Total Maximum Daily Loads for Fecal Coliform for Newfound Creek, North Carolina

[Waterbody ID NC_6-84b, Waterbody ID NC_6-84c,
Waterbody ID NC_6-84d]

Final Report
January 2005
(Approved February 8, 2005)

Upper French Broad River Basin

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SUMMARY SHEET

Total Maximum Daily Load (TMDL)

1. 303(d) Listed Waterbody Information

State: North Carolina

County: Buncombe

Major River Basin: Upper French Broad River Basin

Watershed: Newfound Creek in Upper French Broad River Watershed HUC 06010105

Impaired Waterbody (2002 303(d) List):

Waterbody Name - (ID)	Water Quality Classification	Impairment	Length (mi)
Newfound Creek NC_6-84b	Class C Waters	Fecal Coliform	1.3
Newfound Creek NC_6-84c	Class C Waters	Fecal Coliform	2.3
Newfound Creek NC_6-84d	Class C Waters	Fecal Coliform	6.6

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 for fecal coliform bacteria were based on cumulative frequency distribution of flow conditions in the watershed. A predictive upper confidence limit about the regression line on load versus flow is compared to a criterion limit curve, calculated as the load that would occur at 90 percent of the water quality criterion (thus incorporating a margin of safety). Necessary reductions in load are calculated as the maximum distance between the confidence-bound on the regression line and the limit curve.

Critical Conditions:

Critical conditions are accounted for in the load curve analysis by determining the 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 continuous flow estimates 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
Newfound Creek	Fecal coliform (counts/day)	3.62×10^{12}	0.00	2.61×10^{11}	Explicit 10% MOS	92.8%	2.90×10^{11}

Notes:

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

[1] WLA = TMDL - LA - MOS; where TMDL is the average allowable load between the 95th and 10th percent flow exceeded.

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

4. Public Notice Date:

November 15th, 2004

5. Submittal Date: January 6th, 2005

6. Establishment Date:

7. Endangered Species (yes or blank):

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

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

1 Introduction

This report presents the development of a Total Maximum Daily Load (TMDL) for fecal coliform impairment of Newfound Creek. Newfound Creek near Asheville, North Carolina has been placed on the North Carolina 2002 list of impaired waters (the 303(d) list) and requires estimation of a TMDL for fecal coliform to meet the water quality standards specified for Class C waters. Newfound Creek is a headwater tributary to the French Broad River, located within Buncombe County (Figure 1), draining an area of approximately 34.7 square miles.

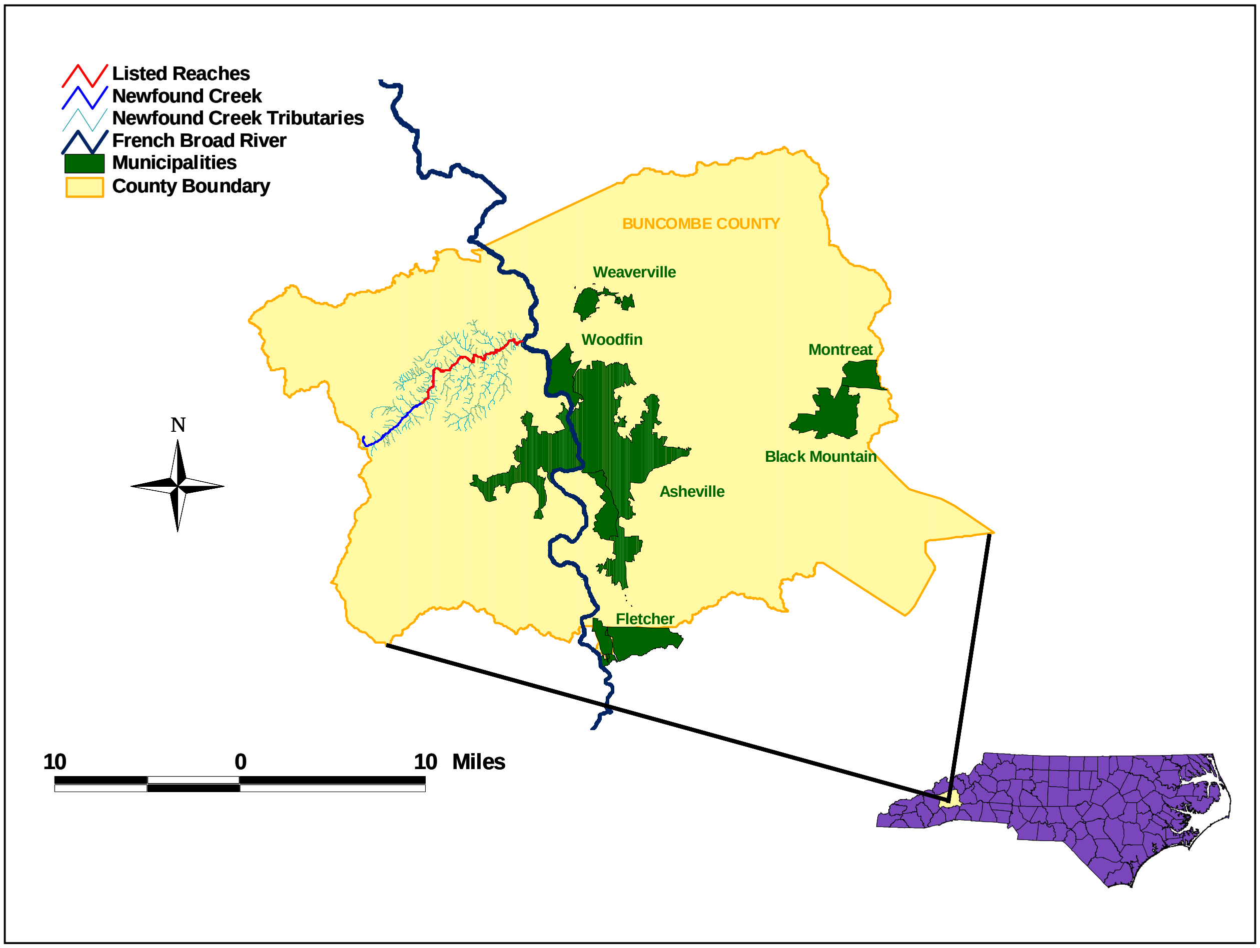

Figure 1. Location of Newfound Creek in Western Buncombe County

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 having 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, 1999) and the Federal Advisory Committee (USEPA, 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 Newfound Creek Fecal Coliform Impairments

The Newfound Creek listings are contained in the *North Carolina Water Quality Assessment and Impaired Waters List (2002 Integrated 305(b) and 303(d) Report)* (NCDENR, 2003). The segments of Newfound Creek considered impaired due to fecal coliform [Waterbody ID NC_6-84b, NC_6-84c, NC_6-84d] extend 10.2 miles from State Road 1296 to the French Broad River. Potential sources listed are non-urban development, agriculture, and pasture grazing in upland and riparian areas.

Newfound Creek has a designated use classification of Class C, which is intended to protect aquatic life and secondary recreational uses (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

Newfound Creek is located within Buncombe County in North Carolina (Figure 1). Newfound Creek extends 14.5 miles from its headwaters to the French Broad River (NC Subbasin 40301) and includes approximately 35.5 miles of mainstem and tributary perennial stream reaches. The creek drains approximately 34.7 square miles of land.

1.2.1 Land Use Distribution in the Newfound Creek Watersheds

Aerial photographs of the Newfound Creek Watershed were taken by the Tennessee Valley Authority in the year 2000 for purposes of developing a nonpoint source pollution inventory of the watershed. The land use distributions reported by TVA (2002) are summarized in this report and form the basis of the land use analysis.

Land use distribution was tabulated for the entire Newfound Creek Watershed. As shown in Table 1, the watershed is primarily forest (45.2 percent), pasture (35.4 percent), and residential land uses (14.7 percent). The upper portion of the watershed is primarily forest land in the headwaters with pasture and single family residential land uses along the streams (Figure 2). In the lower parts of the watershed, the land uses are primarily single family residential and pasture land with relatively less forested area.

Table 1. Land Use for the Newfound Creek Watershed, Acreage and Percent Composition (TVA, 2002)

Land Use	Forest	Pasture, Grass	Residential	Row Crop	Comm, Ind, Trans	Other	Total
Area (ac)	10,029.4	7,866.7	3,266.2	757.7	179.6	90.0	22,189.7
Area (%)	45.20%	35.45%	14.72%	3.41%	0.81%	0.41%	100.00%

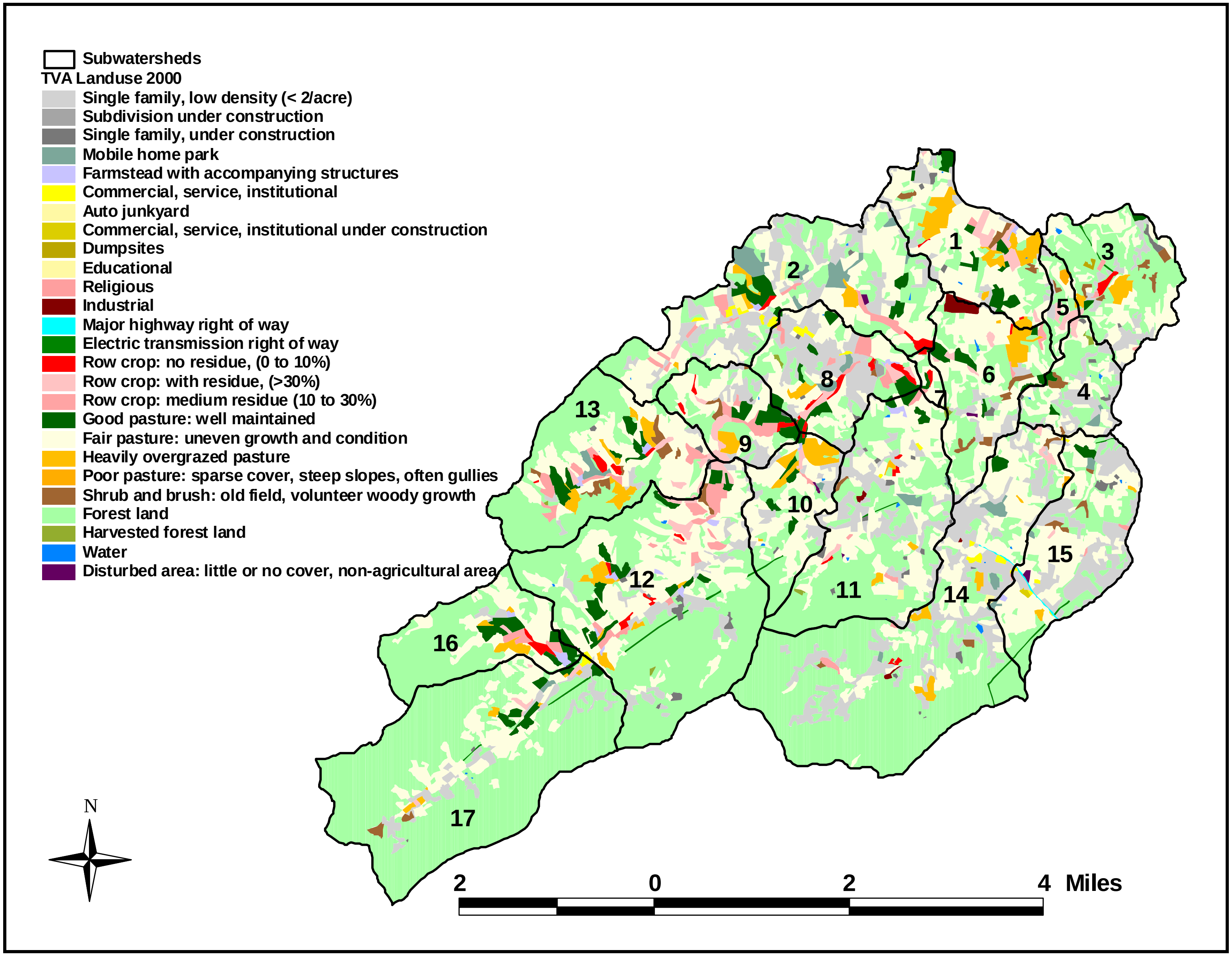

Figure 2. Newfound Creek Watershed Land Use (TVA, 2002)

1.3 FLOW GAGING

The U.S. Geological Survey (USGS) began monitoring flow on Newfound Creek at Jenkins Valley Road (Gage 03451690) in December 2000. Flow statistics for the gage are presented in Table 2 and Figure 3. Newfound Creek flow prior to December 2000 could not be scaled from nearby watersheds because the watersheds were either too large or differed significantly in land use distribution. Two of the larger watersheds had similar land use characteristics to the Newfound Creek Watershed: USGS 03453000 on Ivy River near Marshall and USGS 03500240 on Cartoogechaye Creek near Franklin. The Ivy River watershed is 57 square miles, and the Cartoogechaye watershed is 158 square miles. Flows prior to December 2000 were estimated for Newfound Creek by a regression analysis dependent on flows at the two gages. The natural log of flow at the Newfound Creek gage was regressed on the natural log of flow from the Ivy River and Cartoogechaye gages. As a result of the regression, the following equation was used to estimate flow for Newfound Creek.

$$F_{NF} = 0.21 F_C^{0.44} F_{IV}^{0.45}$$

where F_{NF} = Newfound Creek Flow (cfs);

F_C = Cartoogechaye Creek Flow (cfs); and

F_{IV} = Ivy River Flow (cfs)

The above equation explains nearly 80 percent of the variability in Newfound Creek flow (R^2= 0.79) and estimates reliable flows greater than the 10^{th} percentile (flows less than 28 cfs). Gaged and estimated flows on Newfound Creek were scaled to each monitoring station based on drainage area using the proportions in Table 3. These proportions represent the ratio of monitoring station drainage area to gaging station drainage area.

Table 2. Flow Statistics for USGS Gage 03451690 (Newfound Creek at Jenkins Valley Road)

Flow Parameter	Value (cfs)
Mean	16.1
Min	1.8
Max	694
High flow range	> 30
Transitional flow range	19 - 30
Typical flow range	8 - 19
Low flow range	< 8

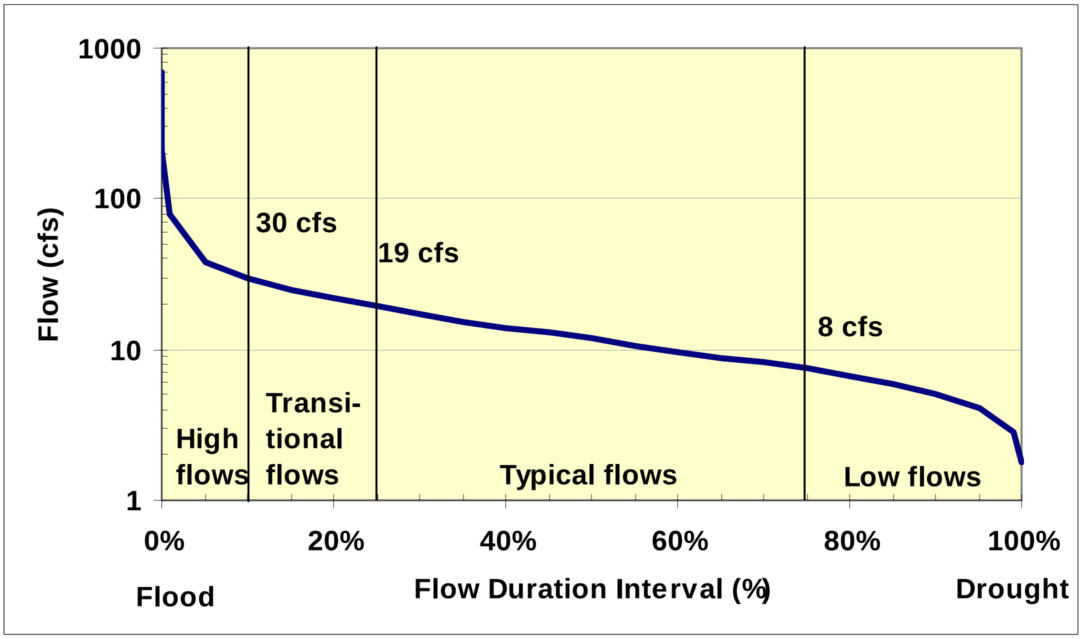

Figure 3. Flow Regimes for USGS Gage 03451690 (Newfound Creek at Jenkins Valley Road)

Table 3. Relative Proportion of Flow at USGS Gage 03451690 (Newfound Creek at Jenkins Valley Road) for Each Monitoring Station Drainage Area

Stream	Station	Relative Proportion of Gage Flow
Newfound Creek	Jenkins Valley Road (SR 1641)	1.00
Newfound Creek	Highway 63	0.47
Newfound Creek	McPeters Road	0.061

1.4 WATER QUALITY MONITORING

Water quality monitoring in the Newfound Creek Watershed has been conducted by three agencies (Figure 4). Data are presented in Appendix A. The North Carolina Department of Environment and Natural Resources (NCDENR) collected fecal coliform samples from three locations in the watershed from October 1996 through June 2003. Samples were collected at McPeters Road, Highway 63, and Jenkins Valley Road. The U.S. Geological Survey (USGS) collected fecal coliform samples on 5/28/2003 and 11/19/2003 at four locations along Newfound Creek (Haylandy Drive, State Road 1297, Old Newfound Road, and Jenkins Valley Road) and one location on Round Hill Branch at Rabbit Ham Road. The Buncombe County Soil and Water Conservation District (BCSWCD) began monitoring fecal coliform in April 2002 at ten locations in the watershed: four on Newfound Creek, four on Round Hill Branch, and two on Morgan Branch.

Water quality monitoring performed by NCDENR for fecal coliform has shown a number of excursions above the water quality standard at all three monitoring locations. Additional fecal coliform monitoring data, collected by the USGS and BCSWCD further supports the decision to list Newfound Creek for fecal coliform impairment.

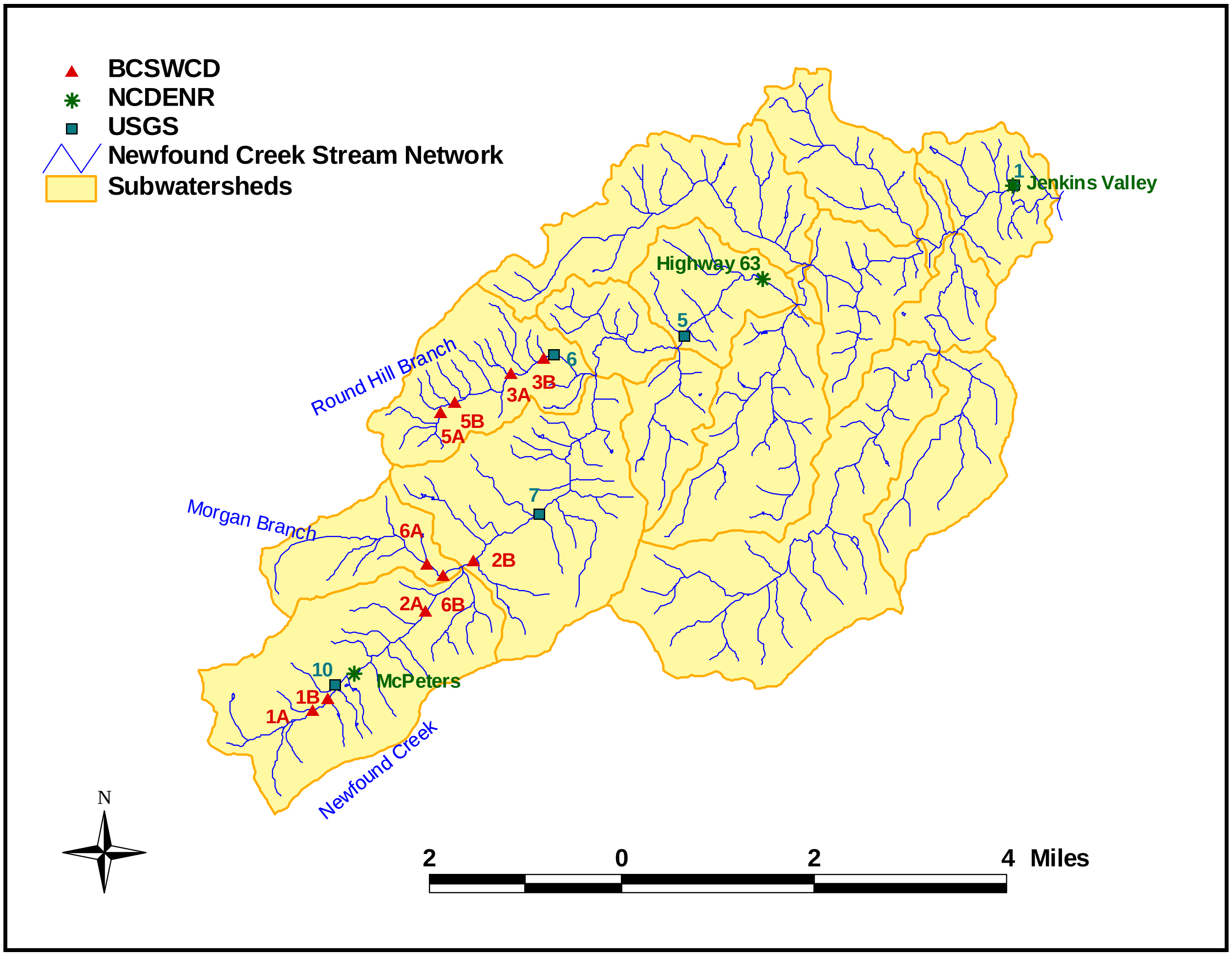

Figure 4. Newfound Creek Monitoring Locations

1.4.1 NCDENR Monitoring

Water quality monitoring in Newfound Creek was performed by NCDENR at three stations (Figure 4). Regular monitoring was performed at McPeters Road for the period from 12/16/1996 through 6/14/1999, at Highway 63 from 11/25/1996 through 6/14/1999, and at Jenkins Valley Road from 10/22/1996 through 6/14/1999. These data were collected approximately monthly. At Highway 63 and Jenkins Valley Road, intensive fecal coliform monitoring was performed during the period from 4/14/2003 through 6/20/2003 to assess the impairment status with regards to the standards specification requiring five samples per 30-day period. Table 4 presents a summary of the fecal coliform data collected. Fecal coliform concentrations are expressed as number of colony forming units and may be written as "#/100 mL" or "cfu/100 mL."

Table 4. Summary of NCDENR Water Quality Monitoring for Fecal Coliform Impairment

Station	Period	Minimum; Maximum; Mean	Instantaneous Criterion Excursions/ Observations[a]	Percent Instantaneous Criterion Excursions	Geomean Criterion Excursions/ Observations[b]
Newfound Creek at McPeters Road	12/96 – 6/99	12 1800 281	5/21	23.8%	na[c]
Newfound Creek at Highway 63	11/96 – 6/03	140 57,000 6,694	23/30	76.7%	3/3
Newfound Creek at Jenkins Valley Road	10/96 – 6/03	20 65,000 3,804	27/35	77.1%	5/5

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

[b] Criterion excursions (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

[c] Sample number requirements for geometric mean calculation not met

The McPeters Road monitoring station is not along the listed portion of Newfound Creek, but monitoring data indicate that the instantaneous standard is exceeded more than 20 percent of the time.

1.4.2 USGS Monitoring

In the year 2003, USGS began monitoring coliform concentrations in the Newfound Creek Watershed to address concerns of bacterial contamination and to identify target areas for BMPs. Two sampling events, one low flow and one high flow, have been conducted at ten locations in the watershed. Fecal coliform was measured at five sites (1, 5, 6, 7, 10) (Figure 4); *E. coli* was measured at all ten. To distinguish between animal or human sources of contamination, serotyping was performed at five locations; however, these results are not yet available.

The USGS data is presented in Table 5. During the low flow event, the instantaneous standard for fecal coliform was exceeded at four of five locations. During the high flow event, the instantaneous standard was exceeded at all five locations sampled.

Table 5. Summary of USGS Coliform Monitoring Data

Station	Low Flow Event (5/28/2003)		High Flow Event (11/19/2003)	
	E. coli **(#/100mL)**	**Fecal Coliform (#/100mL)**	***E. coli*** **(#/100mL)**	**Fecal Coliform (#/100mL)**
1. Newfound Creek at Jenkins Valley Rd.	1,300	930	27,000	24,000
5. Newfound Creek at Old Newfound Rd.	1,100	1,400	22,000	29,000
6. Round Hill Branch at Rabbit Ham Rd.	130	140	20,000	6,000
7. Newfound Creek at Browntown Rd.	2,400	8,700	18,000	11,000
10. Newfound Creek at Haylandy Drive	670	1,300	4,700	2,900
Minimum	130	140	4,700	2,900
Maximum	2,400	8,700	27,000	29,000
Mean	1,120	2,494	18,340	14,580

1.4.3 BCSWCD Monitoring

The Buncombe County Soil and Water Conservation District (BCSWCD) has been monitoring fecal coliform concentrations in the Newfound Creek Watershed since April 2002 (Figure 4). Ten sites are currently monitored, four on Newfound Creek, four on Round Hill Branch, and two on Morgan Branch. A summary of data collected is presented in Table 6. No valid 30-day geometric means can be calculated from this data set.

Table 6. BCSWCD Fecal Coliform Monitoring Data

Site Number	Site Name	Minimum; Maximum; Mean	Instantaneous Criterion Excursions/ Observations[a]
1A	Brookshire #2, Worley's Farm	46 6,000 1,513	19/32
1B	Dark Cove Rd.	200 47,000 6,226	30/32
2A	Duckett Residence/Off Newfound Rd.	100 22,600 3,261	28/32
2B	Newfound Community Center/ Corner of Newfound Rd. & Morgan Branch Rd.	520 12,000 3,105	32/32
3A	Janice Buckner Dairy BMP/ Green Valley Rd.	178 32,500 3,936	26/32
3B	Janice Buckner BMP/ Rabbit Ham Rd.	100 31,000 2,812	24/32
5A	Inez Brown Beef Cattle Farm/ Green Valley Rd.	137 69,000 5,974	14/20
5B	Downstream Inez Brown/ Green Valley Rd.	455 59,500 10,099	20/20
6A	Max Morgan Upstream	940 1,160 1,050	2/2
6B	Max Morgan Downstream	1,200[b]	1/1

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

[b] Only one sample collected.

2 Source Assessment

A critical step in developing a useful and defensible TMDL is the assessment of potential sources of contamination. Tetra Tech primarily relied upon the recent TVA (2002) nonpoint source pollution inventory to categorize the major sources in the Newfound Creek Watershed including septic systems, land use runoff, and animal operations. An estimate of wildlife contributions was added. These sources are summarized in this section of the report. There are currently no point sources in the watershed.

2.1 General Sources of Fecal Coliform

Both point and nonpoint sources may contribute fecal coliform bacteria to 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 land use/cover, septic system usage, and animal operation 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 the TVA nonpoint source pollution inventory (2002), GIS information, census data, and personal communication with local and state officials. The principal sources investigated were land use runoff, animal operations, septic systems, and wildlife populations.

Runoff Contributions

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

A land use map of the Newfound Creek Watershed is presented in Figure 2. In general, the watershed can be divided roughly into two halves: the forested upstream areas and the agricultural/residential downstream areas. Throughout the watershed, single family residential and pasturelands are adjacent to almost every stream reach. Thus, it is likely that runoff contributes to the instream fecal coliform load.

TVA estimated the percent of impervious cover from land use and land cover data obtained during the nonpoint source pollution inventory. Figure 5 shows the percent impervious cover from land uses in the Newfound Creek Watershed (imperviousness due to roads is not depicted). Impervious surfaces in urban areas cause an increase in runoff volumes and pollutant loadings. The majority of the Newfound Creek Watershed is rural, and 97 percent of the watershed is classified as having a percent imperviousness of less than 10 percent.

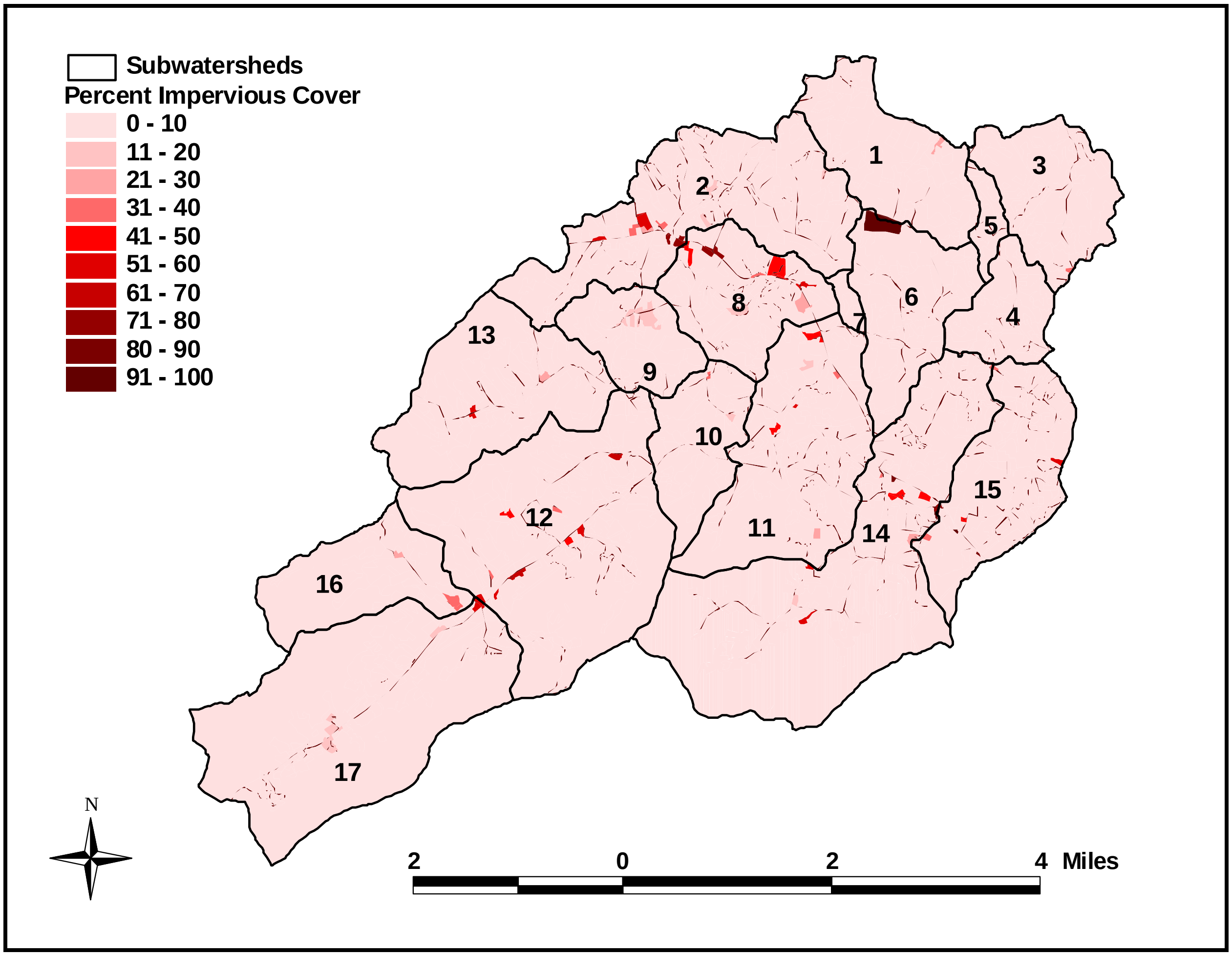

Figure 5. Percent Impervious Cover in the Newfound Creek Watershed (TVA, 2002)

Animal Operations

Pasture land represents 35 percent of the Newfound Creek Watershed area and in some subwatersheds comprises as much as 68 percent of the total area. The nonpoint source pollution inventory (TVA, 2002) contains data on the type, size, and location of each animal operation in the watershed. There are approximately 1,680 beef cattle in the watershed, and over 73 percent are located on land that is adjacent to a perennial or intermittent stream. There are approximately 930 dairy cows in the watershed, and all are located on land that is adjacent to a perennial or intermittent stream. There are approximately 20 swine in the watershed; all are confined, but located on land that is adjacent to a perennial or intermittent stream. The horse population in the watershed is approximately 165, and over 27 percent are on land that is adjacent to a perennial or intermittent stream. There are no poultry houses reported. Figure 6 shows the type and location of each animal operation in the watershed.

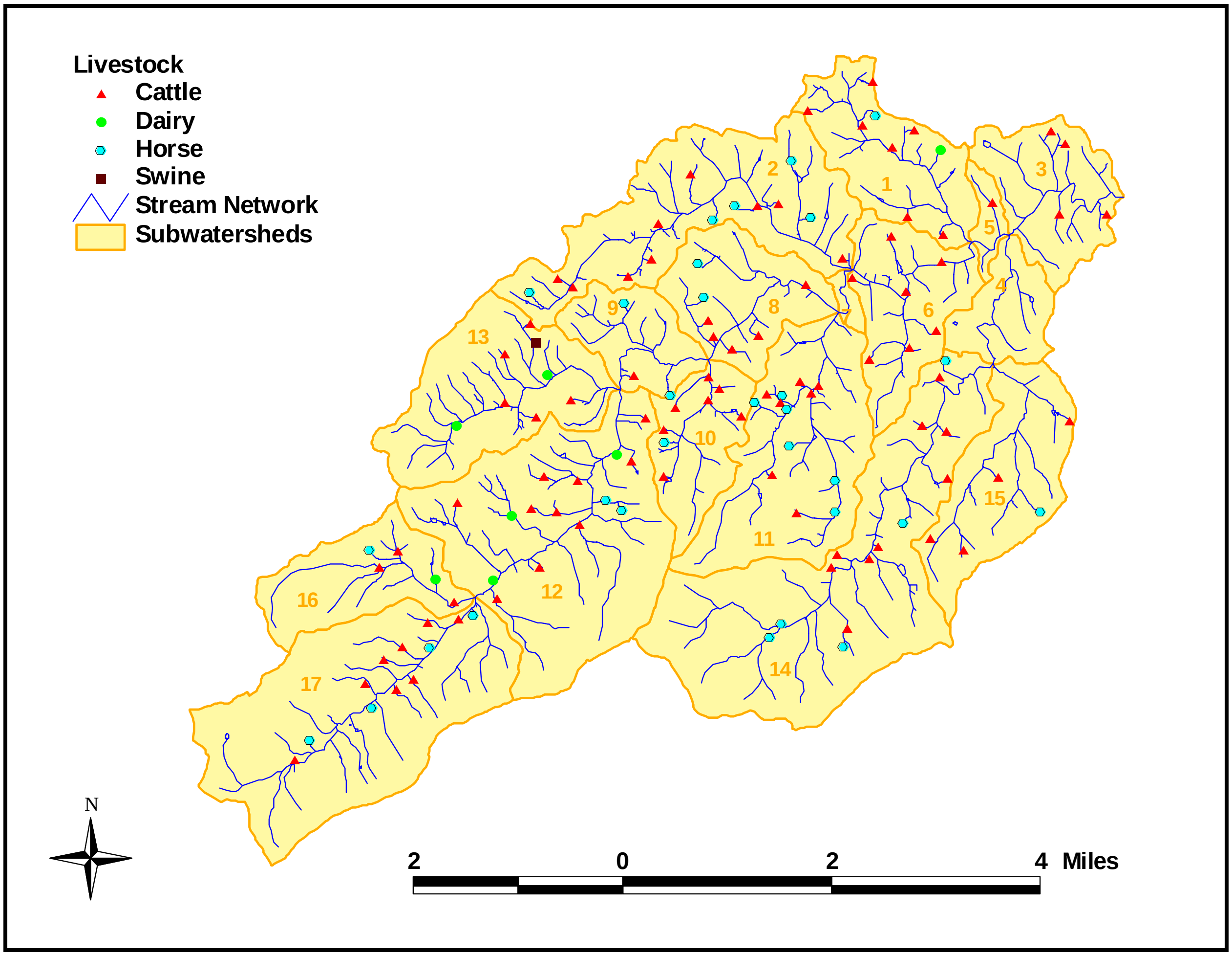

Figure 6. Animal Operations in the Newfound Creek Watershed (TVA, 2002)

The TVA also inventoried animal access to streams for those farms located adjacent to streams (Figure 7). Of the 141,983 feet of perennial and intermittent streams in the Newfound Creek Watershed that were inventoried, 3,386 feet show signs of direct and constant animal access; 67,598 feet show probable animal access (animals are present on adjacent land and no animal barriers are in place; 71,000 feet are classified as potential animal access (no signs of animal access currently present).

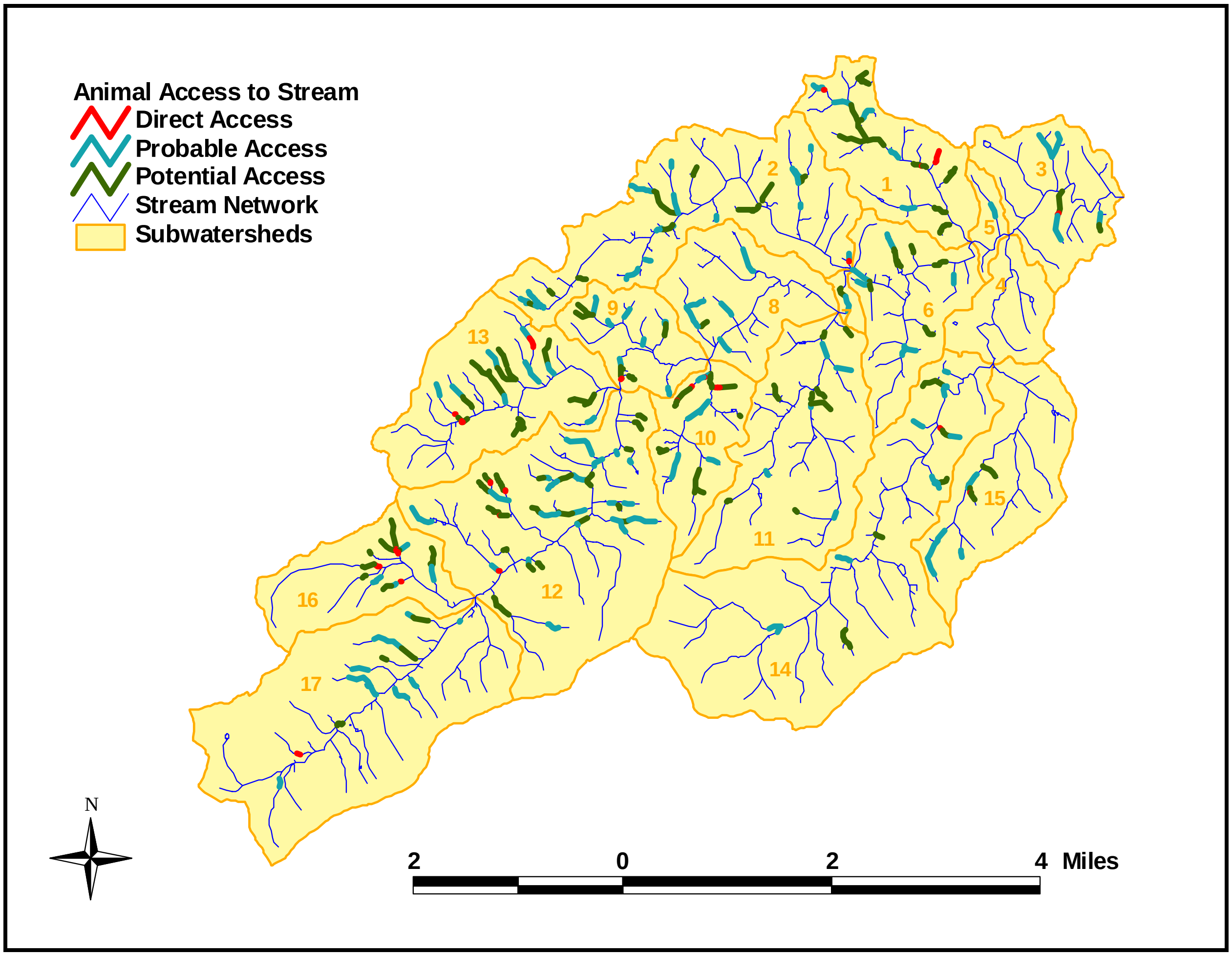

Figure 7. Animal Access to Streams (TVA, 2002)

Septic Systems

Septic tanks are one of several possible causes of low flow exceedances. Other sources of low flow fecal coliform loading are illicit discharges or other direct inputs of raw sewage. Figure 8 shows the location and type of septic systems in the watershed as reported in the TVA nonpoint source pollution inventory. There is no sewer service in the watershed.

In Newfound Creek, low flow exceedances have been measured at all three NCDENR monitoring stations. Septic systems are one possible source of low flow fecal coliform loading in these areas, particularly where residential land uses are adjacent to the streams. Older septic systems, like sand filters, may be responsible for a large portion of the fecal coliform loading, depending on their location and condition. TVA reported the condition of each septic system (Figure 9, Table 7) in the watershed based on the moisture patterns surrounding drain fields that were detected by aerial photography. Of the 687 systems inventoried, one has a distinctive moisture pattern indicative of ponding, 110 have a suspicious moisture pattern but no visible drain field, 16 have no apparent plume and appear to be properly functioning, and the 560 remaining systems are suspect due to their location near rock outcrops, streams, or on very steep slopes.

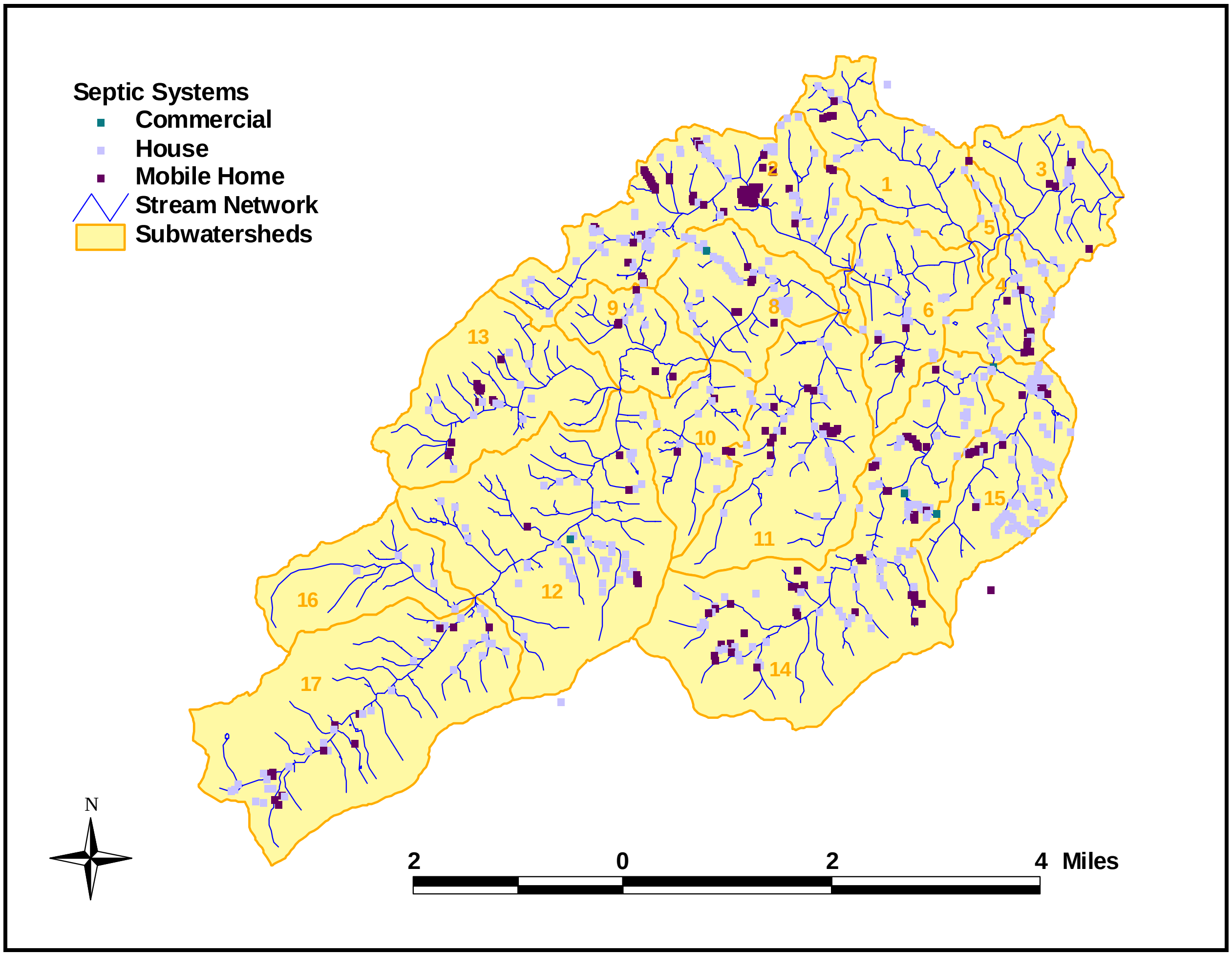

Figure 8. Location and Type of Septic Systems in the Newfound Creek Watershed (TVA, 2002)

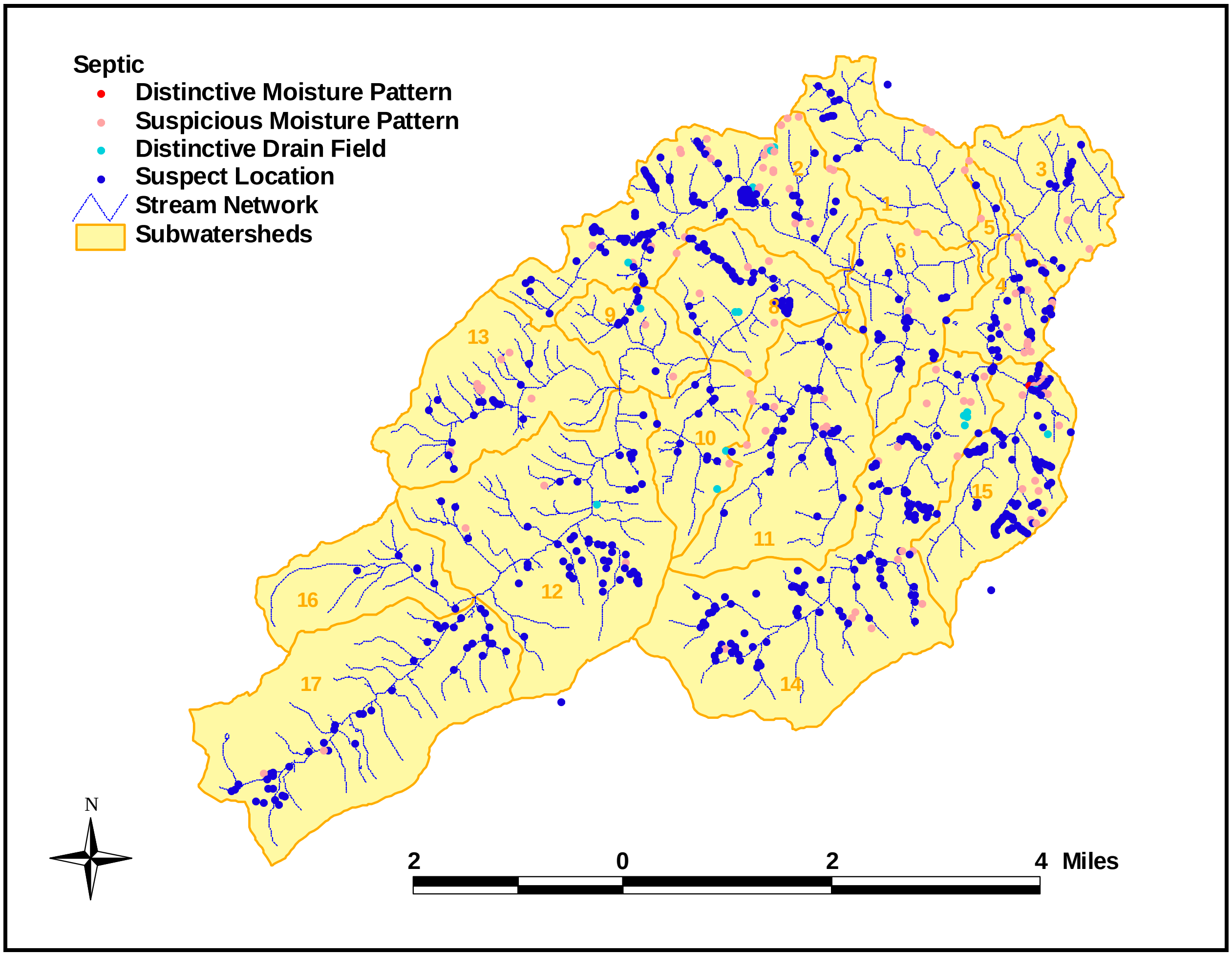

Figure 9. Condition of Septic Systems in the Newfound Creek Watershed (TVA, 2002)

Table 7. Description of TVA Septic System Conditions

Condition	Description
Distinctive moisture pattern	Effluent plume from visible drain field pattern or prominent ponding down slope from the drain field
Suspicious moisture pattern	Visible plume pattern, but no drain field apparent; can be straight-pipe from septic system, roof drainage, gray water disposal or natural seepage/spring
Distinctive drain field	Visible drain field pattern, but no plume evident; may indicate slow leaching, but no apparent breakout of a seasonally or hydraulically stressed system; or evapotranspiration characteristics of a functioning system or newly installed system
Suspect Location	No plume or drain field visible; home sites on very steep slope, small lots, visible rock outcrops, or in close proximity to streams or reservoirs, especially those on heavily-wooded lots

Riparian Buffer Disturbance

A well maintained stream buffer provides several benefits including the filtration of nutrients, sediment, and pathogens. To assess the functionality of riparian corridors along the streams in the Newfound Creek Watershed, the TVA categorized the width and percent cover for buffers along the perennial streams. Areas on the left and right banks were then classified as "adequate," "marginal," or "inadequate" based on a matrix of buffer width and percent vegetated cover. The matrix as defined by TVA (2002) is depicted in Table 8. Results of the inventory are presented in Table 9 and Figure 10.

Table 8. TVA Riparian Buffer Classification

Buffer Width	0 to 33 Percent Cover	34 to 66 Percent Cover	67 to 100 Percent Cover
0 to 25 feet	Inadequate	Marginal	Marginal
26 to 100 feet	Marginal	Marginal	Adequate
Over 100 feet	Marginal	Adequate	Adequate

Table 9. Condition of Riparian Buffers Along Perennial Streams in the Newfound Creek Watershed (TVA, 2002)

Length (feet)	Percent	Condition
49,520	29.24%	Inadequate on Both Banks
15,390	9.09%	Inadequate on One Bank
73,100	43.16%	Marginal on Both Banks
19,050	11.25%	Marginal on One Bank
12,310	7.27%	Adequate on Both Banks
169,370	100.00%	Total Length Inventoried

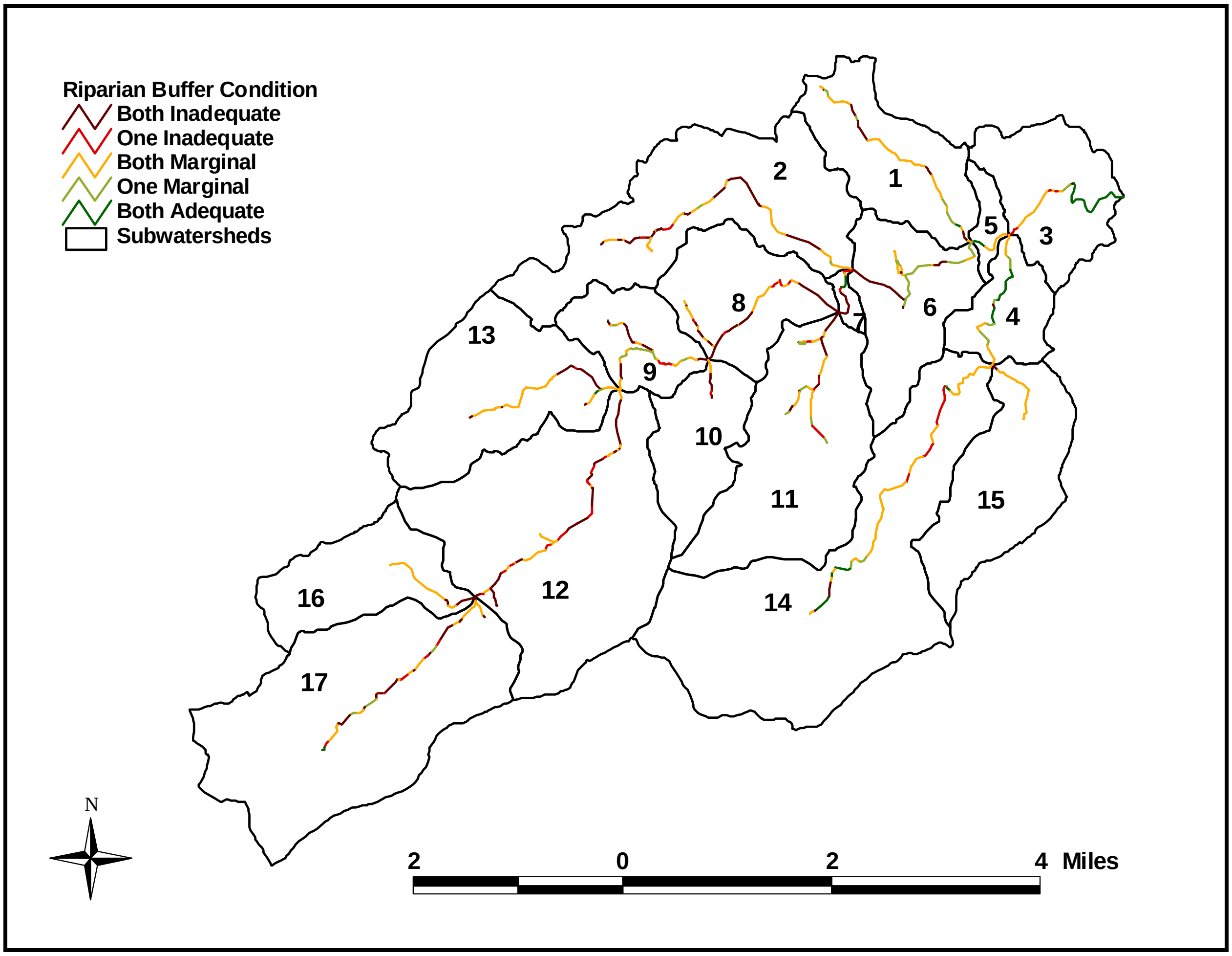

Figure 10. Riparian Condition Along Perennial Streams in the Newfound Creek Watershed (TVA, 2002)

2.1.2 Summary of Fecal Coliform Trends

The data collected by NCDENR, USGS, and BCSWCD show elevated fecal coliform concentrations during storm events as well as during typical and low flow periods. Because criterion excursions occur across all flow regimes, a wide range of sources may contribute to stream impairment.

Comparison of fecal coliform concentrations at the three NCDENR sites shows an increasing trend in concentration in the downstream direction (Figure 11). In fact, the most upstream site at McPeters Road is not among the listed segments of Newfound Creek. Concentrations at this site exceeded the instantaneous standard in 3 of 12 baseflow samples and 2 of 9 stormflow samples. The maximum concentration recorded at this site is 1,800, measured on 1/7/1998 during a storm event. Given the land uses reported by TVA upstream of this site, pasture and residential land are likely sources of elevated concentrations.

In the lower half of the watershed, NCDENR monitors two sites for fecal coliform. The site at Highway 63 captures approximately two thirds of the total watershed area and is located in a more developed area than the upstream site at McPeters Road. Excursions of the instantaneous standard occurred in 7 of 10 baseflow samples and 6 of 9 stormflow samples. The NCDENR site furthest downstream is located near the mouth of Newfound Creek. This site exceeded the instantaneous standard in 7 of 12 baseflow samples and 10 of 11 stormflow samples. At the two downstream sites, the frequency of excursions and the total bacterial count were higher during storm events. At McPeters Road, the frequency of exceedances was approximately the same under wet and dry conditions.

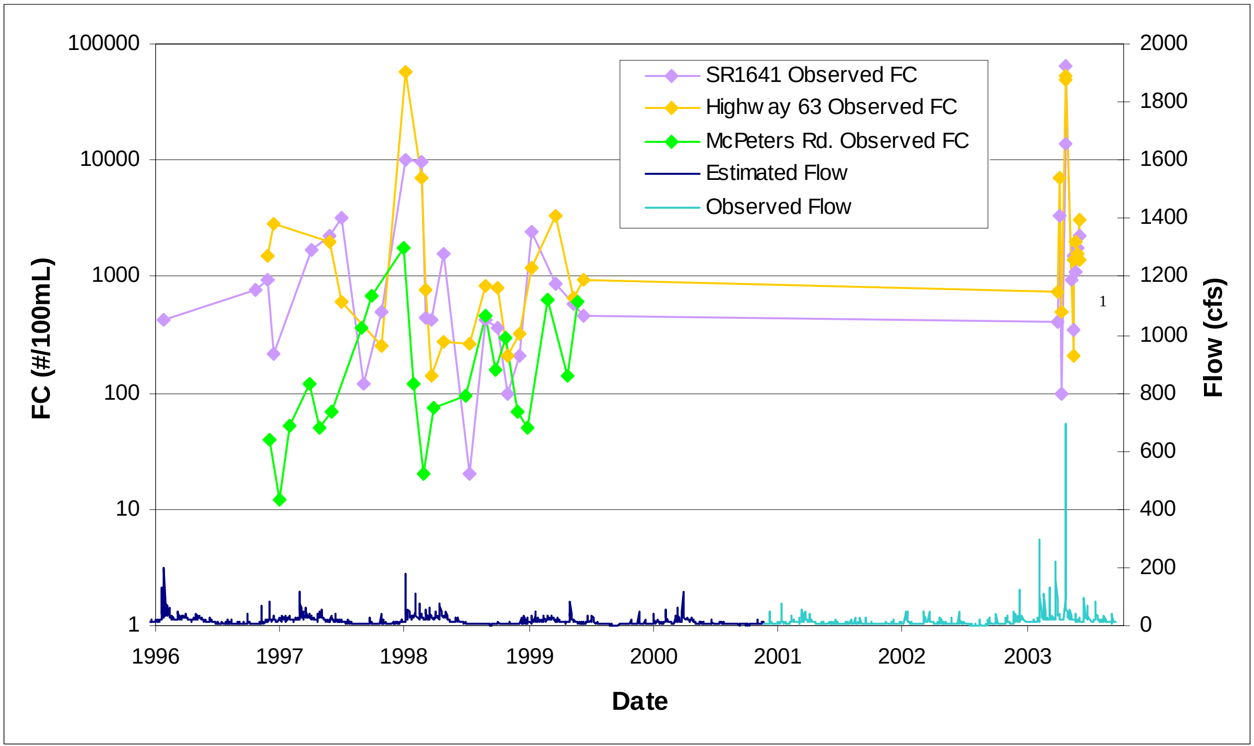

Figure 11. Newfound Creek Monitoring Data at Three NCDENR Sites

Table 10 summarizes the land use percentages, animal populations, and septic system densities upstream of each NCDENR monitoring site. Given that the McPeters Road Site has a relatively low maximum fecal coliform concentration (1,800) and low densities of animal operations and pastureland, washoff from animal operations are probably not the main source of fecal contamination at this site although direct deposition from animals with access to streams may be. However, relative to the other watersheds, the septic system density is also low. The Highway 63 and Jenkins Valley Road sites have fecal coliform concentrations observed in the tens of thousands. Pastureland comprises more than 30 percent of the total watershed area in each watershed, and the animal densities are approximately 10 times higher than that in the McPeters Road watershed. The Jenkins Valley Road watershed has the highest septic system density, but relatively few low-flow exceedances of the fecal coliform instantaneous standard.

Table 10. Summary of Pollutant Loadings Upstream of the NCDENR Monitoring Sites

Source	McPeters Road	Highway 63	Jenkins Valley Road
Septic System Density (#/sq. mi.)	11.2	12.5	20.0
Large Animal Density[a] (#/sq. mi.)	9.3	103.1	81.3
Percent Forest Land	85.4	52.3	45.2
Percent Pasture Land	7.8	32.3	34.6
Percent Residential Land	5.5	34.6	14.7

[a]Large animal density is the total number of beef cattle, dairy cows, swine, and horses per square mile.

The USGS samples show a similar trend. At the upstream Newfound Creek sites (Haylandy Road and Browntown Road), stormflow samples were greater than baseflow samples by a factor of 1.3 to 2.2. At the downstream sites, concentrations were 20 to 25 times higher during stormflow conditions compared to baseflow. Total bacterial counts were higher during baseflow at the upstream sites and during stormflow at the downstream sites.

The BCSWCD sites are located in the upper portion of the watershed. The two sites on Morgan Branch exceeded the instantaneous standard on each sampling event. Four sites are located on Round Hill Branch; each exceeded the instantaneous standard in at least 70 percent of observations. Four sites are located on Newfound Creek. The furthest upstream site (1A) exceeded the instantaneous standard in 60 percent of observations; 94 percent of observations at the next site (1B) exceeded the standard. A similar pattern occurs at sites 2A and 2B, where the frequency of excursions are is 88 percent and 100 percent, respectively.

2.1.3 Point Source Fecal Coliform Contributions

There are no point source dischargers in the Newfound Creek Watershed according to the USEPA Water Discharge Permits Compliance System database.

3 Technical Approach

Given the results of the initial data analysis and schedule 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 is presented in Section 4.

3.1 TMDL ENDPOINTS

The achievement of the TMDL objectives requires 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 endpoints for the determination of the fecal coliform TMDL for Newfound Creek.

3.2 LOAD-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 Load-Duration Curve Method (Stiles 2002, Cleland 2002) was used to estimate fecal coliform impairment. 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 first 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. Flows in Newfound Creek were based on USGS observations at Gage 03451690 from December 2000 to September 2004. Flows prior to December 2000 were estimated based on regression with flows at two other USGS gages (Section 1.3).

Once the relative rankings were calculated for flow in Newfound Creek, 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. Criterion excursions that occur only during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Criterion excursions 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 12 through Figure 17, the flow-duration water quality analysis is presented for the three NCDENR monitoring stations on Newfound Creek. One USGS observation at Jenkins Valley Road was used so that two additional geometric means could be calculated. All stations show excursions of the instantaneous fecal coliform water quality standard (400 cfu/100 mL) during all flow regimes. However, a lower percentage of excursions occurs during low flow conditions, and the magnitudes of the excursions are much lower compared to typical, transitional, and high flow conditions. The data suggest that both storm-event runoff and low-flow sources, such as illicit discharges or septic systems, contribute to high fecal coliform loading in Newfound Creek, but that storm driven events drive concentrations significantly higher. Concentrations greater than 1,000/100 mL were only measured at flow duration intervals less than 55 percent, and concentrations greater than 10,000/100 mL were only measured at flow duration intervals less than 0.8 percent.

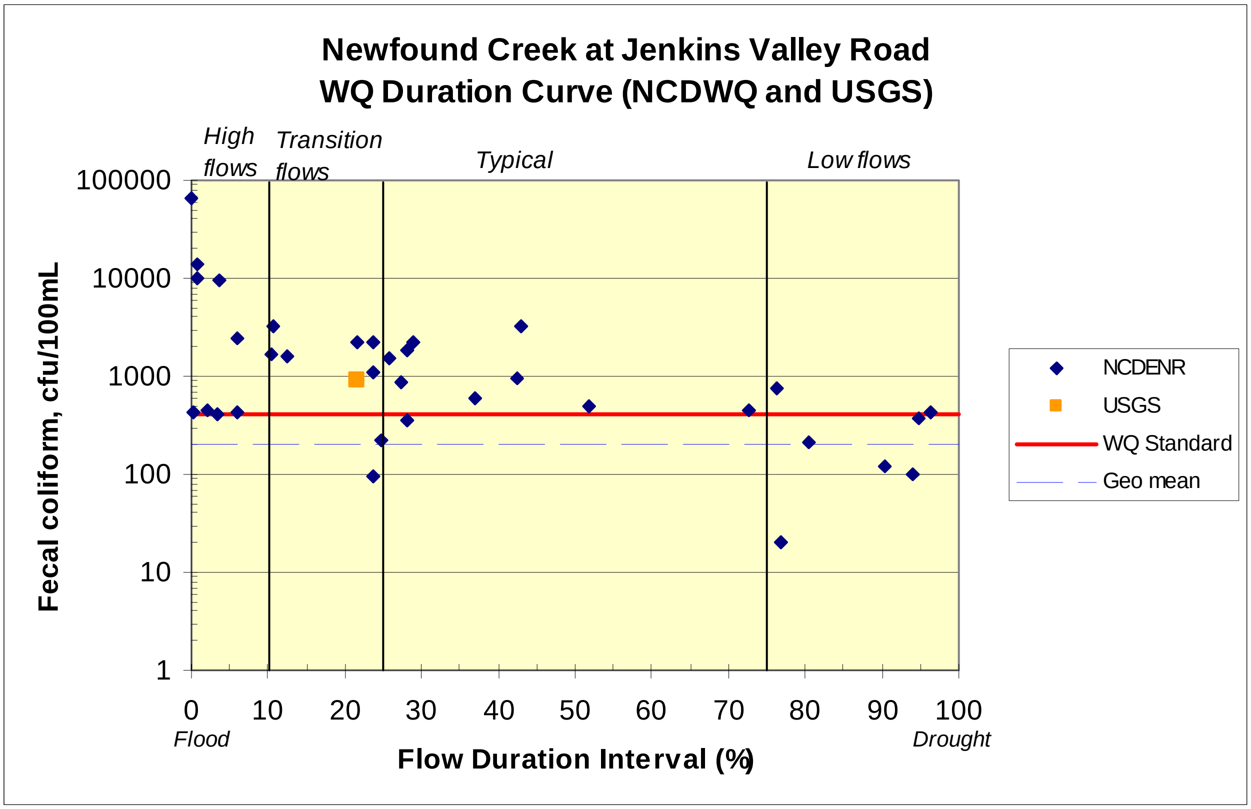

Figure 12. Flow-Duration Curve for NCDENR and USGS Fecal Coliform Data for Newfound Creek at Jenkins Valley Road (1/27/96 through 6/20/03)

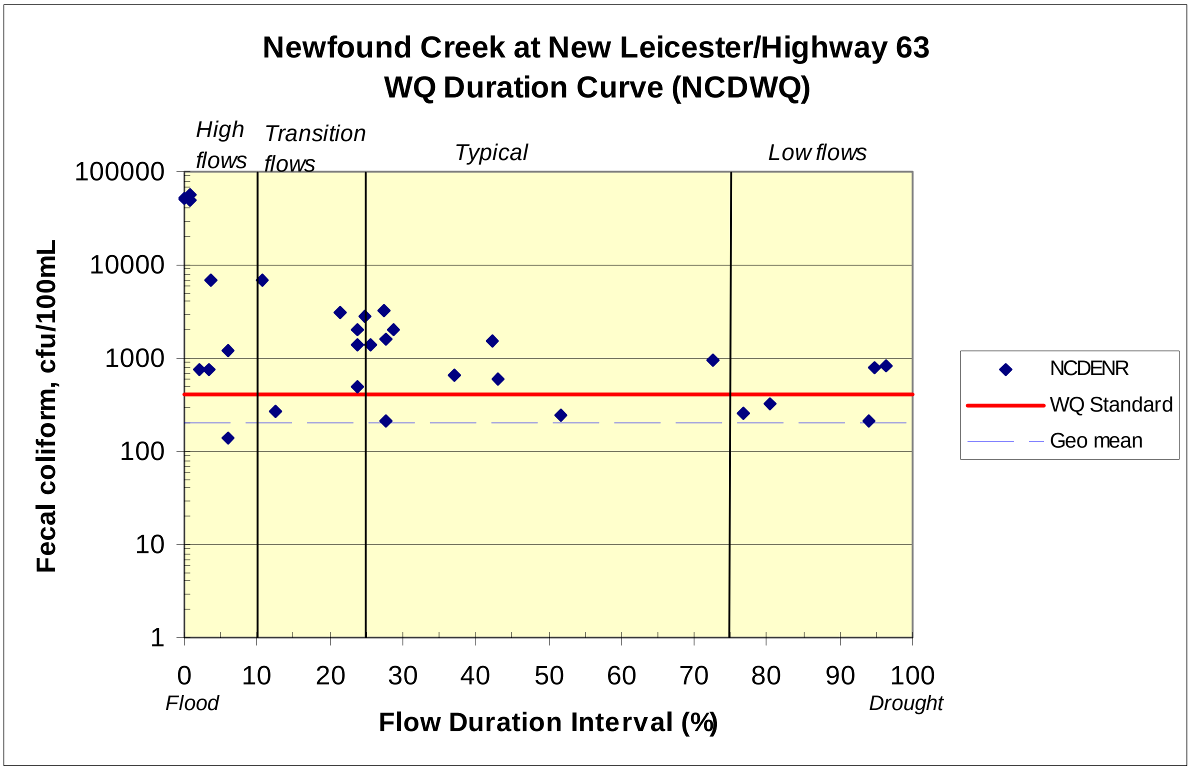

Figure 13. Flow-Duration Curve for NCDENR Fecal Coliform Data for Newfound Creek at Highway 63 (11/25/96 through 6/20/03)

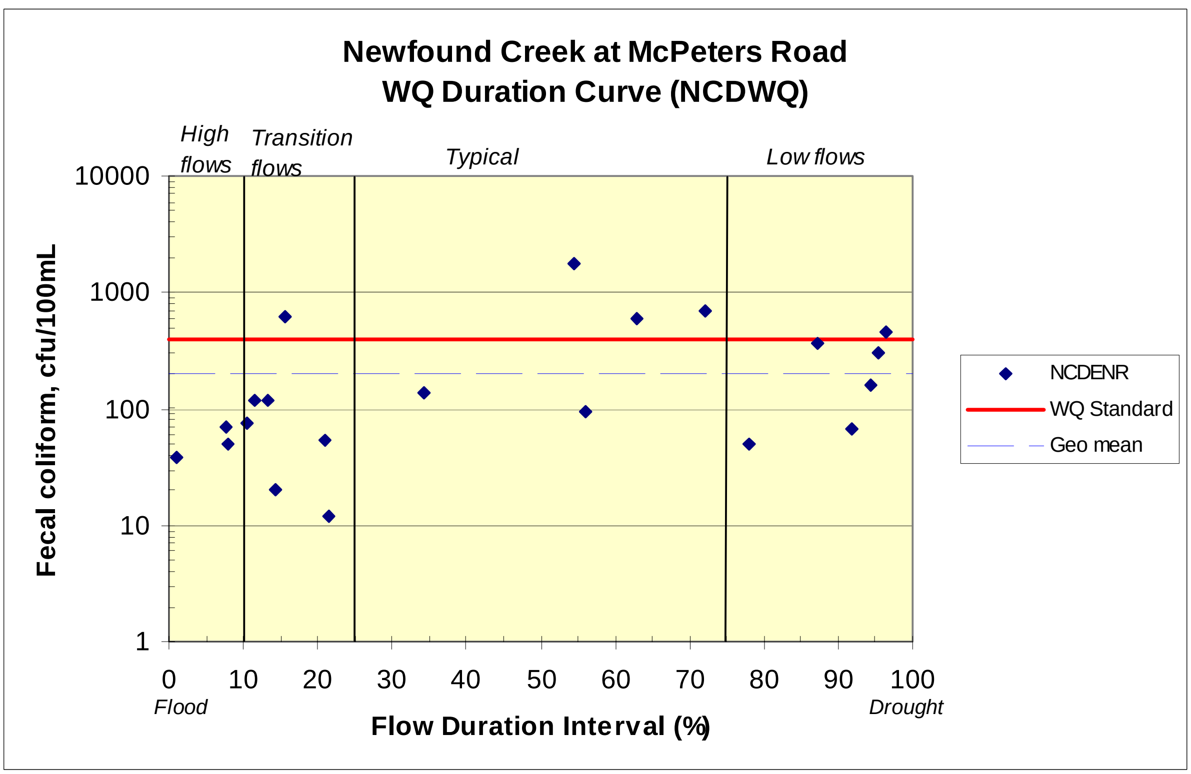

Figure 14. Flow-Duration Curve for NCDENR Fecal Coliform Data for Newfound Creek at McPeters Road (12/1/96 through 6/1/99)

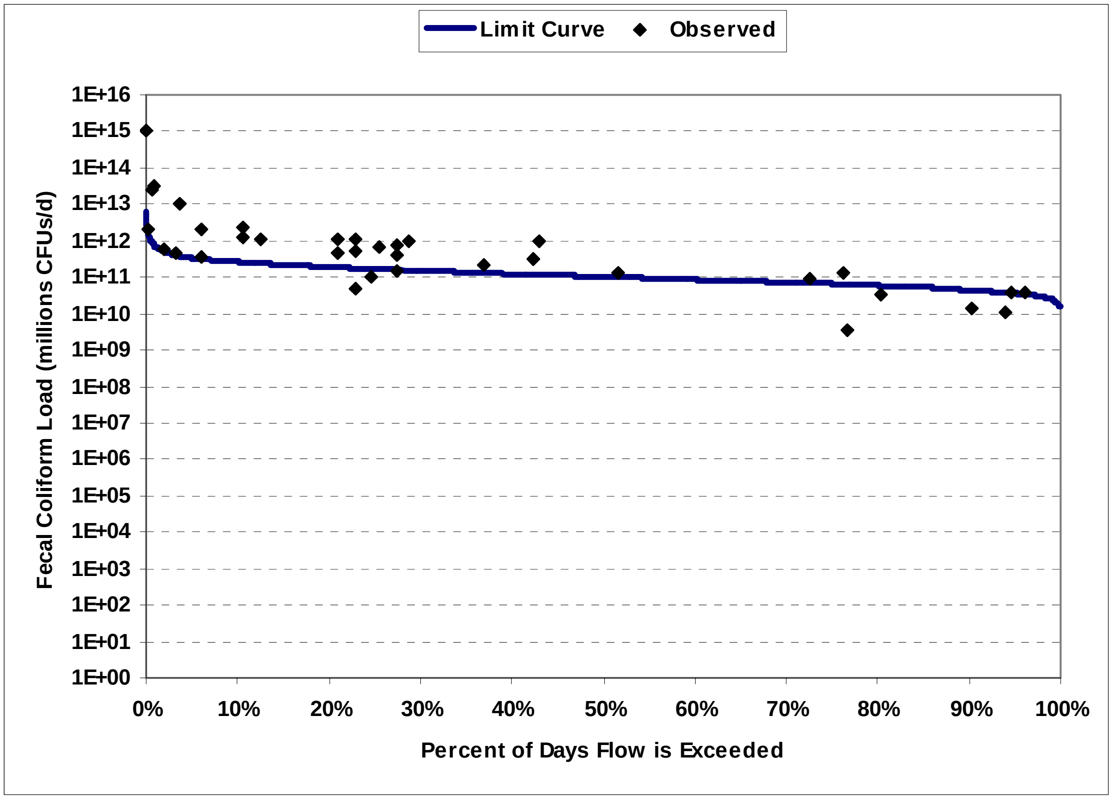

Figure 15. Load-Duration Analysis for NCDENR and USGS Fecal Coliform Data for Newfound Creek at Jenkins Valley Road (1/27/96 through 6/20/03)

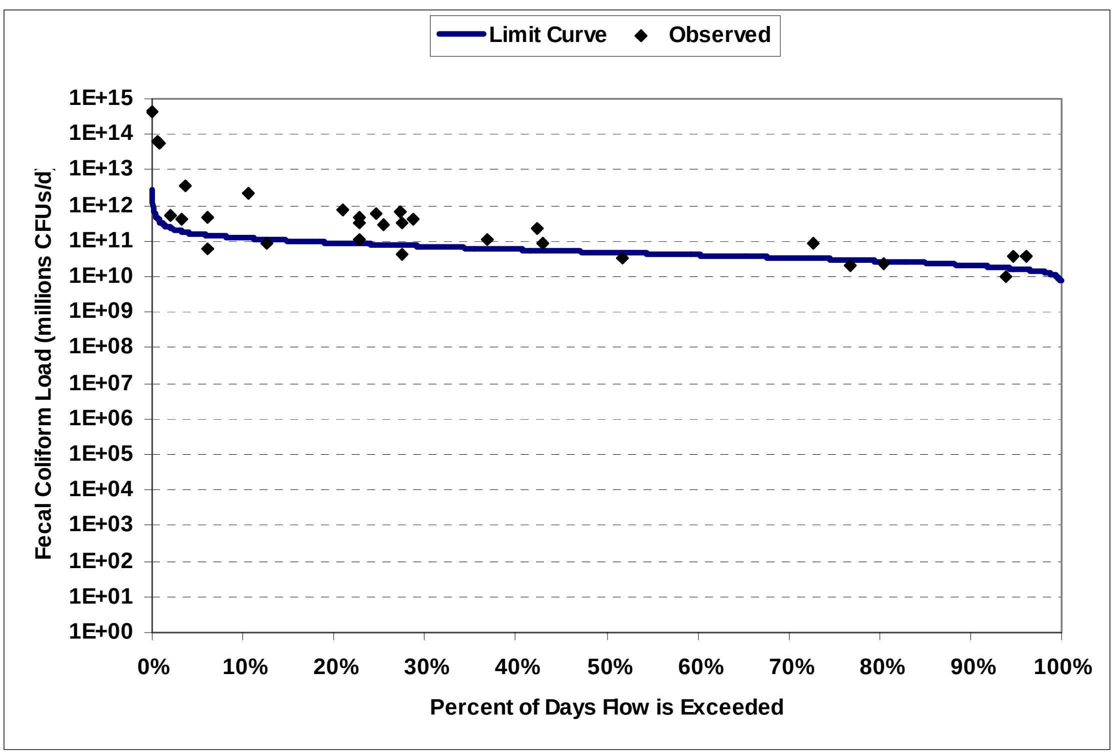

Figure 16. Load-Duration Analysis for NCDENR Fecal Coliform Data for Newfound Creek at Highway 63 (11/25/96 through 6/20/03)

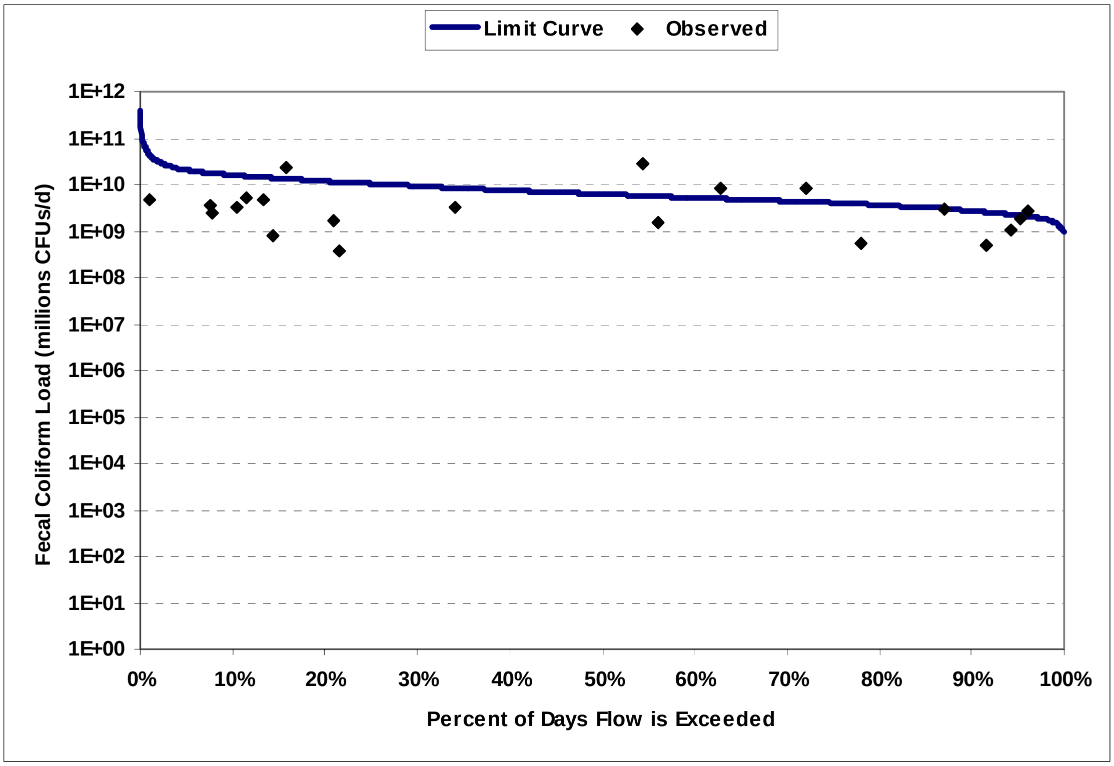

Figure 17. Load-Duration Analysis for NCDENR Fecal Coliform Data for Newfound Creek at McPeters Road (12/1/96 through 6/1/99)

3.3 Determination of Existing Fecal Coliform Load and Assimilative Capacity

The fecal coliform assessment uses the Load-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.

3.3.1 Instantaneous (20 Percent) Criterion

The water quality criterion for instantaneous fecal coliform concentrations allows up to 20 percent of samples within a 30-day period to exceed the target. The regulations clearly recognize that some excursions of the 200 CFU/100 mL target are expected to occur during washoff events. This frequency component needs to be taken into account when determining the assimilative capacity.

In some past applications, NCDWQ has used an ad hoc approach to the analysis of the difference between existing load and assimilative capacity. This approach involved fitting a regression line through those observations that were above the criterion limit curve and associated with the 10th through 95th percentile of the flow distribution. 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. Then, the natural log of the coliform loads exceeding the criterion was regressed on the natural log of the flow interval, and this regression curve was used to estimate the existing loading at every 5th percentile flow recurrence. The existing loading was then compared to the allowable loading (with a margin of safety), and the difference used to establish needed reductions. Because the regression line goes through the center of the distribution of points above the criterion limit curve, it allows a fraction of the observations to exceed the criterion; however, this fraction is not explicitly tied to the 20 percent frequency of allowable excursions specified in the criterion.

For this TMDL, a more rigorous quantitative approach is used. The essence of this approach is as follows:

- Establish a regression model to predict existing load as a function of flow percentage.
- Develop a prediction confidence interval on the regression line, with the confidence interval set at a level that reflects the allowed 20 percent frequency of excursions.
- Calculate a reduced criterion limit curve at 90 percent of the criterion concentration, thus incorporating a 10 percent margin of safety.
- Evaluate needed reductions based on the maximum difference between the prediction confidence interval and the reduced criterion limit curve, incorporating a margin of safety, between the 10^{th} and 95^{th} percentile flows.

The confidence interval is based on the point prediction interval about the regression line. That is, it reflects the range of expected values for individual observations at a given flow frequency, and incorporates both the uncertainty in the regression line and the natural variability of individual points about the regression line. In theory, the upper 60^{th} percentile confidence interval is just sufficient to meet the criterion (20 percent of observations are expected to fall in both the high and low tails of the distribution). However, the TMDL also requires a Margin of Safety. This is achieved by evaluating needed reductions in relation to the criterion limit curve reduced by 10 percent (that is, evaluated at 360 rather than 400 CFU/100 mL). The Margin of Safety is thus assigned explicitly through a 10 percent reduction in the criterion.

Complete details of the methodology for establishing the regression line and prediction confidence interval are presented in Appendix B. A comparison of regression methods at Jenkins Valley Road showed that the best fit was obtained with a log-linear regression (adjusted R^2 = 65 percent), yielding a model of the following form:

$$Ln\left(Coliform\ Load\ in\ CFU/d\right) = 28.04 - 4.614 \cdot Flow\ Fraction,$$

where flow fraction is the percentile of the flow expressed as a fraction.

Application of the regression equation and its upper 60^{th} percentile prediction interval at Jenkins Valley Road is shown in Figure 18. Comparison of the upper 60^{th} percentile prediction interval with the reduced limit curve shows that reductions are needed across all flow intervals, with the highest reduction (92.9 percent) needed during high flow conditions.

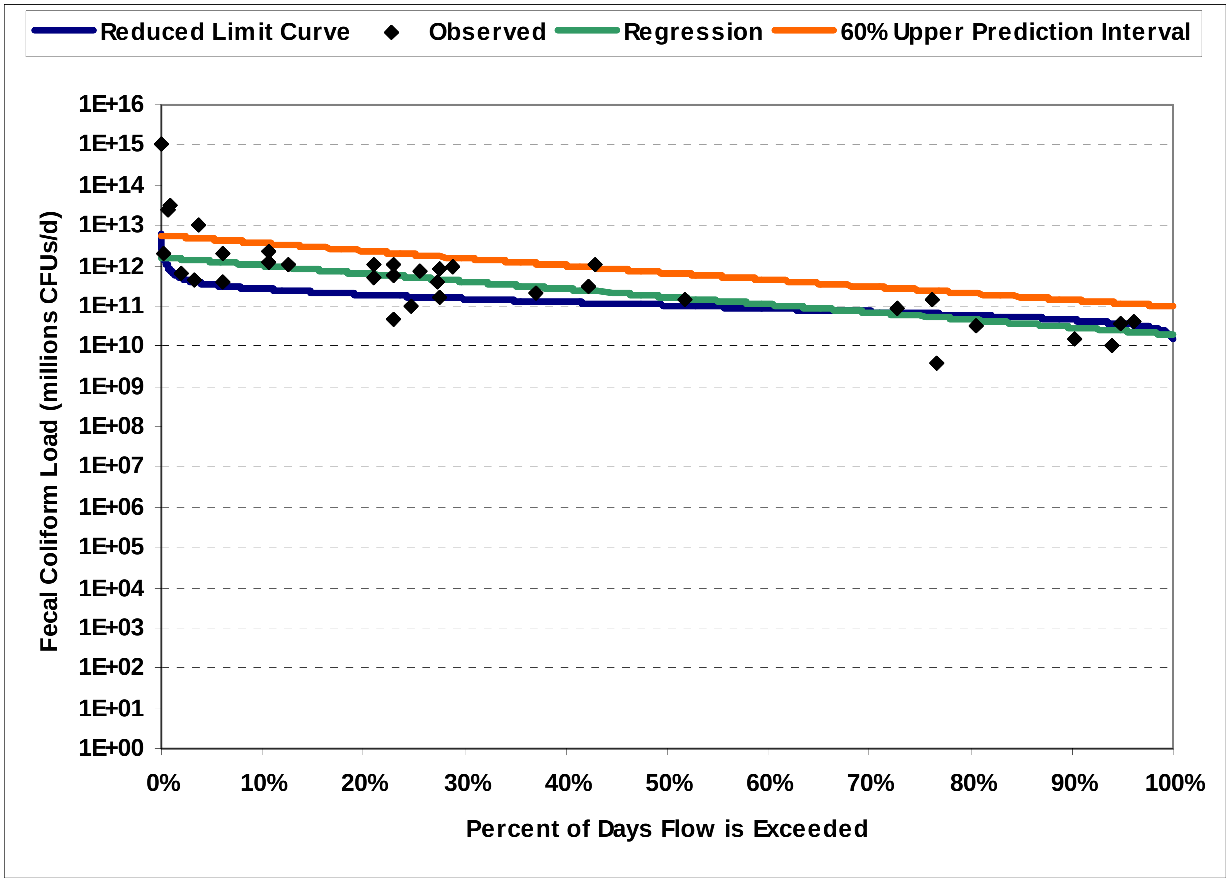

Figure 18. Regression Analysis of the Instantaneous Fecal Coliform Load-Duration Curve, Jenkins Valley Road

Figure 19 shows the regression analysis at Highway 63. The regression line through this data set has an adjusted R^2 of 50 percent:

$$Ln\left(Coliform\ Load\ in\ CFU/d\right) = 27.04 - 3.424 \cdot Flow\ Fraction$$

At Highway 63 reductions are required at all flow intervals with the highest reductions needed at very low flows (92.8 percent reduction at flow interval 100 percent) and at moderate flows (91.5 percent reduction at flow interval 14.8 percent).

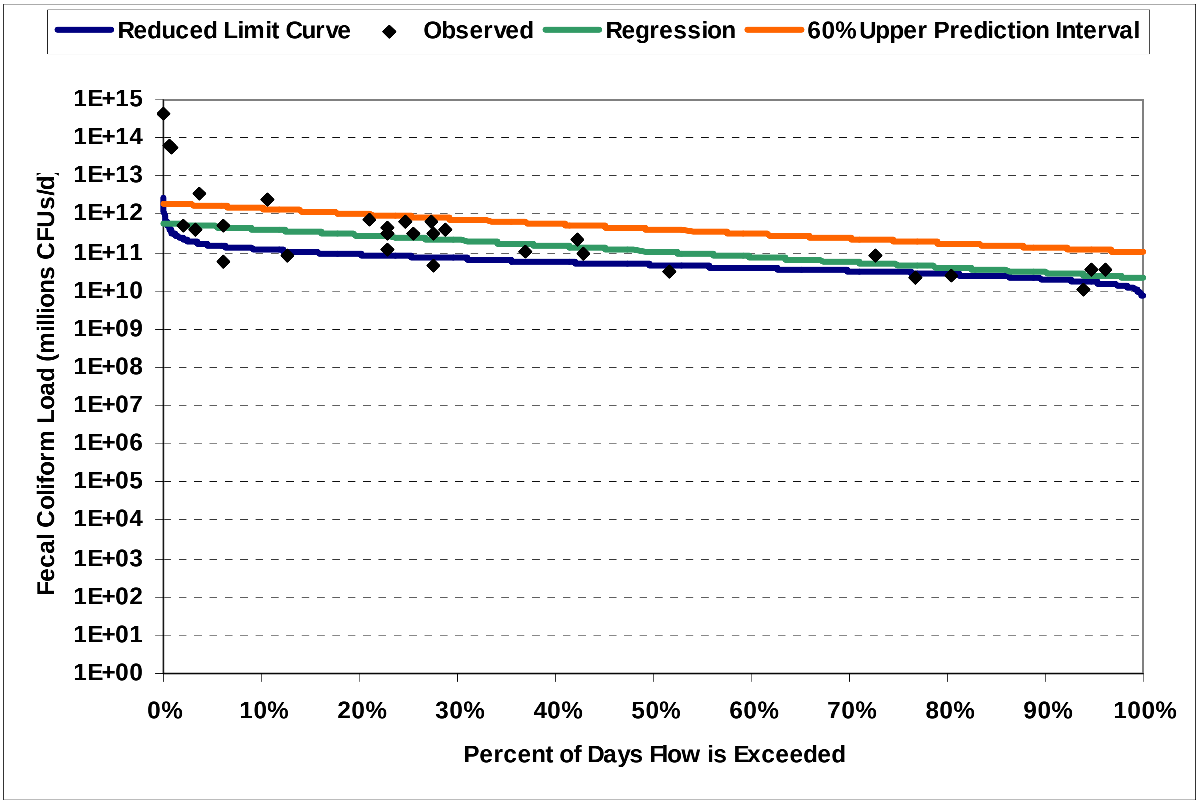

Figure 19. Regression Analysis of the Instantaneous Fecal Coliform Load-Duration Curve, Highway 63

At McPeters Road, fecal coliform load is slightly dependent upon flow with an adjusted R^2 of minus 1 percent. The estimated load and upper 60^{th} percentile prediction interval are highly dependent on the mean.

$$Ln\left(Coliform\ Load\ in\ CFU/d\right) = 22.01 - 0.664 \cdot Flow\ Fraction$$

Figure 20 shows the analysis for observations at McPeters Road. The mean load is $5.21x10^9$ CFUs/d. At flow intervals less than 21.7 percent, no reduction is required. The highest reduction (89.3 percent) is required under extreme dry conditions.

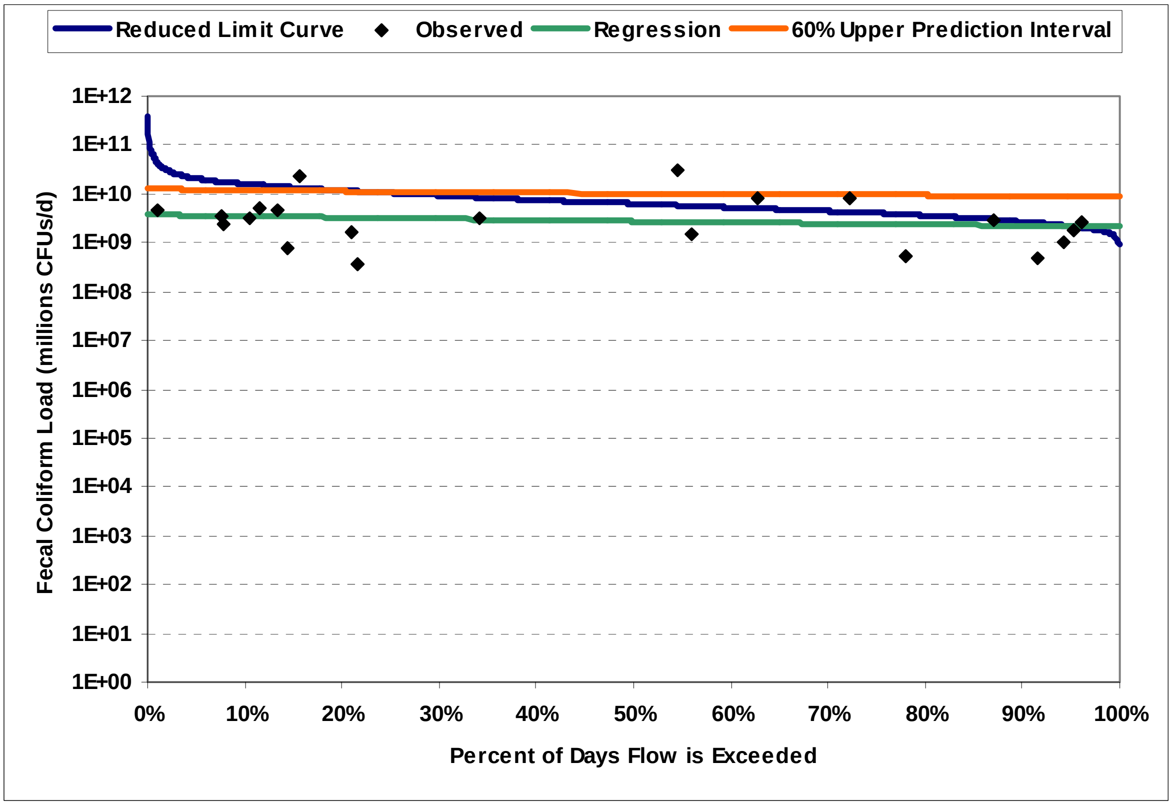

Figure 20. Regression Analysis of the Instantaneous Fecal Coliform Load-Duration Curve, McPeters Road

Each of the three stations have greater than 20 percent of observations exceeding the reduced limit curve: 24 percent of observations exceed the curve at McPeters Road, 77 percent exceed at Highway 63, and 77 percent exceed at Jenkins Valley Road.

Table 11 through Table 13 summarize the reduction requirements at each station under six ranges of flow. Critical percentiles are the values within the flow range at which the ratio of the 60^{th} percentile (60^{le}) prediction limit to target load is greatest. The flow column gives the flow corresponding to the critical percentile. The target load is the value of 90 percent of the instantaneous criterion limit curve at the specified flow and percentile, thus incorporating a 10 percent margin of safety. The 60^{le} prediction limit is the upper prediction interval about the regression line at the 60 percent confidence level. The reduction required is calculated as (60^{le} Prediction Limit – Target Load)/(60^{le} Prediction Limit). As discussed above, only calculations between the 10^{th} and 95^{th} percentile are used in the estimation of the TMDL.

Table 11. Fecal Coliform Target Load and Reduction Requirements Calculated Using the Load-Duration Curve Approach at Jenkins Valley Road

Flow Range	Critical Percentile	Flow (cfs)	Target Load (CFU/d)	60[le] Prediction Limit (CFU/d)	Reduction Required
0-10% (High Flows)	7.34%	33.0	2.91×10^{11}	4.09×10^{12}	92.89%
10-40% (Moist Conditions)	10.06%	29.6	2.61×10^{11}	3.62×10^{12}	92.78%
40-60% (Mid-Range Flows)	40.00%	14.0	1.23×10^{11}	1.00×10^{12}	87.70%
60-90% (Dry Conditions)	60.00%	9.7	8.54×10^{10}	4.46×10^{11}	80.86%
90-95% (Low Flows)	94.73%	4.1	3.61×10^{10}	1.17×10^{11}	69.05%
95-100% (Drought)	100.00%	1.8	1.59×10^{10}	9.58×10^{10}	83.46%

Table 12. Fecal Coliform Target Load and Reduction Requirements Calculated Using the Load-Duration Curve Approach at Highway 63

Flow Range	Critical Percentile	Flow (cfs)	Target Load (CFU/d)	60[le] Prediction Limit (CFU/d)	Reduction Required
0-10% (High Flows)	9.56%	14.05	1.24×10^{11}	1.45×10^{12}	91.46%
10-40% (Moist Conditions)	14.85%	11.70	1.03×10^{11}	1.22×10^{12}	91.55%
40-60% (Mid-Range Flows)	40.00%	6.55	5.77×10^{10}	5.59×10^{11}	89.67%
60-90% (Dry Conditions)	60.00%	4.54	4.00×10^{10}	3.12×10^{11}	87.17%
90-95% (Low Flows)	94.73%	1.92	1.69×10^{10}	1.19×10^{11}	85.83%
95-100% (Drought)	100.00%	0.84	7.42×10^{9}	1.04×10^{11}	92.84%

Table 13. Fecal Coliform Target Load and Reduction Requirements Calculated Using the Load-Duration Curve Approach at McPeters Road

Flow Range	Critical Percentile	Flow (cfs)	Target Load (CFU/d)	60^{le} Prediction Limit (CFU/d)	Reduction Required
0-10% (High Flows)	NA[1]	NA[1]	NA[1]	NA[1]	NA[1]
10-40% (Moist Conditions)	40.00%	0.86	$7.57x10^{9}$	$1.02\ x10^{10}$	25.92%
40-60% (Mid-Range Flows)	60.00%	0.59	$5.25\ x10^{9}$	$1.10\ x10^{10}$	52.20%
60-90% (Dry Conditions)	90.00%	0.31	$2.70\ x10^{9}$	$1.26\ x10^{10}$	78.59%
90-95% (Low Flows)	95.00%	0.25	$2.21\ x10^{9}$	$1.29\ x10^{10}$	82.94%
95-100% (Drought)	100.00%	0.11	$9.73\ x10^{8}$	$1.33\ x10^{10}$	92.68%

[1] No reduction needed at flow durations less than 21.7 percent.

Figure 21 shows the reductions needed at each monitoring station to meet the instantaneous fecal coliform standard. The necessary reductions at McPeters Road are inversely proportional to flow with the greatest reduction (92.7 percent) needed during drought conditions. Downstream at Highway 63, required reductions are greater than 85.8 percent under each flow regime and are approximately the same under extreme high and low flow conditions (approximately 92 percent). At Jenkins Valley Road, reductions greater than 69 percent are needed under each flow regime and at very high flows, reductions of 92.9 percent are required to meet the instantaneous standard.

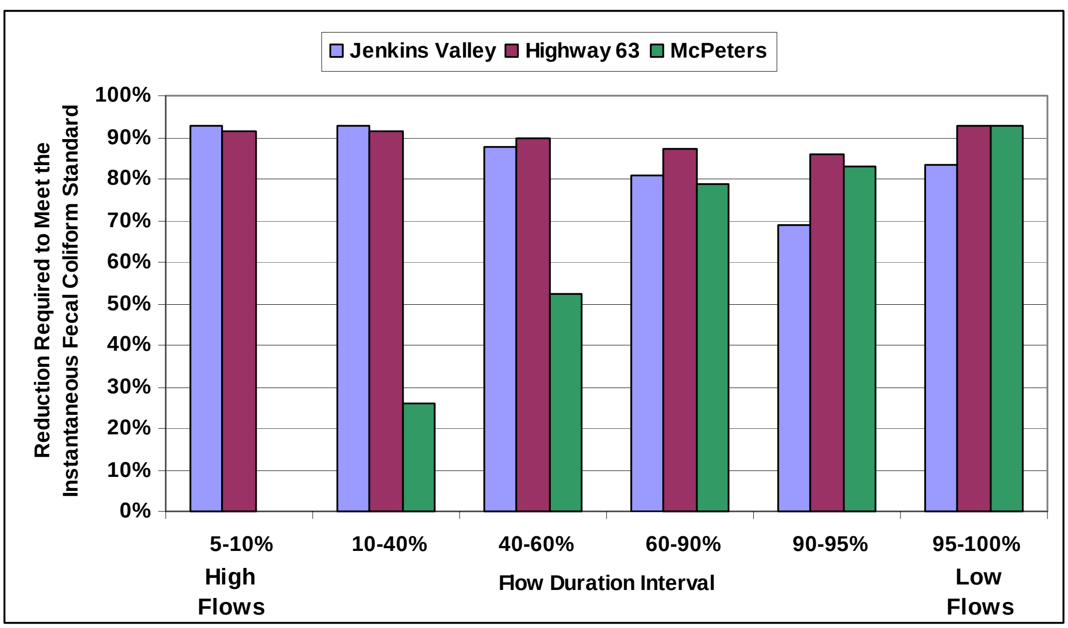

Figure 21. Reductions Needed in Fecal Coliform Loading Along Newfound Creek to Meet the Instantaneous Standard

3.3.2 Geometric Mean Criterion

NCDENR conducted special assessments at Highway 63 and at Jenkins Valley Road during the summer of 2003 to calculate 5-day geometric means at these stations. Loads were calculated by averaging the flows observed on each of the five days. The target load is calculated for each flow duration interval based on a fecal coliform concentration of 180/100 mL (10 percent Margin of Safety).

Figure 22 shows the geometric mean loads calculated for Newfound Creek at Jenkins Valley Road. Five geometric means were calculated (2603, 3385, 993, 1180, and 1704); all exceed the standard of 200/100 mL. The geometric mean of the observed loads compared to the geometric mean of the target load shows that a reduction of 89.9 percent is required to meet the standard at this station.

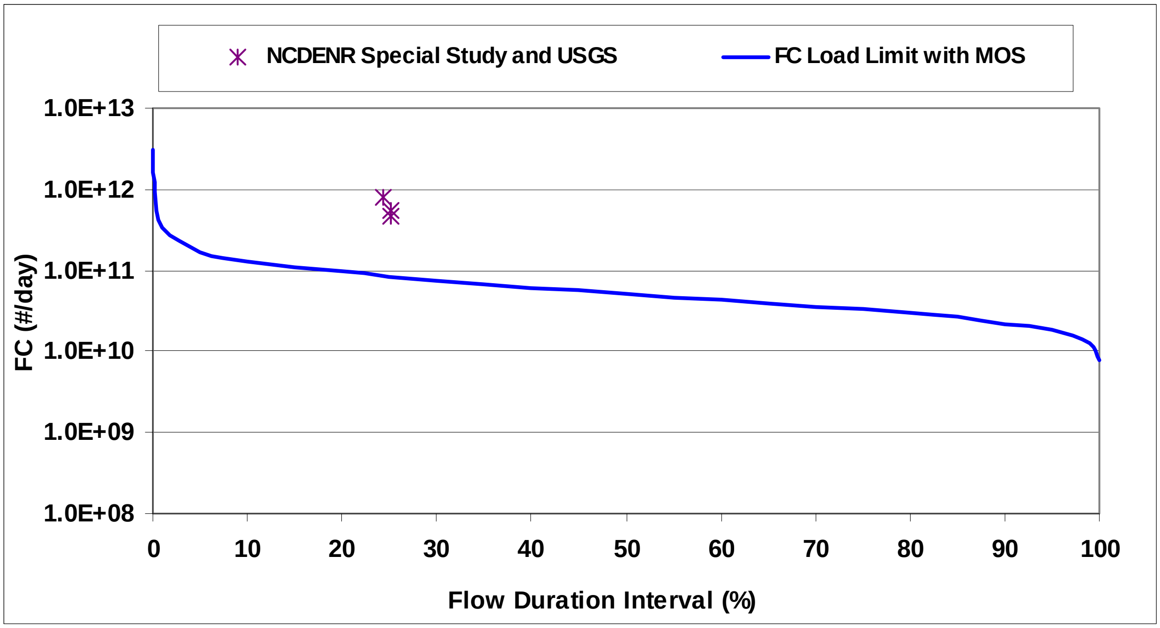

Figure 22. Geometric Mean Fecal Coliform Load-Duration Curves for Newfound Creek at Jenkins Valley Road

Figure 23 shows the geometric mean loads calculated at Highway 63, where three geometric means were calculated (5844, 1239, and 1810/100 mL). A reduction of 92.4 percent is required to meet the geometric mean standard at this station.

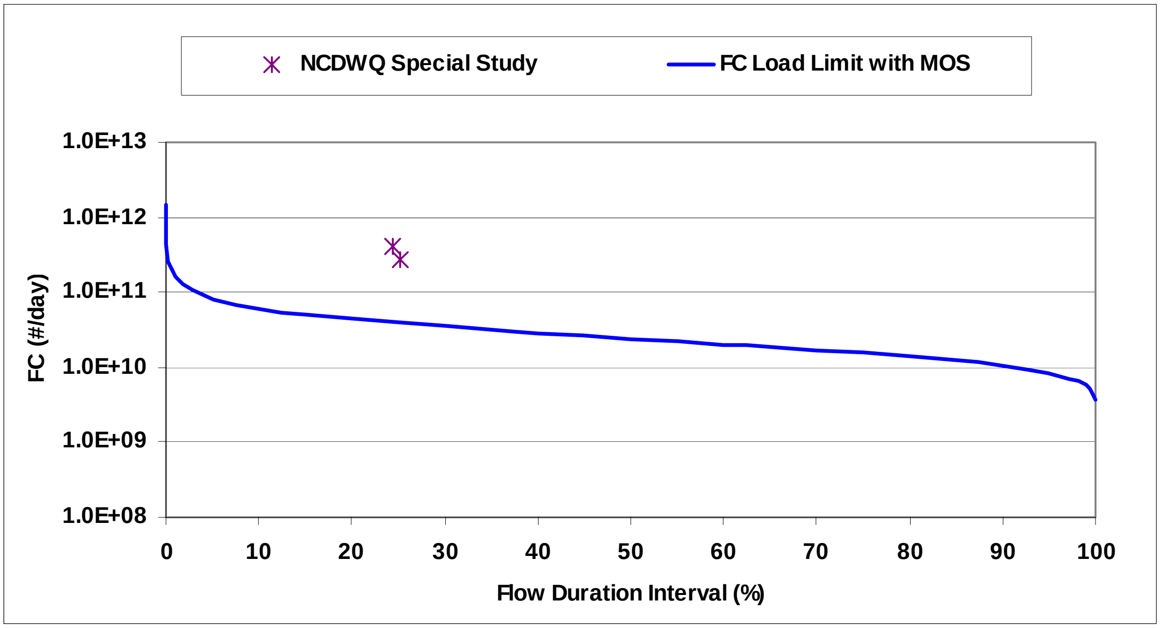

Figure 23. Geometric Mean Fecal Coliform Load-Duration Curves for Newfound Creek at Highway 63

At both stations, the reduction under the instantaneous standard is greater than under the geometric mean standard. Jenkins Valley Road requires the greatest reduction under the instantaneous standard (92.9 percent).

3.3.3 Source Assessment

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 such as stormwater runoff are likely to be the main focus of the inventory in this case.

The TVA performed a detailed source assessment for nutrients and sediment in the Newfound Creek Watershed. As part of the assessment, TVA developed a spreadsheet to estimate loading from potential sources in the watershed. Rural landuse loading estimates are based on the Universal Soil Loss Equation (USLE). Urban loadings were developed based on runoff volumes and Event Mean Concentrations (EMCs). The land use characterization discussed in Section 1.2 was used to determine the distribution of land use types in each watershed.

The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources including agricultural and land use information, GIS coverages, past TMDL studies, literature sources, and discussion with local resource agency staff.

3.3.3.1 Urban Nonpoint Source Loads

Urban loading rates were developed using a method described in the USEPA report *Urban Targeting and BMP Selection: An Information and Guidance Manual for State Nonpoint Source Program Staff Engineers and Managers* (EPA 1990). This method estimates runoff from various land use types depending on the impervious fraction of each. The annual runoff is then multiplied by an EMC to develop an annual loading rate for each landuse. The TVA loading tool developed for this purpose was modified to include fecal coliform loads for the sources identified by TVA. The EMCs for fecal coliform were based on runoff characteristics of different land use types measured as part of a detailed stormwater characterization effort (USGS, 1999). In addition, loadings from septic systems and wildlife were added to complete the source characterization.

3.3.3.2 Septic Systems

Residential septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. Fecal coliform bacteria naturally die-off as the effluent percolates through the soil to the groundwater. These systems effectively remove fecal coliform bacteria when properly installed and maintained. A septic system failure occurs when there is a discharge of waste to the soil surface where it is available for washoff into surface waters. Failing septic systems can deliver high bacteria loads to surface waters, depending on the proximity of the discharge to a stream and the timing of rainfall events. Septic system failures typically occur in older systems that are not adequately maintained with periodic sewage pump-outs.

The Buncombe County Health Department typically suggests a failure rate of 10 percent. However, the TVA source assessment indicated that a majority of the systems are classified as suspect in some way (location on small lots, steep slopes, rock outcroppings, or in close proximity to streams), so it is likely that the failure rate is much higher. The TVA source assessment estimated that approximately 668 septic systems in the watershed appeared to be suspect or failing to some extent. Of the systems inventoried, one has a distinctive moisture pattern indicative of ponding, and 110 have a suspicious moisture pattern but no visible drain field. These septic systems were assumed to be failing for the purpose of determining an annual load. Another 16 have no apparent plume and appear to be properly functioning. While the 560 remaining systems are suspect due to their location, it is unlikely that all were completely failing. For the purpose of the annual loading contributions, it was assumed that 50 percent were failing.

A fecal coliform bacteria concentration of 8.3×10^6 cfu/100mL and a septic system waste flow of 70 gallons/person/day was used to estimate the contribution from failing septic systems to surface waters (Thomann and Mueller, 1987). Houses considered to have a normally functioning septic system were assumed to have a negligible contribution of fecal bacteria to surface waters.

3.3.3.3 Agriculture

Bacteria produced by livestock can be deposited on the land, directly deposited in the stream (as is common when grazing animals have stream access), manually applied to cropland and other agricultural lands as fertilizer, or contributed to surface waters through illicit discharges from animal confinement areas. Estimates for loading from livestock animals are based on the TVA survey of animal operations, manure production by animal type, and the fecal content of different livestock manure. The results of these calculations are presented in Table 14.

Table 14. Livestock Fecal Coliform Bacteria Production Rates

Livestock Species	Daily Production (cfu/animal/day)	Source
Beef cattle	4.46×10^{10}	ASAE 1998
Dairy cattle	3.90×10^{10}	ASAE 1998
Chickens	6.75×10^{7}	ASAE 1998
Turkeys	9.30×10^{7}	ASAE 1998
Hogs/Pigs	1.08×10^{10}	ASAE 1998

Bacteria deposited on the land, either directly or through manure application, are available for washoff into surface waters during rainfall events. Grazing animals, such as beef and dairy cattle, typically spend portions of the day confined to loafing lots, grazing on pasturelands, and watering in nearby streams. The percentage of time spent in each area effects the relative contribution of bacteria loads to the stream. These factors were taken into consideration to estimate the fraction of the total fecal coliform load produced by livestock that would be delivered to the stream.

The estimate for loading from animal operations that were not directly adjacent to tributaries of Newfound Creek was set to 10 percent of the produced load. Loading from animal operations adjacent to the streams was only reduced by 75 percent to account for the lower potential for transport losses and decay.

3.3.3.4 Wildlife

Wildlife species in the watershed were identified through discussion with the NC Wildlife Commission. The predominant species include geese, deer, beaver, and raccoon. The population of each wildlife species was estimated using the population density per square mile of habitat area and estimates for the area of suitable habitat in the watershed.

As with grazing livestock, wildlife deposit fecal matter on the land and directly to surface waters. The percentage of fecal coliform bacteria that was directly deposited to surface waters was estimated based on the habitat of each species. The remaining fecal coliform load was applied to the upland land uses, according to the total area of each land use within established habitat areas. The typical fecal coliform density for each wildlife species was used to calculate fecal coliform bacteria loads (Table 15).

Table 15. Fecal Coliform Bacteria Production Rates For Wildlife Species

Wildlife Species	Daily Production (cfu/animal/day)	Source
Ducks	7.35×10^{9}	ASAE 1998
Geese	7.99×10^{8}	ASAE 1998
Deer	3.47×10^{8}	Yagow 1999
Raccoon	5.0×10^{9}	Yagow 1999

3.3.3.5 Total Loads

The results of the watershed loading estimates are shown in Figure 24. The contribution of fecal coliform to Newfound Creek is dominated by loadings from animal operations, which constitute 98 percent of the estimated load. These are grouped with other agricultural sources in Figure 24, but the contributions from non-manured crops (exclusive of wildlife) are estimated to be minimal. Septic systems also appear to play a significant role in fecal coliform impairments contributing 1.3 percent of the estimated total load. This combination of sources helps to explain the impairment of Newfound Creek under most flow conditions.

While these estimates are based on a number of assumptions, they are suitable for a general assessment of the nonpoint sources in the watershed. Wherever possible, detailed information was used to quantify the potential sources in the watershed. It should be noted, however, that incorporation of best management practices (BMPs) is not included in the source estimates. Recent adoption of agricultural BMPs may play a role in the reduction of high fecal coliform loads under high flow events.

The aggregate contributions by subwatershed were calculated to help provide some insight into the areas which potentially contribute the highest fecal coliform loadings and which may provide reduction opportunities (Figure 25).

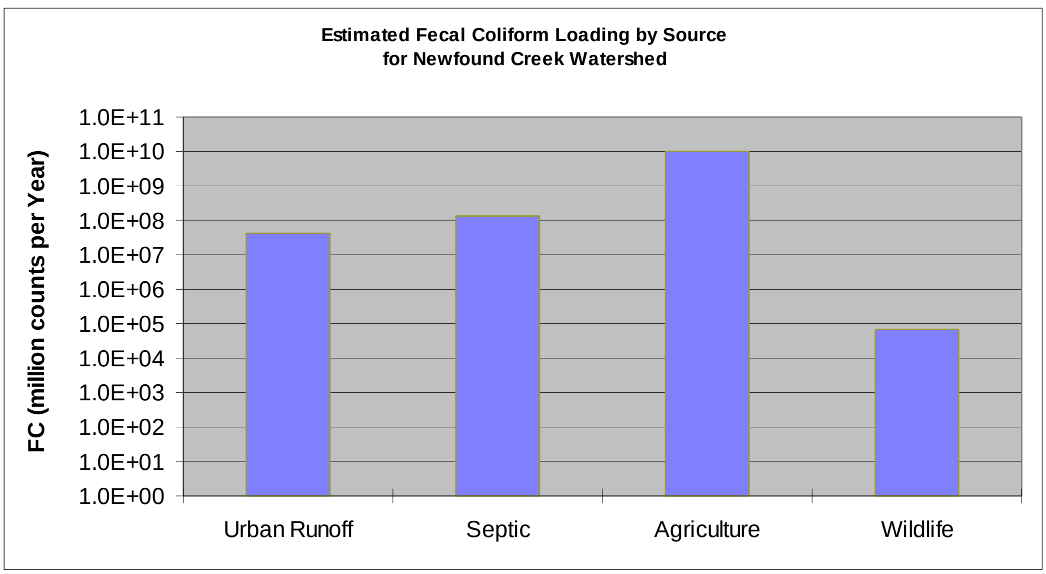

Figure 24. Fecal Coliform Loading by Source in the Newfound Creek Watershed

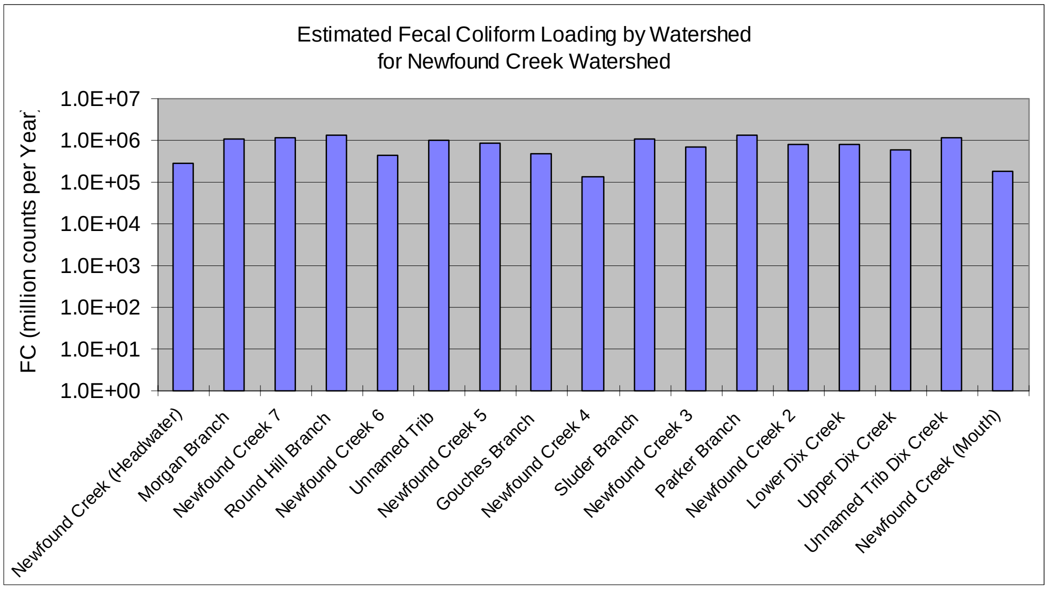

Figure 25. Fecal Coliform Loading by Subwatershed in the Newfound Creek Watershed

At McPeters Road in the rural, upstream section of the watershed, excursions of the instantaneous standard have a relatively low magnitude (maximum observed 1800/100 mL) and occur during low to medium flows. Exceedances at this station are likely due to slow, continuous sources such as septic systems. Pastureland adjacent to the stream may also contribute loads during rain events.

At Highway 63, the watershed is more developed with pasture and single-family residential lands. Excursions occur with greater frequency and higher magnitude during high flow conditions. The maximum fecal coliform concentration observed at Highway 63 is 57,000/100 mL. Three observations collected when the flow duration interval was less than 1 percent were all over 49,000/100 mL. Concentrations of this magnitude that occur during high flow events are likely due to runoff from animal operations.

At Jenkins Valley Road, the maximum concentration observed was 65,000, which occurred at a flow duration interval of less than 1 percent. The majority of excursions occur during wet events and are likely due to runoff from animal operations and residential land use.

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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 Total Maximum Daily Load (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 Class C waters). 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:

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

For Newfound Creek, there are no permitted point sources. Thus the TMDL contains no WLAs.

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 criterion of 200 cfu/100 mL will be considered.

4.3 Critical Conditions

The Load-Duration Curve approach addresses the load reductions required during all flow regimes. Unlike a steady state analysis, it does not depend on the identification of critical conditions to determine allocations. The load-duration analysis in Section 3.3, however, indicates that excursions of the criterion are primarily associated with higher flows with significant surface runoff. Therefore, implementation of the TMDL should focus on storm washoff events as a critical condition.

As shown in Table 11 in Section 3.3.1, the maximum reduction in existing loads (within the 10-95% flow range) is required at a flow of 29.6 cfs at Jenkins Valley Road. At this flow, the assimilative capacity (the maximum load that just meets the instantaneous limit of 400 CFU/100 mL) is 2.61×10^{11} CFU/d.

4.4 Seasonal Variations

Seasonal variation is considered in the development of the TMDLs because the allocation applies to all seasons. In Newfound Creek, exceedances occur during all months. For example in Figure 26, exceedances follow a similar pattern during winter and summer months at Jenkins Valley Road.

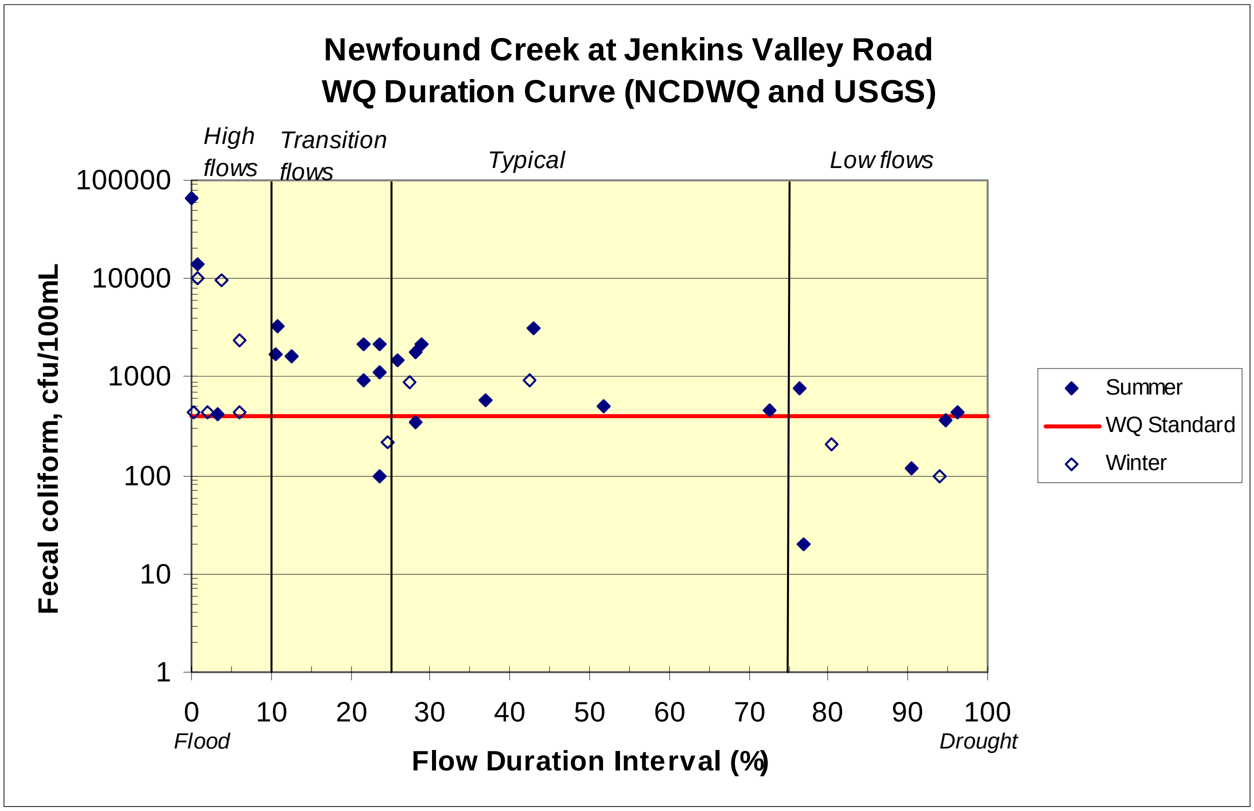

Figure 26. Flow Duration Curve of NCDENR Fecal Coliform Data for Newfound Creek at Jenkins Valley Road (12/1/96 through 6/1/99) with Summer and Winter Observations Distinguished

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.

At the critical flow of 29.6 cfs at Jenkins Valley Road, the assimilative capacity is 2.90×10^{11} CFU/d, while the target load is 2.61×10^{11} CFU/d – a 10 percent reduction. Therefore, the explicit MOS is 2.60×10^{10} CFU/d at the critical flow of 33 cfs.

4.6 Load Allocation

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 percent MOS. A summary of the estimated reductions required to meet the TMDL target is presented in Table 16. It can be seen that the instantaneous target is the most stringent for Newfound Creek at each station.

Table 16. Summary of Estimated Reductions

Stream	Pollutant	Target	Reduction Required
Newfound Creek at Jenkins Valley Road	Fecal coliform (Instantaneous Limit)	<360 cfu/100 mL	92.8
Newfound Creek at Highway 63	Fecal coliform (Instantaneous Limit)	<360 cfu/100 mL	91.6
Newfound Creek at McPeters Road	Fecal coliform (Instantaneous Limit)	<360 cfu/100 mL	82.9

Note: Maximum reduction calculated between 10^{th} and 95^{th} percentile flows

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 reductions required for Newfound Creek were highest at Jenkins Valley Road. The highest reduction requirements 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 17.

Table 17. TMDL Reductions for Fecal Coliform

Stream	Pollutant	Target	Target Load (#/day)	Margin of Safety (#/day)	Existing Load (#/day)	Reduction Required
Newfound Creek	Fecal coliform (Instantaneous Limit)	<360 cfu/100 mL	$2.61x10^{11}$	$2.60x10^{10}$	$3.62.x10^{12}$	92.8%

In the case of Newfound Creek, all of the fecal coliform loading is due to nonpoint sources. Thus the TMDL will be allocated in terms of nonpoint source (LA) loadings only. TMDL allocations are summarized in Table 18.

Table 18. Newfound Creek TMDL Components

Segment	Pollutant	Existing	WLA[1]	LA	MOS[2]	TMDL
Newfound Creek	Fecal coliform (counts/day)	$4.09 x10^{12}$	0.00	$2.61x10^{11}$	$2.60x10^{10}$	$2.90x10^{11}$

Source analysis (Section 3.3.3.5) suggests that the vast majority of the existing load is due to domestic animals. Therefore, it appears that needed reductions should be sought primarily from this sector. However, it will also be important to identify failing septic systems, as loads of human waste present a greater health risk.

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5 Report Summary

This report presents the development of a TMDL for fecal coliform impairment of Newfound Creek near Asheville, North Carolina. Newfound Creek was 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 rural source contributions, such as animal operations, septic systems, and runoff from farms and residential developments, are a significant source of much of the fecal coliform impairment. These results were used to derive the allocations required by the TMDL. The specified reductions can be achieved with an increased emphasis on BMPs for animal operations, protection of riparian buffers, and identification and repair of aging or failing septic systems.

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6 TMDL Implementation Plan

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.

The preliminary source assessment suggests that large domesticated animals (particularly cattle) may be the major source of fecal coliform loading to Newfound Creek. Therefore, reductions for fecal coliform should first be sought through installation and maintenance of agricultural BMPs for farm animals. Key efforts could include exclusion of animals from streams and maintenance of adequate riparian buffers. Although estimated to contribute less than two percent of the total load, identification and repair of aging or failing septic systems is also advisable for the protection of human health. Implementation could also target storm-driven sources such as runoff from residential areas and crop land.

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7 Stream Monitoring

Fecal coliform monitoring should continue at Jenkins Valley Road, Highway 63, and McPeters Road monitoring sites. The continued monitoring of fecal coliform concentrations will allow for the evaluation of progress towards the goal of reaching water quality standards. NCDENR does not have ambient monitoring stations at these sites. Therefore, we recommend the establishment of an ambient monitoring site at Jenkins Valley Road. 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.

BCSWCD will continue monthly monitoring of their ten water quality sites, excluding sites 5A and 5B which will not be monitored after July 29th, 2004. USGS has no scheduled events for the five fecal coliform sites.

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8 Future Efforts

The Buncombe County Soil and Water Conservation District offers grant money through the Clean Water Management Trust Fund program to assist residents interested in using BMPs to reduce pollutant loads from their land. Existing installations include livestock fences, constructed wetlands, streambank stabilization, and waste treatment lagoons.

Septic systems must be properly maintained and inspected periodically. Maintenance records submitted to Buncombe County may help identify systems in need of attention. Community outreach through advertising should target owners of septic systems who are unaware of maintenance guidelines, such as pumping every five years.

Other potential mechanisms for reduction of fecal coliform include local regulations or ordinances related to zoning, land use, 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 publicly noticed through various means, including notification in the local newspapers on November 15th, 2004 (see Appendix C). DWQ will electronically distribute the draft TMDL and public comment information to known interested parties. The TMDL is also be available from the Division of Water Quality's website at http://h2o.enr.state.nc.us/tmdl/ during the comment period. The public notice period lasted 30 days and ended on December 15, 2004.

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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:

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Appendix A Water Quality Sampling Data

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Table A-1. NCDENR Ambient Monitoring Data for Newfound Creek at Jenkins Valley Road (1996-1999)

Date	Flow (cfs)[1]	Flow Interval	Observed FC (#/100 mL)
1/27/1996	199.0	0.00	430
10/22/1996	7.3	0.76	760
11/25/1996	13.3	0.42	940
12/16/1996	19.4	0.25	220
4/7/1997	29.2	0.11	1,700
5/28/1997	17.7	0.29	2,200
6/30/1997	13.1	0.43	3,200
9/8/1997	5.0	0.90	120
10/29/1997	11.3	0.52	500
1/7/1998	99.8	0.01	9,900
2/23/1998	43.0	0.04	9,500
3/9/1998	57.3	0.02	440
3/23/1998	35.5	0.06	430
4/28/1998	27.1	0.13	1,600
7/13/1998	7.3	0.77	20
9/1/1998	3.8	0.96	430
10/5/1998	4.1	0.95	370
11/5/1998	4.3	0.94	100
12/9/1998	6.6	0.81	210
1/15/1999	35.5	0.06	2,400
3/26/1999	18.1	0.27	880
5/18/1999	14.8	0.37	590
6/14/1999	7.9	0.73	460

[1]Flow estimated from nearby gages USGS 03453000 and USGS 03500240.

Table A-2. NCDENR Special Study Monitoring Data for Newfound Creek at Jenkins Valley Road (2003)

Date	Flow (cfs) [1]	Flow Interval	Observed FC (#/100 mL)
4/14/2003	46.0	0.03	410
4/21/2003	29.0	0.11	3,300
4/28/2003	20.0	0.24	97
5/5/2003	95.0	0.01	14,000
5/6/2003	694.0	0.00	65,000
6/2/2003	18.0	0.28	350
6/3/2003	19.0	0.26	1,500
6/9/2003	20.0	0.24	1,100
6/10/2003	18.0	0.28	1,800
6/17/2003	21.0	0.22	2,200
6/20/2003	20.0	0.24	2,200

[1]Observed flow is from USGS Gage 03451690, Newfound Creek.

Table A-3. NCDENR Ambient Monitoring Data for Newfound Creek at Highway 63 (1996-1999)

Date	Flow (cfs) [1]	Flow Interval	Observed FC (#/100 mL)
11/25/1996	6.2	0.42	1,500
12/16/1996	9.1	0.25	2,800
5/28/1997	8.3	0.29	2,000
6/30/1997	6.1	0.43	600
10/29/1997	5.3	0.52	250
1/7/1998	46.7	0.01	57,000
2/23/1998	20.1	0.04	7,000
3/9/1998	26.8	0.02	770
3/23/1998	16.6	0.06	140
4/28/1998	12.7	0.13	270
7/13/1998	3.4	0.77	260
9/1/1998	1.8	0.96	840
10/5/1998	1.9	0.95	790
11/5/1998	2.0	0.94	210
12/9/1998	3.1	0.81	320
1/15/1999	16.6	0.06	1,200
3/26/1999	8.4	0.27	3,300
5/18/1999	6.9	0.37	660
6/14/1999	3.7	0.73	950

[1]Flow estimated and scaled from nearby gages USGS 03453000 and USGS 03500240.

Table A-4. NCDENR Special Study Monitoring Data for Newfound Creek at Highway 63 (2003)

Date	Flow (cfs) [1]	Flow Interval	Observed FC (#/100 mL)
4/14/2003	21.5	0.03	750
4/21/2003	13.6	0.11	7,000
4/28/2003	9.4	0.24	500
5/5/2003	44.4	0.01	49,000
5/6/2003	324.7	0.00	53,000
6/2/2003	8.4	0.28	210
6/3/2003	8.9	0.26	1,400
6/9/2003	9.4	0.24	2,000
6/10/2003	8.4	0.28	1,600
6/17/2003	9.8	0.22	3,100
6/20/2003	9.4	0.24	1,400

[1]Observed flow scaled from USGS Gage 03451690, Newfound Creek.

Table A-5. NCDENR Ambient Monitoring Data for Newfound Creek at McPeters Road (1996-1999)

Date	Flow (cfs) [1]	Flow Interval	Observed FC (#/100 mL)
12/1/1996	4.9	0.01	39
1/1/1997	1.3	0.22	12
2/1/1997	1.3	0.21	53
4/1/1997	1.7	0.12	120
5/1/1997	2.0	0.08	50
6/1/1997	2.0	0.08	70
9/1/1997	0.3	0.87	360
10/1/1997	0.5	0.72	690
1/1/1998	0.7	0.55	1,800
2/1/1998	1.6	0.13	120
3/1/1998	1.6	0.14	20
4/1/1998	1.8	0.11	76
7/1/1998	0.6	0.56	94
9/1/1998	0.2	0.96	460
10/1/1998	0.3	0.94	160
11/1/1998	0.2	0.95	300
12/1/1998	0.3	0.92	68
1/1/1999	0.4	0.78	50
3/1/1999	1.5	0.16	620
5/1/1999	1.0	0.34	140
6/1/1999	0.6	0.63	600

[1]Flow estimated and scaled from nearby gages USGS 03453000 and USGS 03500240.

Table A-6. USGS Monitoring Data for Stations on Newfound Creek and Tributaries (1997, 2003)

Date	Station	Flow (cfs)[1]	Observed FC (#/100 mL)
4/8/1997	01	36.00	2,700
5/28/2003	01	22.00	930
11/19/2003	01	195.00	24,000
5/28/2003	05	13.80	1,400
11/19/2003	05	88.40	29,000
5/28/2003	06	1.16	140
11/19/2003	06	15.00	6,000
5/28/2003	07	9.17	8,700
11/19/2003	07	51.10	11,000
5/28/2003	10	2.70	1,300
11/19/2003	10	13.50	2,900

[1]Flow measured at water quality station.

Table A-7. Buncombe County Monitoring Data for Stations on Newfound Creek and Tributaries (2002-2004)

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
4/30/2002	1A	7.5	208
5/13/2002	1A	15	370
5/30/2002	1A	7.2	360
10/16/2002	1A	33	1,582
11/6/2002	1A	9.6	200
12/17/2002	1A	17	820
1/7/2003	1A	16	62
1/16/2003	1A	12	144
1/21/2003	1A	14	46
1/30/2003	1A	12	2,800
2/12/2003	1A	13	620
2/25/2003	1A	38	380
3/19/2003	1A	24	6,000
4/28/2003	1A	20	740

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
6/12/2003	1A	21	138
7/2/2003	1A	75	3,200
7/24/2003	1A	18	230
8/6/2003	1A	28	455
8/20/2003	1A	14	720
9/3/2003	1A	19	525
9/15/2003	1A	14	505
10/1/2003	1A	13	260
10/15/2003	1A	14	445
11/5/2003	1A	15	4,700
11/19/2003	1A	590	3,800
12/10/2003	1A	39	2,900
12/17/2003	1A	30	333
2/18/2004	1A	24	207
3/9/2004	1A	17	5,000
3/24/2004	1A	17	4,400
4/7/2004	1A	16	4,750
4/20/2004	1A	22	1,513
5/3/2004	1A	NA	1,692
5/19/2004	1A	16	3,000
6/16/2004	1A	34	2,500
7/14/2004	1A	17	600
7/29/2004	1A	NA	1,160
4/30/2002	1B	7.5	2,800
5/13/2002	1B	15	5,300
5/30/2002	1B	7.2	3,500
10/16/2002	1B	33	2,200
11/6/2002	1B	9.6	5,500
12/17/2002	1B	17	580
1/7/2003	1B	16	16,533
1/16/2003	1B	12	210
1/21/2003	1B	14	5,550
1/30/2003	1B	12	200
2/12/2003	1B	13	760

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
2/25/2003	1B	38	1,750
3/19/2003	1B	24	6,000
4/28/2003	1B	20	1,100
6/12/2003	1B	21	2,017
7/2/2003	1B	75	11,600
7/24/2003	1B	18	1,517
8/6/2003	1B	28	2,100
8/20/2003	1B	14	3,400
9/3/2003	1B	19	1,080
9/15/2003	1B	14	6,800
10/1/2003	1B	13	1,275
10/15/2003	1B	14	7,900
11/5/2003	1B	15	47,000
11/19/2003	1B	590	4,067
12/10/2003	1B	39	28,000
12/17/2003	1B	30	521
2/18/2004	1B	24	1,160
3/9/2004	1B	17	7,800
3/24/2004	1B	17	9,800
4/7/2004	1B	16	6,200
4/20/2004	1B	22	5,000
5/3/2004	1B	NA	11,333
5/19/2004	1B	16	21,667
6/16/2004	1B	34	2,100
7/14/2004	1B	17	1,415
7/29/2004	1B	NA	2,600
4/30/2002	2A	7.5	673
5/13/2002	2A	15	2,300
5/30/2002	2A	7.2	1,209
10/16/2002	2A	33	1,855
11/6/2002	2A	9.6	904
12/17/2002	2A	17	164
1/7/2003	2A	16	1,277
1/16/2003	2A	12	2,100

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
1/21/2003	2A	14	22,600
1/30/2003	2A	12	156
2/12/2003	2A	13	100
2/25/2003	2A	38	275
3/19/2003	2A	24	6,000
4/28/2003	2A	20	840
6/12/2003	2A	21	1,733
7/2/2003	2A	75	4,900
7/24/2003	2A	18	1,450
8/6/2003	2A	28	2,100
8/20/2003	2A	14	1,817
9/3/2003	2A	19	3,500
9/15/2003	2A	14	4,000
10/1/2003	2A	13	505
10/15/2003	2A	14	2,200
11/5/2003	2A	15	6,500
11/19/2003	2A	590	7,600
12/10/2003	2A	39	9,200
12/17/2003	2A	30	625
2/18/2004	2A	24	870
3/9/2004	2A	17	1,295
3/24/2004	2A	17	4,200
4/7/2004	2A	16	5,900
4/20/2004	2A	22	5,500
5/3/2004	2A	NA	5,600
5/19/2004	2A	16	1,120
6/16/2004	2A	34	1,607
4/30/2002	2B	7.5	560
5/13/2002	2B	15	1,291
5/30/2002	2B	7.2	1,200
10/16/2002	2B	33	9,500
11/6/2002	2B	9.6	1,044
12/17/2002	2B	17	4,750
1/7/2003	2B	16	1,215

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
1/16/2003	2B	12	575
1/21/2003	2B	14	580
1/30/2003	2B	12	2,200
2/12/2003	2B	13	1,180
2/25/2003	2B	38	2,400
3/19/2003	2B	24	12,000
4/28/2003	2B	20	740
6/12/2003	2B	21	820
7/2/2003	2B	75	6,000
7/24/2003	2B	18	1,000
8/6/2003	2B	28	2,500
8/20/2003	2B	14	680
9/3/2003	2B	19	2,900
9/15/2003	2B	14	5,950
10/1/2003	2B	13	520
10/15/2003	2B	14	860
11/5/2003	2B	15	4,350
11/19/2003	2B	590	10,400
12/10/2003	2B	39	9,200
12/17/2003	2B	30	1,438
2/18/2004	2B	24	4,700
3/9/2004	2B	17	2,400
3/24/2004	2B	17	1,600
4/7/2004	2B	16	2,500
4/20/2004	2B	22	2,300
5/3/2004	2B	NA	2,900
5/19/2004	2B	16	9,600
6/16/2004	2B	34	2,100
4/30/2002	3A	7.5	260
5/13/2002	3A	15	636
5/30/2002	3A	7.2	330
10/16/2002	3A	33	8,000
11/6/2002	3A	9.6	619
12/17/2002	3A	17	857

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
1/7/2003	3A	16	540
1/16/2003	3A	12	333
1/21/2003	3A	14	4,350
1/30/2003	3A	12	1,225
2/12/2003	3A	13	740
2/25/2003	3A	38	680
3/19/2003	3A	24	11,500
4/28/2003	3A	20	178
6/12/2003	3A	21	630
7/2/2003	3A	75	4,400
7/24/2003	3A	18	480
8/6/2003	3A	28	960
8/20/2003	3A	14	515
9/3/2003	3A	19	470
9/15/2003	3A	14	3,100
10/1/2003	3A	13	365
10/15/2003	3A	14	400
11/5/2003	3A	15	11,600
11/19/2003	3A	590	12,000
12/10/2003	3A	39	4,950
12/17/2003	3A	30	32,500
2/18/2004	3A	24	2,400
3/9/2004	3A	17	4,450
3/24/2004	3A	17	14,533
4/7/2004	3A	16	1,180
4/20/2004	3A	22	760
5/3/2004	3A	NA	700
5/19/2004	3A	16	720
6/16/2004	3A	34	1,160
7/14/2004	3A	17	1,492
7/29/2004	3A	NA	1,877
4/30/2002	3B	7.5	100
5/13/2002	3B	15	360
5/30/2002	3B	7.2	222

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
10/16/2002	3B	33	3,600
11/6/2002	3B	9.6	540
12/17/2002	3B	17	922
1/7/2003	3B	16	480
1/16/2003	3B	12	230
1/21/2003	3B	14	2,900
1/30/2003	3B	12	1,374
2/12/2003	3B	13	475
2/25/2003	3B	38	700
3/19/2003	3B	24	4,700
4/28/2003	3B	20	138
6/12/2003	3B	21	560
7/2/2003	3B	75	5,500
7/24/2003	3B	18	260
8/6/2003	3B	28	900
8/20/2003	3B	14	270
9/3/2003	3B	19	460
9/15/2003	3B	14	1,283
10/1/2003	3B	13	235
10/15/2003	3B	14	420
11/5/2003	3B	15	6,000
11/19/2003	3B	590	12,000
12/10/2003	3B	39	10,900
12/17/2003	3B	30	31,000
2/18/2004	3B	24	1,454
3/9/2004	3B	17	470
3/24/2004	3B	17	435
4/7/2004	3B	16	578
4/20/2004	3B	22	520
5/3/2004	3B	NA	360
5/19/2004	3B	16	370
6/16/2004	3B	34	640
7/14/2004	3B	17	700
7/29/2004	3B	NA	660

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
1/7/2003	5A	16	940
1/21/2003	5A	14	1,862
6/12/2003	5A	21	1,417
7/2/2003	5A	75	2,200
7/24/2003	5A	18	6,000
8/6/2003	5A	28	154
8/20/2003	5A	14	137
9/3/2003	5A	19	290
9/15/2003	5A	14	1,040
10/1/2003	5A	13	163
10/15/2003	5A	14	470
11/5/2003	5A	15	6,700
11/19/2003	5A	590	12,000
12/10/2003	5A	39	9,938
12/17/2003	5A	30	69,000
2/18/2004	5A	24	4,600
3/9/2004	5A	17	254
3/24/2004	5A	17	1,575
4/7/2004	5A	16	520
4/20/2004	5A	22	220
5/3/2004	5A	NA	320
5/19/2004	5A	16	2,900
6/16/2004	5A	34	580
7/14/2004	5A	17	500
1/7/2003	5B	16	4,000
1/21/2003	5B	14	15,733
6/12/2003	5B	21	1,100
7/2/2003	5B	75	2,133
7/24/2003	5B	18	6,000
8/6/2003	5B	28	500
8/20/2003	5B	14	760
9/3/2003	5B	19	4,900
9/15/2003	5B	14	2,800
10/1/2003	5B	13	455

Date	Site	Flow (cfs)[1,2]	Observed FC (#/100 mL)
10/15/2003	5B	14	620
11/5/2003	5B	15	7,600
11/19/2003	5B	590	12,000
12/10/2003	5B	39	45,000
12/17/2003	5B	30	20,500
2/18/2004	5B	24	3,550
3/9/2004	5B	17	4,225
3/24/2004	5B	17	4,900
4/7/2004	5B	16	59,500
4/20/2004	5B	22	5,700
5/3/2004	5B	NA	626
5/19/2004	5B	16	670
6/16/2004	5B	34	875
7/14/2004	5B	17	1,625
7/14/2004	6A	17	1,160
7/29/2004	6A	NA	940
7/29/2004	6B	NA	1,200

[1]Flow measured at water quality station.

[2]NA = flow measurement not available

Appendix B Assimilative Capacity and Load Reduction Calculations

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B.1 DEVELOPMENT OF REGRESSION EQUATIONS

Regression equations were developed to predict fecal coliform load in Newfound Creek (CFU/d) at each NCDENR monitoring station as a function of flow frequency. The regression relationship for each site is a log-linear relationship (natural log of load as a function of flow frequency). All sampling data are shown on the regression graphs, but the regression line is only based on observations with a flow duration interval greater than 5 percent. High flow observations (duration less than 10 percent) are not used to calculate load reductions, but may be useful in the estimation of the regression line. However, observations at estimated durations less than about 5 percent (very high flows) appear to deviate from the log-linear relationship and are excluded from the calculation of the regression line to prevent outliers from biasing the predictions.

Results of the regression analyses for each station are summarized in Table B-1 through Table B-3.

Table B-1. Regression of Natural Logarithm of Fecal Coliform Load on Flow Frequency, Newfound Creek at Jenkins Valley Road

Regression Statistics						
Multiple R	0.8148					
R Square	0.6639					
Adjusted R Square	0.6509					
Standard Error	1.0065					
Observations	28					
ANOVA						
	df	**SS**	**MS**	**F**	**Significance F**	
Regression	1	52.0172	52.0172	51.3481	1.30768E-07	
Residual	26	26.3388	1.0130			
Total	27	78.3560				
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	28.0458	0.3300	84.9892	2.52E-33	27.3675	28.7241
Flow %le	-4.6140	0.6439	-7.1658	1.31E-07	-5.9376	-3.2905

Table B-2. Regression of Natural Logarithm of Fecal Coliform Load on Flow Frequency, Newfound Creek at Highway 63

Regression Statistics						
Multiple R	0.7211					
R Square	0.5200					
Adjusted R Square	0.4982					
Standard Error	0.9782					
Observations	24					
ANOVA						
	df	**SS**	**MS**	**F**	**Significance F**	
Regression	1	22.8036	22.8036	23.8309	7.02E-05	
Residual	22	21.0516	0.9569			
Total	23	43.8552				
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	27.0418	0.3478	77.7437	0.0000	26.3205	27.7632
Flow %le	-3.4241	0.7014	-4.8817	0.0001	-4.8787	-1.9694

For McPeters Road, the regression has low explanatory power – indicating that load is only weakly correlated to flow. The same approach may be used, however. In this case, the regression analysis collapses toward an estimate of uncertainty at the predicted mean load.

Table B-3. Regression of Natural Logarithm of Fecal Coliform Load on Flow Frequency, Newfound Creek at McPeters Road

Regression Statistics						
Multiple R	0.1952					
R Square	0.0381					
Adjusted R Square	-0.0153					
Standard Error	1.1885					
Observations	20					
ANOVA						
	df	**SS**	**MS**	**F**	**Significance F**	
Regression	1	1.0074	1.0074	0.7131	0.4095	
Residual	18	25.4267	1.4126			
Total	19	26.4341				
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	22.0067	0.4567	48.1897	1.75E-20	21.0472	22.9661
Flow %le	-0.6635	0.7857	-0.8445	0.4095	-2.3143	0.9872

B.2 ESTIMATION OF PREDICTION INTERVALS

The method requires the estimation of a prediction interval about the regression line. In addition, because the regression is in log space, the bias inherent in conversion from log space to arithmetic space must be addressed.

The regression equation yields a minimum variance unbiased estimate of the local mean value, μ_0 of the natural logarithms of load, conditional on a corresponding value of the independent variable, x_0, (expressed as the deviation from the mean of all observed x values), in this case representing the flow fraction:

$$\mu_0 = \beta_0 + \beta_1 \cdot x_0 + \varepsilon \,,$$

where ε is a random disturbance term. The desired confidence limit (in log space) is given by the prediction interval estimate for an individual realization y_0 with mean μ_0. This interval addresses both the uncertainty in estimating the mean and the variability of individual observations about the mean and is given by:

$$y_0 = \mu_0 \pm t_{\alpha, n-2} \cdot s_y \cdot \sqrt{\frac{1}{n} + \frac{x_0^{\ 2}}{\sum x_i^{\ 2}} + 1} \,,$$

where s_y is the sample standard deviation of the *y* values, and $t_{\alpha,\ n-2}$ is the Student's *t* statistic with tail area α and *n*-2 degrees of freedom. For a two-tailed 90 percent confidence interval, $\alpha = 0.05$.

Conversion from logarithmic to arithmetic space introduces a bias, as the transform is not symmetrical. The exact minimum variance unbiased estimator of the arithmetic mean from the logarithmic mean does not have a closed-form solution, but, for large samples, is closely approximated by (Gilbert, 1987):

$$w_0 = e^{\left(y_0 + {s_{y0}}^2 / 2 \right)},$$

where w_0 is the estimator in arithmetic space and s_{y0}^2 is the local variance about the mean line, or

$$s_{y0} = s_y \cdot \sqrt{\frac{1}{n} + \frac{{x_0}^2}{\sum {x_i}^2}}\ .$$

Appendix C Public Notice

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Public Notice
State of North Carolina
Division of Water Quality

Availability of the
Fecal Coliform
Total Maximum
Daily Loads (TMDLs) for
Newfound Creek,
North Carolina

Copies of the TMDL may be obtained by calling Robin Markham at (919) 733-5083 ext. 558 or on the internet at http://h2o.enr.state.nc.us/tmdl.

Written comments regarding this TMDL will be accepted until December 15th, 2004. Please mail comments to NCDWQ – Planning Branch, attn: Adugna Kebede, 1617 Mail Service Center, Raleigh, NC 27699.

November 15, 2004
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AFFIDAVIT OF PUBLICATION

BUNCOMBE COUNTY
SS.
NORTH CAROLINA

Before the undersigned, a Notary Public of said County and State, duly commissioned, qualified and authorized by law to administer oaths, personally appeared **Darryl Rhymes,** who, being first duly sworn, deposes and says: that he is the **Legal Billing Clerk** of **The Asheville Citizen-Times,** engaged in publication of a newspaper known as **The Asheville Citizen-Times**, published, issued, and entered as second class mail in the City of Asheville, in said County and State; that he 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 Asheville Citizen-Times** on the following date: November 15, 2004 said newspaper in which said notice, paper, document or legal advertisement were published were, at the time of each and every publication, a newspaper meeting all of the requirements and qualifications of Section 1-597 of the General Statues of North Carolina and was a qualified newspaper within the meaning of Section 1-597 of the General Statues of North Carolina.

Signed this 16th day of November 2004

(Signature of person making affidavit)

Sworn to and subscribed before me the 16th day of November 2004

(Notary Public)
My Commission expires the 3rd day of [illegible] 2008.

KATRINA JOYE PETREY
NOTARY
PUBLIC
BUNCOMBE CO., N.C.

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