Total Maximum Daily Loads for Fecal Coliform for Richland Creek and Muddy Creek, North Carolina

Final Report
February 2004
(Approved May 17, 2004)

Cape Fear River Basin

Prepared by:
NC Department of Environment and Natural Resources
Division of Water Quality
Water Quality Section
1617 Mail Service Center
Raleigh, NC 27699-1617
(919) 733-5083

With support from:
TetraTech, Inc.
Cape Fear Bldg., Suite 105
3200 Chapel Hill-Nelson Hwy.
Research Triangle Park, NC 27709
NC DWQ Contract Number EW030318; Project Number 1-5

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SUMMARY SHEET

Total Maximum Daily Load (TMDL)

1. 303(d) Listed Waterbody Information

State: North Carolina

County: Guilford and Randolph

Major River Basin: Cape Fear River Basin

Watershed: Richland Creek and Muddy Creek in Deep River Watershed HUC 03030003

Impaired Waterbody (2002 303(d) List):

Waterbody Name - (ID)	Water Quality Classification	Impairment	Length (mi)
Richland Creek - 17-7-(0.5)	WS-IV - Aquatic life and secondary contact recreation	Fecal Coliform	6.4
Richland Creek - 17-7-(4)	WS-IV CA- Aquatic life and secondary contact recreation	Fecal Coliform	2.6
Muddy Creek - 17-9-(1)	WS-IV - Aquatic life and secondary contact recreation	Fecal Coliform	5.6
Muddy Creek – 17-9-(2)	WS-IV CA- Aquatic life and secondary contact recreation	Fecal Coliform	0.5

Constituent(s) of Concern: Fecal Coliform Bacteria

Designated Uses: Biological integrity, propagation of aquatic life, and recreation.

Applicable Water Quality Standards for Class C Waters:

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.

2. TMDL Development

Analysis/Modeling:

Load duration curves based on cumulative frequency distribution of flow conditions in the watershed. Allowable loads are average loads over the recurrence interval between the 95th and 10th percent flow exceeded (excludes extreme drought (>95th percentile) and floods (<10th percentile)). Percent reductions expressed as the average value between existing loads (calculated using an equation to fit a curve through actual water quality violations) and the allowable load at each percent flow exceeded.

Critical Conditions:

Critical conditions are accounted for in the load curve analysis by determining the average difference between the existing load violation trend line and the allowable load line. This approach was chosen because existing load violations occur at all flow levels.

Seasonal Variation:

Seasonal variation in hydrology, climatic conditions, and watershed activities are represented through the use of a continuous flow gage and the use of all readily available water quality data collected in the watershed.

3. Allocation Watershed/Stream Reach

Segment	Pollutant	Existing	WLA[1]	LA	MOS[2]	Reduction Required	TMDL
Richland Creek	Fecal Coliform	5.47E+11	7.05E+10	2.94E+10	Explicit 10% MOS	82%	9.99E+10
Muddy Creek	Fecal Coliform	3.85E+11	2.86E+10	5.01E+10	Explicit 10% MOS	80%	7.87E+10

Notes:

WLA = wasteload allocation, LA = load allocation, MOS = margin of safety

[1]WLA includes NPDES continuous point sources plus MS4 stormwater load.

[2]Margin of safety (MOS) equivalent to 10 percent of the target concentration for fecal coliform.

4. Public Notice Date: 2/19/2004

5. Submittal Date: 3/29/2004

6. Establishment Date: 5/17/2004

7. Endangered Species (yes or blank):

8. EPA Lead on TMDL (EPA or blank):

9. TMDL Considers Point Source, Nonpoint Source, or both: both

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1 Introduction

This report presents the development of Total Maximum Daily Loads (TMDLs) for fecal coliform impairment of Richland Creek and Muddy Creek. Richland Creek and Muddy Creek near High Point, North Carolina have been placed on the North Carolina 2002 list of impaired waters (the 303(d) list) and require estimation of a TMDL for fecal coliform to meet the water quality standards specified for WS-IV and WS-IV CA waters. Richland Creek and Muddy Creek are headwater tributaries to the Deep River, located within Guilford and Randolph Counties (Figure 1), draining an area of approximately 30 square miles.

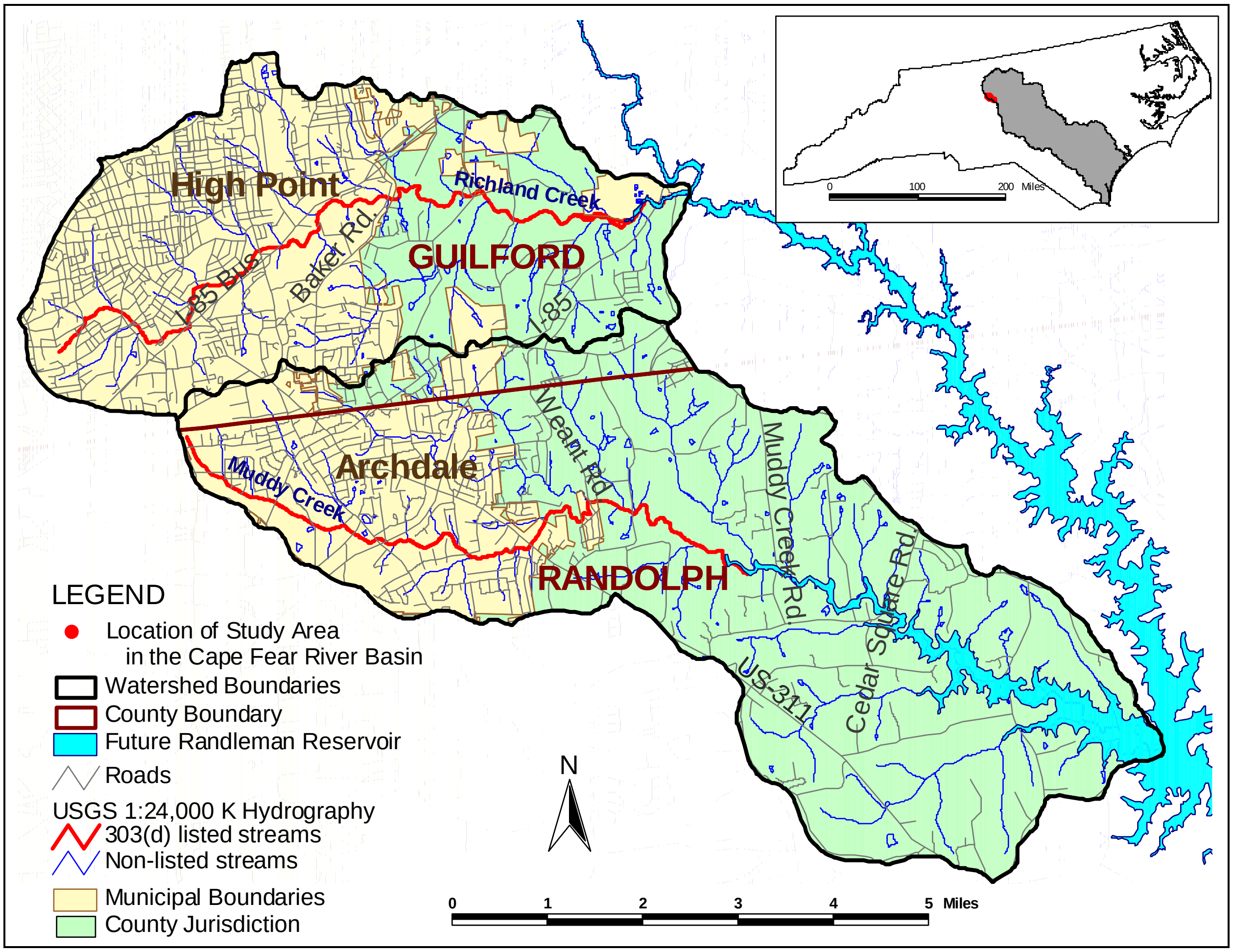

Figure 1. Location of Richland Creek and Muddy Creek

1.1 Problem Definition

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. Development of a TMDL requires an assessment of the assimilative capacity of the stream, assessment of the sources within the watershed contributing to the total instream load, and a recommendation of the reductions required from each source.

1.1.1 TMDL Components

The 303(d) process requires that a TMDL be developed for each of the waters appearing on Part I of the 303(d) list. 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 (FACA, 1998) are as follows:

Target identification or selection of pollutant(s) and end-point(s) for consideration. The pollutant and end-point are generally associated with measurable water quality related characteristics that indicate compliance with water quality standards. North Carolina indicates known pollutants on the 303(d) list.

Source assessment. All sources that contribute to the impairment should be identified and loads quantified, where sufficient data exist.

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 end-point. Generally, this component is identified through water quality modeling.

Allocation of pollutant loads. Allocating 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. Similarly, the load allocation portion of the TMDL accounts for the loads associated with existing and future non-point sources, stormwater, and natural background.

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 or implicitly due to conservative assumptions.

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

Critical Conditions. Critical conditions indicate the combination of environmental factors that result in just meeting the water quality criterion and have an acceptably low frequency of occurrence.

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 Category 4a of the Integrated Report. Waterbodies remain in Category 4a 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.

1.1.2 Richland Creek and Muddy Creek Fecal Coliform Impairments

The Richland Creek and Muddy Creek listings are contained in the *North Carolina Water Quality Assessment and Impaired Waters List (2002 Integrated 305(b) and 303(d) Report).* The segments of Richland Creek considered to be impaired due to fecal coliform [Waterbody ID 17-7-(0.5) and 17-7-(4)] extend 9.0 miles from the headwaters down to the inlet for Randleman Reservoir. The segments of Muddy Creek considered to be impaired due to fecal coliform [Waterbody ID 17-9-(1) and 17-9-(2)] extend 6.1 miles from the headwaters down to the inlet for the Muddy Creek arm of Randleman Reservoir.

Richland Creek and Muddy Creek each have a designated use classification of WS-IV, which is intended to protect drinking water supplies. This designation also encompasses the more general Class C requirements that protect aquatic life and secondary contact recreation (NCDENR 2003). 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 200/100 mL (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.

1.2 WATERSHED DESCRIPTION

Richland Creek and Muddy Creek are located within Guilford and Randolph Counties in North Carolina (Figure 1). Richland Creek extends 9.0 miles from its headwaters in southern High Point to its entrance into Randleman Reservoir and includes approximately 43 miles of mainstem and tributary stream reaches. The creek drains approximately 16 square miles of land, including a portion of the City of High Point. Muddy Creek extends 6.1 miles from its headwaters in northwestern Archdale to its entrance into the Muddy Creek Arm of the Randleman Reservoir and includes approximately 40 miles of mainstem and tributary stream reaches. The creek drains approximately 14 square miles of land, including most of the City of Archdale.

1.2.1 Landuse Distribution in the Richland Creek and Muddy Creek Watersheds

The National Land Cover Data (NLCD; USEPA, 2004) were used to determine the landuse distribution within the watershed. This dataset was developed using satellite data collected during the period from 1992 to1993. Landuse distribution was tabulated for the portions of Richland Creek and Muddy Creek Watersheds that drain to the 303(d) listed segments. As shown in Table 1 and Figure 2, the upstream half of each watershed is highly developed, while the downstream portions contain agricultural land and forest.

The population density within the study area grew from about 630 people per square mile to 660 people per square mile between 1990 and 2000 (U.S. Census, 1990 and 2000). This small increase in population indicates that the watersheds have experienced minimal growth and that the NLCD is likely to provide a relatively accurate description of current residential development. The density of farms has decreased, which suggests that some agricultural land may have been converted to residential developments. The conversion of rural landuses will typically shift the nonpoint source contribution of fecal coliform from agricultural activities such as cattle grazing and manure application to urban sources such as fecal waste from household pets, sanitary-sewer overflows (SSOs), and leaking sewer lines.

Table 1. Watershed NLCD Landuse Acreage and Percent Composition

Landuse	Barren	Crop	Pasture	Other Grasses	Forest	Urban	Water/ Wetland	Total
Richland Creek								
Area (ac)	82	915	199	129	3,687	5,211	97	10,321
Area (%)	0.8	8.9	1.9	1.3	35.7	50.5	0.9	100.0
Muddy Creek								
Area (ac)	8	1,351	423	64	2,508	2,869	48	7,272
Area (%)	0.1	18.6	5.8	0.9	34.5	39.4	0.7	100.0

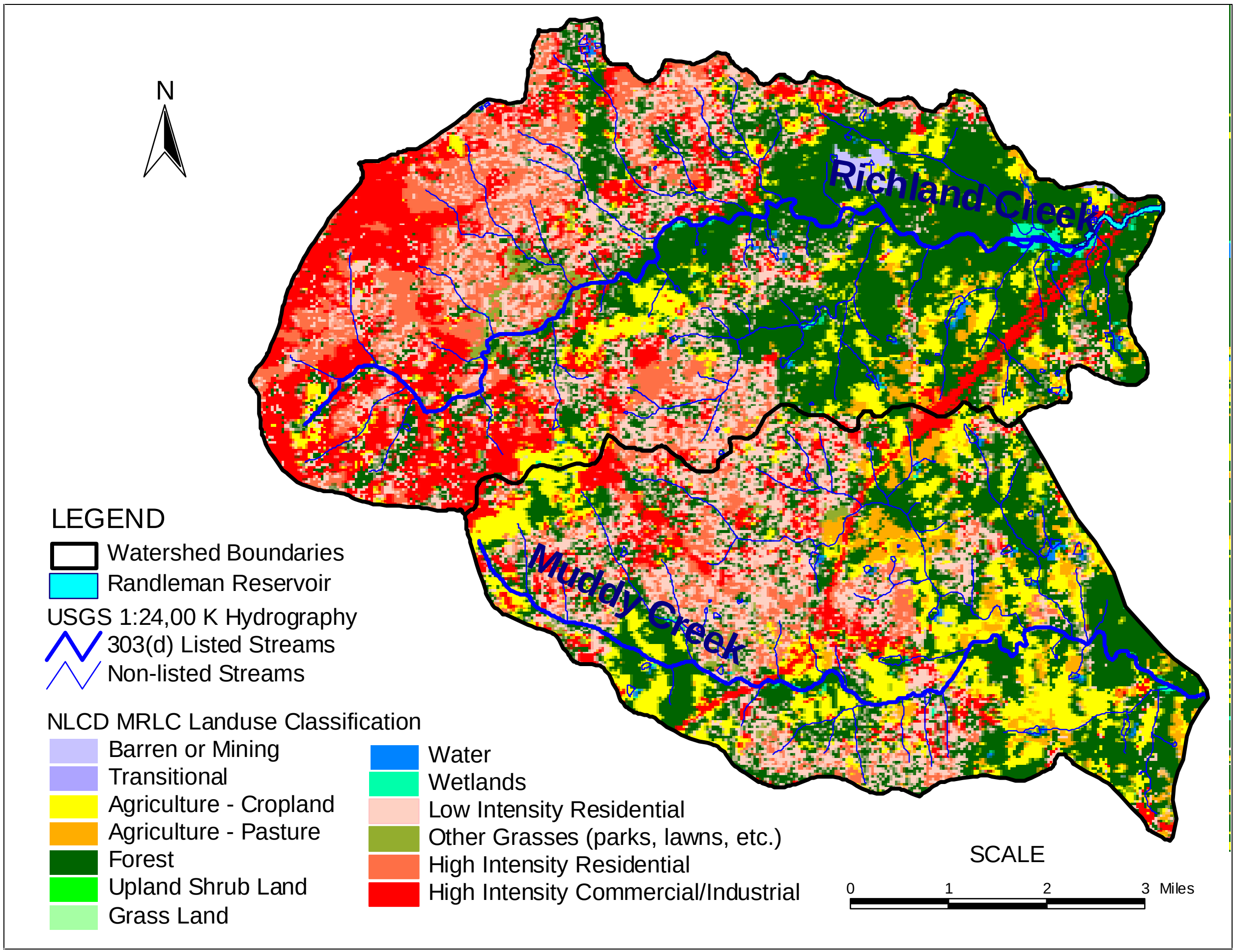

Figure 2. Richland Creek and Muddy Creek NLCD Landuse

1.3 Water Quality Monitoring

Water quality monitoring performed by NCDENR for fecal coliform has shown a number of excursions above the water quality standard. Additional fecal coliform monitoring data, collected by the Upper Cape Fear River Basin Association (UCFRBA), further supports the decision to list Richland Creek and Muddy Creek for fecal coliform impairment.

1.3.1 NCDENR Monitoring

Water quality monitoring for Richland Creek and Muddy Creek was performed by NCDENR at two stations in Richland Creek and three stations in Muddy Creek (Figure 3). Regular monitoring was performed on Richland Creek at Riverdale Road (B4410000) for the period from 10/23/1997 through 6/28/2000. These data were collected approximately monthly and include observations for fecal coliform. At all NCDENR stations, intensive fecal coliform monitoring was performed during the period from 5/20/2003 through 7/2/2003 to assess the impairment status with regards to the standards specification requiring five samples per 30-day period. Table 2 presents a summary of the fecal coliform data collected.

Table 2. Summary of NCDENR Water Quality Monitoring for Fecal Coliform Impairment

Station	Period	Instantaneous Exceedances/ Observations[a]	Geomean Exceedances/ Observations[b]
Richland Creek at Baker Road	5/03 – 7/03	9/11	7/7
Richland Creek at Riverdale Road	10/97 – 9/02	12/38	7/12
Muddy Creek at Weant Road	5/03 – 7/03	9/11	7/7
Muddy Creek at Muddy Creek Road	5/03 – 7/03	8/11	7/7
Muddy Creek at SR 1936	5/03 – 7/03	9/11	7/7

[a] Exceedances (Instantaneous fecal coliform measurements > 400 cfu/100 mL)/Total number of samples

[b] Exceedances (Geometric mean of 5 fecal coliform measurements within a 30-day period > 200 cfu/100 mL)/Number of 5-sample groups within a 30-day period

1.3.2 UCFRBA Fecal Monitoring Data

The Upper Cape Fear River Basin Association (UCFRBA) measured fecal coliform concentrations for Richland Creek at Baker Road and Muddy Creek at Cedar Square Road from 4/27/00 through 6/5/03. These data are part of an ongoing monitoring program that replaces the in-stream monitoring requirements of point source dischargers participating with UCFRBA (CFRA, 2003). UCFRBA has a memorandum of agreement with NCDWQ to conduct this monitoring. A state-approved lab was used to analyze the fecal coliform samples (Patrick, 2003). A summary of the data collected is presented in Table 3. The data do not contain any groups of five samples within a 30-day period.

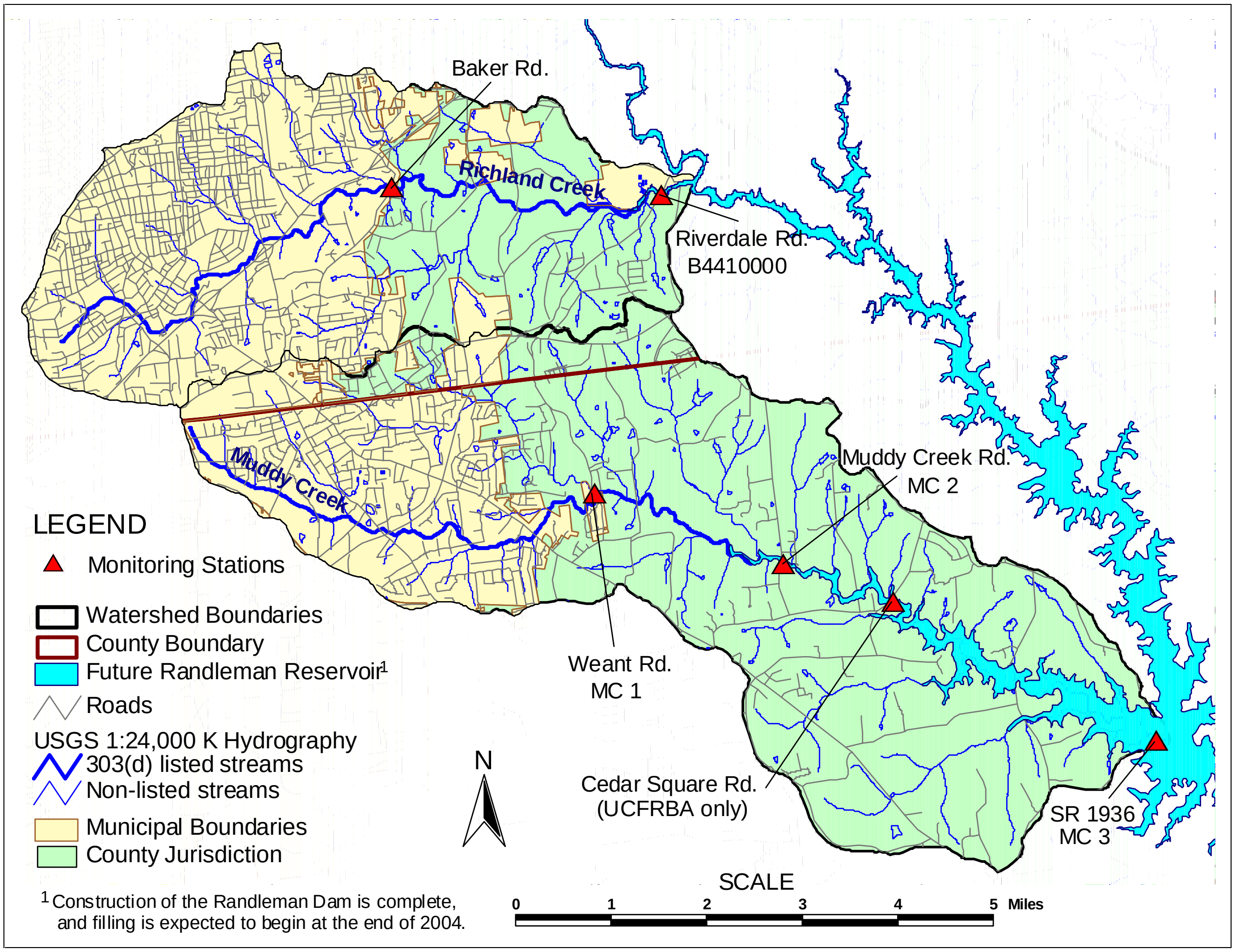

Figure 3. NCDENR and UCFRBA Monitoring Locations

Table 3. Summary of UCFRBA Fecal Coliform Monitoring Data (4/27/00 through 6/5/03)

Station	Number of Samples	Number Greater Than Standard [a]
Richland Creek, Baker Road	39	24
Muddy Creek, Cedar Square Road	39	21

[a] Instantaneous fecal coliform measurements > 400 cfu/100 mL

1.3.3 Summary of Fecal Coliform Trends

The data collected by NCDENR and UCFRBA show an increase in fecal coliform concentrations during storm events as well as during typical and low flow periods. Since exceedances occur across all flow regimes, a wide range of sources may contribute to stream impairment. For Richland Creek, high fecal coliform concentrations at the Baker Road station indicate that urban sources in the headwaters are contributing to impairment. During the summer of 2003, fecal coliform concentrations at Baker Road correlated with measurements at Riverdale Road, and the concentrations at the Riverdale Road station were consistently lower than at the Baker Road station (Figure 4). These results are not surprising as the flow from each segment contributes to the total flow in the downstream reach. However, it does show that the fecal coliform concentrations at Riverdale Road are highly dependent on contributions upstream of Baker Road and that problems in the headwaters are a major cause of the elevated levels in Richland Creek.

Fecal coliform concentrations were correlated at each Muddy Creek station during the summer of 2003, but the upstream effects appear to be less significant than in Richland Creek. None of the stations are consistently higher than the other stations (Figure 5). Therefore, urban sources appear to contribute to impairment, but sources in the rural, downstream areas are also likely to be significant.

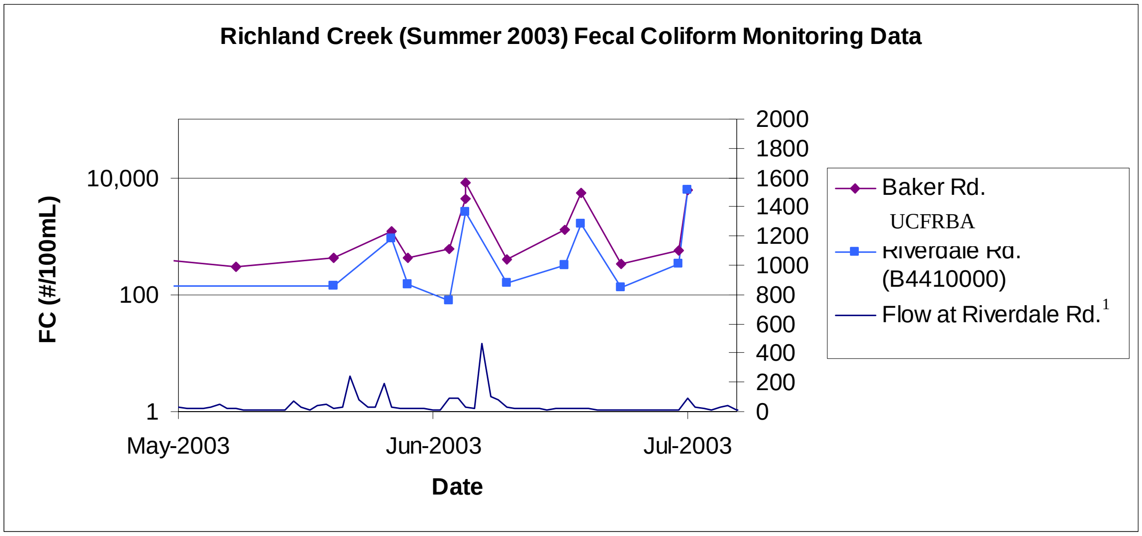

Figure 4. Richland Creek Monitoring Data May 1 through July 2, 2003[1]

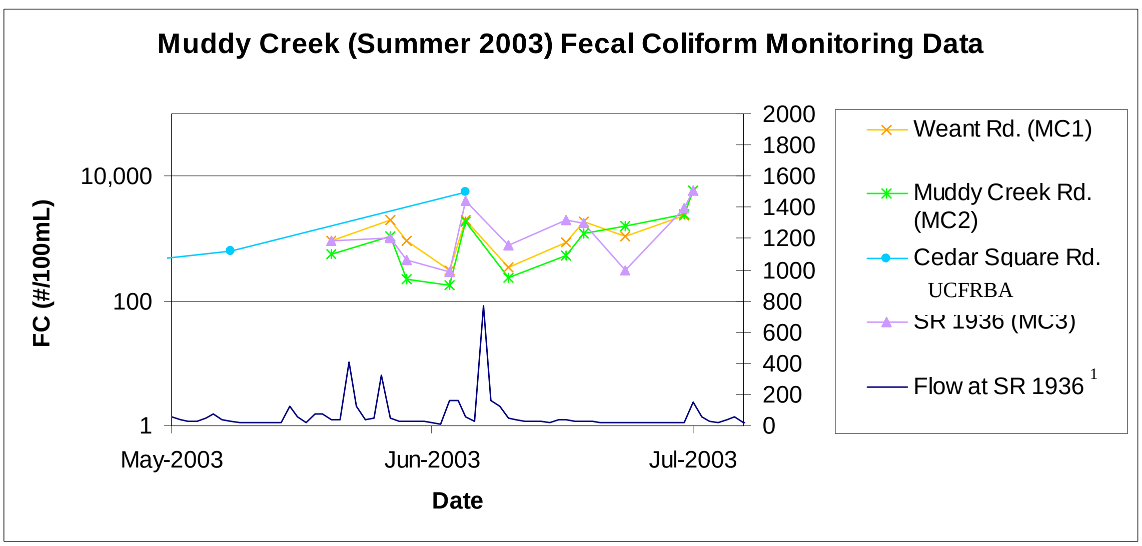

Figure 5. Muddy Creek Monitoring Data May 1 through July 2, 2003[1]

[1] Flow was estimated from measurements at the USGS East Fork Deep River gage.

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2 Source Assessment

A critical step in developing a useful and defensible TMDL is the assessment of potential sources. Tetra Tech performed a watershed-wide review of sources that potentially contribute to high turbidity fecal coliform loading. This review included data from the National Pollutant Discharge Elimination System, septic use and public sewer boundaries, and landuse/landcover information. Geographical information systems and digital orthophotos were used to gain an understanding of the sources within the watershed. Discussion with local jurisdictions and field personnel were also used to identify and quantify potential sources.

2.1 General Sources of Fecal Coliform

Both point and nonpoint sources may contribute fecal coliform to the waterbodies. Potential sources of fecal coliform loading are numerous and often occur in combination. In rural areas, runoff can transport significant loads of fecal coliform from sources such as agricultural activities and wildlife contributions. Septic systems, illicit discharges, broken sewer pipes, and stormwater runoff can be potential sources in urban areas.

Potential sources of fecal coliform loading in the watershed were identified based on an evaluation of current landuse/cover, septic system/sewer use, and SSO data. The source assessment was used as the basis of the TMDL allocations.

2.1.1 Nonpoint Source Fecal Coliform Contributions

Research was performed to assess the most probable nonpoint sources of fecal coliform. Information on sources was gathered from GIS information, census data, and personal communication with local and state officials. The principal sources investigated were landuse distribution, septic systems, sewer pipe defects, sanitary sewer overflows, and the populations of wildlife and domestic animals.

Runoff Contributions

Runoff from landuses in the watershed can contribute significant fecal coliform loading to streams. Stormwater runoff carries wildlife and domestic animal feces from urban areas and fecal coliform from pasture and other agricultural lands near streams.

A landuse map of the Richland and Muddy Creek watersheds is presented in Figure 2. According to the landuse data, the watersheds can be divided roughly into two halves: the urban, upstream portions, and the rural, downstream portions. In the early 1990s when the landuse data were developed, forest comprised about 35 percent of both watersheds. In the Richland Creek watershed, about half of the watershed drained developed areas, including low intensity residential, high intensity urban, and commercial/industrial areas. The Muddy Creek watershed was about 40 percent developed, with most development in low intensity residential (23 percent). Muddy Creek also drains more farmland than Richland Creek; about one-tenth of Richland Creek watershed contained agricultural land whereas about one-quarter of Muddy Creek contained agricultural land.

Review of census data (Figure 6) shows that the density of housing units in the watersheds has not changed dramatically between 1990 and 2000. The 2000 distribution of housing units confirms that the urban area boundaries have remained fairly constant in both watersheds. A comparison of agricultural census data between 1990 and 2000 shows that farming has declined in both watersheds (Figure 6). It is likely that some livestock operations remain in both watersheds and that these operations may be source of fecal coliform during wet weather events.

In the urban, upstream portions of both creeks, the likely sources of runoff fecal coliform loading include domestic animal feces and wildlife such as geese that populate the golf courses. In the rural, downstream portions of Richland Creek and Muddy Creek, fecal coliform loading may be caused by domestic animals, agricultural practices, or wildlife.

Although Richland Creek and Muddy Creek share similar upstream and downstream landuse trends, the two watersheds differ by the density of urban and agricultural landuses. The Richland Creek watershed contains higher housing densities than Muddy Creek. Higher housing densities may lead to more fecal coliform loading from pets and more frequent sanitary sewer overflows (SSOs) during storm events. Richland Creek and its tributaries also flow through golf courses and parks, and geese populations attracted by these open spaces may contribute fecal coliform to urban runoff. As discussed in Section 1.3.3, the monitoring data indicate that much of the fecal coliform loading to Richland Creek originates in upstream reaches. Accordingly, the downstream, rural areas likely contribute less to fecal coliform impairment than the upstream, urban sources since high and transition flow exceedances are less frequent at Riverdale Road than at Baker Road (Figure 9 and Figure 10). In addition, the downstream portion of Richland Creek had a fairly contiguous forested buffer in the early 1990s. If this forest remains, the stream would be buffered from some of the residential and agricultural runoff, suggesting that wildlife is the more important wet weather source in the downstream portion of the watershed.

The effects of urban landuse on Muddy Creek impairment appear to be less pronounced than for Richland Creek. Since its urban density is lower than High Point, the City of Archdale may experience less frequent SSOs, have smaller geese populations or have lower residential densities. Despite these differences, urban runoff remains a factor in Muddy Creek. Directly downstream of the urban area, instream concentrations are elevated, especially above the Weant Road monitoring station. In the rural portion of Muddy Creek, wet weather fecal coliform loading may be caused by manure application to cropland, cattle access to streams, or low density residential areas with pets. Agricultural land had encroached significantly into the riparian corridor in the 1990s, which may point to agriculture rather than wildlife is a more important source of fecal coliform during storm events. Unlike Richland Creek, high and transition flow fecal coliform exceedances in Muddy Creek do not decrease in frequency from upstream to downstream (Figure 4). The landuse and monitoring data indicate that while urban runoff is the major source of wet weather loading in Richland Creek, both urban and agricultural runoff may contribute fecal coliform to Muddy Creek.

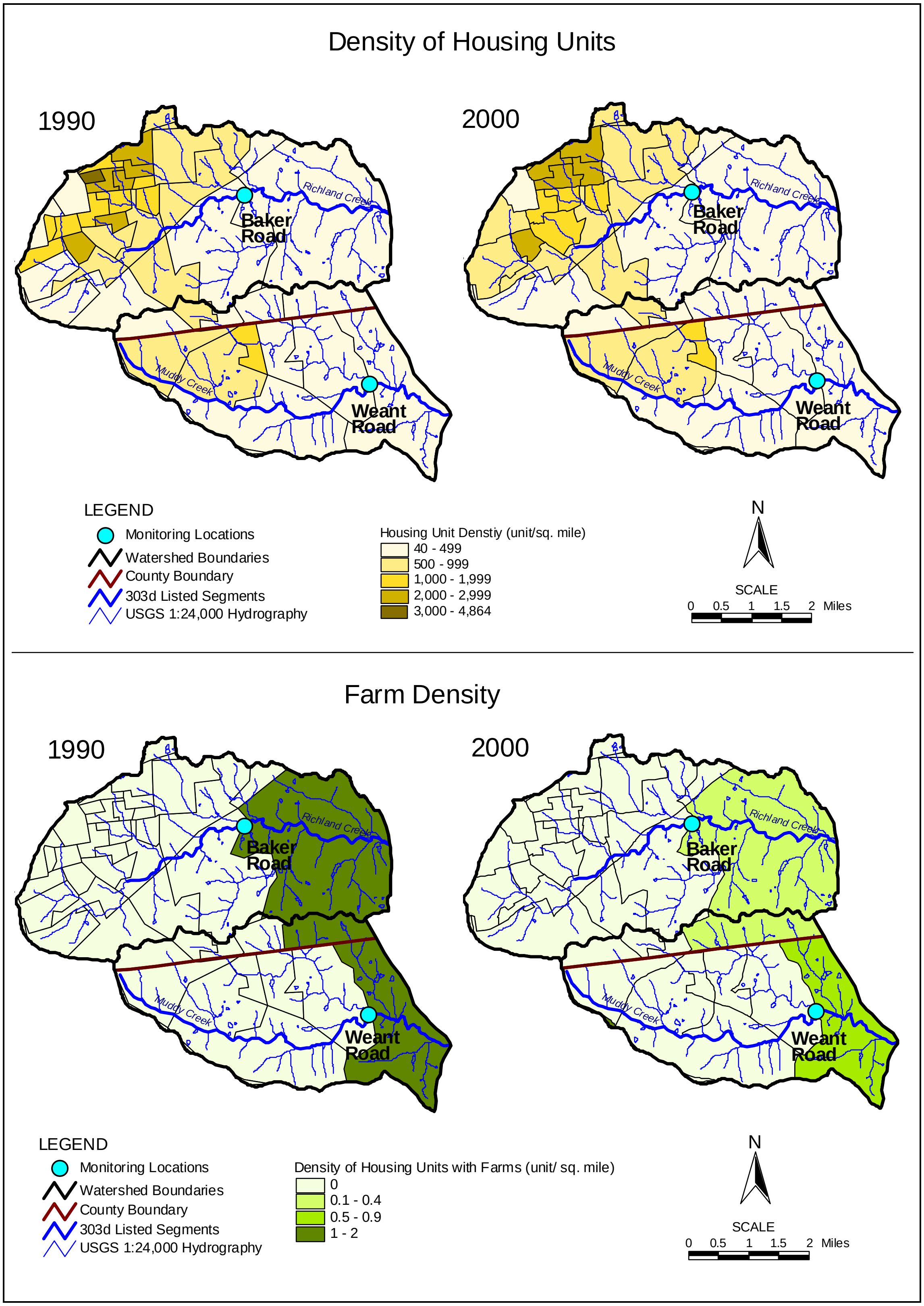

Figure 6. Comparison of Farm and Housing Unit Density between 1990 and 2000 (U.S. Census)

Septic Systems

Septic tanks are one of several possible causes of low flow exceedances. Other sources of low flow fecal coliform loading are leaking sewer pipes, illicit discharges, and other direct inputs of raw sewage. Figure 7 shows the density of septic system use throughout the watersheds according to the 1990 census. The use of septic systems was concentrated in the downstream half of both watersheds in 1990, although some septic systems were being used in the urban areas. Since septic system use data was not included in the 2000 census, population growth was used to assess how septic tank use has changed over the decade. The comparison of population densities between 1990 and 2000 in Figure 7 shows that most of the population growth has occurred south of High Point in the headwaters of Richland Creek and east of Archdale upstream of the Muddy Creek Road monitoring station. Few septic systems were found south of High Point in 1990, and it is likely that new households are using sanitary sewers. Only a small amount of growth occurred in the downstream portions of Richland Creek and Muddy Creek, and the use of septic systems has probably remained similar to 1990 levels.

In Richland Creek, low flow exceedances have only been measured at the Baker Road monitoring stations (Figure 9). Septic systems are one possible source of low flow fecal coliform loading in the urban, upstream portion of Richland Creek since some septic tanks may remain in downtown High Point. Older septic systems, like sand filters, may be responsible for a large portion of the fecal coliform loading, depending on their location and condition. Other likely low flow sources are sewer pipe defects.

For Muddy Creek, the UCFRBA data at Cedar Square Road are the only monitoring data collected during low flow events. At Cedar Square Road, a few low flow exceedances were measured. Since this station is located downstream of the 303(d) listed reach, both urban and rural sources could be contributing to the low flow events. Septic systems throughout the watershed are one possible source of low flow fecal coliform loading. According to the Randolph County Health Department, the public sewer system has only been extended to a few subdivisions west of Archdale (Walker, 2003). Otherwise, the majority of households outside of Archdale “proper” continue to use septic systems. Contribution of fecal coliform by septic systems could explain the low flow exceedances at the Muddy Creek monitoring stations.

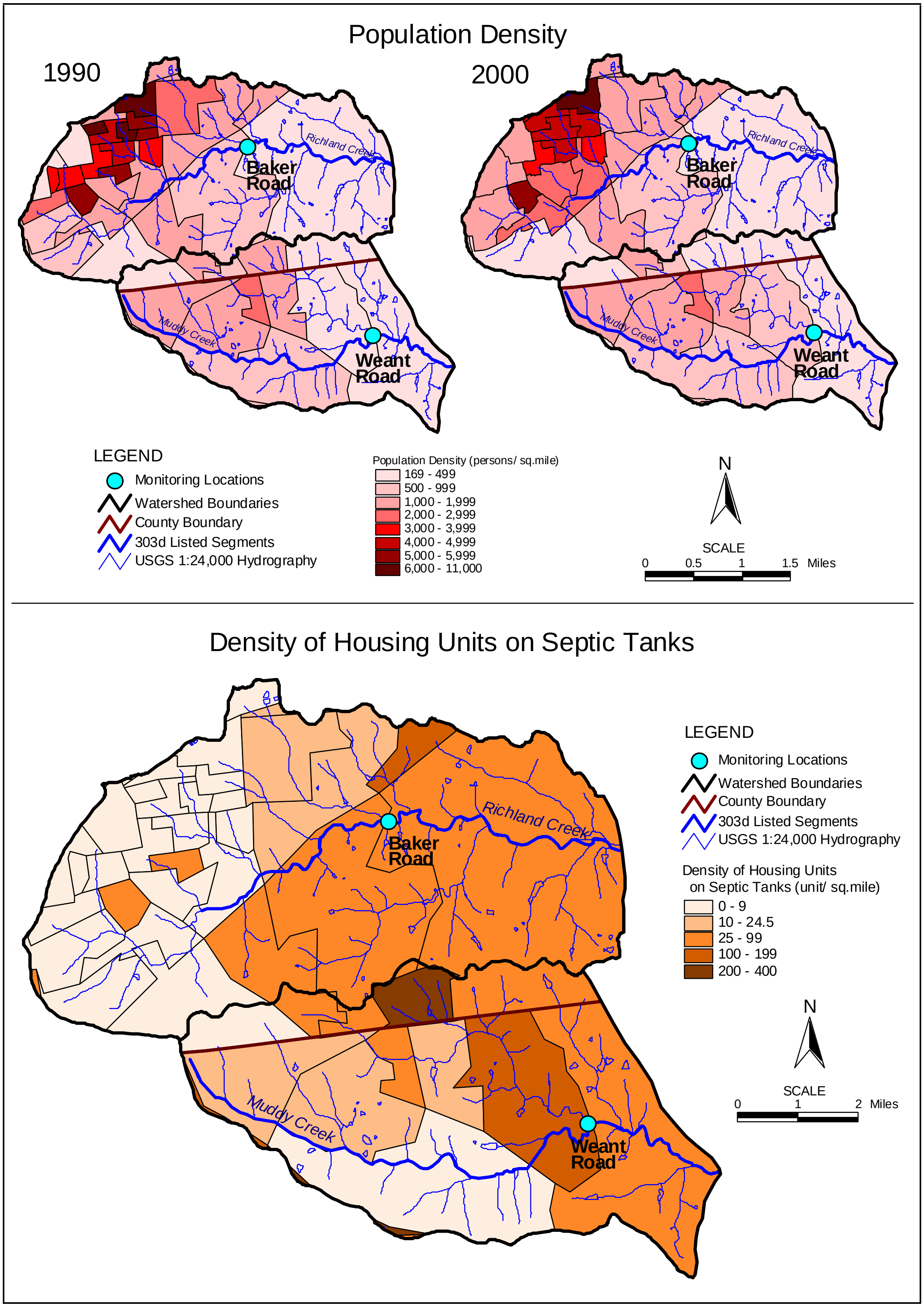

Figure 7. Comparison of Population Change between 1990 and 2000 and Septic Tank Density in 1990 According to the 1990 and 2000 U.S. Census

Sewer Overflows

Fecal coliform may enter surface water when sewer pipes are clogged, damaged, or flooded by stormwater. Infiltration of rainfall can enter the sewer system through cracks and leaks in pipes. This additional flow volume, in combination with the existing sewer flow, can exceed the capacity of the system resulting in a sanitary-sewer-overflow (SSO).

Based on data provided by NC DWQ, sixteen SSO events have been reported in High Point during the last two years (Mauney, 2003). Of these sixteen events, ten contributed less than 5,000 gallons or were single occurrences at the discharge location. However, six relatively significant events ranging from 18,000 to 318, 590 gallons occurred near 5745 Riverdale Road. The Riverdale Road overflows may constitute a significant, reoccurring source contributing to fecal coliform impairment in Richland Creek.

The City of Archdale does not have any SSOs on record within the past three years (Shuler, 2003). A lift station is located on Weant Road in Muddy Creek and may be a source of high flow fecal coliform loading to Muddy Creek.

Sewer Defects

Defects in sewer pipes, including cracked and corroded pipes, allow sewage to leak into surface water. Sewer pipe leaks are a likely cause of low flow fecal coliform exceedances as they contribute high loads during periods where there is a minimal amount of stream flow to dilute their contribution. Richland and Muddy Creeks drain some of the oldest sections of the High Point and Archdale, where sewer pipes may have developed cracks and corrosion over many years of use. The city officials are not aware of any specific location of sewer defects (Shuler, 2003; Hepler, 2003). The wide range of flows during which exceedances occur and the elevated levels in the urban areas suggest that sewer defects are potentially a very significant problem.

2.1.2 Point Source Fecal Coliform Contributions

Two low-scale wastewater treatment plants, termed “package plants,” are permitted to discharge into the Muddy River and its tributaries within the listed segment (Figure 8). Table 4 presents the average flow, loading, and permit limits for the NPDES facilities discharging fecal coliform to Muddy Creek. Some of the facilities may need to be repaired or upgraded (Mauney, 2003; Walker, 2003). These plants are potential causes of high fecal coliform measurements at MC1 (Weant Road) and MC2 (Muddy Creek Road) during all flow regimes. At present, only the Penman Heights facility is discharging to the Muddy Creek watershed. This facility discharges to a tributary a quarter mile from Muddy Creek between stations MC1 and MC2.

As discussed in the source assessment, urban stormwater runoff can contribute fecal coliform to Richland Creek and Muddy Creek. Much of this runoff is considered a point source and is regulated in compliance with the Storm Water Phase II Final Rule (EPA, 2000). This rule applies to a unit of government such as a city or county, which owns or operates a municipal separate storm sewer system (MS4). The MS4 is required to obtain a National Point Source Discharge Elimination System (NPDES) permit for their stormwater discharges to surface waters. As such, stormwater runoff from areas within an MS4 is considered a point source. The City of High Point, the City of Archdale, and Guilford County fall under the Phase II Rule and therefore maintain stormwater management programs. Loadings of fecal coliform from stormwater runoff are considered to be point source discharges for the purpose of the TMDL.

Table 4. NPDES Facilities Discharging Fecal Coliform

Facility Name	NPDES Permit No.	NPDES Permit Limits			Status
		Permitted Avg. Flow (MGD)	Fecal Coliform Loading Geomean (#/100mL)	Fecal Coliform Loading Maximum (#/100mL)	
Penman Heights	NC0055191	0.0250	200	400	Active
Rimmer Mobile Home Court	NC0069451	0.0204	200	400	Not active

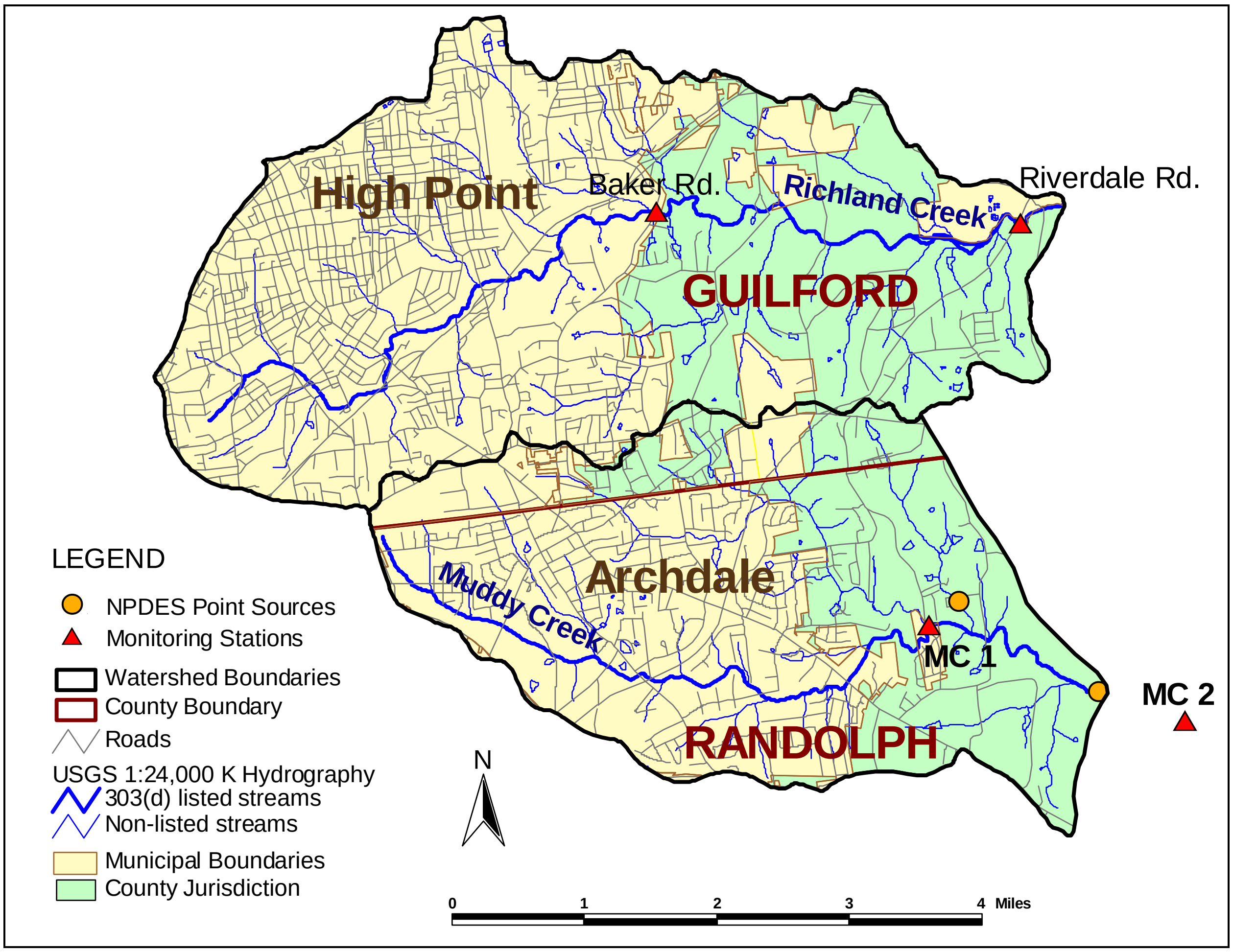

Figure 8. Locations of NPDES Point Sources Permitted to Discharge Fecal Coliform

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3 Technical Approach

Given the results of the initial data analysis and time and budget constraints, an approach focusing on the magnitude of water quality standard exceedances and potential sources contributing to the stream during the exceedances was used. This approach used a flow-duration curve analysis to determine the flow conditions under which impairment occurs. In addition, the approach was used to identify source types, specify the assimilative capacity of the stream, and estimate the magnitude of load reduction required to meet the water quality standards. The potential sources determined from the load-duration curve were inventoried and assessed for their relative contributions to allocate reductions among sources. The results of this assessment were used to derive the allocations required by the TMDL.

This section describes the process used to specify the endpoints and calculate the existing loading and assimilative capacity. The determination of the TMDL reductions and loads are presented in Section 4.

3.1 TMDL Endpoints

The achievement of the TMDL objectives require the instream concentrations to meet both the instantaneous standard of 400 cfu/100 mL and the geometric mean standard of 200 cfu/100 mL. Both standards are considered to be the endpoints for the determination of the fecal coliform TMDL for the Richland Creek and Muddy Creek.

3.2 Flow-Duration Curves for Fecal Coliform

The analysis of pollutant levels in conjunction with water quality standards and measured flow is a useful tool for assessing critical conditions, as well as existing and target loads. The Flow-Duration Curve Method (Stiles 2002, Cleland 2002) was used for fecal coliform. This method plots flow and observed data to analyze the flow conditions under which impairment occurs and water quality deviates from the standard. The method was used to determine the seasonality and flow regimes during which the exceedances occur and to determine maximum daily load based on the flow duration and applicable standard.

A flow-duration curve analysis was performed to identify the flow regimes during which exceedances of the water quality standards occur. This method determines the relative ranking of a given flow based on the percent of time that historic flows exceed that value. The flow gage nearest to Richland and Muddy Creeks was USGS Station 02099000 on the East Fork of the Deep River. This gage is about ten miles upstream of Richland Creek on the Deep River and drains a watershed with a similar landuse distribution. Flow statistics for the gage are presented in Table 5. Since no flow gages were on Richland Creek or Muddy Creek, the flow data from USGS Station 02099000 were scaled to each monitoring station based on drainage area using the proportions in Table 6. These proportions represent the ratio of monitoring station drainage area to gauging station drainage area. Daily gauging data for the period from 1/1929 through 12/2002 was multiplied by these proportions and used to establish the historic flow regimes and ranges for the high, transitional, typical, and low flow conditions.

Table 5. Flow Statistics for USGS Gage 02099000

Flow Parameter	Value (cfs)
Mean	17.4
Min	0.6
Max	1670.0
High flow range	26.0 – 1,670.0
Transitional flow range	12.0 – 26.0
Typical flow range	4.7 – 12.0
Low flow range	0.6 – 4.7

Table 6. Relative Proportion of Flow at USGS Gage 02099000 (East Fork Deep River) for Each Monitoring Station Drainage Area

Stream	Station	Relative Proportion of Gage Flow
Richland Creek	Baker Road	0.57
Richland Creek	Riverdale Road	1.10
Muddy Creek	Weant Rd	0.58
Muddy Creek	Muddy Creek Road	0.99
Muddy Creek	Cedar Square Road	1.14
Muddy Creek	SR 1936	1.80

Once the relative rankings were calculated for flow, monitoring data were matched by date to compare observed water quality to the flow regime during which it was collected. This type of analysis can help define the flow regime during which exceedances occur and also pinpoint the source of the impairment. Exceedances that occur only during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Exceedances that occur during high-flow events are generally driven by storm-event runoff. A mixture of point and nonpoint sources may cause exceedances during normal flows.

In Figure 9 through Figure 12, the flow-duration analysis is presented for the six monitoring stations in the study area. All stations show exceedances of the instantaneous-fecal-coliform water quality standard (400 cfu/100 mL) during high-flow and typical-flow regimes, indicating contributions from moderate and high-flow-storm events as well as some intermittent discharges. Fecal coliform concentrations are expressed as number of colony forming units and may be written as “#/100 mL” or “cfu/100 mL.”

Figure 9 and Figure 12 indicate that while many exceedances occur during high and transition-flow events, fecal coliform also exceeds the instantaneous standard during typical and low flows. The data suggest that both storm-event runoff and low-flow sources, such as illicit discharges, septic systems, or broken sewer lines, contribute to high fecal coliform loading. It should be noted that Cedar Square Road is the only Muddy Creek station where low flow measurements are available.

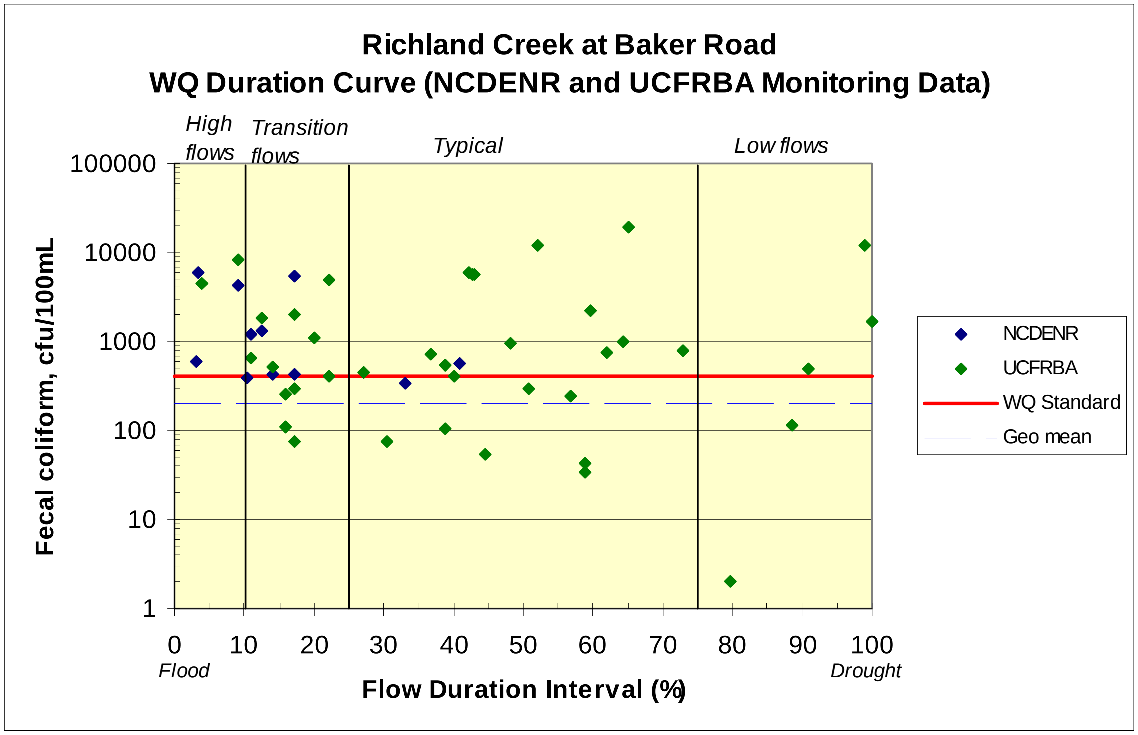

Figure 9. Flow-Duration Curve for NCDENR and UCFRBA Fecal Coliform Data for Richland Creek at Baker Road (4/27/00 through 7/02/03)

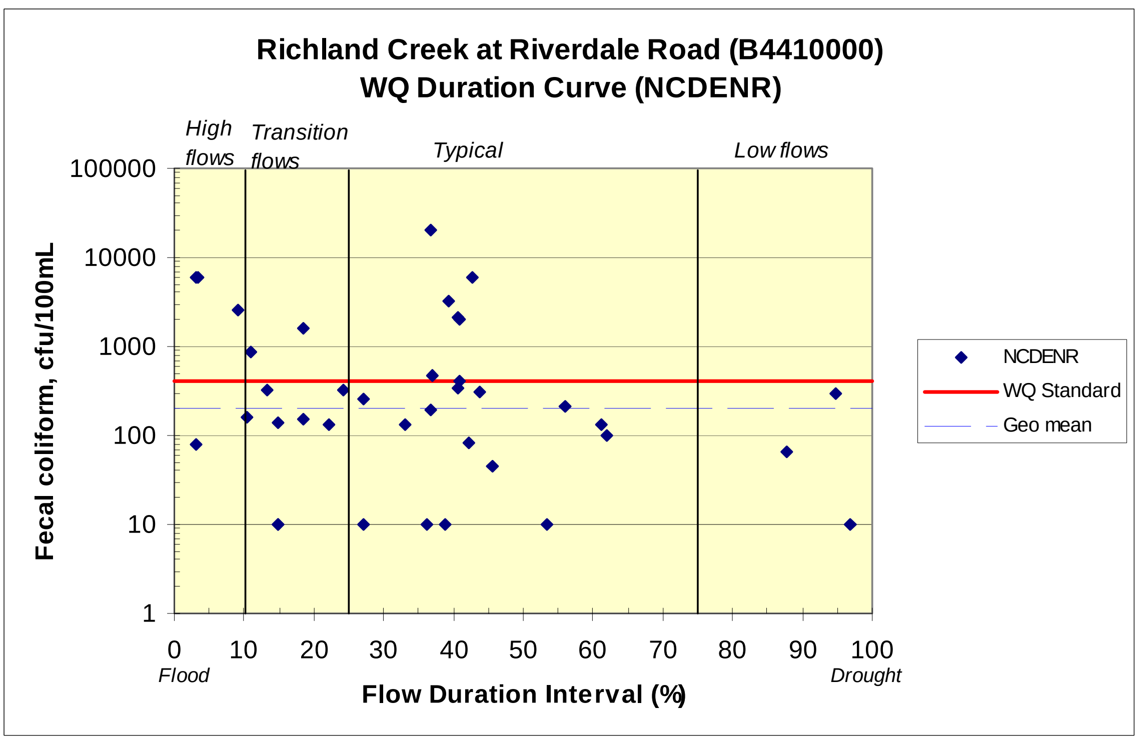

Figure 10. Flow-Duration Curve for NCDENR Fecal Coliform Data for Richland Creek at Riverdale Road (10/23/97 through 7/02/03)

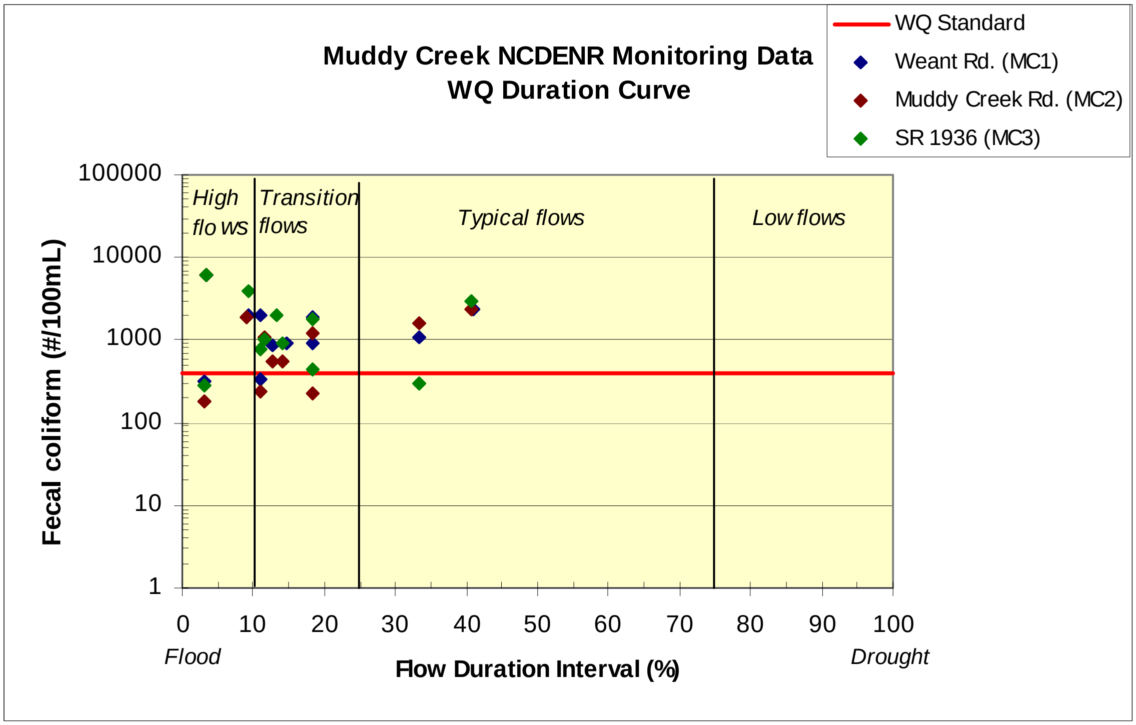

Figure 11. Flow-Duration Curve for NCDENR Fecal Coliform Data for Muddy Creek Stations MC1, MC2, and MC3 (2003)

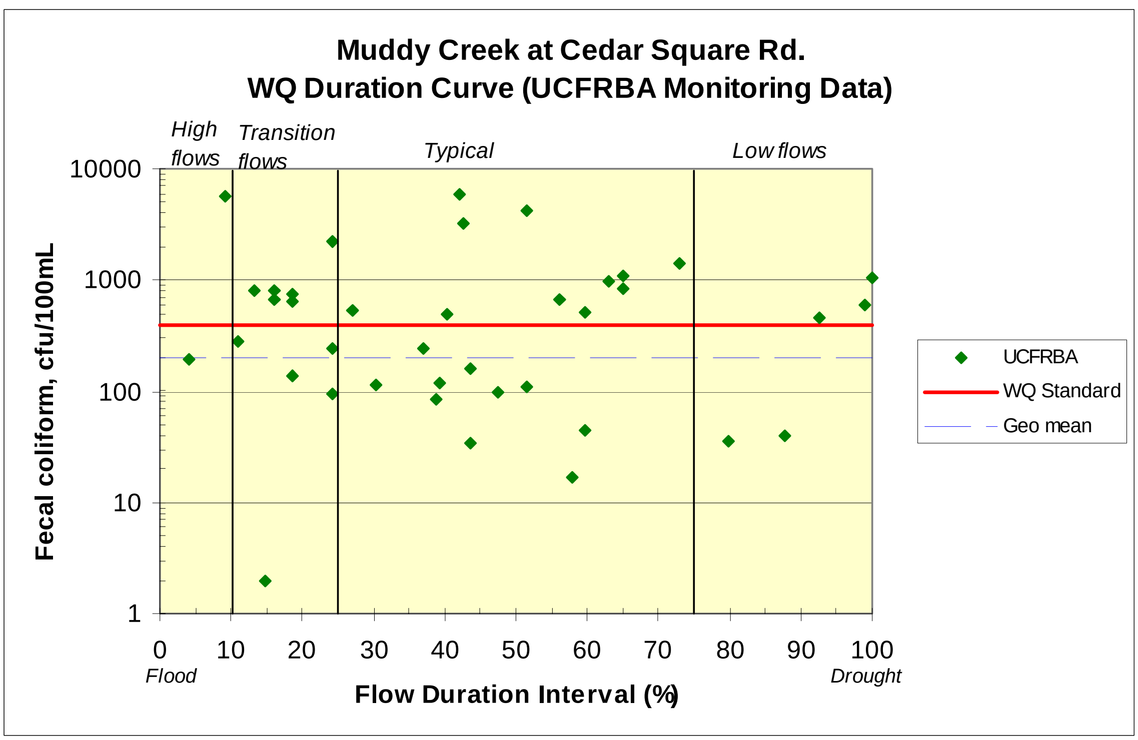

Figure 12. Flow-Duration Curve for NCDENR Fecal Coliform Data for Muddy Creek at Cedar Square Road (4/27/00 through 6/5/03)

3.3 Determination of Existing Fecal Coliform Load and Assimilative Capacity

The fecal coliform assessment uses the Flow-Duration Curve approach for determination of the existing load and assimilative capacity. The analysis was performed for both the instantaneous and geometric mean standard to determine the most conservative measure of impairment. Figure 13 through Figure 18 present the results of the instantaneous and geometric mean load-duration analyses based on NCDENR data collected for Richland Creek at Riverdale Road and for Muddy Creek at Muddy Creek Road and State Road 1936. The average of the five flow observations corresponding to the five fecal coliform sample dates was used as the flow for each geometric mean load.

The load-duration curves developed in this section provide guidance in the determination of the pollutant sources that are likely to be the primary contributors to elevated levels of fecal coliform. For example, elevated fecal coliform levels that occur only during typical and high flow events are not likely to be caused by continuously discharging sources, such as failing septic systems. Nonpoint sources and sporadic sources such as sanitary sewer overflows are likely to be the main focus of the inventory in this case.

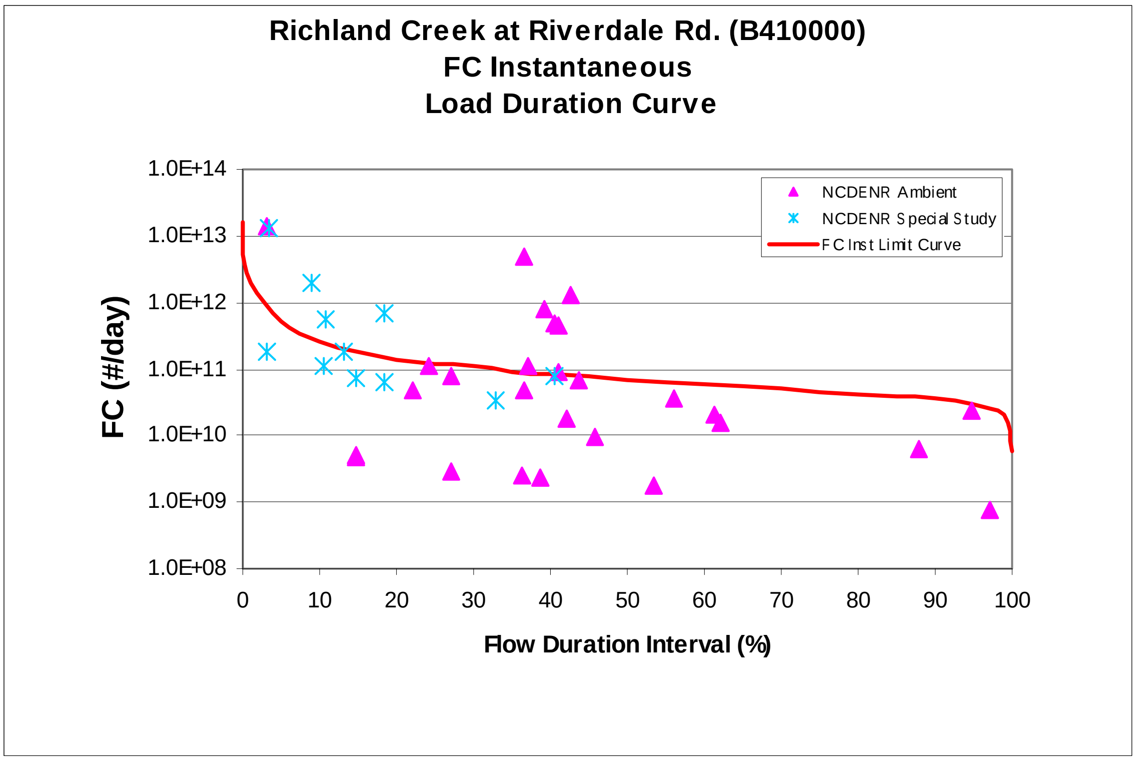

Figure 13. Instantaneous Fecal Coliform Load-Duration Curve for Richland Creek at Riverdale Road

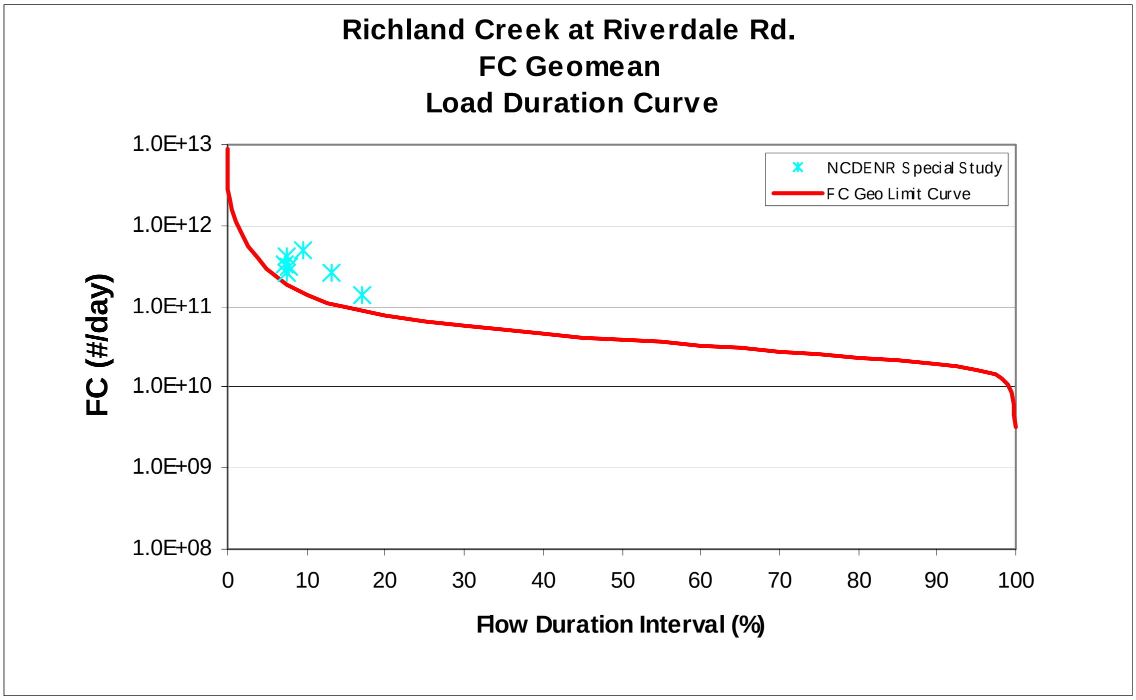

Figure 14. Geometric Mean Fecal Coliform Load-Duration Curves for Richland Creek at Riverdale Road

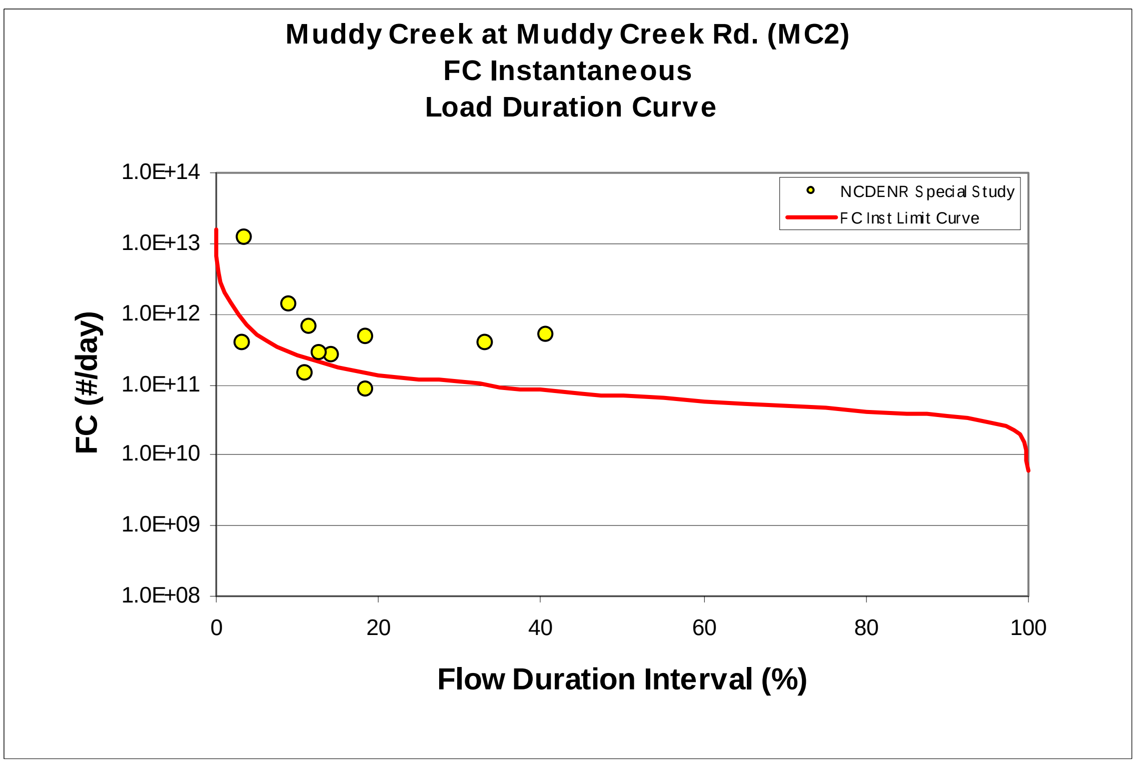

Figure 15. Instantaneous Fecal Coliform Load-Duration Curve for Muddy Creek at Muddy Creek Road (MC2)

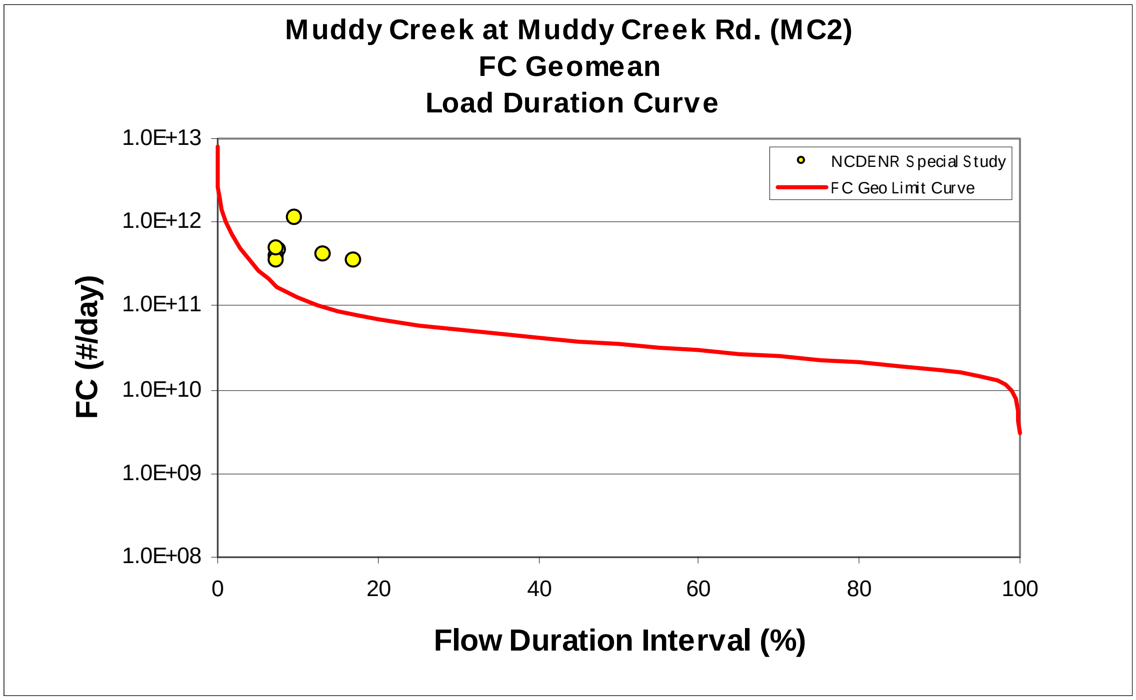

Figure 16. Geometric Mean Fecal Coliform Load-Duration Curves for Muddy Creek at Muddy Creek Road (MC2)

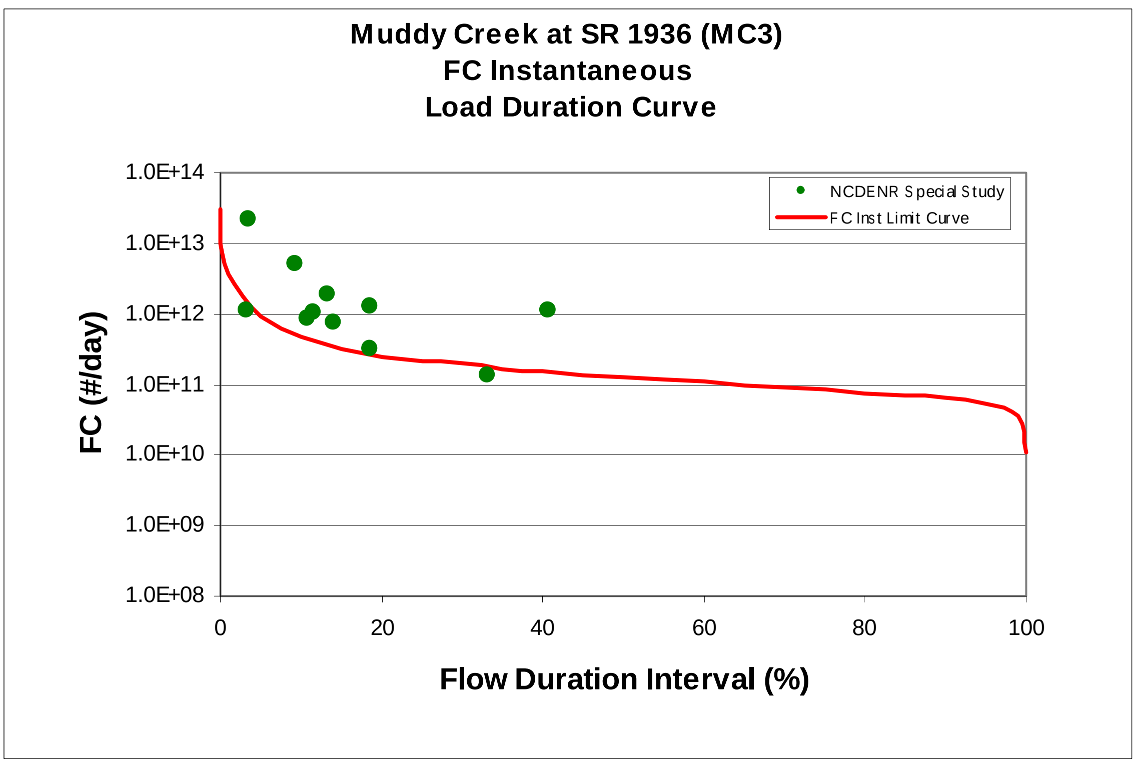

Figure 17. Instantaneous Fecal Coliform Load-Duration Curve for Muddy Creek at SR 1936 (MC3)

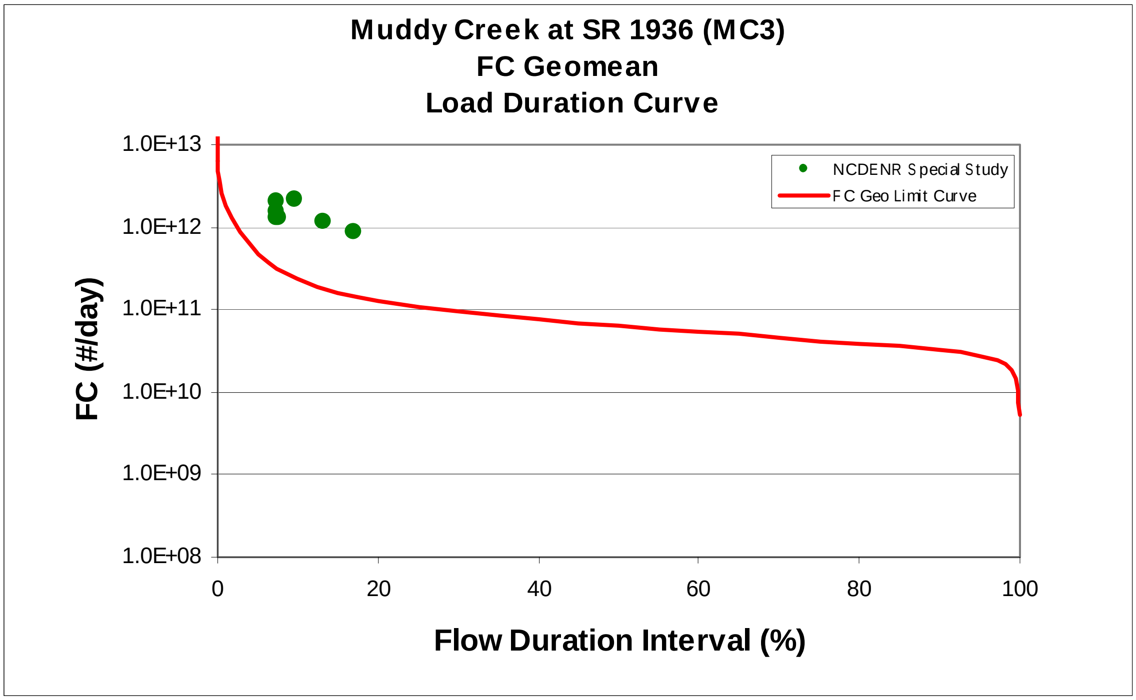

Figure 18. Geometric Mean Fecal Coliform Load-Duration Curves for Muddy Creek at SR 1936 (MC3)

4 TMDL Development

Sections 1 through 3 described the processes and rationale required to identify the endpoints, critical conditions, potential sources, and target loadings for each pollutant. These efforts formed the basis for the TMDL process. This section describes the key components required by the TMDL guidelines and synthesizes the project efforts to set the final TMDL allocations.

4.1 TMDL DEFINITION

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality criteria (in this case a target for warm water aquatic habitat). TMDLs can be expressed in terms of mass per time or by other appropriate measures such as concentration. TMDLs are comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

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

4.2 TMDL ENDPOINTS

TMDL endpoints represent the instream water quality targets used in quantifying TMDLs and their individual components. As discussed in Section 3, there are two endpoints that will be used to determine the fecal coliform TMDL, as specified in the North Carolina water quality standards. Both the instantaneous limit of 400 cfu/100 mL and the geometric mean of 200 cfu/100 mL will be considered.

4.3 CRITICAL CONDITIONS

Based on the load-duration curves, the greatest frequency of exceedances for fecal coliform occur during the summer period. The Load-Duration-Curve approach addresses the load reductions required during all flow regimes and all seasons.

4.4 SEASONAL VARIATIONS

Seasonal variation is considered in the development of the TMDLs because the allocation applies to all seasons. As noted in the critical conditions section, the majority of the exceedances occur during the summer months.

4.5 MARGIN OF SAFETY (MOS)

There are two methods for incorporating a MOS in the analysis: 1) by implicitly incorporating the MOS using conservative model assumptions to develop allocations; or 2) by explicitly specifying a portion of the TMDLs as the MOS and using the remainder for allocations. For the purposes of this analysis, an explicit 10 percent margin of safety was specified.

4.6 TMDL CURVES

The load-duration curves presented in Section 3.3 provide the basis for the reductions required to meet the TMDL targets. Allowable load curves were calculated using the water quality standards and a 10% MOS. Based on guidance from EPA Region 4 and NCDENR, data collected during extreme drought conditions (>95th percentile) and floods (<10th percentile) were excluded from the reduction analysis. Load-duration curves were generated from historical monitoring data and combined flow and observed concentrations to show the times when the assimilative capacity of the stream was exceeded.

Reductions were first estimated by developing a regression between exceedance points and the flow interval. At every 5th percentile flow recurrence, the existing loads were calculated from the regression equation the allowable loadings were calculated from the TMDL target value. Review of the statistical power of these regressions, however indicated that valid regression curves for existing loading could not be estimated from the observed data. Therefore, the geomean of the exceedances was used as an estimate of the existing load.

The allowable loads using the instantaneous standard for each exceedance were calculated based on the TMDL target value of 360 CFU/100mL. Similarly, for the geomean standard, the allowable loadings were calculated from the TMDL target value of 180 CFU/100mL. The geomeans of the exceedances and the allowable loads were used to calculate the percent that the existing load exceeded the target. The target curves based on the allowable loads and the exceedances used for the existing loads are shown in Figure 19 through Figure 22.

The loading estimates as well as the average values are presented in Appendix B. A summary of the estimated reductions required to meet the TMDL target are presented in Table 7. It can be seen that the instantaneous target is the most stringent for Richland Creek, whereas in Muddy Creek the geometric mean limit is more stringent at MC2. The target on Muddy Creek is based on MC2 because its location is likely to be more indicative of future riverine conditions, whereas MC3 is located well within Randleman Reservoir. Nonetheless, the reductions will apply to the entire watershed.

Table 7. Summary of Estimated Reductions

Stream	Pollutant	Target	Reduction Required
Richland Creek at Riverdale Road	Fecal coliform (Instantaneous Limit)	<360 cfu/100 mL	**82%**
Richland Creek at Riverdale Road	Fecal coliform (Geometric Mean Limit)	<180 cfu/100 mL	55%
Muddy Creek at MC2	Fecal coliform (Instantaneous Limit)	<360 cfu/100 mL	66%
Muddy Creek at MC2	Fecal coliform (Geometric Mean Limit)	<180 cfu/100 mL	**80%**

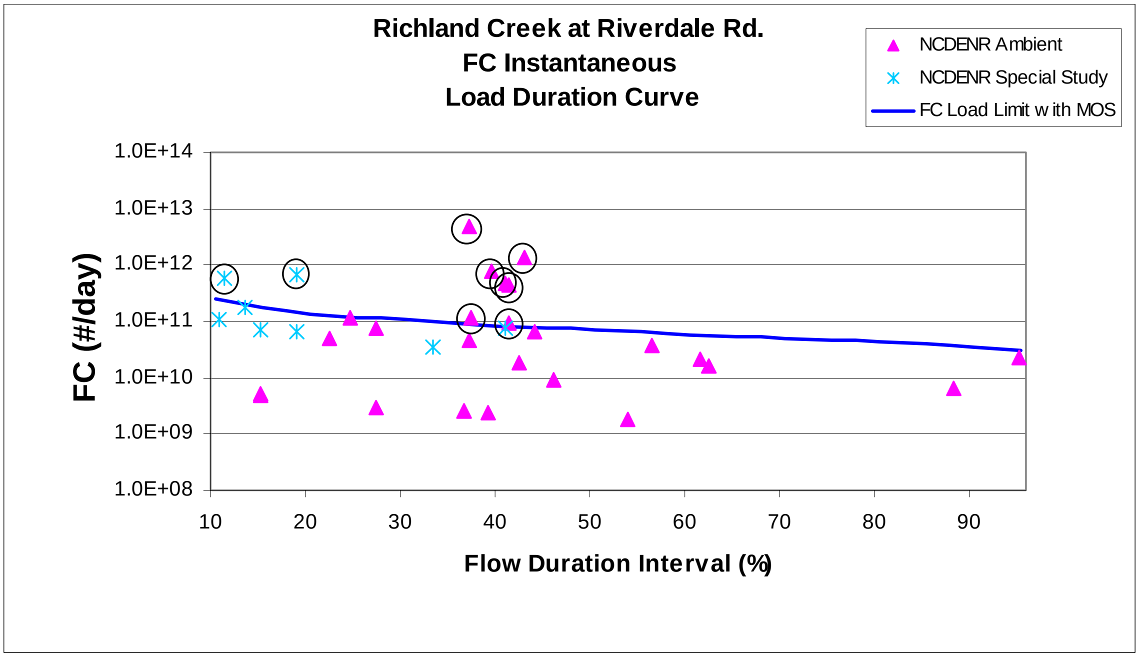

Figure 19. TMDL Curve Based on Instantaneous Fecal Coliform Standard for Richland Creek at Riverdale Road, Exceedances Circled

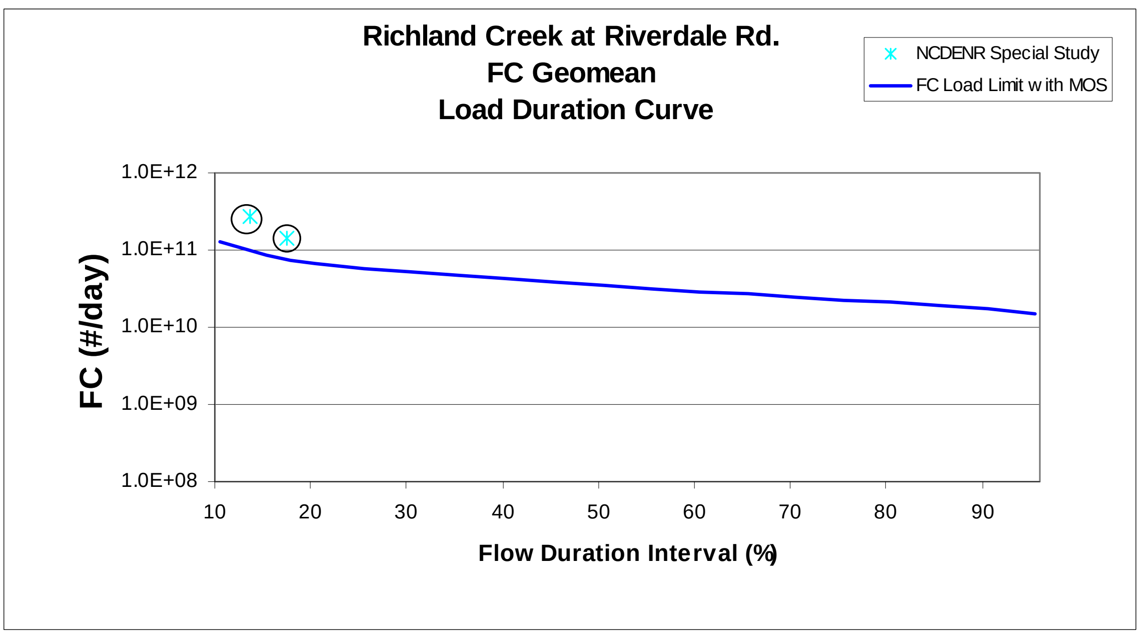

Figure 20. TMDL Curve Based on Geometric Mean Fecal Coliform Standard for Richland Creek at Riverdale Road, Exceedances Circled

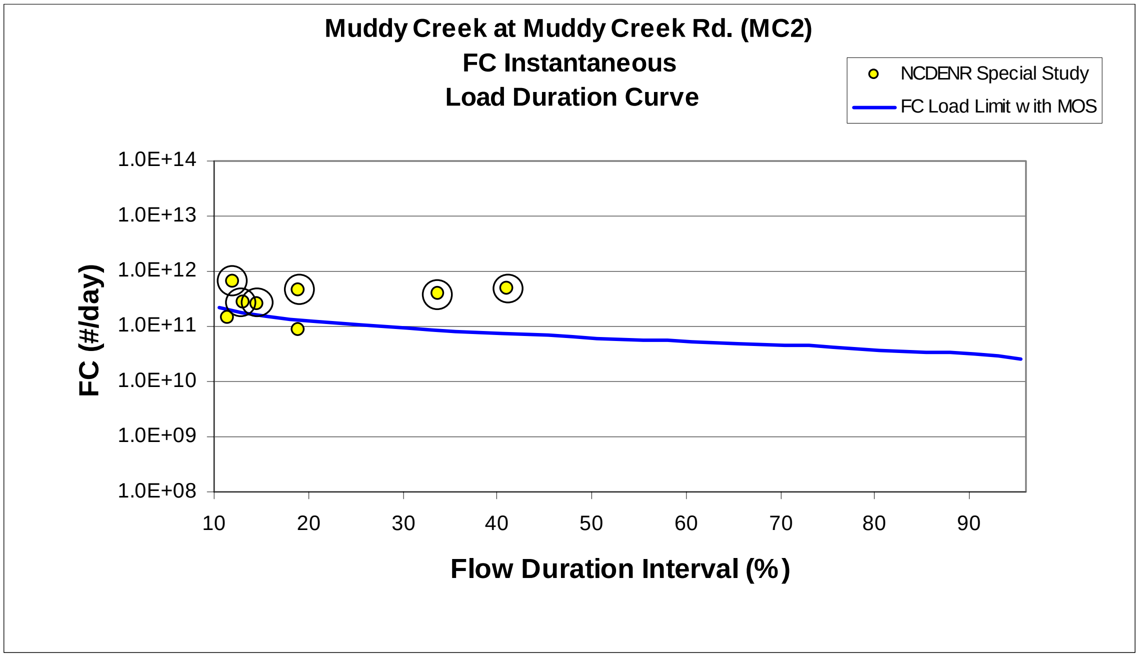

Figure 21. TMDL Curve Based on Instantaneous Fecal Coliform Standard for Muddy Creek at Muddy Creek Road, Exceedances Circled

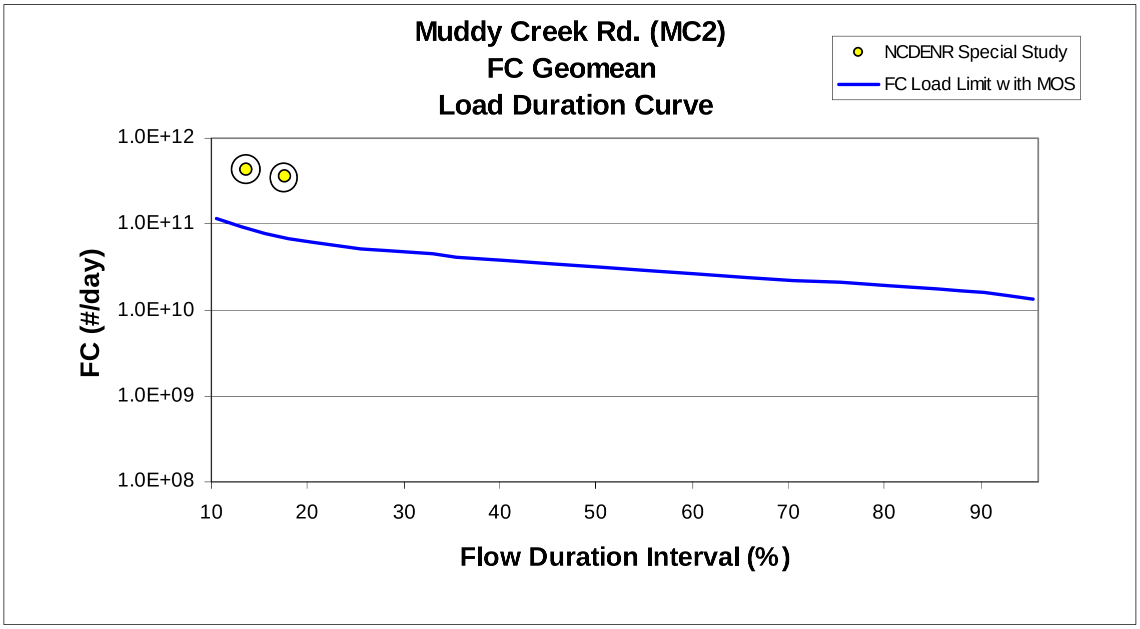

Figure 22. TMDL Curve Based on Geometric Mean Fecal Coliform Standard for Muddy Creek at Muddy Creek Road, Exceedances Circled

4.7 TMDL SUMMARY

The load-duration curves for the existing and target conditions were evaluated to determine the reductions needed to meet the TMDL endpoints. The higher reduction requirement will be selected to provide an added margin of safety to the TMDL. To achieve the specified TMDL targets, significant reductions were required. These are summarized in Table 8.

Table 8. TMDL Reductions for Fecal Coliform

Stream	Pollutant	Target	Existing Load (#/day)	Target Load (#/day)	Reduction Required
Richland Creek	Fecal coliform (Instantaneous Limit)	<360 cfu/100 mL	5.47E+11	9.99E+10	82%
Muddy Creek	Fecal coliform (Geometric Mean Limit)	<180 cfu/100 mL	3.85E+11	7.87E+10	80%

Further analysis was required to determine the breakdown between point source (WLA) and nonpoint source (LA) loadings that meet the TMDL objectives. Based on the EPA guidance in regards to the Phase II Rule, urban stormwater runoff from an MS4 is considered as a WLA component.

The entire Richland Creek watershed falls within the Phase II boundaries. Therefore, all fecal loadings from urban landuses are assigned to the WLA component. Loadings from agricultural and forested areas are considered as nonpoint sources and are reported as LAs. The distribution of the urban and rural landuses, 51.3 percent and 48.7 percent respectively, was determined from the NLCD landuse coverage discussed in Section 2. Similarly, the distribution of urban and rural lands inside and outside of the MS4 areas were determined for Muddy Creek.

The relative loading rates between the urban and rural landuse types was determined based on analysis of fecal coliform runoff data collected by USGS and summarized in the report *Relation of Land Use to Streamflow and Water Quality at Selected Sites in the City of Charlotte and Mecklenburg County, North Carolina, 1993-98* (USGS, 1999). Water quality data was collected at nine sites which drained relatively homogeneous landuses in order to estimate the pollutant yields from each. Average fecal coliform concentrations were calculated by combining the estimates for the urban and rural watersheds (See Appendix B). The relative percent contributions of fecal coliform were combined with the landuse distribution to estimate the overall relative loading ratios for urban (MS4) and rural (non MS4) areas (Table 9).

Table 9. Relative Fecal Coliform Contributions Rates

Stream	Urban (% of Load)	Rural (% of Load)
Richland Creek	70	30
Muddy Creek	36	64

The assimilative capacity determined in Section 3.3 was split based on the relative contributions presented in Table 9 to determine the WLA and LA components. The results of these calculations are summarized in Table 10.

Table 10. Richland Creek and Muddy Creek TMDL Components

Segment	Pollutant	Existing	WLA[1]	LA	MOS[2]	TMDL
Richland Creek	Fecal coliform (counts/day)	5.47E+11	7.05E+10	2.94E+10	Explicit 10% MOS	9.99E+10
Muddy Creek	Fecal coliform (counts/day)	3.85E+11	2.86E+10	5.01E+10	Explicit 10% MOS	7.87E+10

[1]WLA includes NPDES continuous point sources (0.035E+10 counts/day) plus MS4 load.

[2]Margin of safety (MOS) equivalent to 10 percent of the target concentration for fecal coliform.

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5 Report Summary

This report presents the development of Total Maximum Daily Loads (TMDLs) for fecal coliform impairments of Richland Creek and Muddy Creek near High Point, North Carolina. These waterbodies were placed on the North Carolina 2002 list of impaired waters (the 303(d) list) for fecal coliform. Available water quality data were reviewed to determine the frequency of exceedances. The flow-duration curve method was applied to determine the critical periods and the sources that lead to exceedances of the standard.

The potential sources determined from the load-duration curve were inventoried, and an assessment of their relative contributions was used to allocate reductions among sources. A review of fecal coliform data indicates that urban source contributions, such as leaking sewer-pipes and septic systems, are a significant source of much of the fecal coliform impairment. Additional fecal coliform loading from nonpoint sources such as stormwater runoff also appear to contribute to instream concentrations. These results were used to derive the allocations required by the TMDL. The specified reductions can be achieved with an increased emphasis on identification and repair of aging sewer and septic systems, minimization of SSO events, and review of current agricultural manure control practices.

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6 TMDL Implementation Plan

Reductions for fecal coliform should be sought through identification and repair of aging sewer and septic systems and removal of SSOs. Implementation should also target storm-driven sources such as runoff from residential areas and agricultural land.

The TMDL analysis was performed using the best data available to specify the fecal coliform reductions necessary to achieve water quality criteria. The intent of meeting the criteria is to support the designated use classifications in the watershed. A detailed implementation plan is not included in this TMDL. The involvement of local governments and agencies will be needed in order to develop an implementation plan.

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7 Stream Monitoring

Monitoring of Richland and Muddy Creeks will be conducted during the next basinwide cycle following approval of the TMDL. The continued monitoring of fecal coliform will allow for the evaluation of progress towards the goal of achieving water quality standards and intended best uses. While the TMDLs has been set at Riverdale Road on Richland Creek and Muddy Creek Road on Muddy Creek, DWQ will need to assess whether additional monitoring locations are needed once the Randleman Reservoir is completed.

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8 Future Efforts

MS4 jurisdictions within the study area are Guilford County, the City of Archdale, and the City of High Point. Randolph County was not required to have an MS4 permit in 2003. Guilford County submitted its Phase II MS4 permit application in 2003 and has been enforcing watershed protection since 1984. According to its permit application and current development ordinance, the county will continue to enforce the use of stormwater BMPs in water supply watersheds and improve the monitoring of these BMPs (Guilford County, 2003).

The City of High Point and the City of Archdale submitted applications for Phase II MS4 permits in March 2003. High Point requires erosion control plans for any land-disturbing activity greater than 1 acre (City of High Point, 2003). The city began requiring stormwater controls in 1993 (Boone, 2003). The city requires a watershed development plan for any lot greater than 20,000 square feet (City of High Point, 2003). The City of Archdale began requiring storm water controls in the mid-1990s (Wells, 2003).

All of the MS4 jurisdictions in the study area enforce state water-supply-watershed development regulations for Randleman Reservoir. Richland Creek and Muddy Creek drain the General Watershed Overlay District and the downstream portions of the watersheds include Randleman Reservoir's Critical Area.

The City of Archdale and the City of High Point include areas which may have aging infrastructure. These areas can be significant sources of fecal coliform during low flow periods due to leaking sewers and during high flow events due to increased infiltration and subsequent sanitary sewer overflows. Review of past monitoring data and additional monitoring efforts can be used to identify potential problem areas which require additional maintenance.

The current discharge permits for the NPDES permitted point sources are designed to meet water quality standards at the end of the pipe. Inspection and enforcement efforts should be continued to ensure that these limits are being met.

Other potential mechanisms for reduction of fecal coliform include local regulations or ordinances related to zoning, landuse, or storm water runoff controls. Local governments can provide funding assistance through general revenues, bond issuance, special taxes, utility fees, and impact fees. Additional mechanisms may employ concurrent education and outreach, training, technology transfer, and technical assistance with incentive-based pollutant management measures. The State and local governments will take the primary lead in the TMDL implementation.

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9 Public Participation

A draft of the TMDL was noticed through various public means, including notification in the local newspapers, *High Point Enterprise* and *Courier Tribune*. DWQ distributed the draft TMDL and public comment information to known interested parties. The TMDL was available from the Division of Water Quality's website at http://h2o.enr.state.nc.us/tmdl/ during the comment period. A public meeting was held on March 9 to present the TMDL and answer questions. Three people plus DWQ staff attended. The public comment period lasted from February 19, 2004 to March 22, 2004. No comments were received.

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10 Further Information

Further information concerning North Carolina's TMDL program can be found on the Internet at the Division of Water Quality website**:**

http://h2o.enr.state.nc.us/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the DWQ Modeling/TMDL Unit:

J. Todd Kennedy, Modeler and Project Manager

e-mail: Todd.Kennedy@ncmail.net

Michelle Woolfolk, Supervisor

e-mail: Michelle.Woolfolk@ncmail.net

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12 Appendices

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APPENDIX A WATER QUALITY SAMPLING DATA

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Table 11. NCDENR Ambient Monitoring Data for Richland Creek (1997-2000)

Date	Flow (cfs)[a]	Flow Regime (%)	Riverdale Road (#/100 mL)
10/23/1997	9.0	38.0	470
11/19/1997	8.8	38.3	10
12/17/1997	7.7	45.7	45
1/26/1998	13.0	24.3	320
2/26/1998	11.0	30.4	10
3/17/1998	9.2	36.7	10
4/22/1998	11.0	30.4	260
5/20/1998	8.2	42.6	81
6/17/1998	8.3	41.0	410
7/16/1998	19.0	14.8	10
8/18/1998	5.9	61.2	130
9/9/1998	9.1	36.7	190
10/14/1998	3.0	95.7	290
11/5/1998	2.8	97.0	10
12/15/1998	6.7	54.1	10
1/19/1999	18.0	16.0	10
3/17/1999	8.1	42.6	6000
7/27/1999	3.7	87.8	64
8/31/1999	8.0	43.7	310
9/30/1999	89.0	3.1	6000
10/28/1999	6.5	56.1	210
11/23/1999	5.8	62.0	
12/28/1999	5.8	62.0	100
2/23/2000	8.7	39.2	3300
3/30/2000	8.4	41.0	2100
4/26/2000	9.1	36.7	20000
5/30/2000	8.3	41.0	2000
6/28/2000	14.0	22.1	130

[a] Flow adjusted from USGS East Fork Deep River Gage 02099000

Table 12. NCDENR Special Study Monitoring Data for Richland Creek and Muddy Creek (2003)

Date	Flow (cfs) [a]	Flow Regime (%)	Baker Road (#/100 mL)	Muddy Creek Road (#/100 mL)	Riverdale Road (#/100 mL)	SR 1936 (#/100 mL)	Weant Road (#/100 mL)
5/20/2003	19	14.8	420	560	140	900	930
5/27/2003	24	11.5	1200	1100	880	1000	2000
5/29/2003	16	18.5	420	220	150	440	900
6/3/2003	86	3.2	600	180	80	290	310
6/5/2003	29	9.2	4300	1900	2600	4000	2000
6/10/2003	25	10.9	390	240	160	770	340
6/17/2003	21	13.2	1300	540	320	2000	870
6/19/2003	16	18.5	5500	1200	1600	1800	1900
6/24/2003	9.9	33.2	340	1600	130	300	1100
7/1/2003	8.4	41.0	570	2400	340	3000	2300
7/2/2003	81	3.4	6000	6000	6000	6000	6000

[a] Flow adjusted from USGS East Fork Deep River Gage 02099000

Table 13. UCFRBA Monitoring Data for Richland Creek and Muddy Creek (2000-2003)

Date	Flow (cfs) [a]	Flow Regime (%)	Baker Road (#/100 mL)	Cedar Square Road (#/100 mL)
4/27/2000	8.00	0.44	5600	160
5/5/2000	7.00	0.52	290	110
6/6/2000	13.00	0.24	5000	2200
7/7/2000	5.50	0.66	19000	840
8/3/2000	8.30	0.41	6000	5800
9/7/2000	11.00	0.30	460	530
10/11/2000	6.40	0.56	240	660
11/21/2000	5.60	0.65	1000	1080
12/6/2000	6.10	0.60	42	44
1/18/2001	16.00	0.19	1990	740
2/16/2001	21.00	0.13	1820	820
3/15/2001	68.00	0.04	4600	195
4/6/2001	16.00	0.19	74	140
5/11/2001	9.10	0.37	730	240
6/15/2001	8.10	0.43	5600	3200

Date	Flow (cfs) [a]	Flow Regime (%)	Baker Road (#/100 mL)	Cedar Square Road (#/100 mL)
7/2/2001	5.80	0.62	770	960
8/2/2001	8.70	0.39	534	120
9/4/2001	19.00	0.15	520	2
10/3/2001	4.80	0.73	800	1400
11/2/2001	3.70	0.88	114	40
12/14/2001	6.00	0.61	2200	520
1/4/2002	8.80	0.38	103	83
2/6/2002	7.90	0.44	54	34
3/6/2002	6.20	0.59	34	17
4/3/2002	4.40	0.79	2	36
5/3/2002	7.40	0.47	960	100
6/4/2002	3.40	0.91	500	460
7/2/2002	6.90	0.52	12000	4200
8/7/2002	0.64	1.00	1700	1060
9/3/2002	8.50	0.41	400	500
10/3/2002	2.20	0.99	12000	600
11/8/2002	13.00	0.24		245
11/15/2002	14.00	0.22	1080	
12/10/2002	17.00	0.17	255	800
1/7/2003	10.00	0.33	74	115
2/5/2003	17.00	0.17	110	680
3/11/2003	13.00	0.24	400	95
4/14/2003	24.00	0.12	640	280
5/8/2003	16.00	0.19	295	640
6/5/2003	29.00	0.09	8400	5600

[a] Flow adjusted from USGS East Fork Deep River Gage 02099000

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APPENDIX B LOAD REDUCTION CALCULATIONS

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Table 14. Richland Creek at Riverdale Road: Estimation of Load Reduction (#/day) Based on Fecal Coliform Instantaneous Standard

Flow Interval	Target Load	Existing Load
37	8.74E+10	1.14E+11
41	8.06E+10	9.18E+10
42.6	7.87E+10	1.31E+12
39.2	8.45E+10	7.75E+11
40.6	8.16E+10	4.76E+11
36.7	8.84E+10	4.91E+12
41	8.06E+10	4.48E+11
10.9	2.33E+11	5.70E+11
18.5	1.55E+11	6.91E+11
Geomean	**9.99E+10**	**5.47E+11**

Table 15. Richland Creek at Riverdale Road: Estimation of Load Reduction (#/day) Based on Fecal Coliform Geometric Mean Standard

Flow Interval	Target Load	Existing Load
13.2	9.80E+10	2.66E+11
17.1	7.80E+10	1.41E+11
Geomean	**8.75E+10**	**1.93E+11**

Table 16. Muddy Creek at Muddy Creek Road: Estimation of Load Reduction (#/day) Based on Fecal Coliform Instantaneous Standard

Flow Interval	Target Load	Existing Load
14.1	1.66E+11	2.58E+11
11.5	2.10E+11	6.41E+11
12.6	1.84E+11	2.75E+11
18.5	1.40E+11	4.66E+11
33.2	8.66E+10	3.85E+11
40.6	7.35E+10	4.90E+11
Geomean	**1.34E+11**	**3.99E+11**

Table 17. Muddy Creek at Muddy Creek Road: Estimation of Load Reduction (#/day) Based on Fecal Coliform Geometric Mean Standard

Flow Interval	Target Load	Existing Load
13.2	8.82E+10	4.22E+11
17.1	7.02E+10	3.52E+11
Geomean	**7.87E+10**	**3.85E+11**

Table 18. Estimates of Fecal Coliform Loading Rates for Urban and Rural Lands

Landuse Type	FC Conc. (mg/L)[1]
Mixed forest/pasture/ low density residential	15
Mixed forest, pasture, medium- and low-density residential	20
Mixed forest, pasture, medium- and low-density residential	24.5
Average Rural	**19.8**
Industrial	27.5
Industrial	14.6
Medium-density residential	29
Medium-density residential	26.5
High-density residential	15
Developing	13
Average Urban	**20.9**

Source: USGS 1999

[1] Loading estimates not developed by USGS for coliform

Table 19. Estimates of Direct Fecal Coliform Contribution from Urban Sources

Typical SSO and Sewer Effluent Concentration (#/100mL)	Estimated Percent of Storm Event Contribution	Additional Contribution to Urban Fecal Loading Rate (#/100mL)
10,000[1]	0.256[2]	25.6

[1] Source: (EPA, 2001)

[2] Based on reported SSO overflows

Table 20. Relative Urban and Rural Fecal Coliform Areal Loading for Richland Creek

Landuse	Landuse Distribution	Relative FC Rate	FC Loading Ratio
Rural (non-MS4)	50.5%	19.8	29.9%
Urban (MS4)	49.5%	46.5	70.1%

Note: Fecal coliform data collected at nine urban and rural sites were analyzed to estimate average fecal coliform concentrations in stormwater runoff. The urban rate estimate was increased based on available SSO and sewer break monitoring and literature to represent the non-runoff associated contributions. The relative percent contributions of fecal coliform were multiplied by the landuse distribution and normalized to estimate the relative loading ratio for urban (MS4) and rural (non MS4) areas.

Table 21. Relative Urban and Rural Fecal Coliform Areal Loading for Muddy Creek

Landuse	Landuse Distribution	Relative FC Rate	FC Loading Ratio
Rural (non-MS4)	28.2%	19.8	64.3%
Rural (in MS4 area)	32.3%	19.8	Combined with Rural (non-MS4) contribution
Urban (not in MS4 area)	4.9%	46.5	Combined with Rural (non-MS4) contribution
Urban (MS4)	34.6%	46.5	35.7%

Note: Fecal coliform data collected at nine urban and rural sites were analyzed to estimate average fecal coliform concentrations in stormwater runoff. The relative percent contributions of fecal coliform were multiplied by the landuse distribution and normalized to estimate the relative loading ratio for urban (MS4) and rural (non MS4) areas.

APPENDIX C AFFIDAVITS OF PUBLICATION FOR PUBLIC NOTICE

NORTH CAROLINA-
RANDOLPH COUNTY

AFFIDAVIT OF PUBLICATION

Before the undersigned, a Notary Public of said County and State, duly commissioned, qualified, and authorized by law to administer oaths, personally appeared

MARIA R. SHAW

who being first duly sworn, deposes and says, that he (she) is

BUSINESS MANAGER

of The Courier-Tribune, engaged in the publication of a newspaper known as The Courier-Tribune, published, issued, and entered as second class mail in the City of Asheboro, in said County and State; and that he (she) is authorized to make this affidavit and sworn statement; that the notice or other legal advertisement, a true copy of which is attached hereto, was published in The Courier-Tribune on the following dates:

February 19, 2004

and that the said newspaper in which such notice, paper, document, or legal advertisement was published was, at the time of each and every such publication, a newspaper meeting all of the requirements and qualifications of Section 1-597 of the General Statutes of North Carolina, 1943, as amended, and was a qualified newspaper within the meaning of Section 1-597 of the General Statutes of North Carolina.

This 19th day of February, 2004

Maria Shaw

Sworn to and subscribed before me this 19th day of February, 2004

Janice W Skinner

Notary Public

My commission expires: 6/19/06

Public Notice
State of North Carolina
Division of Water Quality

[illegible]

NORTH CAROLINA
GUILFORD COUNTY

AFFIDAVIT OF PUBLICATION

Before the undersigned, a Notary Public of said County and State, duly commissioned, qualified, and authorized by law to administer oaths, personally appeared Carol F. Elliott, who being first duly sworn, deposes and says: that she is Advertising billing Manager of THE HIGH POINT ENTERPRISE, INC. engaged in the publication of a newspaper known as THE HIGH POINT ENTERPRISE, published, issued, and entered as second class mail in the City of High Point in said County and State; that (she) is authorized to make this affidavit and sworn statement; that the notice or other legal advertisement, a true copy of which is attached hereto, was published in The High Point Enterprise on the following dates:

February 19, 2004

and that the said newspaper in which such notice, paper, document, or legal advertisement was published was, at the time of each and every such publication, a newspaper meeting all the requirements and qualifications of Section 1-597 of the General Statutes of North Carolina and was a qualified newspaper within the meaning of Section 1-597 of the General Statutes of North Carolina.

This 23rd day of March 20 04

Carol F. Elliott

Sworn to and subscribed before me, this 23rd day of March 20 04

Retta G. Edwards
Notary Public

My Commission expires

OFFICIAL SEAL
DAVIDSON COUNTY
My Commission Expires

My Commission Expires 1-16-2006