South Carolina
Department of Health and Environmental Control

Total Maximum Daily Load Development for Thompson Creek: Stations PD-246 and PD-247 Fecal Coliform Bacteria

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Bureau of Water

DHEC

PROMOTE PROTECT PROSPER

South Carolina Department of Health
and Environmental Control

Abstract

These TMDLs were developed for Thompson Creek (03040201-060), a small stream that is a tributary of the Pee Dee River. The watershed area affected by these TMDLs is located predominately in Chesterfield County, South Carolina (100 square miles), with several large tributary systems flowing south from Anson County, North Carolina (49.8 square miles).

The Clean Water Act requires that impaired water bodies be listed under Section 303(d) of the Act. Waters that are placed on the 303(d) list must have a TMDL determined for the pollutant of concern. Thompson Creek is impaired at water quality monitoring stations PD-246 and PD-247 near the Town of Chesterfield. Concentrations of fecal coliform bacteria exceeded the standard of 400 coliform forming units (cfu) per 100ml in more than ten percent of the samples acquired at these stations. Due to these fecal coliform bacteria excursions, recreational uses are not supported. The State of South Carolina has, therefore, placed Thompson Creek at PD-246 and PD-247 on the 303(d) list.

The part of Thompson Creek watershed that is included in this report is predominantly forest, with substantial cropland, and small amounts of pasture and wetlands. Less than 1 % of the land area is built-up. There is one permitted discharger in the watershed, the Town of Chesterfield’s wastewater treatment facility, which is just upstream of PD-247. The nonpoint sources that have been determined to be contributors to Thompson Creek impairment include wildlife; grazing livestock and livestock depositing manure directly into streams; land application of poultry litter; and malfunctioning septic systems.

HSPF was selected as the model to simulate existing conditions and load reduction allocations for the portion of the watershed upstream of PD-246. The application of this model to the project watershed area of Thompson Creek accounted for localized seasonal variations in hydrology, climatic conditions, and watershed land use activities. A load duration curve was generated to estimate loads for PD-247. The existing load and the TMDL load allocation (LA) for PD-247 were determined from the load duration curve.

The total maximum daily loads (TMDL) for these two creeks for fecal coliform bacteria were determined to be 5.56E+12 cts /30-days (PD-246) and 4.74E+14 cts /30-days (PD-247). These TMDL values would require reductions of 68 % and 82 % in the current loads to the creeks, respectively, to meet standards.

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NOTICE

The TMDL for Thompson Creek at PD-246 was developed through a 319 grant. Thompson Creek is also impaired at PD-247, just down stream of PD-246. Rather than redoing the modeling work for this small additional area, the simpler Load-duration curve method was used for this additional station. Documentation for PD-247 has been added.

1.0 BACKGROUND

Levels of fecal coliform bacteria can be elevated in water bodies as the result of both point and nonpoint sources of pollution. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for water bodies that are not meeting designated uses under technology-based pollution controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and in-stream water quality conditions so that states can establish water quality-based controls to reduce pollution and restore and maintain the quality of water resources (USEPA, 1991).

The South Carolina Department of Health and Environmental Control (DHEC) has identified Thompson Creek in Chesterfield County as being impacted by fecal coliform bacteria at two locations, as reported on the State of South Carolina 1998, 2000, and 2002 303(d) lists of water quality impaired waters. The two monitoring stations are about 2 miles apart; PD-246 at S-13-243 and PD-247 at SC-9. It is assumed that water bodies possessing high concentrations of fecal coliform bacteria may also be contaminated by pathogens, or disease producing bacteria or viruses, which may exist in fecal material. Some waterborne diseases associated with fecal material include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal contamination is, therefore, an indicator that a potential health risk exists for individuals exposed to this water.

1.1 Watershed Description

Thompson Creek is a small stream that rises near Pageland and flows through the Town of Chesterfield before it meets the Little Pee Dee River. The watershed is located in Chesterfield County, South Carolina and Anson County, North Carolina. This report is concerned with that part of the watershed upstream of SC-9, which has an area of 100 square miles. Several large tributaries, including Deadfall, Clay, Cedar, and Jimmies Creeks, flow south from Anson County (watershed area of 49.8 square miles).

Thompson Creek has two water quality monitoring stations: PD-246 at secondary road S-13-243 and PD-247 at SC-9. References to the project watershed indicate the part of the watershed draining to PD-246. Jimmies Creek and the small section of Thompson Creek between PD-246 and PD-247 will be discussed separately. The predominant soil types consist of an association of the Alpin-Tatum-Candor-Troup series, where the erodibility of the soil (K) averages 0.20; and the slope of the terrain averages 12 percent, ranging from 0 to 25 percent. The Natural Resources Conservation Service (NRCS) District Conservationist for Chesterfield County, South Carolina estimates that approximately 90 percent of the cropland acreage in the watershed project area is located on Highly Erodible Land (1999).

As portrayed in the Multi-Resolution Land Characteristics (MRLC) consortium's National Land Cover Data, land use in the Thompson Creek watershed project area

(Table 1-1) is predominately forest (74.7 percent); the remaining being cropland, (18.7 percent), pasture (6.1 percent), and developed (0.6 percent). The eight sub-basins in the project watershed area include:

- Lower Thompson Creek main-stem (18.7 square miles);
- Middle Thompson Creek main-stem (12.4 square miles);
- Upper Thompson Creek main-stem (8.1 square miles);
- Deep Creek (36.2 square miles);
- Cedar Creek (7.4 square miles);
- Deadfall Creek (30.2 square miles);
- Clay Creek (12.3 square miles); and
- Stone House Creek (8.0 square miles).

The following sub-watershed was not part of the 319 project and will be discussed separately:

- Jimmies Creek (13.1 square miles).

Table 1-1 shows that the most concentrated agricultural land use activities occur in two of the smaller Sub-basins: Cedar Creek (42.7 percent) and the Upper Thompson Creek main-stem (45.8 percent). Conversely, Deadfall Creek is the second largest Sub-basin, but contains the lowest concentration of agricultural land uses (7.9 percent). Agricultural land use information pertinent to fecal coliform bacteria loading in the Thompson Creek watershed project area provided by the NRCS field office personnel in May of 1999 included the following:

Chesterfield County, South Carolina

- Approximately 6,000 acres of active cropland; of which 3,500 acres utilize poultry litter as a main source of fertilization;
- Approximately 4,000 acres of pasture; of which 1,500 acres utilize poultry litter as a main source of fertilization;
- Nine poultry houses producing 3,500 tons of litter annually. Eight of the houses are concentrated in the Stone House Creek Sub-basin. Additional quantities of poultry litter are trucked in from North Carolina. Most litter is stockpiled prior to application, and the majority of poultry litter is over applied.

Anson County, North Carolina

- Approximately 5,700 acres of active cropland, much of which is receiving poultry litter;
- Approximately 1,350 acres of pasture and hay land;
- Two large swine operations (one of which possesses 880 animals) and two nursery operations (possessing a total of 4,400 swine) are active.
- Boiler and turkey operations possessing a total of approximately 400,000 and 44,000 birds, respectively.

The watershed for Jimmies Creek is largely forested, but is 23 % in agricultural land use and 12.5 % in wetlands (Table 1-2). Approximately 31 % of the watershed is in Anson County, North Carolina.

There are no permitted discharge facilities in the project watershed area or the area upstream of PD-246. The Town of Chesterfield's wastewater treatment facility is located downstream of Jimmies Creek and just upstream of monitoring station, PD-247. It is estimated that approximately 300 to 1,000 septic systems are currently in use in the project watershed area. The Town of Chesterfield relies on Thompson Creek as a source of public drinking.

1.2 Water Quality Standard

The impaired stream, Thompson Creek above S-13-243, is designated as Class Freshwater. Waters of this class are described as follows:

> Freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses. (R.61-68).

The South Carolina standard for fecal coliform bacteria in Freshwater is:

> Not to exceed a geometric mean of 200/100 ml, based on five consecutive samples during any 30-day period: nor shall more than 10 percent of the total samples during any 30-day period exceed 400/100 ml. (R.61-68).

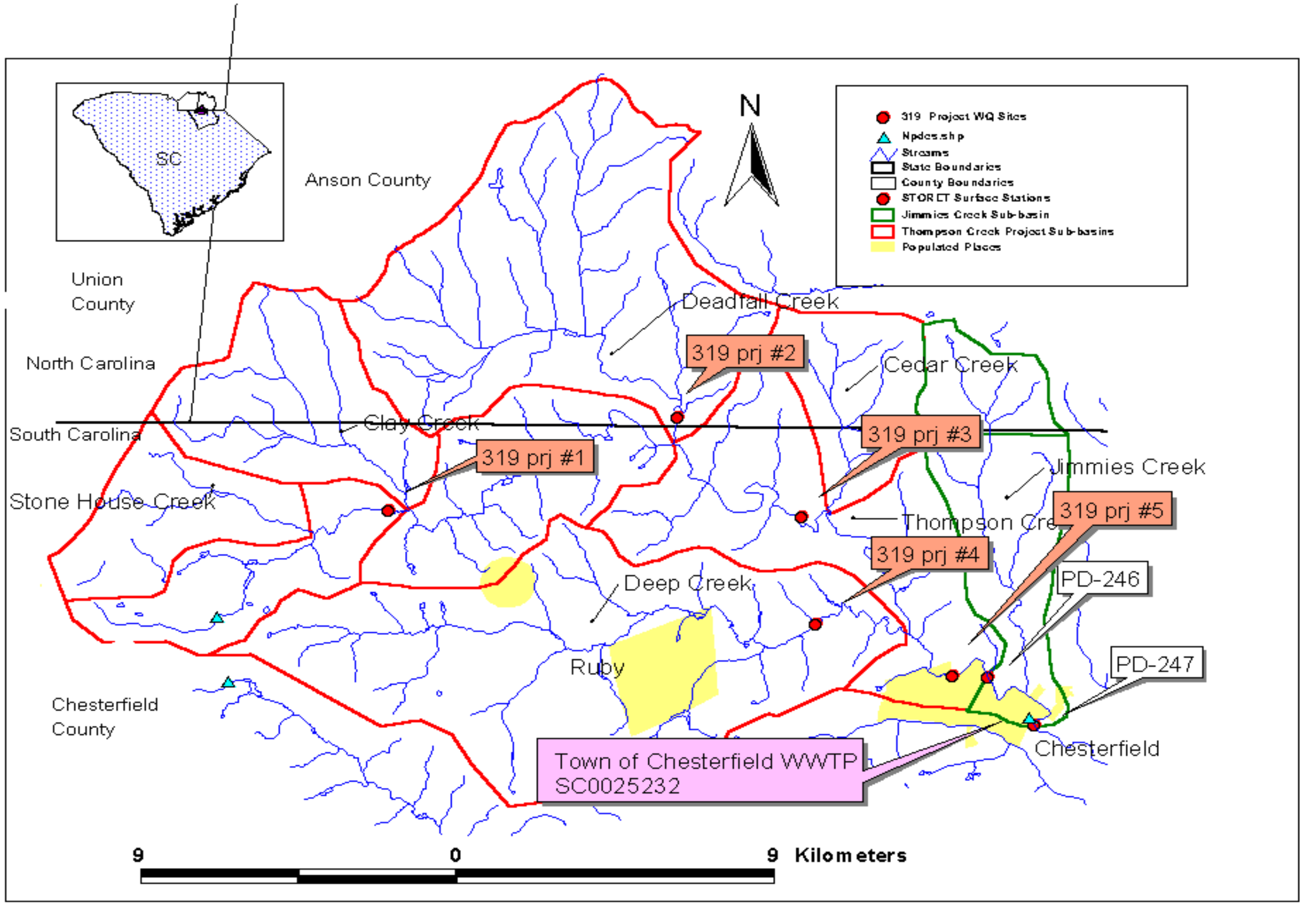

Figure 1-1. Map of the Thompson Creek watershed, Chesterfield County, SC and Anson County, NC.

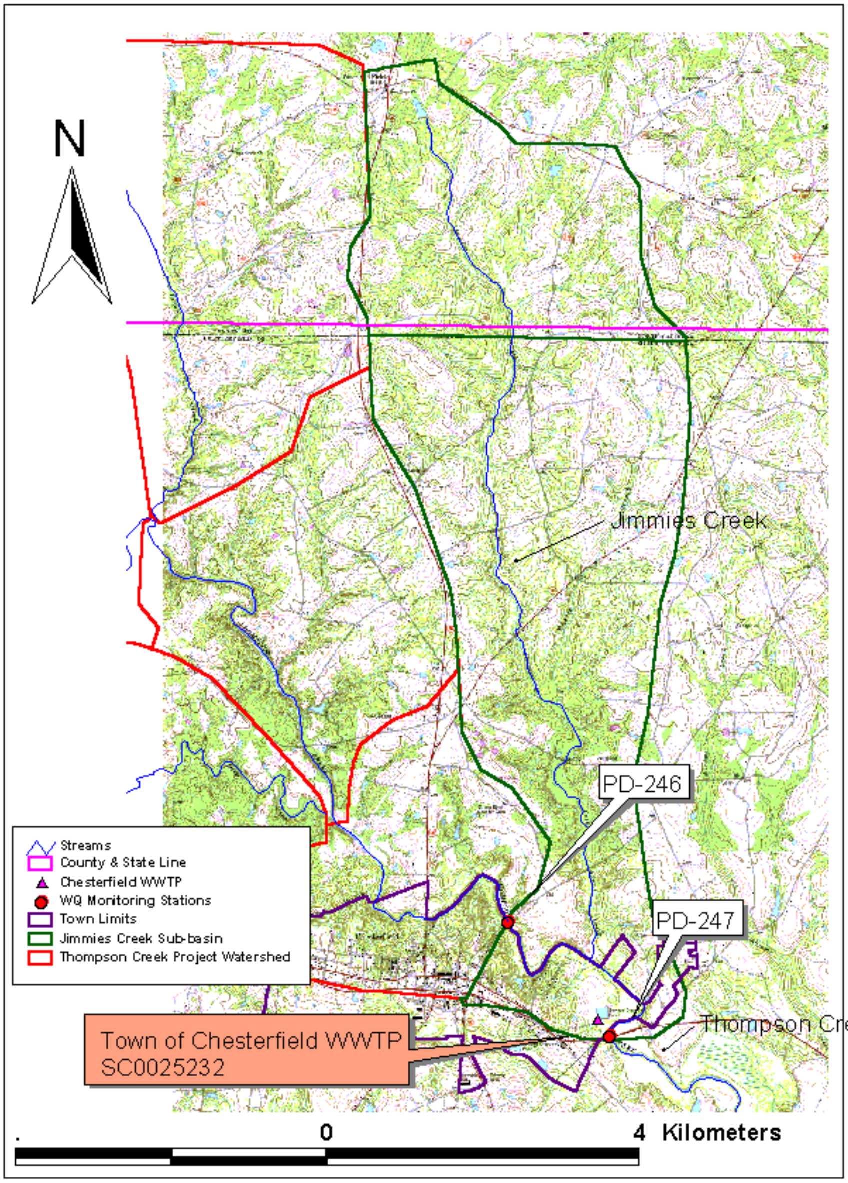

Figure 1-2. Map of the Jimmies Creek sub-basin of Thompson Creek watershed.

Table 1-1. Area and land use by sub-basins and counties.

Sub-Basin	Name	Area	Area in Anson County		Area in Chesterfield County		Area in Union County		Land Use (%)			
		(acres)	(acres)	%	(acres)	%	(acres)	%	Forest	Pas-ture	Crop-land	Deve-loped
1	Lower Thompson Creek	11,944	1,114	9.3	10,830	90.7	0	0.0	65.4	7.0	25.3	2.3
2	Middle Thompson Creek	7,938	1,254	15.8	6,684	0.8	0	0.0	81.8	5.2	12.9	0.0
3	Upper Thompson Creek	5,168	0	0.0	5,168	1.0	0	0.0	53.3	6.5	39.3	0.9
4	Deep Creek	23,178	0	0.0	23,178	1.0	0	0.0	70.5	4.2	24.7	0.6
5	Cedar Creek	4,727	3,436	72.7	1,291	0.3	0	0.0	57.3	9.6	33.1	0.0
6	Deadfall Creek	19,357	19,234	99.4	123	0.0	0	0.0	92.1	3.1	4.8	0.0
7	Clay Creek	7,893	4,302	54.5	3,248	0.4	342	0.0	77.5	12.8	9.7	0.0
8	House Creek	5,099	0	0.0	5,081	1.0	17	0.0	71.5	10.6	17.6	0.2
All	Thompson Creek up-stream of S-13-243	85,304	29,340	34.4	55,603	0.7	359	0.0	74.7	6.1	18.7	0.6

Table 1-2. Land use in the Jimmies and Thompson Creek watersheds (Thompson Creek between PD-246 and PD-347 only).

Land Use	Area (hectares)	Area (acres)	Percentage
Water	7.0	17.4	0.2%
Developed	54.8	135.3	1.6%
Barren or Mining	1.7	4.1	0.0%
Transitional	68.2	168.6	2.0%
Forest	2046.9	5057.9	60.5%
Agriculture - Pasture	29.2	72.2	0.9%
Agriculture - Cropland	755.5	1866.8	22.3%
Wetlands	421.9	1042.6	12.5%
Total	3385.2	8364.9	100.0%

2.0 WATER QUALITY ASSESSMENT

Prior to a detailed source assessment and modeling analysis, it is helpful to examine the spatial, seasonal, and hydrologic variability and co-variability in bacteria data. Such information provides insight into the mode and magnitude of coliform loading to the stream. For example, high concentrations during low-flow, warm weather conditions are consistent with in-stream sources (e.g., livestock lounging in the stream). Similarly, if a station had consistently higher concentrations than other stations, one would examine the upstream drainage area of that station for sources that are not as prevalent in the other drainage area of other stations.

For Thompson Creek above highway S-13-243, there are two primary sources of fecal coliform data collected since 1990 that aided this assessment. DHEC has performed bacterial monitoring during the warm weather months (May-October) at station PD-246, on highway S-13-243 (Figure 1-1) since the 1970s. Most samples from this station were collected under dry weather conditions, and results from this station were the basis for the 303(d) listing of this segment as impaired for bacteria. Limited bacteria data were also available from three other DHEC stations in the study area (PD- 145, PD-146, and PD-148), although none of these data were more recent than 1980. Water quality data from PD-246 are tabulated in Appendix A.

Although DHEC station PD-246 provides a useful long-term record, additional monitoring was desired to attain better spatial, seasonal, and hydrologic coverage of the watershed. Therefore, five additional water quality monitoring stations were established as part of the 319 project (Figure 1-1). The 319 project stations were sampled nine times between November 2000 and November 2002, under different seasonal conditions. Samples were collected under both dry weather and storm events, although the 2000-2002 drought limited the opportunity to sample a wide range of hydrologic events. Water quality data collected during the 319-project are tabulated in Appendix A.

Water quality data collected at PD-247, Appendix A, exhibit a similar pattern to those collected at PD-246. PD-247 had a higher violation rate for the period of record, 46 %, than PD-246 (37 %).

2.1 Spatial Variability

Bacteria data collected at the five 319 project stations shows that the five stations tend to “track” together with regard to magnitude of fecal coliform concentration (Figure 2-1). In other words, the concentration was of a similar order of magnitude at most stations during a particular monitoring event. No station was *consistently* higher or lower than present throughout the basin.

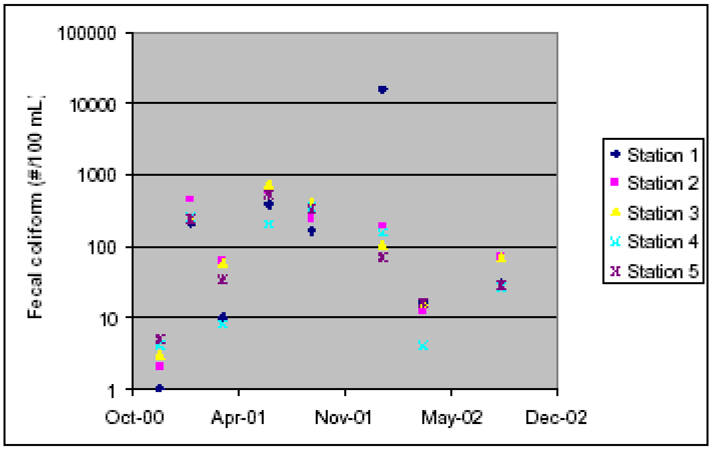

Figure 2-1. Fecal coliform concentrations v. time at the five 319 project stations.

2.2 Seasonal Variability

Fecal coliform concentration had a marked seasonal variability in the study area, in that the May-September period had significantly higher mean concentrations than the colder periods of the year (Figure 2-2). A significant drop-off in mean concentration occurred in October, and January had the lowest mean concentrations of all months for which data were available. There are several explanations for the observed seasonal pattern. A certain amount of temperature-dependent fluctuation is expected due to higher coliform die-off rates in colder periods of the year. For obvious reasons, livestock such as cattle spend much more time in the stream during hot weather than during cold weather. Finally, animal waste such as poultry litter is applied to the land surface primarily during the warm weather months.

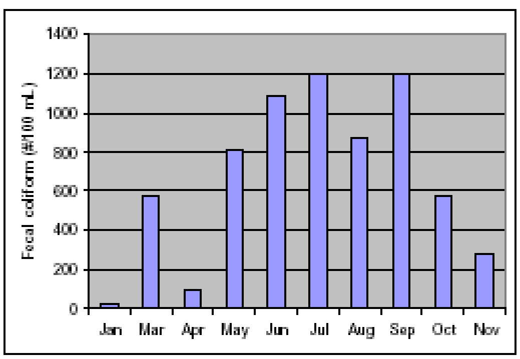

Figure 2-2: Mean fecal coliform concentrations v. month in the Thompson Creek study area. Mean values were calculated using 1970-2002 data from DHEC stations PD-145, PD-146, PD 147, PD-246 and 319 project stations 1-5.

2.3 Hydrologic Variability

Thompson Creek lacks a USGS stream gage and thus does not have an historical streamflow record for comparison with bacteria data. However, it is possible to assess hydrologic variability of fecal coliform concentration with estimates of streamflow predicted by the HSPF model created for the 319 project. Described more fully in section 4, this model was used to estimate streamflow as a function of hourly precipitation data, potential evapo-transpiration, and hydrologic characteristics of the watershed. Although not as accurate as USGS data, these estimate provide a means to classify bacteria samples into low, medium, and high flow categories.

A scatterplot of fecal coliform concentration v. estimated streamflow (Figure 2-3) demonstrates that the geometric mean of fecal coliform concentration remained in the 100-1,000 ct/100 mL range over a wide range of flow conditions. The data appear to be much more variable under low-to-moderate streamflow conditions than when streamflow exceeds 500 cfs. However, this can be attributed to the fact that there are many more data in the low-to-moderate streamflow range, and thus a higher probability of observing data over a wider range of concentrations. The highest concentration observed (actually a censored datum, “too numerous to count” and plotted as the 16,000 ct/100 mL reporting limit) was collected under very low flow conditions—about 6 cfs.

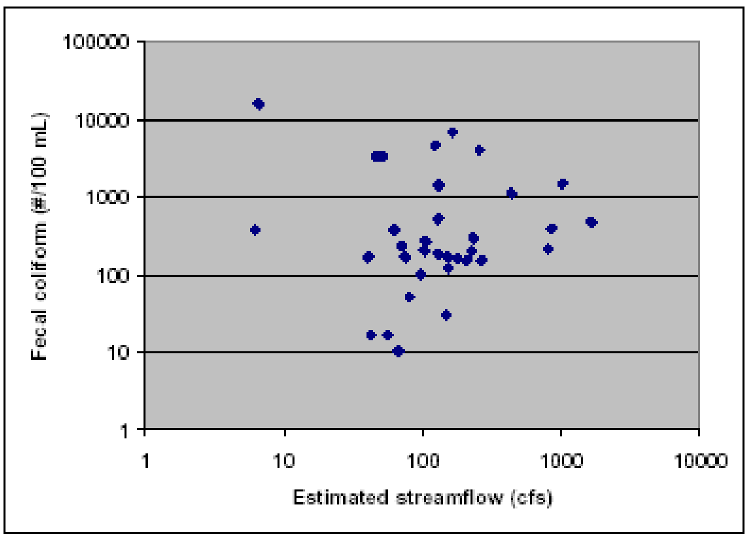

Figure 2-3: Fecal coliform concentration v. estimated streamflow in the Thompson Creek study area, 1995-2002. Streamflow estimates were obtained from HSPF model output.

Table 2-1 summarizes the geometric mean fecal coliform concentrations for a range of streamflow percentiles. These statistics would suggest a weak but positive correlation between streamflow and fecal coliform concentration in Thompson Creek. However, Mann-Whitney tests do not lead to rejection of the null hypothesis that fecal coliform concentrations are equal when streamflow exceeds the 75th percentile or 95th percentile, compared with when streamflow is below these values (Table 2-2).

Table 2-1. Geometric Mean of Fecal Coliform Concentration v. Estimated Streamflow. [Based on HSPF estimates of stream flow and all DHEC and 319 project bacteria data collected in study area during 1990-2002]

Estimated Streamflow Percentile Range	**Estimated Streamflow Range (cfs)**	**Number of Samples**	**Geometric Mean Fecal Coliform (ct/100 mL)**
0-25	0-72	10	274
25-75	72-191	14	280
75-90	191-341	5	350
90-99	341-1410	5	578

Table 2-2. Results of Mann-Whitney Tests of Significant Differences in Fecal Coliform Concentration [Null hypothesis is that median fecal coliform concentrations are equal above and below the cited streamflow threshold]

Estimated Streamflow Percentile	**Estimated Streamflow Threshold (cfs)**	**p-value of Mann-Whitney Test**	**Reject Null Hypothesis at 95% confidence level?**
75	191	0.316	No
90	341	0.138	No

If dry weather sources were not important, concentrations would be expected to decrease under low flow conditions. On the other hand, if washoff-related sources were unimportant, storm events would be expected to dilute and reduce the coliform concentrations. The fact that coliform concentrations remain relatively high under both low and high flow conditions indicates that both dry-weather and washoff- related sources of coliform loading to the stream are important under different hydrologic conditions. Potential dry weather sources include livestock in streams, failing septic systems, and straight-pipe discharges of wastewater. Runoff-related sources include livestock manure deposited on pastureland, wildlife, and application of poultry litter.

A major purpose of the source assessment (Section 3) and modeling (Section 4) is to quantify the relative importance of these variance sources in the Thompson Creek watershed. To be successful, the water quality modeling performed should reproduce the spatial, seasonal, and hydrologic patterns described in this section. Specifically, the calibrated model should predict fecal coliform concentrations that: (1) are similar at different locations throughout the basin at any particular time; (2) show a marked seasonal variation; and (3) are elevated under both low- flow and high- flow conditions, though perhaps from different sources.

3.0 SOURCE ASSESSMENT

The source assessment phase of this study involved the identification and quantification of fecal coliform loads to the land surface in the Thompson Creek watershed, or directly to the stream in the case of in-stream animals and failing septic systems. Such estimates are used as input to the dynamic water quality model, as described in Section 4. The accuracy and precision of these estimates are reduced by many sources of uncertainty and environmental variability. However, both local knowledge and a large body of previous studies and tools provide a basis for assessing the potential order-of- magnitude of various bacteria sources. This section describes how various sources were quantified for input into the HSPF model.

In order to remain consistent with previous regulator-approved studies, this study followed methods described in the *Protocol for Developing Pathogen TMDLs* (USEPA, 2001). The basic tool for quantifying various sources was the Bacterial Indicator Tool (BIT) developed by USEPA as part of its BASINS family of software expressly for this purpose (USEPA, 2000a). The BIT is a spreadsheet that calculates HSPF loading factors for various animal sources including wildlife, unconfined livestock, and manure application as fertilizer. The spreadsheet requires user- input of the number of deer, cattle, chickens, etc. in each subbasin, as well as the acreage of forest, pastureland, cropland, and built- up land in each subbasin. For compatibility with the BIT, the Anderson level II land use classifications of the 1992 National Land Cover Data (NLCD) were aggregated into these four land use classifications, and the acreage of each land use classification was calculated for each of the eight sub-basins of Thompson Creek above highway S-13-243 (Figure 3-1; Table 1-1).

3.1 Point Sources

There are no regulated point source discharges to Thompson Creek and its tributaries above highway S-13-243 (PD-246). However, the Town of Chesterfield WWTP discharges just downstream of the model stream watershed and upstream of PD-247. This facility is permitted to discharge 0.45 mgd (1.7E+06 l/day) of wastewater. Flow and fecal coliform data from this facility is presented in Appendix B. An assessment of the DMR data indicates that the WWTP was not a major contributor to the impairment of Thompson Creek at PD-247, even though the facility has had some apparent violations of the standard. DHEC has taken enforcement actions requiring treatment upgrades and diversion of excess flows to avoid future violations of permit limits.

3.2 Nonpoint Sources

Nonpoint sources of fecal coliform loading that were explicitly considered included wildlife, cattle, poultry litter application, and failing septic systems/straight pipe discharges, as described in this section. Estimates of the number of fecal coliform counts per animal per day were based on default values of the BIT and are summarized in Table 3-1. Other sources are expected to be relatively minor by comparison, and are implicitly modeled to some extent by inclusion in the other sources. For example, the small number of horses, sheep, and goats in the basin can be conceptually lumped into the cattle source.

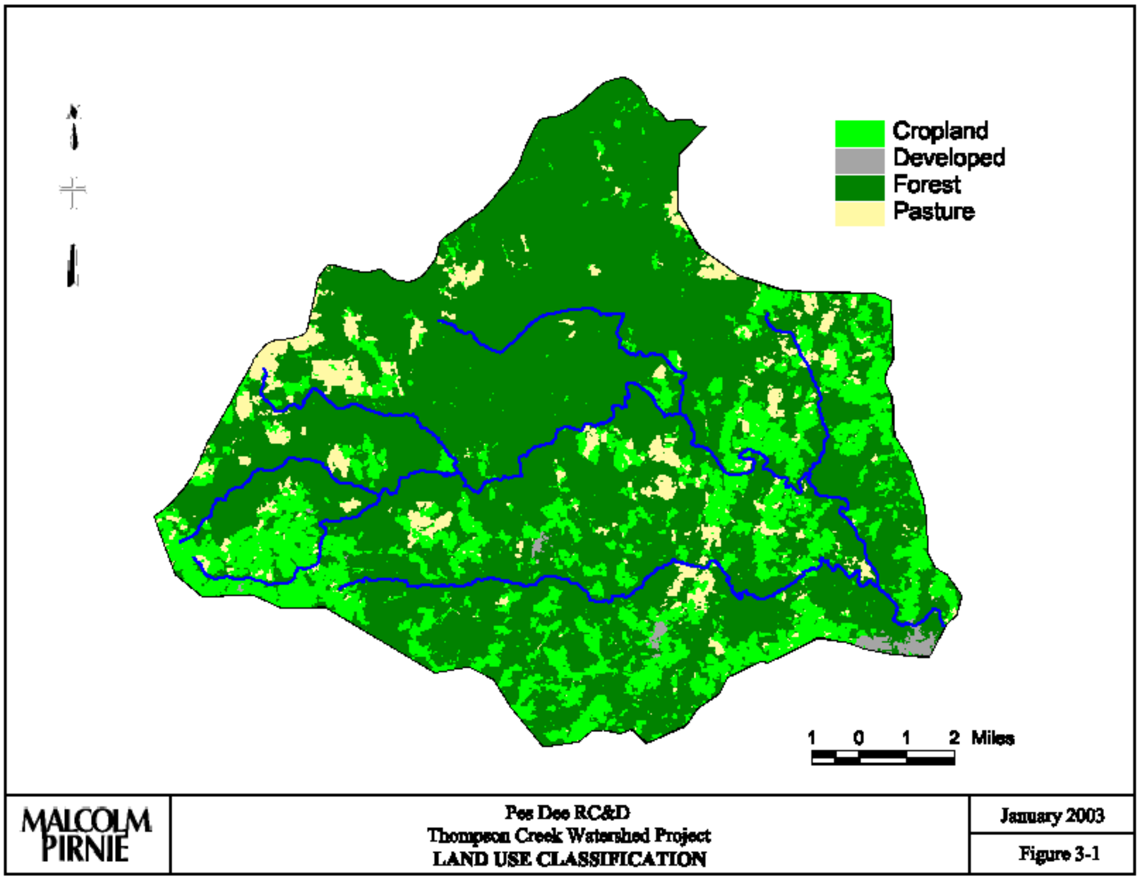

Figure 3-1. Land use map of the Thompson Creek project area.

There are a few confined hog operations in the North Carolina portion of the basin that spray-irrigate with water from lagoons that contain hog manure. Although this is a potential source of bacteria loading, the North Carolina sub-basins did not have higher fecal coliform concentrations than other parts of the Thompson Creek watershed, and so spray irrigation of water from hog lagoons was not explicitly modeled. Rather, this source is implicitly included as part of the "background" coliform concentrations as described in section 3.2.1.

3.2.1 Wildlife

A value of 35 deer per square mile was assumed for forest, pasture, and cropland, based on estimates provided for mid-northern Chesterfield County by the South Carolina Department of Natural Resources (personal comm., Charles Ruth, Deer Project Supervisor, SCDNR, 4 Nov 2002). A value of 32 raccoons per square mile was assumed for these same land uses, based on the upper end of the raccoon density range given in the South Carolina Piedmont according the SCDNR Wildlife Management Guide for Raccoon (1997). Although the actual raccoon density might be as much as 10 times lower, the upper end of the range was used to implicitly account for 'other' wildlife such as birds, rodents, etc. In-stream contributions from the wildlife sources were assumed to result in a 30 ct/100 mL background concentration under base flow conditions, similar to the background wildlife contributions assumed for previous South Carolina TMDL studies (SCDHEC, 2000).

Table 3-1. Fecal coliform loading rates from various sources.

Source	Fecal Coliform loading rate	Units	BIT Reference
Deer	5.0E+0	Counts/animal/day	Best professional judgement.
Raccoon	1.2E+0	Counts/animal/day	Best professional judgement.
Cattle	1.0E+11	Counts/animal/day	ASAE, 1998
Poultry litter	1.3E+0	Counts/gram of litter	LIRPB, 1978
Septage	1.0E+0		Horsley and Witten, 1996
Developed Land	1.1E+0	Counts/acre/day	Homer, 1992

3.2.2 Cattle

Cattle density on pastureland was estimated by dividing the total number of cattle in Chesterfield and Anson Counties (according to the USDA 1997 Census of Agriculture) by the area of pastureland in those counties (according to the NLCD). This resulted in an estimate of about 4,700 cattle in the Thompson Creek watershed. There are no significant dairy and few feedlot operations in the watershed (pers. comm., Charles Babb, District Conservationist, Chesterfield Co. SWCD, 17 Jun 2002), and so cattle were assumed to be evenly distributed on pastureland in each sub-basin. Other key assumptions included:

- Cattle spend the following percentage of time in streams[1]
  - April 33%
  - May 33%
  - June 50%
  - July 50%
  - August 50%
  - September 33%
  - October 33%
  - November 17%

- Cattle manure is not collected nor applied as fertilizer to cropland (pers. comm., Charles Babb, District Conservationist, Chesterfield Co. SWCD, 17 Jun 2002).

[1] During the model calibration phase, the loading from in-stream cattle was greatly reduced. These values represent initial estimates based on default values of the BIT.

3.2.3 Poultry Litter

Assumptions regarding the magnitude, timing, and frequency of poultry litter application were based largely on the local knowledge and professional judgment of the District Conservationist, Charles Babb. Poultry litter was assumed to be applied to both cropland and pastureland at a rate of 2.75 tons/acre. In any given year, 60% of cropland and 25% of pastureland was assumed to receive an application. Most of the litter application occurs in the spring, but continues through mid-October according to the schedule shown in Table 3-2.

Table 3-2. Monthly Breakdown of Annual Poultry Litter Application

Month	Litter Application to Cropland (%)	Litter Application to Pastureland (%)
February	5	4
March	27	23
April	36	30
May	22	19
June	2	5
July	2	5
August	2	5
September	2	5
October	2	5

3.2.4 Failing Septic Systems

The Thompson Creek watershed is relatively sparely populated except in the vicinity of the Town of Chesterfield itself, which is served by the Town of Chesterfield Wastewater Treatment Plant. The total number of septic systems within the modeled portion of the Thompson Creek watershed was estimated to be 1,600 (or about 12 per square mile). based on the average septic system density in Chesterfield County according to 1990 census data.

The failure rate of septic system was assumed to be 5 percent. Implicitly included with failing septic systems are “straight-pipe” discharges of wastewater directly to the stream. Default values of the BIT that were used for this project include 2.5 persons served per septic system, a volume of 70 gallons wastewater generated per person per day, and a fecal coliform count of 10,000 counts per 100 mL in wastewater reaching the stream (Horsley and Witten, 1996).

3.2.5 Urban/Suburban Runoff

Runoff from developed land can have elevated concentrations of fecal coliforms from domestic animals and, to a lesser extent, wildlife. Rather than explicitly calculating the numbers of cats, dogs, etc. in the watershed, the BIT uses literature-based rates of fecal coliform accumulation on different types of built-up land. For the Thompson Creek watershed, an average value of 1.1×10^7 counts/acre/day based on the work of Horner

(1992), as referenced by the BIT. Because the modeled portion of the Thompson Creek watershed contains such a small proportion (<1%) of developed land, model results are not sensitive to this value.

4.0 MODELING – PD-246

The primary tool selected for modeling of bacterial transport in the Thompson Creek basin was the Hydrologic Simulation Program—Fortran (HSPF). HSPF is a dynamic model that is capable of simulating most major hydrologic processes (evapo-transpiration, runoff, infiltration, open channel flow, etc.) as well as the transport of a variety of different types of water quality constituents. Inputs to the model include time series of precipitation, potential evapo-transpiration, and any point source or continuous loads to the stream. For modeling the accumulation and washoff of bacteria, the user must also provide information on monthly loading rates of bacteria to the land surface based on information such as that discussed in Section 3. HSPF outputs include predictions of streamflow, loads, and in-stream concentrations over time and at different locations within the basin. Calibration of HSPF requires adjustment of a large number of parameters that describe the hydrologic characteristics of the watershed, as well as parameters related to the transport of the modeled water quality constituent(s).

HSPF was selected for this project because it is powerful and flexible enough to simulate complex loading scenarios under a wide range of seasonal and hydrologic conditions, and has a successful track record of DHEC and USEPA approval for similar pathogen TMDL applications across the nation. The USEPA endorsement of this approach is explicit in the *Protocol for Developing Pathogen TMDLs* (USEPA, 2001). The use of HSPF for pathogen TMDLs has been greatly facilitated by USEPA's development of the BASINS family of software including the BASINS-to HSPF utility (for building an HSPF user's control input file from GIS data), WinHSPF (a graphical user interface for HSPF), WDMUtil (for creating and editing time series files), GENSCN (for post-processing), and the BIT (for estimating coliform loads to the land surface and stream). Primary disadvantages of HSPF are the intensive input data requirements, large number of model parameters that require estimation, and time requirements for set-up, calibration, and post-processing. However, it was determined that sufficient data and resources were available for successful application of HSPF to Thompson Creek.

4.1 Approach and Model Segmentation

For modeling purposes, Thompson Creek above highway S-13-243 was conceptually divided into eight sub-basins and eight corresponding stream segments (Figure 4-1). Each of the four major land uses (forest, pasture, cropland, and developed) within each sub-basin represented a single pervious land segment (PERLND) within the model, resulting in a total of 28 PERLND in the modeled area. Each stream segment represented a single stream reach (RCHRES). The areas of each PERLND and length of each RCHRES are tabulated by sub-basin in Appendix C. Due to the negligible proportion of impervious land within the modeled area, no impervious land segments (IMPLNDs) were included.

Rather, the small developed land segments were simulated as PERLNDs of low perviousness.

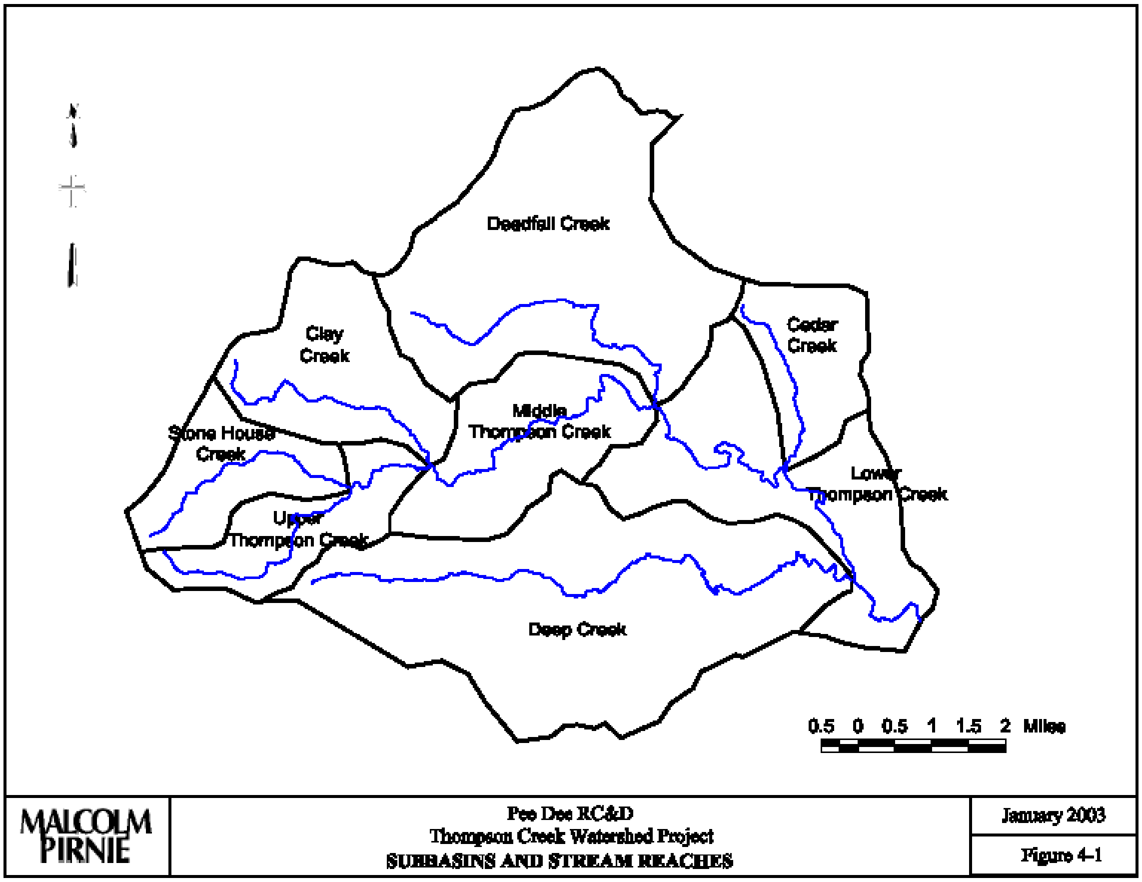

Figure 4-1. Sub-basin delineation of Thompson Creek for the HSPF model.

The modules of HSPF modules employed for the Thompson Creek model are summarized in Table 4-1. The hydrologic simulation did not include simulation of SNOW because of the generally mild winters of the study area, and the fact that warm weather conditions are more critical with respect to the fecal coliform water quality standard. Within the PQUAL section, coliform bacteria were modeled as constituents that accumulate at specified monthly rates (with a maximum accumulation that is not exceeded) and are washed off into the stream during storms (QUALOFs). Accumulation rates varied by month and by land type, based on assumptions discussed in Section 3.2.

Within the stream, coliform counts were modeled using the GQUAL section as constituents that are transported by advection only, without settling, resuspension, or adsorption. However, first-order decay of coliform counts was simulated. In-stream cattle and failing septic systems were treated as point sources of coliform counts to each stream reach. In-stream contributions from wildlife were simulated by assigning a 30 ct/100 mL concentration to base flow from each PERLND.

The Thompson Creek model was executed at a one- hour time step. Based on the availability of input hydrologic data (see Section 4.2) the model calibration period extended from October 1, 1995 to June 28, 2002, or about 6.75 years.

Table 4-1. HSPF Modules Employed for the Thompson Creek Model

Module	Section	Subroutine(s)	Comment
PERLND	PWATER	ICEPT, SURFAC, INTFLW, UZONE, LZONE, GWATER, EVAPT	Standard hydrologic simulation; no simulation of snow.
	PQUAL	QUALOF	Accumulation and removal of a constituent (fecal coliform counts) by washoff
		QUALGW	Assigned a coliform concentration to base flow to simulate in-stream wildlife sources.
RCHRES	HYDR	ROUTE, AUXIL	Simulation of open channel flow.
	ADCALC	-	Required to simulate advective transport of constituents.
	GQUAL	DDECAY	Simulation of coliform bacteria as an advectively-transported constituent with first-order decay kinetics.

4.2 Meteorological Data Sources

HSPF requires input times series of precipitation and potential evapo-transpiration (PET) at the time step of the model—in this case, hourly. The closest station for which hourly precipitation data were available the was the National Weather Service (NWS) cooperative station 380736 in Bishopville, SC, about 37 miles south of the Town of Chesterfield. The distance between this weather station and the watershed of interest was expected to cause some inaccuracies, especially with regard to the timing and magnitude of isolated thunderstorm-type events. However, the Bishopville data were expected to be more accurate for winter-type rain events and generally useful for calibrating the seasonal and annual flow volumes.

PET was estimated from two data sources. Daily pan evaporation data were available from the NWS cooperative station 387666 (Sand Hills Research Station) in Chesterfield Co. for the period October 1995 to June 1998. These data were multiplied by a pan coefficient (0.52) to estimate PET, and were disaggregated into hourly data using the PET disaggregation utility of WDMUtil. For the remaining period of record, PET was calculated from daily solar radiation data from NWS cooperative station 314464 at Jackson Springs, NC and daily temperature extreme data from NWS cooperative station 380736 in Bishopville, SC. Daily PET was calculated using the Jensen PET function of WDMUtil, and then disaggregated to an hourly time step using the using the PET disaggregation utility of WDMUtil.

4.3 Hydrologic Simulation

Initial values for HSPF parameters related to hydrology were selected from a variety of sources to represent the soil, geologic, vegetative, and topographic conditions of the four pervious land types (forest, pasture, cropland, and developed) in the Thompson Creek watershed (Table 4-2). *BASINS Technical Note 6—Estimating Hydrology and Hydraulic Parameters for HSPF* (USEPA, 2000b) provided guidance on typical ranges of these parameters that were useful for selecting initial values. The length of overland flow (LSUR) slope of the overland flow plane (SLSUR) were initially calculated by the BASINS-to-HSPF utility using information in the National Hydrographic Dataset and the USGS Digital Elevation Model (DEM) for the area of interest. The channel cross-sectional geometry and flow rating tables (F-TABLES) were also calculated by the BASINS-to-HSPF utility, which relies on relations between channel geometry and sub-basin area developed by the USGS (USEPA, 2001).

Table 4-2 Hydrologic parameters used in the Black Creek/Thompson Creek HSPF Models.

Parameter	Units	Initial/Final Value				Comment
		Forest	Pasture	Cropland	Developed	
LZSN	in	9.5/4	9.5/4	9.5/4	9.5/4	Initially estimated as 1/8 the annual rainfall plus four inches; adjusted downward during calibration.
INFILT	in/hr	0.3/0.2	0.2	0.2	0.05/0.04	Typical class B soils except for lower permeability developed land.
LSUR	ft	variable/300	variable/300	variable/300	variable/300	Initially calculated by B2HSPF utility; adjusted downward during calibrations.
SLSUR	ft/ft	0.01	0.01	0.01	0.01	Initially calculated by B2HSPF utility; estimated from DEM.
KVARY	in^{-1}	0	0	0	0	No evidence for seasonal variations in base flow recession rate.
AGWRC	--	0.99/0.98	0.99/0.98	0.99/0.98	0.99/0.98	Adjusted downward during calibration.
INFEXP	--	2.0	2.0	2.0	2.0	Recommended default value (USEPA, 2000b)
INFILD	--	2.0	2.0	2.0	2.0	Recommended default value (USEPA, 2000b)
DEEPFR	--	0.0	0.0	0.0	0.0	Losses to deep groundwater not significant.
BASETP	--	0.0	0.0	0.0	0.0	Riparian ET not significant.
AGWTP	--	0.0	0.0	0.0	0.0	Wetland ET not significant.
CEPSC	in	0.18/0.1	0.10/0.1	0.15/0.1	0.05/0.1	Adjusted downward during calibration.
UZSN	in	1.33/0.52	0.760.39	0.76/0.39	0.76/0.12	Adjusted downward during calibration.
NSUR	--	0.38/0.4	0.25/0.20	0.20/0.20	0.15/0.10	Adjusted during calibration
INTFW	--	2.0/3.0	2.0/3.0	2.0/3.0	2.0/3.0	Adjusted upward during calibration
IRC	--	0.6/0.5	0.6/0.5	0.6/0.5	0.6/0.5	Adjusted downward during calibration.
LZETP (max)	--	0.7/0.6	0.5/0.4	0.6/0.4	0.2/0.1	Varies monthly; adjusted downward during calibration.

Thompson Creek lacks a USGS gage with historical records of observed streamflow for model calibration. Therefore, in order to calibrate the Thompson Creek model it was necessary to use a paired watershed approach. The watershed selected for hydrologic calibration was Black Creek (Figure 4-2), which has a USGS gage (02130900) near McBee. This watershed was selected because it is adjacent to the Thompson Creek watershed, is of similar size (only about 19 percent smaller), and is similar with respect to the overall proportions of the four major land types. For calibration purposes, a separate HSPF model input file was developed for Black Creek. The watershed was divided into seven sub-basins and stream reaches of a size similar to those created for Thompson Creek (Figure 4-2), and the model was segmented into pervious land segments based on sub-basin and land type as done for Thompson Creek.

The Black Creek HSPF model was run for the period 1 Oct 1995 to 20 Sept 1999, and calibrated by adjustment of the model parameters tabulated in Table 4-2. Despite the good relatively good agreement in the overall magnitude and pattern of streamflow (Figure 4-3), the Black Creek model predictions have some obvious discrepancies with observed streamflow values. Most of these are caused by discrepancies between the precipitation data record from Bishopville and the actual rainfall in the Black Creek watershed. The NWS rain gage did not register many small-to-moderate precipitation events and under predicted others, causing the observed streamflow to show a storm peak at many times for which the predicted streamflow does not. There are also differences between the predicted and simulated volumes of individual storms, where more or less rain fell in Bishopville than in the Black Creek Basin. However, a comparison of ten storms shows that that the HSPF model accurately predicts the *average* peak height within 20 percent.

The Black Creek model systematically under predicted the total flow volume for most years, and for the entire calibration period (Table 4-3) by about 13 percent. Although additional calibration could have obtained a closer agreement, it actually desired that the model under predict flow due to the fact that the Bishopville gauge recorded less precipitation and fewer precipitation events than actually occurred in the Black Creek basin, as evidence by the observed streamflow record.

Table 4-3. Observed and Predicted Flow Volumes in Black Creek near McBee, SC

Water Year[1]	**Streamflow-Observed (acre-ft)**	**Streamflow-Predicted (acre-ft)**	**Percent Difference (%)**
1996	103,785	90,496	-13
1997	112,008	128,537	+15
1998	192,752	141,339	-27
1999	95,843	76,214	-20
Entire calibration period (Water years 96-99)	504,388	436,587	-13

[1]The water year extends from Oct 1 of the previous calendar year to Sept 30 of the listed year.

The Black Creek model did not accurately predict the timing of storm peaks; i.e., the ‘observed’ storm peak generally occurred several hours after the ‘predicted’ peak. This is probably caused by two reasons: (1) the Black Creek watershed has small impoundments and borrow pits, which delay the downstream transmission of storm peaks; and (2) the Black Creek watershed has very sandy soils, which results in more infiltration and less direct runoff. It was not desired to calibrate the model to these peak timings and then apply those calibrated values to the Thompson Creek, which has fewer impoundments and borrow pits and a greater diversity of soil permeabilities. Instead, the Thompson Creek model was further calibrated by comparison of predicted streamflow to stream stage data collected at the Town of Chesterfield Water Treatment Plant as part of the 319 project. These data allowed adjustment of hydrologic parameters to correctly predict the timing of storm peaks (Figure 4-4). Final calibrated values for major hydrologic parameters are tabulated in Table 4-2.

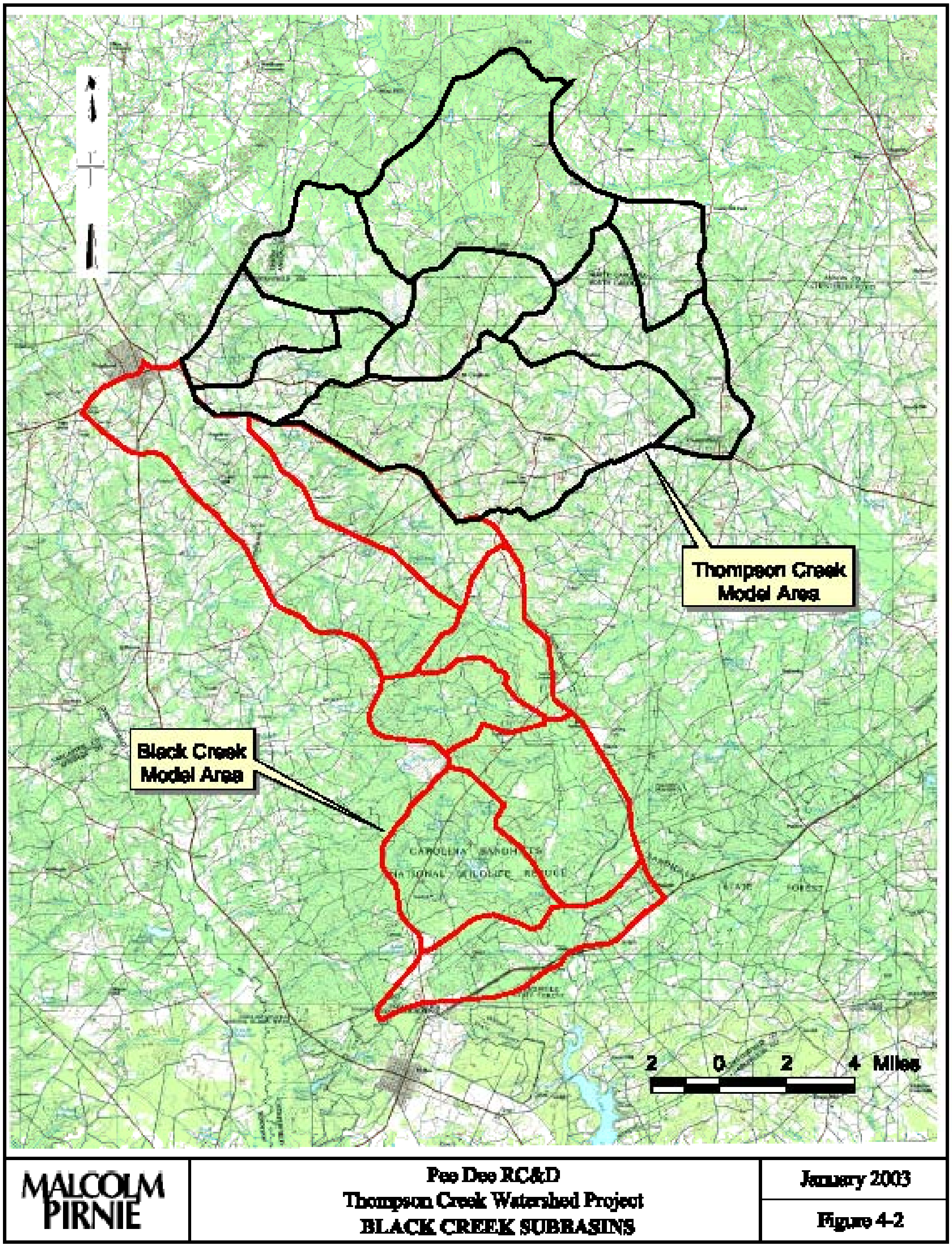

Figure 4-2 The Thompson Creek and Black Creek watersheds.

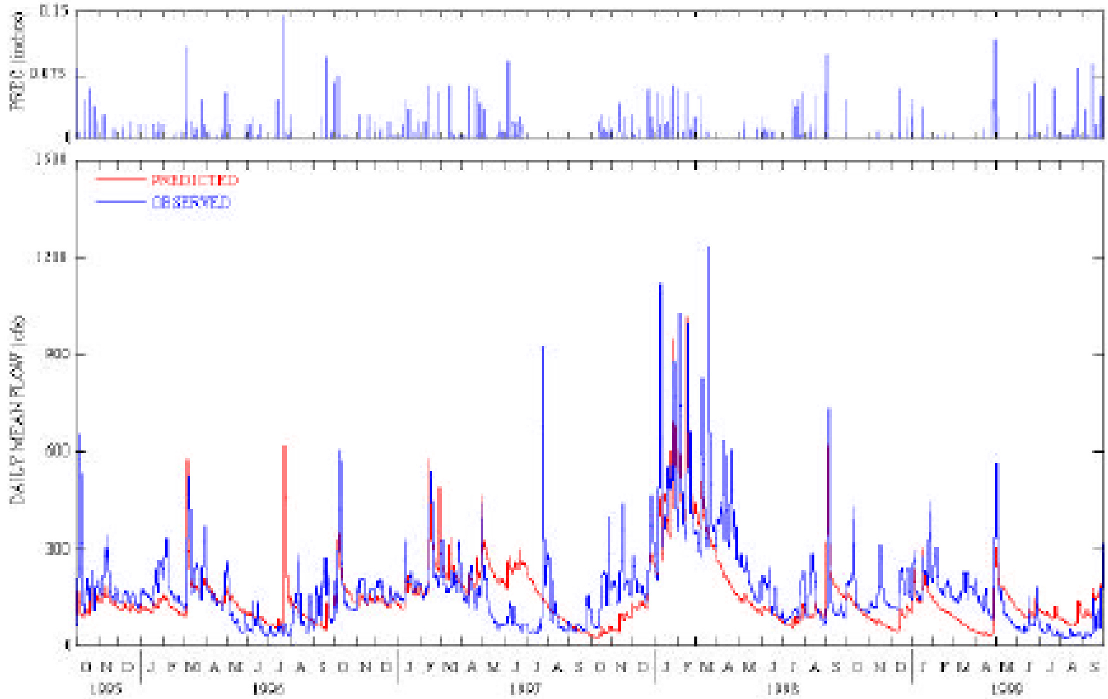

Figure 4-3. Observed and predicted mean daily streamflow at USGS gaging station 02130900 (Black Creek near McBee, SC).

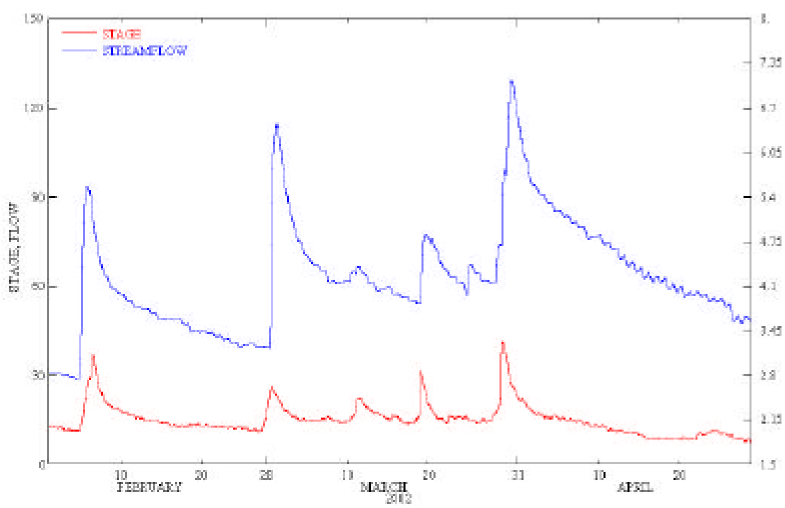

Figure 4-4. Observed stage and predicted hourly streamflow in Thompson Creek above highway S-13-243 (RCHRES 1).

4.4 Water Quality Simulation

Coliform loads from wildlife, livestock, and poultry litter to each pervious land segment were estimated as described in Section 3. The specific accumulation rate of coliform counts (i.e., the ACQOP value in HSPF, expressed in counts/acre/day) was calculated directly in the BIT for each land segment and each month of the year. HSPF also requires the entry of a maximum accumulation of coliform counts on each segment (SQOLIM, expressed in counts/acre). This accounts for die-off on the land surface and prevents coliform loads from accumulating to indefinite magnitudes. Based on the approach of the BIT, it was assumed that the maximum accumulation was 1.5 and 1.8 times the daily accumulation for warm and cold months, respectively, as derived from the work of Horsley and Witten (1986). Loads from failing septic systems and in-stream livestock were also calculated in the BIT and input as continuous point-source loads to each stream segment. In-stream loads from wildlife were modeled by assigning a 30 count/100 mL concentration to baseflow from each land segment.

Two other important water-quality-related parameters are WSQOP, the rate of surface runoff that results in washoff of 90-percent of the accumulated coliform counts in one hour; and FSTDEC, the first-order decay rate of coliform counts in the stream. WSQOP was assigned a value of 2.15 inches/hour, and FSTDEC was assigned a value of 2.5 day^{-1}. These values were based on the final value used in a well-calibrated HSPF model of coliform counts in a similar agricultural watershed (SAIC, 2001).

Model adjustment: Initial runs of the Thompson Creek HSPF model showed much higher warm weather fe cal coliform concentrations than were observed. For example, summer in-stream concentrations were predicted to commonly exceed 100,000 counts/100 mL. The main driver of these concentrations was in-stream cattle deposition during low flow periods. Because there is no reason to believe that Thompson Creek has an unusually high decay rate of fecal coliform bacteria in the stream, it was concluded that the unadjusted model overestimated the in-stream deposition by cattle. Therefore, the model was adjusted by reducing the in-stream cattle loads. The final values of the instream livestock loads were approximately 0.1 percent of the original values. This shows that, using the USEPA/BIT approach, predicted in-stream coliform concentrations are very sensitive to the number of in-stream cattle assumed. A small to moderate number of in-stream cattle more than sufficient to “explain” the observed coliform concentrations in Thompson Creek. The final values of loading-related PQUAL parameters are tabulated by land type, month, and sub-basin in Appendix D.

Predicted v. observed coliform counts in the adjusted model are displayed in Figure 4-5. As is common with bacterial transport models, there is a high degree of variance between individual observations and model predictions. This reflects the many causes of natural variation that are not accounted for by the model. However, the HSPF model successfully reproduces the patterns and magnitude of coliform concentrations in the creek, including

- The spatial pattern of similar concentrations at the five monitoring stations

- The seasonal pattern of higher concentrations in the warm weather months, and the approximate range in magnitude of those concentrations
- The hydrologic pattern of elevated concentrations under both low flow and high flow conditions.

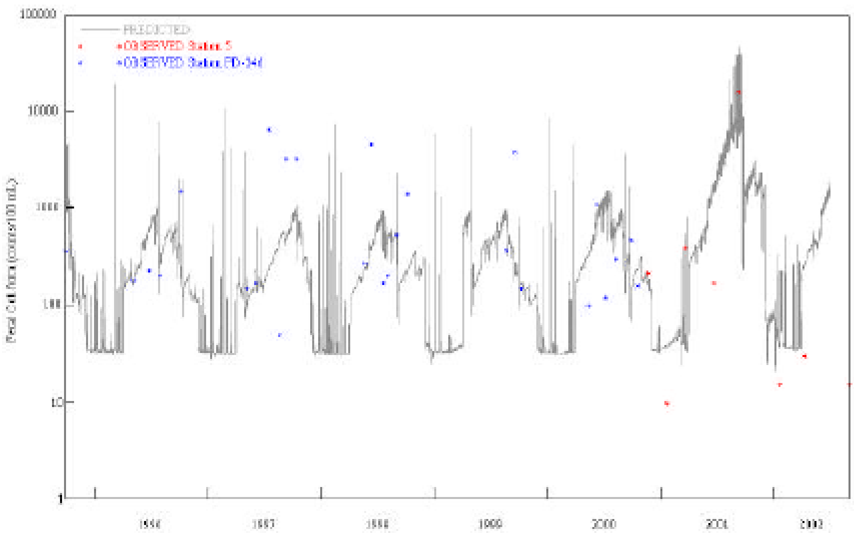

Figure 4-5. Observed and predicted fecal coliform concentration in Thompson Creek above highway S-13-243 (RCHRES 1).

In-stream coliform concentrations are predicted to rise under low flow conditions due to the lack of dilution of in-stream deposition from cattle. Storm events are predicted to dilute the in-stream coliform concentrations during the late summer, but cause spikes in concentrations during the winter and spring. Extremely low flows during the summer drought of 2001 caused the model to over-predict coliform concentrations for this season.

4.5 Critical Conditions

EPA regulations [40 CFR 130.7(c)(1)] require that TMDLs consider critical seasonal and hydrologic conditions. The critical seasonal condition is the warm weather period when in-stream livestock deposition and poultry litter application are active. As both monitoring and modeling results demonstrate, the coliform standard can be exceeded under both flow and high flow conditions, although from different sources. February through May are the most critical months for high-flow violations because that is when poultry litter application peaks and coincides with spring rains. July and August are the most critical months for low-flow violations, because that is when cattle spend the maximum time in streams and baseflow is the often at the lowest level of the year.

July and August were selected as the most critical months with regard to violation of the standard. This has the effect of biasing load allocations to address the sources that are most active during low flow—most importantly, in-stream livestock deposition. However, this is considered appropriate because (1) exceedances of the criteria magnitude during high flow events are much less frequent and shorter in duration, resulting in much fewer standards violations; and (2) there is less probability of recreational use of Thompson Creek under high-flow conditions. Hydrologically, the critical period was chosen as the lowest August streamflow observed during the model calibration period, excluding the extreme drought of 2001 to which the model was not adjusted. This flow (54 cfs) occurred in August 1999. Therefore, the period from July 29 to 27, 1999 was selected as the critical period for load allocations.

5.0 MODEL RESULTS – PD-246

This section summarizes the model predictions of the sources of fecal coliform loading under different seasonal and hydrologic conditions.

5.1 Existing Conditions

Average annual fecal coliform loads to Thompson Creek were calculated from model output for the six- year period from 1996 to 2001 (Table 5-1). Livestock is predicted to be the single largest source on an annual basis, followed by poultry litter, and then by wildlife. Urban runoff and failing septic systems are predicted to be negligible components of the annual load, which is not surprising given the small proportion of developed land and low density of the population in the basin.

Table 5-1. Average Annual Coliform Loads to Thompson Creek at PD-246 (S-13-243).
[based on HSPF model predictions for 1996-2001]

Source	**Average Annual Load (counts/year)**	**Percent of Total Annual Load (%)**
Wildlife	3.87E+13	10
Livestock: land surface	1.15E+14	31
Livestock: in-stream deposition	1.23E+14	33
Poultry litter application	9.03E+13	25
Urban Runoff	3.51E+10	< 1
Failing septic systems	1.93E+12	< 1
All	3.68E+14	100

Fecal coliform criteria are predicted to be exceeded under both baseflow and storm conditions during the warm weather months, but fall below the criteria during baseflow conditions in the winter. Although runoff-related sources (e.g., poultry litter application, land deposition from cattle and wildlife) comprise the majority of the total annual load, contributions from in-stream cattle control the in-stream coliform concentrations during low-flow, warm weather conditions when runoff-related sources are not entering the stream (Figure 5-1). Because low-flow conditions predominate during the warm weather months (especially the late summer), deposition from in-stream livestock is predicted to be the most *frequent* cause of exceedances of the coliform criteria.

Runoff-related sources can also cause violations of the standards during wet weather events. This is especially true for large precipitation events during months of highest poultry litter application (February-May). During this period, streamflow peaks greater than 800 cfs are usually accompanied by coliform concentrations that exceed 400 counts/100 mL (Figure 5-2). In contrast, smaller, shorter storm events commonly observed in summer actually dilute in-stream concentrations because in-stream concentrations (dominated by contributions from in-stream cattle) are higher than the concentrations in runoff.

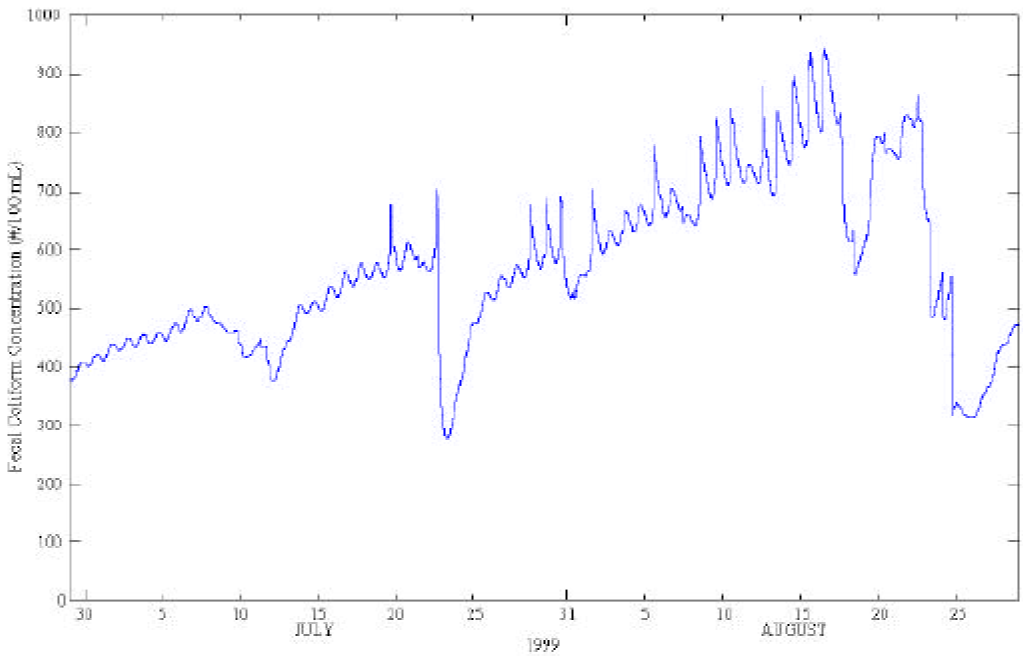

Figure 5-1. Predicted fecal coliform concentration in Thompson Creek at PD-246 (S-13-243) under low-flow, summer conditions.

Table 5-2. Existing Loads to Thompson Creek for Thompson Creek at PD-246 and PD-247, calculated by different methods. Loads in cts/30-days. * See text for explanation.

Location	Wastewater Discharges	Runoff from Land	Cattle-in-Streams	Failing Septic Systems	Total Existing Load *
Thompson Creek at PD-246	0.00E+00	1.75E+12	1.46E+13	2.70E+09	1.64E+13
Thompson Creek at PD-247	1.02E+11				2.57E+14

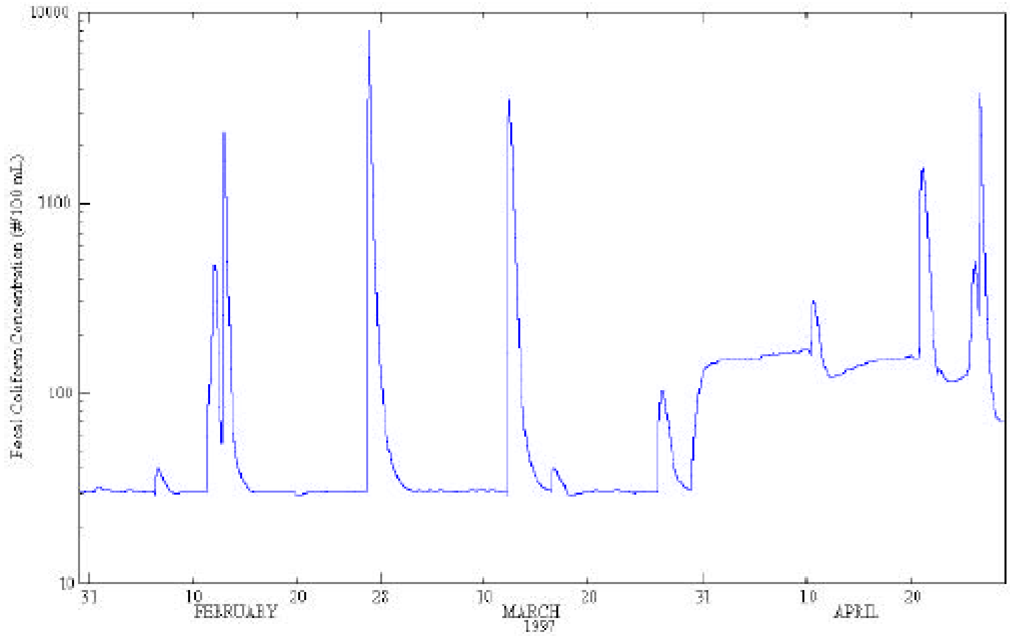

Figure 5-2. Predicted fecal coliform concentrations in Thompson Creek at PD-246 under spring conditions.

5.2 Critical Conditions

During the critical period (July 29 - August 27, 1999) shown on Figure 5-1, the predicted 30-day geometric mean fecal coliform concentration was 672 counts/100 mL, well above the criteria of 200 counts/100 mL. Similarly, the predicted concentrations exceeded 400 counts/100 mL approximately 97 percent of the time during this 30-day period, well above the 10 percent allowed by the standard.

It is also useful to examine conditions during a period during which wet-weather sources are more dominant, such as February-April 1997. Numerous rain events caused “spikes” in the predicted fecal coliform concentration during this month, some of which exceeded 1,000 counts/100 mL (Figure 5-2). However, most of these peaks receded in a few days, such that the 30-day geometric mean did not exceed 200 counts/100 mL. Similarly, the predicted in-stream concentration exceeded 400 counts/100 mL only about 5 percent of the time during this period. These results validate the selection of late summer conditions as the critical period for load allocations.

5.3 Model Uncertainty

As in any hydrologic and water quality model, there are numerous sources of uncertainty and error in the model predictions. These include errors in meteorological data, spatial and temporal variations in both input data and model parameters, simplifications inherent in the model formulation, and processes not accounted for by the model algorithm (e.g., in-stream deposition and resuspension of bacteria). The basic confidence in the usefulness of the model results comes from (1) confidence in the basic load assessment and modeling methodology, which is accepted by regulators; and (2) the ability of the model to accurately predict the spatial, seasonal, and hydrologic patterns and magnitude of streamflow and bacteria concentration in the stream. Although this modeling exercise and the resulting load allocation are inherently quantitative, the model is best viewed as an exploratory tool to assist environmental managers direct resources toward where the greatest benefits can be achieved. Model uncertainties should be considered in evaluating the recommendations resulting from this analysis.

6.0 LOAD-DURATION CURVE – PD-247

The drainage area for PD-247 is about 15 % larger than that for PD-246 so that the additional land area has a relatively small impact on the water quality compared to PD-246. Rather than redo the modeling, we used the load-duration curve method to estimate the existing load and the Load Allocation for PD-247. Improvement in water quality in Thompson Creek above PD-246 would improve the water quality at PD-247.

The simulated flows from the model were used as the basis of flows at PD-247. The PD-246 flows were multiplied by the increased drainage area to estimate the PD-247 flows for the period of record 1995-2001. The flows were ranked from low to high and plotted against the percentage of days flow exceeded (Figure 6-1). The Load-Duration curve is generated by calculating the load from the sample concentration and the corresponding flow and plotting the value against the appropriate flow recurrence interval. A target line is created by calculating the allowable load from the flow and the appropriate standard minus the MOS. Loads above this line are violations of the standard, while loads below the line are not.

The existing load is estimated from values along a trend line for the loads exceeding the standard. The Load Allocation is calculated from the target line. Most of the violating loads were between the 10 % and 70 % recurrence intervals. Both the existing load and the Load Allocation were averages of loads from the 10 % recurrence to 70 % at 5 % intervals: 10, 15, 20, 25 … 70. There were only 2 standard violations at flows above the 70 % recurrence level and none above 77 %. The trend line for Thompson Creek with the best fit was an exponential curve, with the r^2 of 0.627.

The existing load and the TMDL calculated for PD-247 by this method are both an order of magnitude larger than those calculated for PD-246. The loads from the load-duration curve are determined for the non-extreme flow conditions over the period of record. The loads calculated for PD-246 were determined for a specific 30-day critical period, which was a period of low flows. Because of the difference in methods and critical periods the existing loads for the two locations are not directly comparable. However, the reduction percentages required to meet the TMDL are similar (68 % for PD-246 and 82 % for PD-247). This strongly suggests that the two loads though quite different in size and critical period are both valid and lead to similar improvements in water quality in Thompson Creek.

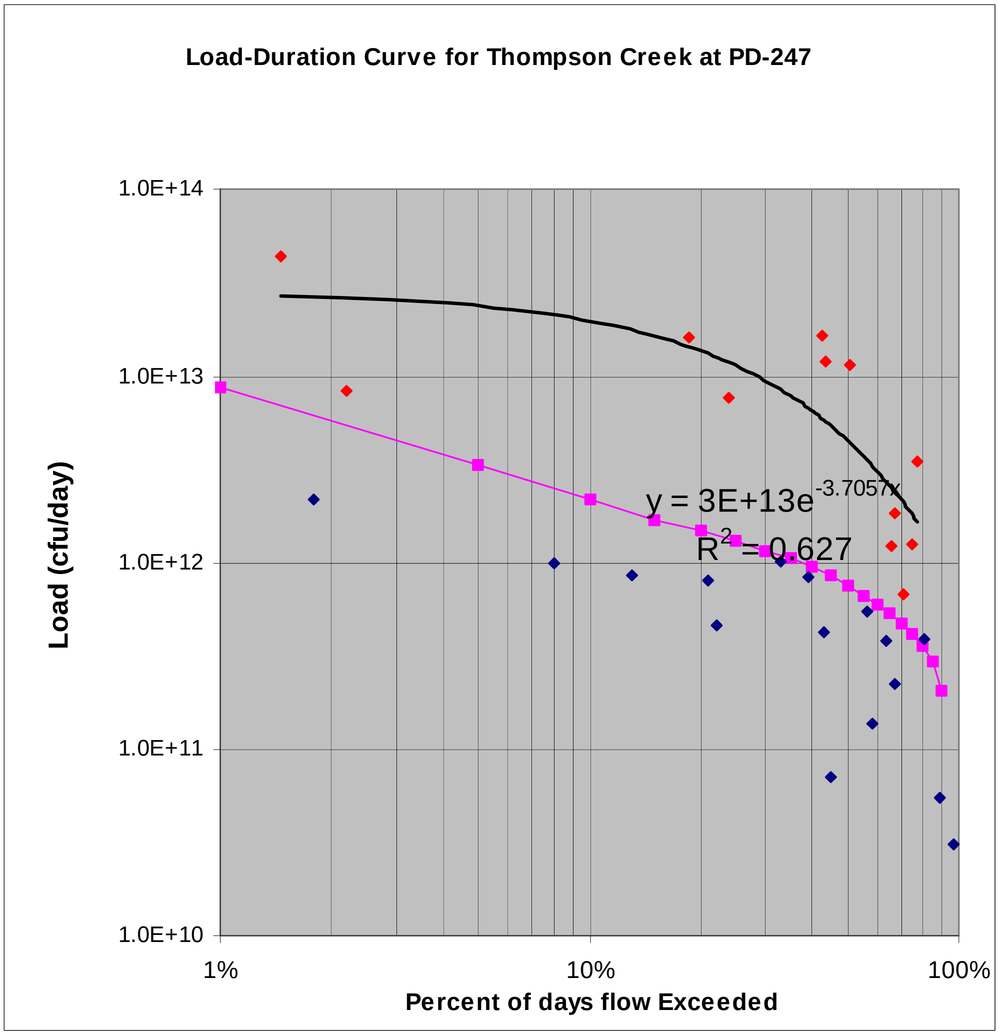

Figure 6-1. Load-Duration Curve for Thompson Creek at PD-247.

7.0 TMDL

Potential load allocations may be determined by modeling a combination of loading reductions that eliminate violations of the water quality standard for fecal coliform bacteria in Thompson Creek above highway S-13-243. SCDHEC has previously used a margin of safety of 10 counts/100 mL to help ensure that the standard will not be violated and that precedent will following in this report. As discussed in Section 5, the dominance of in-stream livestock sources during baseflow periods causes the predicted violation rate to be highly sensitive to these loads, and relatively insensitive to other sources. However, the recommended load allocations are also based on good engineering and agricultural practices. For example, although failing septic systems are not a major cause of water quality violations, their elimination is important for public health reasons. Similarly, the reduction of loads from poultry litter application will help reduce exceedances of the criteria magnitude during spring storm events, and also prevent over fertilization of certain crops (e.g., soybeans).

7.1 Wasteload Allocations

Thompson Creek upstream of PD-246 has no current or planned point source discharges, therefore its WLA is NA. The WLA for Thompson Creek at PD-247 has a WLA of 1.02E+11 ct/30-days (Table 7-1).

7.2 Load Allocations

The load allocation for PD-246 is given in Table 7-1. The Thompson Creek HSPF model indicates that this loading scenario will result in a geometric mean fecal coliform concentration of 189 counts/100mL under critical conditions (July 29 - August 27, 1999). Figure 7-1 displays the time series of the predicted fecal coliform concentration under existing conditions and under the recommended loading scenario. The load allocation for PD-247 was determined from the target line on the load duration curve. The load allocation for PD-247 was based on a wide range of flows (see Chapter 6.0 for an explanation).

7.3 Margin of Safety

An explicit margin of safety (MOS) of 5 % was used for these TMDLs. The actual MOS loads are included in Table 7-1.

7.4 TMDL

The TMDLs for Thompson Creek at both PD-246 and PD-247 are given in Table 7-1. The TMDL value for PD-246 requires a reduction of 68 % from the calculated existing load. The TMDL value for PD-247 requires a reduction of 82 % from the estimated existing load. The two TMDLs were calculated differently and have different critical periods. However, because the drainage area for PD-246 is 91 % of the drainage for PD-247, improvement at both stations should be linked.

Table 7-1. TMDLs for Thompson Creek at PD-246 and PD-247 (cts/30days).

Location	WLA	LA	MOS	TMDL	% Reduction
PD-246	NA	5.28E+12	2.8E+11	5.56E+12	68
PD-247	1.0E+11	4.50E+13	2.4E+12	4.74E+13	82

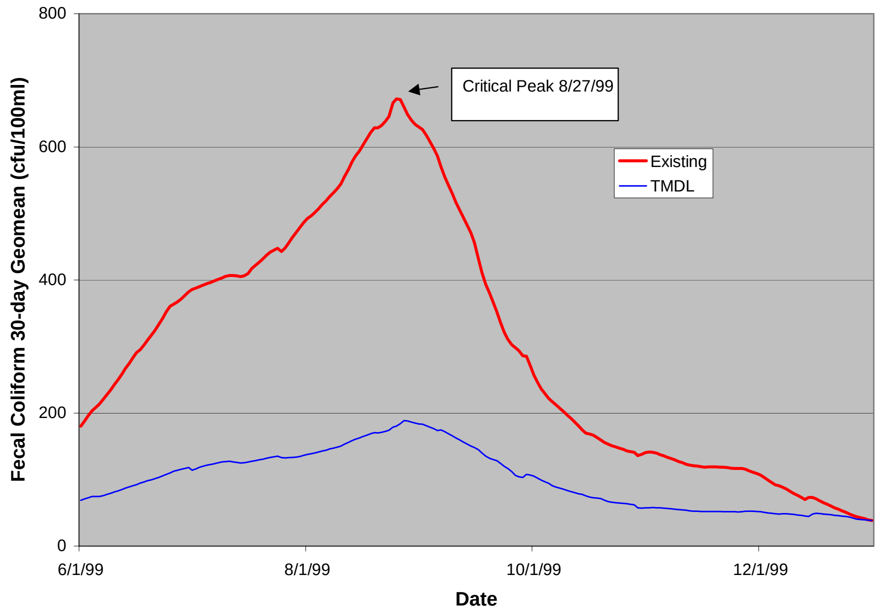

Figure 7-1. 30-day geometric mean values for Existing and TMDL conditions during the critical period July 29 – August 27, 1999.

8.0 IMPLEMENTATION PLANNING RECOMMENDATIONS

Implementation planning was begun as part of the 319 grant project. The stakeholders in the Thompson Creek watershed are expected to continue and refine this process with a 319 implementation proposal.

9.0 REFERENCES

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Appendix A Water Quality Data

Thompson Creek Fecal Coliform Data					0.6979
	PD-246			PD-247	
Date	Time	FC (cfu/100ml)	Remark Code	Time	FC (cfu/100ml)
1-May-90	1323	220	D	1310	390
13-Jun-90	1330	280	D	1309	230
9-Jul-90	1256	210	D	1239	270
10-Sep-90	1327	360	D	1458	1000
4-Oct-90	1330	140	J	1310	500
21-May-91	1255	260	D	1247	330
11-Jun-91	1135	170	J	1155	380
29-Jul-91	1440	900	D	1420	1000
19-Aug-91	1200	220	D	1220	230
3-Sep-91	1015	290	D	1030	160
21-Oct-91	1205	170	J	1230	310
21-May-92	1200	160	J	1220	240
18-Jun-92	1155	230	D	1210	360
16-Jul-92	1220	920	D	1240	390
26-Aug-92	1355	30	J	1340	70
16-Sep-92	1210	80	J	1220	1100
29-Oct-92	1155	200	D	1205	210
12-May-93	1010	250	D	955	290
17-Jun-93	1230	370	D	1215	190
14-Jul-93	1000	520	D	1020	230
17-Aug-93	1225	190	J	1215	150
9-Sep-93	1000	400	D	1020	400
21-Oct-93	1245	300	D	1228	100
4-May-94	1000	3300	J	1015	2400
30-Jun-94	1005	10000	J	1030	6800
5-Jul-94	1112	240	J	1129	140
23-Aug-94	1020	520	D	1045	880
15-Sep-94	1100	220	J	1114	460
13-Oct-94	1015	780	D	1030	500
10-May-95	1130	480	D	1340	570
14-Jun-95	1210	220	D	1221	900
27-Jul-95	1025	480	D	1042	720
10-Aug-95	1012	280	D	1020	280
13-Sep-95	1005	460	D	1025	240
3-Oct-95	1050	370	D	1111	200
7-May-96	1130	180	J	1146	340
25-Jun-96	1030	230	D	1045	520
25-Jul-96	945	200	D	1000	120

	PD-246			PD-247	
Date	**Time**	**FC (cfu/100ml)**	**Remark Code**	**Time**	**FC (cfu/100ml)**
9-Oct-96	1120	1500	K	1135	2200
7-May-97	1425	150	J	1412	150
5-Jun-97	1205	170	J	1230	120
16-Jul-97	1130	6600	L	1150	2100
20-Aug-97	1135	50	J	1150	310
11-Sep-97	1145	3300	J	1200	1100
15-Oct-97	1155	3300	J	1215	3300
19-May-98	1315	270	D	1330	310
11-Jun-98	1150	4600	D	1205	4900
20-Jul-98	1305	170	J	1325	1300
5-Aug-98	1305	200	L	1320	250
2-Sep-98	1300	530	D	1320	170
8-Oct-98	1130	1400	J	1150	6600
5/5/99		220			170
6/16/99		210			5700
7/19/99		140			160
8/23/99		370			400
9/16/99		3900			3800
10/7/99		150			200
5/11/00		100			80
6/6/00		1100			860
7/5/00		120			90
8/9/00		300			
9/25/00		470			570
10/17/00		160			30
Statistics for the 1996 - 2000 Assessment Period					
Geo Mean		410.5			494.4
Median		225			340
# Violations		10			12
% Violations		37%			46%

Fecal Coliform Concentrations from 319 Project Study

	Fecal Coliform Bacteria Concentrations (cts/100ml)								
Location	11/20/00	01/20/01	03/21/01	06/14/01	09/05/01	01/15/02	04/02/02	08/29/02	11/13/02
1	216	10	388	170	TNTC	16	30	16	146
2	440	60	604	230	186	12	70	298	544
3	232	58	720	420	106	16	72	14	494
4	248	8	208	352	154	< 4	26	320	234
5	232	34	536	318	72	16	28	TNTC	632

Note: TNTC is Too Numerous to Count

Appendix B Town of Chesterfield WWTP Data

Town of Chesterfield Thompson Creek WWTP							SC0025232		
Permit Limit:		**0.45**	**mgd**						
	Flow (mgd)			**FC (cfu/100ml)**				**FC Load (cfu/day)**	
Date	**Mean**	**Max**		**Mean**		**Max**			
1/31/89	0.28	0.4		143		160		1.52E+09	
2/28/89	0.21	0.44		34		75		2.70E+08	
3/31/89	0.1	0.32		20.5		106		7.76E+07	
4/30/89	0.19	0.42		142		314		1.02E+09	
5/31/89	0.13	0.36		22.5		510		1.11E+08	
6/30/89	0.05	0.14		19.4		376		3.67E+07	
7/31/89	0.05	0.29		26		660		4.92E+07	
8/31/89	0.02	0.06		29		220		2.20E+07	
9/30/89	0.035	0.17		6.3		40		8.35E+06	
10/31/89	0.086	0.25		147		320		4.79E+08	
11/30/89	0.079	0.14		22		493		6.58E+07	
12/31/89	0.14	0.35	<	1	<	1		5.30E+06	
1/31/90	0.12	0.25		11		120		5.00E+07	
2/28/90	0.27	0.55		5		30		5.11E+07	
3/31/90	0.25	0.39	<	1	<	1		9.46E+06	
4/30/90	0.16	0.36		2.6		7		1.57E+07	
5/31/90	0.16	0.46		44.7		2000		2.71E+08	
6/30/90	0.13	0.36	<	1	<	1		4.92E+06	
7/31/90	0.09	0.15	<	1	<	1		3.41E+06	
8/31/90	0.1	0.25		27		720		1.02E+08	
9/30/90	0.07	0.17		209		2000		5.54E+08	
10/31/90	0.13	0.43	<	1	<	1		4.92E+06	
11/30/90	0.05	0.14		18		320		3.41E+07	
12/31/90	0.12	0.52		62		3900		2.82E+08	
1/31/91	0.2	0.49		12.2		150		9.24E+07	
2/28/91	0.25	0.52		23		540		2.18E+08	
3/31/91	0.33	0.67		315		3300		3.93E+09	
4/30/91	0.33	0.47		866		1500		1.08E+10	
5/31/91	0.29	0.43		230		1200		2.52E+09	
6/30/91	0.17	0.29		7		50		4.50E+07	
7/31/91	0.21	0.39		48		2300		3.82E+08	
8/31/91	0.3	0.49		4.9		24		5.56E+07	
9/30/91	0.16	0.27		30		920		1.82E+08	
10/31/91	0.12	0.24		15		240		6.81E+07	
11/30/91	0.13	0.37		17		300		8.37E+07	
2/29/92	0.21	0.5		31		970		2.46E+08	
3/31/92	0.23	0.34		1697		2400		1.48E+10	
4/30/92	0.24	0.61		438		620		3.98E+09	

	Flow (mgd)			FC (cfu/100ml)				FC Load (cfu/day)	
Date	Mean	Max		Mean		Max			
5/31/92	0.2	0.32		8		10		6.06E+07	
6/30/92	0.24	0.42		84		100		7.63E+08	
7/31/92	0.19	0.38		300		975		2.16E+09	
8/31/92	0.22	0.44		850		1400		7.08E+09	
10/31/92	0.21	0.3		750		750		5.96E+09	
11/30/92	0.28	0.43		20		20		2.12E+08	
12/31/92	0.25	0.57		1580		3150		1.50E+10	
1/31/93	0.41	0.63		5		10		7.76E+07	
2/28/93	0.4	0.78	<	10		10		1.51E+08	
3/31/93	0.4	0.68		959		1700		1.45E+10	
4/30/93	0.34	0.47	<	10		10		1.29E+08	
5/31/93	0.24	0.53	<	6		10		5.45E+07	
6/30/93	0.16	0.22		215		420		1.30E+09	
7/31/93	0.14	0.24		65		90		3.44E+08	
8/31/93	0.16	0.23		1910		3450		1.16E+10	
9/30/93	0.17	0.3		52		100		3.35E+08	
10/31/93	0.1	0.28		245		480		9.27E+08	
11/30/93	0.1	0.14		17		280		6.44E+07	
12/31/93	0.15	0.19		787		1820		4.47E+09	
1/31/94	0.251	0.422		964	>	3000		9.16E+09	
2/28/94	0.307	0.643		315		320		3.66E+09	
3/31/94	0.342	0.698		587		1150		7.60E+09	
4/30/94	0.228	0.375		28		400		2.42E+08	
5/31/94	0.155	0.337		22.3		250		1.31E+08	
6/30/94	0.133	0.41		7		10		3.52E+07	
7/31/94	0.266	0.665		3.1	<	10		3.12E+07	
8/31/94	0.51	0.68		334		1600		6.45E+09	
9/30/94	0.32	0.55		33		1050		4.00E+08	
10/31/94	0.26	0.46		152		580		1.50E+09	
11/30/94	0.23	0.44		154		1200		1.34E+09	
12/31/94	0.34	0.94		14		20		1.80E+08	
1/31/95	0.39	0.81		671		2500		9.91E+09	
2/28/95	0.42	0.67		16		25		2.54E+08	
3/31/95	0.37	0.64	<	10	<	10		1.40E+08	
4/30/95	0.23	0.26		77		590		6.70E+08	
5/31/95	0.16	0.28		114		1300		6.90E+08	
6/30/95	0.33	0.53		2258		3000		2.82E+10	
7/31/95	0.24	0.47		1364		1550		1.24E+10	
8/31/95	0.19	0.5		760		1700		5.47E+09	
9/30/95	0.19	0.33		141		2000		1.01E+09	
10/31/95	0.29	0.68		775		3000		8.51E+09	
11/30/95	0.29	0.52		78		600		8.56E+08	
12/31/95	0.17	0.29	<	10	<	10		6.44E+07	

	Flow (mgd)			FC (cfu/100ml)				FC Load (cfu/day)	
Date	Mean	Max		Mean		Max			
1/31/96	0.23	0.39	<	14	<	20		1.22E+08	
2/29/96	0.29	0.41	<	114		1300		1.25E+09	
3/31/96	0.33	0.37	<	1200	<	3000		1.50E+10	
4/30/96	0.29	0.39		50		250		5.49E+08	
5/31/96	0.21	0.27	<	10	<	10		7.95E+07	
6/30/96	0.13	0.18	<	67		450		3.30E+08	
7/31/96	0.13	0.13		277		1100		1.36E+09	
8/31/96	0.14	0.16		2950		3000		1.56E+10	
9/30/96	0.21	0.26	>	1339	>	3400		1.06E+10	
10/31/96	0.25	0.35		1775		3000		1.68E+10	
11/30/96	0.19	0.22		155		1200		1.11E+09	
12/31/96	0.2	0.23		379		480		2.87E+09	
1/31/97	0.26	0.3		490		500		4.82E+09	
2/28/97	0.31	0.39		123.3		760		1.45E+09	
3/31/97	0.35	0.37		40		160		5.30E+08	
4/30/97	0.19	0.25		10		10		7.19E+07	
5/31/97	0.14	0.24		69		80		3.66E+08	
6/30/97	0.14	0.15		84.9		720		4.50E+08	
7/31/97	0.21	0.39		45		200		3.58E+08	
8/31/97	0.19	0.23		14.14		20		1.02E+08	
9/30/97	0.14	0.16		14		20		7.42E+07	
10/31/97	0.2	0.27		14		20		1.06E+08	
12/31/97	0.27	0.36		20	<	20		2.04E+08	
1/31/98	0.51	0.59		514		1650		9.92E+09	
2/28/98	0.53	0.6		204		260		4.09E+09	
3/31/98	0.54	0.6		245	>	3000		5.01E+09	
4/30/98	0.52	0.65		161		1300		3.17E+09	
5/31/98	0.3	0.37		98		160		1.11E+09	
6/30/98	0.17	0.23		2872		3000		1.85E+10	
7/31/98	0.16	0.19		14		20		8.48E+07	
8/31/98	0.11	0.14		20		20		8.33E+07	
9/30/98	0.15	0.16		10		10		5.68E+07	
10/31/98	0.16	0.19		155		400		9.39E+08	
11/30/98	0.14	0.18	<	20	<	20		1.06E+08	
12/31/98	0.17	0.22		424		500		2.73E+09	
1/31/99	0.24	0.34		20		40		1.82E+08	
2/28/99	0.25	0.37		40		80		3.79E+08	
3/31/99	0.23	0.29		14	<	20		1.22E+08	
4/30/99	0.18	0.24	<	10	<	10		6.81E+07	
5/31/99	0.29	0.46	<	14	<	20		1.54E+08	
6/30/99	0.16	0.18	<	14	<	20		8.48E+07	
7/31/99	0.14	0.15	<	10	<	10		5.30E+07	
8/31/99	0.11	0.14	<	60		360		2.50E+08	

	Flow (mgd)			FC (cfu/100ml)				FC Load (cfu/day)	
Date	Mean	Max		Mean		Max			
9/30/99	0.17	0.27	<	14		20		9.01E+07	
10/31/99	0.21	0.25	<	10	<	10		7.95E+07	
11/30/99	0.13	0.16	<	10	<	10		4.92E+07	
12/31/99	0.17	0.2	<	10	<	10		6.44E+07	
1/31/00	0.27	0.32		1		1		1.02E+07	
2/29/00	0.36	0.4		1		1		1.36E+07	
3/31/00	0.28	0.3		178.9		200		1.90E+09	
4/30/00	0.23	0.26		1		1		8.71E+06	
5/31/00	0.1	0.18		8.1		65		3.07E+07	
6/30/00	0.12	0.16		5		25		2.27E+07	
7/31/00	0.14	0.17		1		1		5.30E+06	
8/31/00	0.17	0.23		1		1		6.44E+06	
9/30/00	0.2	0.4		1		1		7.57E+06	
10/31/00	0.13	0.19		5.9		35		2.90E+07	
11/30/00	0.07	0.1		14.1		200		3.74E+07	
12/31/00	0.09	0.1		1		1		3.41E+06	
1/31/01	0.08	0.09		17.3		60		5.24E+07	
2/28/01	0.08	0.09		1		1		3.03E+06	
3/31/01	0.14	0.18		1		1		5.30E+06	
4/30/01	0.08	0.12		10		100		3.03E+07	
5/31/01	0.07	0.11		10		100		2.65E+07	
6/30/01	0.08	0.1		1		1		3.03E+06	
7/31/01	0.08	0.13		1		1		3.03E+06	
8/31/01	0.11	0.12		47.4		90		1.97E+08	
9/30/01	0.08	0.13		3.2		10		9.69E+06	
10/31/01	0.06	0.09		12.65		160		2.87E+07	
11/30/01	0.13	0.14		6.32		40		3.11E+07	
12/31/01	0.12	0.15		1		1		4.54E+06	
1/31/02	0.19	0.23		4.5		20		3.24E+07	
2/28/02	0.3	0.44		1		1		1.14E+07	
3/31/02	0.29	0.3		1		1		1.10E+07	
4/30/02	0.21	0.27		194.9		200		1.55E+09	
5/31/02	0.14	0.19		60.83		185		3.22E+08	
6/30/02	0.1	0.11		131.34		150		4.97E+08	
7/31/02	0.1	0.16		11.4		130		4.32E+07	
8/31/02	0.12	0.16		44.72		80		2.03E+08	
9/30/02	0.12	0.15		5.66		32		2.57E+07	
10/31/02	0.18	0.22		33.94		36		2.31E+08	
11/30/02	0.19	0.22		34.8		48		2.50E+08	
12/31/02	0.19	0.23		13.5		52		9.71E+07	
1/31/03	0.24	0.3		23.2		116		2.11E+08	

Appendix C

Hydrologic Parameters Used in the Black Creek/Thompson Creek HSPF Models

Parameter	units	Initial/Final Value				Comment
		Forest	Pasture	Cropland	Developed	
LZSN	in	9.5/4	9.5/4	9.5/4	9.5/4	Initially estimated as 1/8 of the annual rainfall plus 4 inches; adjusted downward during calibration.
INFILT	In/hr	0.3/0.2	0.2	0.2	0.05/0.04	Typical class B soils except for lower permeability developed land.
LSUR	ft	Variable /300	Variable /300	Variable /300	Variable /300	Initially calculated by B2HSPF utility; adjusted downward during calibration.
SLSUR	ft/ft	0.001	0.001	0.001	0.001	Initially calculated by B2HSPF utility; estimated from DEM.
KVARY	In -1	0	0	0	0	No evidence for seasonal variations in base flow recession rate.
AGWRC	---	0.99/0.98	0.99/0.98	0.99/0.98	0.99/0.98	Adjusted downward during calibration.
INFEXP		2.0	2.0	2.0	2.0	Recommended default value (EPA, 2000b)
INFILD		2.0	2.0	2.0	2.0	Recommended default value (EPA, 2000b)
DEEPFR		0.0	0.0	0.0	0.0	Losses to deep groundwater not significant.
BASETP		0.0	0.0	0.0	0.0	Riparian ET not significant.
AGWTP		0.0	0.0	0.0	0.0	Wetland ET not significant.
CEPSC	in	0.18/0.1	0.1/0.1	0.15/0.1	0.05/0.1	Adjusted downward during calibration.
UZSN	in	1.33/0.52	0.76/0.39	0.76/0.39	0.76/0.12	Adjusted downward during calibration.
NSUR	---	0.38/0.4	0.25/0.2	0.20/0.2	0.15/0.1	Adjusted during calibration.
INTFW	---	2.0/3.0	2.0/3.0	2.0/3.0	2.0/3.0	Adjusted upward during calibration.
IRC	---	0.6/0.5	0.6/0.5	0.6/0.5	0.6/0.5	Adjusted downward during calibration.
LZETP (Max)	---	0.7/0.6	0.5/0.4	0.6/0.4	0.2/0.1	Varies monthly; adjusted downward during calibration.

APPENDIX D PUBLIC PARTICIPATION

Prior to the receipt of the TMDL report for PD-246 by SC DHEC from the consultants, two public meetings were held in Chesterfield. At the first meeting preliminary results of the 319 study for Thompson Creek to PD-246 were presented and comments received. At the second meeting the final report was presented and a plan to implement the TMDL was discussed. Representatives from North Carolina DENR and Anson County, NC NRCS were present at the second meeting.

The following notice was placed in the Morning News (Florence, SC) on July 8, 2003, was sent to a list of interested parties, and was placed on the Department web site.

PUBLIC NOTICE

AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD FOR WATERS AND POLLUTANTS OF CONCERN IN THE STATE OF SOUTH CAROLINA

Thompson Creek, Chesterfield County, SC

Section 303(d)(1) of the Clean Water Act (CWA), 33 U.S.C. **§**1313(d)(1)(C), and the implementing regulation of the US Environmental Protection Agency (EPA, 40 C.F.R. **§** 130.7(c) (1), require the establishment of total maximum daily loads (TMDLs) for waters identified as impaired pursuant to **§** 303(d)(1)(A) of the CWA. The South Carolina Department of Health and Environmental Control (DHEC) has developed a proposed fecal coliform bacteria TMDL for the identified **§** 303(d)(1)(A) water. Upon review of public comment and revision, if necessary, the Department will submit this TMDL to EPA for approval as final. Persons wishing to comment on the proposed TMDLs or to offer new data are invited to submit the same in writing no later than 5:00pm, August 7, 2003, to:

DHEC Bureau of Water

2600 Bull St.

Columbia, S.C. 29201

Attn: Mark Giffin

or to giffinma@dhec.sc.gov . Persons may also contact Kathy Stecker at 803-898-4011 . Copies of the TMDL can be obtained from the Bureau web site: www.scdhec.net/water/ or by writing or e-mailing Mr. Giffin. Comments received will be provided to EPA in a summary of public comment and DHEC responses.

APPENDIX E Responsiveness Summary

Comments: Thompson Creek Fecal Coliform TMDL

Commenters:

Chesterfield Soil and Water Conservation District

Pee Dee Resource Conservation and Development Area Council, Inc.

Comment: A commenter strongly endorsed this TMDL and encourages implementation of the TMDL.

The Department appreciates the support.

Comment: A commenter concurs with and supports the proposed TMDL. The proposed TMDL compliments their *Area Plan* goal to improve water quality.

The Department appreciates the support.