Total Maximum Daily Load Document

Upper Four Hole Swamp and Tributaries

Stations E-111, RS-01036, RS-04537, RS-07213

Hydrologic Unit Codes 030502050103, 030502050104, 030502050105, 030502050108

Escherichia coli Bacteria Pathogen Indicator

March 2020

Bureau of Water

Technical Document Number 010-2020

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On reverse: Clockwise starting at left: Four Hole Swamp at Highway 210 (E-111); Middle Pen Swamp at Big Buck Boulevard, Goodbys Swamp at Carriage Hill Road.

Abstract

§303(d) of the Clean Water Act (CWA) and EPA's *Water Quality Planning and Management* Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for water bodies that are included on the §303(d) list of impaired waters. A TMDL is the maximum amount of pollutant a waterbody can assimilate while meeting water quality standards for the pollutant of concern. All TMDLs include a waste load allocation (WLA) for any National Pollutant Discharge Elimination System (NPDES)-permitted discharges, a load allocation (LA) for all nonpoint sources, and an explicit and/or implicit margin of safety (MOS). This report describes the development of *Escherichia coli (E. coli)* TMDLs for impaired water quality monitoring (WQM) stations E-111, RS-01036, RS-04537, and RS-07213 in the Upper Four Hole Swamp Watershed located in Orangeburg and Calhoun Counties, South Carolina. These stations are included as impaired for recreational uses on the State's finalized 2016 §303(d) list and draft 2018 303(d) list due to excessive fecal coliform and *E. coli* bacteria. Bacteria counts exceeded recreational use water quality standards at these stations 30 to 63.6% of the time.

Probable sources of fecal contamination include direct and indirect loading from livestock, failing septic systems, surrounding wildlife, and other agricultural activities. The load-duration curve methodology was used to calculate existing and TMDL loads for each impaired station. Existing pollutant loadings and proposed TMDL reductions for critical hydrologic conditions are presented in Table Ab-1. Critical hydrologic conditions were defined as either moist, mid-range, or dry depending on which condition demonstrated the highest load reductions necessary to meet water quality standards. To achieve the target load (slightly less than the maximum load due to the margin of safety) for the Upper Four Hole Swamp Watershed, reductions in the existing loads of 74% at E-111, 56% at RS-01036, 68% at RS-04537, and 55% at RS-07213 will be necessary.

For SCDOT, existing and future NPDES MS4 permittees, compliance with terms and conditions of their NPDES permit is effective implementation of the WLA to the Maximum Extent Practicable (MEP) and demonstrates consistency with the assumptions and requirements of the TMDL. For existing and future NPDES construction and Industrial stormwater permittees, compliance with terms and conditions of their permit is effective implementation of the WLA. Required load reductions in the LA portion of this TMDL can be implemented through voluntary measures and are eligible for CWA §319 grants.

The South Carolina Department of Health and Environmental Control (SCDHEC) recognizes that adaptive management/implementation of these TMDLs might be needed to achieve the water quality standard and we are committed towards targeting the load reductions to improve water quality in the Upper Four Hole Swamp Watershed. As additional data and/or information become available, it may become necessary to revise and/or modify the TMDL target accordingly.

Table Ab1. Total Maximum Daily Loads for Upper Four Hole Swamp Watershed

	Existing Load		TMDL		Margin of Safety		Waste Load Allocation (WLA)			Load Allocation (LA)		
Station	Existing FC Load (cfu/day)	Existing *E. Coli* Load (MPN/day)	FC Bacteria (cfu/day)	*E. coli* (MPN/day)	FC Bacteria (cfu/day)	*E. coli* (MPN/day)	Continuous Source[1] (MPN/day)	Non-Continuous Sources[2,3] (% Reduction)	Non-Continuous SCDOT[3,4] (% Reduction)	FC Bacteria (cfu/day)	*E. coli* (MPN/day)	% Reduction to Meet LA[3]
RS-01036	2.78E+10	2.43E+10 (see note 5)	1.29E+10	1.13E+10 (see note 5)	6.47E+08	5.50E+08 (see note 5)	(see note 1)	56%	56%	1.23E+10	1.07E+10 (see note 5)	56%
RS-04537	7.96E+09	6.94E+09 (see note 5)	2.65E+09	2.31E+09 (see note 5)	1.33E+08	1.13E+08 (see note 5)	(see note 1)	68%	68%	2.52E+09	2.20E+09 (see note 5)	68%
RS-07213	8.93E+09	7.80E+09 (see note 5)	4.19E+09	3.66E+09 (see note 5)	2.10E+08	1.78E+08 (see note 5)	(see note 1)	55%	55%	3.98E+09	3.48E+09 (see note 5)	55%
E-111	---	3.31E+12	---	8.89E+11	---	4.33E+10	1.19E+08 (see note 1)	74%	74%	---	8.46E+11	74%

1. WLAs are expressed as a daily maximum. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern. Future loadings will be developed based upon permitted flow and an allowable permitted maximum *E. coli* concentration of 349 MPN/100ml.
2. Percent reduction applies to all NPDES-permitted stormwater discharges, including current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction due to the uncertain nature of stormwater discharge volumes and recurrence intervals. Stormwater discharges are required to meet percentage reduction or the existing instream standard for pollutant of concern in accordance with their NPDES Permit.
3. Percent reduction applies to existing instream *E. coli*.
4. By implementing the best management practices that are prescribed in either the SCDOT annual SWMP or the SCDOT MS4 permit to address fecal coliform bacteria or *E. coli*, SCDOT will comply with these TMDLs and their applicable WLAs to the maximum extent practicable (MEP) as required by its MS4 permit.
5. Expressed as *E. coli* (MPN/day). Loadings are developed by applying a conversion factor to values calculated for FC bacteria. This conversion factor is derived from an established relationship between FC bacteria and *E. coli* WQS in freshwaters.

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1.0 Introduction

1.1 Background

The federal *Clean Water Act (CWA)* directs each state to review the quality of its waters every two years to determine if water quality standards are being met. If it is determined that the standard is not being met, the states are to list the impaired water body under §303(d) of the *CWA*. These impairments are then addressed by a Total Maximum Daily Load (40 CFR 130.31(a)).

A Total Maximum Daily Load (TMDL) document is a written plan and analysis to determine the maximum pollutant load a waterbody can receive and still meet applicable water quality standards. The TMDL process includes estimating pollutant loadings from all sources, linking these sources to their impacts on water quality, allocation of pollutant loads to each source, and establishment of control mechanisms to achieve water quality standards. All TMDLs include a waste load allocation (WLA) for all National Pollutant Discharge Elimination System (NPDES) permitted discharges, a load allocation (LA) for all unregulated nonpoint sources, and an explicit and/or implicit margin of safety (MOS).

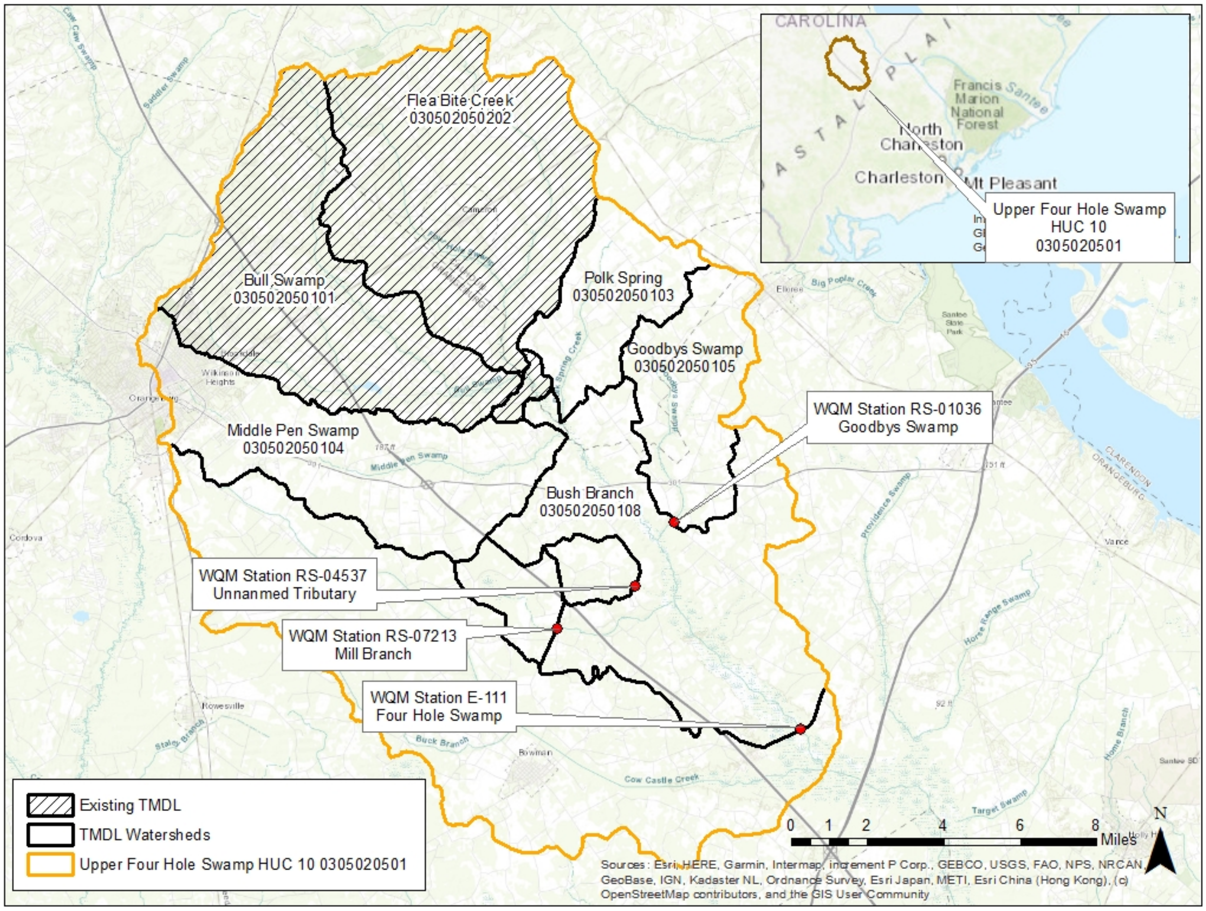
Escherichia coli (E. coli) bacteria are members of the fecal coliform group of bacteria and are part of the normal flora of the gastrointestinal tract of warm-blooded animals. These bacteria play an important role in preventing the overgrowth of harmful bacteria in the gut, vitamin K production, lactose digestion, and fat metabolism. Some Shiga toxin producing strains of *E. coli*, such as 0157:H7 can cause gastrointestinal illnesses, kidney failure and death. *E. coli* bacteria in surface waters are indicators of recent human or animal waste contamination and may originate from failing septic systems, agricultural runoff, and leaking sewers, among other sources (Blount, 2015, Wolfson and Harrigan, 2010).

This TMDL document details the development of *E. coli* bacteria TMDLs for four water quality monitoring (WQM) stations. Four Hole Swamp (E-111), Mill Branch (RS-07213), Goodbys Swamp (RS-01036), and an unnamed tributary to Four Hole Swamp (RS-04537) were included on South Carolina's finalized 2016 303(d) list, as well the draft 2018 303(d) list, by the South Carolina Department of Health and Environmental Control (SCDHEC) for impairment due to *E. coli* bacteria exceedances.

With the exception of E-111, these WQM sites are historical. The sites beginning with RS are part of the random sampling strategy employed by SCHEC to ensure better coverage of streams statewide. These stations are sampled monthly for one year. RS-04537 was sampled in 2004, RS-07213 was sampled in 2007 and WQM station RS-01036 was sampled in 2001 and again in 2012. E-111 is a current sampling site and has been sampled monthly since 2001.

Until 2013, SCDHEC used fecal coliform bacteria as a pathogen indicator. In 2013, SCDHEC changed the pathogen indicator used to determine support of recreational uses from fecal coliform bacteria to *E. coli.* Beginning with the development of South Carolina's 2014 §303(d) list, any site that had been determined to be impaired for freshwater recreational use based on the previous standard was listed for *E. coli* bacteria rather than fecal coliform bacteria. In this analysis, fecal coliform loadings from the random sites were converted to *E. coli* loadings. Data from E-111 include both fecal coliform and *E. coli*, but only the *E. coli* data were used.

Figure 1. Upper Four Hole Swamp Watershed with Locations of Impaired WQM Stations



1.2 Watershed Description

The impaired stations are within the Upper Four Hole Swamp watershed (hydrologic unit code (HUC) 0305020501), which occupies portions of Orangeburg and Calhoun counties. This watershed is 262 square miles in area. The northwestern portion is in the Atlantic Southern Loam Plains ecoregion and the southeastern part is in the Carolina Flatwoods ecoregion. The predominant land use categories are forested (deciduous 3.8%, evergreen 19%, and woody wetlands 21.5%) and agriculture (cultivated crops 40.9% and pasture/hay 1.6%). There is a small amount of development concentrated in the northwest end of the watershed (8.7%). The towns of Elloree, Cameron, Bowman, and part of the city of Orangeburg lie within the watershed and there is a moderate potential for growth due to the presence of Interstate 26 and other major highways crossing the area.

The areas included in this TMDL document are delineated in Figure 1 and include the portion of the 10-digit HUC that drains to E-111. A TMDL document was prepared and approved for parts of this watershed in 2005 as described in section 1.3 of this document.

Table 1. Land Use in Upper Four Hole Swamp HUC 10 0305020501 (National Land Cover Database (NLCD), 2016)

Land Use Description	Area (Square Miles)	Percent of Total
Open Water	1.2	0.5%
Developed Open Space	15.3	5.8%
Developed Low Intensity	5.5	2.1%
Developed Medium Intensity	1.7	0.6%
Developed High Intensity	0.6	0.2%
Barren	0.1	0.0%
Deciduous Forest	10.1	3.8%
Evergreen Forest	49.7	19.0%
Mixed Forest	0.8	0.3%
Shrub/Scrub	4.5	1.7%
Grassland/Herbaceous	4.0	1.5%
Pasture/Hay	4.2	1.6%
Cultivated Crops	107.3	40.9%
Woody Wetlands	56.3	21.5%
Emergent Herbaceous Wetlands	0.9	0.3%
Total	262.0	100.0%

Table 2. Impaired WQM Stations in Upper Four Hole Swamp Watershed

Stream Name	WQM Station	Description
Four Hole Swamp	E-111	Four Hole Swamp at SC 210
Goodbys Swamp	RS-01036	Goodbys Swamp at US 176
Unnamed Tributary (UT)	RS-04537	UT to Four Hole Swamp at S-38-92
Mill Branch	RS-07213	Mill Branch at S-38-36

For purposes of analyses of pollutant loads, sources, and subsequent allocation, the drainage areas associated with each of these stations are addressed individually as subwatersheds in this document. Subwatershed 01036 is the area that drains to RS-01036, subwatershed 04537 drains to RS-04537, and subwatershed 07213 drains to RS-07213. Subwatershed 111 drains to E-111 but excludes areas of the watershed with existing TMDLs (section 1.3, Figure 1) and the other subwatersheds included in this TMDL document.

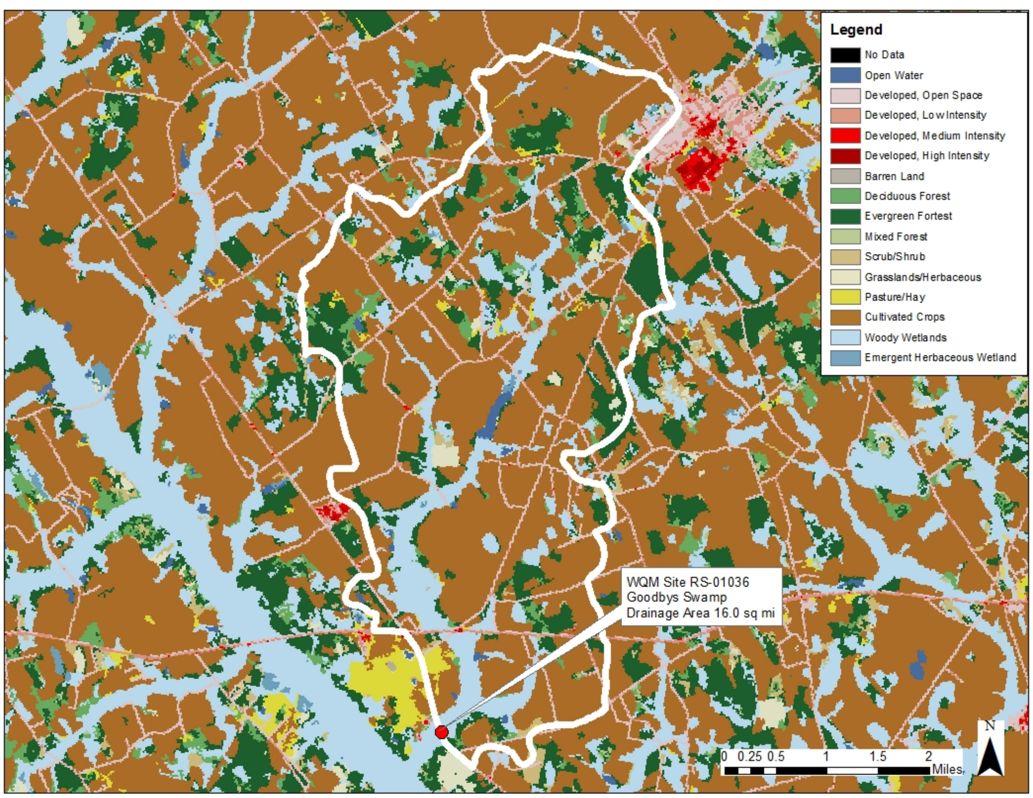
1.2.1 Subwatershed 01036

Subwatershed 01036 drains 16 square miles. The headwaters of Goodbys Swamp originate near the Town of Elloree as Keller Branch. Keller Branch enters a large impoundment on the main channel which is used for irrigation. Goodbys Swamp emerges from the outlet of this reservoir and drains to Four Hole Swamp. Land use in the watershed is predominantly agriculture with approximately 60% of the land devoted to cultivated crops and pasture/hay. Less than 7% of the watershed is developed.

Table 3. Land Use in Subwatershed 01036 (NLCD, 2016)

Land Use Description	Area (Square Miles)	Percent of Total
Open Water	0.1	0.6%
Developed Open Space	0.9	5.4%
Developed Low Intensity	0.2	1.3%
Developed Medium Intensity	0.0	0.1%
Developed High Intensity	0.0	0.0%
Barren	0.0	0.0%
Deciduous Forest	0.4	2.7%
Evergreen Forest	2.1	13.1%
Mixed Forest	0.0	0.2%
Shrub/Scrub	0.2	0.9%
Grassland/Herbaceous	0.2	1.0%
Pasture/Hay	0.2	1.1%
Cultivated Crops	9.5	59.7%
Woody Wetlands	2.2	13.5%
Emergent Herbaceous Wetlands	0.0	0.3%
Total	16.0	100.0%

Figure 2. Land Use in Subwatershed 01036 (NLCD, 2016)



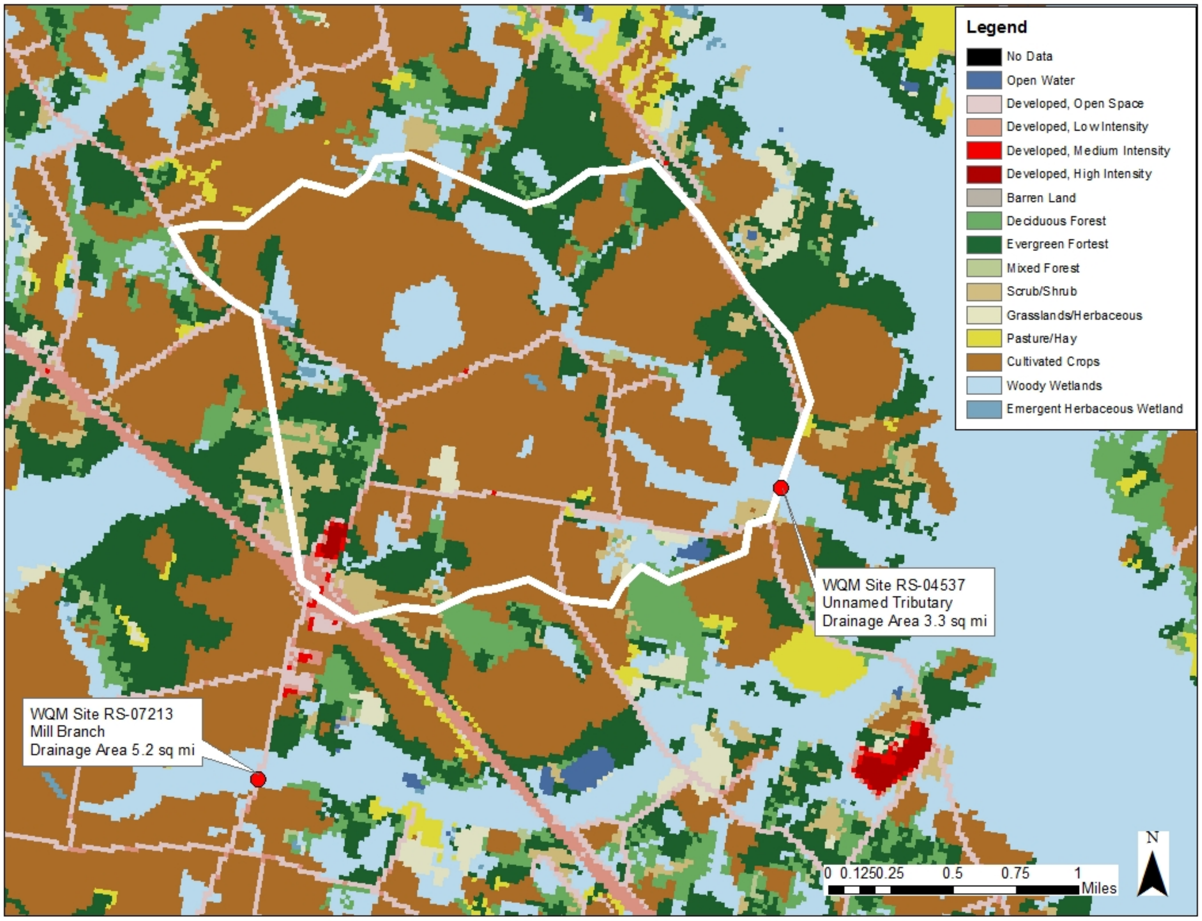
1.2.2 Subwatershed 04537

Subwatershed 04537 encompasses 3.3 square miles. WQM site RS-04537 is located on an unnamed tributary that drains to Four Hole Swamp. Land use is primarily cultivated crops and pasture/hay (57.1%). Approximately 30% is forested and there is minimal development (6%).

Table 4. Land Use in Subwatershed 04537 (NLCD, 2016)

Land Use Description	Area (square miles)	Percent of Total
Open Water	0.0	0.2%
Developed Open Space	0.1	4.4%
Developed Low Intensity	0.0	1.1%
Developed Medium Intensity	0.0	0.2%
Developed High Intensity	0.0	0.3%
Deciduous Forest	0.1	2.0%
Evergreen Forest	0.5	16.2%
Mixed Forest	0.0	0.1%
Shrub/Scrub	0.1	3.6%
Grassland/Herbaceous	0.0	0.8%
Pasture/Hay	0.0	0.1%
Cultivated Crops	1.9	57.0%
Woody Wetlands	0.4	13.6%
Emergent Herbaceous Wetlands	0.0	0.3%
Total	3.3	100.0%

Figure 3. Land Use in Subwatershed 04537 (NLCD, 2016)



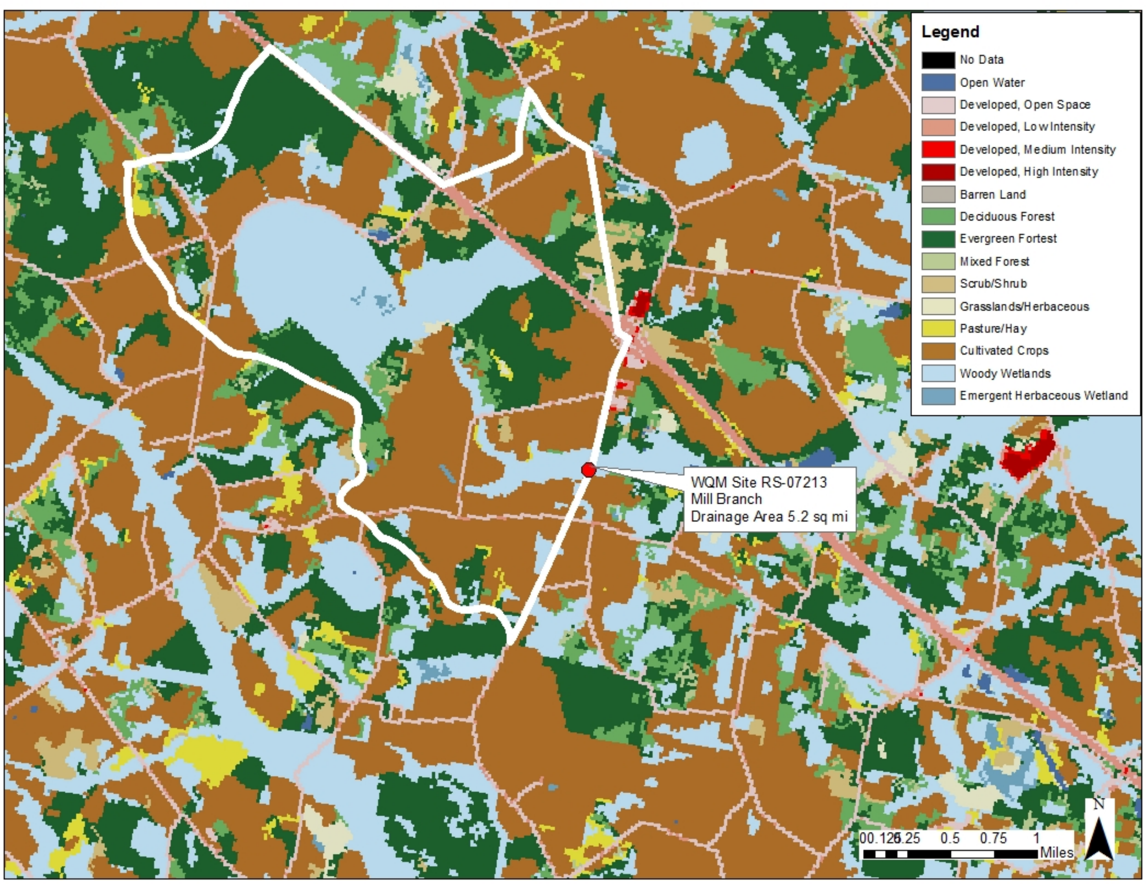
1.2.3 Subwatershed 07213

Subwatershed 07213 measures 5.2 square miles. WQM RS-07213 is located on Mill Branch which drains to Four Hole Swamp. Land use in this small watershed is largely forested (51%) with a substantial amount of agriculture (46% cultivated crops and pasture/hay). There is little development (< 6%).

Table 5. Land Use in Subwatershed RS-07213 (NLCD 2016)

Land Use Description	Area (Square Miles)	Percent of Total
Open Water	0.0	0.1%
Developed Open Space	0.2	3.6%
Developed Low Intensity	0.1	2.2%
Developed Medium Intensity	0.0	0.0%
Deciduous Forest	0.2	3.5%
Evergreen Forest	1.2	23.3%
Mixed Forest	0.0	0.1%
Shrub/Scrub	0.1	2.3%
Grassland/Herbaceous	0.0	0.3%
Pasture/Hay	0.1	1.1%
Cultivated Crops	2.0	39.4%
Woody Wetlands	1.2	23.8%
Emergent Herbaceous Wetlands	0.0	0.3%
Total	5.2	100.0%

Figure 4. Land Use in Subwatershed 07213



1.2.4 Subwatershed 111

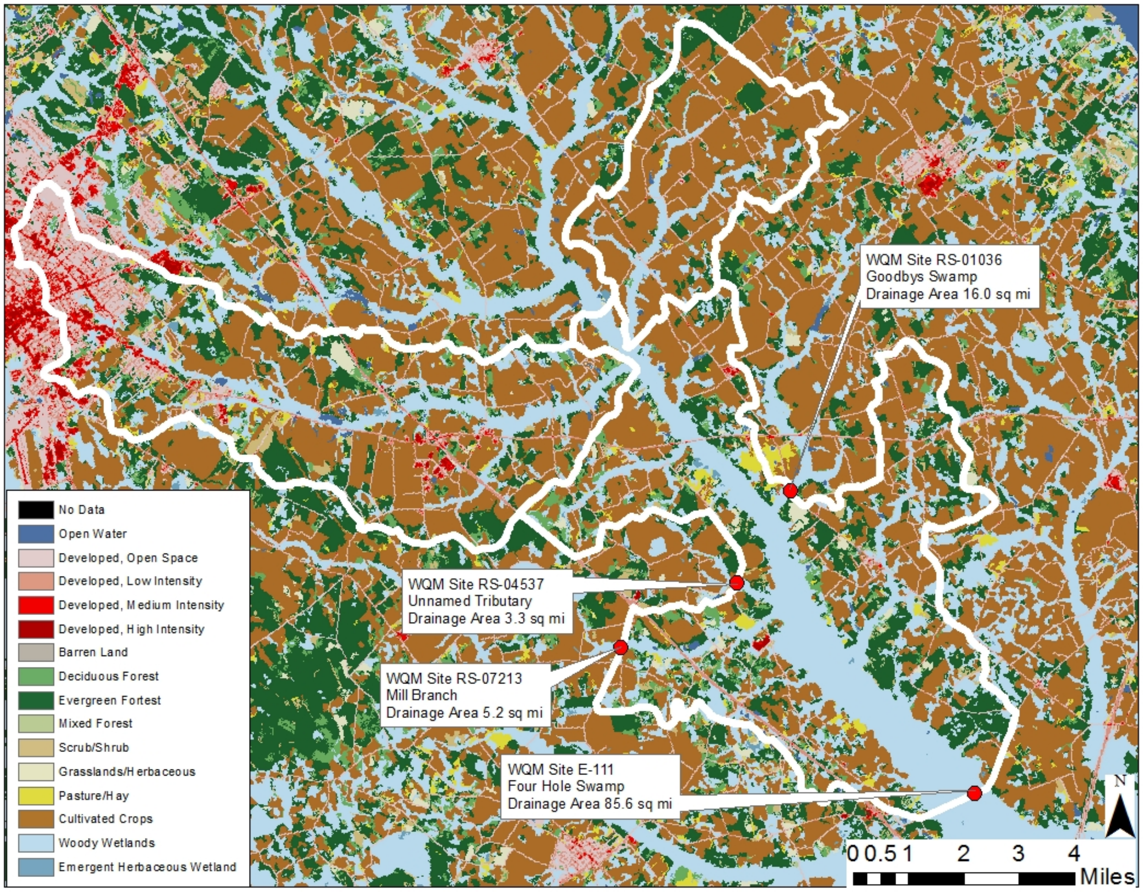
A total area of 191.9 square miles drains to WQM station E-111. This drainage area includes two existing approved TMDL watersheds as well as the other three impaired stations assessed in this TMDL document (Figure 1). When these areas are subtracted, the drainage area for subwatershed 111 is 85.6 square miles.

Middle Pen Swamp, Little Bull Creek, Flea Bite Creek and Polk Spring Creek join to form the main stem of Four Hole Swamp. Land use in this subwatershed (excluding the existing TMDL watersheds and the others evaluated within this document) is primarily agricultural (41.9%) and forested (43%). There is a moderate amount of development (11.1%). Most of the development is in the Middle Pen Swamp watershed which includes the eastern extent of the City of Orangeburg.

Table 6. Land Use in Subwatershed 111 (NLCD, 2016)

Land Use Description	Area (Square Miles)	Percent of Total
Open Water	0.4	0.5%
Developed Open Space	5.6	6.5%
Developed Low Intensity	2.7	3.1%
Developed Medium Intensity	0.9	1.1%
Developed High Intensity	0.3	0.4%
Barren	0.0	0.0%
Deciduous Forest	2.9	3.3%
Evergreen Forest	13.2	15.4%
Mixed Forest	0.4	0.4%
Shrub/Scrub	1.5	1.7%
Grassland/Herbaceous	0.9	1.0%
Pasture/Hay	1.3	1.5%
Cultivated Crops	34.6	40.4%
Woody Wetlands	20.8	24.3%
Emergent Herbaceous Wetlands	0.3	0.3%
Total	85.6	100.0%

Figure 5. Land Use in Subwatershed 111 (NLCD, 2016)



1.3 Existing Total Maximum Daily Load for Four Hole Swamp

In 2005, a TMDL document was approved for six fecal coliform-impaired WQM sites in the Four Hole Swamp watershed (SCDHEC Technical Document 015-06, https://www.scdhec.gov/sites/default/files/docs/HomeAndEnvironment/Docs/fourhole_fc-tmdl_112105.pdf). Three of these WQM sites are in watersheds that drain into the area addressed in this TMDL document (Figure 1, Table 7). Sampling at these sites was discontinued in 2009 (E-059 and E-076) and 2010 (E-022). Because there is little new data with which to reassess these areas, these TMDLs will not be revised and their loads, wasteloads, and margin of safety allocations are still valid.

The existing TMDL evaluation showed that violations of the recreational use fecal coliform standard occurred under a range of flow conditions (high, average, and low flow) indicating that there are a variety of sources for the bacteria.

Table 7. Previously Approved TMDL Sites within the Drainage Area of this TMDL Assessment

WQM Station	Location
E-022	Gramling Creek on SC 33
E-076	Tributary to Gramling Creek at SC 33
E-059	Four Hole Swamp at S-38-50

1.4 Water Quality Standard

The impaired streams addressed by this TMDL document are designated as Class Freshwater (FW) (Goodbys Swamp, Mill Branch, Unnamed Tributary) and FW* (Four Hole Swamp). Both are defined in South Carolina Regulation 61-69 (2012):

"Freshwaters are 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. Suitable for fishing and the survival and propagation of a balanced aquatic community of fauna and flora. Suitable also for industrial and agricultural uses".

South Carolina's water quality standard (WQS) for recreational use in freshwater is *E. coli* (R.61-68, 2014):

"Not to exceed a geometric mean of 126/100 ml based on at least four samples collected from a given sampling site over a 30 day period, nor shall a single sample maximum exceed 349/100 ml"

Prior to February 28, 2013, South Carolina's WQS for recreational use was fecal coliform (FC) bacteria:

"Not to exceed a geometric mean of 200/100 mL based on five consecutive samples during any 30 day period; nor shall more than 10% of the total samples during any 30 day period exceed 400/100mL."

In 1986, the United States Environmental Protection Agency (EPA) documented that *E. coli* and enterococcal species are better indicators than the FC bacteria group in predicting the presence of gastroenteritis-causing pathogens in freshwaters. The EPA study was based on data collected in areas where swimmers were directly exposed in freshwater lakes with established public swimming areas. The results indicated that *Enterococcus* and *E. coli* are more specific to sewage and other fecal sources than the FC bacteria group. In light of this information, EPA recommended the use of either *E. coli* or *Enterococcus* as the pathogen indicator for freshwaters.

To determine which of these pathogen indicators was better suited in South Carolina as the recreational use water quality standard in freshwaters, SCDHEC designed a pathogen indicator study, conducted in 2009. Weekly water samples were collected from 73 stations statewide and analyzed for *E. coli*, *Enterococcus*, and for FC bacteria. The study results showed *E. coli* is a better indicator for predicting the presence of pathogens in South Carolina freshwaters.

During 2012, following the public participation and public comment period and legislative processes, SCDHEC submitted a proposed amendment to EPA to change the pathogen indicator from FC bacteria to *E. coli* in R. 61-68. The proposed amendment was approved by EPA on February 28, 2013. Beginning on this date, *E. coli* as a pathogen indicator was promulgated in R. 61-68 and is now the applicable water quality standard for recreational use in freshwaters.

Beginning with the 2014 303(d) list of impaired waters, sites that had previously been listed as impaired for recreational use by FC bacteria exceedences would now be listed as impaired by *E. coli*. Once sufficient *E. coli* data are collected from impaired stations, future TMDLs will be calculated based on *E. coli* data. Until this time, TMDLs for FC impaired stations can be calculated using FC data. These FC TMDLs can then be converted to *E. coli* TMDLs by multiplying the FC TMDL by 0.8725. This ratio was derived by dividing the current single sample maximum WQS for *E. coli*, 349 MPN/100 ml, by the former single sample maximum WQS for FC bacteria, 400 cfu/100 ml.

2.0 Water Quality Assessment

Four WQM stations in the Upper Four Hole Swamp watershed are addressed in this TMDL document. Three of these are random sites and one is an active site. Two of the random sites were sampled monthly for one year, and one was sampled monthly during two separate years (Table 8). All the sites were included in the state's final 2016 303(d) list and the draft 2018 303(d) list due to *E. coli* exceedences. The random sites were sampled when the standard for freshwater recreational uses was FC bacteria. Station E-111 has been sampled monthly or bimonthly from January 2001 to present and was included for the first time in the state's 2004 303(d) list for exceeding the FC bacteria WQS. Since 2013 when the freshwater indicator changed from FC bacteria to *E. coli*, this site has been listed for *E. coli* exceedences. The TMDL for the random sites was calculated using FC data and converted to the *E. coli* standard in accordance with the description above. The TMDL for E-111 was calculated using only *E. coli* sampling data collected from 2/2013 through 1/2018.

For recreational use, if greater than 10% of the monthly geometric mean of available data collected during an assessment period exceeds the criterion, the station is included on South Carolina's §303(d) list. If sufficient data are not available to calculate a geometric mean, then the available sample results are compared against the single sample maximum (SSM) criterion. If greater than 10% of these samples exceed this criterion then the station is included on South Carolina's §303(d) list as not supporting recreational use. Table 8 provides a summary of the number of samples collected, number of exceedences, and the percentage of exceedences.

Table 8. Exceedence Summary for WQM Stations E-030 and E-115

Station	Waterbody	Number of Samples	Number Exceeding SSM	Percent Exceeding SSM	Year(s) Sampled
RS-01036	Goodbys Swamp	22	9	41%	2001, 2012
RS-04537	Unnamed Tributary	11	7	64%	2004
RS-07213	Mill Branch	10	3	30%	2007
E-111	Four Hole Swamp	36	16	44%	2013 - 2018

3.0 Source Assessment

While there are assays available for specific human pathogens that may be present in surface water, it is not possible to test for every potential pathogenic organism. For this reason, indicator bacteria (such as *E. coli*) are used to indicate the possible presence of human pathogens. These bacteria are easy to measure, have similar sources as pathogens of concern, and persist in surface waters for a similar or longer length of time. There are also pathogenic forms of *E. coli*. These may be found in the gastrointestinal tracts of ruminant animals such as cattle, goats, sheep, deer and elk, and can produce toxins (Shiga toxin-producing *E. coli* or STEC). Of these, cattle are the major source for human illnesses. A STEC infection may occur through accidental ingestion of water (through recreational contact) contaminated with feces.

There are many potential sources of pathogens in surface waters. In general, these sources may be classified as point and nonpoint sources. With the implementation of technology-based controls, pollution from continuous point sources, such as factories and wastewater treatment facilities, has been greatly reduced. These point sources are required by the CWA to obtain a NPDES permit and in South Carolina, NPDES permits require that dischargers of sanitary wastewater meet the state standard for the relevant pathogen indicator at the point of discharge. Municipal and private sanitary wastewater treatment facilities may occasionally be sources of pathogens. However, if these facilities are discharging wastewater that meets their permit limits, they cannot be causing an impairment. If any of these facilities are not meeting their permit limits, enforcement actions/mechanisms are required.

Municipal Separate Storm Sewer Systems (MS4s) and stormwater discharges from regulated construction or industrial sites are considered non-continuous point sources. These sources are required to obtain NPDES discharge permits for industrial and construction activities under the NPDES stormwater regulations. They are also required to comply with the state standard for the pollutant(s) of concern. If MS4s and discharges from construction sites meet the percentage reduction or the water quality standard as prescribed in Section 5 of this TMDL development document and required in their MS4 permits, they should not be causing or contributing to an instream pathogen impairment.

Nonpoint sources of pollution come from many sources. It is usually the result of overland runoff and as such, may be the predominate source in wet conditions. Malfunctioning septic tanks, sanitary sewer overflows, pet waste, and poorly managed livestock operations are some of the potential nonpoint sources of pathogens in surface water.

3.1 Point Sources

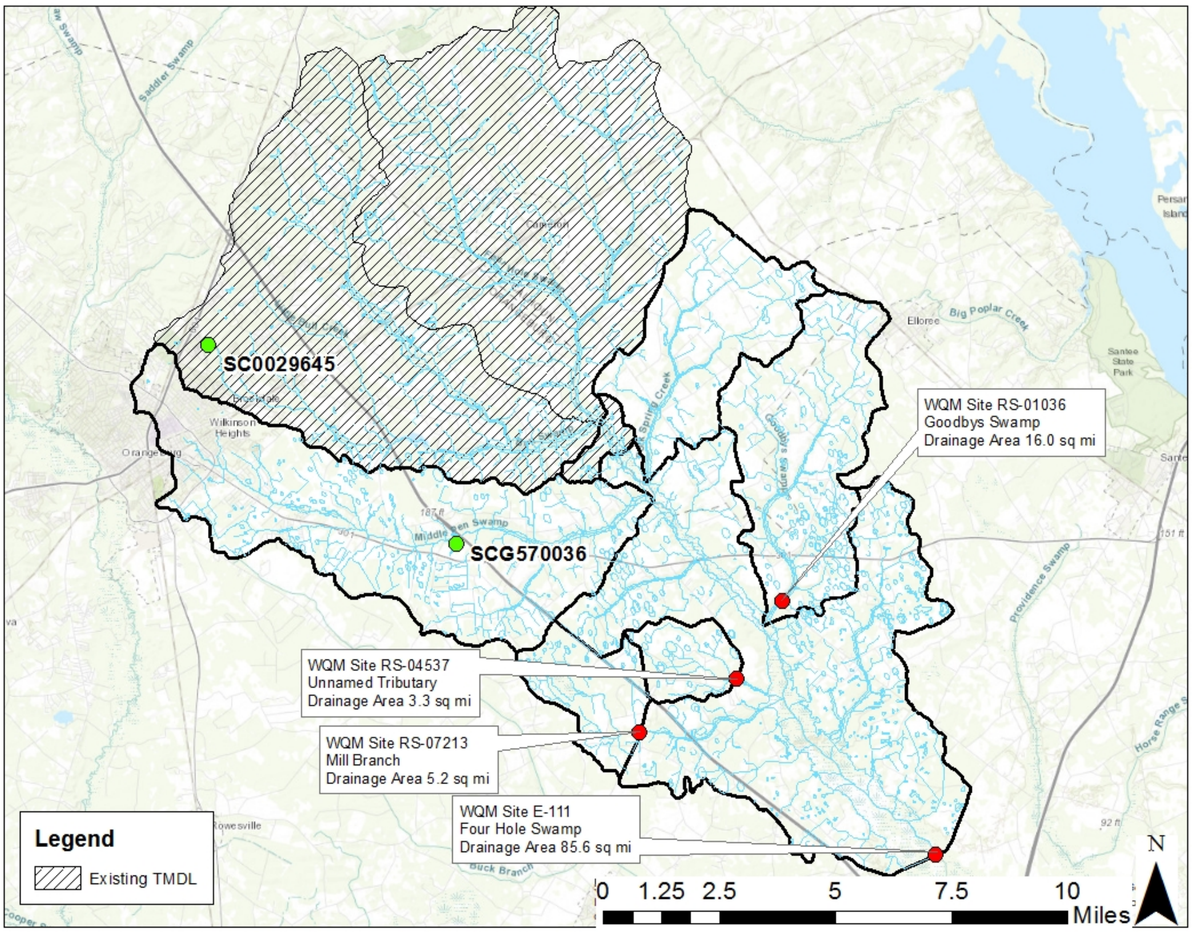
Point sources are defined as pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from municipal wastewater treatment plants, industrial waste treatment facilities, or regulated storm water discharges. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river. Point sources can be further broken down into continuous and non-continuous.

3.1.1 Continuous Point Sources

There are two NPDES permitted continuous point sources in the entire watershed that can be expected to discharge bacteria. These are small domestic wastewater treatment facilities. One of these (SC0029645) is within in the approved TMDL watershed and was assigned a wasteload allocation that continues to be valid at the time this document was being drafted. The other, SCG570036 is permitted to discharge 0.0676 MGD of treated sanitary wastewater to Middle Pen Swamp. This facility has reported no violations of its permit limits dating back to 2000. In South Carolina, NPDES permittees discharging sanitary wastewater must meet the water quality criterion for E. coli bacteria at the point of discharge (a daily maximum of 349 MPN/100ml, and a 30-day maximum geometric mean of no more than 126 MPN/100ml). As such, a facility meeting their discharge limits would not cause a violation in the stream.

Any future NPDES-permitted dischargers of *E. coli* and other FC bacteria in this watershed will be required to implement the WLA portion of the TMDL and demonstrate consistency with the assumptions and requirements of this TMDL.

Figure 6. Location of NPDES Permitted Wastewater Treatment Plants



3.1.2 Non-Continuous Point Sources

Non-continuous point sources include all NPDES-permitted stormwater discharges, including current and future MS4s, construction and industrial discharges covered under permits numbered SCS and SCR and regulated under SC *Water Pollution Control Permits* Regulation R61-9, §122.26(b)(4),(7),(14) - (21) (SCDHEC, 2011). All regulated MS4 entities have the potential to contribute *E. coli*, FC bacteria loadings, and other pathogens in the delineated drainage area used in the development of these TMDLs and as such may be subject to the WLA portion of the TMDL. The percentage of developed land within a watershed may indicate the potential for impacts from non-continuous point sources (as well as other sources). Developed land use in the Upper Four Hole Swamp Watershed is 8.7% of the total (approximately 23 square miles) and ranges from a low of 5.8% in subwatershed 07213 to a high of 11.1% in subwatershed 111 (Table 9).

The South Carolina Department of Transportation (SCDOT) is currently the only designated MS4 within the Upper Four Hole Swamp Watershed. The SCDOT operates under NPDES MS4 Permit SCS040001 and owns and operates roads within the watershed. However, the Department recognizes that SCDOT is not a traditional MS4 in that it does not possess statutory taxing or enforcement powers. SCDOT does not regulate land use or zoning, issue building or development permits.

Based on information available at time of TMDL development there are no SCDOT facilities located in the Upper Four Hole Swamp watershed. According to the SCDOT website, there are two highway rest areas located in the watershed. One is located at mile marker 150 on Interstate 26 eastbound. This rest area is in the Bull Swamp watershed and was included in the approved Four Hole Swamp TMDL document. The second rest area is at mile marker 152 on interstate 26 westbound. This rest area is within the drainage area of subwatershed 111.

Industrial facilities that have the potential to cause or contribute to a violation of a water quality standard due to storm water discharge are covered by the NPDES Storm Water Industrial General Permit (SCR000000). Construction activities are usually covered by the NPDES Storm Water Construction General Permit SCR100000. Where construction has the potential to affect the water quality of a water body with a TMDL, the Storm Water Pollution Prevention Plan (SWPPP) for the site must address any pollutants of concern and adhere to any waste load allocations in the TMDL. Note that there may be other stormwater discharges not covered under permits numbered SCS and SCR that occur in the referenced watershed. These activities are not subject to the WLA portion of the TMDL.

The City of Orangeburg, part of which is included in the TMDL drainage area, is a potentially designated MS4. Like regulated MS4s, potentially designated MS4 entities (as listed in 64 FR, 235, P.68837) or other unregulated MS4 communities located in the Upper Four Hole Swamp watershed have the potential to contribute *E. coli* and other FC bacteria in stormwater runoff. Because this area is currently unregulated, it and other unregulated MS4 entities will be subject to the LA for the purposes of this TMDL (section 3.2).

Sanitary sewer overflows (SSOs) are considered non-continuous point sources. SSOs to surface waters have the potential to severely impact water quality. It is the responsibility of the NPDES wastewater discharger, or collection system operator (for non-permitted 'collection only' systems), to ensure that releases do not occur. Unfortunately, releases to surface waters from SSOs are not always preventable or reported. A portion of subwatershed 111 is served by the City of Orangeburg WWTP. Sewer lines are present and therefore the potential for SSOs exists. This facility discharges its effluent outside of the watershed, however.

The Department acknowledges that progress with the assumptions and requirements of the TMDL by MS4s is expected to take one or more permit iteration. Progress towards achieving the WLA reduction for the TMDL may constitute MS4 compliance with its SWMP, provided the Maximum Extent Possible (MEP) definition is met, even where the numeric percent reduction may not be achieved in the interim.

Table 9. Developed Area within Each Subwatershed

WQM Station	Drainage Area (Square Miles)	Total Developed Area (Square Miles)	Percent Developed Area
RS-01036	16.00	1.07	6.69%
RS-04537	3.27	0.20	6.12%
RS-07213	5.17	0.30	5.80%
E-111*	85.62	9.50	11.10%

*Total area excludes existing TMDL watersheds and watersheds associated with the other WQM stations in this TMDL

3.2 Nonpoint Sources

Nonpoint source pollution is defined as pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, agriculture, forestry practices, wildlife and urban and rural runoff.

Wildlife, agricultural activities, grazing animals, malfunctioning septic tanks, and other nonpoint source contributors located within unregulated areas (outside the regulated MS4 area) may contribute to *E. coli* in the Upper Four Hole Swamp watershed. Nonpoint sources located in unregulated areas are subject to the LA and not the WLA of the TMDL.

Nonpoint source contributions to *E. coli* may be expected to increase in response to rainfall. Because of this, a strong positive correlation between rainfall and bacteria concentrations may indicate that nonpoint sources are predominantly responsible for bacteria exceedences. In the Upper Four Hole Swamp Watershed as a whole, there was no clear relationship between rainfall amounts and bacteria exceedances. At WQM station E-111, there was a positive correlation between rainfall and bacteria amounts with a coefficient of determination (r^2) of 0.42 and a correlation coefficient (r) of 0.64 (Figures 7 and 8). However, correlations ranged from negative to positive at the other WQM stations (Table 10, Appendix A).

Figure 7. Correlation Between Rainfall and *E. coli* at E-111

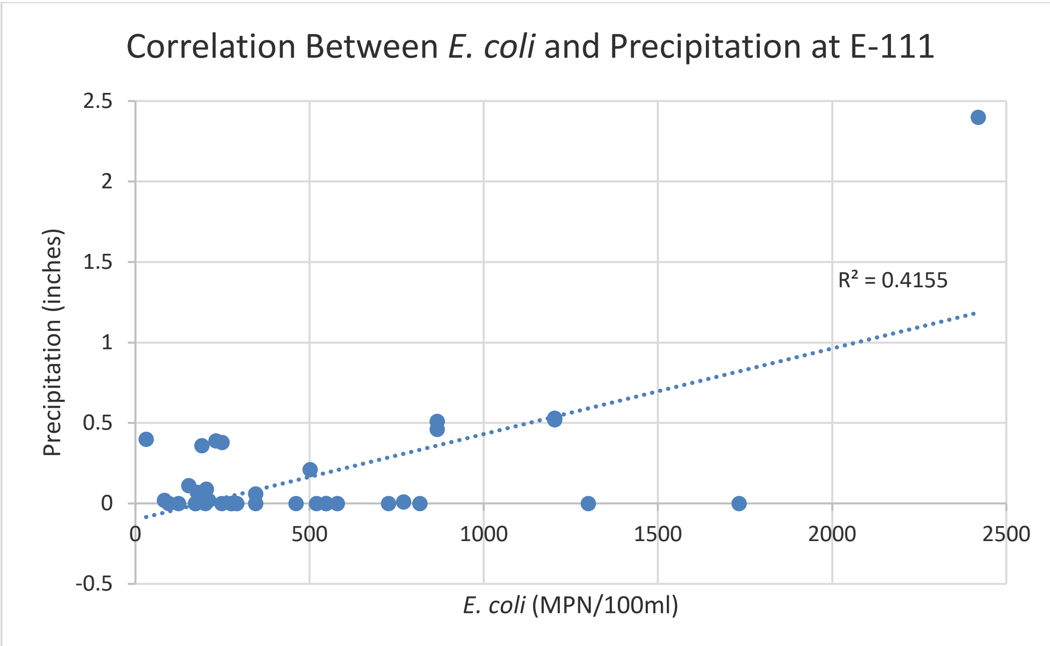


Figure 8. *E. Coli* and Precipitation at E-111

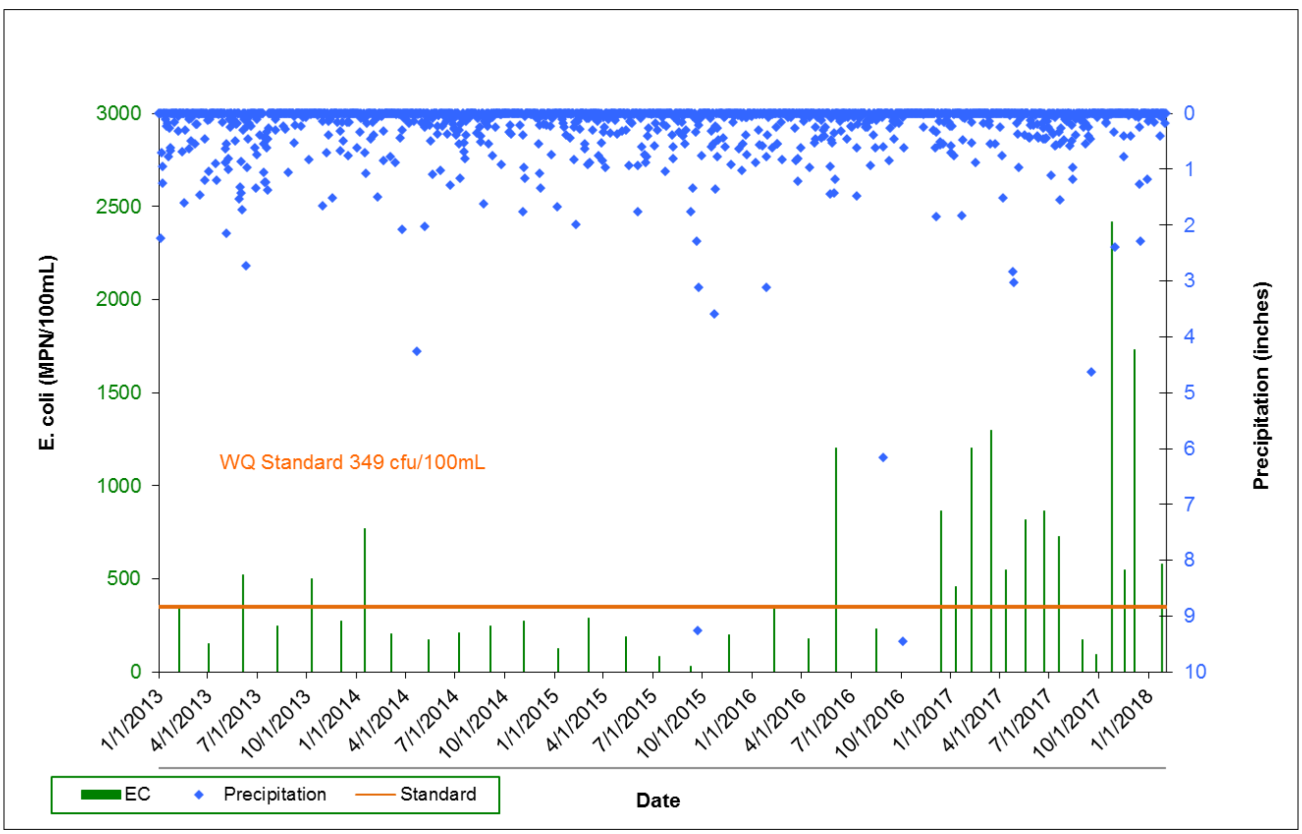


Table 10. Correlations Between Precipitation and Bacteria

Station	Waterbody	Correlation Coefficient (r)	Coefficient of Determination (r^2)
RS-01036	Goodbys Swamp	0.32	0.10
RS-04537	Unnamed Tributary	0.04	0.002
RS-07213	Mill Branch	-0.26	0.07
E-111	Four Hole Swamp	0.64	0.42

3.2.1 Wildlife

Wildlife can contribute to *E. coli* and other FC bacteria found in waterways. Wildlife inhabiting this area includes deer, squirrels, raccoons, and a variety of birds. Wildlife feces are carried into nearby streams by runoff following rainfall or deposited directly in streams. According to a study conducted by South Carolina Department of Natural Resources (SCDNR) in 2013 and GIS analysis, the total deer population within the TMDL watersheds ranges from 5757 to 8,636. The SCDNR study estimated deer density of 30 to 45 per square mile based on suitable habitat (forests, croplands, and pastures). The FC bacteria production rate for deer has been shown to be 347 x 10^6 cfu/head-day in a study conducted by Yagow (1999), of which only a portion will enter the water. Wildlife may contribute a significant portion of the overall bacterial load within this mostly-rural watershed.

Wildlife observed during a visit to the watershed included a group of black vultures roosting over the headwaters of Goodbys Swamp, beavers, turtles, alligators, and other birds (Appendix E).

3.2.2 Agriculture

Agricultural activities that involve livestock or animal wastes are potential sources of pathogen contamination of surface waters. Fecal matter can enter the waterway via runoff from the land or by direct deposition into the stream. Agricultural activities may represent a significant source of bacteria due to the large numbers of bacteria associated with animal waste.

3.2.2.1 Agricultural Animal Facilities

Owners/operators of most commercial animal growing operations are required by SC Regulation 61-43, *Standards for the Permitting of Agricultural Animal Facilities*, to obtain permits for the handling, storage, treatment (if necessary) and disposal of the manure, litter and dead animals generated at their facilities (SCDHEC, 2002). The requirements of R. 61-43 are designed to protect water quality; therefore, there is a reasonable assurance that facilities operating in compliance with this regulation should not contribute to downstream water quality impairments. The state of South Carolina does not have any confined animal feeding operations (CAFOs) under NPDES coverage at this time; however, the state does have permitted animal feeding operations (AFOs) covered under R. 61-43. These permitted operations are not allowed to discharge to waters of the state and are covered under 'no discharge' (ND) permits. Discharges from these operations to waters of the state are illegal and are subject to enforcement actions by SCDHEC.

There are several animal feeding operations within the Upper Four Hole Swamp watershed with regulated structures and activities, including land application of manure (Figure 9, Table 11).

Figure 9. Locations of AFO Facilities and Manure Land Application Sites

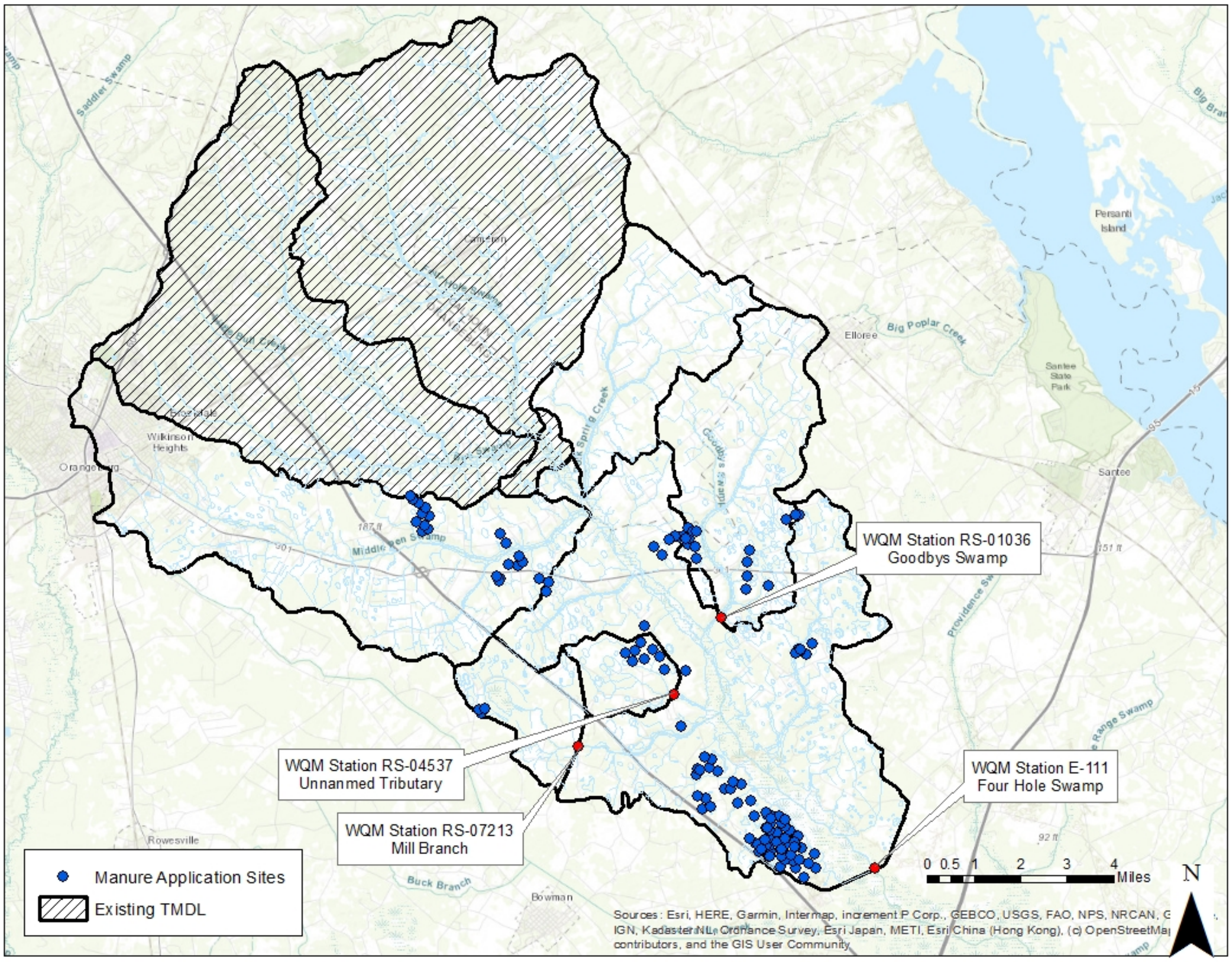


Table 11. AFO Permits in the TMDL Watersheds

Permit Number	Animal Type	AFO Size	Number of Animals
ND0070157	Dairy	Medium	300
ND0069965	Poultry	Medium	104000
ND0069973	Poultry	Large	150000
ND0069990	Poultry	Medium	124000
ND0071331	Poultry	Large	172000
ND0079758	Poultry	Large	150000
ND0011843	Swine	Large	6319
ND0012785	Swine	Small	725
ND0073741	Swine	Small	728
Total			708,072

3.2.2.2 Grazing

Livestock, especially cattle, are frequently a contributor of *E. coli* and other FC bacteria in streams. Cattle produce approximately 1.0E+11 cfu/day/animal FC bacteria (ASAE 1998). Grazing cattle and other livestock may contaminate streams with bacteria indirectly by runoff from pastures or directly by defecating into streams and ponds. Direct loading by cattle or other livestock to surface waters within the Upper Four Hole Swamp watershed is a possible contributing source of *E. coli* and other FC bacteria. However, the grazing of livestock in pastures is not regulated by SCDHEC.

The United States Department of Agriculture's National Agricultural Statistics Service reported 12,670 cattle in Orangeburg County and 3552 cattle in Calhoun County in 2017 (USDA 2019). Assuming an even distribution across the hay / pasture land in the counties, subwatershed 111 contains 636, subwatershed 01036 contains 89, subwatershed 04537 contains 2, and subwatershed 07213 contains 27 head of cattle at pasture. These cattle can be expected to contribute up to 7.58E+13 cfu fecal coliform bacteria per day to the entire watershed, some fraction of which may enter the waterways (Tables 12, 13).

The NLCD land classification 'pasture / hay' includes grazing land (pasture) with land planted for seed or hay crops (hay). The latter will be harvested and is not grazed. Also, not all cattle counted by the USDA census are grazed. Dairy cattle and feedlot cattle are usually confined and would therefore not be evenly distributed across the pasture / hay land. For these reasons, the calculations provide only a rough estimate of the cattle population.

Few instances of grazing were observed during a site visit of the watersheds evaluated in this document, and no livestock was observed in or adjacent to streams or ponds. There were dairy cattle, goats and a few horses observed in subwatershed 111. All the animals appeared to be fenced out of waterways and in the case of the dairy cattle, a wooded buffer exists between the pasture and drainage ditches and streams (Appendix E).

Table 12. Grazing Cattle per Acre of Pasture/Hay in Each County

County	Number of Cattle	Acres Pasture-Hay	Cattle/Acre Pasture-Hay
Calhoun	3552	4132	0.86
Orangeburg	12,670	16,818	0.75

Table 13. Grazing Cattle and Bacteria Produced in Each Subwatershed

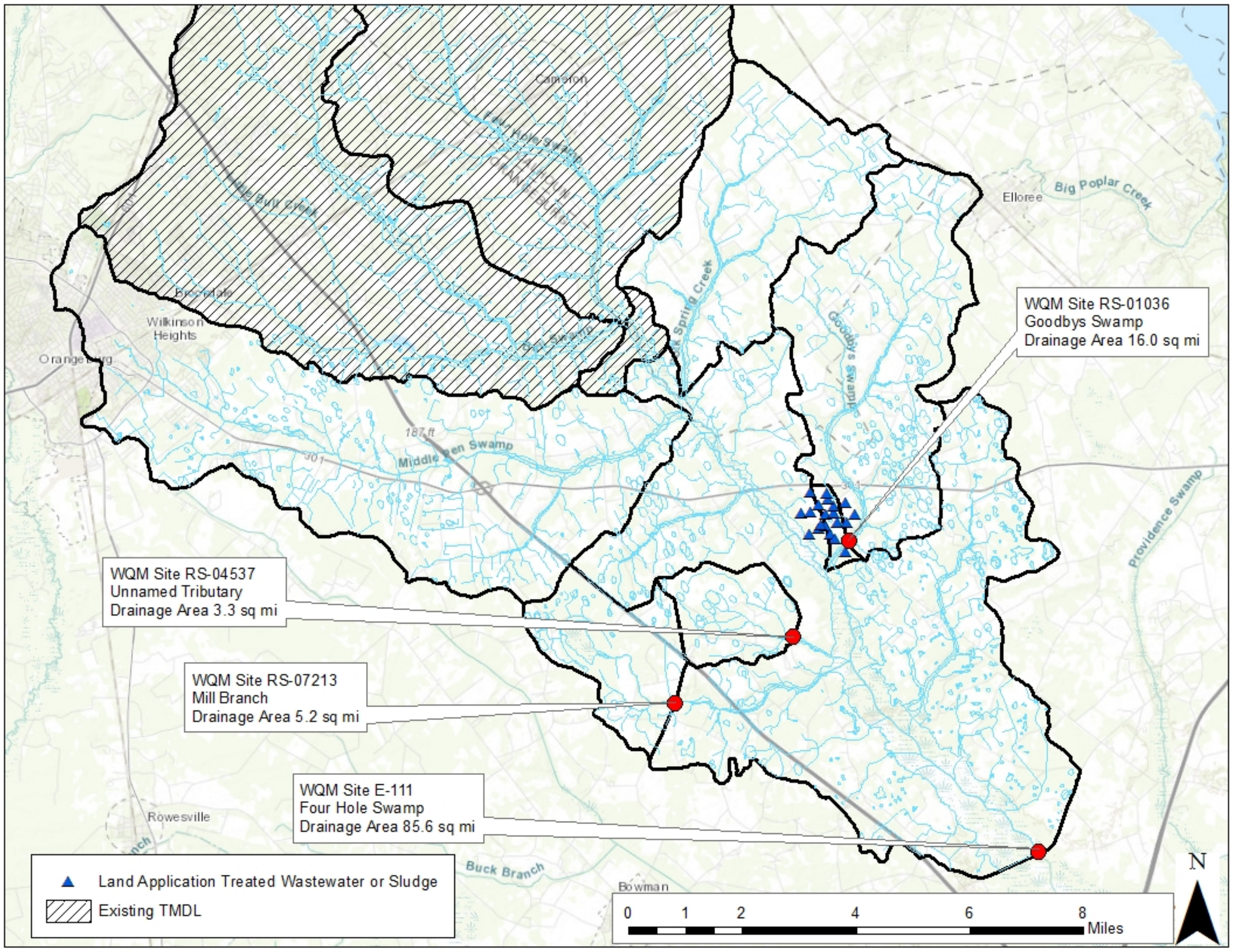
WQM Station	County	Pasture-Hay Acres	Cattle /Acre Pasture-Hay	Number of Cattle Grazing in Subwatershed	Bacteria Produced in Subwatershed (cfu/day)
RS-01036	Calhoun County	27.6	0.86	24	8.9E+12
	Orangeburg County	87.0	0.75	65	
RS-04537	Orangeburg County	2.4	0.75	2	2.0E+11
RS-07213	Orangeburg County	36.2	0.75	27	2.7E+12
E-111	Calhoun County	30.5	0.86	26	6.4E+13
	Orangeburg County	813.7	0.75	610	

3.2.3 Land Application of Industrial, Domestic Sludge, or Treated Wastewater

NPDES-permitted industrial and domestic wastewater treatment processes may generate solid waste bi-products known as sludge. In some cases, facilities may be permitted to apply sludge to land at designated locations and under specific conditions. There are also some NPDES-permitted facilities authorized to apply treated effluent to land at designated locations and under specific conditions. Land application permits for industrial and domestic wastewater facilities may be covered under SC Regulation 61-9, Sections 503, 504, or 505. If properly managed, waste is applied at a rate that ensures pollutants will be incorporated into the soil or plants and pollutants will not enter streams. Land applications sites can be a source of fecal coliform bacteria and stream impairment if not properly managed. Similar to AFO land application sites, land application sites are not allowed to directly discharge to the waterways. Direct discharges from land applications sites to surface waters of the State are illegal and are subject to enforcement actions by SCDHEC.

Orangeburg County's Goodbys Creek Regional Wastewater Treatment Facility holds permit ND0086461 for land application of treated wastewater to approximately 50 acres in the watershed. In addition, there are six locations to which sludge generated by Santee Public Service District (ND0065676) is applied (Figure 10). Use of these areas is regulated by the permit to avoid overapplication of wastewater and any resulting ecological harm.

Figure 10. Sites of Land Application of Sludge and Treated Wastewater

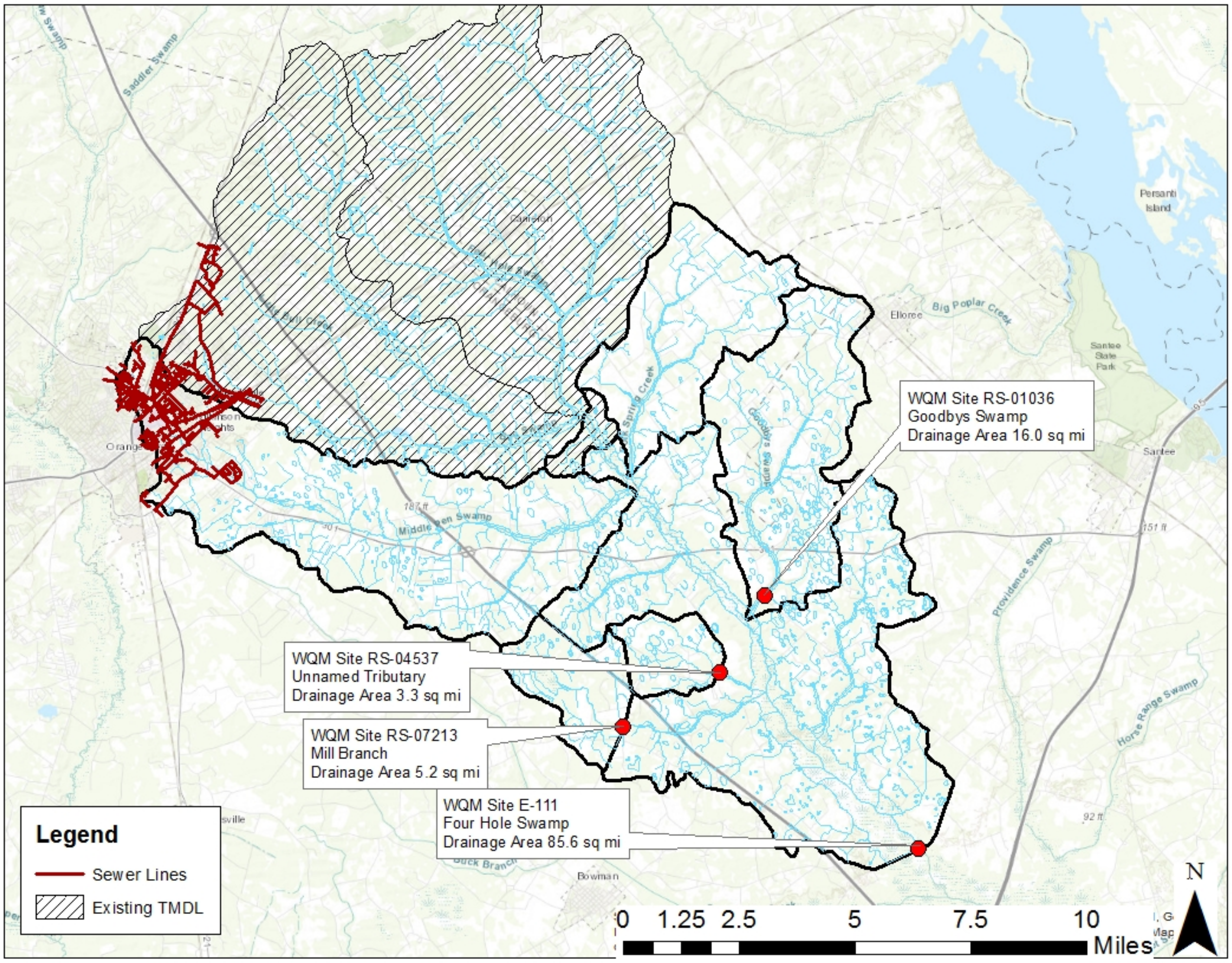


3.2.4 Leaking Sanitary Sewers and Illicit Discharges

Leaking sewer pipes and illicit sewer connections represent a direct threat to public health since they result in discharge of partially treated or untreated human waste to the surrounding environment. Quantifying these sources is extremely speculative without direct monitoring of the source because the magnitude is directly proportional to the volume and its proximity to the surface water. Typical values of FC bacteria in untreated domestic wastewater range from 10^4 to 10^6 MPN (Most Probable Number)/100mL (Metcalf and Eddy 1991). A small area of the Upper Four Hole Swamp watershed draining to E-111 is covered by a sanitary sewer system serving approximately 7333 individuals according to the 2010 census (Figure 11). This estimate does not include those in the area covered by an approved TMDL.

Illicit sewer connections into storm drains result in direct discharge of sewage via the storm drainage system outfalls. Monitoring of storm drain outfalls during dry weather is needed to document the presence or absence of sewage in the drainage systems.

Figure 11. Location of Sewer Lines in Upper Four Hole Swamp Watershed



3.2.5 Failing Septic Systems

Studies demonstrate that groundwater located four feet below properly functioning septic systems contain on average less than one FC bacteria organism per 100 mL (Ayres Associates 1993). Failed or non-conforming septic systems, however, can be a major contributor of *E. coli* and other FC bacteria to the Upper Four Hole Swamp watershed. Waste from failing septic systems enters surface waters either as direct overland flow or via groundwater. Although loading to streams from failing septic systems is likely to be a continual source, wet weather events can increase the rate of transport of pollutants from failing septic systems because of the wash-off effect from runoff and the increased rate of groundwater recharge.

Based on the 2010 U.S. census, there are an estimated 5,430 households with 13,335 people in the drainage area covered by this TMDL document. Only a small area in the western extent of subwatershed 111 is served by a sewer system. It is estimated that 3140 households containing 7,333 people are connected to this sewer system. This means an estimated 2290 households with 6002 people are using septic systems. Some of these are likely to be failing and contributing to bacteria in the streams.

Table 14. Census Data (2010) and Septic Tank Estimate

Subwatershed	Number of People	Number of Households	Number of Households on Septic Tanks**
01036	630	333	333
04537	100	42	42
07213	126	50	50
111	12,479	5,006	2,290
Entire Drainage Area*	13,335	5,431	2,715

*Excluding areas covered by existing TMDL

**Assumes one septic tank per household not served by municipal WWTP

3.2.6 Urban and Suburban Runoff

Dogs, cats, and other domesticated pets are the primary source of *E. coli* and other FC bacteria deposited on the urban and suburban landscape. There are also 'urban' wildlife sources, squirrels, raccoons, pigeons, and other birds, all of which contribute to the bacteria load. Urban runoff is likely negligible within most of the Upper Four Hole Swamp watershed since there is little development. The exception to this is in the upper reaches of the Middle Pen Swamp watershed which includes parts of Orangeburg. There are several major highways in the area as well, including Interstate 26. This area may see growth in the future as communities and industries spread outward from the Charleston area, increasing the potential for urban and suburban runoff.

The City of Orangeburg is a potentially designated MS4. Like regulated MS4s, potentially designated MS4 entities (as listed in FR 64, 235, p.68837) and any other unregulated MS4 communities located in the Upper Four Hole Swamp watershed have the potential to contribute *E. coli* and FC bacteria in stormwater runoff. Future permitted stormwater systems in this watershed will be required to comply with the load reductions prescribed in the WLA and demonstrate consistency with the assumptions and requirements of the TMDL.

4.0 Load-Duration Curve Method

The load-duration curve method was developed as a means of incorporating natural variability, uncertainty, and risk assessment into TMDL development (Bonta and Cleland 2003). The analysis is based on the range of hydrologic conditions for which there are appropriate water quality data. The load-duration curve method uses the cumulative frequency distribution of stream flow and pollutant concentration data to estimate existing and TMDL loads for a water body. Development of the load-duration curve is described in this section.

The load-duration curve method depends on an adequate period of record for stream flow data with which to create a flow-duration curve. Since the streams within the TMDL watersheds are not gauged, similar gauged streams were identified. The United States Geological Survey (USGS) gauge used to evaluate subwatersheds 01036, 04537, and 07213 was 002174250 on Cow Castle Creek near Bowman, South Carolina. This gauge is within the Upper Four Hole Swamp HUC 10 drainage area and was active from 1970 through 1981 and 1995 through 2012. Its drainage area is small (23.4 square miles) as are the drainage areas for the subwatersheds evaluated using its data. The gauge measures flow originating in and flowing through the same ecoregions as the three WQM stations it was used to evaluate (Atlantic Southern Loam Plains and Carolina Flatwoods). Flow data from 1995 through 2012 were used to construct a flow duration curve for these sites.

Because the gauge on Cow Castle Creek was not active when *E. coli* data were being collected at E-111, it was necessary to choose a different gauge to evaluate flow at this site. In this case, USGS 02175500 on the Salkehatchie River near Miley was used. This gauge has been active since 1951. It is located in the same ecoregion as E-111 (Mid-Atlantic Floodplains and Low Terraces) and drains the same ecoregions as well (Atlantic Southern Loam Plains and Carolina Flatwoods). Its drainage area is larger (341 square miles) as is the drainage area of E-111 (191.9 square miles) (Figure 12). Flow data from 1998 through 2018 were used to construct a flow duration curve for this site.

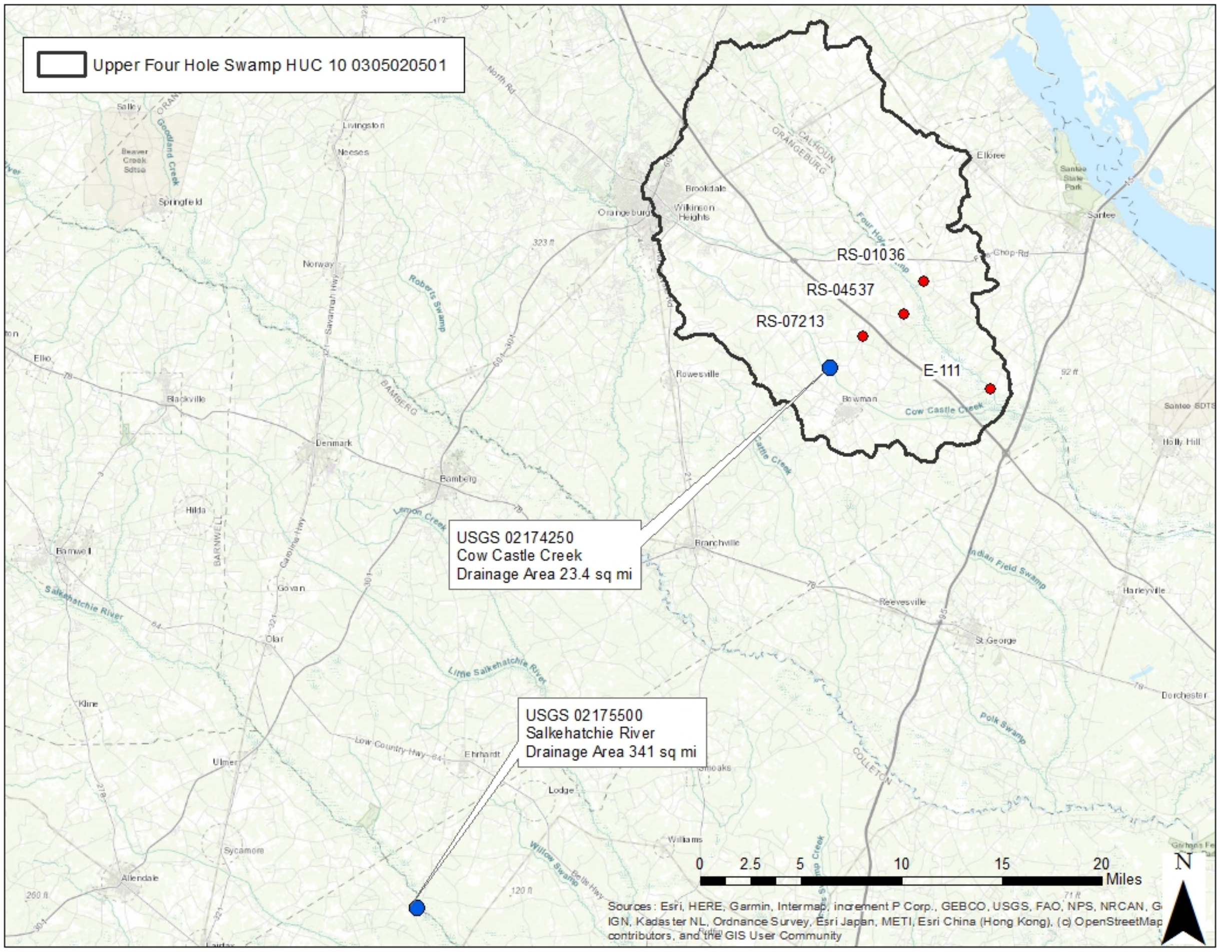
The drainage areas for the WQM stations were delineated using USGS topographic maps and ArcGIS (Figure 1). Flows at the impaired WQM stations were estimated based on the ratio of the WQM station drainage area to the drainage area of the appropriate USGS gauge. For example, 02175550 records flow from 341 square miles. The drainage area for E-111 is 191.9 square miles, or 56% of the drainage area at 02175500. Daily flows at the gauge were multiplied by 0.56 to arrive at an estimated flow at E-111. Table 15 contains a summary of drainage area statistics used to establish flows at the WQM stations and Figure 12 provides an illustration of monitoring and gauge locations.

Table 15. Drainage Area Statistics

Site	Area (square miles)	Ratio Used to Estimate Flow at WQM Sites
USGS Gauge 02174250	23.4	
RS-01036	16.0	16.0 / 23.4 = 0.68
RS-04537	3.3	3.3/ 23.4 = 0.14
RS-07213	5.2	5.2/23.4=0.22
USGS Gauge 02175500	341	
E-111	191.9*	191.9/341=0.56

*Area includes existing TMDL watersheds for purpose of estimating flow at WQM station

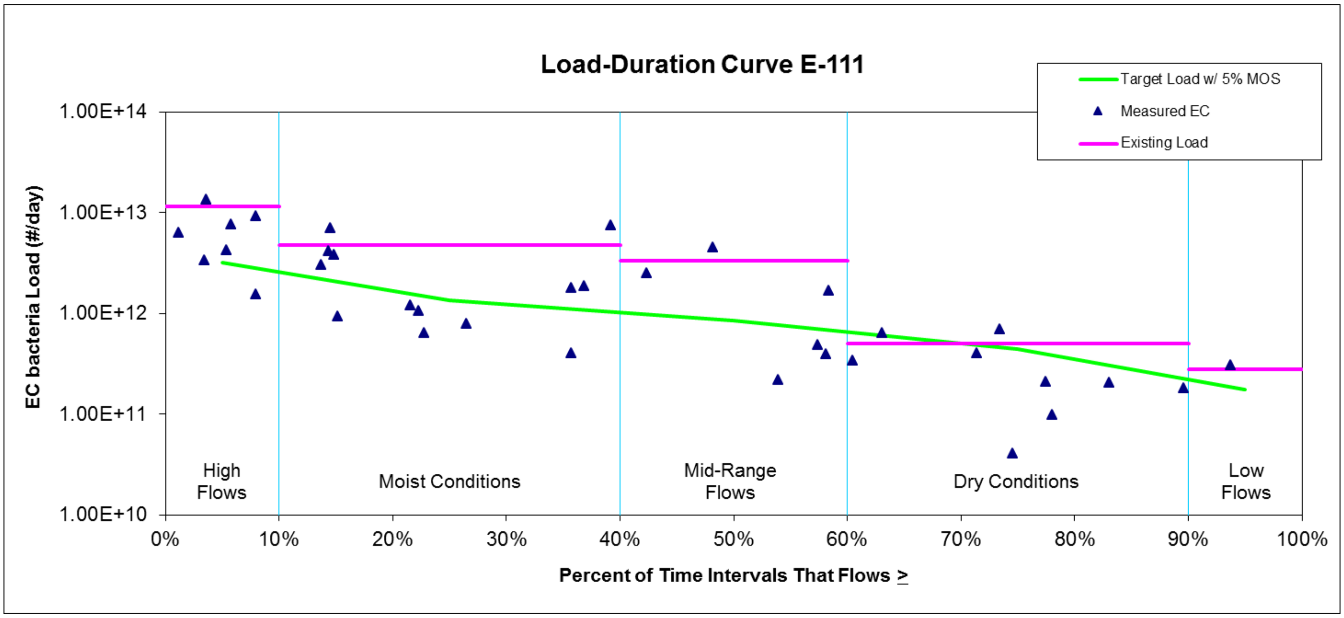
Figure 12. Locations of USGS Gauges Used in Load Duration Analysis



Flow duration curves were created by ranking estimated flows at each WQM site from highest to lowest and calculating the probability of occurrence (presented as a percentage or duration interval), where zero corresponds to the highest flow. The duration interval can be used to determine the percentage of time a given flow is achieved or exceeded, based on the period of record. The flow duration curve was divided into five hydrologic condition categories (High Flows, Moist Conditions, Mid-Range, Dry Conditions and Low Flows). Categorizing flow conditions and plotting sampling data on the same graph can assist in determining which hydrologic condition results in the greatest number of exceedences. A high number of exceedences under dry conditions might indicate a point source or illicit connection issue, whereas wetter conditions may indicate nonpoint sources. Data within the High Flow and Low Flow categories are generally not used in the development of a TMDL due to their infrequency.

For WQM site E-111, the load-duration curve was created using *E. coli* bacteria data. The allowable load was determined using daily flow and the *E. coli* water quality criterion. The water quality target was set at 332 MPN/100ml which is 5% lower than the instantaneous water quality criterion of 349 MPN/100ml. This allows a 5% explicit margin of safety (MOS) to be reserved from the water quality criterion. The load duration curve for E-111 is presented in Figure 13.

Figure 13. Load Duration Curve E-111



The load duration curves for the remaining impaired WQM sites were created using FC bacteria data. The water quality target was set to 380cfu/100ml which is 5% lower than the FC bacteria instantaneous criterion of 400cfu/100ml (the criterion in place before the water quality standard was changed to *E. coli*). A 5% explicit MOS was reserved from the water quality criterion. The allowable load of *E. coli* bacteria was then determined using daily flow, the FC bacteria water quality criterion, and a unit conversion factor that converts the FC bacteria load to an *E. coli* load. The unit conversion factor used for FC data was derived from the relationship established between FC bacteria and *E. coli* bacteria in freshwaters determined during SCDHEC's 2009 pathogen indicator study.

In a load-duration curve, the independent variable (X axis) represents the percentage of time that the estimated flow would be greater than X. In this case flows are represented by categories: high, moist, mid-range, dry, and low. The dependent variable (Y axis) represents the bacteria load (cfu/100ml for FC bacteria and MPN/100ml for *E. coli*) at each flow. In each of the flow ranges represented on the graph, existing and target loads for E-111 were calculated by the following:

Existing Load (MPN/day) = Mid-Point Flow in Each Hydrologic Category (ft^3/s) x 90^{th} Percentile *E. coli* Concentration x Conversion Factor (24465758.4)

Target Load (*E. coli* bacteria MPN/day) = Mid-Point Flow in Each Hydrologic Category (ft^3/s) x 332 (*E. coli* Bacteria WQ criterion minus a 5% MOS (MPN/100 ml)) x Conversion Factor (24465758.4)

Percent Reduction = (Existing Load – Target Load) / Existing Load

Instantaneous loads were calculated for each station by converting measured bacteria concentrations into a load, or number of bacteria per day. *E. coli* or FC bacteria samples (MPN or cfu/100ml) were multiplied by the estimated in-stream flow on the day of sampling. This value was then multiplied by a conversion factor to determine loading. Load data were plotted on the load-duration graph based on the flow duration interval for the day of sampling. Samples that lie above the target line on the load-duration curve are violations of the WQS while those below it are in compliance (Figure 13). Only the instantaneous WQS was targeted because there were insufficient data to evaluate against the 30-day geometric mean.

An existing load was determined for each hydrologic category for the TMDL calculations. The 90^{th} percentile of measured bacteria concentrations within each of the hydrologic categories was multiplied by the flow at each category midpoint (i.e., flow at the 25% duration interval for moist conditions, 50% interval for mid-range, and 75% for dry conditions). Existing loads were then plotted on the load-duration curve (Figure 13). These values were compared to the target load (which includes an explicit 5% MOS) at each hydrologic category midpoint to determine the percent load reduction necessary to achieve compliance with the WQS. The TMDL assumes that if the highest percent reduction is achieved then the WQS will be attained under all flow conditions.

5.0 Development of the Total Daily Maximum Load

A TMDL for a given pollutant and water body is comprised of the sum of individual waste load allocations (WLAs) for point sources, and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicit or explicit, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by the equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving water body while still achieving compliance with the WQS. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established and this provides the basis to establish water quality-based controls.

For most pollutants, TMDLs are expressed as a mass load (e.g., kilograms per day). For bacteria, however, TMDLs are expressed in terms of number, colony forming units (cfu), organism counts (or resulting concentration), or MPN, in accordance with 40 CFR 130.2(l).

5.1 Critical Conditions

These TMDLs are based on flow intervals between 10% and 90% and exclude extreme high and low flow conditions. Flows that are characterized as 'Low' or 'High' were not included in the analysis. The critical condition for each monitoring station is identified as the flow condition requiring the largest percent reduction, within the 10-90% duration intervals. Critical conditions for the Upper Four Hole Swamp Watershed pathogen impaired stations are listed in Table 16. These data indicate that for WQM site E-111, mid-range conditions result in larger bacteria loads and this is the critical condition for that station.

For the other stations, dry conditions result in larger bacteria loads and this is the critical condition for these stations.

5.2 Existing Load

An existing load was determined for each hydrologic category for the TMDL calculations as described in Section 4.0 of this TMDL document. The existing load under the critical condition described in Section 5.1 was used in the TMDL calculations. Loadings from all potential sources are included in this value: cattle, failing septic systems as well as wildlife. The existing loads for all stations are provided in Appendix D.

Table 16. Percent Reduction Necessary to Achieve Target Load by Hydrologic Category

WQM Site	Stream	Moist Conditions	Mid-Range Flow	Dry Conditions
RS-01036	Goodbys Swamp	38%	0%*	56%
RS-04537	Unnamed Tributary	0%*	37%	68%
RS-07213	Mill Branch	27%	0%*	55%
E-111	Four Hole Swamp	72%	74%	12%

*There were no exceedences during these conditions

Highlighted cells indicate critical conditions.

5.3 Waste Load Allocation

The waste load allocation (WLA) is the portion of the TMDL allocated to NPDES-permitted point sources (USEPA 1991). Note that all illicit dischargers, including SSOs, are illegal and not covered under the WLA of these TMDLs.

5.3.1 Continuous Point Sources

There is one permitted domestic wastewater treatment plant with *E. coli* limits in the TMDL watershed. The Connie Maxwell Children's Home operates under general permit number SCG570036 which allows a discharge of up to 9,000 gallons per day into Middle Pen Swamp (subwatershed 111). To determine the WLA for this facility, the design flow was multiplied by the allowed permitted maximum *E. coli* concentration (349 MPN/100ml) and a unit conversion factor (Table 17).

Table 17. Wasteload Allocation for Subwatershed 111

WQM Station	Facility Name	Permit Number	Flow (MGD)	WLA *E. coli* (MPN/day)
E-111	Connie Maxwell Children's Home	SCG570036	0.009	1.19E+08

Any future continuous discharges will be required to meet the prescribed loading for *E. coli* based on permitted flow and an allowable permitted maximum concentration of 349MPN/100mL.

5.3.2 Non-continuous Point Sources

Non-continuous point sources include all NPDES-permitted stormwater discharges, including current and future MS4s, construction and industrial stormwater discharges covered under permits numbered SCS000000 & SCR100000 regulated under SC *Water Pollution Control Permits* Regulation 122.26(b)(14) & (15). Illicit discharges, including SSOs, are not covered under any NPDES permit and are subject to enforcement mechanisms. Any area defined as an "Urbanized Area" by the US Census is required under the NPDES Phase II Stormwater Regulations to obtain a permit for the discharge of stormwater. Other non-urbanized areas may be required under the NPDES Phase II Stormwater Regulations to obtain a permit for the discharge of stormwater.

The City of Orangeburg was not automatically designated as a regulated small (Phase II) MS4 and as such is considered a potentially designated MS4. Potentially designated MS4s may be subject to permitting by SCDHEC if they meet the following criteria (FR 64, No. 235/Wed., Dec. 8, 1999/p. 68735):

- Population density of at least 10,000 and >1000 people/square mile
- They are found to contribute substantially to the pollutant loadings from an existing MS4
- A TMDL defines the need to cover unregulated small MS4s, construction activities, and industrial/commercial sources
- It is determined that discharges from the above sources contribute to violation of water quality standards

As a potentially designated small MS4 entity, the City of Orangeburg is subject to the LA for the purposes of this TMDL document until such time that the MS4 becomes regulated and is issued a stormwater permit.

The South Carolina Department of Transportation (SCDOT) is currently the only designated MS4 within the Upper Four Hole Swamp Watershed. SCDOT operates under NPDES MS4 Permit SCS040001 and owns and operates roads within the watershed. However, the Department recognizes that SCDOT is not a traditional MS4 in that it does not possess statutory taxing or enforcement powers. SCDOT does not regulate land use or zoning, issue building or development permits.

Waste load allocations for stormwater discharges are expressed as a percentage reduction instead of a numeric loading due to the uncertain nature of stormwater discharge volumes and recurrence intervals. All current and future stormwater discharges are required to meet the percentage reduction or the existing instream standard for the pollutant of concern. The percent reduction is based on the maximum percent reduction (critical condition) within any hydrologic category necessary to achieve target conditions. Table 18 presents the reduction needed for the impaired stations. The reduction percentages in these TMDLs also apply to the FC bacteria or *E. coli* waste load attributable to those areas of the watershed that are covered or will be covered under NPDES MS4 permits.

As appropriate information is made available to further define the pollutant contributions for the permitted MS4, an effort may be made to revise these TMDLs. This effort will be initiated as resources permit and if deemed appropriate by the Department. For the Department to revise these TMDLs the following information should be provided, but not limited to:

1) An inventory of service boundaries of the MS4 covered in the MS4 permit, provided as ARCGIS compatible shape files.

2) An inventory of all existing and planned stormwater discharge points, conveyances, and drainage areas for the discharge points, provided as ArcGIS compatible shape files. If drainage areas are not known, any information that would help estimate the drainage areas should be provided. The percentage of impervious surface within the MS4 area should also be provided.

3) Appropriate and relevant data should be provided to calculate individual pollutant contributions for the MS4 permitted entities. At a minimum, this information should include precipitation, water quality, and flow data for stormwater discharge points.

Table 18. Percent Reduction Necessary to Achieve Target Load

WQM Site	Stream	% Reduction
RS-01036	Goodbys Swamp	56%
RS-04537	Unnamed Tributary	68%
RS-07213	Mill Branch	55%
E-111	Four Hole Swamp	74%

Compliance with terms and conditions of existing and future NPDES sanitary and stormwater permits (including all construction, industrial and MS4) will effectively implement the WLA and demonstrate consistency with the assumptions and requirements of the TMDL.

5.4 Load Allocation

The Load Allocation applies to the nonpoint sources of *E. coli* and other FC bacteria and is expressed both as a load and as a percent reduction. The load allocation is calculated as the difference between the target load under the critical condition and the point source WLA. The load allocation is listed in Table 19. There may be other unregulated MS4s located in the Upper Four Hole Swamp Watershed that are subject to the LA components of these TMDLs. At such time that the referenced entities, or other future unregulated entities become regulated NPDES MS4 entities and are subject to applicable provisions of SC Regulation 61-68D, they will be required to meet load reductions prescribed in the WLA component of the TMDL. This also applies to future discharges associated with industrial and construction activities that will be subject to SC R. 61-9 122.26(b)(14) & (15) (SCDHEC 2011).

5.5 Seasonal Variability

Federal regulations require that TMDLs consider the seasonal variability in watershed loading. The variability in these TMDLs is accounted for by using multi-year hydrological and water quality sampling data sets.

5.6 Margin of Safety

The margin of safety (MOS) may be explicit and/or implicit. The explicit margin of safety is 5% of the TMDL, or in the case of FC TMDLs, 20 cfu/100mL of the instantaneous criterion of 400 cfu/100 mL (380 cfu/100mL); and in the case of *E. coli* TMDLs, 17 MPN/100mL of the instantaneous criterion of 349 MPN/100 mL (332 MPN/100mL). The MOS is expressed as the value calculated from the critical condition defined in Section 5.1 and is the difference between the TMDL and the sum of the WLA and LA.

A 5% MOS in freshwaters impaired for *E. coli* may be calculated as the ratio of *E.coli* MPN/100 mL to FC bacteria cfu/100 mL or 20*0.8725 = 17 MPN/100 mL of the instantaneous *E. coli* criterion of 349 MPN/100 mL (332 MPN/100 mL). This conversion is deemed appropriate by the Department and was derived from an established relationship between FC bacteria and *E. coli* WQS in freshwaters determined during the 2009 Pathogen Indicator Study.

5.7 TMDL

For most pollutants, TMDLs are expressed as a mass load (e.g., kilograms per day). For bacteria, however, TMDLs are expressed in terms of cfu or MPN or organism counts, in accordance with 40 CFR 130.2(l). Only the instantaneous water quality criterion was targeted for the Upper Four Hole Swamp Watershed because there is insufficient data to evaluate against the 30-day geometric mean. The target load is defined as the load (from point and nonpoint sources) minus the MOS that a stream station can receive while meeting the WQS. The TMDL value is the median target load within the critical condition (i.e., the middle value within the hydrologic category that requires the greatest load reduction) plus the WLA and MOS.

While TMDL development was primarily based on instantaneous water quality criterion, terms and conditions of NPDES permits for continuous discharges require facilities to demonstrate compliance with both geometric mean and instantaneous water quality criteria for FC bacteria in treated effluent. NPDES permits for continuous dischargers require data collection sufficient to monitor for compliance of both criteria at the point of outfall.

Table 19 indicates the percentage reduction or water quality standard required for each subwatershed in the Upper Four Hole Swamp Watershed. Note that all future regulated NPDES-permitted stormwater discharges will also be required to meet the prescribed percentage reductions, or the water quality standard. It should be noted that in order to meet the WQS for *E. coli* bacteria prescribed load reductions must be targeted from all sources, including NPDES permitted and nonpoint sources.

Based on the available information at this time, the portion of the Upper Four Hole Swamp Watershed that drains directly to a regulated MS4 and that which drains through an unregulated MS4 has not been clearly defined within the MS4 jurisdictional area. Loading from both types of sources (regulated and unregulated) typically occurs in response to rainfall events, and discharge volumes as well as recurrence intervals are largely unknown. Therefore, where applicable, the regulated MS4 is assigned the same percent reduction as the non-regulated sources in the watershed. Compliance with the MS4 permit in regard to this TMDL document is determined at the point of discharge to waters of the state. The regulated MS4 entity is only responsible for implementing the TMDL WLA in accordance with their MS4 permit requirements and is not responsible for reducing loads prescribed as LA in this TMDL document.

Table 19. Total Maximum Daily Loads for Upper Four Hole Swamp

	Existing Load		TMDL		Margin of Safety		Waste Load Allocation (WLA)			Load Allocation (LA)		
Station	**Existing FC Load (cfu/day)**	**Existing *E. Coli* Load (MPN/day)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**Continuous Source[1] (MPN/day)**	**Non-Continuous Sources[2,3] (% Reduction)**	**Non-Continuous SCDOT[3,4] (% Reduction)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**% Reduction to Meet LA[3]**
RS-01036	2.78E+10	2.43E+10 (see note 5)	1.29E+10	1.13E+10 (see note 5)	6.47E+08	5.50E+08 (see note 5)	(see note 1)	56%	56%	1.23E+10	1.07E+10 (see note 5)	56%
RS-04537	7.96E+09	6.94E+09 (see note 5)	2.65E+09	2.31E+09 (see note 5)	1.33E+08	1.13E+08 (see note 5)	(see note 1)	68%	68%	2.52E+09	2.20E+09 (see note 5)	68%
RS-07213	8.93E+09	7.80E+09 (see note 5)	4.19E+09	3.66E+09 (see note 5)	2.10E+08	1.78E+08 (see note 5)	(see note 1)	55%	55%	3.98E+09	3.48E+09 (see note 5)	55%
E-111	---	3.31E+12	---	8.89E+11	---	4.33E+10	1.19E+08 (see note 1)	74%	74%	---	8.46E+11	74%

1. WLAs are expressed as a daily maximum. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern. Future loadings will be developed based upon permitted flow and an allowable permitted maximum *E. coli* concentration of 349 MPN/100ml.

2. Percent reduction applies to all NPDES-permitted stormwater discharges, including current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction due to the uncertain nature of stormwater discharge volumes and recurrence intervals. Stormwater discharges are required to meet percentage reduction or the existing instream standard for pollutant of concern in accordance with their NPDES Permit.

3. Percent reduction applies to existing instream *E. coli.*

4. By implementing the best management practices that are prescribed in either the SCDOT annual SWMP or the SCDOT MS4 permit to address fecal coliform bacteria or *E. coli*, SCDOT will comply with these TMDLs and their applicable WLAs to the maximum extent practicable (MEP) as required by its MS4 permit.

5. Expressed as E. coli (MPN/day). Loadings are developed by applying a conversion factor to values calculated for FC bacteria. This conversion factor is derived from an established relationship between FC bacteria and *E. coli* WQS in freshwaters.

5.8 Reasonable Assurance

NPDES permits are issued for regulated dischargers, including continuous and non-continuous sources of pathogenic bacteria. In freshwaters, the applicable recreational use water quality standard is *E. coli* bacteria. Continuous discharges are required to target the *E. coli* water quality standard at the point of discharge. For regulated non-continuous discharges, the *E. coli* standard should be targeted to the maximum extent practicable. There may be other regulated activities present that could contribute to *E. coli* loadings in the watershed. New septic tanks, animal feeding operations (AFOs), land application of treated sludge or wastewater also require permits that reduce the potential for runoff of bacteria into waters of the State.

Unregulated sources of *E. coli* loadings in the watershed may include wildlife, improper agricultural or silvicultural activities, urban and suburban runoff. These sources may be reduced through means such as best management practices, local ordinances, and outreach education efforts, as well as 319 grant funded opportunities. SCDHEC has fostered effective partnerships between other federal, state and local entities to help reduce the potential for runoff of bacteria into waters of the State. Once implemented, all these reduction mechanisms will provide reasonable assurance that the recreational use water quality standard will be attained in this watershed.

6.0 Implementation

Implementation of both point (WLA) and non-point (LA) source components of the TMDL are necessary to bring about the required reductions in *E. coli* bacteria loading to the Upper Four Hole Swamp Watershed. Using existing authorities and mechanisms, implementation guidance providing information on how point and non-point sources of pollution may be abated to meet water quality standards is provided. Sections 6.1.1-6.1.7 presented below correspond with sections 3.1.1-3.2.6 of the source assessment presented in the TMDL document. As the implementation strategy progresses, SCDHEC will continue to monitor the effectiveness of implementation measures and evaluate water quality where deemed appropriate.

Point sources are discernible, confined, and discrete conveyances of pollutants to a water body including but not limited to pipes, outfalls, channels, tunnels, conduits, man-made ditches, etc. The Clean Water Act's primary point source control program is the National Pollutant Discharge Elimination System (NPDES). Point sources can be broken down into continuous and non-continuous point sources. Some examples of a continuous point source are wastewater treatment facilities (WWTF) and industrial facilities. Some examples of non-continuous point sources include MS4s and construction activities. Current and future NPDES discharges in the referenced watershed are required to comply with the load reductions prescribed in the waste load allocation (WLA).

Nonpoint source pollution originates from multiple sources over a relatively large area. It is diffuse in nature and indistinct from other sources of pollution. It is generally caused by the pickup and transport of pollutants from rainfall moving over and through the ground. Nonpoint sources of pollution may include, but are not limited to wildlife, agricultural activities, illicit discharges, failing septic systems, and urban runoff. Nonpoint sources located in unregulated portions of the Upper Four Hole Swamp Watershed are subject to the load allocation (LA) and not the WLA of the TMDL document.

South Carolina has several tools available for implementing the non-point source components of these TMDLs. The *Implementation Plan for Achieving Total Maximum Daily Load Reductions from Nonpoint Sources for the State of South Carolina* (SCDHEC 1998) document is one example. Another key component for interested parties to control pollution and prevent water quality degradation in the Upper Four Hole Swamp Watershed would be the establishment and administration of a program of Best Management Practices (BMPs). Best management practices may be defined as a practice or a combination of practices that have been determined to be the most effective, practical means used in the prevention and/or reduction of pollution.

Interested parties (local stakeholder groups, universities, local governments, etc.) may be eligible to apply for CWA §319 grants to install BMPs that will implement the LA portions of these TMDLs and reduce nonpoint source *E. coli* loading to the Upper Four Hole Swamp Watershed. Congress amended the Clean Water Act (CWA) in 1987 to establish the Section 319 Nonpoint Source Management Program. Under Section 319, States receive grant money to support a wide variety of activities including the restoration of impaired waters. TMDL implementation projects are given highest priority for 319 funding. SCDHEC will also work with existing agencies in the area to provide nonpoint source education in the Upper Four Hole Swamp Watershed.

The Department recognizes that adaptive management/implementation of these TMDLs might be needed to achieve the water quality standard and we are committed towards targeting the load reductions to improve water quality in the Upper Four Hole Swamp Watershed. As additional data and/or information become available, it may become necessary to revise and/or modify the TMDL target accordingly.

6.1 Implementation Strategies

The strategies presented in this document for implementation of the Upper Four Hole Swamp Watershed TMDL are not inclusive and are to be used only as guidance. The strategies are informational suggestions that may lead to the required load reductions being met while demonstrating consistency with the assumptions and requirements of the TMDL. Application of certain strategies provided may be voluntary and are not a substitute for actual NPDES permit conditions.

6.1.1 Continuous Point Sources

Continuous point source WLA reductions are implemented through NPDES permitting. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern and demonstrate consistency with the assumptions and requirements of the TMDL. *E. coli* loadings are developed based upon permitted flow and an allowable permitted maximum *E. coli* concentration of 349 MPN/100mL.

6.1.2 Non-continuous Point Sources

An iterative BMP approach as defined in the general stormwater NPDES MS4 permit is expected to provide significant implementation of the WLA. Permit requirements for implementing WLAs in approved TMDLs will vary across waterbodies, discharges, and pollutant(s) of concern. The allocations within a TMDL can take many different forms – narrative, numeric, specific BMPs – and may be complimented by other special requirements such as monitoring.

The level of monitoring necessary, deployment of structural and non-structural BMPs, evaluation of BMP performance, and optimization or revisions to the existing pollutant reduction goals of the Storm Water Management Plan (SWMP) or any other plan is TMDL and watershed specific. Hence, it is expected that NPDES permit holders will evaluate their existing SWMP or other plans in a manner that would effectively address implementation of these TMDLs with an acceptable schedule and activities for their permit compliance. The Department (permit writers, TMDL project managers, and compliance staff) is willing to assist in developing or updating the referenced plan as deemed necessary. Please see Appendix C for additional information on evaluating the effectiveness of an MS4 Permit as it relates to compliance with approved TMDLs. For SCDOT, existing and future NPDES MS4 permittees, compliance with terms and conditions of the NPDES permit is effective implementation of the WLA to the Maximum Extent Practicable (MEP) and demonstrates consistency with the assumptions and requirements of the TMDL. For existing and future NPDES construction and industrial stormwater permittees, compliance with terms and conditions of the permit is effective implementation of the WLA. Required load reductions in the LA portion of this TMDL can be implemented through voluntary measures and are eligible for CWA §319 grants.

The Department acknowledges that progress with the assumptions and requirements of the TMDL by MS4s is expected to take one or more permit iteration. Achieving the WLA reduction for the TMDL may constitute MS4 compliance with its SWMP, provided the MEP definition is met, even where the numeric percent reduction may not be achieved in the interim.

Regulated MS4 entities are required to develop a SWMP that includes the following: public education, public involvement, illicit discharge detection & elimination, construction site runoff control, post construction runoff control, and pollution prevention/good housekeeping. These measures are not exhaustive and may include additional criteria depending on the type of NPDES MS4 permit in question. The following examples are recognized as acceptable stormwater practices and may be applied to unregulated MS4 entities or other interested parties in the development of a stormwater management plan.

An informed and knowledgeable community is crucial to the success of a stormwater management plan (USEPA, 2005). MS4 entities may implement a public education program to distribute educational materials to the community or conduct equivalent outreach activities about the impacts of stormwater discharges on local waterbodies and the steps that can be taken to reduce stormwater pollution. Some appropriate BMPs may be brochures, educational programs, storm drain stenciling, stormwater hotlines, tributary signage, and alternative information sources such as websites, bumper stickers, etc. (USEPA, 2005).

The public can provide valuable input and assistance to a stormwater management program and they may have the potential to play an active role in both the development and implementation of the stormwater program where deemed appropriate by the entity. There are a variety of practices that can involve public participation such as public meetings/citizens panels, volunteer water quality monitoring, volunteer educators, community clean-ups, citizen watch groups, and “Adopt a Storm Drain” programs which encourage individuals or groups to keep storm drains free of debris and monitor what is entering local waterways through storm drains (USEPA, 2005).

Illicit discharge detection and elimination efforts are also necessary. Discharges from MS4s often include wastes and wastewater from non-stormwater sources. This enters the system through either direct connections or indirect connections. The result is untreated discharges that contribute high levels of pollutants, including heavy metals, toxics, oil and grease, solvents, nutrients, viruses, and bacteria to receiving waterbodies (USEPA, 2005). Pollutant levels from these illicit discharges have been shown in EPA studies to be high enough to significantly degrade receiving water quality and threaten aquatic, wildlife, and human health. MS4 entities may have a storm sewer system map which shows the location of all outfalls and to which waters they discharge. If not already in place, an ordinance prohibiting non-stormwater discharges into a MS4 with appropriate enforcement procedures may be developed. Entities may also have a plan for detecting and addressing non-stormwater discharges. The plan may include locating problem areas through infrared photography, finding the sources through dye testing, removal/correction of illicit connections, and documenting the actions taken to illustrate that progress is being made to eliminate illicit connections and discharges.

A program might also be developed to reduce pollutants in stormwater runoff to the MS4 area from construction activities. An ordinance or other regulatory mechanism may exist requiring the implementation of proper erosion and sediment controls on applicable construction sites. Site plans should be reviewed for projects that consider potential water quality impacts. It is recommended that site inspections should be conducted, and control measures enforced where applicable. A procedure might also exist for considering information submitted by the public (USEPA, 2005). For information on specific BMPs please refer to the SCDHEC Stormwater Management BMP Handbook online at: https://scdhec.gov/environment/water-quality/stormwater/bmp-handbook

Post-construction stormwater management in areas undergoing new development or redevelopment is recommended because runoff from these areas has been shown to significantly affect receiving waterbodies. Many studies indicate that prior planning and design for the minimization of pollutants in post-construction stormwater discharges is the most cost-effective approach to stormwater quality management (USEPA, 2005). Strategies might be developed to include a combination of structural and/or non-structural BMPs. An ordinance or other regulatory mechanism may also exist requiring the implementation of post-construction runoff controls and ensuring their long term-operation and maintenance. Examples of non-structural BMPs are planning procedures and site-based BMPs (minimization of imperviousness and maximization of open space). Structural BMPs may include but are not limited to stormwater retention/detention BMPs, infiltration BMPs (dry wells, porous pavement, etc.), and vegetative BMPs (grassy swales, filter strips, rain gardens, artificial wetlands, etc.).

Pollution prevention is also a key element of stormwater management programs. This requires the MS4 entity to examine and alter their programs or activities to ensure reductions in pollution are occurring. A plan should be developed to prevent or reduce pollutant runoff from municipal operations into the storm sewer system and employees trained on ways to incorporate and document pollution prevention/good housekeeping techniques. The MS4 operator can use training materials that are available from EPA or relevant organizations (USEPA, 2005).

6.1.3 Wildlife

Methods for managing the bacteria contribution from wildlife will vary from location to location. In developed areas it may make sense to divert wildlife from sensitive areas by fencing, mowing, landscaping changes, and trimming trees to reduce bird roosting. Food sources for wildlife can be kept to a minimum by prohibiting feeding by the public, by removing trash, pet food, and palatable plant species. In rural, undeveloped areas, which includes much of the Upper Four Hole Swamp Watershed, these methods would not be practical.

Although there are many ways to discourage birds and other wildlife from waterways by removing attractants or harassing nuisance species, any plans to do so should be undertaken only with a good understanding of the animal populations in question. Federal and state permits may be required to interfere with wildlife, and some nuisance species such as Canada geese and other migratory birds are protected by federal law. It is recommended that the South Carolina Department of Natural Resources, USDA-APHIS, and the United States Fish and Wildlife Service be consulted prior to interfering with wildlife (USEPA, 2001).

6.1.4 Agricultural Activities

Suggested forms of implementation for agricultural activities will vary depending on location. Agricultural BMPs can be vegetative, structural, or management oriented. When selecting BMPs, it is important to keep in mind that nonpoint source pollution occurs when a pollutant becomes available, is detached, and then transported to nearby receiving waters. For BMPs to be effective, the transport mechanism of the pollutant, in this case *E. coli* bacteria, needs to be identified.

For livestock in the watershed, installing fencing along the streams within the watershed and providing an alternative water source where livestock are present would eliminate direct contact with the streams. When grazing animals have access to streams, they have a large impact on bacteria loads even if few in number. If fencing is not feasible, it has been shown that installing water troughs within a pasture area reduced the amount of time livestock spent drinking directly from streams by 92% (Sheffield et al.,1997). In addition to reducing bacteria in the stream, this BPM resulted in a 77% reduction in stream bank erosion.

Most of the agricultural activities observed in the Upper Four Hole Swamp Watershed consisted of row crops, sod farming, hay fields and silviculture. For row crops, many practices exist to reduce nonpoint source pollution. Unstabilized soil directly adjacent to surface waters can contribute to bacteria loading during periods of runoff after rain events. Agricultural field borders and filter strips (vegetative buffers) can provide erosion control around fields. These borders may be harvested as hay and provide an area in which farmers can turn equipment around when working the field (SCDNR, 1997). A study conducted in 1998 by the American Society of Agricultural and Biological Engineers (ASABE 1998) demonstrated that a vegetative buffer measuring 6.1 meters in width can reduce fecal bacteria runoff concentrations to a non-detectable amount. A buffer of this width was also shown to reduce phosphorous and nitrogen concentrations in runoff by 75%.

The agricultural BMPs listed above are just a sample of the many accepted practices that are currently available. Many other techniques such as conservation tillage, responsible pest management, and precision agriculture also exist and may contribute to an improvement in overall water quality in the Upper Four Hole Swamp Watershed. Education should be provided to local farmers on these methods as well as acceptable manure spreading and holding (stacking sheds) practices. South Carolina-specific information on agriculture BMPs is available from the Clemson Cooperative Extension Service. http://www.clemson.edu/extension/water

The Natural Resources Conservation Service (NRCS, a division of USDA) provides financial and technical assistance to help landowners address natural resource concerns, promote environmental quality, and protect wildlife habitat on property they own or control. Their website contains a wealth of information on agriculture BMPs and water quality issues associated with agricultural practices. Cost-share funds are available through the NRCS's Environmental Quality Incentives Program (EQIP). EQIP helps farmers improve production while protecting environmental quality by addressing such concerns as soil erosion and productivity, grazing management, water quality, animal waste, and forestry concerns. More information about conservation and funding sources may be found at: https://www.farmers.gov/ and https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/ .

6.1.5 Leaking Sanitary Sewers

Leaking sanitary sewers and illicit discharges, although illegal and subject to enforcement, may be occurring the Upper Four Hole Swamp Watershed. Due to the high concentration of pollutant loading that is generally associated with these discharges, their detection may provide a substantial improvement in overall water quality in the watershed. Detection methods may include, but are not limited to: dye testing, air pressure testing, static pressure testing, and infrared photography. SCDHEC recognizes illicit discharge detection and elimination activities are conducted by regulated MS4 entities pursuant to compliance with existing MS4 permits. Note that these activities are designed to detect and eliminate illicit discharges that may contain FC bacteria or *E. coli*. It is the intent of SCDHEC to work with the MS4 entities to recognize FC bacteria or *E. coli* load reductions as they are achieved. SCDHEC acknowledges that these efforts to reduce illicit discharges and SSOs are ongoing and some reduction may already be accountable (i.e., load reductions occurring during TMDL development process). Thus, the implementation process is an iterative and adaptive process. Regular communication between all implementation stakeholders will result in successful remediation of controllable sources over time. As designated uses are restored, SCDHEC will recognize efforts of implementers where their efforts can be directly linked to restoration.

6.1.6 Failing Septic Systems

A septic system, also known as an onsite wastewater system, is defined as failing when it is not treating or disposing of sewage in an effective manner. The most common reason for failure is improper maintenance by homeowners. Untreated sewage not only contains disease-causing bacteria and viruses, but also unhealthy amounts of nitrate and other chemicals. Failed septic systems can allow untreated sewage to seep into and pollute wells, groundwater, and surface water bodies. Pumping a septic tank is probably the single most important thing that can be done to protect the system. Information on how a septic tank works and proper maintenance is available here: https://scdhec.gov/environment/your-home/septic-tanks and tips on proper usage here: https://www.epa.gov/septic/dos-and-donts-homeowners-brochure

6.1.7 Urban and Suburban Runoff

Urban runoff is surface runoff of rainwater created by urbanization outside of regulated areas. Pavement, compacted areas, roofs, reduced tree canopy and open space increase runoff volumes that rapidly flow into receiving waters. The increase in volume and velocity of runoff may cause stream bank erosion, channel incision and sediment deposition in stream channels. In addition, runoff from these developed areas can increase stream temperatures. This, along with the increase in flow rate and pollutant loads negatively affect water quality and aquatic life (USEPA 2005). Runoff can pick up bacteria along the way. Many strategies currently exist to reduce bacteria loading from urban runoff and the USEPA nonpoint source pollution website provides extensive resources on this subject:

https://www.epa.gov/nps/nonpoint-source-urban-areas

Some examples of urban nonpoint source BMPs are street sweeping, stormwater wetlands, pet waste receptacles (equipped with waste bags), and educational signs which can be installed adjacent to receiving waters in the watershed such as parks, common areas, apartment complexes, trails, etc. Low impact development (LID) may also be effective. LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treats stormwater as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements (USEPA, 2009).

Education should be provided to individual homeowners in the referenced watershed on the contributions to bacteria loading from pet waste. Education to homeowners in the watershed on the fate of substances poured into storm drain inlets should also be provided. For additional information on urban runoff please see the SCDHEC nonpoint source program web page:

https://www.scdhec.gov/environment/your-water-coast/watersheds-program/section-319-nonpoint-source-program

7.0 Resources for Pollution Management

- Citizen's Guide to Protecting Our Water Resources from Runoff Pollution

  https://scdhec.gov/sites/default/files/media/document/CR-002358.pdf

- Polluted Runoff: Nonpoint Source (NPS) Pollution – EPA's landing page for all things NPS

  https://www.epa.gov/nps

- National Menu of Best Management Practices (BMPs) for Stormwater – Based on the six minimum control measures for Phase I and Phase II MS4s

  https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu

- South Carolina Forestry Commission Best Management Practices – Includes streamside management, stream crossings, and managing drainage to protect water quality

  https://www.state.sc.us/forest/refbmp.htm#contents

- Clemson Public Service and Agriculture – Center for Watershed Excellence offers professional training for managing stormwater ponds, assessing BMPs, and landscape managing to protect waterways

  https://www.clemson.edu/public/water/watershed/

- SCDOT Stormwater Management

  https://www.scdot.org/business/storm-water.aspx

- Agricultural Waste Management Field Handbook

  https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?&cid=stelprdb1045935

- Manure Management for Small Farms

https://lpelc.org/manure-management-on-small-farms/

- Managing Canada Geese in Urban Environments

  https://ecommons.cornell.edu/handle/1813/66

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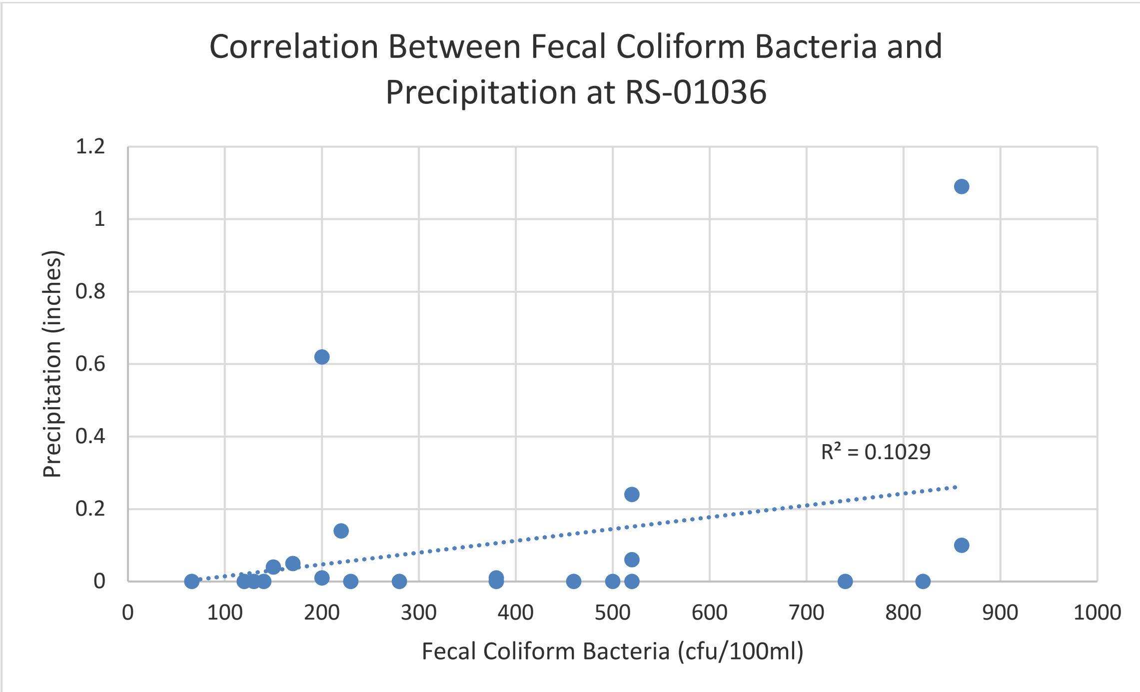
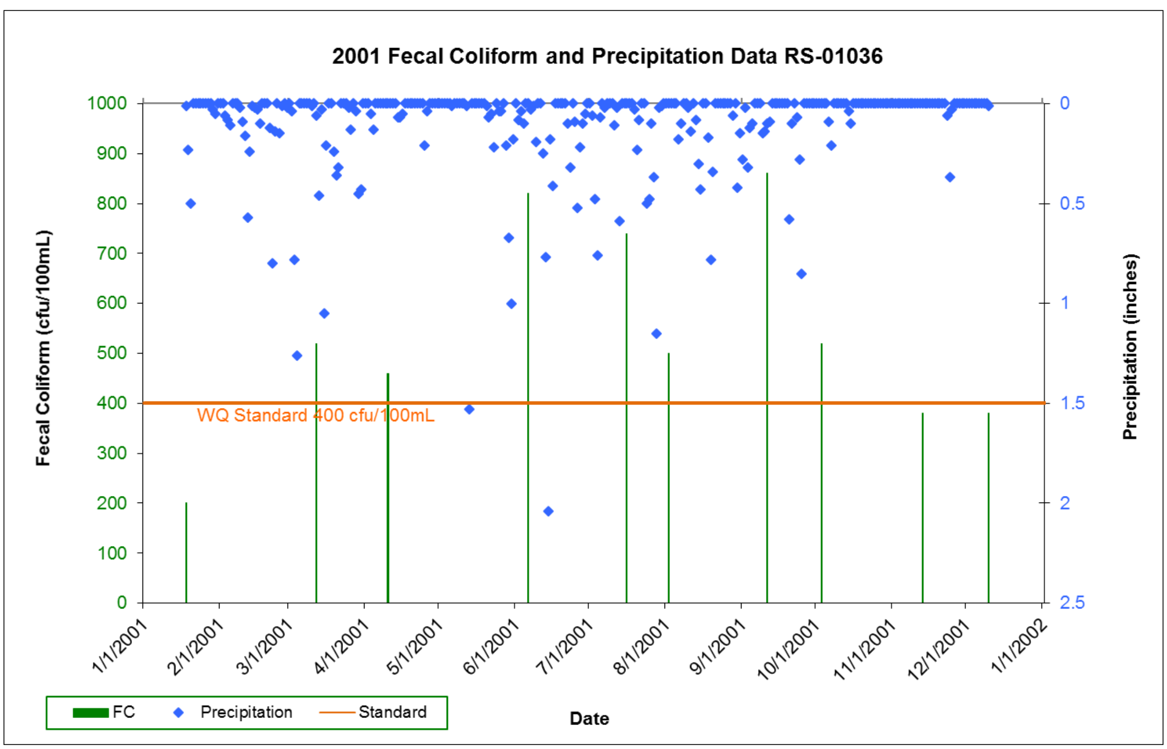
Appendix A: Additional Rain Charts

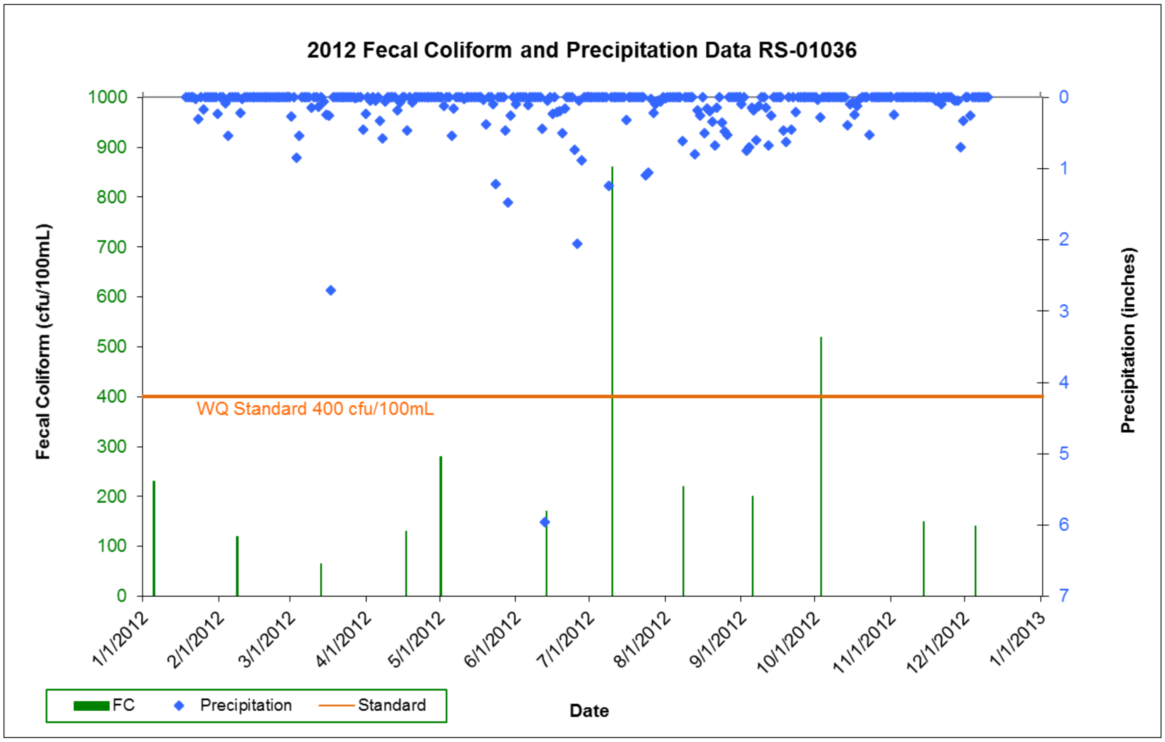
Correlation Between Fecal Coliform Bacteria and Precipitation at RS-01036



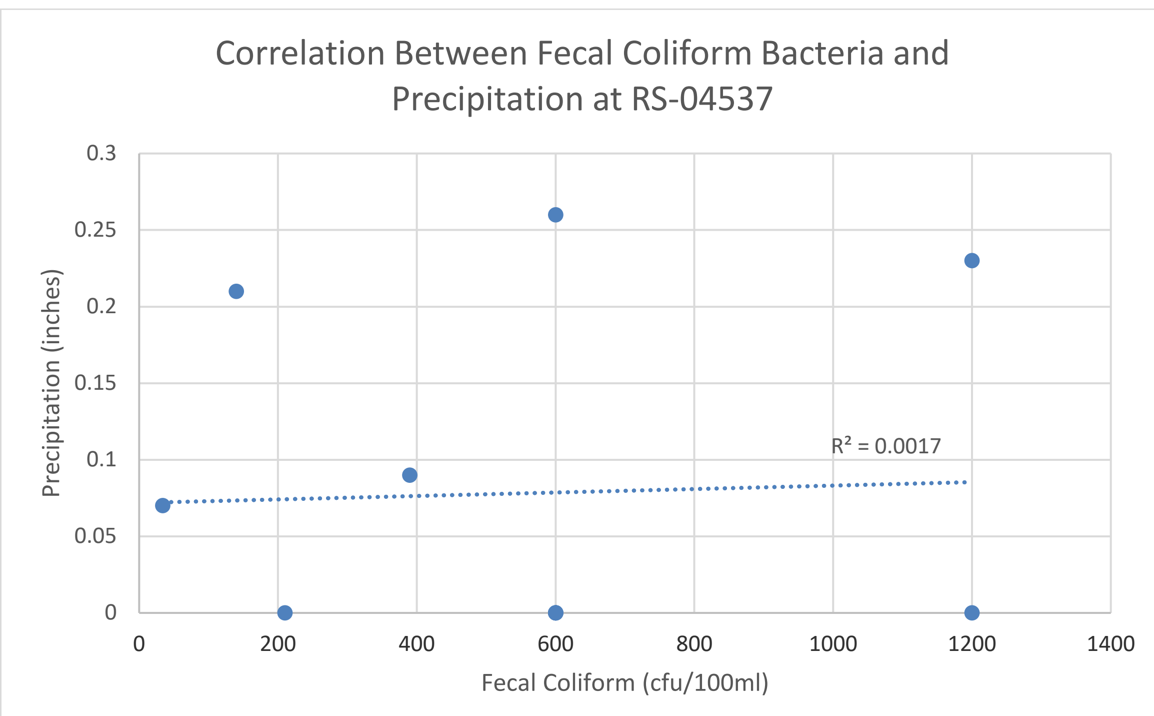
Fecal Coliform Bacteria and Precipitation at RS-01036 in 2001



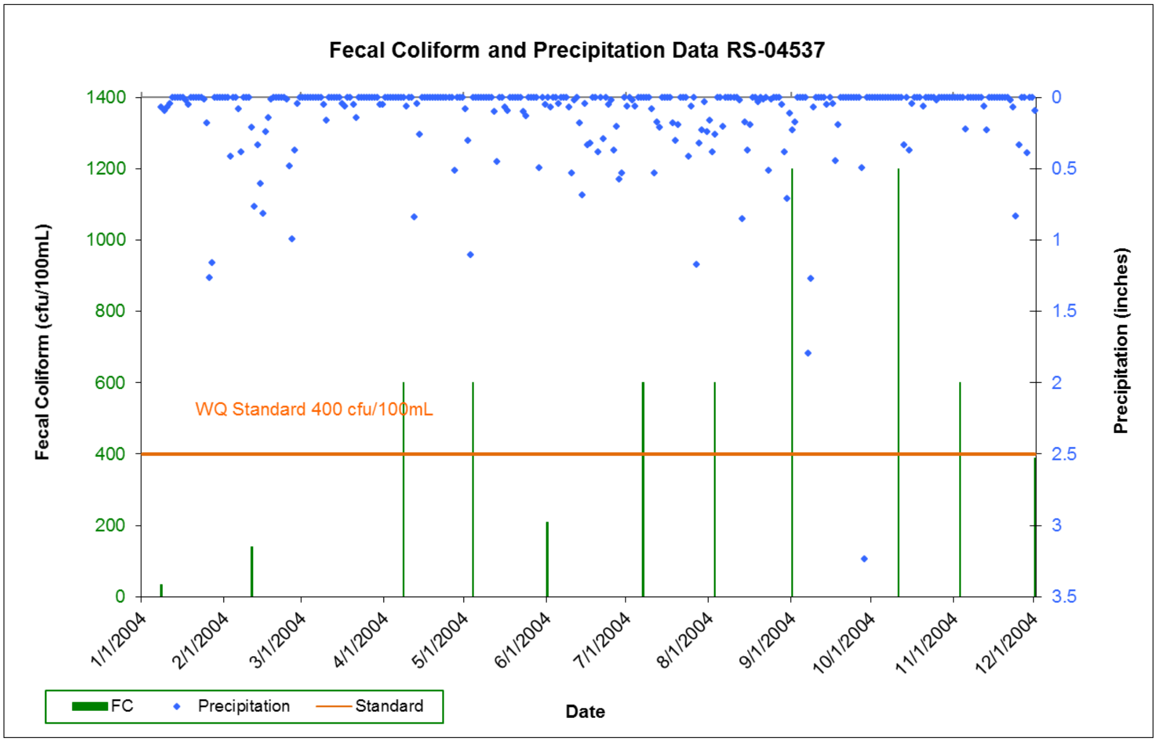
Fecal Coliform Bacteria and Precipitation at RS-01036 in 2012



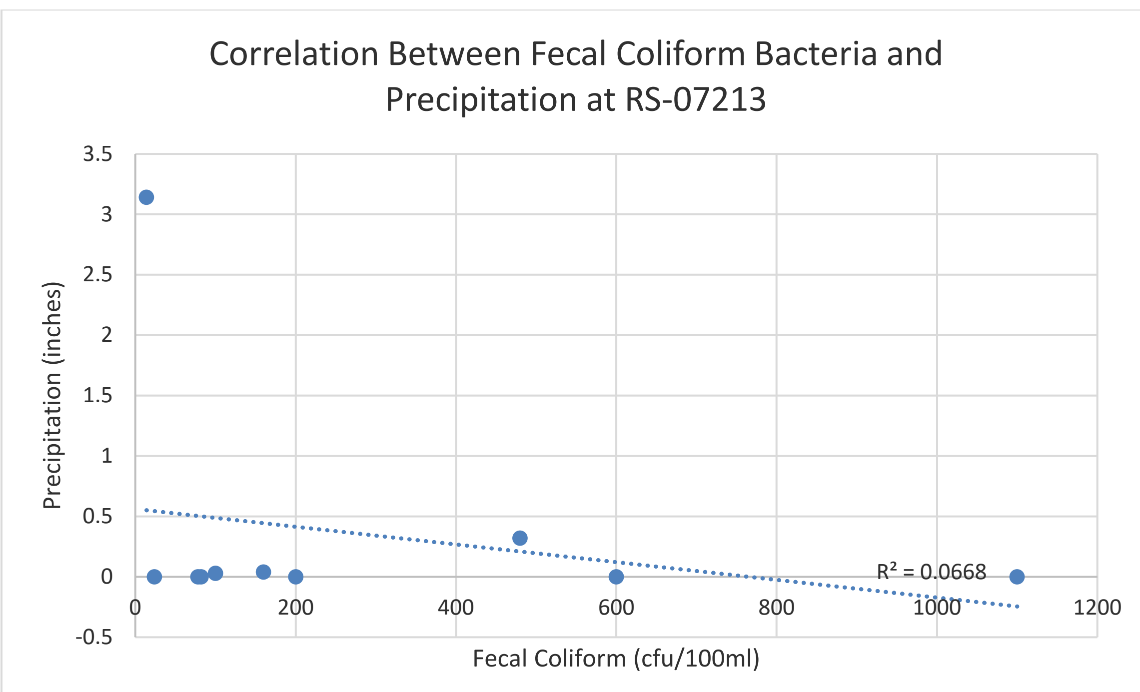
Correlation Between Fecal Coliform Bacteria and Precipitation at RS-04537



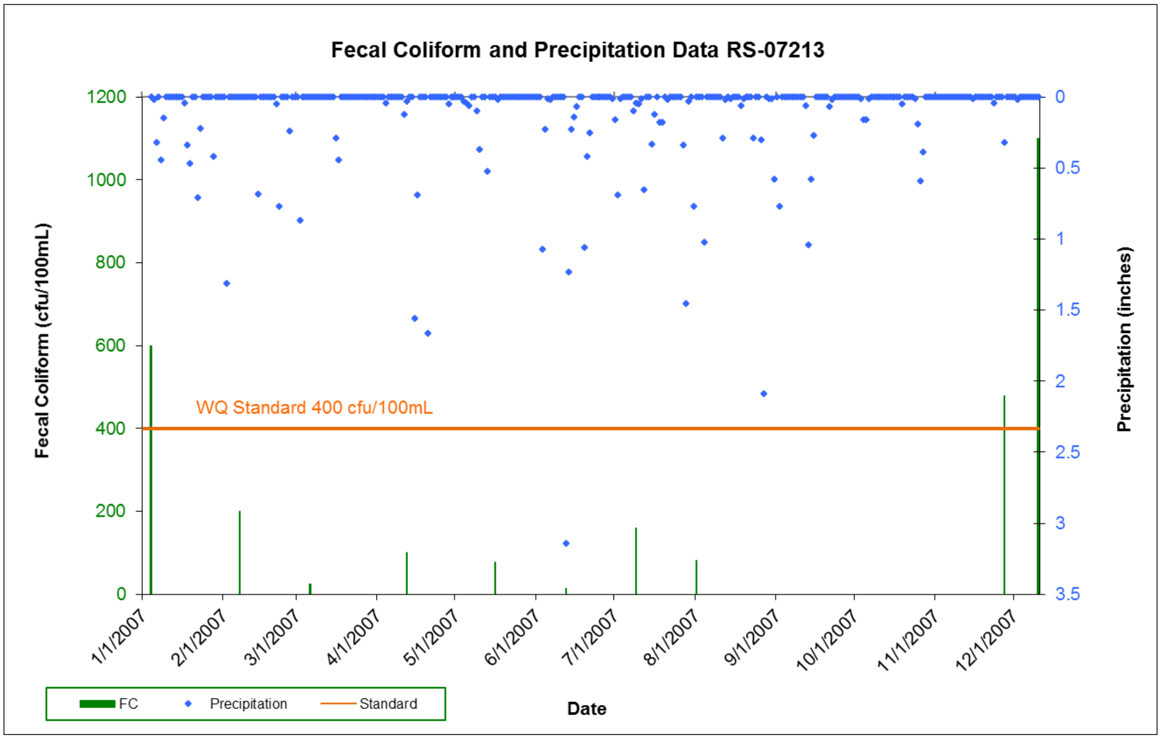
Fecal Coliform Bacteria and Precipitation at RS-04537



Correlation Between Fecal Coliform Bacteria and Precipitation at RS-07213

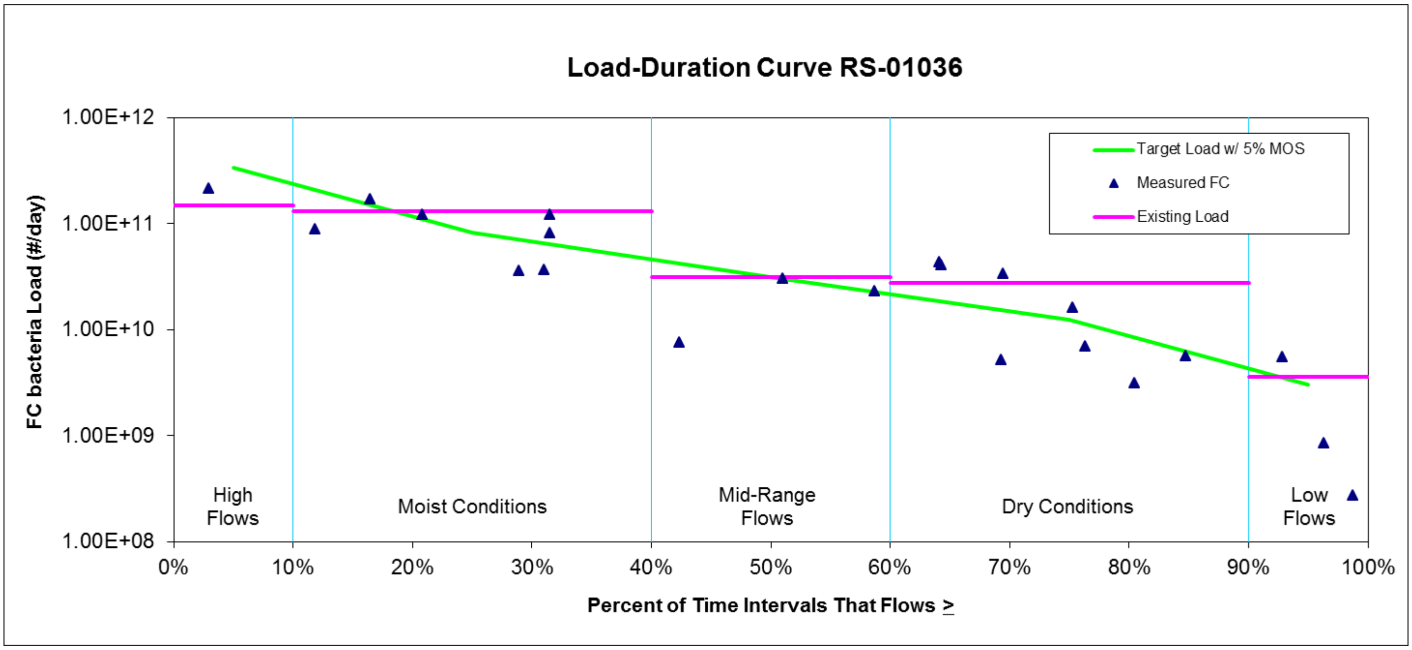


Fecal Coliform Bacteria and Precipitation at RS-07213

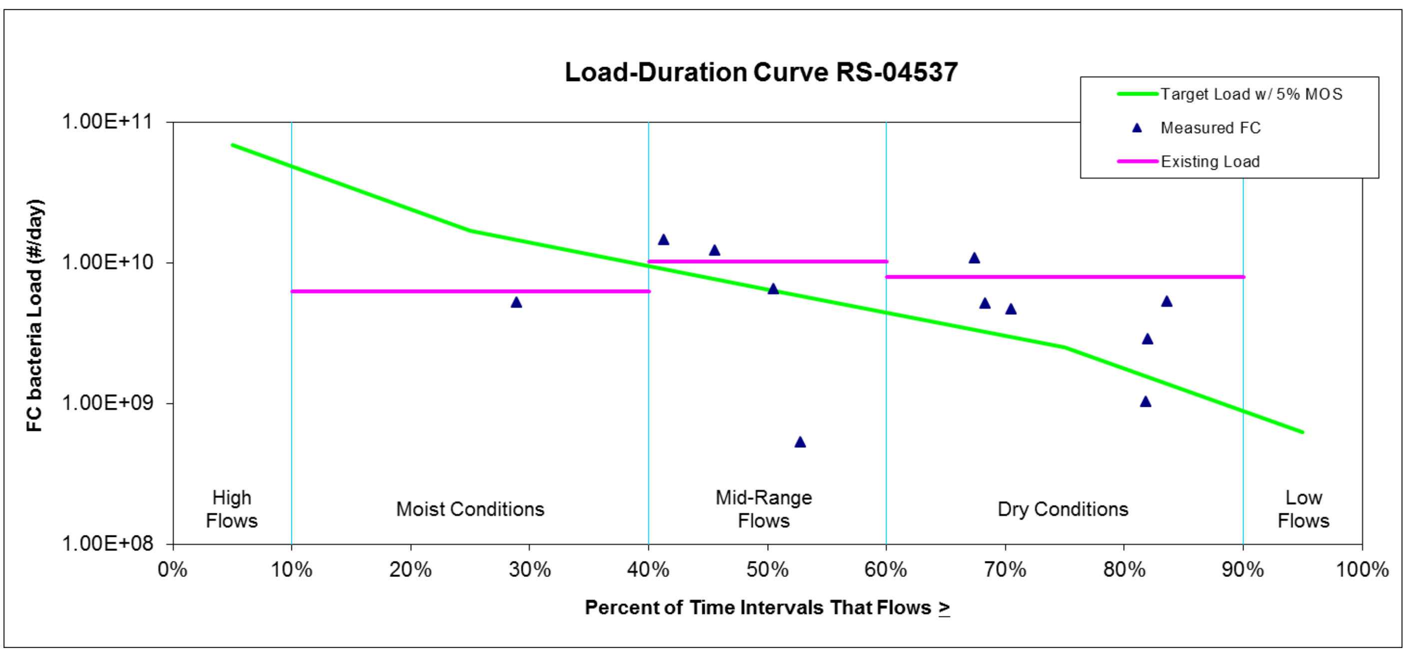


Appendix B: Additional Load Duration Curves

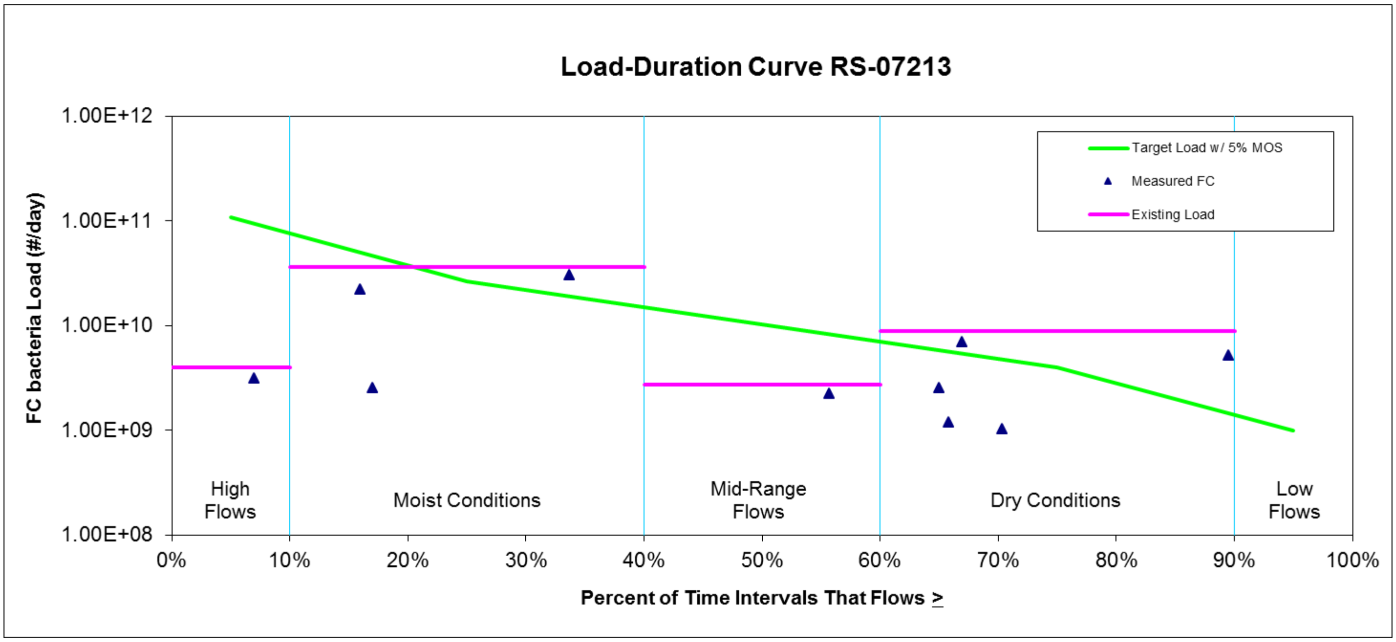
Load Duration Curve RS-01036



Load Duration Curve RS-04537



Load Duration Curve RS-07213



Appendix C: Evaluating the Progress of MS4 Programs

Described below are approaches that may be used by MS4 permit holders and others implementing TMDLs. These are recommendations and examples only. SCDHEC-BOW recognizes that other approaches may be utilized or employed to meet compliance goals.

1. Calculate pollutant load reduction for each best management practice (BMP) deployed:
   - Retrofitting stormwater outlets
   - Creation of green space
   - LID activities (e.g., creation of porous pavements)
   - Creations of riparian buffers
   - Stream bank restoration
   - Scoop the poop program (how many pounds of poop were scooped/collected)
   - Street sweeping program (amount of materials collected etc.)
   - Construction & post-construction site runoff controls
2. Description & documentation of programs directed towards reducing pollutant loading:
   - Document tangible efforts made to reduce impacts to urban runoff
   - Track type and number of structural BMPs installed
   - Parking lot maintenance program for pollutant load reduction
   - Identification and elimination of illicit discharges
   - Zoning changes and ordinances designed to reduce pollutant loading
   - Modeling of activities & programs for reducing pollutant reductions
3. Description & documentation of social indicators, outreach, and education programs:
   - Number/Type of training & education activities conducted and survey results
   - Activities conducted to increase awareness and knowledge – residents, business owners. What changes have been made based on these efforts? Any measured behavior or knowledge changes?
   - Participation in stream and/or lake clean-up events or activities
   - Number of environmental action pledges
4. Water quality monitoring: A direct and effective way to evaluate the effectiveness of stormwater management plan activities:
   - Use of data collected from existing monitoring activities (e.g., SCDHEC data for ambient monitoring program available through STORET; water supply intake testing; voluntary watershed group's monitoring, etc)
   - Establish a monitoring program for permitted outfalls and/or waterbodies within MS4 areas as deemed necessary– use a certified lab
   - Monitoring should focus on water quality parameters and locations that would both link pollutant sources and BMPs being implemented

Useful Links:

Evaluating the Effectiveness of Municipal Stormwater Programs.

https://www3.epa.gov/npdes/pubs/region3_factsheet_swmp.pdf

The International Stormwater Best Management Practices Database Project

http://www.bmpdatabase.org/

National Water Quality Monitoring Council - Water Quality Data

https://www.waterqualitydata.us/portal/

Spreadsheet Tool for Estimating Pollutant Loads (STEPL)

https://www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl

Measurable Goals Guidance for Phase II Small MS4s

https://www3.epa.gov/npdes/pubs/measurablegoals.pdf

National Menu of BMPs for Stormwater

https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu

SCDHEC – BOW: The 319 grant program (https://www.scdhec.gov/environment/your-water-coast/watersheds-program/watersheds-program-contacts) can provide guidance on estimating load reductions for the following BMPs:

- Septic tank repair or replacement
- Removing livestock from streams
- Livestock fencing
- Waste Storage Facilities
- Strip cropping
- Prescribed grazing
- Critical Area Planting
- Runoff Management System
- Waste Management System
- Solids Separation Basin
- Riparian Buffers

Appendix D: Data Tables

Sampling Data WQM Station E-111

E. coli MPN (exceedences highlighted)

Date	MPN/100mL
2/6/2013	344.8
4/2/2013	152.9
6/4/2013	520.25
8/7/2013	248.9
10/9/2013	501.2
12/3/2013	275.5
1/15/2014	770.1
3/4/2014	203.5
5/13/2014	172.3
7/7/2014	209.8
9/4/2014	248.1
11/4/2014	275.5
1/6/2015	123.6
3/3/2015	290.9
5/12/2015	190.4
7/13/2015	83.3
9/8/2015	30.5
11/17/2015	201.4
2/9/2016	344.8
4/13/2016	178.2
6/2/2016	1203.3
8/16/2016	231
12/13/2016	866.4
1/10/2017	461.1
2/8/2017	1203.3
3/16/2017	1299.7
4/12/2017	547.5
5/17/2017	816.4
6/21/2017	866.4
7/19/2017	727
8/30/2017	172.3
9/26/2017	96
10/24/2017	2419.6
11/16/2017	547.5
12/5/2017	1732.9
1/24/2018	579.4

90th Percentile *E. coli* Concentration (MPN/100ml) by Hydrologic Category

WQM Site	High Flow 0-10%	Moist Cond. 10-40%	Midrange 40-60%	Dry Cond. 60-90%	Low Flow 90-100%	Number of Samples
E-111	1203	1194	1300	376	520	36

Flow (cfs) at Midpoint of Each Hydrologic Category

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-111	391.7	164.9	104.1	54.6	21.8

Existing Load (number *E. coli*/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-111	1.15E+13	4.82E+12	3.31E+12	5.02E+11	2.77E+11

TMDL (number *E. coli*/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-111	3.34E+12	1.41E+12	8.89E+11	4.66E+11	1.86E+11

Load Reduction Necessary (number *E. coli*/day) at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-111	NA	3.41E+12	2.42E+12	3.60E+10	NA

Percent Reduction Necessary at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-111	NA	72%	74%	12%	NA

Sampling Data WQM Station RS-01036

Fecal Coliform cfu (exceedences highlighted)

Date	cfu/100mL
1/18/2001	200
3/12/2001	520
4/10/2001	460
6/6/2001	820
7/16/2001	740
8/2/2001	500
9/11/2001	860
10/3/2001	520
11/13/2001	380
12/10/2001	380
1/5/2012	230
2/8/2012	120
3/13/2012	66
4/17/2012	130
5/1/2012	280
6/13/2012	170
7/10/2012	860
8/8/2012	220
9/5/2012	200
10/3/2012	520
11/14/2012	150
12/5/2012	140

90th Percentile FC Bacteria Concentration (cfu/100ml) by Hydrologic Category

WQM Site	High Flow 0-10%	Moist Cond. 10-40%	Midrange 40-60%	Dry Cond. 60-90%	Low Flow 90-100%	Number of Samples
RS-01036	170	608	380	860	446	22

Flow (cfs) at Midpoint of Each Hydrologic Category

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-01036	36.2	8.9	3.4	1.3	0.3

Existing Load (number FC bacteria/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-01036	1.50E+11	1.32E+11	3.17E+10	2.78E+10	3.57E+09

TMDL (number FC bacteria/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-01036	3.54E+11	8.68E+10	3.34E+10	1.29E+10	3.20E+09

Load Reduction Necessary (number FC bacteria/day) at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-01036	NA	4.52E+10	0*	1.49E+10	NA

*No exceedences occurred during this flow condition, therefore no reduction needed

Percent Reduction Necessary at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-01036	NA	38%	0%*	56%	NA

*No exceedences occurred during this flow condition, therefore no reduction needed

Sampling Data WQM Station RS-04537

Fecal Coliform cfu (exceedences highlighted)

Date	cfu/100mL
1/8/2004	34
2/11/2004	140
4/8/2004	600
5/4/2004	600
6/1/2004	210
7/7/2004	600
8/3/2004	600
9/1/2004	1200
10/11/2004	1200
11/3/2004	600
12/1/2004	390

90th Percentile FC Bacteria Concentration (cfu/100ml) by Hydrologic Category

WQM Site	High Flow 0-10%	Moist Cond. 10-40%	Midrange 40-60%	Dry Cond. 60-90%	Low Flow 90-100%	Number of Samples
RS-04537	*	140	600	1200	*	11

*No samples collected during these flow conditions

Flow (cfs) at Midpoint of Each Hydrologic Category

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-04537	7.4	1.8	0.7	0.3	0.1

Existing Load (number FC bacteria/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-04537	*	6.22E+09	1.03E+10	7.96E+09	*

*No samples collected during these flow conditions

TMDL (number FC bacteria/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-04537	7.25E+10	1.78E+10	6.84E+09	2.65E+09	6.56E+08

Load Reduction Necessary (number FC bacteria/day) at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-04537	NA	0*	3.46E+09	5.31E+09	NA

*No exceedences occurred during this flow condition, therefore no reduction needed

Percent Reduction Necessary at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-04537	NA	0%*	37%	68%	NA

*No exceedences occurred during this flow condition, therefore no reduction needed

Sampling Data WQM Station RS-07213

Fecal Coliform cfu (exceedences highlighted)

Date	cfu/100mL
1/4/2007	600
2/7/2007	200
3/6/2007	24
4/12/2007	100
5/16/2007	78
6/12/2007	14
7/9/2007	160
8/1/2007	82
11/27/2007	480
12/10/2007	1100

90th Percentile FC Bacteria Concentration (cfu/100ml) by Hydrologic Category

WQM Site	High Flow 0-10%	Moist Cond. 10-40%	Midrange 40-60%	Dry Cond. 60-90%	Low Flow 90-100%	Number of Samples
RS-07213	14	520	100	852	*	10

*No samples collected during this flow condition

Flow (cfs) at Midpoint of Each Hydrologic Category

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-07213	11.7	2.9	1.1	0.4	0.1

Existing Load (number FC bacteria/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-07213	4.01E+09	3.65E+10	2.70E+09	8.93E+09	*

*No samples collected during this flow condition

TMDL (number FC bacteria/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-07213	1.15E+11	2.81E+10	1.08E+10	4.19E+09	1.04E+09

Load Reduction Necessary (number FC bacteria/day) at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-07213	NA	8.40E+09	*	4.74E+09	NA

*No exceedences occurred during this flow condition, therefore no reduction needed

Percent Reduction Necessary at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
RS-04537	NA	27%	*	55%	NA

*No exceedences occurred during this flow condition, therefore no reduction needed

Appendix E: Source Assessment Pictures

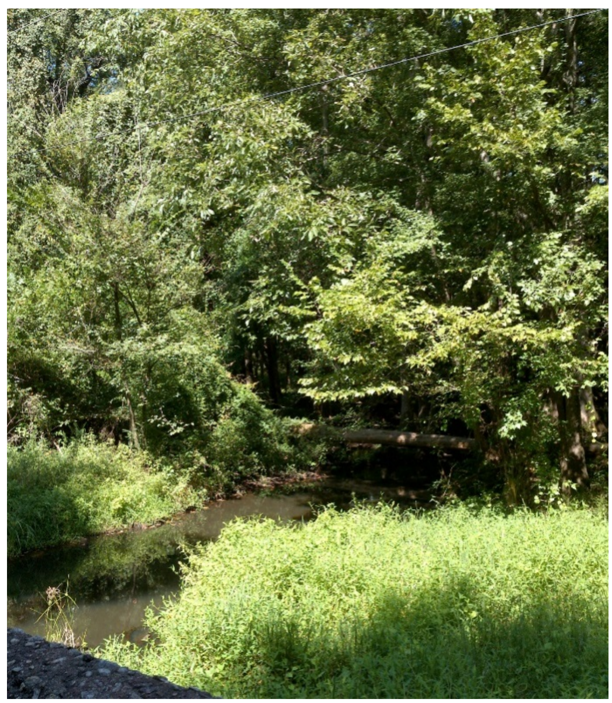
Figure 14. Stream characteristics in the Upper Four Hole Swamp Watershed

This area of the state is characterized by little slope, low stream velocities, and at times, very low flow. Flood plains are wide, often wooded, and sometimes inundated for long periods of time. Larger streams and rivers such as Four Hole Swamp have multiple braided channels. Pictured clockwise from upper left are the headwaters of Goodbys Swamp, Middle Pen Swamp and Four Hole Swamp at E-111. These pictures were taken August 2019.

During the August site visit, WQM site RS-04537, located at the headwaters of an unnamed tributary to Four Hole Swamp, was dry (pictured left).

RS-07213, close to the headwaters of Mill Branch (lower left), contained some pools of standing water.

RS-01036 (Goodbys Swamp) is located near the outlet of the watershed. The stream at this location had two channels with flow (lower right). This area is used recreationally, as evidenced by fishing line, bait containers and trash left behind.



The middle reach of Goodbys Swamp (left and bottom left) and Middle Pen Swamp (bottom right) contain large impoundments. The upper end of the impoundment on Goodbys Swamp had a heavy growth of floating and rooted aquatic plants.

Figure 15. Agriculture and Silviculture

Over 60% of the watershed draining to E-111 is used for agriculture: cultivated crops and hay/pasture. This percentage does not include the many acres devoted to silviculture. During a visit to the area (August 2019), most of the crops seen were cotton, peanuts, corn, and sod. This area also includes significant amounts of animal agriculture

Figure 16. Wildlife

Due to the rural nature of this watershed, wildlife is expected to be abundant and to contribute significantly to the bacteria load in the water.

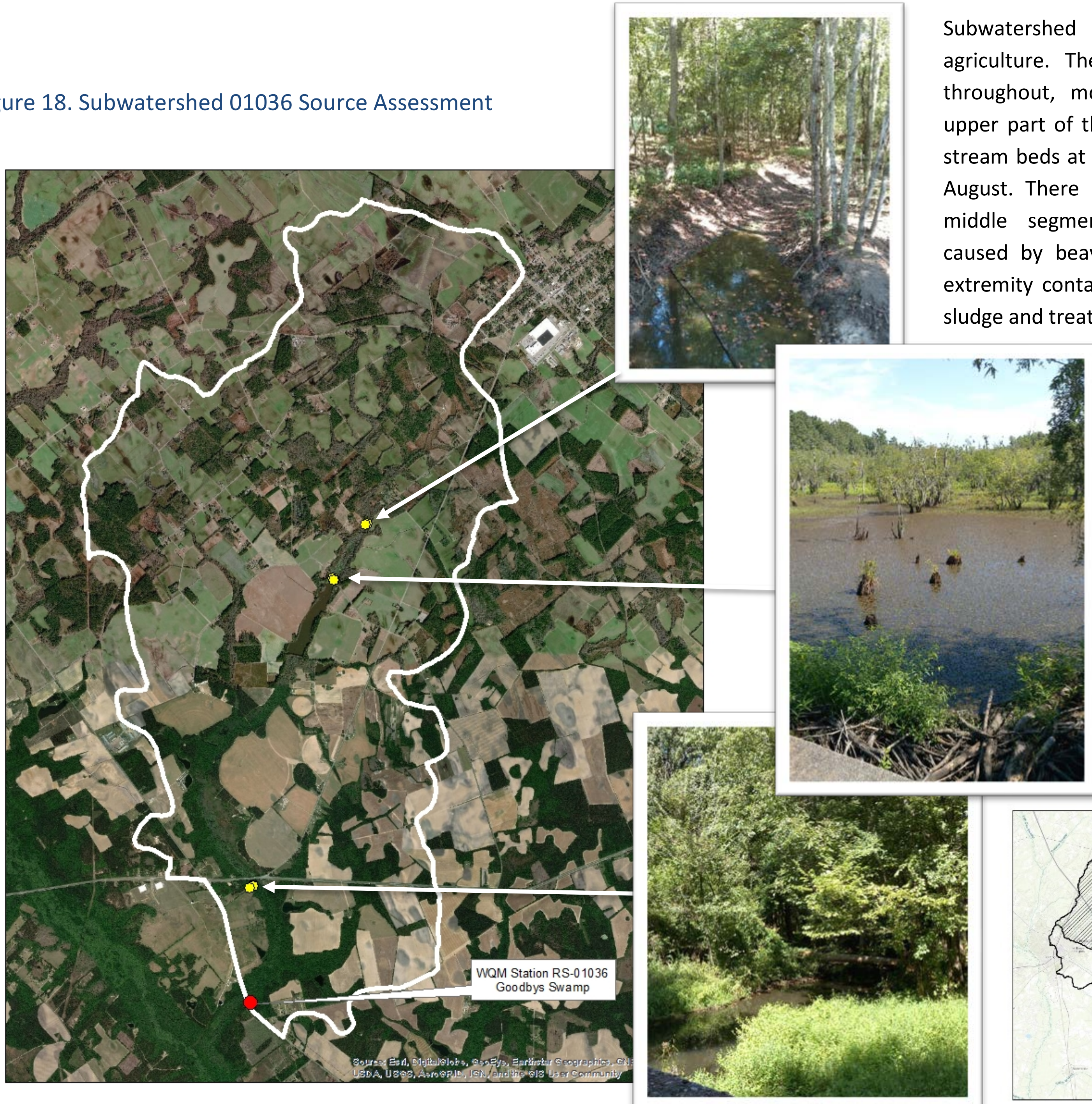
Although no beavers were seen, there is an established beaver dam on Goodbys Swamp that has resulted in a large impoundment. This area was also inhabited by a noisy flock of black vultures roosting over and next to the water.

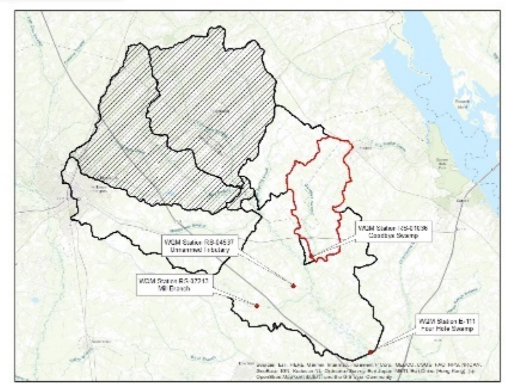
There were many turtles and a juvenile alligator spotted during the site visit, but these are not expected to contribute to *E. coli*.

Figure 17. Other Nonpoint Sources

Moving northwest in subwatershed 111 reveals increasing amounts of impervious surfaces and development. There are hobby farms with evidence of grazing adjacent to Middle Pen Swamp, and settlements and suburbs that may contribute pet waste and which may not be connected to municipal sewer systems.

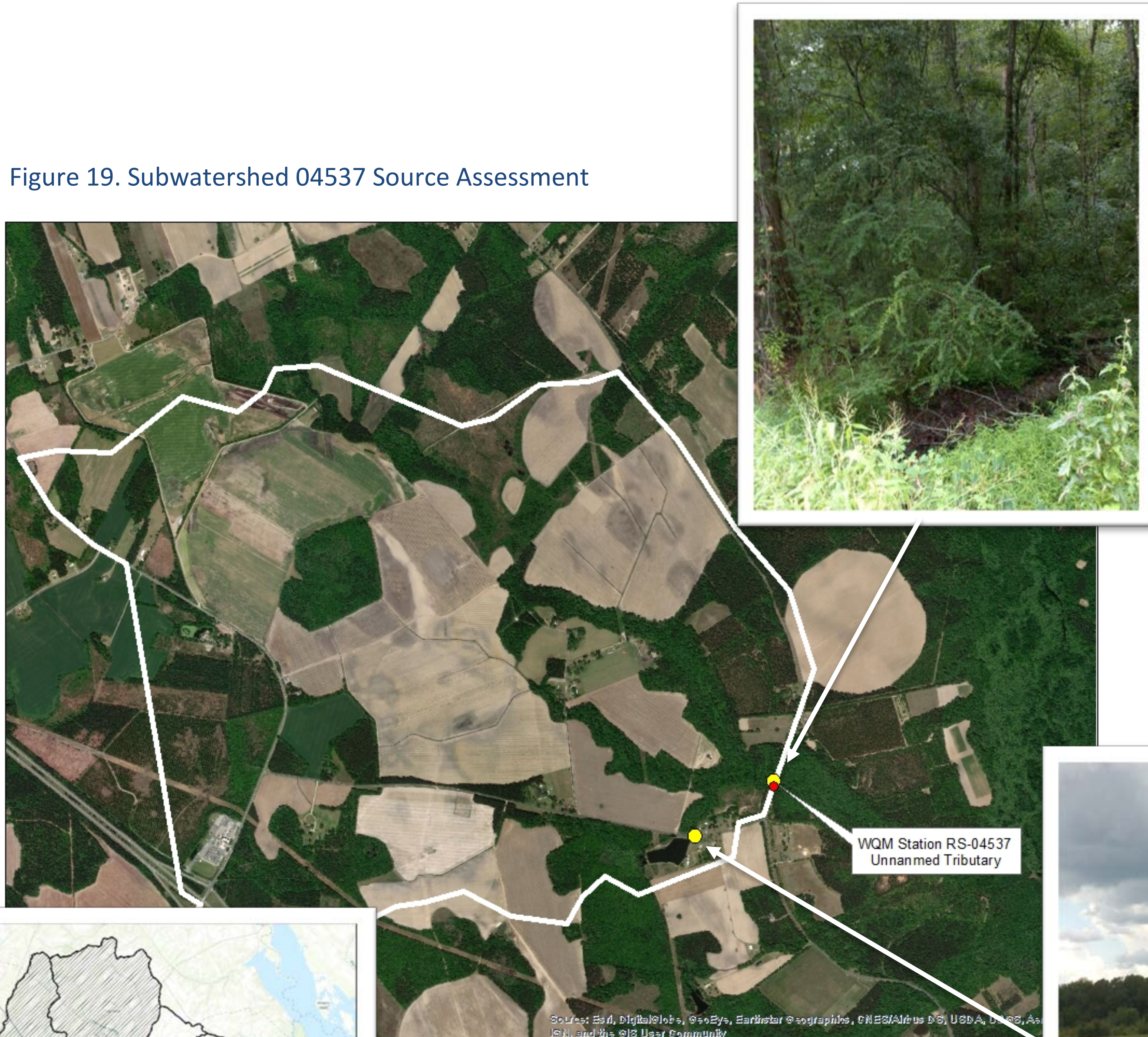
Figure 18. Subwatershed 01036 Source Assessment





Subwatershed 01036 is dominated by agriculture. There are houses scattered throughout, most on septic tanks. The upper part of the watershed revealed dry stream beds at the time of the site visit in August. There are impoundments in the middle segment, both manmade and caused by beaver activity. The southern extremity contains several areas to which sludge and treated wastewater are applied.

Figure 19. Subwatershed 04537 Source Assessment



Approximately 70% of land use in subwatershed 04537 is cultivated crops. There are several permitted animal feeding operations in the watershed and many of the surrounding fields are permitted manure utilization areas. The WQM site was dry when visited in August. There are a few houses in the area on septic tanks. One of these had two horses on pasture. There is an impoundment just upstream of the WQM site.

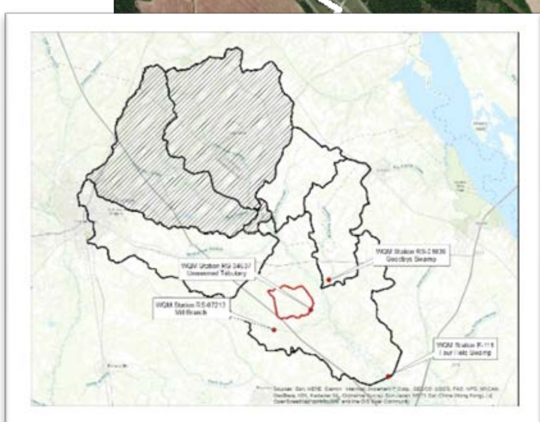
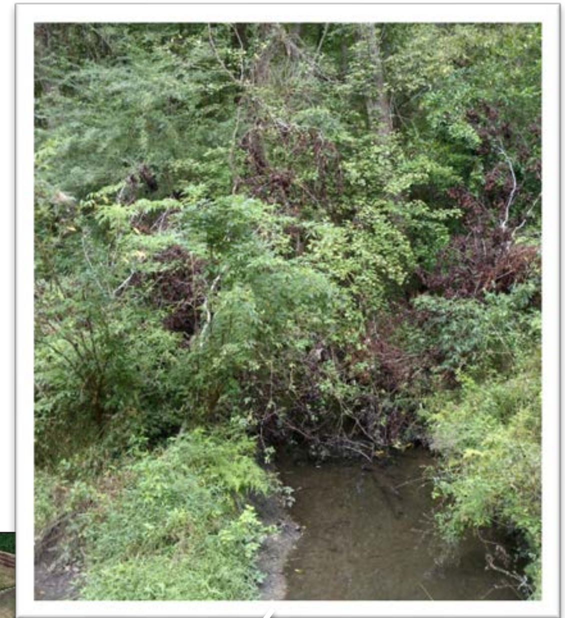


Figure 20. Subwatershed 07213 Source Assessment

Subwatershed 07213 drains farmed (46%) and forested land (51%). Although there is very little development, Interstate 26 runs through this watershed. There was standing water in the streambed of Mill Branch when visited in August with no discernable flow.



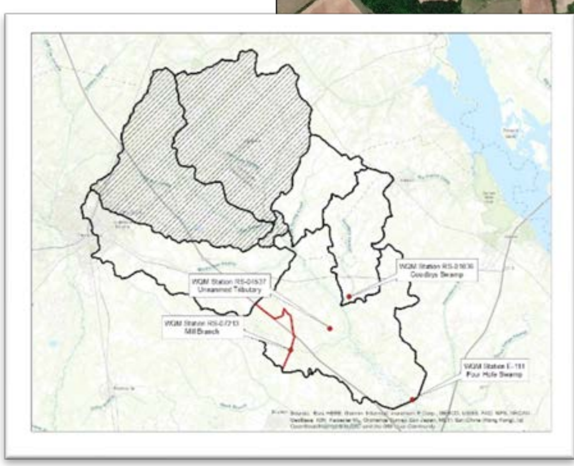
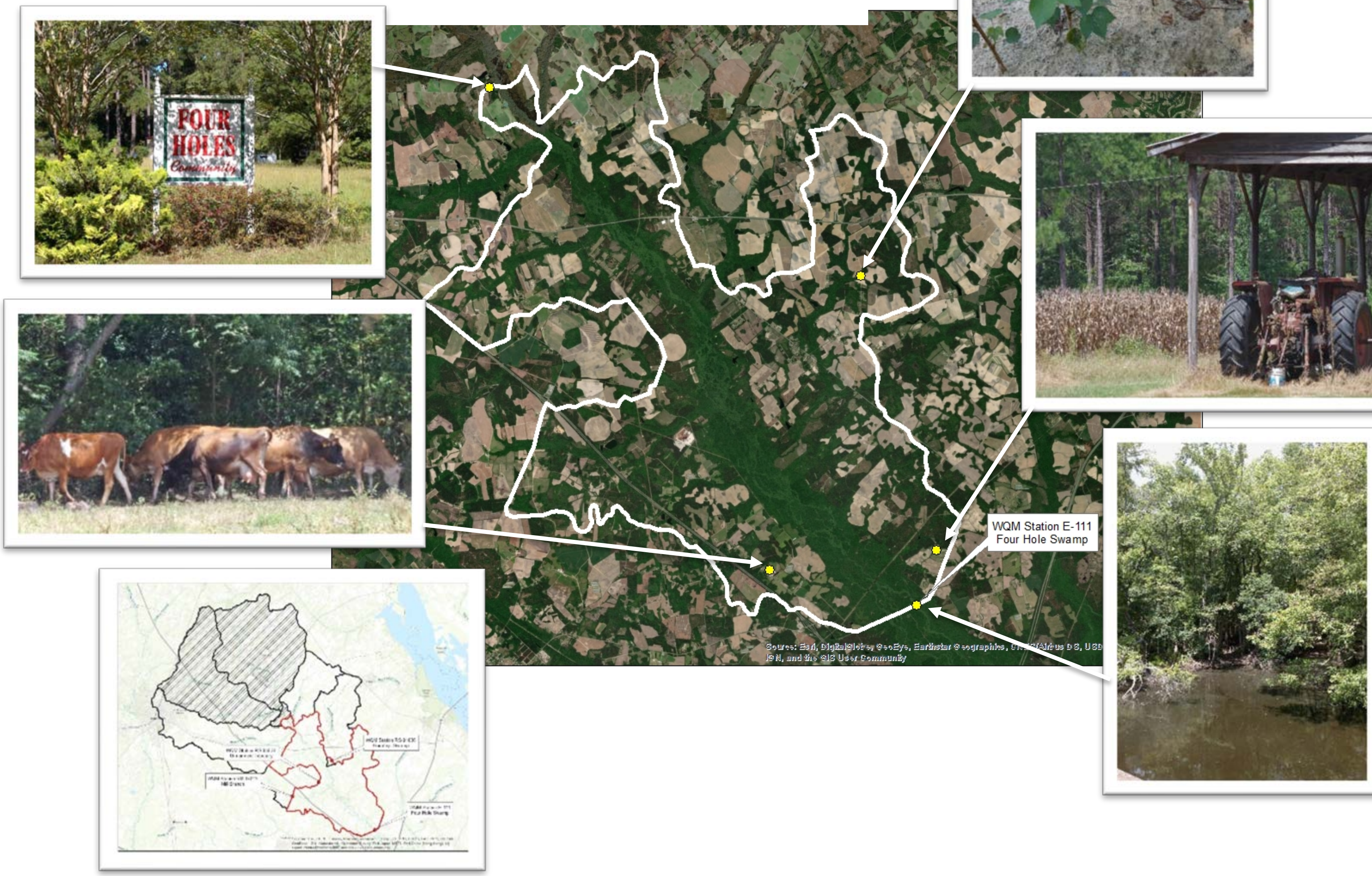


Figure 21. Subwatershed E-111 Source Assessment

Land use in this watershed is mostly agricultural (> 65%) with several small communities and scattered houses, most likely served by septic tanks. There are many animal feeding operations with associated manure utilization areas as well. Interstate 26 passes through the southwestern part of the watershed.



The headwaters of Middle Pen Swamp originate in the City of Orangeburg. This area contains a high number of impervious surfaces enhancing runoff of pollutants into the stream. Land use gradually changes from urban to suburban to rural as one moves downstream. There are some impoundments on the stream with pasture nearby. Interstate 26 crosses the watershed and there is some development near the interchange with U.S. 301 as well. This area is part of subwatershed 111.

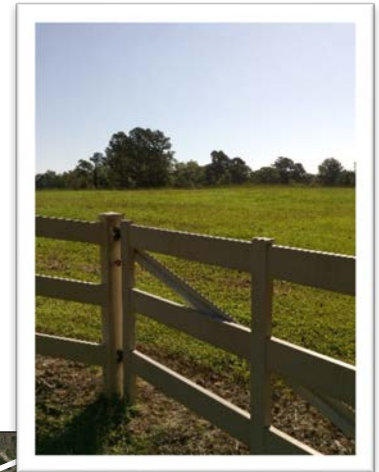


Figure 22. Polk Spring Creek (HUC 030502050103) Source Assessment

Polk Spring Creek drains to Four Hole Swamp and ultimately to E-111. Land use in this watershed is largely agriculture and silviculture. On the day of the site visit in August 2019, the creek bed was dry near the headwaters area.