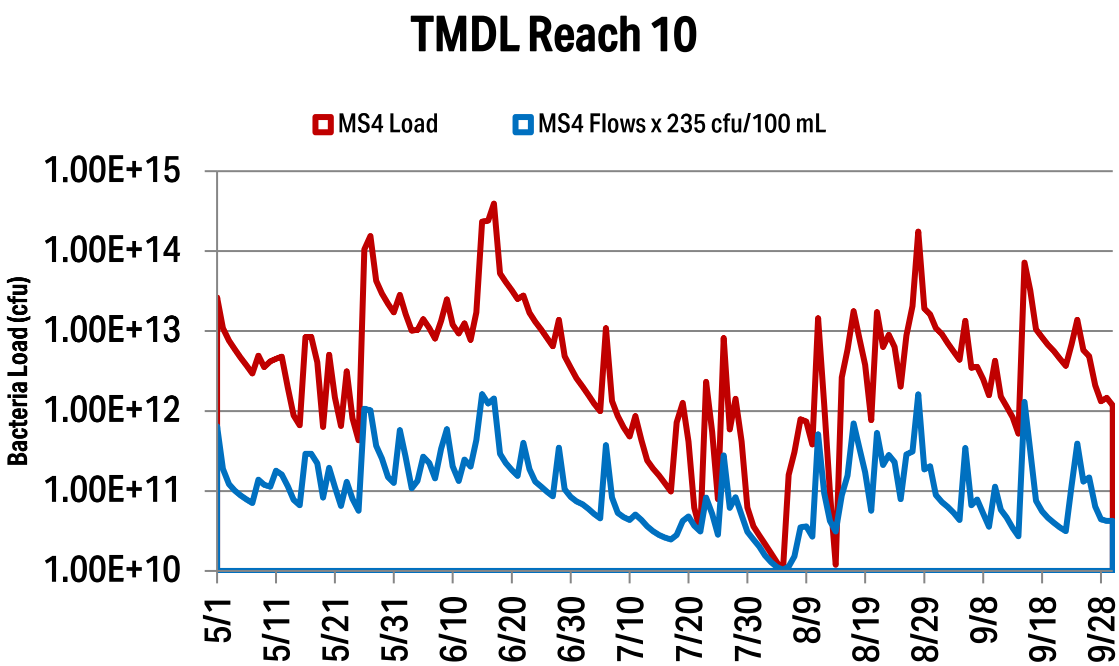

Figure 3-8. Time Series of Average Daily Municipal Separate Storm Sewer Systems Load and the Product of Municipal Separate Storm Sewer Systems Flows and Daily Maximum Criteria in Reach 10.

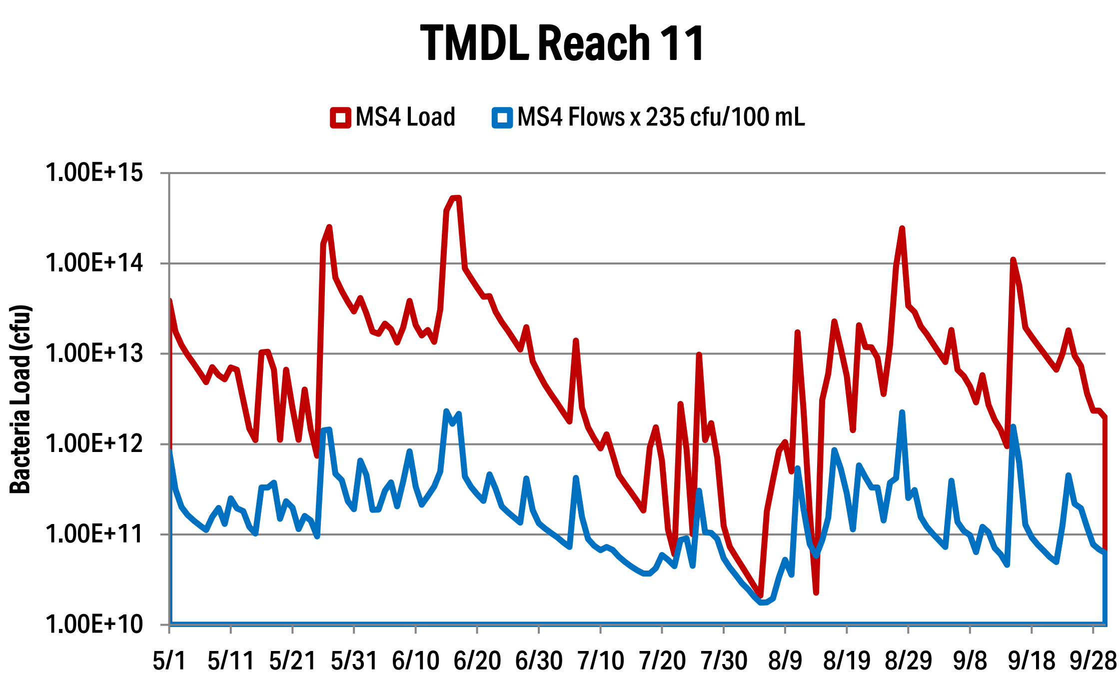

Figure 3-9. Time Series of Average Daily Municipal Separate Storm Sewer Systems Load and the Product of Municipal Separate Storm Sewer Systems Flows and Daily Maximum Criteria in Reach 11.

Note that the *E. coli* water quality standard of 235 mpn/100 mL is not written for the MS4 flows from the city of Sioux Falls. However, if the same standard would be applied to the MS4 flows, the required reduction in bacteria loads from the city, calculated with graphed values, would be 99 percent in Reaches 10 and 11.

4.0 TECHNICAL ANALYSES

The TMDL was developed using the load-duration curve (LDC) approach which resulted in a flow variable target that considers the entire flow regime within the recreational season (May 1–September 30). The LDC is a dynamic expression of the allowable daily load for any given flow within the recreational season. To interpret and implement the TMDL, the LDC flow intervals were grouped into five flow zones: very high flows (0–10 percent), high conditions (10–40 percent), mid flows (40–60 percent), low conditions (60–90 percent), and very low flows (90–100 percent) according to the EPA [2007]. When bacteria loads are higher during higher flow conditions, it generally reflects potential indirect source contributions from stormwater runoff [EPA, 2007]. Loads exceeding the criteria more often in the low-flow zone would indicate potential direct source load contributions or sources in close proximity to the stream, such as failing septic systems or livestock in the stream channel [EPA, 2007].

Both geometric mean loads and daily maximum loads calculated using simulated flow and observed concentrations are shown on the LDCs. The locations of the water quality monitoring sites where observed data were collected on the Big Sioux River are provided in Figure 1-3. Observed bacteria data collected between 2013 and 2017 during the recreation season were applied to the LDC of the reach in which they were collected. In LDCs, the daily maximum loads should be compared to the daily maximum criteria curve and the geometric mean loads should be compared to the geometric mean criteria curve. The LDCs in Figures 4-1 through 4-4 show that exceedance of criterion occurred during all flow conditions in all four TMDL reaches.

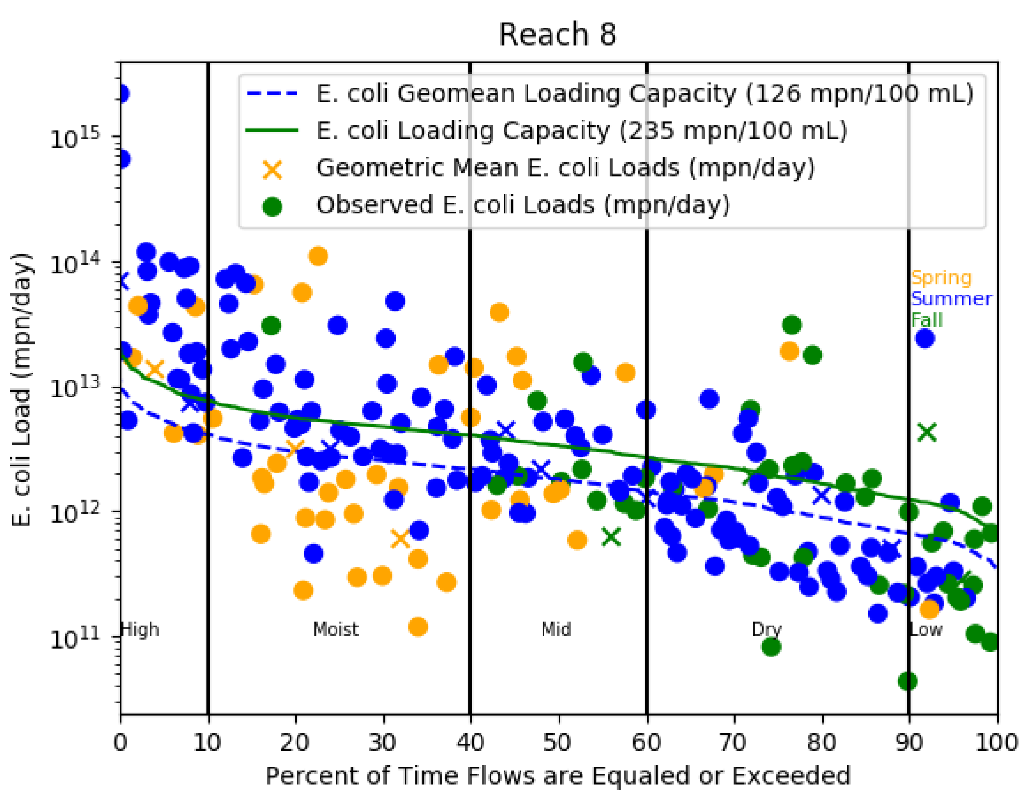

Figure 4-1. Reach 8 Load-Duration Curve Generated With Observed *E. coli* (BSR020) and Simulated Flow.

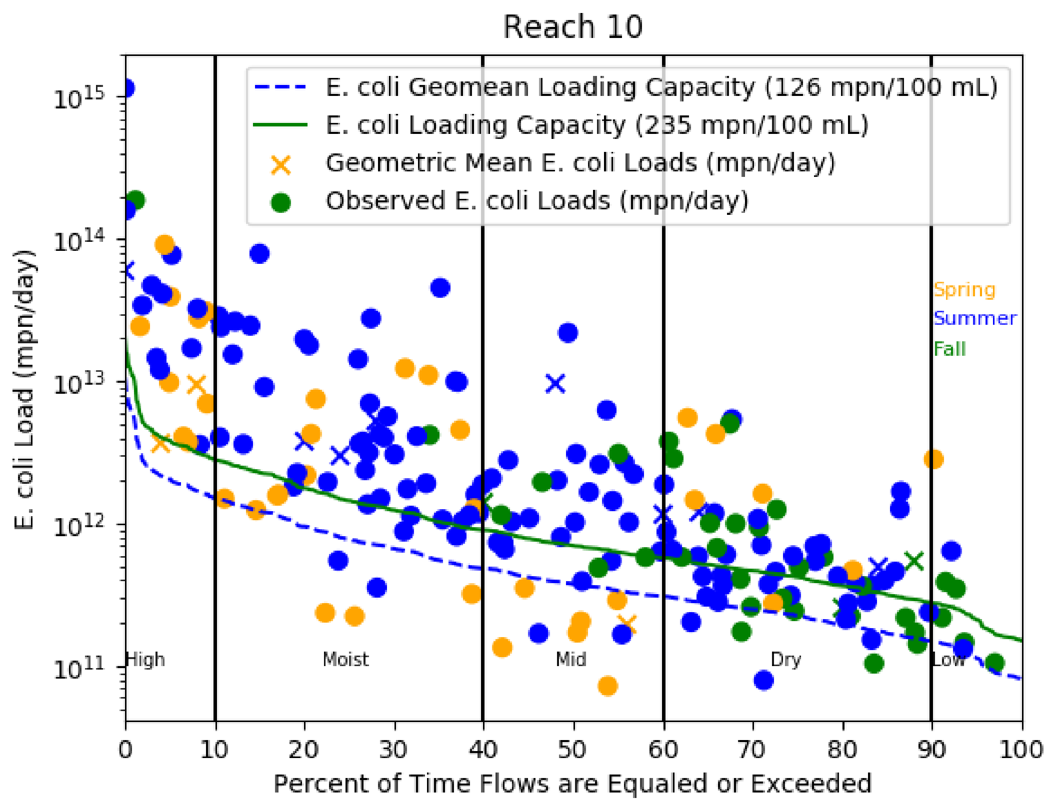

Figure 4-2. Reach 10 Load-Duration Curve Generated With Observed *E. coli* (BSR070) and Simulated Flow.

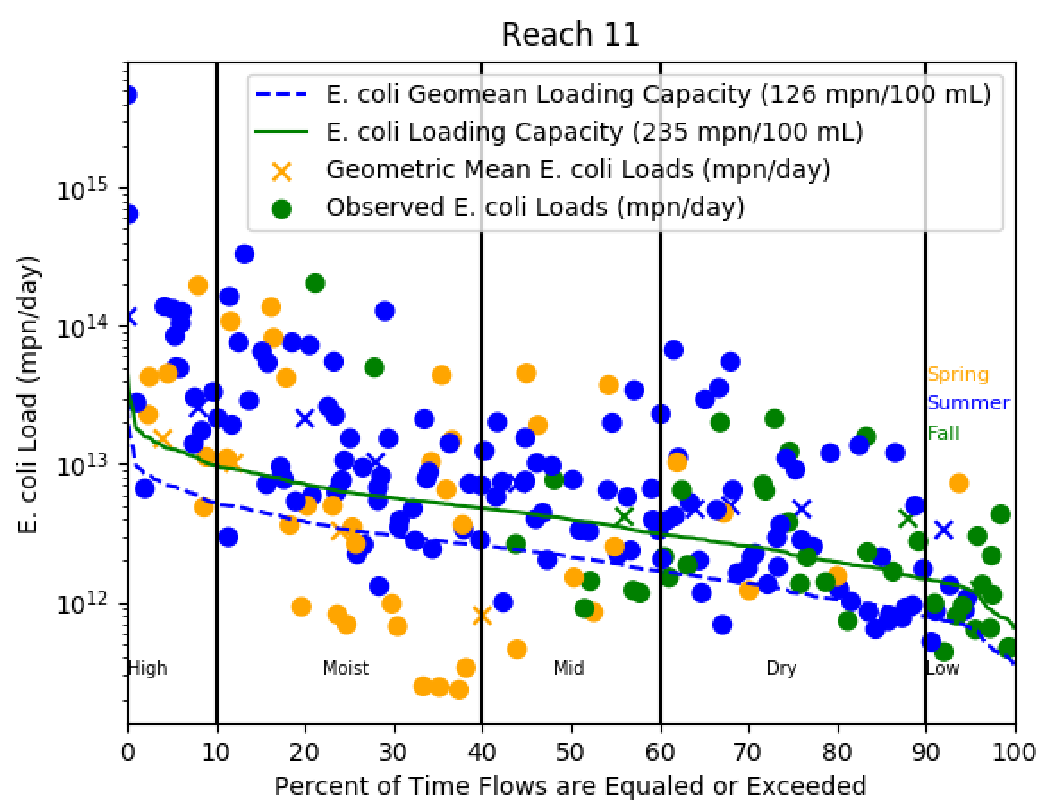

Figure 4-3. Reach 11 Load-Duration Curve Generated With Observed *E. coli* (BSR090) and Simulated Flow.

For this report, critical criteria were defined as the criteria with the highest percent exceedance. The percent exceedance of the geometric mean bacteria criteria was higher than the daily maximum in all impaired reaches. Both conditions will be addressed by reducing geometric mean loads throughout the watershed.

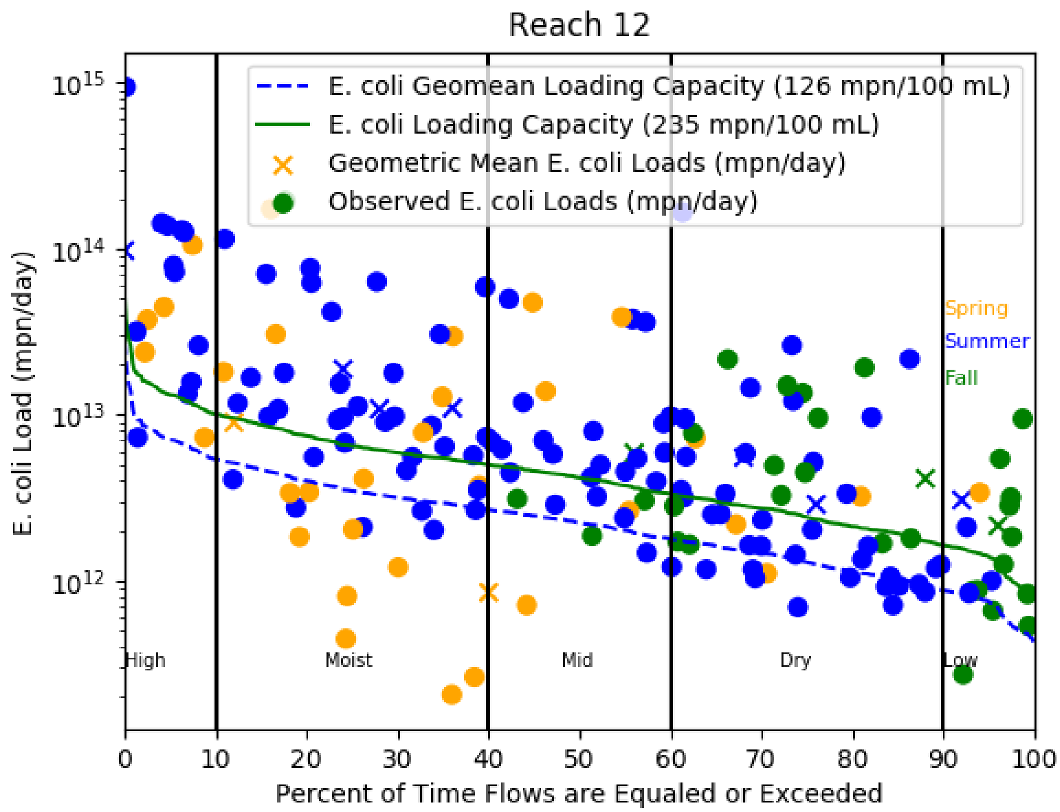

Figure 4-4. Reach 12 Load-Duration Curve Generated With Observed *E. coli* (BSR105) and Simulated Flow.

5.0 TOTAL MAXIMUM DAILY LOAD AND ALLOCATIONS

To ensure that all applicable *E. coli* criteria are met and to aid in the TMDL implementation, load allocations were calculated for the five flow zones (high flows [0–10 percent], moist conditions[10–40 percent], midrange flows [40–60 percent], dry conditions [60–90 percent], and low flows [90–100 percent]) using both the daily maximum and geometric mean criteria. The critical criteria for this TMDL are the geometric mean criteria because exceedances of this criteria were higher in all impaired reaches. Thus, the TMDL tables are focused on the reduction required to meet the geometric mean *E. coli* criteria. TMDL tables were constructed using simulated *E. coli* concentrations and flow at the outlet of each impaired reach. The TMDL is in effect from May 1 through September 30, because the *E. coli* criteria are applicable only during this period, and only data from this time period were used to develop the TMDL allocations and load reduction goals. Daily maximum-based TMDL tables calculated with simulated flow and single-sample observed data from the recreation season (2013–2017) are available in Appendix A.

5.1 LOADING CAPACITY

The TMDL loading capacity is the sum of the load allocation (LA), the WLA, and margin of safety (MOS). For each of the five flow zones, the geometric mean loading capacity was calculated as the product of the median monthly average flow, the geometric mean *E. coli* criteria (126 mpn/100 mL), and a conversion factor at each reach endpoint.

5.2 WASTE LOAD ALLOCATION

Multiple point sources of *E. coli* bacteria discharge directly into the impaired reaches of the Big Sioux River within the Sioux Falls project area. Point-source discharges also exist upstream of the impaired reaches. These discharges are indirectly accounted for by using boundary condition loads. Bacteria loads from these facilities do not likely have a large impact on the impaired reaches of the Big Sioux River because of the travel time and decay rates of the bacteria in addition to the relatively small loads of facilities; e.g., lagoons. These facilities should not cause exceedance of those standards because bacterial limits are set at the water quality standard. The CAFOs in the project area are not allowed to discharge except in the rare case of a precipitation event that produces a volume of water greater than the facility's design capacity, and they were therefore not given WLAs.

The WLA for each reach in the Sioux Falls TMDL is the sum of the point-source allocations (PSAs) within that reach and the MS4 loads. The PSAs were derived in cfu per day SD DENR staff using the product of the effluent flow, the *E. coli* concentration limit, and a conversion factor of 3785000000. Flows and concentrations used are shown in Table 3-1. For Baltic and Dell Rapids, the effluent flow did not change from the 2012 TMDL and was based on each facility's storage capacity and estimated effluent volume during a discharge event one week in duration. For L.G. Everest, the effluent flow was set at twice the 2012 inspection average flow. The city of Sioux Falls effluent flow was set at the future peak flow to allow for future domestic municipal wastewater growth. The effluent flow for Smithfield Foods was set at the 25 percent above the current peak to allow for future growth. A future industrial growth PSA (calculated using 10 MGD) was added to each reach. The size of the future growth WLA was based on the projected loading from these potential new industries. As new industries that discharge these pollutants are permitted, there will be a paragraph in the statement of basis for the permit explaining how much of the future growth WLA will be assigned to that permit and how much is still available for future permits. The permit and statement of basis will be public noticed for 30 days prior to issuance of the permit. EPA is notified of all permits that we public notice and issue. Point sources currently make up less than one percent of the load contributions in the impaired reaches. Additionally, the permit limits for each facility are such that they cannot discharge at concentrations above the daily maximum water quality standards. The allowable load from the point sources makes up a small percent of the total allowable loads, and concentrations used to calculate PSAs were based on daily maximum permit limits where possible so that the facilities can be evaluated on a daily time step. The MS4 allocation was based upon the modeled MS4 flow contribution percentage at the outlet of each impaired reach (Table 5-1). The MS4 flow contribution was calibrated in the HSPF model based upon data collected at various outfalls throughout the MS4 area. TMDL tables use this percentage to estimate the MS4 loads by flow zone. Construction and industrial stormwater WLAs were not included because *E. coli* is not typically contributed from construction or industrial stormwater. Construction and industrial storm water activities were evaluated using the percentage of estimated impacted acres area weighted by county and were determined to make up less than 1.5 percent of the total area.

Table 5-1. Big Sioux River *E. coli* Wasteload Allocations and Municipal Separate Storm Sewer Systems Percentage

Reach	PSA	*E. coli* PSA (mpn/Day)	Reach PSA Sum (mpn/Day)	MS4 Percent of (TMDL–PSA)
SD-BS-R-BIG_SIOUX_08	L. G. Everest	N/A	1.68×10^{11}	0
	Dell Rapids WWTP	3.90×10^{10}		
	Baltic WWTP	4.06×10^{10}		
	Future Industrial Growth	8.89×10^{10}		
SD-BS-R-BIG_SIOUX_10	Future Industrial Growth	8.89×10^{10}	8.89×10^{10}	15
SD-BS-R-BIG_SIOUX_11	John Morrell & Company	4.67×10^{10}	1.36×10^{11}	4
	Future Industrial Growth	8.89×10^{10}		
SD-BS-R-BIG_SIOUX_12	Sioux Falls WWTP	5.07×10^{11}	5.96×10^{11}	0
	Future Industrial Growth	8.89×10^{10}		

5.3 MARGIN OF SAFETY

An explicit MOS identified using a duration curve framework is an unallocated assimilative capacity that is intended to account for uncertainty (e.g., loads from tributary streams and effectiveness of controls). An explicit MOS was calculated as 10 percent of the loading capacity. This method is appropriate because the TMDL is based upon the 90th percentile concentration, and an impaired reach exceeds the standard more than 10 percent of the time.

5.4 LOAD ALLOCATION

To develop the *E. coli* LA for each of the four TMDL reaches, the loading capacity was first determined using the data sources specified. Portions of the loading capacity were allocated to the MOS to account for uncertainty in the calculations and portions of the loading capacity were allocated to the WLA. The LA was calculated as the TMDL minus the WLA and the MOS.

5.5 BASELINE CONDITIONS

Simulated *E. coli* concentrations and simulated flow were used to estimate current daily loads (mpn/day) by calculating the product of the 90th percentile of the simulated monthly geometric mean *E. coli* concentrations (mpn/100 mL), the median of the monthly average simulated flows (cubic feet per second [cfs]), and a unit conversion factor (24,465,715).

Tables 5-2 through 5-5 present load allocations for Reaches 8 through 12 based on the geometric mean criterion for each flow zone. The PSAs from each table are described in Table 5-1. The tables indicate that load reductions are required for the upper four flow zones in all of the reaches. The highest load reductions are generally required in the highest flow zone and no reductions are required in the lowest flow zones, indicating that stormwater is a large contributor.

Table 5-2. Big Sioux River *E. coli* Bacteria Total Maximum Daily Load Based on the Geometric Mean Criterion for Reach 8

TMDL Component (Mpn/Day)		Flow Zone									
		High		Moist		Midrange		Dry		Low	
TMDL		4.40E+12		2.72E+12		1.66E+12		1.22E+12		6.41E+11	
MOS		4.40E+11		2.72E+11		1.66E+11		1.22E+11		6.41E+10	
PSA	WLA	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11
MS4		0		0		0		0		0	
LA		3.79E+12		2.28E+12		1.33E+12		9.28E+11		4.09E+11	
Current Load		6.89E+13		6.77E+12		2.70E+12		3.58E+12		3.55E+11	
Load Reduction		94%		60%		39%		66%		0%	

Table 5-3. Big Sioux River *E. coli* Bacteria Total Maximum Daily Load Based on the Geometric Mean Criterion for Reach 10

TMDL Component (Mpn/Day)		Flow Zone									
		High		Moist		Midrange		Dry		Low	
TMDL		1.64E+12		8.91E+11		4.56E+11		2.78E+11		1.36E+11	
MOS		1.64E+11		8.91E+10		4.56E+10		2.78E+10		1.36E+10	
PSA	WLA	8.89E+10	3.34E+11	8.89E+10	2.23E+11	8.89E+10	1.57E+11	8.89E+10	1.31E+11	8.89E+10	1.09E+11
MS4		2.45E+11		1.34E+11		6.84E+10		4.17E+10		2.03E+10	
LA		1.14E+12		5.79E+11		2.53E+11		1.19E+11		1.29E+10	
Current Load		3.78E+13		1.07E+13		1.09E+12		7.18E+11		5.90E+10[a]	
Load Reduction		96%		92%		58%		61%		0%	

(a) Based on model simulation, no observed data available.

Table 5-4. Big Sioux River *E. coli* Bacteria Total Maximum Daily Load Based on the Geometric Mean Criterion for Reach 11

<table>
<tr><th colspan="2" rowspan="2">TMDL Component (mpn/day)</th><th colspan="10">Flow Zone</th></tr>
<tr><th colspan="2">High</th><th colspan="2">Moist</th><th colspan="2">Midrange</th><th colspan="2">Dry</th><th colspan="2">Low</th></tr>
<tr><td colspan="2">TMDL</td><td colspan="2">5.39E+12</td><td colspan="2">3.53E+12</td><td colspan="2">2.28E+12</td><td colspan="2">1.43E+12</td><td colspan="2">7.26E+11</td></tr>
<tr><td colspan="2">MOS</td><td colspan="2">5.39E+11</td><td colspan="2">3.53E+11</td><td colspan="2">2.28E+11</td><td colspan="2">1.43E+11</td><td colspan="2">7.26E+10</td></tr>
<tr><td>PSA</td><td rowspan="2">WLA</td><td>1.36E+11</td><td rowspan="2">3.51E+11</td><td>1.36E+11</td><td rowspan="2">2.77E+11</td><td>1.36E+11</td><td rowspan="2">2.27E+11</td><td>1.36E+11</td><td rowspan="2">1.93E+11</td><td>1.36E+11</td><td rowspan="2">1.65E+11</td></tr>
<tr><td>MS4</td><td>2.16E+11</td><td>1.41E+11</td><td>9.12E+10</td><td>5.73E+10</td><td>2.90E+10</td></tr>
<tr><td colspan="2">LA</td><td colspan="2">4.50E+12</td><td colspan="2">2.90E+12</td><td colspan="2">1.82E+12</td><td colspan="2">1.09E+12</td><td colspan="2">4.88E+11</td></tr>
<tr><td colspan="2">Current Load</td><td colspan="2">9.47E+13</td><td colspan="2">1.94E+13</td><td colspan="2">1.30E+13[(a)]</td><td colspan="2">4.32E+12</td><td colspan="2">1.75E+12</td></tr>
<tr><td colspan="2">Load Reduction</td><td colspan="2">94%</td><td colspan="2">82%</td><td colspan="2">*82%</td><td colspan="2">67%</td><td colspan="2">59%</td></tr>
</table>

(a) Based on model simulation, no observed data available.

Table 5-5. Big Sioux River *E. coli* Bacteria Total Maximum Daily Load Based on the Geometric Mean Criterion for Reach 12

<table>
<tr><th colspan="2" rowspan="2">TMDL Component (mpn/day)</th><th colspan="10">Flow Zone</th></tr>
<tr><th colspan="2">High</th><th colspan="2">Moist</th><th colspan="2">Midrange</th><th colspan="2">Dry</th><th colspan="2">Low</th></tr>
<tr><td colspan="2">TMDL</td><td colspan="2">5.54E+12</td><td colspan="2">3.66E+12</td><td colspan="2">2.40E+12</td><td colspan="2">1.54E+12</td><td colspan="2">8.09E+11</td></tr>
<tr><td colspan="2">MOS</td><td colspan="2">5.54E+11</td><td colspan="2">3.66E+11</td><td colspan="2">2.40E+11</td><td colspan="2">1.54E+11</td><td colspan="2">8.09E+10</td></tr>
<tr><td>PSA</td><td rowspan="2">WLA</td><td>5.96E+11</td><td rowspan="2">5.96E+11</td><td>5.96E+11</td><td rowspan="2">5.96E+11</td><td>5.96E+11</td><td rowspan="2">5.96E+11</td><td>5.96E+11</td><td rowspan="2">5.96E+11</td><td>5.96E+11</td><td rowspan="2">5.96E+11</td></tr>
<tr><td>MS4</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">LA</td><td colspan="2">4.39E+12</td><td colspan="2">2.70E+12</td><td colspan="2">1.56E+12</td><td colspan="2">7.87E+11</td><td colspan="2">1.32E+11</td></tr>
<tr><td colspan="2">Current Load</td><td colspan="2">7.65E+13</td><td colspan="2">1.54E+13</td><td colspan="2">8.62E+12</td><td colspan="2">4.49E+12</td><td colspan="2">3.01E+12</td></tr>
<tr><td colspan="2">Load Reduction</td><td colspan="2">93%</td><td colspan="2">76%</td><td colspan="2">72%</td><td colspan="2">66%</td><td colspan="2">73%</td></tr>
</table>

The flow-weighted percent reductions that are for all combined flow zones required to meet the TMDL based on the geometric mean water quality criteria were 81, 92, 87, and 83 in Reach 8, 10, 11, and 12, respectively.

6.0 SEASONALITY

Stream flows and *E. coli* concentrations in the Big Sioux River showed seasonal variation. *E. coli* data at the most downstream location of each reach (2013–2017) were used to generate boxplots of *E. coli* concentrations throughout the project area. Figure 6-1 depicts higher *E. coli* concentrations during the spring, summer, and early fall. Monthly median flows were calculated for the four local USGS sites and are shown in Figure 6-2. Flows were typically highest during spring and early summer and lowest during fall and winter.

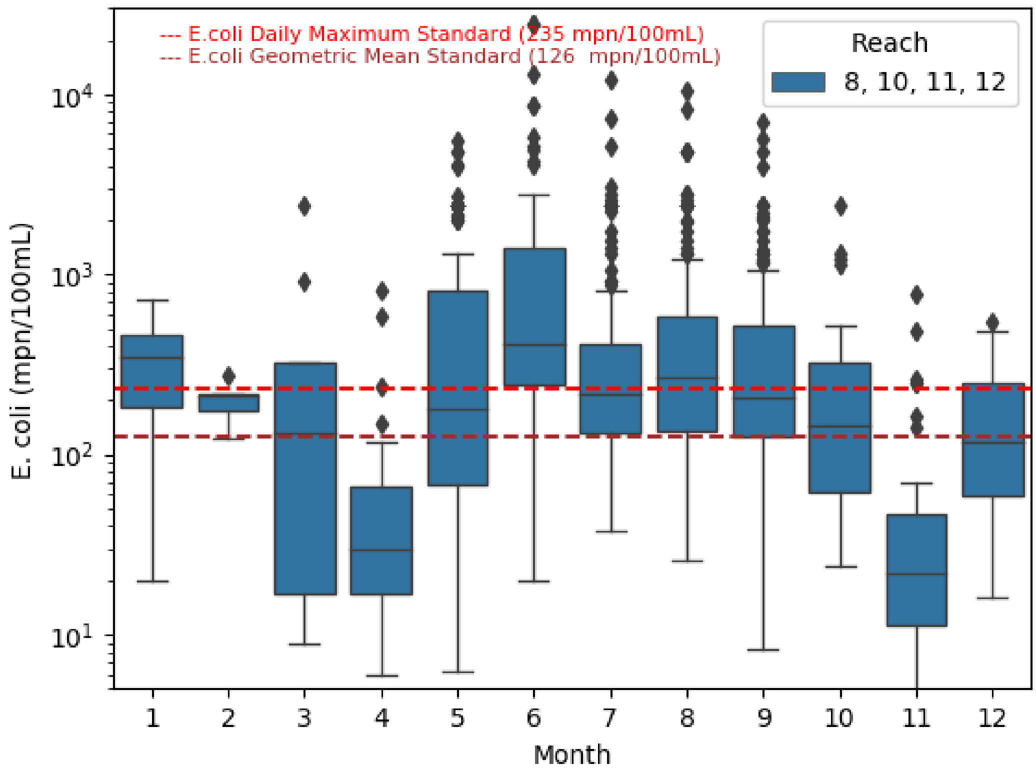

Figure 6-1. *E. coli* Concentration Boxplots (BSR020, BSR070, BSR090, and BSR105 From 2013 Through 2017).

The highest bacteria concentrations generally occurred during the recreational season. Short-duration, high-intensity rainstorms are common during the summer months. These localized summer storms can cause significant runoff and increased bacteria concentrations for a relatively short period of time while only slightly increasing stream flows. However, by developing the TMDL allocations with the LDC approach, seasonal variability in flow and *E. coli* loads are considered because stream flow and bacteria delivery to the stream are related to changes in precipitation.

This *E. coli* bacteria TMDL is seasonal because it is effective only during the period of May 1 through September 30; therefore, the TMDL is also applicable only during this time period. Summer is also a critical time period because of seasonal differences in precipitation patterns and land uses. Livestock are often allowed to graze along the streams during the summer months. The combination of a peak in bacteria sources and the high-intensity rainstorm events common during the summer produces a significant amount of *E. coli* load because of bacterial washoff from the watershed.

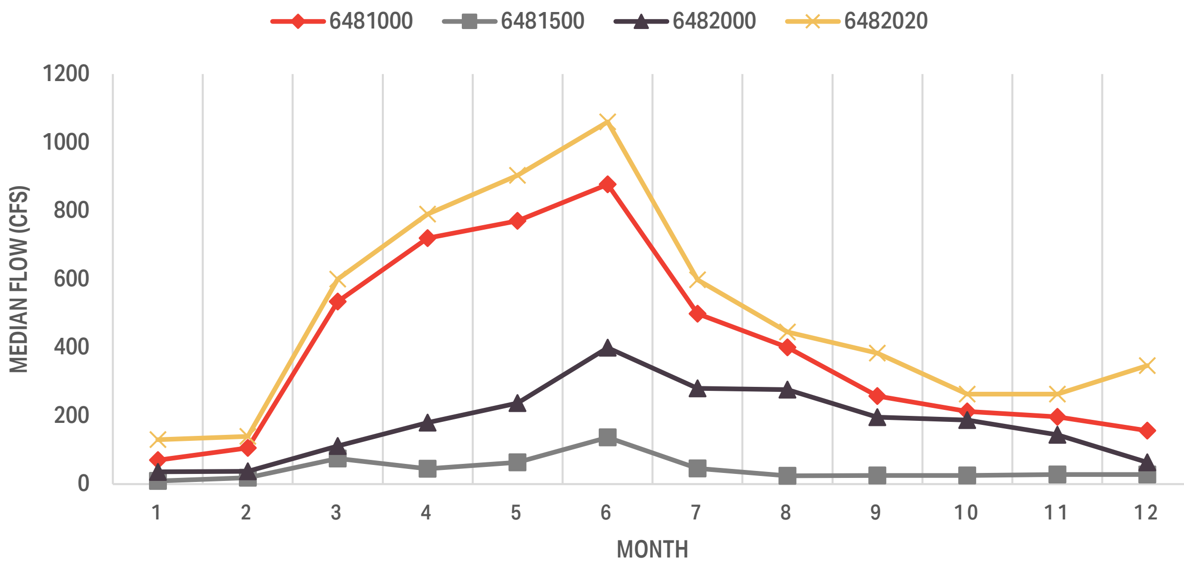

Figure 6-2. Monthly Median Flows From Local US Geological Survey Data (2013–2017).

7.0 PUBLIC PARTICIPATION

During the development of the previous version of Big Sioux River *E. coli* bacteria TMDL, efforts focused on public education, review, and comment. The findings of the assessment were provided to local groups in the watershed, and a 30-day public notice period was provided for public review and comment. The results of these public meetings and comments were considered when developing the TMDLs. The public notice was published in the *Sioux Falls Argus Leader* and the *Dell Rapids Tribune*, and the document was also made available through the SD DENR's website. The public notice of this updated version of the TMDL was also published in the *Sioux Falls Argus Leader* and the *Dell Rapids Tribune*, and the updated document was also made available through the SD DENR's website.

Several meetings and presentations were held for the Steering Committee regarding the previous versions of the TMDLs: one in March 2009, one in April 2009 regarding Sioux Falls land use, one in November 2009 regarding monitoring, and one in October 2010 regarding modeling. Steering Committee members include Mr. Robert Kappel and Mr. Andy Berg (City of Sioux Falls), Mr. John Meyer (John Morrell & Co.), Ms. Deb Springman (East Dakota Water Development District [EDWDD]), and Mr. Rich Hanson and Ms. Kelli Buscher (SD DENR). Regular updates were provided to the Public Works Department, the City of Sioux Falls, EDWDD, John Morrell & Company, and the SD DENR. Two public meetings were held at the Kuehn Community Center in Sioux Falls as part of this project (May and November 2009), and one public meeting was held at the Sioux Falls Main Public Library (November 2010). Additionally, presentations on the different aspects of the project were given at the annual Western South Dakota Hydrology Conference and the Eastern South Dakota Water Conference. Scientists and engineers from the Midwest with a background in water quality and stream health regularly attend these conferences in addition to many local stakeholders. The project team provided project updates to the professional and stakeholder communities and received comments during on the technical aspects of the project during the conference. A Sioux Falls TMDL website was made available during the development of the original version of this TMDL and an EPA MS4 workshop was held in July 2009. A TMDL public education video was also available on the City of Sioux Falls website. For the TMDL updates, a public meeting was held at City of Sioux Falls Environmental Office on November 26, 2018. The draft TMDL report was made available for download on the SD DENR website from May 16 to June 17, 2019, for public review. The notice for the public review period was published on May 13 in the *Sioux Falls Argus Leader*, the *Madison Daily Leader*, and the *Moody County Enterprise*. No comments were received during the comment period.

8.0 MONITORING STRATEGY

During and after the implementation of management practices, monitoring will be necessary to ensure attainment of the TMDLs. Stream water quality monitoring will be accomplished through SD DENR's ambient water quality monitoring stations on the Big Sioux River and through the City of Sioux Falls monitoring program. Additional monitoring should continue to be used to implement effective BMPs and to evaluate existing BMPs. Monitoring locations should be based on the location and the type of BMPs installed. In 2017, two BMPs (the Galway BMP and the Swift Park Extended Detention Basin) within the city of Sioux Falls were monitored for effectiveness. The results of the Galaway BMP were inclusive, but the Swift Park Extended Detention Basin reduced *E. coli* concentrations by 33 percent during storm flows and by 33 percent during baseflows.

The SD DENR may adjust the load and/or wasteload allocations in this TMDL to account for new information or circumstances that develop during the TMDL implementation phase. New information generated during TMDL implementation may include monitoring data, BMP effectiveness information, and land-use information. The SD DENR will propose adjustments only in the event that (1) any adjusted LA or WLA will not result in a change to the loading capacity; (2) the adjusted TMDL, including the WLAs and LAs, will be set at a level necessary to implement the applicable water quality standards; and (3) any adjusted WLA will be supported by demonstrating that LAs are practical. The SD DENR will notify the EPA of any adjustments to this TMDL within 30 days of their adoption. The LA and WLA will only be adjusted after an opportunity for public participation.

9.0 RESTORATION STRATEGY

The watershed area affecting the Big Sioux River from near the Brookings/Moody county line to the Sioux Fall's Wastewater Treatment Facility (WWTF) has had several BMPs implemented since the previous version of the Sioux Falls Big Sioux River TMDLs was approved. Many BMPs were also installed prior to the approval of the 2012 TMDLs. Practices were installed through several 319 implementation projects, Environmental Quality Incentives Program, National Water Quality Initiative (NWQI), and other participating programs. The focus of these BMPs is to reduce nutrient, sediment, and bacteria loading to impaired streams in the area and make progress in achieving existing TMDLs. The implemented BMPs used ranged from riparian area protection buffers to agricultural waste management systems (AWMS) to cattle grazing management systems. BMP funding were from a variety of local producers as well as city, state, and federal agencies.

The SD DENR funding for BMP installation and technical guidance to implementation projects in this area over several years. A large part of this funding is from the EPA Section 319 grants. The following Section 319 funded implementation projects have operated in the area:

- 303(d) Watershed Planning and Assistance Project (March 2003–June 2010)
- Central Big Sioux River Watershed Project Segment 1 (August 2005–September 2010)
- Central Big Sioux River Interim Project (December 2010–September 2011)
- Central Big Sioux Implementation Project Segment 2 (July 2011–July 2015)
- Big Sioux River Implementation Project Segment 3 (July 2015–Current)
- Grassland Management & Planning Project (July 2008–December 2009)
- Grassland Management Planning & Assistance Project Segment 3 (June 2010–July 2013)
- Grassland Management Planning & Assistance Project Segment 4 (July 2013–July 2017)

9.1 RECENT IMPLEMENTATION

Many BMPs have been installed throughout and above the project area in recent years that are expected to improve the conditions of the Big Sioux River within the project area. Each practice that was installed through a 319 Implementation Project was required to have estimated load reductions. The spreadsheet tool for estimating pollutant load (STEPL) model, developed for the EPA Office of Water Grants Reporting and Tracking System by Tetra Tech, was used to estimate these load reductions. These load reductions were entered into the DENR internet-based tracker system along with a location for BMP placement. The combination of the aforementioned projects has led to significant reductions in the area over the years

A map of BMP locations installed with assistance from 319 implementation projects in the area is shown in Figure 9-1. This map also shows the different types of BMPs that have been put in place. Each type of BMP in the STEPL model can have several supporting BMPs that collectively make up the same load reductions. Because multiple supporting BMPs could also be covered under the same project expenses, separating specific load reductions and actual cost of individual supporting practices can be difficult. The BMP summary in Table 9-1 shows the quantity of supporting BMPs and the total funds used to install those BMPs.

RESPEC

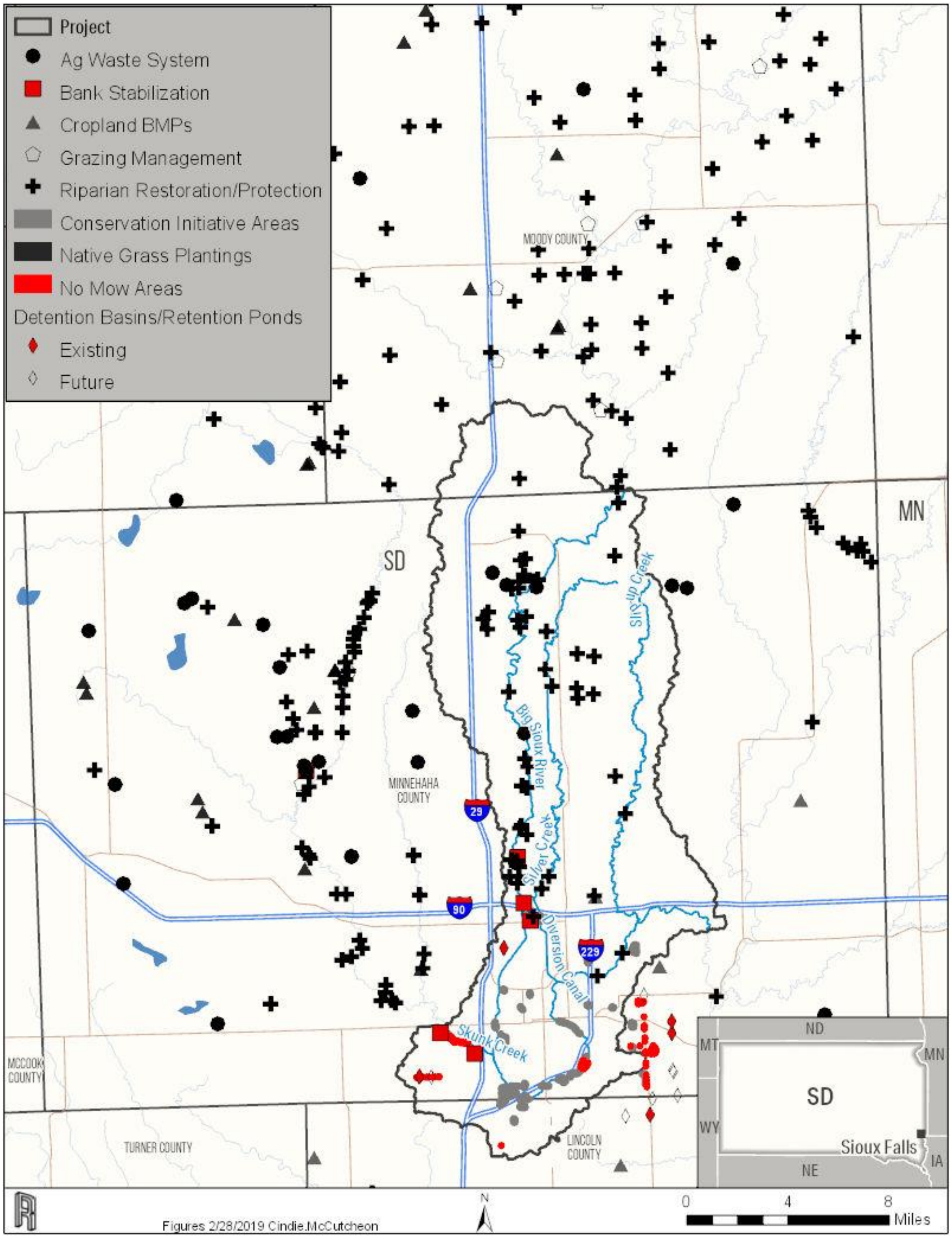

Figure 9-1. Best Management Practices Installed Within and Upstream of the Project Area.

Table 9-1. STEPL Load Reductions Realized by Best Management Practice Type

Type of BMP	Sediment (Tons/Year)	Phosphorus (Pounds/Year)	Nitrogen (Pounds/Year)
Agricultural Waste System	584	23,496	93,091
Bank Stabilization	49,028	26,354	68,458
Cropland BMPs	2,647	3,773	10,222
Grazing Management	70	118	637
Riparian Restoration/Protection	8,982	20,810	74,232
Total	**61,311**	**74,551**	**246,640**

9.1.1 AGRICULTURAL WASTE SYSTEMS

Sixteen AWMS have been installed in the Big Sioux River Watershed in conjunction with 319 implementation projects. Each system also included a nutrient management plan to apply manure from the system to local cropland. Many of these systems were installed at facilities along or very near an impaired stream.

Table 9-2 provides a summary of individual AWMS supporting practices that were installed or completed for the area. More engineering has been completed than systems installed because system installation is ongoing.

Table 9-2. Agricultural Waste System Supporting Best Management Practices

BMP	Quantity Implemented
Engineering	21
Livestock Feedlot Relocation	2
Nutrient Management	17
Waste Facility Cover	3
Waste Storage Facility	19

Installing an AWMS has been very costly in the past and has increased in price over the years. Table 9-3 provides a summary of funds that have been used to construct AWMS in the area. Most of the cost for installing these systems is from the producer as seen, in the in this summary for the local contribution in Table 9-3.

Table 9-3. Agricultural Waste System Cost Summary

USDA	319	State	EDWDD	City	Local	Total
$2,323,817	$209,969	$47,103	$101,608	$613,941	$4,968,062	$8,264,500

9.1.2 BANK STABILIZATION

Several homes are located along high eroding banks of Skunk Creek in Sioux Falls. The City of Sioux Falls was concerned with erosion that may affect these homes. Therefore, the City of Sioux Falls employed Mussetter Engineering, Inc (Fort Collins, CO). to developed recommendations and preliminary designs for stabilizing approximately 10,000 feet along Skunk and Silver Creek near Dunham Park to reduce this erosion. Stockwell Engineers, Inc. prepared construction plans and specifications from the recommendations and designs for these areas. Construction was completed during the winter of 2006 and 2007. The cost for this stabilization was paid entirely from Sioux Falls State Revolving Fund Nonpoint Source (SRF-NPS) loans in the amount of $1,609,000.

The Agricultural Research Service completed a study of bank stability on the Big Sioux River from Sioux Falls to Watertown during January 2009. Several areas were identified as having high amounts of erosion. The City of Sioux Falls decided to design bank stabilization for several of the sites between Sioux Falls and Baltic that had greater than 5 feet per year of lateral recession. Large sod blocks could be found at many of these sites. Sites were ranked and divided into four phases with the first two phases constructed during the winter of 2009/2010 and the remaining sites constructed during the winter of 2010 and 2011.

The total cost for Big Sioux River stabilization was approximately $1,989,000. Funds were spent on engineering, construction, tree planting, fencing, and placing alternate water along the river where cattle were present. The stabilization installation required landowners to provide at least a 15foot buffer and planting of trees atop the bank. Most of these sites have greater than 15 ft buffers and great stands of grass and trees. Installing stabilization in many cases has led to involving other riparian BMP practices (e.g., Seasonal Riparian Area Management [SRAM] and grazing management). Stabilization along the Big Sioux is estimated to be 27,735 linear-feet with more stabilization expected in the future.

9.1.3 CROPLAND BEST MANAGEMENT PRACTICES

Practices placed on cropland were not funded for most of the 319 implementation projects but were strongly recommended with assistance from other USDA programs. Table 9-4 summarizes supporting practices for cropland BMPs. This list may not represent all of that have been installed throughout the years since only practices with direct implementation project involvement were reported.

Table 9-4. Cropland Supporting Best Management Practices

BMP	Quantity Implemented
Conservation Reserve Program	139.74 acres
Conservation Tillage	1,301.9 acres
Continuous Conservation Reserve Program-Buffers	47.5 acres
Filter Strip	33.1 acres
Grassed Waterway	2,841 AC acres
Terrace	13,794 feet
Terrace Restoration	1,080 feet
Wetland Restoration	170.5 acres

Several of the cropland BMPs in the area were completed using USDA funds with only a few implementation project funds. Table 9-5 is a summary of funds used for cropland BMPs.

Table 9-5. Cropland Cost Summary

USDA	319	Local	Total
$102,797.00	$894.15	$5,779.05	$109,470.20

9.1.4 GRAZING MANAGEMENT AND RIPARIAN RESTORATION/PROTECTION

Producers that grazed or farmed along rivers, creeks, and other bodies of water in this area were encouraged to install fence to keep cattle out of the water and create riparian buffers. These practices included alternative sources of water or placing a buffer between the water and farming practices. Grazing BMPs were often part of riparian protection because cattle often graze along bodies of water. For this reason, the two BMP categories were combined in this section.

Supporting BMPs practices used to protect riparian areas are shown in Table 9-6. The SRAM was a BMP developed by the Central Big Sioux Implementation Project that has had great success in the area, and several producers along Skunk Creek have taken advantage of this program. Water quality monitoring was also ongoing in this area as part of the NWQI program that demonstrated SRAM effectiveness.

Table 9-6. Grazing Management and Riparian Restoration/Protection Supporting Best Management Practices

BMP	Quantity Implemented
Alternative Water Sources	24
BMP Installation	101
BMP Plans	128
Conservation Easements	16.8 AC
Conservation Reserve Program	220.6 AC
Cropland Riparian Buffer	48.7 AC
Easement- 30 years/Permanent	16 AC
Fence	49,047 FT
Grass Seeding	183 AC
Grazing Planned Systems	1,172.7 AC
Grazing System	12
Livestock Pipeline	23,921 FT
Riparian Area Management	70.53 AC
Rock Crossing	1
Seasonal Riparian Area Management	1,687.63 AC
Stream Exclusion with Grazing Land Management	235,952 FT
Streambank and Shoreline Protection	9,716 FT
Tank/Trough	11

Most of the funding for these BMPs came from the City of Sioux Falls SRF-NPS loans with assistance from other programs. Table 9-7 is a summary of the funds used in the area for Grazing Management and Riparian Restoration/Protection.

Table 9-7. Grazing Management and Riparian Restoration/Protection Cost Summary

USDA	319	EDWDD	City	Local	Total
$164,630.83	$139,085.91	$30,633.29	$2,091,687.28	$110,678.28	$2,536,715.35

9.1.5 CITY BEST MANAGEMENT PRACTICES

The City of Sioux Falls has also been working to implement BMPs to improve the *E. coli* and sediment concentrations in the impaired reaches. Table 9-8 and Figure 9-1 provide the locations of all of the BMPs installed since 2011 as well as the planned BMPs through 2026. All of these BMPs are extended detention-basin designs except identifying 7-5, 303-4, and 400W, which are retention pond designs. Additionally, the city has been planting areas with native grasses and implanting a "no-mow" policy in certain areas shown in Figure 9-1. In 2018, the governor of South Dakota approved an $8,829,000 million state revolving fund loan for Sioux Falls storm sewer and nonpoint-source projects in the city [SD DENR, 2018b].

Table 9-8. Locations of Installed and Planned Best Management Practices

Year	Identification	Location
2011	89	Benson and Westport
2014	13	41st and Ellis
2016	17-5	69th and Highway 11
2017	303-4	Arrowhead and Six Mile Rd
2017	25-3	10th and Six Mile Rd
2018	25-1W	Powderhouse and Madison
2019	7-4	69th and Sycamore
2020	25-1E	Powderhouse and Madison
2021	51-1	85th and Cliff
2022	400W	SE of 41st & Six Mile
2023	401-2	½ Mile SE of 57th and Highway 11
2024	400E	SE of 41st and Six Mile
2025	13-1	41st and Grinnell
2026	401-1	½ Mile East of 57th and Six Mile

9.2 SIMULATED MANAGEMENT SCENARIOS

A variety of BMPs could be considered when developing a water quality management implementation plan in the project area. While several types of control measures are available for reducing *E. coli* bacteria loads, the practical control measures listed and discussed in the following text are recommended to address the identified sources in the Sioux Falls area.

Because the HSPF model application calibration was updated to represent more recent years, it is assumed that the updated version represents the BMPs that have been implemented throughout the watershed. Therefore, scenarios for the restoration strategy aim to meet load reductions that are required in this updated TMDL.

The management scenarios that were simulated for each bacteria-impaired reach using the HSPF model include incorporating the following: future land use (Scenario 1), Big Sioux River upstream of Dell Rapids and Skunk Creek compliance with the limited contact recreation geometric mean water quality standard (Scenario 2), Big Sioux River upstream of Dell Rapids and Skunk Creek compliance with the immersion recreation geometric mean water quality standard (Scenario 3), a ninety-five percent load reduction on agricultural land within the project area boundary north of Sioux Falls local to the Big Sioux River and Silver Creek (Scenario 4), a ninety-five percent load reduction on the MS4 within the project area boundary (Scenario 5), and Scenarios 3, 4, and 5 combined (Scenario 6). Modeled load reduction results are presented for each of the TMDL reach endpoints in Table 9-9. Percent geometric mean load reductions were calculated for the recreation season (May 1 through September 30).

Table 9-9. Summary of Load and Exceedance Reductions for *E. coli* Best Management Practices

Scenario	Scenario Description	Percent Load Reduction			
		Reach 8	Reach 10	Reach 11	Reach 12
1	Future Land Use	0	33	24	30
2	Big Sioux River and Skunk Creek Capped at Limited Contact Criteria	0	8	3	2
3	Big Sioux River and Skunk Creek Capped at Immersion Criteria	8	12	6	4
4	95% Load Reduction on Agriculture Land[a]	81	63	78	85
5	95% Load Reduction on All MS4 Land	0	78	48	30
6	Cumulative Scenario (Scenarios 3, 4, and 5)	88	94	93	94
TMDL Load Reduction Needed		81	92	87	83

Implementing future Sioux Falls land use (Scenario 1) was completed using expected build out information from the city of Sioux Falls. The future growth WLA was not included in this scenario. Scenario 1 would result in load reductions of 1, 33, 24, and 30 percent in Reaches 8, 10, 11, and 12, respectively. Changes may be favorable when residential areas replace agricultural lands with relatively higher existing loads.

If the Big Sioux River above the project area and Skunk Creek were capped at the limited contact geometric mean criteria (Scenario 2), which is currently the standard for these reaches, load reductions would be 0, 8, 3, and 2 percent in Reaches 8, 10, 11, and 12, respectively.

Currently, the Big Sioux River above the project area and Skunk Creek have a daily maximum and geometric mean *E. coli* criteria of 1,178 mg/L and 630 mg/L, respectively, which are higher than the daily maximum criteria and geometric mean criteria of 235 mg/L and 126 mg/L, respectively, in the impaired Big Sioux River Reaches. Skunk Creek also contributes significant volume to Reaches 10, 11, and 12, which significantly influences water quality on the Big Sioux River, and the project team is working closely with SD DENR to determine if Skunk Creek should be reassigned a more stringent standard. If the Big Sioux River above the project area and Skunk Creek were capped at the immersion recreation geometric mean criteria (Scenario 3), which is lower than the current standard for these reaches, load reductions would be 8, 12, 6, and 4 percent in Reaches 8, 10, 11 and 12, respectively. Because the existing TMDLs for upstream waterbodies (i.e., the Big Sioux River upstream of Reach 8 and Skunk Creek) are not conducive in meeting the Big Sioux River TMDL goals for this project, redevelopment of these TMDLs using the immersion recreation *E. coli* criteria should be considered.

A 95 percent reduction of loads from agricultural land within the project area (Scenario 4) would be expected to reduce the load by 81, 63, 78, and 85 percent in Reaches 8,10, 11, and 12, respectively.

A 95 reduction of loads from the MS4 within the project area (Scenario 5) would be expected to reduce the load by 0, 78, 48, and 30 percent in Reaches 8, 10, 11, and 12, respectively.

A cumulative scenario (Scenario 6) was run with the goal of meeting the geometric mean TMDL reductions needed in each reach. The cumulative scenario was the combination of Scenarios 3 through 5. The cumulative scenario achieved the goal of meeting the necessary TMDL reductions with an 88, 94, 93, and 94 percent reduction in Reaches 8, 10, 11, and 12, respectively. Therefore, there is reasonable assurance that the cumulative implementation of Scenarios 3 through 5 would be an effective method for achieving the *E. coli* TMDLs in the Big Sioux River throughout the project area.
In addition to evaluating load reductions for each scenario, the change in percent exceedance was also calculated. From the cumulative scenario, the modeled geometric mean percent exceedance was reduced from 72 to 8 percent in Reach 8, 84 to 16 percent in Reach 10, 76 to 16 percent in Reach 11, and 72 to 20 percent in Reach 12. This evaluation shows that although *E. coli* removal in runoff from the city would have a fairly large impact on load reduction but a fairly small impact on overall *E. coli* concentrations, which is ultimately necessary to avoid human health risks. The extremely high exceedance in the project area is driven by extreme concentrations from significant rainfall events on the MS4 area through stormwater outfalls. The most effective load and concentration reductions are believed to occur through implementing BMPs outlined in the city of Sioux Falls' MS4 permit.
Water quality trading options and a more detailed cost and water quality benefit ratio of BMP implementation have been and will continue to be completed for the Sioux Falls project area to ensure that both loading and concentration goals are realized. Ozone treatment, ultraviolet treatment, and de/chlorination are other promising, but costly, options for decreasing bacteria concentrations in the Big Sioux River study area.

The City of Sioux Falls led the development of the Central Big Sioux River Watershed Implementation Plan. Within this plan, a watershed-scale, decision-support framework based on cost optimization was developed to support government and local planning agencies as they considered watershed-scale investments to improve water quality. This decision-support framework assisted in developing the TMDL implementation plan, identifying management practices to achieve pollutant reductions under an MS4 stormwater permit, and developing a phased BMP installation plan that is optimized for both cost and water quality effectiveness.

Achieving the load reductions necessary to meet the TMDLs will require proper planning between state and local regulatory agencies, organizations, and stakeholders; BMP implementation; and access to adequate financial resources. Funds to implement watershed water quality improvements can be obtained through the SD DENR and the USDA. Specifically, the SD DENR administers three major funding programs that provide low-interest loans and grants for projects that protect and improve water quality in South Dakota. These programs include the Consolidated Water Facilities Construction Program, the Clean Water State Revolving Fund Program, and the Section 319 Nonpoint-Source Program. If the preferred concentrations cannot be met with implementing the recommended BMPs, pollutant trading should be considered for the Sioux Falls Big Sioux River project area.

9.3 REASONABLE ASSURANCE

When a TMDL is developed for waters impaired by both point and nonpoint sources and the WLA is based on an assumption that nonpoint-source load reductions will occur, the EPA states that the TMDL should provide reasonable assurances that nonpoint-source control measures will achieve expected load reductions. Big Sioux River Reaches 8, 10, 11, and 12 are impaired by nonpoint sources and permitted point sources (including MS4s); therefore, the requirement to provide reasonable assurances applies to the *E. coli* TMDLs for these reaches.

The WLAs for the non-MS4 point sources are calculated based on the *E. coli* water quality criterion and discharge volumes estimated by the SD DENR for each point source. The concentration used in these calculations is equal to the TMDL target. Modeling demonstrates that the non-MS4 point sources at these WLAs contribute less than 1 percent of the *E. coli* load in these reaches. Therefore, further reductions in the WLAs for the non-MS4 point sources is not likely to be effective in meeting the *E. coli* water quality criteria in these reaches. Point-source permit limits are currently written for fecal coliform instead of *E. coli*. Baltic WWTP did not discharge during the modeling period. The Dell Rapids WWTP exceeded their 30-day average permit limit (200 org/100 mL fecal coliform) and their daily maximum permit limit (400 org/100 mL fecal coliform) one time since May of 2005 (13 percent of samples). The Sioux Falls WWTP exceeded their daily maximum permit limit (400 org/100 mL) in six of 149 samples taken since May of 2005 (4 percent of samples). Smithfield Foods (John Morrell) exceeded their daily maximum permit limit (400 org/100 mL) in 14 of 157 samples taken since January of 2005 (9 percent of samples).

The following elements provide assurances that nonpoint-source control measures can be designed to reduce the *E coli* loading in these reaches, are likely to be effective, and have a reasonably high probability of being implemented successfully in the Big Sioux River project area:

- Continued cooperation among stakeholders will facilitate implementing BMPs. The water quality assessment work and the TMDL development for these reaches were performed as a cooperative project among the City of Sioux Falls, USGS, the EDWDD, RESPEC, and SD DENR. The cooperation among local stakeholders, state and local regulatory agencies, and organizations is expected to continue through the implementation phase, which will increase the probability of success.
- Simulation of management scenarios indicates that they are likely to be effective. Potential BMP scenarios of the four reaches have been conceptually developed and the HSPF model was used to predict the effectiveness of individual and cumulative scenarios. The HSPF model predicts that implementing the cumulative scenario will achieve the required load reductions needed in all four impaired reaches.

- The percent of reductions in nonpoint-source loading required to meet the TMDL is the difference between the baseline loading and the TMDL. The baseline loading value for the four reaches was calculated using the 90th percentile of the monthly geometric mean *E. coli* concentration for each flow zone and the median of the monthly average discharge. This method conservatively calculates necessary loading reductions.
- A TMDL implementation plan has been written, resources have been committed, and work has been completed on a watershed-scale decision-support framework. The cost-effective framework supports government and local planning agencies in coordinating investments to achieve required load reductions. This decision-support framework outlines strategies with the best probability of success and milestones for implementation. BMP implementation strategies have already been developed within the City of Sioux Falls MS4 permit and the Central Big Sioux River Implementation Plan.
- SD DENR is committed to revising the Skunk Creek TMDL. The HSPF model predicts that Management Scenario 3 will result in significant load and concentration reductions. Under Scenario 3, both Reach 7 of the Big Sioux River and Skunk Creek will be managed to the immersion recreation *E. coli* standards instead of their currently designated limited contact recreation standards. The SD DENR intends to revise the TMDLs for these stream reaches to reflect this *E coli* standard change. Revising these TMDLs provides additional assurance that the necessary load reductions will be achieved. The WLA for the MS4 that drains into Skunk Creek will need to be incorporated into the revised TMDL for Skunk Creek. It is expected that revisions to the TMDL will be completed within 5 years.

9.4 ADAPTIVE IMPLEMENTATION APPROACH

An adaptive implementation approach will be followed for this TMDL. The EPA defines adaptive implementation as "an iterative implementation process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities" [EPA, 2006]. Using an adaptive implementation approach for this TMDL is based on several areas of uncertainty that exist in the TMDL. These areas are presented below, and recommended studies to reduce the level of uncertainty are also presented appropriately.

- **Loading sources:** The source assessment presented in Chapter 3.0 of this TMDL is based on relatively general sources of load contributions. To effectively achieve *E. coli* reduction in the Big Sioux River, further understanding of specific sources of *E. coli* in the impaired reaches is needed. The International Stormwater BMP Database project team states, "those working to address pathogen impairments on streams should focus first and foremost on source controls. This requires a clear identification of the primary sources of bacteria" [Clary et al., 2010]. To obtain a better understanding of the sources, a relatively intensive monitoring network consisting of spatially distributed sampling locations would need to be established within the project area. The benefit of the recommended monitoring would be that portions of the watershed with elevated bacteria levels may be potentially isolated and investigated further for potential source areas and remedial actions. Bacterial source tracking analyses for the identification sources of bacteria of human origin could be included in this monitoring effort.

- **BMP effectiveness:** The uncertainty in the effectiveness of stormwater BMPs with regard to bacteria in unknown. A recent analysis of data available in the International Stormwater BMP Database indicates that “the majority of conventional stormwater BMPs in the BMP database do not appear to be effective at reducing fecal indicator bacteria concentrations to primary contact (i.e., Immersion Recreation) stream standards, which is the ultimate target of TMDLs” [Clary et al., 2010]. However, this study also found that select BMP categories (specifically, retention [wet] ponds, bioretention, and various types of media filters) provide reduction in bacteria concentrations [Clary et al., 2010]. Additional BMP efficacy data are needed to guide implementing stormwater bacteria controls in systems such as the Big Sioux River Watershed. As a result, this TMDL implementation should include identification, monitoring and further identification of applicable BMPs that are effective in reducing bacteria loads to the impaired reaches.

These areas of uncertainty support using an adaptive implementation approach for this TMDL based on phased implementation rather than water quality-based effluent limitations within the MS4 permit. As noted in Chapter 8.0, SD DENR will notify the EPA of any adjustments to this TMDL within 30 days of their adoption.

10.0 REFERENCES

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APPENDIX A

DAILY MAXIMUM CRITERIA TOTAL MAXIMUM DAILY LOAD TABLES

TMDLs in the daily maximum TMDL tables were developed using the median simulated daily average flow and the daily maximum criteria in each flow zone. Current loads in the daily maximum TMDL tables were developed using the 90th percentile observed daily average concentration and the median simulated daily average flow in each flow zone.

Table A- 1. *E. coli* Total Maximum Daily Load Based on the Daily Maximum Criterion for Reach 8

TMDL Component (Mpn/Day)		Flow Zone									
		High		Moist		Midrange		Dry		Low	
TMDL		1.02E+13		5.07E+12		3.35E+12		1.88E+12		1.05E+12	
MOS		1.02E+12		5.07E+11		3.35E+11		1.88E+11		1.05E+11	
PSA	WLA	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11	1.68E+11
MS4		0		0		0		0		0	
LA		8.98E+12		4.39E+12		2.85E+12		1.52E+12		7.78E+11	
Current Load		1.09E+14		4.10E+13		1.31E+13		3.09E+12		1.16E+12	
Load Reduction		91%		88%		74%		39%		9%	

Table A- 2. *E. coli* Total Maximum Daily Load Based on the Daily Maximum Criterion for Reach 10

TMDL Component (mpn/day)		Flow Zone									
		High		Moist		Midrange		Dry		Low	
TMDL		3.83E+12		1.45E+12		7.01E+11		4.22E+11		2.11E+11	
MOS		3.83E+11		1.45E+11		7.01E+10		4.22E+10		2.11E+10	
PSA	WLA	8.89E+10	6.64E+11	8.89E+10	3.06E+11	8.89E+10	1.94E+11	8.89E+10	1.52E+11	8.89E+10	1.21E+11
MS4		5.75E+11		2.17E+11		1.05E+11		6.33E+10		3.17E+10	
LA		2.78E+12		9.98E+11		4.37E+11		2.28E+11		6.94E+10	
Current Load		7.96E+13		1.49E+13		3.08E+12		2.08E+12		1.02E+12	
Load Reduction		95%		90%		77%		80%		79%	

Table A- 3. *E. coli* Total Maximum Daily Load Based on the Daily Maximum Criterion for Reach 11

TMDL Component (mpn/day)		Flow Zone									
		High		Moist		Midrange		Dry		Low	
TMDL		1.29E+13		6.23E+12		3.93E+12		2.20E+12		1.22E+12	
MOS		1.29E+12		6.23E+11		3.93E+11		2.20E+11		1.22E+11	
PSA	WLA	1.36E+11	6.50E+11	1.36E+11	3.85E+11	1.36E+11	2.93E+11	1.36E+11	2.24E+11	1.36E+11	1.85E+11
MS4		5.14E+11		2.49E+11		1.57E+11		8.79E+10		4.89E+10	
LA		1.10E+13		5.22E+12		3.24E+12		1.76E+12		9.15E+11	
Current Load		2.25E+14		6.41E+13		1.83E+13		1.62E+13		3.90E+12	
Load Reduction		94%		90%		79%		86%		69%	

Table A- 4. *E. coli* Total Maximum Daily Load Based on the Daily Maximum Criterion for Reach 12

TMDL Component (mpn/day)		Flow Zone									
		High		Moist		Midrange		Dry		Low	
TMDL		1.31E+13		6.48E+12		4.15E+12		2.41E+12		1.40E+12	
MOS		1.31E+12		6.48E+11		4.15E+11		2.41E+11		1.40E+11	
PSA	WLA	5.96E+11	5.96E+11	5.96E+11	5.96E+11	5.96E+11	5.96E+11	5.96E+11	5.96E+11	5.96E+11	5.96E+11
MS4		0		0		0		0		0	
LA		1.12E+13		5.24E+12		3.14E+12		1.57E+12		6.64E+11	
Current Load		1.35E+14		6.44E+13		4.27E+13		1.38E+13		5.28E+12	
Load Reduction		90%		90%		90%		83%		73%	