# TOTAL MAXIMUM DAILY LOADS

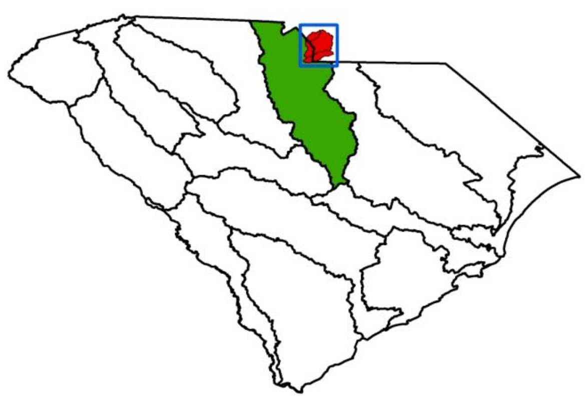
# FOR

# FECAL COLIFORM

# FOR

# Sixmile Creek, Twelvemile Creek, Waxhaw Creek Watersheds in the Catawba River Basin, South Carolina

## HYDROLOGIC UNIT CODE: 03050103
## (STATIONS CW-176, CW-083, CW-145)



Catawba River Basin

**September 2005**

**SCDHEC Technical Report Number: 031-05**

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 Sixmile Creek, Twelvemile Creek and Waxhaw Creek in the Catawba River Basin. Subsequent actions must be consistent with this TMDL.

| | |
|---|---|
| James D. Giattina, Director<br>Water Management Division | Date |

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# ACRONYMS AND ABBREVIATIONS

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

# SECTION 1
# INTRODUCTION

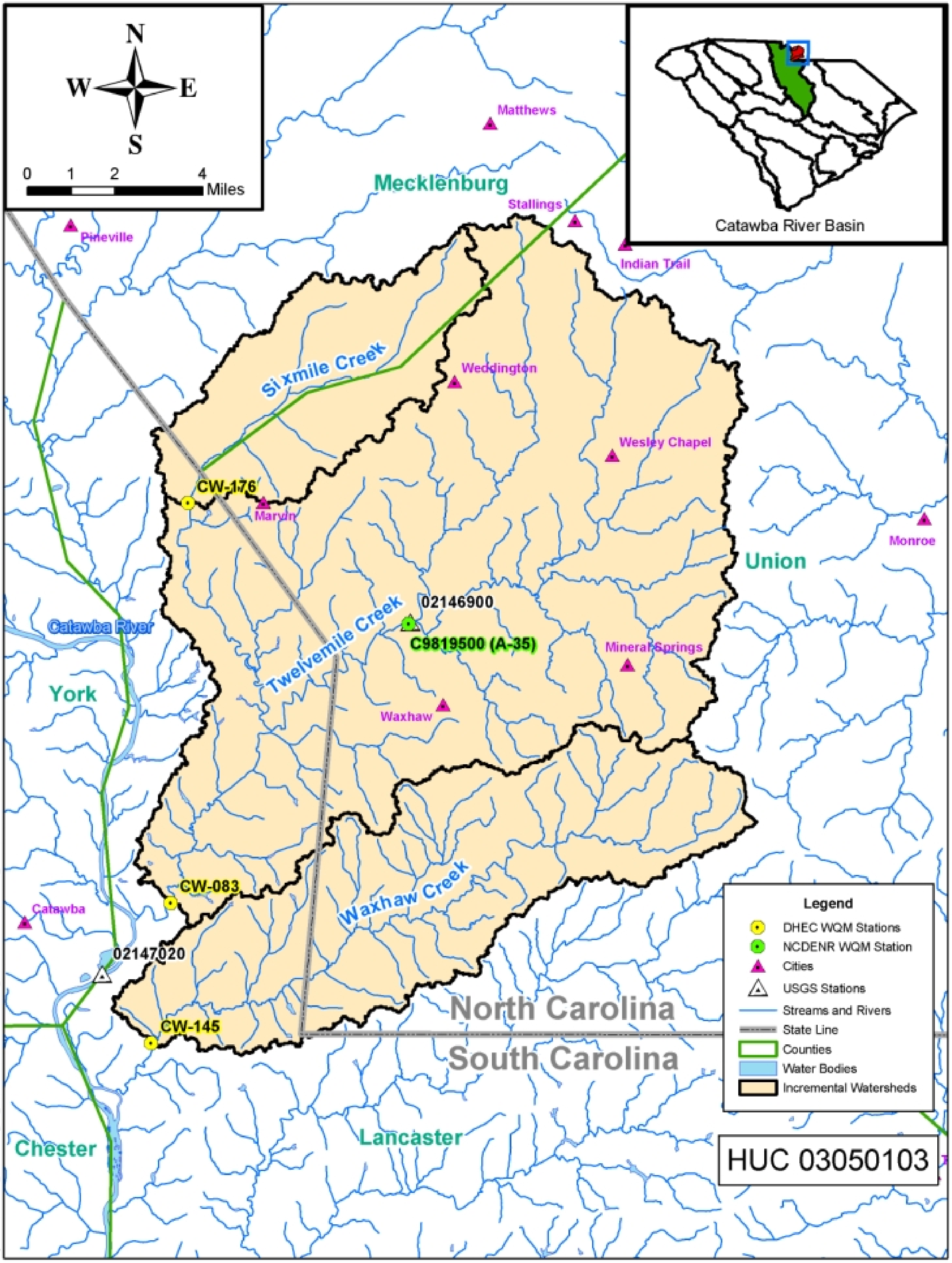
## 1.1 Background

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

This report documents the data and assessment utilized to establish TMDLs for fecal coliform bacteria for certain water bodies in the Catawba River Basin in accordance with the requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), USEPA guidance, and South Carolina (SC) Department of Health and Environmental Control (SCDHEC) guidance and procedures. States are required to submit all TMDLs to USEPA for review and approval. Once USEPA approves a TMDL, then the water body may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003). The purpose of this TMDL report is to assist SCDHEC with establishing pollutant load allocations for impaired water bodies. TMDLs determine the pollutant loading a water body can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a water body based on the relationship between pollutant sources and in-stream water quality conditions. A TMDL consists of a wasteload allocation (WLA), a load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL that accounts for the uncertainty associated with model assumptions and data limitations.

SCDHEC included three water quality monitoring (WQM) stations from Hydrologic Unit Code (HUC) 03050103 within the Catawba River Basin on the 2004 South Carolina §303(d) list for exceedances of the fecal coliform bacteria WQS. Figure 1-1 is an orientation map showing a portion of the 8-digit HUC of the Catawba River Basin where the 303(d)-listed WQM stations are located.

**Figure 1-1 Sixmile Creek, Twelvemile Creek, and Waxhaw Creek Watersheds**



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

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

| Water Body Name | SCDHEC WQM Stations | WQM Station Locations |
|---|---|---|
| HUC 03050103030 | | |
| Sixmile Creek | CW-176 | Sixmile Creek at S-29-54 |
| Twelvemile Creek | CW-083 | Twelvemile Creek at S-29-55 0.3 miles northwest of Van Wyck |
| Waxhaw Creek | CW-145 | Waxhaw Creek at S-29-29 |

## 1.2 Watershed Description

**General.** The Catawba River Basin is in the north central portion of SC and extends into North Carolina (NC) near Charlotte. Headwaters of the Catawba River originate in the eastern slopes of the Blue Ridge mountains in NC. It flows east, and then south into Lake Wylie, which extends across the NC-SC border. The Catawba River then flows out of Lake Wylie and is joined by a number of tributaries, including Twelvemile Creek and Waxhaw Creek. The Twelvemile Creek watershed originates in NC and accepts drainage from various tributaries, including Sixmile Creek. Waxhaw Creek is located downstream of Twelvemile Creek and accepts drainage from Causar Creek and Mill Branch. The Catawba River drains through various reservoirs and joins Big Wateree Creek to form the Wateree River which flows through Lake Wateree.

The Catawba River Basin includes 2,943 stream miles and 26,308 acres of lake waters. The basin consists of forested land, agricultural land, scrub/shrub land, forested wetlands, urban land, barren land, and nonforested wetlands (SCDHEC 2003). The Catawba River Basin is divided into three geographical regions: the Piedmont (an area of gently rolling to hilly slopes with narrow stream valleys dominated by forests, farms, and orchards; elevations 375 to 1,000 feet above mean sea level [msl]), the Sand Hills (an area of gently sloping to strongly sloping uplands with a predominance of sandy areas and scrub vegetation; elevations 250 to 450 feet msl), and the Upper Coastal Plain (an area of gentle slopes with increased dissection and moderate slopes in the northwest section that contain the State’s major farming areas; elevations 100 to 450 feet msl) (SCDHEC 2003). Although the Catawba River Basin encompasses 21 watersheds and 2,322 square miles, only the Sixmile, Twelvemile, and Waxhaw Creek watersheds are addressed in this TMDL report.

Portions of Sixmile Creek, Twelvemile Creek, and Waxhaw Creek watersheds are within Lancaster County, SC; however, the majority of the watersheds are within Union County, NC. Over 90 percent of the Sixmile Creek watershed is in NC. All three watersheds are south of the rapidly growing sections of the Charlotte, NC urban area; however, development within the watersheds is currently limited due to lack of sewer service. There are a few small towns, Weddington, Wesley Chapel, Mineral Springs, and Waxhaw, located in the Twelvemile Creek watershed. The predominant soil type is an association of the Appling-Vance-Cecil-Enon series (SCDHEC 2003).

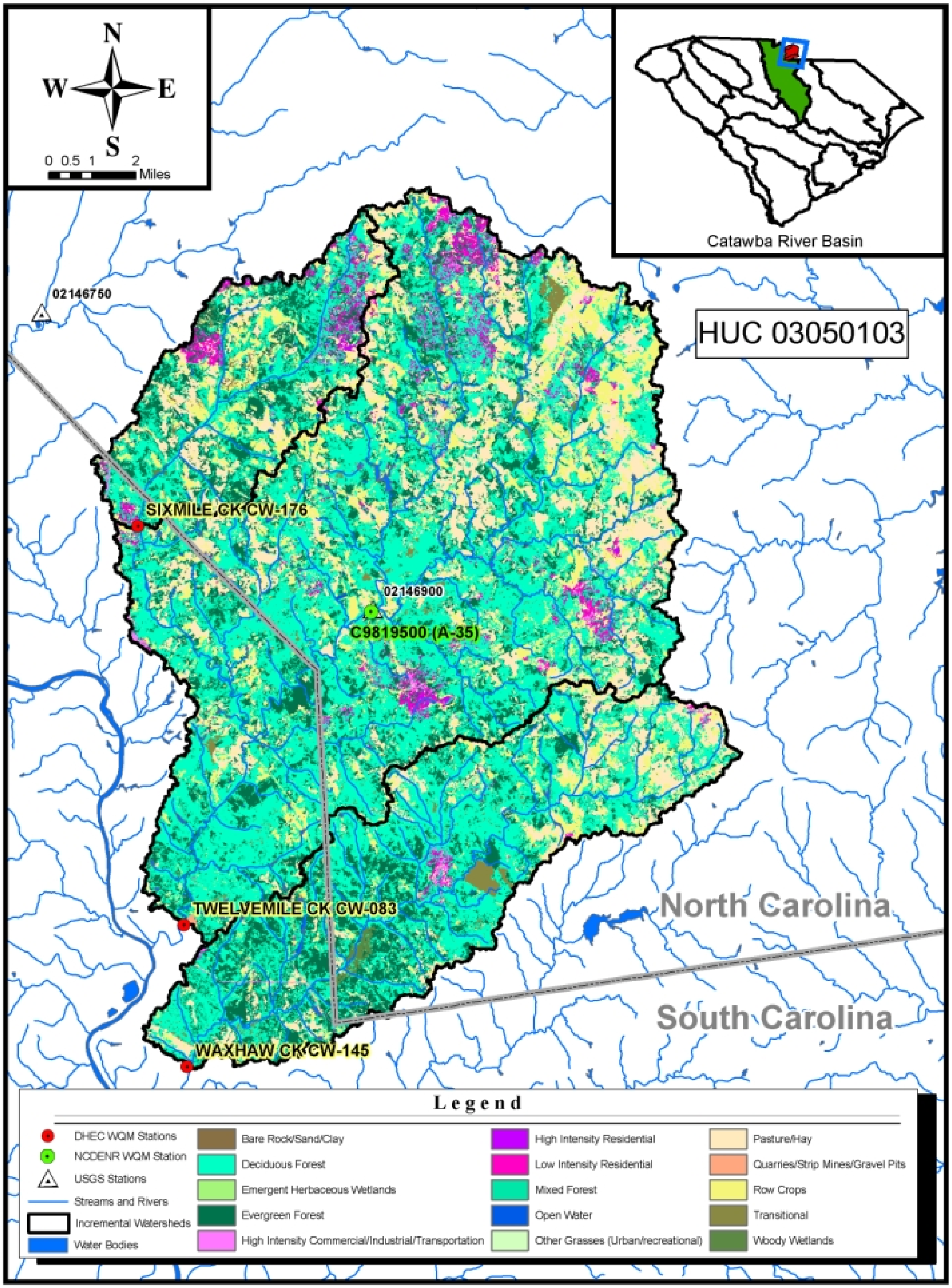
**Precipitation.** According to South Carolina's 30-year climatological record, normal yearly rainfall in the Catawba River area during the period 1971 to 2000 was 45.95 inches (SCDHEC 2003). Data from National Weather Service stations in Chester, Winnsboro, Winthrop College, Camden, Catawba, Great Falls, Wateree Dam, Fort Mill, and Tilghman for Nursery were compiled by SCDHEC to determine general climatic information for the Catawba River area. The highest seasonal rainfall during this period occurred in the summer (13.14 inches); rainfall in the fall, winter, and spring was 9.26, 11.19, and 11.86 inches, respectively (SCDHEC 2003).

**Land Use.** Table 1-2 summarizes general land use categories and the associated percentages for the contributing watersheds upstream of each WQM station. There are 15,221 acres in Sixmile Creek watershed, 78,097 acres in Twelvemile Creek watershed, and 30,678 acres in Waxhaw Creek watershed. The land use/land cover data were derived from 1996 U.S. Geological Survey (USGS) Multi-Resolution Land Characteristic land use data. Figure 1-2 depicts the land use categories occurring within the Sixmile Creek, Twelvemile Creek, and Waxhaw Creek watersheds. The watersheds are predominately (approximately 70 percent) forested area with some pastures and row crops (approximately 25 percent combined). Residential and commercial/industrial land use only accounted for 6.36 acres, 3.56 acres, and 1.16 acres in the Sixmile Creek, Twelvemile Creek, and Waxhaw Creek watersheds, respectively.

**Table 1-2 Land Use Summary for the Sixmile Creek, Twelvemile Creek, and Waxhaw Creek Watersheds**

| Description | Code | CW-176 | CW-083 | CW-145 |
|---|---|---|---|---|
| Open Water | 11 | 82 | 365 | 98 |
| Open Water Percent | 11 | 0.54 | 0.47 | 0.32 |
| Low Intensity Residential | 21 | 801 | 2,251 | 202 |
| Low Intensity Residential Percent | 21 | 5.26 | 2.88 | 0.66 |
| High Intensity Residential | 22 | 95 | 141 | 2 |
| High Intensity Residential Percent | 22 | 0.62 | 0.18 | 0.01 |
| High Intensity Commercial/Industrial/Transportation | 23 | 72 | 390 | 151 |
| High Intensity Commercial/Industrial/Transportation Percent | 23 | 0.48 | 0.50 | 0.49 |
| Bare Rock/Sand/Clay | 31 | 155 | 175 | 60 |
| Bare Rock/Sand/Clay Percent | 31 | 1.02 | 0.22 | 0.20 |
| Quarries/Strip Mines/Gravel Pits | 32 | 0 | 30 | 7 |
| Quarries/Strip Mines/Gravel Pits Percent | 32 | 0.00 | 0.04 | 0.02 |
| Transitional | 33 | 0 | 542 | 402 |
| Transitional Percent | 33 | 0.00 | 0.69 | 1.31 |
| Deciduous Forest | 41 | 3,518 | 30,186 | 11,969 |
| Deciduous Forest Percent | 41 | 23.12 | 38.65 | 39.02 |
| Evergreen Forest | 42 | 3,606 | 11,686 | 6,551 |
| Evergreen Forest Percent | 42 | 23.69 | 14.96 | 21.35 |
| Mixed Forest | 43 | 2,108 | 9,379 | 4,369 |
| Mixed Forest Percent | 43 | 13.85 | 12.01 | 14.24 |
| Pasture/Hay | 81 | 2,628 | 12,925 | 3,843 |
| Pasture/Hay Percent | 81 | 17.27 | 16.55 | 12.53 |
| Row Crops | 82 | 1,978 | 9,211 | 2,595 |
| Row Crops Percent | 82 | 12.99 | 11.79 | 8.46 |
| Other Grasses (Urban/recreational) | 85 | 16 | 153 | 52 |
| Other Grasses (Urban/recreational) Percent | 85 | 0.10 | 0.20 | 0.17 |
| Woody Wetlands | 91 | 152 | 636 | 374 |
| Woody Wetlands Percent | 91 | 1.00 | 0.81 | 1.22 |
| Emergent Herbaceous Wetlands | 92 | 10 | 27 | 1 |
| Emergent Herbaceous Wetlands Percent | 92 | 0.06 | 0.04 | 0.00 |
| | | | | |
| **Total Acres** | | **15,221** | **78,097** | **30,678** |

**Figure 1-2 Land Use Map: Sixmile Creek, Twelvemile Creek, and Waxhaw Creek Watersheds**



# SECTION 2
# WATER QUALITY ASSESSMENT

## 2.1 Water Quality Standards

Water quality standards for the State of South Carolina were promulgated in the South Carolina Pollution Control Act, Section 48-1-10 *et seq*. Chapter 61, R61-68 (SCDHEC 2001). All water bodies in the Catawba River Basin are designated as freshwater. Waters of this class are defined in Regulation 61-68, §610, *Water Classifications and Standards,* and designated uses are described as follows:

> *Freshwater suitable for primary and secondary contact recreation and as a source for drinking water supply, after conventional treatment, in accordance with the requirements of the Department. These waters are suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. This class is also suitable for industrial and agricultural uses.* (SCDHEC 2001)

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

> *Not to exceed a geometric mean of 200 cfu/100ml, based on five consecutive samples during any 30 day period; nor shall more than 10 percent of the total samples during any 30 day period exceed 400 cfu/100ml.* (SCDHEC 2001)

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

All three of the streams addressed in this report are interstate waters, flowing from North Carolina to South Carolina. As with all interstate waters, the CWA requires that water quality standards be met at the North Carolina/South Carolina state line. None of these three water bodies are currently on the North Carolina Department of Environment and Natural Resources' (NCDENR) 303(d) List for fecal coliform. The NC WQS for primary and secondary contact recreation in freshwater is defined in the NC Administrative Code as:

*Organisms of the coliform group: fecal coliforms shall not exceed a geometric mean of 200 cfu/100ml based upon at least five consecutive samples examined during any 30 day period, nor exceed 400cfu/100ml in more than 20 percent of the samples examined during such period; violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution; all coliform concentrations are to be analyzed using the membrane filter technique unless high* *turbidity or other adverse conditions necessitate the tube dilution method; in case of controversy over results, the most probable number 5-tube dilution technique shall be used as the reference method (NC Administrative Code 2004).*

## 2.2 Assessment of Existing Water Quality Data

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

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

| WQM Station | Total Number of Samples | Maximum Concentration cfu/100 ml | Total Number of Samples > 400 cfu/100 ml | Percentage of Samples > 400 cfu/100 ml |
|---|---|---|---|---|
| CW-176 | 48 | 5,600 | 17 | 35% |
| CW-083 | 44 | 20,000 | 11 | 25% |
| CW-145 | 32 | 18,000 | 16 | 50% |

Fecal coliform data for WQM station CW-083 (Twelvemile Creek) represent only spring, summer, and fall months, while CW-176 (Sixmile Creek) was sampled each year on a monthly basis. CW-145 (Waxhaw Creek) was sampled only in 1992, 1993, 1998, 2001, and 2002, with monthly samples being collected in 2001 and 2002. Because land practices and bacteria load delivery mechanisms are considered relatively consistent over the course of a year, it was assumed for CW-145 that winter loading would be consistent with that of periods for which data existed (SCDHEC 2003a). Thirty-five and 25 percent of the samples collected from 1998 through 2002 at Sixmile Creek and Twelvemile Creek, respectively, exceeded the numeric criterion. Waxhaw Creek at station CW-145 indicated frequent high fecal coliform concentrations with 50 percent of the samples exceeding the WQS.

The NCDENR collected fecal coliform data between September 1997 and August 2002 from only one of the three water bodies; WQM station C9819500 (A-35) located at NC 16 on Twelvemile Creek near Waxhaw (NCDENR 2003). Twelvemile Creek is a Class C water body and is assigned a secondary contact recreation use. Of the 57 ambient fecal coliform samples collected at this WQM station, 31.6 percent of them exceeded the NCDENR WQS of 400 cfu/100 ml (NCDENR 2003). However, Twelvemile Creek is not on the NCDENR 303(d) list as impaired in 2002 or the on the Draft 2004 303(d) list at this time since additional targeted monitoring of five times in 30 days has not been completed to verify the secondary contact recreation use impairment (NCDENR 2003a). However, these measured exceedances of the NC numeric criterion in Twelvemile Creek indicate that excessive fecal coliform loading is occurring in the Twelvemile Creek watershed. While fecal coliform data is not available for the NC portions of Sixmile Creek and Waxhaw Creek given their similar watershed characteristics it is possible that these water bodies could also be experiencing similar exceedances of the fecal coliform WQS. Potential sources of fecal coliform from both NC and SC are discussed in Section 3 of this report.

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

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

**WQM Station CW-176 (Sixmile Creek).** For the period examined comparing ambient fecal coliform data and NOAA precipitation data (77 data points) there were only 2 days in which the 3-day average rainfall exceeded 0.3 inches, and on those dates a single fecal coliform measurement exceeded the WQS. The maximum fecal coliform value of 20,000 cfu/100 ml occurred on August 20, 2002. No measurable rainfall occurred on this date.

**WQM Station CW-083 (Twelvemile Creek).** For the period examined (57 data points) the 3-day average rainfall on October 16, 2002 resulted in the highest fecal coliform concentration recorded which was 20,000 cfu/100 ml. There were 15 other exceedances that occurred between 1994 and 2002 however these all occurred when there was no measurable rainfall recorded. This suggests there is little relationship between wet weather conditions and higher fecal coliform concentrations, although to fully determine this relationship a continuous time series of precipitation would need to be evaluated.

**WQM Station CW-145 (Waxhaw Creek).** For the period examined (26 data points) there were only 2 days in which the 3-day average rainfall exceeded 0.3 inches resulting in one fecal coliform measurement exceeding the WQS. Ten other exceedances of the WQS occurred on dates when no measurable rainfall was recorded. The maximum fecal coliform density measured was 18,000 cfu/100 ml on November 6, 2001.

Based on an examination of the data shown in the plots in Appendix B it is difficult to demonstrate a correlation between rainfall and fecal coliform concentrations. Several general conclusions could be derived from this data analysis:

- Nearly all of the ambient fecal coliform samples were collected under dry conditions and the majority of fecal coliform samples exceeding the WQS occurred under dry weather conditions;
- In a few instances it appears that fecal coliform exceedances of the WQS are associated with peak runoff events.
- It is difficult to discern a direct correlation between rainfall and fecal coliform concentrations at each WQM station without more localized precipitation data recorded from within each watershed.

**Relationship between fecal coliform exceedances at WQM Station CW-176 (Sixmile Creek) and WQM Station CW-083 (Twelvemile Creek).** An additional method was used to discern if there may be a relationship between fecal coliform concentrations at CW-176 and CW-083 which is downstream. Figure 2-1 is a plot showing the fecal coliform data from both the Sixmile Creek and Twelvemile Creek based on data collected between 1990 and 2002. This plot is designed to show any potential relationship between exceedances occurring at the upstream tributary WQM station (Sixmile Creek) and the downstream receiving water (Twelvemile Creek). This is an important part of the source assessment because it helps to explain contributions of fecal coliform from upstream sources. Based on this plot, thirteen of the nineteen exceedances observed between 1990 and 2002 at Twelvemile Creek may be associated with high fecal coliform concentrations measured from the upstream location on Sixmile Creek. There are several key exceptions to this trend. There are approximately six occasions between 1990 and 2002 where elevated fecal coliform loadings occurred at CW-176 (Sixmile Creek) but were not observed at the downstream (Twelvemile Creek) WQM station. There is no clear explanation for this phenomenon. In summary, it appears that the upstream monitoring location has more effect on the downstream fecal coliform density than does precipitation.

More specifically regarding precipitation, these data indicate that fecal coliform WQS exceedances do not correlate with days during which measurable precipitation occurred. This lack of such a relationship suggests that fecal coliform exceedances may be associated with point or nonpoint sources that are not significantly affected by rainfall, although to fully determine this relationship a continuous time series of precipitation would need to be evaluated. Section 3.3 provides a more detailed discussion of fecal coliform sources by watershed and the effect dry and wet weather conditions may have on fecal coliform loading.

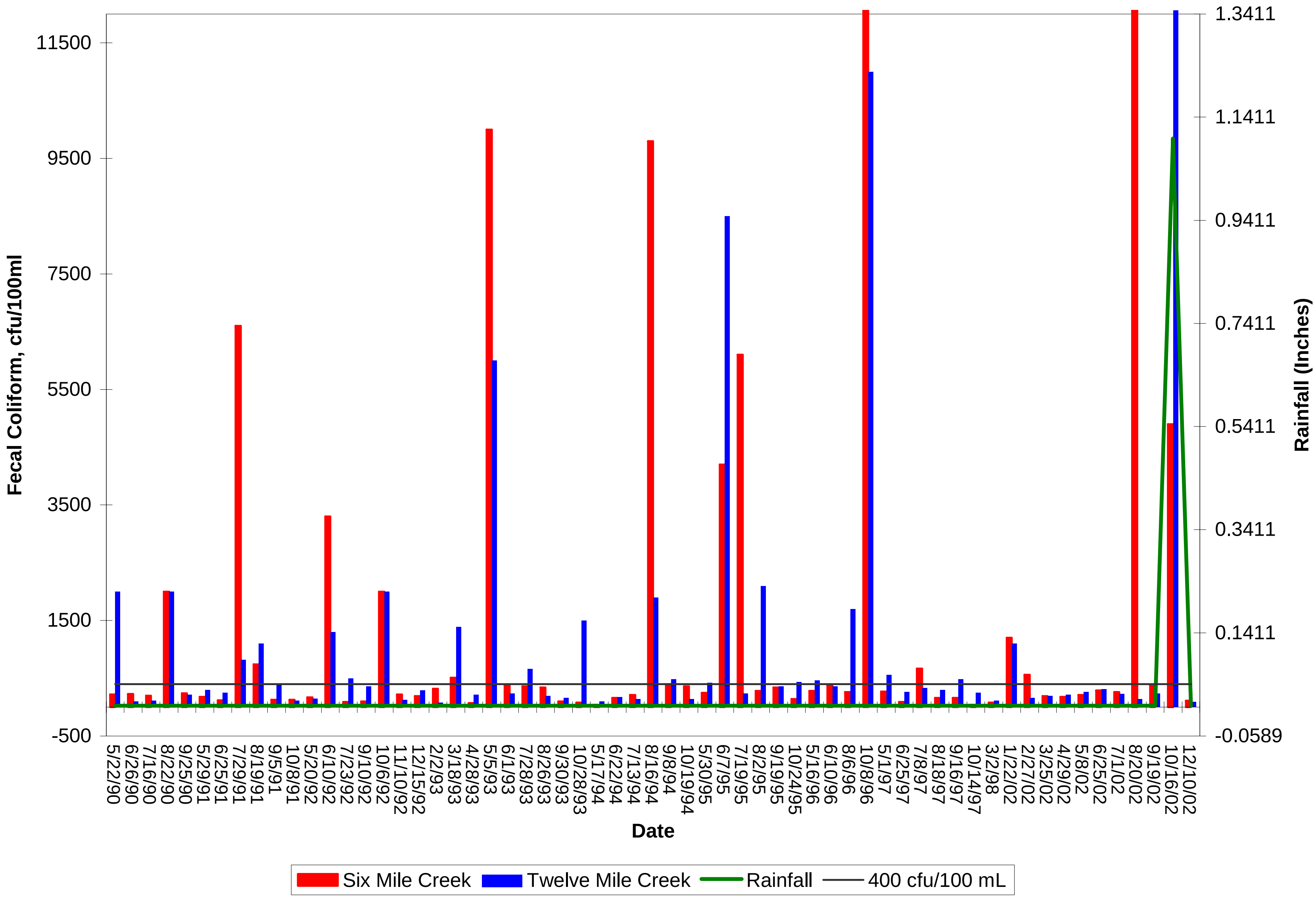
## 2.3 Establishing the Water Quality Target

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

> The water quality target is 380 cfu/100ml for the instantaneous criterion, which is 5 percent lower than the water quality criteria of 400 cfu/100 ml. A 5 percent explicit MOS was reserved from the water quality criteria in developing the load duration 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 (SCDHEC 2003a).

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

**Figure 2-1 Comparison of Fecal Coliform Concentrations at CW-176 and CW-083**



# SECTION 3
# POLLUTANT SOURCE ASSESSMENT

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

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

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

## 3.1 Point Source Discharges

There are two types of point sources discharging fecal coliform bacteria into the streams addressed in this report; they are continuous point sources and Municipal Separate Storm Sewer Systems (MS4). Continuous point source discharges such as wastewater treatment plants (WWTP), could result in discharge of elevated concentrations of fecal coliform bacteria if the disinfection unit is not properly maintained, is of poor design, or if flow rates are above the disinfection capacity. Stormwater runoff from MS4 areas, which is now regulated under the USEPA NPDES Stormwater Program, can also contain high fecal coliform bacteria concentrations and is discussed in Subsection 3.1.2. The following is a brief discussion of point source discharges in the Sixmile Creek, Twelvemile Creek, and Waxhaw Creek watersheds.

### 3.1.1 Continuous Point Sources

Table 3-1 lists two active NPDES point sources continuously discharging upstream of two of the three WQM stations. The active NPDES facilities, Health South WWTP (SC0041807) located in SC upstream of CW-145 and the Union County Twelvemile Creek WWTP (NC0085359) located in NC upstream of CW-083, are shown in Figure 3-1. Inactive permits or industrial dischargers are not included in this table.

Discharge Monitoring Reports (DMR) and design flow of the discharges were used to determine the number of fecal coliform analyses performed for NPDES Permit NC0085359 (1998 through 2004) and NPDES Permit SC0041807 (1998 through 2003), the maximum concentration during this period, the number of violations occurring when the monthly geometric mean concentration exceeded 200 cfu/100 ml, and the number of violations when a daily concentration exceeded 400 cfu/100 ml. DMR data for the Union County Twelvemile Creek WWTP in NC was obtained from the USEPA Permit Compliance System database. SCDHEC provided the DMR data for the Health South WWTP. No fecal coliform violations occurred at the Health South WWTP (SC0041807) and therefore this WWTP is not considered a source of fecal coliform loading in the Waxhaw Creek watershed.

Union County Twelvemile Creek WWTP (NC0085359), which discharges into Twelvemile Creek (CW-083), had no monthly geometric mean fecal coliform violations above the 200 cfu/100 ml reporting limit but had 20 values (24 percent) above the 400 cfu/100 ml daily maximum limit between January 1998 and December 2004. The exceedances of the daily maximum limit were significant from time to time ranging from 420 cfu/100 ml to 4000 cfu/100 ml. While these permit violations did not coincide with WQS exceedances at WQM station CW-083, the Union County Twelvemile Creek WWTP (NC0085359) may have contributed to the excessive fecal coliform loads that influenced 303(d) listing. . The DMR data for each WWTP are provided in Appendix C.

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

### 3.1.2 Municipal Separate Storm Sewer Systems

**Phase I MS4 - Charlotte**

In 1990 the USEPA developed rules establishing Phase I of the NPDES Stormwater Program, designed to prevent harmful pollutants from being washed by stormwater runoff into MS4s (or from being dumped directly into the MS4) and then discharged into local water bodies (SCDHEC 2002). Phase I of the program required operators of medium and large MS4s (those generally serving populations of 100,000 or greater) to implement a stormwater management program as a means to control polluted discharges. Approved stormwater management programs for medium and large MS4s are required to address a variety of water quality-related issues, including roadway runoff management, municipal-owned operations, and hazardous waste treatment. Charlotte, NC has a Phase I MS4 permit and portions of the Sixmile Creek (CW-176) watershed are covered under this permit. Each designated local government is required to develop and implement a stormwater management program that includes public education, illicit discharge detection and elimination, storm sewer system and land use mapping, and analytical monitoring (NCDENR 2005).

Charlotte's stormwater management program has evolved since 1990 and is now a collaborative program between the City and Mecklenburg County. The program has a stormwater utility fee that provides resources allowing the program to adjust and deal with the continual growth facing the Charlotte metropolitan area. Both the City of Charlotte (Phase I MS4) and Mecklenburg County (Phase II MS4) have comprehensive information on the stormwater management program on their websites which can be found at:

**City of Charlotte**

http://www.charmeck.org/Departments/Stormwater+-+City/home.htm

**Mecklenburg County**

http://www.charmeck.org/Departments/LUESA/Water+and+Land+Resources/Programs/Water+Quality/Phase+II+Storm+Water.htm

**Figure 3-1 Locations of NPDES Dischargers in Twelvemile Creek and Waxhaw Creek Watersheds**

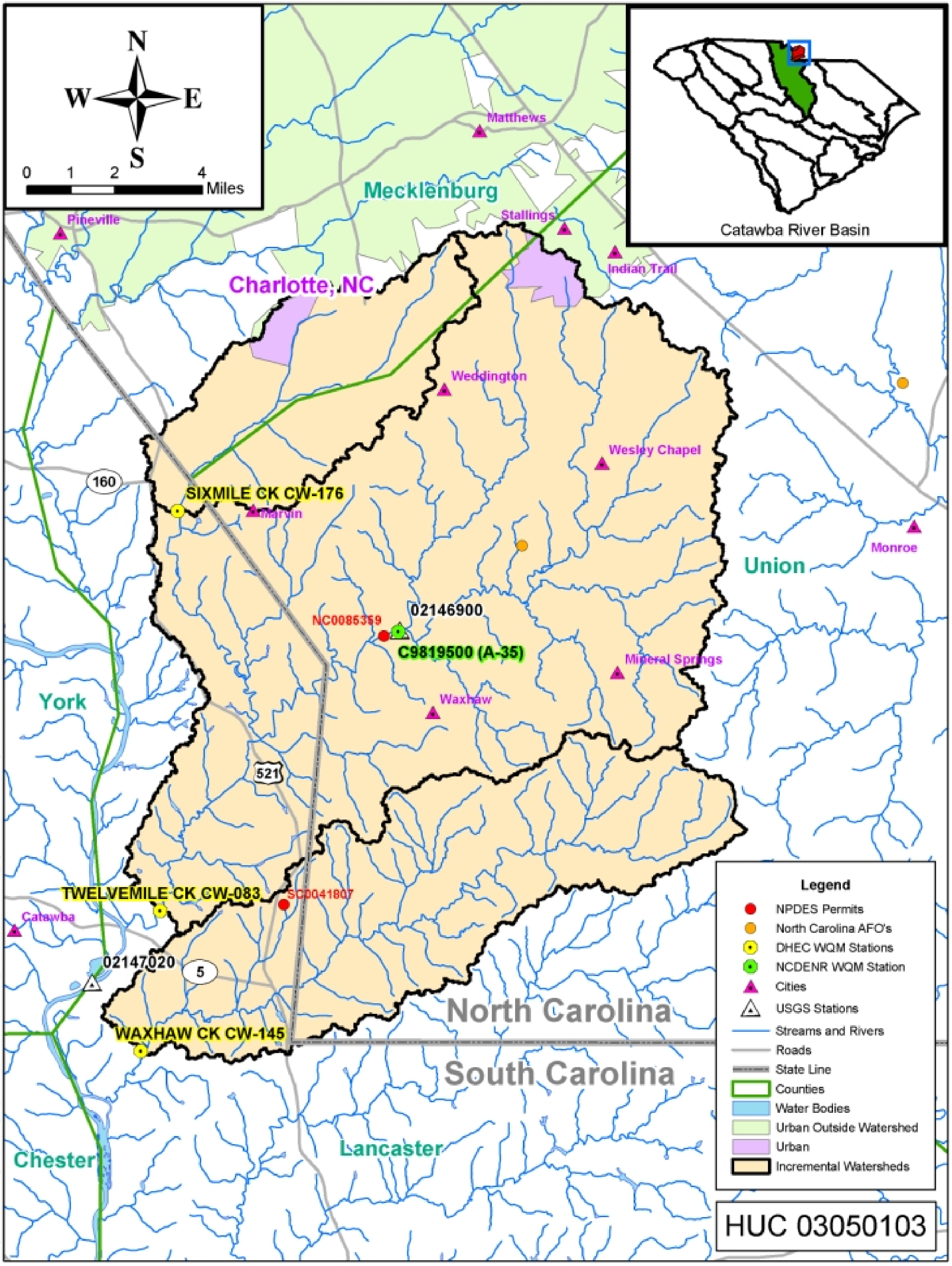


**Table 3-1 Permitted Facilities Discharging Fecal Coliform Bacteria**

| Water Quality Monitoring Station / Permittee | NPDES Permit Number | Receiving Water | Flow (mgd) | Number of Discharge Monitoring Reports* | Maximum Concentration cfu/100 ml | Monthly Average >200 cfu/100 ml | Maximum Daily Concentration >400 cfu/100 ml | Percent of Samples Exceeding Permit Limits |
|---|---|---|---|---|---|---|---|---|
| HUC 3050103030 | | | | | | | | |
| **CW-176 Sixmile Creek at S-29-54** | | | | | | | | |
| No Active NPDES Dischargers with Fecal Coliform Limits | | | | | | | | |
| **CW-083Twelvemile Creek at S-29-55 0.3 mi NW of Van Wyck** | | | | | | | | |
| Union Co Twelve Mile Crk WWTP (North Carolina) | NC0085359 | Twelvemile Creek | 2.5 | 85 | 4,000 | 0 | 20 | 24% |
| **CW-145 Waxhaw Creek at S-29-29** | | | | | | | | |
| Health South | SC0041807 | Causar Creek | 0.008 | 72 | 195 | 0 | 0 | 0% |

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

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

| Water Quality Monitoring Station / Permittee | NPDES Permit Number | Receiving Water | 90th percentile load (cfu/day) |
|---|---|---|---|
| HUC 03050103030 | | | |
| **CW-176 Sixmile Creek at S-29-54** | | | |
| No Active NPDES Dischargers with Fecal Coliform Limits | | | |
| **CW-083Twelvemile Creek at S-29-55 0.3 mi NW of Van Wyck** | | | |
| Union Co Twelve Mile Crk WWTP (North Carolina) | NC0085359 | Twelvemile Creek | 8.45E+08 |
| **CW-145 Waxhaw Creek at S-29-29** | | | |
| Health South | SC0041807 | Causar Creek | 4.74E+06 |

### Phase II MS4

Phase II of the rule extends coverage of the NPDES stormwater program to certain small MS4s. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Stormwater Program. Phase II requires operators of regulated small MS4s to obtain NPDES permits and develop a stormwater management program. Programs are designed to reduce discharges of pollutants to the "maximum extent practicable," protect water quality, and satisfy appropriate water quality requirements of the CWA. Small MS4 stormwater programs must address the following minimum control measures:

- Public Education and Outreach;
- Public Participation/Involvement;
- Illicit Discharge Detection and Elimination;
- Construction Site Runoff Control;
- Post- Construction Runoff Control; and
- Pollution Prevention/Good Housekeeping.

The following municipalities were designated by USEPA for inclusion in the Phase II stormwater program Mecklenburg County, Marvin (CW-176), Weddington, Indian Trail, Stallings, and Wesley Chapel (CW-083). The municipalities were designated because their municipal boundaries intersected a US Census-defined Urbanized Area. The NCDENR Division of Water Quality was required to prepare draft permits for municipalities designated by the 1990 Census by November 1, 2004. Draft permits for the Stallings, Indian Trails, and Mecklenburg County are available on the NCDENR website (NCDENR 2005c). There are no Phase II MS4s in the Waxhaw Creek (CW-145) watershed.

A study under USEPA's National Urban Runoff Project indicated that average fecal coliform concentration from 14 watersheds in different areas within the United States was approximately 15,000 cfu/100 ml in stormwater runoff (USEPA 1983). Runoff from urban areas not permitted under the MS4 program can be a significant source of fecal coliform bacteria. Water quality data collected from streams draining many of the nonpermitted communities show existing loads of fecal coliform bacteria at levels greater than the State's instantaneous standards. BMPs such as buffer strips and proper disposal of domestic animal waste reduce fecal coliform bacteria loading to water bodies. The NCDENR Mooresville regional office indicated that Sixmile Creek and the headwaters of Twelvemile Creek (West Fork Twelvemile Creek, Price Mill Creek, and East Fork Twelvemile Creek) are all experiencing significant construction and conversion of farm land to residential and commercial development. Consequently stormwater runoff may be a significant pathway for fecal coliform loading in these watersheds.

Sanitary sewer overflows (SSO), typically associated with urban growth areas, are also a potential source of fecal coliform loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of the pipes by grease and tree roots. A summary of the SSOs and the potential for fecal coliform bacteria from urbanized areas is provided below.

The Union County's Department of Public Works has reported SSOs which are summarized in their annual Wastewater System Performance Summary reports. Twelve different spills were reported and summarized throughout Union County, however only one of those was released into a tributary of Twelvemile Creek. This release of approximately 400,000 gallons to Davis Mine Creek occurred on October 29, 2001 (Union County 2002). In the 2004 Union County Wastewater System Performance Summary report 42 spills were recorded throughout the Union County wastewater collection system (Union County 2004). Two small releases to Twelvemile Creek occurred on May 14 and 25, 2004 and were not considered significant sources of fecal coliform loading.

The Union County Public Works Water and Sewer Department was contacted to ascertain whether leaking sewer lines are a potential source of fecal coliform in any of the three watersheds. The department indicated there is a small wastewater collection system for the community of Jaars in the Waxhaw Creek watershed. The collection system is pumped from Jaars to Waxhaw to the Union County Twelvemile Creek WWTP through two different Union County pump stations. Union County Public Works Water and Sewer Department was not aware of leaking sewer lines associated with this collection system but stated it is possible these older sewer lines could be a source of fecal coliform from time to time. In Twelvemile Creek watershed, the town of Mineral Springs relies exclusively on onsite wastewater disposal systems (OSWD). The Town of Waxhaw has a small sewer collection system operated by Union County, with most of the wastewater treatment needs being handled by individual OSWD systems. The sewer lines in the Town of Waxhaw are the oldest of the communities in the Twelvemile Creek watershed and have experienced inflow and infiltration problems in the past. Union County has an ongoing project underway to up grade this sewer collection system. The sewer line systems of the growing communities of Marvin, Weddington and Wesley Chapel are less than 15 years old. With the rapid growth occurring in these municipalities the sewer collection system may be experiencing inflow and capacity problems which could contribute fecal coliform loading. However, Union County did not have specific data or evidence of that leaking sewer lines are a consistent problem with these community systems. Other potential sources of fecal coliform may be associated with leaking sewer lines associated with the portions of the growing municipalities of Stallings and Indian Trail Creek that fall within the Twelvemile Creek watershed (Union County Public Works Department 2005a).

## 3.2 Nonpoint Sources

Nonpoint sources include those sources that cannot be identified as entering the water body at a specific location. Because fecal coliform is associated with warm-blooded animals, nonpoint sources of fecal coliform may originate from both rural and urbanized areas. The following discussion highlights some of the major nonpoint sources of fecal coliform identified in the watersheds. These sources include wildlife, agricultural activities, domesticated animals, onsite wastewater disposal systems (OSWD), and domestic pets. It should be noted that a large percentage of the watershed for each WQM station is within NC. While WQS are expected to be met at the NC/SC state line, this pollutant source assessment evaluated nonpoint sources in NC since fecal coliform loadings from NC maybe affecting water quality at each WQM station.

### 3.2.1 Wildlife

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

Deer population density in the Sixmile, Twelvemile Creek, and Waxhaw Creek watersheds on the SC side of the border exceeds 45 deer per square mile. On the NC side of the border, deer population density in the Sixmile Creek watershed ranges from 15 to 45 deer per square mile and from 30 to 45 deer per square mile in the Twelvemile Creek watershed, with less than 15 deer per square mile from the center to the northern part of the watershed. The NC portion of the Waxhaw Creek watershed has the highest density of deer population, with most areas being greater than 45 deer per square mile, and other areas ranging from 30 to 45 deer per square mile.

According to a study conducted by Yagow (1999), fecal coliform production rate for deer is $347 \times 10^6$ cfu/head-day. Although only a portion of the fecal coliform produced by deer may enter into a water body, the large population of deer in the watersheds may be a significant source of fecal coliform loading.

There are currently no available data for other wildlife and avain species known to inhabit these watersheds which could potentially contribute to the fecal coliform load. However given the representative statistics for deer population and the large amount of rural area (forest, cropland, and pasture) in the three watersheds, other wildlife are considered to be a contributing source of fecal coliform loading.

### 3.2.2 Agricultural Activities and Domesticated Animals

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

- cattle release approximately 100 billion fecal coliform per animal per day;
- horses - 400 million per animal per day;
- pigs - 11 billion per animal per day;
- chickens – 1.4 billion per animal per day;
- turkeys - 1 billion per animal per day; and
- sheep - 12 billion per animal per day.

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

Stormwater leaving a concentrated animal feeding operation (CAFO) is regulated under the NPDES program; however, there are currently no NPDES-permitted CAFOs in SC. The SCDHEC currently maintains a list of statewide animal feeding operations (AFO) categorized by the type of facility (cattle, swine, poultry) and size which is defined by the specific number of animal units (large, medium, small). Using the SCDHEC spatial data no AFOs are located in the SC portion of Sixmile Creek, Twelvemile Creek, or Waxhaw Creek watersheds. Based on spatial data provided by NCDENR, there is one cattle AFO permitted at 130 animal units, located in the Twelvemile Creek watershed upstream of the USGS gage station 02146900 (see Figure 3-1). However, small farms with livestock do exist in all three watersheds. The following describes the estimated fecal coliform production from various livestock.

**Cattle:** Between 1997 and 2002 the number of cattle farms in Lancaster County, SC decreased by about 20 percent from 427 to 347 based on the U.S. Department of Agriculture (USDA) census data (USDA 2002). The number of cattle in Lancaster County decreased from 13,454 to 12,520 during the same 5-year period. Between 1997 and 2002 the number of cattle farms in Union County, NC also decreased by about 20 percent from 699 to 556 based on the USDA census data (USDA 2002). The number of cattle in Union County decreased from 24,861 to 23,126 during the same 5-year period. A 1,000-pound beef or dairy cow produces approximately 11 tons and 15 tons of manure per year, respectively. Assuming the average cow weighs 750 pounds and manure production is 12 tons per animal per year, 100 cows would produce approximately 2.5 tons per day. These statistics were used to estimate manure production from cattle for each watershed presented in Table 3-3. The number of cattle within each WQM station watershed was estimated by dividing the number of cattle in each county by the total acres of pasture land in each county. This cattle density value was then multiplied by the number of acres of pasture land in each watershed.

**Table 3-3 Estimated Tons of Manure by WQM Station**

| WQM Station | Number of Cattle and Calves in Watershed* | Tons of Manure Deposited Daily in Watershed |
|---|---|---|
| CW-176 | 541 | 13 |
| CW-083 | 3499 | 86 |
| CW-145 | 1015 | 25 |

* Includes Agriculture Census data for both South and North Carolina

Both SCDHEC and NCDENR have verified that cattle from the small farms throughout all three watersheds have direct access to the creeks. For many farmers these creeks are the only water source for their cattle. With the typical low flows of Sixmile Creek and Waxhaw Creek (43.8 cfs and 48.8 cfs, respectively), fecal waste from a few cattle discharged into those creeks could potentially result in exceedance of the WQSs. While Twelvemile Creek has more assimilative capacity with an estimated median flow of 270 cfs, the larger cattle population in the Twelvemile Creek watershed still presents a significant source of fecal coliform loading. Fecal coliform loading from cattle manure, whether deposited directly into the creeks or transported from land by rainfall runoff, is likely to be significant in all three watersheds.

**Swine:** According to the USDA census data, there were 40,696, hogs and pigs in Union County, NC. Lancaster County, SC and Mecklenburg County, NC have insignificant numbers of swine at 106 and 37, respectively (USDA 1997; USDA 2002). 1997 census data were used when 2002 data were not available. While there are no swine AFOs located in any of the three watersheds, it is assumed there are some small farms with swine located in Twelvemile Creek and Waxhaw Creek watersheds. However, it is difficult to discern the magnitude of fecal coliform loading within a given watershed since swine are not evenly distributed throughout Union County. Furthermore, the Twelvemile Creek watershed covers 14.5 percent, Waxhaw Creek watershed covers only 5.5 percent and Sixmile Creek watershed is less than 1 percent of the total acreage in Union County. Unlike cattle, swine do not have direct access to creeks. The combination of these factors suggests that fecal coliform loading from swine is negligible in the Twelvemile Creek and Waxhaw Creek watersheds.

**Sheep:** In 2002, there were 154, 399, and 54 sheep in Mecklenburg, Union, and Lancaster Counties, respectively (USDA 2002). Given these small numbers, the contribution of fecal coliform loading from sheep within the three watersheds is negligible.

**Poultry:** The 2002 Census data estimated approximately 1,303,000 chickens in Union County (USDA 2002). Lancaster County, SC and Mecklenburg County, NC have small numbers of poultry at 357 and 783 chickens, respectively (USDA 1997; USDA 2002). The ASAE manure production rate estimate for chickens was 11.4 billion fecal coliform per chicken per day (ASAE 1998). Since poultry are not evenly distributed throughout Union County and given that Twelvemile Creek watershed covers 14.5 percent, Waxhaw Creek watershed covers only 5.5 percent and Sixmile Creek watershed is less than 1 percent of the total acres in Union County, it is difficult to discern the magnitude of fecal coliform loading within a given watershed. Based on SCDHEC spatial data and direct communication with NCDENR (NCDENR 2005a), there are no poultry facilities in these three watersheds.

There are eleven fields that are permitted for animal waste application from turkey facilities within the SC portion of the three watersheds. All of these land application fields may not actually be in use; SCDHEC 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 within the SC portion of the three watersheds. It is important to note that insufficient data are available to adequately estimate fecal coliform concentrations in stormwater runoff from land application fields where manure is applied. These operations are permitted; therefore problems are managed through SCDHEC enforcement mechanisms. Information on the number of land application fields or acreage was not available from NCDENR.

The combination of these factors indicate that poultry operations in Union County, NC are a minor potential source of fecal coliform loading in Sixmile, Creek, Twelvemile Creek and Waxhaw Creek watersheds.

### 3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

According to the 1990 U.S. census, there were 757 onsite wastewater disposal (OSWD) systems in the Sixmile Creek watershed, 5,659 in the Twelvemile Creek watershed and 1,026 in the Waxhaw Creek watershed. The density of OSWD systems within each watershed was estimated by dividing the number of OSWD systems in each census tract by the number of acres in each census tract. This density was then applied to the number of acres of each census tract within a WQM station watershed. Census tracts crossing a watershed boundary required an additional calculation to estimate the number of OSWD systems based on the proportion of the census tracking falling within each watershed. This step involved adding all the OSWD systems for each whole or partial census tract. Since subdivisions are built on large land tracts (hundreds of acres) the number of OSWD systems per 100 acres is easier to visualize; therefore, the following equation was used to estimate the number of OSWD systems as presented in Table 3-4:

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

**Table 3-4 OSWD Systems Summary**

| WQM Station | Estimated Number of OSWD Systems in WQM Station Watershed | Average Number of OSWD Systems per 100-Acres in WQM Station Watershed |
|---|---|---|
| CW-176 | 757 | 5 |
| CW-083 | 5659 | 7 |
| CW-145 | 1026 | 3 |

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

The Department Of Health and Environmental Control, Regulations 61-56 of the State of South Carolina Code of Regulations do not require a minimum lot size, but requires minimum setbacks, such as property lines, that dictate the required size of each individual lot. The minimum setback distance to a surface water body is 50 linear feet. There is no single family residence requirement to reserve a backup area should the original OSWD system fail. According to the National Small Flows Clearinghouse (NSFC), SC does not require an inspection of the OSWD systems prior to the sale of a property (NSFC 1996). NCDENR has an OSWD system inspection program that requires replacement of failed systems (NCDENR 2005a). According to the NCDENR On-site Activity Report for FY03-04, 723 OSWD systems failed in Union County (NCDENR 2005b). These failed systems have been or will be replaced in the near future.

Failing OSWD systems can contribute to fecal coliform WQS exceedances. OSWD systems are considered to be a source of fecal coliform loading in Sixmile Creek and Twelvemile Creek watersheds given their estimated density. In the Waxhaw Creek watershed, failing OSWD systems are considered a minor contributor of fecal coliform loading.

### 3.2.4 Domestic Pets

Pets can be a major contributor of fecal coliform to streams. A study conducted by Weiskel *et al.* (1996) found that pets produce 450 million fecal coliform per animal per day. On average nationally, there are 0.58 dogs and 0.66 cats per household (American Veterinary Medical Association 2004). Using the U.S. census data (U.S. Census Bureau 2000), dog and cat populations can be estimated for the counties as shown in Table 3-5.

A study in a Washington, D.C. suburb found that dogs produce approximately 0.42 pounds of fecal waste per day (Thorpe 2003). A comparable number for waste produced by cats was not available; therefore, only the estimated tons per day of dog waste produced is provided in Table 3-5. Fecal coliform from dogs and cats transported by runoff from urban and suburban areas can be a potential source of loading. These calculations were provided for informational purposes to demonstrate that pet populations are higher in urbanized areas and that they can be a significant source of fecal coliform.

It is difficult to derive the density of dogs and cats from the estimated county totals in Table 3-5 given that Sixmile Creek watershed is only a small percentage of land area in Mecklenburg, and Union Counties. However, the rapid increase in the number of households in the Sixmile Creek watershed over the past 5 years suggests that pets are a source of fecal coliform loading. Likewise, it is difficult to derive the density of dogs and cats from the estimated county totals in Table 3-5 given that Twelvemile Creek and Waxhaw Creek watersheds combine to make up less than 20 percent of Lancaster County and Union County. Based on the small number of households in these two watersheds, it is assumed that fecal coliform contributions from pets are negligible.

**Table 3-5 Estimated Numbers of Household Pets**

| County | Number of Households | Number of Dogs | Number of Cats | Tons of Dog Waste per Day |
|---|---|---|---|---|
| **South Carolina Counties** | | | | |
| Lancaster | 23,178 | 13,443 | 15,297 | 2.8 |
| **North Carolina Counties** | | | | |
| Mecklenburg | 273,416 | 158,581 | 180,455 | 33.3 |
| Union | 43,390 | 25,166 | 28,637 | 5.3 |

## 3.3 Summary of Fecal Coliform Sources

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

- Watershed land use and land cover;
- Watershed soil characteristics;
- Fecal coliform production rate;
- Agricultural census data, including livestock populations;

- Households served by OSWD systems and OSWD system failure rates;
- AFOs;
- Domestic pet census data; and
- NPDES permitted point sources and discharge monitoring reports.

Based on the foregoing information and data presented and analyzed in this report, the following inferences can be made regarding the sources and magnitude of fecal coliform contributions to the 303(d)-listed WQM stations in Sixmile Creek, Twelvemile Creek, and Waxhaw Creek watersheds. To adequately summarize the pollutant source assessment for the three 303(d)-listed WQM stations in SC (CW-176, CW-083, CW-145) pollutant sources from both the SC and NC portions of the watersheds must be considered. The dominant land use in all three watersheds is forest, with the second and third most prevalent land use being pasture and row crops. Given the large percentage of each watershed located in NC, some percentage of fecal coliform loading at each of the three SC WQM stations originates in NC. This is substantiated by the fact that 31.6 percent of the 57 ambient fecal coliform samples collected between 1997 and 2002 by NCDENR at the WQM station C9819500 on Twelvemile Creek exceeded the NC WQS of 400 cfu/100 ml (NCDENR 2003). While fecal coliform data is not available for the NC portions of Sixmile Creek and Waxhaw Creek, given their similar watershed characteristics it is possible that these water bodies could also be experiencing similar exceedances of the NC fecal coliform WQS. The predominantly rural characteristics of all three watersheds suggest that key sources of fecal coliform loading are nonpoint sources. There are continuous point sources of fecal coliform in two of the three watersheds; one WWTP in the Twelvemile Creek (CW-083) watershed and one WWTP in the Waxhaw Creek (CW-145) watershed.

**WQM Station CW-176, Sixmile Creek**

The watershed for WQM station CW-176 contains 15,221 acres, 845 in SC and 14,376 in NC. The estimated median flow is approximately 134 cfs. While the 1996 land use data used to support this assessment indicates that approximately 6 percent of the watershed is urban land use, the watershed has experienced considerable conversion of forest and pastureland to residential land use in the last five years. Associated with this urban land use are a variety of sources contributing fecal coliform to Sixmile Creek including urban runoff (MS4) and leaking sanitary sewers, and an increasing population of pets. A portion of the watershed is within the City of Charlotte MS4 and stormwater runoff may be a significant source of fecal coliform loading. The upper portion of Sixmile contains an MS4 area for the City of Charlotte. One water quality station (MC-51) is located on Sixmile Creek downstream of this Phase I MS4 area. An ambient water sample collected at MC-51 on 5/1/03 contained 580 cfu/100 ml. Dye tests of sewers in other Charlotte MS4 watersheds indicate sewage leaks into the storm water conveyance system. Therefore, a possible source of fecal coliform is leaking sewers. No storm water data was available for this station. Storm water quality data from other parts of the MS4 contained fecal coliform concentration typical for a city of this size (i.e., a few below 400 cfu/100 ml to as high as 90,000 cfu/100 ml) as documented by EPA's National Urban Runoff Program (NURP) study. Fecal coliform concentrations in storm water from the MS4 area within the Sixmile Creek watershed would therefore be expected to exceed 400 cfu/100 ml on occasion.

The watershed is largely forested (~61) and approximately 30 percent is pasture land and row crops combined. The estimated deer density in the SC portion of Sixmile Creek exceeds 45 deer per square mile and 15 to 45 deer per square mile in the NC portion of the watershed. There are a variety of nonpoint sources contributing fecal coliform to Sixmile Creek including wildlife and livestock (cattle). The estimated density of OSWDs in this watershed is 5 per 100 acres, the majority of which are located in NC. The sources of fecal coliform in this watershed include a combination of stormwater runoff from MS4 areas, leaking sewer lines, wildlife, cattle watering in creeks, and failing OSWDs. There are no WWTPs discharging to the Sixmile Creek watershed.

**WQM CW-083, Twelvemile Creek**

The watershed for WQM station CW-083 contains 78,097 acres, 17,455 in SC and 60,642 in NC. The estimated median flow at this station is approximately 827 cfs. The urban land use (~3 percent) is minimal but expanding. Associated with this urban land use are a variety of sources contributing fecal coliform to Twelvemile Creek including urban runoff from MS4s (Marvin, Weddington, Wesley Chapel, Indian Trail, Stallings), SSOs, leaking sanitary sewers, and an increasing population of pets. All of these municipalities are experiencing significant growth and as a result nonpoint source runoff and corresponding pollutant loading is accelerating in the headwaters of Twelvemile Creek. SSOs are also a source of fecal coliform loading with spills reported in the Twelvemile Creek watershed from Stallings and Indian Trail. Both SSOs and urban stormwater runoff are also considered wet weather sources. Leaking sewer systems associated with the municipalities of Marvin, Stallings, Indian Trail, Weddington, and Wesley Chapel are also a minor source of fecal coliform loading. The municipalities of Marvin, Weddington, and Wesley Chapel have been upgrading their sewer line system and have plans for additional improvements. There is one continuous point source in the Twelvemile Creek (CW-083) watershed. Based on DMR data, the Union County Twelvemile Creek WWTP may be contributing to fecal coliform loading.

The watershed is mostly forested (~66 percent) and approximately 29 percent is pastureland and row crops combined. Fecal coliform loading is also emanating from a wide array of nonpoint sources including wildlife, livestock, land application fields, and OSWDs. The estimated deer density in the SC portion of Twelvemile Creek exceeds 45 deer per square mile and 15 to 45 deer per square mile in the NC portion of the watershed. There are a considerable number of cattle in the watershed (~3500) which can access creeks for watering. Land application fields registered in the SC portion of the watersheds may also be an intermittent source of fecal coliform loading. The relationship of fecal coliform production from various animals (domestic and wildlife) to instream loading is currently not available, and actual loading is likely less than the estimated number of fecal coliform produced by animals due to various environmental factors affecting transport and longevity of fecal organisms. There are also a large number of OSWDs within this watershed with the majority of them located in NC. The sources of fecal coliform in this watershed include a combination of stormwater runoff from MS4 areas, SSOs, leaking sewer lines, wildlife, cattle watering in creeks, land application fields, and failing OSWDs.

**WQM CW-145, Waxhaw Creek**

The watershed for WQM station CW-145 contains 30,678 acres, 7,786 in SC and 22,892 in NC. The estimated median flow at this station is approximately 353 cfs. The watershed is largely forested (~75 percent) with pastureland and row crop totaling 21 percent. The urban land use (~1 percent) is insignificant. There are no MS4s, SSOs, or known leaking sewer systems in this watershed. There is one continuous point source discharger, the HealthSouth WWTP, in the Waxhaw Creek watershed but it is considered an insignificant source of fecal coliform loading.

Fecal coliform loading is also emanating from a wide array of nonpoint sources including wildlife, livestock, land application fields, and OSWDs. The estimated deer density in the SC portion of Waxhaw Creek exceeds 45 deer per square mile. The NC portion of the Waxhaw Creek watershed has the highest density of deer population, with most areas being greater than 45 deer per square mile, and other areas ranging from 30 to 45 deer per square mile. There are an estimated 1015 cattle throughout the watershed which can access the water bodies for watering. Land application fields registered in the SC portion of the watersheds may also be an intermittent source of fecal coliform loading. The relationship of fecal coliform production from various animals (domestic and wildlife) to instream loading is currently not available, and actual loading is likely less than the estimated number of fecal coliform produced by animals due to various environmental factors affecting transport and longevity of fecal organisms.

There density of OSWDs within this watershed is relatively sparse, with the majority of them located in NC. The sources of fecal coliform in this watershed include a combination of wildlife, cattle watering in creeks, land application fields, and failing OSWDs.

# SECTION 4
# TECHNICAL APPROACH AND METHODOLOGY

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

This definition can be expressed by the following equation:

**TMDL = Σ WLA + Σ LA + MOS**

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

## 4.1 Using Load Duration Curves to Develop TMDLs

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

## 4.2 Explanation of the Steps Used to Perform TMDL Calculations

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

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

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

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

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

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

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

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

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow duration of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. However, at extreme low and high flow values, flow duration curves may exhibit a "stair step" effect due to the USGS flow data rounding conventions near the limits of quantitation. The extreme high flow conditions (<10$^{th}$ percentile) and low flow conditions (>95 percentile) are not considered in development of these TMDLs. The overall slope of the flow duration curve is an indication of the flow variability of the stream.

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

**Table 4-1 Hydrologic Condition Classes**

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

Source: Cleland 2003.

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

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

*Where:*

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

**Step 4: Estimate Current Loading and Identify Critical Conditions.** It is not possible to estimate current nonpoint loading due to lack of specific water quality and flow information that would assist in estimating the relative proportion of non-specific sources within the watershed. Therefore, existing instream loads were used as a conservative surrogate for nonpoint loading. It was calculated by multiplying the concentration by the flow matched to the specific sampling date. Then using the hydrologic flow intervals shown in Table 4-1, the $90^{th}$ percentile nonpoint loading within each of the intervals would then represent the nonpoint loading estimate for that interval. Existing loads have been estimated using a regression-based relationship developed between observed fecal coliform loads and flow or flow exceedance percentile

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

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

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

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

*Where: WQS = 400 cfu/100 ml*

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

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

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

**Step 7: Calculate WLA.** As previously stated, the pollutant allocation for point sources is defined by the WLA. A point source can be either a wastewater (continuous) or stormwater (municipal separate storm sewer system [MS4]) discharge. Stormwater point sources are typically associated with urban and industrialized areas, and recent USEPA guidance includes permitted stormwater discharges as point source discharges and, therefore, part of the WLA.

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

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

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

*Where: WQS = 400 cfu /100ml*

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

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

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

**LA = TMDL – MOS - ∑WLA**

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

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

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

# SECTION 5
# TMDL CALCULATIONS

## 5.1 Results of TMDL Calculations

The calculations and results of the TMDLs for the 303(d)-listed WQM stations in the Catawba River Basin are provided in this section. The methodology for deriving these results is specified in Section 4. All three of the 303(d)-listed WQM stations addressed in this report are interstate water bodies. The TMDLs established in Section 5.7 of this report are achievable if WQS for fecal coliform are met at the state line.

## 5.2 Critical Conditions and Estimated Loading

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

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

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

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

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

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

After existing loading and percent reductions are calculated under each hydrologic condition class, the critical condition for each TMDL is identified as the flow condition requiring the largest percent reduction. However, the "high flow" (<10th percentile flow exceedance) or "low flow" (> 90th percentile flow exceedance) hydrologic conditions will not be selected as critical conditions because these extreme flows are not representative of typical conditions, and few observations are available to reliably estimate loads under these conditions. In the example shown in Table 5-1 for WQM station CW-083, while similar load reductions are required under all hydrologic condition classes, the critical condition occurs under "Mid-Range Flows," when a 98 percent loading reduction is required to meet the WQS.

**Table 5-1 Estimated Existing Fecal Coliform Loading for Station CW-083 (Twelvemile Creek) with Critical Condition Highlighted**

| Hydrologic Condition Class* | Estimated Existing Loading (cfu/100 ml) | Percent Reduction Required |
|---|---|---|
| High Flows | 2.94E+14 | NA |
| Moist Conditions | 9.21E+13 | 82% |
| Mid-Range Conditions | 3.64E+14 | 98% |
| Dry Conditions | 1.81E+13 | 79% |
| Low Flows | 3.16E+12 | NA |

* Hydrologic Condition Classes are derived from Cleland 2003.

The LDC for WQM station CW-083 shown in Figure 5-1 indicates actual fecal coliform loads are exceeding the instantaneous load of the WQS during all flow conditions. The LDCs were developed for the time period from January 1990 through December 2002.

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

**Figure 5-1 Estimated Fecal Coliform Load and Critical Conditions, Station CW-083 (Twelvemile Creek)**

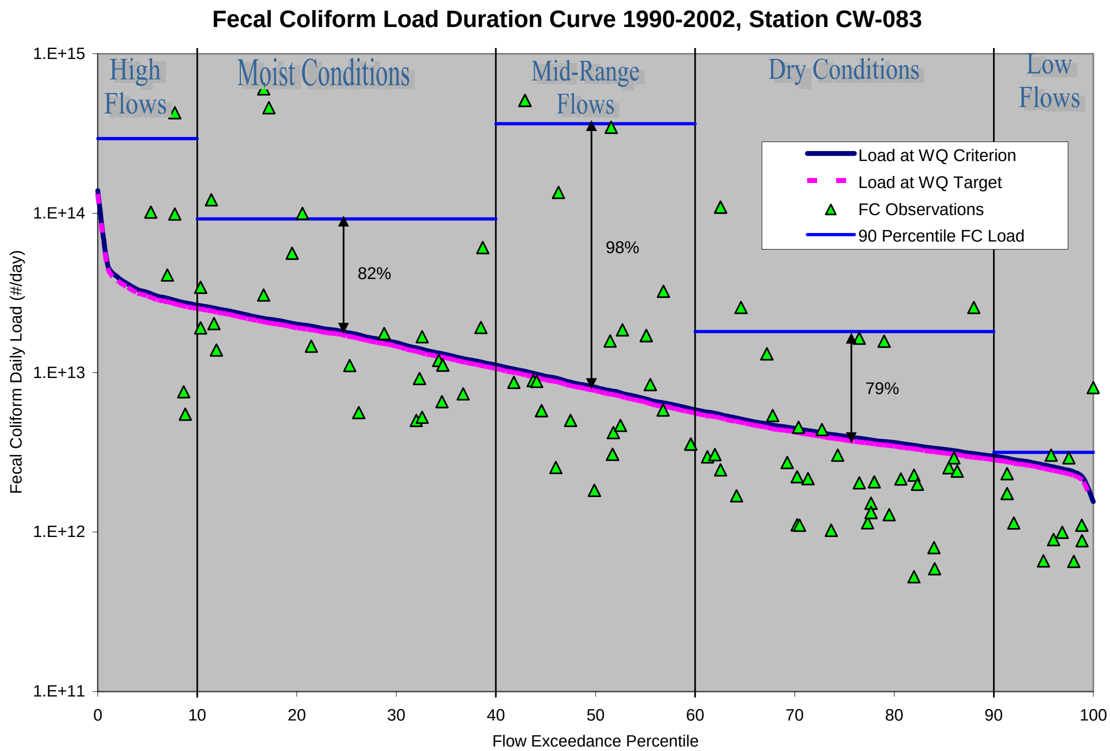



**Table 5-2 Summary of Critical Conditions for each WQM Station as Derived from Load Duration Curves**

| SCDHEC WQM Station | Moist Conditions | Mid-Range Conditions | Dry Conditions |
|---|---|---|---|
| CW-176 | | ✱ | |
| CW-083 | | ✱ | |
| CW-145 | | | ✱ |

The existing load for each WQM station was derived from the critical condition line depicted on the LDCs as described above and provided in Appendix E. Estimated existing loading is derived from the 90$^{th}$ percentile of observed fecal coliform loads corresponding to the critical condition identified at each WQM station identified in Table 5-2. This estimated loading is indicative of loading from all sources including continuous point source dischargers, MS4s, SSOs, failing septic systems, wildlife, land application fields, livestock and pets. The total estimated existing load for each station is provided in Table 5-3.

**Table 5-3 Estimated Existing Loading at Each WQM Station**

| SCDHEC WQM Station | 90th Percentile Load Estimation (cfu/day) | Flow Exceedance Percentile |
|---|---|---|
| CW-176 | 1.63E+13 | 50 |
| CW-083 | 3.46E+14 | 50 |
| CW-145 | 1.10E+13 | 75 |

## 5.3 Wasteload Allocation

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

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

*Where: WQS = 400 cfu/100ml*

*flow (mgd) = permitted flow*

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

**Table 5-4 Wasteload Allocations for NPDES-Permitted Facilities**

| Water Quality Monitoring Station / Permittee | NPDES Permit Number | Flow (mgd) | Load (cfu/day) |
|---|---|---|---|
| **HUC 03050103030** | | | |
| **CW-176 Sixmile Creek at S-29-54** | | | |
| No Active NPDES Dischargers with Fecal Coliform Limits | | | |
| **CW-145 Waxhaw Creek at S-29-29** | | | |
| Health South WWTP | SC0041807 | 0.008 | 1.21E+08 |

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding WQM station. When there are no NPDES WWTPs discharging into the contributing watershed of a WQM station, then the WLA is zero.

## 5.4 Load Allocation

As discussed in Section 3, nonpoint source fecal coliform loading to the receiving streams of each WQM station emanate from a number of different sources. As discussed in Section 4, nonpoint source loading was estimated and depicted under all flow conditions using LDCs. Figure 5-1 displays the LDC for CW-083 which displays the relationships between the TMDL water quality target, the MOS, and the WLA for continuous point source discharges. The data analysis and the LDCs demonstrate that exceedances at most of the WQM stations are the result of nonpoint source loading from sources such as failing septic systems, cattle in streams, land application fields, and fecal loading from wildlife and domestic pets transported by runoff events.

## 5.5 Seasonal Variability

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

## 5.6 Margin of Safety

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

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

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

## 5.7 TMDL Calculations

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

This definition can be expressed by the following equation:

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

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

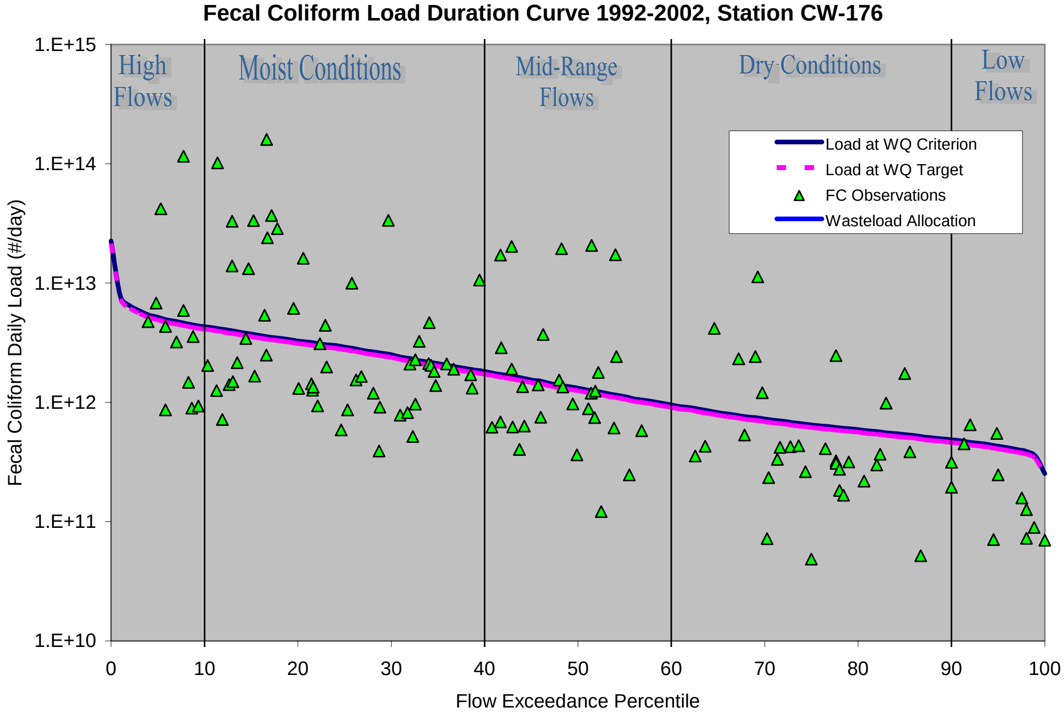
$$\textit{Average LA} = \textit{average TMDL} - \textit{MOS} - \sum \textit{WLA}$$

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

**Table 5-5 TMDL Summary for WQM Stations in Sixmile Creek, Twelvemile Creek, and Waxhaw Creek Watersheds**

| SCDHEC WQM Station | WLAs (cfu/day) | LA (cfu/day or % reduction) | MOS | TMDL (cfu/day or % reduction) | Percent reduction |
|---|---|---|---|---|---|
| **Sixmile Creek at S-29-54** | | | | | |
| CW-176 | 0 | 1.25E+12 | 6.58E+10 | 1.32E+12 | 92 |
| | | | | | |
| **Twelvemile Creek at S-29-54, 0.3 Miles Northwest of Van Wyck** | | | | | |
| CW-083 | 0 | 7.69E+12 | 4.05E+11 | 8.10E+12 | 98 |
| | | | | | |
| **Waxhaw Creek at S-29-29** | | | | | |
| CW-145 | 1.21E+08 | 1.57E+12 | 8.28E+10 | 1.66E+12 | 86 |

## Figure 5-2 TMDL for CW-176 Sixmile Creek




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

## Figure 5-3 TMDL for CW-083 Twelvemile Creek

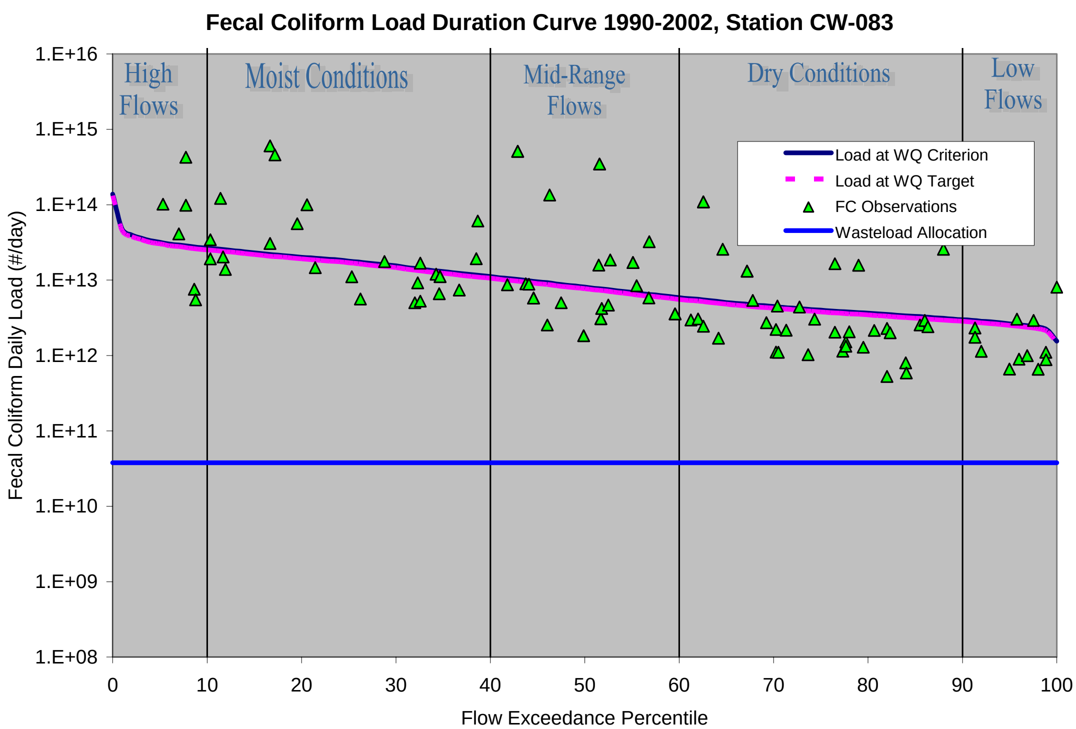
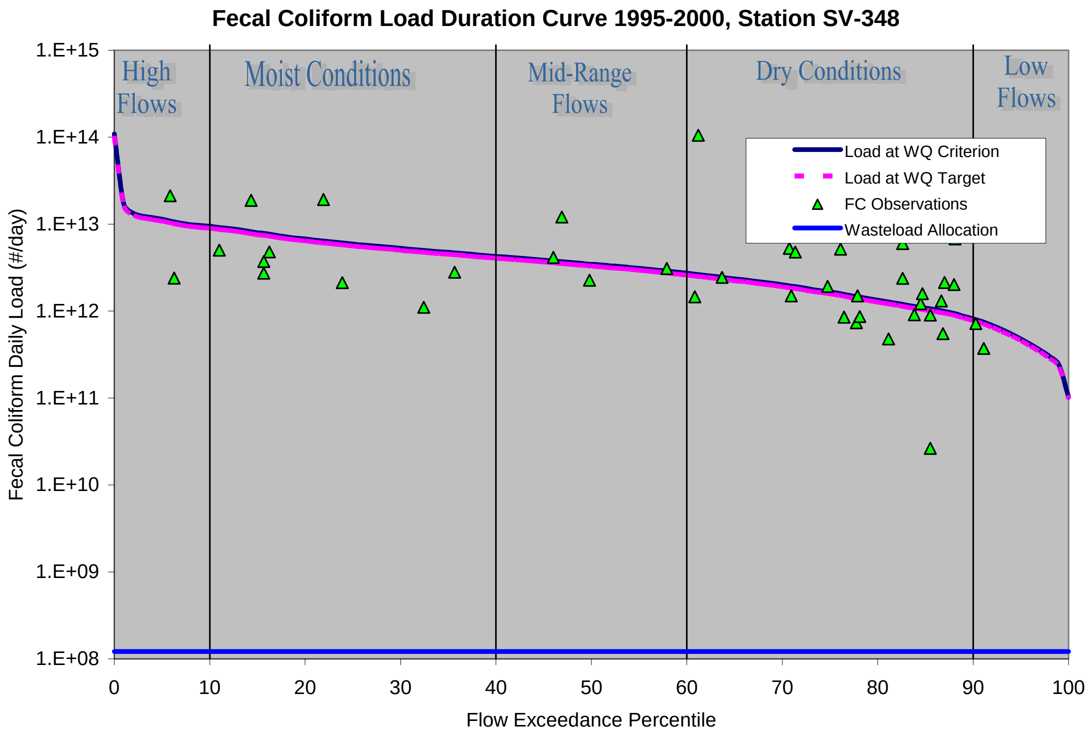


**Figure 5-4 TMDL for CW-145 Waxhaw Creek**



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

# APPENDIX B
# PLOTS COMPARING PRECIPITATION AND FECAL COLIFORM CONCENTRATIONS

# APPENDIX C
# NPDES PERMIT DISCHARGE MONITORING REPORT DATA

# APPENDIX D
# ESTIMATED FLOW EXCEEDANCE PERCENTILES

# APPENDIX E
# LOAD DURATION CURVES – ESTIMATED LOADING AND CRITICAL CONDITIONS