Watershed Characterization Document
(Hydrologic Unit Code: 03050204070-010)
Roberts Swamp, Site E-039
Fecal Coliform Bacteria

June 2005

SCDHEC Technical Report Number: 021-05

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

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Date

Abstract

Roberts Swamp is a tributary of the Edisto River, South Carolina. Site E-039 (Roberts Swamp at SC 332) has been placed on South Carolina's 303(d) list of impaired waters for fecal coliform standard violations. During the assessment period for the 2004 303(d) list (1998-2002), 31 % of samples violated the standard. The Roberts Swamp Watershed is predominately rural and agricultural. There are poultry and swine farms located within the watershed. In the early 1990's the watershed was 46% cropland, 32% forest and 10% wetlands. There are no permitted point sources in the watershed. The probable sources of fecal coliform bacteria in the creek are runoff from agricultural lands (higher flow events) and cattle-in-streams (lower flow events).

Load-duration curve methodology was used to calculate the existing load and the TMDL load for Roberts Swamp at SC 332. The existing load was estimated to be 4.82×10^{11} cfu/day. The TMDL load was determined to be 1.11×10^{11} cfu/day, consisting of the Load Allocation of 1.05×10^{11} cfu/day and margin of safety of 5.54×10^{09} cfu/day. In order to reach the target load, which is equal to the Load Allocation, a reduction in the existing load to the creek of 78 % will be necessary. There are no MS4s in this watershed. Several TMDL implementation strategies to bring about these reductions are suggested.

Table Ab-1. TMDL Components for Roberts Swamp at Station E-039

Impaired Station	WLA cfu/day	LA cfu/day	MOS cfu/day	TMDL cfu/day	% Reduction
E-039	N/A	1.05E+11	5.54E+09	1.11E+11	78 %

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Tables and Figures

Roberts Swamp (HUC 03040204070-010)

1.0 INTRODUCTION

1.1 Background

Levels of fecal coliform bacteria can be elevated in water bodies as the result of both point and nonpoint sources of pollution. Section 303(d) of the Clean Water Act 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 not meeting designated uses under technology-based pollution controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and in stream water quality conditions so that states can establish water quality-based controls to reduce pollution and restore and maintain the quality of water resources (USEPA 1991).

1.2 Watershed Description

The Roberts Swamp watershed is located in Orangeburg County, in the southeastern plains ecoregion of South Carolina (Figure 1). Roberts Swamp drains into the South Fork Edisto River upstream of the North and South Fork confluence. There is no municipal sewer service available in the 82.3 km^2 (20346 acres) watershed. The area is not designated as a municipal storm sewer system (MS4).

South Carolina DHEC has one monitoring station along Roberts Swamp; site E-039 is impaired and included on the 2004 303(d) list for fecal coliform bacteria. The water quality monitoring station is at SC 332 and approximately 20 km southwest of Orangeburg, SC.

There are currently no NPDES-permitted facilities in the Roberts Swamp Watershed.

The predominant land uses (MRLC) in the part of the Roberts Swamp watershed that drains to E-039 cropland (46%), forest (32%) and wetlands (10%) (Table 1; Figure 2). At the time the MRLC data were collected the developed land was under 1%.

1.3 Water Quality Standard

The impaired stream segment, Roberts Swamp, is designated as Class Freshwater. Waters of this class are described as follows:

> "Freshwaters 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 indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses." (R.61-68)

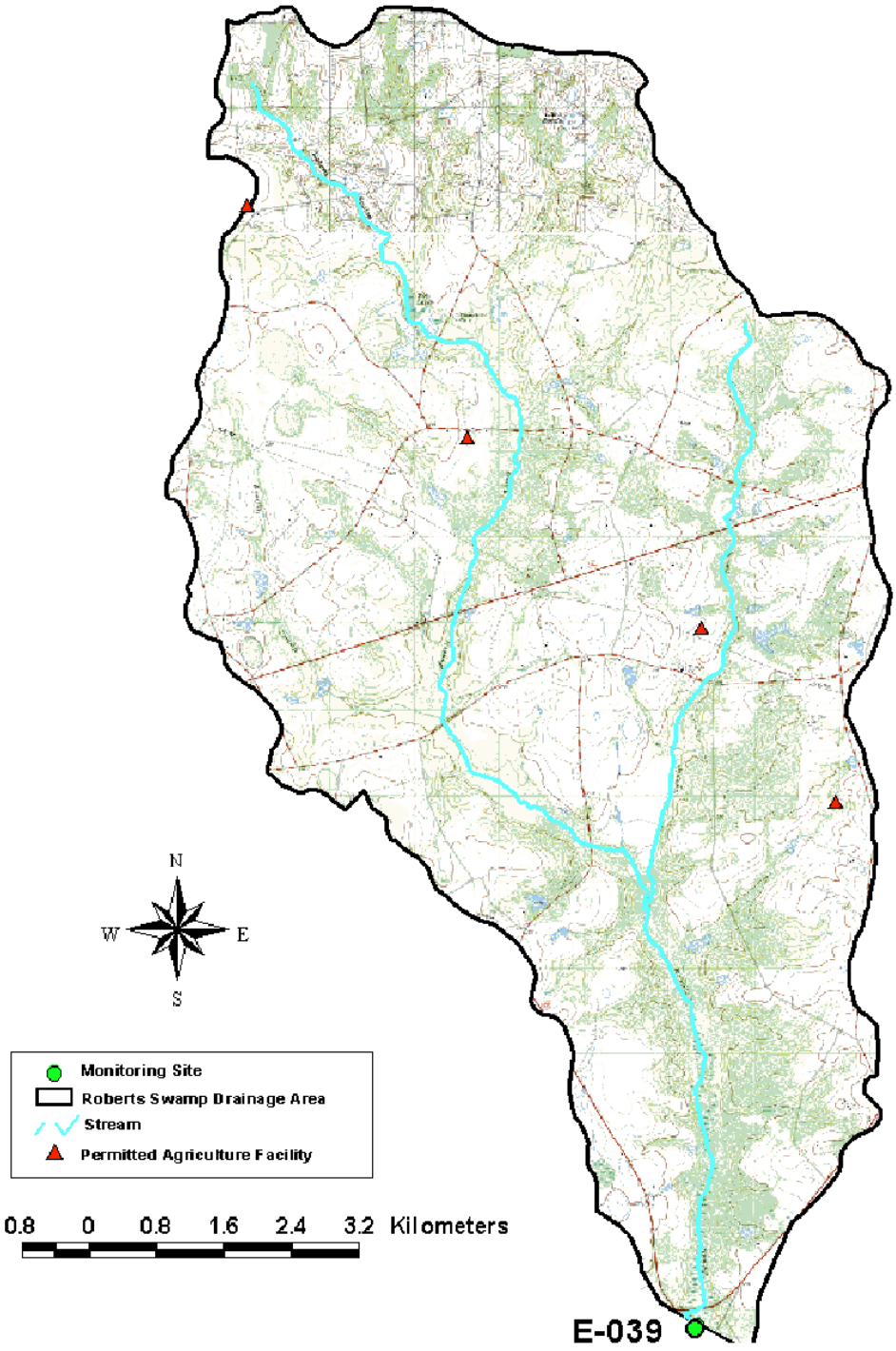

Figure 1. Map of the Roberts Swamp Watershed in Southeastern Plains Ecoregion Hydrologic Unit Code (HUC): 03050204070-010

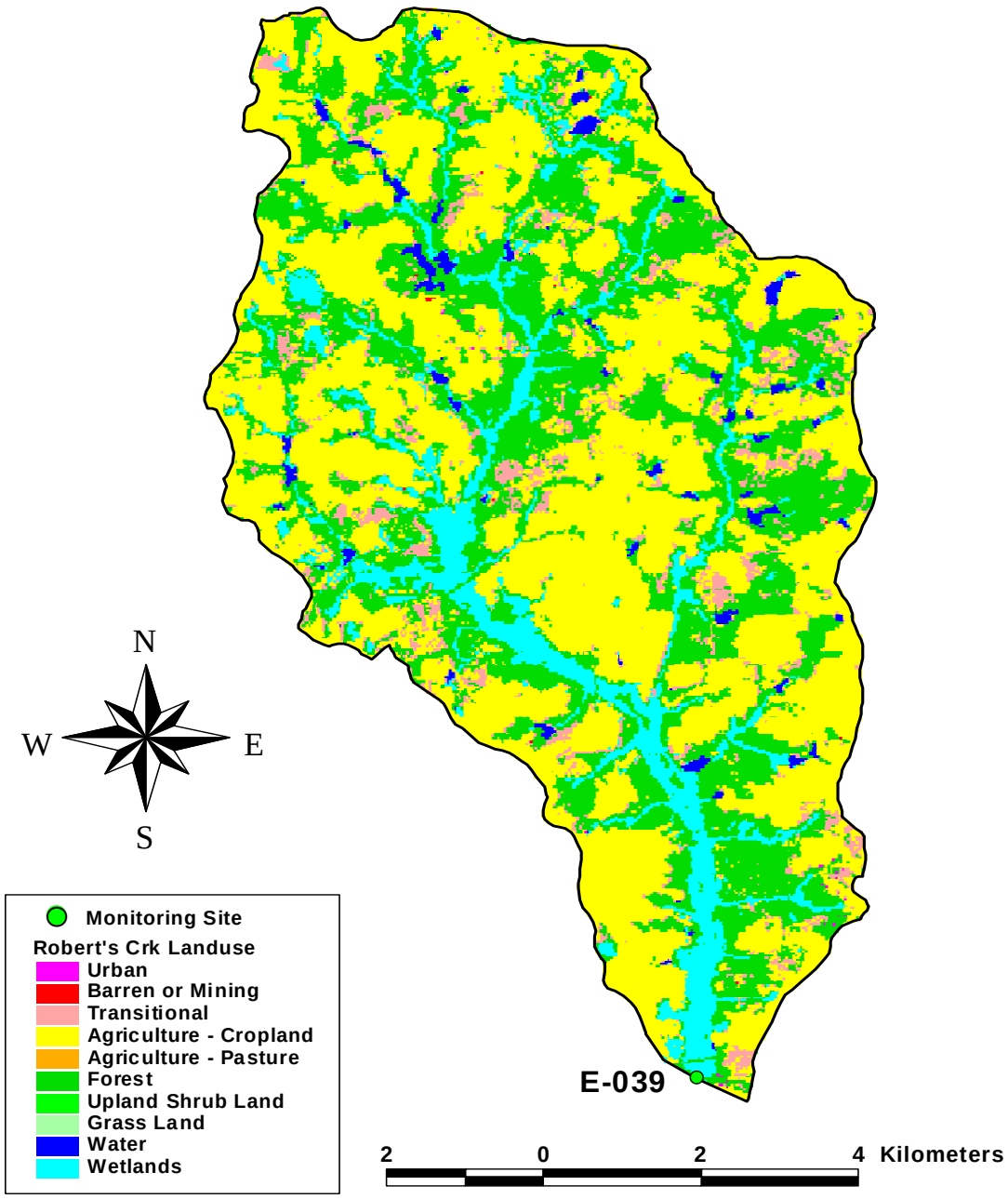

Figure 2. Map showing land uses in Roberts Swamp Watershed Hydrologic Unit Code(HUC): 03050204070-010

South Carolina's standard for fecal coliform in Freshwater is:

> "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 400/100 ml."(R.61-68).

Table 1. Land uses in the Roberts Swamp watershed upstream of E-039.

Land Use	Area (hectares)		Percent
Water	**119.3**		**1.5 %**
Residential Low	3.3		0.04%
Residential HI	0.4		0.00%
Developed Total		**3.7**	**0.04%**
Transitional	**459.8**		**5.60%**
Bare Rock, Sand,Clay	**3.5**		**0.00%**
Deciduous Forest	1024.6		12.4%
Evergreen Forest	1020.0		12.4%
Mixed Forest	618.4		7.5%
Forest - Total		**2663**	**32.3%**
Pasture/Hay	**329.7**		**4.0%**
Row Crops	3796.2		46.1%
Agriculture		**3796.2**	**46.1%**
Woody Wetlands	842.0		10.2%
Emergent Herbaceous Wetlands	16.5		0.2%
Wetlands - Total		**858.5**	**10.4%**
Total Area	**8233.7**		**100.0%**

2.0 WATER QUALITY ASSESSMENT

An assessment of water quality data collected 1998 through 2002 at water quality monitoring station E-039 indicated that Roberts Swamp at this location is impaired for recreational use. In addition to being listed on the 2004 303(d) list, Roberts Swamp was also on the 1998 list for fecal coliform bacteria. Waters in which no more than 10% of the samples collected over a five year period are greater than 400 fecal coliform counts or cfu / 100 ml are considered to comply with the South Carolina water quality standard for fecal coliform bacteria. Waters with more than 10 percent of samples greater than 400 cfu/100 ml are considered impaired and listed for fecal coliform bacteria on South Carolina's 303(d) list. During the assessment period (1998-2002), 31 % of the samples

did not meet the fecal coliform criterion at E-039. Roberts Swamp fecal coliform data (1992-2002) are provided in Appendix A.

There is not a simple relationship between precipitation and fecal coliform concentrations in Roberts Swamp (Figure 3). Fecal coliform concentrations show some increase with rainfall, as measured in nearby Bamberg (cooperative monitoring station); but the relationship is not clear. This pattern suggests that there are both sources of fecal coliform bacteria, such as cattle in the creeks, and rainfall associated sources, such as runoff from land application of waste.

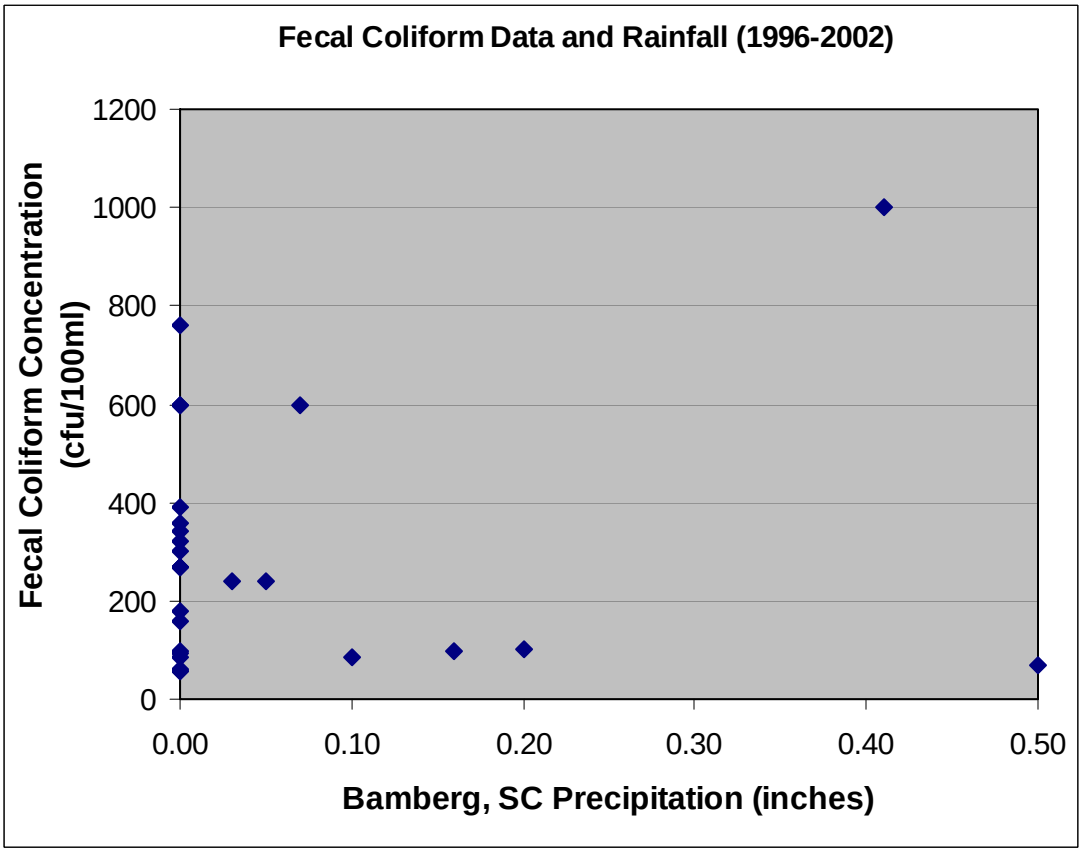

Figure 3. Comparison between precipitation and fecal coliform concentration in Roberts Swamp.

3.0 SOURCE ASSESSMENT AND LOAD ALLOCATION

Surface waters may be contaminated by fecal coliform bacteria that originate from both point and nonpoint sources. Point sources are facilities, such as wastewater treatment plants and factories, that have NPDES permits and discharge wastewater through a pipe or similar structure. Until recently poorly treated or untreated municipal sewage has been a major source of fecal coliform bacteria. With improved treatment and enforcement brought about by the Clean Water Act, point sources are seldom sources of fecal coliform contamination. All point sources must have a NPDES permit and are required to treat wastewater to a minimum level. In South Carolina NPDES permittees that discharge sanitary wastewater must meet the state standards for fecal coliform at the point of discharge.

3.1 Point Sources in the Roberts Swamp Watershed

There are no NPDES-permitted facilites or Confined Animal Farms Operations (CAFOs) with NPDES coverage in this watershed. Also, this area is not designated as a regulated MS4.

3.2 Nonpoint Sources in Roberts Swamp Watershed

3.2.1 Wildlife

Wildlife (mammals and birds) contribute a low level of fecal coliform to surface waters. Wildlife wastes are carried into nearby streams by runoff during rainfall events or by direct deposition. Because of the higher infiltration rates reduce the amount of runoff and organic material on the land surface slows the velocity of the water that does runoff, forests typically do not contribute much fecal coliform bacteria to streams flowing through them. Of wildlife in the Roberts Swamp watershed, deer, being the largest wild animals, are the most obvious. The SC Department of Natural Resources (Charles Ruth, DNR Deer Project Supervisor, personal communication, 2000) has estimated a density of 30-45 deer/mi^2 for this area. Other wildlife that are likely to be significant sources of fecal coliform bacteria in Roberts Swamp are water birds. Wildlife are unlikely to be the primary source of fecal coliform bacteria in Roberts Swamp. In any case control of these sources would be difficult to implement.

3.2.2 Land Applied Manure

Livestock litter that is not properly stored and applied is a potential sources of fecal coliform bacteria. Application of excessive amounts of litter, that is adding more nitrogen or phosphorus than the crop can assimilate, and applying the litter too close to streams are the principal methods by which litter can pollute streams. Roberts Swamp watershed has three actively-permitted animal feeding operations. Two facilities are permitted to have a total of 900 swine (ND0073571 and ND0067504). The other facility, a poultry operation, is permitted for a total of 100000 broilers (ND0082490). An additional facility permitted for 150 swine closed in 1999. In addition, there are

approximately 60 sprayfields associated with agricultural operations and located within or near the watershed. There are 15 fields that are permitted for that animal waste application. All of these sprayfields may not actually be in use; estimates represent a total number of *permitted* land application sites and not *operating* disposal sites. Improperly applied manure is a possible source of fecal coliform bacteria in Roberts Swamp. These operations are permitted, therefore problems are managed through SCDHEC enforcement mechanisms.

3.2.3 *Grazing Animals*

Other livestock such as cattle, goats, and horses spend most of their time grazing on pasture land. Runoff from rainfall may wash some of the manure deposited on the pastures into nearby by streams. Good grass cover on the pastures and intact riparian buffers should reduce the likelihood of the bacteria reaching streams. The 2002 Agricultural Census reports that there were 16735 cattle and calves in Orangeburg County. Assuming cattle are distributed evenly throughout each county within the pasture land, the ratio of pasture in the watershed to the county as a whole indicates that about 575 animals are in the watershed. Although this number varies throughout the year depending on farm operations, the estimate is representative of the Roberts Swamp watershed (Orangeburg County NRSC Staff Communication, 2004). Grazing cattle were observed during a July 27, 2004 site visit to the Roberts Swamp Watershed.

Cattle and other livestock that are allowed access to streams deposit manure directly into the streams. Manure deposited in streams can be a significant source of fecal coliform bacteria. As a result of the drought many farmers have found alternate sources of water to provide their livestock, which would reduce the likelihood of the cattle accessing streams.

3.2.4 Failing Septic Systems

Improperly designed or installed septic systems and septic systems that no longer function properly are potential sources of fecal coliform contamination. Using a GIS, the 2000 census database layer was compared to a sewer line data layer and the boundaries of the Roberts Swamp watershed. There is currently no sewer service available to homes there. An estimated 1780 people in 770 households in the Roberts Swamp watershed are connected to septic systems. The precise failure rate of these septic systems is unknown; but Schueler (1999) has reported failure rates of 20 %. However, in this watershed the load from failing septic systems is probably much smaller than the load from agricultural activities. It should also be noted that domestic sewer service will be available in the near future. A site visit was conducted on July 27, 2004. Sewer lines are currently being installed in portions of the watershed; thus, the number of septic tanks in use will likely decrease. A complete unknown is the possibility of direct or illicit discharges to the creek in this rural watershed.

3.2.5 Urban Runoff

Urbanized or developed land typically generates an increased loading for pollutants relative to forest and other undeveloped land uses. Dogs, cats, and other pets are the primary source of fecal coliform deposited on the urban landscape. There are also 'urban' wildlife, such as squirrels, raccoons, pigeons, and other birds, all of which contribute to the fecal coliform load. Impervious surfaces increase the amount of runoff relative to predevelopment conditions. Less than 1% of the total land area of the Roberts Swamp Watershed is considered urban; therefore, urban fecal coliform loading is considered insignificant.

4.0 LOAD-DURATION METHOD

Load-duration (L/D) curves were introduced as a method of TMDL development that applies to all hydrologic conditions. The L/D curve method uses the cumulative frequency distribution of stream flow and pollutant concentration data to estimate the existing and the TMDL loads for a water body. Development of the L/D curve is described in this chapter.

In the ideal situation a long period of record for flow data would be available for the water body of interest. A longer period of record increases the confidence in the results of the L/D method. Roberts Swamp, like most small streams in South Carolina is not gauged. Nearby Cow Castle Creek, Orangeburg County is comparable, gauged, in the same ecoregion, and with similar land uses & topography. Data from USGS gauge 02174250 on Cow Castle Creek, South Carolina for the period of record 1996 - 2002 were used to generate the flow-duration curve. Flow data was not available for the 1992-1995 time-frame; therefore, fecal coliform data collected prior to 1996 was not considered for the L/D curve. The Roberts Swamp watershed is larger, 82.4 km^2 compared to 60.6 km^2 for Cow Castle Creek gauge.

The flow for Roberts Swamp was estimated by multiplying the daily flow rates from Cow Castle Creek by the ratio of Roberts Swamp drainage area to that of Cow Castle Creek (1.36:1). The flows were ranked from low to high and the values that exceed certain selected percentiles determined. The L/D curve was generated by calculating the load from the observed fecal coliform concentrations, the flow rate that corresponds to the date of sampling, and a conversion factor (Figure 4). The load was plotted against the appropriate flow recurrence interval to generate the curve. The target line was created by calculating allowable load from flow and the appropriate fecal coliform standard concentration in the same manner. Sample loads above this line are violations of the standard, while loads below the line are in compliance.

The water quality target was set at 380 counts per 100 mL for the instantaneous criterion, which is five percent lower than the water quality criteria of 400 counts per 100 mL. A five percent explicit MOS was reserved from the water quality criteria in developing the L/D curves. The instantaneous criterion was targeted as a conservative approach and

should be protective of both the instantaneous and 30-day geometric mean fecal coliform bacteria standards.

The trend line was determined for loads that are above the target line. The trend line for Roberts Swamp with the best fit was a power curve; the r^2 was 0.9817. The equation for the line and supporting data are provided in Appendix B. This trend line represents samples that violated the water quality standard. The existing load to Roberts Swamp was calculated from values along this trend line. Violating loads were between the 5 % and 86 % flow recurrence intervals. The existing load is the average of loads from the 10 % to 90 % recurrence intervals at 5 % intervals, i.e. 5, 10, 15, 20, 25 … 90.

The TMDL load is calculated from the target line in the same manner, that is the average of loads at 5 % intervals from 10 % to 90 %. The Load Allocation values are 95 % of the loads from the target line, that is the TMDL load minus the Margin of Safety. Calculations for both existing and TMDL loads are provided in Appendix B.

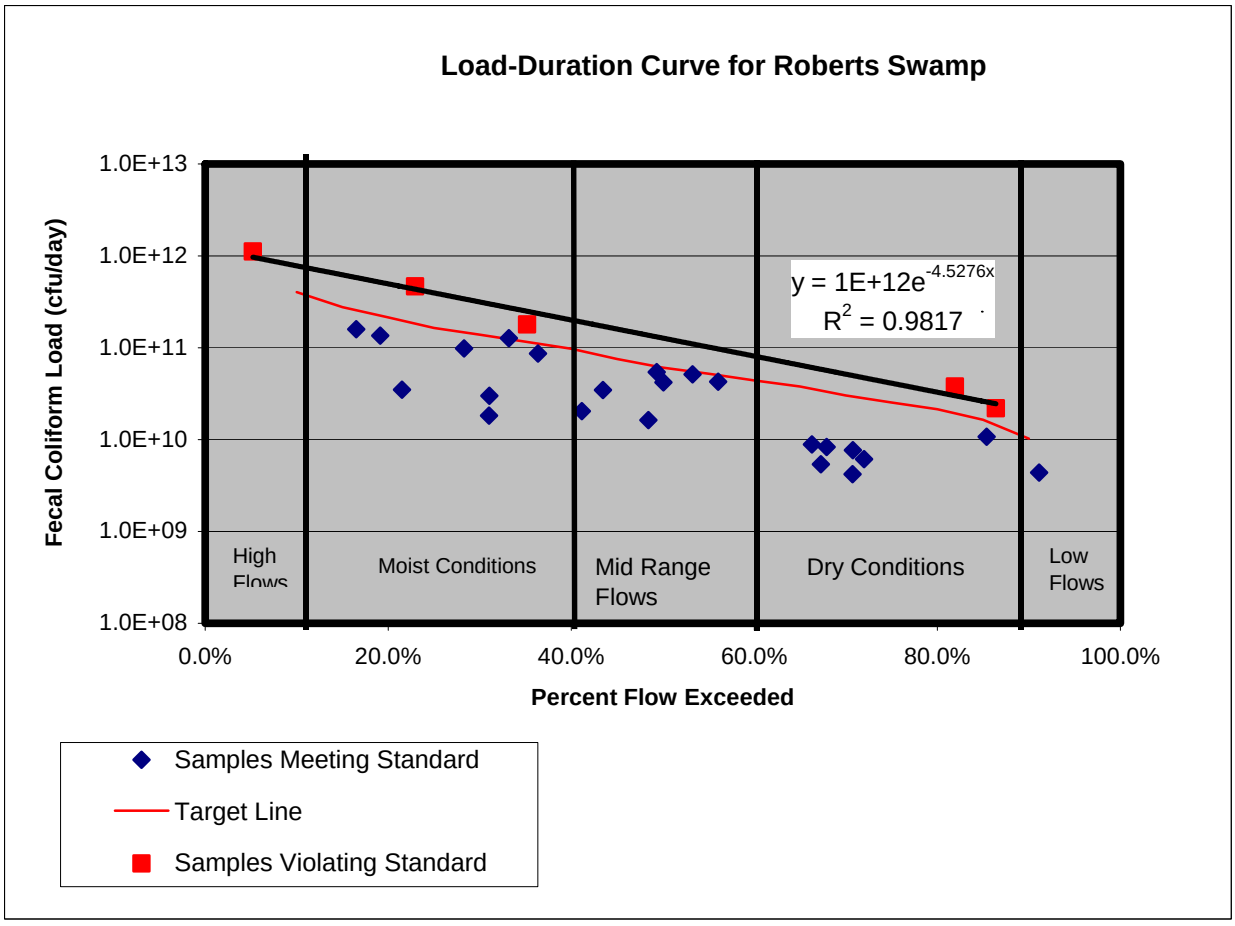

Figure 4. Load-Duration plot of Roberts Swamp at E-039. Based on 1996 – 2002 fecal coliform data.

5.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

A total maximum daily load (TMDL) for a given pollutant and water body is comprised of the sum of individual wasteload 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 implicitly or explicitly, 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:

$$\mathbf{TMDL = \Sigma WLA + \Sigma LA + MOS}$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving water body while still achieving water quality standards. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established and thereby provide 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 (#), cfu, or organism counts (or resulting concentration), in accordance with 40 CFR 130.2(l).

5.1 Critical Conditions

Critical conditions for Roberts Swamp occur and both high and low flows; as when a long period of low flow is followed by rainfall event that produces runoff. At low flow rates, continual sources including cattle in streams and failing septic systems may cause the concentration of the fecal coliform in the creek to rise as dilution decreases. During the long dry period, fecal coliform bacteria build up on the land surface. Rainfall flushes much of this accumulation into the creek with runoff, which causes the already high concentrations to increase further. Because Roberts Swamp is predominantly an agricultural watershed, runoff from land application sites may be a primary cause of violations at higher flows.

Standard violations occurred over much of the total range of flows. The inclusion of all flow conditions in the load-duration curve analysis insures that the critical conditions are protected. Existing loads were calculated from the 10 – 90 % flow exceedence intervals; TMDL loads were calculated from the 10 – 90 % flow exceedence intervals.

5.2 Existing Load

The existing load was calculated from the trend line of observed values that exceeded the water quality standard and were between and including 5 and 86 % recurrence limits. Loadings from all sources are included in this figure: failing septic systems, cattle-in-streams, and loading from runoff. The total existing load for E-039 is 4.82×10^{11} cfu/day.

5.3 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 20 counts/ 100ml of the instantaneous criterion of 400 counts per 100 mL. For E-039 this is equivalent to 5.54×10^{09} cfu/day**.** Through the use of conservative assumptions in the model the margin of safety also has an implicit component.

5.4 Total Maximum Daily Load

The Total Maximum Daily Load (TMDL) represents the maximum load the stream may carry and meet the water quality standard for the pollutant of interest. For this TMDL the load will be expressed as cfu/day (colony forming units/day). The TMDL is presented in fecal coliform counts to be protective of both the instantaneous, per day, and geometric mean, per 30-day, criteria.

There is no Waste Load Allocation for this TMDL because this watershed has no NPDES facilities or permitted MS4 areas.

The Load Allocation (LA) was determined from the TMDL load by subtracting out the margin of safety. The load allocation for Roberts Swamp at E-039 is 1.05×10^{11} cfu/day (Table 2).

The required reduction is the difference between the existing load and the target load expressed as a percentage. The target load to the creek is the TMDL minus the MOS and for Roberts Swamp is equivalent to the LA. The target loading for Roberts Swamp at E-039 requires a reduction of 78 % from the current load of 4.82×10^{11} cfu/day.

Table 2.TMDL Components for Roberts Swamp

Impaired Station	WLA cfu/day	LA cfu/day	MOS cfu/day	TMDL cfu/day	% Reduction
E-039	N/A	1.05E+11	5.54E+09	1.11E+11	78 %

6.0 IMPLEMENTATION

As discussed in the *Implementation Plan for Achieving Total Maximum Daily Load Reductions From Nonpoint Sources for the State of South Carolina* (SCDHEC 1998), South Carolina has several tools available for implementing this nonpoint source TMDL. Specifically, SCDHEC's animal agriculture permitting program addresses animal operations and land application of animal wastes. There are also a number of *voluntary* measures available to interested parties. SCDHEC will work with the existing agencies in the area to provide nonpoint source education in the Roberts Swamp Watershed. Local sources of nonpoint source education and assistance include Clemson Extension Service, the Natural Resource Conservation Service (NRCS), the Orangeburg County Soil and Water Conservation Services, and the South Carolina Department of Natural Resources. Clemson Extension Service offers a 'Farm-A-Syst' package to farmers. Farm-A-Syst allows the

farmer to evaluate practices on their property and determine the nonpoint source impact they may be having. It recommends best management practices (BMPs) to correct agricultural nonpoint source problems. NRCS can provide cost share money to land owners installing BMPs.

SCDHEC is empowered under the State Pollution Control Act to perform investigations of and pursue enforcement for activities and conditions which threaten the quality of waters of the state. In addition, other interested parties (universities, local watershed groups, etc.) may apply for section 319 grants to install BMPs that will reduce fecal coliform loading to Roberts Swamp. TMDL implementation projects are given highest priority for 319 funding.

In addition to the resources cited above for the implementation of this TMDL in the Roberts Swamp watershed, Clemson Extension has developed a Home-A-Syst handbook that can help urban or rural homeowners reduce sources of NPS pollution on their property. This document guides homeowners through a self-assessment, including information on proper maintenance practices for septic tanks. SCDHEC also employs a nonpoint source educator who can assist with distribution of these tools as well as provide additional BMP information.

Using existing authorities and *voluntary* mechanisms, these measures will be implemented in the Roberts Swamp watershed in order to bring about a 78 % reduction in fecal coliform bacteria loading to Roberts Swamp. DHEC will continue to monitor, according to the basin monitoring schedule, the effectiveness of implementation measures and evaluate stream water quality as the implementation strategy progresses.

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APPENDIX A Flow, Fecal Coliform and Precipitation Data

Date	E-039 24Hr Q (cfs)*	FECCOLI	Prec.(in)**
05/13/92	No Measurement	100	
06/17/92	No Measurement	300	
07/21/92	No Measurement	570	
08/17/92	No Measurement	1000	
09/08/92	No Measurement	500	
10/14/92	No Measurement	210	
11/26/96	3.0	84	0.10
12/05/96	3.1	100	0.20
01/07/97	3.5	96	0.16
02/04/97	9.8	85	0.00
03/19/97	20.4	70	0.50
04/15/97	6.8	98	0.00
05/21/97	3.7	60	0.00
06/18/97	13.6	90	
07/29/97	3.1	55	0.00
08/14/97	1.6	270	0.00
09/15/97	1	180	0.00
10/08/97	3.8	95	0.00
01/10/01	14.9	270	0.00
02/06/01	12.2	600	0.00
03/12/01	27.2	240	0.05
04/17/01	13.3	390	0.00
06/27/01	23.1	240	0.03
07/18/01	11.8	300	0.00
08/07/01	8.8	160	0.00
10/31/01	5.4	320	0.00
11/20/01	6.5	340	0.00
12/13/01	6.4	270	0.00
02/05/02	1.5	600	0.00
03/06/02	5.8	360	0.00
04/01/02	19	1000	0.41
05/07/02	2	760	0.00
11/13/02	76.1	600	0.07
12/02/02	13.6	55	0.00
*Based on USGS 02174250, Cow Castle Creek, and a			
1.36 cfs/mi^2 generation coefficient.			
**Based on Bamberg, SC Precipitation Data (1996-2002)			

APPENDIX B Calculations

Load Allocation

Target FC Conc: 380

% Exceeded	Flow (cfs)	
10%	43.49	4.04E+11
15%	29.90	2.78E+11
20%	23.10	2.15E+11
25%	17.67	1.64E+11
30%	14.95	1.39E+11
35%	12.50	1.16E+11
40%	10.46	9.73E+10
45%	8.13	7.56E+10
50%	6.52	6.06E+10
55%	5.60	5.21E+10
60%	4.76	4.42E+10
65%	4.08	3.79E+10
70%	3.26	3.03E+10
75%	2.72	2.53E+10
80%	2.31	2.15E+10
85%	1.77	1.64E+10
90%	1.10	1.02E+10
	Average	1.05E+11

Not Meeting Standard

Rank	%Exceeded	Load
348	86.4%	2.19E+10
462	81.9%	3.79E+10
1658	35.2%	1.80E+11
1971	22.9%	4.65E+11
2425	5.2%	1.12E+12

Meeting Standard

Rank	%Exceeded	Load
227	91.1%	4.37E+09
374	85.4%	1.08E+10
716	72.0%	6.14E+09
748	70.8%	7.65E+09
749	70.7%	4.21E+09
821	67.9%	8.30E+09
837	67.3%	5.39E+09
862	66.3%	8.84E+09
1124	56.1%	4.26E+10
1196	53.2%	5.15E+10
1277	50.1%	4.22E+10
1296	49.3%	5.43E+10
1319	48.4%	1.63E+10
1446	43.5%	3.46E+10
1505	41.2%	2.03E+10
1628	36.4%	8.68E+10
1709	33.2%	1.27E+11
1764	31.0%	2.99E+10
1765	31.0%	1.83E+10
1834	28.3%	9.87E+10
2008	21.5%	3.49E+10
2069	19.1%	1.36E+11
2136	16.5%	1.60E+11

Existing Load Equation:
Y=1E+12e^-4.5276x
Using Equation, Calculation of Existing Load for E-039:

%Exceeded	Load
10%	6.36E+11
15%	1.76E+12
20%	1.34E+12
25%	1.02E+12
30%	7.75E+11
35%	5.90E+11
40%	4.49E+11
45%	3.41E+11
50%	2.60E+11
55%	1.98E+11
60%	1.50E+11
65%	1.14E+11
70%	8.70E+10
75%	6.62E+10
80%	5.04E+10
90%	2.91E+10
	4.82E+11

Margin of Safety

Target FC Conc: 20

%Exceeded	Flow (cfs)	
10%	43.49	2.13E+10
15%	29.90	1.46E+10
20%	23.10	1.13E+10
25%	17.67	8.64E+09
30%	14.95	7.31E+09
35%	12.50	6.12E+09
40%	10.46	5.12E+09
45%	8.13	3.98E+09
50%	6.52	3.19E+09
55%	5.60	2.74E+09
60%	4.76	2.33E+09
65%	4.08	1.99E+09
70%	3.26	1.60E+09
75%	2.72	1.33E+09
80%	2.31	1.13E+09
85%	1.77	8.64E+08
90%	1.10	5.39E+08
	Average	5.54E+09

$$\mathbf{TMDL = \Sigma\ WLA + \Sigma\ LA + MOS}$$

1.11E+11 cfu/day = 0 + 1.05E+11 + 5.54E+09 or a 78% reduction from existing loading is required.

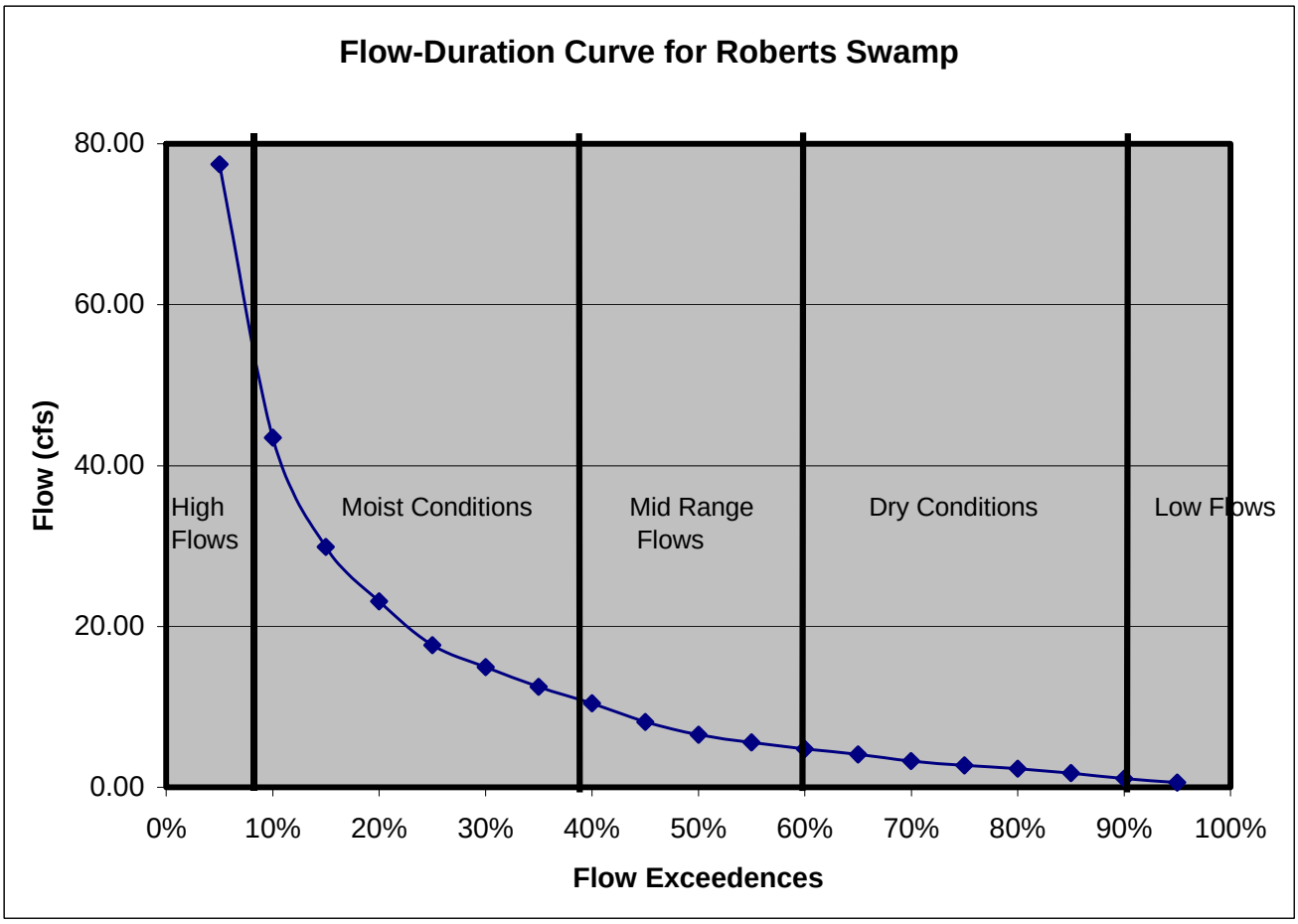

Figure B-1: Flow Duration Curve for Roberts Swamp

APPENDIX C Public Participation