Total Maximum Daily Load Development for the Halfway Swamp Creek Watershed (Hydrological Unit Code: 03050111-020) and Warley Creek (Hydrological Unit Code: 03050111-010-030); Stations: C-058, C-063, CW-241, SC-006 and SC-007 Fecal Coliform Bacteria

July 2005

SCDHEC Technical Report Number: 023-05

United States Environmental Protection Agency

Region 4 serving the southeast

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

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James D. Giattina, Director Date
Water Management Division

Abstract

The Halfway Swamp Creek watershed and Warley Creek (11-digit HUC 03050111-020 and –010-030) is located in the Upper Coastal Plain region in Calhoun County (Figure 1-1). Five water quality monitoring stations in the watershed have been placed on the South Carolina §303(d) list of impaired waters for violations of the fecal coliform bacteria standard, as shown in Table 1-1. The 72 square mile Halfway Swamp Creek watershed is composed of mostly forested (51%) with a large percentage of cropland (35%). There is one active continuous point source discharging fecal coliform bacteria into Halfway Swamp Creek, SC0028801 the St. Matthews South Plant. The 13 square mile Warley Creek watershed has similar land use activities, 51 percent forested with a large percentage of cropland (40%) and no point sources discharging into waterbodies.

The load-duration curve methodology was used to establish allowable fecal coliform loads in the watershed. The existing load was determined using measured data from the impaired water quality monitoring stations. Loads were established from measured concentrations and a power trend line was fit to samples violating the instantaneous standard. The existing load and allowable total maximum daily load for impaired stations is presented in Table I. To achieve the TMDL target, reductions of fecal coliform loads will be necessary, as shown in Table I.

Table I Total Maximum Daily Loads for Impaired Water Quality Stations in the Halfway Swamp Creek and Warley Creek (03050111-020 and –010-030)

Station ID	Existing Waste Load Continuous (counts/day)	TMDL WLA Continuous[1] (counts/day)	Existing Load (counts/day)	TMDL LA (counts/day)	MOS (counts/day)	TMDL[2] (counts/day)	Percent Reduction[3]
C-058	NA	NA	7.28E+11	2.94E+10	1.63E+09	3.11E+10	96%
C-063	NA	NA	2.29E+11	9.96E+10	5.53E+09	1.05E+11	54%
CW-241	8.33E+09	8.33E+09	6.52E+11	3.53E+11	2.01E+10	3.81E+11	46%
SC-006	NA	NA	1.40E+11	7.69E+10	4.27E+09	8.12E+10	42%
SC-007	8.33E+09	8.33E+09	4.89E+11	3.10E+11	1.77E+10	3.36E+11	31%

Table Notes:
1. Total monthly wasteload (#/30 days) cannot exceed loads listed in Table 3-3.
2. TMDLs expressed as monthly load (#/30 days) by station are listed in Table B-1.
3. Percent reduction applies to LA component.

Table of Contents

Figures

Tables

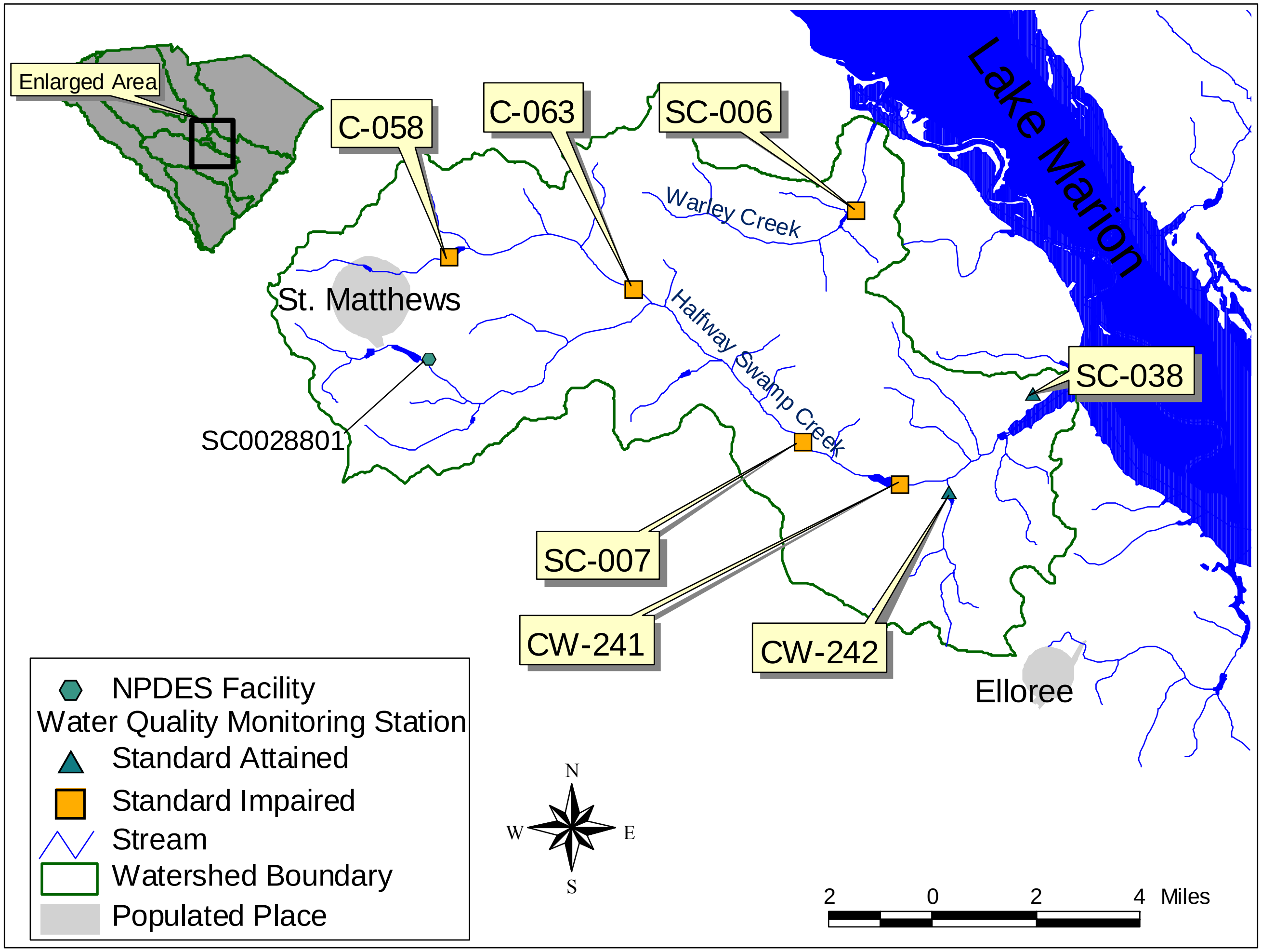

Figure 1-1 Halfway Swamp Creek Watershed (03050111-020) and Warley Creek (03050111-010-030)

1.0 INTRODUCTION

1.1 Background

Levels of fecal coliform bacteria can be elevated in waterbodies 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 waterbodies 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 waterbody based on the relationship between pollution sources and instream 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).

The State of South Carolina has placed five monitoring stations in the Halfway Swamp Creek (11-digit HUC 03050111-020) on South Carolina's 2002 Section §303(d) list for impairment due to fecal coliform bacteria. These stations are identified in Table 1-1.

Table 1-1 Water Quality Monitoring Stations Impaired by Fecal Coliform in the Halfway Swamp Creek and Warley Creek (03050111-020 and –010_030)

Waterbody Name	Waterbody ID	Waterbody Location
Lake Inspiration	C-058	Lake Inspiration – St. Matthews (Front of the Health Department)
Halfway Swamp Crk	C-063	Halfway Swamp Creek at S-09-43, 3 miles East of St. Matthews
Halfway Swamp Crk	CW-241	Halfway Swamp Creek at S-09-72
Warley Crk	SC-006	Warley Creek at SC 267
Halfway Swamp Crk	SC-007	Halfway Swamp Creek at SC 33

1.2 Watershed Description

The Halfway Swamp Creek (11-digit HUC 03050111-020) and Warley Creek (14-digit HUC 03050111-010-030) (Figure 1-1) are located in the Upper Coastal Plain region of South Carolina. Halfway Swamp Creek originates near the Town of St. Matthews and ultimately drains to Lake Marion. The 72 square mile watershed has a number of small lakes and ponds and a total of 55.7 stream miles. The Warley Creek watershed shares the northeastern ridgeline with Halfway Swamp Creek and also drains to Lake Marion.

Based on 1996 USGS Multi-Resolution Land Characteristic (MRLC) land use data, 50 percent of both the Halfway Swamp Creek and Warley Creek watersheds are forest and wetlands. The remaining area in both watersheds is composed of mostly cropland with a small mix of pastureland, urban area, water and barren land uses. Table 1-2 presents the percentage of total watershed area for each aggregated land use. The percentage of land use area in each monitoring station drainage area is presented in Appendix A (Table A-1). The actual areas in square miles are presented in Table A-2. Figure 1-2 illustrates land use activities in each watershed.

Table 1-2 MRLC Aggregated Land Use for Halfway Swamp Creek and Warley Creek watersheds (03050111-020 and –010-030)

Aggregated Land Use	Percent of Total Area in Halfway Swamp Creek	Total Area (Miles^2) Halfway Swamp Creek	Percent of Total Area in Warley Creek	Total Area (Miles^2) Warley Creek
Urban	2.0%	1.4	0.1%	0.0
Barren	5.0%	3.6	4.3%	0.6
Row Crops	35.3%	25	40.2%	5.3
Pasture	5.4%	3.9	3.2%	0.4
Forest	51.4%	37	51.2%	6.7
Water	0.8%	0.6	1.0%	0.1

1.3 Water Quality Standard

The impaired stream segments of the Halfway Swamp Creek and Warley Creek are designated as Class Freshwater. Waters of this class are described as:

> "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)

South Carolina's standard for fecal coliform bacteria 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 percent of the total samples during any 30 day period exceed 400/100 mL." (R.61-68).

2.0 WATER QUALITY ASSESSMENT

Fecal coliform bacteria data collected in the Halfway Swamp Creek and Warley Creek watersheds from 1990 through 2001 were assessed to determine impairment of standards for recreational use. The State of South Carolina monitors fecal coliform bacteria at six stations in the Halfway Swamp Creek watershed and one on Warley Creek. The States Public Service Authority (SCPSA) monitors two of the stations, SC-006 and SC-007. Figure 1-1 shows the location of water quality monitoring stations in the watershed.

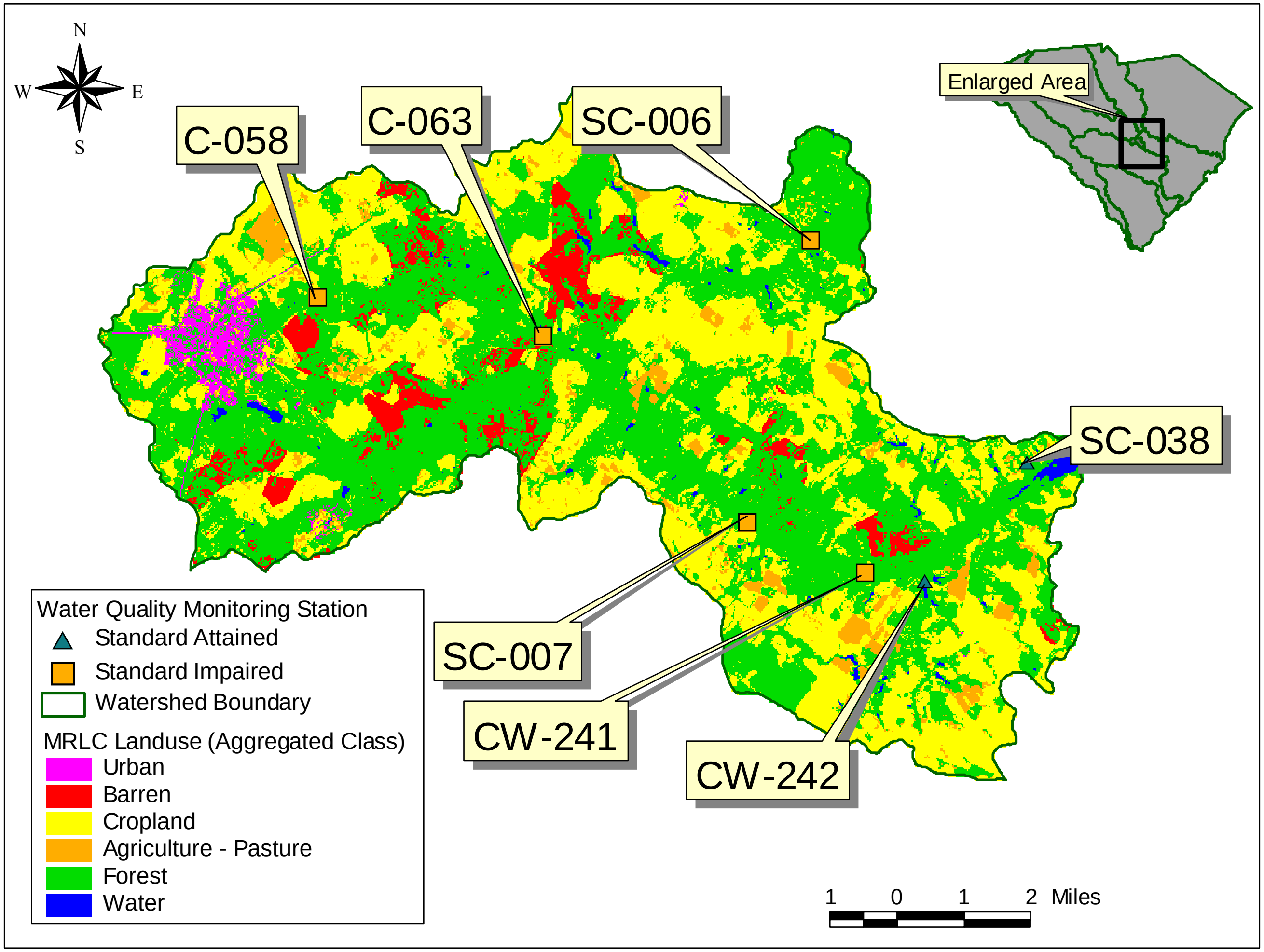

Figure 1-2 Halfway Swamp Creek and Warley Creek Land Use

Four water quality monitoring stations in the Halfway Swamp Creek watershed and one station in Warley Creek have been identified on the State of South Carolina's Section §303(d) list for 2002 as impaired (Table 1-1). Table 2-1 presents the statistical information supporting the listing of impaired water quality monitoring sites in the watershed. Waters in which no more than 10 percent of the samples collected over a five year period are greater than 400 fecal coliform counts per 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 counts per 100 mL are considered impaired and were listed for fecal coliform bacteria on the State of South Carolina's Section §303(d) list. The fecal coliform bacteria data collected at impaired water quality monitoring stations is presented in Appendix A (Tables A-3 and Table A-4).

Table 2-1 Statistical Assessment of Observed Fecal Coliform Bacteria Collected from 1996 through 2000

Station	Total Number of Samples	Total Number of Samples >400 #/100 mL	Percent of Samples >400 #/100 mL
C-058	30	3	10%
C-063	30	18	60%
CW-241	7	1	14%
SC-006	9	4	44%
SC-007	9	3	33%

The timeframe, both annually and seasonally, of water quality monitoring at each station varies greatly. The statistical assessment presented in Table 2-1 was based on data collected over the five-year period from 1996 through 2000.

After determining compliance with water quality standards, observed violations were assessed to determine conditions critical to impairment. Data were compared with estimated streamflows to establish a relationship between instream concentrations and hydrologic conditions. Due to limited streamflow data in the watershed, observed data were plotted with the load-duration curves generated based on area-weighted flows. The development of load-duration curves is discussed further in Section 4.0 of this report. Load-duration curves plotted for each station in Figures B-1 through B-4 and in Figure 2-1 (for C-063) are equal to the TMDL target based on the criteria for instantaneous events. The observed fecal coliform bacteria data were also converted from counts per 100 mL to loads in counts per day to assess hydrologic conditions when the standard is not attained.

The percent of flow exceeded in Figure 2-1 and Figures B-1 through B-4 represent flow conditions at each monitoring station. Hydrologic conditions for very dry events, likely to be exceeded in 99.99 percent of measured events, are represented as 99.99 percent. Extremely wet events that occur rarely are represented as 0.01 percent.

Violations of the instantaneous standard occur at various flow conditions. The impaired water quality monitoring station C-058, in Lake Inspiration, in the headwaters of the Halfway Swamp Creek watershed has violations during low and average flow events, shown in Figure B-1. Given the location of this station, violations during low flows are likely due to direct instream sources. Overland sources from urban areas in St. Matthews are likely the cause of violations at the 30 and 60 percentile. The data collected at SC-007 has consistent violations at all flow regimes, as shown in Figure B-4. Violations during various flow events suggest both overland, instream, and continuous sources, such as groundwater, of fecal coliform bacteria. A similar assumption about the sources of fecal coliform bacteria can be made for C-063 and SC-006 (Figures 2-1 and B-3).

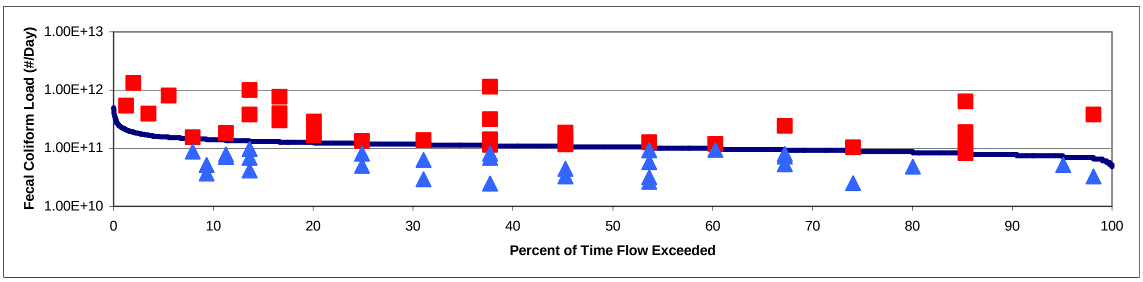

Figure 2-1 Fecal Coliform Bacteria Load-Duration Curve for Station C-063 Illustrating Observed Fecal Coliform Bacteria Loads Over Various Hydrologic Conditions

3.0 SOURCE ASSESSMENT AND LOAD ALLOCATION

Fecal coliform bacteria enter surface waters of the Halfway Swamp Creek and Warley Creek watersheds from both point and nonpoint sources. Point sources are facilities that discharge at a specific location through pipes, outfalls, and/or conveyance channels. All point sources must have a National Pollutant Discharge Elimination System (NPDES) permit and are often municipal wastewater treatment plants or industrial waste treatment facilities. Nonpoint sources are diffuse sources that have multiple routes of entry into surface waters. Some nonpoint sources are related to land use activities that accumulate fecal coliform bacteria on the land surface (i.e. pastureland) and runoff during storm events.

3.1 Point Sources

There is one active continuous point source discharging fecal coliform bacteria in the Halfway Swamp Creek watershed, SC0028801 the Saint Matthews South Plant. In South Carolina, NPDES permittees that discharge sanitary wastewater must meet the State criteria for fecal coliform bacteria at the point of discharge (i.e. a daily maximum concentration of 400 counts per 100 mL, and a 30-day geometric mean of 200 counts per 100 mL).

The Saint Matthews South Plant (SC0028801) is a municipal facility permitted to discharge 0.55 MGD to Antley Spring Branch, a tributary to the Halfway Swamp Creek, as shown in Figure 1-1. The facility is located approximately 11.5 miles upstream of impaired water quality monitoring station CW-241. Table 3-1 lists permit information pertinent to fecal coliform bacteria TMDL development.

Table 3-1 Permitted Facility Discharging Fecal Coliform Bacteria into the Halfway Swamp Creek Watershed

Facility Name	NPDES No.	Permitted Flow Limit (MGD)	Receiving Stream
Saint Matthews South Plant	SC0028801	0.55	Antley Spring Branch

Table 3-2 Impaired Water Quality Monitoring Stations Draining NPDES Facilities in the Halfway Swamp Creek Watershed

SC0028801
CW-241
SC-007

The TMDLs presented in this report were developed using the permitted flows (0.55 MGD) and permitted concentrations for fecal coliform bacteria. Limited information was available to determine the survival rate of fecal coliform bacteria discharging from permitted facilities to establish the impact downstream. Therefore, for the purpose of fecal coliform bacteria TMDL development in the Halfway Swamp Creek watershed, wasteloads for continuous discharges are cumulative for a given drainage area. Estimated existing loads and the permitted geometric mean concentration of 200 counts per 100 mL and instantaneous concentration of 400 counts per 100 mL are listed in Table 3-3.

The collection system for Saint Matthews' sewage treatment facility is also a potential source of fecal coliform bacteria. Sewage collection systems typically are placed adjacent to waterways. At these locations, there is a potential for collection system leaks which could result in elevated instream concentrations of fecal coliform bacteria. Sanitary sewer overflows (SSOs) are also a potential source, particularly after periods of intense rainfall. This source is associated with infrequent events, limited in duration and likely to have an insignificant long-term impact instream. Identified collection system and/or SSO problems are addressed by SCDHEC through compliance and enforcement mechanisms. Sewer lines are adjacent to Halfway Swamp Creek in Saint Matthews and Antley Springs Creek downstream of Saint Matthews.

Table 3-3 Estimated Existing Fecal Coliform Bacteria Loads for NPDES Facility SC0028801 in the Halfway Swamp Creek Watershed

NPDES Facility	Flow (MGD)	Existing Loading (counts/days)	Existing Loading (counts/30days)
SC0028801	0.55	8.33E+09	1.25E+11

3.2 Nonpoint Sources

The land use distribution of the Halfway Swamp Creek and Warley Creek watersheds provides insight into determining nonpoint sources of fecal coliform bacteria (Figure 1-2). In the Halfway Swamp Creek watershed, 51 percent of the land area is classified forested (including wetlands), 35 percent is cropland, 5 percent is barren (including transitional areas) and 5 percent is pastureland. In the Warley Creek watershed, 51 percent of the land area is also forested (including wetlands), 40 percent is cropland, 4 percent is barren (including transitional areas) and 3 percent is pastureland. Key nonpoint sources identified in the watershed include wildlife, manure application, failing septic systems, illicit discharges (including leaking and overflowing sewers), over land contributions from impervious surfaces, and natural sources.

3.2.1 Wildlife

Fecal coliform bacteria are found in forested areas, wetlands, and cropland due to the presence of wild animal sources such as deer, raccoons, and waterfowl. The Department of Natural Resources in South Carolina estimates the deer habitat in the basin at a density of 30 to more than 45 deer per square mile (SC Deer Density 2000 map). Deer habitat was assumed to include forests, wetlands, and cropland. Wildlife waste is transported over land surfaces during rainfall events or may be directly deposited by animals into streams. The high percentage of permeable surfaces in forested areas increases the infiltration rate over the watershed area. This process ultimately reduces the runoff reaching streams by overland flow and reduces the significance of fecal coliform contributions transported over land.

3.2.2 Failing Septic Systems and Illicit Discharges

Failing septic systems and illegal discharges represent a nonpoint source that can contribute fecal coliform to receiving waterbodies through surface, subsurface malfunctions or direct discharges. Based on 1990 census information, population change from 1990 and 2000, and assuming an average of 2.5 people per household (U.S. Census, 2000), nearly 2,500 people in the combined area of the Halfway Swamp Creek and Warley Creek watershed use septic systems. Though the precise failure rate is unknown, Schueler (1999) suggests an average septic failure rate of 20 percent. Many of these areas are also on sewer systems that may leak and/or overflow during rain events contributing significant loads of fecal coliform bacteria directly to streams.

3.2.3 Agricultural Activities and Grazing Animals

Agricultural land can be a source of fecal coliform bacteria. Runoff from pastures, improper land application of animal wastes, livestock operations, and livestock with access to water bodies are all agricultural sources of fecal coliform bacteria. Agricultural best management practices (BMPs) such as buffer strips, alternative watering sources, limiting livestock access to streams, and the proper land application of animal wastes reduce fecal coliform bacteria loading to water bodies.

There are five permitted animal feeding operations in the Halfway Swamp watershed. There are also a number of fields permitted for the application of animal wastes in the watershed, these fields are in the lower part of the watershed and do not drain to the impaired parts of the creek.

3.2.4 Urban Runoff

Runoff from urban areas is a potential though minor source of fecal coliform bacteria in the Halfway Swamp Creek watershed. The town of Saint Matthews is the only developed area in either the Halfway Swamp and Warley Creek watersheds. The high percentage of impervious surface, the population of pets, and urban wild animals tends to increase fecal coliform bacteria loading during storm events. Water quality data collected from streams draining Saint Matthews show existing loads of fecal coliform bacteria at levels greater than 50 percent of the State's instantaneous standards, see Table 5-3. Best management practices (BMPs) such as buffer strips and the proper disposal of domestic animal wastes reduce fecal coliform bacteria loading to waterbodies.

4.0 TECHNICAL APPROACH – LOAD-DURATION METHOD

Load-duration curves were developed for water quality stations in the Halfway Swamp Creek and Warley Creek watersheds to establish allowable fecal coliform bacteria loads under various hydrologic conditions. The load-duration methodology uses the cumulative frequency distribution of streamflow and pollutant concentration (fecal coliform bacteria) data to estimate the allowable loads for a waterbody. Allowable load-duration curves were established in the basin using the instantaneous concentration of fecal coliform bacteria, minus a five percent margin of safety (MOS), and streamflow measured at various USGS stations in from surrounding watersheds, as shown in Figure 1-1 and listed in Table 4-1. Unfortunately, no continuous streamflow data was available in the Halfway Swamp Creek watershed.

Table 4-1 USGS Stations Used to Establish Area-Weighted Flows

Site Number	Site Name	From	To	Drainage Area (mile2)
02172640	Dean Swamp Creek near Salley, SC	10/1/1980	9/30/2000	30.5
02135517	Pocotaligo River at Sumter, SC	10/1/1992	9/30/1995	134
02135300	Scape Ore Swamp near Bishopville, SC	7/26/1968	9/30/2001	164

Streamflow data was not available at each impaired water quality monitoring station to develop load-duration curves. Therefore, flows were determined by area-weighted data collected at USGS stations listed in Table 4-1. Data collected at these stations through 2000 were used to develop loading curves. For USGS station 02135517, the Pocotaligo River at Sumter, where data were collected from October 1992 through September 1995, the program MOVE.1 was used to interpolate streamflow by comparing overlapping records with USGS station 02135300, Scape Ore Swamp near Bishopville, SC. Statistical analysis from matched stations and technical clarification of the MOVE.1 methods can be found in Appendix D.

Watershed characteristics (including the distribution of land use activities, ecoregion, and topography) for the USGS stations and impaired water quality monitoring sites were compared to associate stations to develop load-duration curves. Table 4-2 lists the impaired water quality monitoring stations and associated streamflow stations used to develop area-weighted flow relationships. The location of both USGS and water quality monitoring stations are identified in Figure 1-1.

Table 4-2 USGS Stations and Associated Water Quality Stations

USGS Gage	Waterbody ID	Waterbody Name
02135517	C-058	Lake Inspiration
02172640	C-063	Halfway Swamp Crk
	CW-241	Halfway Swamp Crk
	SC-006	Warley Creek
	SC-007	Halfway Swamp Crk

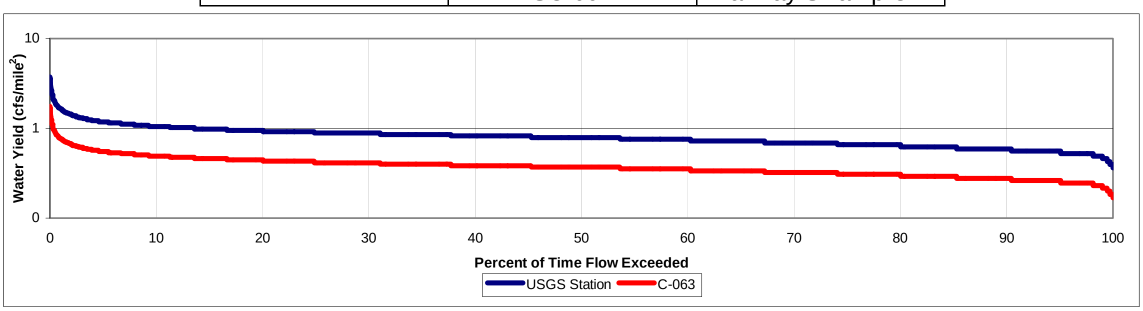

Figure 4-1 Water Yield (cubic feet per second per square mile) Based on Measured Daily Streamflow from USGS station 02172640 for C-063

After calculating streamflow for each impaired monitoring station the data were ranked to determine the percent of time streamflow was exceeded. The streamflow was then multiplied by a concentration of 380 counts/100 mL (based on the instantaneous concentration and a five percent MOS) to generate a load-duration curve for each impaired station, shown in Figures B-1 through B-4 of Appendix B. The result of the load-duration curve is the TMDL target.

To define the TMDL for each station, an average of the load-duration curve was calculated. The average was calculated using loads at five percent intervals from the 10th percentile of flow exceeded to the 90th percentile of flow exceeded. Loads occurring at less than the 10th percentile of flow exceeded are extreme high flow events and the data collected at greater than the 90th percentile of flow exceeded are extreme low flow events and therefore were not considered in developing theses TMDLs. Loads established at intervals and the mean load for each station can be found in Appendix B, Table B-1.

5.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

A total maximum daily load (TMDL) for a given pollutant and waterbody 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 waterbody. Conceptually, this definition is represented by the equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

The TMDL is the total amount of a pollutant that can be assimilated by the receiving waterbody 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 some pollutants, TMDLs are expressed on a mass-loading basis (e.g., pounds per day). For bacteria, however, TMDLs can be expressed in terms of organism counts (or resulting concentration), in accordance with 40 CFR 130.2(l).

5.1 Critical Conditions

Critical conditions for fecal coliform bacteria in the Halfway Swamp Creek and Warley River watersheds occur at various flow regimes. The load-duration curve methodology used to establish TMDLs in the watershed considers various hydrologic conditions critical in maintaining water quality standards.

5.2 Existing Load

The existing load for each impaired station was established using observed fecal coliform bacteria data and area-weighted streamflow. The measured data occurring at less than the 10th percentile of flow exceeded is an extreme high flow event and the data collected at greater than the 90th percentile of flow exceeded is an extreme low flow event and therefore not considered as critical conditions for these TMDLs.

The data violating the instantaneous concentration were isolated and a best-fit trendline was fit to violating data. The power trendline was determined using a best-fit relationship that was most representative of the violating data. The equation representing the trendline was then used to calculate the average violating load that occurred between the 10th and 90th percentiles, at every fifth percentile. This average load is equal to the existing instream fecal coliform bacteria load at the associated station. The existing nonpoint source load is equal to the existing instream load minus the wasteload from point sources.

Figure 5-1 presents the power best-fit trendline for station C-063, the impaired station on Halfway Swamp Creek. Interval loads calculated for existing instream conditions are presented in Table B-2. Power trendlines are presented in Figures B-1 through B-4 of Appendix B. Existing nonpoint loads calculated for each station are listed in Table 5-1.

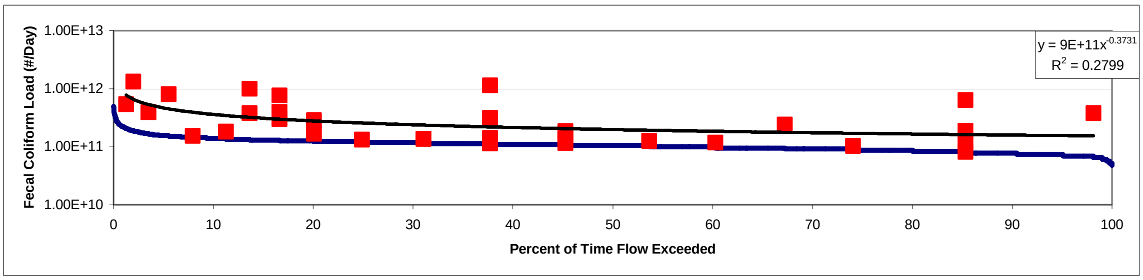

Figure 5-1 Power Trendline Generated from Violating Fecal Coliform Bacteria at C-063

Table 5-1 Existing Loads for Impaired Water Quality Stations in the Halfway Swamp Creek (03050111-020) and Warley Creek (03050111-010-030)

Station ID	Existing Load (counts/day)
C-058	7.28E+11
C-063	2.29E+11
CW-241	6.52E+11
SC-006	1.40E+11
SC-007	4.89E+11

5.3 Existing Wasteload

The existing wasteload was calculated for each NPDES permitted continuous discharge. The facilities were assumed to discharge at permitted flows (design flows when a flow limit was not designated in the permit) and permitted limits of fecal coliform bacteria equal to the State criteria for both instantaneous and geometric mean loads. In South Carolina, NPDES permittees that discharge sanitary wastewater must meet the State's criteria for fecal coliform bacteria at the point of discharge (i.e. a daily maximum concentration of 400 counts per 100 mL, and a 30-day geometric mean of 200 counts per 100 mL). Under these permitted concentrations facilities should not be in exceedance of the fecal coliform bacteria water quality criteria, and therefore, not considered to be a major contributing source. If facilities are discharging at greater than permitted concentrations this is an illicit discharge and regulated through the NPDES program.

Allowable TMDL wasteloads for impaired stations, as shown in Table 5-2, are equal to loads calculated for facilities in the basin.

Table 5-2 Wasteloads from NPDES Continuous Discharges to Impaired Water Quality Stations in the Halfway Swamp Creek (03050111-020)

Station ID	Existing Waste Load Continuous (counts/day)
CW-241	8.33E+09
SC-007	8.33E+09

5.4 Margin of Safety

There are two methods for incorporating a margin of safety (MOS) in the analysis: a) by implicitly incorporating the MOS using conservative assumptions to develop allocations; or b) by explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations. For the TMDLs presented in this report, both methods were applied to incorporate a MOS. An implicit MOS was incorporated through the use of conservative assumptions in developing the TMDL, such as the use of the design or permitted flow for NPDES facilities and the use of a trendline to establish a total instream load. A five percent explicit MOS was reserved from the water quality criteria in developing the load-duration curves. Specifically, the water quality target was set at 190 counts per 100 mL for the geometric mean 30-day period and 380 counts per 100 mL for the instantaneous criterion, which is five percent lower than the water quality criteria of 200 and 400 counts per 100 mL, respectively.

5.5 Total Maximum Daily Load

The TMDL represents the maximum fecal coliform bacteria load the stream may carry and still meet water quality standards. The TMDL is presented in fecal coliform counts to be protective of both the instantaneous, per day, and geometric mean, per 30-day, criteria. Table 5-3 defines the fecal coliform bacteria total maximum daily load for protection of water quality standards for impaired stations in the Halfway Swamp Creek and Warley Creek watersheds.

Table 5-3 Total Maximum Daily Loads for Impaired Water Quality Stations in the Halfway Swamp Creek (03050111-020) and Warley Creek (03050111-010-030)

Station ID	Existing Waste Load Continuous (counts/day)	TMDL WLA Continuous[1] (counts/day)	Existing Load (counts/day)	TMDL LA (counts/day)	MOS (counts/day)	TMDL[2] (counts/day)	Percent Reduction[3]
C-058	NA	NA	7.28E+11	2.94E+10	1.63E+09	3.11E+10	96%
C-063	NA	NA	2.29E+11	9.96E+10	5.53E+09	1.05E+11	54%
CW-241	8.33E+09	8.33E+09	6.52E+11	3.53E+11	2.01E+10	3.81E+11	46%
SC-006	NA	NA	1.40E+11	7.69E+10	4.27E+09	8.12E+10	42%
SC-007	8.33E+09	8.33E+09	4.89E+11	3.10E+11	1.77E+10	3.36E+11	31%

Table Notes:

1. Total monthly wasteload (#/30 days) cannot exceed loads listed in Table 3-3.
2. TMDLs expressed as monthly load (#/30 days) by station are listed in Table B-1.
3. Percent reduction applies to LA component.

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. In addition, SCDHEC will work with the existing agencies in the area to provide nonpoint source education in the Halfway Swamp and Warley Creek watersheds. Local sources of nonpoint source education and assistance include Clemson Extension Service, the Natural Resource Conservation Service (NRCS), the Calhoun and Orangeburg Counties 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 nonpoint source problems on the farm. 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 Halfway Swamp and Warley Creeks. 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 Halfway Swamp and Warley Creek watersheds, 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 mechanisms, these measures will be implemented in the Halfway Swamp and Warley Creek watersheds in order to bring about the necessary reductions in fecal coliform bacteria loading to Halfway Swamp and Warley Creeks. 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 Data

Table A-1 Percent of Watershed Area Aggregated by Land Use Class for Areas Draining to Streamflow and Water Quality Monitoring Stations

Monitoring Station ID	Water	Urban	Row Crop	Pasture	Forest	Barren
C-058	0.0%	19%	31%	4.9%	39%	5.8%
C-063	0.1%	5.9%	36%	6.8%	46%	5.9%
CW-241	0.4%	2.8%	31%	4.8%	55%	6.3%
SC-006	1.1%	0.1%	47%	3.6%	43%	5.0%
SC-007	0.5%	3.1%	31%	3.6%	54%	7.0%
USGS 02135300	0.8%	11%	35%	5.4%	47%	0.7%
USGS 02172640	0.4%	1.1%	27%	2.2%	59%	9.6%

Table A-2 Watershed Area in Square Miles Aggregated by Land Use Class for Areas Draining to Streamflow and Water Quality Monitoring Stations

Monitoring Station ID	Water	Urban	Row Crop	Pasture	Forest	Barren	Total
	(Miles^2)						
C-058	0.0	0.8	1.3	0.2	1.7	0.2	4.3
C-063	0.0	0.8	5.1	1.0	6.5	0.8	14
CW-241	0.2	1.4	16	2.5	28	3.3	52
SC-006	0.1	0.0	5.2	0.4	4.8	0.6	11
SC-007	0.2	1.4	14	2.2	25	3.2	46
USGS 02135300	1.1	15	49	7.4	65	1.0	139
USGS 02172640	0.1	0.3	8.4	0.7	18	2.9	31

Table A-3 Fecal Coliform Data Collected between 1990 and 2001 at Water Quality Monitoring Stations in Halfway Swamp Creek

C-058	
Date	Result
5/25/1990	92
6/22/1990	60
7/20/1990	920
8/17/1990	100
9/21/1990	70
10/17/1990	45
5/27/1993	60
6/18/1993	6
7/7/1993	7
8/25/1993	25
9/30/1993	19
10/22/1993	22
5/6/1994	500
6/24/1994	45000
7/22/1994	10
8/5/1994	140
9/30/1994	20
10/6/1994	8
5/23/1995	290
6/22/1995	130
7/13/1995	130
8/24/1995	93
9/20/1995	23
10/18/1995	43
5/7/1996	11
6/4/1996	3
7/25/1996	35

C-058	
Date	Result
8/6/1996	190
9/10/1996	7
10/24/1996	4
5/15/1997	11
6/26/1997	1
7/31/1997	280
8/7/1997	7
9/11/1997	450
10/22/1997	37
05/13/98	10
06/11/98	1100
07/23/98	10
08/20/98	45
09/14/98	1
10/29/98	3
5/13/1999	1
6/10/1999	100
7/15/1999	15
8/5/1999	300
9/9/1999	130
10/14/1999	13
5/25/2000	33
6/6/2000	520
7/6/2000	77
8/1/2000	3
9/7/2000	300
10/10/2000	5

Table A-3 Continued

C-068	
Date	Result
5/25/1990	440
6/22/1990	460
7/20/1990	470
8/17/1990	2200
9/21/1990	130
10/17/1990	250
5/17/1991	720
6/7/1991	200
7/11/1991	97
8/14/1991	210
9/17/1991	180
11/10/1991	330
5/27/1993	200
6/18/1993	500
7/7/1993	320
8/25/1993	220
9/30/1993	1300
10/22/1993	350
5/6/1994	130
6/24/1994	410
7/22/1994	2000
8/5/1994	1100
9/30/1994	500
10/6/1994	400
5/23/1995	260
6/22/1995	200
7/13/1995	510
8/24/1995	2300
9/20/1995	430
10/18/1995	460

C-068	
Date	Result
5/7/1996	680
6/4/1996	420
7/25/1996	210
8/6/1996	410
9/10/1996	280
10/24/1996	240
5/15/1997	350
6/26/1997	450
7/31/1997	4000
8/7/1997	220
9/11/1997	330
10/22/1997	900
05/13/98	140
06/11/98	900
07/23/98	1100
08/20/98	2900
09/14/98	500
10/27/98	480
10/14/1999	200
9/9/1999	370
8/5/1999	560
7/15/1999	470
6/10/1999	920
5/13/1999	110
10/24/2000	190
9/7/2000	1000
8/1/2000	520
7/6/2000	2200
6/6/2000	3100
5/25/2000	280

Table A-3 Continued

CW-241	
Date	Result
11/18/1992	100
12/11/1992	160
1/7/1993	2700
2/4/1993	86
3/26/1993	900
4/15/1993	98
5/27/1993	220
6/18/1993	300
7/7/1993	160
8/25/1993	400
9/30/1993	220
10/22/1993	230
03/19/98	1000
04/29/98	220
05/13/98	100
06/11/98	1200
07/23/98	120
08/20/98	280
09/14/98	120
10/27/98	120

Table A-3 Continued

SC-007	
Date	Result
1/2/1990	142
2/5/1990	380
3/5/1990	89
4/2/1990	100
5/1/1990	116
7/5/1990	124
8/6/1990	123
9/4/1990	232
10/1/1990	1000
11/5/1990	166
12/3/1990	124
1/7/1991	68
2/5/1991	81
3/12/1991	19
4/8/1991	62
5/6/1991	970
7/9/1991	106
8/12/1991	450
9/3/1991	98
10/7/1991	152
11/4/1991	168
12/4/1991	610
1/6/1992	250
2/12/1992	104
3/11/1992	84
4/2/1992	40
5/19/1992	135
6/2/1992	50
8/3/1992	770
9/23/1992	104
11/4/1992	50
12/7/1992	430
1/4/1993	72
2/2/1993	62
3/8/1993	50
4/15/1993	66
5/18/1993	78
6/8/1993	98

SC-007	
Date	Result
7/14/1993	88
8/2/1993	88
9/20/1993	94
10/7/1993	163
11/8/1993	430
1/3/1994	310
2/1/1994	100
3/15/1994	86
4/7/1994	210
5/2/1994	78
6/7/1994	560
7/12/1994	125
8/2/1994	1520
9/20/1994	710
10/5/1994	470
11/8/1994	94
12/12/1994	220
1/5/1995	174
2/8/1995	2
3/6/1995	113
4/4/1995	72
5/15/1995	70
6/6/1995	600
7/11/1995	440
9/11/1995	450
10/10/1995	138
11/13/1995	2
12/5/1995	100
1/9/1996	220
7/22/1996	200
6/30/1997	130
1/6/1998	910
07/28/98	18
06/15/99	600
01/11/00	600
07/11/00	116
09/05/00	390

Table A-4 Fecal Coliform Data Collected between 1990 and 2001 at Water Quality Monitoring Stations in Warley Creek

SC-006		SC-006	
Date	Result	Date	Result
1/2/1990	38	6/8/1993	130
2/5/1990	82	7/14/1993	82
3/5/1990	23	8/2/1993	90
4/2/1990	35	9/20/1993	72
5/1/1990	80	10/7/1993	200
6/4/1990	290	11/8/1993	114
7/5/1990	97	1/3/1994	86
8/6/1990	336	2/1/1994	82
9/4/1990	62	3/15/1994	60
10/1/1990	490	4/7/1994	320
11/5/1990	57	5/2/1994	270
12/3/1990	205	6/7/1994	480
1/7/1991	80	7/12/1994	220
2/5/1991	23	8/2/1994	440
3/12/1991	59	9/20/1994	102
4/8/1991	58	10/5/1994	168
5/6/1991	550	11/8/1994	68
7/9/1991	300	12/12/1994	114
8/12/1991	2	1/5/1995	80
9/3/1991	94	2/8/1995	270
10/7/1991	210	3/6/1995	28
11/4/1991	125	4/4/1995	70
12/4/1991	730	5/15/1995	118
1/6/1992	116	6/6/1995	1820
2/12/1992	68	7/11/1995	188
3/11/1992	200	9/11/1995	270
4/2/1992	68	10/10/1995	200
5/19/1992	290	11/13/1995	2
6/2/1992	15	12/5/1995	40
8/3/1992	440	1/9/1996	100
9/23/1992	110	7/22/1996	360
11/4/1992	68	6/30/1997	230
12/7/1992	168	01/06/98	720
1/4/1993	76	07/28/98	920
2/2/1993	62	6/15/99	1520
3/8/1993	27	1/11/00	230
4/15/1993	46	7/11/00	200
5/18/1993	280	9/5/00	1420

APPENDIX B Calculations

Table B-1 TMDL Loads

Station	C-058
Instantaneous Conc. (#/100 ml)	380
Geo. Mean Conc. (#/100 ml)	190

Mean	3.11E+10
Allowable Load (#/day)	3.11E+10
Geometric Mean Load (#/30days)	4.66E+11

Percent Exceedance (%)	Load(#/Day)
10	8.51E+10
15	6.69E+10
20	5.76E+10
25	5.05E+10
30	4.42E+10
35	3.95E+10
40	3.45E+10
45	3.04E+10
50	2.65E+10
55	2.21E+10
60	1.83E+10
65	1.46E+10
70	1.15E+10
75	9.13E+09
80	7.45E+09
85	5.70E+09
90	4.05E+09

Station	C-063
Instantaneous Conc. (#/100 ml)	380
Geo. Mean Conc. (#/100 ml)	190

Mean	1.05E+11
Allowable Load (#/day)	1.05E+11
Geometric Mean Load (#/30days)	1.58E+12

Percent Exceedance (%)	Load(#/Day)
10	1.39E+11
15	1.30E+11
20	1.26E+11
25	1.17E+11
30	1.17E+11
35	1.13E+11
40	1.09E+11
45	1.09E+11
50	1.04E+11
55	1.00E+11
60	1.00E+11
65	9.56E+10
70	9.13E+10
75	8.70E+10
80	8.70E+10
85	8.26E+10
90	7.83E+10

Station	CW-241
Instantaneous Conc. (#/100 ml)	380
Geo. Mean Conc. (#/100 ml)	190

Mean	3.81E+11
Allowable Load (#/day)	3.81E+11
Geometric Mean Load (#/30days)	5.72E+12

Percent Exceedance (%)	Load(#/Day)
10	5.05E+11
15	4.73E+11
20	4.58E+11
25	4.26E+11
30	4.26E+11
35	4.10E+11
40	3.94E+11
45	3.94E+11
50	3.79E+11
55	3.63E+11
60	3.63E+11
65	3.47E+11
70	3.31E+11
75	3.16E+11
80	3.16E+11
85	3.00E+11
90	2.84E+11

Table B-1 Continued

Station	SC-006
Instantaneous Conc. (#/100 ml)	380
Geo. Mean Conc. (#/100 ml)	190

Mean	8.12E+10
Allowable Load (#/day)	8.12E+10
Geometric Mean Load (#/30days)	1.22E+12

Percent Exceedance (%)	Load(#/Day)
10	1.07E+11
15	1.01E+11
20	9.74E+10
25	9.06E+10
30	9.06E+10
35	8.73E+10
40	8.39E+10
45	8.39E+10
50	8.06E+10
55	7.72E+10
60	7.72E+10
65	7.39E+10
70	7.05E+10
75	6.71E+10
80	6.71E+10
85	6.38E+10
90	6.04E+10

Station	SC-007
Instantaneous Conc. (#/100 ml)	380
Geo. Mean Conc. (#/100 ml)	190

Mean	3.36E+11
Allowable Load (#/day)	3.36E+11
Geometric Mean Load (#/30days)	5.04E+12

Percent Exceedance (%)	Load(#/Day)
10	4.45E+11
15	4.17E+11
20	4.03E+11
25	3.76E+11
30	3.76E+11
35	3.62E+11
40	3.48E+11
45	3.48E+11
50	3.34E+11
55	3.20E+11
60	3.20E+11
65	3.06E+11
70	2.92E+11
75	2.78E+11
80	2.78E+11
85	2.64E+11
90	2.50E+11

Table B-2 Existing Loads

	Station	C-058
Trend Line:		Power
Equation: y=4E+14*x^(-2.3083)		

Existing Load (#/Day):	**7.28E+11**
Average (#/Day):	**7.28E+11**

Percent Exceedance(%)	Load(#/Day)
10	1.97E+12
15	1.63E+12
20	1.25E+12
25	1.02E+12
30	8.60E+11
35	7.46E+11
40	6.59E+11
45	5.91E+11
50	5.36E+11
55	4.91E+11
60	4.53E+11
65	4.20E+11
70	3.93E+11
75	3.68E+11
80	3.47E+11
85	3.28E+11
90	3.11E+11

	Station	C-063
Trend Line:		Power
Equation: y=9E+11*x^(-0.3731)		

Existing Load (#/Day):	**2.29E+11**
Average (#/Day):	**2.29E+11**

Percent Exceedance(%)	Load(#/Day)
10	3.81E+11
15	3.28E+11
20	2.94E+11
25	2.71E+11
30	2.53E+11
35	2.39E+11
40	2.27E+11
45	2.17E+11
50	2.09E+11
55	2.02E+11
60	1.95E+11
65	1.90E+11
70	1.84E+11
75	1.80E+11
80	1.75E+11
85	1.72E+11
90	1.68E+11

	Station	CW-241
Trend Line:		Power
Equation: y=4E+12*x^(-0.4976)		

Existing Load (#/Day):	**6.52E+11**
Average (#/Day):	**6.52E+11**

Percent Exceedance(%)	Load(#/Day)
10	1.27E+12
15	1.04E+12
20	9.01E+11
25	8.06E+11
30	7.36E+11
35	6.82E+11
40	6.38E+11
45	6.02E+11
50	5.71E+11
55	5.45E+11
60	5.21E+11
65	5.01E+11
70	4.83E+11
75	4.67E+11
80	4.52E+11
85	4.39E+11
90	4.26E+11

Table B-2 Continued

Station	SC-006
Trend Line:	Power
Equation: y=5E+11*x^(-0.3469)	

Existing Load (#/Day):	1.40E+11
Average (#/Day):	1.40E+11

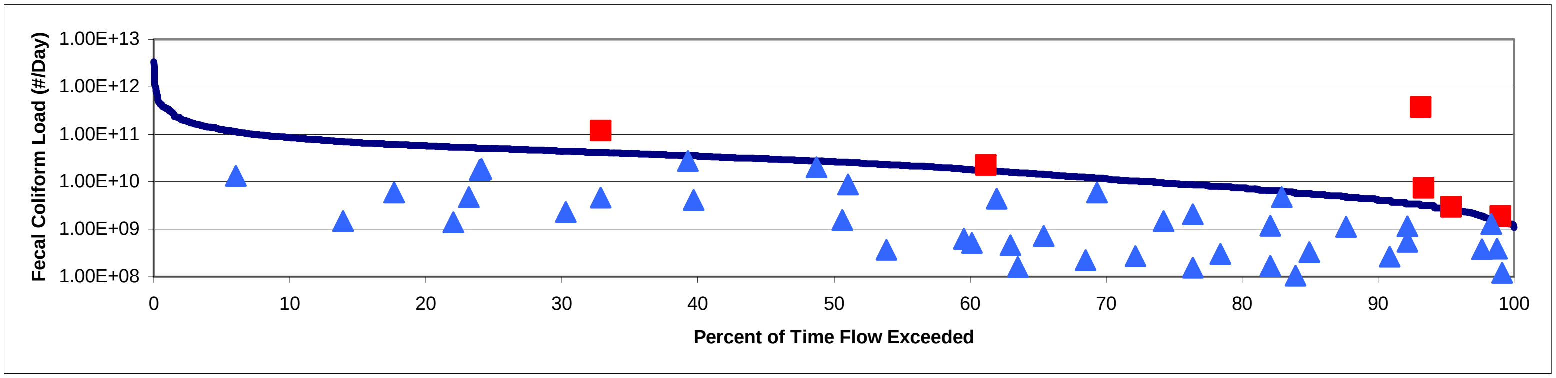
Percent Exceedance(%)	Load(#/Day)
10	2.25E+11
15	1.95E+11
20	1.77E+11
25	1.64E+11
30	1.54E+11
35	1.46E+11
40	1.39E+11
45	1.33E+11
50	1.29E+11
55	1.25E+11
60	1.21E+11
65	1.18E+11
70	1.15E+11
75	1.12E+11
80	1.09E+11
85	1.07E+11
90	1.05E+11

Station	SC-007
Trend Line:	Power
Equation: y=1E+12*x^(-0.193)	

Existing Load (#/Day):	4.89E+11
Average (#/Day):	4.89E+11

Percent Exceedance(%)	Load(#/Day)
10	6.41E+11
15	5.93E+11
20	5.61E+11
25	5.37E+11
30	5.19E+11
35	5.03E+11
40	4.91E+11
45	4.80E+11
50	4.70E+11
55	4.61E+11
60	4.54E+11
65	4.47E+11
70	4.40E+11
75	4.35E+11
80	4.29E+11
85	4.24E+11
90	4.20E+11

Figure B-1 Load Duration Curve with All Measured Data and Power Trend Line Generated from Violating Fecal Coliform Bacteria Measured at C-058



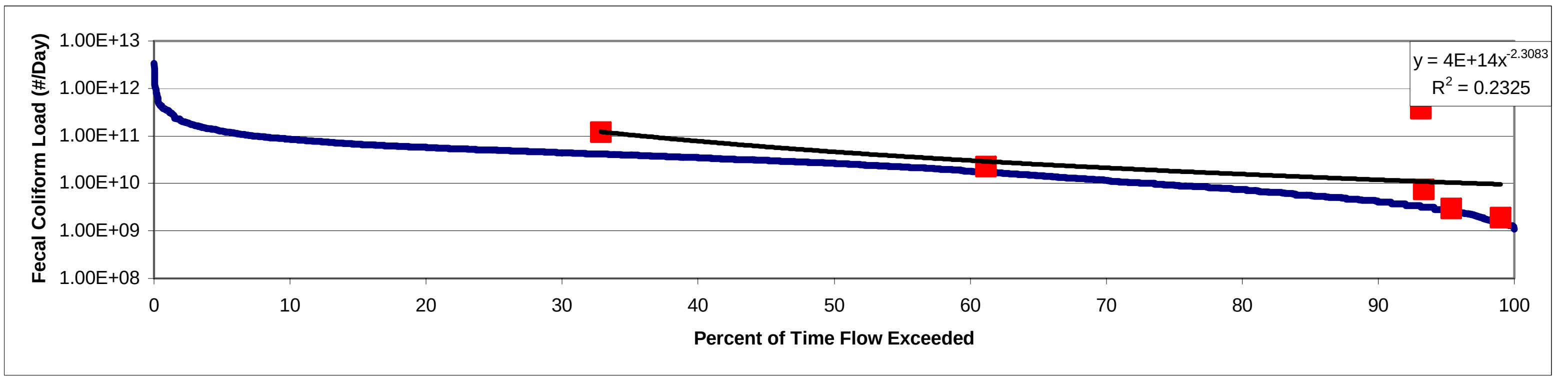
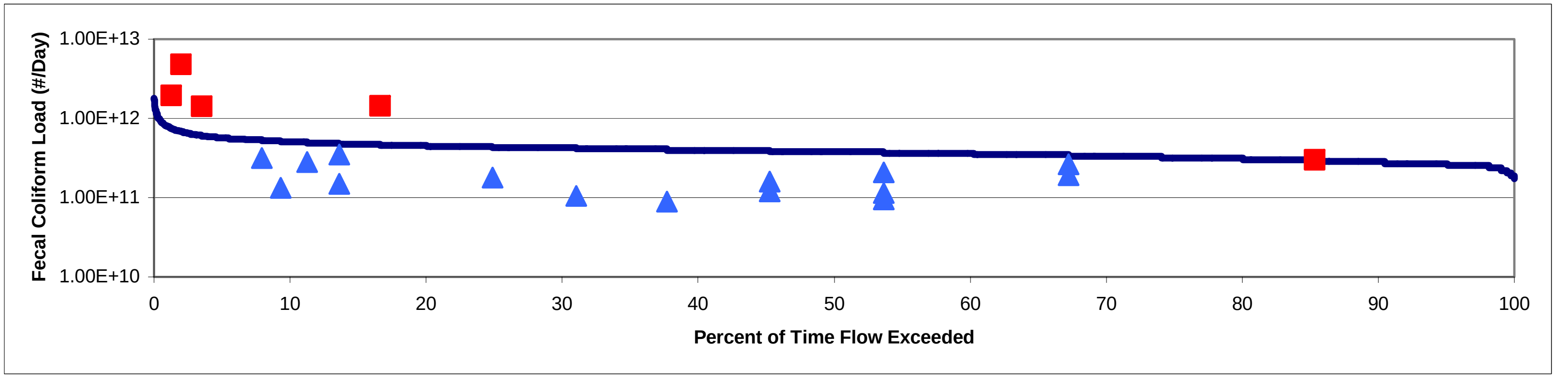


Figure B-2 Load Duration Curve with All Measured Data and Power Trend Line Generated from Violating Fecal Coliform Bacteria Measured at CW-241



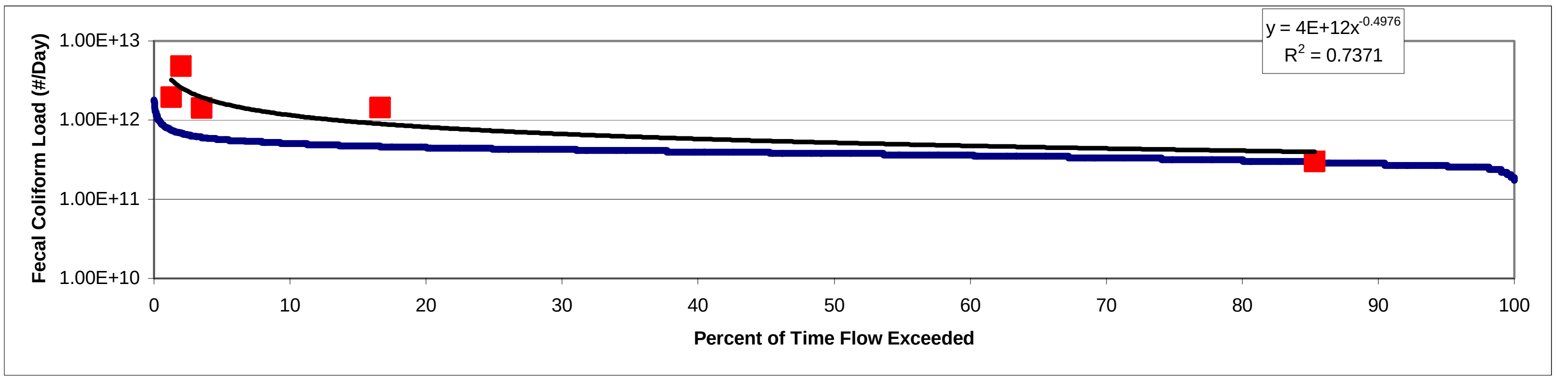
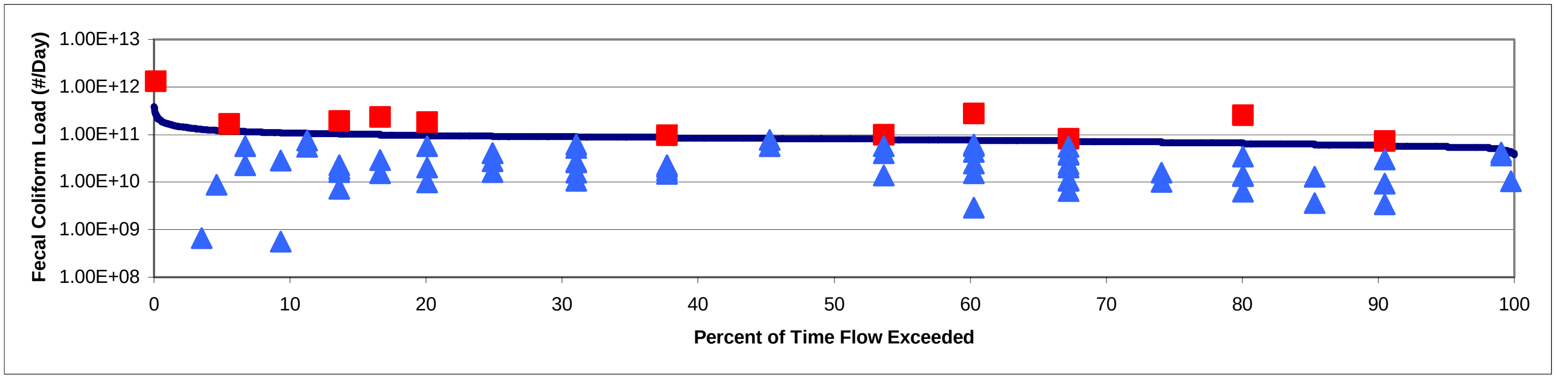


Figure B-3 Load Duration Curve with All Measured Data and Power Trend Line Generated from Violating Fecal Coliform Bacteria Measured at SC-006



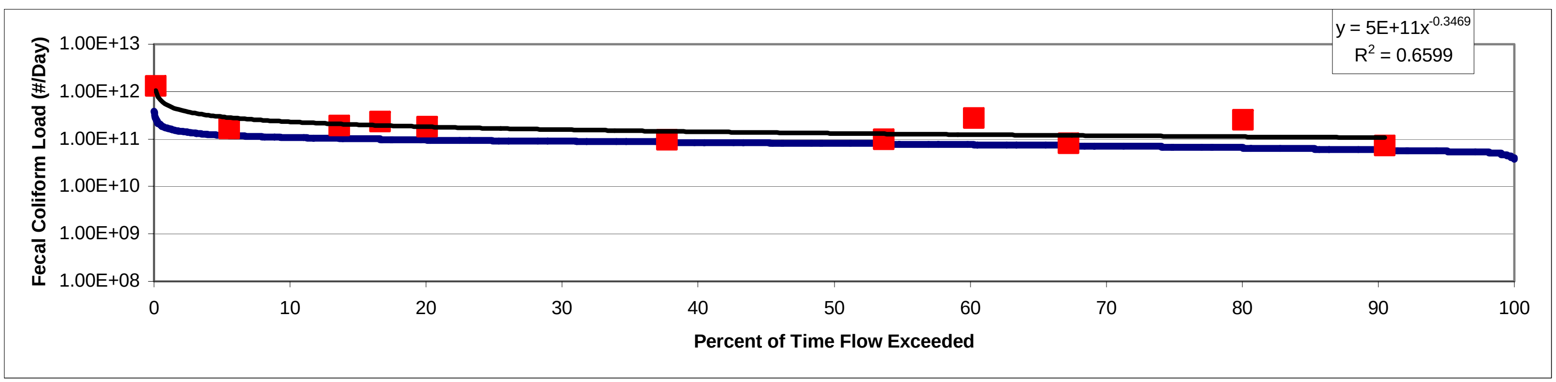
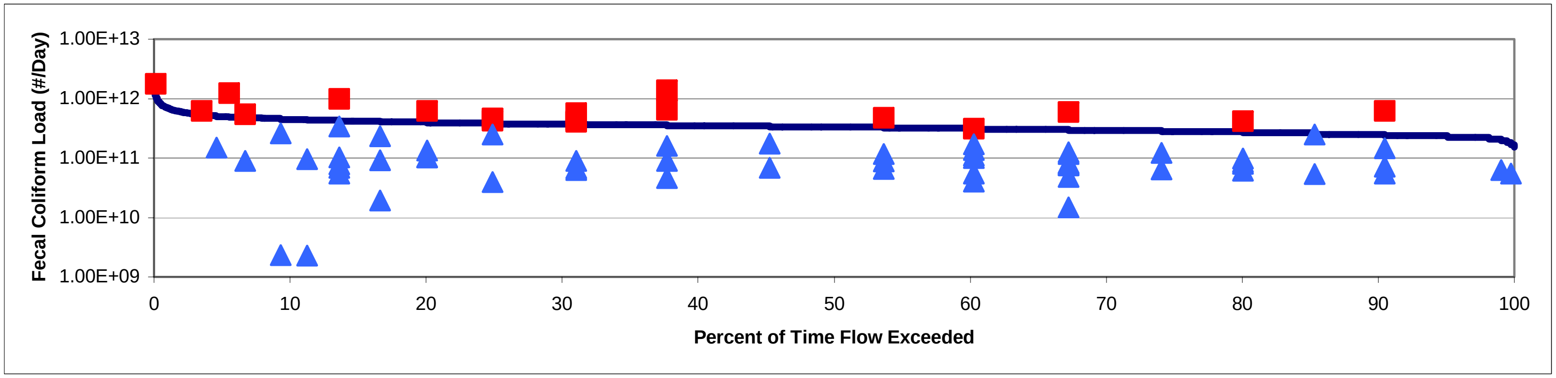


Figure B-4 Load Duration Curve with All Measured Data and Power Trend Line Generated from Violating Fecal Coliform Bacteria Measured at SC-007



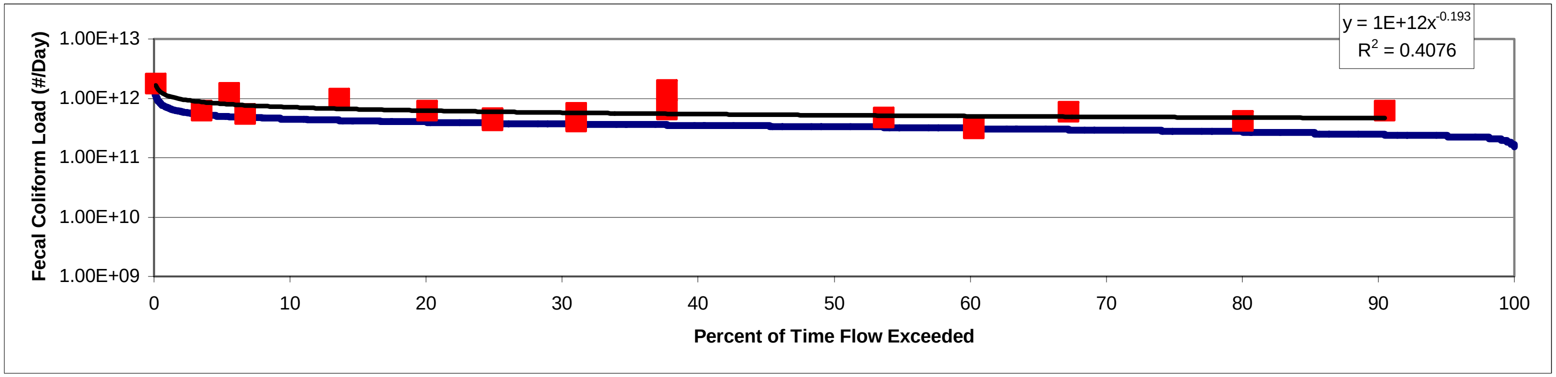


Figure B-5 Water Yield (cubic feet per second per square mile) Based on Measured Daily Streamflow from USGS station 02135517

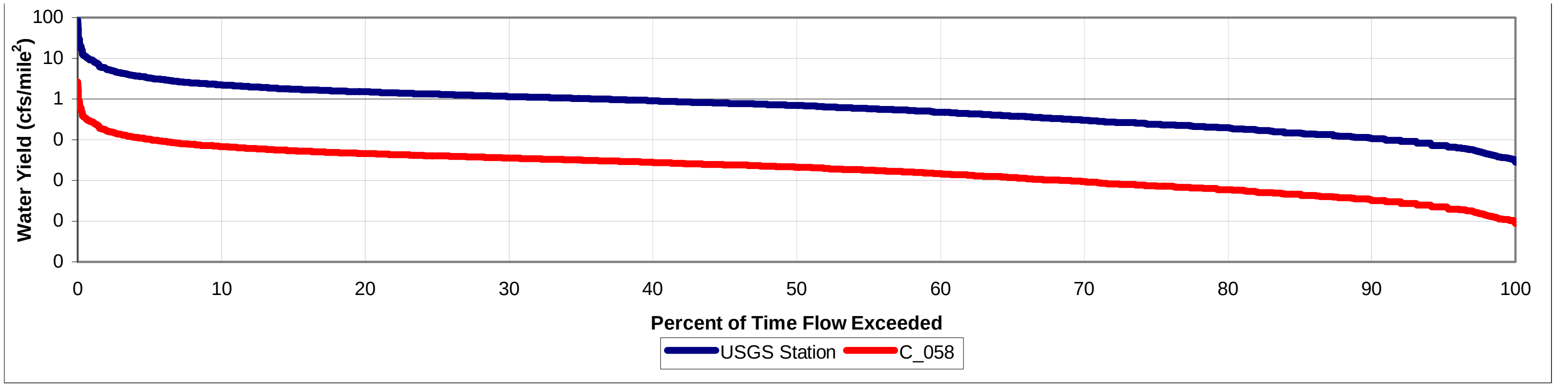
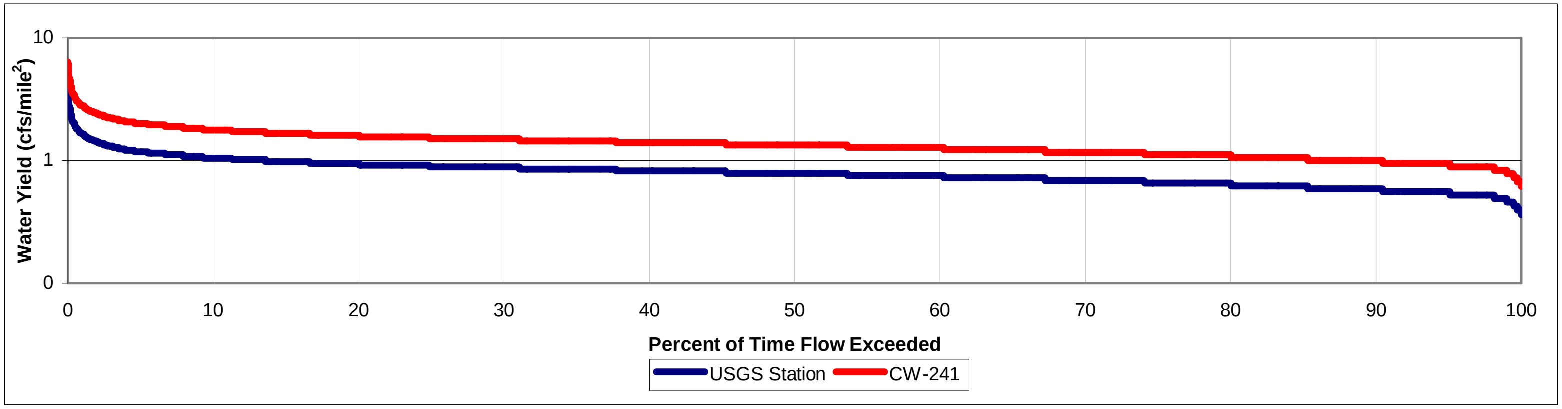


Figure B-6 Water Yield (cubic feet per second per square mile) Based on Measured Daily Streamflow from USGS station 02172640



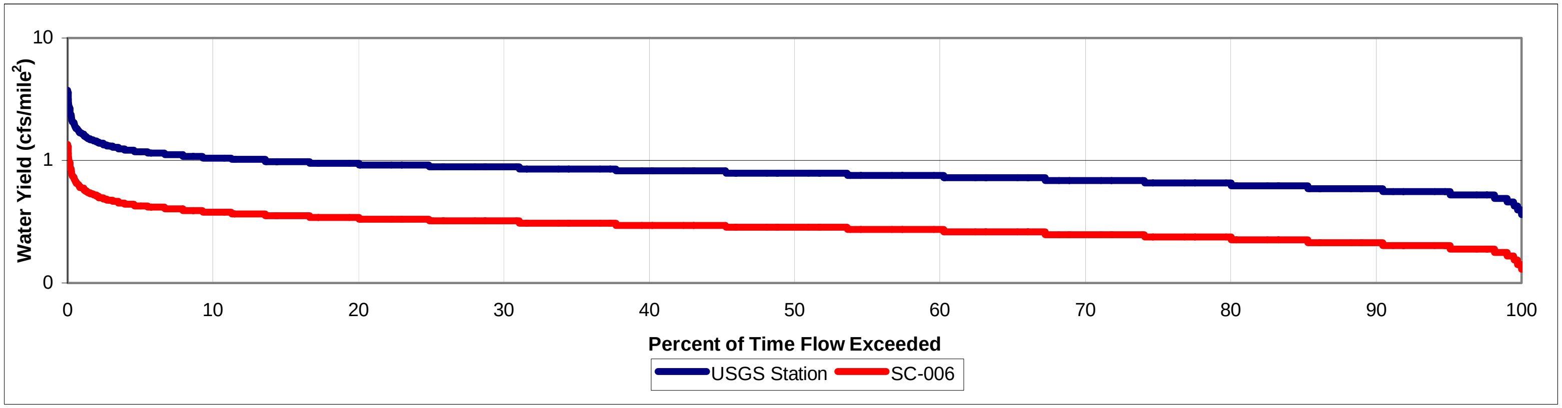
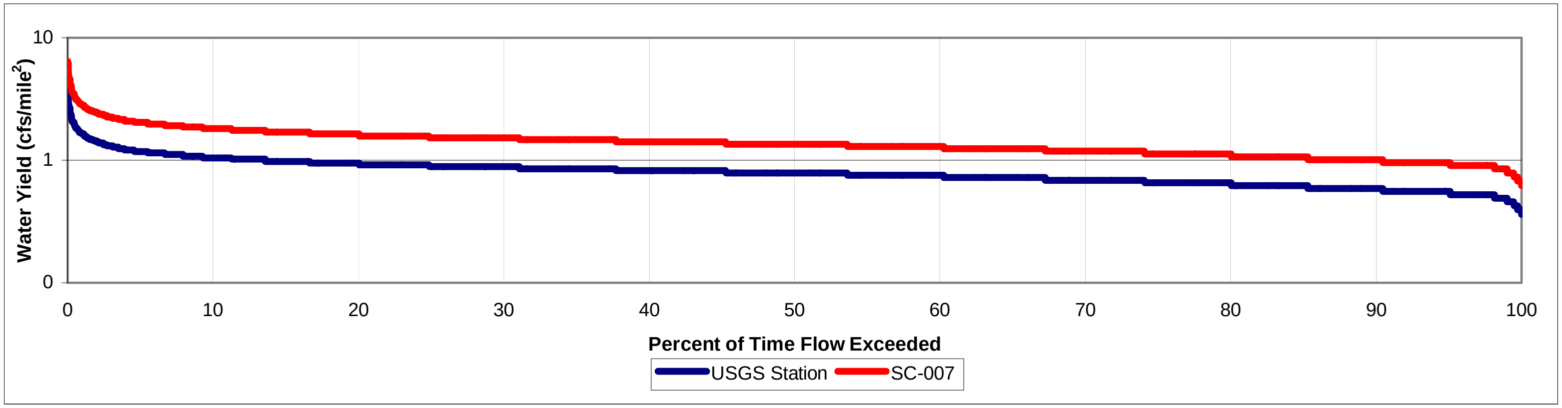


Figure B-6 Continued



APPENDIX C Public Notification

APPENDIX D MOVE.1

Constructing Flow Curves Using MOVE.1

The concept of record extension is to transfer the characteristics of distribution shape, serial correlation, and seasonality from the base station to the short-record station with adjustments of location and scale appropriate to the short-record station. MOVE.1 is a statistical technique developed by the USGS (Hirsch, 1982) for extending discharge records at partial or discontinued gages using continuous records at a base station having a common period of record as the partial station. Record extension is based on the following equation:

$$Y(i) = m(y_1) + (S(y_1)/S(x_1))(x(i) - m(x_1)) \qquad \text{Equation 1}$$

Where: Y = discharge at partial record station on particular date
$m(y_1)$ = mean value at partial record station
$S(y_1)$ = standard deviation of discharge record at partial station
$S(x_1)$ = standard deviation of discharge record at continuous station
$X(i)$ = discharge at continuous gage on a particular date
$m(x_1)$ = mean value at continuous record station

Application of the MOVE.1 technique is explained below; however, for more information on the derivation of the equations used in the analysis, please refer to Hirsch (1982).

The record extension procedure can be easily performed in a spreadsheet, such as Excel, having the “analysis toolpak” feature loaded as an add-in program. In Excel, the “descriptive statistic” feature in the “analysis toolpak” is used to compute the complex statistical parameters described in Equation 1. The first step in utilizing MOVE.1 is to compute the logarithms of the discharges at each gage during the concurrent time period. By selecting the “descriptive statistic” feature from the data analysis menu (in Excel, this is located under the “tools” menu bar), and highlighting the cells containing the logarithms of the discharges at both the partial and continuous record stations, the summary statistics used in Equation 1 can be calculated. Flows at other time periods at the partial record station can be estimated by using Equation 1, the summary statistics from the analysis toolpak, and flow at the continuous record station.

A partial flow record is available for the Pocotaligo River at Sumter, SC at USGS station 02135517. MOVE.1 was used to establish the missing period of record from 1990 through 1992 and 1995 though 2000 for the purpose of developing loads for water quality samples. The partial station was matched with a USGS station with complete records. The USGS station 02135300 on Scape Ore Swamp near Bishopville, SC was used to extend the record at USGS station 02135517. The concurrent time period for each pair was used in the MOVE.1 analysis. Statistical parameters derived from the MOVE.1

analysis are shown in Table D-1. The resulting flow duration curve is presented in Figure D-1.

Table D-1 Statistical Parameters Derived from the MOVE.1 Analysis Comparing USGS 02135300 and USGS 02135517

log 02135300		***log 02135517***	
Mean	1.88	Mean	1.99
Standard Error	0.01	Standard Error	0.02
Median	2	Median	2.03
Mode	1.38	Mode	1.51
Standard Deviation	0.40	Standard Deviation	0.48
Sample Variance	0.16	Sample Variance	0.23
Kurtosis	-0.36	Kurtosis	-0.09
Skewness	-0.33	Skewness	0.00
Range	2.42	Range	2.87
Minimum	0.96	Minimum	0.79
Maximum	3.38	Maximum	3.66
Sum	1891.99	Sum	2005.82
Count	1006	Count	1006
Standard Deviation Y / Standard Deviation X = 1.19			

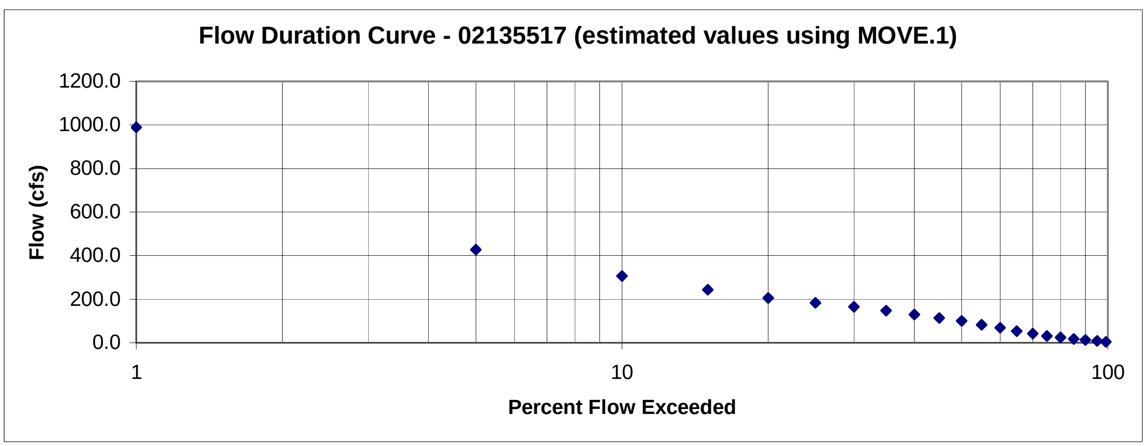


Figure D-1 Flow Duration Curve for the Pocotaligo River at Sumter (Estimated Using MOVE.1)