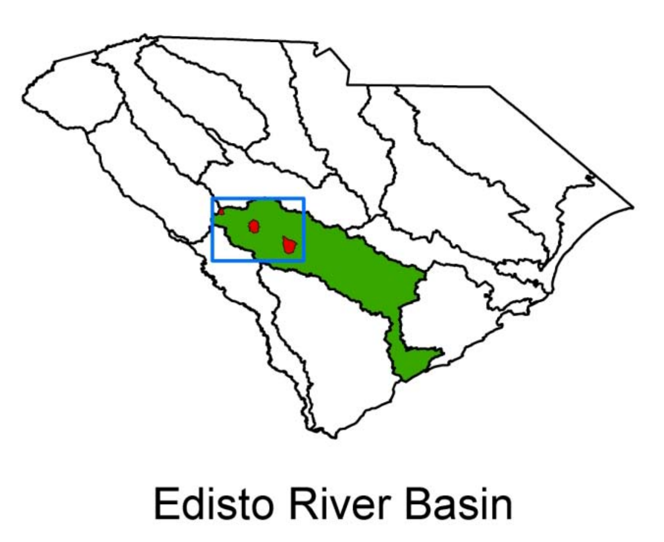
Total Maximum Daily Load For Fecal Coliform For South Fork Edisto River, Rocky Springs Creek, and Goodland Creek Watershed in the Edisto River Basin, South Carolina

HYDROLOGIC UNIT CODE: 03050204
(STATIONS E-002, RS-01034, E-036)



September 2005

SCDHEC Technical Report Number: 030-05

United States Environmental Protection Agency
Region 4 serving the southeast

In compliance with the provisions of the Federal Clean Water Act, 33 U.S.C §1251 et.seq., as amended by the Water Quality Act of 1987, P.L. 400-4, the U.S Environmental Protection Agency is hereby establishing a Total Maximum Daily Load (TMDL) for Fecal Coliform for South Fork Edisto River, Rocky Springs Creek, and Goodland Creek Watershed in the Edisto River Basin. Subsequent actions must be consistent with this TMDL.

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James D. Giattina, Director Date

Water Management Division

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ACRONYMS AND ABBREVIATIONS

AFO	Animal feeding operation
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming units
CWA	Clean Water Act
DMR	Discharge monitoring report
HUC	Hydrologic unit code
LA	Load allocation
LDC	Load duration curve
mg	Million gallons
mgd	Million gallons per day
ml	Milliliter
MOS	Margin of safety
MS4	Municipal separate storm sewer system
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSFC	National Small Flows Clearinghouse
OSWD	Onsite wastewater disposal
PRG	Percent reduction goal
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SSO	Sanitary sewer overflow
TMDL	Total maximum daily load
USC	United States Code
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard
WWTP	Wastewater Treatment Plant

SECTION 1
INTRODUCTION

1.1 Background

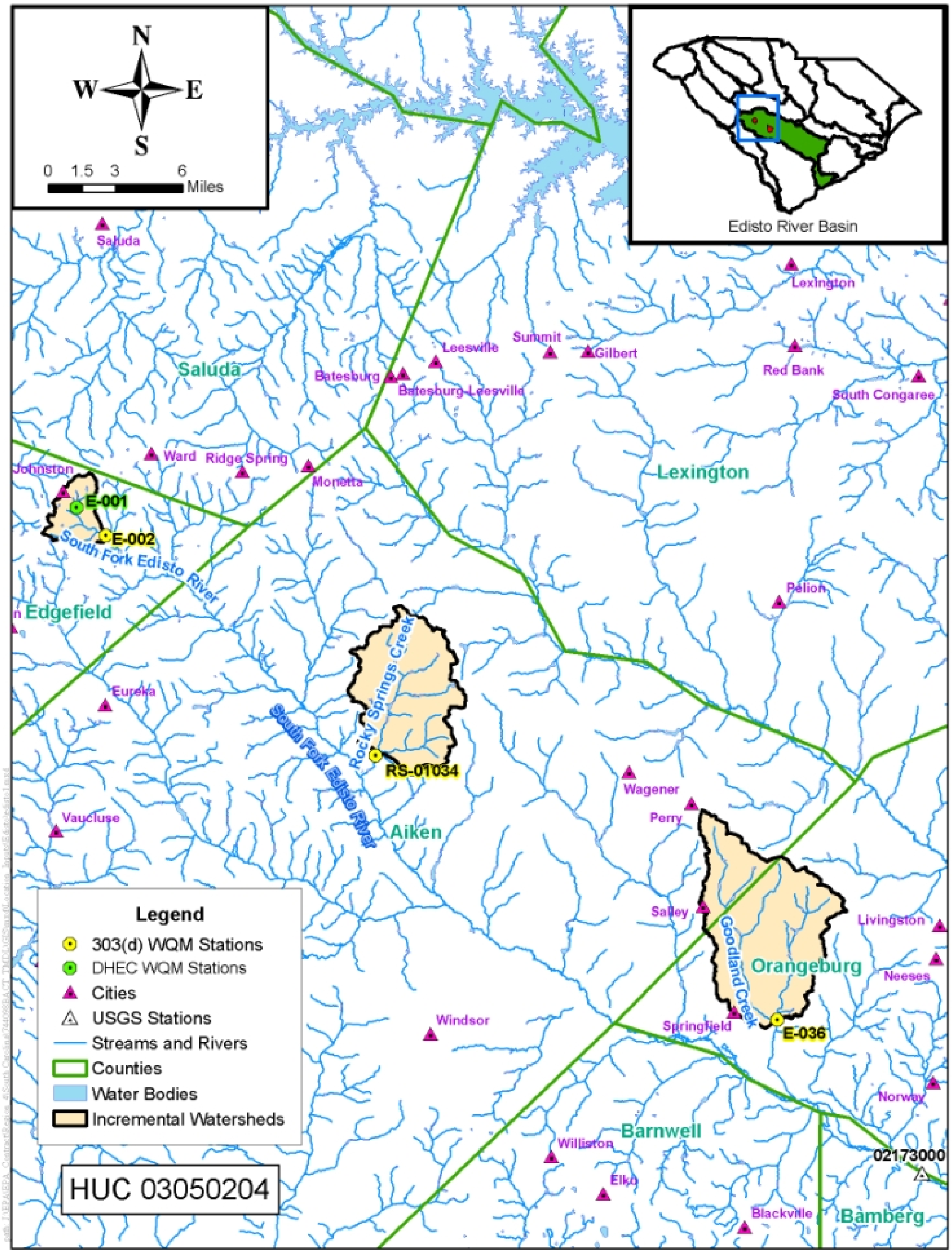
Section 303(d) of the Clean Water Act (CWA) and U.S. Environmental Protection Agency (USEPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) require states to develop total maximum daily loads (TMDL) for water bodies not meeting designated uses where technology-based controls are in place. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and in-stream water quality conditions, so states can implement water quality-based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of its water resources (USEPA 1991).

This report documents the data and assessment utilized to establish TMDLs for fecal coliform bacteria for certain water bodies in the Edisto River Basin in accordance with the requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), USEPA guidance, and South Carolina (SC) Department of Health and Environmental Control (SCDHEC) guidance and procedures. States are required to submit all TMDLs to USEPA for review and approval. Once USEPA approves a TMDL, then the water body may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this TMDL report is to assist SCDHEC with establishing pollutant load allocations for impaired water bodies. TMDLs determine the pollutant loading a water body can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a water body based on the relationship between pollutant sources and in-stream water quality conditions. A TMDL consists of a wasteload allocation (WLA), a load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL that accounts for the uncertainty associated with model assumptions and data limitations.

SCDHEC included three water quality monitoring (WQM) stations from Hydrologic Unit Code (HUC) 03050204 within the Edisto River Basin on the 2004 South Carolina §303(d) list for exceedances of the fecal coliform bacteria WQS. Figure 1-1 is an orientation map showing a portion of the 8-digit HUC of the Edisto River Basin where the 303(d)-listed WQM stations are located.

Figure 1-1 South Fork Edisto River, Rocky Springs Creek, and Goodland Creek Watersheds



The 303(d)-listed WQM stations associated with these water bodies are shown in Table 1-1 below and are generally listed upstream to downstream. The WQM stations are grouped by HUCs identified with 11 digits to further define their geographic location. The presence of fecal coliform bacteria in aquatic environments indicates the receiving water is contaminated with human or animal fecal material. Fecal coliform bacteria contamination is an indication that a potential health risk exists for individuals exposed to the water. Implementation of fecal coliform bacteria loading controls will be necessary to restore the primary contact recreation use designated for each water body listed in Table 1-1.

Table 1-1 Water Quality Monitoring Stations on 2004 303(d) List for Fecal Coliform in the Edisto River Basin

Water Body Name	SCDHEC WQM Stations	WQM Station Locations
HUC 03050204010		
South Fork of Edisto River	E-002	South Fork Edisto River at S-19-57
Rocky Springs Creek	RS-01034	Rocky Springs Creek at Moore Road of County Road 264, 7 Miles Northeast of Aiken
HUC 03050204060		
Goodland Creek	E-036	Goodland Creek at SC 4, 2.1 Miles East of Springfield

1.2 Watershed Description

General. The Edisto River Basin is completely within the south central portion of SC. The Edisto River is one of the longest free-flowing blackwater rivers in the United States. Headwaters of the Edisto River originate in the Sand Hills region of SC and flow through the Upper and Lower Coastal Plain Regions and into the Coastal Zone region. The South Fork Edisto River accepts drainage from various creeks and swamps, including Rocky Springs Creek and Goodland Creek. The South Fork Edisto River merges with the North Fork Edisto River to form the Edisto River, which then discharges into the Atlantic Ocean (SCDHEC 2004).

The Edisto River Basin includes 2,775.1 stream miles and 31.7 square miles of estuarine areas. The basin consists of forested land, agricultural land, scrub/shrub land, forested wetlands, urban land, barren land, and nonforested wetlands (SCDHEC 2004). The Edisto River Basin is divided into four geographical regions: the Sand Hills (an area of gently sloping to strongly sloping uplands with a predominance of sandy areas and scrub vegetation; elevations range from 250 to 450 feet), the Upper Coastal Plain (an area of gentle slopes with increased dissection and moderate slopes in the northwestern section that contain the state's major farming areas; elevations range from 100 to 450 feet), the Lower Coastal Plain (an area that is nearly level and dissected by many broad, shallow valleys with meandering stream channels; elevations range from 25 to 125 feet), and the Coastal Zone (a mostly tidally-influenced area that is nearly level and dissected by many broad, shallow valleys with meandering stream channels; most of the valleys terminate in tidal estuaries along the coast; elevations range from sea level to about 25 feet) (SCDHEC 2004). Although the Edisto River Basin encompasses 30 watersheds and 2 million acres, only the South Fork Edisto River, Rocky Springs Creek, and Goodland Creek watersheds are addressed in this TMDL report.

South Fork Edisto River and Rocky Springs Creek watersheds are located entirely within Edgefield and Aiken County, respectively. Goodland Creek watershed is located mostly in Orangeburg County, with the Northwestern portion of the watershed extending into Aiken County. Growth potential is low to moderate in the South Fork Edisto River watershed, which contains a portion of the Town of Johnston, which has the ability to connect into the regional sewer collection system in the future. Growth potential for Rocky Springs Creek and Goodland Creek watersheds are both low even though Goodland Creek watershed includes portions of the Towns of Salley, Perry, and Springfield. The predominant soil type for South Fork Edisto River and Rocky Springs Creek watersheds is an association of the Troup-Fuquary-Lakeland series. The predominant soil type for Goodland Creek watershed is an association of the Fuquary-Dothan-Troup series (SCDHEC 2004).

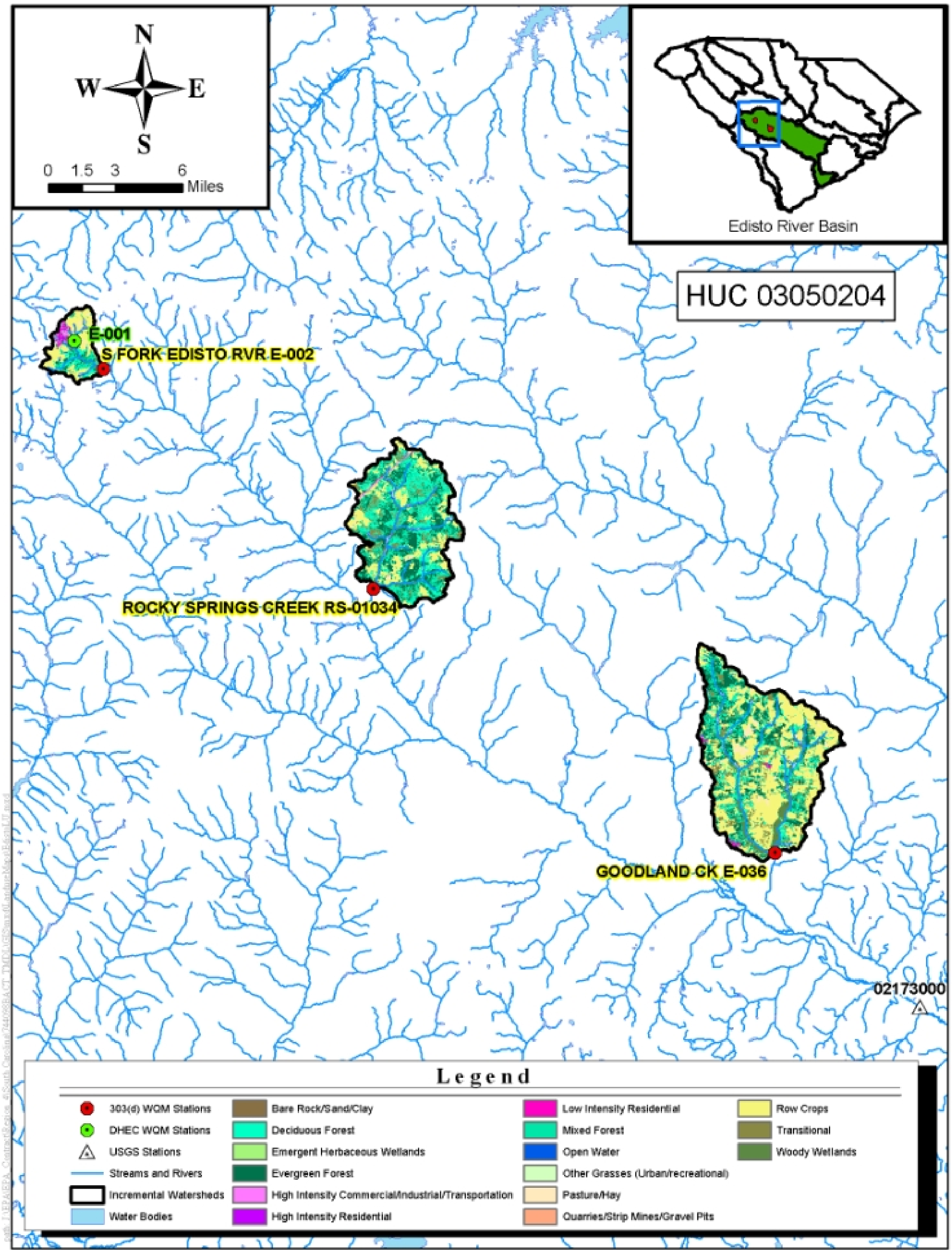
Precipitation. According to SC's 30-year climatological record, normal yearly rainfall in the Edisto River area during the period 1971 to 2000 was 48.52 inches (SCDHEC 2004). Data from National Weather Service stations in Aiken, Blackville, Bamberg, Branchville, Walterboro, Pelion, and Springfield were compiled by SCDHEC to determine general climatic information for the Edisto River area. The highest seasonal rainfall during this period occurred in the summer (15.75 inches); rainfall in the fall, winter, and spring was 9.88, 11.94, and 10.95 inches, respectively (SCDHEC 2004).

Land Use. Table 1-2 summarizes general land use categories and the associated percentages for the contributing watersheds upstream of each WQM station. There are 3,628 acres in South Fork Edisto River watershed, 16,221 acres in Rocky Springs Creek watershed, and 23,821 acres in the Goodland Creek watershed. The land use/land cover data were derived from 1996 U.S. Geological Survey (USGS) Multi-Resolution Land Characteristic land use data (USGS 2005). Figure 1-2 depicts the land use categories occurring within the South Fork Edisto River, Rocky Springs Creek, and Goodland Creek watersheds. The South Fork Edisto River and Goodland Creek watersheds are predominately (approximately 50 and 45 percent, respectively) pasture and row crop, followed by forested areas (approximately 35 and 39 percent, respectively). Residential and commercial/industrial land use accounted for roughly 9 percent of the South Fork Edisto River watershed, and less than 1 percent for Rocky Springs Creek and Goodland Creek watersheds. Rocky Springs Creek watershed is dominated by forested areas (approximately 65 percent), with some pastures and row crops (approximately 21% combined).

Table 1-2 Land Use Summary for the South Fork Edisto River, Rocky Springs Creek, and Goodland Creek Watersheds

Description	Code	E-002	RS-01034	E-036
Open Water	11	70	147	147
Open Water Percent	11	1.92	0.91	0.62
Low Intensity Residential	21	162	35	110
Low Intensity Residential Percent	21	4.46	0.22	0.46
High Intensity Residential	22	63	0	31
High Intensity Residential Percent	22	1.73	0.00	0.13
High Intensity Commercial/Industrial/Transportation	23	106	90	9
High Intensity Commercial/Industrial/Transportation Percent	23	2.91	0.56	0.04
Bare Rock/Sand/Clay	31	4	19	11
Bare Rock/Sand/Clay Percent	31	0.10	0.11	0.04
Quarries/Strip Mines/Gravel Pits	32	0	0	0
Quarries/Strip Mines/Gravel Pits Percent	32	0.00	0.00	0.00
Transitional	33	0	1,320	1,589
Transitional Percent	33	0.00	8.14	6.67
Deciduous Forest	41	536	4,654	3,197
Deciduous Forest Percent	41	14.77	28.69	13.42
Evergreen Forest	42	337	3,788	4,087
Evergreen Forest Percent	42	9.30	23.35	17.16
Mixed Forest	43	400	2,116	2,000
Mixed Forest Percent	43	11.01	13.05	8.40
Pasture/Hay	81	125	213	979
Pasture/Hay Percent	81	3.44	1.31	4.11
Row Crops	82	1,695	3,260	9,704
Row Crops Percent	82	46.71	20.09	40.74
Other Grasses (Urban/recreational)	85	12	16	2
Other Grasses (Urban/recreational) Percent	85	0.32	0.10	0.01
Woody Wetlands	91	110	544	1,909
Woody Wetlands Percent	91	3.02	3.35	8.01
Emergent Herbaceous Wetlands	92	11	19	45
Emergent Herbaceous Wetlands Percent	92	0.31	0.12	0.19
Total Acres		3,628	16,221	23,821

Figure 1-2 Land Use Map: South Fork Edisto River, Rocky Springs Creek, and Goodland Creek Watersheds



SECTION 2
WATER QUALITY ASSESSMENT

2.1 Water Quality Standards

Water quality standards for SC were promulgated in the South Carolina Pollution Control Act, §48w1-10, *et seq*. Chapter 61, R61-68 (SCDHEC 2001). All water bodies in the Edisto River Basin are designated as freshwater. Waters of this class are defined in Regulation 61-68, §610, *Water Classifications and Standards,* and designated uses are described as follows (SCDHEC 2001):

> *Freshwater suitable for primary and secondary contact recreation and as a source for drinking water supply, after conventional treatment, in accordance with the requirements of the Department. These waters are suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. This class is also suitable for industrial and agricultural uses.*

SC's numeric criteria for fecal coliform bacteria to protect for primary contact recreation use in freshwater are (SCDHEC 2001):

> *Not to exceed a geometric mean of 200 cfu/100 ml, based on five consecutive samples during any 30-day period; nor shall more than 10 percent of the total samples during any 30-day period exceed 400 cfu/100 ml*.

The State of South Carolina Integrated Report for 2004 identified the WQM stations requiring fecal coliform TMDLs (SCDHEC 2004a). Fecal coliform bacteria monitoring data collected primarily by the SCDHEC Bureau of Water from 1998 through 2002 were used in the 2004 303(d) listing procedure. While SC WQSs stipulate two separate water quality criterion for assessing primary contact recreation, there are insufficient data available to calculate the 30-day geometric mean since most water quality samples are collected once a month. As a result, monitoring stations with greater than 10 percent of the samples exceeding 400 colony-forming units (cfu) per 100 milliliter (ml) were considered impaired and were placed on the list for TMDL development. Targeting the instantaneous criterion of 400 cfu/100 ml as the water quality goal corresponds to the basis for 303(d) listing and is expected to be protective of the geometric mean criterion as well.

2.2 Assessment of Existing Water Quality Data

Table 2-1 summarizes data supporting the decision to place the WQM stations targeted in this report on the SCDHEC 2004 303(d) list. Additional ambient fecal coliform data for each WQM station from 1990 to 2002 (if available) are provided in Appendix A. Ambient fecal coliform data were provided by SCDHEC and obtained from USEPA Storage and Retrieval Database (USEPA 2005).

Table 2-1 Fecal Coliform Bacteria Samples from 1998 through 2002

Station	Total Number of Samples	Maximum Concentration cfu/100 ml	Total Number of Samples > 400 cfu/100 ml	Percentage of Samples > 400 cfu/100 ml
E-002	29	1200	5	17
RS-01034	11	1200	2	18
E-036	40	1000	12	30

The majority of the fecal coliform data for WQM station E-002 (South Fork Edisto River) and station E-036 (Goodland Creek), were collected during the spring, summer, and fall months. However, data were collected monthly during 2001 at WQM station E-002 and monthly during 2001 and 2002 at WQM station E-036. WQM station RS-01034 (Rocky Springs Creek) was sampled on a monthly basis; however, monitoring was only conducted for the year 2001. Because land practices and bacteria load delivery mechanisms are considered relatively consistent over the course of a year, it was assumed for E-002 and E-036 that winter loading would be consistent with that of periods for which data existed (SCDHEC 2003). Seventeen and 30 percent of the samples from station E-002 and E-036, respectively, exceeded the numeric criterion. Eighteen percent of the 2001 samples for station RS-01034 exceeded the criterion.

Additional analyses were performed using fecal coliform data and precipitation data from the period 1994 through 2002, where available, to develop a better understanding of the potential relationship between rainfall and elevated fecal coliform bacteria loads in individual watersheds. Precipitation data from local National Oceanic and Atmospheric Administration (NOAA) weather stations were plotted against SCDHEC ambient fecal coliform data at each WQM station to evaluate the potential statistical relationship between fecal coliform exceedances and rainfall. Rainfall data for a 3-day period (2 days prior to and the day of each fecal coliform sample collection date) selected from weather stations proximal to each WQM station were averaged. Data from the NOAA weather monitoring stations Columbia Metro Airport and Orangeburg, SC were used (NOAA 2005) to generate the plots. Plots for each WQM station and a map showing the location of the NOAA weather stations and their station identification numbers are provided in Appendix B.

Inferences from the comparison of fecal coliform concentration with rainfall data for each WQM station are summarized below.

WQM Station E-002 (South Fork Edisto River). Comparison of ambient fecal coliform data and NOAA precipitation data (51 data points) for the period examined (1994 and 2002) revealed 19 days in which the 3-day average rainfall exceeded 0.1 inch. For those dates, three fecal coliform measurements exceeded the WQS. There were five additional exceedances that occurred on days which the 3-day average rainfall was less than 0.1 inch. The highest fecal coliform concentration of 1,200 cfu/100 ml was recorded in September 1999 where the 3-day average rainfall was 0.0 inch. This suggests there is little relationship between wet weather conditions and high fecal coliform concentrations. The lack of such a relationship suggests that fecal coliform exceedances may be associated with sources not significantly affected by rainfall.

WQM Station RS-01034 (Rocky Springs Creek). For the period examined (8 data points), there were 4 days in which the 3-day average rainfall exceeded 0.1 inch. However, the only exceedance occurred on October 10, 2001 where the 3-day average rainfall was 0.0 inch. The maximum fecal coliform value of 1,200 cfu/100 ml occurred on November 15, 2001; however, there was no rainfall recorded on that date. This suggests there is little relationship between wet weather conditions and higher fecal coliform concentrations. Although to fully determine this relationship, additional fecal coliform measurements and a continuous time series of precipitation would be needed for this evaluation.

WQM Station E-036 (Goodland Creek). For the period examined (68 data points) there were only 5 days in which the 3-day average rainfall exceeded 0.1 inch. For those dates, three fecal coliform measurements exceeded the WQS. This suggests that wet weather events may have some influence on fecal coliform concentrations. The highest fecal coliform concentration of 1,200 cfu/100 ml was recorded on September 9, 1993, when no measurable rainfall was recorded. Fifteen other exceedances of the WQS occurred on dates when the 3-day average rainfall was 0.0 inch. This suggests fecal coliform concentrations are not significantly affected by rainfall.

Based on examination of the data shown in the plots in Appendix B, it is difficult to demonstrate a correlation between rainfall and fecal coliform concentrations. General conclusions can be derived from these data analysis:

- Most of the ambient fecal coliform samples for E-036 were collected under dry conditions, and the majority of fecal coliform samples exceeding the WQS occurred under dry weather conditions;
- It is difficult to discern a direct correlation between rainfall and fecal coliform concentrations at each WQM station without more localized precipitation data recorded from within each watershed.

Subsection 3.3 provides a more detailed discussion of fecal coliform sources by watershed and the effect dry and wet weather conditions may have on fecal coliform loading.

2.3 Establishing the Water Quality Target

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." For the WQM stations requiring TMDLs in this report, defining the water quality target is straightforward and dictated by the fecal coliform numeric criteria established for the protection and maintenance of the primary contact recreation use as defined in the SC WQSs (See Subsection 2.1). However, because available fecal coliform data were collected on an approximate monthly basis (See Appendix A) instead of at least five samples over a 30–day period, data for these TMDLs are analyzed and presented in relation to the instantaneous criterion of 400 cfu/100 ml, which requires that no more than 10 percent of the samples can exceed this numeric criterion. Therefore, the water quality target for each impaired WQM station will be expressed as: 380 cfu/100 ml for the instantaneous criterion, which is 5 percent lower than the water quality criteria of 400 cfu/100 ml. The 5 percent explicit MOS was reserved from the water quality criteria in developing the load duration curves (LDC). The instantaneous criterion was targeted as a conservative approach and should be protective of both the instantaneous and 30-day geometric mean fecal coliform bacteria standards (SCDHEC 2003).

This water quality target will be used to determine the allowable bacteria load which is derived by using the actual or estimated flow record multiplied by the instream fecal coliform criteria minus a 5 percent MOS. The line drawn through the allowable load data points is the water quality target which represents the maximum load for any given flow that still satisfies the WQS (SCDHEC 2003).

SECTION 3
POLLUTANT SOURCE ASSESSMENT

A source assessment characterizes known and suspected sources of pollutant loading to impaired water bodies. Sources within a watershed are categorized and quantified to the extent that information is available. Fecal coliform bacteria originate from warm-blooded animals and some plant life. Although fecal coliform are not harmful, they are present in mammal waste that also contains harmful bacteria and viruses.

Sources of fecal coliform bacteria may be point or nonpoint in nature. Point sources are permitted through the NPDES program. NPDES facilities that discharge treated wastewater effluent are required to monitor fecal coliform bacteria concentrations in accordance with their permit. Some stormwater discharges may be regulated under the NPDES program as well, although there are no such discharges known in the three watersheds addressed in this report.

Nonpoint sources are diffuse sources that typically cannot be identified as entering a water body at a single location. These sources may involve land activities that contribute fecal coliform bacteria to surface water as a result of stormwater runoff. The following discussion describes what is known regarding point and nonpoint sources of fecal coliform bacteria in the impaired watersheds.

3.1 Point Source Discharges

Continuous point source discharges such as wastewater treatment plants (WWTP), could result in discharge of elevated concentrations of fecal coliform bacteria if the disinfection unit is not properly maintained, is of poor design, or if flow rates are above the disinfection capacity. Stormwater runoff carrying fecal coliform bacteria is another type of point source currently regulated under the USEPA NPDES Stormwater Program. However, there are currently no Municipal Separate Storm Sewer Systems (MS4) permits in the watersheds discussed in this report and, therefore, only continuous point source discharges are addressed. The following is a brief discussion of point source discharges in the South Fork Edisto River, Rocky Springs Creek, and Goodland Creek watersheds.

3.1.1 Continuous Point Sources

Table 3-1 lists two active NPDES point sources continuously discharging upstream of two of the three WQM stations. The active NPDES facilities, ECW&SA/Johnston #1 Plant (SC0025691) located upstream of E-002 and the Springfield/Plant #2 (SC0023281) located upstream of E-036, are shown in Figure 3-1. Inactive permits or industrial dischargers are not included in Table 3-1.

Discharge Monitoring Reports (DMR) and design flow of the discharges were used to determine the number of fecal coliform analyses performed for NPDES Permits SC0025691 and SC0023281 (1998 through 2004), the maximum concentration during this period, the number of violations occurring when the monthly geometric mean concentration exceeded 200 cfu/100 ml, and the number of violations when a daily concentration exceeded 400 cfu/100 ml. All DMR data were provided by SCDHEC. No fecal coliform violations occurred at either of these NPDES facilities, and therefore, these WWTPs are not considered to have contributed to the excessive fecal coliform loads that influenced the 303(d) listing for the

South Fork Edisto River watershed. The DMR data for each WWTP are provided in Appendix C.

Table 3-2 summarizes the existing load estimates for each NPDES facility. Existing point source loads of fecal coliform discharged were estimated by multiplying monthly average flow rates by the monthly geometric mean (if available) and using a unit conversion factor. The fecal coliform values were extracted from the DMR of each point source. The 90th percentile value was used to express the estimated existing load in cfu per day.

Sanitary sewer overflows (SSO), typically associated with urban growth areas, are also a potential source of fecal coliform loading to streams. SSOs are permit violations that must be addressed by the responsible NPDES permittee. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of the pipes by grease and tree roots. A summary of SSOs from ECW&SA/Johnston #1 Plant (SC0025691) located upstream of E-002 and the Springfield/Plant #2 (SC0023281) located upstream of E-036, is provided below. There were no reported SSOs associated with WQM station RS-01034 in Aiken County for the time period in question.

Edgefield County: The watershed associated with the 303(d)-listed WQM station E-002 (South Fork of the Edisto River) is located in Edgefield County. There were 14 reported SSOs occurring from ECW&SA Johnston #1 WWTP (NPDES SC0025691) in Edgefield County between October 1998 and February 2004, 11 of which reached a receiving water. Volumes of these SSOs ranged from 0 to 200,000 gallons, with four of these discharges greater than 10,000 gallons (February 2 1999 was 10,000 gallons; February 25, 1999 was 100,000 gallons; August 11, 2000 was 100,000 gallons; and January 24, 2001 was 200,000 gallons). Elevated concentrations of fecal coliform samples collected from WQM station E-002 corresponding to the dates of the SSOs did not correlate with the occurrence of SSOs for any of the 14 incidents.

Orangeburg County: The watershed associated with the 303(d) listed WQM station E-036 (Goodland Creek) is located in Orangeburg County. There were two reported SSOs occurring from the Springfield Plant #2 (NPDES SC0023281) in Orangeburg County between July 2000 and October 2000, none of which reached a receiving water. The reported volume for both of these events was 5,000 gallons. Elevated concentrations of fecal coliform samples collected from WQM station E-036 corresponding to the dates of the SSOs did not correlate with the occurrence of SSOs for either of the two reported incidents.

The Edgefield County Water and Sewer Authority and Orangeburg County Public Works Department Wastewater Division were contacted to ascertain whether leaking sewer lines are a potential source of fecal coliform in any of the South Fork Edisto River and Goodland Creek watersheds. There are currently no sewer lines located in the Rocky Springs Creek watershed (see Figure 3-1) and therefore, sewer lines are not a potential source of fecal coliform to this watershed. Both local agencies indicated no known leakage in the sewer lines, and that the sewer system in the South Fork Edisto River watershed was upgraded in 2005 (Edgefield County Water and Sewer Authority 2005; Orangeburg County Public Works Department Wastewater Division 2005). Therefore, contribution of fecal coliform from leaking sewer lines is likely negligible in South Fork Edisto River and Goodland Creek watersheds.

Figure 3-1 Locations of NPDES Dischargers in South Fork Edisto River and Goodland Creek Watersheds

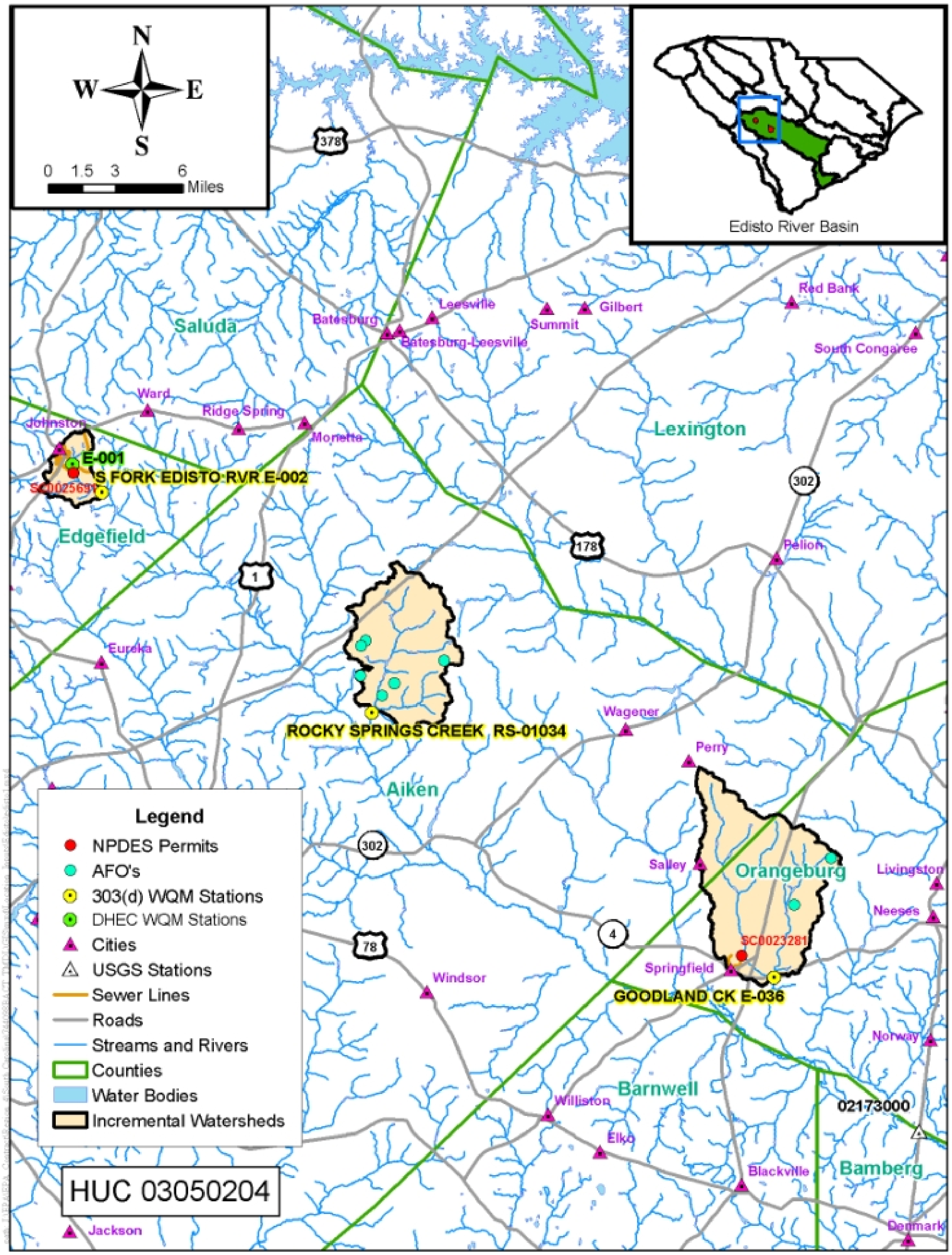


Table 3-1 Permitted Facilities Discharging Fecal Coliform Bacteria

Water Quality Monitoring Station / Permittee	NPDES Permit Number	Receiving Water	Flow (mgd)	Number of Discharge Monitoring Reports*	Maximum Concentration cfu/100 ml	Monthly Average >200 cfu/100 ml	Maximum Daily Concentration >400 cfu/100 ml	Percent of Samples Exceeding Permit Limits
HUC 03050204010								
E-002 South Fork of Edisto River								
ECW&SA/JOHNSTON #1 PLANT	SC0025691	South Fork of Edisto River	0.968	11	396	0	0	0
HUC 03050204060								
E-036 Goodland Creek								
SPRINGFIELD/ PLANT #2	SC0023281	Goodland Creek	0.06	84	350	0	0	0

* Each DMR provides two fecal coliform values: the average of all samples for the month and the maximum of the samples.

Table 3-2 Estimated Existing Fecal Coliform Loading from NPDES Facilities

Water Quality Monitoring Station / Permittee	NPDES Permit Number	Receiving Water	90th percentile load (cfu/day)
HUC 03050204010			
E-002 South Fork of Edisto River			
ECW&SA/JOHNSTON #1 PLANT	SC0025691	South Fork of Edisto River	2.89E+08
HUC 03050204060			
E-036 Goodland Creek			
SPRINGFIELD/ PLANT #2	SC0023281	Goodland Creek	7.57E+06

3.2 Nonpoint Sources

Nonpoint sources include those sources that cannot be identified as entering the water body at a specific location. Because fecal coliform is associated with warm-blooded animals, nonpoint sources of fecal coliform may originate from both rural and urbanized areas. The following discussion highlights some of the major nonpoint sources of fecal coliform identified in the watersheds. These sources include wildlife, agricultural activities, land application fields, domesticated animals, onsite wastewater disposal systems (OSWD), and domestic pets. Runoff from small urban areas not permitted under the MS4 program is probably a significant source of fecal coliform bacteria into streams. Water quality data collected from streams draining many of the un-permitted communities show existing loads of fecal coliform bacteria at levels greater than the State's instantaneous standards. BMPs such as buffer strips and the proper disposal of domestic animal wastes may reduce fecal coliform bacteria loading to water bodies.

3.2.1 Wildlife

Fecal coliform bacteria are produced by warm-blooded animals such as deer, wild turkey, raccoons, beavers, other small mammals, and avian species. The SC Department of Natural Resources (SCDNR) conducted a study in 2000 to estimate whitetail deer density based on suitable habitat (SCDNR 2000). This study assumed that deer habitat includes forests, croplands, and pastures.

Deer population density in the South Fork Edisto River and Rocky Springs Creek watersheds ranged from 15 to 30 deer per square mile. While less than 15 deer per square mile were associated with the Goodland Creek watershed. According to a study conducted by Yagow (1999), fecal coliform production rate for deer is 347 x 10^6 cfu/head-day. Although only a portion of the fecal coliform produced by deer may enter into a water body, the population of deer in the South Fork Edisto River and Rocky Springs Creek watersheds may be a relatively significant source of fecal coliform loading. Deer population in the Goodland Creek may only be a minor source of fecal coliform loading.

There are currently no available data for other wildlife and avian species known to inhabit these watersheds which could potentially contribute to the fecal coliform load. However, given the representative statistics for deer population and the large amount of rural area (forest, cropland, and pasture) in the South Fork Edisto River and Rocky Springs Creek watersheds, other wildlife are a contributing source of fecal coliform loading in these watersheds. Due to the small deer population and smaller percentage of forested area in the Goodland Creek watershed, wildlife are considered to be a minor source of fecal coliform loading.

3.2.2 Agricultural Activities and Domesticated Animals

Domesticated animals produce significant amounts of waste and are recognized as a source of fecal coliform loading. For example, according to a livestock study conducted by the American Society of Agricultural Engineers (ASAE 1998), the following fecal coliform production rates were estimated:

- cattle release approximately 100 billion fecal coliform per animal per day;
- pigs - 11 billion per animal per day;

- chickens – 1.4 billion per animal per day;

Manure generated by livestock at pasture or in an animal feedlot, which is typically used as fertilizer on crop lands, forests, and pastures, is therefore a potential source of fecal coliform loading. The CWA does not regulate nonpoint source runoff from agriculture lands receiving agronomic applications of manure (CWA§502(14)). Furthermore, for the purposes of this pollutant source assessment, insufficient data are available to estimate fecal coliform concentrations in stormwater runoff from land application fields where manure is applied.

Stormwater leaving a concentrated animal feeding operation (CAFO) is regulated under the NPDES program; however, there are currently no NPDES-permitted CAFOs in SC. The SCDHEC currently maintains a list of statewide animal feeding operations (AFO) categorized by the type of facility (cattle, swine, poultry) and size which is defined by the specific number of animal units (large, medium, small).

Table 3-3 lists the broiler AFO facilities located in each HUC derived from the SCDHEC statewide list of AFOs. All the AFOs are classified as no discharge facilities. No AFO facilities are located in the South Fork Edisto River watershed. There are currently two large and four medium poultry operations located in Rocky Springs Creek watershed. There were three other medium broiler facilities that were operation between 1998 and 2002 in Rocky Springs Creek watershed that are no longer active. Similarly, there is one large and three medium poultry operations in the Goodland Creek watershed. In addition, there was one small swine facility in the Goodland Creek watershed that became inactive in March 1999 and one large broiler facility that became inactive in 2004.

While Table 3-3 and Figure 3-1 present the spatial distribution of specific AFO facilities upstream of each 303(d)-listed WQM station, the following information is provided to summarize the estimated manure production and potential contributions of fecal coliform loading for different livestock. County agricultural census data, if available, were used to estimate the number of livestock for each watershed (USDA 2002).

Table 3-3 Animal Feeding Operations

NPDES	TYPE	DESIGN COUNT	AFO SIZE	COUNTY NAME	HUC CODE14
HUC 03050204010					
ND0069302	BROILERS	108000	medium	Aiken	03050204010060
ND0071803	BROILERS	64500	medium	Aiken	03050204010060
ND0072290	BROILERS	102000	medium	Aiken	03050204010060
ND0076988	BROILERS	102000	medium	Aiken	03050204010060
ND0078760	BROILERS	140000	large	Aiken	03050204010060
ND0081566	BROILERS	141600	large	Aiken	03050204010060
HUC 03050204060					
ND0083569	BROILERS	109600	medium	Orangeburg	03050204060010
ND0083569	BROILERS	109600	medium	Orangeburg	03050204060010
ND0082457	BROILERS	135000	large	Orangeburg	03050204060020
ND0082554	BROILERS	90000	medium	Orangeburg	03050204060020

Cattle: A 1,000-pound beef or dairy cow produces approximately 11 tons and 15 tons of manure per year, respectively. Assuming the average cow weighs 750 pounds and manure production is 12 tons per animal per year, 100 cows would produce approximately 2.5 tons per day. These statistics were used to estimate manure production from cattle for each watershed presented in Table 3-4. The number of cattle within each WQM station watershed was estimated by dividing the number of cattle in each county by the total acres of pasture land in each county. This cattle density value was then multiplied by the number of acres of pasture land in each watershed.

Table 3-4 Estimated Tons of Manure by WQM Station

WQM Station	Number of Cattle and Calves in Watershed	Tons of Manure Deposited Daily in Watershed
E-002	170	4
RS-01034	185	5
E-036	720	18

The SCDHEC has verified that cattle from small farms throughout all three watersheds have direct access to the creeks. For many farmers these creeks are the only water source for their cattle. With the typical low flows of South Fork Edisto River, Rocky Springs Creek, and Goodland Creek watersheds (2.1, 9.6, and 13.5 cubic feet per second [cfs], respectively), a small amount of fecal waste deposited into those creeks from a few cattle could potentially result in temporary exceedance of the WQSs. Fecal coliform loading from cattle manure, whether deposited directly into the creeks or transported from land by rainfall runoff, is a likely source of fecal coliform in all three watersheds.

Swine: According to the USDA census data, there were 72, 1,846, and 98,629 hogs and pigs in Edgefield, Aiken, and Orangeburg County, respectively. (USDA 2002). However, it is difficult to estimate the population of swine in each 303(d)-listed watershed since it cannot be assumed that swine are evenly distributed throughout each county. Furthermore, all three watersheds cover only a small portion of their respective county and, unlike cattle, swine do not have direct access to creeks. The combination of these factors suggests that fecal coliform loading from swine is negligible in the South Fork Edisto River and Rocky Springs Creek watersheds. The individual swine AFO located in the Goodland Creek watershed (WQM station E-036) is no longer active but may have been a minor source of fecal coliform load.

Poultry: In general, 2002 USDA census data estimated approximately 4,633,022 and 1,886,422 broilers in Aiken and Orangeburg County, respectively (USDA 2002). The estimated number of broilers in Edgefield County is undisclosed in both the 1997 and 2002 census data. The ASAE manure production rate estimate for chickens was 11.4 billion fecal coliform per chicken per day (ASAE 1998). There are no poultry AFOs located upstream of WQM station E-002; however, there may be some small farms with broilers located in the South Fork Edisto River watershed. It is difficult to estimate the population of poultry in each 303(d)-listed watershed since it cannot be assumed that broilers are evenly distributed throughout each county. Furthermore, all three watersheds cover only a small portion of their respective county and, unlike cattle, poultry do not have direct access to creeks.

There are approximately 98 fields totaling 1,825 acres permitted for animal waste application from poultry and swine facilities within these watersheds. Table 3-5 provides a summary of the land application field acreage based on SCDHEC data within the watersheds of each WQM station.

Table 3-5 Acreage of Land Application Fields within Watersheds of Each WQM Station

WQM Station	Acres of Land Application Fields	AFO Type
E-002	29	NA
RS-01034	788	Poultry
E-036	1008	Poultry

All these land application fields may not actually be in use; SCDHEC estimates represent a total number of permitted land application sites, not operating disposal sites. Improperly applied manure is a possible source of fecal coliform bacteria within the three watersheds. It is important to note that insufficient data are available to adequately estimate fecal coliform concentrations in stormwater runoff from land application fields where manure is applied. These operations are permitted; therefore, problems are managed through SCDHEC enforcement mechanisms.

The combination of these factors indicate that poultry operations in Aiken and Orangeburg Counties are a minor potential source of fecal coliform loading in Rocky Springs Creek and Goodland Creek watersheds, and a negligible source in South Fork Edisto River watershed.

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

According to the 1990 U.S. census, there were 104, 164, and 385 OSWD systems in the South Fork Edisto River, Rocky Springs Creek, and Goodland Creek watersheds. The density of OSWD systems within each watershed was estimated by dividing the number of OSWD systems in each census tract by the number of acres in each census tract. This density was then applied to the number of acres of each census tract within a WQM station watershed. Census tracts crossing a watershed boundary required an additional calculation to estimate the number of OSWD systems based on the proportion of the census tracking falling within each watershed. This step involved adding all the OSWD systems for each whole or partial census tract. Since subdivisions are built on large land tracts (hundreds of acres) the number of OSWD systems per 100 acres is easier to visualize; therefore, the following equation was used to estimate the number of OSWD systems as presented in Table 3-6:

OSWD systems 100 acres = (number of OSWD tanks / number of acres in the watershed) x 100

Table 3-6 OSWD Systems Summary

Watershed	Onsite Wastewater Systems	Onsite Wastewater Systems per 100-acres
E-002	104	2.9
RS-01034	164	1.0
E-036	385	1.6

Over time, most OSWD systems operating at full capacity will fail. OSWD system failures are also proportional to the adequacy of a state's minimum design criteria (Hall 2002). Failures include surface ponding or runoff or failure of treatment prior to effluent mixing with groundwater. Fecal coliform-contaminated groundwater discharges to creeks through springs and seeps. Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range or even larger would cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSWD systems per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1986). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSWD systems experience malfunctions during the year (U.S. Census Bureau 1995). Fecal coliform loading from failing OSWD tanks can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater.

The Department of Health and Environmental Control, Regulations 61-56 of the State of South Carolina Code of Regulations do not require a minimum lot size, but requires minimum setbacks, such as property lines, that dictate the required size of each individual lot. The minimum setback distance to a surface water body is 50 linear feet. There is no single family residence requirement to reserve a backup area should the original OSWD system fail. According to the National Small Flows Clearinghouse (NSFC), SC does not require an inspection of the OSWD systems prior to the sale of a property (NSFC 1996).

Failing OSWD systems can contribute to fecal coliform WQS exceedances. OSWD systems are considered to be a minor source of fecal coliform loading in all three watersheds given their estimated density.

3.2.4 Domestic Pets

Pets can be a major contributor of fecal coliform to streams. A study conducted by Weiskel *et al.* (1996) found that pets produce 450 million fecal coliform per animal per day. On average nationally, there are 0.58 dogs and 0.66 cats per household (American Veterinary Medical Association 2004). Using the U.S. census data (U.S. Census Bureau 2000), dog and cat populations can be estimated for the counties as shown in Table 3-7.

A study in a Washington, D.C. suburb found that dogs produce approximately 0.42 pounds of fecal waste per day (Thorpe 2003). A comparable number for waste produced by cats was not available; therefore, only the estimated tons per day of dog waste produced is provided in Table 3-7. Fecal coliform from dogs and cats transported by runoff from urban and suburban areas can be a potential source of loading. These calculations were provided for informational purposes to demonstrate that pet populations are higher in urbanized areas and that they can be a significant source of fecal coliform.

It is difficult to derive the density of dogs and cats from the estimated county totals in Table 3-7 given that all three watersheds occupy only a small percentage of land area in the three counties. The small number of households in the South Fork Edisto River watershed suggests that fecal coliform contributions from pets are negligible. Similarly, fecal coliform contributions from pets are negligible in the Rocky Springs Creek and Goodland Creek watersheds due to the even smaller number of households and household pets in these watersheds.

Table 3-7 Estimated Numbers of Household Pets

County	Number of Households	Number of Dogs	Number of Cats	Tons of Dog Waste per Day
Edgefield	8,270	4,797	5,458	1.0
Aiken	55,587	32,240	36,687	6.8
Orangeburg	34,118	19,788	22,518	4.2

3.3 Summary of Fecal Coliform Sources

The following data and information were used to identify point and nonpoint sources of fecal coliform and to describe pathways of fecal coliform loading at each WQM station.

- Watershed land use and land cover;
- Watershed soil characteristics;
- Fecal coliform production rate;
- Agricultural census data, including livestock populations;
- Households served by OSWD systems;
- AFOs;
- Land application of poultry manure;
- Domestic pet census data; and
- NPDES permitted point sources and discharge monitoring reports.

Based on the foregoing information and data presented and analyzed in this report, the following inferences can be made regarding the sources (point and nonpoint) and magnitude of fecal coliform contributions to the 303(d)-listed WQM stations in the Edisto River Basin.

3.3.1 South Fork Edisto River Watershed

South Fork Edisto River watershed is located entirely in Edgefield County, SC, and includes two WQM stations, E-001 and E-002 within HUC 03050204010. Station E-001 is located upstream of the WWTP and is not listed for fecal coliform impairment, only station E-002 is listed as impaired for fecal coliform and is discussed in this report.

WQM Station E-002, South Fork of Edisto River at S-19-57

The watershed for WQM station E-002 contains 3,628 acres, and the estimated median flow is only 4.8 cfs. This watershed contains the most urban land use among the three watersheds analyzed in this report (~9 percent). The watershed is largely row crops and pastureland (~50 percent combined), with approximately 35 percent forested land. There are only an estimated 170 head of cattle in this watershed, with projected deer density ranging from 15 to 30 individuals per square mile. Wildlife and livestock are nonhuman sources contributing to fecal coliform loading. Domestic pets are not expected to be a major source due to low human population density.

Seventy-four water samples were collected from this watershed from 1990 through 2001. Analysis indicated that 17 percent of the water samples contained fecal coliform concentrations above the WQS. The one active NPDES discharger in this watershed is not considered a contributor of fecal coliform loading given its excellent compliance record. There are an estimated 104 OSWD systems in the watershed, with an estimated density of 2.9 systems per 100 acres, which is below the guideline of 6.25 systems per 100 acres proposed by Canter and Knox (1986). With respect to a potential relationship between rainfall and fecal coliform excursions in this watershed, for the period examined (51 data points) it appeared there is little relationship between fecal coliform concentration and rainfall suggesting that fecal coliform exceedances may be associated with sources that are not significantly affected by rainfall. Fecal coliform sources within this watershed include a combination of failing OSWD systems, SSOs, wildlife, and cattle watering in the creek. Fecal coliform contribution from leaking sewer lines and domestic pets is likely negligible because almost all sewer lines and residential areas are located upstream of the non-impaired WQM station E-001.

3.3.2 Rocky Springs Creek Watershed

The Rocky Springs Creek watershed drains 16,221-acres and includes WQM station RS-01034 within HUC 03050204010.

WQM Station RS 01034, Rocky Springs Creek at Moore Road of County Road 264, 7 Miles Northeast of Aiken

WQM station RS-01034 in the Rocky Springs Creek watershed has an estimated median flow of 21.9 cfs and the amount of urban land use is insignificant within this watershed (<1 percent). This watershed also is composed of a high percentage of forest (~65 percent), with approximately 21 percent in pastureland and row crops combined. There are an estimated 185 head of cattle in this watershed, with projected deer density ranging from 15 to 30 individuals per square mile. Wildlife and livestock are nonhuman sources contributing to fecal coliform loading. Domestic pets are expected to be a negligible source due to low human population density.

Only 11 water samples were collected from this watershed in 2001. Analysis indicated that two of the water samples (18 percent) contained fecal coliform concentrations above the WQS. There is no NPDES discharger in this watershed. There are an estimated 164 OSWD systems in the watershed, with an estimated density of one system per 100 acres, which is below the guideline of 6.25 systems per 100 acres proposed by Canter and Knox (1986).

With respect to a potential relationship between rainfall and fecal coliform excursions in this watershed, for the period examined (8 data points) there were 4 days in which rainfall exceeded 0.1 inch. The only exceedance during this period occurred on October 10, 2001 where the 3-day average rainfall was 0.0 inch. The maximum fecal coliform value of 1,200 cfu/100 ml occurred on November 15, 2001, where no measurable rainfall was recorded. This suggests little relationship between wet weather conditions and higher fecal coliform concentrations. Although to fully determine this relationship, additional fecal coliform measurements may be needed. Fecal coliform sources within this watershed include a combination of failing OSWD systems, birds and wildlife, land application fields, and cattle watering in the creek.

3.3.3 Goodland Creek Watershed

The Goodland Creek watershed drains 23,821 acres and includes WQM station E-036 within HUC 03050204060.

WQM Station E-036, Goodland Creek at SC 4, 2.1 Miles East of Springfield

WQM station E-036 in the Goodland Creek watershed has an estimated median flow of 31 cfs. The amount of urban land use is insignificant within this watershed (<1 percent). This watershed also is composed of a high percentage of pastureland and row crops combined (~45 percent), and with less extensive forested area (~39 percent). Despite the relatively larger watershed compared to South Fork Edisto River and Rocky Springs Creek watersheds, there are relatively more extensive cattle activities in this watershed (an estimated 720 head of cattle). The projected deer density is less than the other two watersheds with only less than 15 individuals per square mile. As with the above WQM stations, there are nonhuman sources potentially contributing to fecal coliform loading, including wildlife and livestock. Domestic pets are expected to be a negligible source due to relatively low human population density.

Ninety-one water samples were collected from this watershed from 1990 through 2002. Analysis indicated that 30 percent of the water samples contained fecal coliform concentrations above the WQS. The one active NPDES discharger in this watershed is not considered a contributor of fecal coliform loading given its excellent compliance record. There are an estimated 385 OSWD systems in the watershed, with an estimated density of 1.6 systems per 100 acres, which is well below the guideline of 6.25 systems per 100 acres proposed by Canter and Knox (1986).

With respect to a potential relationship between rainfall and fecal coliform excursions in this watershed, for the period examined (91 data points) there were only 5 days in which rainfall exceeded 0.1 inch, and during those days it appears that fecal coliform densities for three measurements were elevated relative to the days during which little or no rainfall occurred (by far the majority). This suggests that wet weather events may have some influence on fecal coliform concentrations. Fifteen other exceedances of the WQS occurred on dates when the 3-day average rainfall was 0.0 inch. There were only two SSOs reported in the watershed and neither reached a receiving water so SSOs have not contributed to excessive fecal coliform concentrations. This suggests that sources not significantly affected by rainfall influence fecal coliform concentrations. Fecal coliform sources within this watershed include a combination of failing OSWD systems, birds and wildlife, land application fields, and cattle watering in the creek.

SECTION 4
TECHNICAL APPROACH AND METHODOLOGY

A TMDL is defined as the total quantity of a pollutant that can be assimilated by a receiving water body while achieving the WQS. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for uncertainty concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

TMDL = Σ WLA + Σ LA + MOS

The objective of the TMDL is to estimate allowable pollutant loads and to allocate these loads to the known pollutant sources in the watershed so the appropriate control measures can be implemented and the WQS achieved. 40 CFR §130.2 (1) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For fecal coliform, TMDLs are expressed as cfu per day where possible or as percent reductions, and represent the maximum one-day load the stream can assimilate while still attaining the WQS.

4.1 Using Load Duration Curves to Develop TMDLs

LDCs are graphical analytical tools that illustrate the relationships between stream flow and water quality and assist in decision making regarding this relationship. Flow is an important factor affecting the loading and concentration of fecal coliform. Both point and nonpoint source loads of pollutants to streams may be affected by changes in flow regime. Given an understanding of the potential loading mechanisms of fecal coliform and how those mechanisms relate to flow conditions, it is possible to infer and quantify the major contributing sources of pollutants to a stream by examining the relationship between flow and pollutant concentration or load. The fecal coliform TMDLs presented in this report are designed to be protective of typical flow conditions. The following discussion provides an overview of the approach used to develop LDCs and TMDL calculations. Results and calculations are presented in Section 5.

4.2 Explanation of the Steps Used to Perform TMDL Calculations

The following discussion provides a summary of the steps involved in the calculation of the key components of the fecal coliform TMDLs presented in Section 5 of this report.

Step 1: Develop Flow Percentiles for each WQM Station. Direct flow measurements are not available for all of the WQM stations addressed in this report. This information, however, is vitally important to understanding the relationship between water quality and stream flow. Therefore, to characterize flow, in some cases flow data were derived from a flow estimation model for each relevant watershed. Flow data to support development of flow duration curves will be derived for each SCDHEC WQM station from USGS daily flow records (USGS 2005a) in the following priority:

i) In cases where a USGS flow gage coincides with, or occurs within one-half mile upstream or downstream of a SCDHEC WQM station and simultaneous daily flow data matching the water quality sample date are available, these flow measurements will be used.

ii) If flow measurements at the coincident gage are missing for some dates on which water quality samples were collected, gaps in the flow record will be filled, or the record extended, by estimating flow based on measured streamflows at a nearby gage. First, the most appropriate nearby stream gage is identified. All flow data are first log-transformed to linearize the data because flow data are highly skewed. Linear regressions are then developed between 1) daily streamflow at the gage to be filled/extended; and 2) streamflow at all gages within 95 miles that have at least 300 daily flow measurements on matching dates. The station with the strongest flow relationship, as indicated by the highest correlation coefficient (r-squared value), is selected as the index gage. R-squared indicates the fraction of the variance in flow explained by the regression. The regression is then used to estimate flow at the gage to be filled/extended from flow at the index station. Flows will not be estimated based on regressions with r-squared values less than 0.25, even if that is the best regression. This value was selected based on familiarity with using regression analysis in estimating flows. In some cases, it will be necessary to fill/extend flow records from two or more index gages. The flow record will be filled/extended to the extent possible based on the strongest index gage (highest r-squared value), and remaining gaps will be filled from successively weaker index gages (next highest r-squared value), and so forth.

iii) In the event no coincident flow data are available for a WQM station, but flow gage(s) are present upstream and/or downstream, flows will be estimated for the WQM station from an upstream or downstream gage using a watershed area ratio method derived by delineating subwatersheds, and relying on the Natural Resources Conservation Service runoff curve numbers and antecedent rainfall condition. Drainage subbasins will first be delineated for all impaired 303(d)-listed WQM stations, along with all USGS flow stations located in the 8-digit HUCs with impaired streams. All USGS gage stations upstream and downstream of the subwatersheds with 303(d)-listed WQM stations will be identified.

Step 2: Develop Flow Duration Curves. Flow duration curves serve as the foundation of LDC TMDLs. Flow duration curves are graphical representations of the flow regime of a stream at a given site. The flow duration curve is an important tool of hydrologists, utilizing the historical hydrologic record from stream gages to forecast future recurrence frequencies.

Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations exceeding that flow is calculated. The flow rates for each 5^{th} percentile for each WQM station are provided in Appendix D. The flow value is read from the ordinate (y-axis), which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the abscissa, which is numbered from 0 to 100 percent, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100 percent, indicating that flow has equaled or exceeded this value 100 percent of the time, while the highest measured flow is found at an exceedance frequency of 0 percent. The median flow occurs at a flow exceedance frequency of 50 percent.

While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than 1 year of observations, and encompasses inter-annual and seasonal variations. Ideally, the drought and flood of record are included in the observations. For this purpose, the long term flow gaging stations operated by the USGS are ideal.

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow duration of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. However, at extreme low and high flow values, flow duration curves may exhibit a “stair step” effect due to the USGS flow data rounding conventions near the limits of quantitation. The overall slope of the flow duration curve is an indication of the flow variability of the stream.

Flow duration curves can be subjectively divided into several hydrologic condition classes. These hydrologic classes facilitate the diagnostic and analytical uses of flow and LDCs. The hydrologic classification scheme utilized in the development of these TMDLs is presented in Table 4-1.

Table 4-1 Hydrologic Condition Classes

Flow Duration Interval	Hydrologic Condition Class*
0-10%	High flows
10-40%	Moist Conditions
40-60%	Mid-Range Conditions
60-90%	Dry Conditions
90-100%	Low Flows

Source: Cleland 2003.

Step 3: Estimate Current Point Source Loading. In SC, NPDES permittees that discharge treated sanitary wastewater must meet the state WQS for fecal coliform bacteria at the point of discharge (see discussion in Section 2). However, for TMDL analysis it is necessary to understand the relative contribution of WWTPs to the overall pollutant loading and their general compliance with required effluent limits. The fecal coliform load for continuous point source dischargers was estimated by multiplying the monthly average flow rates by the monthly geometric mean and a conversion factor. The data were extracted from each point source’s DMR from 1998 through 2003. The 90th percentile value of the monthly loads was used to express the estimated existing load in cfu/day. The current pollutant loading from each permitted point source discharge as summarized in Section 3 was calculated using the equation below.

*Point Source Loading = monthly average flow rates (million gallons day [mgd]) * geometric mean of corresponding fecal coliform concentration * unit conversion factor*

Where:

unit conversion factor = 37,854,120 100-ml/million gallons (mg)

Step 4: Estimate Current Loading and Identify Critical Conditions. It is difficult to estimate current nonpoint loading due to lack of specific water quality and flow information that would assist in estimating the relative proportion of non-specific sources within the watershed. Therefore, existing instream loads were used as a conservative surrogate for nonpoint loading. It was calculated by multiplying the concentration by the flow matched to the specific sampling date. Then using the hydrologic flow intervals shown in Table 4-1, the 90th percentile nonpoint loading within each of the intervals would then represent the nonpoint loading estimate for that interval. Existing loads have been estimated using a regression-based relationship developed between observed fecal coliform loads and flow or flow exceedance percentile

In many cases, inspection of the LDC will reveal a critical condition related to exceedances of WQSs. For example, criteria exceedances may occur more frequently in wet weather, low flow conditions, or after large rainfall events. The critical conditions are such that if WQSs were met under those conditions, WQSs would likely be met overall. Given that the instantaneous fecal coliform criterion indicates that no more than 10 percent of samples should exceed 400 cfu/100 ml, it is appropriate to evaluate existing loading as the 90th percentile of observed fecal coliform concentrations. Together with the MOS, the reduction calculated in this way should ensure that no more than 10 percent of samples will exceed the criterion.

Existing loading is calculated as the 90th percentile of measured fecal coliform concentrations under each hydrologic condition class multiplied by the flow at the middle of the flow exceedance percentile. For example, in calculating the existing loading under dry conditions (flow exceedance percentile = 60-90%), the 75th percentile exceedance flow is multiplied by the 90th percentile of fecal coliform concentrations measured under the 60-90th percentile flows. The “high flow” or “low flow” hydrologic conditions will not be selected as critical conditions because these extreme flows are not representative of typical conditions, and few observations are typically available to reliably estimate loads under these conditions. This methodology results in multiple estimates of existing loading. However, TMDLs are typically expressed as a load or concentration under a single scenario. Therefore, these TMDLs will assume that if the highest percent reduction associated with the difference between the existing loading and the LDC (TMDL) is achieved, the WQS will be attained under all other flow conditions.

Step 5: Develop Fecal Coliform Load Duration Curves (TMDL). LDCs are based on flow duration curves, with the additional display of historical pollutant load observations at the same location, and the associated water quality criterion or criteria. In lieu of flow, the ordinate is expressed in terms of a fecal coliform load (cfu/day). The curve represents the single sample water quality criterion for fecal coliform (400 cfu/100 ml) expressed in terms of a load through multiplication by the continuum of flows historically observed at the site. The points represent individual paired historical observations of fecal coliform concentration and flow. Fecal coliform concentration data used for each WQM station are provided in Appendix A. The fecal coliform load (or the y-value of each point) is calculated by multiplying the fecal coliform WQS by the instantaneous flow (cfs) from the same site and time, with appropriate volumetric and time unit conversions.

*TMDL (cfu/day) = WQS * flow (cfs) * unit conversion factor*

Where: WQS = 400 cfu/100 ml

*unit conversion factor = 24,465,525 ml*s / ft^3*day*

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured flow; in other words, the percent of historical observations that equal or exceed the measured flow. It should be noted that the site daily average stream flow is often used if an instantaneous flow measurement is not available. Fecal coliform loads representing exceedance of water quality criteria fall above the water quality criterion line.

Step 6: Develop LDCs with MOS. An LDC depicting slightly lower estimates than the TMDL is developed to represent the TMDL with MOS. An explicit MOS is defined for each TMDL by establishing an LDC using 95 percent of the TMDL value (5 percent of the 400 cfu/100 ml instantaneous water quality criterion) to slightly reduce assimilative capacity in the watershed, thus providing a 5 percent MOS. The MOS at any given percent flow exceedance, therefore, is defined as the difference in loading between the TMDL and the TMDL with MOS.

Step 7: Calculate WLA. As previously stated, the pollutant allocation for point sources is defined by the WLA. A point source can be either a wastewater (continuous) or stormwater (MS4) discharge. However, as mentioned earlier, there is no MS4 discharge in the three watersheds of concern; therefore, point source is defined as wastewater discharge only in this report.

The LDC approach recognizes that the assimilative capacity of a water body depends on the flow, and that maximum allowable loading will vary with flow condition. TMDLs can be expressed in terms of maximum allowable concentrations, or as different maximum loads allowable under different flow conditions, rather than single maximum load values. This concentration-based approach meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs "...in terms of mass per time, toxicity, or other appropriate measures...." and is consistent with USEPA's *Protocol for Developing Pathogen TMDLs* (USEPA 2001).

WLA for WWTP. Wasteload allocations may be set to zero in cases of watersheds with no existing or planned continuous permitted point sources. For watersheds with permitted point sources, wasteloads may be derived from NPDES permit limits. A WLA may be calculated for each active NPDES wastewater discharger using a mass balance approach as shown in the equation below. The permitted average flow rate used for each point source discharge and the water quality criterion concentration are used to estimate the WLA for each wastewater facility. All WLA values for each subwatershed are then summed to represent the total WLA for the watershed.

*WLA (cfu/day) = WQS * flow * unit conversion factor*

Where: WQS = 400 cfu /100 ml

flow (mgd) = permitted flow or design flow (if unavailable)

unit conversion factor = 37,854,120 100-ml/mg

Step 8: Calculate LA. Load allocations can be calculated under different flow conditions as the water quality target load minus the WLA. The LA is represented by the area under the LDC but above the WLA. The LA at any particular flow exceedance is calculated as shown in the equation below.

$$\mathbf{LA = TMDL - MOS - \sum WLA}$$

However, to express the LA as an individual value, the LA is derived using the equation above but at the median point of the hydrologic condition class requiring the largest percent reduction as displayed in the LDCs provided in Appendix E. Thus, an alternate method for expressing the LA is to calculate a PRG for fecal coliform. Load allocations are calculated as percent reductions from current estimated loading levels required to meet water quality criteria.

Step 9: Estimate WLA Load Reduction. The WLA load reduction was not calculated because it was assumed that the continuous dischargers (NPDES permitted WWTPs) are adequately regulated under existing permits and, therefore, no WLA reduction would be required.

Step 10: Estimate LA Load Reduction. After existing loading estimates are computed for the three different hydrologic condition classes described in Step 2, nonpoint load reduction estimates for each WQM station are calculated by using the difference between estimated existing loading (Step 5) and the LDC (TMDL). This difference is expressed as a percent reduction, and the hydrologic condition class with the largest percent reduction is selected as the critical condition and the overall PRG for the LA. Results of all these calculations are discussed in Section 5.

SECTION 5
TMDL CALCULATIONS

5.1 Results of TMDL Calculations

The calculations and results of the TMDLs for the 303(d)-listed WQM stations in the Edisto River Basin are provided in this section. The methods for deriving these results are specified in Section 4.

5.2 Critical Conditions and Estimated Loading

USEPA regulations (40 CFR §130.7(c)(1)) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. Available instream WQM data were evaluated with respect to flows and magnitude of water quality criteria exceedance using LDCs. Load duration curve analysis involves using measured or estimated flow data, instream criteria, and fecal coliform concentration data to assess flow conditions in which water quality exceedances are occurring (SCDHEC 2003). The goal of flow weighted concentration analysis is to compare instream observations with flow values to evaluate whether exceedances generally occur during low or high flow periods (SCDHEC 2003).

To calculate the fecal coliform load at the WQS, the instantaneous fecal coliform criterion of 400 cfu/100 ml is multiplied by the flow rate at each flow exceedance percentile, and a unit conversion factor ($24{,}465{,}525\ ml*s / ft^3*day$). This calculation produces the maximum fecal coliform load in the stream without exceeding the instantaneous standard over the range of flow conditions.

The allowable fecal coliform loads at the WQS establish the TMDL and are plotted versus flow exceedance percentile as an LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a fecal coliform load.

To estimate existing loading, the loads associated with individual fecal coliform observations are paired with the actual or estimated flow at the same site on the same date. Fecal coliform loads are then calculated by multiplying the measured fecal coliform concentration by the flow rate and a unit conversion factor of $24{,}465{,}525\ ml*s / ft^3*day$. The associated flow exceedance percentile is then matched with the measured flow from the tables provided in Appendix D. The observed fecal coliform loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of fecal coliform. Points above the LDC indicate the fecal coliform instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample met the WQS.

The LDC approach recognizes that the assimilative capacity of a water body depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading, and load reductions required to meet the TMDL water quality target can also be calculated under different flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required. Given that the instantaneous fecal coliform criterion indicates that no more than 10 percent of samples should exceed 400 cfu/100 ml, it is appropriate to evaluate existing loading as the 90^{th} percentile of observed fecal coliform concentrations. Together with the MOS, the reduction calculated in this way should ensure that no more than 10 percent of samples will exceed the criterion.

Existing loading is calculated as the 90th percentile of measured fecal coliform concentrations under each hydrologic condition class multiplied by the flow at the middle of the flow exceedance percentile. For example, in calculating the existing loading under dry conditions (flow exceedance percentile = 60-90 percent), the 75th percentile exceedance flow is multiplied by the 90th percentile of fecal coliform concentrations measured under 60-90th percentile flows.

After existing loading and percent reductions are calculated under each hydrologic condition class, the critical condition for each TMDL is identified as the flow condition requiring the largest percent reduction. In the example shown in Table 5-1 for WQM station E-036, while load reductions are required under all the hydrologic condition classes, the critical condition occurs under "Mid-Range Conditions," when a 34 percent loading reduction is required to meet the WQS.

Table 5-1 Estimated Existing Fecal Coliform Loading for Station E-036 (Goodland Creek) Critical Condition Highlighted

Hydrologic Condition Class*	Estimated Existing Loading (cfu/100 ml)	Percent Reduction Required
High Flows	4.00E+11	NA
Moist Conditions	4.25E+11	3%
Mid-Range Conditions	4.37E+11	34%
Dry Conditions	2.98E+11	30%
Low Flows	1.65E+11	NA

* Hydrologic Condition Classes are derived from Cleland 2003.

The LDC for WQM station E-036 shown in Figure 5-1 indicates that actual fecal coliform loads are exceeding the instantaneous load of the WQS primarily during "Mid-Range" conditions. The LDCs were developed for the time period from January 1990 through December 2002 if data were available.

The existing instream fecal coliform load (actual or estimated flow multiplied by observed fecal coliform concentration) is compared to the allowable load for that flow. Any existing loads above the allowable LDCs represent an exceedance of the WQS. For a low flow loading situation, there are typically observations in excess of criteria at the low flow side of the chart. For a high flow loading situation, observations in excess of criteria at the high flow side of the chart are typical. For water bodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when WWTP effluents would dominate the base flow of the impaired water. Based on these characteristics, critical conditions for each WQM station are summarized in Table 5-2.

Figure 5-1 Estimated Fecal Coliform Load and Critical Conditions, Station E-036 (Goodland Creek)

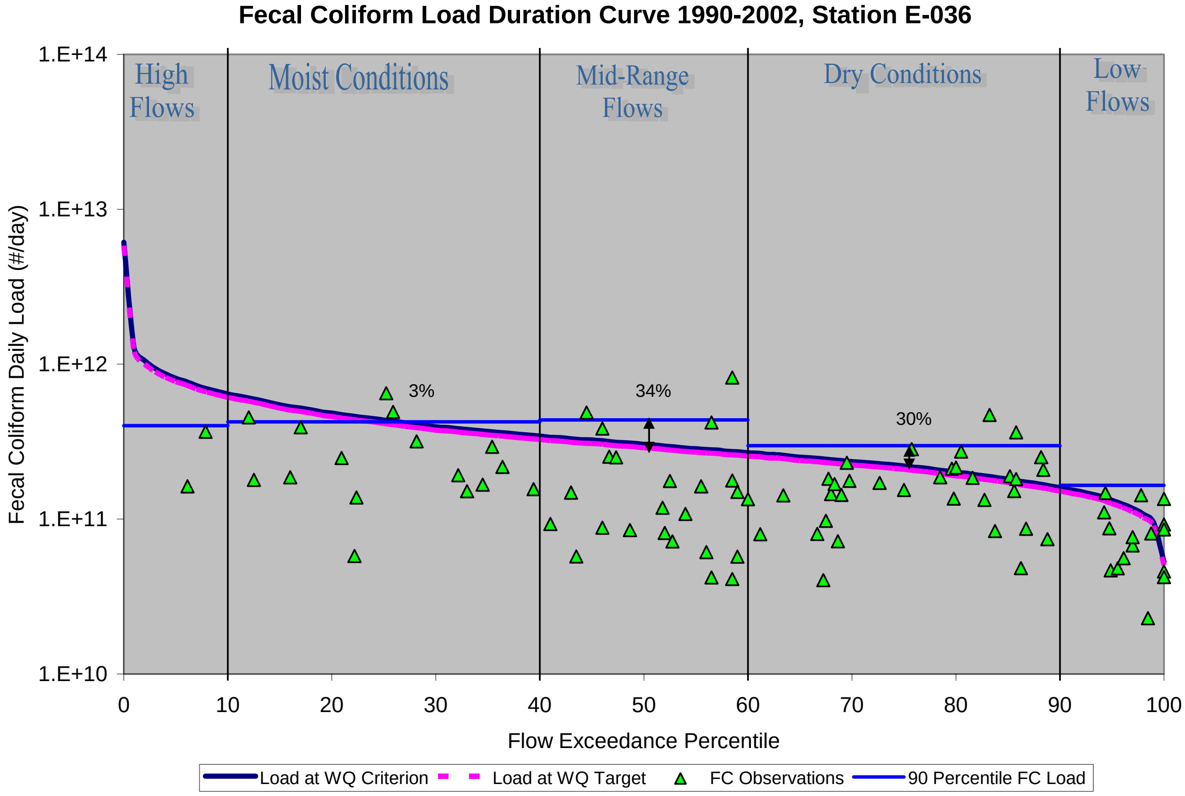


Table 5-2 Summary of Critical Conditions for each WQM Station as Derived from Load Duration Curves

SCDHEC WQM Station	Moist Conditions	Mid-Range Conditions	Dry Conditions	Low Flow
E-002		✱		
RS-01034				✱
E-036		✱		

The existing load for each WQM station was derived from the critical condition line depicted on the LDCs as described above and provided in Appendix E. Estimated existing loading is derived from the 90th percentile of observed fecal coliform loads corresponding to the critical condition identified at each WQM station identified in Table 5-2. This estimated loading is indicative of loading from all sources including continuous point source dischargers, SSOs, failing septic systems, land application fields, wildlife, livestock and pets. The total estimated existing load for each station is provided in Table 5-3.

Table 5-3 Estimated Existing Loading at Each WQM Station

SCDHEC WQM Station	90th Percentile Load Estimation (counts/day)	Flow Exceedance Percentile
E-002	6.20E+10	50
RS-01034	2.35E+11	95
E-036	4.37E+11	50

5.3 Wasteload Allocation

Table 5-4 summarizes the WLA of the permitted NPDES facilities within the watershed of each WQM station. The WLA for each facility is derived from the following equation:

*WLA = WQS * flow * unit conversion factor (#/day)*

Where: WQS = 400 cfu/100 ml

flow (mgd) = permitted flow

unit conversion factor = 37,854,120 100-ml/mg

Table 5-4 Wasteload Allocations for NPDES-Permitted Facilities

Water Quality Monitoring Station / Permittee	NPDES Permit Number	Flow (mgd)	Load (cfu/day)
HUC 03050204010			
E-002 South Fork of Edisto River			
ECW&SA/JOHNSTON #1 PLANT	SC0025691	0.968	1.47E+10
HUC 03050204060			
E-036 Goodland Creek			
SPRINGFIELD/ PLANT #2	SC0023281	0.06	9.08E+08

The WLA for each continuous point source is included in the TMDL calculation for the corresponding WQM station. In the case of Rocky Springs Creek watershed, where there is no NPDES WWTP discharge, the WLA is set to zero.

5.4 Load Allocation

As discussed in Section 3, nonpoint source fecal coliform loading to the receiving streams of each WQM station emanate from a number of different sources. As discussed in Section 4, nonpoint source loading was estimated and depicted under all flow conditions using LDCs. Figure 5-1 displays the LDC for E-036 which displays the relationships between the TMDL water quality target, the MOS, and the percent reduction goal (PRG) that can serve as an alternative for expressing the LA. The data analysis and the LDCs demonstrate that exceedances at most of the WQM stations are the result of nonpoint source loading from sources such as failing septic systems, cattle in streams, land application fields, and fecal loading from wildlife and domestic pets transported by runoff events. The LAs, calculated as the difference between the TMDL, MOS, and WLA, for each WQM station are presented in Table 5-5.

5.5 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs take into consideration seasonal variation in watershed conditions and pollutant loading. Seasonal variation was accounted for in these TMDLs by using more than 5 years of water quality data (1990-2002) whenever possible and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.6 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the uncertainty associated with calculating the allowable fecal coliform pollutant loading to ensure WQSs are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for uncertainty, then the MOS is considered explicit.

For the explicit MOS the water quality target was set at 380 cfu/100 ml for the instantaneous criterion, which is 5 percent lower than the water quality criterion of 400 cfu/100 ml. The net effect of the TMDL with MOS is that the assimilative capacity of the watershed is slightly reduced. These TMDLs incorporate an explicit MOS by using a curve representing 95 percent of the TMDL as the average MOS. The MOS at any given percent flow exceedance, therefore, can be defined as the difference in loading between the TMDL and the TMDL with MOS. For consistency, the explicit MOS at each WQM station will be expressed as a numerical value derived from the same critical condition as the largest load reduction goal at the respective 25^{th}, 50^{th}, or 75^{th} flow exceedance percentile (see Table 5-3).

There are other conservative elements utilized in these TMDLs that can be recognized as an implicit MOS such as the use of instream fecal coliform concentrations to estimate existing loading. This conservative approach to establishing the MOS will ensure that both the 30-day geometric mean and instantaneous fecal coliform bacteria standards can be achieved and maintained.

5.7 TMDL Calculations

The fecal coliform TMDLs for the 303(d)-listed WQM stations covered in this report were derived using LDCs. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for uncertainty concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS$$

For each WQM station the TMDLs presented in this report are expressed in cfu per day or as a percent reduction. The TMDLs are presented in fecal coliform counts to be protective of both the instantaneous, per day, and geometric mean, per 30-day, criteria. To express a TMDL as an individual value, the LDC is used to derive the LA, the MOS, and the TMDL based on the median percentile of the critical condition (*i.e.*, the median percentile of the hydrologic condition class requiring the greatest percent reduction to meet the instantaneous criterion which is the water quality target). The WLA component of each TMDL is the sum of all WLAs within the contributing watershed of each WQM station which is derived from each NPDES facilities' maximum design flow and the permitted 1-day maximum concentration of 400 cfu/100 ml. The LDC and the simple equation of:

$$\textit{Average LA} = \textit{average TMDL} - \textit{MOS} - \sum \textit{WLA}$$

can provide an individual value for the LA in cfu per day which represents the area under the TMDL target line and above the WLA line. Percent reductions necessary to achieve the water quality target are also provided for all WQM stations as another acceptable representation of the TMDL. Like the LA, the percent reduction is derived from the median percentile of the critical condition (*i.e.*, the median percentile of the hydrologic condition class requiring the greatest percent reduction to meet the instantaneous criterion which is the water quality target). Table 5-5 summarizes the TMDLs for each WQM station within the South Fork Edisto River, Rocky Springs Creek, and Goodland Creek watersheds, and Figures 5-2, 5-3, and 5-4 present the LDCs for the same WQM stations depicting the TMDL, MOS, and WLA.

For the Rocky Springs Creek (WQM Station RS-01034) TMDL, the calculations are based on nonpoint source load reductions occurring during the lowest flows (90 to 100 % flow exceedance). This is atypical for most TMDLs calculated using LDCs and is the result of a variety of characteristics unique to this WQM station. The small data set of only 11 data points collected in 2001, several of which were collected during estimated lowest flows, does not represent a full range of hydrologic conditions typically experienced at this WQM station. Calculating load reductions at the lowest hydrologic flow conditions is associated with a high degree of uncertainty, in part, because the lack of dilution capability could make even a small fecal coliform input appear out of compliance with the WQS. Regardless, it is appropriate to derive the PRG for the LA from the low flow hydrologic condition since this represents the reduction of pollutant loading necessary to achieve WQS. If more data were available, uncertainty would be reduced and possible excursions and LAs/reductions in other flow ranges would become apparent.

Table 5-5 TMDL Summary for WQM Stations in South Fork Edisto River, Rocky Springs Creek, and Goodland Creek Watersheds

SCDHEC WQM Station	WLAs (cfu/ day)	LA (cfu/day or % reduction)	MOS	TMDL (cfu/day or % reduction)	Percent reduction
HUC 0350204010					
E-002	1.47E+10	3.00E+10	2.35E+09	4.70E+10	28
RS-01034	0	8.93E+10	4.70E+09	9.39E+10	62
HUC 0350204060					
E-036	9.08E+08	2.87E+11	1.52E+10	3.03E+11	34

Figure 5-2 TMDL for E-002 South Fork of Edisto River

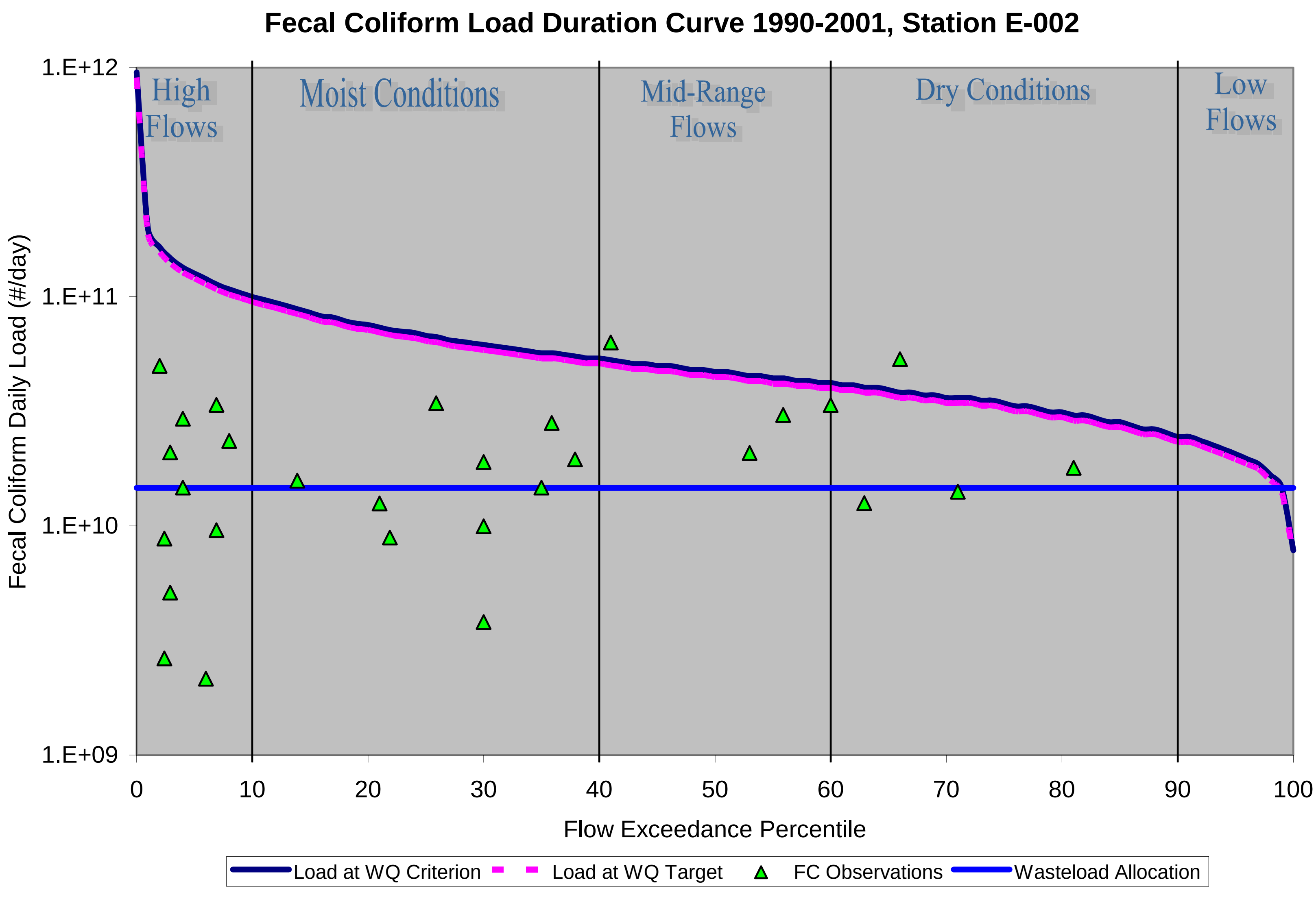
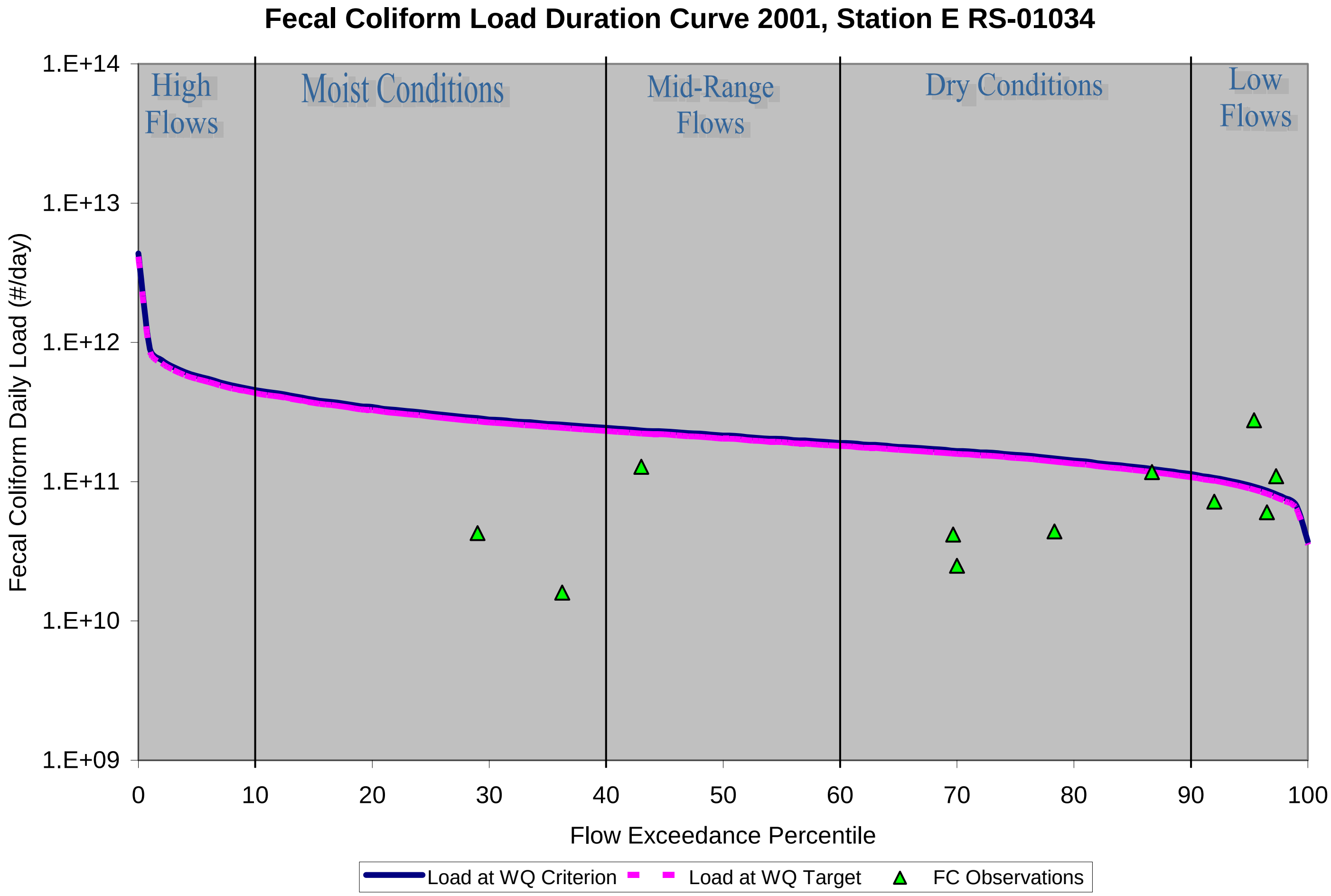
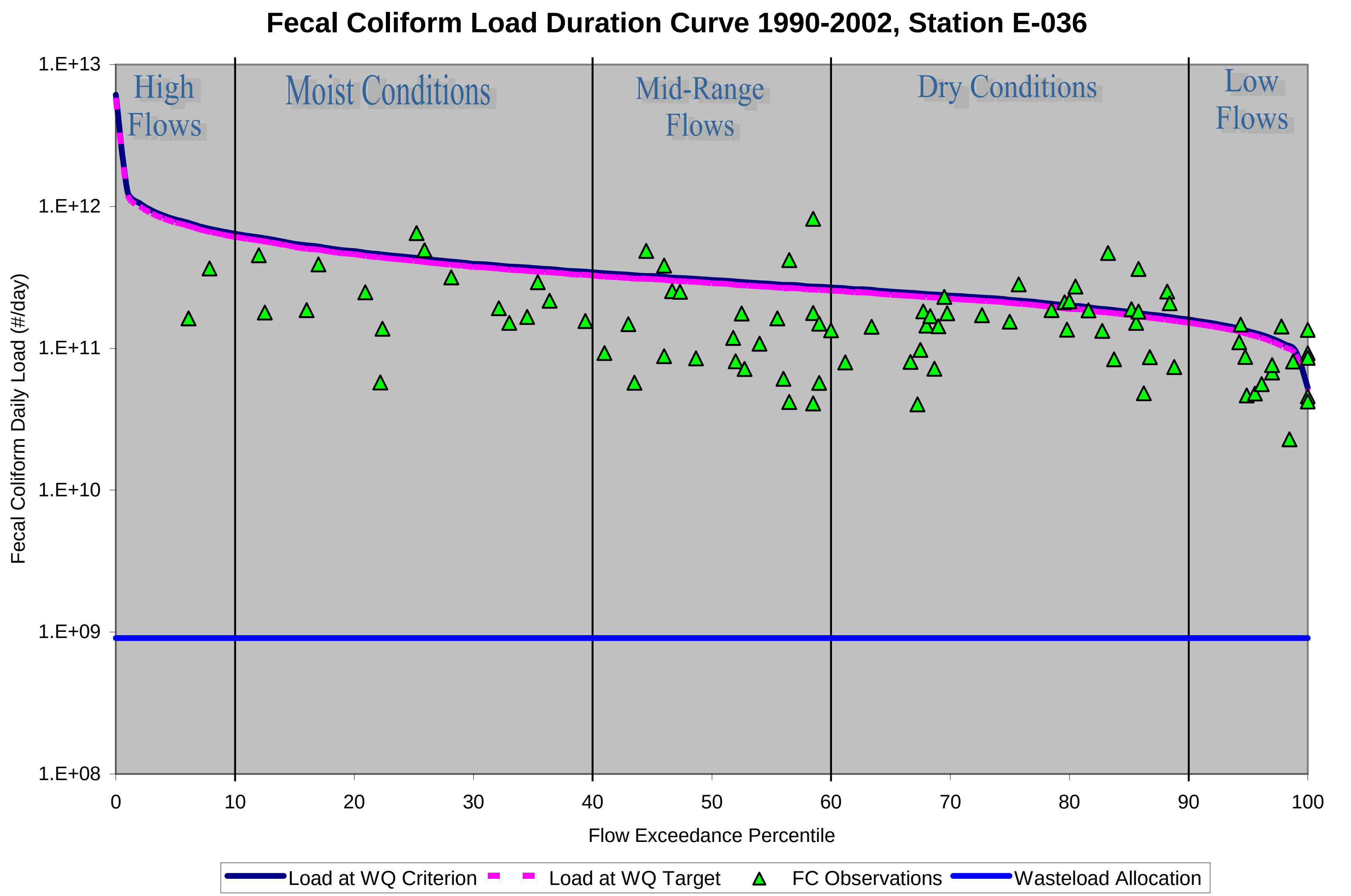


Figure 5-3 TMDL for RS-01034 Rocky Springs Creek



Note: The blue line representing the wasteload allocation along the y-axis is not displayed in this graph because there are no point source dischargers in this watershed.

Figure 5-4 TMDL for E-036 Goodland Creek



SECTION 6
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APPENDIX A
SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
FECAL COLIFORM DATA – 1990 - 2002

APPENDIX B
PLOTS COMPARING PRECIPITATION AND FECAL COLIFORM CONCENTRATIONS

APPENDIX C
NPDES PERMIT DISCHARGE MONITORING REPORT DATA

APPENDIX D
ESTIMATED FLOW EXCEEDANCE PERCENTILES

APPENDIX E
LOAD DURATION CURVES – ESTIMATED LOADING AND CRITICAL CONDITIONS