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Thompson Creek Nonpoint Source Assessment Project

Load Reduction Management Plan

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EXECUTIVE SUMMARY

This report presents a Load Reduction Management Plan Supporting Fecal Coliform Bacteria Total Maximum Daily Load (TMDL) Development for the impaired sections of Thompson Creek upstream of highway S-23-243. The project watershed area is located predominately in Chesterfield County, South Carolina (86.9 square miles), with several large tributary systems flowing south from Anson County, North Carolina (45.8 square miles). The mainstem of Thompson Creek flows in an easterly direction and eventually discharges into the Pee Dee River outside of the project area. Water quality data collected at strategic points in the project watershed area show that fecal coliform bacteria concentrations routinely exceed the South Carolina water quality standard. Although no sampling site(s) produced uniquely higher concentrations of fecal coliform bacteria, all the sampling sites showed substantially elevated concentrations during the summer months.

Fecal Coliform Bacteria Impairment. 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 station PD-246 located at the Route 102 Bridge adjacent to the Town of Chesterfield. Concentrations of fecal coliform bacteria exceeded the standard of 400 coliform forming units (cfu) per 100ml for more than ten percent of the samples acquired at this station. Due to these fecal coliform bacteria excursions, recreational uses are not supported. The State of South Carolina has, therefore, placed Thompson Creek upstream of highway S-13-243 on the 303(d) list.

Sources of Fecal Coliform Bacteria. No permitted discharge facilities are located in the project watershed area of Thompson Creek. This Load Reduction Management Plan has, therefore, focused entirely on nonpoint sources of fecal coliform bacteria. 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.

Agricultural Land Use Characterization. A geographic information system (GIS) database was developed to characterize potential fecal coliform bacteria loading sources from agricultural land uses. Every United States Department of Agriculture Farm Service Agency (FSA) recognized farm field in the watershed was digitized. Database attribute information included the location of pastures, poultry litter application areas, hog farm spray fields, sites possessing existing Best Management Practices (BMPs), and other information pertinent to fecal coliform bacteria loading. Information was compiled for approximately 2,000 farm fields from interviews with local agricultural agency experts, and field surveys. The database will be used during TMDL implementation planning to identify viable pasture, poultry litter application and other types of farm field sites for BMP implementation.

Water Quality Modeling. HSPF was selected as the modeling framework to simulate existing conditions and load reduction allocations. 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. The project watershed area was divided into eight discrete subbasin areas. Hourly flow data obtained from a USGS gage on Black Creek near McBee, South Carolina (02130900), were used to calibrate the hydrologic flow for the Thompson Creek project watershed, supplemented with stream stage data collected in Thompson Creek for this project. Fecal coliform bacteria and nutrient samples were acquired over a two-year period at five strategically located sites in the project watershed area. This information was consolidated with water quality data obtained at water quality monitoring station PD-246 to calibrate fecal coliform bacteria predictions, and develop a fecal coliform bacteria Load Reduction Management Plan for the Thompson Creek project watershed area.

Load Reduction Management Plan. Under existing conditions, HSPF results indicated violations of the standard throughout the watershed. To achieve compliance with water quality standards, it is recommended to reduce fecal coliform bacteria loads from direct deposition of animal waste in streams, failed septic systems, and runoff from poultry litter application areas/pastures by 77, 100, and 20 percent, respectively. The implementation of this load reduction allocation scenario would result in an overall reduction of fecal coliform bacteria loading from all sources equivalent to about 70 percent, and includes a 25 counts/100 mL margin of safety for the water quality criteria.

Stakeholder Development. Stakeholder recruitment and participation from a number of working group partners was prioritized throughout the development of this Load Reduction Management Plan. The final working group of stakeholders and community participants included:

- The Pee Dee Resource Conservation and Development (RC&D) Council;
- The Chesterfield and Brown Creek Soil and Water Conservation Districts;
- The Chesterfield and Anson County Natural Resources Conservation Service (NRCS) field offices;
- The Town of Chesterfield;
- The South Carolina Department of Natural Resources;
- The North Carolina Division of Soil and Water Conservation;
- The Chesterfield County and Anson County FSA field offices;
- The County of Chesterfield; and
- Consulting firms.

A stakeholder meeting was scheduled on October 26, 2001 in the Anson County, North Carolina Agriculture Service Center to recruit appropriate North Carolina Agency support. Moreover, the recruitment of localized support for the Load Reduction Management Plan goals and activities included presentations on September 19, 2000 to an assortment of local Chesterfield County landowners and farmers, Chesterfield County Farm Bureau representatives, and other organizations potentially affected by long-term TMDL implementation endeavors. Final Load Reduction Management Plan results will be presented to this same localized group of growers and organizations, and the numerous South Carolina and North Carolina agricultural agency representatives in January 2003.

Recommendations for TMDL Implementation. This Load Reduction Management Plan supporting fecal coliform bacteria TMDL development for Thompson Creek provides the framework and management tools for making informed decisions about the strategic selection, siting, and implementation of effective BMPs in the project watershed area. The long-term goal of the Load Reduction Management Plan is to develop a TMDL implementation plan that can be met through BMP implementation. To achieve this goal, three watershed planning components have been developed. Consultation with watershed stakeholders, including NRCS District Conservationists, has resulted in the development of a load reduction allocation scenario that can be both reasonably implemented and addresses the main sources of fecal coliform bacteria loading. In addition, a GIS database has been provided to watershed management decision makers that will assist to identify potential sources of fecal coliform bacteria loading, and target ideal farm field sites corrective action implementation. Finally, a group of agency and farming organizations in South Carolina and North Carolina have been recruited to provide advocacy assistance during the implementation planning phase of the project.

These three watershed planning components provide a starting point for developing effective implementation strategies. Modeling shows that periods of low flow (summer months) are the most critical for water quality. This result points out the primary need to reduce direct deposition of fecal coliform bacteria to the stream from livestock, and a secondary need to reduce runoff from pasture and cropland. To meet these needs, implementation funding must be acquired from a variety of sources. With the periodic and sporadic acquisition of these funds, a phased implementation planning approach is recommended where an iterative process for implementation is adhered. Sets of farm fields would be targeted and prioritized for implementation as funds are obtained. A continued review of sampling results acquired at the water quality monitoring station PD-246 and other strategically located sites in the project watershed area would occur following the implementation of prioritized farm field sets to measure (i.) the effectiveness of these implementation strategies, (ii.) the need for amending these strategies, and/or (iii.) progress toward the eventual removal of the impairment from the 303(d) list.

1 INTRODUCTION

1.1 BACKGROUND

Levels of fecal coliform bacteria can be elevated in water bodies as the result of both point and nonpoint sources of pollution. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires 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 upstream of highway S-13-243 as being impacted by fecal coliform bacteria, as reported on the State of South Carolina 1998 303(d) list of water quality impaired waters. In addition, DHEC placed this stream length of Thompson Creek in their highest priority ranking for impaired water bodies (DHEC, 1998). 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. The objective of this study is to develop a Load Reduction Management Plan supporting future TMDL development efforts that will result in a reduction of fecal coliform bacteria concentrations to levels that do not present a health risk, and that are below the state standard.

1.2 WATERSHED DESCRIPTION

The Thompson Creek watershed above highway S-13-243 is located mainly in Chesterfield County, South Carolina (watershed area of 86.9 square miles). Several large tributaries, including Deadfall, Clay, and Cedar Creeks, also flow south from Anson County, North Carolina (watershed area of 45.8 square miles). The sum of the stream reaches in this project watershed area approximates 143 miles. 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 (NLCD), land use in the Thompson Creek watershed project area (Table 3-1) is predominately forest (74.7 percent); the remaining being cropland (18.7 percent), pasture (6.1 percent), and developed (0.6 percent). The eight subbasins in the project watershed area include:

- Lower Thompson Creek mainstem (18.7 square miles);
- Middle Thompson Creek mainstem (12.4 square miles);
- Upper Thompson Creek mainstem (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).

Table 3-1 shows that the most concentrated agricultural land use activities occur in two of the smaller Subbasins: Cedar Creek (42.7 percent) and the Upper Thompson Creek mainstem (45.8 percent). Conversely, Deadfall Creek is the second largest Subbasin, 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 Subbasin. 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 hayland;

- Two large swine operations are currently in use (one of which possesses 880 animals); and two nursery operations are active (possessing a total of 4,400 swine).

- Boiler and turkey operations possessing a total of approximately 400,000 and 44,000 birds, respectively.

Although no permitted discharge facilities are located in the project watershed area of Thompson Creek, it is estimated that approximately 300 to 1,000 septic systems are currently in use.

The Town of Chesterfield relies on Thompson Creek for a source of public drinking water and to assimilate wastewater loads. The water supply intake structure and the wastewater discharge point are both less than two-miles downstream of the impaired project watershed area. The Town, therefore, has expressed public health concerns and a concern for their wasteload allocation.

1.3 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).

2 WATER QUALITY ASSESSMENT

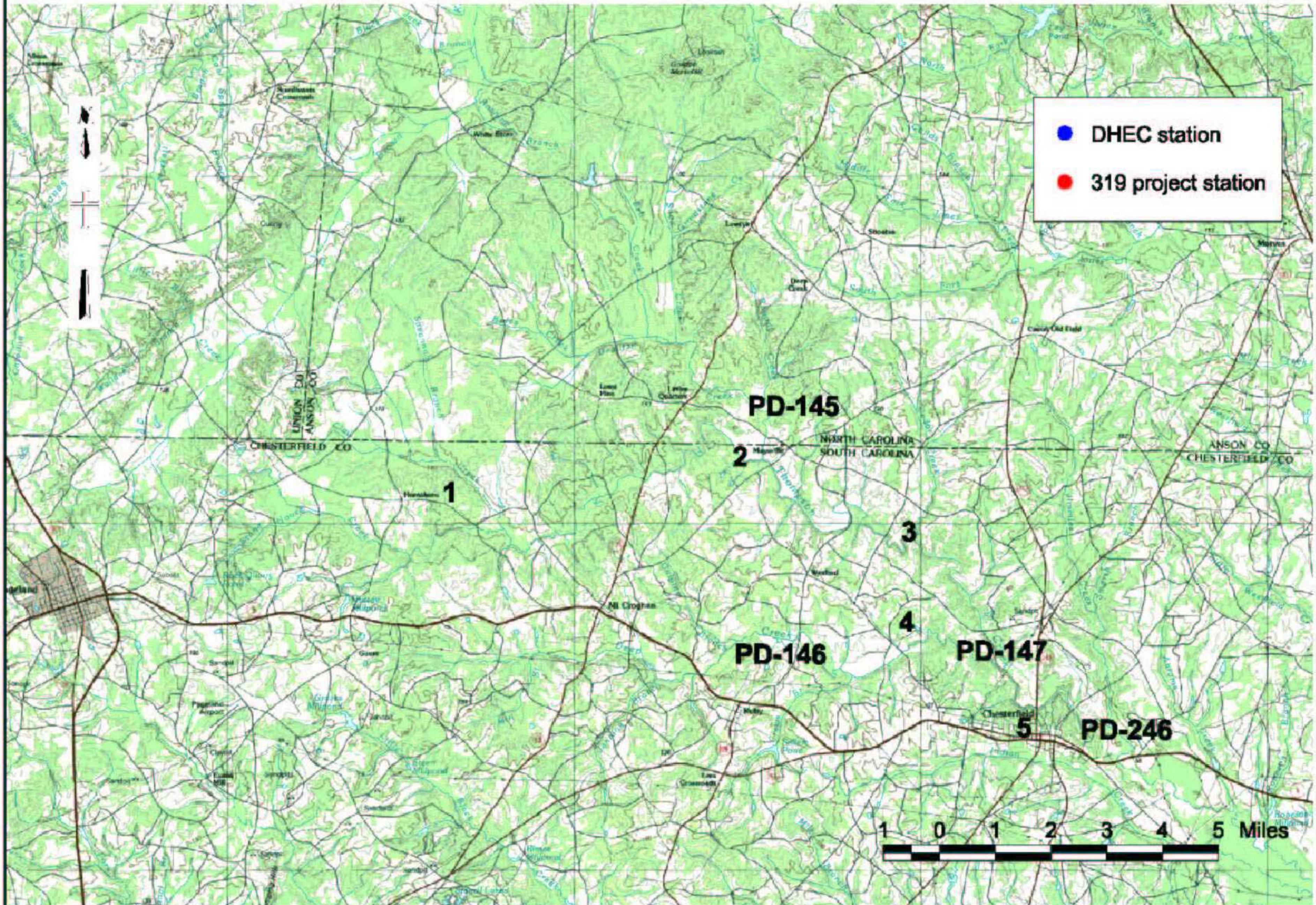
Prior to a detailed source assessment and modeling analysis, it is helpful to examine the spatial, seasonal, and hydrologic variability and co-variability in bacteria data. Such information provides insight into the mode and magnitude of coliform loading to the stream. For example, high concentrations 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 SC-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 SC-13-243 (Figure 2-1) since the 1970s. Most samples from this station were collected under dry weather conditions, and results from this station were the primary 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 DHEC monitoring stations 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 2-1). The 319 project stations were sampled eight times between November 2000 and August 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 B.

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



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Thompson Creek Watershed Project
WATER QUALITY STATION LOCATIONS

January 2003

Figure 2-1

2-2). 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 another. This spatial pattern of concentrations is consistent with nonpoint sources that are present throughout the basin.

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 2-3). 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 explanation 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.

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 5, this model was used to estimate streamflow as a function of hourly precipitation data, potential evapotranspiration, 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 2-4) 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

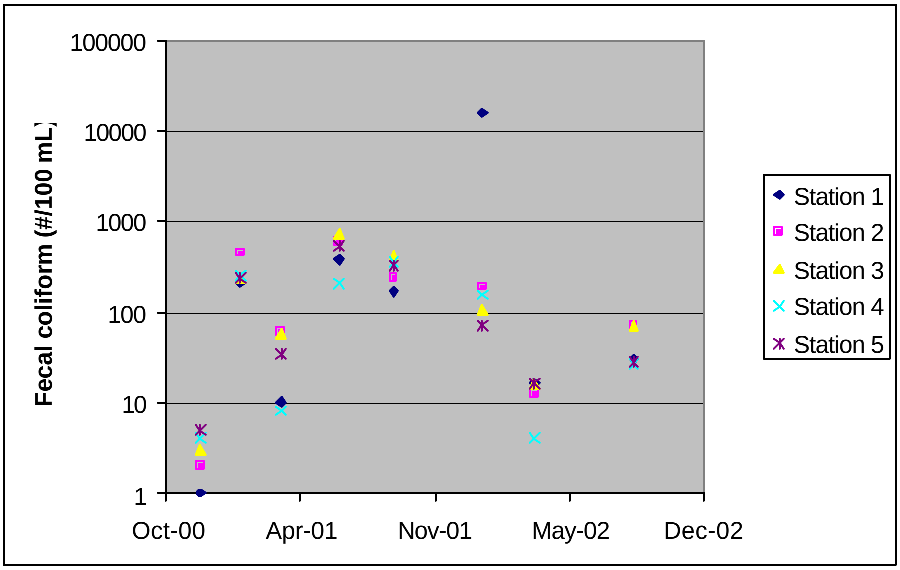


Figure 2-2: Fecal coliform concentrations v. time at the five 319 project stations.

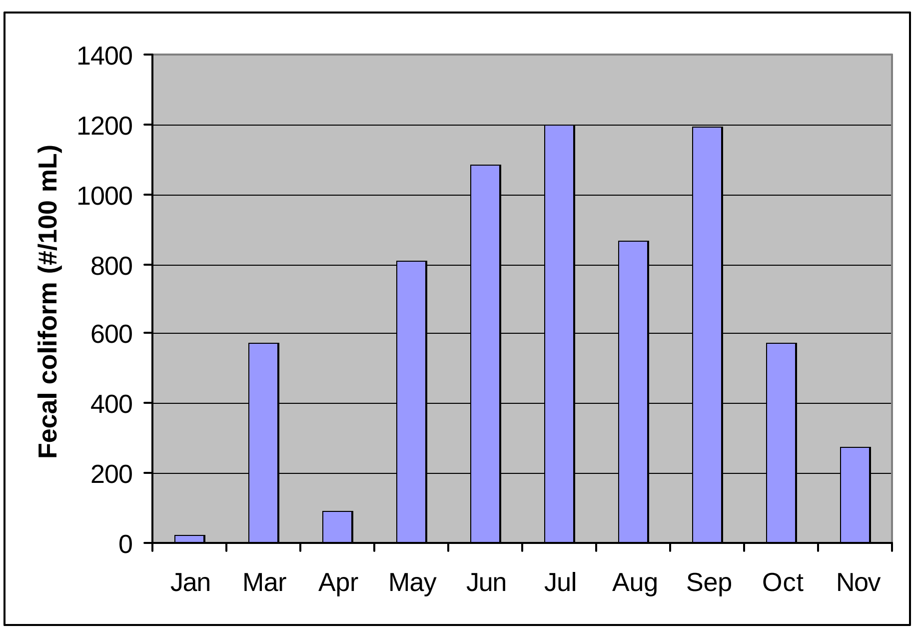


Figure 2-3: Mean fecal coliform concentration v. month in the Thompson Creek study area. Mean values were calculated using 1970-2002 data from DHEC stations PD-145, PD-146, PD 147, PD-246 and 319 project stations 1-5.

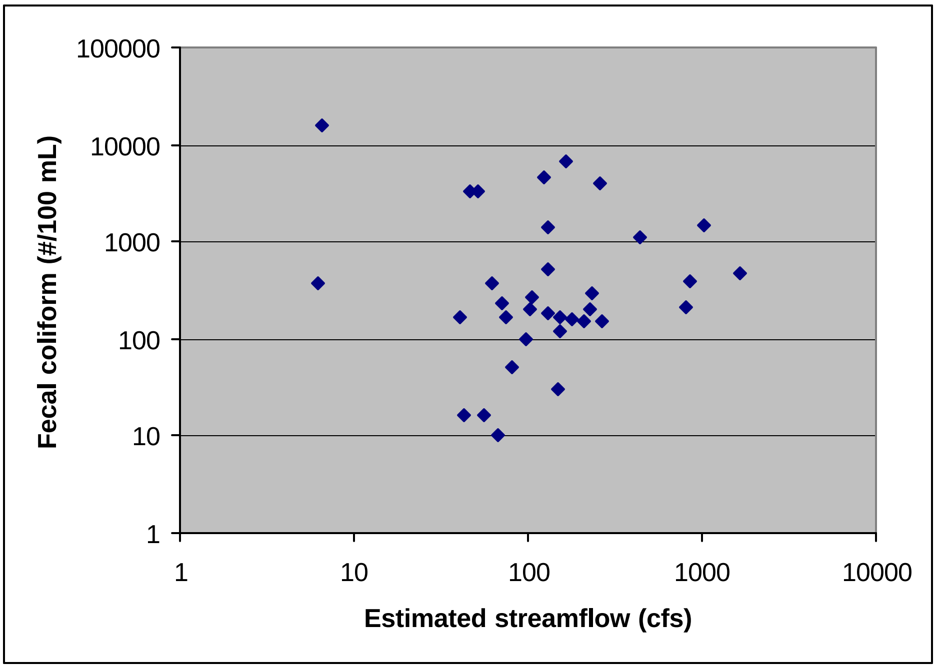


Figure 2-4: Fecal coliform concentration v. estimated streamflow in the Thompson Creek study area, 1995-2002. Streamflow estimates were obtained from HSPF model output.

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.

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	341-1,410	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 concentration 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.

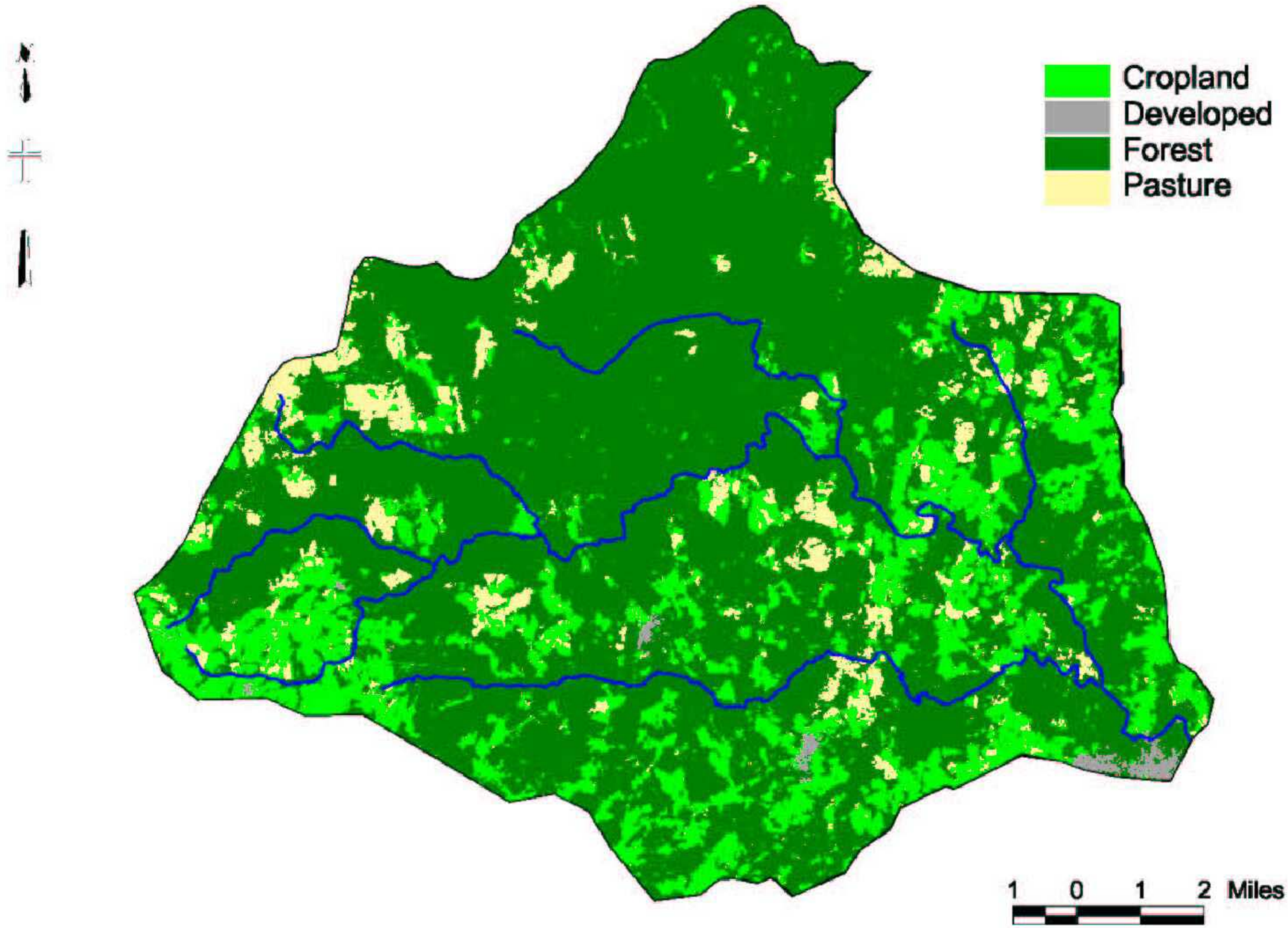
3 SOURCE ASSESSMENT

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 subbasins of Thompson Creek above highway SC 13-243 (Figure 3-1; Table 3-1).

3.1 POINT SOURCES

There are no regulated point source discharges to Thompson Creek and its tributaries above highway SC-13-243, although the Town of Chesterfield WWTP discharges just downstream of this segment. Failing septic systems and straight-pipe discharges were treated as nonpoint sources and were quantified as described in section 3.2.4.



MALCOLM PIRNIE

Pes Dee RC&D
Thompson Creek Watershed Project
LAND USE CLASSIFICATION

January 2003

Figure 3-1

TABLE 3-1

Area and Land Use Classification by Subbasin

Subbasin	Name	Total Area	Area in Anson Co		Area in Chesterfield Co		Area in Union Co		Percentage by land type (%)			
		(acres)	(acres)	(%)	(acres)	(%)	(acres)	(%)	Forest	Pasture	Cropland	Developed
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 Cr	7,938	1,254	15.8	6,684	84.2	0	0.0%	81.8	5.2	12.9	0.0
3	Upper Thompson Cr	5,168	0	0.0	5,168	100.0	0	0.0%	53.3	6.5	39.3	0.9
4	Deep Cr	23,178	0	0.0	23,178	100.0	0	0.0%	70.5	4.2	24.7	0.6
5	Cedar Cr	4,727	3,436	72.7	1,291	27.3	0	0.0%	57.3	9.6	33.1	0.0
6	Deadfall Cr	19,357	19,234	99.4	123	0.6	0	0.0%	92.1	3.1	4.8	0.0
7	Clay Cr	7,893	4,302	54.5	3,248	41.2	342	4.3%	77.5	12.8	9.7	0.0
8	House Cr	5,099	0	0.0	5,081	99.7	17	0.3%	71.5	10.6	17.6	0.2
All	Thompson Creek upstream of SC-13-243	85,303	29,340	34.4	55,604	65.2%	360	0.4%	74.7	6.1	18.7	0.6

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 3-2. 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. 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 subbasins 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.

TABLE 3-2

Fecal Coliform Unit Loading Rates

Source	Fecal Coliform Loading Rate	Units	BIT Reference
Deer	5.0×10^{8}	count/animal/day	Best professional judgment
Raccoon	1.2×10^{8}	count/animal/day	Best professional judgment
Cattle	1.0×10^{11}	count/animal/day	ASAE, 1998
Poultry (litter)	1.3×10^{6}	count/gram litter	LIRPB, 1978
Septage	1.0×10^{4}	count/100 mL	Horsley and Witten, 1996
Developed Land	1.1×10^{7}	counts/acre/day	Horner, 1992

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).

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 subbasin. 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 3-3.

TABLE 3-3

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 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 MODELING

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 (evapotranspiration, 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 evapotranspiration, 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 SC-13-243 was conceptually divided into eight subbasins and eight corresponding stream segments (Figure 4-1). Each of the four major land uses (forest, pasture, cropland, and developed) within each subbasin 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 subbasin 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.

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.

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.

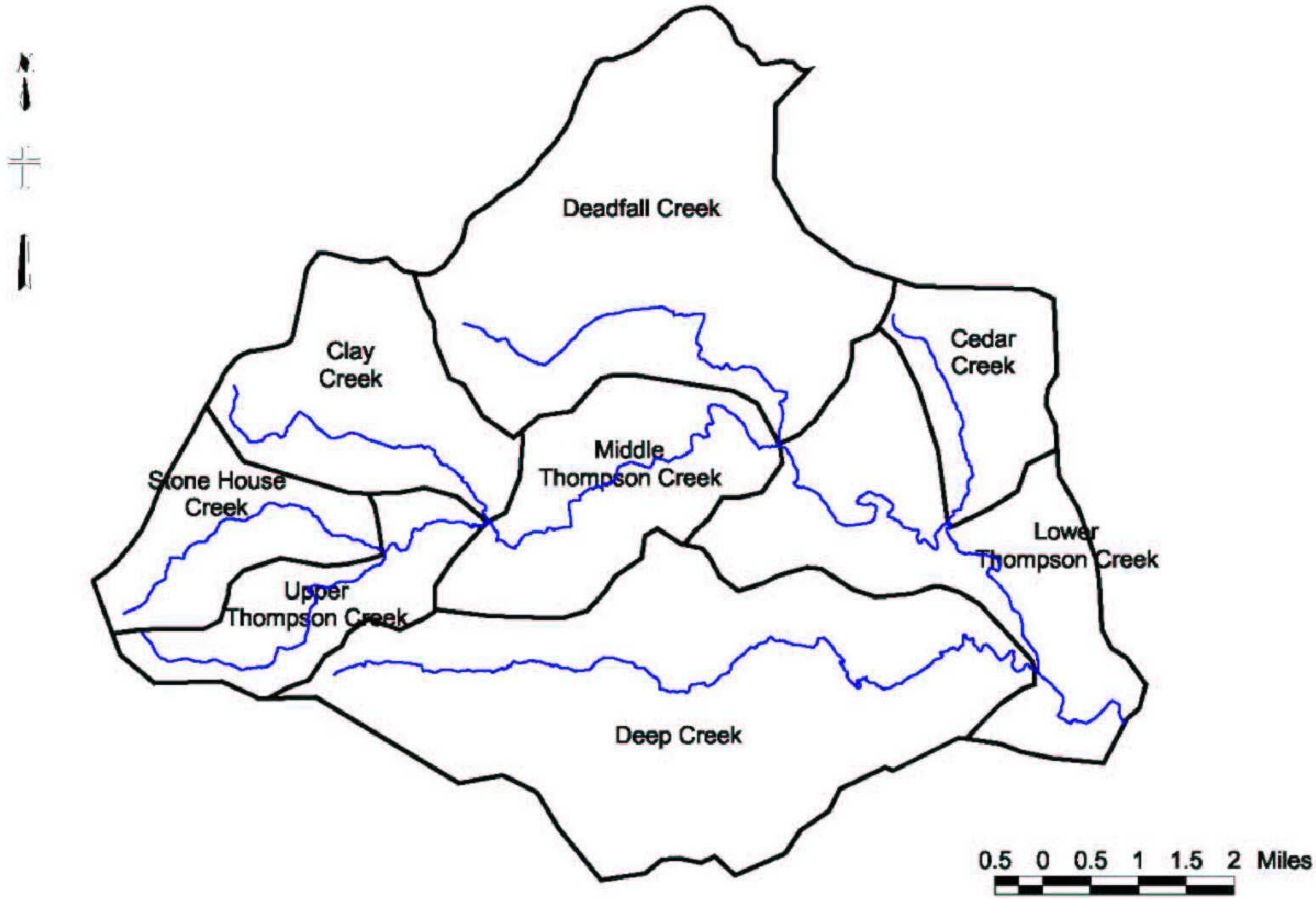


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Figure 4-1

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.

4.2 METEOROLOGICAL DATA SOURCES

HSPF requires input times series of precipitation and potential evapotranspiration (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 subbasin area developed by the USGS (USEPA, 2001).

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 subbasins 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 subbasin 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

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.

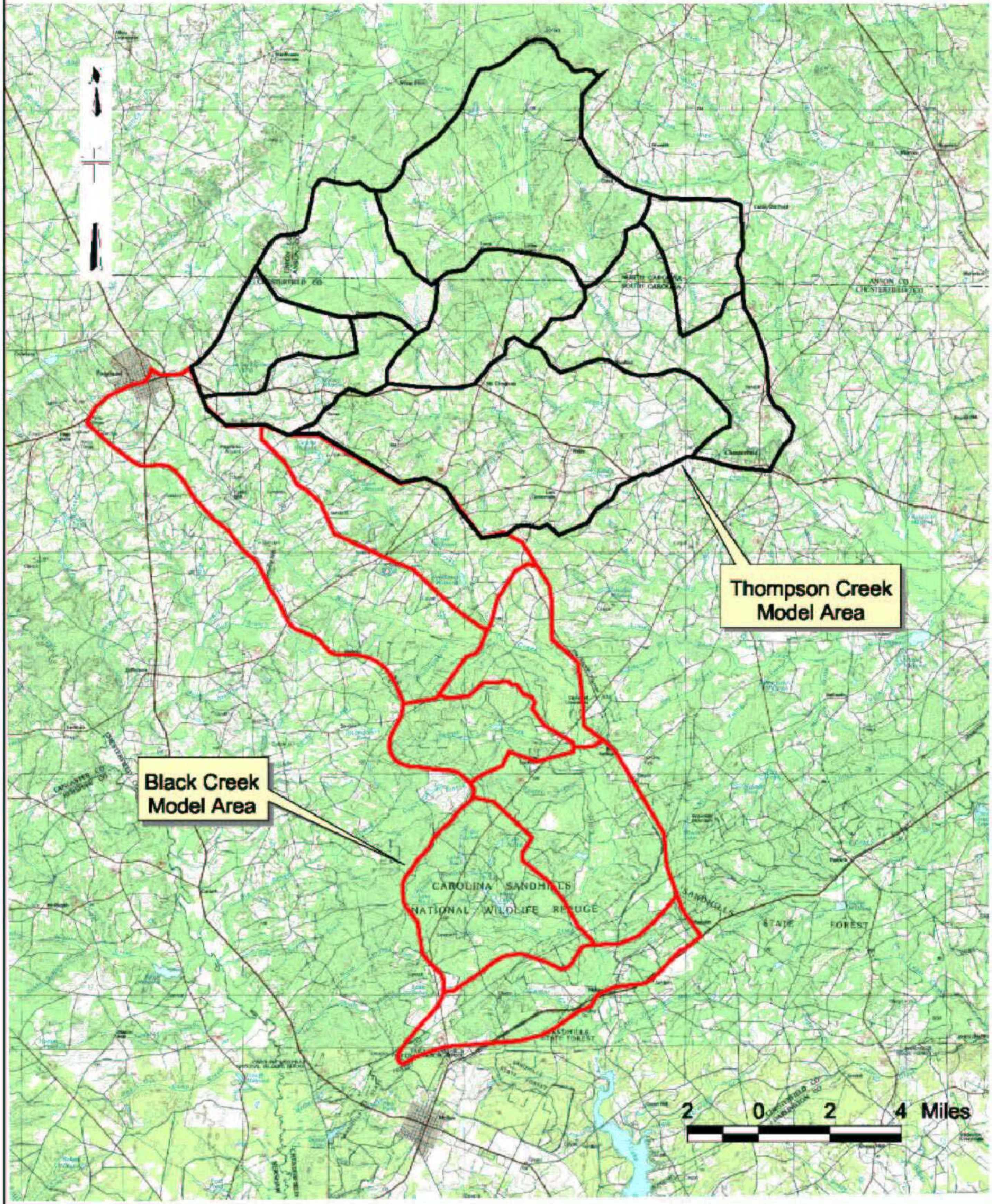

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Figure 4-2

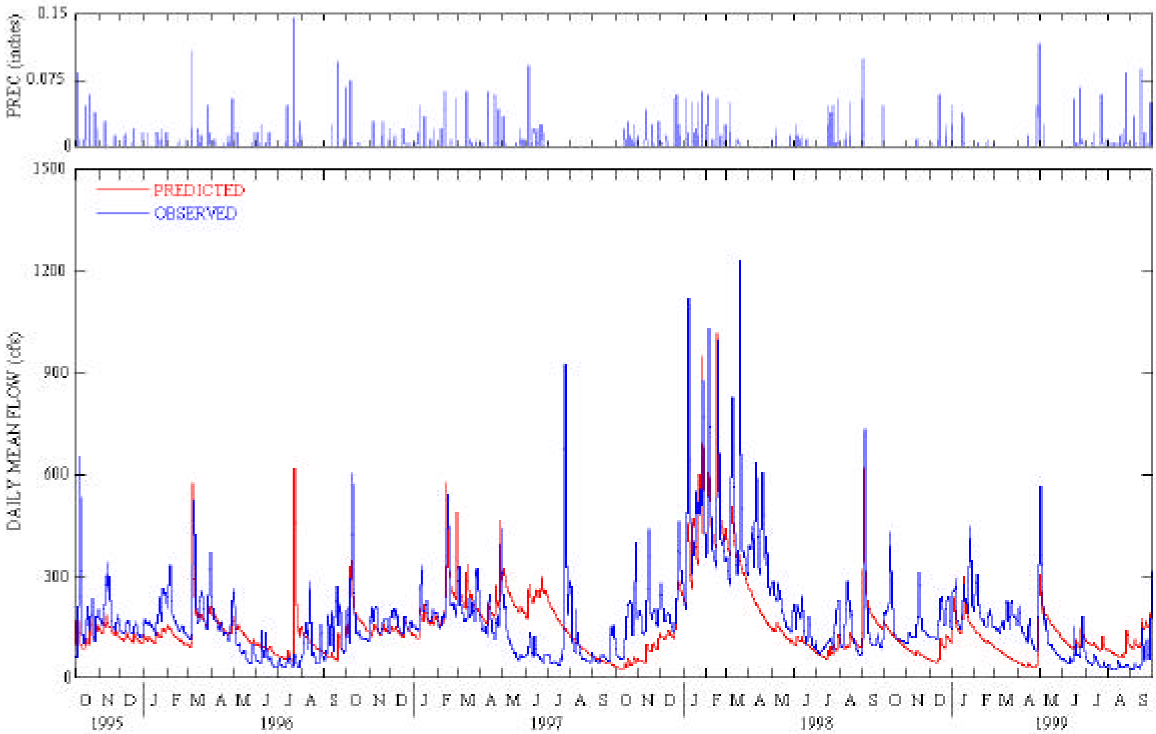


Figure 4-3: Observed and predicted mean daily streamflow at USGS gaging station 02130900 (Black Creek near McBee, SC).

events and underpredicted 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 underpredicted 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 underpredict 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/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.

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 fecal 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

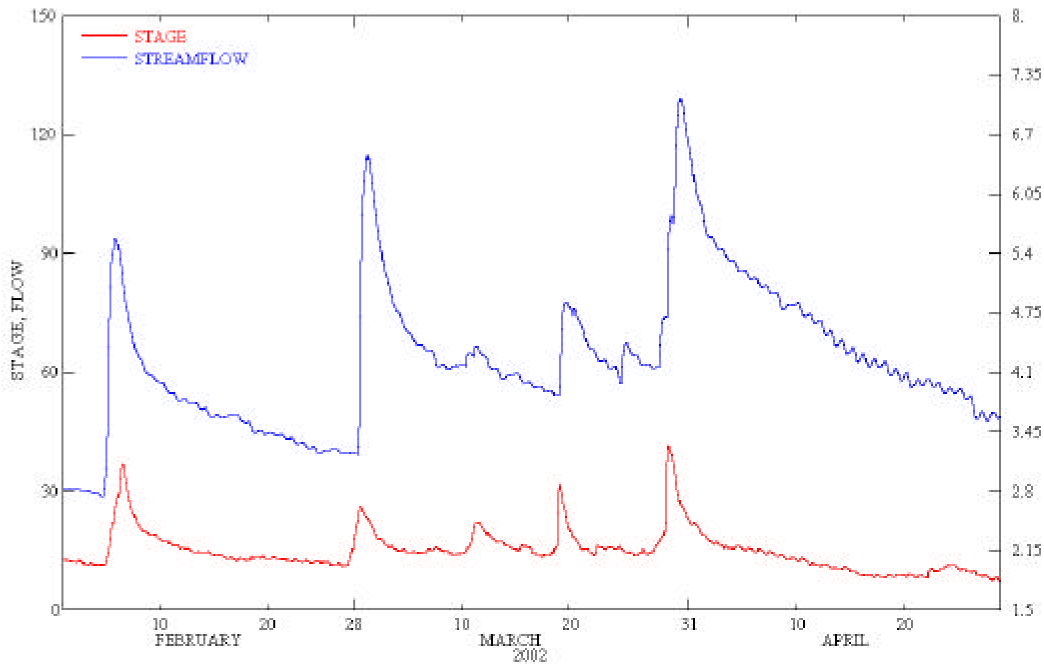


Figure 4-4: Observed stage and predicted hourly streamflow in Thompson Creek above highway SC-13-243 (RCHRES 1).

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 in-stream 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 subbasin 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.

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

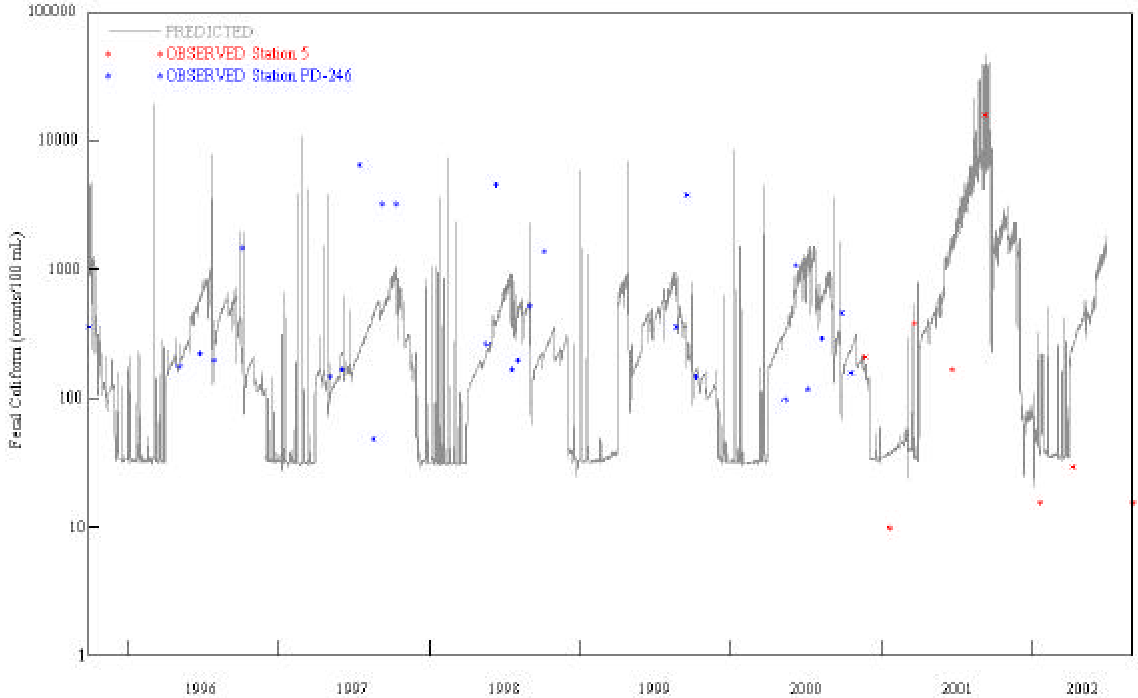


Figure 4-5: Observed and predicted fecal coliform concentration in Thompson Creek above highway SC-13-243 (RCHRES 1).

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.

August was selected as the most critical 30-day period 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 August 1 to 30, 1999 was selected as the critical period for load allocations.

5 RESULTS

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 Above Highway SC-13-243
[based on HSPF model predictions for 1996-2001]

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

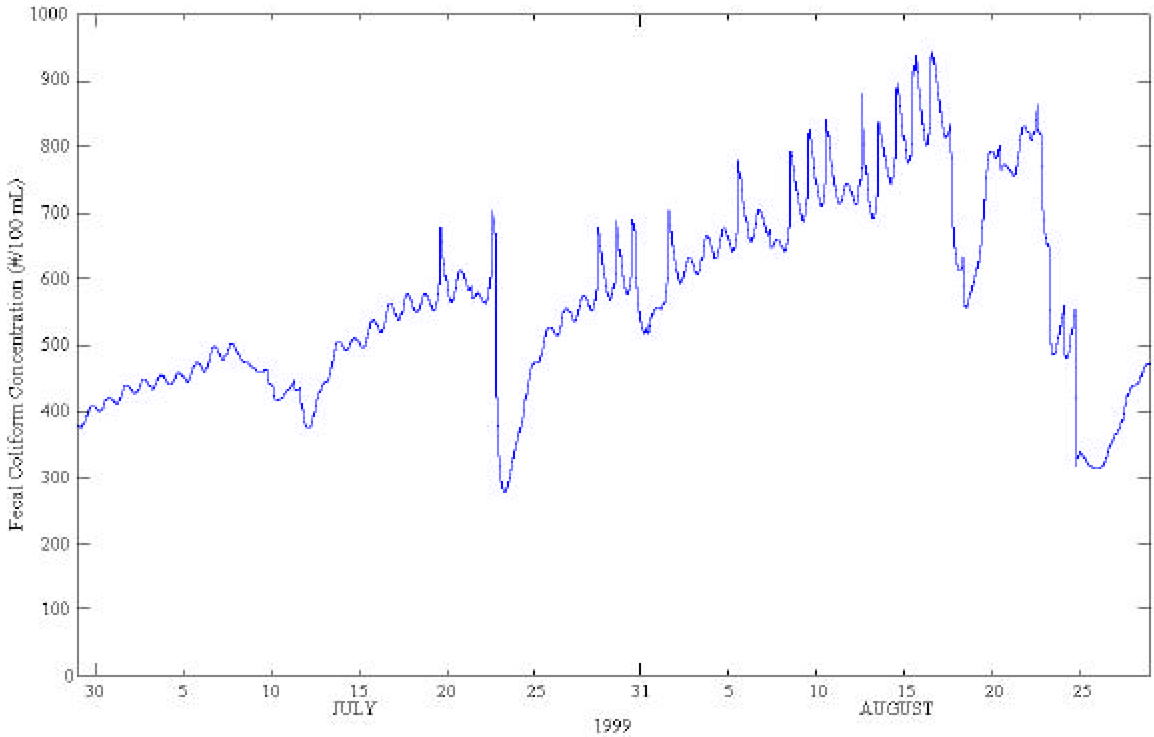


Figure 5-1: Predicted fecal coliform concentration in Thompson Creek above highway SC-13-243 (RCHRES 1) under low-flow, summer conditions.

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.

5.2 CRITICAL CONDITIONS

During the critical period (August 1999) shown on Figure 5-1, the predicted 30-day geometric mean fecal coliform concentration was 638 counts/100 mL, well above the criteria of 200 counts/100 mL. Similarly, the predicted concentrations exceeded 400 counts/100 mL approximately 91 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 EXPLORATORY LOAD REDUCTION SCENARIOS

Several loading reduction scenarios were developed to explore the response of in-stream concentrations to the removal of different sources. These scenarios were not intended to represent realistic or desirable implementation scenarios, but merely to characterize which sources are and are not important causes of the standards violations.

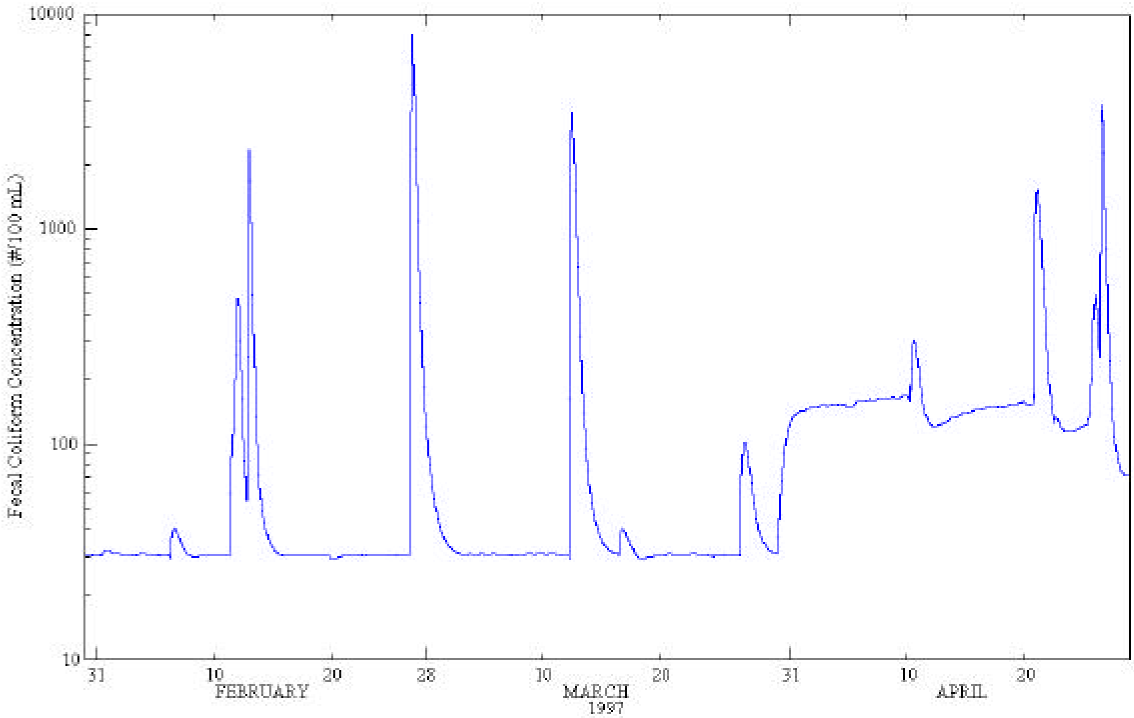


Figure 5-2: Predicted fecal coliform concentration in Thompson Creek above highway SC-13-243 (RCHRES 1) under spring conditions.

The exploratory scenarios were as follows:

> *Scenario #1*: 50-percent reduction in loads from in-stream cattle, with the cattle load increased by a corresponding amount on pasture land as if half the cattle were fenced from the stream.
>
> *Scenario #2*: 100-percent reduction in loads from instream cattle, with the cattle load increased by a corresponding amount on pasture land as if all cattle were fenced from the stream.
>
> *Scenario #3*: 50-percent reduction in loads from cattle, as if the number of cattle in the basin were reduced but the proportion spending time in streams was unchanged.
>
> *Scenario #4*: 50-percent reduction in poultry litter application rates.
>
> *Scenario #5*: 100-percent reduction in loads from failing septic systems.
>
> *Scenario #6*: 50-percent reduction in loads from wildlife.

Scenario results were interpreted graphically (Figure 5-3) and by examination of the predicted geometric mean fecal coliform concentration for the critical period (Table 5-2). As expected, only reductions in in-stream cattle loads were predicted to cause large decreases in the 30-day geometric mean fecal coliform concentration during the critical period. Reductions in loads from in-pasture cattle and poultry litter reduced the peak concentrations during spring and summer storm events, but had little effect on concentrations during baseflow periods. Reductions in wildlife loads reduced concentrations in winter baseflow and winter storm events, but had little effect during warm weather months because the majority of the bacteria available for washoff was derived from agricultural sources during these months. Elimination of the minor load from failing septic systems had a negligible effect on concentrations under all conditions.

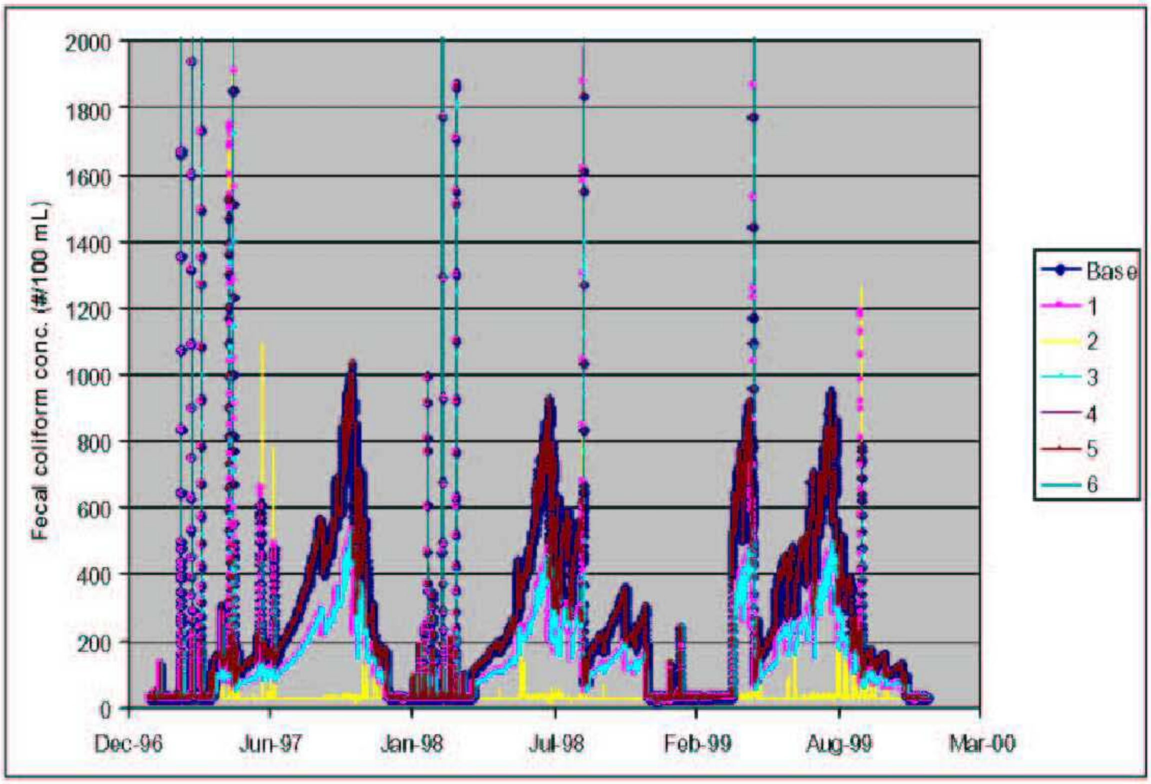


Figure 5-3: Predicted fecal coliform concentration in Thompson Creek above highway SC-13-243 (RCHRES 1) under base (existing) conditions and for six exploratory load reduction scenarios.

TABLE 5-2

Predicted 30-Day Geometric Mean for the Critical Period Under the Exploratory Scenarios

[Critical period defined as Aug 1-30, 1999]

Scenario	Description	30-Day Geometric Mean (counts/100 mL)
BASE	Existing conditions	638
1	50% reduction in instream cattle	343
2	100% reduction in instream cattle	42
3	50% reduction in cattle	339
4	50% reduction in poultry litter application	638
5	100% reduction in failing septic systems	634
6	50% reduction in wildlife	622

5.4 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 POTENTIAL ALLOCATIONS

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 SC-13-243. SCDHEC has previously used a margin of safety of 25 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 overfertilization of certain crops (e.g., soybeans).

6.1 WASTELOADS

Because the stream segment of interest has no current or planned point source discharges, the recommended load allocation included no wasteloads.

6.2 LOADS

The recommended allocation includes a 77-percent in loads from in-stream livestock, a 100-percent reduction in failing septic systems and a 20-percent reduction in loads from poultry litter. The net result is a 68-percent reduction in the 30-day load of fecal coliform (Table 6-1) to Thompson Creek above highway SC-13-243 under critical conditions. The Thompson Creek HSPF model indicates that this loading scenario will result in a geometric mean fecal coliform concentration of 160 counts/100mL under critical conditions (August 1999) and will not violate the water quality standard except during extreme drought conditions. Figure 6-1 displays the time series of the predicted fecal coliform concentration under existing conditions and under the recommended loading scenario.

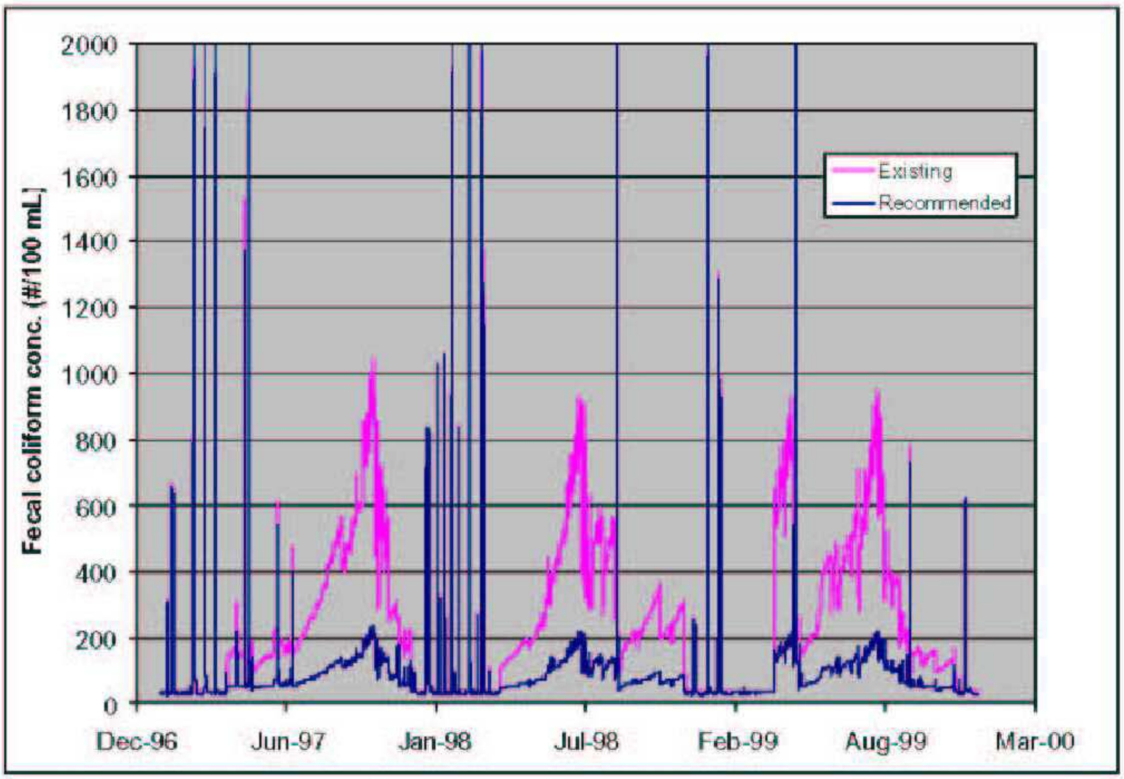


Figure 6-1: Predicted fecal coliform concentration in Thompson Creek above highway SC-13-243 (RCHRES 1) under base (existing) conditions and under the recommended load allocation scenario.

TABLE 6-1

Recommended Load Allocations for Thompson Creek Above Highway SC-13-243

Type of Load	Existing Load (counts/30 days)	Recommended Load (counts/30 days)
Wasteload	0	0
Load	2.42×10^{13}	7.69×10^{12}
Margin of safety	--	2.97×10^{11}
Total	--	7.98×10^{12}

7.0 AGRICULTURAL LAND USE CHARACTERIZATION

7.1 GIS DATA LAYER: DEVELOPMENT OF AGRICULTURAL LAND USES

Numerous agricultural agencies in South Carolina and North Carolina are charged with the responsibility of satisfying the provisions described in this fecal coliform bacteria Load Reduction Management Plan, and any future requirements resulting from state TMDL development endeavors. GIS datalayers have been developed for the South Carolina and North Carolina portions of the Thompson Creek project watershed area to help accomplish the following future implementation planning tasks:

- Assess potential sources of fecal coliform bacteria loading from specific pasture and cropland land use areas;
- Effectively and efficiently consolidate and monitor corrective actions (i.e., Best Management Practices (BMPs) and conservation practices) associated with meeting the goals of the Load Reduction Management Plan;
- Facilitate consensus building among the various agencies and landowners during implementation decision making.

The datalayer development effort included the following steps:

1. Approximately 2,000 pastures, croplands, and haylands located in the project watershed area were digitized using available Digital Ortho Quarter Quadrangle (DOQQ) photos. 1999 color and 1993/1994 Black and white DOQQs were acquired from appropriate South Carolina and North Carolina agencies, respectively. Farm field boundaries were obtained by referencing hand-marked FSA hardcopy aerial photographs located in the Chesterfield County and Anson County Agriculture Service Centers in Chesterfield, South Carolina and Wadesboro, North Carolina, respectively.

2. Farm field administrative attribute information was also obtained from the hand-marked FSA hardcopy aerial photographs. This included respective farm tract and field (common land use) numbers, and farm field acreages. The South Carolina FSA aerial photographs were being updated during GIS datalayer development efforts, and as a result, the majority of the bounded farm fields lacked administrative information. A project-specific numbering scheme was, therefore, applied to the respective South Carolina farm field boundaries for project referencing purposes.

3. Additional fecal coliform bacteria loading attribute information applicable to specific farm field boundary areas were acquired from two sources:

- Interviews conducted with agricultural agency field experts in both Chesterfield and Anson Counties;
- Field surveys of the Anson County portion of the Thompson Creek watershed conducted on February 21 and 22, 2002 by the Pee Dee RC&D Council and MSD Associates.
- Known or field verified attribute information included agricultural land use cover types (i.e., pasture, cropland, hayland); presence of animals; litter application sites; poultry houses; poultry litter piles; and hog operations and associated spray fields

7.2 AGRICULTURAL LAND USE CHARACTERIZATION RESULTS

The results of the agricultural land use characterization are detailed below for each of the eight Thompson Creek project watershed area subbasins. The Upper Thompson Creek mainstem and Stone House Creek subbasin areas were consolidated and reviewed as a single subbasin. **Table 7-1** depicts an assortment of farm field information pertinent to fecal coliform bacteria loading and applicable to each subbasin. The information was acquired during this agricultural land use characterization.

TABLE 7-1

Farm Field Characteristics Pertinent to Fecal Coliform Bacteria Loading

Subbasin	Total Farm Fields (Number)	Pastures Lacking BMPs (Number)	Farm Fields Receiving Litter (Number)	Concentration of Farm Fields (Number per Square Mile)	Concentration of Pastures Lacking BMPs (Number per Square Mile)	Concentration of Farm Fields Receiving Litter (Number per Square Mile)
Clay Creek	158	46	9	12.8	3.7	0.7
Deadfall Creek	282	66	28	9.3	2.2	0.9
Cedar Creek	279	93	17	37.7	12.6	2.3
Lower Thompson Creek Mainstem	299	107	42	16.0	5.7	2.2
Middle Thompson Creek Mainstem	109	43	21	8.8	3.5	1.7
Upper Thompson Creek Mainstem and Stone House Creek	230	37	32	14.3	2.3	2.0
Deep Creek	560	163	71	15.5	4.5	2.0
Total	*1,917*	*555*	*220*	*14.4*	*4.2*	*1.7*

Two conclusions can be derived from a review of these agricultural land use practices in the project watershed area:

- The quantities of potential sources of fecal coliform bacteria from agricultural land use activities are extremely large, and are located throughout the entire project watershed area; which coincides with the consistently high concentrations of fecal coliform bacteria at *all five* sampling sites; and

- It is probable that a considerable amount of time and resources will be expended during the implementation phase of the project in both Chesterfield and Anson Counties to reduce the amounts of fecal coliform bacteria loading to acceptable levels.

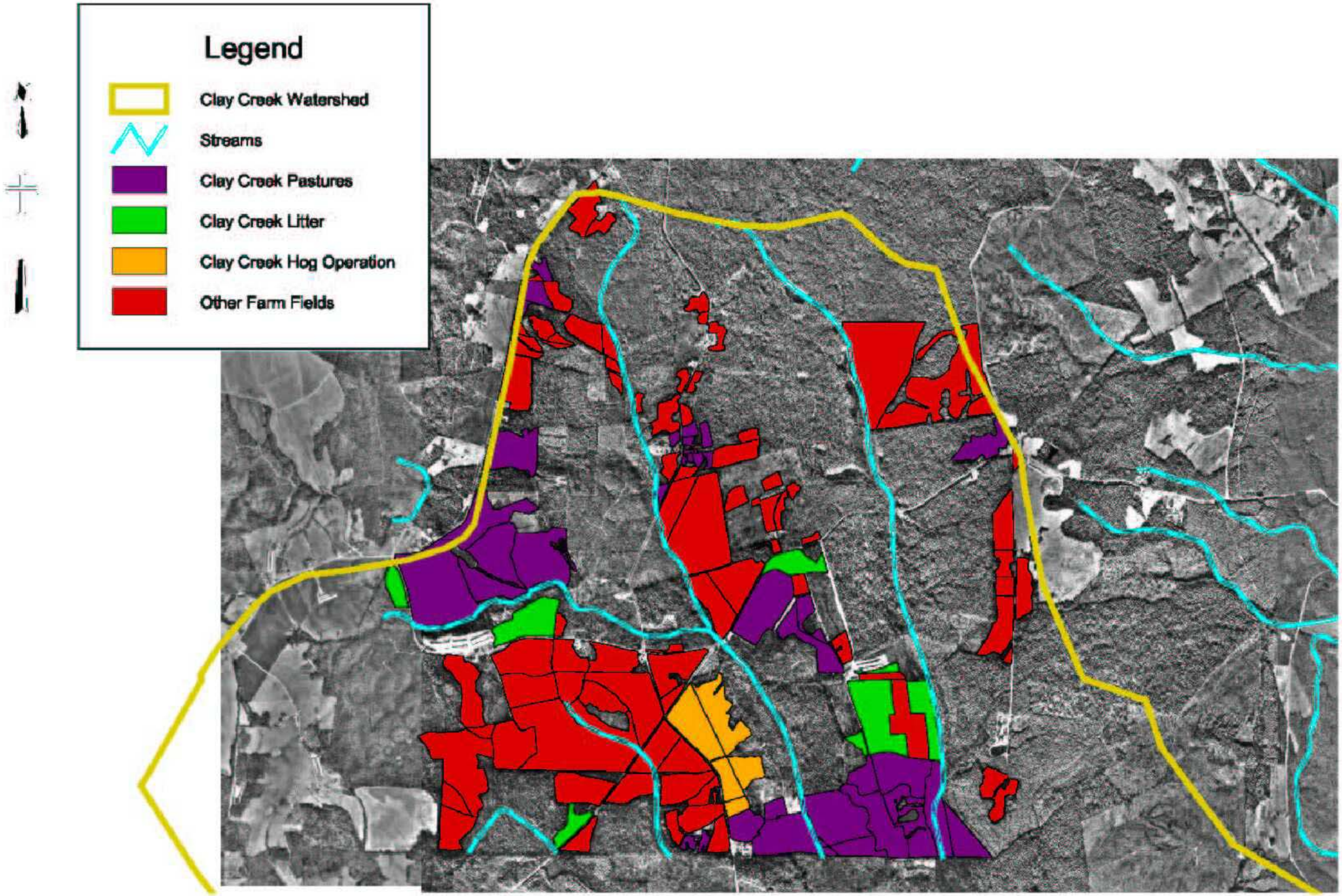
This land use information will be consolidated with BASIN modeling results and stakeholder recruitment efforts to initiate the development of an effective TMDL implementation plan. The following subbasin descriptions and figures provide a detailed accounting of agricultural practices in the project watershed area.

Clay Creek Subbasin

The Clay Creek Subbasin is located predominately in North Carolina. Clay Creek discharges directly into the Upper Thompson Creek mainstem. As noted in Figures 7-1 and 7-2, the Clay Creek Subbasin area contains a number of pastures and poultry operations (particularly in the North Carolina portion of the Subbasin). Litter piles were noted at three locations during the February field verification trip, and based on conversations with NRCS District Conservationists, considerable amounts of poultry litter is transported both ways across the North Carolina / South Carolina state line. A small number of farm fields located in the headwater areas of this Subbasin are situated in Union County, North Carolina. These farm fields were not reviewed during this agricultural land use characterization.

Deadfall Creek Subbasin

The Deadfall Creek watershed is the second largest Subbasin in the project watershed area and is located entirely in Anson County. As shown in Figure 7-3, the vast majority of land use activity is related to the forestry industry. As a result, the

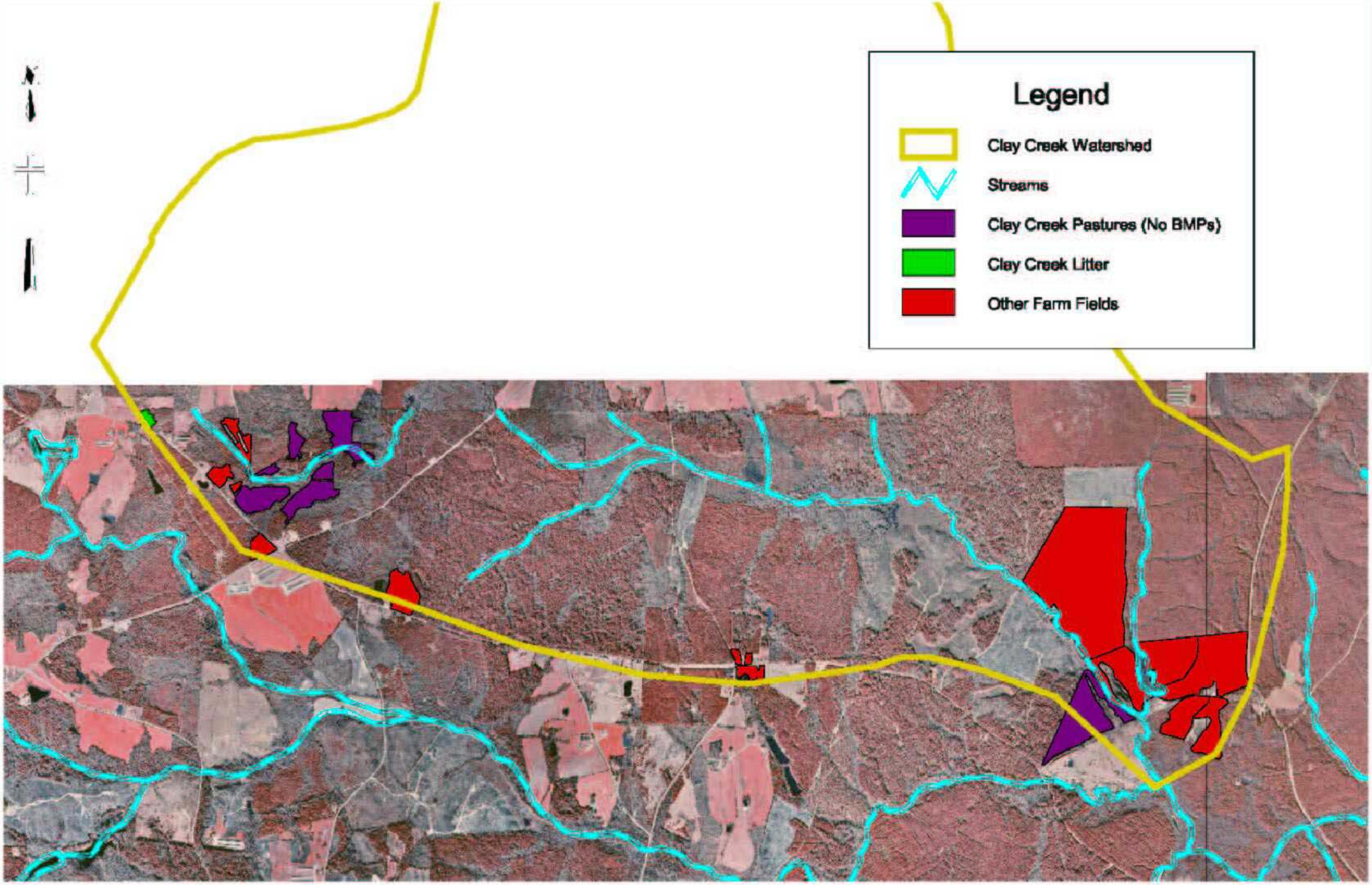


MALCOLM PIRNIE

Pee Dee RC&D
Thompson Creek Watershed Project
CLAY CREEK SUBBASIN (NC)

January 2003

Figure 7-1



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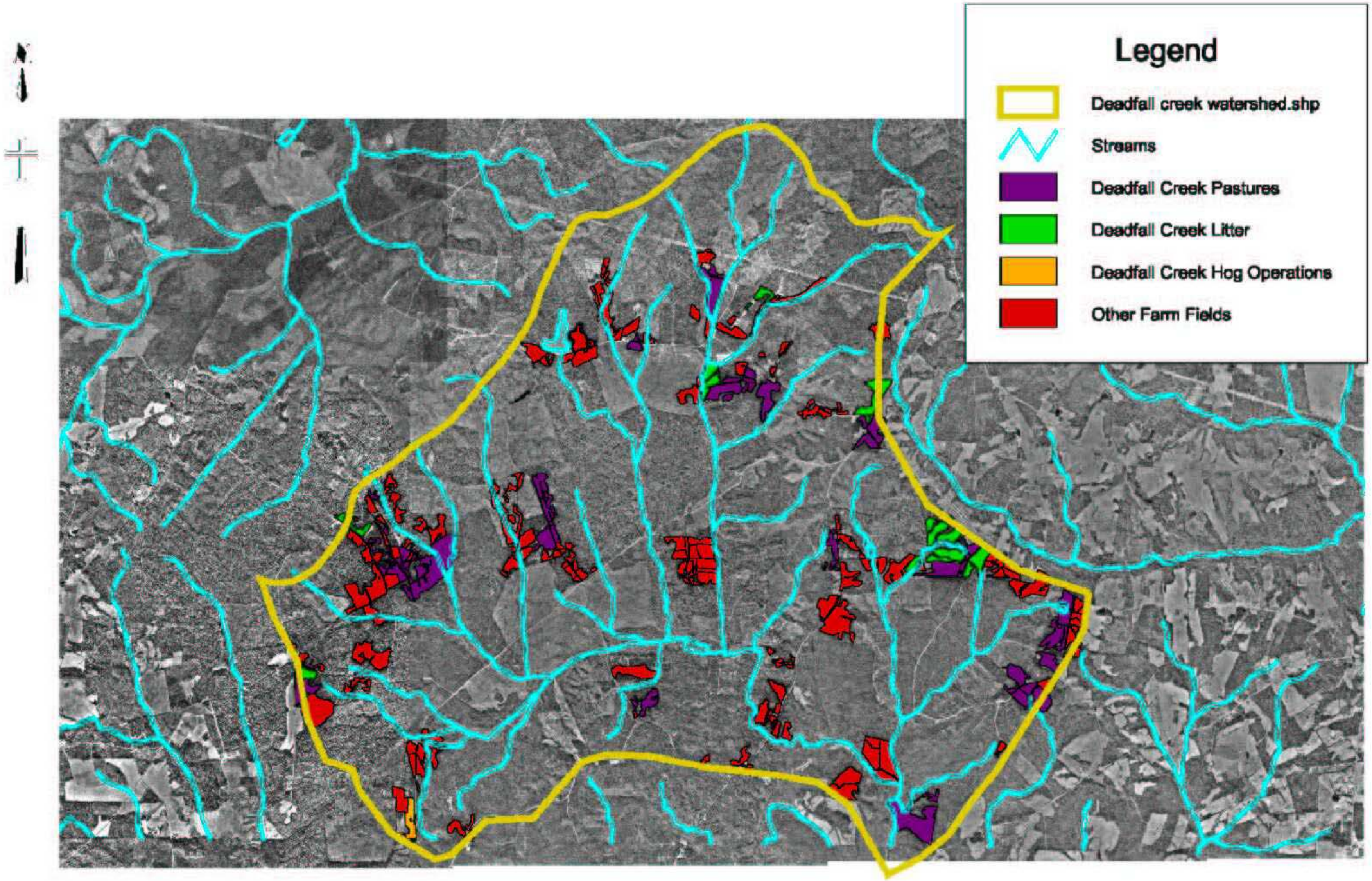
Pee Dee RC&D
Thompson Creek Watershed Project
CLAY CREEK SUBBASIN (SC)

January 2003

Figure 7-2



MALCOLM PIRNIE

Pee Dee RC&D
Thompson Creek Watershed Project
DEADFALL CREEK SUBBASIN

January 2003

Figure 7-3

agricultural land use activities on a square mile basis are small in comparison to the majority of subbasins in the project watershed area, and are limited to two hog operations, and a scattering of pastures and poultry litter application areas. A sampling station located in the vicinity of the Deadfall Creek discharge point into Thompson Creek shows consistent violations to the state fecal coliform bacteria standard.

Cedar Creek Subbasin

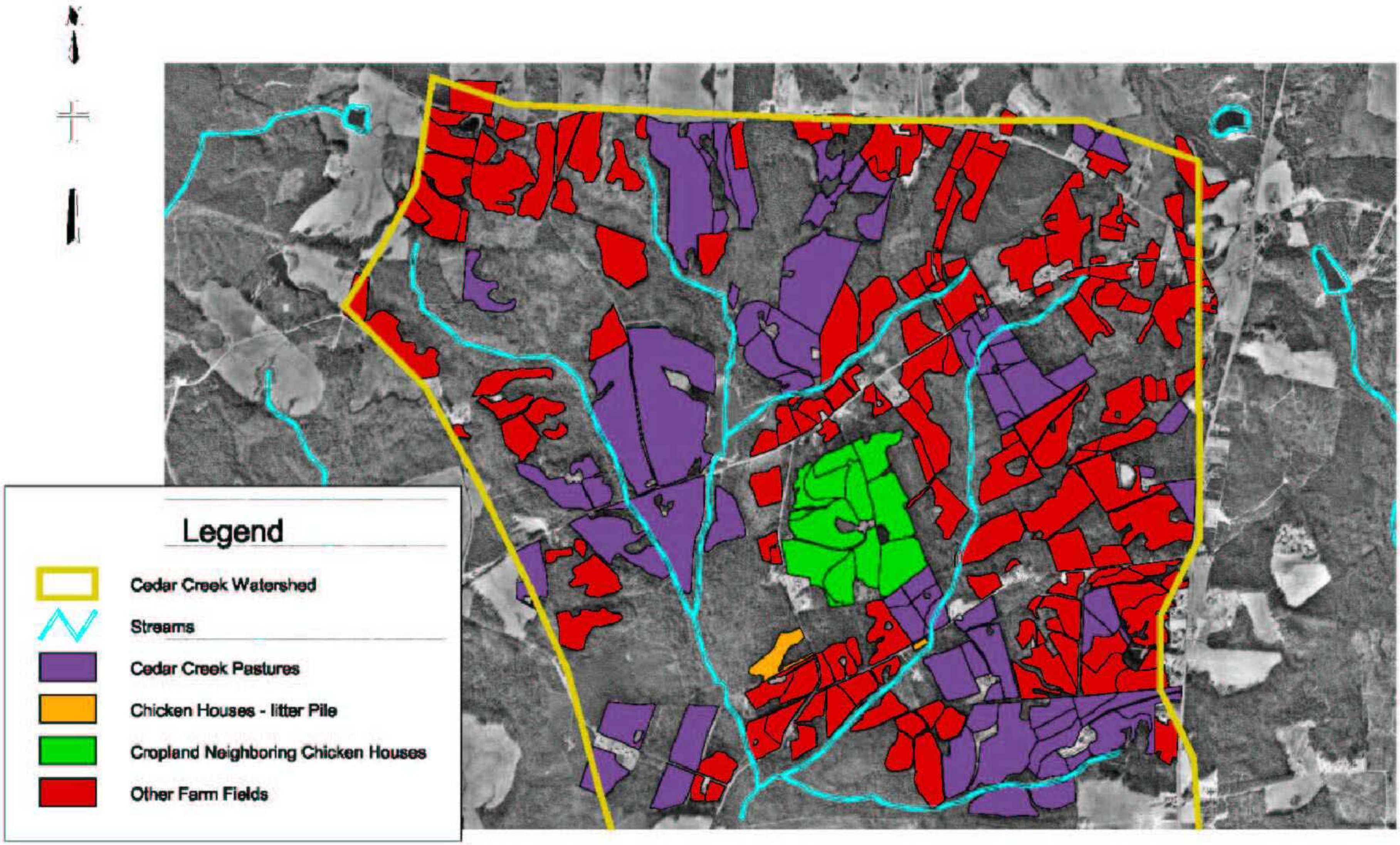
The Cedar Creek watershed ranks as both the smallest subbasin area and the most intensely farmed in the project watershed area. The majority of land use activities occur in North Carolina. Cedar Creek discharges directly into the Lower Thompson Creek mainstem. Figures 7-4 and 7-5 illustrate the locations of large quantities of pastures in both North Carolina and South Carolina. In addition, poultry houses and the probable application of litter to neighboring cropland areas are found in Anson County, North Carolina.

Lower Thompson Creek Subbasin

The Lower Thompson Creek Subbasin includes the Thompson Creek mainstem and small tributary systems located between the Deadfall Creek discharge point and the DHEC water quality monitoring station PD-246. As depicted in Figures 7-6 and 7-7, a heavy concentration of farm fields within this Subbasin can be found along the Thompson Creek mainstem between the Deadfall Creek and Cedar Creek discharge points. Numerous pastures and farm fields receiving litter application are found in this zone, particularly in the Subbasin watershed area south of Thompson Creek. Two sampling stations are sited in this Subbasin. One is located in the middle of this concentrated zone of farm fields; and a second is sited in the less farmed southeastern corner of this Subbasin; in the vicinity of the Town of Chesterfield. Both show consistent violations of the state fecal coliform bacteria standard.

Middle Thompson Creek Subbasin

The Middle Thompson Creek Subbasin includes the Thompson Creek mainstem and small tributary systems between the Clay Creek and Deadfall Creek discharge

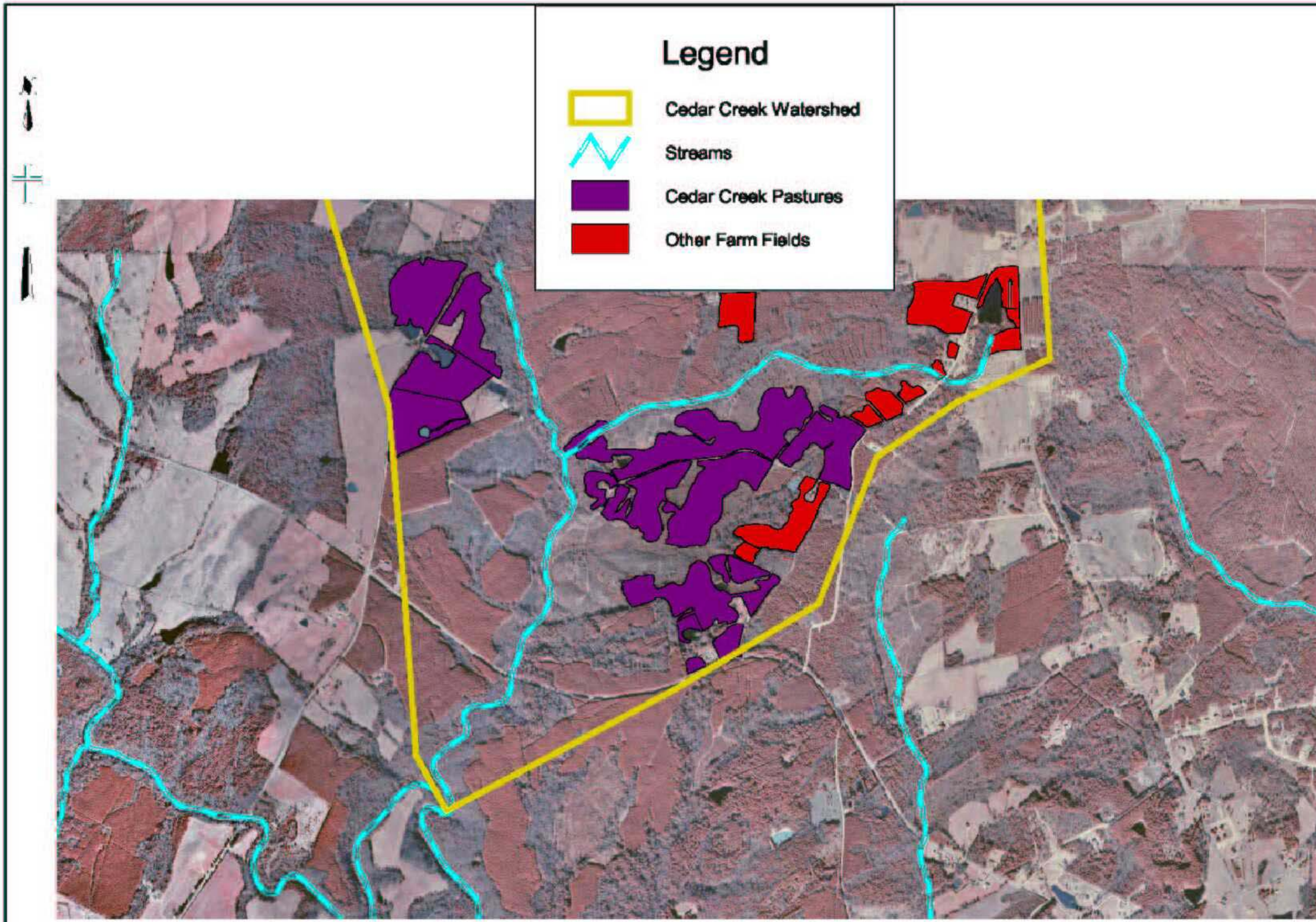


MALCOLM PIRNIE

Pee Dee RC&D
Thompson Creek Watershed Project
CEDAR CREEK SUBBASIN (NC)

January 2003

Figure 7-4



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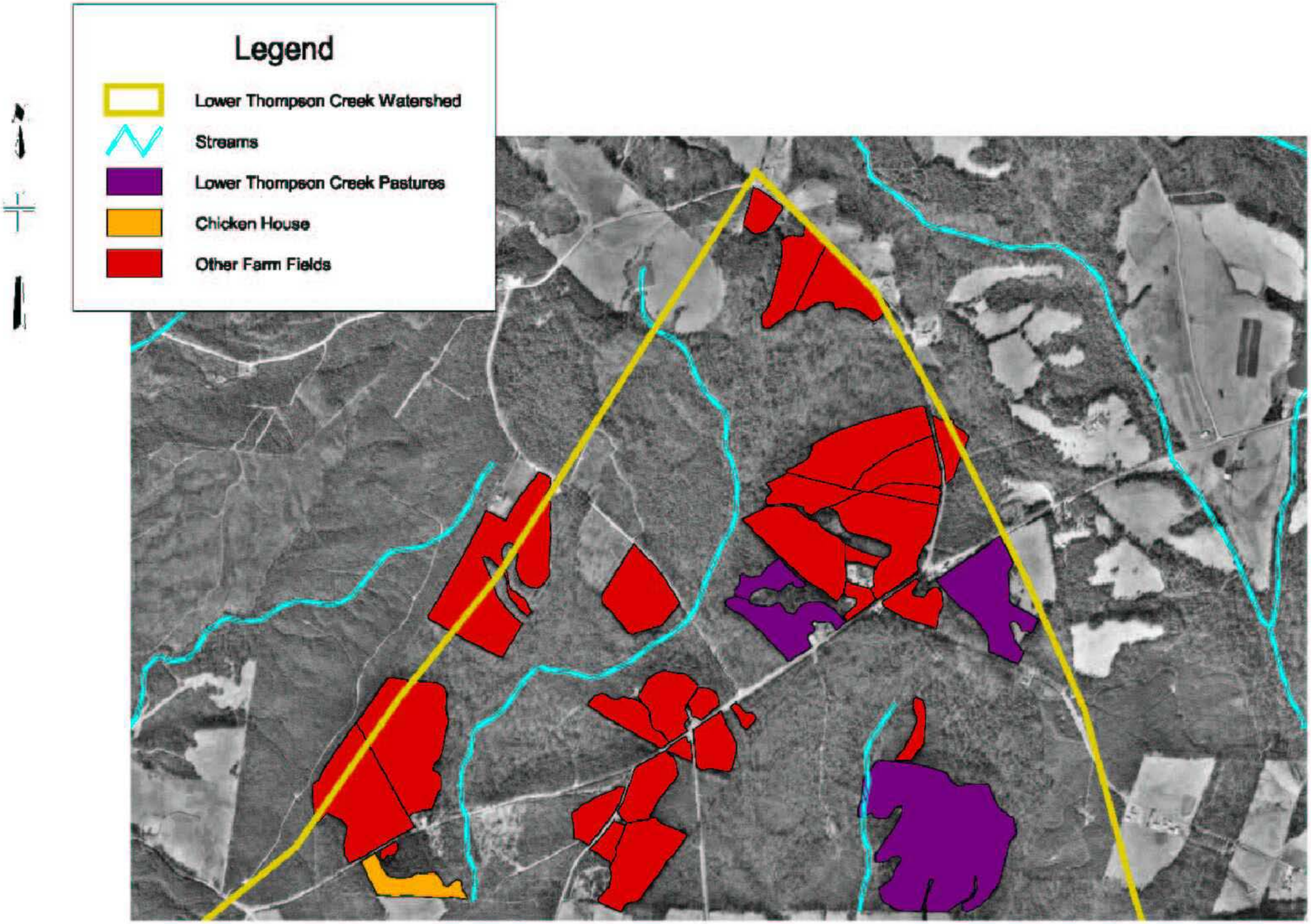
Thompson Creek Watershed Project
CEDAR CREEK SUBBASIN (SC)

January 2003

Figure 7-5



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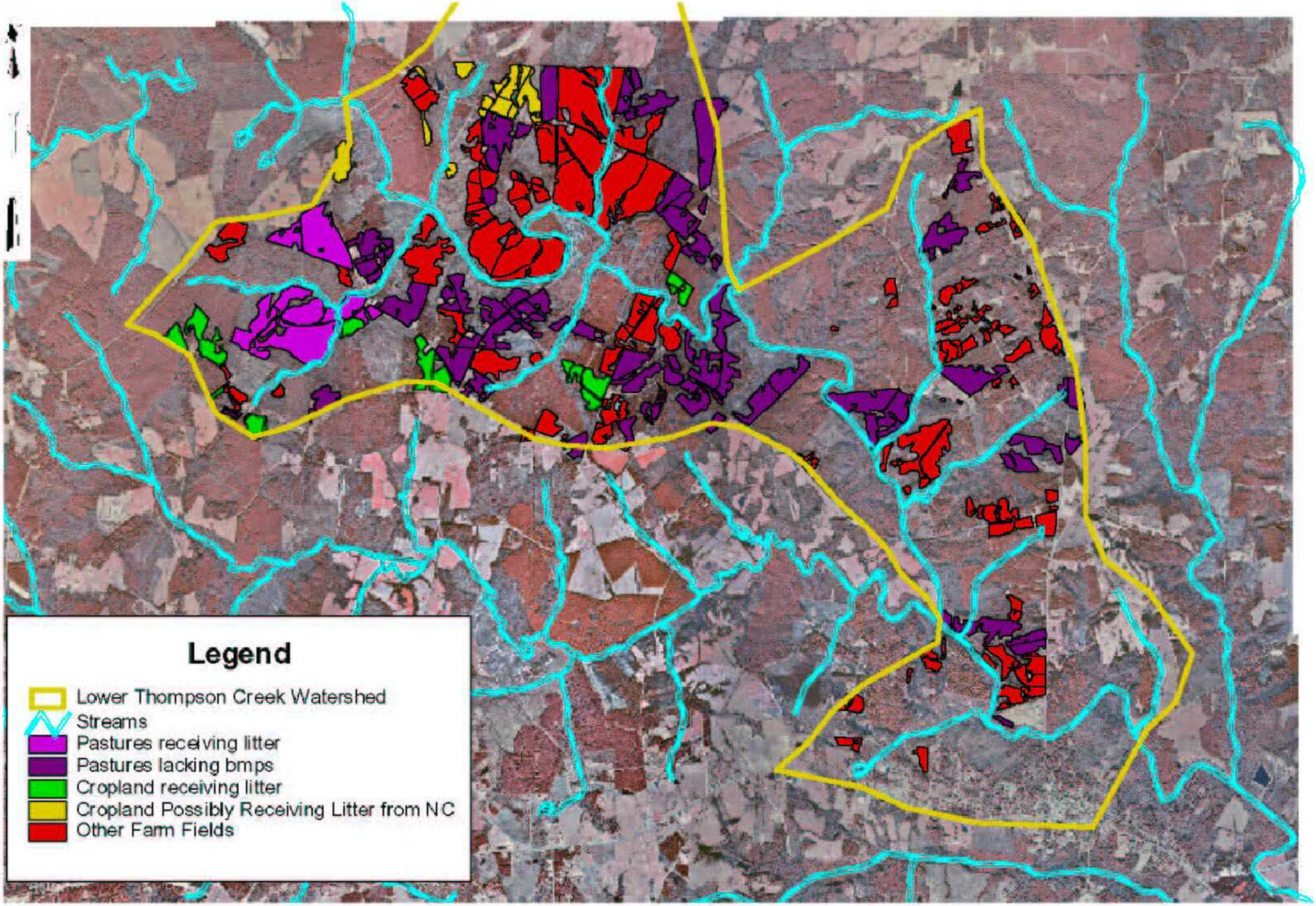
Thompson Creek Watershed Project
LOWER THOMPSON CREEK SUBBASIN (NC)

January 2003

Figure 7-6



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Thompson Creek Watershed Project
LOWER THOMPSON CREEK SUBBASIN (SC)

January 2003

Figure 7-7

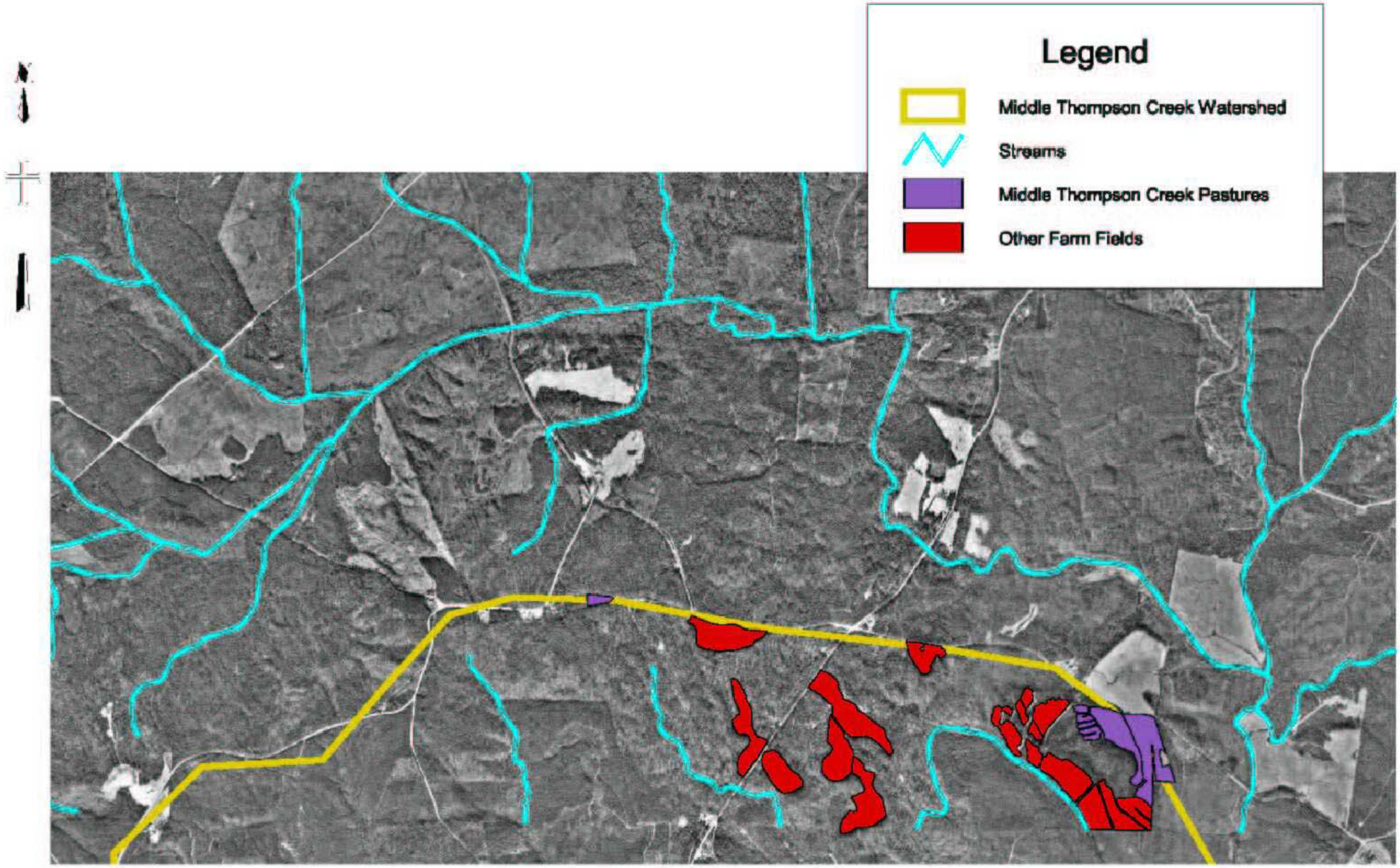
locations. Figures 7-8 and 7-9 show a concentration of pastures in the upper end of the Subbasin along tributaries entering the Thompson Creek mainstem from the south. The application of litter to farm fields is occurring principally along the mainstem in the lower end of this Subbasin.

Upper Thompson Creek and Stone House Creek Subbasins

These two Subbasins originate in the headwater portions of the project watershed area and terminate at the Clay Creek discharge point into the Thompson Creek mainstem. Figure 7-10 illustrates the intensive application of poultry litter to farm fields in the Stone House Creek tributary watershed, and quantities of pastures dispersed throughout the two Subbasin areas. A sampling station sited between the Stone House Creek and Clay Creek discharge locations into the mainstem shows consistent violations to the state standard for fecal coliform bacteria.

Deep Creek Subbasin

The Deep Creek Subbasin is the largest component of the project watershed area and is located south of the Thompson Creek mainstem. The Deep Creek Tributary runs in an easterly direction parallel to Thompson Creek for several miles prior to discharging into the Thompson Creek mainstem. Farm fields are predominately located in a zone towards the lower end of the Subbasin. A distinct area of concentrated litter application is taking place just northeast of the Town of Ruby. Figure 7-11 also shows heavy pasture land use occurring further downstream of this litter application area, particularly south of the Deep Creek mainstem. A sampling station showing consistent violations to the fecal coliform bacteria state standard is sited downstream of both these litter application and pasture areas.



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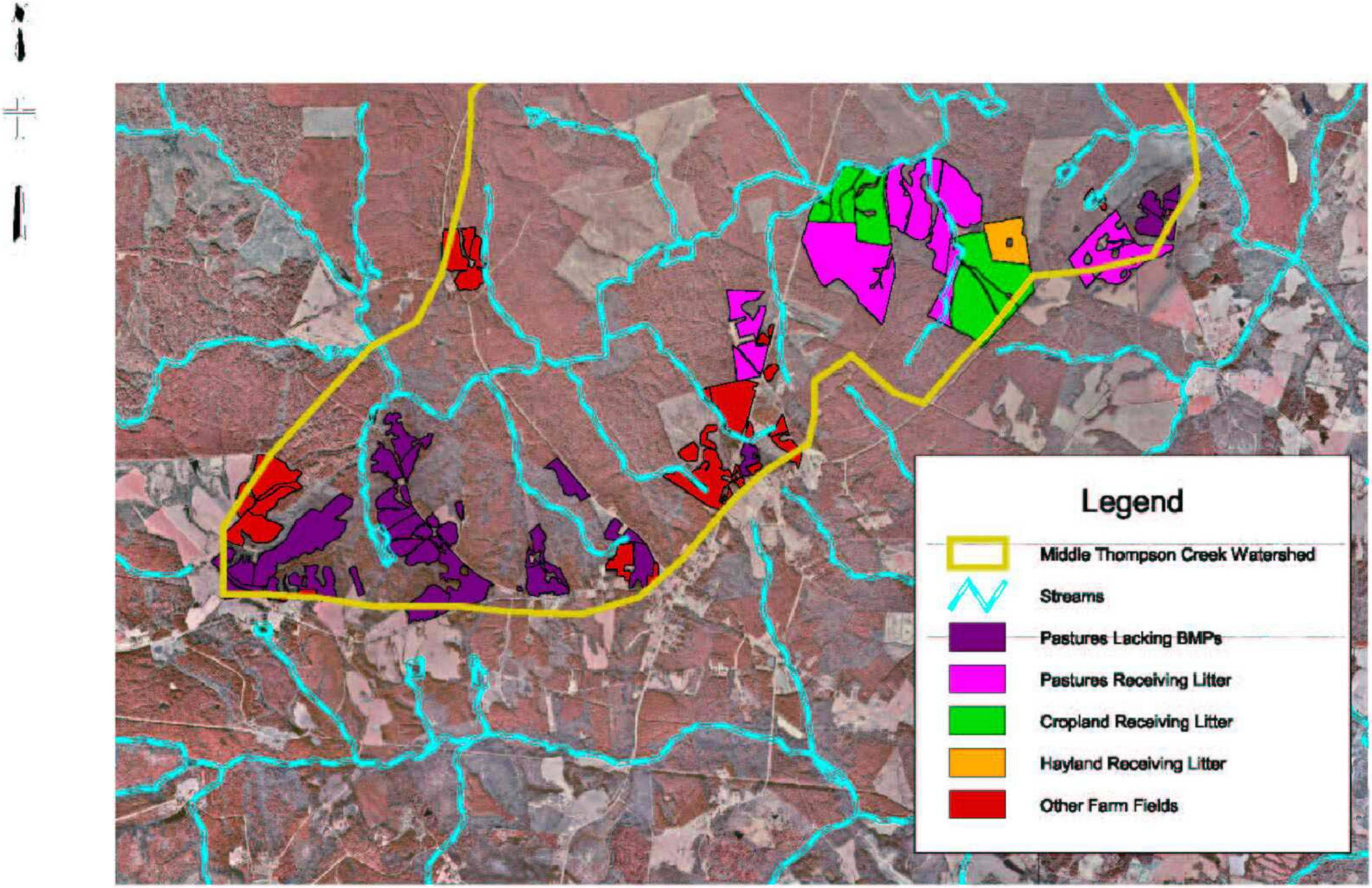
Pee Dee RC&D
Thompson Creek Watershed Project
MIDDLE THOMPSON CREEK SUBBASIN (NC)

January 2003

Figure 7-8



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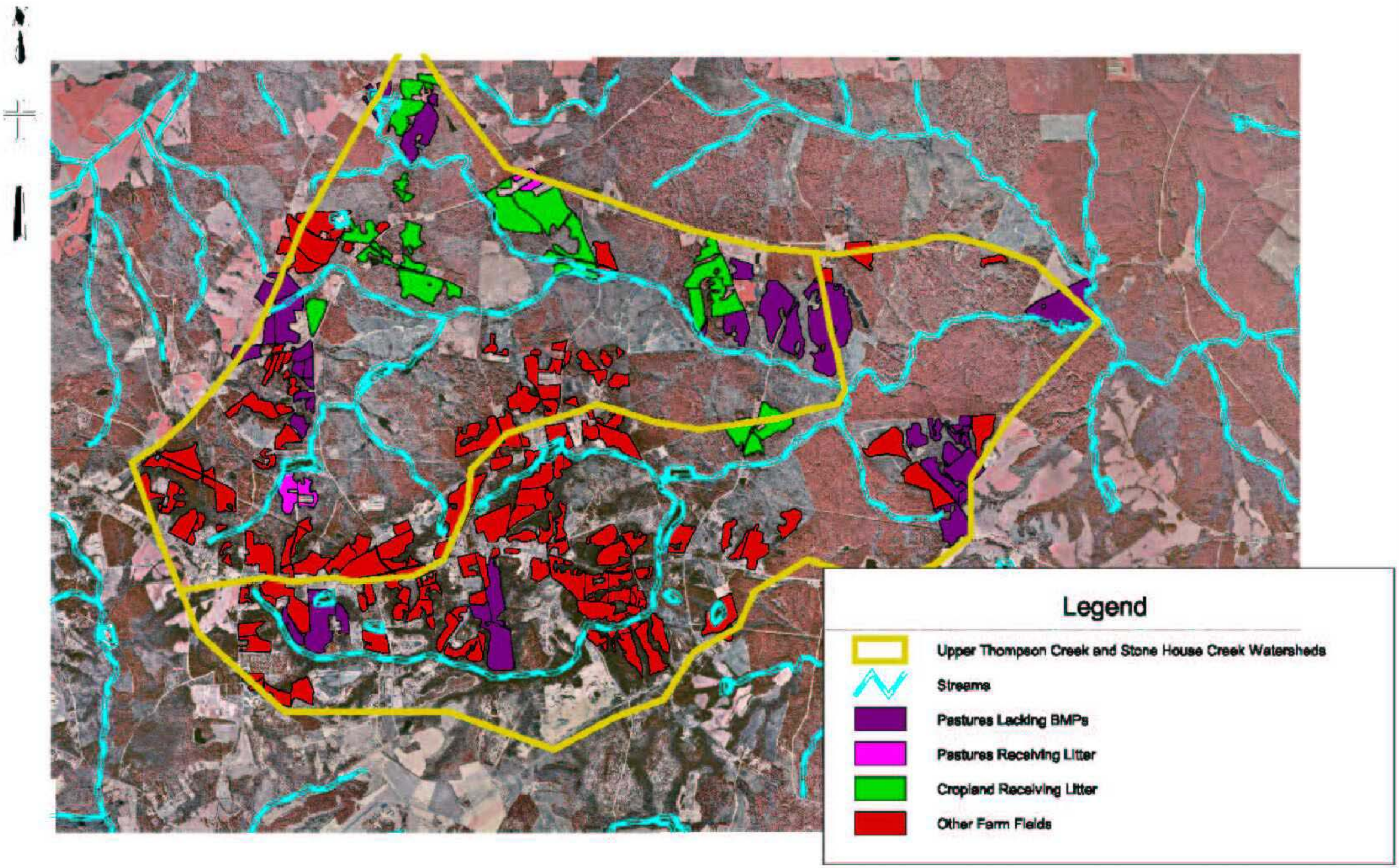
Pee Dee RC&D
Thompson Creek Watershed Project
MIDDLE THOMPSON CREEK SUBBASIN (SC)

January 2003

Figure 7-9



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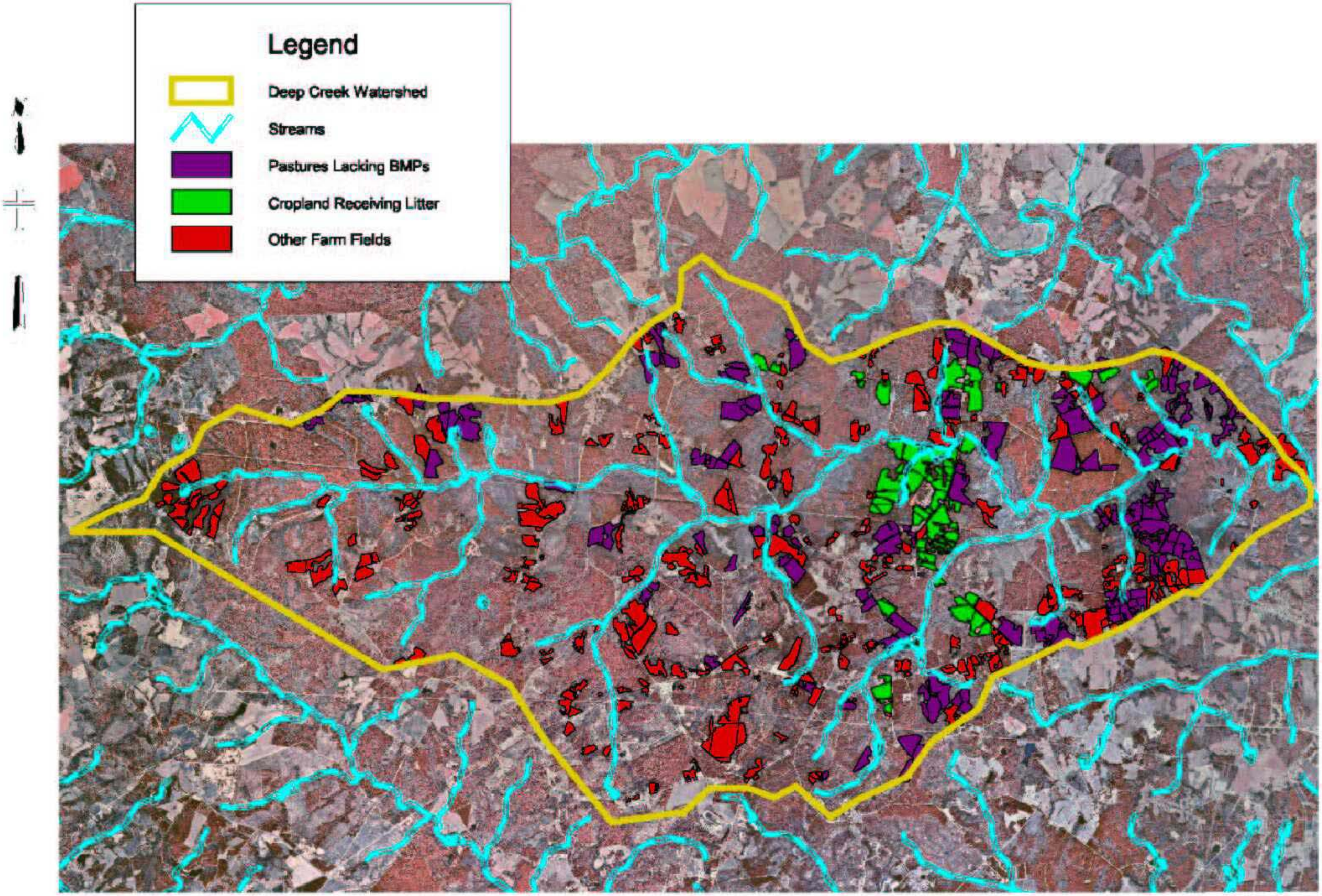
Pee Dee RC&D
Thompson Creek Watershed Project
UPPER THOMPSON CREEK AND STONE HOUSE CREEK SUBBASINS

January 2003

Figure 7-10



MALCOLM PIRNIE

Pee Dee RC&D
Thompson Creek Watershed Project
DEEP CREEK SUBBASIN

January 2003

Figure 7-11

8 IMPLEMENTATION PLANNING RECOMMENDATIONS

The Load Reduction Plan was developed using the best data available to identify a *load reduction allocation scenario* that, when implemented, will meet the state water quality goals for fecal coliform bacteria in the Thompson Creek project watershed area. Additional watershed planning efforts included in this Load Reduction Plan consist of a *detailed characterization and accounting of agricultural land uses* and the formation of an *interstate stakeholder group and an informed citizenry*. These three Load Reduction Plan components will facilitate and provide a structure for the development and application of an effective TMDL implementation plan. Four implementation planning strategies are recommended:

- Watershed Management and Planning Administration;
- Selection and Implementation of Corrective Actions;
- Citizen Awareness and Education; and
- Continued Water Quality Sampling.

Watershed Management and Planning

To reduce the quantities of fecal coliform bacteria from the potential loading sources within the project watershed area, a decision-making framework and management process is required. This framework will be developed to:

- Foster intra- and interstate cooperation between federal, state and local agencies and partners; and
- Advance a coordinated approach to acquiring landowner support for the implementation of corrective actions that meet the goals of the load reduction allocation scenario.

The recommended framework will contain provisions that address the monitoring of implementation tasks (and their measured success) in South Carolina and North Carolina, the application of a citizen awareness and education program, and the administration of multiple and concurrent grant projects.

Selection and Implementation of Corrective Actions

The administration of the load reduction allocation scenario suggests the need for a multi-phased approach to TMDL implementation to meet the applicable water quality standards and support the recreation use classification. The load reduction allocation scenario identifies a primary need for corrective actions that address fecal coliform bacteria loading reductions from direct livestock deposition into the stream; and secondary corrective actions that address loading from two agricultural land use sources of runoff: pastures harboring grazing livestock and farm fields receiving poultry litter. A sampling program has shown that the concentrations of fecal coliform bacteria are frequently in violation of the state standard. In addition, the extent of the violation is consistent throughout the project watershed area. The agricultural land use characterization has identified several hundred farm field cover type practices that are potential sources of fecal coliform bacteria. The spatial distribution of these problematic livestock, pasture management, and litter application practices supports the sampling results by demonstrating a uniformity of occurrence throughout the project watershed area.

Prioritization of Farm Fields. As a result of these quantities and widespread locations of potential fecal coliform bacteria loading sources, the targeting and ranking of farm fields for implementation measures is a necessary component to implementation planning. It not only ensures the optimum utilization of implementation revenues, but also facilitates a multi-phased implementation approach where stakeholders can identify and prioritize sets of farm fields for corrective action based on their probability of success and the availability of implementation funds. It is recommended that the farm field prioritization effort follow the following general principles:

- *Discrete Geographic Focus:* Distinct prioritization assessments applied to each of the eight subbasin areas; with a specific geographic focus on the concentrated agricultural land use practice areas within the respective subbasins;

- *Simplistic Approach:* Generic prioritization assessment scheme for farm field selection that is duplicable and can be readily applied to each of the eight subbasin areas;

- *Comprehensive Methodology:* Prioritization assessment scheme intent on targeting *all* farm fields identified as potential sources of fecal coliform bacteria (i.e., pastures and litter application areas) located in sensitive areas (i.e., within a specific distance of the mainstem or principle tributary; possessing specific soil types, slope, and hydrologic grouping; within specific elevation of streambed).

- *Supports Phased Approach to Implementation:* A tiering or grouping of potential fecal coliform bacteria farm field loading sources based on their potential to affect Thompson Creek water quality (i.e., farm fields directly adjacent to the mainstem or principle tributary vs. farm fields upland in the subbasin separated from mainstem or principle tributary by other farm fields or forested areas).

The GIS database supporting the agricultural land use characterization will also assist project decision-makers during efforts to develop and apply effective prioritization assessment schemes.

Corrective Action Implementation. Once farm fields have been prioritized based on their potential for causing unacceptable loads of fecal coliform bacteria, fundable and site-specific corrective actions will be selected. The South Carolina Department of Natural Resources and the NRCS have jointly developed a handbook of conservation practices applicable to South Carolina farming concerns entitled *Farming for Clean Water in South Carolina* (July, 1997). The Handbook provides descriptions of several corrective actions that address various sources of fecal coliform bacteria loading, and the relative costs for the implementation of these respective corrective actions. Corrective actions that are applicable to the direct deposition of farm animal waste into streams include:

- 'Stream protection' that promotes the fencing off buffer zones and managing livestock access to streams;

- 'Stream crossings' which allows livestock to drink and cross streams a designated points; and

- 'Water tanks' and 'Farm Ponds' that provide livestock with alternative sites for drinking water.

To limit fecal coliform bacteria loading from pasture runoff, ‘pasture management’ and ‘runoff management’ are recommended by the Handbook where rotational grazing, proper pasture stocking rates, paddock planning based on cutting intervals for forage, methods of keeping feedlots and loafing areas dry, and other grazing techniques that improve water quality are promoted.

To address the over-application and non-uniform application of poultry litter on farm fields in the project watershed area, the Chesterfield County NRCS District Conservationist has suggested the adoption of an education program. This program could be designed to promote the following activities specified in the ‘Nutrient Management’ and ‘Manure Testing’ sections of the Manual:

- Testing litter at the poultry houses for fertilizer value;
- Testing farm field soils to determine if and how much litter should be applied to meet crop yield goals;
- Calibrating litter spreading by trucks to apply proper rates; and
- Applying litter at proper times and frequencies.

The stockpiling of litter has been field verified at numerous locations within the project watershed area. The leaching and runoff of litter from the open stockpiles could result in marked fecal coliform bacteria loading. Corrective actions could include the short-term application of plastic sheeting or long-term use of covered facilities with impervious ground liners.

Site-specific corrective actions for the sources of fecal coliform bacteria outlined in the load reduction allocation scenario will be made by technical experts following on-site farm field investigations.

Citizen Awareness and Education

The success of this multi-phased approach to implementation also requires support and acceptance from the landowners, growers, and operators farming in the project watershed area. A citizen awareness and education program is, therefore, suggested to make the local citizenry aware of:

- The human health risks of fecal coliform bacteria impaired water bodies;
- The different sources of fecal coliform bacteria;
- How these sources are contributing to the specific water quality impairment in the project watershed area; and
- The available, voluntary, and often cost-shared corrective actions utilized to minimize fecal coliform bacteria loading into Thompson Creek and its tributaries.

Outreach plan components may include field days where successful and demonstration corrective actions are endorsed; workshops presenting water quality issues and the benefits of corrective actions; use of agricultural operators willing to share management solutions; partner building with commodity groups to promote conservation; the use of local school districts to take part in water quality sampling or corrective action implementation and construction; and the development of brochures specific to fecal coliform bacteria impairment in the Thompson Creek project watershed area. The brochures could be used to facilitate the advancement of project goals at large forums or at one-on-one meetings with landowners, growers, and operators.

A foundation of support for implementation endeavors has been established during the development of this Load Reduction Plan. Local, state, and federal agricultural and environmental agencies have dedicated an interest in the project from both South Carolina and North Carolina; and landowners, growers, operators and farming organizations located in the watershed project area were introduced to the project at a project kick-off meeting. Moreover, project results will be presented to this group of agencies and local farming concerns in January 2003.

Continued Water Quality Sampling

It is recommended that sampling at the five strategically located sites in the project watershed area continues throughout the implementation stage of the project to:

- Measure progress towards meeting the goals of the load reduction allocation scenario;
- Determine the effectiveness of the load reduction allocation scenario;
- Identify subbasin areas requiring a more intensive implementation focus; and
- Allow for implementation flexibility by providing justification for making mid-course changes to the load reduction allocation scenario.

An evaluation of the sampling site locations should also occur during initial implementation planning. Decisions to change site locations or reduce the number of sites would be based partially on findings from the detailed agricultural land use characterization.

Potential action item tasks associated with the four recommended implementation planning strategies are depicted in Table 8-1. Suggested lead organizations and funding sources for each action item task are also listed.

TABLE 8-1

Recommended Implementation Action Items

Action Item	Lead Organization	Funding Source
WATERSHED MANAGEMENT PLANNING AND ADMINISTRATION		
Development of Decision Making Stakeholder Group for Implementation Planning.	Pee Dee RC&D Council	EPA Section 319 Program.
Project Management and Coordination of Tasks and Agencies/Organizations in South Carolina and North Carolina.	Pee Dee RC&D Council.	EPA Section 319 Program.
Identification of Funding Sources, Proposal Development, and Grant Administration.	Pee Dee RC&D Council.	EPA Section 319 Program.
Continuous Measurement of Project Success and Administration of Mid-Course Changes to Meet Project Goals.	Pee Dee RC&D Council.	EPA Section 319 Program.
SELECTION AND IMPLEMENTATION OF CORRECTIVE ACTIONS		
Targeting and Prioritizing Farm Fields for Implementation Using GIS Database of Farm Field Information (Criteria for Selection may Include Vicinity to Stream, Soil Types, Slopes, Land Use Practices, etc.).	Chesterfield and Brown Creek SWCD with Support from NRCS District Conservationists.	EPA Section 319 Program.
Selection and Implementation of Farm Field Specific Corrective Actions.	Chesterfield and Brown Creek SWCD with Support from NRCS District Conservationists.	EPA Section 319 Program, USDA Conservation Reserve Program (CRP), USDA Environmental Quality Incentives Program (EQIP), USDA Wildlife Habitat Incentives Program (WHIP), USDA Wetland Reserve Program (WRP), North Carolina Clean Water Management Trust Fund, North Carolina Agricultural Cost - Share Program.
CITIZEN AWARENESS AND EDUCATION		
Development and Implementation of an Outreach Plan (and Outreach Materials; including Home*A*Syst and Farm*A*Syst Information) that Builds Support for Implementing Corrective Actions.	Pee Dee RC&D Council / SC Department of Natural Resources / NC Division of Soil and Water Conservation / SC DHEC.	EPA Environmental Education and/or Environmental Justice Grant Programs.
Promotion of Various Voluntary BMP / Conservation Practices to Landowners of Prioritized Farm Fields at One-on-One Meetings.	Chesterfield and Brown Creek SWCD with Support from NRCS District Conservationists.	EPA Section 319 Program, USDA Conservation Reserve Program (CRP), USDA Environmental Quality Incentives Program (EQIP), USDA Wildlife Habitat Incentives Program (WHIP), USDA Wetland Reserve Program (WRP), North Carolina Clean Water Management Trust Fund, North Carolina Agricultural Cost - Share Program.
Poultry Litter Application Training.	Chesterfield and Brown Creek SWCD with Support from NRCS District Conservationists.	EPA Section 319 Program. EPA Section 319 Program, USDA Conservation Reserve Program (CRP), USDA Environmental Quality Incentives Program (EQIP), USDA Wildlife Habitat Incentives Program (WHIP), USDA Wetland Reserve Program (WRP), North Carolina Clean Water Management Trust Fund, North Carolina Agricultural Cost - Share Program.
CONTINUED WATER QUALITY SAMPLING		
Evaluation of Sampling Site Locations.	Chesterfield and Brown Creek SWCD with Support from NRCS District Conservationists.	EPA Section 319 Program.

Collect and Analyze Water Quality Samples for Fecal Coliform Bacteria Concentrations Under all Flow Conditions.	Chesterfield and Brown Creek SWCD with Support from NRCS District Conservationists.	EPA Section 319 Program.
Document Water Quality Improvements from Farm Field Specific Corrective Actions at the Respective Water Quality Sampling Sites.	Pee Dee RC&D.	EPA Section 319 Program.

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APPENDIX A

BACTERIAL DATA FROM
SC DHEC MONITORING STATIONS

APPENDIX A

FECAL COLIFORM DATA FROM DHEC MONITORING STATIONS

[all data reported in counts/100 mL]

DHEC STATION	LOCATION	DATE	TIME	VALUE	REMARK
PD-145	BRDG OVER THOMPSON CK SEC RD 57	8/27/70	2500	80	
		8/31/70	2500	130	
		9/1/70	2500	130	
		9/7/72	2500	360	
		5/9/73	945	70	
		7/2/73	940	140	
		9/6/73	915	470	
PD-146	BRDG OVER DEEP CK ON SEC RD 34	8/27/70	2500	330	
		8/31/70	2500	790	
		9/1/70	2500	330	
		5/15/73	1125	540	
		6/28/74	1040	1800	
		8/5/74	1005	400	
		9/5/74	1035	315	
		10/2/74	1035	155	
		10/23/74	1050	6	
		6/17/75	1045	700	
		7/23/75	1040	4200	
		8/22/75	1100	400	
		9/18/75	1010	300	
		4/29/76	930	390	
		5/28/76	1000	230	
		5/15/80	1300	520	
		6/20/80	1230	560	
		7/30/80	1320	220	
		8/28/80	1245	640	
		9/30/80	1205	1200	L
		10/24/80	1100	633	J
PD-147	BRDG OVER THOMPSON CK ON RD 59	8/27/70	2500	230	
		8/31/70	2500	330	
		9/1/70	2500	230	
		5/15/73	1110	90	
		6/28/74	1025	210	
		8/5/74	955	460	
		9/5/74	1025	260	
		10/2/74	1020	530	
		6/17/75	1030	100	K
		7/23/75	1030	3100	
		8/22/75	1045	300	
		9/18/75	940	390	
		4/29/76	945	75	
		5/28/76	1035	190	
PD-246	THOMPSON CK ON S-13-243 .8 MI NE OF CHESTERFIELD	7/9/68	2500	790	
		7/22/68	2500	790	
		7/23/68	2500	490	
		8/27/70	2500	330	
		8/31/70	2500	330	

APPENDIX A

FECAL COLIFORM DATA FROM DHEC MONITORING STATIONS
[all data reported in counts/100 mL]

		9/1/70	2500	330	
		9/7/72	2500	360	
		5/9/73	1040	115	
		7/2/73	1005	70	
		9/6/73	1000	370	
		3/13/74	905	990	
		8/5/74	1015	840	
		9/5/74	1100	1200	
		10/2/74	1205	70	
		6/17/75	1100	380	
		8/22/75	1200	750	
		9/18/75	1030	770	
		4/29/76	1015	60	
		5/28/76	1020	150	
		7/2/76	930	560	
		8/2/76	1005	120	
		9/2/76	1105	180	J
		9/30/76	1030	460	
		5/23/77	930	2000	L
		6/16/77	1200	6000	L
		7/20/77	1230	5200	
		8/19/77	900	5100	
		9/13/77	1000	6000	L
		5/23/78	1110	9600	
		6/23/78	1045	1900	J
		8/8/78	1050	800	J
		9/7/78	2500	1200	L
		10/30/78	1130	1265	
		5/17/79	1245	1032	
		6/28/79	1150	561	J
		7/19/79	1200	1040	
		8/30/79	1220	420	
		9/25/79	1050	380	
		10/25/79	1045	480	
		5/15/80	1205	166	J
		6/20/80	1220	350	
		7/30/80	1230	240	
		8/28/80	1225	1021	
		9/30/80	1235	6000	L
		10/24/80	1130	200	J
		8/27/81	840	260	
		8/27/81	1315	320	
		8/27/81	1830	153	J
		8/25/83	1100	330	
		5/16/84	1215	300	J
		6/22/84	1155	230	
		7/16/84	1310	250	
		8/15/84	1215	310	

APPENDIX A

FECAL COLIFORM DATA FROM DHEC MONITORING STATIONS

[all data reported in counts/100 mL]

		9/4/84	1145	1200	L
		10/25/84	1245	333	J
		5/20/85	1320	410	
		6/25/85	1135	67	J
		7/24/85	1030	600	L
		8/21/85	1220	1200	L
		9/30/85	1155	133	J
		10/24/85	1250	360	
		6/23/86	1100	490	
		8/20/86	1040	1200	L
		9/26/86	1000	50	J
		10/15/86	1115	320	
		5/13/87	1330	300	
		6/1/87	1235	450	
		7/15/87	1200	2100	
		8/18/87	1035	440	
		9/24/87	1005	350	
		10/7/87	1130	340	
		5/3/88	959	520	
		6/6/88	1021	530	
		7/25/88	1200	380	
		9/28/88	1200	330	
		10/19/88	1130	1000	
		5/22/89	1339	230	
		6/12/89	1350	350	
		7/18/89	1053	1800	
		8/30/89	1300	320	
		9/6/89	1127	290	
		10/4/89	1429	230	
		5/1/90	1323	220	
		6/13/90	1330	280	
		7/9/90	1256	210	
		9/10/90	1327	360	
		10/4/90	1330	140	J
		5/21/91	1255	260	
		6/11/91	1135	170	J
		7/29/91	1440	900	
		8/19/91	1200	220	
		9/3/91	1015	290	
		10/21/91	1205	170	J
		5/21/92	1200	160	J
		6/18/92	1155	230	
		7/16/92	1220	920	
		8/26/92	1355	30	J
		9/16/92	1210	80	J
		10/29/92	1155	200	
		5/12/93	1010	250	
		6/17/93	1230	370	

APPENDIX A

FECAL COLIFORM DATA FROM DHEC MONITORING STATIONS

[all data reported in counts/100 mL]

		7/14/93	1000	520	
		8/17/93	1225	190	J
		9/9/93	1000	400	
		10/21/93	1245	300	
		5/4/94	1000	3300	J
		6/30/94	1005	10000	J
		7/5/94	1112	240	J
		8/23/94	1020	520	
		9/15/94	1100	220	J
		10/13/94	1015	780	
		5/10/95	1130	480	
		6/14/95	1210	220	
		7/27/95	1025	480	
		8/10/95	1012	280	
		9/13/95	1005	460	
		10/3/95	1050	370	
		5/7/96	1130	180	J
		6/25/96	1030	230	
		7/25/96	945	200	
		10/9/96	1120	1500	K
		5/7/97	1425	150	J
		6/5/97	1205	170	J
		7/16/97	1130	6600	L
		8/20/97	1135	50	J
		9/11/97	1145	3300	J
		10/15/97	1155	3300	J
		5/19/98	1315	270	
		6/11/98	1150	4600	
		7/20/98	1305	170	J
		8/5/98	1305	200	L
		9/2/98	1300	530	
		10/8/98	1130	1400	J
		8/23/99		370	
		9/16/99		3900	
		10/7/99		150	
		5/11/00		100	
		6/6/00		1100	
		7/5/00		120	
		8/9/00		300	
		9/25/00		470	
		10/17/00		160	

APPENDIX B

WATER QUALITY DATA FROM
319 PROJECT MONITORING STATIONS

APPENDIX B
WATER QUALITY DATA FROM 319 PROJECT STATIONS

Station	Date	Time	Sample Number	Total Suspended Solids (mg/L)	Fecal coliforms (#/100 mL)	Total Dissolved Phophorus (mg/L)	Nitrate-plus-Nitrite (mg/Las N)	pH	Water Temperature (deg C)	Dissolved Oxygen (mg/L)
1	36850	12:40	112000-1	79.7	216	<0.1	<0.1	Not Samp	Not Samp	Not Samp
2	36850	12:40	112000-2	3.2	440	<0.1	<0.1	Not Samp	Not Samp	Not Samp
3	36850	12:40	112000-3	7.6	232	<0.1	<0.1	Not Samp	Not Samp	Not Samp
4	36850	12:40	112000-4	6.5	248	<0.1	<0.1	Not Samp	Not Samp	Not Samp
5	36850	12:40	112000-5	8.3	232	<0.1	<0.1	Not Samp	Not Samp	Not Samp
1	36911	11:00	012001-1	<4.0	10	Not Samp	Not Samp	7.2	6.2	12.39
2	36911	11:00	012001-2	5	60	Not Samp	Not Samp	7.1	5.3	12.13
3	36911	11:00	012001-3	11	58	Not Samp	Not Samp	7.2	5.3	12.01
4	36911	11:00	012001-4	<4	8	Not Samp	Not Samp	7.2	5.2	12.45
5	36911	11:00	012001-5	10	34	Not Samp	Not Samp	7.1	5.7	12.33
1	36971	10:00	032101-1	58	388	Not Samp	Not Samp	6.4	10.4	10.57
2	36971	10:00	032101-2	70	604	Not Samp	Not Samp	6.5	9.4	10.58
3	36971	10:00	032101-3	120	720	Not Samp	Not Samp	6.6	9.7	10.62
4	36971	10:00	032101-4	43	208	Not Samp	Not Samp	6.5	10.5	10.95
5	36971	10:00	032101-5	192	536	Not Samp	Not Samp	6.7	10.1	10.73
1	37056	8:40	061401-1	12	170	Not Samp	Not Samp	6.5	22.8	6.75
2	37056	8:40	061401-2	15	230	Not Samp	Not Samp	6.7	21.7	6.25
3	37056	8:40	061401-3	46	420	Not Samp	Not Samp	6.9	22.1	6.26
4	37056	8:40	061401-4	25	352	Not Samp	Not Samp	7	22.1	6.95
5	37056	8:40	061401-5	73	318	Not Samp	Not Samp	6.9	22.2	6.97
1	37139	11:30	090501-1	51	TNTC	Not Samp	Not Samp	6.1	23.2	3.81
2	37139	11:30	090501-2	8	186	Not Samp	Not Samp	6.6	22.2	4.48
3	37139	11:30	090501-3	10	106	Not Samp	Not Samp	6.8	25.2	8.28
4	37139	11:30	090501-4	10	154	Not Samp	Not Samp	7	21.7	8.78
5	37139	11:30	090501-5	19	72	Not Samp	Not Samp	6.7	23.2	6.05
1	37271	10:30	011502-1	<4	16	Not Samp	Not Samp	6.5	5.2	12.2
2	37271	10:30	011502-2	4	12	Not Samp	Not Samp	7.2	4.3	12.2
3	37271	10:30	011502-3	<4	16	Not Samp	Not Samp	6.7	4.7	10.3
4	37271	10:30	011502-4	<4	<4	Not Samp	Not Samp	6.5	4.4	11.6
5	37271	10:30	011502-5	6	16	Not Samp	Not Samp	6.6	4.4	10.8
1	37348	9:30	040202-1	7	30	<0.1	<0.1	6.8	15.7	7.96
2	37348	9:30	040202-2	8	70	<0.1	<0.1	6.9	15.6	8.3
3	37348	9:30	040202-3	8	72	<0.1	<0.1	7.1	15.4	8.2

APPENDIX B
WATER QUALITY DATA FROM 319 PROJECT STATIONS

Station	Date	Time	Sample Number	Total Suspended Solids (mg/L)	Fecal coliforms (#/100 mL)	Total Dissolved Phophorus (mg/L)	Nitrate-plus-Nitrite (mg/Las N)	pH	Water Temperature (deg C)	Dissolved Oxygen (mg/L)
4	37348	9:30	040202-4	7	26	<0.1	<0.1	7.1	16.2	7.94
5	37348	9:30	040202-5	10	28	<0.1	<0.1	7.1	16.3	8.25
1	37497	10:25	082902-1	2	16	Not Samp	Not Samp	6.6	22.2	5.35
2	37497	10:25	082902-2	5	298	Not Samp	Not Samp	6.8	22.2	1.4
3	37497	10:25	082902-3	3	14	Not Samp	Not Samp	6.9	22.7	1.77
4	37497	10:25	082902-4	22	320	Not Samp	Not Samp	7	21.5	5.06
5	37497	10:25	082902-5	11	TNTC	Not Samp	Not Samp	6.9	22.8	3.71
1	37530	10:00	100102-01	<1	Not Samp	<0.1	0.2	6.5	21.1	3.97
2	37530	10:00	100102-2	5	Not Samp	<0.1	0.2	7	21	2.72
3	37530	10:00	100102-3	3	Not Samp	<0.1	0.2	7.1	21.7	3.1
4	37530	10:00	100102-4	<1	Not Samp	<0.1	0.2	7.2	20.8	3
5	37530	10:00	100102-5	4	Not Samp	<0.1	0.2	7.1	22.2	5.22
1	37573	11:00	111302-1	16	146	Not Samp	Not Samp	6.2	14.8	8.52
2	37573	11:00	111302-2	14	544	Not Samp	Not Samp	6.6	14.8	8.39
3	37573	11:00	111302-3	24	494	Not Samp	Not Samp	6.6	15.3	7.79
4	37573	11:00	111302-4	9	234	Not Samp	Not Samp	6.6	14.8	8.43
5	37573	11:00	111302-5	33	632	Not Samp	Not Samp	6.6	15	9.26

APPENDIX C

SEGMENTS OF THE THOMPSON CREEK HSPF MODEL

APPENDIX C

Segments of the Thompson Creek HSPF Model

RCHRES	NAME	LENGTH (miles)	DISCHARGES TO RCHRES
1	Lower Thompson Creek	11.54	basin outlet
2	Middle Thompson Creek	7.40	1
3	Upper Thompson Creek	7.86	2
4	Deep Creek	14.98	1
5	Cedar Creek	4.20	1
6	Deadfall Creek	8.00	1
7	Clay Creek	6.31	2
8	Stone House Creek	5.42	3

PERLND	LAND USE	AREA (acres)	DISCHARGES TO RCHRES
101	Forest	7,806	1
102	Pasture	835	1
103	Cropland	3,014	1
104	Developed	276	1
201	Forest	6,494	2
202	Pasture	415	2
203	Cropland	1,026	2
301	Forest	2,756	3
302	Pasture	334	3
303	Cropland	2,032	3
304	Developed	46	3
401	Forest	16,316	4
402	Pasture	973	4
403	Cropland	5,718	4
404	Developed	150	4
501	Forest	2,688	5
502	Pasture	451	5
503	Cropland	1,553	5
601	Forest	17,813	6
602	Pasture	597	6
603	Cropland	921	6
701	Forest	6,116	7
702	Pasture	1,008	7
703	Cropland	767	7
801	Forest	3,645	8
802	Pasture	542	8
803	Cropland	899	8
804	Developed	12	8

APPENDIX D

FINAL VALUES OF ACQOP, SQOLIM, MON-ACCUM, AND MON-SQOLIM IN THE THOMPSON CREEK HSPF MODEL

APPENDIX D
VALUES OF ACQOP, SQOLIM, MON-ACCUM, and MON-SQOLIM

All Months	FOREST		BUILT-UP	
SUBBASIN	ACQOP (count/acre/day)	SQOLIM (count/acre)	ACQOP (count/acre/day)	SQOLIM (count/acre)
1	3.36E+07	6.05E+07	8.62E+06	1.55E+07
2	3.36E+07	6.05E+07	0.00E+00	0.00E+00
3	3.36E+07	6.05E+07	8.62E+06	1.55E+07
4	3.36E+07	6.05E+07	8.62E+06	1.55E+07
5	3.36E+07	6.05E+07	0.00E+00	0.00E+00
6	3.36E+07	6.05E+07	0.00E+00	0.00E+00
7	3.36E+07	6.05E+07	0.00E+00	0.00E+00
8	3.36E+07	6.05E+07	8.62E+06	1.55E+07

SUBBASIN	CROPLAND		PASTURELAND	
	MON-ACCUM (count/acre/day)	MON-SQOLIM (count/acre)	MON-ACCUM (count/acre/day)	MON-SQOLIM (count/acre)
January				
1	3.36E+07	6.05E+07	9.94E+10	1.79E+11
2	3.36E+07	6.05E+07	9.82E+10	1.77E+11
3	3.36E+07	6.05E+07	1.01E+11	1.82E+11
4	3.36E+07	6.05E+07	1.01E+11	1.82E+11
5	3.36E+07	6.05E+07	8.74E+10	1.57E+11
6	3.36E+07	6.05E+07	8.24E+10	1.48E+11
7	3.36E+07	6.05E+07	8.65E+10	1.56E+11
8	3.36E+07	6.05E+07	1.01E+11	1.82E+11
February				
1	1.13E+10	2.03E+10	1.05E+11	1.89E+11
2	1.13E+10	2.03E+10	1.04E+11	1.87E+11
3	1.13E+10	2.03E+10	1.07E+11	1.92E+11
4	1.13E+10	2.03E+10	1.07E+11	1.92E+11
5	1.13E+10	2.03E+10	9.31E+10	1.68E+11
6	1.13E+10	2.03E+10	8.80E+10	1.58E+11
7	1.13E+10	2.03E+10	9.21E+10	1.66E+11
8	1.13E+10	2.03E+10	1.06E+11	1.92E+11
March				
1	6.10E+10	1.10E+11	1.30E+11	2.34E+11
2	6.10E+10	1.10E+11	1.29E+11	2.32E+11
3	6.10E+10	1.10E+11	1.32E+11	2.37E+11
4	6.10E+10	1.10E+11	1.32E+11	2.37E+11
5	6.10E+10	1.10E+11	1.18E+11	2.12E+11
6	6.10E+10	1.10E+11	1.13E+11	2.03E+11
7	6.10E+10	1.10E+11	1.17E+11	2.11E+11
8	6.10E+10	1.10E+11	1.31E+11	2.37E+11
April				
1	8.41E+10	1.26E+11	1.08E+11	1.63E+11
2	8.41E+10	1.26E+11	1.08E+11	1.61E+11
3	8.41E+10	1.26E+11	1.10E+11	1.64E+11
4	8.41E+10	1.26E+11	1.10E+11	1.64E+11
5	8.41E+10	1.26E+11	1.00E+11	1.51E+11
6	8.41E+10	1.26E+11	9.70E+10	1.46E+11

APPENDIX D
VALUES OF ACQOP, SQOLIM, MON-ACCUM, and MON-SQOLIM

SUBBASIN	CROPLAND		PASTURELAND	
	MON-ACCUM (count/acre/day)	MON-SQOLIM (count/acre)	MON-ACCUM (count/acre/day)	MON-SQOLIM (count/acre)
7	8.41E+10	1.26E+11	9.97E+10	1.50E+11
8	8.41E+10	1.26E+11	1.09E+11	1.64E+11
May				
1	5.09E+10	7.63E+10	9.17E+10	1.38E+11
2	5.09E+10	7.63E+10	9.09E+10	1.36E+11
3	5.09E+10	7.63E+10	9.29E+10	1.39E+11
4	5.09E+10	7.63E+10	9.29E+10	1.39E+11
5	5.09E+10	7.63E+10	8.37E+10	1.26E+11
6	5.09E+10	7.63E+10	8.04E+10	1.21E+11
7	5.09E+10	7.63E+10	8.31E+10	1.25E+11
8	5.09E+10	7.63E+10	9.27E+10	1.39E+11
June				
1	4.70E+09	7.06E+09	5.67E+10	8.51E+10
2	4.70E+09	7.06E+09	5.61E+10	8.42E+10
3	4.70E+09	7.06E+09	5.76E+10	8.64E+10
4	4.70E+09	7.06E+09	5.76E+10	8.64E+10
5	4.70E+09	7.06E+09	5.07E+10	7.61E+10
6	4.70E+09	7.06E+09	4.82E+10	7.23E+10
7	4.70E+09	7.06E+09	5.03E+10	7.54E+10
8	4.70E+09	7.06E+09	5.75E+10	8.62E+10
July				
1	4.55E+09	6.83E+09	5.65E+10	8.48E+10
2	4.55E+09	6.83E+09	5.59E+10	8.39E+10
3	4.55E+09	6.83E+09	5.74E+10	8.61E+10
4	4.55E+09	6.83E+09	5.74E+10	8.61E+10
5	4.55E+09	6.83E+09	5.05E+10	7.58E+10
6	4.55E+09	6.83E+09	4.80E+10	7.20E+10
7	4.55E+09	6.83E+09	5.00E+10	7.51E+10
8	4.55E+09	6.83E+09	5.72E+10	8.58E+10
August				
1	4.55E+09	6.83E+09	5.65E+10	8.48E+10
2	4.55E+09	6.83E+09	5.59E+10	8.39E+10
3	4.55E+09	6.83E+09	5.74E+10	8.61E+10
4	4.55E+09	6.83E+09	5.74E+10	8.61E+10
5	4.55E+09	6.83E+09	5.05E+10	7.58E+10
6	4.55E+09	6.83E+09	4.80E+10	7.20E+10
7	4.55E+09	6.83E+09	5.00E+10	7.51E+10
8	4.55E+09	6.83E+09	5.72E+10	8.58E+10
September				
1	4.70E+09	7.06E+09	7.33E+10	1.10E+11
2	4.70E+09	7.06E+09	7.25E+10	1.09E+11
3	4.70E+09	7.06E+09	7.45E+10	1.12E+11
4	4.70E+09	7.06E+09	7.45E+10	1.12E+11
5	4.70E+09	7.06E+09	6.53E+10	9.80E+10
6	4.70E+09	7.06E+09	6.19E+10	9.29E+10
7	4.70E+09	7.06E+09	6.47E+10	9.70E+10

APPENDIX D

VALUES OF ACQOP, SQOLIM, MON-ACCUM, and MON-SQOLIM

SUBBASIN	CROPLAND		PASTURELAND	
	MON-ACCUM (count/acre/day)	MON-SQOLIM (count/acre)	MON-ACCUM (count/acre/day)	MON-SQOLIM (count/acre)
8	4.70E+09	7.06E+09	7.43E+10	1.11E+11
October				
1	4.55E+09	8.20E+09	7.31E+10	1.32E+11
2	4.55E+09	8.20E+09	7.23E+10	1.30E+11
3	4.55E+09	8.20E+09	7.43E+10	1.34E+11
4	4.55E+09	8.20E+09	7.43E+10	1.34E+11
5	4.55E+09	8.20E+09	6.51E+10	1.17E+11
6	4.55E+09	8.20E+09	6.17E+10	1.11E+11
7	4.55E+09	8.20E+09	6.45E+10	1.16E+11
8	4.55E+09	8.20E+09	7.40E+10	1.33E+11
November				
1	3.36E+07	6.05E+07	8.29E+10	1.49E+11
2	3.36E+07	6.05E+07	8.18E+10	1.47E+11
3	3.36E+07	6.05E+07	8.43E+10	1.52E+11
4	3.36E+07	6.05E+07	8.43E+10	1.52E+11
5	3.36E+07	6.05E+07	7.29E+10	1.31E+11
6	3.36E+07	6.05E+07	6.87E+10	1.24E+11
7	3.36E+07	6.05E+07	7.21E+10	1.30E+11
8	3.36E+07	6.05E+07	8.40E+10	1.51E+11
December				
1	3.36E+07	6.05E+07	9.94E+10	1.79E+11
2	3.36E+07	6.05E+07	9.82E+10	1.77E+11
3	3.36E+07	6.05E+07	1.01E+11	1.82E+11
4	3.36E+07	6.05E+07	1.01E+11	1.82E+11
5	3.36E+07	6.05E+07	8.74E+10	1.57E+11
6	3.36E+07	6.05E+07	8.24E+10	1.48E+11
7	3.36E+07	6.05E+07	8.65E+10	1.56E+11
8	3.36E+07	6.05E+07	1.01E+11	1.82E+11

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