TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

For FECAL COLIFORM in the

ROCK CREEK WATERSHED

(HUC 03160110)

Cullman, Lawrence, and Winston Counties, Alabama

United States Environmental Protection Agency

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

James D. Giattina, Director   Date
Water Management Division

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1.0 EXECUTIVE SUMMARY: ROCK CREEK

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify waterbodies which are not meeting water quality standards and to determine the Total Maximum Daily Load (TMDL) for pollutants causing the impairment. TMDLs are the sum of individual wasteload allocations for point sources (WLAs), load allocations (LAs) for nonpoint sources, including natural background levels, and a margin of safety (MOS).

The State of Alabama has identified Rock Creek on the 1996, 1998, and 2000 303(d) list as partially supporting its designated use of Fish and Wildlife for organic enrichment/dissolved oxygen (OE/DO) and pathogens. Water quality data collected in Rock Creek in 1990-1991 and 1997 was used for listing the stream from Blevens Creek to Smith Lake. This TMDL addresses only the impairment from pathogens.

Rock Creek in Cullman, Lawrence and Winston Counties lies within the Sipsey Fork of the Black Warrior River basin, hydrologic unit 03160110. Rock Creek is a tributary to Smith Lake. The watershed, defined as the area draining into Rock Creek upstream of monitoring station RCK-4, is predominantly agricultural and forested with little urban or developed area. The drainage area is approximately 51,379 acres (80.3 sq. mi.).

Fecal coliform is used as the indicator for pathogen TMDLs in Alabama. A geometric mean concentration of 200 colonies/100mL was established as the target for this TMDL. To ensure the TMDL is protective during all conditions, model results during the critical period were also compared to the instantaneous criteria of 2000 counts/100mL.

The Nonpoint Source Model (NPSM) was chosen as the model to complete this TMDL. The Watershed Characterization System (WCS), a geographic information system (GIS) interface, was used to display, analyze and compile spatial and attribute data. Rock Creek was delineated into five subwatersheds based on Reach File 3 (RF3) stream coverage and a Digital Elevation Model (DEM) of the area. The farthest downstream point of the delineation was the water quality sampling station RCK-4.

Fecal coliform loads for Rock Creek are attributed to sources modeled as both point and nonpoint sources. Addison High School (NPDES Permit AL0051811) is currently the only point source in the watershed. The load from this facility is assumed constant, and over any 30-day period contributes about 3.64×10^9 counts/30 days to the stream. Nonpoint source loading rates applied to the land surface varied monthly based on the watershed characteristics and monthly application rates of animal manure to cropland and pastureland.

A continuous simulation period of 10 years (1/1/89 – 12/31/98) was the basis of the TMDL. Using a 10-year simulation period offered the opportunity to observe the impact of seasonal trends in loading conditions on instream fecal coliform concentrations. From these trends, a critical period can be evaluated on which the TMDL is based. Often the critical period is the highest violation of the target concentration. Reducing the loads associated with the critical period will result in attainment of the standard during other weather conditions.

For Rock Creek the critical period was 8/27/97 to 9/25/97. Although this time period was not the highest violation of the geometric mean concentration it occurred at a time when simulated flows best matched estimated flows. During the critical period, the average simulated stream flow was about 31 cfs. A continuous flow gage was not located in the Rock Creek watershed. An estimate of flow in Rock Creek during September was based on flow measured in the Sipsey Fork River, a nearby continuous flow gage, and the ratio of the drainage area of the two streams. Using this method, the average flow in Rock Creek during September is about 26 cfs. A good match between simulated and observed stream flow patterns provides a strong confidence in the water quality calibration.

Using the calibrated model, loads from existing nonpoint sources were combined to form three load groups. The first group, runoff from all lands, contributed 5.26×10^{13} counts/30 days and consisted of deposits from grazing animals, an estimate of loading based on the deer population (wildlife) and loads from land applied manure. The second group, leaking septic systems, contained only information related to septic systems and contributed 3.11×10^{11} counts/30 days. The final group, miscellaneous sources, consisting of livestock with stream access and an estimate of unknown (i.e., illicit) instream sources contributed 2.28×10^{12} counts/30 days to the total existing load.

An allocation scenario that predicts compliance with instream water quality standards requires reductions in individual categories: runoff from all lands (87%), leaking septic systems (75%) and miscellaneous sources (75%). The components for the resulting TMDL are summarized below.

Watershed	**WLA**	**LA**	**MOS**	**TMDL**
	cnts/30 days	**cnts/30 days**		**cnts/30 days**
Rock Creek	3.64×10^{9}	6.98×10^{12}	Implicit	6.98×10^{12}

Both an explicit and implicit margin of safety (MOS) were incorporated into the TMDL. For the proposed allocation scenario, reductions were applied to the various sources until the instream concentration was less than the target. For this TMDL, the simulated instream concentration during critical conditions was about 170 counts/100mL. This resulted in an explicit MOS of about 15 percent. The implicit MOS is based on conservative modeling techniques. Conservative assumptions included: use of the most stringent water quality standard year round, loads from leaking septic systems are assumed to be directly connected to the stream, nonpoint loads are assumed to have direct paths to streams.

2.0 TMDL: ROCK CREEK

2.1 Introduction

2.1.1 The TMDL Process

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify waterbodies which are not meeting water quality standards and to determine the Total Maximum Daily Load (TMDL) for pollutants causing the use impairment. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between the pollution sources and instream water quality conditions, so that states can establish water quality based controls to reduce pollution and to restore and maintain the quality of their water resources (USEPA 1991).

TMDLs are the sum of individual wasteload allocations for point sources (WLAs), load allocations (LAs) for nonpoint sources, including natural background levels, and a margin of safety (MOS). The margin of safety can be included either explicitly or implicitly and accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. If the MOS is accounted for explicitly, a portion of the total TMDL is specified; in most cases, the MOS is implicit and accounted for with conservative modeling techniques. A TMDL is denoted by the equation:

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

TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. For bacteria, TMDLs are expressed in terms of organism counts (or resulting concentration), in accordance with 40 CFR Part 130.2(i).

2.1.2 Watershed Description

The State of Alabama has identified Rock Creek on the 1996, 1998, and 2000 303(d) list as partially supporting its designated use for Fish and Wildlife for OE/DO and pathogens. Rock Creek is located in Cullman, Lawrence, and Winston, counties and lies within the Sipsey Fork of the Black Warrior River basin, hydrologic unit 03160110 (see Figure 1). Rock Creek is a tributary to Smith Lake. The watershed, defined as the area upstream of the monitoring station draining into Rock Creek, is predominantly forest, followed by agriculture. The size of the watershed is approximately 51,379 acres (80.3 sq. mi.). Table 1 provides a breakdown of land use in acres, square miles and percent of total. The distribution of land use in the watershed is based on Multi-Resolution Land Characteristics (MRLC) digital images dated 1990-1993 and is shown graphically in Figure 2.

Table 1. Rock Creek Watershed Land Use Distribution

Landuse	Acres	Square Miles	Percent of Total Watershed
Cropland	4,002	6.3	7.8%
Pastureland	9,531	14.9	18.6%
Forest Land	37,276	58.2	72.6%
Urban Land	570	0.9	1.1%
Total	**51,379**	**80.3**	**100.0%**

2.1.3 Designated Use of the 303(d) Stream

The use classification for Rock Creek is Fish and Wildlife, which is described in ADEM Admin. Code R. 335-6-10-.09(5)(a), (b), (c), and (d).

(a). Best usage of waters:
Fishing, propagation of fish, aquatic life, and wildlife, and any other usage except for swimming and water-contact sports or as a source of water supply for drinking or food processing purposes.

(b). Conditions related to best usage:
The waters will be suitable for fish, aquatic life and wildlife propagation. The quality of salt and estuarine waters to which this classification is assigned will also be suitable for the propagation of shrimp and crabs.

(c). Other usage of waters:
It is recognized that the waters may be used for incidental water contact and recreation during June through September, except that water contact is strongly discouraged in the vicinity of discharges or other conditions beyond the control of the Department or the Alabama Department of Public Health.

(d). Conditions related to other usage:
The waters, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water-contact sports.

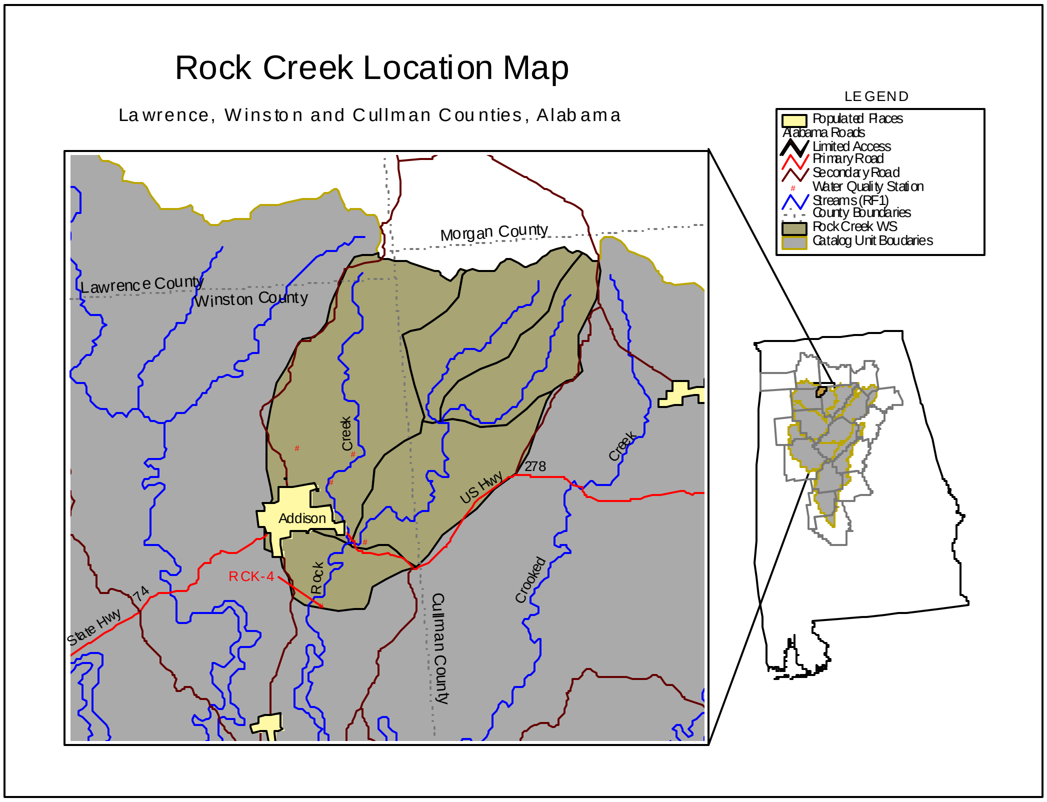

Figure 1. Rock Creek watershed location map.

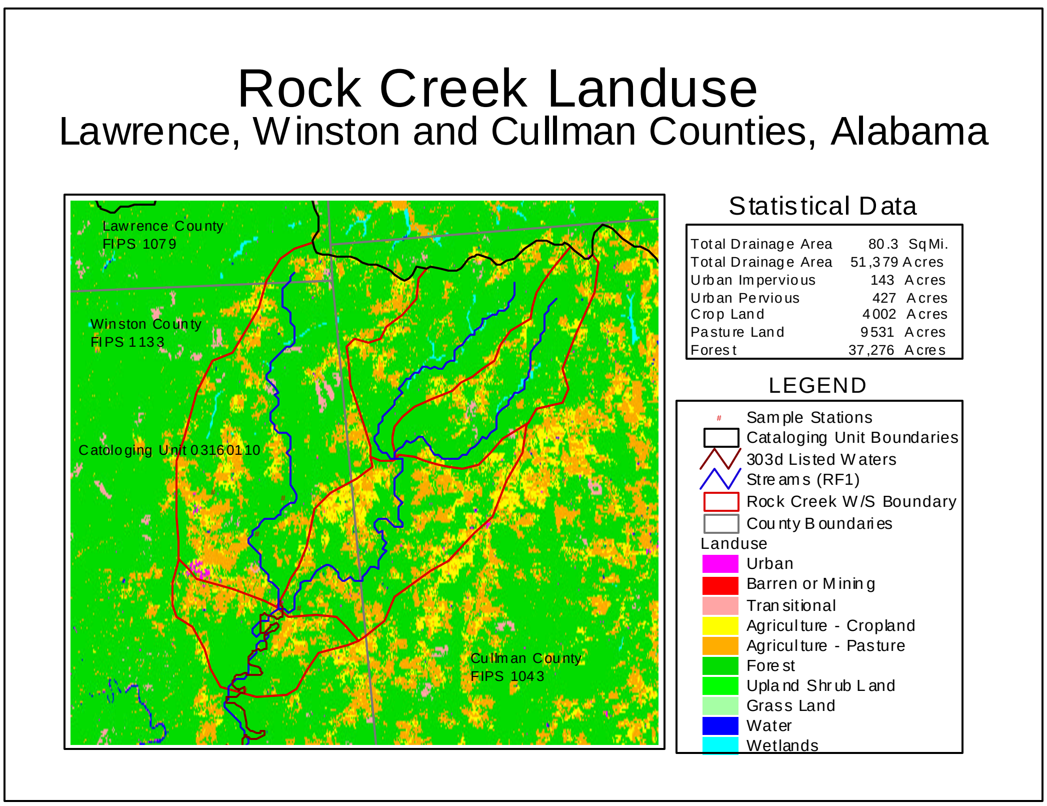

Figure 2. Rock Creek landuse distribution and statistics.

2.2 TMDL Indicators and Numeric Targets

In Alabama, fecal coliform bacteria is used as an indicator of the presence of pathogens in a stream. Criteria for acceptable bacteria levels for the Fish and Wildlife use classification are presented in ADEM Admin. Code R. 335-6-10-.09(5)(e)7.(i) and (ii).

i. Bacteria of the fecal coliform group shall not exceed a geometric mean of 1,000 colonies/100mL; nor exceed a maximum of 2,000 colonies/100mL in any sample. The geometric mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours.

ii. For incidental water contact and recreation during June through September, the bacterial quality of water is acceptable when a sanitary survey by the controlling health authorities reveals no source of dangerous pollution and when the geometric mean fecal coliform organism density does not exceed 100 colonies/100mL in coastal waters and 200 colonies/100mL in other waters. The geometric mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours. When the geometric mean fecal coliform organism density exceeds these levels, the bacterial water quality shall be considered acceptable only if a second detailed sanitary survey and evaluation discloses no significant public health risk in the use of the waters. Waters in the immediate vicinity of discharges of sewage or other wastes likely to contain bacteria harmful to humans, regardless of the degree of treatment afforded these wastes, are not acceptable of swimming or other whole body water-contact sports.

Incidental water contact and recreation is the most stringent of the use classifications. The geometric mean standard of 200 counts/100mL was used as the target level for TMDL development. To ensure the TMDL is protective during all conditions, model results were compared to the instantaneous criteria of 2000 counts/100mL for the years the data were collected (i.e., 1991 and 1997; calendar year 1997 includes the critical period) as this is when the greatest confidence exists for comparing simulated concentrations to the instantaneous criterion. The TMDL for Rock Creek represents the total load the stream can assimilate over a 30-day period and meet the target geometric mean concentration of 200 counts/100mL.

2.3 Water Quality Assessment

Water quality data collected on Rock Creek in 1991 and 1997 were used for listing the stream on Alabama's 303(d) list and is shown in Table 2. Insufficient data were collected to calculate 30-day geometric mean values; however, one sample collected in June 1991 exceeded the maximum daily value of 2000 counts/100mL. As a result, Rock Creek, from Blevens to Smith Lake, was listed as partially supporting its designated use and was scheduled for TMDL evaluation. The water quality sampling station for Rock Creek, RCK-4, is located on Rock Creek at Winston County road downstream of Jones Branch. The station location is shown on Figure 1.

Table 2. Water quality sampling data collected at RCK-4 for Rock Creek.

Date	Fecal Coliform Concentration (counts/100mL)	Date	Fecal Coliform Concentration (counts/100mL)
6/4/91	17,000	6/11/97	181
7/9/91	860	7/1/97	1120
8/8/91	10	8/5/97	52
9/9/91	1300	9/2/97	Not collected
10/7/91	90		

2.4 Source Assessment

2.4.1 Background

The concentration of fecal coliform bacteria entering the stream from any source is dependent on the quantity stored on the land, surface runoff rate, and the susceptibility of the constituent to wash off to the stream. In the model, loads are expressed as rates of accumulation of fecal coliform on the land surface in units of counts/acre/day. The quantity of fecal coliform stored on the land is subject to decay prior to washing off into the stream. In general, fecal coliform from forested land are the least susceptible to wash off due to the dense tree cover and brush covering the ground surface. Urban areas have the highest runoff potential. Point sources have the greatest impact on stream quality during storm events when fecal coliform on the land discharges into the stream.

Derivation of the loads discharging from the various land covers used in the model are included in Appendix A. The load that discharges into the stream from the various sources is only a portion of the total load produced. A portion of the fecal coliform bacteria decays or is incorporated into the soil prior to washing off the land surface. The loads in Appendix A are initial values based on literature values and geographic information system (GIS) coverages contained in WCS.

2.4.2 Point Source Assessment

A point source is defined as any discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source discharges of industrial wastewater, treated sanitary wastewater, storm water associated with industrial activity, or storm water from municipal storm sewer systems that serve over 100,000 people must be authorized by National Pollutant Discharge Elimination System (NPDES) permits. NPDES facilities are the only contributors to the wasteload allocation (WLA) component of the TMDL.

Permitted facilities impacting the impaired stream are entered as hourly point sources having constant flow and load based on design flow and permit limits for fecal coliform bacteria. Addison High School (AL0051811) is currently the only NPDES facility in the Rock Creek watershed. The design flow of this facility is 0.016 million gallons per day (mgd). The permit limits for fecal coliform bacteria in the wastewater from the facility is

200 counts/100mL (based on a geometric mean concentration). The hourly load included in the model from this facility is about 5.05 x 10^6 counts/hr. Over any 30-day period, this hourly load is equivalent to 3.64 x 10^9 counts/30 days. All future NPDES facilities will be required to meet end-of-pipe criteria equivalent to the water quality standard for fecal coliform bacteria of 200 counts/100mL.

2.4.3 Nonpoint Source Assessment

Nonpoint sources of fecal coliform bacteria are diffuse sources that cannot be identified as entering the waterbody at a single location. These sources generally involve land activities that contribute fecal coliform bacteria to streams during rainfall runoff events. All sources considered to be nonpoint sources contribute to the load allocation (LA) portion of the TMDL. Typical nonpoint sources of fecal coliform bacteria include:

- Septic Systems
- Livestock in streams
- Land application of manure
- Wildlife
- Urban Runoff
- Pastures

Septic Systems and Urban Runoff

Leaking septic systems were modeled as hourly point sources having a constant flow and load. Literature values were used to estimate the loadings from failing septic systems in the watershed using a representative effluent flow and concentration. Horsley and Witten (1996) estimate septic systems to have an average daily discharge of 70 gallons/person-day with septic effluent concentrations ranging from 10^4 to 10^7 counts/100mL. Stormwater runoff from urban areas also contributes to fecal coliform nonpoint source loads by delivering litter and the waste of domestic pets and wildlife to the stream.

The number of people in the Rock Creek watershed on septic systems was estimated using 1997 U.S. Census Bureau county data and are shown in Table 3. Using best professional judgment, it was assumed that 10 percent of the total septic systems in the watershed would leak or fail. Each household was assumed to house 2.5 people. Assuming an effluent concentration of 10^4 counts/100mL, the load from failing septic systems was estimated to be 2.64 x 10^8 counts/hr. Over any 30-day period, this hourly load is equivalent to 1.90 x 10^{11} counts/30 days. This value is a conservative estimate of the load as it assumes septic systems discharge directly into the stream rather than through the soil layer.

Table 3. Estimated Population on Septic Systems.

Watershed	Estimate of Individuals on Septic Systems
Rock Creek	3,988

Land Application of Animal Manure

Beef cattle and poultry are the predominant livestock in the watershed. Model loading rates for land applications of animal manure are based on county estimates of livestock and literature values for fecal coliform concentrations in various manures. County livestock data were obtained from U.S. Department of Agriculture (USDA) National Agriculture Statistics System (USDA 1997) and are shown in Table 4. Fecal coliform loading rates for various livestock were estimated to be 1.06×10^{11} counts/day/beef cow, 1.04×10^{11} counts/day/dairy cow, 1.24×10^{10} counts/day/hog, and 1.38×10^{8} counts/day/chicken (NCSU 1994). To derive model loading rates, the numbers of livestock in the county were populated based on the percentage of area in the watershed described as pasture or hay.

Table 4. Agricultural animals in Cullman and Winston counties (USDA 1997).

Animal	Cullman County	Winston County
Cattle	72,612	20,317
Beef Cattle	40,826	11.017
Poultry	140,009,465	24,036,088
Swine	380	37
Dairy Cattle	1,981	850

ADEM requires a general NPDES permit for all concentrated animal feeding operations (CAFOs) in excess of 1000 animal units and for poultry operations in excess of 125,000 birds. The general NPDES permit for CAFOs is a ‘no discharge’ permit except during the 25-year, 24-hour storm event, and then the CAFO facility can discharge only process overflow wastewater to the stream. Based on the number of cattle and poultry animals in the counties, CAFOs could be causing or contributing to the impairment of Rock Creek as indicated by the 303(d) listing. This TMDL requires CAFO facilities to comply with their permits and to not cause or contribute to water quality impairment. If future water quality monitoring data indicate CAFOs are causing impairment, individual permits may be required of these facilities.

Agricultural operations with confined animals generally stack or hold their manure until it can be applied to cropland or pasture land. Poultry litter that is not stockpiled can be used as a feed material for cows, composted or sold. Estimated application rates used in the model vary monthly and by type of animal operation and are listed in Table 5. In the Rock Creek watershed, poultry litter is predominately spread on pastureland. If the litter is not spread at agronomic rates, then a large portion of the fecal coliform bacteria present in the litter could wash off to the stream during a storm event. Model rates for the accumulation of fecal coliform from land applications of animal manure to cropland varied from 5.2×10^{6} to 2.1×10^{8} counts/acre/day. The model accumulation rates assumed for pastureland varied from 8.9×10^{9} to 1.2×10^{10} counts/acre/day.

Table 5. Estimated land application rates for confined animal manure (NRCS 2000).

	% Of One Years Confined Manure Applied In Each Month												% Applied to	
Operation	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Pasture**	**Crop Land**
Swine	2	2	10	17	10	6	6	9	17	13	6	2	90	10
Beef	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	100	0
Dairy	4	4	9	14	9	7	7	9	14	12	7	4	50	50
Broiler	1	5	10	14	10	10	10	10	10	14	5	1	70	30
Layer	1	1	10	19	10	10	9	10	10	14	5	1	90	10

Livestock in Streams and Unknown Sources

Livestock often have access to small streams in their grazing areas. In any watershed, other sources such as illicit discharges may exist that impact water quality. Given the limited data available in the watershed, these sources are unknown and are included in the load estimated for livestock in streams. Loads attributed to livestock in streams and unknown sources were modeled as an hourly point source of constant flow and load. Initial loads were based on the beef cattle population in the watershed and literature values for fecal coliform bacteria produced daily per beef cow. In computing the load, it was assumed 50 percent of the beef cattle had access to the streams and of those, 25 percent deposit wastes in or near the stream bank for a short period of time each day. The percentage of time cattle spend in the stream was assumed about 0.026 percent. In the model the load attributed to livestock in streams and unknown sources in the various subwatersheds ranged from $3x10^8$ to $1.2x10^9$ counts/hr. Over any 30-day period, this hourly load is equivalent to $2.2x10^{11}$ to $8.4x10^{11}$ counts/30days.

Wildlife and Background Load

Wildlife, including deer, raccoons, wild turkeys, waterfowl, etc., is considered significant contributor to background concentrations of fecal coliform. Due to the lack of population estimates for raccoons, waterfowl and other wildlife that may inhabit the watershed, the deer population was used to estimate the fecal coliform load from wildlife. Based on discussions with ADEM, the population of deer in the watershed was estimated at 45 deer/sq. mile. The fecal coliform loading rate from deer was estimated by linear interpolation using the rates for other animals, such as turkey and cattle, reported in Metcalf and Eddy (1991). The interpolation was based on animal weight and fecal coliform production rate. The resulting loading rate from deer was estimated at 5.0×10^8 counts/animal/day. Using this rate and the assumption of equally distributed population of deer between forest and agricultural lands, the fecal coliform accumulation rate applied in the model was estimated as 3.5×10^7 counts/acre/day.

2.5 Linking the Sources to the Indicators and Targets

Establishing the relationship between instream water quality and sources of fecal coliform, the pathogen indicator, is an important component of the TMDL. It provides the relative contribution of the sources, as well as a predictive examination of water quality resulting from changes in these source contributions.

2.5.1 Model Selection

The model selected for this TMDL needed to meet several objectives. The first objective was to simulate the time varying behavior of the deposition and transport of fecal coliform bacteria from the land surface to receiving water bodies. The second was to use a continuous simulation period to identify the critical condition from which to develop the TMDL. Having the ability to use a continuous simulation period while varying the monthly loading rates provided the means to evaluate seasonal effects on the production and fate of fecal coliform bacteria.

The Nonpoint Source Model (NPSM) is a dynamic computer model capable of simulating nonpoint source runoff and associated pollutant loads, accounting for point source discharges, and performing flow and water quality routing through stream reaches. It is based on the Hydrologic Simulation Program – FORTRAN (HSPF) and has the ability to incorporates the buildup and wash off of pollutants on both pervious and impervious surfaces. In addition, HSPF allows discrete simulation of the required components of the TMDL (i.e., WLA and LA components).

The Watershed Characterization System (WCS), a geographic information system (GIS) interface, was used to display, analyze and compile spatial and attribute data. Available data sources included land use classification, point source discharges, soil type and characteristics, population data (human and livestock), digital elevation data, stream characteristics, precipitation and flow data. Results from these analyses provided input to loading spreadsheets developed by Tetra Tech, Inc. Output from the spreadsheets included fecal coliform loading rates from surface runoff and from direct sources including leaking septic systems and livestock with stream access. This output was used to support and estimate the initial water quality model parameters.

2.5.2 Model Setup

Rock Creek was delineated into five subwatersheds to isolate the major tributaries flowing into Rock Creek. The delineation was based on Reach File 3 (RF3) stream coverage and a Digital Elevation Model (DEM) of the area. The farthest downstream point of the delineation was the water quality sampling station RCK-4. Land use in the watershed was characterized based on Multi Resolution Land Characteristics (MRLC) digital images dated 1990-1993. A continuous simulation period of 10 years (1/1/88 - 12/31/98) was used as this incorporates a wide range of meteorological events for evaluating the worst-case scenario. This long time period also allows the TMDL to be based on a range of seasonal conditions.

2.5.3 Hydrology Calibration

NPSM is driven by precipitation; therefore, it is important to calibrate hydrologic parameters prior to attempting a calibration for water quality. The hydrologic calibration is the foundation of the water quality model. Long-term hourly precipitation data were obtained from the National Oceanic and Atmospheric Association (NOAA) for the Huntsville, AL weather station provided the meteorological data used in the simulation.

In the hydrology calibration, simulated stream flows were compared to the historic stream flow data recorded at a continuous stream gage operating in the watershed. In the calibration process, hydrologic parameters such as infiltration, upper and lower zone storage, groundwater storage and recession, interflow, and evapotranspiration, were adjusted until the simulated and observed hydrographs matched.

A continuous flow gage was not located in the Rock Creek watershed; therefore, a hydrologic calibration was performed at a nearby gage in the Sipsey Fork watershed (USGS 02450250). The hydrologic parameters used to calibrate the model developed at the Sipsey Fork gage were assumed to apply to the Rock Creek watershed. The period from 1/1/89 to 12/31/98 was used as the calibration period for the hydrologic parameters as this was the extent of available meteorological data. Relative fit of the modeled flow compared to recorded flow at the Sipsey Fork gage for calendar year 1989 is shown in Figure 3.

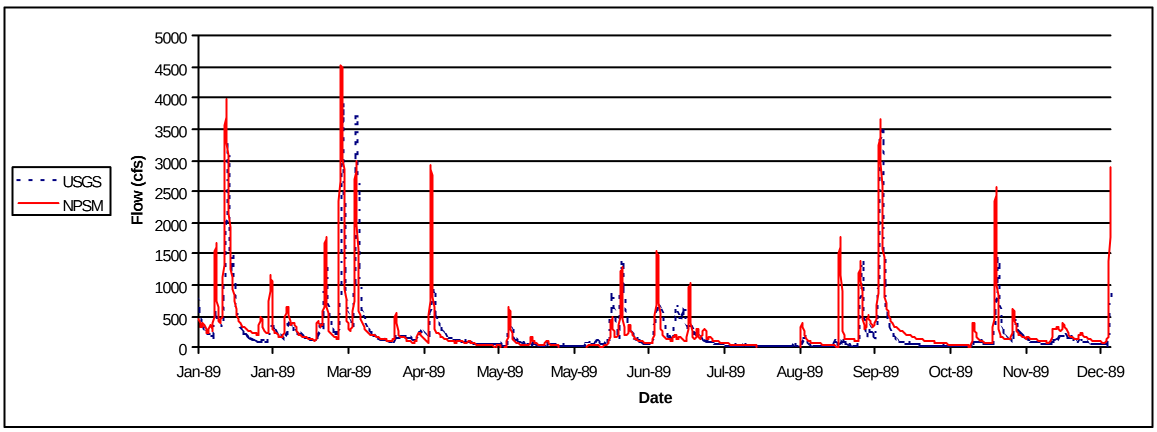

Figure 3. Simulated and observed flows recorded at USGS 02450250 Sipsey Fork.

2.5.4 Water Quality Calibration

Water quality model calibration follows the hydrology calibration. The water quality parameters were adjusted until acceptable agreement was achieved between simulated and observed fecal coliform concentrations. To calibrate the model, several parameters were adjusted including the rates of fecal coliform bacteria accumulation, wash-off rates, maximum storage of fecal coliform bacteria and contributions of direct sources. Water quality data are often limited but by matching the trends in simulated and observed concentrations resulting from peak and base flows, the model can be a reasonable predictor of instream water quality and be considered calibrated. The inability to accurately simulate specific observed data points can sometimes be attributed to differences in rainfall at the meteorological station and what occurs in the watershed.

In the water quality calibration, samples collected at RCK-4 in 1991 and 1997 were compared to simulated concentrations and rainfall collected at the weather station. The results are shown in Figures 4 and 5. Results indicate that the model adequately simulated the response of fecal coliform bacteria during storm and low flow events.

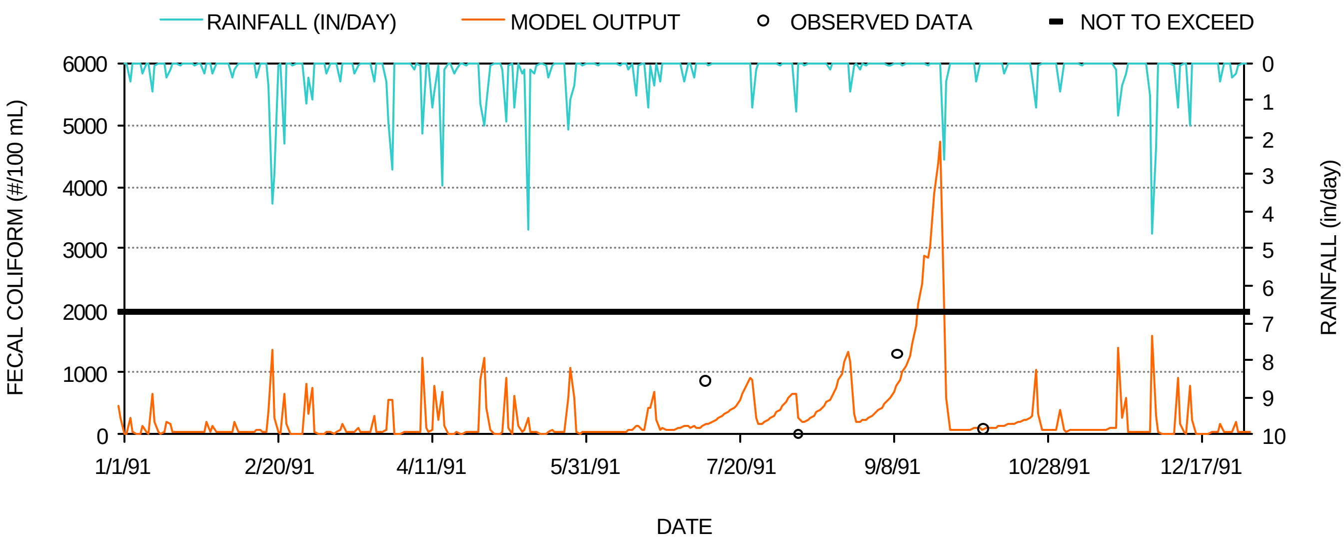

Figure 4. Simulated and observed fecal coliform concentrations at Station RCK-4 in 1991.

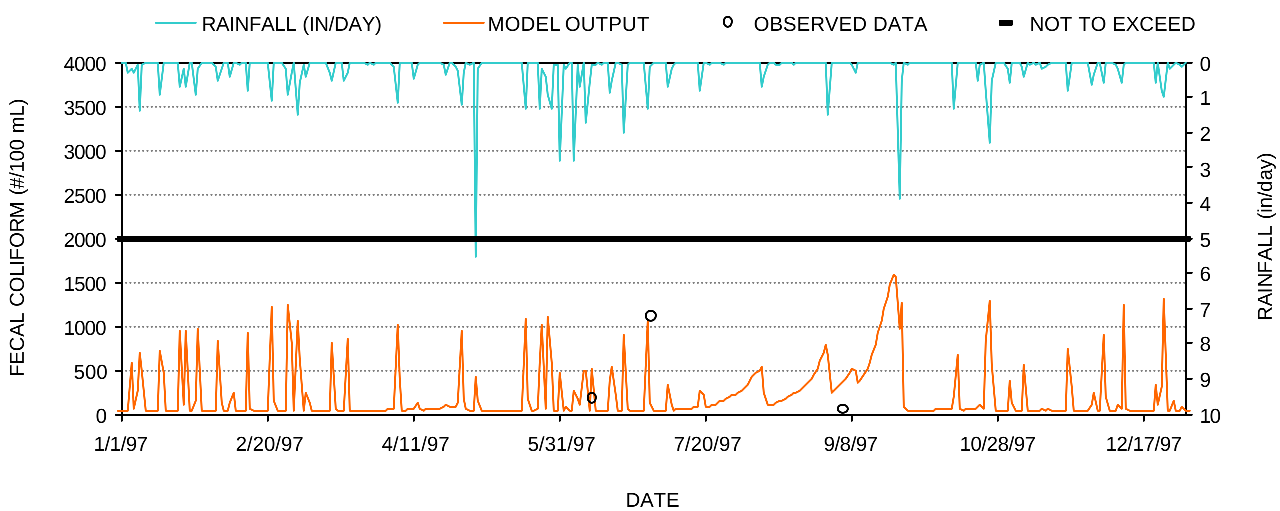

Figure 5. Simulated and observed fecal coliform concentrations at Station RCK-4 in 1997.

2.5.4 Results from Water Quality Modeling

Loading rates representing existing conditions were determined in the following manner:

- The calibrated model was run for a 10-year period.
- Simulated fecal coliform concentrations for the 10-year period were plotted as running 30-day geometric mean concentrations and compared to the standard criteria of 200 counts/100mL (see Figure 6).
- From Figure 6, critical conditions were determined.
- The simulated daily fecal coliform loads from all sources were summed for the 30-day critical period. These values, shown in Table 6, represent existing loads.

In this table, *runoff from all lands* includes: deposits from grazing animals including deer, an estimate from urban areas, and loads from land applied manure. *Leaking septic systems* contains only information related to septic systems. *Miscellaneous sources* include two components: livestock with stream access as well as an estimate of unknown, or illicit, instream sources. Model results indicate that runoff from all lands during storm events provide the largest load of fecal coliform bacteria to the stream. Loads from leaking septic systems and miscellaneous sources are constant loads to the stream. These sources will have the greatest impact on water quality during periods of low flows.

Table 6. Summary of predicted existing coliform loads in the Rock Creek watershed.

Runoff From All Lands	Leaking Septic Systems	Miscellaneous Sources	Instream Concentration3
Counts/30 Days[1]	Counts/30 Days	Counts/30 Days[2]	Counts/100mL
3.63×10^{11}	1.90×10^{11}	2.23×10^{12}	627

1 Includes grazing animals, dear population, land-applied manure, and urban runoff.
2 Includes livestock with stream access and illicit discharges.
3 Maximum simulated concentration during the critical period

2.6 Allocation

2.6.1 Total Maximum Daily Load (TMDL)

Once the model was calibrated for water quality, load reductions were applied until the simulated 30-day geometric mean concentration for the 10-year period did not exceed the water quality geometric mean criteria of 200 counts/100mL (Figure 6). In addition, the simulated concentrations for the allocation scenario were compared to the instantaneous criterion of 2000 counts/100mL during the sampling periods. This ensures the TMDL protective for daily fluctuations in concentration (Figure 7 and 8). The 30-day geometric mean concentrations over a 10-year period are a better indication of average conditions in the stream than the instantaneous criterion. Since the instantaneous criterion is used to calibrate the model, a comparison of the simulated concentrations resulting from the allocation scenario is used to verify the TMDL loads for the calibration period only.

The wasteload allocation (WLA) portion of the TMDL includes NPDES permitted facilities in the watershed. The load allocation (LA) portion includes coliform from grazing animals, animals with access to streams, urban runoff and illicit discharges, leaking septic systems and runoff from land applied animal manure.

An allocation scenario that predicts compliance with instream water quality standards and the required reductions from the individual categories is shown in Table 7. The allocated loads for the TMDL components are shown in Table 8.

Table 7. Allocation scenario for TMDL conditions

Runoff From All Lands	**Leaking Septic Systems**	**Miscellaneous Sources**	**Instream Concentration[1]**
Counts/30 Days	**Counts/30 Days**	**Counts/30 Days**	**Counts/100mL**
2.18×10^{11}	7.61×10^{10}	3.49×10^{11}	171
40%	60%	84%	73%

1 Maximum simulated instream concentration during the critical period. Percent reduction represents the difference in simulated instream concentrations between existing and allocation scenarios.

Table 8. TMDL components for Rock Creek.

Watershed	**WLA**	**LA**	**MOS[1]**	**TMDL**
	cnts/30 days	**cnts/30 days**		**cnts/30 days**
Rock Creek	3.64×10^{9}	6.98×10^{12}	Explicit and Implici	6.98×10^{12}

1 Explicit MOS equivalent to 15 percent as instream fecal coliform concentration for the allocated scenario is reduced this amount below the target of 200 counts/100mL (i.e., (200-171)/200*100 = 15%).

2.6.2 Seasonal Variation

A 10-year simulation period was used to assess loads and their affect on water quality; this period included seasonal variation. In addition, loading rates were varied monthly in the model. These rates were based on reports obtained from the Watershed Characterization System and on monthly application rates of animal manure to cropland and pastureland.

2.6.3 Margin of Safety

Both an explicit and an implicit MOS were incorporated in this TMDL. The explicit MOS is based on the simulated instream concentrations during the critical period. For the allocation scenario, the simulated instream concentration was reduced to 171 counts/100mL (29 counts/100mL below the water quality criterion, or 15 percent). The implicit MOS is based on conservative modeling techniques, including:

- The TMDL target was developed against the most stringent water quality standard.

- Loads from leaking and failing septic systems were treated as point sources with a constant concentration and flow. In reality, septic systems discharge to the groundwater system where a portion of the fecal coliform bacteria may become incorporated into the soils prior to discharge into the stream.
- All landuses were modeled as if they were directly connected to the stream.

2.6.4 Critical Conditions

The critical condition for nonpoint source fecal coliform loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, fecal coliform bacteria builds up on the land surface, and are transported to the stream by rainfall. The critical condition for point source loading occurs during periods of low stream flow when dilution is minimized. Both conditions are simulated in the water quality model.

The 10-year period from 1/1/89 to 12/31/98 was used to simulate a continuous 30-day geometric mean distribution to compare to the target (see Figure 6). This 10-year period contained a range of hydrological conditions that included both low and high stream flows from which critical conditions were identified. The simulated concentrations were also compared to the instantaneous criterion of the recreational standard. This ensures the TMDL is protective for daily fluctuations in concentrations (see Figures 7 and 8).

The 30-day critical period in the model is the period preceding the largest simulated violations of the geometric mean standard and should reflect average conditions in the stream. The critical period excludes periods of model instability, when the simulated stream flow approaches zero and causes concentrations to become negative, or abnormal weather conditions such as floods or drought. Meeting water quality standards during the critical period ensures that water quality standards can be achieved throughout the simulation period.

For Rock Creek, the 30-day critical period is 8/27/97 to 9/25/97 and is shown graphically in Figure 9. During the critical period the simulated stream flow in Rock Creek was about 31 cfs. An estimate of flow in Rock Creek was based on measured flow in Sipsey Fork River and the ratio of the drainage area of the two streams. Using this method, the average flow in Rock Creek during September 1997 should be about 26 cfs. A good match in the hydrology provides a strong confidence in the water quality calibration.

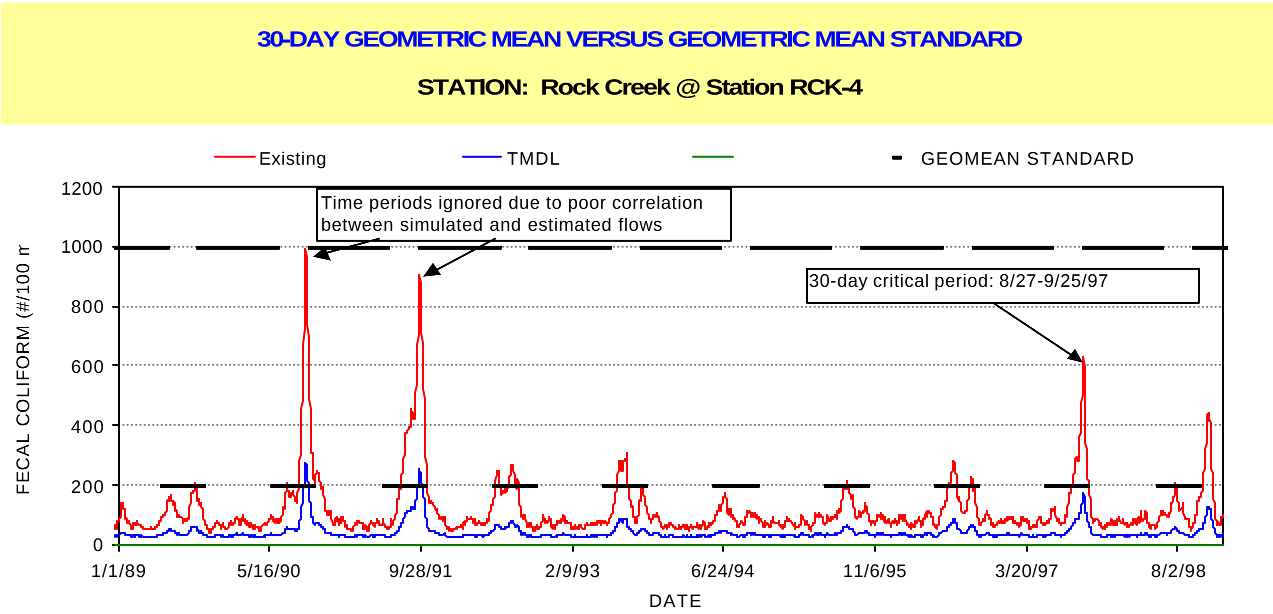

Figure 6. Simulated geometric mean concentrations for existing and TMDL conditions (1989-1998).

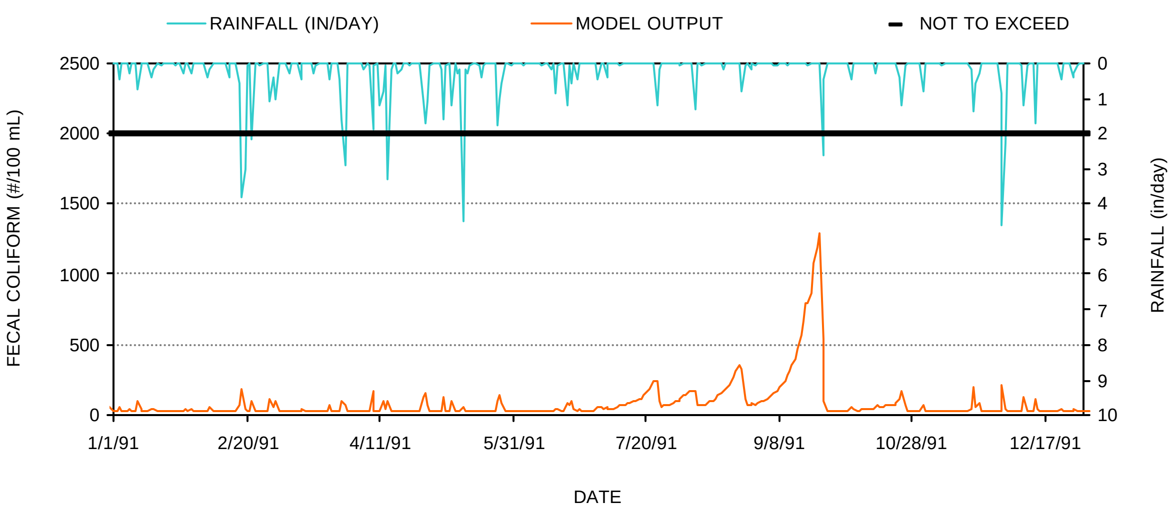

Figure 7. Comparison of instantaneous criterion and simulated daily fecal coliform concentrations for TMDL conditions during 1991 sampling period.

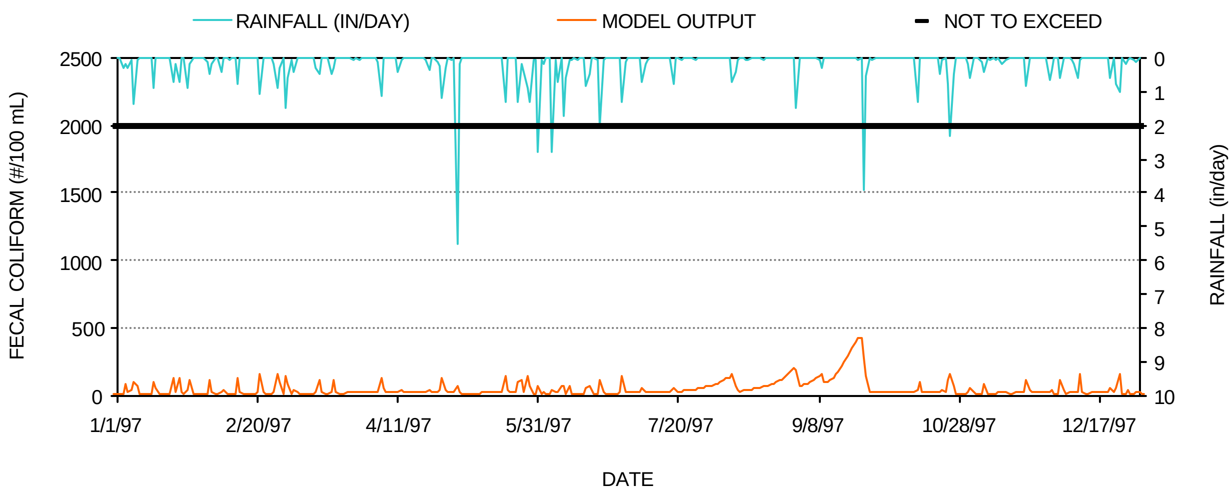

Figure 8. Comparison of instantaneous criterion and simulated daily fecal coliform concentrations for TMDL conditions during 1997 sampling period.

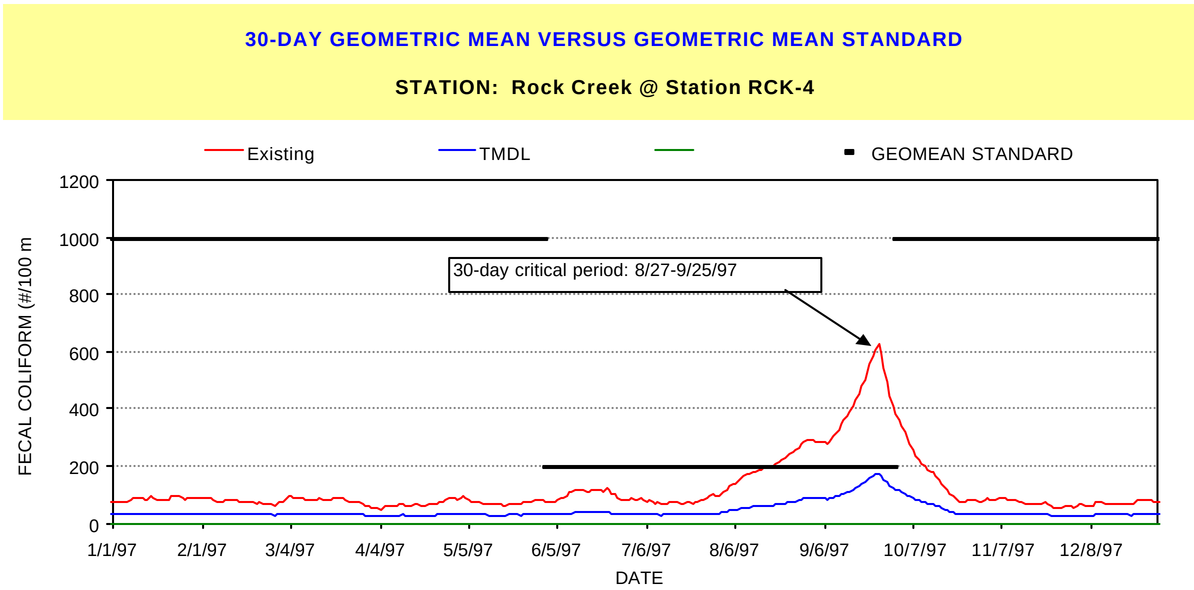

Figure 9. Simulated geometric mean concentrations during critical period.

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APPENDIX A
Example Calculations of Loading Rates

EXAMPLE CALCULATION OF RUNOFF LOAD (example shown for runoff from pastureland in Cullman Co)

COUNTY	AGRICULTURAL ANIMALS (NRCS and WWW.NASS.GOV for horses)							
	CATTLE	BEEF	DAIRY	SWINE	SHEEP	BROILERS	LAYERS	cattle access to stream
Cullman Co.	72612	40826	1921	380	515	137070310	2939155	yes

LOAD ESTIMATES BASED ON COUNTY ANIMAL POPULATION AND LAND APPLICATION OF MANURE

Runoff from pastureland (COUNTS/DAY) = Number animals * Fecal concentration (counts/animal/day) * Fecal content multiplier * Runoff rate * monthly application rate* percentage applied to pasture

Hog Manure Available for Wash-off

Fecal concentration	1.24E+10	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	1	(stored in lagoons before applying to pastureland - by assuming no decay in the lagoon is a conservative assumption)
Fraction available for runoff	0.6	(EPA assumption)
Fraction applied to pastureland	1	

Hog manure application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December	
Fraction of manure applied each month	0.02	0.02	0.1	0.17	0.1	0.06	0.06	0.09	0.17	0.13	0.06	0.02	1

Hog manure runoff from pastureland (counts/day):

Cullman Co.	9.42E+10	9.42E+10	4.71E+11	8.01E+11	4.71E+11	2.83E+11	2.83E+11	4.24E+11	8.01E+11	6.13E+11	2.83E+11	9.42E+10

Beef Cattle Manure Available for Wash-off

Fecal concentration	1.06E+11	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	1	(a value of 1 assumes fresh application - worse case scenario)
Fraction available for runoff	0.63	(EPA assumption)
Fraction applied to pastureland	1	

Beef cattle manure application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December	
Fraction of manure applied each month	0.0833	0.0833	0.0833	0.0833	0.0833	0.0834	0.0834	0.0834	0.0834	0.0833	0.0833	0.0833	1

Beef manure runoff from pastureland (counts/day):

Cullman Co.	2.27E+14	2.27E+14	2.27E+14	2.27E+14	2.27E+14	2.27E+14	2.27E+14	2.27E+14	2.27E+14	2.27E+14	2.27E+14	2.27E+14

Dairy Cattle Manure Available for Wash-off

Fecal concentration	1.04E+11	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	1	(a value of 1 assumes fresh application - worse case scenario)
Fraction available for runoff	0.63	(EPA assumption)
Fraction applied to pastureland	0.5	

Dairy cattle manure application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December	
Fraction of manure applied each month	0.04	0.04	0.09	0.14	0.09	0.07	0.07	0.09	0.14	0.12	0.07	0.04	1

Dairy manure runoff from pastureland (counts/day):

Cullman Co.	2.52E+12	2.52E+12	5.66E+12	8.81E+12	5.66E+12	4.41E+12	4.41E+12	5.66E+12	8.81E+12	7.55E+12	4.41E+12	2.52E+12

Poultry Litter Available for Wash-off (from layers)

Fecal concentration	1.38E+08	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	1	(a value of 1 assumes fresh application - worse case scenario)
Fraction available for runoff	0.0047	(EPA assumption - based on NRCS information)
Fraction applied to pastureland	0.9	

Poultry litter application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December	
Fraction of litter applied each month	0.01	0.05	0.1	0.14	0.1	0.1	0.1	0.1	0.1	0.14	0.05	0.01	1

Poultry litter runoff from pastureland (counts/day):

Cullman Co.	1.72E+10	8.58E+10	1.72E+11	2.40E+11	1.72E+11	1.72E+11	1.72E+11	1.72E+11	1.72E+11	2.40E+11	8.58E+10	1.72E+10

Poultry Litter Available for Wash-off (from broilers)

Fecal concentration	1.38E+08	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	1	(a value of 1 assumes fresh application - worse case scenario)
Fraction available for runoff	0.0047	(EPA assumption - based on NRCS information)
Fraction applied to pastureland	0.7	

Poultry litter application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December	
Fraction of litter applied each month	0.01	0.05	0.1	0.14	0.1	0.1	0.1	0.1	0.1	0.14	0.05	0.01	1

Poultry litter runoff from pastureland (counts/day):

Cullman Co.	6.22E+11	3.11E+12	6.22E+12	8.71E+12	6.22E+12	6.22E+12	6.22E+12	6.22E+12	6.22E+12	8.71E+12	3.11E+12	6.22E+11

Runoff load from pastureland (counts/day)	January	February	March	April	May	June	July	August	September	October	November	December
from all animals - Cullman Co.	2.30E+14	2.33E+14	2.40E+14	2.46E+14	2.40E+14	2.38E+14	2.38E+14	2.40E+14	2.43E+14	2.44E+14	2.35E+14	2.30E+14

Accumulation Rate (counts/acre/day) Used in Model = runoff load/watershed area where watershed area covered by pasture = 7209 acres

	January	February	March	April	May	June	July	August	September	October	November	December
Accumulation Rate (counts/acre/day)	3.20E+10	3.23E+10	3.32E+10	3.41E+10	3.32E+10	3.31E+10	3.31E+10	3.33E+10	3.38E+10	3.39E+10	3.26E+10	3.20E+10

Estimation of load from animal access to streams (for calculation purposes assume only beef cattle have access to streams)
assume 50 % of beef cattle in the watershed have access to streams and of those 25% defecate in or near the stream banks about 3 minutes per day
(resulting stream access is 0.00025 (i.e., 0.5 x 0.25 x 3min/(24*60))

Total load from cattle in stream =number beef cows in watershed * fecal concentration * 0.00025

Beef cows in one of the five subwatershed =	82		
Total load from cattle in stream =	9.05E+07	counts/hr	**Model input as point source of constant flow and load (flow negligible)**

Fecal Coliform Contribution from Wildlife (deer)

Estimated deer per sq. mile:	45	
fecal coliform load (counts/animal/day)	5.00E+08	
Accumulation Rate (counts/acre/day)	3.52E+07	**Model input parameter ACQOP**

ESTIMATION OF LOAD FROM LEAKING SEPTIC SYSTEMS - input in model as point source of constant flow and load

Fecal Coliform Concentration in human waste	10,000	counts/100ml	(literature values 10^4 to 10^7 counts/100ml - Horsley & Witten, 1996)
Estimated failure rate	10	percent (assumed)	
Estimated occupants per household	2.5	people (assumed)	
Typical septic overcharge flow rate	70	gal/day/person	(Horsley & Witten, 1996)
Population in example subwatershed on septics	51	people	(US Census, estimated for 1997)
# Failing septic systems	2.04	systems	(population on septic/# people per household) * failure rate/100
Total # people on failed septics	5.1	people	(# failing septic systems * # occupants per household)

Septic flow rate = # failing septic systems * total # people served * overcharge flow rate * conversion factor to units of cfs
Septic flow rate = 2.04 systems * 51 people * 70 gal/day/person * 0.00000155 = 5.53 x10^{-4} cfs

Fecal coliform rate (counts/hr) = # people on failing septic systems * overcharge flow rate * fecal coliform concentration * conversion factor
Fecal coliform rate (counts/hr) = 5.1 people * 70 gal/day/person * 10,000 counts/100ml * (3.785 L/gal) * (1000mL / L) * (day/24 hr) = 5.63E+06 counts/hr