Total Maximum Daily Load for Fecal Coliform Bacteria to Little Troublesome Creek, North Carolina

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Cape Fear River Basin

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1.0 INTRODUCTION

On the 2000 North Carolina 303(d) list, the North Carolina Division of Water Quality (DWQ) has identified a 5.0-mile segment (16-7b) of Little Troublesome Creek in the Cape Fear Basin as impaired by fecal coliform bacteria. The impaired segment is located between the Reidsville WWTP and Little Troublesome Creek's confluence with the Haw River. This section of the stream is located in subbasin 03-06-01 and is designated as a class C water. Class C waters are freshwaters that are protected for secondary recreation, fishing, and propagation and survival of aquatic life.

Section 303(d) of the Clean Water Act (CWA) requires states to develop a list of waters not meeting water quality standards or which have impaired uses. This list, referred to as the 303(d) list, is submitted biennially to the U.S. Environmental Protection Agency (EPA) for review. The 303(d) process requires that a Total Maximum Daily Load (TMDL) be developed for each of the waters appearing on Part I of the 303(d) list. A TMDL is the maximum amount of a pollutant (e.g., fecal coliform) that a waterbody can receive and still meet water quality standards, and an allocation of that load among point and nonpoint sources. The objective of a TMDL is to estimate allowable pollutant loads and allocate to known sources so that actions may be taken to restore the water to its intended uses (USEPA, 1991). Generally, the primary components of a TMDL, as identified by EPA (1991, 2000a) and the Federal Advisory Committee are as follows:

Target identification or selection of pollutant(s) and endpoint(s) for consideration. An endpoint is an instream numeric target. The pollutant and endpoint are generally associated with measurable water quality related characteristics that indicate compliance with water quality standards. North Carolina indicates known problem pollutants on the 303(d) list.

Source assessment. Sources that contribute to the impairment should be identified and loads quantified, to the extent that that is possible.

Reduction target. Estimation or level of pollutant reduction needed to achieve water quality goal. The level of pollution should be characterized for the waterbody, highlighting how current conditions deviate from the target endpoint. Generally, this component is identified through water quality modeling.

Margin of safety. The margin of safety addresses uncertainties associated with pollutant loads, modeling techniques, and data collection. Per EPA (2000a), the margin of safety may be expressed explicitly as unallocated assimilative capacity (portion of TMDL) or implicitly through conservative assumptions. The margin of safety should be included in the reduction target

Allocation of pollutant loads. Allocating available pollutant load (TMDL), and hence pollutant control responsibility, to the sources of impairment. The wasteload allocation portion of the TMDL accounts for the loads associated with existing and future point sources. The load allocation portion of the TMDL accounts for the loads associated with existing and future nonpoint sources. Any future nonpoint source loading should remain within the TMDL that is calculated in this assessment; in other words, this TMDL does not leave allocation for future sources.

Seasonal variation. The TMDL should consider seasonal variation in the pollutant loads and endpoint. Variability can arise due to streamflows, temperatures, and exceptional events (e.g., droughts, and hurricanes).

Critical conditions. Critical conditions occur when fecal coliform levels exceed the standard by the largest amount. If the modeled load reduction is able to meet the standard during critical conditions, then it should meet the standard at all, or nearly all, times.

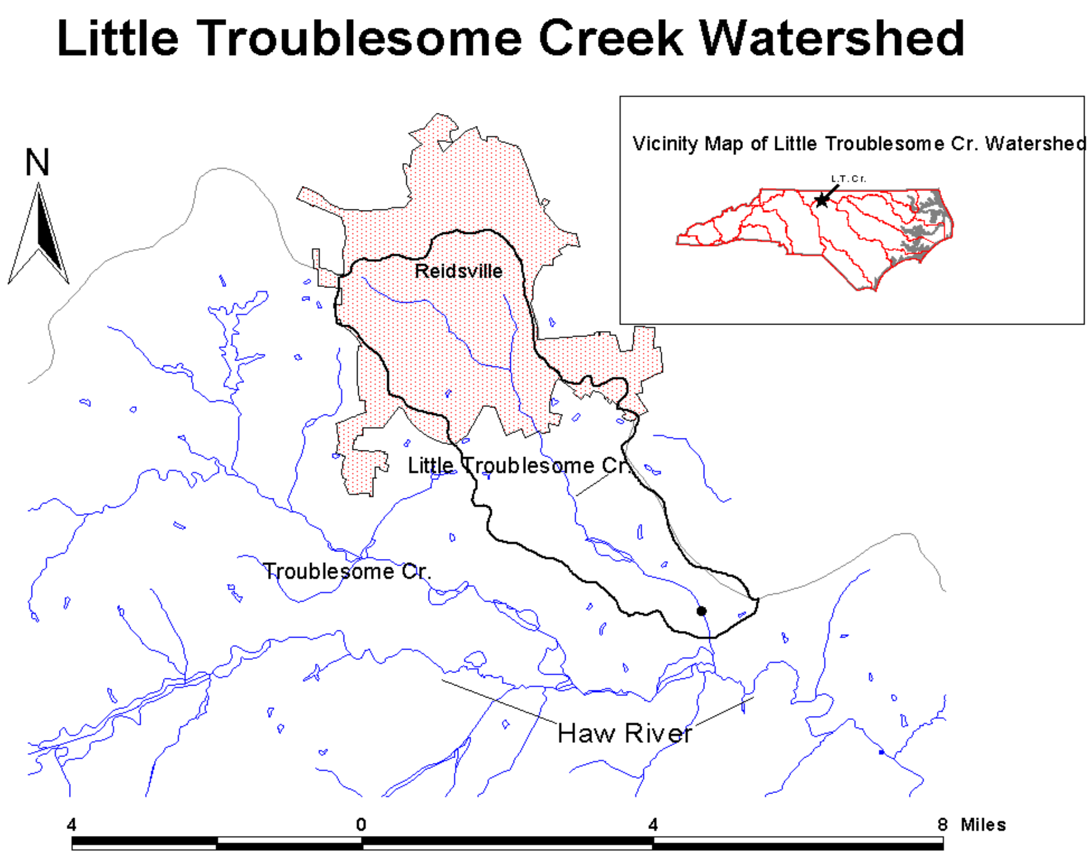
Section 303(d) of the CWA and the Water Quality Planning and Management regulation (USEPA, 2000a) require EPA to review all TMDLs for approval or disapproval. Once EPA approves a TMDL, then the waterbody may be moved to Part III of the 303(d) list. Waterbodies remain on Part III of the list until compliance with water quality standards is achieved. Where conditions are not appropriate for the development of a TMDL, management strategies may still result in the restoration of water quality.

The goal of the TMDL program is to restore designated uses to water bodies. Thus, the implementation of bacteria controls will be necessary to restore designated uses in Little Troublesome Creek. Although an implementation plan is not included as part of this TMDL, reduction strategies are needed. The involvement of local governments and agencies will be critical in developing an implementation plan and reduction strategies. DWQ will seek to begin development of the implementation plan during public review of the TMDL.

1.1 Watershed Description

Little Troublesome Creek, located in the upper Cape Fear River basin, drains into the Haw River about fifteen miles northeast of the City of Greensboro (see Figure 1). The creek's watershed lies entirely within Rockingham County and is slightly less than 12 square miles in area. The City of Reidsville (2000 population of 14,485) covers approximately the upper half of the watershed. DWQ has an ambient water quality monitoring site (Storet number B0160000) near the creek's confluence with the Haw; this appears as a dot near the base of the watershed in Figure 1.

Figure 1.



The land use/land cover characteristics of the watershed were determined using 1996 land cover data that were developed from 1993-94 LANDSAT satellite imagery. The North Carolina Center for Geographic Information and Analysis, in cooperation with the NC Department of Transportation and the United States Environmental Protection Agency Region IV Wetlands Division, contracted Earth Satellite Corporation of Rockville, Maryland to generate comprehensive land cover data for the entire state of North Carolina. Tabulated land cover/land use data for the Little Troublesome watershed are shown in Table 1. During the formation of this geographic dataset, developed land was identified using the proportion of synthetic cover present; low density developed was 50-80% synthetic cover, and high density developed was 80-100% synthetic cover (Earth Satellite Corporation, 1997). Assuming that synthetic cover is impervious, and that all non-developed land cover classes have 1% impervious cover, the Little Troublesome Cr. watershed is estimated to have 9-13% impervious surface.

Table 1. Land use/land cover in Little Troublesome Cr. watershed.

Land Use/Land Cover	**Little Troublesome Cr. Watershed Acres**
High Density Developed	389 (5.2%)
Low Density Developed	644 (8.6%)
Cultivated	189 (2.5%)
Managed Herbaceous	1895 (25.4%)
Forest	4329 (58.1%)
Total	7446

The USGS 14-digit hydrologic unit code (HUC) for Little Troublesome Cr. is 03030002010030.

1.2 Water Quality Monitoring Program

There are three sources of fecal coliform data for this project: 1) ambient monitoring data; 2) data from NPDES permit requirements (DMR data); and 3) special study data. More information on each of these is provided below.

Little Troublesome Cr. was listed as impaired based on data from the previously mentioned ambient monitoring station, which is located on SR 2600 (Mizpah Church Rd.) or about 1 mile upstream from the confluence with the Haw River.

Additional data exist from upstream/downstream monitoring by the Reidsville Wastewater Treatment Plant. The plant monitored fecal coliform in Little Troublesome Cr. above their discharge at SR 2670 (S. Scales St.) and below their discharge at SR 2600 (ambient site) on a weekly to thrice weekly (June-Sept.) basis until October 1998. At that time, the plant began to shunt the wastewater downstream and discharge it to the Haw River. Subsequently, monitoring of Little Troublesome Cr. by the treatment plant ceased. These data were used primarily to gage the relative impact on instream fecal coliform levels by the City of Reidsville.

The final bacteria monitoring in Little Troublesome Cr. was conducted by DWQ's Environmental Sciences Branch in the spring of 2001. In this study, 10 samples were collected from four separate sites, including SR 2670 (upstream DMR site) and SR 2600 (ambient site), over a six and one-half week period. The purposes of this study were to evaluate whether the creek was complying with the state fecal coliform standard, and to provide information on potential bacteria source areas in the watershed.

Only the ambient monitoring and special study data were used in model calibration, because DWQ chose to not mix data analyzed by separate laboratories (DMR data are analyzed separately). Also, future monitoring will be done by DWQ through the ambient monitoring program, so it seems most appropriate to base the TMDL on these data. Each of the three data sources provides information for the source assessment portion of this document. The monitoring data used for calibration may be seen in Appendix I.

1.3 Water Quality Target

The North Carolina fresh water quality standard for fecal coliform in Class C waters (T15A: 02B.0211) states:

> Organisms of the coliform group: fecal coliforms shall not exceed a geometric mean of 200/100ml (membrane filter count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100 ml in more than 20 percent of the samples examined during such period; violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution; all coliform concentrations are to be analyzed using the membrane filter technique unless high

> turbidity or other adverse conditions necessitate the tube dilution method; in case of controversy over results, the MPN 5-tube dilution technique will be used as the reference method.

The instream numeric target, or endpoint, is the restoration objective expected to be reached by implementing the specified load reductions in the TMDL. The target allows for the evaluation of progress towards the goal of reaching water quality standards for the impaired stream by comparing the instream data to the target. For this TMDL the water quality target is the geometric mean concentration of 200cfu/100ml over a 30-day period. A geometric mean is obtained by calculating the average of the log values of the individual samples; basically, the geometric mean will discount higher values so that it should be lower than the arithmetic mean (average of measurements, no log taken). Cfu stands for colony-forming units; it may also be referred to as simply 'counts' in this assessment. In this TMDL, DWQ will consider the entire model period to address the portion of the standard that limits the percentage of instantaneous excursions over 400cfu/100ml to twenty percent.

In order to evaluate the fecal coliform model, monitor water quality conditions and assess progress of the TMDL, an evaluation location was established for the Little Troublesome Cr. watershed. The evaluation location of this watershed is Little Troublesome Cr. at SR 2600, which is the location of the ambient monitoring station.

2.0 SOURCE ASSESSMENT

A source assessment is used to identify and characterize the known and suspected sources of fecal coliform bacteria in the watershed. DWQ completed a source assessment and used it to develop the water quality model for the TMDL calculation.

2.1 Point Source Assessment

General sources of fecal coliform bacteria are divided between point and nonpoint sources. Currently, there are no facilities in the watershed that discharge waste through the National Pollutant Discharge Elimination System (NPDES), which is considered to be the regulatory approach for all but the smallest of point sources. Recall that the Reidsville WWTP moved their discharge to the Haw River from Little Troublesome Cr. in October, 1998.

2.2 Nonpoint Source Assessment

Nonpoint sources of fecal coliform bacteria include those sources that can not be identified as entering the waterbody at a specific location (e.g., a pipe). Nonpoint source pollution includes urban, agricultural and background (e.g., forest, wildlife) sources. Fecal coliform bacteria may originate from human and non-human sources. Table 2 lists the potential human and animal nonpoint sources of fecal coliform bacteria (Center for Watershed Protection, 1999). The nonpoint sources of fecal coliform bacteria in Little Troublesome Cr. include wildlife, livestock (via grazing animals, there is no land application of manure), urban development (stormwater), failing septic systems, and sewer line systems (illicit connections, leaky sewer lines and sewer system overflows).

Table 2. Potential sources of fecal coliform bacteria in urban and rural watersheds (Center for Watershed Protection, 1999).

Source Type		**Source**
Human Sources	Sewered watershed	Combined sewer overflows
		Sanitary sewer overflows
		Illegal sanitary connections to storm drains
		Illegal disposal to storm drains
	Non-sewered watershed	Failing septic systems
		Poorly operated package plant
		Landfills
		Marinas
Non-human Sources	Domestic animals and urban wildlife	Dogs, cats
		Rats, raccoons
		Pigeons, gulls, ducks, geese
	Livestock and rural wildlife	Cattle, horse, poultry
		Beaver, muskrats, deer, waterfowl

2.2.1 Livestock

DWQ derived initial estimates for cattle, hogs, horses, sheep and chickens by first determining the ratio of managed herbaceous land cover (pastureland) in Little Troublesome Cr. watershed to the same land cover in Rockingham Co. Second, DWQ multiplied this ratio by the 1997 Agricultural Census of Rockingham Co. estimates for each species of livestock (Agriculture Census, 2001). Mr. Ben Chase, the Rockingham County agriculture extension agent, reviewed the initial estimates and offered his best professional judgment for the final estimates (Chase, 2001). The final estimates are 275 beef cattle, 50 horses, 12 sheep and 100 ostrich. There are two ostrich farms in the watershed below the City of Reidsville. There are no confined animal operations in the watershed, so the livestock waste will be applied to pastureland only (versus collected manure from confined operations applied to cropland).

Cattle, including both dairy and beef cows, and horses graze on pastureland and deposit feces onto the land. During a rainfall runoff event, a portion of the fecal material that contains coliform bacteria is transported to the streams. Cattle in the stream will be treated separately (in the miscellaneous sources section which follows), because it is necessary to calibrate instream fecal coliform sources as a whole.

2.2.2 Miscellaneous Sources

The combination of cattle in stream, point sources with general permits, and illicit discharges (e.g., straight pipes) are called 'miscellaneous sources' in the TMDL allocation; in the model, they are treated as a constant, instream source of bacteria. It is necessary to separate these instream sources from land based ones, because they are defined as one instream source through modeling. That is, it is difficult to determine individual estimates for the fecal coliform that originates from cattle in the stream, point sources with general permits (no monitoring requirement) and illicit discharges, but it is possible to estimate them cumulatively in the model, during periods of low streamflow. To some extent, DWQ attempted to calibrate this variable.

When cattle or horses have access to streams, feces may be deposited directly into a stream. There are reaches immediately above the ambient monitoring site at SR 2600 where fencing, designed to exclude livestock from the stream channel, is not totally effective (Yocum, 2001). Also, livestock often have access to small drainages in their pastures. Loads attributed to livestock in streams were included 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 cattle (ASAE, 1998); this amounted to 2.5×10^{11} counts/hour. Since this is a calibrated variable, illicit discharges and point sources with general permits are assumed to be included in this estimate. In other words, what is being fit to the model, through calibration, is a constant instream source of fecal coliform.

2.2.3 Failed Septic Systems

Failing septic systems have been cited as a potential source of fecal coliform bacteria to water bodies (USEPA, 2000). The Division of Environmental Health has estimated that Rockingham County has approximately 5,800 housing units on septic systems (DEH, 1999). In the Little Troublesome Creek watershed, household waste from the city of Reidsville is treated at the municipal treatment plant, while household waste south of the City of Reidsville (see Figure 1 on page 3 for city extent) is treated using septic systems. Using a ratio of the area of the watershed divided by the area of the county, DWQ estimates that there are 112 septic systems in the lower Little Troublesome Cr. watershed. Additionally, DWQ assumed that, on average, there are 4.5 people per system. Septic system failure rate data in North Carolina are very limited. A study conducted in 1981 by the North Carolina Office of State Budget and Management suggested that approximately 11% of systems that were surveyed experienced malfunctions or failures over a year (DEH, 2000). Assuming the average concentration of septic waste reaching the stream is 1.0×10^{4} counts/100 ml and that the septic overcharge flow rate is 70 gallons/day/person (Horsely & Whitten, 1996), the contribution from failing septic systems is 5.96×10^{7} counts/hour. DWQ also assumed that 60% of the septic overcharge reached the stream channel; this estimate is not scientifically based and was selected as a seemingly moderate to high number for transport from a failing septic system to the stream network. The loading rate from septic systems using these assumptions was 2.57×10^{10} counts/30 days.

2.2.4 Urban Development/Sanitary Sewer Overflows

Fecal coliform bacteria can originate from various urban sources. These sources include pet waste, runoff through stormwater sewers, illicit discharges/connections of sanitary waste, leaky sewer systems and sanitary sewer overflows.

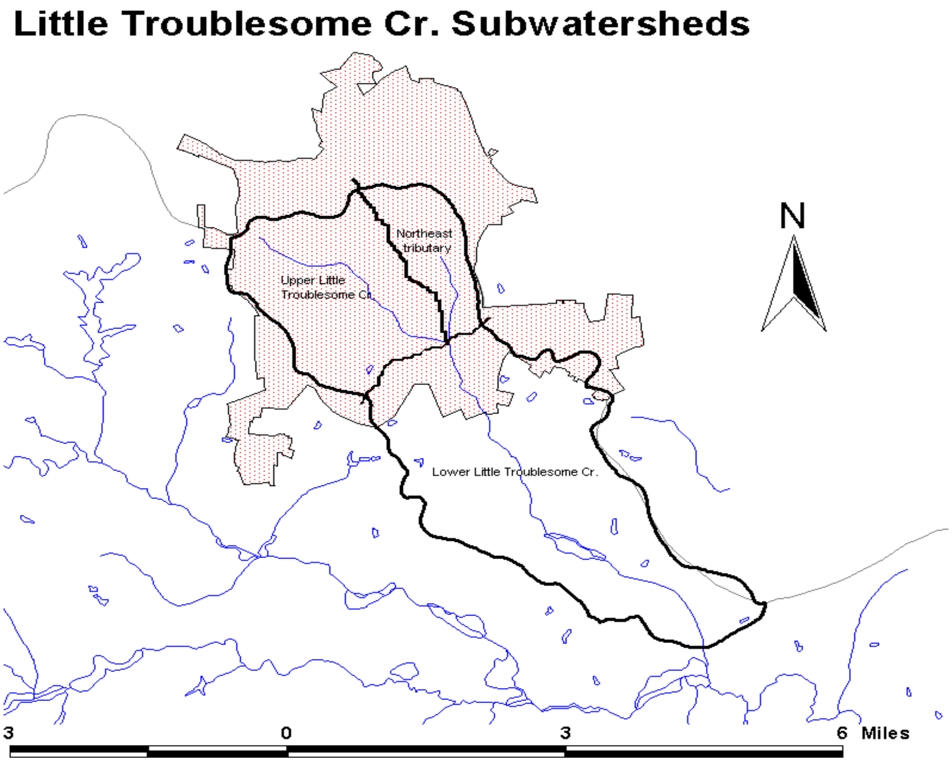
Fecal coliform accumulation rates on urban land cover were derived using the following:

1) the proportions of each subwatershed that are covered by high and low density developed land cover (see Figure 2 on the following page for subwatershed delineation);
2) the types of urban land use that occur in each subwatershed (e.g., residential, and heavy and light commercial);
3) the fecal coliform build-up (accumulation) rates for each land-use in 2), as calculated from instream stormwater samples collected by the United States Geological Survey (USGS) from December 1993 to September 1997 in Mecklenburg County (Bales et al., 1999). In the USGS study, each of the urban land uses was paired with a sample site. The land use descriptions and calculated accumulation rates for fecal coliform may be seen in Table 3.

Table 3. Rate of accumulation and maximum storage of fecal coliform by land use (from Bales et al., 1999).

Land Use	**Rate of Accumulation** (count per acre per day)	**Maximum Storage** (count per acre)
Residential	6.86×10^{9}	1.44×10^{10}
Heavy Commercial	2.68×10^{9}	5.63×10^{9}
Light Commercial/Light Industrial	3.20×10^{10}	6.72×10^{10}
Woods/Brush	5.48×10^{9}	1.15×10^{10}

Figure 2.



To derive accumulation rates for each of the three Little Troublesome Cr. subwatersheds, DWQ calculated the proportion of low and high-density land cover in each subwatershed. Using local knowledge of the watershed, the land cover data was converted into the four of land use classes referenced by the USGS study (see Table 4). By combining the proportions of the four land classes with the accumulation rates, DWQ assigned a comprehensive urban accumulation rate of fecal coliform for each subwatershed. These accumulation rates are important model parameters that describe how much fecal coliform is generated on each land use; actual fecal coliform loading to the stream network is determined through subsequent modeling. Essentially, the model tracks fecal coliform build-up through the accumulation rate and simulates fecal coliform wash-off as precipitation falls. More description of the model appears later in this document.

Table 4. Estimated conversion from NC GIS land use/land cover to land use in USGS study. Note that this is for urban (developed) land cover only*

Subwatershed	**Land cover** classification (from GIS database)	**Land use** classification (estimated)
Northeast tributary	47.3% high density developed, 52.7% low density developed	27% light commercial/industrial 20% heavy commercial 40% light residential 13% woods/brush
Upper L. Troublesome Cr.	12.8% high density developed, 87.2% low density developed	8% light commercial/industrial 5% heavy commercial 72% light residential 15% woods/brush
Lower L. Troublesome Cr.	67.5% high density developed, 32.5% low density developed	30% light commercial/industrial 35% heavy commercial 25% light residential 10% woods/brush

This information yielded initial estimates of accumulation and maximum storage by subwatershed shown in Table 5.

Table 5. Initial (pre-calibration) estimates of accumulation and storage.

Subwatershed	**Rate of Accumulation** (count per acre per day)	**Maximum Storage** (count per acre)
Northeast tributary	1.26×10^{10}	2.28×10^{10}
Upper L. T. Cr.	8.46×10^{9}	1.52×10^{10}
Lower L. T. Cr.	1.28×10^{10}	2.31×10^{10}

Since these numbers are based on studies in somewhat distant watersheds (Mecklenburg Co.), they were subject to calibration in the model.

The city of Reidsville owns and operates a wastewater treatment plant and sewage collection system. From 1997-2001, Reidsville reported eleven sanitary sewer overflows (SSOs) of greater than 1000 gallons, including five SSOs of greater than 50,000 gallons. DWQ did not explicitly account for SSOs in the modeling; rather, DWQ used a relatively high (compared to other land uses), constant value for urban interflow fecal coliform concentration in the calibration model, which, along with the constant miscellaneous instream source input (cattle in stream, illicit discharges, point sources with general permit), may account for leaky sewers and infrequent SSOs.

2.2.5 Wildlife

Wildlife can be a source of fecal coliform bacteria in forested, wetland, pasture and cropland areas. Wildlife deposit fecal material in these areas, which can be transported to a stream in a rain event. Wildlife in Rockingham County area includes deer, turkey, beaver, raccoons, squirrels, and birds (including waterfowl). DWQ derived population density estimates for all but squirrels and non-waterfowl; consequently, these animals were not included in the model.

DWQ obtained estimates for deer and turkey population densities from the North Carolina Wildlife Resources Commission (WRC, 2001). These estimates are 30-45 deer per square mile and 16-25 turkey per square mile. The lower ends of the ranges (30 and 16) were applied to cropland and pastureland, and the higher ends of the ranges (45 and 25) were applied to forestland.

Beaver estimates were developed by applying the best professional judgment of a NC Wildlife Resources Commission furbearer biologist, George Straighter, who is familiar with Rockingham Co. and the Little Troublesome Cr. watershed. Mr. Straighter offered that there is: 1) about one beaver dam every ¼ mile of linear stream in the lower reaches of Little Troublesome Cr.; 2) one beaver den per dam; and 3) that there are 6-8 beaver per den (Straighter, 2001). From this, DWQ estimated that there are 12 beaver per square mile of one specific forestland type, bottomland forest / hardwood swamp, which is identified in the NC GIS land use / land coverage.

There was very little basis for estimating populations of raccoon, duck and geese density – this is one of many areas of uncertainty in the model. DWQ considered that there are 5 geese and 10 ducks per square mile of cropland and forestland (none on pastureland), and that there are 10 raccoons per square mile of cropland, forestland and pastureland. The numbers for geese, duck and raccoon are not scientifically based and are intended as a rough, moderate estimate.

2.3 Source Assessment Conclusion

All of the aforementioned source assessment data were entered into a spreadsheet called Fecal Tool, which calculates accumulation rates on the different land covers, and loading from direct sources such as leaking septic systems and cattle in the stream. TetraTech, Inc. developed Fecal Tool. Output from this spreadsheet was used as the initial estimates for the corresponding parameters in the water quality model. Some of the input values calculated in spreadsheet were later altered through calibration (e.g., urban coliform accumulation values).

3.0 MODELING APPROACH

An important component of the TMDL is to establish the relationship between instream water quality and sources of fecal coliform. A model that simulates or statistically characterizes hydrology and water quality is a helpful tool for this purpose. Models provide the relative contribution of the sources, as well as the predictions of water quality resulting from changes in these source contributions; these are the basic elements of Total Maximum Daily Load determination.

3.1 Model Framework

The model selected for this TMDL needed to meet several objectives:

1) To simulate watershed loading and instream transport of fecal coliform bacteria, and to capture some of the temporal and spatial variation that those processes demonstrate.
2) To simulate instream fecal coliform concentrations over several years, so that critical conditions (definition on page 2) may be identified. Critical conditions will be the basis for this TMDL.
3) To evaluate seasonal effects on the production and fate of fecal coliform bacteria.

EPA's BASINS software includes a model, Nonpoint Source Model (NPSM), that is suited for TMDL development. NPSM is based on another model, the Hydrologic Simulation Program – FORTRAN (HSPF).

NPSM (HSPF) is a dynamic watershed model capable of simulating nonpoint source runoff and associated pollutant loads. It does this by tracking water and fecal coliform in the watershed. Specifically, modules named PWATER and IWATER are used to calculate the components of the water budget, and to predict the runoff from pervious and impervious areas, respectively (EPA, 1993). The model considers the following hydrologic processes: precipitation, interception, surface runoff, interflow, groundwater, evaporation and evapotranspiration; these processes are simulated by fluxes or storages within subroutines of model. Fecal coliform is simulated in the PQUAL and IQUAL modules (from pervious and impervious land segment) using simple relationships with water. Fecal coliform occurs in both the surface and subsurface outflow, though the former is considered to be more complex in the model. On the surface, fecal coliform can be affected by adhesion to the soil, and by light, wind, temperature and direct human influence. The approach is to simulate fecal coliform using basic accumulation (build-up) and depletion rates, in concert with depletion by wash-off; in other words, fecal coliform outflow from the surface is a function of the water flow and the amount of fecal coliform in storage (EPA, 1993). Constant rates are assumed for subsurface loading from the different land use categories.

Also, NPSM (HSPF) performs flow routing and pollutant decay in stream reaches. It does this through the RCHRES module. Here, flow is assumed to be unidirectional and decay is assumed to be first-order in nature (see section 3.2.1 below). Finally, NPSM allows discrete simulation of the required components of the TMDL (e.g., WLA and LA components). Because it meets the objectives stated above, DWQ chose NPSM as the model for this TMDL.

3.2 Model Setup

Little Troublesome Creek was delineated into three subwatersheds (see Figure 2) based on Reach File 3 (RF3) stream coverage and a digital elevation model of the area. The farthest downstream point of the delineation was the DWQ ambient water quality sampling station, B0160000, or Little Troublesome Cr. at SR 2600 near Reidsville. Dewberry and Davis Consultants compiled hourly meteorological data from a weather station near Greensboro (See Figure 3 for specific location and its proximity to Little Troublesome Cr. watershed). The meteorological data begin on 7/1/1996 and end on 8/11/2001. DWQ measured stream channel cross sections at each of the three subwatershed locations (Appendix 3).

3.2.1 Instream Decay Rate

Once fecal coliform bacteria reach a waterbody, environmental factors influence the extent of their growth and decay. Physical factors that influence the bacteria populations include photo-oxidation, adsorption, flocculation, coagulation, sedimentation and temperature (USEPA, 1985). Chemical toxicity, pH, nutrient levels, algae and the presence of fecal matter may also influence the fecal coliform population. The water quality model utilizes a first order decay rate to calculate instream decay of fecal coliform bacteria.

$$C_t = C_o e^{-kt}$$

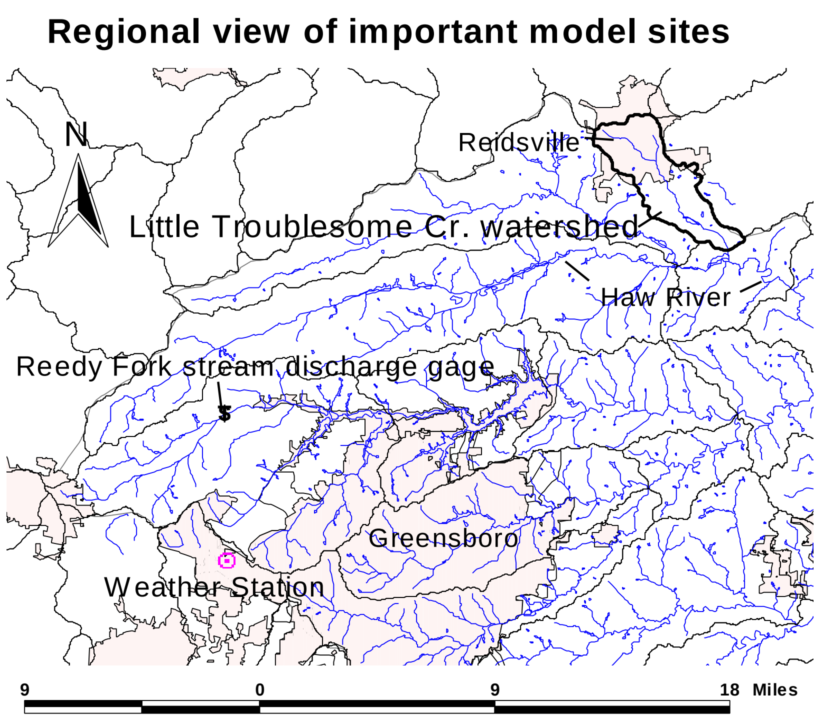
C_t= coliform concentration at time t (cfu/100ml)
C_o= initial coliform concentration (cfu/100ml)
k= decay rate constant (day^{-1})
t = exposure time (days)

Bacterial die-off has been modeled as a first-order decay equation, using a decay rate between 0.7/day and 1.5/day (Center for Watershed Protection, 1999). Another study found that the median decay rate for fecal coliform was 1.15/day (Lombardo, 1972); that value was used in the Little Troublesome Cr. model for the existing condition and allocation runs.

3.3 Hydraulic Calibration

Because NPSM is driven by precipitation and by the subsequent treatment of the water budget, it is important to calibrate the hydraulic parameters prior to calibrating the water quality parameters. In the hydraulic calibration, simulated streamflows were compared to the historic streamflow data recorded at a continuous stream gage. There is not a continuous gage in Little Troublesome Cr., so instead DWQ used one at Reedy Fork near Oak Ridge (USGS 02093800), which is nearby (see Figure 3 below). To calibrate the model, hydraulic parameters, including infiltration, upper and lower zone storage, groundwater storage and recession, interflow, and evapotranspiration, were adjusted within a recommended range until the simulated and observed hydrographs were as close as possible. DWQ determined the best match by assessing statistical fit (R^2 and root mean squared error, descriptions below).

Figure 3.

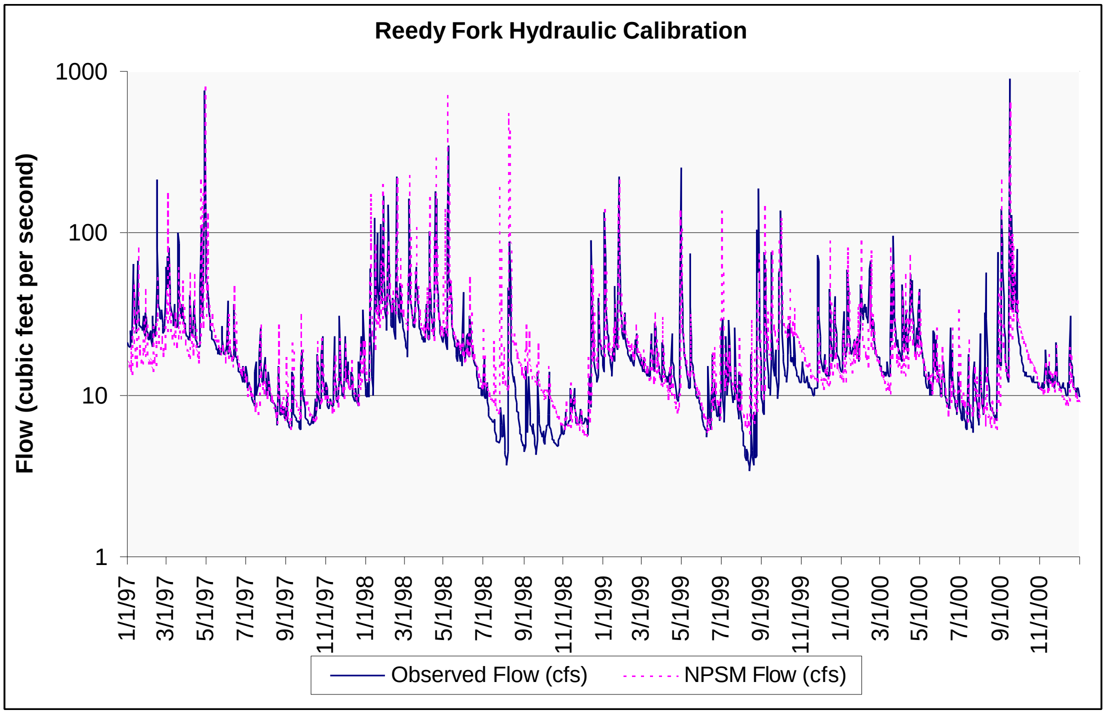


A four-year period from 1/1/97 to 12/31/00 was used as the calibration period for the hydraulic parameters. Relative fit of the modeled flow compared to the recorded flow is shown in Figure 4 below. The hydraulic parameters used to calibrate the model developed at the Reedy Fork gage were assumed to apply to the Little Troublesome Creek watershed, and were used to develop the water quality model for Little Troublesome Creek watershed.

Two conventional statistics for assessing model fit are R^2 and the root mean squared error. R^2 is a measure of the variability in the observed data that is explained by the model. The closer it is to one, the better. For the Reedy Fork hydraulic calibration, using log base 10 values, the four-year R^2 is 0.628; this is a typical level of prediction for hydrologic models.

The root mean squared error (RMSE) is the standard deviation of the model residuals, which are the difference between the model predictions and observed data. A lower RMSE is better, though its value is relative to what the model attempts to predict; the mean of the observed data is a good measure to compare. In this application, the RMSE is 0.187 and the observed mean is 1.20 (log base 10 values), which indicates moderate precision.

Figure 4. Simulated and observed flows recorded at USGS 02093800 Reedy Fork, 1997-2001.



Upon applying the Reedy Fork calibration parameters to the Little Troublesome Cr. model, predicted runoff yielded a median flow of 10 cubic feet per second (cfs) and mean flow of 15.7 cfs. This compares favorably with a USGS estimate of mean streamflow of 12 cfs for Little Troublesome Cr., which comes from a low flow study conducted for DWQ in 1987.

3.4 Water Quality Calibration

Once the hydraulic calibration is complete, water quality is calibrated by adjusting parameters until simulated and observed fecal coliform concentrations achieve acceptable agreement. To calibrate the model, several parameters were adjusted including the accumulation rates of fecal coliform bacteria, wash-off rates, maximum storage of fecal coliform bacteria and contributions from direct sources. By matching the trends in simulated and observed concentrations resulting from peak and base flows, the model may be a reasonable predictor of instream water quality.

Through model calibration, DWQ estimates that the constant instream source (see miscellaneous sources, Section 2.2.2) is 2.7 x 10^{11} counts/30 days. Cattle in the stream, illicit discharges and point sources with general permits are assumed to be included in this estimate.

DWQ focused calibration of urban coliform accumulation rates on the upper two watersheds (Upper Little Troublesome Cr. and Northeast tributary), where a higher percentage of urban land cover and where some subwatershed-specific data from a special study exist. Also, the general calibration (using evaluation location) was helpful in adjusting accumulation and maximum storage rates. Consequently, these values decreased by approximately 81% from the values shown in Table 5. It seems rather evident that the Charlotte values are much too high for the Little Troublesome Cr. watershed. DWQ also calibrated urban interflow concentration, which was considered as a constant value in the model.

The calibration period for the water quality model spanned October, 1996 into August, 2001. The beginning time was limited by the meteorological file, which began in July, 1996. DWQ allowed three months for the model to stabilize before comparing predicted and observed data.

3.4.1 Prediction Uncertainty

The inability to accurately simulate specific observed data points can sometimes be attributed to more specific aspects of a model, such as differences in rainfall at the meteorological gage and in the watershed, or illicit point discharges. More often though, the lack of agreement between modeled and observed fecal coliform is due to the general high degree of uncertainty associated with predicting any water quality variable, especially fecal coliform. Prediction uncertainty comes from a number of sources, including (from Reckhow and Chapra, 1983 and Reckhow, 1995):

- Gaps in our scientific knowledge.

- Natural variability – spatial and temporal variability in chemistry, hydrology and ecology is great. Model predictions are on a much coarser scale than what occurs in nature.
- Measurement error – measurement of fecal coliform in the field and laboratory has error.
- Aggregation error – with increased endpoint specificity (space and time), the uncertainty associated with the prediction increases.
- Model error:
    - Mis-specification – model expressions that characterize processes may be wrong.
    - Error in parameters – reaction rates may be inappropriate.
    - Error in model inputs – e.g., loading terms such as accumulation rate of bacteria have error.

Unfortunately, many water quality models employed for TMDL analysis, including NPSM, are not adept at characterizing prediction uncertainty. With these models, all we know is that the uncertainty is certain to be large. Emphasizing an adaptive management approach is one way to address this. Specifically, the model may guide initial decision making, but continued observation of the watershed and creek, as fecal coliform controls are implemented (e.g., exclusion fencing, leaky sanitary sewer repair), is expected to be our best approach for determining the appropriate level of management.

3.4.2 Calibration Results

Fecal coliform samples collected at B0160000 (the ambient monitoring station) between October, 1996 and August, 2001 were compared to simulated concentrations and rainfall collected at the meteorological stations. The results are shown in Figures 5 and 6. Graphical results indicate that the model does a fair job at simulating the response of fecal coliform bacteria over time with variations in flow.

Figure 5. Simulated versus observed fecal coliform concentrations from 10/1997–3/1999.

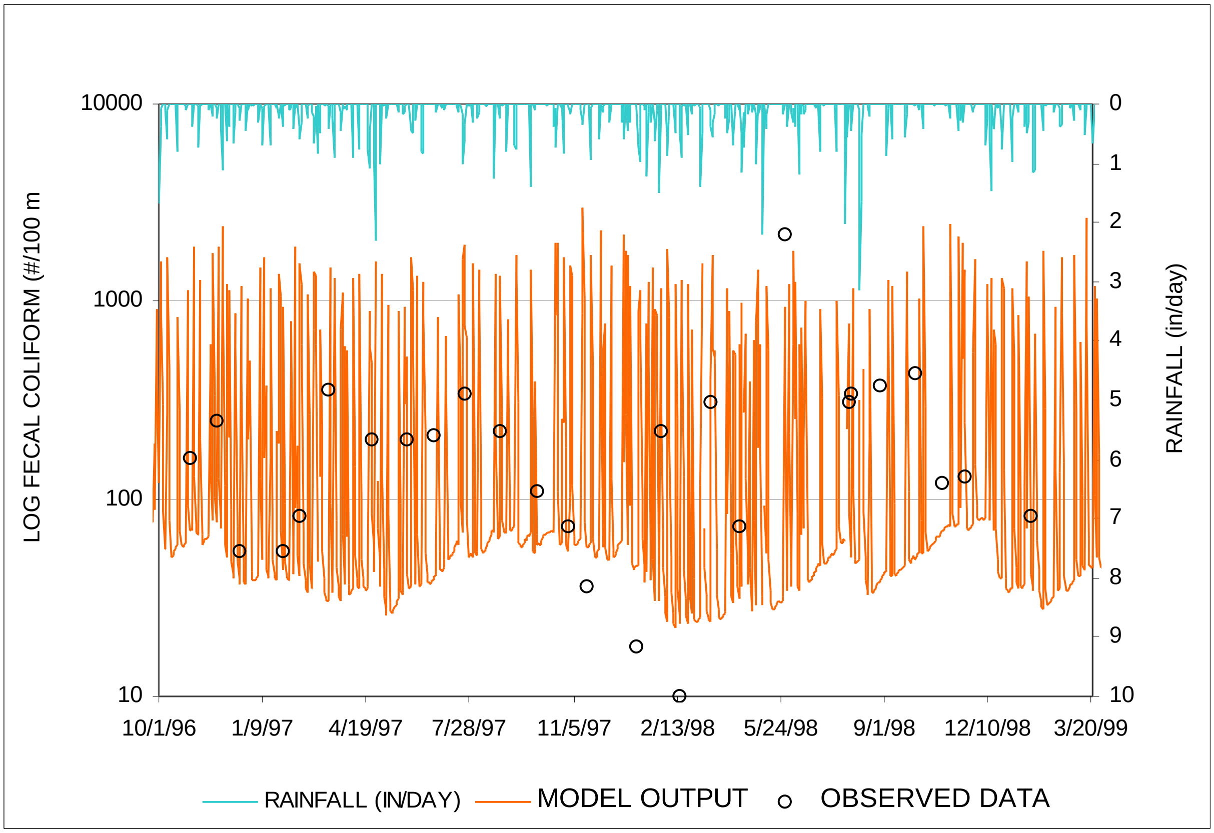
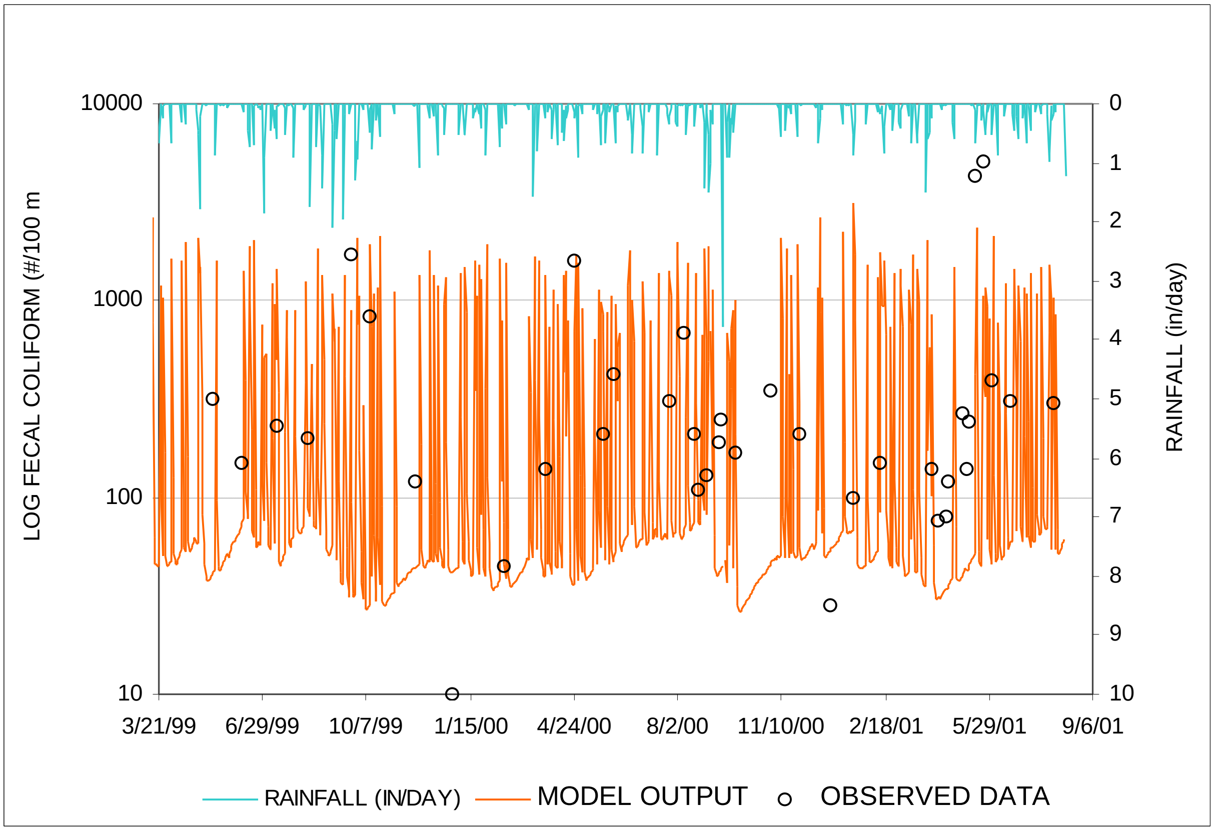


Figure 6. Simulated versus observed fecal coliform concentrations from 3/1999-8/2001.



The model calibration statistics for fecal coliform are not nearly as good as those for the hydraulic calibration. The R^2 in this case is 0.164 and the RMSE is 0.464, with an observed mean of 2.27 (again, these are based on log base 10 values). The low R^2 indicates a lack of predictive power. On the other hand, the relatively small RMSE suggests that the model may predict the mean fairly well, but there may be a lot of individual scatter about the mean. To resolve this discrepancy, DWQ examined modeling efficiency, which is calculated using the following formula:

$$\frac{\left(\sum_{i=1}^{n}(Oi-\bar{O})^2-\sum_{i=1}^{n}(Pi-Oi)^{2}\right)}{\sum_{i=1}^{n}(Oi-\bar{O})^2}$$

where:
O_i = ith observation
P_i = ith prediction

$\bar{O}$ = mean of the observations

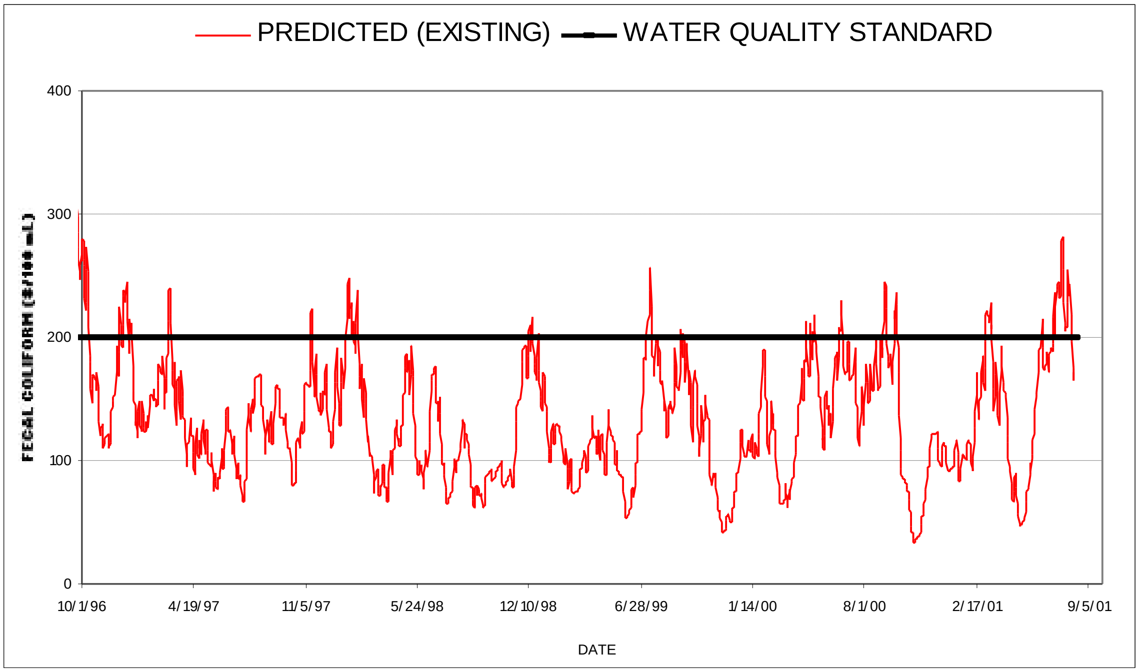
The closer to 1 the better.
if > 0, then the model predicts better than the mean of the observations
if < 0, then the mean of the observations does better than the model

The modeling efficiency for the Little Troublesome Cr. coliform model is –0.577. This means that the model predictive precision is low. The recommendation for adaptive management is the best approach for overcoming this problem.

3.5 Critical Conditions

In terms of the TMDL, critical conditions occur within the calibrated model when fecal coliform levels exceed the standard by the largest amount. The Little Troublesome Cr. fecal coliform monitoring data indicate that elevated fecal coliform levels occur throughout the year, during both dry and wet weather conditions. The model was run for a nearly five year simulation period (October, 1996 into August, 2001). The highest 30-day geometric mean of the predicted daily fecal coliform concentration, 280 colonies per 100 ml, occurred between June 22 and July 21, 2001. Rain was recorded in Greensboro on 11 days during that 30-day period. Additionally, the critical period was preceded by a somewhat dry spell (1.81 and 2.52 inches of precipitation in April and May, respectively) and the largest amount of rain that fell during a single day of the critical period was 0.67 inches. In other words, a relative abundance of fecal coliform was probably available for wash-off during the critical period. Also, wash-off during the critical period appears to have occurred in a piecemeal fashion, which maintained high concentrations through the 30 days by limiting dilution, as well as mass wash-off.

Figure 7. Rolling 30-Day Geometric Mean of Predicted Daily Fecal Coliform Concentrations (cfu/100 ml)



3.6 Water Quality Model Results

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

1) The calibrated model was rerun for the entire, nearly 5-year period.
2) Simulated fecal coliform concentrations for the nearly 5-year period were plotted as rolling 30-day geometric mean concentrations and compared to the standard criteria of 200 counts/100mL (see Figure 7 above).
3) From Figure 7, DWQ determined critical conditions, which is the highest 30-day geometric mean during the model run. June 21-July 22, 2001 as described above.
4) The simulated daily fecal coliform loads from sources such as runoff from all lands, leaking septic systems and miscellaneous sources were summed for the 30-day critical period. These values represent existing loads and are shown in Table 6. Please see source assessment section on page 8 for more information on how these loads were calculated.

DWQ separated the principal coliform source categories, as used in NPSM, in Table 6; these include runoff from all lands, leaking septic systems and miscellaneous sources. **Runoff**

from all lands includes estimated fecal coliform load from deposits by livestock and wildlife, as well as an estimate of loading from urban areas. **Leaking septic systems** only estimates loading related to septic systems. **Miscellaneous sources** is an estimate of loading from livestock in the stream, from point sources with general permits, as well as from unknown, or illicit, instream sources. According to the model, storm-driven runoff from all land provides the largest load of fecal coliform bacteria to the stream. Loads from miscellaneous sources are constant loads that are applied directly to the stream; these sources will have the greatest impact on instream water quality during periods of low flow.

Table 6. Summary of predicted existing coliform loads in the Little Troublesome Cr. watershed.

Runoff from all lands[1] (counts/30 days)	Leaking septic systems (counts/30 days)	Miscellaneous sources[2] (counts/30 days)	Instream conc.[3] (counts/100 ml)
1.20×10^{13}	2.57×10^{10}	2.70×10^{11}	280

[1] Includes livestock in pasture, wildlife, and urban runoff.
[2] Includes livestock with stream access and illicit discharges.
[3] Maximum simulated concentration during the critical period (geometric mean).

4.0 Total Maximum Daily Load

A Total Maximum Daily Load is the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount among point and nonpoint sources. A TMDL comprises the sum of wasteload allocations (WLA) for point sources, load allocations (LA) for nonpoint sources, and a margin of safety. This definition is expressed by the equation:

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

The objectives of the TMDL are to estimate allowable pollutant loads, and to allocate to the known pollutant sources in the watershed, so the appropriate control measures can be implemented and the water quality standard can be achieved.

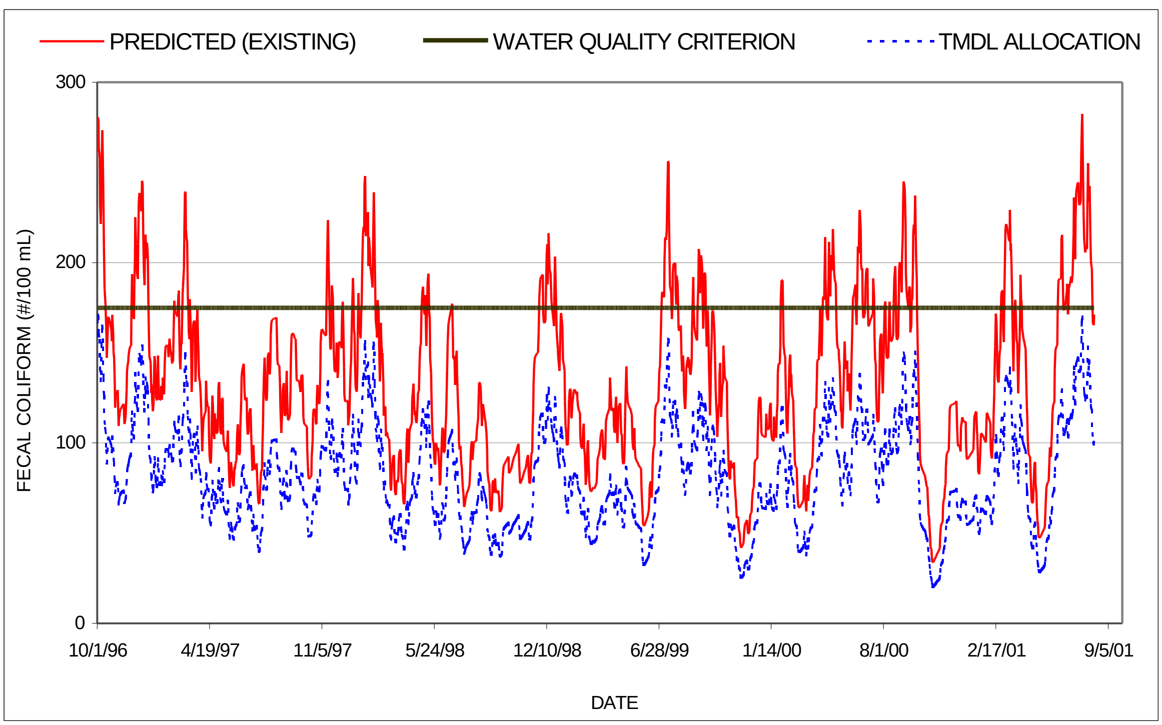
The TMDL will be expressed in units of counts/30 days, as this is the period over which the water quality target/standard is evaluated.

The two main components of a TMDL, the reduction target, including a margin of safety, and the allocation strategy will be presented in the following sections.

4.1 Reduction Target

Using the calibrated water quality model, DWQ applied load reductions to the bacteria sources until the simulated 30-day geometric mean for fecal coliform bacteria concentrations did not exceed the 170 counts/100 ml (standard is 200 counts/100 ml, however, see margin of safety section below) at any time. Thus, with no predicted exceedances of the standard, the model fulfills the TMDL criterion of allowing the maximum load while still achieving water quality standards. The predicted 30-day geometric means, after DWQ applied the load reductions in the model, can be seen as the allocation line in Figure 8. The model predicts that a 40 percent reduction from existing loads must be taken to achieve the instream water quality (TMDL) criterion.

Figure 8. Reduction of fecal coliform from existing loading to TMDL allocation (both as rolling 30-day geometric mean).



To assess the instantaneous portion of the fecal coliform standard, DWQ considered observed data and predictions from the full modeling period. The observed data from 1995 to 2001 show that 21% of the samples were over 400 counts/100 ml. The calibrated model has 24% of the daily predictions over 400 counts/100 ml. The TMDL model that meets the geometric mean part of the fecal coliform standard (overall about a 40% reduction) drops the percent of daily predictions above 400 counts/100 ml to 20% over the nearly 5 year model period.

4.1.1 Margin of Safety

A TMDL requirement is that a margin of safety must be included to provide further insurance that the impaired waterbody will meet its designated uses once load reductions are realized. The margin of safety may be accounted for implicitly, through conservative (more protective of water quality) model assumptions, or explicitly, by reserving a portion of the allocated load. The Little Troublesome Cr. TMDL includes explicit and implicit margins of safety; more explanation on the margin of safety follows below.

In Figure 8, observe that the target for the rolling 30-day geometric mean of fecal coliform is 170 counts/100 ml, instead of the standard of 200 counts/100 ml. By using this lower target, DWQ provides an explicit margin of safety for the Little Troublesome Cr. TMDL. This explicit margin of safety may be interpreted to account for 15% greater assurance of achieving the instream water quality target.

$$[(200-170)/200]*100 = 15\%$$

Also, an implicit margin of safety is included because the model assumes that bacteria delivered from the land surface do not decay as it travels from its source to the stream network.

4.2 Allocation

The allocation strategy for the Little Troublesome Cr. fecal coliform TMDL is limited to nonpoint sources, as there are no permitted point sources in the watershed. An allocation scenario that predicts compliance with the instream water quality criterion and the required reductions from the individual categories may be seen in Table 7.

Table 7. Allocation strategy by major nonpoint sources for TMDL conditions

Runoff from all lands (counts/30 days)	Leaking septic systems (counts/30 days)	Miscellaneous Sources (counts/30 days)	Instream f.c. concentration[1] (counts/100 ml)
7.42×10^{12}	1.54×10^{10}	1.62×10^{11}	170
40% reduction	40% reduction	40% reduction	39% reduction

[1] Maximum simulated instream concentration during critical period. Percent reduction represents the difference in simulated instream concentration between the existing loads (Table 6., 280 counts/100 ml) and TMDL allocation scenario (Table 7., 170 counts/100 ml).

The nonpoint sources are summed to produce a wasteload allocation (WLA), which is displayed in Table 8 below.

Tables 8 and 9. Allocation strategy by TMDL components for Little Troublesome Cr.

In terms of load:

Wasteload allocation (WLA) (counts/30 days)	Load allocation (LA) (counts/30 days)	Explicit Margin of safety (MOS) (counts/30 days)	TMDL (counts/30 days)
0	7.60×10^{12}	1.34×10^{12}	8.94×10^{12}

In terms of concentration:

Wasteload allocation (WLA) (counts/100 ml)	Load allocation (LA) (counts/100 ml)	Explicit Margin of safety (MOS)[1] (counts/100 ml)	TMDL (counts/100 ml)
0	170	30	200

[1] Explicit margin of safety is equal to 15.0% since the instream water quality target is reduced to 170 counts/100 ml from 200 counts/100 ml (e.g., [(200-170)/200] = 15%).

The implicit margin of safety, from the assumption that fecal coliform bacteria do not decay as they are transported from the land surface to the stream network, is not quantified nor included in the tables above. Basically though, by not including this decay, the listed load allocation is higher than if the decay were included. Consequently, the actual (expected) load allocation will be lower than what is shown in Tables 8 and 9; therein lies the implicit margin of safety.

4.3 Seasonal variation

DWQ used a nearly 5-year simulation period to assess the TMDL. This longer period allows for consideration of seasonal variation. Additionally, some of the loading rates varied monthly within the model.

5.0 SUMMARY AND FUTURE CONSIDERATIONS

The sources of fecal coliform in the Little Troublesome Cr. watershed include urban sources in the Reidsville area, livestock grazing on agricultural lands, and wildlife in the forested areas of the watershed. The Nonpoint Source Model in EPA's Basins software was used to simulate instream fecal concentrations and to allocate the fecal coliform loads to the various sources. In order for the water quality target to be met, the final allocation of the fecal coliform requires the major sources (not wildlife as that is considered part of background) to reduce loading by approximately 40%. DWQ considers the major sources to be runoff from urban area, possibly including leaking sewer lines, miscellaneous instream sources (particularly illicit discharges and cattle in the stream) and septic systems. Based on the special study monitoring which is shown in Appendix I, and the model results, it appears to be most important to reduce fecal coliform loading from the urban areas in and around the City of Reidsville. More minor sources include pastureland, where a 10% reduction in loading is expected.

5.1 Monitoring

Fecal coliform monitoring will continue on a monthly interval at the ambient monitoring site (SR2600). The continued monitoring of fecal coliform concentrations will allow for the evaluation of progress towards the goal of reaching water quality standards. In addition to this data collection, further fecal coliform monitoring may be considered. Additional monitoring could focus on fecal coliform source assessment in the watershed; this would further aid in the evaluation of the progress towards meeting the water quality standard. Also, a synoptic survey or two of instream fecal coliform during storm events may improve model calibration during those important loading events.

To comply with EPA guidance, North Carolina may adopt new bacteria standards utilizing Escherichia coli (E. coli) and enterococci in the near future. Thus, future monitoring efforts to measure compliance with this TMDL should include E. coli and enterococci. Per EPA recommendations (EPA, 2000b), if future monitoring for E. coli/enterococci indicates the standard has not been exceeded, these monitoring data may be used to support delisting the water body from the 303(d) list. If a continuing problem is identified using E. coli/enterococci, the TMDL may be revised.

5.2 Implementation

An implementation plan is not included in this TMDL. The involvement of local governments and agencies will be needed in order to develop the implementation plan. If local cooperation is secured, and indications are that local interest is positive, then DWQ will assist in developing the implementation plan. Thus far, DWQ contributed to a local planning agency's proposal for Section 319 funds to implement the Little Troublesome fecal coliform TMDL.

6.0 PUBLIC PARTICIPATION

The City of Reidsville was notified of DWQ's intention to develop the Little Troublesome Cr. fecal coliform TMDL. The county extension service supplied agricultural information to aid in the source assessment portion of the TMDL.

To publicly notice the Little Troublesome fecal coliform TMDL, DWQ submitted a legal advertisement to the newspapers for Greensboro and Reidsville. The advertisement appeared in each of these newspapers on March 14, 2002. Additionally, DWQ electronically distributed a draft of the TMDL and public comment information to the known interested parties on March 12, 2002. Finally, DWQ held a public meeting in Reidsville on March 21, 2002 to present the TMDL and offer opportunity for questions and comments by the public. The advertised comment period was 30 days, and DWQ did not receive any comments by April 22, 2002.

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APPENDIX I. OBSERVED DATA

Table A. Data from DWQ Ambient Station – Little Troublesome Cr. at SR 2600

DATE	Fecal Coliform (#/100 ml)	DATE	Fecal Coliform (#/100 ml)
1/9/95	230	9/30/98	430
2/8/95	60	10/27/98	120
3/14/95	20	11/17/98	130
4/10/95	70	1/20/99	82
5/25/95	410	5/11/99	320
6/26/95	240	6/8/99	150
7/25/95	1600	7/12/99	230
9/25/95	3400	8/11/99	200
10/31/95	850	9/22/99	1700
12/4/95	45	10/11/99	840
12/7/95	18	11/22/99	120
1/17/96	200	12/29/99	10
2/26/96	140	2/16/00	45
3/28/96	3500	3/28/00	140
4/16/96	3000	4/25/00	1600
5/22/96	2000	5/23/00	210
6/11/96	3300	6/1/00	420
7/22/96	820	7/24/00	310
8/22/96	100	8/8/00	680
9/26/96	91	8/17/00	210
10/30/96	160	8/22/00	110
11/25/96	250	8/30/00	130
12/18/96	54	9/11/00	190
1/29/97	54	9/12/00	250
2/13/97	82	9/27/00	170
3/13/97	360	10/31/00	350
4/24/97	200	11/28/00	210
5/29/97	200	12/28/00	28
6/23/97	210	1/18/01	100
7/23/97	340	2/12/01	150
8/25/97	220	4/4/01	140
9/30/97	110	4/10/01	76
10/30/97	73	4/17/01	79
11/17/97	36	4/19/01	120
1/5/98	18	5/3/01	270
1/29/98	220	5/8/01	140
2/16/98	10	5/9/01	240
3/18/98	310	5/16/01	4260
4/14/98	72	5/23/01	5120
5/27/98	2200	5/31/01	390
7/29/98	310	6/18/01	310
7/30/98	340	7/31/01	300
8/27/98	370	8/21/01	130

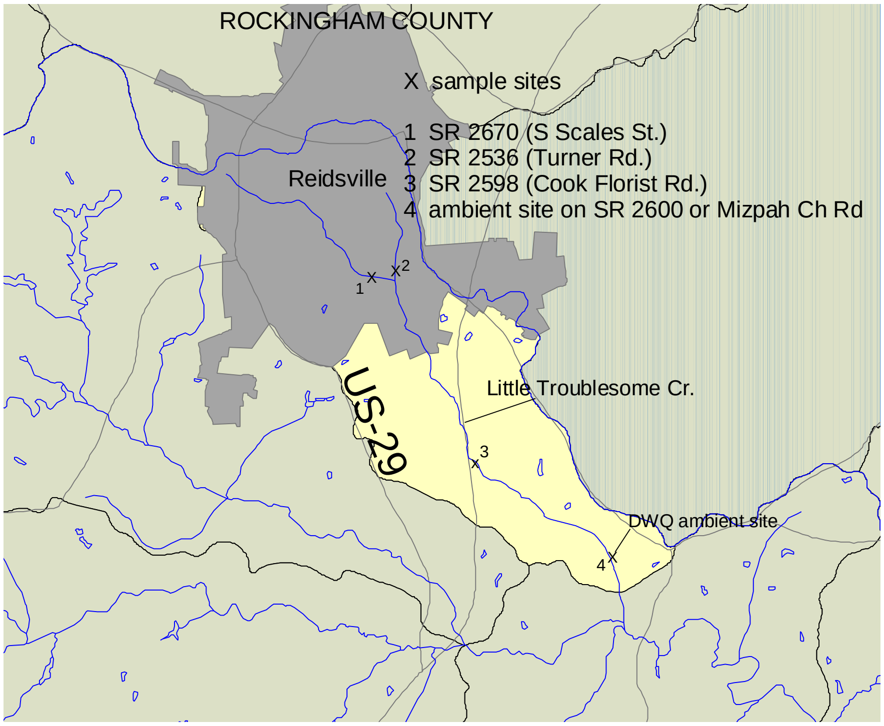
Shaded values are from DWQ special study in April and May, 2001

Summary of Little Troublesome Creek Fecal Coliform Data from DWQ Special Study
(for station locations see map on next page)

Station Description	Dates	Number of Days	Observations	Geometric Mean
L.T. Cr. at SR 2670	4/10/2001 to 5/9/2001	30	15	258
L.T. Cr. at SR 2670	4/17/2001 to 5/16/2001	30	15	748
L.T. Cr. at SR 2670	4/19/2001 to 5/23/2001	35	15	1733
L.T. Cr. at SR 2670	5/3/2001 to 5/31/2001	29	15	1146
L.T. Cr. at SR 2536	4/10/2001 to 5/9/2001	30	15	396
L.T. Cr. at SR 2536	4/17/2001 to 5/16/2001	30	15	644
L.T. Cr. at SR 2536	4/19/2001 to 5/23/2001	35	15	1049
L.T. Cr. at SR 2536	5/3/2001 to 5/31/2001	29	15	1358
L.T. Cr. at SR 2598	4/10/2001 to 5/9/2001	30	15	141
L.T. Cr. at SR 2598	4/17/2001 to 5/16/2001	30	15	342
L.T. Cr. at SR 2598	4/19/2001 to 5/23/2001	35	15	607
L.T. Cr. at SR 2598	5/3/2001 to 5/31/2001	29	15	739
L.T. Cr. at SR 2600	4/10/2001 to 5/9/2001	30	15	135
L.T. Cr. at SR 2600	4/17/2001 to 5/16/2001	30	15	301
L.T. Cr. at SR 2600	4/19/2001 to 5/23/2001	35	15	694
L.T. Cr. at SR 2600	5/3/2001 to 5/31/2001	29	15	883
All Stations	4/10/2001 to 5/9/2001	30		210
All Stations	4/17/2001 to 5/16/2001	30		481
All Stations	4/19/2001 to 5/23/2001	35		936
All Stations	5/3/2001 to 5/31/2001	29		1114

Note that the SR 2670 and SR 2536 sites drain the primarily urban (especially northeast tributary subwatershed, or SR 2536) headwaters of the Little Troublesome Cr. watershed. Those samples tend to be higher than the samples from lower in the watershed. This provides evidence that the City of Reidsville (e.g., stormwater runoff, leaky sewer pipes, etc.) is likely to be a primary source of fecal coliform in the Little Troublesome Cr. watershed. Consequently, management efforts should focus there.

Little Troublesome coliform sampling sites



APPENDIX II. MODEL CALIBRATION INFORMATION

Calibrated Hydraulic Parameters for HSPF application to Little Troublesome Cr.

Parameter	**Description / Units**	**Calibration value**	**Typical range***
LZSN	Lower zone nominal storage (inches)	7.0	3 - 8
INFILT	Soil infiltration rate (in./hr.)	0.10	0.01 – 0.25
LSUR	Length of assumed overland plane (ft.)	300	200 - 500
SLSUR	Slope of assumed overland plane	0.035	0.01 – 0.15
AGWRC	Groundwater recession rate (/day)	0.99-forest, 0.96-nonforest	0.92 – 0.99
UZSN	Upper zone nominal storage (inches)	0.56	0.10 – 1.0
INTFW	Interflow inflow (no units)	0.60	Default is 0.75
IRC	Interflow recession coefficient	0.40	0.5 – 0.7
LZETP	Lower zone evapotranspiration	0.20	0.2 – 0.7

* From Basins Technical Note 6 – Estimating Hydrology and Hydraulic Parameters for HSPF

Calibrated Water Quality Parameter for HSPF application to Little Troublesome Cr.

Land use/PARAMETER	ACQOP*	SQOLIM	WSQOP	IOQC
Urban (NE tributary)	2.36×10^9	4.27×10^9	0.7	1.12×10^6
Urban (Upper L.T. Cr.)	1.59×10^9	2.85×10^9	0.7	1.12×10^6
Urban (Lower L.T. Cr.)	2.4×10^9	4.33×10^9	0.7	1.12×10^6
Pasture (Upper L.T. Cr.)* *monthly values*	4.36×10^9 to 8.61×10^9	6.54×10^9 to 1.29×10^{10}	1.5	10,000
Pasture (Lower L.T. Cr.) *monthly values*	4.76×10^9 to 9.14×10^9	7.14×10^9 to 1.64×10^{10}	1.5	10,000
Cropland	2.77×10^7	4.99×10^7	1.5	10,000
Cropland (Lower L.T. Cr.)# *monthly values*	2.77×10^7 to 1.51×10^8	4.16×10^7 to 2.27×10^8	1.5	10,000
Upland Forest	3.88×10^7	6.98×10^7	2.8	5,000
Bottomland Forest	4.54×10^7	8.46×10^7	2.8	5,000

ACQOP is the accumulation rate in count/acre/day

SQOLIM is the maximum storage rate in count/acre

WSQOP is the surface runoff rate removing 90% of pollutant in inches

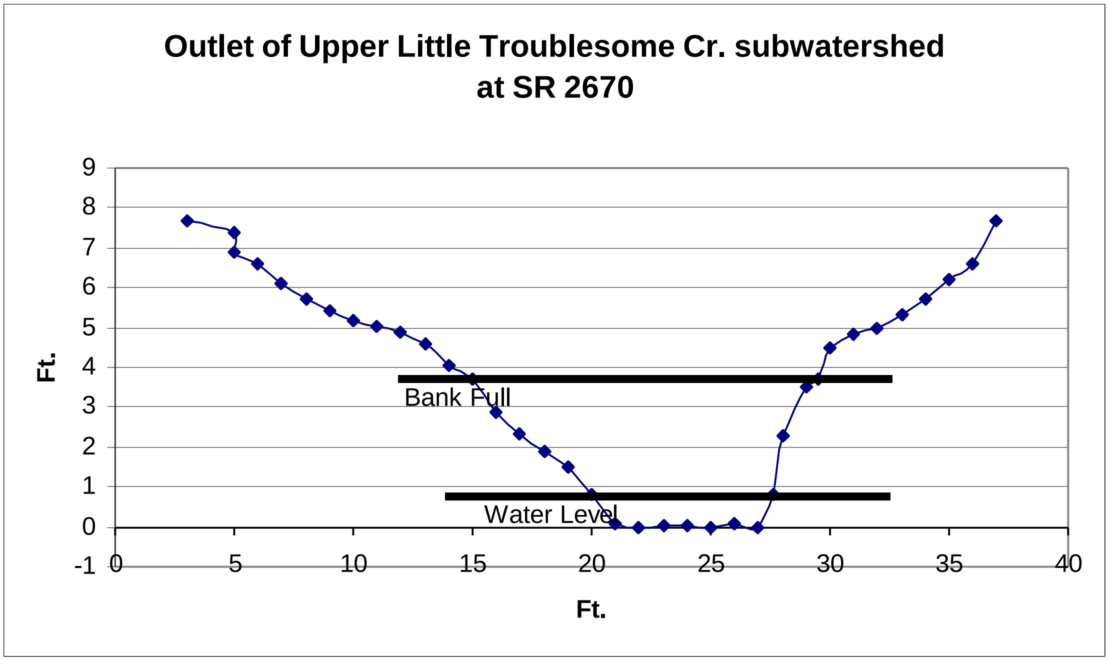
IOQC is the interflow concentration in count/acre/day

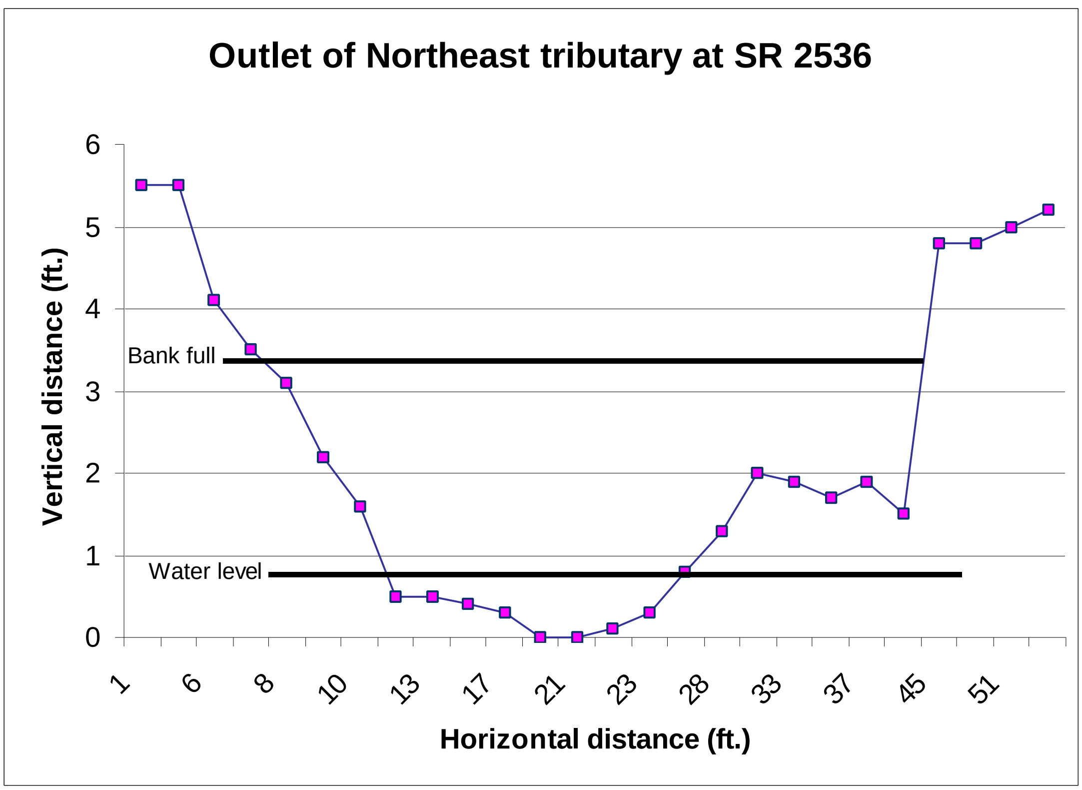
These values were calculated in Fecal Tool

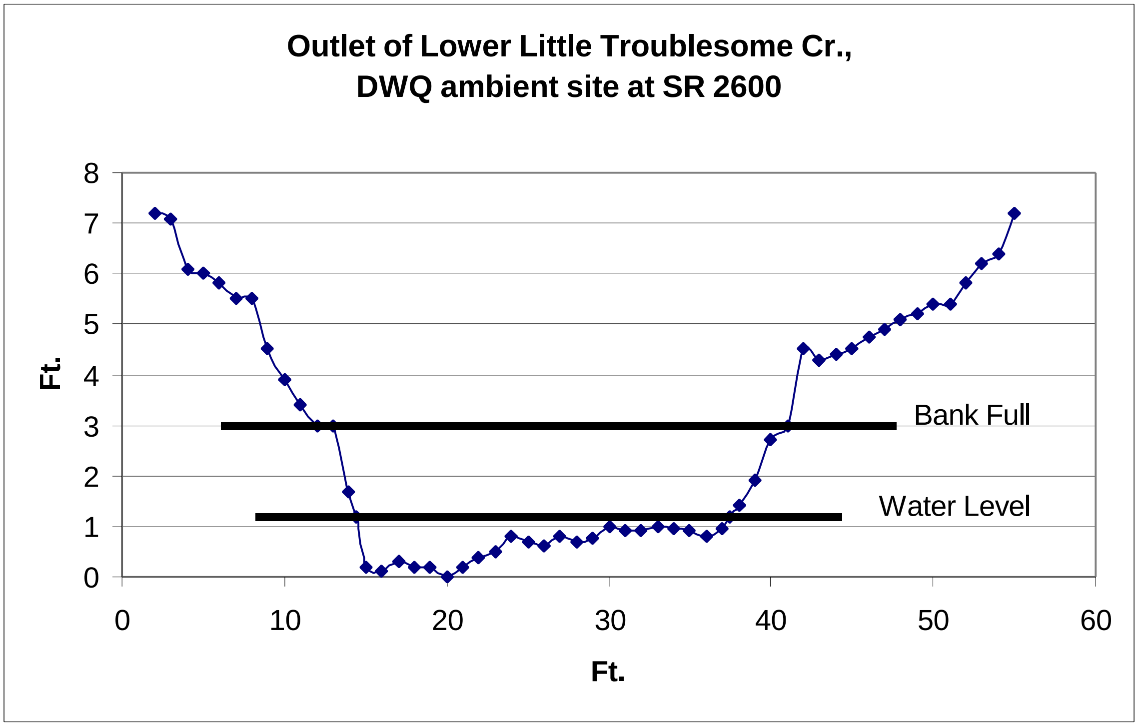
* Monthly values exist for pasture because cattle were assumed to spend varying amounts of time in the stream, depending on the air temperature.

Monthly values exist for cropland because sludge from the treatment plant was assumed to be applied on this land use two months out of the year. Reductions are not expected from either cropland or land applied sludge, as it is assumed that they are part of the background loading (only cropland sources of coliform are wildlife and land applied sludge is an already regulated process).

APPENDIX III. Stream Channel Cross Sections for Subwatersheds






Outlet of Lower Little Troublesome Cr.,
DWQ ambient site at SR 2600
Ft.
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
Ft.
Bank Full
Water Level