Total Maximum Daily Load – Steele Creek
(Hydrologic Unit Code 030501030108)
Stations CW-009, CW-011, CW-203
Fecal Coliform Bacteria

May 2007
Bureau of Water

PROMOTE PROTECT PROSPER
South Carolina Department of Health and Environmental Control

SCDHEC Technical Report Number: 010-07

Abstract

The Steele Creek watershed is a tributary of Sugar Creek located within Mecklenburg County, North Carolina and York County, South Carolina (HUC 030501030108). Water quality monitoring stations CW-009, CW-203 and CW-011 are listed on the 2004 and 2006 303(d) lists as impaired for recreational uses due to exceeding the fecal coliform standard.

The primary land use in the Steele Creek watershed is developed. Forested area also covers a large portion of the watershed. The upper portion of the watershed is generally more developed and the lower portion more forested. There are three permitted point source discharges in the South Carolina portion of the watershed. There are no permitted animal feeding operations. The main probable source of fecal coliform bacteria in the watershed is urban non-point source pollution.

The TMDL and existing load for the Steele Creek watershed was developed using the load-duration curve methodology. The TMDL for station CW-009 is $7.50*10^{10}$ cfu/day, $1.11*10^{11}$ cfu/day for CW-203 and $1.67*10^{11}$ cfu/day for station CW-011. To reach the TMDL, existing load must be reduced by 75% to 87%.

Table of Contents

Tables and Figures

1.0 INTRODUCTION

1.1 Background

A Total Maximum Daily Load (TMDL) is a written plan and analysis to determine the maximum pollutant load a waterbody can receive and still meet applicable water quality standards. The TMDL process includes estimating pollutant loadings from all sources, linking pollutant sources to their impacts on water quality, allocation of pollutant loads to each source and establishment of control mechanisms to achieve water quality standards (US EPA, 1999). TMDLs are required to be developed for each waterbody and pollutant combination on the State 303(d) list by 40 CFR 130.31(a) (US EPA, 1999).

1.2 Watershed Description

The Steele Creek watershed is located within York County in South Carolina and Mecklenburg County in North Carolina. The Steele Creek watershed is a sub-watershed of the Catawba River Basin and is represented by the 12-digit hydrologic unit code (HUC) 030501030108 (Figure 1). Steele Creek originates in North Carolina and accepts drainage from Blankmanship Branch and Jackson Branch before flowing through the Town of Fort Mill and into Sugar Creek.

There are three SC DHEC ambient water quality monitoring (WQM) stations on Steele Creek, CW-009 (Steele Ck at S-46-22 N of Fort Mill), CW-011 (Steele Ck at S-46-270) and CW-203 (Steele Ck at S-46-98). All three ambient monitoring stations are on the 2006 303(d) list as impaired for recreational uses due to exceeding the fecal coliform standard. Station CW-009 is also listed as impaired for Aquatic Life due to dissolved oxygen. There is also one macroinvertebrate monitoring site in Steele Creek, CW-681 (Steele Cr at US Bypass 21). This station is listed on the 2006 303(d) list as impaired for Aquatic Life uses due to biological criteria.

Figure 1. Location of the Steele Creek Watershed

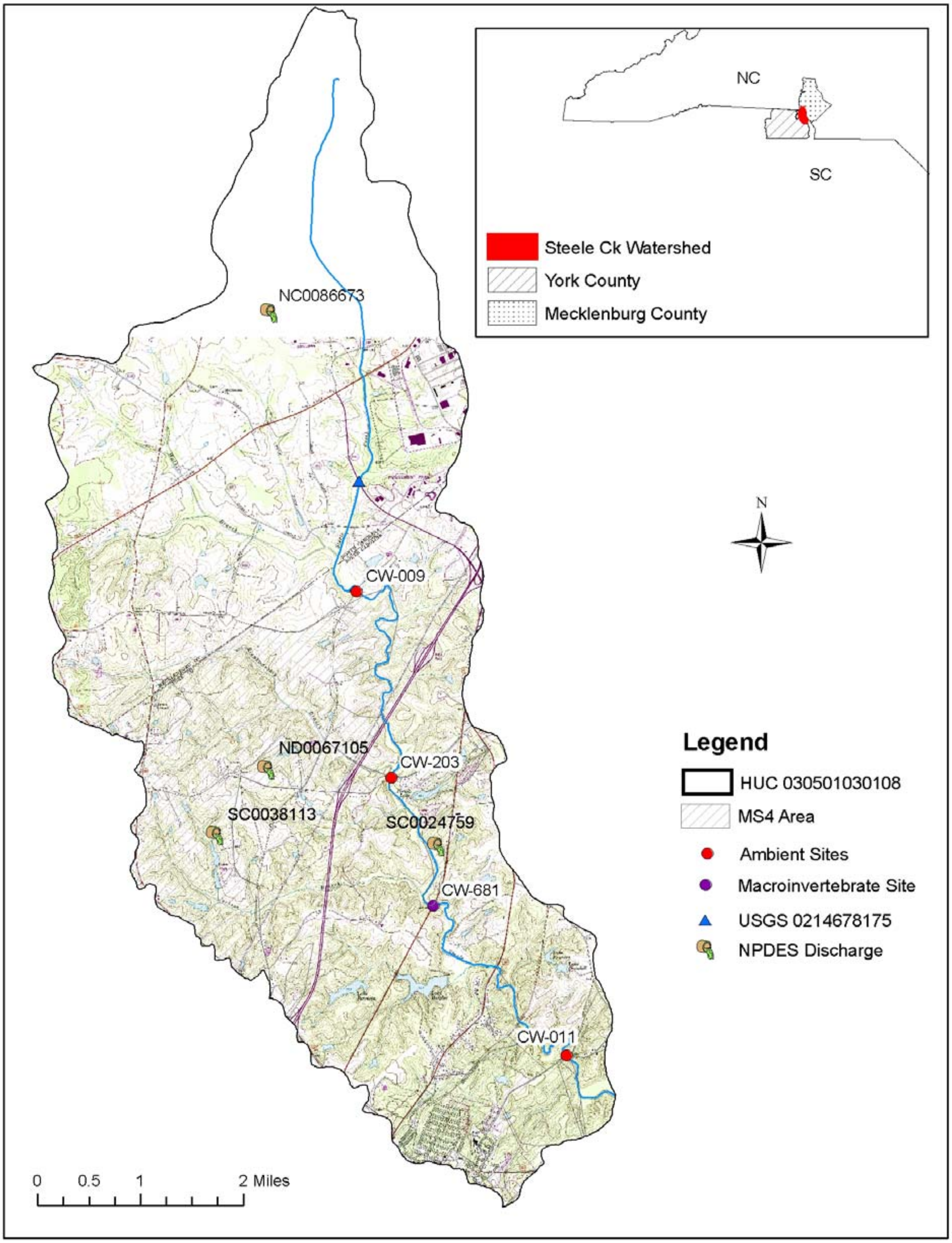
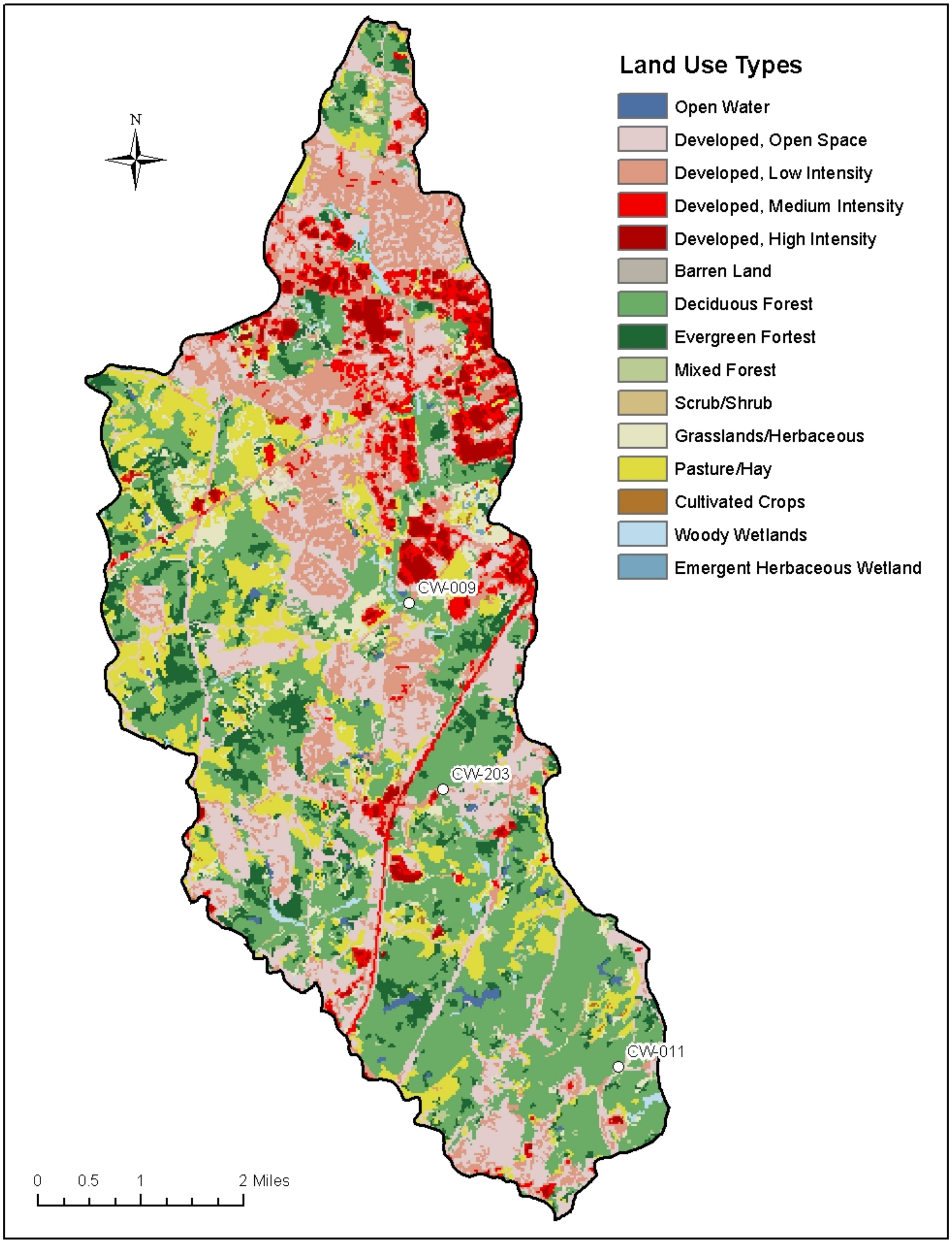


Figure 2. Land Use Within the Steele Creek Watershed



According to the United States Geological Survey (USGS) 2001 National Land Cover Dataset (NLCD), the primary land use in the Steele Creek watershed is developed. Forested area also covers a large portion of the watershed (Table 1). Land use varies slightly between stations with the upper portion of the watershed being more developed and the lower portion more forested. This area has experienced considerable growth. Comparing the 1992 NLCD to the 2001 NLCD, developed area has increased by nearly 30% replacing forested and agricultural area.

Table 1. Land Use Summary, 2001 NLCD

Land Use	Station CW-009		Station CW-203		Station CW-011		HUC 030501030108	
	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%
Developed, Open Space	2.60	17.98%	4.10	19.12%	6.39	19.86%	6.63	19.84%
Developed, Low Intensity	3.34	23.14%	4.17	19.49%	4.81	14.95%	4.92	14.74%
Developed, Medium Intensity	1.20	8.29%	1.48	6.89%	1.68	5.23%	1.70	5.10%
Developed, High Intensity	0.81	5.63%	0.94	4.38%	1.03	3.19%	1.04	3.11%
Total Developed	***7.95***	***55.03%***	***10.69***	***49.87%***	***13.90***	***43.24%***	***14.29***	***42.79%***
Deciduous Forest	2.57	17.81%	4.61	21.52%	9.34	29.05%	9.98	29.87%
Evergreen Forest	0.81	5.64%	1.56	7.29%	2.29	7.12%	2.36	7.07%
Mixed Forest	0.08	0.58%	0.14	0.63%	0.32	1.01%	0.34	1.03%
Total Forested	***3.47***	***24.03%***	***6.31***	***29.45%***	***11.95***	***37.17%***	***12.68***	***37.97%***
Pasture/Hay	1.91	13.22%	2.93	13.70%	4.21	13.10%	4.26	12.75%
Cultivated Crops	0.04	0.26%	0.05	0.24%	0.08	0.23%	0.08	0.23%
Total Agricultural	***1.95***	***13.48%***	***2.99***	***13.94%***	***4.29***	***13.33%***	***4.33***	***12.98%***
Woody Wetlands	0.12	0.85%	0.15	0.71%	0.23	0.70%	0.25	0.75%
Emergent Herbaceous Wetland	0.02	0.11%	0.02	0.10%	0.02	0.06%	0.02	0.06%
Total Wetlands	***0.14***	***0.96%***	***0.17***	***0.81%***	***0.25***	***0.77%***	***0.27***	***0.81%***
Barren Land	0.00	0.02%	0.00	0.01%	0.00	0.01%	0.00	0.01%
Scrub/Shrub	0.10	0.68%	0.12	0.55%	0.18	0.57%	0.18	0.55%
Grasslands/Herbaceous	0.80	5.54%	1.09	5.11%	1.39	4.32%	1.44	4.31%
Open Water	0.04	0.24%	0.06	0.26%	0.19	0.59%	0.19	0.58%
Total Other	***0.94***	***6.49%***	***1.27***	***5.94%***	***1.77***	***5.49%***	***1.82***	***5.44%***
Total Area	14.45	100.00%	21.42	100.00%	32.15	100.00%	33.40	100.00%

1.3 Water Quality Standard

Water quality standards are based on the classification of the waterbody and are designed to protect the designated uses of that classification. Steele Creek is designated as Freshwaters (FW) by R.61-69, Classified Waters (SC DHEC, 2004a). Freshwaters are defined as:

> "freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements for the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses" (SC DHEC, 2004c pg. 25).

The fecal coliform standard for FW includes a geometric mean and a single sample standard. The geometric mean standard is 200cfu/100mL, based on five consecutive samples during any

30-day period. The single sample standard is no more than 10% of samples in any 30-day period exceeding 400cfu/100mL (SC DHEC, 2004c).

2.0 WATER QUALITY ASSESSMENT

Monitoring stations CW-009, CW-203, and CW-011 are listed on the 2004 and the 2006 303(d) lists as impaired for recreational use (SC DHEC 2004b, SC DHEC 2006). Waters in which no more than 10% of the samples collected over a five year period are greater than the single sample standard of 400 cfu/100mL are considered to comply with the South Carolina water quality standard for fecal coliform bacteria. Waters with more than 10% of samples exceeding the single sample standard are considered impaired. During the assessment period for the 2004 303(d) list, 48%, 63% and 63% of samples for stations CW-009, 203, and 011 respectively, exceeded the standard. For the 2006 list 35%, 72%, and 82% of samples exceeded the standard (Table 2). Fecal coliform and precipitation sample data used for this analysis is available in Appendix A.

Fecal coliform data are also collected in the North Carolina portion of Steele Creek by Mecklenburg County under agreement with the City of Charlotte. Data is collected from Steele Creek at Carowinds Blvd. Fewer excursions of the South Carolina water quality standard for fecal coliform occurred at the North Carolina station as compared to the South Carolina stations (Table 3).

Table 2. Percent Exceedances for 1998-2006 303(d) Lists

303(d) List Year	Time Period Included	Station CW-009		Station CW-203		Station CW-011	
		# Samples	% Exceeds	# Samples	% Exceeds	# Samples	% Exceeds
2004	1998-2002	29	48%	30	63%	19	63%
2006	2000-2004	17	35%	18	72%	11	82%

Table 3. Water Quality Sample Summary

Station	Total # Samples 1992-2004	Exceeds Standard	Average (cfu/100mL)	Maximum (cfu/100mL)	Minimum (cfu/100mL)
CW-009	67	42%	1436	20000	20
CW-203	67	37%	1087	20000	0
CW-011	30	37%	679	6600	0
NC	39*	18%	261	930	10

* Data collected 1998 – 2005.

There is a weak relationship between fecal coliform and precipitation for the available South Carolina data. The Pearson Correlation Coefficient between the natural log of fecal coliform and precipitation at Fort Mill 4 NW is –0.11. This lack of relationship may be due to the small data set or the gage not adequately representing the watershed. The Fort Mill 4 NW station is approximately 2.5 miles west of the southern portion of the watershed. Graphs of daily precipitation plotted with fecal coliform concentrations are available in Appendix B.

3.0 SOURCE ASSESSMENT AND LOAD ALLOCATION

Surface waters may be contaminated by fecal coliform bacteria that originate from both point and nonpoint sources. Point sources are facilities, such as wastewater treatment plants and factories that have National Pollutant Discharge Elimination System (NPDES) permits and discharge wastewater through a pipe or similar structure. Historically, poorly treated or untreated point sources of waste were a major source of fecal coliform bacteria. Implementation of the Clean Water Act has remedied this problem. All point sources must have a NPDES permit and are required to treat wastewater to a satisfactory level. In South Carolina, NPDES permittees that discharge sanitary wastewater must meet the state standards for fecal coliform at the point of discharge.

3.1 Point Sources

3.1.1 Continuous Point Sources

There are three NPDES permitted dischargers in the South Carolina portion of the Steele Creek watershed and one in the North Carolina portion (Table 4, Figure 1). Lazy Daze Campground (ND0067105) is a land application site with up to 0.0217 MGD of wastewater going to a 6.4 acre sprayfield. This discharger had one fecal coliform violation during the 1998-2004 time period. Carowood Subdivision (SC0038113) discharges to a tributary of Jackson Branch which flows into Steele Creek near station CW-681 (Figure 1). Carowood Subdivision is permitted to discharge up to 0.02 MGD. Carowood Subdivision had one fecal coliform violation during the 1998-2004 time period. Pinelakes Campground (SC0024759) discharges directly to Steele Creek between stations CW-203 and CW-681 (Figure 1). Pinelakes is permitted to discharge up to 0.0375 MGD. Pinelakes Campground has an active NPDES permit, but has not been in operation since prior to 1998. Each of these discharges is limited to a monthly average fecal coliform concentration of 200/100ml and a weekly average of 400/100ml. The North Carolina discharger, SNL Corp/Aqua-Air Site (NC0086673) is a groundwater remediation site with no fecal coliform expected in the effluent. These sources are not expected to contribute to exceedance of the fecal coliform standard as long as they are in compliance with their permit limits.

Table 4. NPDES Dischargers in Steele Creek Watershed

NPDES	Name	State	Discharge Location
ND0067105	Lazy Daze Campground	SC	Land application to sprayfield
SC0038113	Carowood SD	SC	Tributary to Jackson Branch
SC0024759	Pinelakes Campground	SC	Steele Creek
NC0086673	SNL Corp/ Aqua-Air Site	NC	Unnamed tributary to Steele Creek

3.1.2 Intermittent Point Sources

Sanitary sewer overflows (SSOs) to surface waters have the potential to severely impact water quality. These untreated sanitary discharges result in violations of the water quality standards. It is the responsibility of the NPDES discharger, or collection system operator for non-permitted 'collection only' systems, to ensure that releases do not occur. Unfortunately releases to surface waters from SSOs are not always preventable or reported. There were 64 reported releases in York County between 1998 and 2004, resulting in the release of approximately 1.9 million gallons of untreated sanitary waste. It is not known what percentage of these releases occurred specifically in the Steele Creek watershed.

The Steele Creek watershed has several designated Municipal Separate Storm Sewer Systems (MS4). The City of Charlotte, NC is a Phase I MS4 located in the northernmost portion of the watershed. The unincorporated areas of Mecklenburg County, NC are also included under the City of Charlotte's permit. York County, SC is designated as a Phase II MS4. Fort Mill, SC is designated as a Phase II MS4 and is located in the southern portion of the watershed. Runoff from developed land that is collected by storm sewers is discharged untreated into streams and may be a major source of fecal coliform bacteria.

There also could be industrial or construction activities going on at any time that could produce stormwater runoff. Industrial facilities that have the potential to cause or contribute to a violation of a water quality standard are covered by the NPDES Storm Water Industrial General Permit (SCR000000). Construction activities are covered by the NPDES Storm Water Construction General Permit from DHEC (SCR100000). Where construction has the potential to affect water quality of a water body with a TMDL, the Storm Water Pollution Prevention Plan (SWPPP) for the site must address any pollutants of concern and adhere to any wasteload allocations in the TMDL. Several large construction activities were seen during the watershed survey. Due to the large amount of growth in this area it is likely that construction activities will be an on-going occurrence.

3.2 Nonpoint Sources

3.2.1 Wildlife

Wildlife can be a significant source of fecal matter, and therefore fecal coliform bacteria. Wildlife wastes are carried into nearby streams by runoff during rainfall events or by direct deposition. Wildlife in this area includes deer, raccoon, beavers and other small mammals as well as a variety of birds. Evidence of beaver activity was seen during a watershed survey. Although wildlife is possibly a source in the watershed, any control of the source would be difficult to implement and not likely to have the desired results.

3.2.2 Agricultural Activities

Agricultural activities that involve livestock or animal wastes are potential sources of fecal coliform contamination of surface waters. Fecal matter can enter the waterway by rainfall runoff from the land or by direct deposition into the stream.

3.2.2.1 Agricultural Animal Facilities

Owners/operators of most commercial animal growing operations are required by R. 61-43, Standards for the Permitting of Agricultural Animal Facilities, to obtain permits for the handling, storage, treatment (if necessary) and disposal of the manure, litter and dead animals generated at their facilities (SC DHEC 2002). The requirements of R. 61-43 are designed to protect water quality; therefore, we have a reasonable assurance that facilities operating in compliance with this regulation should not contribute to downstream water quality impairments. In addition to the state permit, animal operations that are considered Concentrated Animal Feeding Operations (CAFOs) are also required to have an NPDES Permit if they have a discharge to surface waters. There are no permitted CAFOs or animal feeding operations (AFOs) within the Steele Creek watershed.

3.2.2.2 Grazing Animals

Pasture cattle and other grazing animals can contribute to fecal coliform contamination through runoff or direct deposition of manure. Runoff from rainfall may wash manure deposited on pastureland to nearby streams. Cattle and other livestock that are allowed access to streams may deposit manure directly into the waterbody. Defecation directly into a waterbody by cattle can be a very significant source of fecal coliform bacteria, as a single beef or dairy cow can produce $1.0*10^{11}$ organisms/day (ASAE, 1998). Range cattle facilities are not permitted through SC DHEC, but according to the 2002 Census of Agriculture, there are a total of 19,211 cattle and calves in York county (USDA, 2002). Assuming that cattle are evenly distributed across pastureland in the county, an estimate of the number of cattle in the watershed can be obtained by comparing the area of pasture/hay land use of the county to the area of pasture/hay land use within the watershed. This method gives a total of 1,960 cattle within the watershed.

During a watershed survey completed on April 9, 2007, several horse pastures were seen in the watershed. Trails were seen near the creek with evidence of recent use (hoof marks and fecal matter). Horses could be a source of fecal coliform either by direct access to the creek or by manure being washed into the creek from nearby fields and trails.

3.2.3 Leaking Sanitary Sewers and Illicit Discharges

Leaking sewer collection systems and illicit sewer connections represent a direct threat to public health since they result in discharge of partially treated or untreated human wastes to the surrounding environment. Quantifying these sources is extremely speculative without direct monitoring of the source because the magnitude is directly proportional to the volume and its proximity to the surface water. Typical values of fecal coliform in untreated domestic wastewater range from 10^4 to 10^6 MPN/100mL (Metcalf and Eddy 1991).

Illicit sewer connections into storm drains result in direct discharges of sewage via the storm drainage system outfalls. The existence of illicit sewer connections to storm drains is well documented in many urban drainage systems. It is probable that numerous illicit sewer connections exist in the storm drainage system serving the older developed portions of the basin.

Monitoring of storm drain outfalls during dry weather is needed to document the presence or absence of sewage in the drainage systems. Approximately 44% of the Steele Creek watershed is urbanized and is therefore subject to the Stormwater Phase II Final Rule that requires the development and implementation of an illicit discharge detection and elimination plan.

3.2.4 Failing Septic Systems

Failed septic tanks can contribute to bacterial contamination of downstream waterbodies (US EPA, 2001). Wastes from failing septic systems enter surface waters either as direct overland flow or via groundwater. Although loading to streams from failing septic systems is likely to be a continual source, wet weather events can increase the rate of transport of pollutants from failing septic systems because of the wash-off effect from runoff and the increased rate of groundwater recharge.

Due to the highly urbanized characteristics of the watershed, it is likely that the majority of the homes and businesses in the watershed are served by sewer systems. There are likely private septic systems within this area, but the number of private systems is assumed to be low. The failure rate of these systems is unknown.

3.2.5 Urban Runoff

Urban and suburban stormwater runoff from streets, parking lots and lawns can contribute a large bacterial load to receiving waters (Gaffield, 2003). The City of Charlotte, NC, including unincorporated areas of Mecklenburg County, NC has been designated a Phase I MS4 operator under NPDES stormwater rules. York County, SC and the City of Fort Mill, SC have been designated as Phase II MS4 operators. The high percentage of impervious surface in built-up areas increases runoff and reduces infiltration. The additional runoff, compared to undeveloped land, increases the amount of pollutants that are carried into streams. Dogs, cats, and other domesticated pets are the primary source of fecal coliform deposited on the urban landscape. There are also ‘urban’ wildlife; squirrels, raccoons, pigeons, and other birds, all of which contribute to the fecal coliform load.

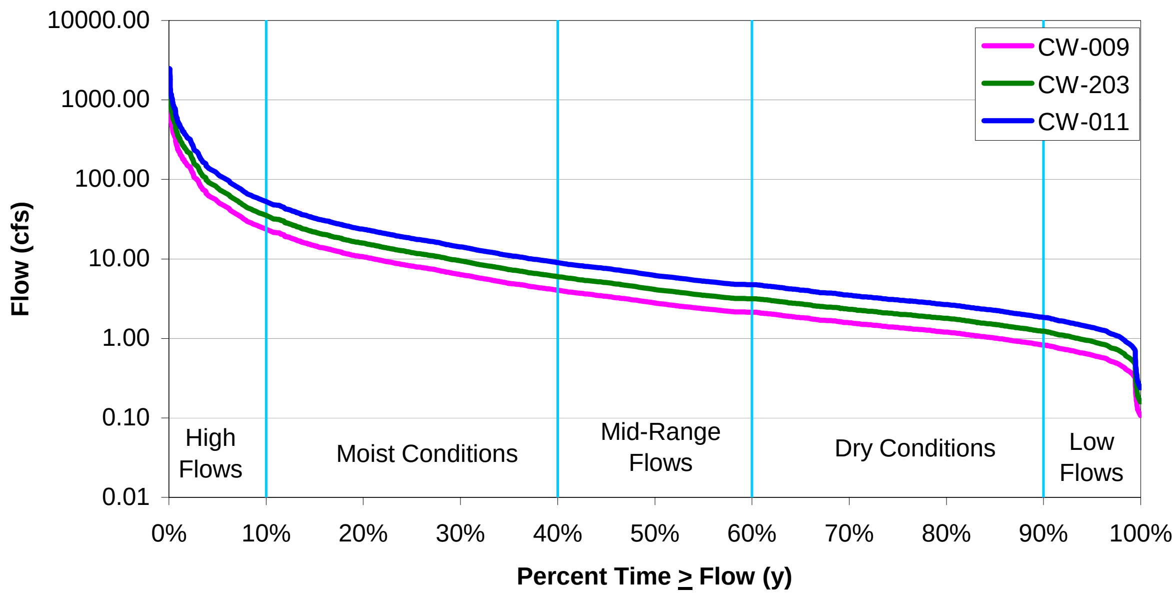
4.0 METHODS

The TMDL for the Steele Creek watershed was developed using the load-duration curve methodology. Load-duration curves were developed as a method of calculating TMDLs that apply to all hydrologic conditions. The load-duration curve method uses the cumulative frequency distribution of stream flow and pollutant concentration data to estimate the existing and the total maximum daily loads for a waterbody.

4.1 Flow-Duration Curve

The first step in the load-duration methodology is the development of a flow-duration curve. Flow-duration curves are used for a variety of management purposes including water-use planning and characterization of erosion and sedimentation problems (Fan and Li, 2004). Flow-duration curves provide a graphic representation of the cumulative frequency of historic flow data over a time period (Cleland, 2003). Flow-duration curves are typically generated from long-term continuous-record flow-gauging USGS stations. Daily mean discharge data from USGS 0214678175 (Steele Creek at SR 1441 near Pineville) for 04/16/1998 through 12/31/2005 was used to generate the flow-duration curve. Daily mean streamflow data was retrieved from http://nc.water.usgs.gov/. This station is located above WQM station CW-009. Daily flow data was adjusted for each sub-watershed to account increases in drainage area by multiplying the daily flow rates from USGS 0214678175 by the ratio of sub-watershed drainage area to that of gage drainage area. The flow-duration curve points are found by ranking the daily flow from highest to lowest and calculating the percent of days these flows were exceeded. These points are then plotted on a semi-log plot with flow on the y-axis and percent on the x-axis to form the curve (Figure 3). Low values of x correspond to the highest flows or flood conditions (flows rarely exceed these values) and high values correspond to the lowest flows, which are nearly always exceeded (drought conditions) (Cleland, 2002).

Figure 3. Flow-Duration Curve



4.2 Load-Duration Curve

After development of the flow-duration curves, load-duration curves are created by combining flow duration data with water quality data (Cleland, 2002). Points for this plot are calculated by multiplying daily stream flows by the water quality standard concentration and a conversion factor to get daily load. These values were calculated at 5% flow intervals from 5%-95% and plotted on semi-log scale with y being the daily load of fecal coliform and x being the percent of time the flow is exceeded and hence the percent of time the load is exceeded. The curves are calculated using the instantaneous water quality standard with a 5% margin of safety, which equals 380 cfu/100mL (Figures 4-6).

Figure 4. Station CW-009 Load-Duration Curve

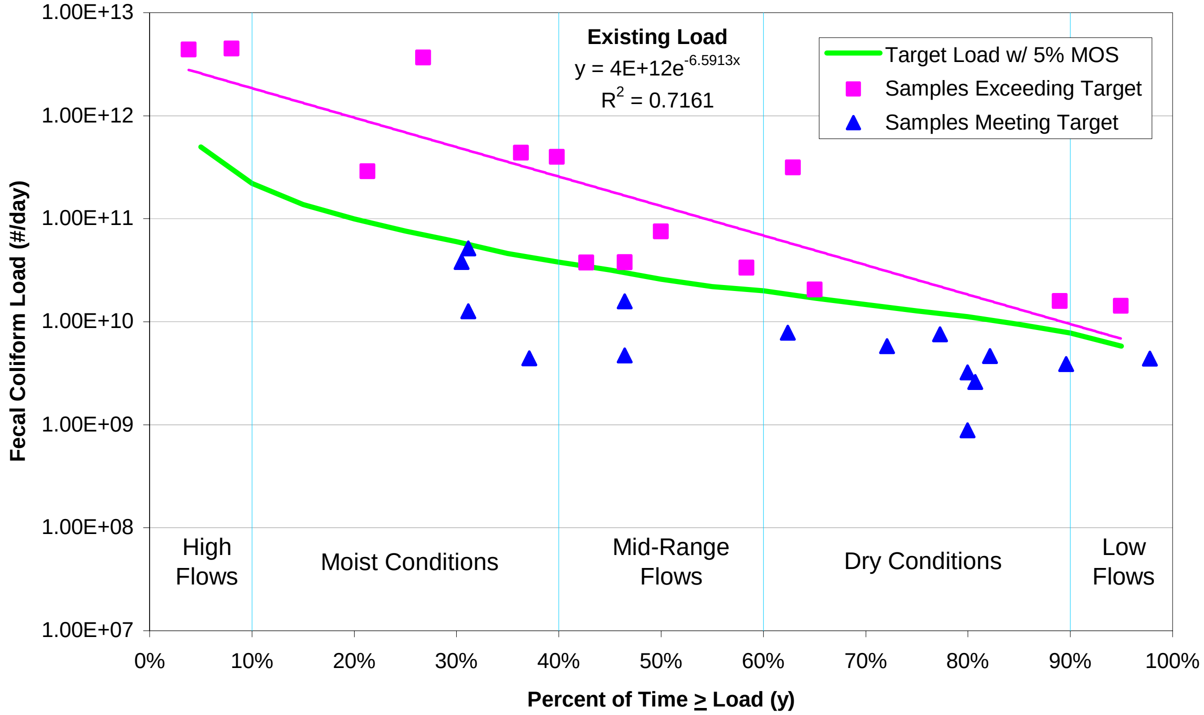


Figure 5. Station CW-203 Load-Duration Curve

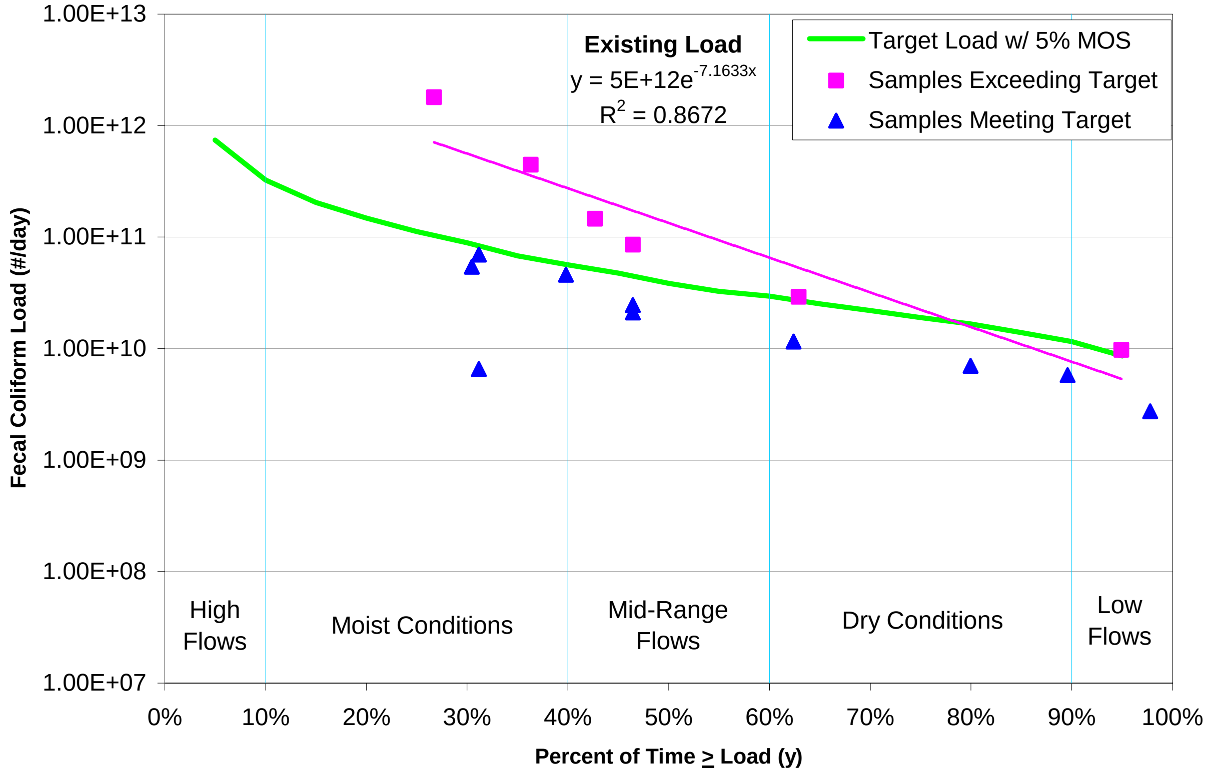
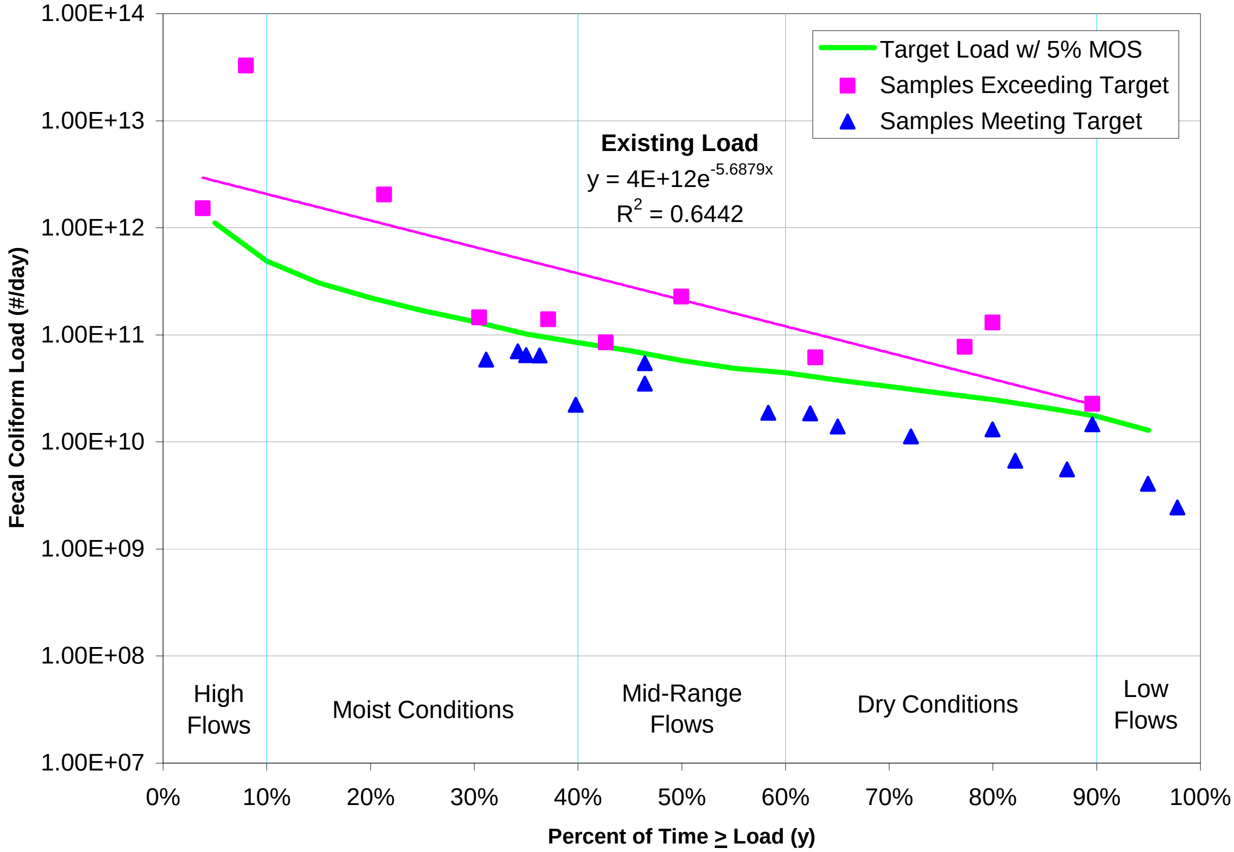


Figure 6. Station CW-011 Load-Duration Curve



4.3 Existing Load Calculation

To calculate the average existing load for development of the TMDL, the water quality sample values are plotted on the load-duration curves. Water quality monitoring data from 1998-2004, was used for calculation of this fecal coliform TMDL. Data used in TMDL development is listed in Appendix A. Daily loads for each water quality sample were calculated by multiplying the sample concentration by the flow on that date and a conversion factor. The flows used for this calculation are those calculated for the flow-duration curve. Flows were not recorded during sample collection. Daily loads are then plotted on the load-duration curve with y being the sample load and x being the percentile corresponding to that day's flow. A line is then fit through the sample loads that exceed the margin of safety standard, in this case an exponential functions provided the best fit (Figures 4-6).

5.0 DEVELOPMENT OF THE TMDL

5.1 Critical Conditions

Critical conditions are the "worst-case" environmental conditions for exceedance of water quality standards and which occur at an acceptable frequency (US EPA, 1999). Load-duration curves allow for visualization of critical conditions. If high samples values are mainly confined to a specific flow range, the critical conditions for establishing the TMDL can be targeted to that flow range. This information can also be used to target potential sources. For example exceedances that occur at low flows could indicate point source contributions, while exceedances at higher flows would be more indicative of non-point sources (Cleland, 2003). In the Steele Creek watershed, standard violations occur over nearly the entire range of flow conditions. Critical conditions for this TMDL are taken to be the flow range between the 5th and 95th percentile, incorporating all but the most extreme flows. This is considered appropriate because the standards are based on not more than 10% exceedance and loading occurring at extreme flows is unlikely to be controllable. Seasonal variation is taken into account since all but the most extreme flows are represented in the calculations.

5.2 Wasteload Allocation

The wasteload allocation (WLA) is the portion of the TMDL allocated to point sources (US EPA, 1999).

5.2.1 Continuous Point Sources

There are two permitted domestic dischargers to surface waters in the Steele Creek watershed that may contribute loading to Steele Creek (SC0038113 and SC0024759). Although Pinelakes Campground (SC0024759) has an active discharge permit the facility is currently unoperational and did not discharge during the 2001-2004 time period. The remaining two dischargers are an industrial discharger with no fecal coliform component (NC0086673) and a land application site (ND0067105). The land application site is not expected to contribute to surface water fecal coliform loading. To determine existing loads for the two domestic dischargers, average measured monthly fecal coliform concentrations and average discharge flow data from Discharge Monitoring Reports (DMRs) from 1998-2004 were used (Appendix C). The 90th percentile of these data is used as the existing load estimate (Table 5). To determine the wasteload allocation (WLA) for the discharger, the maximum permitted flow for the facility was multiplied by the maximum permitted fecal coliform limit (400 cfu/100mL) and a unit conversion factor (Table 5).

Table 5. Existing Load and WLA for NPDES Dischargers

Impaired Station	Facility Name	NPDES	Existing Load (cfu/day)	n	Maximum Permitted Flow (MGD)	WLA (cfu/day)
CW-011	Carowood Subdivision	SC0038113	$3.15*10^7$	84	0.02	$3.03*10^8$
CW-011	Pinelakes Campground	SC0024759	0	n/a	0.0375	$5.68*10^8$

n = number of samples

5.2.2 Intermittent Point Sources

Intermittent point sources include all NPDES-permitted stormwater discharges. In South Carolina, this would include current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction instead of a numeric loading due to the uncertain nature of stormwater discharge volumes and recurrence intervals. Stormwater discharges are required to meet the percentage reduction or the existing instream standard for pollutant of concern, whichever is less restrictive. For the purposes of this TMDL, it will be assumed that water quality will meet standards at the North Carolina/South Carolina state line, based on existing control and/or permitting mechanisms in North Carolina. Meeting the water quality standards at the state line will fulfill the obligations for implementing load reductions for responsible North Carolina entities. Table 7 indicates the MS4 entity(ies) responsible for meeting the percentage reduction or water quality standard, by individual subwatershed (WQM station). Note that all future NPDES-permitted stormwater discharges will also be required to meet the prescribed percentage reductions.

5.3 Load Allocation

The load allocation includes all non-point sources not covered under a NPDES permit. The load allocation was determined from the TMDL load by subtracting out a margin of safety.

5.4 Existing Load

The line fit to the exceedance data is used to calculate existing load. The equation of the fitted line is applied at 5% intervals for the 5^{th} to 95^{th} percentile flows and the resultant loads averaged to determine an average existing load at critical conditions (Appendix D). The average existing load for station CW-009 is $5.38*10^{11}$ cfu/day, CW-203 is $6.10*10^{11}$ cfu/day and CW-011 is $6.37*10^{11}$ cfu/day (Table 6).

5.5 Margin of Safety

A margin of safety (MOS) allows for an accounting of the uncertainty in the relationship between pollutant loads and receiving water quality (US EPA, 1999). Incorporation of a MOS can be done either explicitly within the TMDL calculation or implicitly by using conservative assumptions (US EPA, 1999). The margin of safety component of the TMDL for Steele Creek is calculated explicitly. Five percent or 20 cfu/100mL of the water quality standard (400 cfu/100mL) is reserved in the TMDL calculation as a margin of safety. Again, loads were calculated for the 5^{th} to 95^{th} percentile and averaged (Appendix D). This results in an average margin of safety load of $1.56*10^{10}$ cfu/day (Table 3). Conservative assumptions in the modeling process also contribute to the margin of safety.

5.6 Calculation of the TMDL

A TMDL represents the loading capacity (LC) of a waterbody, which is the maximum loading a waterbody can receive without exceeding water quality standards (US EPA, 1999). The TMDL is the sum of the wasteload allocations (WLA) for point sources, the load allocation (LA) for non-point sources and natural background, and a margin of safety (MOS). The TMDL can be represented by the equation:

$$\text{TMDL} = \text{LC} = \text{WLA} + \text{LA} + \text{MOS (US EPA, 2001)}.$$

The TMDL was calculated as the water quality standard concentration, converted to load and averaged over the 5th to 95th percentile flows. This gives a loading capacity of $7.50*10^{10}$ cfu/day for CW-009, $1.11*10^{11}$ cfu/day for CW-203 and $1.67*10^{11}$ cfu/day for station CW-011 (Appendix D). Since the existing load for each station is greater than the calculated loading capacity or TMDL, a reduction in existing loading is required to meet water quality standards. Percent reduction is calculated as:

$$\frac{\text{Existing Load - Load Allocation}}{\text{Existing Load}} * 100 .$$

This calculation results in an 87% load reduction at station CW-009, 83% at CW-203 and 75% at CW-011 to consistently meet the instantaneous water quality criteria for fecal coliform (Table 6). By meeting the instantaneous standard it is assumed the geometric mean criteria will also be consistently met.

Table 6. TMDL Components for Steele Creek

Station ID	TMDL (cfu/day)	MOS (cfu/day)	WLA		LA (cfu/day)	Existing Load (cfu/day)	% Reduction to Meet Load Allocation[3]
			Continuous Sources[1] (cfu/day)	Intermittent Sources[2] (% Reduction)			
CW-009	$7.50*10^{10}$	$3.75*10^{9}$	NA	87%	$7.13*10^{10}$	$5.38*10^{11}$	87%
CW-203	$1.11*10^{11}$	$5.56*10^{9}$	NA	83%	$1.06*10^{11}$	$6.10*10^{11}$	83%
CW-011	$1.67*10^{11}$	$8.35*10^{9}$	$8.71*10^{8}$	75%	$1.58*10^{11}$	$6.37*10^{11}$	75%

Table Notes:
1. WLA is expressed as total monthly average.
2. Percent reduction applies to all NPDES-permitted stormwater discharges, including current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction due to the uncertain nature of stormwater discharge volumes and recurrence intervals. Stormwater discharges are required to meet percentage reduction or the existing instream standard for pollutant of concern, whichever is less restrictive.
3. Percent reduction applies to existing load.

Table 7. Responsible MS4 Entity

Subwatershed (Station ID)	WLA % Reduction	Responsible MS4 Entity
CW-009	87%	City of Charlotte, NC
CW-203	83%	York County, SC
CW-011	75%	York County, SC City of Fort Mill, SC

6.0 IMPLEMENTATION

As discussed in the *Implementation Plan for Achieving Total Maximum Daily Load Reductions From Nonpoint Sources for the State of South Carolina* (SC DHEC, 1998), South Carolina has several tools available for implementing this nonpoint source TMDL. There are a number of voluntary measures available to interested parties. SC DHEC will work with the existing agencies in the area to provide nonpoint source education in the Steele Creek Watershed. Local sources of nonpoint source education and assistance include Clemson Extension Service, the Natural Resource Conservation Service (NRCS), the York County Soil and Water Conservation Services, and the South Carolina Department of Natural Resources.

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

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

Using existing authorities and voluntary mechanisms, these measures will be implemented in the Steele Creek watershed in order to bring about 75-87% reductions in fecal coliform bacteria loading to Steele Creek. SC DHEC will continue to monitor, according to the basin monitoring schedule, the effectiveness of implementation measures and evaluate stream water quality as the implementation strategy progresses.

7.0 SPECIAL NOTE

A draft version of this document was forwarded to EPA Region 4, NCDENR and all responsible MS4 entities within the Steele Creek Watershed, both SC and NC, on May 04, 2007 to allow a five-day review in advance of the public notice period. There were no changes made to the content of this document from May 04, 2007 until commencement of the 30-day public notice period.

8.0 REFERENCES

American Public Health Association, American Water Works Association and Water Environment Association (APHA). 1992. Standard Methods for the Examination of Water and Wastewater (19^{th} ed.): Washington, D.C., American Public Health Association, p. 2-8 to 2-11.

American Society of Agricultural Engineers (ASAE). 1998. ASAE Standards, 45^{th} Edition. Standards, Engineering Practices, Data.

Cleland, B.R. 2002. "TMDL Development from the "Bottom Up" – Part II: Using Duration Curves to Connect the Pieces." National TMDL Science and Policy 2002 – WEF Specialty Conference. Phoenix, AZ. November 2002.

Cleland, B.R. 2003. "TMDL Development from the "Bottom Up" – Part III: Duration Curves and Wet Weather Assessments." National TMDL Science and Policy 2003 – WEF Specialty Conference, Chicago, IL. November 2003.

Fan, C. and Li, J. 2004. "A Modelling Analysis of Urban Stormwater Flow Regimes and their Implication for Stream Erosion." *Water Quality Research Journal of Canada Vol 39, No 4*: 356-361.

Gaffield, S.J., Goo, R.L., Richards, L.A., Jackson, R.J. 2003. "Public Health Effects of Inadequately Managed Stormwater Runoff." *American Journal of Public Health Vol 93, No. 9*: 1527-1533.

Metcalf and Eddy 1991. Wastewater Engineering: Treatment, Disposal, Reuse. Third Edition.

South Carolina Department of Health and Environmental Control (SC DHEC) Bureau of Water. 1998. Implementation Plan for Achieving Total Maximum Daily Load Reductions from Nonpoint Sources for the State of South Carolina.

South Carolina Department of Health and Environmental Control (SC DHEC) Bureau of Water. 2002. Standards for the Permitting of Agricultural Animal Facilities (R.61-43). Effective June 28,2002. [Electronic Version]; 105pp.

South Carolina Department of Health and Environmental Control (SC DHEC) Bureau of Water. 2003. Total Maximum Daily Load Development for Allison Creek: Station CW-171, Fecal Coliform Bacteria. Technical Report No. 011-03. Approved September 19,2003. [Electronic Version]; 20pp.

South Carolina Department of Health and Environmental Control (SC DHEC) Bureau of Water. 2004a. Classified Waters (R.61-69). Amended May 28, 2004. Printed April 2005; 36pp.

South Carolina Department of Health and Environmental Control (SC DHEC) Bureau of Water. 2004b. State of South Carolina Section 303(d) List for 2004. Approved September 23, 2004. Printed February 2005; 30pp.

South Carolina Department of Health and Environmental Control (SC DHEC) Bureau of Water. 2004c. Water Classifications & Standards (R.61-68). Amended June 25, 2004. Printed April 2005; 56pp.

South Carolina Department of Health and Environmental Control (SC DHEC) Bureau of Water. 2006. Draft State of South Carolina Section 303(d) List for 2006. [Electronic Version]; 47pp.

South Carolina Department of Natural Resources (SC DNR). 2000. SC Deer Density 2000. Retrieved from www.dnr.sc.gov/wildlife/deer March 21, 2006.

United States Department of Agriculture, National Agricultural Statistics Service (USDA). 2002. 2002 Census of Agriculture. Retrieved from www.nass.usda.gov/Census_of_Agriculture/index.asp July 7,2006.

United States Environmental Protection Agency (US EPA). 1999. Draft Guidance for Water Quality-based Decisions: The TMDL Process. Second Edition. Office of Water, EPA 841-D-99-001.

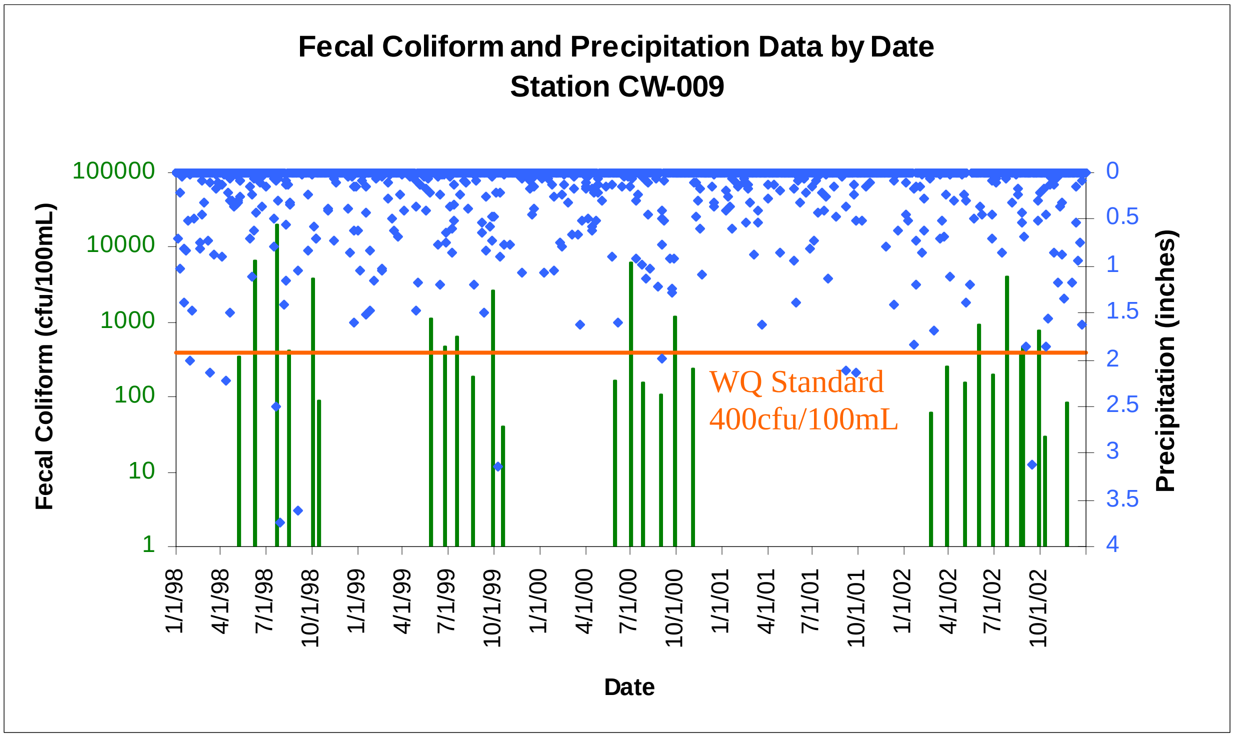
United States Environmental Protection Agency (US EPA). 2001. Protocol for Developing Pathogen TMDLs. First Edition. Office of Water, EPA 841-R-00-002.

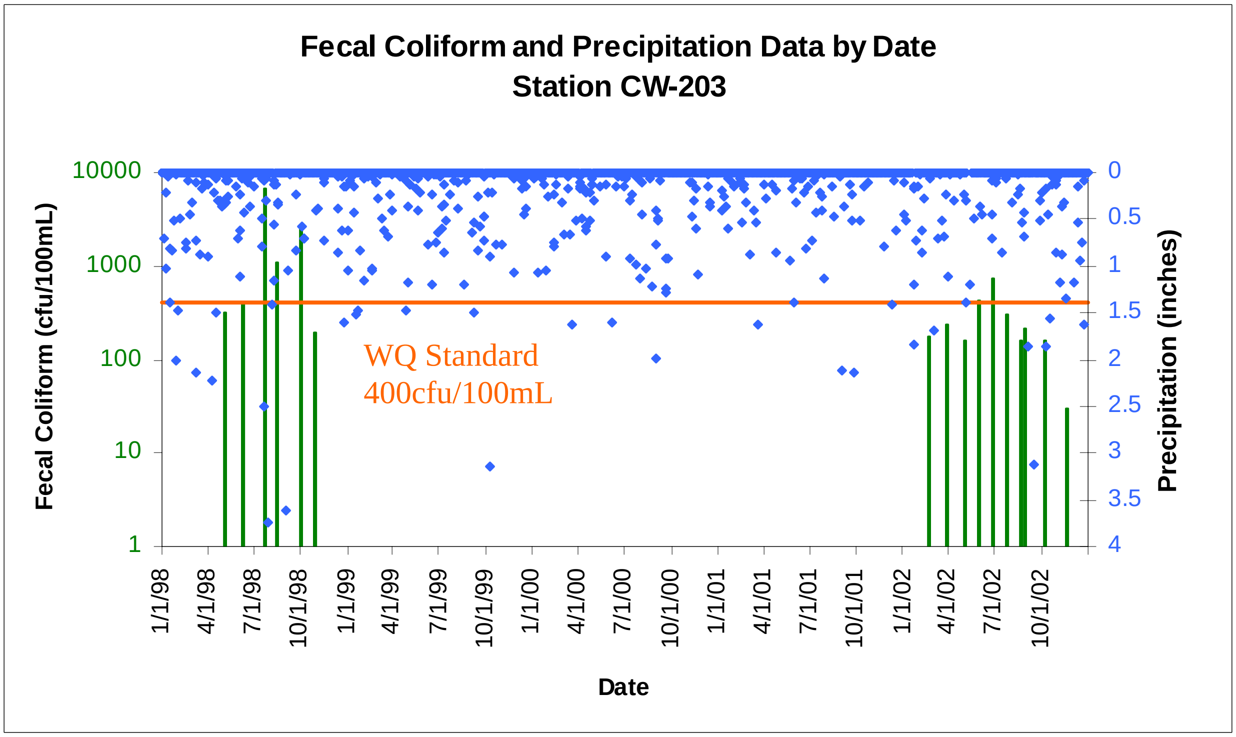
Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, N. Van Driel, 2001. Completion of the 1990s National Land Cover Data Set for the Conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources, Photogrammetric Engineering and Remote Sensing, 67:650-652.

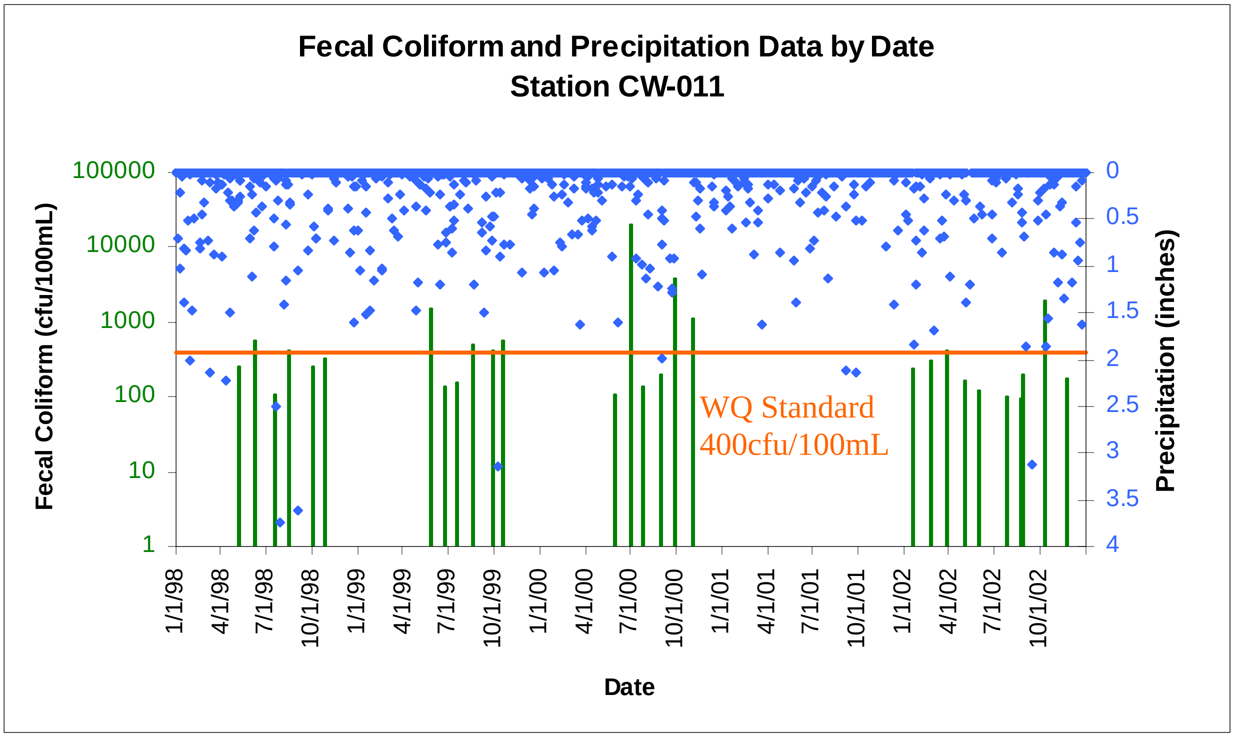
APPENDIX A – WATER QUALITY DATA, 2001-2004

Sample Date	Fecal Coliform (cfu/100mL)			Precipitation (inches)
	CW-009	CW-203	CW-011	
05/04/98	350	320		0
05/05/98			250	0
06/08/98	6600	410	580	0
07/15/98			110	0
07/22/98	20000	6600		0
08/13/98	420	1100	430	0
09/30/98	3800	2600	250	0.03
10/14/98	90			0
10/26/98		190	320	0
05/27/99	1100		1500	0
06/22/99	460		140	0
07/15/99	640		160	0
08/16/99	190		500	0
09/29/99	2700		420	0.47
10/19/99	40		570	0.03
05/30/00	170		110	0
06/29/00	6100		20000	0.15
07/26/00	160		140	0
08/30/00	110		200	0
09/26/00	1200		3800	0
10/31/00	240		1100	0
01/16/02			240	0
02/20/02	60	180	310	0
03/27/02	250	240	430	0
04/30/02	160	160	170	0
05/29/02	940	430	120	0
06/26/02	200	730	0	0.44
07/25/02	4000	310	100	0
08/21/02	380	160	95	0
08/26/02	480	210	200	0
09/25/02	760	0	0	0
10/08/02	30	160	2000	0
11/20/02	86	30	180	0

APPENDIX B – DAILY PRECIPITATION VERSUS FECAL COLIFORM






Fecal Coliform and Precipitation Data by Date
Station CW-011
Fecal Coliform (cfu/100mL)
100000
10000
1000
100
10
1
Precipitation (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
WQ Standard
400cfu/100mL
1/1/98
4/1/98
7/1/98
10/1/98
1/1/99
4/1/99
7/1/99
10/1/99
1/1/00
4/1/00
7/1/00
10/1/00
1/1/01
4/1/01
7/1/01
10/1/01
1/1/02
4/1/02
7/1/02
10/1/02
Date

APPENDIX C – DMR DATA

Date	Daily Average Flow (MGD)	Daily Average Fecal Coliform (cfu/100ml)
Pinelakes Campground (SC0024759)		
no data, not in operation 1998-2004		
Carowood Subdivision (SC0038113)		
31-Jan-98	0.0052	0
28-Feb-98	0.0093	0
31-Mar-98	0.0043	5
30-Apr-98	0.0031	0
31-May-98	0.0068	68
30-Jun-98	0.0037	9
31-Jul-98	0.0081	73
31-Aug-98	0.0038	9
30-Sep-98	0.0069	77
31-Oct-98	0.0051	0
30-Nov-98	0.0118	23
31-Dec-98	0.0076	0
31-Jan-99	0.0106	195
28-Feb-99	0.0071	0
31-Mar-99	0.0122	18
30-Apr-99	0.0102	4
31-May-99	0.0101	27
30-Jun-99	0.0088	4
31-Jul-99	0.0042	200
31-Aug-99	0.0033	0
30-Sep-99	0.0038	0
31-Oct-99	0.01175	0
30-Nov-99	0.0121	20
31-Dec-99	0.0106	15
31-Jan-00	0.0082	120
29-Feb-00	0.01082	75
31-Mar-00	0.0112	160
30-Apr-00	0.0108	0
31-May-00	0.0118	130
30-Jun-00	0.0122	0
31-Jul-00	0.0111	10
31-Aug-00	0.01135	5
30-Sep-00	0.01312	15
31-Oct-00	0.00924	200
30-Nov-00	0.009578	60
31-Dec-00	0.011	15
31-Jan-01	0.012	5
28-Feb-01	0.0102	0

31-Mar-01	0.011	0
30-Apr-01	0.0103	15
31-May-01	0.0116	0
30-Jun-01	0.01	155
31-Jul-01	0.009	1
31-Aug-01	0.0092	1
30-Sep-01	0.01	1
31-Oct-01	0.0092	50
30-Nov-01	0.0095	40
31-Dec-01	0.0111	1
31-Jan-02	0.0093	1
28-Feb-02	0.0099	25
31-Mar-02	0.009	1
30-Apr-02	0.0099	1
31-May-02	0.0102	1
30-Jun-02	0.0092	10
31-Jul-02	0.0089	150
31-Aug-02	0.0091	50
30-Sep-02	0.0099	40
31-Oct-02	0.0096	34
30-Nov-02	0.0099	1
31-Dec-02	0.009	56
31-Jan-03	0.0099	32
28-Feb-03	0.0085	32
31-Mar-03	0.0152	<412.3
30-Apr-03	0.0175	<2.0
31-May-03	0.00895	<2.0
30-Jun-03	0.0137	<2.0
31-Jul-03	0.0131	<2.0
31-Aug-03	0.0122	<2.0
30-Sep-03	0.0115	<2.0
31-Oct-03	0.0109	<2.0
30-Nov-03	0.0067	<2.0
31-Dec-03	0.0071	<2.0
31-Jan-04	0.0062	<2.0
29-Feb-04	0.0154	<2.0
31-Mar-04	0.016	<2.0
30-Apr-04	0.016	<2.0
31-May-04	0.014	<2.0
30-Jun-04	0.0074	<2.0
31-Jul-04	0.006	<2.0
31-Aug-04	0.0092	<2.0
30-Sep-04	0.0068	88
31-Oct-04	0.0108	<2.0
30-Nov-04	0.011	3
31-Dec-04	0.0088	<2.0

APPENDIX D – LOADING CALCULATIONS

Station CW-009

Loading Capacity	
Target: 400 cfu/100ml	
% Exceeded	Load
5%	5.25E+11
10%	2.31E+11
15%	1.45E+11
20%	1.05E+11
25%	7.98E+10
30%	6.30E+10
35%	4.83E+10
40%	3.99E+10
45%	3.36E+10
50%	2.73E+10
55%	2.31E+10
60%	2.10E+10
65%	1.79E+10
70%	1.55E+10
75%	1.34E+10
80%	1.18E+10
85%	9.91E+09
90%	8.19E+09
95%	6.09E+09
Average	**7.50E+10**

Margin of Safety	
Target: 20 cfu/100ml	
% Exceeded	Load
5%	2.63E+10
10%	1.16E+10
15%	7.25E+09
20%	5.25E+09
25%	3.99E+09
30%	3.15E+09
35%	2.42E+09
40%	2.00E+09
45%	1.68E+09
50%	1.37E+09
55%	1.16E+09
60%	1.05E+09
65%	8.97E+08
70%	7.77E+08
75%	6.72E+08
80%	5.88E+08
85%	4.95E+08
90%	4.10E+08
95%	3.05E+08
Average	**3.75E+09**

Existing Load	
$Y = 4*10^{12}e^{-6.5913x}$	
% Exceeded	Load
5%	2.88E+12
10%	2.07E+12
15%	1.49E+12
20%	1.07E+12
25%	7.70E+11
30%	5.54E+11
35%	3.98E+11
40%	2.86E+11
45%	2.06E+11
50%	1.48E+11
55%	1.07E+11
60%	7.67E+10
65%	5.51E+10
70%	3.97E+10
75%	2.85E+10
80%	2.05E+10
85%	1.48E+10
90%	1.06E+10
95%	7.63E+09
Average	**5.38E+11**

Station CW-203

Loading Capacity	
Target: 400 cfu/100ml	
% Exceeded	Load
5%	7.79E+11
10%	3.43E+11
15%	2.15E+11
20%	1.56E+11
25%	1.18E+11
30%	9.35E+10
35%	7.17E+10
40%	5.92E+10
45%	4.99E+10
50%	4.05E+10
55%	3.43E+10
60%	3.12E+10
65%	2.66E+10
70%	2.31E+10
75%	1.99E+10
80%	1.75E+10
85%	1.47E+10
90%	1.22E+10
95%	9.04E+09
Average	**1.11E+11**

Margin of Safety	
Target: 20 cfu/100ml	
% Exceeded	Load
5%	3.90E+10
10%	1.71E+10
15%	1.08E+10
20%	7.79E+09
25%	5.92E+09
30%	4.67E+09
35%	3.58E+09
40%	2.96E+09
45%	2.49E+09
50%	2.03E+09
55%	1.71E+09
60%	1.56E+09
65%	1.33E+09
70%	1.15E+09
75%	9.97E+08
80%	8.73E+08
85%	7.35E+08
90%	6.08E+08
95%	4.52E+08
Average	**5.56E+09**

Existing Load	
$Y = 5*10^{12}e^{-7.1633x}$	
% Exceeded	Load
5%	3.49E+12
10%	2.44E+12
15%	1.71E+12
20%	1.19E+12
25%	8.34E+11
30%	5.83E+11
35%	4.07E+11
40%	2.85E+11
45%	1.99E+11
50%	1.39E+11
55%	9.73E+10
60%	6.80E+10
65%	4.75E+10
70%	3.32E+10
75%	2.32E+10
80%	1.62E+10
85%	1.13E+10
90%	7.93E+09
95%	5.54E+09
Average	**6.10E+11**

Station CW-011

Loading Capacity	
Target: 400 cfu/100ml	
% Exceeded	Load
5%	1.17E+12
10%	5.14E+11
15%	3.23E+11
20%	2.34E+11
25%	1.78E+11
30%	1.40E+11
35%	1.08E+11
40%	8.88E+10
45%	7.48E+10
50%	6.08E+10
55%	5.14E+10
60%	4.68E+10
65%	3.99E+10
70%	3.46E+10
75%	2.99E+10
80%	2.62E+10
85%	2.20E+10
90%	1.82E+10
95%	1.36E+10
Average	**1.67E+11**

Margin of Safety	
Target: 20 cfu/100ml	
% Exceeded	Load
5%	5.84E+10
10%	2.57E+10
15%	1.61E+10
20%	1.17E+10
25%	8.88E+09
30%	7.01E+09
35%	5.38E+09
40%	4.44E+09
45%	3.74E+09
50%	3.04E+09
55%	2.57E+09
60%	2.34E+09
65%	2.00E+09
70%	1.73E+09
75%	1.50E+09
80%	1.31E+09
85%	1.10E+09
90%	9.12E+08
95%	6.78E+08
Average	**8.35E+09**

Existing Load	
$Y=1*10^{13}e^{-5.8423x}$	
% Exceeded	Load
5%	3.01E+12
10%	2.26E+12
15%	1.70E+12
20%	1.28E+12
25%	9.65E+11
30%	7.26E+11
35%	5.46E+11
40%	4.11E+11
45%	3.09E+11
50%	2.33E+11
55%	1.75E+11
60%	1.32E+11
65%	9.92E+10
70%	7.46E+10
75%	5.62E+10
80%	4.23E+10
85%	3.18E+10
90%	2.39E+10
95%	1.80E+10
Average	**6.37E+11**

Response to Comments
Steele Creek FC TMDL

Comments were received from the following:

--City of Charlotte, NC
--Town of Fort Mill, SC

Note that all responsible MS4 entities in this watershed were provided a draft TMDL document in advance of the 30-day public comment period (May 18, 2007-June 18, 2007). The City of Charlotte and Town of Fort Mill submitted comments before May 18, 2007 and no additional comments were received after that time.

Comment 1: One commenter explicitly expressed support for DHEC's efforts to reduce fecal coliform levels within the Steele Creek Watershed.

Response 1: The Department appreciates the support for development and implementation of this TMDL.

Comment 2: One commenter expressed concern that the modeling approach used to calculate the TMDL has limitations with assessing fecal coliform source contributions. There is no discussion given to the respective contributions of sanitary sewer overflows, storm sewer discharges, industrial and construction runoff, or other intermittent or non-point sources to the wasteload allocation (WLA). The commenter would like to see an enhanced source assessment of the intermittent point sources to more effectively implement the TMDL.

Response 2: In the case of stormwater (construction, MS4, industrial), estimates of discharge volume are not available at this time; therefore, the wasteload allocation (WLA) simply identifies a percentage reduction necessary to meet the instantaneous WQ standard for fecal coliform FC bacteria. Implementation of the WLA component is accomplished through existing permitting and enforcement mechanisms and the target is to meet the allowable standard at the point of discharge.

Comment 3: One commenter believed it difficult to meet the fecal coliform standard between the 5th and 95th percentile of flow durations, particularly in the high-flow and moist condition ranges. The commenter also expressed difficulty with controlling fecal coliform loading during wet weather events. It was suggested that the top 10% of fecal coliform loads be removed from the load/duration data set to allow for greater consistency with an allowable 10% exceedence frequency.

Response 3: DHEC selected the 5%-95% range of flows to effectively remove extreme high-flow AND low-flow events that might have also coincided with higher loadings of FC bacteria instream (excursions of allowable to meet the SC WQ standard for FC). Removal of 10% of those extreme flows (and corresponding FC loadings) also allows for some consistency of the SC WQ standard for FC bacteria that prescribes an allowance of 10% exceedences of the instantaneous target of 400/100 ml.

Comment 4: One commenter agreed that utilizing a robust public education would be an effective control measure for implementation of this TMDL given the uncertainty in source assessment. The commenter was reluctant to assume that structural BMPs would be an effective implementation tool in the TMDL in the Steele Creek Watershed and felt that non-structural BMPs should be emphasized.

Reponse 4: DHEC agrees that a strong education program is an effective support for implmentation of this TMDL. We also highly encourage any interested parties to develop a 319 grant proposal to implement the NPS component of the Steele Creek FC TMDL. Those proposals might include a combination structural, non-structural BMPS and outreach education. The Department would like emphasize that implementation of the load allocation (LA) component of the TMDL is voluntary at this time and 319 grant opportunities are available. 319 grant opportunities cannot be awarded for projects covered under any permitting requirements (inlcuding all NPDES permits). The Department acknowledges that projects involving structural BMPs might be limited within the Steele Creek Watershed; however, structural BMPs might be an effective tool reducing some non-human FC bacteria concentrations instream.