Total Maximum Daily Load Development for Laurel Fork Fecal Bacteria, Dissolved Oxygen and General Standard (Benthic)

Prepared for
Virginia Department of Environmental Quality
April 10, 2006

Submitted by:

New River-Highlands RC & D
100 USDA Drive, Suite F
Wytheville, VA 24382
Phone: 276.228.2879, FAX: 276.228.4367

MapTech, Inc.
1715 Pratt Drive, Suite 3200
Blacksburg, VA 24060
Phone: 540.961.7864, FAX: 540.961.6392

CONTENTS

FIGURES

TABLES

ACKNOWLEDGEMENTS

Virginia Department of Environmental Quality (VADEQ), Central Office

VADEQ, Southwest Regional Office

Virginia Department of Conservation and Recreation (VADCR)

Virginia Department of Forestry, Central Office (VADOF)

Tazewell County Agricultural Extension Center

Tazewell Soil and Water Conservation District (TSWCD)

New River-Highlands RC&D

Local citizens and stakeholders in the Laurel Fork watershed

MapTech, Inc. of Blacksburg, Virginia, supported this study as a subcontractor to
New River-Highlands RC&D,
through funding provided by
Virginia Department of Environmental Quality contract #99

EXECUTIVE SUMMARY

Background and Applicable Standards

Laurel Fork was first listed as impaired in 1994. A 2.84-mile segment of Laurel Fork was listed again on the *1996 303(d) TMDL Priority List* for violations of the fecal coliform bacteria standard and the General Standard (benthic) (VADEQ and VADCR, 1996). The *1998 303(d) Total Maximum Daily Load Priority List and Report* lists Laurel Fork for dissolved oxygen (DO) standard violations as well as for violations of the fecal coliform bacteria standard and the General Standard (benthic, sediment) (VADEQ, 1998). Laurel Fork continued to be listed on the *2002 303(d) Report on Impaired Waters* and on the *2004 Virginia Water Quality Assessment 305(b)/303(d) Integrated Report* (VADEQ, 2004). In 2004, an additional 0.07-mile segment of Laurel Fork was included in the report. The impaired stream segment was updated again for the 2006 assessment. Data collected from station 9-LRR005.59 during a Total Maximum Daily Load (TMDL) special monitoring study showed violations of the bacteria standard and so the TMDL impairment reach was extended upstream to Curran Branch at river mile 5.90. The impaired segment extends from river mile 5.90 downstream to the Virginia-West Virginia state line at river mile 1.35 for a total of 4.55 miles.

TMDL Endpoint and Water Quality Assessment

Fecal Coliform

Potential sources of fecal coliform include both point source and nonpoint source (NPS) contributions. Nonpoint sources include: wildlife, grazing livestock, land application of manure, land application of biosolids, urban/suburban runoff, failed and malfunctioning septic systems, and uncontrolled discharges (straight pipes). Three permitted point sources are associated with the Laurel Fork watershed through the Virginia Pollutant Discharge Elimination System (VPDES). All of these facilities are permitted for fecal control, with design discharges ranging from <0.001-0.50 MGD.

Fecal bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard. For this TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126-cfu/100 mL and a single sample maximum of 235-cfu/100 mL. A translator developed by VADEQ was used to convert fecal coliform values to *E. coli* values.

General Standard (benthic) - Sediment

A TMDL must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not, but generally do not provide enough information to determine the cause(s) of the impairment. The process outlined in the Stressor Identification Guidance Document (EPA, 2000) was used to identify stressors affecting Laurel Fork. Chemical and physical monitoring data from VADEQ monitoring stations provided evidence to support or eliminate potential stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity/total dissolved solids, temperature, and organic matter.

The results of the stressor analysis for Laurel Fork are divided into three categories:

> **Non-Stressor(s)**: Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors.
>
> **Possible Stressor(s)**: Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors.
>
> **Most Probable Stressor(s)**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s).

The results indicate that sediment is the Most Probable Stressor for Laurel Fork and were used to develop the benthic TMDL.

Sediment is delivered to Laurel Fork through surface runoff, streambank erosion, and natural erosive processes. During runoff events, sediment is transported to streams from land areas. Rainfall energy, soil cover, soil characteristics, topography, and land management affect the magnitude of sediment loading. Land disturbances from mining, forest harvesting, and construction accelerate erosion at varying degrees. Sediment transport is a natural and continual process that is often accelerated by human activity. An increase in impervious land without appropriate stormwater control increases runoff volume and peaks, which leads to greater potential for channel erosion. During dry periods, sediment from air or traffic builds up on impervious areas and is transported to streams during runoff events. Fine sediments are included in total suspended solids (TSS) loads that are permitted for wastewater, industrial stormwater, and construction stormwater discharge.

Dissolved Oxygen

Potential sources affecting in-stream dissolved oxygen concentrations include both point source and nonpoint source (NPS) contributions. Potential point sources include wastewater treatment plants, industrial facilities, combined sewer overflows, sanitary sewer overflows, and stormwater runoff. Potential nonpoint sources include erosion of sediments, grazing livestock, land application of fertilizers and manure, land application of biosolids, urban/suburban runoff, failed and malfunctioning septic systems, and uncontrolled discharges (straight pipes).

The source of the low dissolved oxygen in Laurel Fork is thought to be non-regulated sewage discharges and exfiltration and overflows from the Pocahontas Sewage Treatment Plant, as well as uncontrolled discharges and sediment. The sources will be addressed by the development of the fecal bacteria TMDL and the benthic TMDL for sediment.

Modeling Procedure

Hydrology

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and fecal coliform loads.

For purposes of modeling watershed inputs to streamflow and in-stream fecal bacteria, the Laurel Fork drainage area was divided into five subwatersheds. A paired watershed approach was utilized to calibrate the hydrology of Laurel Fork. Sand Run in Upshur County, West Virginia (USGS Station #03052500) was selected as the paired watershed based on comparative hydrologic characteristics. The representative time period used for hydrologic calibration of Laurel Fork covered the period 10/1/1992 through 9/30/1997.

Hydrology validation was not performed for Laurel Fork because there were only six measurements of flow collected during the representative modeling period. All observed data collected during this time period was used for hydrology calibration. It was determined that using all available data for calibration would result in a more accurate model.

Fecal Coliform

The fecal coliform calibration for Laurel Fork was conducted using monitored data collected at VADEQ monitoring station 9-LLR001.39. The five years with the most fecal coliform data (23 samples) were used as the calibration time period, 10/1/1994 through 9/30/1999. The fecal coliform validation for Laurel Fork was conducted using monitored data collected at VADEQ monitoring station 9-LLR001.39. For fecal coliform validation, the period selected was 10/1/1990 through 9/30/1994, during which 13 samples were collected. Modeled fecal coliform levels matched observed levels indicating that the model was well calibrated.

The allocation precipitation time period was selected to coincide with the hydrologic calibration time period. The allocation/calibration time period was selected as the years with the most representative rainfall compared to all historic data. The time period used for allocation was 10/1/1992 through 9/30/1997. Modeling during the representative period provided the highest confidence in allocation results.

Sediment

There are no existing in-stream criteria for sediment in Virginia; therefore, a reference watershed approach was used to define allowable TMDL loading rates in the Laurel Fork watershed. The South Fork Powell River watershed was selected as the TMDL reference for Laurel Fork due to the similarity of the watershed characteristics. The TMDL sediment loads were defined as the modeled sediment load for existing conditions from the non-impaired South Fork Powell River watershed and area-adjusted to the Laurel Fork watershed. The Generalized Watershed Loading Function (GWLF) model (Haith et al., 1992) was used for comparative modeling between Laurel Fork and South Fork Powell River.

Existing Conditions

Fecal Coliform

Wildlife populations, the rate of failure of septic systems, domestic pet populations, and numbers of livestock in the Laurel Fork watershed are examples of land-based nonpoint sources used to calculate fecal coliform loads. Also represented in the model were direct nonpoint sources of uncontrolled discharges, direct deposition by wildlife, and direct deposition by livestock. Contributions from all of these sources were updated to 2005 conditions to establish existing conditions for the watershed. The HSPF model provided a comparable match to the VADEQ monitoring data, with output from the model indicating violations of both the instantaneous and geometric mean standards throughout the Laurel Fork watershed.

Sediment

The sediment TMDL goal for Laurel Fork was defined by the average annual sediment load in metric tons per year (Mg/yr) from the area-adjusted South Fork Powell River. The existing conditions were calculated for Laurel Fork. The future conditions were 20.73 Mg/yr greater than the existing conditions; therefore, the sediment loads for future growth conditions was used to determine the sediment TMDL.

The sediment TMDL is composed of three components: waste load allocations (WLA) from permitted point sources, the load allocation (LA) from nonpoint/non-permitted sources, and a margin of safety (MOS), which was set to 10% for this study. The target sediment load was 1,851 Mg/yr. The future load from Laurel Fork was 2,799 Mg/yr.

Load Allocation Scenarios

Fecal Coliform

The next step in the bacteria TMDL process was to reduce the various source loads to levels that would result in attainment of the water quality standards. Because Virginia's *E. coli* standard does not permit any exceedances of the standard, modeling was conducted for a target value of 0% exceedance of the geometric mean standard and 0% exceedance of the single sample maximum *E. coli* standard. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality.

Laurel Fork requires:

- 36% reductions in direct wildlife loads,
- 86% reductions in NPS wildlife loads
- 70% reductions in direct livestock loads,
- 99% reductions in NPS loads from agricultural and urban/residential areas, and
- 100% reductions in loads from straight pipes.

Table ES.1 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Laurel Fork watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Laurel Fork	8.72E+11	1.81E+12	*Implicit*	2.69E+12
VA0091588	*8.71E+11*			
VAG400522	*8.71E+08*			

Sediment

The next step in the sediment TMDL process was to reduce the various source loads to result in average annual sediment load less than the target sediment load. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Allocations were developed at the outlet of Laurel Fork.

The final load allocation scenario for Laurel Fork requires a 33.7% overall reduction in sediment loads to the stream. Sediment loads from straight pipes need to be reduced 100% due to health implications and the requirements of the fecal bacteria TMDL. The final TMDL required similar reductions to sediment loads from abandoned mine land (41%), disturbed forest (41%), pasture (38%), high tillage row crops (38%), and streambank erosion (27%). No reductions to TSS permitted sources were required.

Table ES.2 Average annual sediment loads (metric tons per year) modeled after allocation in the Laurel Fork watershed at the outlet.

Impairment	WLA (Mg/yr)	LA (Mg/yr)	MOS (Mg/yr)	TMDL (Mg/yr)
Laurel Fork	21	1,830	206	2,057

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the fecal coliform, benthic and dissolved oxygen impairment on Laurel Fork. The second step is to develop a TMDL implementation plan (IP). The final step is to implement the TMDL IP and to monitor stream water quality to determine if water quality standards are being attained.

While Section 303(d) of the Clean Water Act (CWA) and current United States Environmental Protection Agency (EPA) regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and waste load allocations can and will be implemented. Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate waterbody. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource.

To address the bacteria TMDL, reducing the human bacteria loading from straight pipes and failing septic systems should be a primary implementation focus because of the health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system installation/repair program. Livestock exclusion from streams has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the direct cattle deposits and by providing additional riparian buffers.

To address the sediment TMDL, it is anticipated that reclamation of abandoned mine land (AML), and the correction of straight pipes will be initial targets of implementation. Erosion and sediment deposition from disturbed land generally abate over time as new growth emerges. One practice that has been successful on some sites involves regrading and vegetating disturbed areas, and constructing diversion ditches to direct water away from the disturbed area.

There is a measure of uncertainty associated with the final allocation development process. Monitoring performed upon completion of specific implementation milestones can provide insight into the effectiveness of implementation strategies, the need for amending the plan, and/or progress toward the eventual removal of the impairments from the 303(d) list.

Public Participation

During development of the TMDLs for Laurel Fork, public involvement was encouraged through two public meetings and one government kickoff meeting. An introduction of the agencies involved, an overview of the TMDL process, and the specific approach to developing the Laurel Fork TMDLs were presented at the first of the public meetings. Details of the pollutant sources and stressor identification were also presented at this meeting. Public understanding of, and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The final model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting and no written comments were received. Watershed stakeholders will have the opportunity to participate in the development of the TMDL IP.

PART I: BACKGROUND AND APPLICABLE STANDARDS

1. INTRODUCTION

1.1 Background

The need for Total Maximum Daily Loads (TMDLs) for the Laurel Fork watershed was based on provisions of the Clean Water Act. The United States Environmental Protection Agency's (EPA) document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA, 1991), states:

> *According to Section 303(d) of the Clean Water Act and the USEPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The waterbodies are considered water quality-limited and require TMDLs.*
>
> *…A TMDL is a tool for implementing State water quality standards, and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.*

The Laurel Fork watershed (contained in USGS Hydrologic Unit Code 05050002), located in Tazewell County, Virginia is part of the New River Basin (Figure 1.1). Laurel Fork is located in the northeastern corner of Tazewell County and flows northeast until its confluence with the Bluestone River in West Virginia downstream of Bluefield. The stream is approximately 13.7 miles long and the last 0.7 miles are in West Virginia. The impaired section begins at the Curran Branch confluence (river mile 5.90) and extends downstream to the Virginia-West Virginia state line. The Laurel Fork watershed is 94% forest, 2% pasture, 1% residential and commercial, 1% cropland, and 1% water; the remaining 1% is made up of other land uses. Laurel Fork flows into the Bluestone River, which flows into the New River, which drains into the Ohio River. The Ohio River flows into the Mississippi River, which ultimately drains into the Gulf of Mexico.

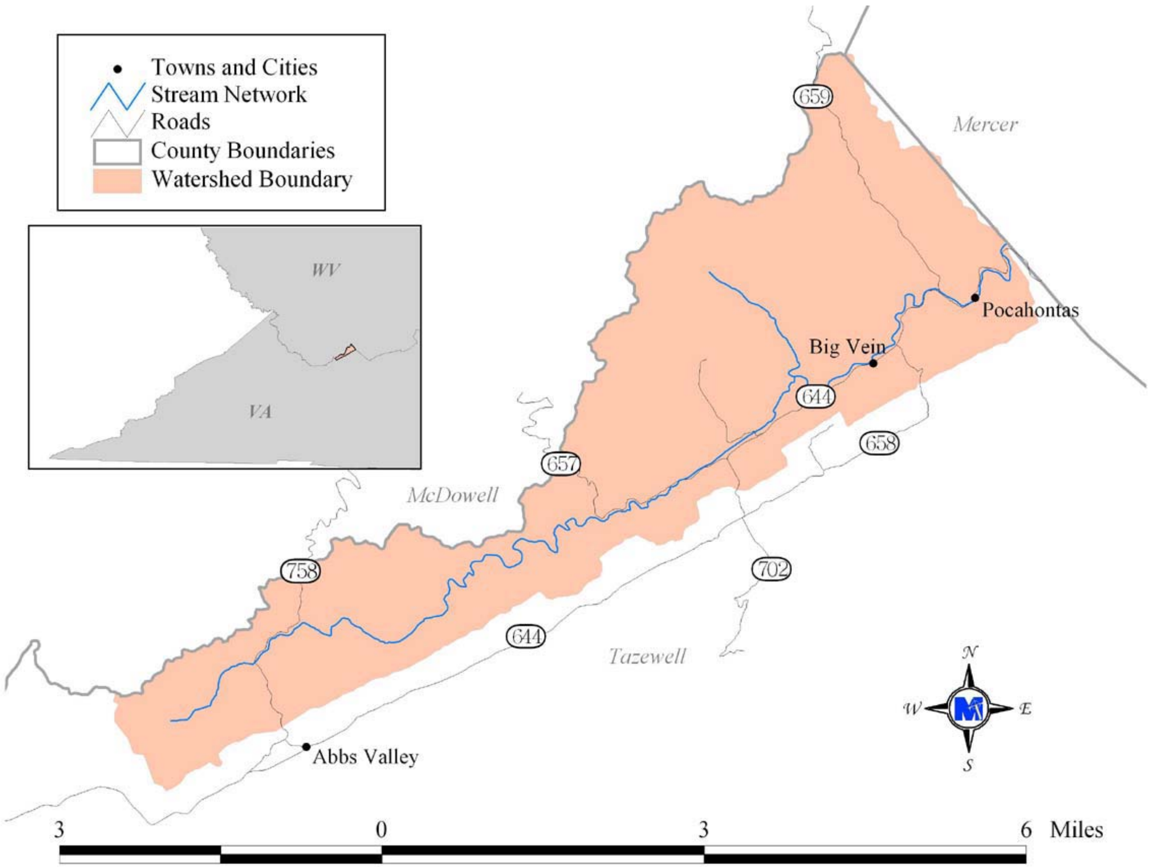

Figure 1.1 Location of the Laurel Fork watershed.

Laurel Fork (waterbody ID # VAS-N37R) was first listed as impaired in 1994. A 2.84-mile segment, which extends from Pocahontas High School to the Virginia-West Virginia state line, appeared on the 1996 *303(d) TMDL Priority List* for violations of the fecal coliform bacteria standard and the General Standard (benthic). Virginia Department of Environmental Quality (VADEQ) assessed the waterbody as not supporting the primary contact use based on results from VADEQ ambient water quality monitoring station 9-LRR002.19 (on the Route 102 bridge downstream of Pocahontas). Results from biological monitoring station 9-LRR001.39 indicated that aquatic life is not supported.

On the 1998 *303(d) Total Maximum Daily Load Priority List and Report*, Laurel Fork was listed for dissolved oxygen (DO) violations as well as for violations of the fecal coliform bacteria standard and the General Standard (benthic, sediment). Monitoring station 9-LRR002.19 had sediment effect range-median value exceedances for lead in

1981, 1993, 1994 and 1995, for zinc in 1993 and 1994, and for antimony, cadmium, chromium, copper, nickel, and thallium in 1994. Data from biological monitoring station 9-LRR001.39 indicated that the segment was severely impaired.

Laurel Fork remained on the 2002 *303(d) Report on Impaired Waters* for violations of DO, fecal coliform, and the General Standard (benthic). Monitoring station 9-LRR002.19 had sediment effect range-median value exceedances for lead, zinc, beryllium, cadmium, chromium, copper, nickel, and thallium. Data from biological monitoring station 9-LRR001.39 indicated that the segment was severely impaired. Laurel Fork was assessed as not supporting aquatic life use, and partially supporting the primary contact use.

On the 2004 *305(b)/303(d) Water Quality Assessment Integrated Report*, the impaired stream segment length was updated to 2.91 miles. At ambient water quality monitoring station 9-LRR002.19, DO violations and three fecal coliform violations occurred in 21 samples. The segment was also listed as a "Water of Concern" for sediment exceedances of total phosphorus (TP) data. The exceedances for lead, zinc, cadmium, chromium, and copper that were noted in 2002 were reported as an "Observed Effect" in the 2004 report. Data from biological monitoring station 9-LRR001.39 indicated that the segment is severely impaired.

The impaired stream segment was updated again for the 2006 assessment. Data collected from station 9-LRR005.59 during a TMDL special monitoring study showed violations of the bacteria standard and so the TMDL impairment reach was extended upstream to Curran Branch at river mile 5.90. The impaired segment extends from river mile 5.90 downstream to the Virginia-West Virginia state line at river mile 1.35 for a total of 4.55 miles (Figure 1.2).

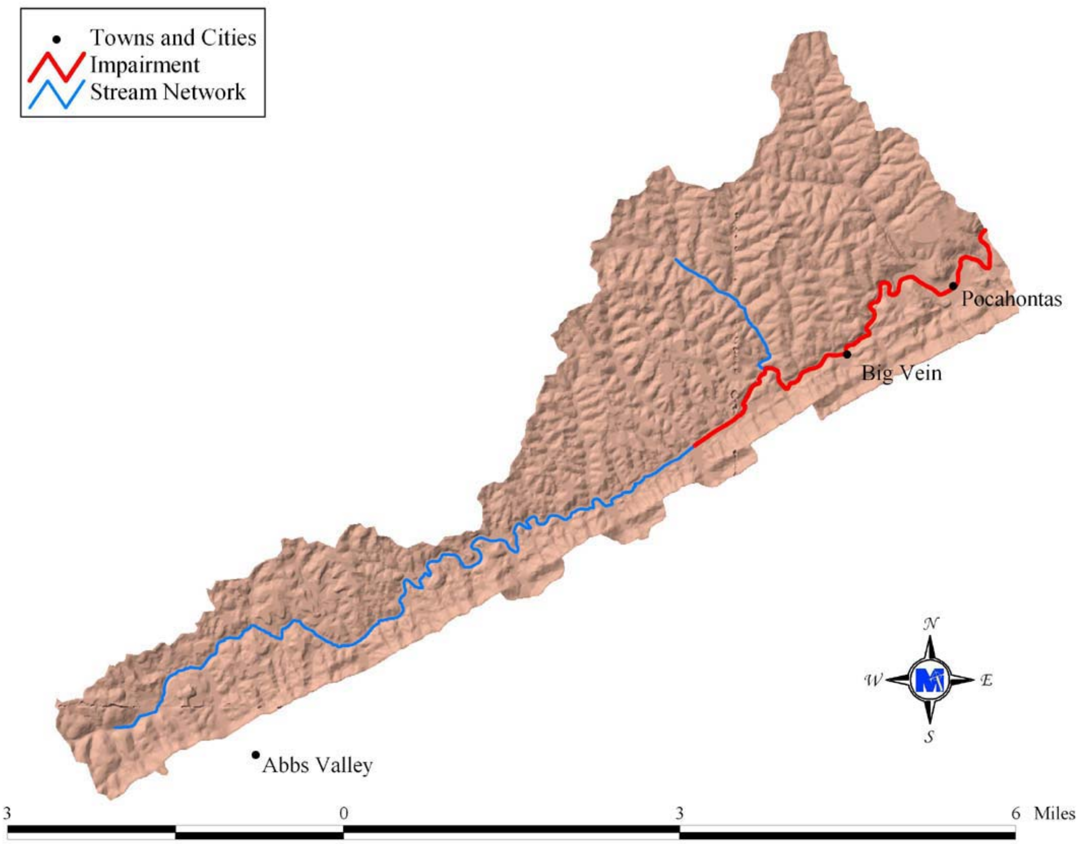

Figure 1.2 Laurel Fork impaired stream segment.

1.2 Applicable Water Quality Standards

According to Section 9 VAC 25-260-5 of Virginia's State Water Control Board *Water Quality Standards*, the term "water quality standards" means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act."

As stated in Virginia state law 9 VAC 25-260-10 (Designation of uses):

> *A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife;*

and the production of edible and marketable natural resources, e.g., fish and shellfish.

♦

D. *At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

Because this study addresses DO, fecal bacteria, and benthic impairments, three water quality criteria are applicable. Section 9 VAC 25-260-50 applies to the DO impairment, Section 9 VAC 25-260-170 applies to the fecal coliform impairment, and the General Standard section (9 VAC 25-260-20) applies to the benthic impairment.

The report of the development of the TMDLs is divided into five parts. Part I is the background and applicable standards. The development of the fecal bacteria TMDL is presented in Part II (Chapters 2 - 5), the General Standard TMDL is given in Part III (Chapters 6 - 10), the development of the DO TMDL is discussed in Part IV (Chapter 11), and Part V is implementation and public participation (Chapters 12 and 13).

PART II: FECAL BACTERIA TMDL

2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Applicable Criteria for Fecal Bacteria Impairments

Prior to 2002, Virginia Water Quality Standards specified the following criteria for a non-shellfish supporting waterbody to be in compliance with Virginia's fecal standard for contact recreational use:

> *A. General requirements. In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 mL at any time.*

If the waterbody exceeded either criterion more than 10% of the time, the waterbody was classified as impaired and the development and implementation of a TMDL was indicated in order to bring the waterbody into compliance with the water quality criterion. Based on the sampling frequency, only one criterion was applied to a particular datum or data set. If the sampling frequency was one sample or less per 30 days, the instantaneous criterion was applied; for a higher sampling frequency, the geometric criterion was applied. This was the measure used for listing the impairments included in this study. Sufficient fecal coliform bacteria standard violations were recorded at VADEQ water quality monitoring stations to indicate that the recreational use designations are not being supported.

EPA has since recommended that all states adopt an *E. coli* or *enterococci* standard for fresh water and *enterococci* criteria for marine waters by 2003. The EPA is pursuing the states' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and *enterococci*) and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and *enterococci* standard is in effect in Virginia as of January 15, 2003.

The new criteria, outlined in 9 VAC 25-260-170, read as follows:

A. In surface waters, except shellfish waters and certain waters identified in subsection B of this section, the following criteria shall apply to protect primary contact recreational uses:

1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.

2. E. coli and enterococci bacteria per 100 mL of water shall not exceed the following:

	Geometric Mean[1]	*Single Sample Maximum[2]*
Freshwater[3]		
E. coli	*126*	*235*
Saltwater and Transition Zone[3]		
enterococci	*35*	*104*

[1] For two or more samples taken during any calendar month.

[2] No single sample maximum for *enterococci* and *E. coli* shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used, as the log standard deviation in freshwater and 0.7 shall be as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.

[3] See 9 VAC 25-260-140 C for freshwater and transition zone delineation.

2.2 Selection of a TMDL Endpoint

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the Laurel Fork bacteria TMDL, the applicable endpoint and associated target value can be determined directly from the Virginia water quality regulations (section 2.1). In order to remove a water body from a state’s list of impaired waters, the Clean Water Act (CWA) requires compliance with that state's water quality standard. Since modeling provided simulated output of *E. coli* concentrations at 1-hour intervals, assessment of the TMDL was made using both the geometric mean standard of 126 cfu/100 mL and the instantaneous standard of 235 cfu/100 mL. Therefore, the in-stream *E. coli* target for this TMDL was a monthly geometric mean not exceeding 126 cfu/100 mL and a single sample not exceeding 235 cfu/100 mL.

2.3 Discussion of In-stream Water Quality

This section provides an inventory of available observed in-stream monitoring data throughout the Laurel Fork watershed. An examination of data from water quality stations used during the Section 303(d) assessments and TMDL development was performed. Sources of data and pertinent results are discussed.

2.3.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information for Laurel Fork are:

- bacteria enumerations from eight VADEQ in-stream monitoring stations in Laurel Fork (Figure 2.1), and
- bacterial source tracking (BST) from one VADEQ in-stream monitoring station (9-LRR001.39) analyzed during TMDL development.

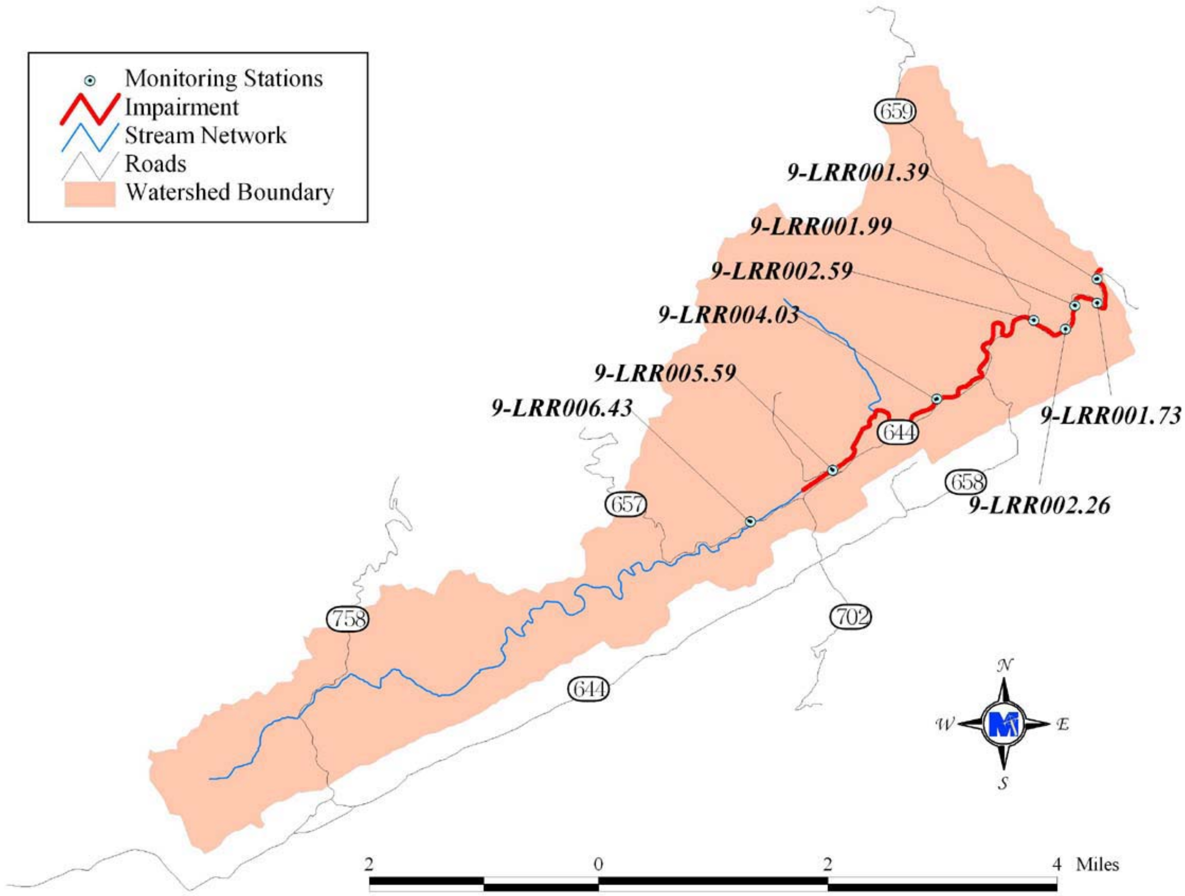

Figure 2.1 Location of VADEQ water quality monitoring stations used for the bacteria TMDL assessment in the Laurel Fork watershed.

2.3.2 Water Quality Monitoring for TMDL Assessment and Development

Data from in-stream bacteria samples in Laurel Fork were collected and analyzed by VADEQ from January 1980 through June 2004 (Tables 2.1 and 2.2) and are included in this study. These tables summarize the bacteria samples collected at the in-stream monitoring stations used for TMDL assessment and development. Fecal coliform samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting concentrations to less than 1,000 cfu/100 mL. Therefore, as a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 mL or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) may not have been analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported concentrations of 100 cfu/100 mL most likely represent concentrations below 100 cfu/100 mL, and reported concentrations of 8,000 or 16,000 cfu/100 mL most likely represent concentrations in excess of these values. *E. coli* samples were collected to evaluate compliance with the state's current bacterial standard, as well as for Bacterial Source Tracking (BST) analysis. The current instantaneous standard for *E. coli* is 235 cfu/100mL.

2.3.3 Analysis of Bacterial Source Tracking

MapTech, Inc.'s Environmental Diagnostics Laboratory (EDL) was contracted to perform analyses of fecal coliform and *E. coli* concentrations as well as BST at Laurel Fork ambient monitoring station 9-LRR001.39 from July 2003 through June 2004. BST is intended to aid in identifying sources (*i.e.,* human, pets, livestock, or wildlife) of fecal contamination in water bodies. Data collected provided insight into the likely sources of fecal contamination, aided in distributing fecal loads from different sources during model calibration, and will improve the chances for success in implementing solutions.

Several procedures are currently under study for use in BST. Virginia has adopted the Antibiotic Resistance Analysis (ARA) methodology implemented by MapTech's EDL. This method was selected because it has been demonstrated to be a reliable procedure for confirming the presence or absence of human, pet, livestock, and wildlife sources in watersheds in Virginia. The BST results were reported as the percentage of isolates acquired from the sample identified as originating from humans, pets, livestock, or wildlife.

Table 2.1 Summary of fecal coliform monitoring conducted by VADEQ for Laurel Fork from January 1980 through June 2004.

VADEQ Station	Collection Dates	Count (#)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Mean (cfu/100mL)	Median (cfu/100mL)	Standard Deviation	Violations[1] %	Violations[2] %
9-LRR001.39	1/80 - 6/04	111	<25	26,200	2,502	800	4,614	44%	61%
9-LRR001.73	8/03 - 6/04	5	25	1,500	440	75	282	20%	40%
9-LRR002.26	7/03 - 6/04	11	25	2,000	606	250	223	18%	45%
9-LRR002.59	7/03 - 6/04	7	25	430	172	120	58	0%	14%
9-LRR004.03	7/03 - 6/04	8	25	620	240	125	81	0%	38%
9-LRR005.59	9/03 - 6/04	8	25	950	194	75	112	0%	13%
9-LRR006.43	7/03 - 6/04	7	25	1,600	289	75	219	14%	14%

[1] Violations are based on the pre-2003 fecal coliform instantaneous standard (1,000 cfu/100mL).
[2] Violations are based on the current fecal coliform instantaneous standard (400 cfu/100mL).

Table 2.2 Summary of *E. coli* monitoring conducted by VADEQ for Laurel Fork from July 2003 through June 2004.

VADEQ Station	Collection Dates	Count (#)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Mean (cfu/100mL)	Median (cfu/100mL)	Standard Deviation	Violations[1] %
9-LRR001.39	7/03 - 6/04	13	10	9,000	884	150	680	38%
9-LRR002.26	7/03 - 6/04	11	10	800	200	160	69	18%
9-LRR002.59	7/03 - 6/04	10	10	300	102	55	34	20%
9-LRR004.03	7/03 - 6/04	7	30	680	207	90	85	29%
9-LRR005.59	8/03 - 6/04	9	10	650	132	30	69	11%
9-LRR006.43	8/03 - 6/04	8	10	60	30	30	7	0%

[1] Violations are based on the *E. coli* instantaneous standard (235 cfu/100mL)

BST results of water samples collected at ambient station 9-LRR001.39 are reported in Table 2.3. The BST results indicate the presence of all sources (*i.e.,* human, wildlife, livestock, and pets) contributing to the fecal bacteria violations. The fecal coliform and *E. coli* enumerations are given to indicate the bacteria concentration at the time of sampling. The proportions reported are formatted to indicate statistical significance (*i.e.,* **BOLD** numbers indicate a statistically significant result) determined through two tests. The first was based on the sample size. A z-test was used to determine if the proportion was significantly different from zero (*alpha* = 0.10). Second, the rate of false positives was calculated for each source category in each library, and a proportion was not considered significantly different from zero unless it was greater than the false-positive rate plus three standard deviations.

Table 2.4 summarizes the results for the station with load-weighted average proportions of bacteria originating from the four source categories. The load-weighted average considers the level of flow in the stream at the time of sampling, the concentration of *E. coli* measured, and the number of bacterial isolates analyzed in the BST analysis.

For Laurel Fork, the most predominant source of fecal bacteria was human, followed by wildlife and pets. Livestock, while present, was the least persistent source. These results are consistent with local residents' insight as to the sources of fecal contamination in this stream.

Table 2.3 Bacterial source tracking results from water samples collected in the Laurel Fork impairment.

Station	Date	Fecal Coliform (cfu/100 mL)	*E. coli* (cfu/100 mL)	Percent Isolates classified as[1]: Wildlife	Human	Livestock	Pets
9-LRR001.39	7/21/2003	2000	670	**67%**	**21%**	0%	12%
	8/5/2003	56,000	39,000	0%	**88%**	0%	12%
	9/17/2003	120	250	**12%**	**59%**	0%	**29%**
	10/15/2003	440	260	**38%**	**25%**	**12%**	**25%**
	11/17/2003	520	154	**55%**	**33%**	**12%**	0%
	12/16/2003	270	300	**12%**	8%	**12%**	**68%**
	1/12/2004	120	32	**27%**	**41%**	5%	**27%**
	2/17/2004	4,100	860	**42%**	**29%**	0%	**29%**
	3/17/2004	150	60	4%	**92%**	0%	4%
	4/20/2004	4,200	9,000	**46%**	8%	**25%**	**21%**
	5/12/2004	80	10	0%	100%	0%	0%
	6/21/2004	2,100	150	**12%**	**88%**	0%	0%

[1]**BOLD** type indicates a statistically significant value.

Table 2.4 Load-weighted average proportions of fecal bacteria originating from wildlife, human, livestock, and pet sources.

Station ID	Stream	Wildlife	Human	Livestock	Pet
9-LRR001.39	Laurel Fork	12%	67%	6%	15%

2.3.4 Trend and Seasonal Analyses

In order to improve TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on fecal coliform concentrations. A Seasonal Kendall Test was used to examine long-term trends. The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends. This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed. For instance, the Seasonal Kendall Test can identify the trend (over many years) in discharge levels during a particular season or month.

A seasonal analysis of fecal coliform concentrations was conducted using the Mood's Median Test. This test was used to compare median values of fecal coliform concentrations in each month.

Water quality monitoring data collected by VADEQ were described in section 2.3.2. The trend and seasonality tests were conducted on fecal coliform concentrations collected at stations used in TMDL assessment if sufficient data were available. Data at station 9-LRR001.39 showed a significant negative long-term trend of -116.67 cfu/100mL/year over the monitoring period. VADEQ station 9-LRR001.39 in the Laurel Fork watershed showed no monthly seasonality in fecal coliform concentrations. Sufficient data were not available to perform trend or seasonality analyses on fecal coliform concentrations at the other stations.

2.4 Selection of a TMDL Critical Condition

EPA regulations at 40 CFR 130.7 (c)(1) (EPA, 2003) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Laurel Fork watershed is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken in order to meet water quality standards. Fecal bacteria sources within the Laurel Fork watershed are attributed to both point and non-point sources. Critical conditions for waters impacted by land-based non-point sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include non-point sources that are not precipitation-driven (*e.g.*, fecal deposition to stream).

A graphical analysis of fecal coliform concentrations and flow duration interval showed that there was no obvious critical flow level (Figure 2.2). (A description of the data used in this analysis is shown in Table 2.1.) That is, the analysis showed no obvious dominance of either non-point sources or point sources. High concentrations were recorded in all flow regimes at monitoring stations where data were collected during all flow regimes. Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons (section 4.4) in order to capture a wide range of hydrologic circumstances for the impaired stream. The resulting periods for calibration and validation for the impaired stream are presented in Chapter 4.

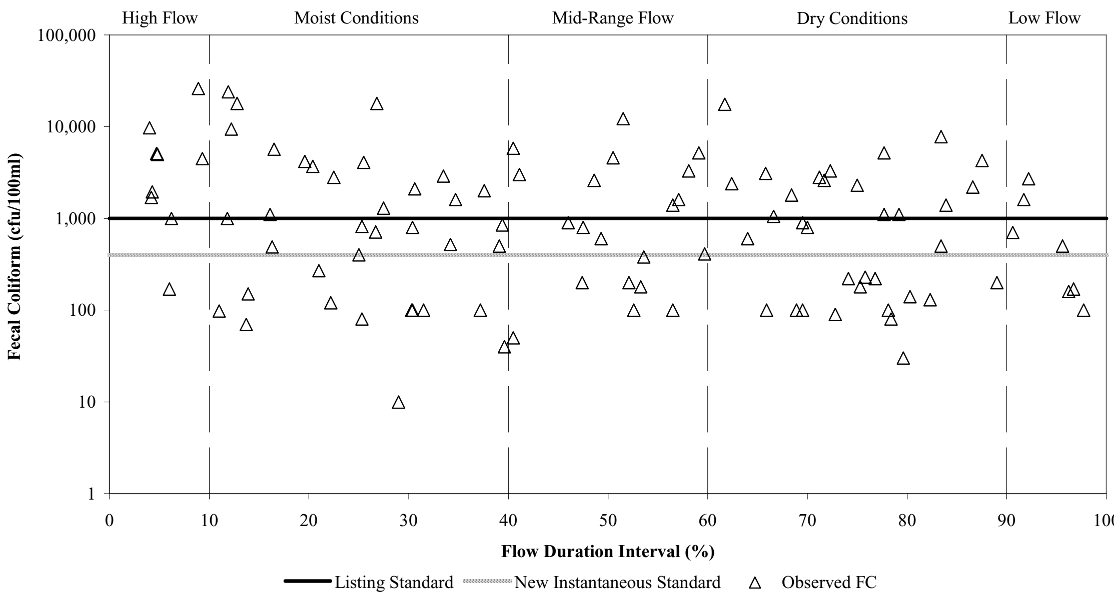

Figure 2.2 Relationship between fecal coliform concentrations (VADEQ Station 9-LRR001.39) and discharge (USGS #03179000 Bluestone River near Pipestem, WV) in the Laurel Fork impairment.

3. SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal coliform in the Laurel Fork watershed. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local management agencies. This section documents the available information and interpretation for the analysis. The source assessment chapter is organized into point and non-point sections. The representation of the following sources in the model is discussed in chapter 4.

3.1 Watershed Characterization

The National Land Cover Data (NLCD), produced cooperatively between USGS and EPA, was utilized for this study. The collaborative effort to produce this dataset is part of a Multi-Resolution Land Characteristics (MRLC) Consortium project led by four U.S. government agencies: EPA, USGS, the Department of the Interior National Biological Service (NBS), and the National Oceanic and Atmospheric Administration (NOAA). Using 30-meter resolution Landsat 5 Thematic Mapper (TM) satellite images taken between 1990 and 1994, digital land use coverage was developed identifying up to 21 possible land use types. Classification, interpretation, and verification of the land cover dataset involved several data sources (when available) including: aerial photography; soils data (NRCS 2004a, NRCS 2004b), population and housing density data; state or regional land cover data sets; USGS land use and land cover (LUDA) data; 3-arc-second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief; and National Wetlands Inventory (NWI) data.

There has been a considerable amount of historic coal mining activity within the watershed. Using information provided by the Virginia Department of Mines, Minerals and Energy, the approximate acreage of abandoned and reclaimed mine lands was determined.

Approximate acreages and land use proportions for the impaired watershed are given in Table 3.1. The land area of the Laurel Fork watershed is approximately 9,526 acres, with forest as the primary land use (Figure 3.1).

Table 3.1 Contributing land use area.

Laurel Fork Land use	Acreage
Agricultural	**273**
Cropland	*84*
Livestock Access	*4*
Pasture/Hay	*185*
Forest	**9,052**
Abandoned Mine Land	*507*
Reclaimed Mine Land	*92*
Woodland	*8,453*
Urban	**86**
Commercial & Services	*14*
Residential/Recreational	*72*
Water	**100**
Wetlands	**15**

The estimated human population within the Laurel Fork drainage area is 1,127 (USCB, 1990, 2000). Among counties, Tazewell County ranks 24th for the number of all cattle and calves, 33rd for beef cattle, 6th for sheep and lambs, and 25th for production of corn silage (Virginia Agricultural Statistics, 2002). Tazewell County is also home to 432 species of wildlife, including 53 types of mammals (*e.g.,* beaver, raccoon, and white-tailed deer) and 166 types of birds (*e.g.,* wood duck, wild turkey, Canada goose) (VDGIF, 2005).

For the period 1959 to 2004, the town of Bluefield, West Virginia, which is near the Laurel Fork watershed, received average annual precipitation of approximately 39.12 inches, with 54% of the precipitation occurring during the May through October growing season (SERCC, 2005). Average annual snowfall is 33.9 inches with the highest snowfall occurring during January (SERCC, 2005). Average annual daily temperature is 52.3 °F. The highest average daily temperature of 78.8 °F occurs in July, while the lowest average daily temperature of 23.5 °F occurs in January (SERCC, 2005).

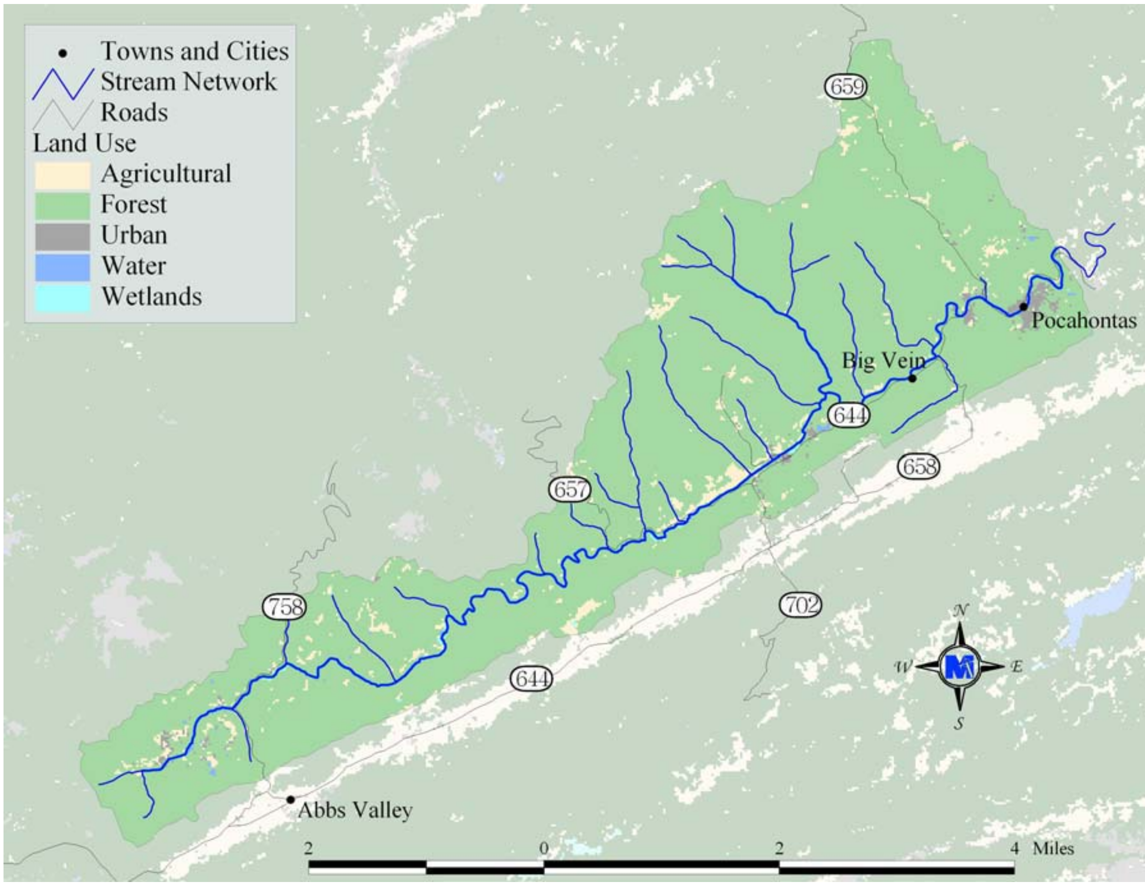

Figure 3.1 Land uses in the Laurel Fork watershed.

3.2 Assessment of Point Sources

Three point sources are permitted in the Laurel Fork watershed through the Virginia Pollutant Discharge Elimination System (VPDES). Figure 3.2 shows the permitted locations. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain a fecal coliform concentration below 200 cfu/100 mL. Currently, these permitted discharges are expected not to exceed the 126 cfu/100 mL *E. coli* standard. Table 3.2 summarizes data from the point sources.

The Northern Tazewell County Wastewater Treatment Facility (WWTF) is a proposed wastewater treatment plant that will replace the current Pocahontas Sewage Treatment Plant (STP) by serving the Town of Pocahontas as well as a new correctional facility outside of town. The facility is expected to be discharging by March 2007 (Spencer, 2006).

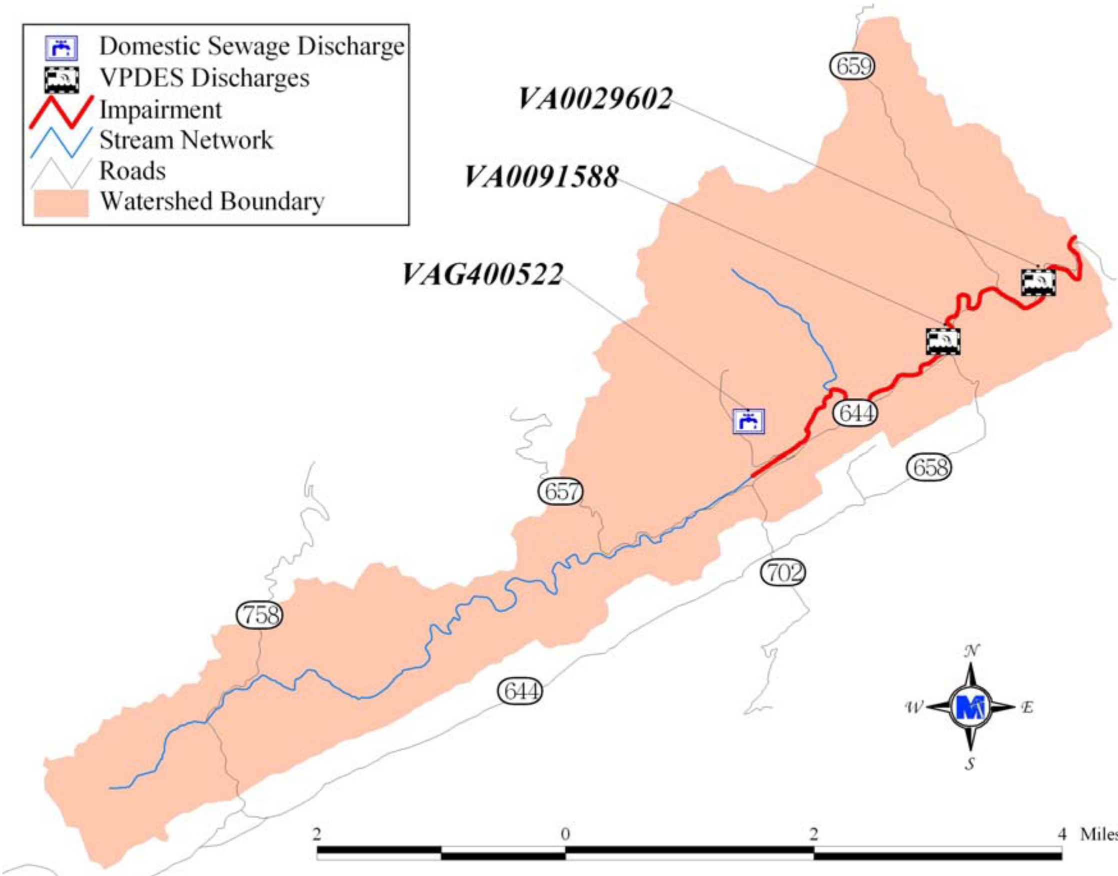

Figure 3.2 Location of VPDES permitted point sources in the Laurel Fork watershed.

Table 3.2 Summary of VPDES permitted point sources in the Laurel Fork watershed.

Permit No.	Facility Name	Design Flow (MGD)	Receiving Stream	River Mile	Type
VA0029602	Pocahontas STP	0.1500	Laurel Fork	1.99	VPDES-Municipal
VA0091588	Northern Tazewell County WWTF	0.5000	Laurel Fork	3.15	VPDES-Municipal
VAG400522	Residence STP	<0.001	Laurel Fork, UT		Domestic Sewage

3.3 Assessment of Nonpoint Sources

In the Laurel Fork watershed, both urban and rural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage treatment systems, livestock, wildlife, and pets. Sources were identified and enumerated. MapTech collected samples of fecal coliform sources (*i.e.,* wildlife, livestock, pet, and human waste) and enumerated the density of fecal coliform bacteria to support the modeling process, and to expand the database of known fecal coliform sources for purposes of BST (section 2.3.3). Where appropriate, spatial distribution of sources was also determined.

3.3.1 Private Residential Sewage Treatment

In U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank or a cesspool, or the sewage is disposed of in some other way. The Census category "Other Means" includes the houses that dispose of sewage other than by public sanitary sewer or a private septic system. The houses included in this category are assumed to discharging sewage directly to the stream. Population, housing units, and types of sewage treatment from U.S. Census Bureau were calculated using geographic information systems (GIS) (Table 3.3).

Table 3.3 Human population, housing units, houses on sanitary sewer, septic systems, and other sewage disposal systems for 2005 in the Laurel Fork watershed.

Impaired Segment	Population	Housing Units	Sanitary Sewer	Septic Systems	Other*
Laurel Fork	1,034	582	189	357	37

* Houses with sewage disposal systems other than sanitary sewer and septic systems.

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant.

When the flow of wastewater exceeds the design capacity, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows. Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system.

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal coliform is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems contribute virtually no fecal coliform to surface waters.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation, the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to proximity. A survey of septic pump-out contractors performed by MapTech showed that failures were more likely to occur in the winter-spring months than in the summer-fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed in the yard.

MapTech sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100mL. An average fecal coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

3.3.2 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the watershed and were the only pets considered in this analysis. Cat and dog populations were derived from American Veterinary Medical Association Center for Information Management demographics in 1997. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was previously measured. Fecal coliform density for dogs and cats was measured from samples collected throughout Virginia by MapTech. A summary of the data collected is given in Table 3.4. Table 3.5 lists the domestic animal populations for the impairment in the Laurel Fork watershed.

Table 3.4 Domestic animal population density, waste load, and fecal coliform density for Virginia.

Type	Population Density (an/house)	Waste load (g/an-day)	FC Density (cfu/g)
Dog	0.534	450	480,000
Cat	0.598	19.4	9

Table 3.5 Estimated domestic animal populations in the Laurel Fork watershed.

Impaired Segment	Dogs	Cats
Laurel Fork	274	307

3.3.3 Livestock

The predominant type of livestock in the Laurel Fork watershed is beef cattle, although other types of livestock identified were considered in modeling the watershed. Animal populations were based on communication with Tazewell Soil and Water Conversation District (TSWCD), Tazewell County Agricultural Extension Agency, landowner input, watershed visits, and review of all publicly available information on animal type and approximate numbers known to exist within Tazewell County. Table 3.6 provides a summary of livestock populations in the Laurel Fork watershed. Values of fecal coliform density of livestock sources were based on sampling performed by MapTech. Reported manure production rates for livestock were taken from ASAE, 1998. A summary of fecal coliform density values and manure production rates is presented in Table 3.7.

Table 3.6 Livestock populations in the Laurel Fork watershed.

Impaired Segment	Total Cattle	Beef Cattle	Hogs	Horses	Sheep
Laurel Fork	116	41	2	20	14

Table 3.7 Average fecal coliform densities and waste loads associated with livestock for Virginia.

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)
Beef calf (350 lb)	21.0	101,000
Beef stocker (850 lb)	51.0	101,000
Hog (135 lb)	11.3	400,000
Horse (1,000 lb)	51.0	94,000
Sheep (60 lb)	2.4	43,000

Fecal coliform produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (*e.g.,* pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Second, grazing livestock deposit manure directly on the land, where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities have drainage systems that divert wash-water and waste directly to drainage ways or streams. No confined animal facilities were identified in the Laurel Fork watershed, so only the second and third pathways were considered.

All livestock were expected to deposit some portion of waste on land areas. Horses were assumed to be in pasture 100% of the time. Based on discussions with the Virginia Cooperative Extension (VCE), it was concluded that beef cattle were expected to make a contribution through direct deposition to streams, where access was available. However, it was also discussed that access would be limited due to topography in the watershed where most of the cattle are grazed. The average amount of time spent by beef cattle in stream access areas (*i.e.,* within 50 feet of the stream) for each month is given in Table 3.8.

Table 3.8 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day.

Month	Pasture (hr)	Stream Access (hr)
January	23.3	0.7
February	23.3	0.7
March	23.0	1.0
April	22.6	1.4
May	22.6	1.4
June	22.3	1.7
July	22.3	1.7
August	22.3	1.7
September	22.6	1.4
October	23.0	1.0
November	23.0	1.0
December	23.3	0.7

3.3.4 Wildlife

The predominant wildlife species in the watershed were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), United States Fish and Wildlife Service (FWS), citizens from the watershed, source sampling, and site visits. Population densities were calculated from data provided by VDGIF and FWS are listed in Table 3.9 (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; and Rose and Cranford, 1987). The numbers of animals estimated to be in the Laurel Fork watershed are reported in Table 3.10. Habitat and seasonal food preferences were determined based on information obtained from the Fire Effects Information System (http://www.fs.fed.us/database/feis) (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996; and Yagow, 1999). Table 3.11 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife waste performed by MapTech. The only value that was not obtained from MapTech sampling was for beaver. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999). Percentage of time spent in stream access areas and percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.,* within 100 feet of stream) are reported in Table 3.12.

Table 3.9 Wildlife population density in Tazewell County.

County	Deer (an/ac of habitat)	Turkey (an/ac)	Goose (an/ac)	Duck (an/ac)	Muskrat (an/ac of habitat)	Raccoon (an/ac of habitat)	Beaver (an/mi of stream)
Tazewell	0.0285	0.01	0.0149	0.0184	0.6442	0.0164	3.8

Table 3.10 Wildlife populations in the Laurel Fork watershed.

Impairment	Deer	Turkey	Goose	Duck	Muskrat	Raccoon	Beaver
Laurel Fork	268	93	18	22	777	156	55

Table 3.11 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	Primary = region within 600 ft of perennial streams Secondary = region between 601 and 7,920 ft from perennial streams Infrequent/Seldom = rest of watershed area including water bodies (lakes, ponds)
Muskrat	100	Primary = water bodies and land area within 66 ft from the edge of perennial streams and water bodies Secondary = region between 67 and 308 ft from perennial streams and water bodies Infrequent/Seldom = rest of the watershed area
Beaver[1]	200	Primary = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) Infrequent/Seldom = rest of the watershed area
Deer	772	Primary = forested, harvested forest land, orchards, grazed woodland, urban grassland, cropland, pasture, wetlands, transitional land Secondary = low density residential, medium density residential Infrequent/Seldom = remaining land use areas
Turkey[2]	320	Primary = forested, harvested forest land, grazed woodland, orchards, wetlands, transitional land Secondary = cropland, pasture Infrequent/Seldom = remaining land use areas
Goose[3]	225	Primary = water bodies and land area within 66 ft from the edge of perennial streams and water bodies Secondary = region between 67 and 308 ft from perennial streams and water bodies Infrequent/Seldom = rest of the watershed area
Duck	150	Primary = water bodies and land area within 66 ft from the edge of perennial streams and water bodies Secondary = region between 67 and 308 ft from perennial streams and water bodies Infrequent/Seldom = rest of the watershed area

[1]Beaver waste load was calculated as twice that of muskrat, based on field observations.
[2]Waste load for domestic turkey (ASAE, 1998).
[3]Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2003).

Table 3.12 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	380,000	5
Turkey	1,332	5
Goose	250,000	50
Duck	3,500	75

4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of the fecal bacteria TMDL for the Laurel Fork watershed, the relationship was defined through computer modeling based on data collected throughout the study area. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration/validation, and model application are discussed.

4.1 Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and to perform fecal bacteria TMDL allocations. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLNDs) and pervious land areas (PERLNDs). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, representing the various land uses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES in that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

4.2 Model Setup

Hourly precipitation data was available near the Laurel Fork watershed at the Flattop, WV National Climatic Data Center (NCDC) Coop station #463072. Missing values were filled with disaggregated daily precipitation from the Richlands NCDC Coop station #447174.

To adequately represent the spatial variation in the watershed, the Laurel Fork drainage areas were divided into five subwatersheds (Figure 4.1). The rationale for choosing these subwatersheds was based on the availability of water quality data and the limitations of the HSPF model. Water quality data (*i.e.*, bacteria concentrations) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with these monitoring stations, since output from the model can only be obtained at the modeled subwatershed outlets. In an effort to standardize modeling efforts across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watershed allowed for a more refined representation of pollutant sources, and a more realistic depiction of hydrologic factors in the watershed.

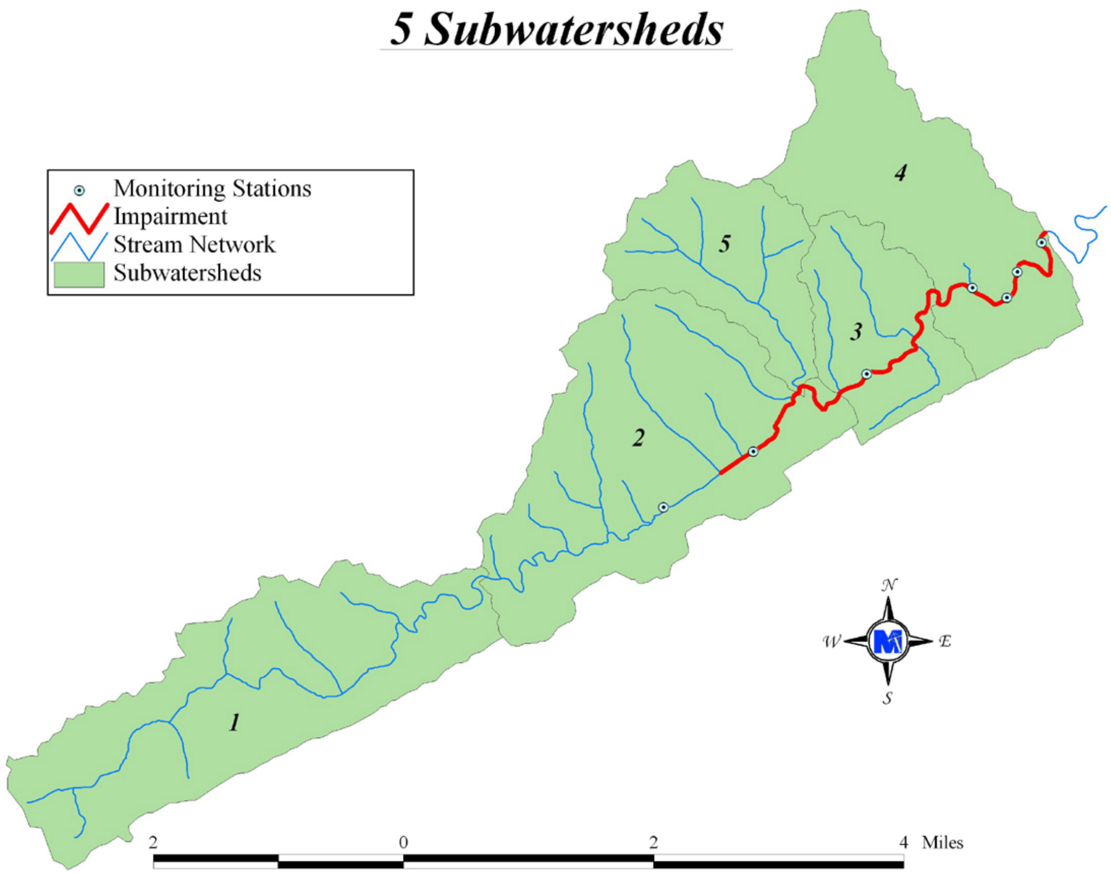

Figure 4.1 Subwatersheds delineated for modeling and location of VADEQ water quality monitoring stations in the Laurel Fork watershed.

The methodology used to identify the land use types in the Laurel Fork watershed is described in section 3.1. The land use types were consolidated into ten categories based on similarities in hydrologic and waste application/production features (Table 4.1). Each land use had parameters associated with it that described the hydrography of the area (*e.g.,* average slope length) and the behavior of pollutants (*e.g.,* fecal coliform accumulation rate). These land use types are represented in HSPF as PERLNDs and IMPLNDs. Impervious areas in the watershed are represented in three IMPLND types, while there are ten PERLND types, each with parameters describing a particular land use (Table 4.1). Some IMPLND and PERLND parameters (*e.g.,* slope length) vary with the particular subwatershed in which they are located. Others vary with season (*e.g*., upper zone storage) to account for plant growth, die-off, and removal.

Table 4.1 Land use categories for the Laurel Fork watershed.

TMDL Land use Categories	Pervious / Impervious (%)	Land use Classifications (MRLC Class No. where applicable)
Abandoned Mine Land	Pervious (75%) Impervious (25%)	Land disturbed by mining operations before 1978 and not reclaimed
Commercial and Services	Pervious (90%) Impervious (10%)	Commercial/Industrial/Transportation (23)
Cropland	Pervious (100%)	Row Crops (82)
Forest	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)
Livestock Access	Pervious (100%)	Pasture/Hay (81) near streams
Pasture	Pervious (100%)	Pasture/Hay (81)
Reclaimed Mine Land	Pervious (100%)	Land regraded and revegetated after mining operations
Residential	Pervious (94%) Impervious (6%)	Low Intensity Residential (21) High Intensity Residential (22)
Water	Pervious (100%)	Open Water (11) National Hydrography Data
Wetland	Pervious (100%)	Emergent Herbaceous Wetlands (92) Woody Wetlands (91)

Die-off of fecal coliform can be handled implicitly or explicitly. For land-applied fecal matter (mechanically applied and deposited directly), die-off was addressed implicitly through monitoring and modeling. Samples of accumulated waste prior to land application (*i.e.,* dairy waste from loafing areas) were collected and analyzed by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal coliform entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

4.3 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.,* stream geometry and resistance to flow). In order to determine a representative stream profile for each stream reach, cross-sections were surveyed at the subwatershed outlets. One outlet was considered the beginning of the next reach, when appropriate. In the case of a confluence, sections were surveyed above the confluence for each tributary and below the confluence on the main stream.

Most of the sections exhibited distinct flood plains with pitch and resistance to flow significantly different from that of the main channel slopes. The streambed, channel banks, and flood plains were identified. Once identified, the streambed width and slopes of channel banks and flood plains were calculated using the survey data. A representative stream profile for each surveyed cross-section was developed and consisted of a trapezoidal channel with pitch breaks at the beginning of the flood plain (Figure 4.2). With this approach, the flood plain can be represented differently from the streambed. To represent the entire reach, profile data collected at each end of the reach were averaged.

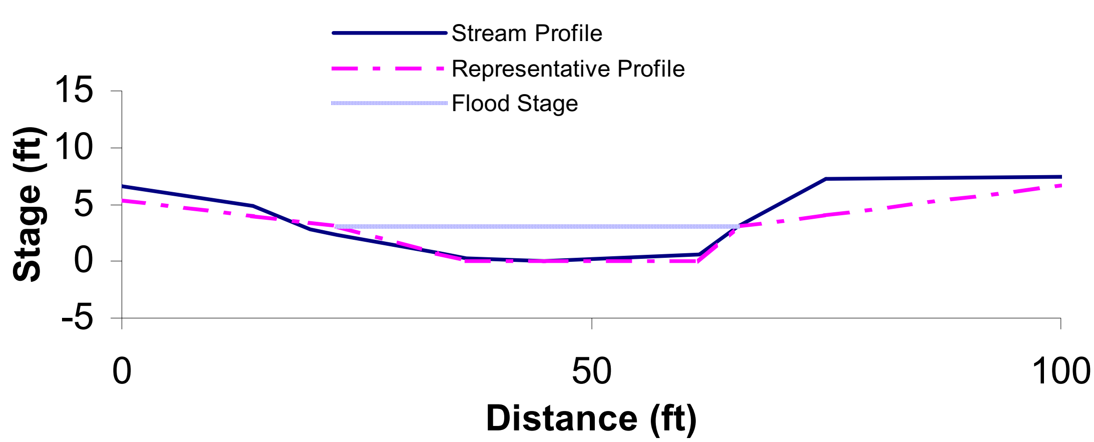

Figure 4.2 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with different values for resistance to flow (Manning's n) assigned to the flood plains and streambeds. The conveyance was calculated for each of the two flood plains and the main channel, then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth.

A key parameter used in the calculation of conveyance is the Manning's roughness coefficient, n. There are many ways to estimate this parameter for a section. The method first introduced by Cowan (1956) and adopted by the Soil Conservation Service (1963) was used to estimate Manning's n. This procedure involves a 6-step process of evaluating the properties of the reach, which is explained in more detail by Chow (1959). Field data describing the channel bed, bank stability, vegetation, obstructions, and other pertinent parameters were collected and photographs were taken of the stream sections. Once the field data were collected, they were used to estimate the Manning's roughness for the section observed. The pictures were compared to pictures reported in Chow (1959) for validation of the estimates of the Manning's n for each section.

The result of the field inspections of the reach sections was a set of characteristic slopes (channel sides and field plains), bed widths, heights to flood plain, and Manning's roughness coefficients. Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from Digital Elevation Models (DEMs) and a stream-flow network digitized from USGS 7.5-minute quadrangle maps (scale 1:24,000). These data were used to derive the Hydraulic Function Tables (F-tables) used by the HSPF model (Table 4.2). The F-tables consist of four columns; depth (ft), area (ac), volume (ac-ft), and outflow (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area represents the surface area of the flow in acres. The volume corresponds to the total volume of the flow in the reach, and is reported in acre-feet. The outflow is simply the stream discharge, in cubic feet per second.

Table 4.2 Example of an F-table calculated for the HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0.0	0.00	0.00	0.00
0.2	21.96	4.37	10.87
0.4	22.16	8.78	34.54
0.6	22.36	13.23	67.92
0.8	22.56	17.73	109.75
1.0	22.77	22.26	159.29
1.3	23.07	29.14	246.88
1.7	23.48	38.44	386.59
2.0	23.78	45.53	507.43
2.3	24.08	52.71	641.30
2.7	24.49	62.43	839.20
3.0	24.79	69.82	1,001.68
6.0	29.42	149.62	3,222.35
9.0	37.08	249.37	6,254.60
12.0	44.73	372.08	10,078.05
15.0	52.38	517.75	14,818.37
25.0	77.32	1,163.48	38,629.43
50.0	92.02	2,796.19	103,246.75

4.4 Selection of Representative Modeling Period

Selection of the representative modeling periods was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Modeling periods were selected for hydrology calibration, water quality calibration and validation, and modeling of allocation scenarios. Special Study data (*i.e.*, instantaneous flow values) at USGS Station #03177750 (Laurel Fork at Pocahontas Sewage Treatment Plant) were available from 1993 to 1994. Due to the sparse amount of data (*i.e.*, 6 observations over a 19 month period), a paired watershed approach was used to set initial parameters for the model, and all available discharge data were used for the hydrology calibration.

Hydrology validation was not performed for Laurel Fork because there were only six measurements of flow collected during the representative modeling period. All observed data collected during this time period was used for hydrology calibration. It was determined that using all available data for calibration would result in a more accurate model.

As shown in the critical conditions section (section 2.4, Figure 2.2), there is no critical flow level at VADEQ Station 9-LRR001.39, where the most bacteria data was collected. This indicates that the modeling time periods must include low and high stream flow regimes.

Daily precipitation data was available near the Laurel Fork watershed at the Flattop, WV NCDC Coop station #463072. The few missing values were filled with daily precipitation from the Richlands NCDC Coop station #447174. The nearest continuous stream flow data was available at USGS station #03177700 on the Bluestone River at Falls Mills, VA from 10/1/1965 to 4/27/1997.

In order to select a modeling period representative of the critical hydrological condition from the available data, the mean daily flow and precipitation for each season were calculated for the period 1965 through 1997. This resulted in 31 observations of flow and precipitation for each season. The mean and variance of these observations were calculated. Next, a candidate period was chosen based on the availability of mean discharge data closest to the fecal coliform assessment period (10/89-9/04). The representative period was chosen from this candidate period such that the mean and variance of each season in the modeled period was not significantly different from the historical data. The results of this analysis are shown in Table 4.3. Therefore, the modeling periods were selected as representing the hydrologic regime of the watershed, accounting for critical conditions associated with all potential sources within the watershed. The resulting representative modeling period is 10/1/1992 through 9/30/1997.

Table 4.3 Comparison of modeled period to historical records.

	Flow (03177700)				Precipitation (463072/447174)			
	Fall	Winter	Summer	Spring	Fall	Winter	Summer	Spring
	Historical Record (1965-1997)							
Mean	41.0	97.7	71.6	27.1	0.103	0.129	0.136	0.128
Variance	432	1190	601	160	0.001	0.001	0.001	0.001
	Calibration Period (10/92 - 9/97)							
Mean	42.2	131	75.8	25.9	0.095	0.133	0.134	0.121
Variance	318.8	648	327	27.4	0.001	0.001	0.001	0.001
	p-Values							
Mean	0.442	0.008	0.339	0.364	0.224	0.359	0.437	0.329
Variance	0.427	0.296	0.343	0.085	0.301	0.443	0.291	0.345

A representative period for fecal coliform calibration for Laurel Fork was selected with consideration given to the hydrology calibration period, availability of water quality data, and the VADEQ assessment periods that led to the inclusion of Laurel Fork on the 1994, 1996, 1998, 2002, and 2004 Section 303(d) lists. Fecal coliform data for Laurel Fork were available in the period from 1/17/1980 through 6/21/2004 at various locations throughout the watershed. The five years with the most fecal coliform data (23 samples) were used as the water quality calibration time period, 10/1/1994 through 9/30/1999 (Table 4.4). The fecal coliform water quality validation modeling period selected was 10/1/1990 through 9/30/1994 (22 samples).

Table 4.4 Summary of modeling time periods for the Laurel Fork watershed.

Impairment	Hydrology Calibration	Water Quality (FC) Calibration	Water Quality (FC) Validation
Laurel Fork	10/1/1992 to 9/30/1997	10/1/1994 to 9/30/1999	10/1/1990 to 9/30/1994

The period selected for modeling of allocation scenarios represents critical hydrological conditions and coincides with the hydrology calibration time periods. Modeling during the calibration period provides the highest confidence in allocation results.

4.5 Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.*, animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Direct depositions by nocturnal animals were modeled as being deposited from 6:00 PM to 6:00 AM, and direct depositions by diurnal animals were modeled as being deposited from 6:00 AM to 6:00 PM. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.,* population). Depending on the timeframe of the simulation being run, different numbers should be used. Data representing 1995 were used for the water quality calibration and validation period (1991-1999). Data representing 2005 were used for the allocation runs in order to represent current conditions.

4.5.1 Point Sources

There are three permitted point discharges in the Laurel Fork watershed. All of these facilities are permitted for fecal control, with design discharges ranging from <0.001-0.50 MGD (Table 3.2).

For the Pocahontas STP (permitted point discharge VA0029602), specific flow data over time provided by VADEQ was used during hydrology and FC calibration. Fecal coliform concentrations were adjusted to account for improper operation of the STP as well as sewer collector line failures and sewer system overflows during the calibration period. Design flow capacities were used for allocation runs. For allocations, the design flow rate was combined with a fecal coliform concentration of 200 cfu/100 mL to ensure that compliance with state water quality standards can be achieved even if the facility were discharging at the maximum allowable flow rate.

For the domestic STP (VAG400522), a flow rate of 0.001 MGD was combined with a fecal coliform concentration of 200 cfu/100 ml for calibration and allocation runs. For the proposed Northern Tazewell County WWTF (VA0091588), no discharge was modeled during calibration, and allocations were modeled using the design flow rate combined with a fecal coliform concentration of 200 cfu/mL, to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels.

Nonpoint sources of pollution that were not driven by runoff are identified in the following sections.

4.5.2 Private Residential Sewage Treatment

The number of septic systems in the subwatersheds modeled for the Laurel Fork watershed was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the watershed to enumerate the septic systems. Households were then distributed among residential land use types. Each land use area was assigned a number of septic systems based on census data. A total of 311 septic systems were estimated in the Laurel Fork watershed in 1995. During allocation runs, the number of households was projected to 2005, based on current Tazewell County growth rates (USCB, 2000) resulting in 357 septic systems (Table 4.5).

Table 4.5 Estimated failing septic systems (2005).

Impaired Segment	Total Septic Systems	Failing Septic Systems	Straight Pipes
Laurel Fork	357	343	37

4.5.2.1 Failing Septic Systems

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. of the Crop and Soil Environmental Sciences Department at Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of a

TMDL for the Laurel Fork watershed. Total septic systems in each category were calculated using U.S. Census Bureau block demographics. The applicable failure rate was multiplied by each total and summed to get the total failed septic systems per subwatershed. After public comment on the estimated numbers indicated that uncontrolled discharges and failing septic systems were not being represented sufficiently, and after confirming this by conversation with the local Virginia Department of Health officials, the number of failing septic systems were increased accordingly (Table 4.5). The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors (VADEQ/VADCR, 2000) to account for more frequent failures during wet months.

4.5.2.2 Uncontrolled Discharges

Uncontrolled discharges were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category "other means" were assumed to be disposing sewage via uncontrolled discharges if located within 200 feet of a stream. Corresponding block data and subwatershed boundaries were intersected using GIS to determine an estimate of uncontrolled discharges in each subwatershed. A 200-foot buffer was created from the stream segments. The corresponding buffer and subwatershed areas were intersected resulting in uncontrolled discharges within 200 feet of the stream per subwatershed. Fecal coliform loads for each discharge were calculated based on the fecal density of human waste and the waste load for the average size household in the subwatershed. The loadings from uncontrolled discharges were applied directly to the stream in the same manner that point sources are handled in the model.

4.5.3 Livestock

Fecal coliform produced by livestock was modeled entering surface waters through two pathways: deposition on land, and direct deposition to streams. The number of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock numbers determined for 2005 were used for the allocation runs, while these numbers were projected back to 1995 for the calibration and validation runs. The numbers are based on data provided by the Tazewell County Agricultural Extension Agency, the TSWCD, and NRCS, as well as taking into account growth rates in Tazewell County (as determined from data reported by the Virginia Agricultural Statistics Service -- VASS, 1995 and VASS, 2005). For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.7). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

4.5.3.1 Deposition on Land

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the study entitled "Modeling Cattle Stream Access" conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR (MapTech, 2002). The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pastureland use type was area-weighted.

4.5.3.2 Direct Deposition to Streams

Beef cattle are the primary sources of direct deposition by livestock in the Laurel Fork watershed. The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in "stream access" areas was calculated based on the "Modeling Cattle Stream Access" study. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a specific land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 30% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

4.5.4 Wildlife

For each species, a GIS habitat layer was developed based on the habitat descriptions that were obtained (section 3.2.5). An example of one of these layers is shown in Figure 4.3. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the waste load, fecal coliform densities, and number of animals for each species.

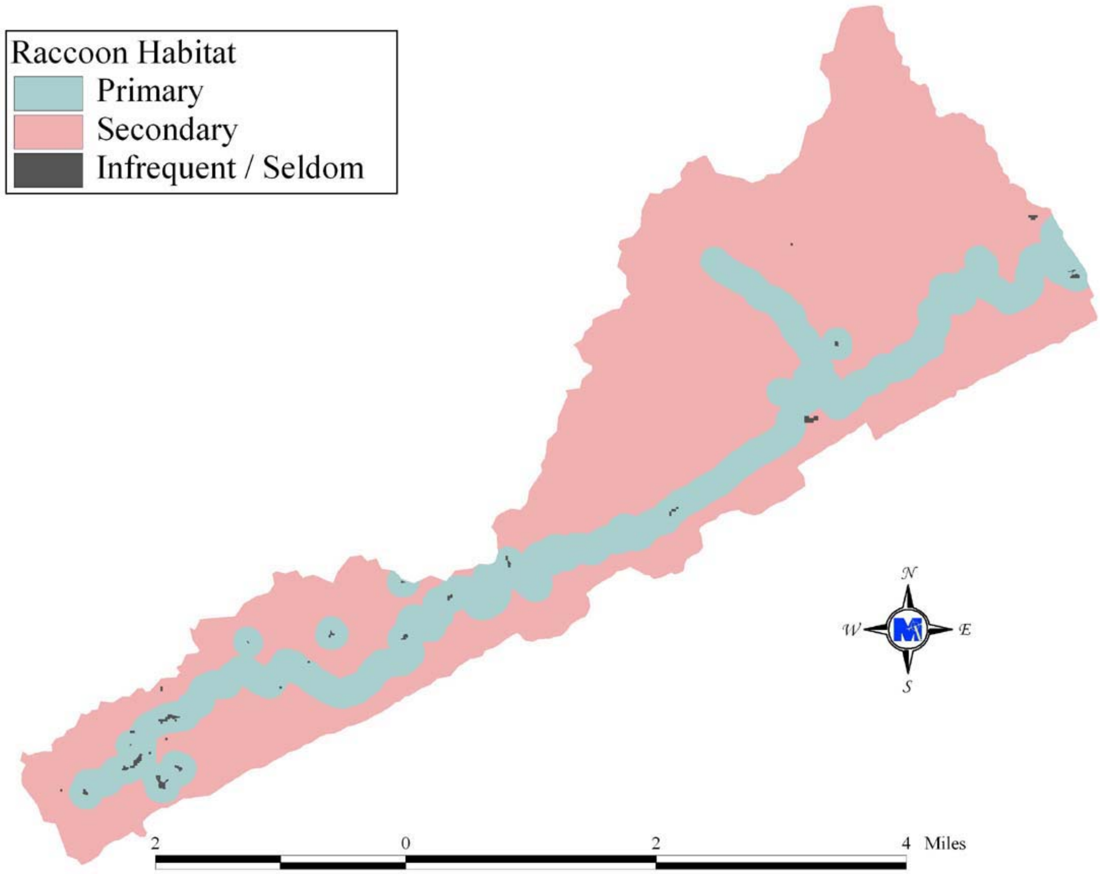

Figure 4.3 Example of raccoon habitat layer developed by MapTech in the Laurel Creek watershed.

Seasonal distribution of waste was determined using seasonal food preferences for deer and turkey. Goose and duck populations were varied based on migration patterns, but the load available for delivery to the stream was never reduced below 40% of the maximum to account for the resident population of birds. No seasonal variation was assumed for the remaining species. For each species, a portion of the total waste load was considered to be land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.12). It was estimated, for all animals other than beaver, that 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams. No long-term (1995–2005) projections were made to wildlife populations, as there was no available data to support such adjustments.

4.5.5 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals/house), waste load, and fecal coliform density are reported in section 3.3.2. Waste from pets was distributed in the residential land uses. The location of households was taken from the 1990 and 2000 Census (USCB, 1990, 2000). The land use and household layers were overlaid, which resulted in number of households per land use. The number of animals per land use was determined by multiplying the number of households by the population density. The amount of fecal coliform deposited daily by pets in each land use segment was calculated by multiplying the waste load, fecal coliform density, and number of animals for both cats and dogs. The waste load was assumed not to vary seasonally. The populations of cats and dogs were projected from 1990 data to 1995 and 2005 based on housing growth rates.

4.6 Sensitivity Analysis

Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.,* seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads). Additional analyses were performed to define the sensitivity of the modeled system to growth or technology changes that impact waste production rates.

Sensitivity analyses were run on both hydrologic and water quality parameters. The parameters adjusted for the hydrologic sensitivity analysis are presented in Table 4.6, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value unless otherwise noted, and the model was run for water years 1993 through 1997. The hydrologic quantities of greatest interest in a fecal coliform model are those that govern peak flows and low flows. Peak flows, being a function of runoff, are important because they are directly related to the transport of fecal coliforms from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration such as INFILT (Infiltration) and AGWRC (Groundwater Recession Rate), and to a lesser extent by LZSN (Lower Zone Storage), which affects soil moisture. Low flows are important in a water quality model because they control the level of dilution during dry periods. Parameters with the greatest influence on low flows (as evidenced by their influence in the *Low Flows* and *Summer Flow Volume* statistics) were AGWRC (Groundwater Recession Rate) and INFILT and, to a lesser extent, LZETP (Lower Zone Evapotranspiration). The responses of these and other hydrologic outputs are reported in Table 4.7.

Table 4.6 Base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
AGWRC	Active Groundwater Coefficient	1/day	0.980
BASETP	Base Flow Evapotranspiration	---	0.010
CEPSC	Interception Storage Capacity	in	0.01 - 0.20
DEEPFR	Fraction of Deep Groundwater	---	0.010
INFILT	Soil Infiltration Capacity	in/hr	0.0500 - 0.3083
INTFW	Interflow Inflow	---	1.000
KVARY	Groundwater Recession Coefficient	1/day	0.000
LZSN	Lower Zone Nominal Storage	in	3.293 - 13.745
LZETP	Monthly Lower Zone Evapotranspiration	---	0.01 - 0.80
NSUR	Manning's *n* for Overland Flow	---	0.100
UZSN	Upper Zone Storage Capacity	in	0.41 - 1.92

Table 4.7 Sensitivity analysis results for hydrologic model parameters.

Model Parameter	Parameter Change (%)	Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume
AGWRC	-10%	-1.12%	28.37%	-35.01%	16.75%	-12.94%	-21.54%	7.27%	34.56%
AGWRC	-1%	-0.45%	5.35%	-8.17%	6.09%	-2.11%	-8.74%	-1.15%	10.67%
AGWRC	1%	0.24%	-7.58%	13.55%	-9.48%	-1.81%	14.73%	6.88%	-20.51%
BASETP	-50%	0.15%	-0.30%	0.54%	-0.29%	0.42%	1.10%	-0.47%	0.20%
BASETP	-10%	0.03%	-0.06%	0.11%	-0.06%	0.08%	0.22%	-0.09%	-0.05%
BASETP	10%	-0.03%	0.06%	-0.11%	0.05%	-0.08%	-0.22%	0.10%	-0.02%
BASETP	50%	-0.15%	0.30%	-0.54%	0.29%	-0.42%	-1.10%	0.48%	-0.14%
CEPSC	-50%	2.04%	-4.06%	5.71%	-2.16%	3.89%	9.16%	-0.67%	3.61%
CEPSC	-10%	0.25%	-0.63%	0.81%	-0.49%	0.59%	1.64%	-0.39%	0.63%
CEPSC	10%	-0.21%	0.58%	-0.73%	0.49%	-0.56%	-1.49%	0.37%	-0.43%
CEPSC	50%	-1.09%	3.01%	-4.05%	2.02%	-2.41%	-6.21%	0.67%	-1.74%
DEEPFR	-50%	0.44%	0.30%	0.51%	0.41%	0.43%	0.50%	0.47%	0.40%
DEEPFR	-10%	0.09%	0.06%	0.10%	0.08%	0.09%	0.10%	0.09%	0.08%
DEEPFR	10%	-0.09%	-0.06%	-0.10%	-0.08%	-0.09%	-0.10%	-0.09%	-0.08%
INFILT	-50%	-1.31%	24.30%	-15.77%	9.48%	-3.73%	-13.86%	-4.13%	3.34%
INFILT	-10%	-0.25%	3.34%	-2.10%	1.34%	-0.56%	-2.37%	-0.45%	0.12%
INFILT	10%	0.25%	-2.81%	1.80%	-1.14%	0.50%	2.20%	0.37%	0.05%
INFILT	50%	1.11%	-10.53%	6.66%	-4.23%	1.99%	8.95%	1.40%	0.84%
INTFW	-50%	-0.04%	0.63%	0.27%	-0.14%	-0.05%	0.14%	-0.02%	-0.38%
INTFW	-10%	-0.01%	0.02%	0.04%	-0.03%	0.00%	0.02%	0.00%	-0.05%
INTFW	10%	0.00%	0.00%	-0.04%	0.02%	0.00%	-0.02%	0.00%	0.04%
INTFW	50%	0.02%	0.08%	-0.15%	0.08%	0.02%	-0.07%	-0.01%	0.15%
LZETP	-50%	10.00%	9.76%	16.11%	11.13%	3.26%	8.08%	21.43%	-6.17%
LZETP	-10%	1.06%	1.00%	1.76%	1.28%	0.39%	0.71%	2.16%	-0.41%
LZETP	10%	-0.95%	-0.86%	-1.60%	-1.13%	-0.36%	-0.67%	-1.92%	0.86%
LZETP	50%	-6.83%	-4.80%	-12.12%	-6.77%	-2.19%	-8.22%	-13.55%	5.53%
LZSN	-50%	4.02%	17.70%	-2.32%	13.06%	2.40%	-9.76%	4.23%	13.33%
LZSN	-10%	0.47%	2.36%	-0.70%	1.70%	0.53%	-1.19%	-0.18%	3.10%
LZSN	10%	-0.38%	-2.01%	0.76%	-1.41%	-0.53%	0.96%	0.42%	-2.63%
LZSN	50%	-1.65%	-8.01%	3.21%	-5.60%	-2.56%	3.35%	2.09%	-11.44%
NSUR	-50%	0.02%	0.72%	-0.25%	0.25%	-0.06%	-0.16%	-0.10%	0.18%
NSUR	-10%	0.00%	0.13%	-0.04%	0.04%	0.00%	-0.04%	-0.02%	0.02%
NSUR	10%	0.00%	-0.12%	0.03%	-0.04%	0.01%	0.03%	0.01%	-0.02%
NSUR	50%	-0.01%	-0.51%	0.15%	-0.20%	0.07%	0.12%	0.07%	-0.13%
UZSN	-50%	1.03%	7.01%	-2.81%	3.42%	1.16%	-0.84%	-1.64%	6.70%
UZSN	-10%	0.17%	1.09%	-0.48%	0.62%	0.16%	-0.20%	-0.26%	1.34%
UZSN	10%	-0.15%	-0.98%	0.47%	-0.60%	-0.13%	0.20%	0.25%	-1.12%
UZSN	50%	-0.67%	-4.29%	2.26%	-2.88%	-0.46%	1.07%	1.22%	-4.71%

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 1995 through 1999 and model parameters established for 1995 conditions. The three parameters impacting the model's water quality response (Table 4.8) were increased and decreased by amounts that were consistent with the range of values for the parameter.

Table 4.8 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	0.0E+00 – 2.2E+11
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	0.00-2.50
FSTDEC	In-stream First Order Decay Rate	1/day	1.00

Since the water quality standard for *E. coli* bacteria is based on concentrations rather than loadings, it was considered necessary to analyze the effect of source changes on the monthly geometric mean *E. coli* concentration. A monthly geometric mean was calculated for all months during the simulation period, and the value for each month was averaged. Deviations from the base run are given in Table 4.9 and plotted by month in Figure 4.4 through Figure 4.6.

In addition to analyzing the sensitivity of the model response to changes in model parameters, the response of the model to changes in land-based and direct loads was analyzed. The impacts of land-based and direct load changes on the annual load are presented in Figure 4.7, while impacts on the monthly geometric mean are presented in Figure 4.8 and Figure 4.9.

Table 4.9 Percent change in average monthly *E. coli* geometric mean for the years 1995-1999.

Model Parameter	Parameter Change (%)	Percent Change in Average Monthly *E. coli* Geometric Mean for 1994-1999											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	30.38	27.33	29.77	33.98	30.04	41.08	45.91	53.12	57.07	56.09	39.68	31.73
FSTDEC	-10	4.87	4.43	4.78	5.27	4.82	6.07	6.63	7.36	7.65	7.52	5.88	4.97
FSTDEC	10	-4.43	-4.06	-4.36	-4.75	-4.39	-5.38	-5.84	-6.40	-6.59	-6.49	-5.22	-4.50
FSTDEC	50	-18.77	-17.34	-18.50	-19.89	-18.62	-22.02	-23.61	-25.43	-25.93	-25.58	-21.42	-18.92
SQOLIM	-50	-19.36	-19.11	-16.88	-13.83	-18.11	-12.86	-13.90	-11.95	-11.99	-11.51	-12.17	-15.79
SQOLIM	-25	-9.03	-8.93	-7.86	-6.49	-8.46	-5.95	-6.38	-5.50	-5.53	-5.38	-5.63	-7.36
SQOLIM	50	14.34	14.17	12.52	10.57	13.53	9.62	10.23	8.80	8.81	8.90	8.86	11.73
SQOLIM	100	26.10	25.53	22.67	19.45	24.49	17.28	18.35	15.73	15.86	16.23	15.84	21.21
WSQOP	-50	22.48	23.93	18.77	15.74	20.47	11.99	13.08	8.82	10.45	10.03	11.83	18.12
WSQOP	-10	3.10	3.23	2.63	2.17	2.83	1.75	1.88	1.34	1.56	1.47	1.71	2.53
WSQOP	10	-2.71	-2.80	-2.31	-1.89	-2.47	-1.56	-1.67	-1.21	-1.40	-1.31	-1.52	-2.22
WSQOP	50	-2.08	-2.09	-1.14	-2.38	-1.43	-2.78	-3.63	-2.66	-3.25	-3.93	-3.56	-3.53

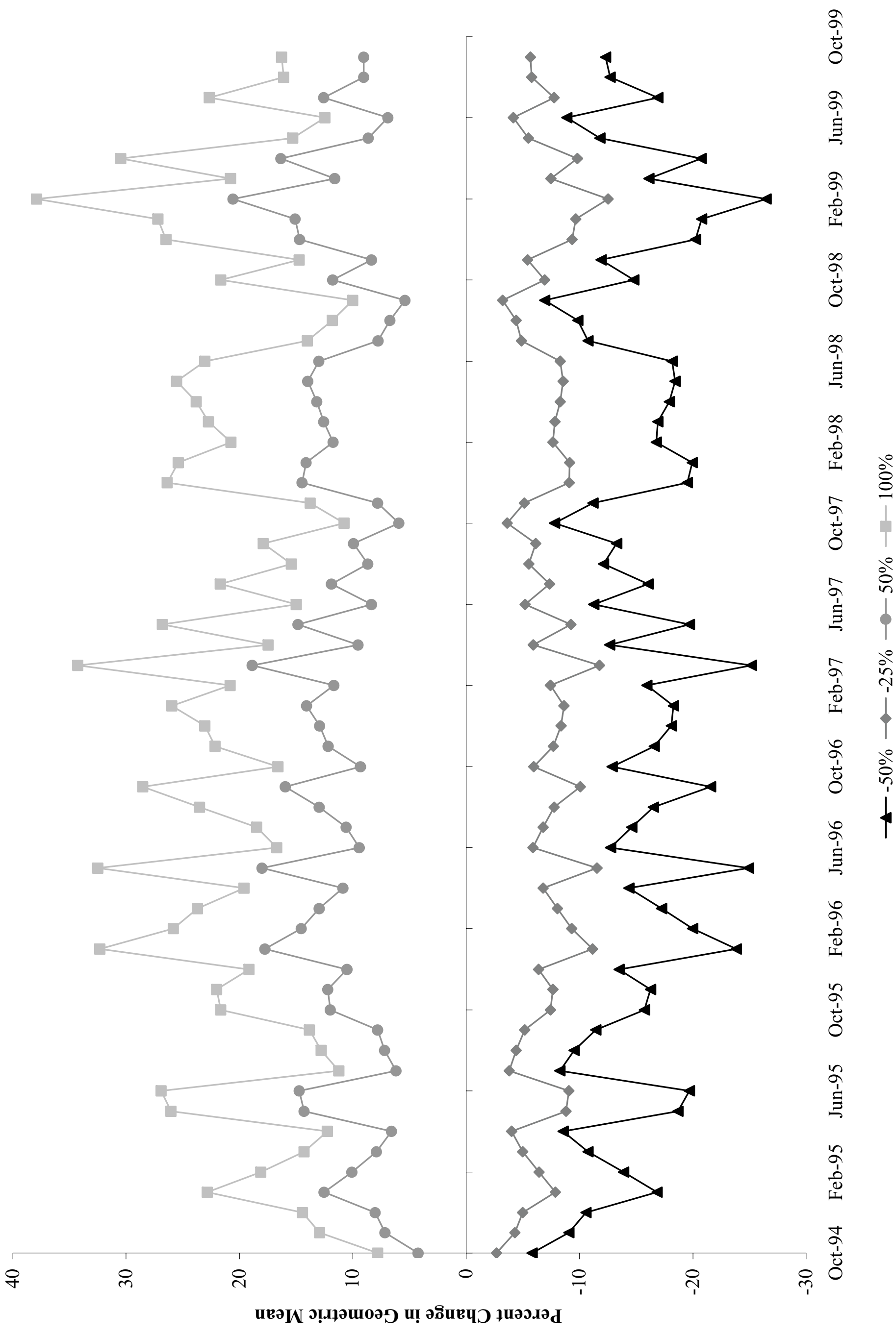

Figure 4.4 Results of sensitivity analysis on monthly geometric-mean concentrations in the Laurel Fork watershed, as affected by changes in maximum FC accumulation on land (MON-SQOLIM).

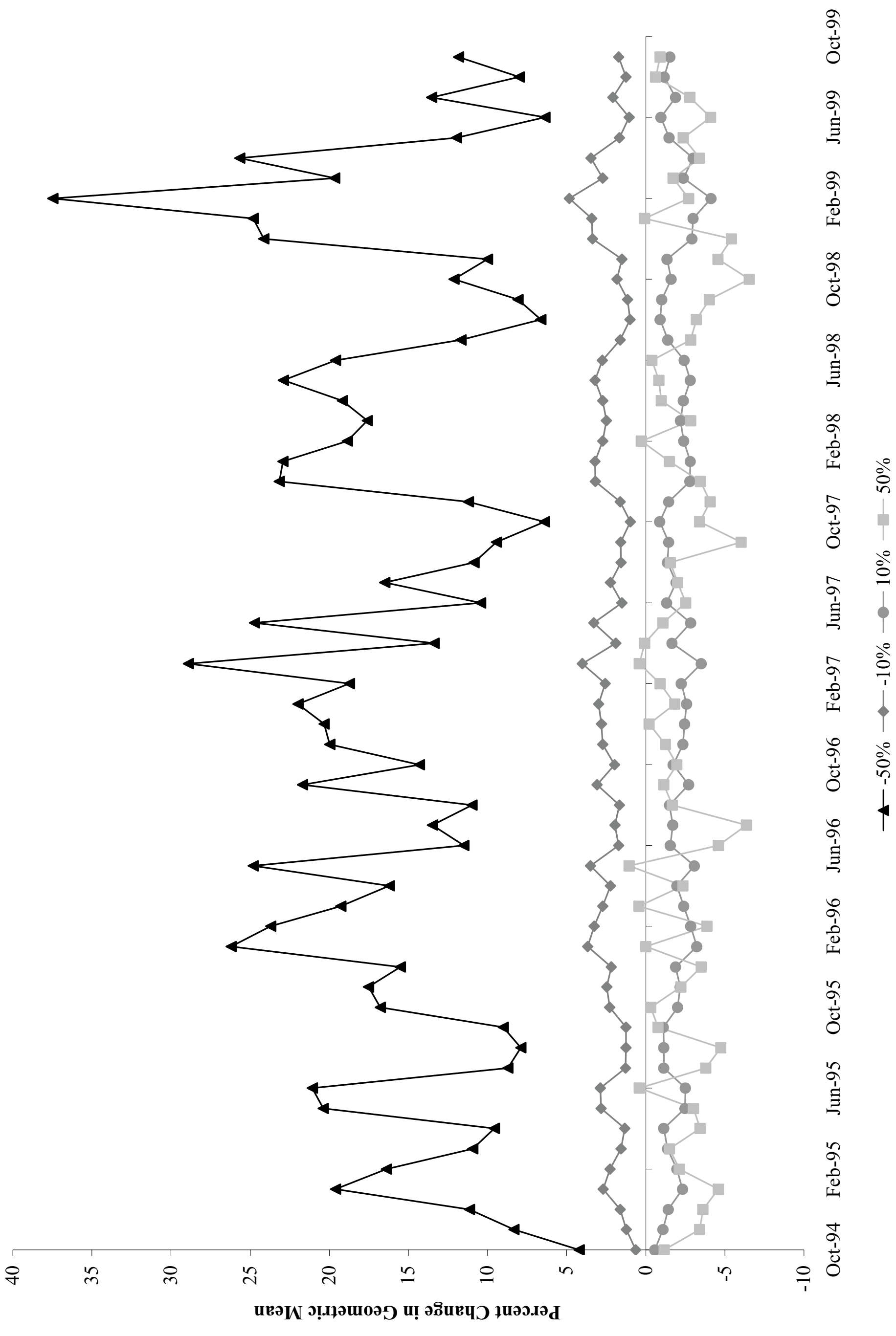

Figure 4.5 Results of sensitivity analysis on monthly geometric-mean concentrations in the Laurel Fork watershed, as affected by changes in the wash-off rate for FC fecal coliform on land surfaces (WSQOP).

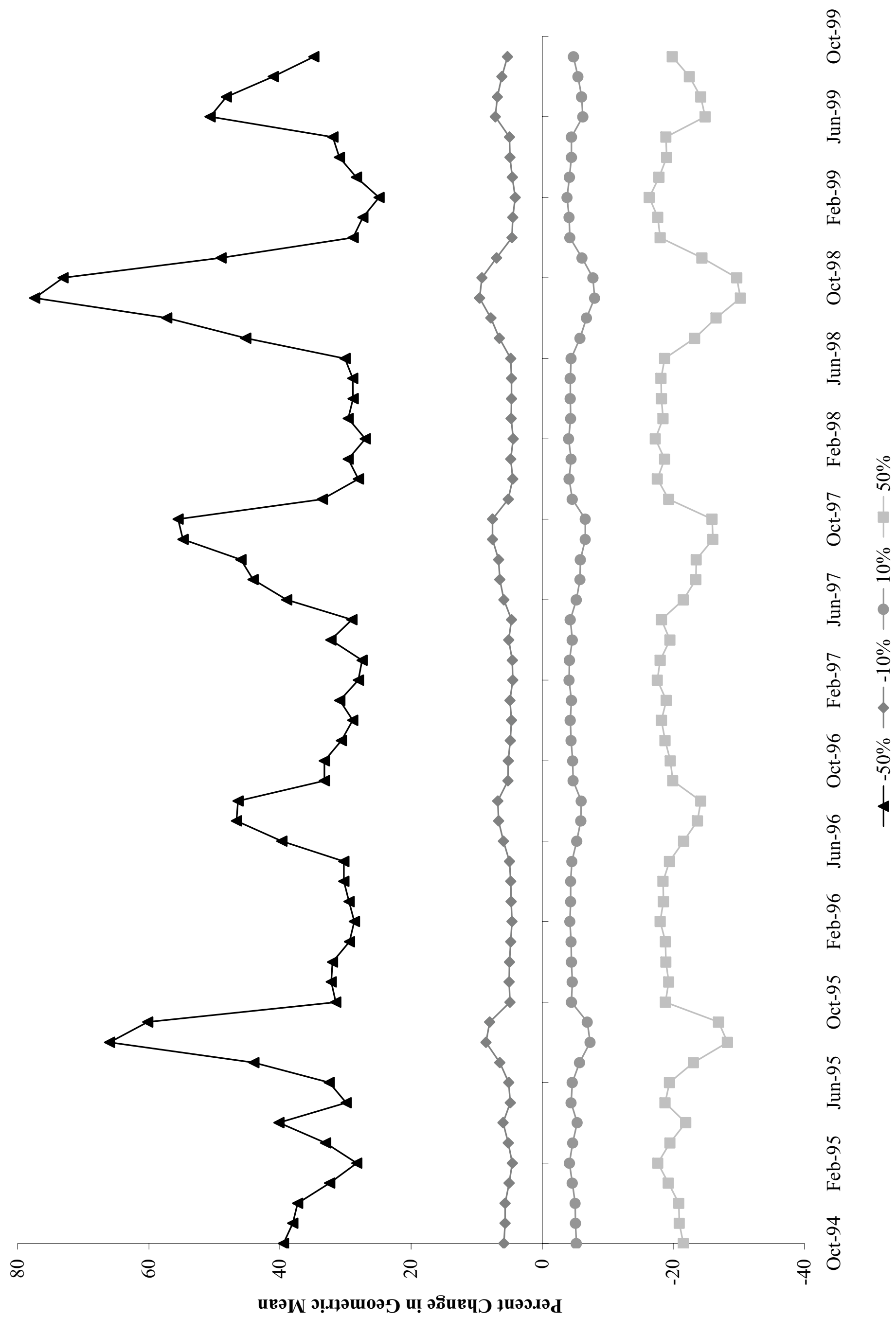

Figure 4.6 Results of sensitivity analysis on monthly geometric-mean concentrations in the Laurel Fork watershed, as affected by changes in the in-stream first-order decay rate (FSTDEC).

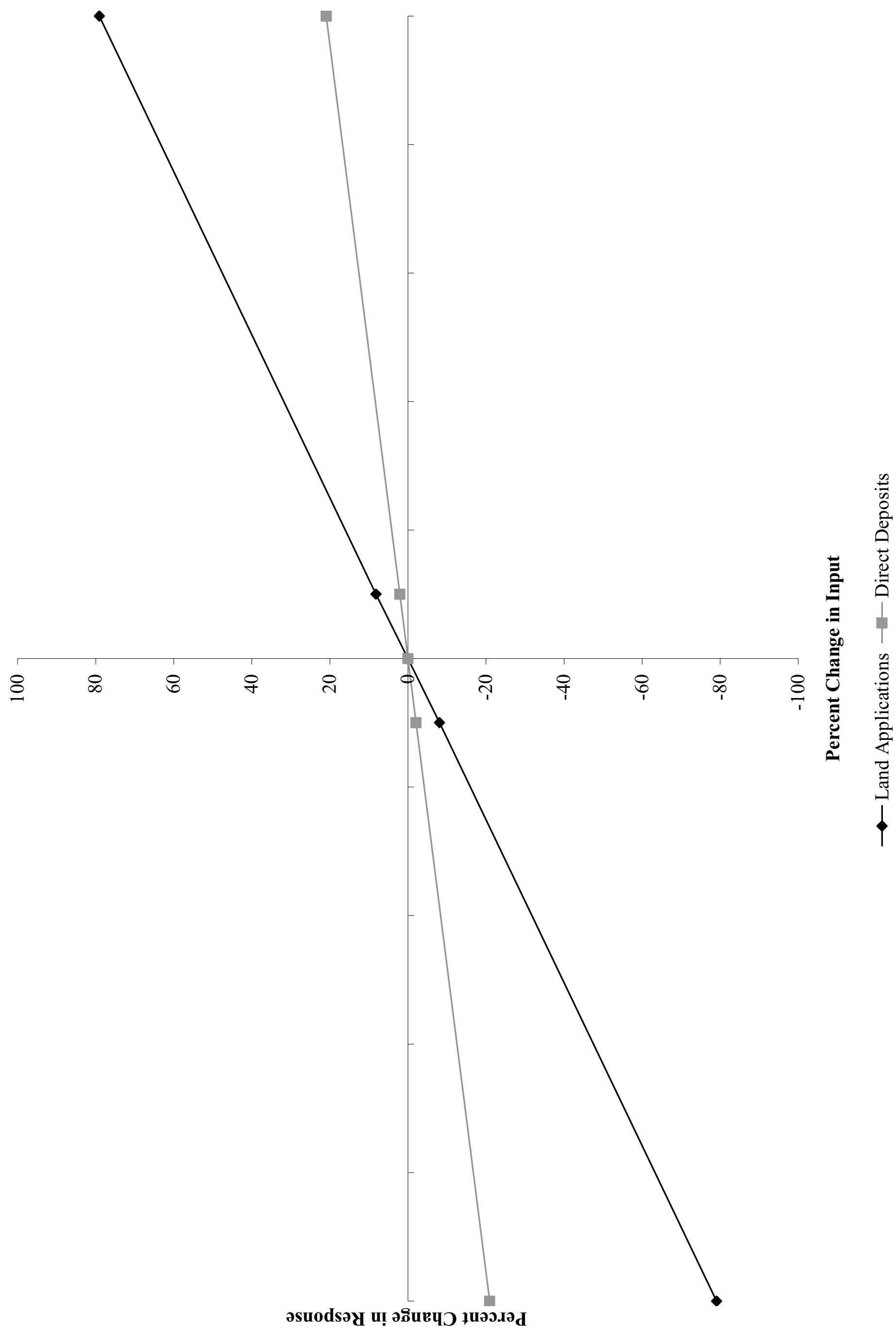

Figure 4.7 Total loading sensitivity to changes in direct and land-based loads for the Laurel Fork watershed.

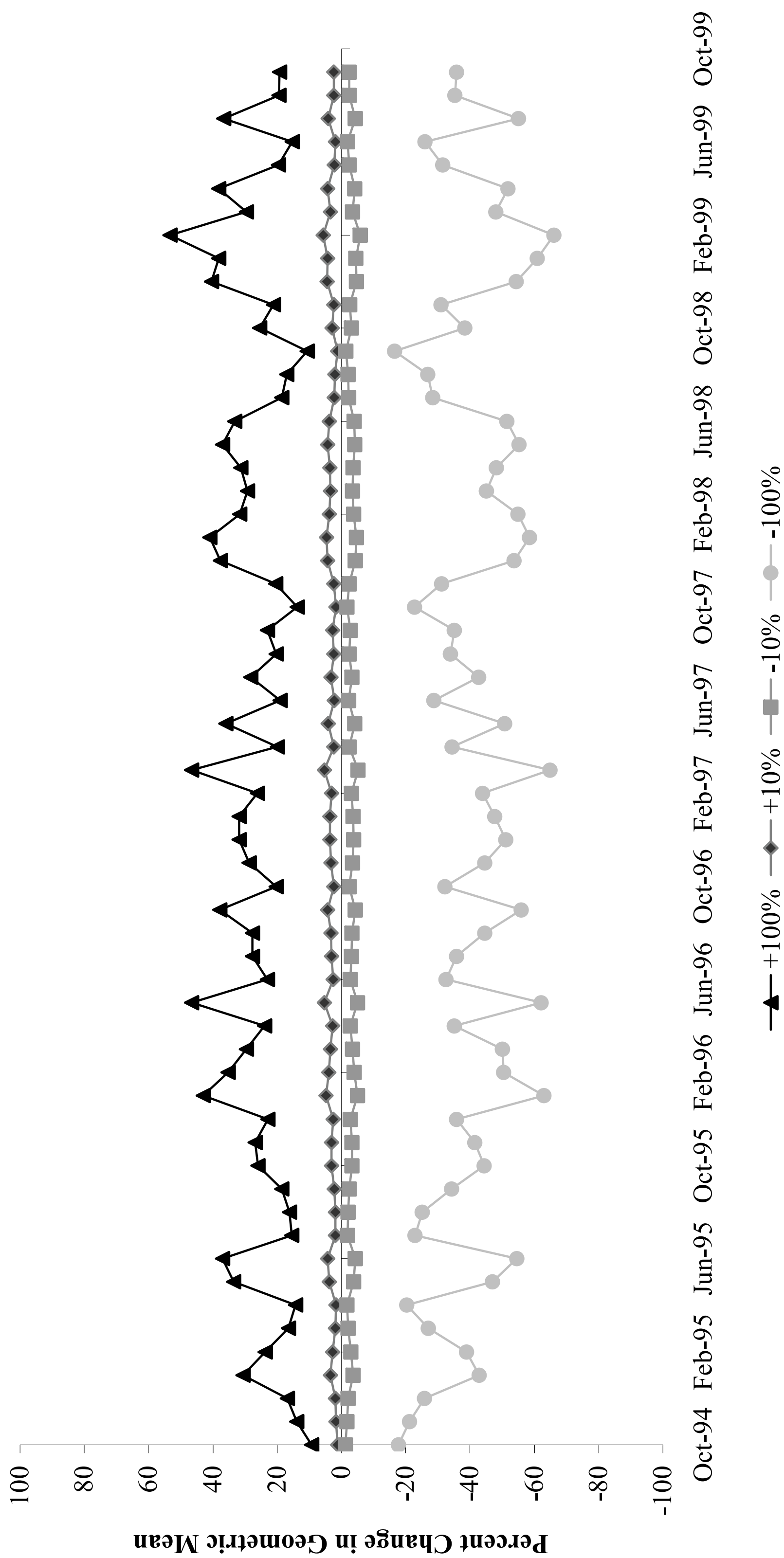

Figure 4.8 Results of sensitivity analysis on monthly geometric-mean concentrations in the Laurel Fork watershed, as affected by changes in land-based loadings.

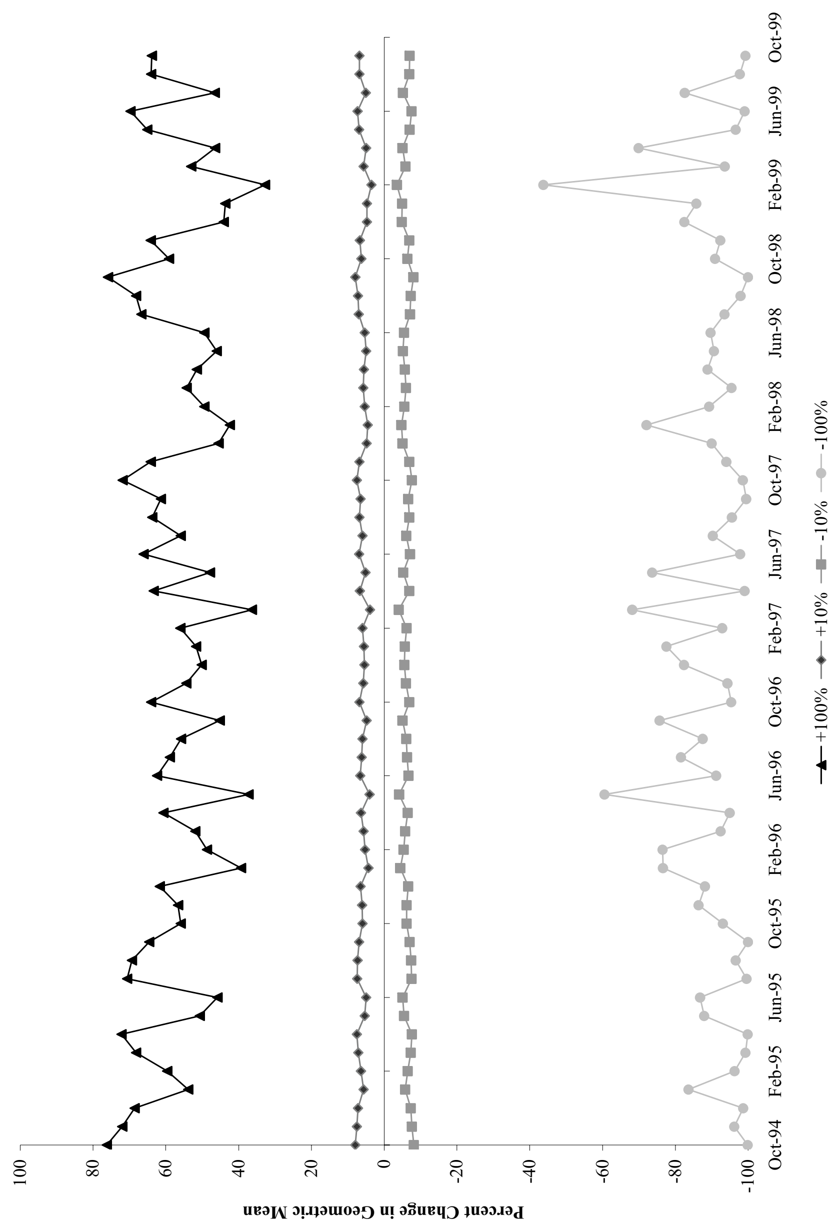

Figure 4.9 Results of sensitivity analysis on monthly geometric-mean concentrations in the Laurel Fork watershed, as affected by changes in loadings from direct nonpoint sources.

4.7 Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. Due to the lack of continuous stream flow data for Laurel Fork, the model's hydrologic parameters were set based on a paired watershed analysis, with consideration for available soils, land use, and topographic data. Qualities of fecal coliform sources were modeled as described in section 4.5. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration. During validation, no adjustments are made to model parameters. The goal of validation is to assess the capability of the model in hydrologic conditions other than those used during calibration.

4.7.1 Hydrologic Calibration

The paired watershed approach, with additional refinement using instantaneous flow measurements from Laurel Fork, was used to calibrate the HSPF model. Through this approach, an HSPF model is calibrated using data from a hydrologically similar watershed, where continuous stream flow data is available. The changes between the initial estimated and final calibrated parameters from the paired watershed model (*e.g.*, lower zone storage) are noted. Then the estimated parameters in the impaired watershed HSPF model are changed by the same percentages. In the case of Laurel Fork, this representation was then refined through calibration to instantaneous flow measurements collected primarily during base-flow conditions.

There are many factors to consider when finding a best-fit paired watershed. Drainage area, shape, proximity to the impaired watershed, land use, hydrologic soil group, ecoregion, and slope are among the most important. Three watersheds were compared to choose the best fit to the Laurel Fork watershed: North River (Augusta

County, VA), Sand Run (Upshur County, WV), and Bluestone River (Tazewell County, VA).

Although the Bluestone River watershed is in close proximity to Laurel Fork, it is considerably larger. Chapter 7 of Watershed Hydrology by P.E. Black (1991) gives a good discussion of the relationship between hydrology and watershed size and shape. Black states that size of the watershed affects peak flows considerably. Larger watersheds tend to have a lower rate of runoff per unit area during a peak flow event. This means the peak may be lower and later in time for a larger watershed, while a smaller watershed may be "flashy" where high flows are higher and low flows are lower than a large watershed.

North River watershed matches the Laurel Fork watershed well regarding many of the parameters but is located in a different ecoregion. Different ecoregions represent distinctions in soils, climate, geology and land use that affect the hydrology of a watershed.

Given that the Sand Run watershed is in the same ecoregion as Laurel Fork (Central Appalachians) and therefore has similar soils, climate, geology, and land use, the Sand Run gaging station was chosen to develop the surrogate hydrology model for Laurel Fork. The hydrologic comparison of the watersheds was established by examining the land use distribution, total drainage area, channel and watershed characteristics, and hydrologic soil group.

The first action taken to implement the paired watershed approach was examining the similarities between the Sand Run and Laurel Fork watersheds. The land use distribution is shown in Table 4.10. The four major land use categories were agricultural, urban, natural and other. The natural land use category included forested and wetlands areas, which accounted for 82% of the Sand Run watershed and 93% of the Laurel Fork watershed.

Table 4.10 Land use distribution for Laurel Fork and Sand Run watersheds.

Land use Categories	Land use	Laurel Fork		Sand Run	
		acres	%	acres	%
Agricultural	Cropland and Pasture	526	5.52	1,674	18.14
Urban	Commercial and Residential	89	0.93	5	0.06
Natural	Forest and Wetlands	8,893	93.36	7,524	81.54
Other	Water	18	0.19	24	0.26
Total		**9,526**	**100**	**9,227**	**100**

The soil hydrologic groups in both watersheds were examined. The soils present in both the Sand Run and Laurel Fork watersheds consist of sandy clay loam and silt loam. Based on the hydrologic soil group classification, the soil series present in the two watersheds predominantly range from “B” to “C”, with "C" being the predominant series.

Watershed characteristics of Sand Run and Laurel Fork, including the drainage area, channel slope, channel length, and the drainage density, were compared. The data, presented in Table 4.11, indicates that these physical characteristics of the watershed are similar.

Table 4.11 Comparison of Sand Run and Laurel Fork watershed characteristics.

Watershed	Drainage Area (acre)	Channel Slope (degrees)	Channel Length (ft)	Drainage Density (ft/acre)
Sand Run	9,227	10	75,966	8.0
Laurel Fork	9,526	16	76,527	8.2

Based on the land use distribution, soil types, and the watershed's physical characteristics, the Sand Run watershed is hydrologically similar to the Laurel Fork watershed. An HSPF model was calibrated and validated for the Sand Run watershed using daily continuous stream flow data from USGS station #03052500 (Sand Run near Buckhannon, WV) and hourly precipitation data from Elkins, WV NCDC Coop station #462718. In order to select a modeling period representative of the historical hydrological condition from the available data, the mean daily flow and precipitation for each season were calculated for the period 1949 through 2004. This resulted in 56 observations of flow and precipitation for each season. The mean and variance of these observations were calculated. The representative period was chosen from this candidate period such that the mean and variance of each season in the modeled period was not significantly different from the historical data. The results of this analysis are shown in Table 4.12. Therefore, the modeling period was selected as representing the hydrologic regime of the watershed. The resulting representative modeling period is 10/1/1991 through 9/30/1995.

Table 4.12 Comparison of modeled period to historical records for Sand Run.

	Flow (03052500)				Precipitation (462718)			
	Fall	Winter	Summer	Spring	Fall	Winter	Summer	Spring
	Historical Record (1949-2004)							
Mean	24.2	47.4	29.8	10.5	0.105	0.119	0.140	0.139
Variance	170	152	157	64	0.0011	0.0011	0.0015	0.0013
	Calibration Period (10/91 - 9/95)							
Mean	26.6	49.3	35.6	9.2	0.103	0.118	0.133	0.152
Variance	134	151	524	63	0.0003	0.0008	0.0018	0.0004
	p-Values							
Mean	0.346	0.384	0.311	0.382	0.386	0.470	0.380	0.127
Variance	0.493	0.597	0.025	0.595	0.153	0.458	0.319	0.180

Parameters that were adjusted during the hydrologic calibration of Sand Run represented the recession rates and variability for groundwater (AGWRC, KVARY), the amount of soil moisture storage in the upper zone (MON-UZSN) and lower zone (LZSN), the infiltration capacity (INFILT), the interflow recession (IRC), the baseflow potential evapotranspiration (BASETP), and the fraction of groundwater inflow to deep recharge (DEEPFR). Table 4.13 contains the typical range for the above parameters along with the initial estimate and final calibrated value. Although HSPF is not a physically based model, and thus parameters are adjusted during calibration in order to match observed data, guidelines are provided by EPA pertaining to typically encountered values. Final calibrated parameters did not go outside of typical values, except in the case of UZSN and LZSN, which ranged just outside the typical low values for the forest and agricultural land uses during the winter months, which coincided with periods of higher than expected flows in the observed record.

The results of hydrology calibration for Sand Run are presented in Table 4.14 and Figures 4.10 through 4.12. Table 4.14 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating a well-calibrated model. The distribution of flow volume between surface runoff, interflow, and groundwater was 57%, 21%, and 22%, respectively.

Table 4.13 Model parameters utilized for hydrologic calibration of Sand Run.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
LZSN	in	2.0 – 15.0	3.0 – 4.0	1.0 –4.0
INFILT	in/hr	0.001 – 0.50	0.0742	0.0168
LSUR	ft	100 – 700	376 - 700	376 - 700
SLSUR	---	0.001 – 0.30	0.049 – 0.195	0.049 – 0.195
KVARY	1/in	0.0 – 5.0	0.0	3.51
AGWRC	1/day	0.85 – 0.999	0.98	0.982
PETMAX	deg F	32.0 – 48.0	40.0	40.0
PETMIN	deg F	30.0 – 40.0	35.0	35.0
INFEXP	---	1.0 – 3.0	2.0	2.0
INFILD	---	1.0 – 3.0	2.0	2.0
DEEPFR	---	0.0 – 0.50	0.01	0.00
BASETP	---	0.0 – 0.20	0.01	0.006
AGWETP	---	0.0 – 0.20	0.0	0.0
INTFW	---	1.0 – 10.0	1.0	1.0
IRC	1/day	0.30 – 0.85	0.5	0.459
MON-INT	in	0.01 - 0.40	0.01 – 0.20	0.01 – 0.20
MON-UZSN	in	0.05 – 2.0	0.08 – 0.48	0.01 – 0.48
MON-LZETP	---	0.1 – 0.9	0.1 – 0.8	0.1 – 0.8
MON-MAN		0.10 – 0.50	0.1	0.1
RETSC	in	0.0 – 1.0	0.1	0.1

Table 4.14 Hydrology calibration criteria and model performance for Sand Run at USGS station #03052500 for the period 10/01/1991 through 9/30/1995.

Criterion	Observed (in)	Modeled (in)	Error
Total In-stream Flow:	109.74	99.32	-9.49%
Upper 10% Flow Values:	56.54	57.29	1.34%
Lower 50% Flow Values:	6.88	7.53	9.42%
Winter Flow Volume	55.54	39.37	-29.11%
Spring Flow Volume	23.12	23.10	-0.08%
Summer Flow Volume	9.45	12.22	29.37%
Fall Flow Volume	21.63	24.62	13.84%
Total Storm Volume	109.44	97.11	-11.27%
Winter Storm Volume	55.47	38.82	-30.01%
Spring Storm Volume	23.05	22.55	-2.17%
Summer Storm Volume	9.38	11.68	24.56%
Fall Storm Volume	21.55	24.06	11.64%

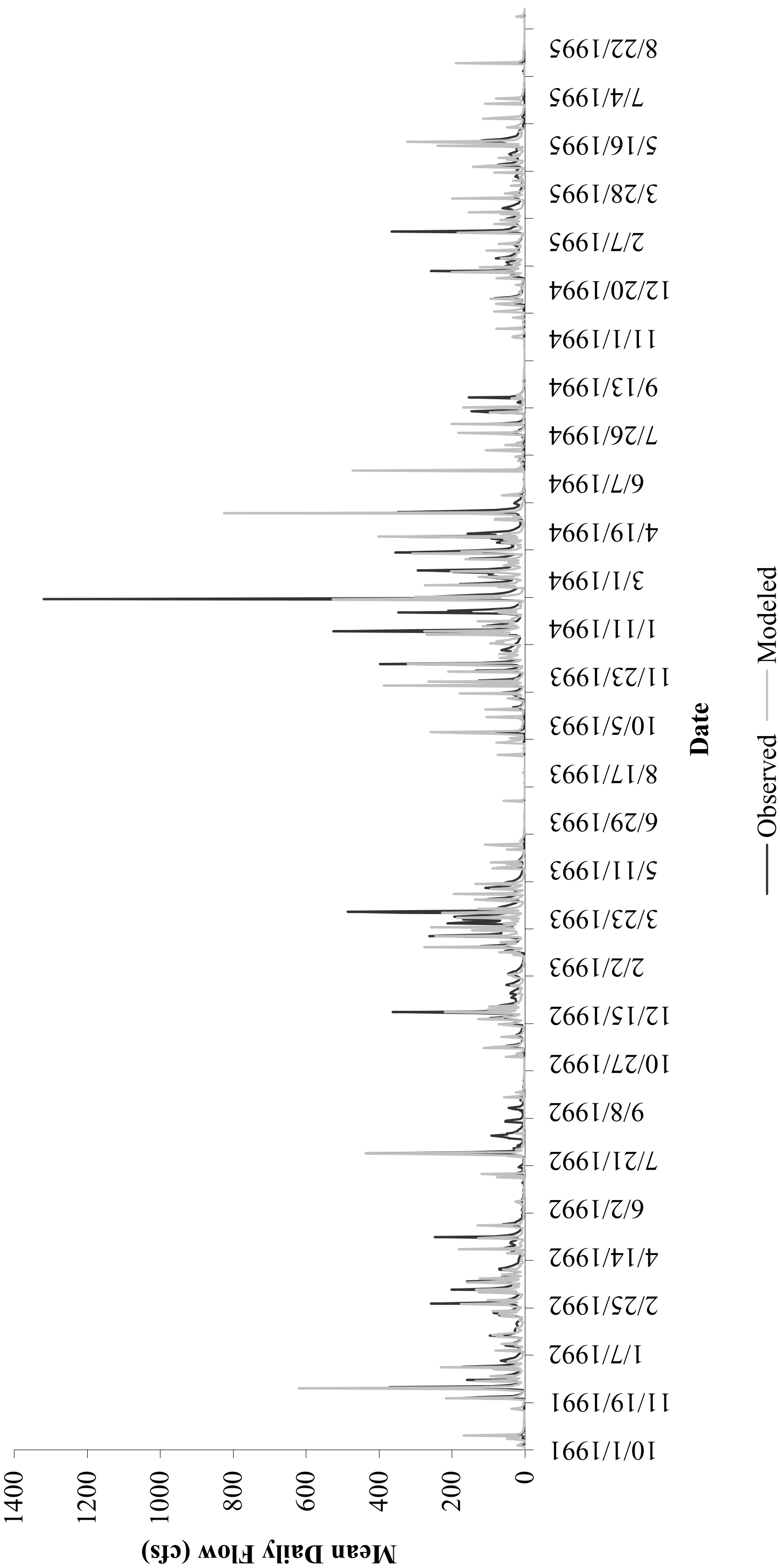

Figure 4.10 Hydrology calibration results for Sand Run at USGS Station #03052500 for the period 1/1/1991 through 9/30/1995.

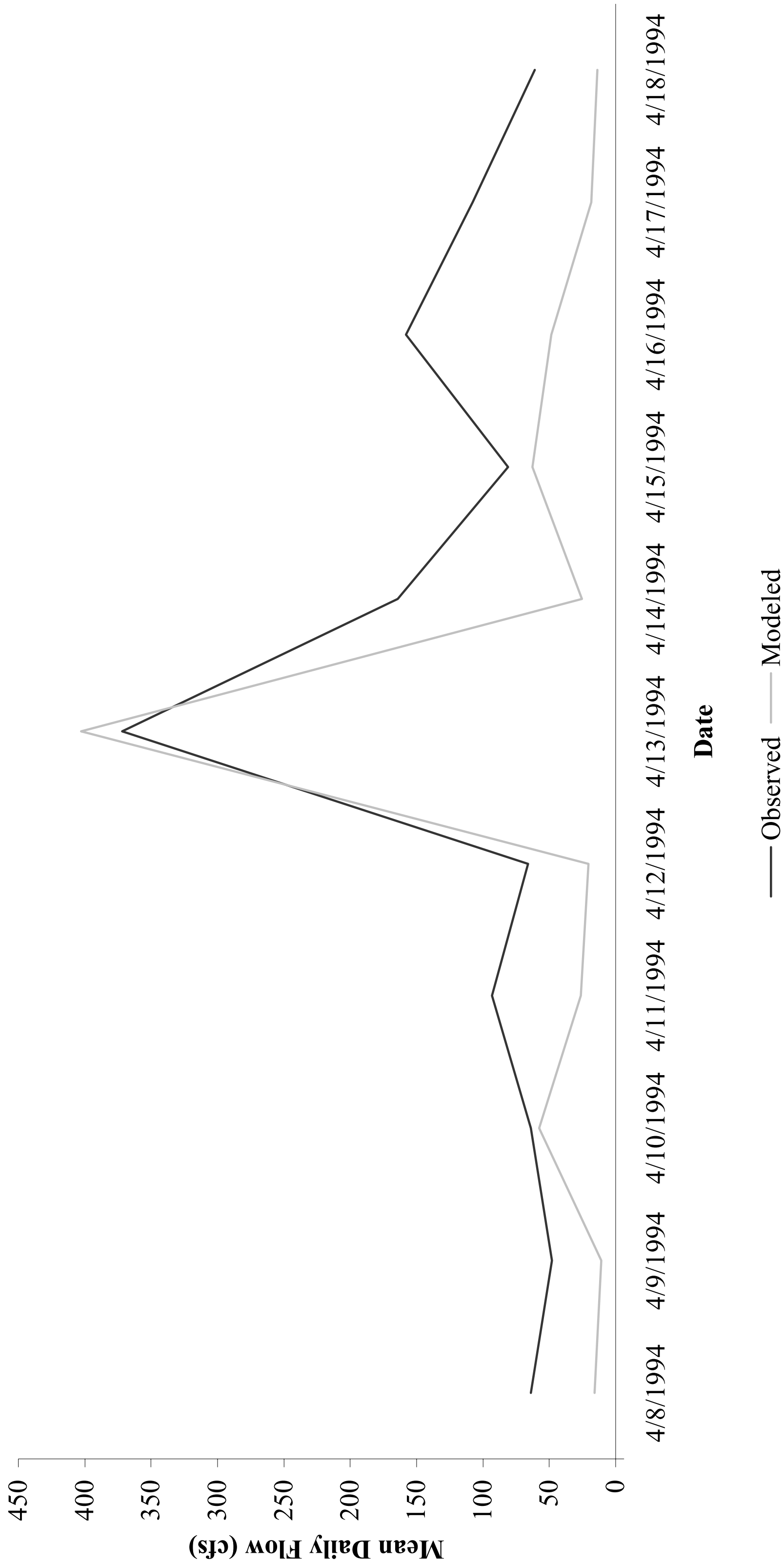

Figure 4.11 Hydrology calibration for a single storm event for Sand Run at USGS Station #03052500 for the period

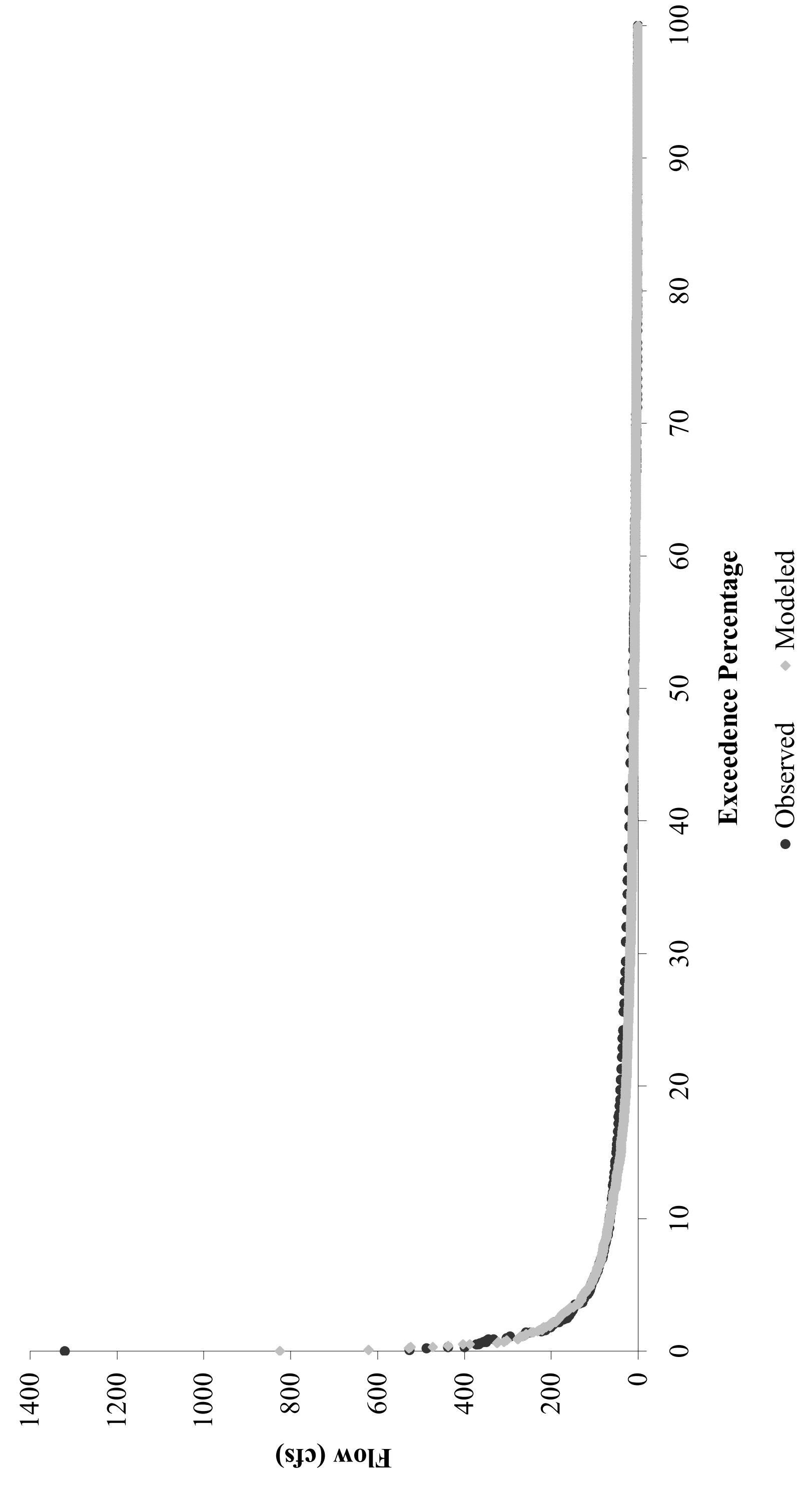

Figure 4.12 Sand Run flow duration at USGS Station #03052500 for 10/1/1991 through 9/30/1995.

The percent change between the initial and final calibrated HSPF parameters for the Sand Run watershed were used as the percent change in base parameters for the Laurel Fork model. Then this model was further calibrated with stream flow values measured by VADEQ at monitoring station 9-LRR001.39 in 1993 and 1994. Table 4.15 contains the typical range for the above parameters along with the initial estimate and final calibrated value. Final calibrated parameters did not go outside of typical values, except in the case of LSUR and SLSUR, which are an estimation of the length and slope of the overland flow path, respectively. These values are calculated using GIS. They are not typically calibrated because they can be estimated with good confidence with digital elevation grids, and are physically measurable values. Final calibrated parameters for DEEPFR, UZSN, and LZETP are outside of the typical values to account for extremely low flows in subwatersheds 2 and 3, and a spring that inputs water to Laurel Fork in subwatershed 4. The final hydrological calibrated HSPF model for Laurel Fork is shown in Figure 4.13

Table 4.15 Model parameters utilized for hydrologic calibration of the Laurel Fork watershed and final calibrated values.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
LZSN	in	2.0 – 15.0	3.293 – 13.745	2.000 – 4.861
INFILT	in/hr	0.001 – 0.50	0.0500 – 0.3083	0.0383 – 0.0665
LSUR	ft	100 – 700	55.23 - 700	55.23 - 700
SLSUR	---	0.001 – 0.30	0.0010 – 0.3918	0.0010 – 0.3918
KVARY	1/in	0.0 – 5.0	0.00	3.51
AGWRC	1/day	0.85 – 0.999	0.980	0.982
PETMAX	deg F	32.0 – 48.0	40.0	40.0
PETMIN	deg F	30.0 – 40.0	35.0	35.0
INFEXP	---	1.0 – 3.0	2.0	2.0
INFILD	---	1.0 – 3.0	2.0	2.0
DEEPFR	---	0.0 – 0.50	0.01	0.90
BASETP	---	0.0 – 0.20	0.010	0.007
AGWETP	---	0.0 – 0.20	0.0	0.0
INTFW	---	1.0 – 10.0	1.000	1.331
IRC	1/day	0.30 – 0.85	0.612	0.612
MON-INT	in	0.01 - 0.40	0.01 – 0.20	0.01 – 0.20
MON-UZSN	in	0.05 – 2.0	0.41 – 1.92	0.05 –2.95
MON-LZETP	---	0.1 – 0.9	0.10 – 0.80	0.01 – 0.88
NSUR		0.10 – 0.50	0.1	0.1
RETSC	in	0.0 – 1.0	0.1	0.1

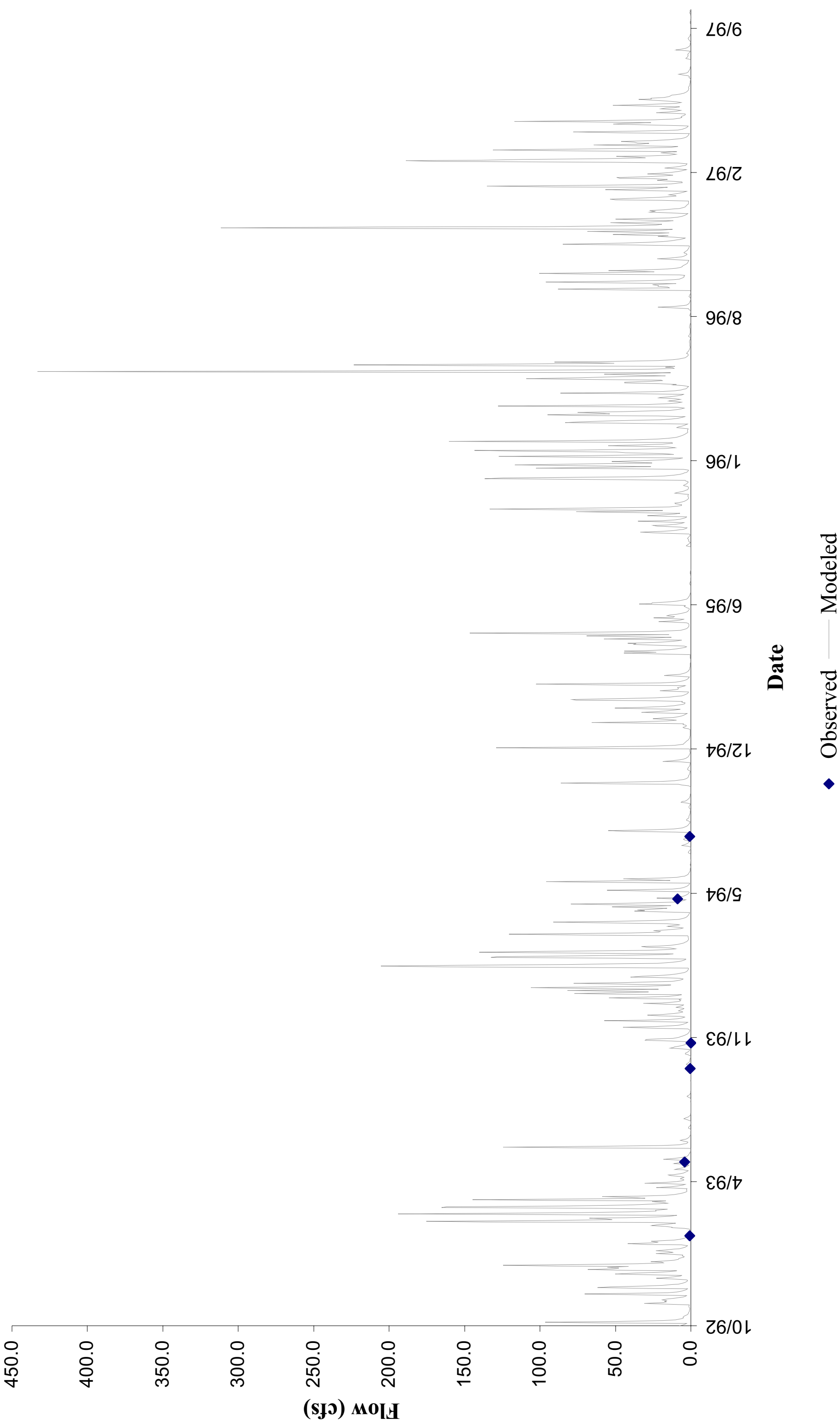

Figure 4.13 Hydrology calibration results for Laurel Fork at the outlet of subwatershed 4.

4.7.2 Water Quality Calibration

Water quality calibration is complicated by a number of factors, some of which are described here. First, water quality concentrations (*e.g.*, fecal coliform concentrations) are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters such as fecal coliform concentration. Second, the concentration of fecal coliform is particularly variable. Variability in location and timing of fecal deposition, variability in the density of fecal coliform bacteria in feces (among species and for an individual animal), environmental impacts on regrowth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling fecal coliform concentrations. Additionally, the limited amount of measured data for use in calibration and the practice of censoring both high (typically 8,000 or 16,000 cfu/100 ml) and low (under 100 cfu/100 ml) concentrations impede the calibration process.

The water quality calibration was conducted using monitored data from 10/1/94 through 9/30/99. Three parameters were utilized for model adjustment; in-stream first-order decay rate (FSTDEC), maximum accumulation on land (SQOLIM), and rate of surface runoff that will remove 90% of stored fecal coliform per hour (WSQOP). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled fecal coliform concentrations was established (Table 4.16). Figure 4.14 shows the results of calibration. Modeled coliform levels matched observed levels during a variety of flow conditions, indicating that the model was well calibrated.

Table 4.16 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
MON-ACCUM	FC/ac*day	0.0E+00 – 1.0E+20	0.0E+00 – 1.1E+11	0.0E+00 – 1.1E+11
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0.0E+00 – 1.1E+11	0.0E+00 – 5.7E+13
WSQOP	in/hr	0.05 – 3.00	0.00 – 2.80	0.00- 2.80
IOQC	FC/ft^3	0.0E+00 – 1.0E+06	0	0
AOQC	FC/ft^3	0 – 10	0	0
DQAL	FC/100ml	0 – 1,000	200	200
FSTDEC	1/day	0.01 – 10.00	1.00	3.00
THFST	---	1.0 – 2.0	1.07	1.07

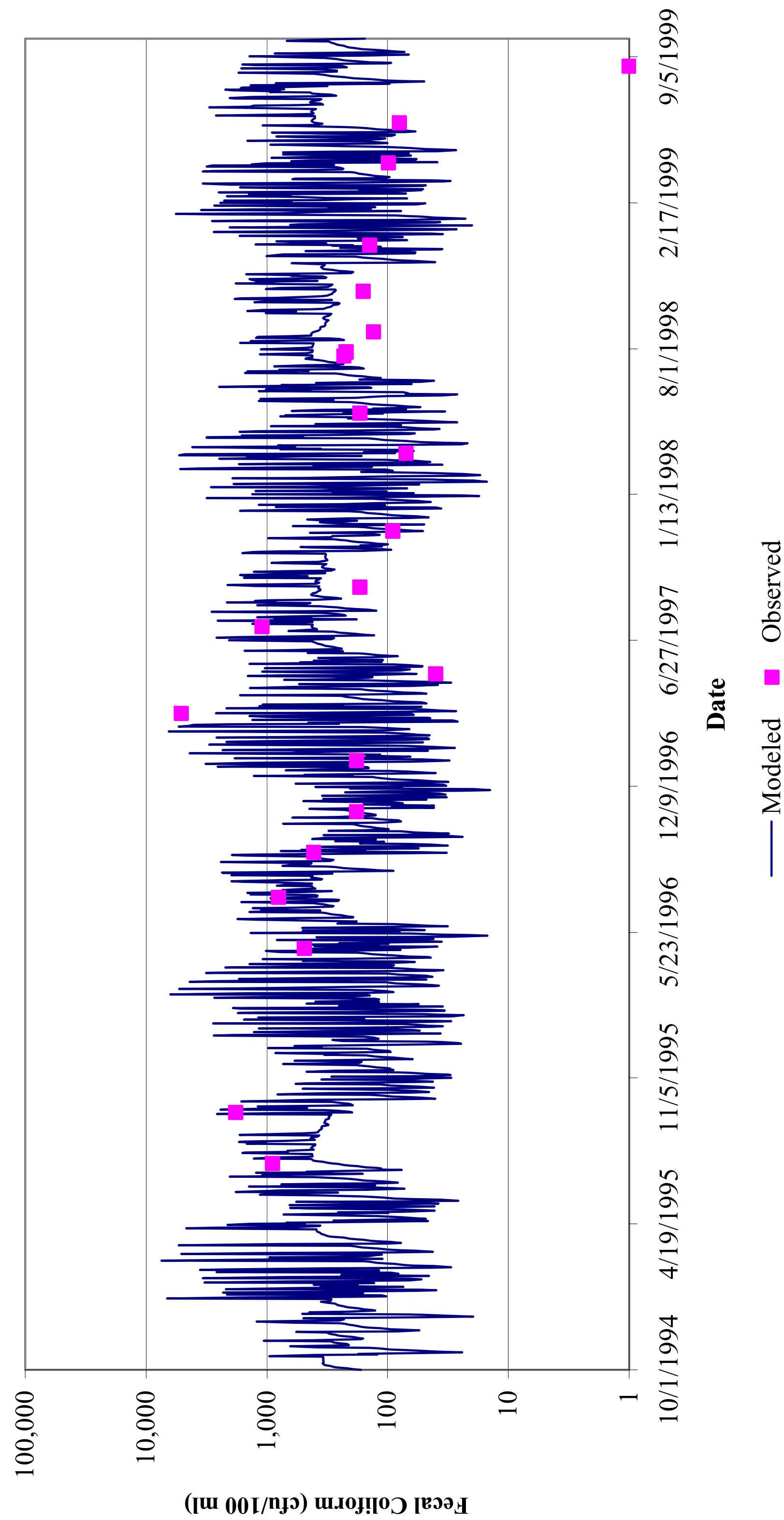

Figure 4.14 Mean daily modeled fecal coliform concentrations compared to instantaneous observed fecal coliform concentrations for subwatershed 4 in the Laurel Fork impairment, during the calibration period.

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. To provide a quantitative measure of the agreement between modeled and measured data while taking the inherent variability of fecal coliform concentrations into account, each observed value was compared with modeled concentrations in a 2-day window surrounding the observed data point. Standard error in each observation window was calculated as follows:

$$Standard\ Error = \frac{\sqrt{\dfrac{\sum_{i=1}^{n}\left(observed - modeled_i\right)^2}{\left(n-1\right)}}}{\sqrt{n}}$$

where

$observed$ = an observed value of fecal coliform

$modeled_i$ = a modeled value in the 2 - day window surrounding the observation

n = the number of modeled observations in the 2 - day window

This 2-day window is considered to be a reasonable time frame to take into account the temporal variability in direct loadings from wildlife and livestock, and the spatial and temporal variability inherent in the use of point measurements of precipitation, and in the use of daily precipitation data. This is a non-traditional use of standard error, applied here to offer a quantitative measure of model accuracy. In this context, standard error measures the variability of the sample mean of the modeled values about an instantaneous observed value. The use of limited instantaneous observed values to evaluate continuous data introduces error and, therefore, increases standard error. The mean of all standard errors for VADEQ monitoring station 9-LRR001.39 was calculated. The standard error in the Laurel Fork model is shown in Table 4.17. This standard error value is considered quite reasonable when one takes into account the value is calculated using daily averages instead of the value simulated at each one-hour time step.

Table 4.17 Mean standard error of the fecal coliform calibrated model for Laurel Fork (10/1/1994 through 9/30/1999).

Subwatershed	WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Monitored Value (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)
4	9-LRR001.39	57.7	5,100	7,554

A comparison between the geometric mean of observed fecal coliform data and the modeled fecal coliform values is shown in Table 4.18. The maximum percent difference between geometric means is 0.7%. The differences between the percent exceedances of the instantaneous standard are also shown. The maximum difference between percent exceedances is 12.8%. These differences are within the standard deviation of the observed data at each station and, therefore, the fecal coliform calibration is acceptable. The column ‘n’ is the number of observations.

4.7.3 Water Quality Validation

The water quality validation was conducted using data for the time period from 10/1/1990 to 9/30/1994. The relationship between observed values and modeled values is shown in Figure 4.15. The results of standard error analyses are reported in Table 4.19. Standard errors calculated from validation runs were higher than standard errors calculated from calibration runs, but still reasonable. A comparison between the geometric mean of observed fecal coliform data and the modeled fecal coliform values is shown in Table 4.20. The maximum percent difference between geometric means is 45.5%. The maximum difference between percent exceedances is 48.1%.

Table 4.18 Comparison of modeled and observed standard violations for the fecal coliform calibrated model for Laurel Fork.

		Modeled Calibration Load Fecal Coliform 10/1/94 - 9/30/99			Monitored Fecal Coliform 10/1/94 - 9/30/99		
Subwatershed	Station ID	*n*	Geometric Mean (cfu/100ml)	Exceedances of Instantaneous Standard	*n*	Geometric Mean (cfu/100ml)	Exceedances of Instantaneous Standard
4	9-LRR001.39	1,826	253.25	34.34%	23	254.96	30.43%

Table 4.19 Mean standard error of the fecal coliform validated model for Laurel Fork (10/1/1990 through 9/30/1994).

Subwatershed	WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Monitored Value (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)
4	9-LRR001.39	178.23	9,400	8,059

Table 4.20 Comparison of modeled and observed standard violations for the fecal coliform validated model for Laurel Fork.

		Modeled Validation Load Fecal Coliform 10/1/90 - 9/30/94			Monitored Fecal Coliform 10/1/90 - 9/30/94		
Subwatershed	Station ID	*n*	Geometric Mean (cfu/100ml)	Exceedances of Instantaneous Standard	*n*	Geometric Mean (cfu/100ml)	Exceedances of Instantaneous Standard
4	9-LRR001.39	1,463	436.25	61.54%	13	237.93	31.96%

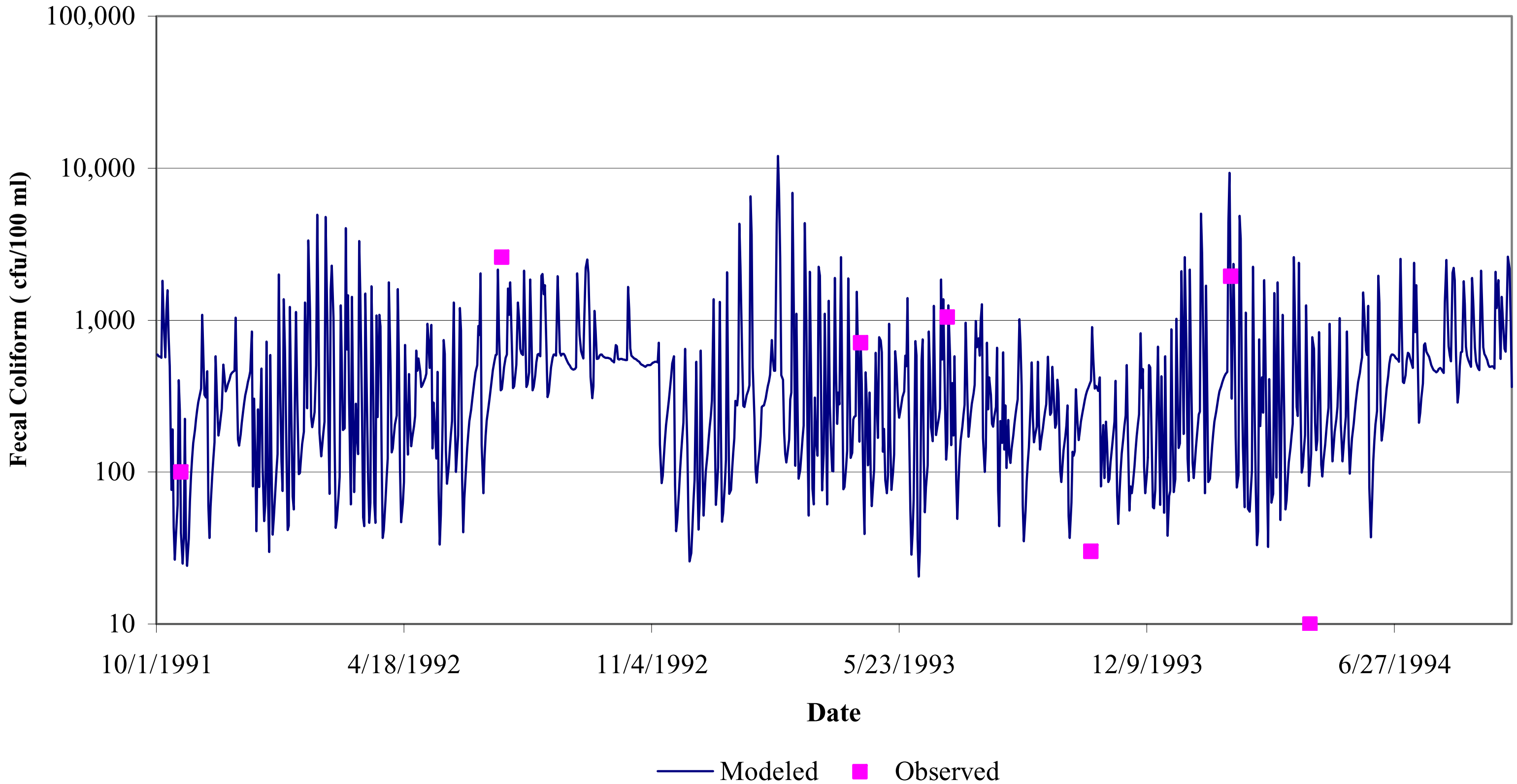

Figure 4.15 Mean daily modeled fecal coliform concentrations compared to instantaneous observed fecal coliform concentrations for subwatershed 4 in the Laurel Fork impairment, during the validation period.

4.8 Existing Loadings

All appropriate inputs were updated to 2005 conditions. All model runs were conducted using precipitation data for a representative period used for hydrologic calibration (10/1/92 through 9/30/97). Figure 4.16 shows the monthly geometric mean of *E. coli* concentrations in relation to the 126 cfu/100 ml standard at the outlet of Laurel Fork. Figure 4.17 shows the instantaneous values of *E. coli* concentrations in relation to the 235 cfu/100 ml standard. A discussion of the translator used to convert modeled fecal coliform loads to *E. coli* loads is found in section 5.2. Appendix B contains tables with monthly loadings to the different land use areas in each subwatershed.

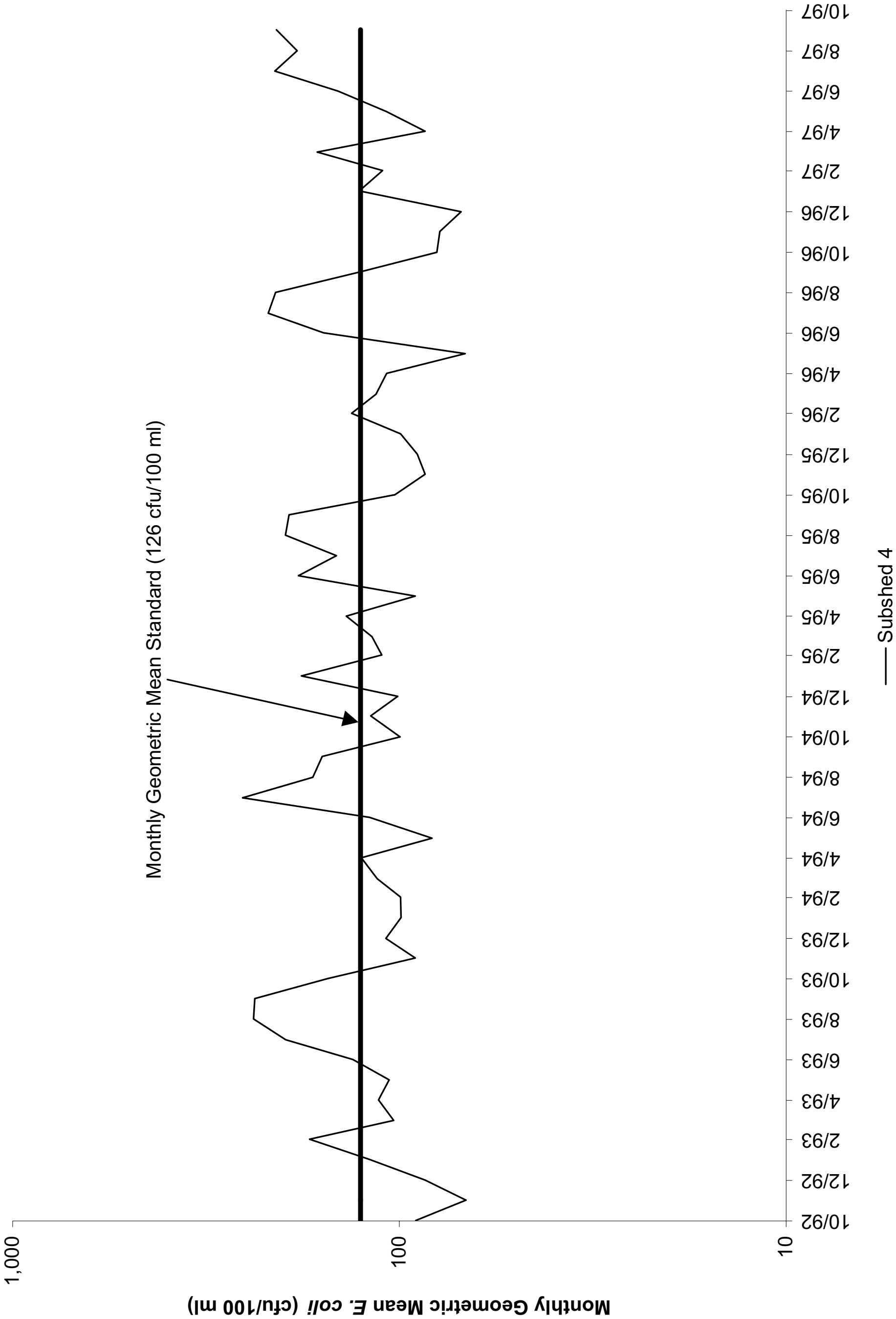

Figure 4.16 Existing conditions (*i.e.*, monthly geometric-mean) of *E. coli* concentrations at the outlet of the Laurel Fork impairment.

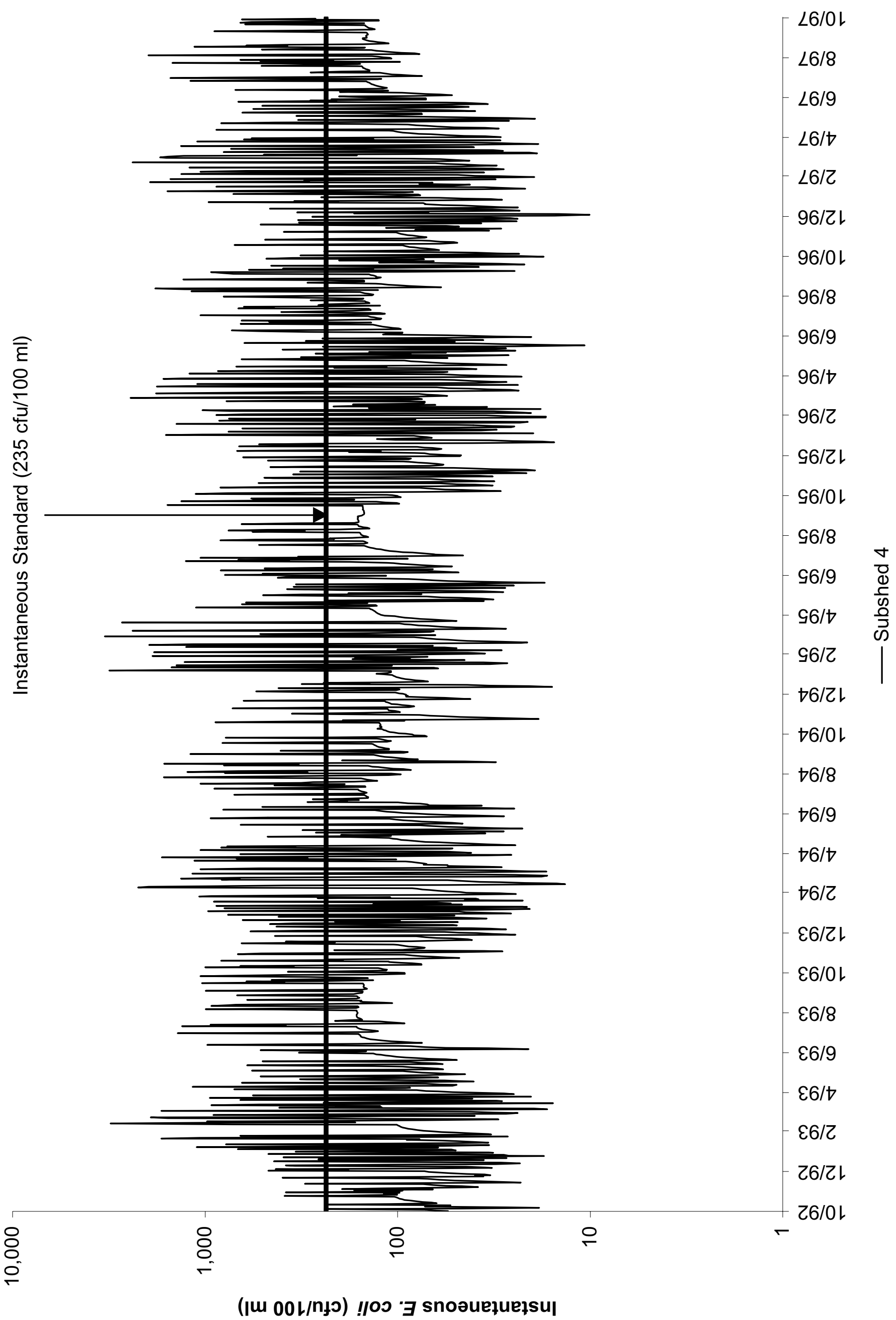

Figure 4.17 Existing conditions (*i.e.*, mean daily) of *E. coli* concentrations at the outlet of the Laurel Fork impairment.

5. FECAL BACTERIA ALLOCATION

TMDLs consist of waste load allocations (WLAs, permitted point sources) and load allocations (LAs, nonpoint/non-permitted sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (*e.g.,* accuracy of wildlife populations). The definition is typically denoted by the expression:

$$TMDL = WLAs + LAs + MOS$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For fecal bacteria, TMDL is expressed in terms of colony forming units (or resulting concentration).

5.1 Incorporation of a Margin of Safety

In order to account for uncertainty in modeled output, an MOS was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. An MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The intention of an MOS in the development of a fecal coliform TMDL is to ensure that the modeled loads do not under-estimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of this TMDL. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will, in fact, succeed in meeting the water quality standard. Examples of implicit MOS used in the development of this TMDL are:

- Allocating permitted point sources at the maximum allowable fecal coliform concentration
- The selection of a modeling period that represented the critical hydrologic conditions in the watershed

5.2 Scenario Development

Allocation scenarios were modeled using HSPF. Existing conditions were adjusted until the water quality standards were attained. The fecal bacteria TMDL developed for Laurel

Fork was based on the Virginia State Standards for *E. coli*. As detailed in section 2.1, the *E. coli* standards state that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 mL, and that maximum single sample concentrations of *E. coli* shall not exceed 235 cfu/100 mL. According to the guidelines put forth by VADEQ (VADEQ, 2003a) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation (developed from a dataset containing n-493 paired data points):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc})$$

Where C_{ec} is the concentration of *E. coli* in cfu/100 mL, and C_{fc} is the concentration of fecal coliform in cfu/100 mL.

Pollutant concentrations were modeled over the entire duration of a representative modeling period, and pollutant loads were adjusted until the standard was met. The development of the allocation scenario was an iterative process that required numerous runs with each run followed by an assessment of source reduction against the water quality target.

5.2.1 Waste Load Allocations

Permited point sources permitted for fecal bacteria control were accounted for in the WLA component of the TMDL. Design flow capacities were used for allocation runs. For allocations, the design flow rate was combined with a fecal coliform concentration of 200 cfu/100 mL (for discharges permitted for fecal control) to ensure that compliance with state water quality standards can be achieved even if the facilities were discharging at the maximum allowable flow rate. Since the Northern Tazewell County WWTF is expected to replace the Pocahontas STP, only the permitted discharges from the Northern Tazewell County WWTF and the Residence STP were included in the WLA.

5.2.2 Load Allocation

Load allocations to nonpoint sources are divided into land-based loadings from land uses and directly applied loads in the stream (*e.g.,* livestock, and wildlife). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads had their most significant impact during high-flow conditions, while direct deposition NPS had their most significant impact on low flow concentrations. BST analysis confirmed the presence of human, pet, livestock and wildlife contamination.

Model results indicate that human direct deposits, and urban and wildlife nonpoint sources are significant in the watershed. This is in agreement with the results of BST analysis presented in Chapter 2. Allocation scenarios for Laurel Fork are shown in Table 5.1. Scenario 1 describes a baseline scenario that corresponds to the existing conditions in the watershed.

Because Virginia's *E. coli* standard does not permit any exceedances of the standard, modeling was conducted for a target value of 0% exceedance of the geometric mean standard and 0% exceedance of the single sample maximum *E. coli* standard. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality.

The first objective of the reduction scenarios was to explore the role of anthropogenic sources in standards violations. First, scenarios were explored to determine the feasibility of meeting standards without wildlife reductions. Following this theme, Scenario 2 resulted from a 100% reduction in uncontrolled direct residential discharges (*i.e.,* straight pipes). A decrease in the violations was observed. This scenario improved conditions in the stream, but failed to eliminate the exceedances of either standard.

Scenario 3 had a 90% reduction in direct livestock deposition, and 50% reductions to land loads from urban and agricultural lands, as well as a 100% reduction of straight pipes. Loads from wildlife were not addressed. This scenario showed improvement, but the standards were still not met. Scenario 4 shows 100% reductions to all anthropogenic sources; however, exceedances still persisted. This scenario shows that reductions to wildlife loads must be made.

Scenario 5 had fewer reductions to agricultural and urban nonpoint source loads to provide more obtainable scenarios (99%). A 36% reduction from direct wildlife and an

86% reduction from land-based loads from natural areas (forest, wetlands, etc.) allow the impaired stream to meet both *E. coli* standards. Scenarios 6, 7, 8, and 9 show that fewer reductions to direct wildlife loads, agricultural lands, and residential lands will not meet the instantaneous standard. Fewer reductions to direct livestock loads (70%) still allows Laurel Fork to meet both standards as shown in Scenario 10. This is the final TMDL scenario. Scenario 11 is the Stage 1 goal and is explained more in Chapter 12.

Table 5.1 Allocation scenarios for bacterial concentration with current loading estimates in the Laurel Fork impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100mL	Single Sample > 235 cfu/100mL
1	0	0	0	0	0	0	43.33	23.62
2	0	0	0	0	100	0	15.00	21.75
3	0	0	90	50	100	50	1.67	15.56
4	0	0	100	100	100	100	0.00	4.05
5	36	86	100	99	100	99	0.00	0.00
6	35	86	100	99	100	99	0.00	0.05
7	36	86	100	98	100	99	0.00	0.05
8	36	86	100	99	100	98	0.00	0.05
9	36	86	69	99	100	99	0.00	0.05
10	36	86	70	99	100	99	0.00	0.00
11	0	0	70	78	100	78	0.00	9.97

5.3 Final Bacteria TMDL for Laurel Fork

Figure 5.1 shows graphically the existing and allocated conditions for the geometric-mean concentrations in Laurel Fork. Figure 5.2 shows the existing and allocated conditions of the instantaneous *E. coli* concentration in Laurel Fork. In the Laurel Fork watershed, subwatershed 3 was the limiting subwatershed, it required the most strict reductions to allocate, and is shown in Figures 5.1 and 5.2.

Table 5.2 indicates the land-based and direct load reductions resulting from the final allocations. Table 5.3 shows the final TMDL loads for the Laurel Fork fecal bacteria impairment.

Table 5.2 Fecal coliform land-based loads deposited on all land uses and direct loads in the Laurel Fork watershed for existing conditions and for the final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land use			
AML	8.25E+12	1.16E+12	86
Commercial	4.24E+11	4.24E+09	99
Crops	2.08E+12	2.08E+10	99
Forest	1.10E+14	1.54E+13	86
Pasture	8.18E+13	8.18E+11	99
Reclaimed	1.11E+12	1.55E+11	86
Residential	6.40E+14	6.40E+12	99
Wetlands	1.20E+12	1.68E+11	86
Direct			
Human	3.52E+12	0.00E+00	100
Livestock	3.08E+11	9.24E+10	70
Wildlife	6.38E+12	4.09E+12	36

Table 5.3 Average annual *E. coli* loads (cfu/year) modeled after allocation in the Laurel Fork watershed at the outlet.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Laurel Fork	8.72E+11	1.81E+12	*Implicit*	2.69E+12
VA0091588	*8.71E+11*			
VAG400522	*8.71E+08*			

To determine if the allocation scenarios presented will be applicable in the future, the same scenarios were evaluated with an increase in permitted loads. The permitted loads were increased by a factor of 4 to simulate a population growth. Laurel Fork currently has three permits for fecal coliform, but only two will be in operation in the future (Northern Tazewell County WWTF *VA0091588,* and Residence STP *VAG400522)*. The TMDL table that reflects this future scenario is in Appendix C.

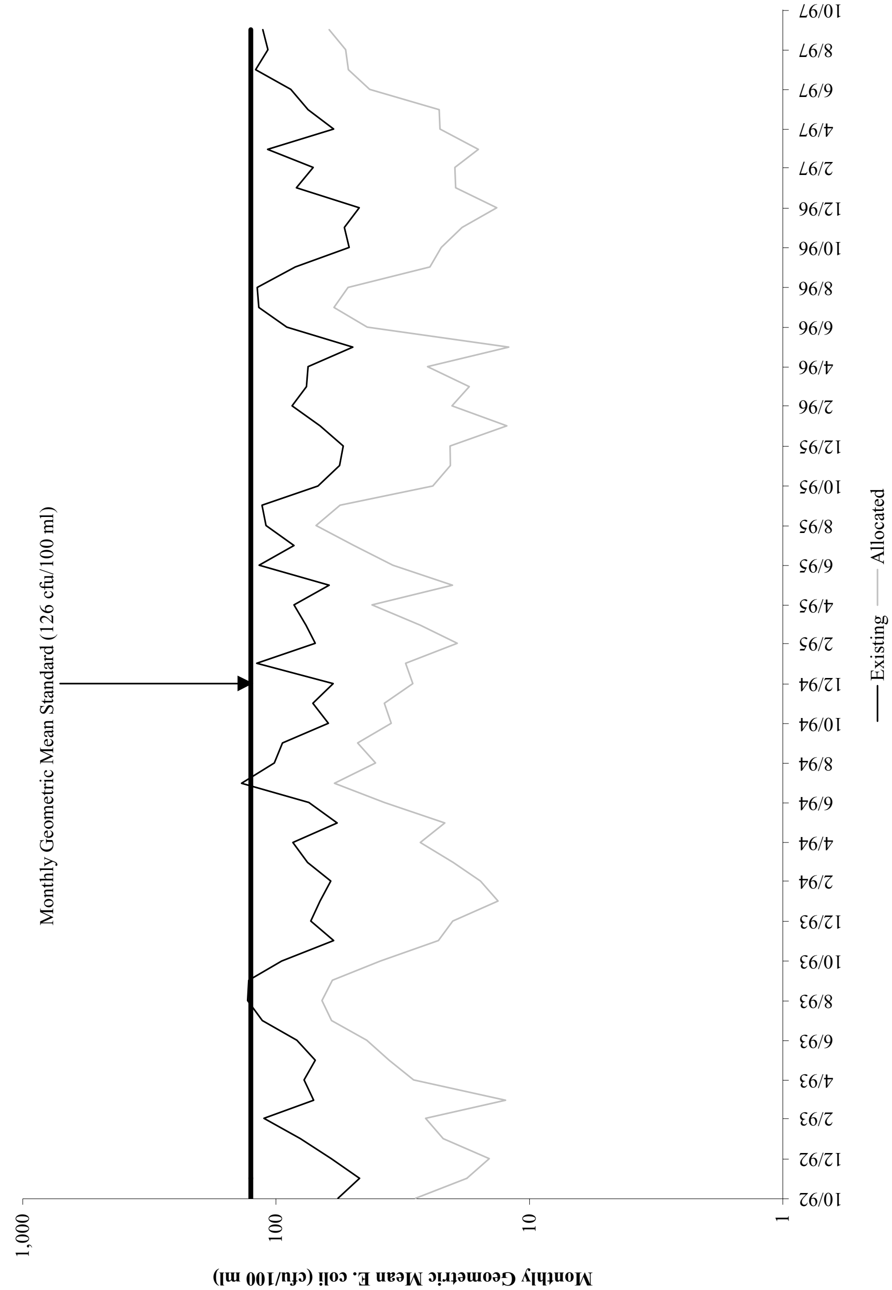

Figure 5.1 Monthly geometric mean *E. coli* concentrations for Laurel Fork at subwatershed 3 under existing and allocated conditions.

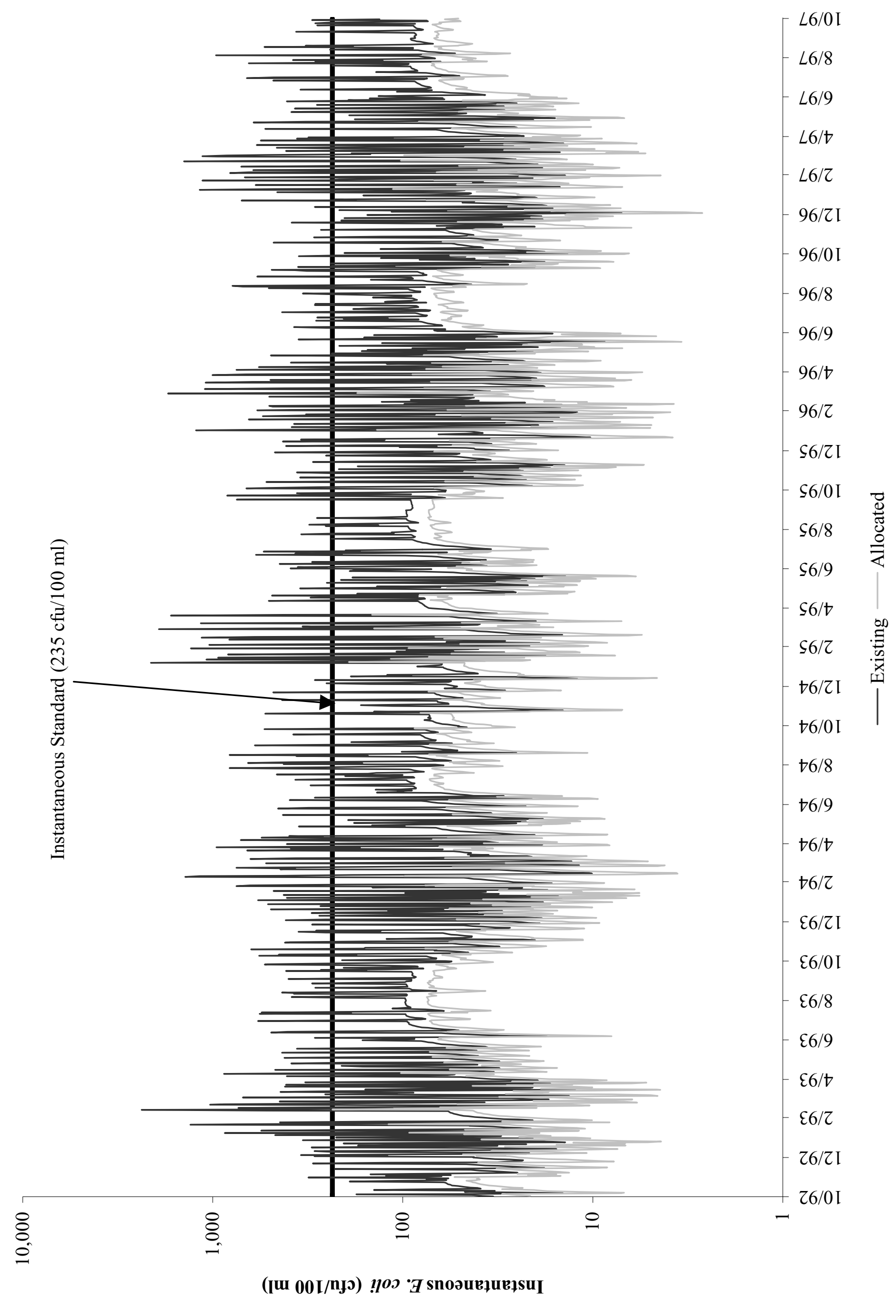

Figure 5.2 Instantaneous *E. coli* concentrations for Laurel Fork at subwatershed 3 under existing and allocated conditions.

PART III: GENERAL STANDARD (BENTHIC) TMDL

6. WATER QUALITY ASSESSMENT

6.1 Applicable Criterion for Benthic Impairment

Additionally, Virginia state law 9VAC25-260-20 defines the **General Standard** as:

> *A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.*

6.2 Benthic Assessment

Laurel Fork was initially listed on the *1996 303(d) TMDL Priority List* for not supporting aquatic life use. The General Standard is implemented by VADEQ through application of the modified Rapid Bioassessment Protocol II (RBP II). Using the modified RBP II, the health of the benthic macroinvertebrate community is typically assessed through measurement of eight biometrics (Table 6.1), which measure different aspects of the community's overall health. Surveys of the benthic macroinvertebrate community performed by VADEQ are assessed at the family taxonomic level. A score within the non-impaired range is the endpoint for General Standard (benthic) impaired streams.

Table 6.1 Components of the modified RBP II Assessment.

Biometric	Benthic Health [1]
Taxa Richness	↑
Modified Family Biotic Index	↓
Scraper to Filtering Collector Ratio	↑
EPT / Chironomid Ratio	↑
% Contribution of Dominant Family	↓
EPT Index	↑
Community Loss Index	↓
Shredder to Total Ratio	↑

[1] An upward arrow indicates a positive response in benthic health when the associated biometric increases.

Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score. These scores are then summed and used to determine the overall bioassessment (*e.g.,* not impaired, slightly impaired, moderately impaired, or severely impaired).

VADEQ performed three modified RBP II benthic surveys at Laurel Fork, one in April 1996 at benthic monitoring station 9-LRR001.39, and two in December 2003 at benthic monitoring stations 9-LRR001.39 and 9-LRR006.43. The results of the modified RBP II benthic monitoring surveys are presented in Table 6.2. The table indicates that surveys at 9-LRR001.39 found severe impairment in 1996 and moderate impairment in 2003.

Table 6.2 Modified RBP II biological monitoring data for station 9-LRR001.39 on Laurel Fork.

Date	Assessment	Reference Station
4/24/1996	Severely Impaired	6ADRK036.38
12/1/2003	Moderately Impaired	9-LRR006.34

An alternative method to the modified RBP II is the Virginia Stream Condition Index (VASCI). The VASCI is being developed, and data is being collected to calibrate and further validate the VASCI method. Eight biometrics are obtained, with higher scores indicating a healthier benthic community. The advantage of the VASCI is that the score does not depend upon values from a reference station. The VASCI has an impairment threshold of 61.3 and the scores for the VADEQ surveys are presented in Table 6.3. Figure 6.1 is a graphical representation of the VASCI scores for VADEQ monitoring stations 9-LRR001.39 and 9-LRR006.43. Note that all three scores at the Laurel Fork monitoring stations were below the impairment threshold of 61.3.

Table 6.3 VASCI biological monitoring scores for stations 9-LRR001.39 and 9-LRR006.43 on Laurel Fork and reference station (Impairment threshold = 61.3

Station Date Metric	9-LRR001.39 4/24/96	6ADRK036.38 4/24/96	9-LRR001.39 12/1/03	9-LRR006.43 12/1/03
Richness Score	13.64	54.55	22.73	54.55
EPT Score	0.00	72.73	0.00	45.45
%Ephem Score	0.00	63.91	0.00	74.77
%PT-H Score	0.00	46.33	0.00	5.85
%Scraper Score	0.00	33.26	35.84	28.56
%Chironomidae Score	8.57	77.32	33.33	92.71
%2Dom Score	5.50	89.26	18.71	72.15
%MFBI Score	55.18	88.69	61.55	67.56
VASCI	**10.36**	**65.75**	**21.52**	**55.20**

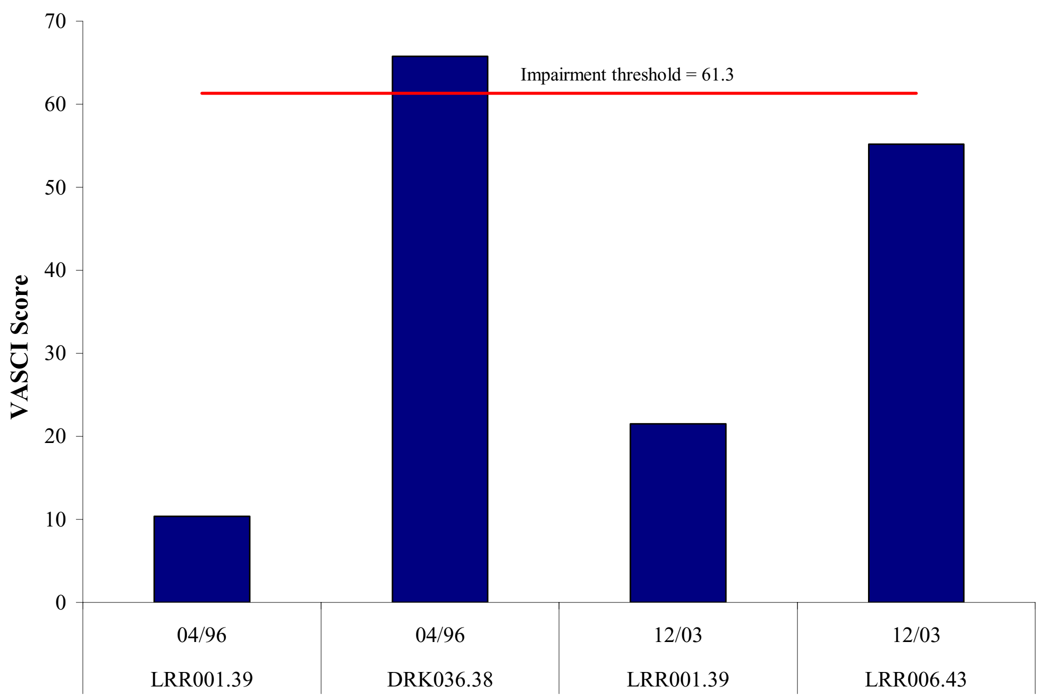

Figure 6.1 VASCI biological monitoring scores for VADEQ benthic monitoring stations 9-LRR001.39 and 9-LRR006.43 on Laurel Fork and reference station.

6.3 Habitat Assessment

Benthic impairments have two general causes: input of pollutants to streams, and alteration of habitat in either the stream or the watershed. Habitat can be altered directly (*e.g.,* by channel modification), indirectly (because of changes in the riparian corridor leading to conditions such as streambank destabilization), or even more indirectly (*e.g.,* due to land use changes in the watershed such as clearing large areas).

Habitat assessments are normally carried out as part of the benthic sampling. The overall habitat score is the sum of 10 individual metrics, each metric ranging from 0 to 20. The classification schemes for both the individual habitat metrics and the overall habitat score for a sampling site are shown in Table 6.4.

Table 6.4 Classification of habitat metrics based on score.

Habitat Metric	Optimal	Sub-optimal	Marginal	Poor
Embeddedness	16 - 20	11 – 15	6 - 10	0 - 5
Epifaunal Substrate	16 - 20	11 – 15	6 - 10	0 - 5
Pool Sediment	16 - 20	11 – 15	6 - 10	0 - 5
Flow	16 - 20	11 – 15	6 - 10	0 - 5
Channel Alteration	16 - 20	11 – 15	6 - 10	0 - 5
Riffles	16 - 20	11 – 15	6 - 10	0 - 5
Velocity	16 - 20	11 – 15	6 - 10	0 - 5
Bank Stability	18 - 20	12 – 16	6 - 10	0 - 4
Bank Vegetation	18 - 20	12 – 16	6 - 10	0 - 4
Riparian Vegetation	18 - 20	12 – 16	6 - 10	0 - 4

The habitat assessment for Laurel Fork includes an analysis of habitat scores recorded by the VADEQ biologist. The VADEQ habitat assessments on Laurel Fork are displayed in Tables 6.5 and 6.6. Embeddedness is a measure of the extent to which the available riffle habitat is surrounded by sediment. Marginal scores indicate that 50 – 75% of the available riffle habitat is surrounded by fine sediment. The 1996 survey at 9-LRR001.39 documented a poor Embeddedness score while the 2003 result was marginal. 9-LRR006.43 had a marginal Embeddedness score in 2003. Pool Sediment is a measure of the amount of sediment that has accumulated in pool areas of the stream. It provides an indication of sediment transport in the stream. Benthic monitoring station 9-LRR001.39 had a marginal pool sediment score in the 1996 survey. A marginal score indicates that 30 - 50% of the stream bottom is covered with sediment. The Riparian Vegetation metric scores were in the marginal category for both surveys at 9-LRR001.39. Riparian Vegetation is a measure of the width of the natural vegetation from the edge of the stream bank through the riparian zone. Marginal scores indicate a zone width between 6 – 12 meters. The Bank Stability metric at 9-LRR001.39 was in the poor category for the 1996 survey. Bank Stability is a measure of the potential for a streambank to erode. A marginal score indicates that 30 – 60% of the stream bank has areas of erosion that may contribute large amounts of sediment during time of high stream flow and/or rainfall.

Table 6.5 Habitat scores for VADEQ monitoring station 9-LRR001.39 on Laurel Fork.

Metric	4/24/1996	12/1/2003
Channel Alteration	14	14
Bank Stability	3	11
Bank Vegetation	15	11
Embeddedness	4	10
Flow	18	18
Riffles	7	5
Riparian Vegetation	7	9
Pool Sediment	9	13
Substrate	14	15
Velocity	14	17
TOTAL SCORE	**105**	**123**

Table 6.6 Habitat scores for station 9-LRR006.43 on Laurel Fork.

Metric	12/1/2003
Channel Alteration	14
Bank Stability	16
Bank Vegetation	12
Embeddedness	9
Flow	18
Riffles	5
Riparian Vegetation	12
Pool Sediment	15
Substrate	16
Velocity	17
TOTAL SCORE	**134**

6.4 Discussion of In-stream Water Quality

This section provides an inventory of available observed in-stream monitoring data throughout the Laurel Fork watershed. An examination of data from water quality stations used in the Section 305(b) assessment and data collected during TMDL development were analyzed. Sources of data and pertinent results are discussed.

6.4.1 Inventory of Water Quality Monitoring Data

The primary source of available water quality information for Laurel Fork is data collected at six monitoring stations on the mainstem of the stream (Table 6.7). The data is summarized in Tables 6.8 through 6.17.

Table 6.7 VADEQ monitoring stations in Laurel Fork.

Station	Type	Data Record
9-LRR001.39	Ambient/Biological/Special Study	1/1990 – 6/2004
9-LRR001.73	Special Study	7/2003 – 6/2004
9-LRR002.26	Special Study	7/2003 – 6/2004
9-LRR002.59	Special Study	7/2003 – 6/2004
9-LRR004.03	Special Study	7/2003 – 6/2004
9-LRR005.59	Special Study	7/2003 – 6/2004
9-LRR006.43	Ambient/Biological	7/2003 – 6/2004

Table 6.8 In-stream water quality data at 9-LRR001.39 (1/90-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity, μmhos/cm	318	299	1,201	107	150	78
DO, mg/L	7.58	8.1	13.2	0.94	3.29	77
Field pH, std units	7.18	7.13	8.45	6.43	0.36	75
Temp, Celsius	11.02	10	20.9	0.4	5.55	77
Alkalinity, Total, mg/L	72.03	74	126	27.2	28.31	65
BOD_5 Day, mg/L	2.08	2	9	1	1.49	48
Chloride, Total, mg/L	10.05	8.4	42.1	2.4	6.65	61
COD High Level, mg/L	9.95	9.3	23	1	4.38	49
Fluoride, Total, mg/L	0.11	0.11	0.15	0.07	0.03	9
Hardness, calculated	135.21	106.86	201.02	95	49.08	5
NH3+NH4-N, Total, mg/L	0.45	0.17	2.95	0.04	0.63	68
Nitrogen, Total Kjeldahl, mg/L	0.71	0.4	3.2	0.1	0.68	64
Nitrogen, Total, mg/L	0.83	0.58	2.18	0.3	0.64	10
NO_2 and NO_3 N, mg/L	0.31	0.18	0.62	0.14	0.2	10
NO_2-N, mg/L	0.04	0.02	0.17	0.01	0.04	46
NO_3-N, mg/L	0.72	0.32	3.82	0.05	0.83	65
Phosphorus, dissolved Ortho, mg/L	0.05	0.04	0.1	0.01	0.03	20
Phosphorus, Total Ortho, mg/L	0.07	0.06	0.35	0.01	0.07	46
Phosphorus, Total, mg/L	0.09	0.08	0.47	0.01	0.08	72
Solids, Total dissolved, mg/L	225.85	257	359	87	82.86	61
Solids, Total Inorganic, mg/L	185.52	185	290	80	62.51	65
Solids, Total Organic, mg/L	48.85	48	120	17	21.75	65
Solids, Total suspended Inorganic, mg/L	8.78	5	116	1	17.01	46
Solids, Total Suspended Organic, mg/L	4.61	3	26	1	4.54	38
Solids, Total Suspended, mg/L	9.83	6	142	1	17.27	71
Solids, Total, mg/L	234.37	249	370	102	79.88	65
Sulfate, Total, mg/L	83.89	74.1	440	26.4	54.82	64
Total Hardness $CaCO_3$, mg/L	143.67	130	236	53	53.21	65
Total Organic Carbon, mg/L	2.94	2.6	8	0.87	1.53	39
Turbidity	9.7	6.95	37	2.2	8.77	20
Turbidity Hach Turbidimeter	8.55	5.27	80	1.04	12.62	45
Turbidity Lab	6.07	5.05	15	3.1	3.63	10
--	--------	--------	--------	--------	--------	------
	Sediment metals					
Aluminum, mg/kg	19,034	6,600	93,500	6,038	32,838	7
Antimony, mg/kg	83.5	83.5	157	10	103.94	2
Arsenic, mg/kg	25	6	83	5	38.68	4
Beryllium, mg/kg	8	8	15	1	9.9	2
Cadmium, mg/kg	26	26	51	1	35.36	2
Chromium, mg/kg	36.54	14.24	242	10	68.26	11
Copper, mg/kg	107.29	38	757	26	216.13	11

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.8 In-stream water quality data at 9-LRR001.39 (1/90-6/04)(cont.).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Sediment metals						
Iron, mg/kg	16,077	17,257	22,300	8,580	4,423	7
Lead, mg/kg	134.28	60.11	787	38	218.48	11
Manganese, mg/kg	435	157	2,090	108	731	7
Mercury, mg/kg	0.12	0.12	0.14	0.1	0.03	2
Nickel, mg/kg	49.69	19.7	332	14.74	93.89	11
Selenium, mg/kg	3.8	1.5	18	1	6.28	7
Zinc, mg/kg	546	132	4,400	97	1,280	11
--	--------	--------	--------	--------	-------	------
Water Column metals						
Iron, Total, µg/L	762	784	1,390	318	448	5
Magnesium, Total, mg/L	12,518	12,585	16,110	8,790	3,952	4
Manganese, Total, µg/L	136.66	159.41	224.67	40.12	79.05	5
Zinc, Total, µg/L	17.32	17.32	20	14.63	3.8	2

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.9 Single sample in-stream water quality data at 9-LRR001.39 (8/5/03).

Water Quality Constituent	Value
Aluminum, µg/L	4.56
Antimony, µg/L	0.25
Arsenic, µg/L	0.48
Barium, µg/L	31
Calcium, dissolved, mg/L	28
Calcium, Total, µg/L	27,270
Chromium, µg/L	0.18
Copper, dissolved, µg/L	0.93
Copper, Total, µg/L	20
Iron, dissolved, µg/L	84
Lead, µg/L	0.26
Magnesium, dissolved, mg/L	6.2
Manganese, dissolved, µg/L	76
Nickel, dissolved, µg/L	1.68
Selenium, dissolved, µg/L	1.42
Zinc, dissolved, µg/L	3.05
Thallium, mg/kg	47

Table 6.10 In-stream water quality data at 9-LRR001.73 (7/03-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity, µmhos/cm	251	254	307	205	44	5
DO, mg/L	7.79	8.33	10.62	3.9	2.53	5
Field pH, std units	6.91	6.74	7.46	6.65	0.33	5
Temp, Celsius	11.9	10.7	20.4	4.7	6.3	5

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.11 In-stream water quality data at 9-LRR002.26 (7/03-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity, µmhos/cm	262	256	396	168	76	10
DO, mg/L	11.01	10.5	17.79	7.77	2.76	10
Field pH, std units	7.51	7.55	8.04	7.09	0.27	10
Temp, Celsius	13.05	13.5	26.8	2	7.48	10

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.12 In-stream water quality data at 9-LRR002.59 (7/03-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD1	N2
Conductivity µmhos/cm	252.41	262.3	363	147	83.26	10
DO, mg/L	9.3	9.23	14.47	4.51	3.12	10
Field pH, std units	7.16	7.31	7.9	6.36	0.53	10
Temp, Celsius	11.6	13.28	21.7	0.03	6.81	10
Nitrogen, Total, mg/L	0.32	0.23	0.71	0.19	0.17	10
NO2 and NO3 N, mg/L	0.21	0.14	0.47	0.08	0.14	10
Phosphorus, Total, mg/L	0.02	0.02	0.03	0.01	0.01	8
Solids, Total dissolved, mg/L	153.65	139.25	226	92	50.55	10
Solids, Total suspended, mg/L	8.75	5	19	3	6.43	8
Turbidity Lab	4.43	4.2	7.7	2	1.72	10

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.13 Single sample in-stream water quality data at 9-LRR002.59 (8/5/03).

Water Quality Constituent	Value
Water Column Metals	
Aluminum, dissolved, µg/L	4.77
Antimony, dissolved, µg/L	0.18
Arsenic, µg/L	0.29
Barium, µg/L	51
Calcium, dissolved, µg/L	29
Chromium, dissolved, µg/L	0.11
Copper, dissolved, µg/L	1.05
Hardness, calculated, mg/L	95
Iron, dissolved, µg/L	56
Magnesium, dissolved, mg/L	5.4
Manganese, dissolved, µg/L	72
NH_3+NH_4-N, Total, mg/L	0.08
Nickel, dissolved, µg/L	10.3
Selenium, dissolved, µg/L	1.4
Zinc, dissolved, µg/L	12.2
--	----------
Sediment Metals	
Aluminum, mg/kg	4,630
Chromium, mg/kg	10.8
Copper, mg/kg	21.8
Iron, mg/kg	10,800
Lead, mg/kg	25.1
Manganese, mg/kg	76.9
Nickel, mg/kg	18.7
Selenium, mg/kg	1
Zinc, mg/kg	86.9

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.14 In-stream water quality data at 9-LRR004.03 (7/03-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity, µmhos/cm	193	195	242	146	30	10
DO, mg/L	8.68	9.12	13.48	1.53	3.69	10
Field pH, std units	7.37	7.48	7.71	6.97	0.27	10
Temp, Celsius	10.93	11.65	20.2	0	6.86	10

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.15 In-stream water quality data at 9-LRR005.59 (7/03-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity, µmhos/cm	192	192	277	145	39	10
DO, mg/L	9.9	9.49	15.02	5.61	2.77	10
Field pH, std units	7.43	7.45	7.66	7.04	0.17	10
Temp, Celsius	12.72	15.05	20.9	0.85	6.9	10
NH3+NH4-N, Total, mg/L	0.06	0.06	0.06	0.05	0.01	2
NO2 and NO3 N, mg/L	0.2	0.1	0.93	0.06	0.27	10
Phosphorus, Total, mg/L	0.04	0.02	0.11	0.01	0.03	8
Solids, Total dissolved, mg/L	123.05	122.75	173	91	23.14	10
Solids, Total suspended, mg/L	19.63	5	104	3	34.52	8
Nitrogen, Total, mg/L	0.41	0.22	1.31	0.18	0.4	10
Turbidity Lab, NTU	13.58	5.05	69	3.3	20.18	10

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.16 In-stream water quality data at 9-LRR006.43 (7/03-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity, µmhos/cm	170.47	172.1	207	126	26.71	10
DO, mg/L	9.94	10.39	13.94	2.47	3.3	10
Field pH, std units	7.49	7.47	8.07	6.96	0.36	10
Temp, Celsius	12.57	12.9	22	0.77	7.35	10
Nitrogen, Total, mg/L	0.22	0.18	0.45	0.15	0.1	10
NO2 and NO3 N, mg/L	0.07	0.07	0.09	0.04	0.02	6
Phosphorus, Total, mg/L	0.02	0.02	0.05	0.01	0.01	8
Solids, Total suspended, mg/L	8.29	4	35	3	11.8	7
Turbidity, Lab , NTU	8.11	4.8	38	2.2	10.7	10

[1]SD: standard deviation, [2]N: number of sample measurements

Table 6.17 Single sample in-stream water quality data at 9-LRR006.43 (8/5/03).

Water Quality Constituent	Value
Water Column Metals	
Aluminum, dissolved, µg/L	1.68
Arsenic, dissolved, µg/L	0.73
Barium, dissolved, µg/L	52
Calcium, dissolved, µg/L	20
Chromium, dissolved, µg/L	0.21
Copper, dissolved, µg/L	0.54
Hardness, calculated, mg/L	72
Iron, dissolved, µg/L	374
Lead, dissolved, µg/L	0.1
Magnesium, mg/L	5.4
Manganese, dissolved, µg/L	173
Nickel, dissolved, µg/L	1.78
--	--------
Sediment Metals	
Aluminum, mg/kg	7,280
Chromium, mg/kg	8.98
Copper, mg/kg	13.7
Iron, mg/kg	12,500
Lead, mg/kg	17.1
Manganese, mg/kg	198
Nickel, mg/kg	15.2
Zinc, mg/kg	49

6.4.2 Fish Tissue and Sediment Results from Laurel Fork

VADEQ performed special fish tissue and sediment sampling at 9-LRR001.39 on 9/13/2000. Tables 6.18 through 6.20 show the results of the sediment sampling. Values in fish tissue samples were well below VADEQ screening and VDH action levels.

Table 6.18 Special study sediment metals results from 9-LRR001.39 on 9/13/2000.

Metal	PEC[1] (mg/kg)	VALUE (mg/kg)
Aluminum	NA	0.40
Silver	NA	0.09
Arsenic	33	7.10
Cadmium	4.98	0.29
Chromium	111	13.00
Copper	149	66.00
Mercury	1.06	0.15
Nickel	48.6	24.00
Lead	128	49.00
Antimony	NA	<0.5
Selenium	NA	0.58
Thallium	NA	<0.3
Zinc	459	118.00

[1] PEC = Probable Effect Concentration.

Table 6.19 Special study sediment organics results from 9-LRR001.39 on 9/13/2000.

Parameter	PEC[1] (μg/kg)	Value (μg/kg)
Total PAH[2]	22,800	9,689
High MW[3] PAH	NA	7,624
Low MW PAH	NA	2,065
NAP[4]	561	27
NAP 2-Me[5]	NA	91
NAP 1-Me[6]	NA	39
Biphenyl	NA	39
NAP d-Me[7]	NA	146
Naphthylene ace~	NA	8
Naphthene ace~	NA	34
NAP t-Me[8]	NA	81
Fluorine	536	76
PHH[9]	1,170	**1,382**
ATH[10]	845	209
PHH 1-Me	NA	336
FTH[11]	2,230	**2,268**
Pyrene	1,520	**1,910**
ATH benz(a)	1,050	681
Chrysene	1,290	889
FTH benzo(b)	NA	476
FTH benzo(k)	NA	343
Pyrene benzo(e)	NA	280
pyrene benzo(a)	1,450	353
Perylene	NA	79
Pyrene IND[12]	NA	138
ATH db(a,h)[13]	NA	57
Perylene benzo(ghi)	NA	149

[1]PEC = Probable Effect Concentration, [2]PAH = Polyaromatic hydrocarbon, also polynuclear aromatic hydrocarbons (PNAs), [3] MW Molecular Weight, [4] NAP Naphthalene, [5] 2-Me Dimethyl, [6] 1-Me Methyl, [7] d-me 2,6 Dimethyl, [8] t-me 2,3,5 Trimethyl, [9] Phenanthrene, [10] Anthracene, [11] Fluoranthene, [12] indeno (1,2,3-cd), [13] dibenzo (a,h), **Bold** Exceeds PEC value

Table 6.20 Special study sediment PCB and pesticide results from 9-LRR001.39 on 9/13/2000.

Parameter	PEC[1] (μg/kg)	Value (μg/kg)
Total PCB[2]	676	16.40
Total4 Chlordane	17.6	5.44
Sum DDE[3]	31.3	0.55
Sum DDD[4]	28	0.34
Sum DDT[5]	62.9	0.48
Total[6] DDT	572	1.37
Total BDE[7]		2.83
HCB[8]		0.24
OCDD[9]		2.40

[1] PEC Probable Effect Concentration [2] denotes sum of polychlorinated biphenyl congeners, [3] Sum DDE denotes sum of dichlorodiphenyl dichloroethylene isomers, [4] Sum DDD denotes sum of dichlorodiphenyl dichloroethane isomers, [5] Sum DDT denotes sum of dichlorodiphenyl trichloroethane isomers, [6] Total DDT denotes sum of isomers of DDE, DDD, and DDT, [7] Total BDE denotes sum of polybrominated diphenyl ether congeners, [8] HCB – Hexachlorobenzene, [9] OCDD - Octachlorodibenzodioxin

Special toxicity sampling was done in November 2004 by VADEQ in the vicinity of Pocahontas, VA. The sample was analyzed by the EPA Wheeling West Virginia Biology Group and no toxicity was found.

6.4.3 VADEQ special water quality study (12/9/1998)

The VADEQ performed an intensive sampling study on Laurel Fork in 1998. Sampling was conducted on seven sites in Laurel Fork and two additional sites in the watershed on July 27, 1998. The most upstream station was at the Rt. 659 bridge above the community of Pocahontas (river mile 2.51). The most downstream station was at the railroad trestle near Wolfe, West Virginia (river mile 0.61). Stream flows at the time of sampling were low and there had been no recent rainfall. Dissolved oxygen concentrations downstream of the Pocahontas STP were below the minimum state water quality standard (WQS) of 4.0 mg/L. Concentrations upstream of the STP were between 6.39 and 8.64 mg/L. The dissolved oxygen concentration of the effluent from the Pocahontas STP was 3.9 mg/L. Ammonia concentrations in the stream at the discharge point were 1.70 mg/L but increased to 10.2 mg/L at station #9 near Wolfe, West Virginia. This could indicate that there was significant denitrification occurring in the bottom sediments further downstream. The fecal coliform count in the effluent discharge was >20,000 cfu/100mL and the fecal count in Laurel Fork upstream of the Pocahontas STP discharge was also

>20,000 cfu/100mL. The study attributed this to sewer collection system failure and/or unpermitted discharges. A follow up inspection of the Pocahontas STP found that the treatment plant was providing minimal treatment (screening and some settling of large solids). The aerators in the aeration basin were not being used, which created septic conditions. In addition, there were no solids handling provisions, so excess solids were simply discharged to Laurel Fork. The study concluded that the Pocahontas STP was the cause of the dissolved oxygen WQS violations downstream of the discharge. The problems found in the inspections at the STP were corrected and it has been in compliance with its VPDES permit limits over the past several years.

6.4.4 VPDES permitted discharges in the Laurel Fork watershed

There are two active individual VPDES permitted discharges in the Laurel Fork watershed, Table 3.2 and Figure 3.2. The Pocahontas STP is scheduled to go off line once the Northern Tazewell County WWTF is completed. The remaining VPDES discharge is a single-family residence general permit.

7. TMDL ENDPOINT: STRESSOR IDENTIFICATION

7.1 Stressor Identification

There are no water quality standards or recommended screening levels for many of the water quality parameters sampled in the Laurel Fork watershed. For parameters without established EPA or VADEQ water quality standards or screening values a 90th percentile screening value was used. The 90th percentile screening values were calculated from 14 monitoring stations in Southwest Virginia on first and second order streams that were used as benthic reference stations or were otherwise found not to have a benthic impairment based on the most recent sampling results. The 90th percentile screening values were used to develop a list of possible stressors. For a parameter to become a probable stressor additional information was required such as benthic habitat and metrics, and scientific references documenting problems for aquatic life. Graphs are shown for parameters that exceeded a 90th percentile value in more than 10% of the samples collected within the impaired segment or if the parameter had extreme values. If a parameter does not exceed a water quality standard, screening value, 90th percentile screening value, or does not have excessive values, median values are shown for each monitoring station from downstream to upstream. Data for parameters with more than one but less than nine data points can be found summarized in section 6.5.1. The presence of nine values was selected as a cutoff in order to avoid using data from stations that were not sampled during different seasons of the year or different flow regimes in Laurel Fork. However, all data collected on Laurel Fork was carefully reviewed to ensure it was consistent with expected values and to document any extreme values.

TMDLs must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not but they usually do not provide enough information to determine the cause(s) of the impairment. The process outlined in the Stressor Identification Guidance Document (EPA, 2000) was used to separately identify the most probable stressor(s) for Laurel Fork. A list of candidate causes was developed from published literature and VADEQ staff input. Chemical and physical monitoring data provided evidence to support or eliminate potential stressors.

Individual metrics for the biological and habitat evaluation were used to determine if there were links to a specific stressor(s). Land use data as well as a visual assessment of conditions along the stream provided additional information to eliminate or support candidate stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity/total dissolved solids, temperature, and organic matter.

The results of the stressor analysis for Laurel Fork are divided into three categories:

> **Non-Stressor(s)**: Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors. A list of non-stressors can be found in Table 7.1.
>
> **Possible Stressor(s)**: Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors. A list of possible stressors can be found in Table 7.2.
>
> **Most Probable Stressor(s)**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s). A list of probable stressors can be found in Table 7.3.

7.2 Non-Stressors

Table 7.1 Non-Stressors in Laurel Fork.

Parameter	Location in Document
Temperature	section 7.2.1
Toxics (except Phenanthrene, Fluoranthene, Pyrene)	section 7.2.2
Metals (except sediment iron and selenium)	section 7.2.3
pH	section 7.2.4

7.2.1 Temperature

The maximum temperature recorded in Laurel Fork was 26.8°C at VADEQ station 9-LRR002.26, which is well below the state standard of 31°C for the mountain zone waters. Median values for all of the monitoring stations are shown in Figure 7.1. Temperature is considered a non-stressor.

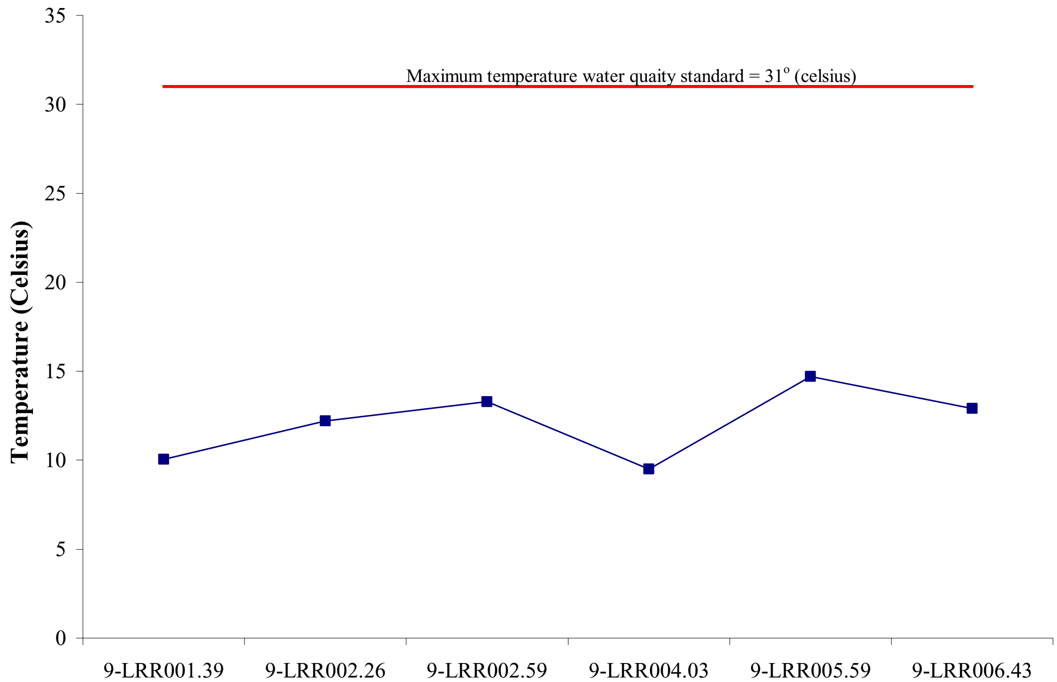

Figure 7.1 Median temperature measurements at VADEQ stations on Laurel Fork.

7.2.2 Toxics

Total ammonia (NH_3/NH_4) concentrations were below the chronic water quality standard at VADEQ monitoring station 9-LRR001.39 (Figure 7.2). Total chloride concentrations were also well below the VADEQ chronic water quality standard of 230 mg/L at monitoring station 9-LRR001.39 (Figure 7.3). Fish tissue and sediment PCBs, organics, and pesticides were collected at VADEQ station 9-LRR001.39 on September 13, 2000. Analysis of the fish tissue indicated that no toxic parameter exceeded a VADEQ screening level or VDH action level. All PCB values were below the established Consensus Probable Effect Concentrations (PEC)values (MacDonald et al., 2000) (Table 6.19). Three polyaromatic hydrocarbons (PAHs) out of 26 reported exceeded the established PEC value in the September 13, 2000 sample. Those three parameters are discussed in the possible stressors section (section 7.3.4). Toxics with the exception of the three PAHs discussed in section 7.3.4 are considered non-stressors.

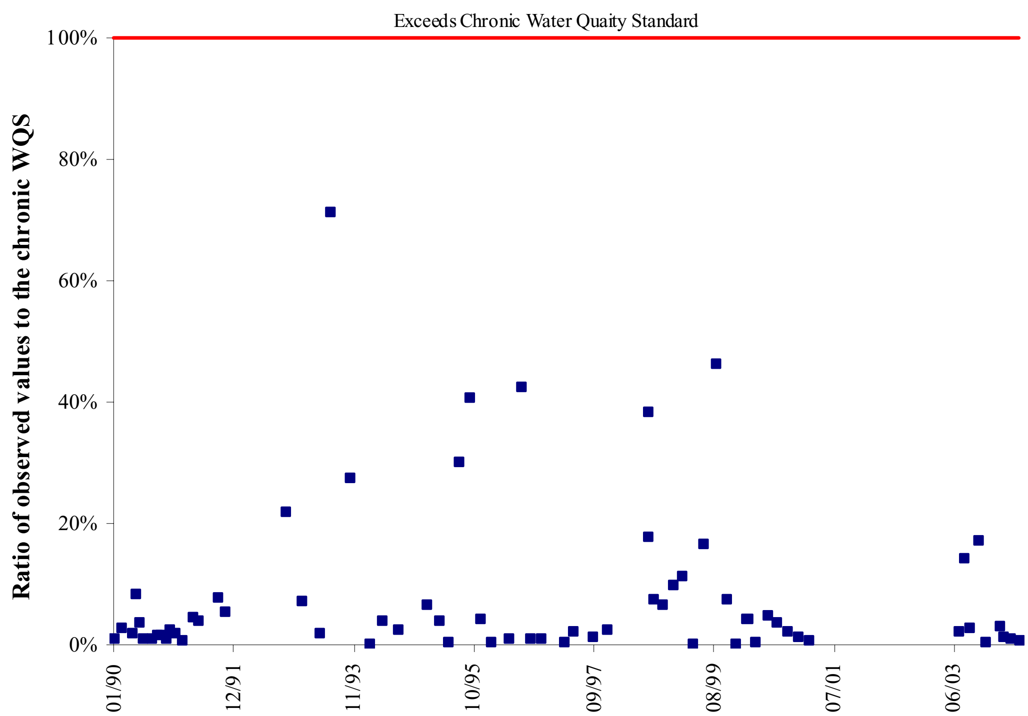

Figure 7.2 Total ammonia at VADEQ monitoring station 9-LRR001.39.

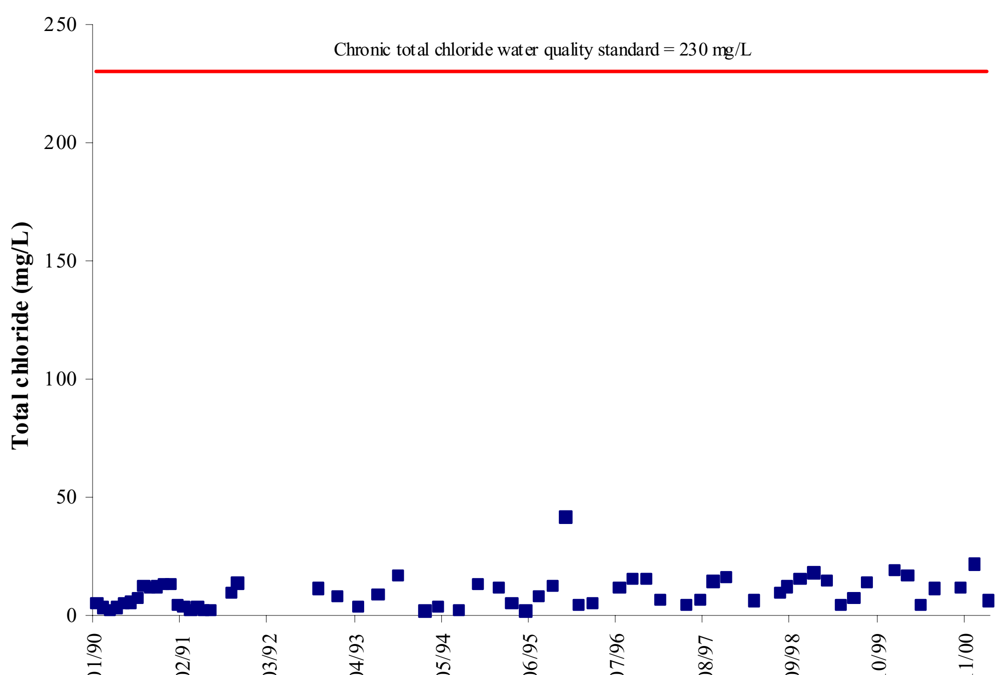

Figure 7.3 Total chloride at VADEQ monitoring station 9-LRR001.39

7.2.3 Metals

This section discusses VADEQ water quality monitoring for metals dissolved in the water column, metals in the sediment, and metals in fish tissue. Water column dissolved metals were sampled by VADEQ at stations 9-LRR001.39, 9-LRR002.59 and 9-LRR006.43 on August 5, 2003, and all results were below the hardness-based water quality standard. Special study sediment metals samples collected by VADEQ on September 13, 2000 were all below the PEC values (Table 6.18).

VADEQ collected sediment samples during its routine monitoring 11 times from March 1990 to August 2003 at 9-LRR001.39 (Figures 7.4 through 7.8) and once at stations 9-LRR002.59 and 9-LRR006.43. All values were below the PEC values with the exception of samples collected on October 27, 1994 at VADEQ monitoring station 9-LRR001.39. Four sediment arsenic samples were collected at 9-LRR001.39 and one exceeded the PEC value of 33 mg/kg (collected on October 27, 1994). Two sediment antimony samples were collected at 9-LRR001.39 and one (collected on October 27, 1994) exceeded the 90th percentile screening value of 12 mg/kg. One sediment manganese sample exceeded the 90th percentile screening value (801 mg/kg) and it was also collected on October 27, 1994. It is interesting to note the values for every metal sample collected on October 27, 1994 were above the PEC or 90th percentile screening value and some were an order of magnitude higher than values collected on the remaining dates. This suggests the possibility of laboratory or data entry error. Based on the results of the dissolved metals, sediment metals, and fish tissue metals data, metals are considered non-stressors.

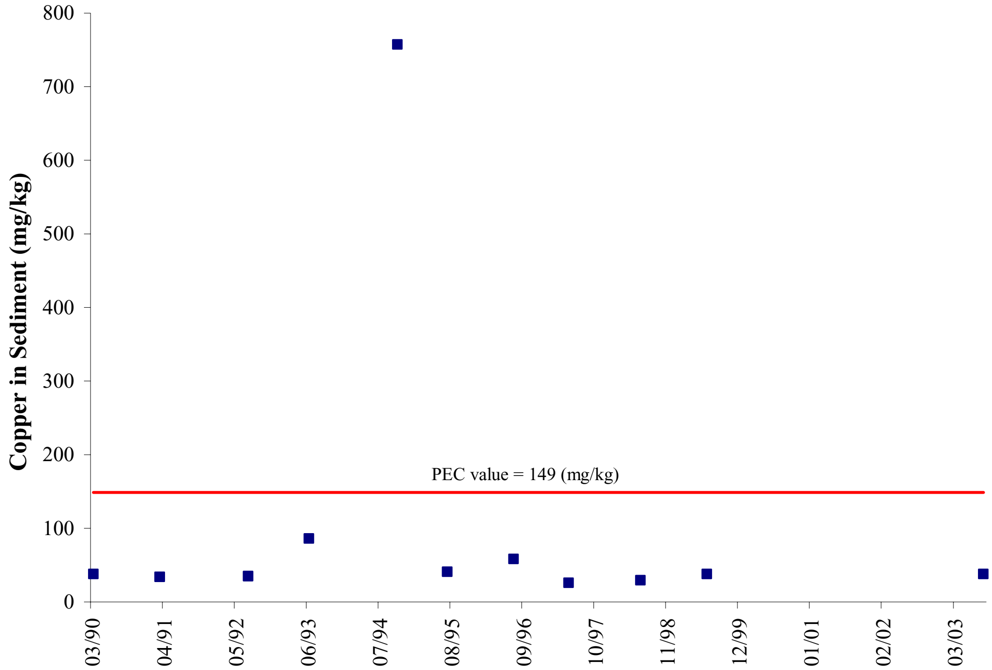

Figure 7.4 Sediment copper values at VADEQ monitoring station 9-LRR001.39.

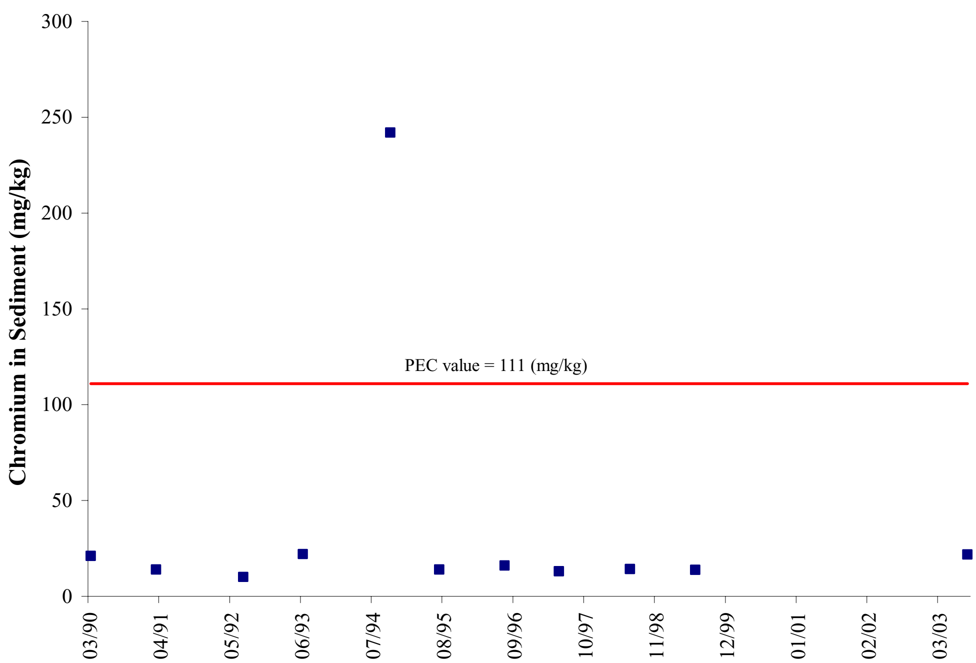

Figure 7.5 Sediment chromium values at VADEQ monitoring station 9-LRR001.39.

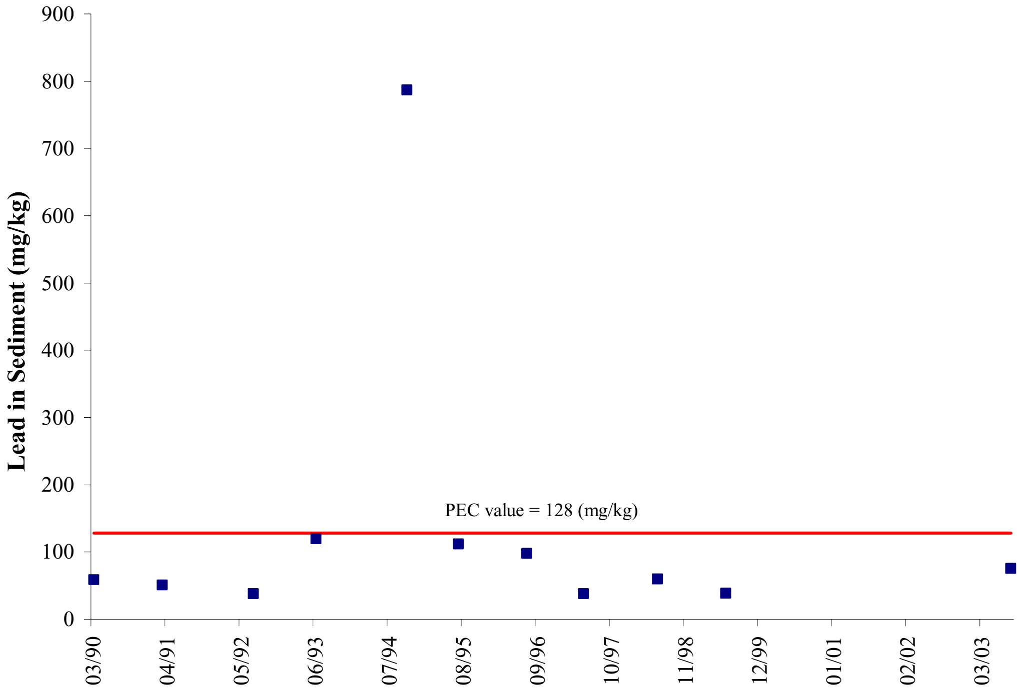

Figure 7.6 Sediment lead values at VADEQ monitoring station 9-LRR001.39.

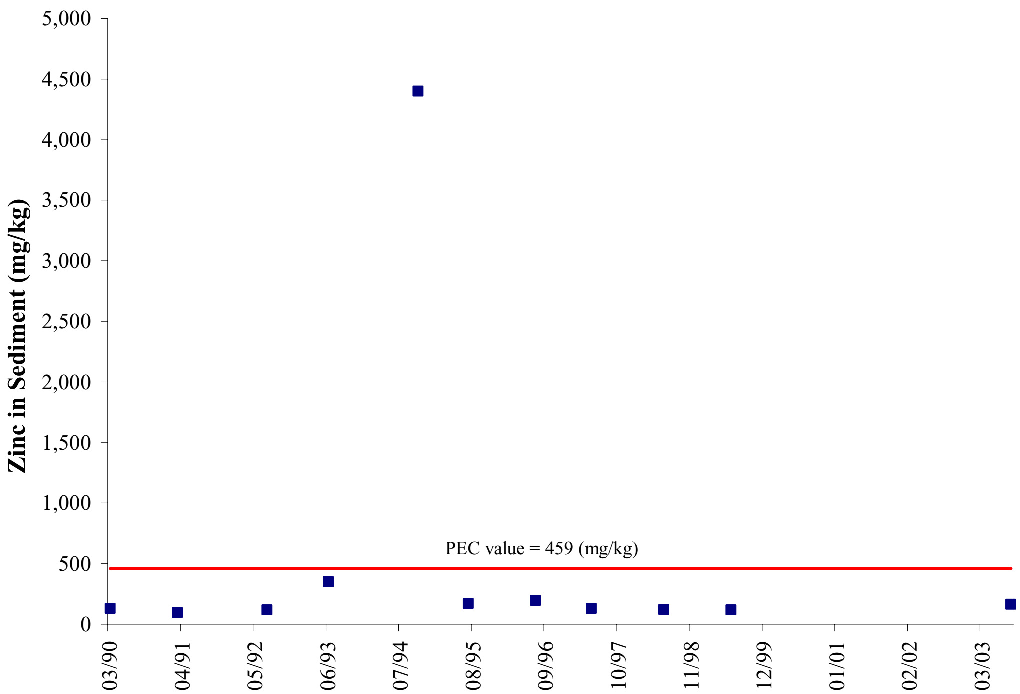

Figure 7.7 Sediment zinc values at VADEQ monitoring station 9-LRR001.39.

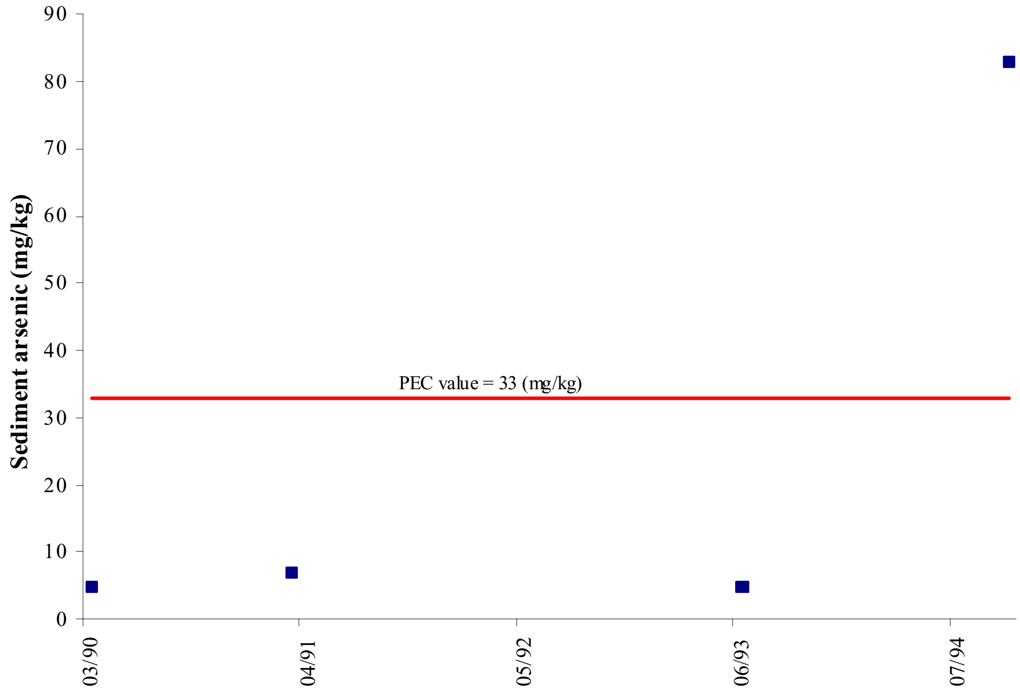

Figure 7.8 Sediment arsenic values at VADEQ monitoring station 9-LRR001.39.

7.2.4 pH

Field pH values were within water quality standards everywhere pH was measured on Laurel Fork. Medians for all VADEQ stations on Laurel Fork are shown in Figure 7.9.

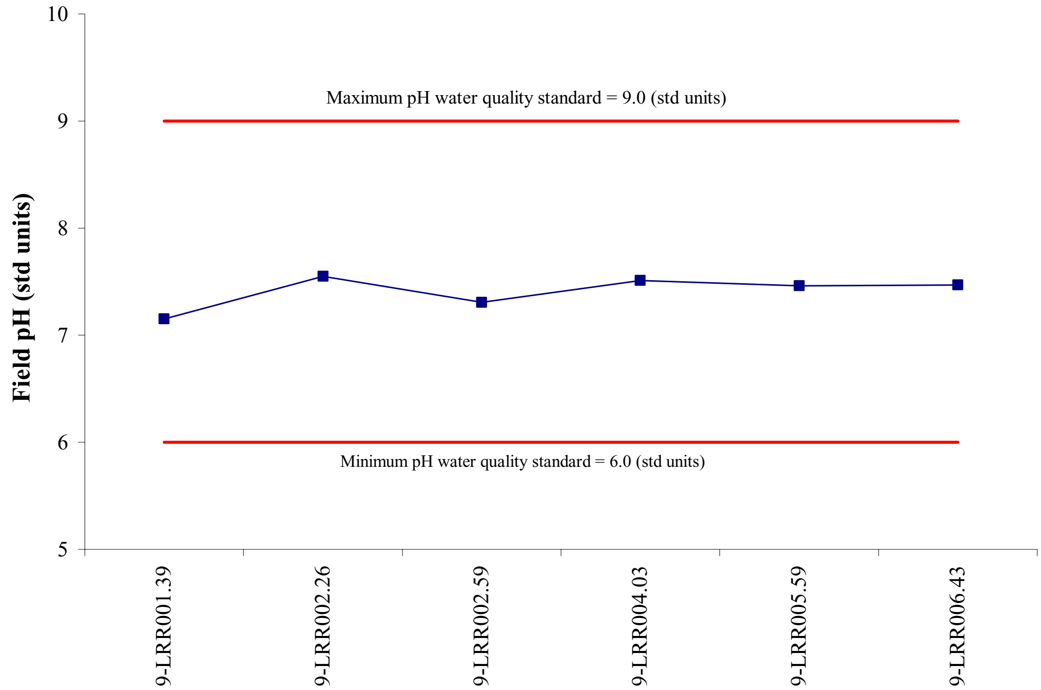

Figure 7.9 Median field pH values at VADEQ monitoring stations on Laurel Fork.

7.3 Possible Stressors

Table 7.2 Possible stressors in Laurel Fork.

Parameter	Location in Document
Organic matter	section 7.3.1
Nutrients	section 7.3.2
Conductivity/Total dissolved solids	section 7.3.3
Toxics (Phenanthrene, Fluoranthene, Pyrene)	section 7.3.4
Sediment iron and selenium	section 7.3.5

7.3.1 Organic matter

Several different parameters were used to determine if organic matter in the stream was impacting the benthic macroinvertebrate community. Biochemical oxygen demand (BOD_5) provides an indication of how much dissolved organic matter is present. Total organic carbon (TOC), chemical oxygen demand (COD), and total volatile solids (TVS, also called total organic solids) provide an indication of dissolved organic matter. The measure of total volatile suspended solids (TVSS, also called total organic suspended solids) provides an indication of particulate organic matter in a stream. Total Kjeldahl nitrogen (TKN) is a measure of the amount of organic nitrogen that is present. BOD_5 concentrations exceeded the 90th percentile screening value of 2.0 mg/L in 11 of 48 samples and a maximum value of 9.0 mg/L was reported in June of 1999 (Figure 7.10). TOC concentrations were at acceptable levels; fewer than 10% were above the 90th percentile screening concentration of 5.0 mg/L. COD concentrations exceeded the 90th percentile screening concentration of 13 mg/L in eight of 49 samples and the maximum concentration was 23 mg/L (Figure 7.11). TVSS concentrations exceeded the 90th percentile concentration of 6.0 mg/L in six of 38 samples and the maximum concentration was 26 mg/L (Figure 7.12). TVS concentrations exceeded the 90th percentile concentration (40 mg/L) in 35 of 65 samples and the maximum concentration was 120 mg/L (Figure 7.13). TKN concentrations exceeded the 90th percentile screening concentration (0.3 mg/L) in 43 of 64 samples and the maximum concentration was 3.2 mg/L (Figure 7.14).

The parameters that are indicative of high organic matter reveal that it is elevated in Laurel Fork. The source of the organic matter is thought to be non-regulated sewage discharges and exfiltration and overflows from the Pocahontas sewerage system. The sources will be addressed by the fecal coliform TMDL being developed concurrently with the benthic TMDL; therefore, organic matter is considered a possible stressor.

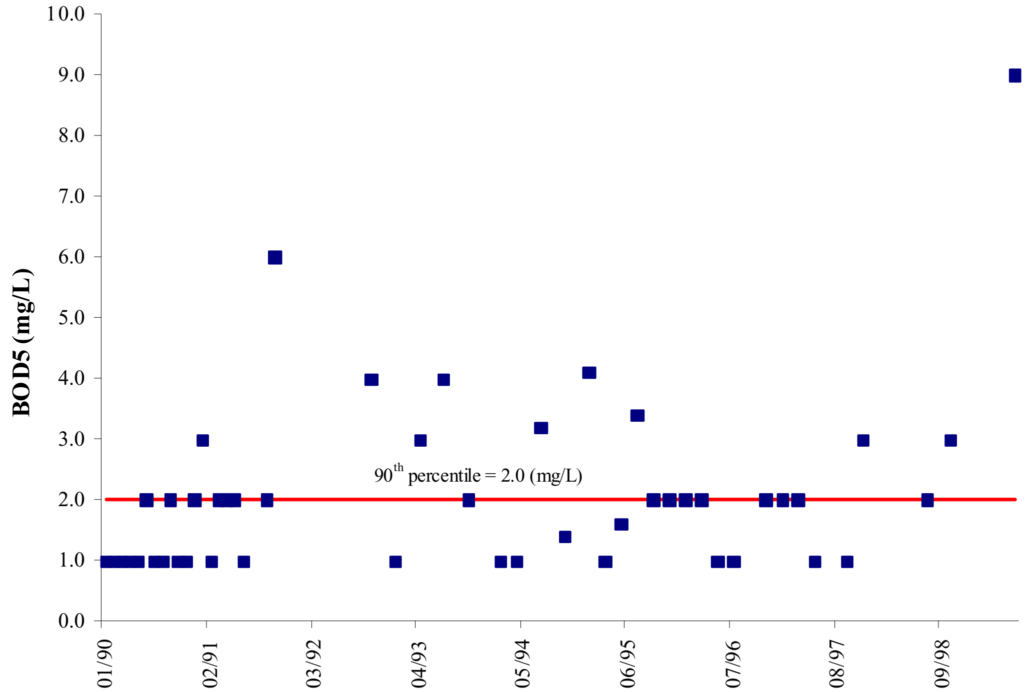

Figure 7.10 BOD_5 concentrations at VADEQ station 9-LRR001.39.

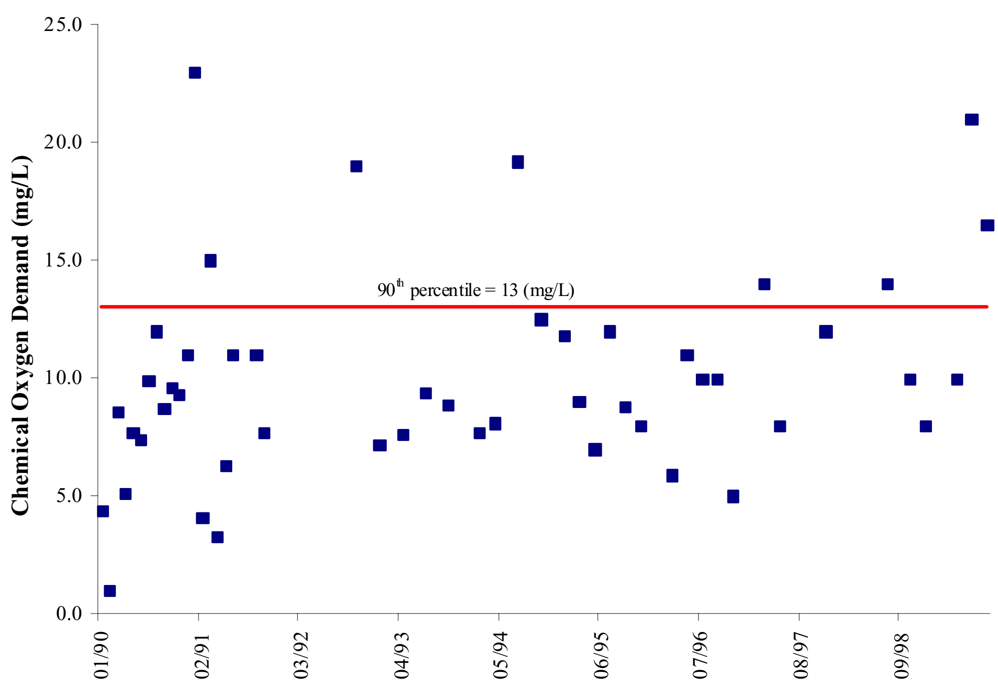

Figure 7.11 COD concentrations at VADEQ station 9-LRR001.39.

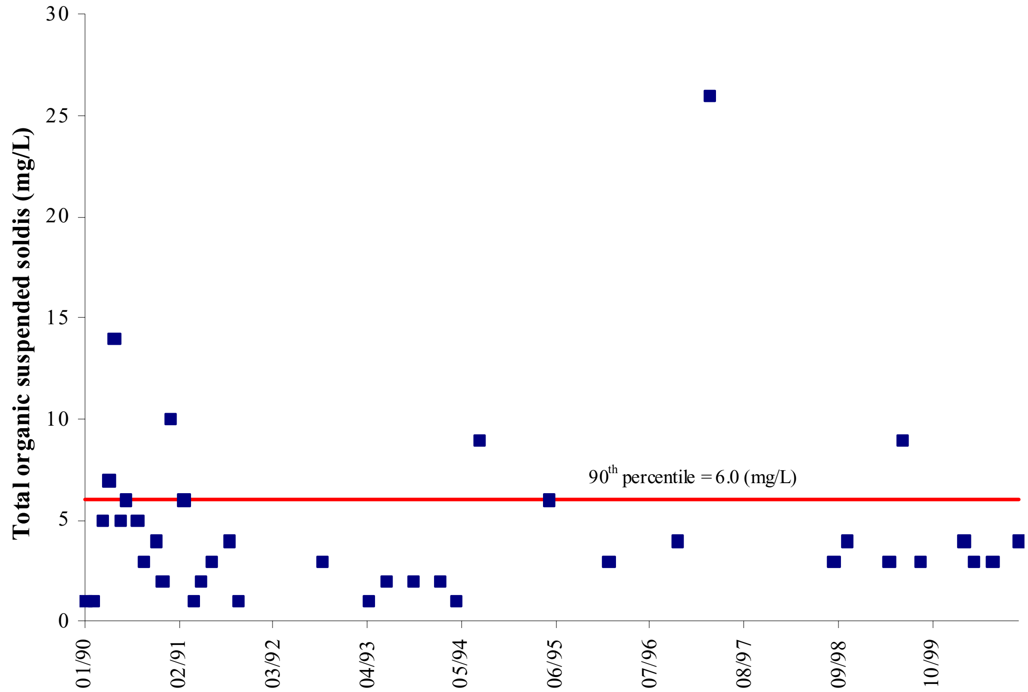

Figure 7.12 TVSS concentrations at VADEQ station 9-LRR001.39.

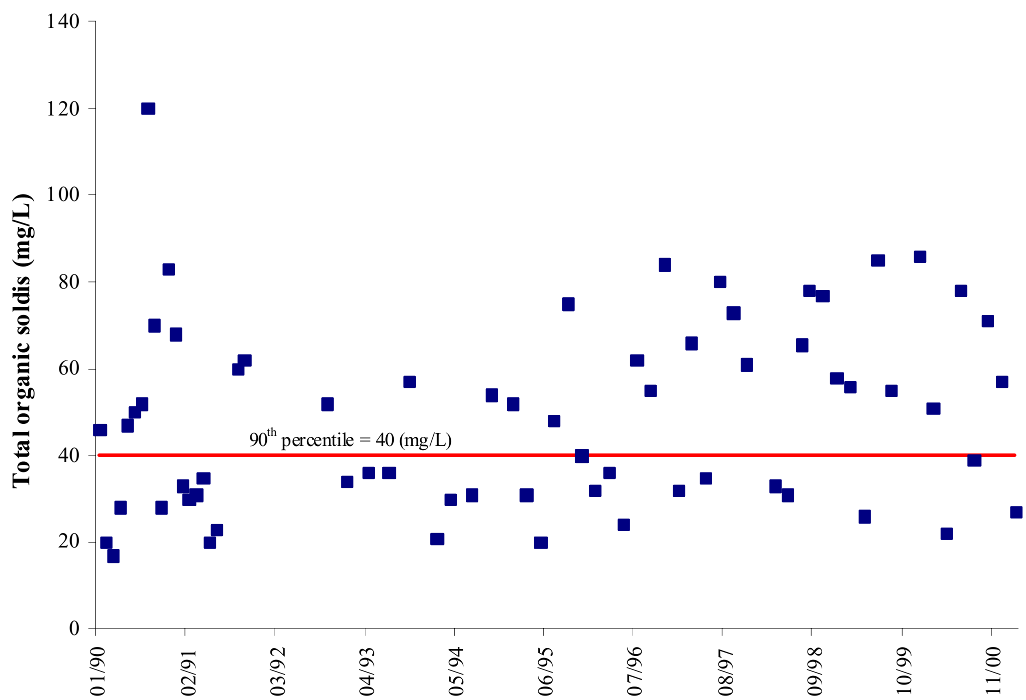

Figure 7.13 TVS concentrations at VADEQ station 9-LRR001.39.

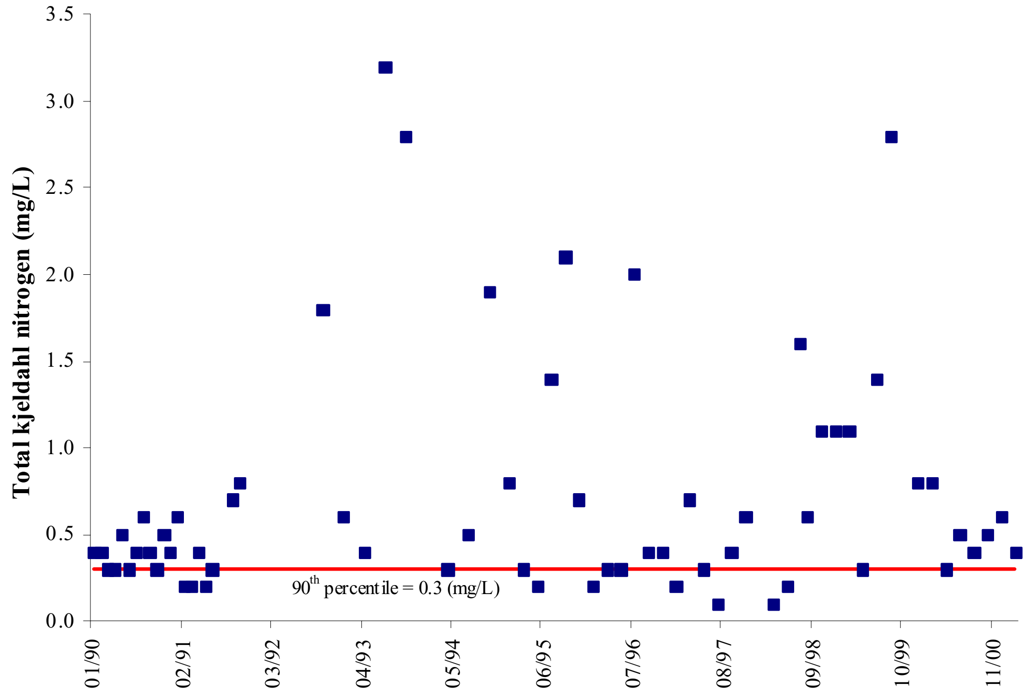

Figure 7.14 TKN concentrations at VADEQ station 9-LRR001.39.

7.3.2 Nutrients

Median total phosphorus (TP) concentrations at 9-LRR001.39 were 0.08 mg/L and the number of concentrations that exceeded the EPA recommended screening concentration of 0.2 mg/L was well below 10% (Figure 7.15). Nitrate-nitrogen (NO_3-N) concentrations exceeded the 90th percentile concentration (0.57 mg/L) in 21 out of 65 samples collected at VADEQ station 9-LRR001.39 and the maximum value reported was 3.82 mg/L (Figure 7.16).

The low total phosphorus concentrations indicate that nutrients from non-point source runoff are not as significant as other sources. The sources of the high nitrate-nitrogen concentrations are considered to be the same as the organic compounds, exfiltration and overflows from the Pocahontas sewerage system and non-regulated sewage discharges. These sources are being addressed by the fecal coliform TMDL being developed concurrently with the benthic TMDL. Nutrients are considered possible stressors.

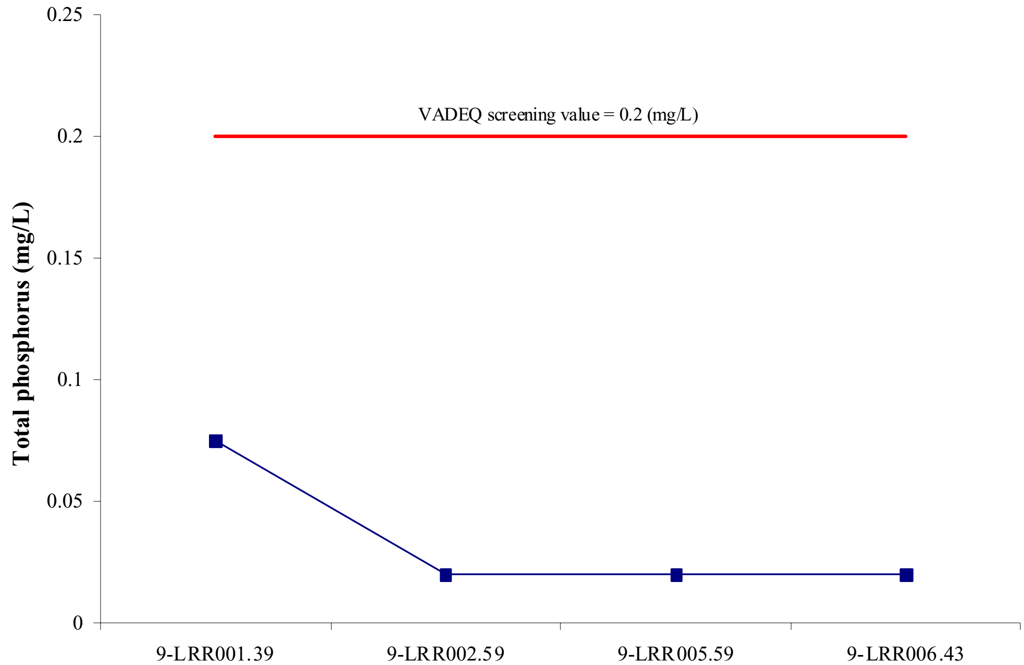

Figure 7.15 Median Total Phosphorus concentrations at VADEQ stations on Laurel Fork.

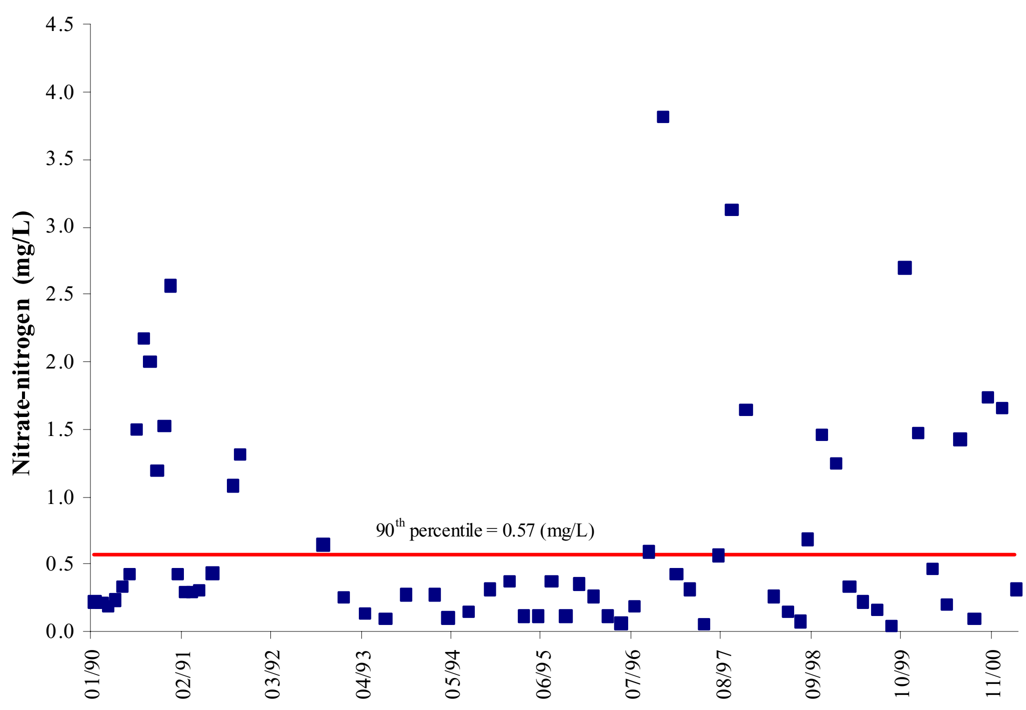

Figure 7.16 NO_3-N concentrations at VADEQ station 9-LRR001.39.

7.3.3 Conductivity/Total Dissolved Solids

Conductivity is a measure of the electrical potential in the water based on the ionic charges of the dissolved compounds that are present. Total dissolved solids (TDS) is a measure of the concentration of dissolved salts plus dissolved metals, minerals, and organic matter and, therefore, there is often a direct correlation with conductivity. While the state of Virginia has no water quality standard for either conductivity or TDS, standards set by other states have values varying between 1,000 and 1,500.

Conductivity values at VADEQ station 9-LRR001.39 exceeded the 90th percentile screening value (285 mmhos/cm) in 41 out of 78 samples and the maximum value recorded was 1,201 mmhos/cm (Figure 7.17). The maximum reported conductivity value was actually an average between the value measured in the field on July 2, 1990 (2,000 μmhos/cm) and the one reported by the State laboratory (402 μmhos/cm). MapTech calculated a TDS value of 301 mg/L for July 2, 1990 by subtracting total suspended solids (11 mg/L) from total solids (312 mg/L). Therefore it is likely that the 2,000-μmhos/cm field value is in error. Conductivity values at station 9-LRR002.26 exceeded the 90th percentile screening value in four out of 10 samples and the maximum value recorded was 396 mmhos/cm (Figure 7.18). Conductivity values at VADEQ station 9-LRR002.59 exceeded the 90th percentile screening value in five out of 10 samples and the maximum value recorded was 363 mmhos/cm (Figure 7.19). Median conductivity values for all VADEQ monitoring stations are shown in Figure 7.20. A 2004 report by the Kentucky Department of Environmental Protection noted, "drastic reductions in mayflies at sites with conductivities generally above 500 mmhos/cm" (approximately 375 mg/L TDS) (Pond, 2004).

One of the primary components of TDS is sulfate, a parameter often used as an indicator of mining waste. Sulfate concentrations exceeded the 90th percentile screening concentration (26 mg/L) in all 64 samples collected (Figure 7.21). In addition, there was a spike of 440 mg/L in July 1996. According to the VADEQ, there is a possibility that some deep mine wastewater from a different drainage basin in West Virginia reaches Laurel Fork through a spring downstream of Pocahontas (VADEQ personal communication, 2005). This could be the explanation for the elevated sulfate concentrations.

TDS concentrations exceeded the 90th percentile screening concentration (156 mg/L) in 52 out of 74 samples at VADEQ station 9-LRR001.39 and the maximum concentration reported was 359 mg/L (Figure 7.22). There is no universal agreement on what concentration of TDS can impair a benthic community. However, after an exhaustive literature search, Kennedy (2002) reported that many authors concluded that concentrations of 1,000 mg/L and higher could cause some type of stress to the benthic community. None of the studies cited by Kennedy found TDS concentrations less than 700 mg/L to cause stress to benthic macroinvertebrates. In fact a comprehensive study by Pond (2004) of Kentucky headwater streams found that impacts to the most sensitive benthic macroinvertebrates are found when conductivities reach 500 μmhos/cm (approximately 375 mg/L TDS). The maximum TDS value found in Laurel Fork was 359 mg/L. In addition TDS concentrations in Laurel Fork are fairly stable (average standard deviation of 43 which is consistent with non-impaired benthic communities in southwest Virginia). Conductivity/TDS are considered possible stressors because of the potential spike in conductivity measured in July 1990 at station 9-LRR001.39, the number of exceedances of the screening value and because the weight of evidence does not support a most probable stressor designation.

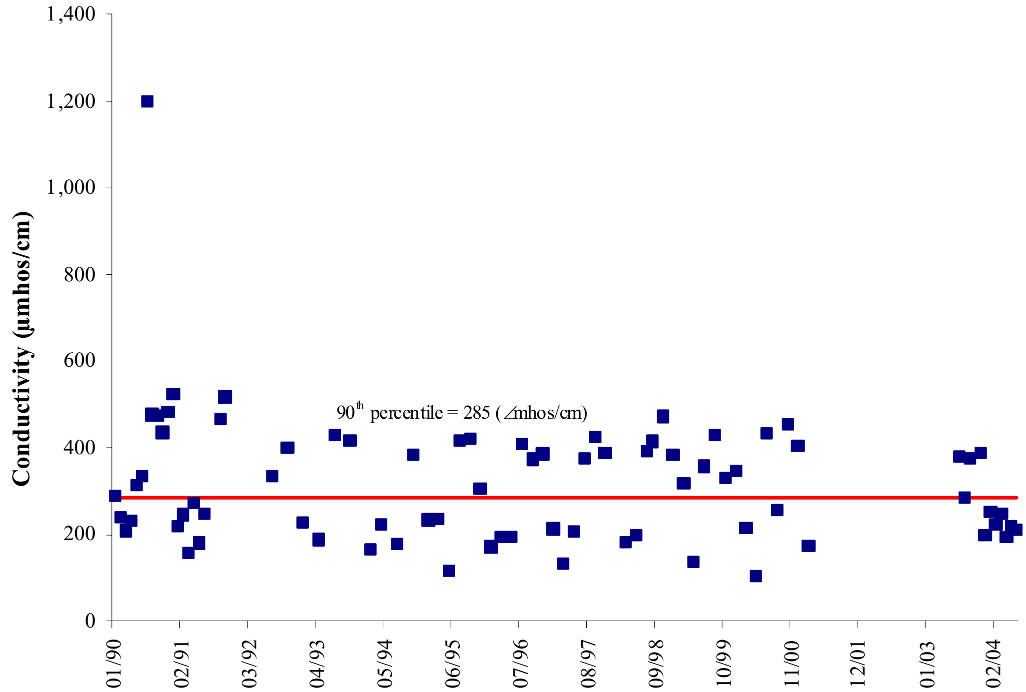

Figure 7.17 Conductivity values at VADEQ station 9-LRR001.39.

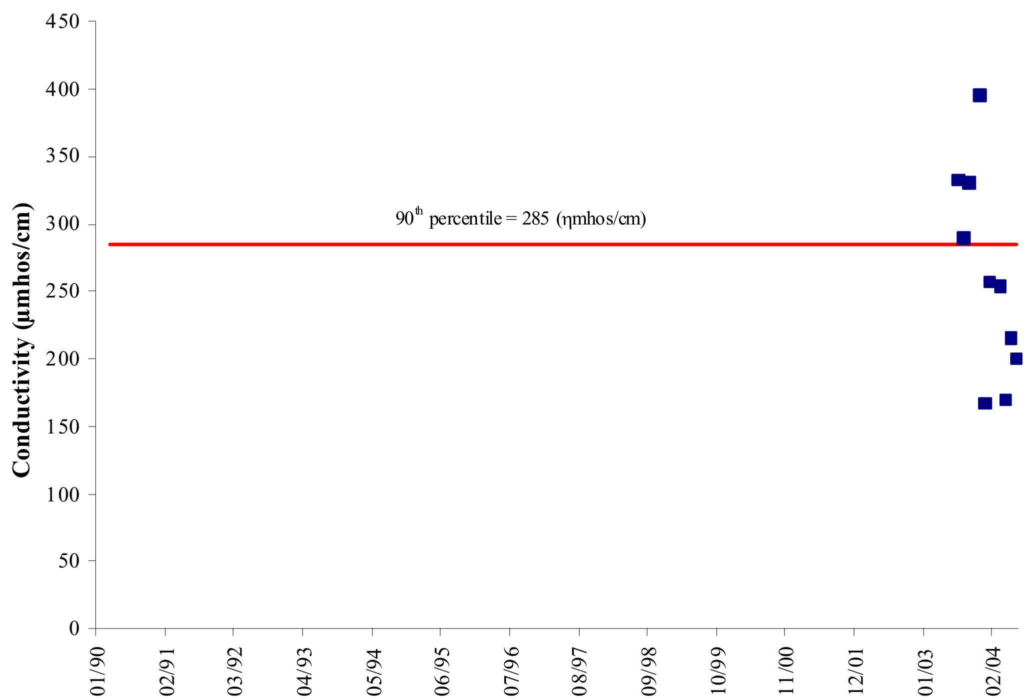

Figure 7.18 Conductivity values at VADEQ station 9-LRR002.26.

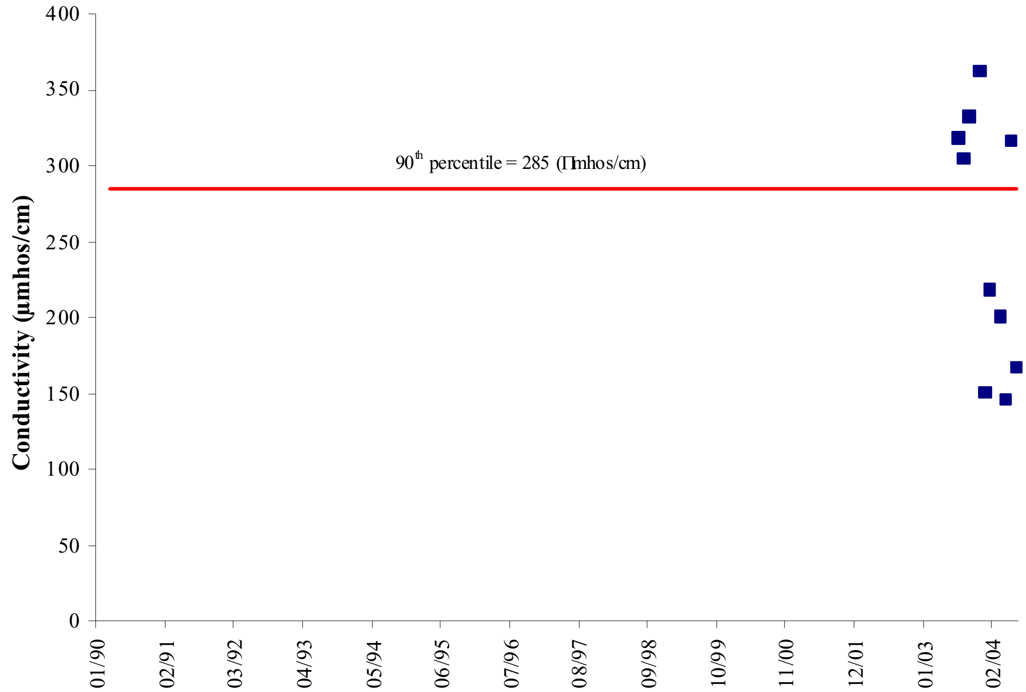

Figure 7.19 Conductivity values at VADEQ station 9-LRR002.59.

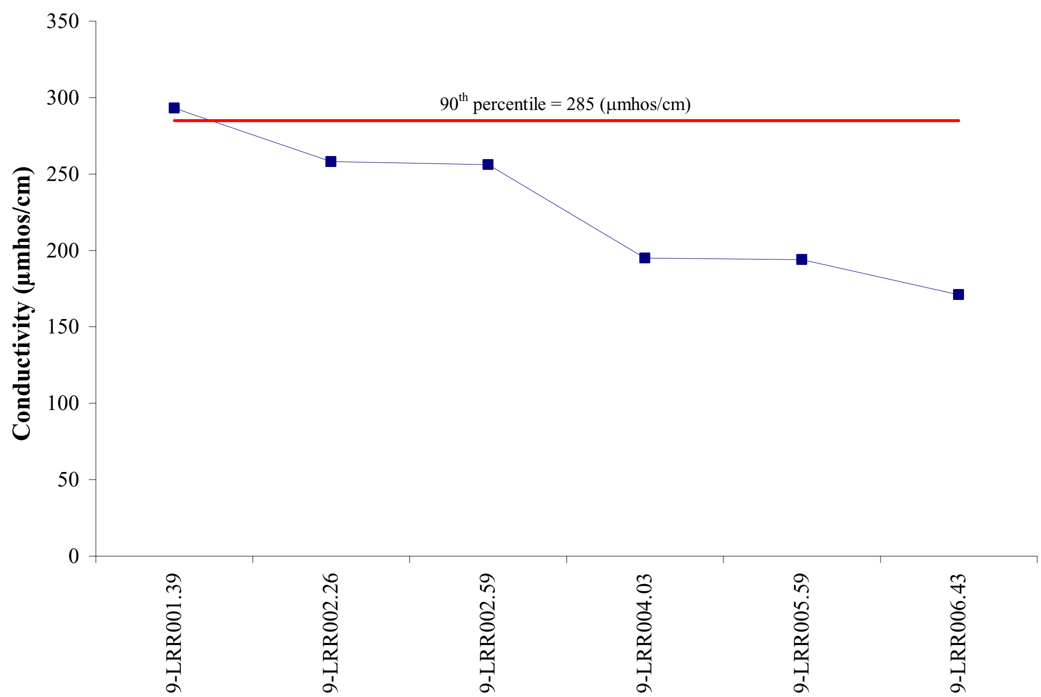

Figure 7.20 Median conductivity values at VADEQ stations on Laurel Fork.

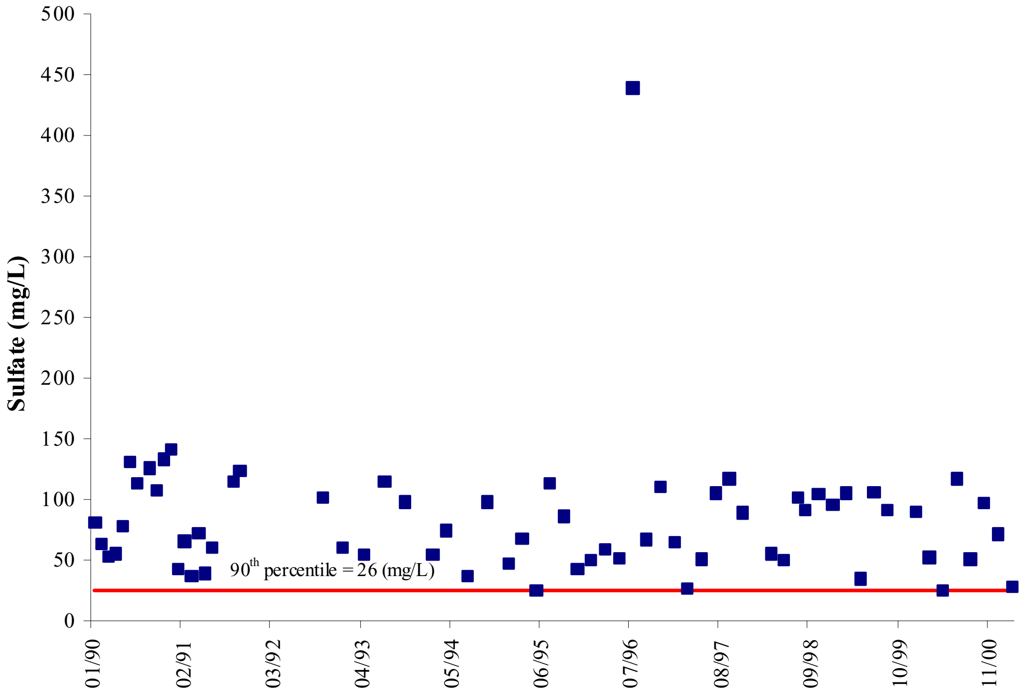

Figure 7.21 Sulfate concentrations at VADEQ station 9-LRR001.39.

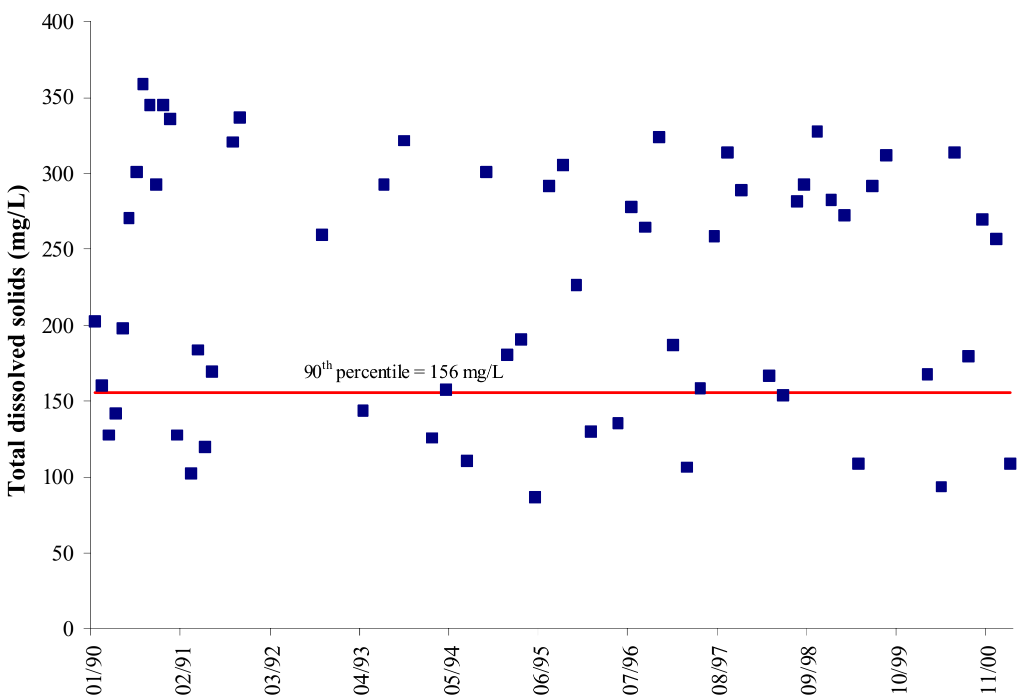

Figure 7.22 TDS concentrations at VADEQ station 9-LRR001.39.

7.3.4 Toxics (Phenanthrene, Pyrene and Fluoranthene)

Phenanthrene, Pyrene and Fluoranthene are compounds collectively known as polyaromatic hydrocarbons. All three are derived from coal tar and are the result of incomplete combustion of fossil fuels. A VADEQ special study sampling at monitoring station 9-LRR001.39 on September 13, 2000 indicated that these three compounds exceeded the consensus PEC values (Table 6.9). PEC values indicate the potential for a compound that is toxic to the benthic community to be bioavailable. The presence of values in excess of the consensus PEC values does not automatically mean that the compound is bioavailable and, therefore, responsible for impairment. The only way to determine bioavailability is to perform sediment toxicity testing. This information is not available for Laurel Fork and therefore, these three compounds are considered possible stressors.

7.3.5 Sediment iron and selenium

Sediment iron values exceeded the 90^{th} percentile screening value (12,420 mg/kg) in six out of seven samples and the maximum value reported was 22,300 mg/kg (Figure 7.23). Sediment selenium exceeded the 90^{th} percentile screening value (1.60 mg/kg) in three out of seven samples and the maximum value reported was 18 mg/kg (Figure 7.24). Neither iron nor selenium have a PEC or other screening value that indicates toxicity, therefore they will be considered possible stressors.

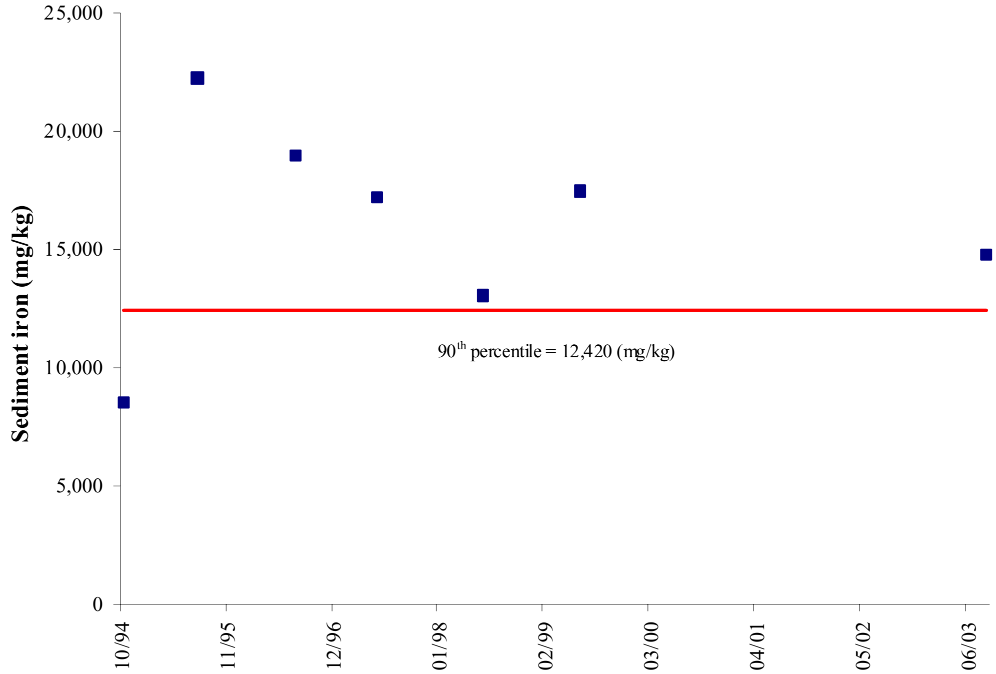

Figure 7.23 Sediment iron values at VADEQ station 9-LRR001.39.

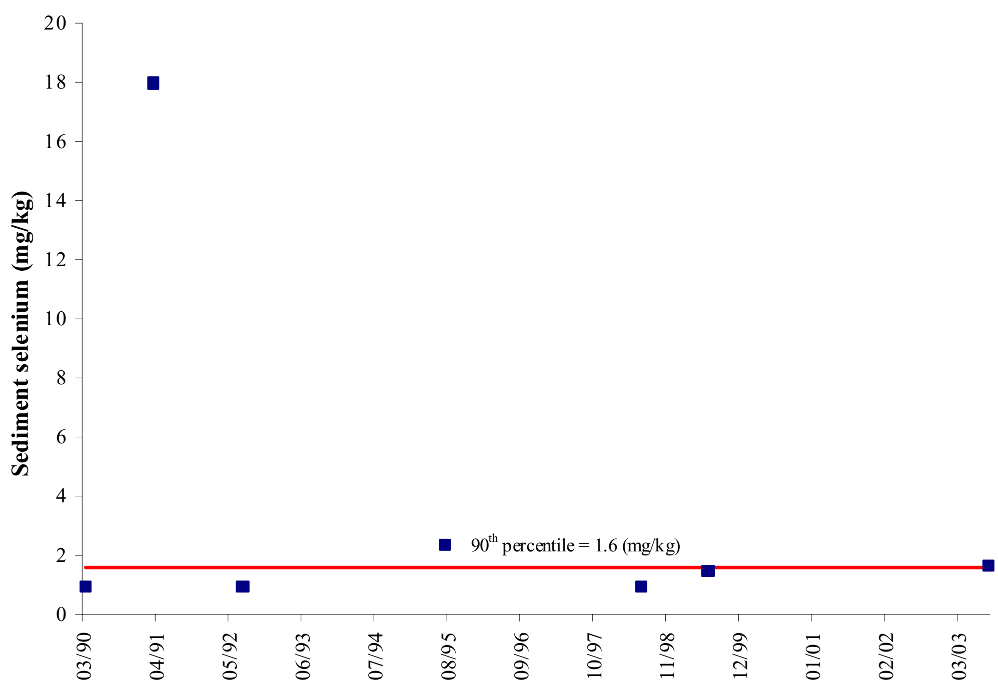

Figure 7.24 Sediment selenium values at VADEQ station 9-LRR001.39.

7.4 Probable Stressors

Table 7.3 Probable stressors in Laurel Fork.

Parameter	Location in Document
Sediment	section 7.4.1
Dissolved Oxygen	section 7.4.2

7.4.1 Sediment

The Embeddedness habitat scores at VADEQ benthic monitoring station 9-LRR001.39 were in the poor category in 1996 and in the marginal category in 2003. Monitoring station 9-LRR006.43 had a marginal score in 2003. This metric is one of the best indicators of sediment problems in riffle areas where the majority of the habitat is located. Pool Sediment scores were marginal at benthic monitoring station 9-LRR001.39 in 2003. Riparian Vegetation scores were marginal at benthic monitoring station 9-LRR001.39 for both surveys. This metric is important because it is a measure of the width of vegetation in the riparian zone. This vegetation helps filter both particulate and dissolved components that run off of the surrounding land during precipitation events. The Bank Stability score was poor at benthic monitoring station 9-LRR001.39 in the 1996 survey. Eroding stream banks can contribute a considerable amount of sediment to the stream during high flow events. A poor score means that more than 75% of the stream bank is prone to eroding during high flows. Total suspended solids (TSS) concentrations exceeded the 90^{th} percentile screening value (20 mg/L) in six out of 71 samples and the maximum value reported was 142 mg/L (Figure 7.25). Median TSS concentrations for all the VADEQ monitoring stations on Laurel Fork where it was collected are shown in Figure 7.26. An inspection of the Pocahontas STP by the VADEQ in 1998 (see section 6.5.3 in Chapter 6) found that there were no solids handling facilities and, as a result, excess solids were discharged to Laurel Fork. The sewage treatment plant has been complying with its permit limits since 2002 and the last TSS concentration to exceed 20 mg/L was in June of 1999. Based on the very low habitat embeddedness scores, low pool sediment scores, and spikes in the TSS data, sediment is considered a probable stressor and will be one of the target pollutants used to address the benthic impairment in Laurel Fork.

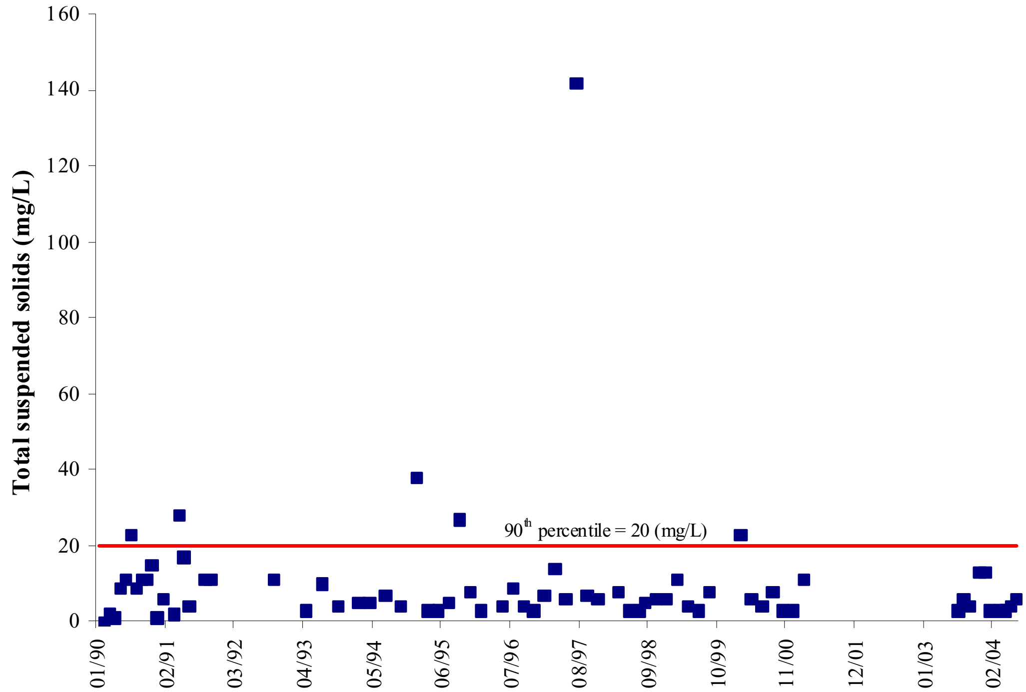

Figure 7.25 TSS concentrations at VADEQ station 9-LRR001.39.

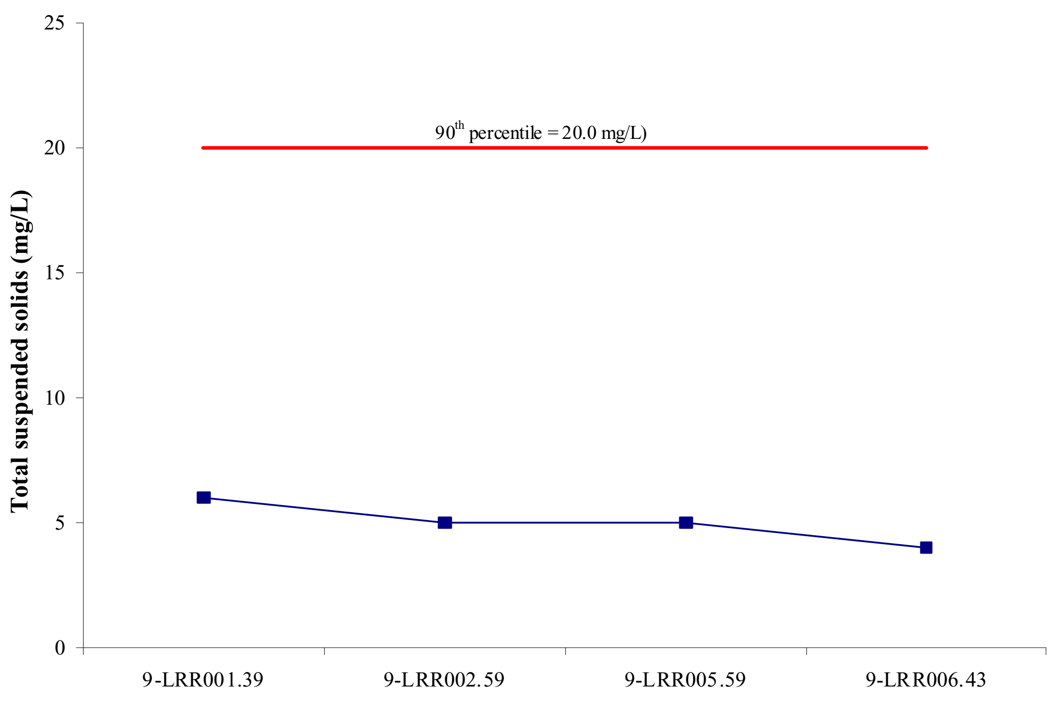

Figure 7.26 Median TSS concentrations at VADEQ stations on Laurel Fork.

7.4.2 Dissolved Oxygen

Dissolved oxygen (DO) concentrations were below the VADEQ minimum standard of 4.0 mg/L 15 times out of 61 samples from monitoring station 9-LRR001.69 on Laurel Fork. The lowest recorded concentration was 0.94 in July 1993 (Figure 7.27). Two of the five upstream stations where DO concentrations have been measured had one value below the water quality standard. Monitoring station 9-LRR004.03 had a DO concentration of 1.53 mg/L in November 2003 (Figure 7.28). Interestingly, the DO concentration at 9-LRR001.39 was 5.5 mg/L that same day. Monitoring station 9-LRR006.43 had a DO concentration of 2.47 mg/L in August of 2003 (Figure 7.29). The DO at monitoring station 9-LRR001.39 was 3.7 mg/L the same day. The problem seems to be the most persistent at the most downstream station, 9-LRR001.39, which could be due to the problems with Pocahontas wastewater treatment plant in the mid to late 1990's. Median DO concentrations are shown in Figure 7.30.

Excess organic matter appears to be responsible for the low dissolved oxygen in Laurel Fork. Microorganisms in the stream decompose excess organic matter and this process requires dissolved oxygen. The possible stressor section noted that many of the parameters that indicate high amounts of organic matter were related to raw sewage from un-regulated discharges and problems with the Pocahontas sewerage system. Therefore, dissolved oxygen is considered a probable stressor and will be one of the target pollutants used to address the benthic impairment in Laurel Fork.

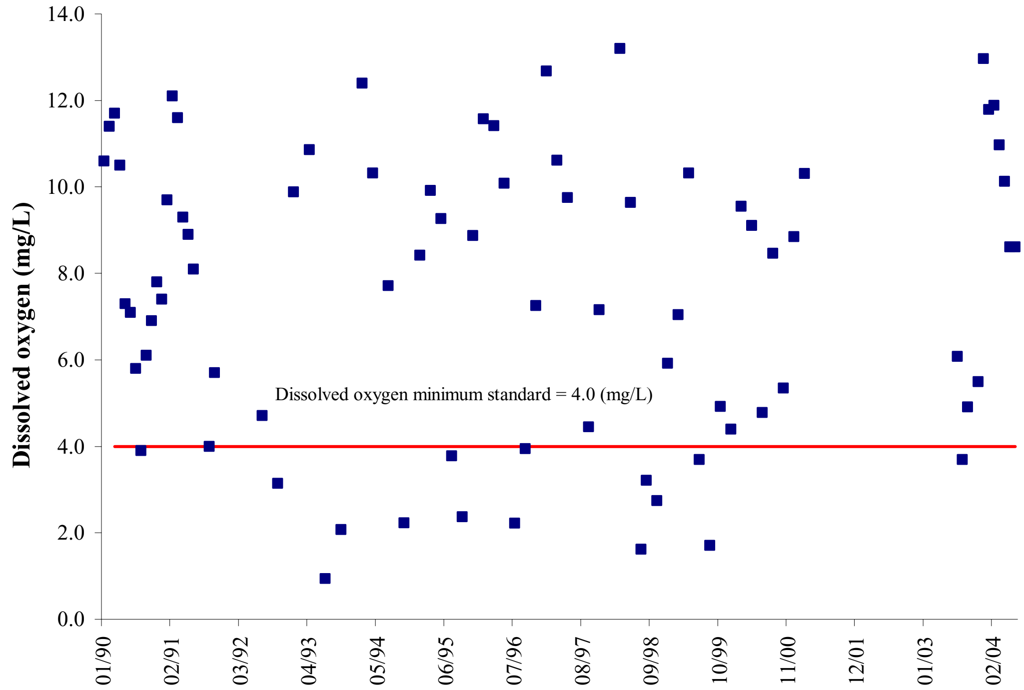

Figure 7.27 DO concentrations at VADEQ station 9-LRR001.39.

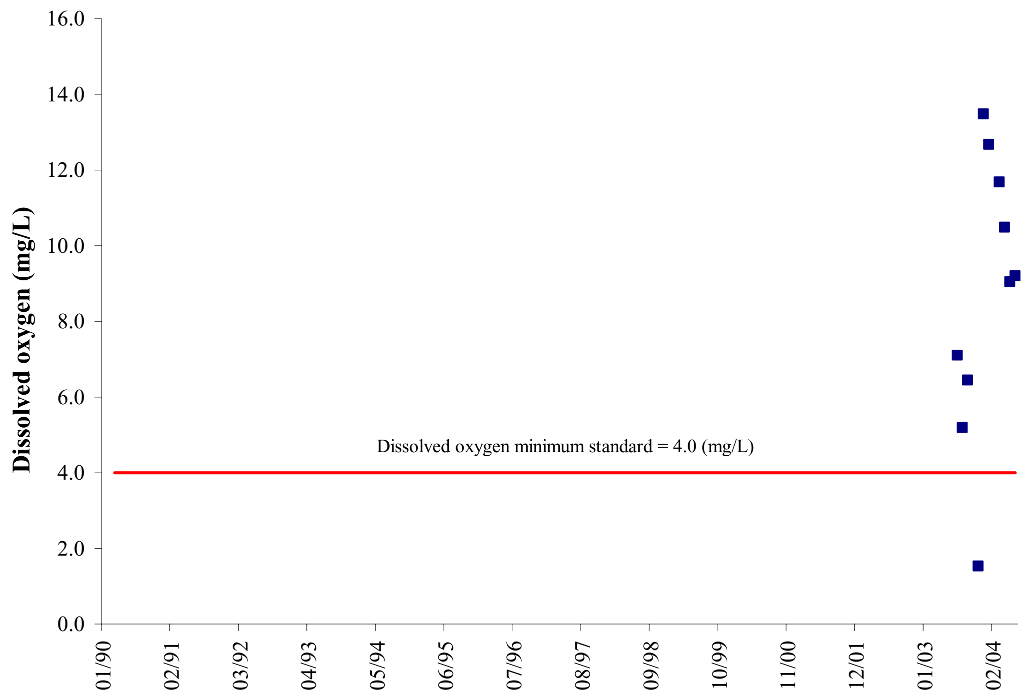

Figure 7.28 DO concentrations at VADEQ station 9-LRR004.03.

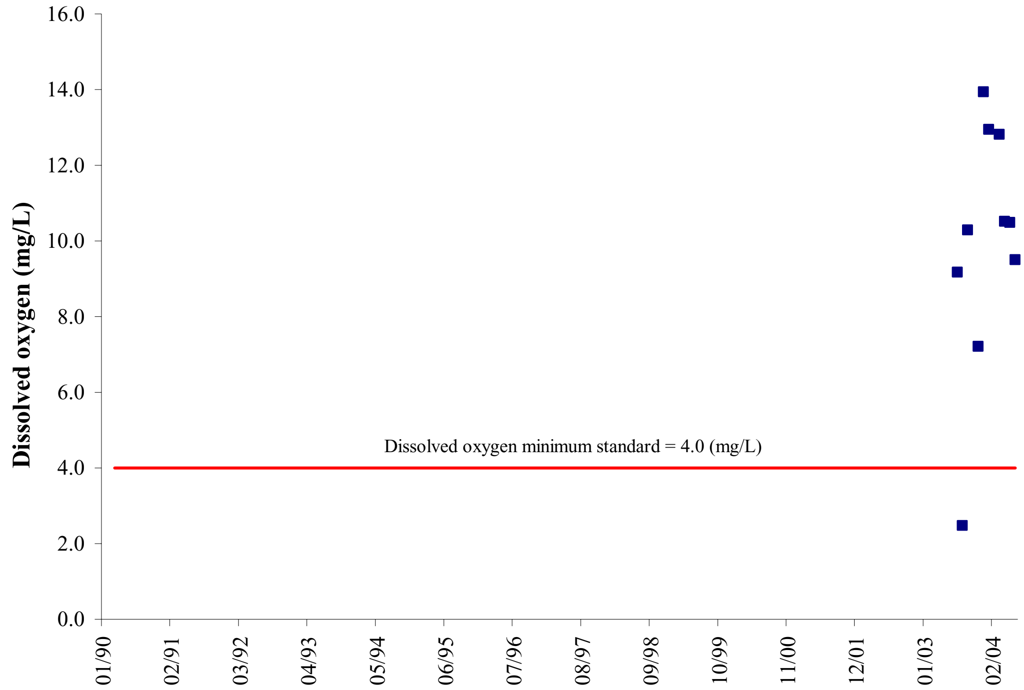

Figure 7.29 DO concentrations at VADEQ station 9-LRR006.43.

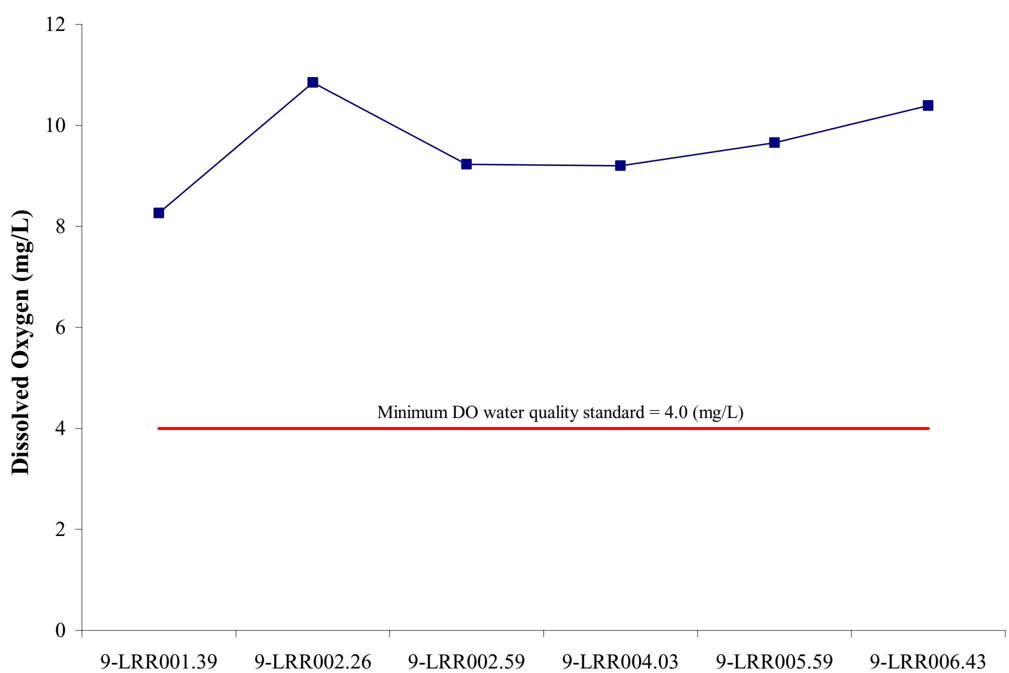

Figure 7.30 Median DO concentrations at VADEQ monitoring stations on Laurel Fork.

Both sediment and low dissolved oxygen are considered the most probable stressors in Laurel Fork. Periodic spikes in TSS concentrations reduce the habitat available for benthic organisms and also have a smothering effect on some of the more sensitive taxa. Organic solids and reduced compounds in the sediment play a direct role in the low dissolved oxygen concentrations frequently measured at VADEQ station 9-LRR001.39. In addition the frequency of sewage overflows and the number of un-regulated sewage discharges in the watershed also directly contribute to the minimum dissolved oxygen water quality standard violations.

7.5 Trend and Seasonal Analyses

In order to improve the TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on water quality parameters that were identified as possible or probable stressors. A Seasonal Kendall Test was used to examine long-term trends. The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends. This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed. For instance, the Seasonal Kendall Test can identify the trend (over many years) in dissolved oxygen levels during a particular season or month. A seasonal analysis of water chemistry results was conducted using the Mood Median Test. This test was used to compare median values of water quality in each season.

Only VADEQ monitoring station 9-LRR001.39 had enough data to perform trend and seasonality analyses. The results of the Seasonal Kendall Test used to detect long-term trends are shown in Table 7.4. The results of the Moods Median Test for water quality data from Laurel Fork are shown in Tables 7.5 through 7.21. Values in seasons with the same median group letter are not significantly different from each other at a 95% confidence level. For example, if winter and spring are in median group “B” they are not significantly different from each other. Water quality constituents BOD_5, TSS, TVS, and TVSS do not display significant seasonality.

Table 7.4 Trend analysis results for water quality data at VADEQ monitoring station 9-LRR001.39 in Laurel Fork.

Water Quality Constituent	Mean	Median	Max	Min	SD	N	Trend
BOD_5	2.077083	2	9	1	1.4879	48	No Trend
Chloride, Total mg/L	10.0459	8.4	42.1	2.4	6.6507	61	0.372
Conductivity, 25C µmho	317.6616	299.25	1201	106.8333	149.5214	78	-5.808
COD, High level, mg/L	9.9531	9.3	23	1	4.3804	49	No Trend
DO mg/L	7.5824	8.1	13.2	0.94	3.2936	77	No Trend
Field pH	7.19333	7.15	8.45	6.43	0.36256	75	-0.025
NH_3+NH_4-N Total, mg/L	0.4517	0.165	2.95	0.04	0.6280	68	No Trend
NO_2-N, Total, mg/L	0.0389	0.02	0.17	0.01	0.0383	46	No Trend
NO_3-N, Total	0.7177	0.32	3.82	0.045	0.8264	65	No Trend
Phosphorus, dissolved orthoP, mg/L as P	0.0475	0.035	0.1	0.01	0.0308	20	No Trend
Phosphorus, Total in orthoP, mg/L P	0.0722	0.055	0.35	0.01	0.0385	46	No Trend
Phosphorus, Total, mg/L P	0.0917	0.075	0.465	0.01	0.0751	72	No Trend
Total Suspended Inorganic Solids, mg/L	8.7826	5	116	1	17.0125	46	No Trend
Total Inorganic Solids, mg/L	185.5154	185	290	80	62.5059	65	-3.500
Total Suspended Solids, mg/L	9.8310	6	142	1	17.2676	71	No Trend
Total Organic Solids, mg/L	48.8538	48	120	17	21.7532	65	No Trend
Total Solids, mg/L	234.3692	249	370	102	79.8756	65	No Trend
Total Suspended Organic Solids, mg/L	4.6053	3	26	1	4.5413	38	No Trend
Silica, dissolved, mg/L	8.8514	8.59	12.2	5.49	2.0319	21	--
Sulfate, Total	83.8875	74.1	440	26.4	54.8161	64	-2.5
Total Alkalinity C_aCO_3, mg/L	72.0346	74	126	27.2	28.3105	65	No Trend
Total Organic Carbon, mg/L	2.9387	2.6	8	0.87	1.5271	39	0.18
TDS	225.8525	257	359	87	82.8647	61	-3.792
Temperature, Celsius	11.0197	10	20.9	0.4	5.5451	77	No Trend
Total Hardness $CaCO_3$, mg/L	143.6738	130	236	53	53.2135	65	-2.667
TKN, mg/L	0.7141	0.4	3.2	0.1	0.6831	64	No Trend
Turbidity, JTU	9.695	6.95	37	2.2	8.7730	20	--
Turbidity Hach Turbidimeter, FTU	8.5454	5.27	80	1.04	12.6222	45	No Trend

Table 7.5 Summary of Moods Median Test on Conductivity at 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	218.3329	133	320.4	A	
Spring	231.3684	106.83	435.67	A	
Summer	427.336	178.5	1201		B
Fall	402.7722	199.67	526		B

Table 7.6 Summary of Moods Median Test on COD at 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	9.392857	1	23	A	B
Spring	7.75	3.3	14	A	
Summer	9.790909	7	12	A	B
Fall	12.95833	7.7	21		B

Table 7.7 Summary of Moods Median Test on DO at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group		
Winter	10.8919	7.04	13.2			C
Spring	8.755789	3.69	10.86		B	
Summer	4.19	0.94	8.46	A		
Fall	6.064444	2.07	12.97	A		

Table 7.8 Summary of Moods Median Test on NO_3-N at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	0.291667	0.12	0.47	A	
Spring	0.29667	0.06	1.43	A	
Summer	0.81	0.05	3.13	A	B
Fall	1.5	0.28	3.82		B

Table 7.9 Summary of Moods Median Test on Sulfate at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	57.19444	27.2	106	A	
Spring	65.0125	26.4	132	A	
Summer	118.84	38.3	440		B
Fall	101.1	43.3	142		B

Table 7.10 Summary of Moods Median Test on Total Organic Carbon at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	2.348333	0.87	4.1	A	B
Spring	2.16	1.33	2.8	A	
Summer	4.035556	2.58	8		B
Fall	3.56375	1.71	7.3	A	B

Table 7.11 Summary of Moods Median Test on Phosphorus Total in orthoP at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	0.035	0.01	0.08	A	
Spring	0.041	0.02	0.11	A	
Summer	0.134167	0.04	0.35		B
Fall	0.073333	0.01	0.13	A	B

Table 7.12 Summary of Moods Median Test on Total Phosphorus at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	0.051053	0.01	0.14	A	
Spring	0.057647	0.02	0.23	A	
Summer	0.148947	0.03	0.47		B
Fall	0.107647	0.02	0.18	A	B

Table 7.13 Summary of Moods Median Test on Residue, dissolved at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	154.4167	103	267	A	
Spring	158.7	84	292	A	
Summer	257.2917	136	318		B
Fall	274.2727	204	325		B

Table 7.14 Summary of Moods Median Test on Total Inorganic Solids at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	136.2222	88	220	A	
Spring	144	80	239	A	
Summer	228.6563	118	290		B
Fall	242.9333	191	278		B

Table 7.15 Summary of Moods Median Test on Total Organic Solids at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group
Winter	36	17	66	A
Spring	36.875	20	85	A
Summer	62.46875	31	120	B
Fall	62.53333	28	86	B

Table 7.16 Summary of Moods Median Test on Total Solids at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group
Winter	172.2222	115	276	A
Spring	180.875	102	317	A
Summer	291.125	149	370	B
Fall	305.4667	231	351	B

Table 7.17 Summary of Moods Median Test on Total Alkalinity C_aCO_3 at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group
Winter	48.5	27.2	83.8	A
Spring	52.2625	28.4	76.3	A
Summer	91.25938	50.1	118	B
Fall	102.5667	76.1	126	B

Table 7.18 Summary of Moods Median Test on Temperature at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group
Winter	6.042857	0.4	12	A
Spring	13.20789	7.2	19.4	B
Summer	16.96368	2.11	20.9	C
Fall	8.241667	1.5	15.6	A

Table 7.19 Summary of Moods Median Test on Total Hardness C_aCO_3 at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group
Winter	102.9889	64.1	180	A
Spring	109.625	53	182	A
Summer	179.625	87	224	B
Fall	190.4667	100	236	B

Table 7.20 Summary of Moods Median Test on TDS at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	157.4667	103	273	A	
Spring	170.75	87	314	A	
Summer	281.9375	111	359		B
Fall	298	227	345		B

Table 7.21 Summary of Moods Median Test on TKN at station 9-LRR001.39.

Season	Mean	Min	Max	Median Group	
Winter	0.447059	0.1	1.1	A	B
Spring	0.3875	0.2	1.4	A	
Summer	1.1	0.1	3.2		B
Fall	0.953333	0.3	2.8		B

8. REFERENCE WATERSHED SELECTION

A reference watershed approach was used to estimate the necessary load reductions that are needed to restore a healthy aquatic community and allow the streams in the Laurel Fork watershed to achieve their designated uses. This approach is based on selecting a non-impaired watershed that has similar land use, soils, stream characteristics (*e.g.*, stream order, corridor, slope), area (not to exceed double or be less than half that of the impaired watershed), and is in the same ecoregion as the impaired watershed. The modeling process uses load rates or pollutant concentrations in the non-impaired watershed as a target for load reductions in the impaired watershed. The impaired watershed is modeled to determine the current load rates and establish what reductions are necessary to meet the load rates of the non-impaired watershed.

Ten potential reference watersheds were selected from the Central Appalachians ecoregion for analyses that would lead to the selection of a reference watershed for Laurel Fork (Figure 8.1). The potential reference watersheds were ranked based on quantitative and qualitative comparisons of watershed attributes (*e.g.*, land use, soils, slope, stream order, and watershed size). Tables 8.1 and 8.2 show Laurel Fork and the potential reference streams and the information that was utilized to compare them.

Based on these comparisons and after conferring with state and regional VADEQ personnel, the South Fork Powell River watershed, Wise County, VA was selected as the reference watershed for the streams in the Laurel Fork watershed. The South Fork Powell River watershed is a good choice as the reference watershed because of the similarities in size, slope and land use. Computer simulation models have been developed to simulate flow and sediment loads in the South Fork Powell River.

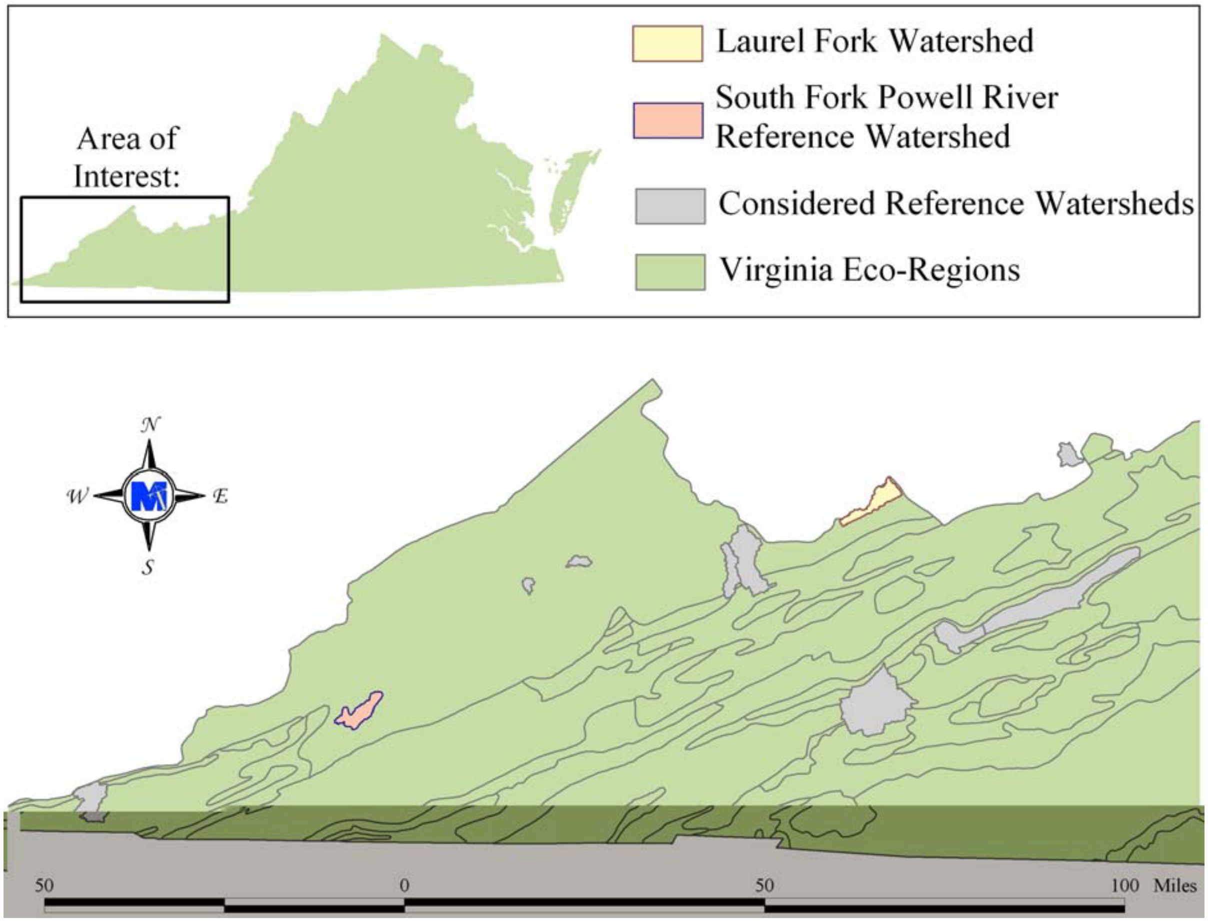

Figure 8.1 Location of selected and potential reference watersheds.

Table 8.1 Reference watershed selection for Laurel Fork - Part 1.

Stream	Laurel Fork	South Fork Powell River	Indian Creek	Middle Creek	Martin Creek	Adair Run
Basin	New River	Tnn_BS	Tnn_BS	Tnn_BS	Tnn_BS	New River
HUC	05050002	06010206	06010206	06010205	06010206	05050002
Area (acres)	9,526	8,420	18,288	7,148	11,220	4,399
Stream Order	2	3	3	2	2	2
Land use						
Active Mining			4.67			
AML/Bare Rock, Sand & Clay	506.44			77.84		
Barren		2.00	162.12	0.89	1.56	1.56
Commercial	14.28		0.89	17.79	0.44	0.00
Crops	84.12	0.22	223.28	31.36	501.93	127.43
Forest	8,446	8,015	16,648	6,932	6,357	3,718
Livestock Access	4			57.60		
Pasture	185.11	305.79	1,204		4,329	548.41
Reclaimed	91.62			26.24		
Residential	71.57	1.33	18.90		20.46	0.67
Water	100.14	66.05	10.45	1.78	6.23	2.00
Wetlands	15.09	32.91	13.79	0.22	5.11	0.00
Slope (degrees):	15.87	16.49	16.93	21.15	13.49	15.94
Aspect (degrees)	165.40	188.89	182.17	186.40	186.64	158.98
Soil Type						
TN134_MUID						
TN151_MUID		4.44	16.92		64.66	
TN164_MUID				1.47		
VA001_MUID						
VA002_MUID						
VA003_MUID	13.90					
VA004_MUID					13.46	
VA005_MUID						

Table 8.1 Reference watershed selection for Laurel Fork - Part 1 (cont.)

Stream	Laurel Fork	South Fork Powell River	Indian Creek	Middle Creek	Martin Creek	Adair Run
Soil Type						
VA006_MUID						
VA007_MUID						
VA016_MUID						
VA017_MUID					4.78	
VA018_MUID						
VA020_MUID						
VA054_MUID			7.01			0.31
VA055_MUID			71.47	76.95		
VA056_MUID		95.56	4.59	21.58	17.11	
VA057_MUID						2.91
VA062_MUID						96.78
VA077_MUID	86.10					
Soil Characteristics						
Hydrologic Group (avg):	2.57	2.68	2.57	2.64	2.30	2.77
Erodibility Kffactor	0.27	0.22	0.27	0.26	0.25	0.25
Available Water Capacity	0.11	0.09	0.11	0.10	0.13	0.10
Unsat SMC	0.96	0.78	0.99	0.86	1.29	1.14
Sub-ecoregion						
Cumberland Mountains	100	100	78.37	92.27	5.20	
Greenbrier Karst						100
Interior Plateau						
Southern Dissected Ridges and Knobs						
Southern Igneous Ridges and Mountains			21.63	1.93	76.27	
Southern Limestone/Dolomite Valleys and Low Rolling Hills					18.54	
Southern Sedimentary Ridges				5.80		
Southern Sandstone Ridges						

Table 8.2 Reference watershed selection for Laurel Fork – Part 2.

Stream	Laurel Fork	Stony Fork	Little Walker Creek	Fox Creek	Left Fork Lick Creek	Middle Fork Holston River
Basin	New River	New River	New River	Tnn_BS	Tnn_BS	Tnn_BS
HUC	05050002	05050001	05050002	05070202	05070202	06010102
Area (acres)	9,526	10,625	36,096	2,196	1,445	37,809
Stream Order	2	2	2	2	2	3
Land use						
Active Mining					0.44	11.56
AML/Bare Rock, Sand & Clay	506.44					
Barren		21.79	128.32	42.03		91.85
Commercial	14.28	13.12	35.58			591.34
Crops	84.12	30.69	539.96	7.34	11.34	390.52
Forest	8,446	10,437	32,665	2,129	1,430	27,388
Livestock Access	4					
Pasture	185.11	119.20	2,713	15.34	5.34	8,668
Reclaimed	91.62					
Residential	71.57	4.45	2.45	0.22	0.44	600.68
Water	100.14	1.56	4.67	1.33		8.01
Wetlands	15.09	0.22				32.69
Slope (degrees):	15.87	18.78	18.55	25.27	25.43	14.78
Aspect (degrees)	165.40	182.88	177.41	193.42	177.80	192.69
Soil Type						
TN134_MUID		72.94	71.28			26.05
TN151_MUID		18.46				29.96
TN164_MUID			13.22			
VA001_MUID		8.60	15.50		51.51	10.92
VA002_MUID						
VA003_MUID	13.90					
VA004_MUID						22.75
VA005_MUID						10.33

Table 8.2 Reference watershed selection for Laurel Fork – Part 2 (cont.)

Stream	Laurel Fork	Stony Fork	Little Walker Creek	Fox Creek	Left Fork Lick Creek	Middle Fork Holston River
Soil Type						
VA006_MUID						
VA007_MUID						
VA016_MUID						
VA017_MUID						
VA018_MUID						
VA020_MUID						
VA054_MUID						
VA055_MUID						
VA056_MUID				100	48.50	
VA057_MUID						
VA062_MUID						
VA077_MUID	86.10					
Soil Properties						
Hydrologic Group (avg):	2.57	2.70	2.75	2.70	2.63	2.70
Erodibility Kffactor	0.27	0.22	0.23	0.22	0.20	0.23
Available Water Capacity	0.11	0.08	0.08	0.09	0.09	0.09
Unsat SMC	0.96	1.03	0.98	0.75	0.71	1.17
Sub-ecoregion						
Cumberland Mountains	100			100	100	
Greenbrier Karst						
Interior Plateau						
Southern Dissected Ridges and Knobs		52.55				23.51
Southern Igneous Ridges and Mountains						30.25
Southern Limestone/Dolomite Valleys and Low Rolling Hills		47.45	100			6.36
Southern Sedimentary Ridges						20.17
Southern Sandstone Ridges						19.70

9. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of a TMDL for the Laurel Fork watershed, the relationship was defined through computer modeling based on data collected throughout the watershed. Monitored water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration, and model application for sediment is discussed.

As described in Chapter 8 of this document, the South Fork Powell River in Wise County, VA was selected as the reference watershed.

9.1 Modeling Framework Selection

A reference watershed approach was used in this study to develop a benthic TMDL for sediment for the Laurel Fork watershed. As noted in Chapters 7, sediment was identified as the probable stressor for Laurel Fork. A watershed model was used to simulate sediment loads from potential sources in Laurel Fork and the South Fork Powell River reference watershed. The model used in this study was the *Visual Basic™* version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The model also included modifications made by Yagow et al., 2002 and BSE, 2003. Numeric endpoints were based on unit-area loading rates calculated for the reference watershed. The TMDL was then developed for the impaired watershed based on these endpoints and the results from load allocation scenarios.

The GWLF model was developed at Cornell University (Haith and Shoemaker, 1987; Haith, et al., 1992) for use in ungaged watersheds. It was chosen for this study as the model framework for simulating sediment. GWLF is a continuous simulation, spatially lumped model that operates on a daily time step for water balance calculations and monthly calculations for sediment and nutrients from daily water balance. In addition to runoff and sediment, the model simulates dissolved and attached nitrogen and phosphorus loads delivered to streams from watersheds with both point and nonpoint sources of pollution. The model considers flow input from both surface and groundwater. Land use classes are used as the basic unit for representing variable source areas. The calculation of nutrient loads from septic systems, stream-bank erosion from livestock access, and the inclusion of sediment and nutrient loads from point sources are also supported. Runoff is simulated based on the Soil Conservation Service's Curve Number method (SCS, 1986). Erosion is calculated from a modification of the Universal Soil Loss Equation (USLE) (Schwab et al., 1981; Wischmeier and Smith, 1978). Sediment estimates use a delivery ratio based on a function of watershed area and erosion estimates from the modified USLE. The sediment transported depends on the transport capacity of runoff.

For execution GWLF uses three input files for weather, transport, and nutrient loads. The weather file contains daily temperature and precipitation for the period of record. Data are based on a water year typically starting in April and ending in March. The transport file contains input data related to hydrology and sediment transport. The nutrient file contains primarily nutrient values for the various land uses, point sources, and septic system types, but does include urban sediment buildup rates.

9.2 GWLF Model Setup

Watershed data needed to run GWLF used in this study were generated using GIS spatial coverage, local weather data, streamflow data, literature values, and other data. Watershed boundaries for the impaired stream segment and the selected reference watershed were delineated from USGS 7.5 minute digital topographic maps using GIS techniques. The reference watershed outlet for South Fork Powell River was located at biological monitoring station 6CSFH098.10. For the sediment TMDL development, the total area for the South Fork Powell River reference watershed was equated with the area of Laurel Fork watershed. To accomplish this, the area of land use categories in reference watershed, South Fork Powell River, was proportionately increased based on the percentage land use distribution. As a result, the watershed area for South Fork Powell River was increase to be equal to the watershed areas for the Laurel Fork watershed.

The GWLF model was developed to simulate runoff, sediment and nutrients in ungaged watersheds based on landscape conditions such as land use/land cover, topography, and soils. In essence, the model uses a form of the hydrologic units (HU) concept to estimate runoff and sediment from different pervious areas in the watershed (Li, 1975; England, 1970). In the GWLF model, the nonpoint source load calculation for sediment is affected by land use activity (*e.g.,* farming practices), topographic parameters, soil characteristics, soil cover conditions, stream channel conditions, livestock access, and weather. The model uses land use categories as the mechanism for defining homogeneity of source areas. This is a variation of the HU concept, where homogeneity in hydrologic response or nonpoint source pollutant response would typically involve the identification of soil land use topographic conditions that would be expected to give a homogeneous response to a given rainfall input. A number of parameters are included in the model to index the effect of varying soil-topographic conditions by land use entities. A description of model parameters is given in section 9.2.1 followed by a description of how parameters and other data were calculated and/or assembled.

9.2.1 Description of GWLF Model Input Parameters

The following description of GWLF model input parameters was taken from a TMDL Draft report prepared by BSE, 2003.

Hydrologic Parameters

Watershed Related Parameter Descriptions

- *Unsaturated Soil Moisture Capacity (SMC): The amount of moisture in the root zone, evaluated as a function of the area-weighted soil type attribute – available water capacity.*

- *Recession Coefficient (/day): The recession coefficient is a measure of the rate at which streamflow recedes following the cessation of a storm, and is approximated by averaging the ratios of streamflow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph.*

- *Seepage Coefficient (/day): The seepage coefficient represents the amount of flow lost to deep seepage.*

Running the model for a 3-month period prior to the chosen period during which loads were calculated, initialized the following parameters.

- *Initial unsaturated storage (cm): Initial depth of water stored in the unsaturated (surface) zone.*
- *Initial saturated storage (cm): Initial depth of water stored in the saturated zone.*
- *Initial snow (cm): Initial amount of snow on the ground at the beginning of the simulation.*
- *Antecedent Rainfall for each of 5 previous days (cm): The amount of rainfall on each of the five days preceding the first day in the weather files.*

Month Related Parameter Descriptions

- *Month: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model and its assumption that stored sediment is flushed from the system at the end of each Apr-Mar cycle. Model output was modified in order to summarize loads on a calendar year basis.*
- *ET CV: Composite evap-transpiration cover coefficient, calculated as an area-weighted average from land uses within each watershed.*
- *Hours per Day: mean number of daylight hours.*
- *Erosion Coefficient: This a regional coefficient used in Richard's equation for calculating daily erosivity. Each region is assigned separate coefficients for the months October-March, and for April-September.*

Sediment Parameters

Watershed-Related Parameter Descriptions

- *Sediment Delivery ratio: The fraction of erosion – detached sediment – that is transported or delivered to the edge of the stream, calculated as the inverse function of watershed size (Evans et al., 2001).*

Land use-Related Parameter Descriptions

- *USLE K-factor (erodibility): The soil erodibility factor was calculated as an area weighted average of all component soil types.*
- *USLE LS-factor: This factor is calculated from slope and slope length.*
- *USLE C-factor: The vegetative cover factor for each land use was evaluated following GWLF manual guidance and Wischmeier and Smith (1978).*
- *Daily sediment build-up rate on impervious surfaces: The daily amount of dry deposition deposited from the air on impervious surfaces on days without rainfall, assigned using GWLF manual guidance.*

Streambank Erosion Parameter Descriptions (Evans, 2002)

- *% Developed Land: Percentage of the watershed with urban-related land uses- defined as all land in MDR, HDR, and COM land uses, as well as the impervious portions of LDR.*
- *Animal density: Calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by watershed area in acres.*
- *Stream length: Calculated as the total stream length of natural stream channel, in meters. Excludes the non-erosive hardened and piped sections of the stream.*
- *Stream length with livestock access: calculated as the total stream length in the watershed where livestock have unrestricted access to streams, resulting in streambank trampling, in meters.*

9.3 Source Assessment

Three source areas were identified as the primary contributors to sediment loading in the impaired watershed that are the focus of this study – surface runoff, point sources, and streambank erosion. The sediment process is a continual process but is often accelerated by human activity. An objective of the TMDL process is to minimize the acceleration process. This section describes predominant sediment source areas, model parameters, and input data needed to simulate sediment loads.

9.3.1 Surface Runoff

During runoff events (natural rainfall or irrigation), sediment is transported to streams from pervious land areas (*e.g.,* agricultural fields, lawns, forest.). Rainfall energy, soil cover, soil characteristics, topography, and land management affect the magnitude of sediment loading. Agricultural management activities such as overgrazing (particularly on steep slopes), high tillage operations, livestock concentrations (*e.g.,* along stream edge, uncontrolled access to streams), forest harvesting, and land disturbance due to mining and construction (roads, buildings, etc.) all tend to accelerate erosion at varying degrees. During dry periods, sediment from air or traffic builds up on impervious areas and is transported to streams during runoff events. The magnitude of sediment loading from this source is affected by various factors (*e.g.,* the deposition from wind erosion and vehicular traffic).

9.3.2 Channel and Streambank Erosion

An increase in impervious land without appropriate stormwater control increases runoff volume and peaks, which leads to greater channel erosion potential. It has been well documented that livestock with access to streams can significantly alter physical dimensions of streams through trampling and shearing (Armour et al., 1991; Clary and Webster, 1989; Kaufman and Kruger, 1984). Increasing the bank full width decreases stream depth, increases sediment, and adversely affects aquatic habitat (USDI, 1996).

9.3.3 TSS Point Sources

Sediment loads from any permitted wastewater, industrial, and construction stormwater dischargers are included in the WLA component of a TMDL, in compliance with 40 CFR§130.2(h). Three VPDES point sources are permitted in the Laurel Fork watershed (Table 3.2 and Figure 3.2). TSS loads from the Pocahontas STP and the Residence STP are included in the existing sediment loads. TSS loads from the Northern Tazewell County WWTF and the Residence STP are included in the future sediment loads.

The TSS loading from uncontrolled discharges (straight pipes) was accounted for in the GWLF model results. A TSS concentration from human waste was estimated as 320 mg/L (Lloyd, 2004).

9.4 Sediment Source Representation – Input Requirements

9.4.1 Streamflow and Weather data

Daily precipitation and temperature data were available within the Laurel Fork watershed at the Flattop National Climatic Data Center (NCDC) Coop station #463072. The missing values were filled with daily values from the Richlands NCDC Coop station #447174. The model for Laurel Fork was calibrated using continuous streamflow data from USGS Station #03177700 on the Bluestone River near Bluefield, VA.

Precipitation and temperature data for the reference watershed were obtained from the Big Stone Gap NCDC Coop station #440735 filled with data from Wise 3E NCDC Coop station #449215.

9.4.2 Land use and Land cover

Land use areas were estimated as described in section 3.1. Land use distributions for Laurel Fork and the South Fork Powell River are given in Table 9.1. Land use acreage for the South Fork Powell River watershed was adjusted by the ratio of impaired watershed to reference watershed maintaining the original land use distribution.

The weighted C-factor for each land use category was estimated following guidelines given in Wischmeier and Smith, 1978, GWLF User's Manual (Haith et al., 1992), and Kleene, 1995. Where multiple land use classifications were included in the final TMDL classification, *e.g.,* pasture/hay, each classification was assigned a C-factor and an area weighted C-factor calculated.

Table 9.1 Land use areas for the impaired, reference, and area-adjusted reference watersheds.

Land use	Laurel Fork (ha)[1]	Reference Watershed So. Fork Powell (ha)[1]	So. Fork Powell Area-Adjusted (ha)[1]
Pervious Area:			
AML	205.01	0.00	0.00
Commercial	3.52	0.49	0.56
Forest-disturbed	12.49	195.34	221.10
Forest	3,408.31	3,060.37	3,463.93
Pasture - Hay	74.99	122.22	138.33
LAX	1.65	0.00	0.00
Residential	26.65	0.37	0.42
High Tillage	23.51	0.00	0.00
Low Tillage	10.56	0.00	0.00
Water	40.52	26.71	30.23
Reclaimed	37.08	0.00	0.00
Wetlands	6.11	0.00	0.00
Impervious Area:			
Commercial	2.25	0.32	0.36
Residential	2.32	0.03	0.04
Watershed Total	**3,855**	**3,406**	**3,855**

[1] 1ha = 2.47 ac

9.4.3 Sediment Parameters

Sediment parameters include USLE parameters K, LS, C, and P, sediment delivery ratio, and a buildup and loss functions for impervious surfaces. The product of the USLE parameters, KLSCP, is entered as input to GWLF. Soils data for the Laurel Fork and the South Fork Powell River were obtained from the Soil Survey Geographic (SSURGO) database for Virginia (SCS, 2004). The K factor relates to a soil's inherent erodibility and affects the amount of soil erosion from a given field. The area-weighted K-factor by land use category was calculated using GIS procedures. Land slope was calculated from USGS Digital Elevation Models (DEMs) using GIS techniques. The length-of-slope was based on VirGIS procedures given in VirGIS Interim Reports (*e.g.,* Shanholtz et al., 1988). The area-weighted

LS factor was calculated for each land use category using procedures recommended by Wischmeier and Smith (1978).

9.4.4 Sediment Delivery Ratio

The sediment delivery ratio specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size. The sediment delivery ratios for impaired and reference watersheds were calculated as an inverse function of watershed size (Evans et al., 2001).

9.4.5 SCS Runoff Curve Number

The runoff curve number is a function of soil type, antecedent moisture conditions, and cover and management practices. The runoff potential of a specific soil type is indexed by the Soil Hydrologic Group (HG) code. Each soil-mapping unit is assigned HG codes that range in increasing runoff potential from A to D. The soil HG code was given a numerical value of 1 to 4 to index HG codes A to D, respectively. An area-weighted average HG code was calculated for each land use/land cover from soil survey data using GIS techniques. Runoff curve numbers (CN) for soil HG codes A to D were assigned to each land use/land cover condition for antecedent moisture condition II following GWLF guidance documents and SCS (1986) recommended procedures. The runoff CN for each land use/land cover condition then was adjusted based on the numeric area-weighted soil HG codes.

9.4.6 Parameters for Channel and Streambank Erosion

Parameters for streambank erosion include animal density, total length of streams with livestock access, total length of natural stream channel, percent of developed land, mean stream depth, and watershed area. The animal density was calculated by dividing the number of livestock (beef and dairy) by watershed area in acres. The total length of the natural stream channel was estimated from USGS NHD hydrography coverage using GIS techniques. The mean stream depth was estimated as a function of watershed area.

9.4.7 Evapo-transpiration Cover Coefficients

Evapotranspiration (ET) cover coefficients were entered by month. Monthly ET cover coefficients were assigned each land use/land cover condition (from MRLC classification) following procedures outlined in Novotny and Chesters (1981) and GWLF guidance. Area-weighted ET cover coefficients were then calculated for each sediment source class.

9.4.8 TSS Point Sources

Permitted loads were calculated as the design flow multiplied by the maximum permitted TSS concentration.

9.5 Selection of Representative Modeling Period

Selection of the modeling period was based on two factors: availability of data (discharge and water-quality) and the need to model representative and critical hydrological conditions. Using these criteria, a modeling period was selected for hydrology calibration.

As described in Chapter 4, an analysis of historic precipitation and streamflow in Laurel Fork was preformed to select a representative time frame (Table 4.3). The time period chosen was water year 1993 through water year 1997.

9.6 Sensitivity Analysis

Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.*, seasonal and spatial variability of land disturbance, runoff curve number, etc.). Sensitivity analyses were run on the runoff curve number (CN) and the combined erosion factor (KLSCP), which combines the effects of soil erodibility, land slope, land cover, and management practices (Table 9.2). For a given simulation, the model parameters in Table 9.2 were set at the base value except for the parameter being evaluated. The parameters were adjusted to -10%, and 10% of the base value. Results are listed in Table 9.3. The results show that the parameters are directly correlated with runoff and sediment load. The relationships show fairly linear responses, with outputs being more sensitive to changes in CN than KLSCP. The results tend to reiterate the need to carefully evaluate conditions in the watershed and follow a systematic protocol in establishing values for model parameters.

Table 9.2 Base watershed parameter values used to determine hydrologic and sediment response for Laurel Fork.

Land use	Laurel Fork CN	Laurel Fork KLSCP
Pervious Area:		
AML	78.67	0.2267
Commercial	70.89	0.0053
Forest-disturbed	72.24	0.1313
Forest	63.40	0.0016
Pasture - Hay	70.02	0.0149
LAX	84.88	0.3410
Residential	68.16	0.0109
High Tillage	80.85	0.6780
Low Tillage	77.71	0.1853
Water	100.00	0.0118
Reclaimed	65.84	0.2819
Wetlands	78.40	0.0001
Impervious Area:		
Commercial	98.00	0.0127
Residential	98.00	0.0016

Table 9.3 Sensitivity of GWLF model response to changes in selected parameters for Laurel Fork.

Model Parameter	Parameter Change (%)	Total Runoff Volume (%)	Total Sediment Load (%)
CN	10	59.37	17.33
CN	-10	-56.94	-18.65
KLSCP	10	0	9.70
KLSCP	-10	0	-9.70

9.7 Hydrology Calibration of GWLF

Although the GWLF model was originally developed for use in ungaged watersheds, calibration was performed to ensure that hydrology was being simulated accurately. This process was preferred in order to minimize errors in sediment simulations due to potential gross errors in hydrology. The model's parameters were assigned based on available soils, land use, and topographic data. Parameters that were adjusted during calibration included the recession constant, the evapotranspiration cover coefficients, the unsaturated soil moisture storage, and the seepage coefficient.

Hydrologic calibration was performed for Laurel Fork and South Fork Powell River at nearby streams, as no suitable stream flow data existed within either watershed. Hydrologic calibration for Laurel Fork was performed at USGS station #03179000, Bluestone River near Pipestem, WV and hydrologic calibration for South Fork Powell River was performed at USGS station #03531500, Powell River near Jonesville, VA.

The same paired watershed that was used to calibrate the HSPF model for the bacteria TMDL (Sand Run in Upshur County, WV) could have been used for the GWLF hydrology calibration, but given that GWLF is not as sensitive to watershed size since it is a simplified lumped-parameter watershed model that calculates the load on a monthly basis, the use of the Bluestone River gaging station was considered appropriate for the GWLF hydrology calibration. Bluestone River is in the same ecoregion with similar topography, climate, soils and land use, and has an added advantage for the GWLF hydrology calibration because of its proximity to Laurel Fork.

9.7.1 South Fork Powell River – Reference Stream

The final GWLF calibration results for the Powell River are displayed in Figures 9.1 and 9.2 for the calibration period with statistics showing the accuracy of fit given in the Table 9.4.

Table 9.4 GWLF flow calibration statistics for Bluestone River and Powell River.

Watersheds	Simulation Period	R^2 Correlation value	Total Volume Error (Sim-Obs)
Bluestone River	4/1/1994 to 4/1/1997	0.854	0.029
Powell River	4/1/1994 to 4/1/1997	0.883	-0.090

9.7.2 Laurel Fork – Impaired Stream

The final GWLF calibration results for Bluestone River are displayed in Figures 9.3 and 9.4 for the calibration period with statistics showing the accuracy of fit given in the Table 9.4.

9.7.3 GWLF Hydrology Calibration Statistics

Model calibrations were considered good for total runoff volume (Table 9.4). Monthly fluctuations were variable but were still reasonable considering the general simplicity of GWLF. Results were also consistent with other applications of GWLF in Virginia (*e.g.,* Tetra Tech, 2002 and BSE, 2003).

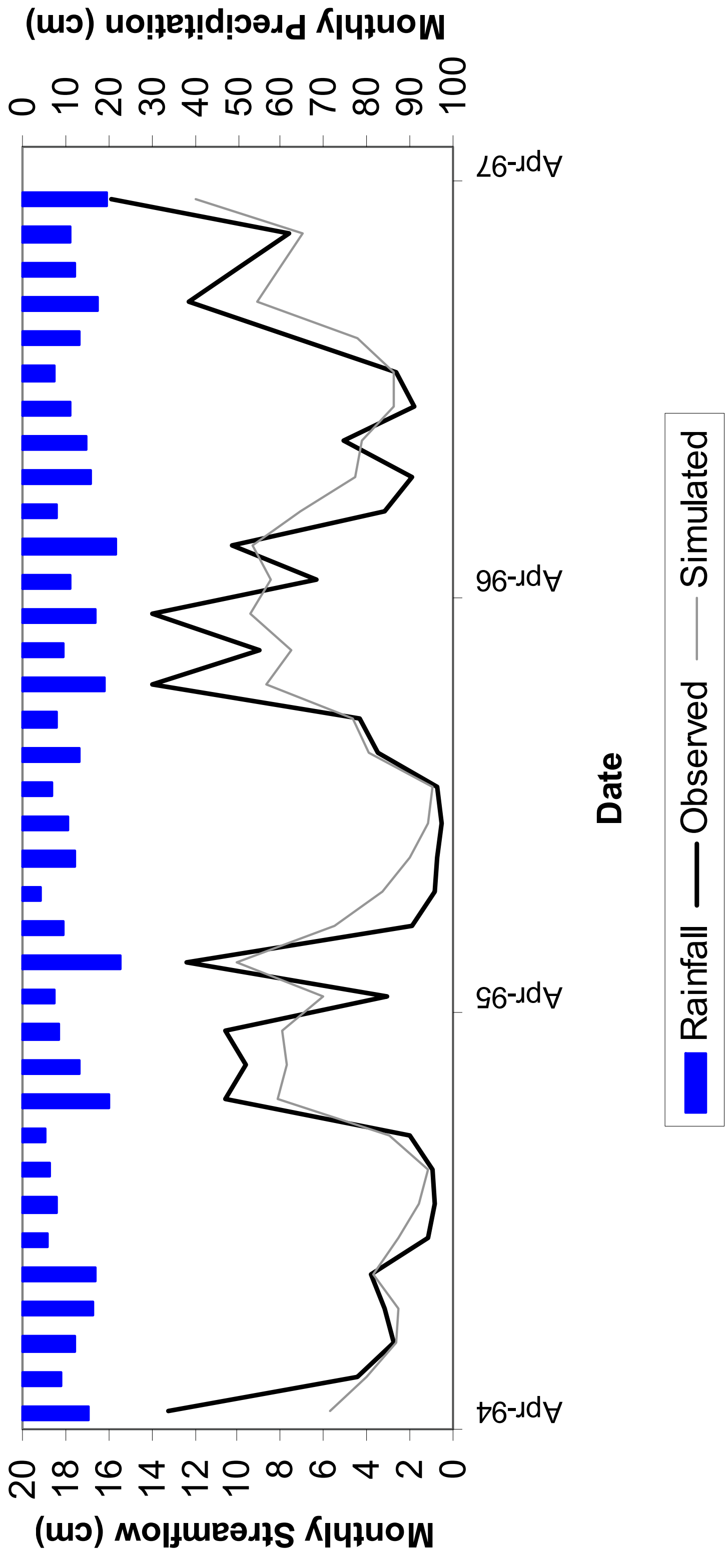

Figure 9.1 Comparison of monthly GWLF simulated (modeled) and monthly observed stream flow at USGS Station #03531500 for the Powell River.

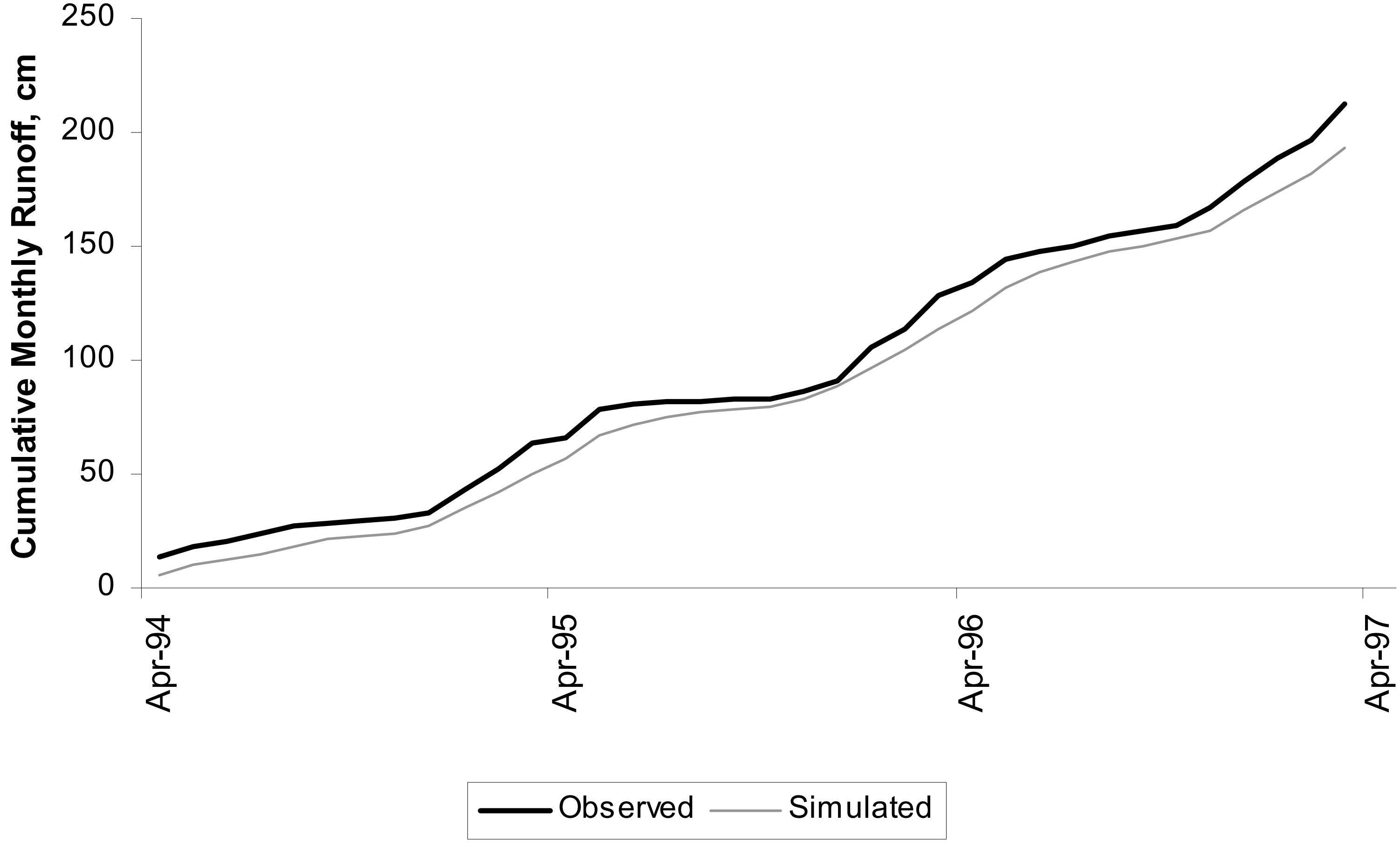

Figure 9.2 **Comparison of cumulative monthly GWLF simulated (Modeled) and cumulative monthly observed stream flow at USGS Station #03531500 for the Powell River.**

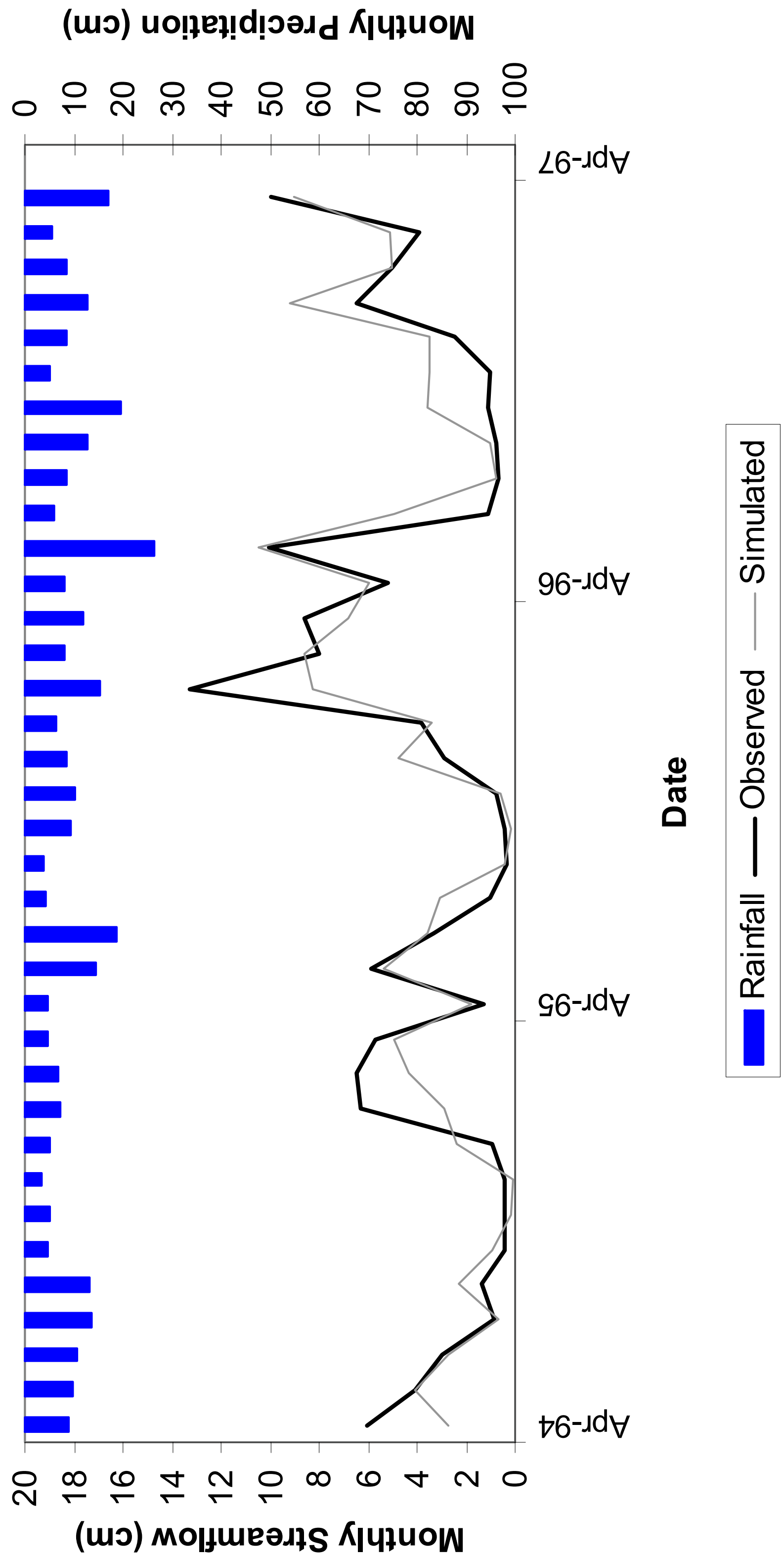

Figure 9.3 Comparison of monthly GWLF simulated (Modeled) and monthly observed stream flow at USGS Station #03179000 for Bluestone River.

Figure 9.4 **Comparison of cumulative monthly GWLF simulated (Modeled) and cumulative monthly observed stream flow at USGS Station #03179000 for Bluestone River.**

9.8 Existing Conditions - GWLF

A listing of parameters from the GWLF transport input files that were finalized during hydrologic calibration for conditions existing at the time of impairment are given in Tables 9.5 through 9.8. Watershed parameters for Laurel Fork and reference watershed South Fork Powell River are given in Table 9.5. Monthly evaporation cover coefficients are listed in Table 9.6.

Table 9.5 GWLF watershed parameters for existing conditions in the calibrated impaired and reference watersheds.

GWLF Watershed Parameter	Units	Laurel Fork	South Fork Powell River
Recession Coefficient	Day^{-1}	0.0454	0.013
Seepage Coefficient	Day^{-1}	0.02	0.0044
Sediment Delivery Ratio	---	0.15	0.15
Unsaturated Water Capacity	(cm)	11	6
Erosivity Coefficient (Apr-Sep)	---	0.25	0.25
Erosivity Coefficient (Oct-Mar)	---	0.06	0.06
% Developed land	(%)	0.90	0.036
Livestock density	(AU/ac)	0.00643	0.0076
Area-weighted soil erodibility (K)	---	0.2147	0.1659
Area weighted runoff curve number	---	65.04	65.68
Total Stream Length	(m)	224,813	48,924
Mean Channel depth	(m)	0.98	0.94

Table 9.6 Laurel Fork and reference watershed South Fork Powell River GWLF monthly evaporation cover coefficients for existing conditions.

Watershed	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Laurel Fork	0.31	0.95	0.95	0.95	0.95	0.95	0.95	0.31	0.31	0.31	0.32	0.32
South Fork Powell	0.32	0.99	0.99	0.99	0.99	0.99	0.99	0.62	0.31	0.31	0.32	0.32

Table 9.7 lists the area-weighted USLE erosion parameter and runoff curve number by land use erosion source areas for Laurel Fork and the reference watershed South Fork Powell River.

Table 9.7 GWLF land use parameters for existing conditions in the impaired and reference watersheds.

Land use	Laurel Fork		So. Fork Powell River	
	CN	KLSCP	CN	KLSCP
Pervious Area:				
AML	78.67	0.2267		
Commercial	70.89	0.0053	79.00	0.0021
Forest-disturbed	72.24	0.1313	70.87	0.2097
Forest	63.40	0.0016	65.00	0.0026
Pasture - Hay	70.02	0.0149	66.70	0.0060
LAX	84.88	0.3410		
Residential	68.16	0.0109	63.34	0.0032
High Tillage	80.85	0.6780		
Low Tillage	77.71	0.1853		
Water	100.00	0.0118	100.00	0.0012
Reclaimed	65.84	0.2819		
Wetlands	78.40	0.0001		
Impervious Area:				
Commercial	98.00	0.0127	98.00	0.0050
Residential	98.00	0.0016	98.00	0.0004

The sediment loads existing at the time of impairment were modeled for Laurel Fork and the reference watershed South Fork Powell River (SFP). The existing condition for the Laurel Fork watershed is the combined sediment load in metric tons per year (Mg/yr), which compares to the area-adjusted reference watershed South Fork Powell River load under existing conditions (Table 9.8).

Table 9.8 Existing sediment loads for the impaired and area-adjusted reference watersheds.

Sediment Source	Laurel Fork (Mg/yr)	Laurel Fork (Mg/ha/yr)	SFP (Area-Adjusted) (Mg/yr)	SFP (Area-Adjusted) (Mg/ha/yr)
Pervious Area:				
AML	1,610.58	7.86	0.00	
Commercial	0.51	0.15	0.05	0.10
Forest-disturbed	48.01	3.85	1,750.04	7.92
Forest	113.40	0.03	277.16	0.08
Pasture - Hay	30.70	0.41	27.60	0.20
LAX	21.63	13.13	0.00	
Residential	6.16	0.23	0.04	0.10
High Tillage	574.98	24.46	0.00	
Low Tillage	66.01	6.25	0.00	
Water	0.00		0.00	
Reclaimed	212.56	5.73	0.00	
Wetlands	0.26	0.04	0.00	
Impervious Area:				
Commercial	12.36	5.49	2.21	6.18
Residential	2.21	0.95	0.04	1.07
NPS Total	*2,699.37*		*2,057.14*	
Streambank Erosion	67.94		0.05	
Straight pipes	4.63		0.00	
Point Sources:				
Pocahontas STP	6.22			
Private residence	0.04			
Direct Sources Total	*78.82*		*0.05*	
Watershed Total	**2,778**		**2,057**	

10. SEDIMENT ALLOCATION

Total Maximum Daily Loads consist of waste load allocations (WLAs, permitted point sources) and load allocations (LAs, nonpoint sources), including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for uncertainties in the process. The definition is typically denoted by the expression:

$$TMDL = WLAs + LAs + MOS$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards. For sediment, the TMDL is expressed in terms of annual load in metric tons per year (Mg/yr).

This section describes the development of a TMDL for sediment for Laurel Fork using a reference watershed approach. The model was run over the period of 4/1/1994 to 3/1/1997 for sediment modeling for Laurel Fork. The target sediment TMDL load for Laurel Fork is the average annual load in metric tons per year (Mg/yr) from the area-adjusted South Fork Powell River watershed under existing conditions minus a 10% Margin of Safety (MOS).

10.1 Incorporation of a Margin of Safety

In order to account for uncertainty in modeled output, an MOS was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. For example, the typical method of assessing water quality through monitoring involves the collection and analysis of grab samples. The results of water quality analyses on grab samples collected from the stream may or may not reflect the “average” condition in the stream at the time of sampling. Calibration to observed data derived from grab samples introduces modeling uncertainty.

An MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The MOS for the Laurel Fork sediment TMDL was explicitly express as 10% of the area-adjusted reference watershed load in metric tons per year (206 Mg/yr).

10.2 Future Land Development Considerations

A review of the Tazewell County Comprehensive Plan (Tazewell County Planning Commission, 1996) indicated there would be minimal residential and commercial growth in the next 5 to 10 years; however, a new sewage treatment plant, the Northern Tazewell County WWTF, is expected to be in service in 2007. This treatment plant will serve a new prison and the town of Pocahontas. The resulting sediment load (Table 10.1) with the removal of the Pocahontas STP and the addition of the Northern Tazewell County WWTF is 14.51 Mg/yr greater than the sediment load from the existing land use scenario (Table 9.8); therefore the final sediment TMDL was calculated using the future scenario.

Table 10.1 Future sediment loads for the impaired and area-adjusted reference watersheds.

Sediment Source	Laurel Fork (Mg/yr)	Laurel Fork (Mg/ha/yr)	SFP (Area-Adjusted) (Mg/yr)	SFP (Area-Adjusted) (Mg/ha/yr)
Pervious Area:				
AML	1,610.58	7.86	0.00	
Commercial	0.51	0.15	0.05	0.10
Forest-disturbed	48.01	3.85	1,750.04	7.92
Forest	113.40	0.03	277.16	0.08
Pasture - Hay	30.70	0.41	27.60	0.20
LAX	21.63	13.13	0.00	
Residential	6.16	0.23	0.04	0.10
High Tillage	574.98	24.46	0.00	
Low Tillage	66.01	6.25	0.00	
Water	0.00		0.00	
Reclaimed	212.56	5.73	0.00	
Wetlands	0.26	0.04	0.00	
Impervious Area:				
Commercial	12.36	5.49	2.21	6.18
Residential	2.21	0.95	0.04	1.07
NPS Total	*2,699.37*		*2,057.14*	
Streambank Erosion	67.94		0.05	
Straight pipes	4.63		0.00	
Point Sources:				
Private residence	0.04			
Northern Tazewell County WWTF	20.73			
Direct Sources Total	*93.34*		*0.05*	
Watershed Total	**2,793**		**2,057**	

10.3 Sediment TMDL

The target TMDL load for Laurel Fork is the average annual load in metric tons per year (Mg/yr) from the area-adjusted South Fork Powell River watershed under existing conditions minus the MOS (206 Mg/yr). To reach the target goal (1,851 Mg/yr), three different scenarios were run with GWLF (Table 10.2). Sediment loads from straight pipes were reduced 100% in all scenarios due to health implications and the requirements of the fecal bacteria TMDL. Scenario 1 shows similar reductions to land-based sediment loads from AML (41%) disturbed forest (41%), pasture – hay (38%), livestock access

(LAX, 38%), high tillage row crops (38%), and streambank erosion (27%). Scenario 2 shows reductions to land-based loads from only AML (57%) and disturbed forest (39%). Scenario 3 shows reductions to sediment loads from AML (57%) and streambank erosion (28%). All three scenarios meet the TMDL goal at a total sediment load reduction of 33.7%. Scenario 1 was chosen to use for the final TMDL due to the similar reductions to many different sediment sources.

Table 10.2 Final TMDL allocation scenario for the impaired watershed.

Sediment Source	Laurel Sediment Loads (Mg/yr)	Scenario 1 Reductions (Final) (%)	Scenario 1 Allocated Loads (Mg/yr)	Scenario 2 Reductions (%)	Scenario 2 Loads (Mg/yr)	Scenario 3 Reductions (%)	Scenario 3 Loads (Mg/yr)
Pervious Area:							
AML	1,610.58	41	950.24	57	692.55	57	692.55
Commercial	0.51	0	0.51	0	0.51	0	0.51
Forest-disturbed	48.01	41	28.33	39	29.29	0	48.01
Forest	113.40	0	113.40	0	113.40	0	113.40
Pasture - Hay	30.70	38	19.03	0	30.70	0	30.70
LAX	21.63	38	13.41	0	21.63	0	21.63
Residential	6.16	0	6.16	0	6.16	0	6.16
High Tillage	574.98	38	356.49	0	574.98	0	574.98
Low Tillage	66.01	0	66.01	0	66.01	0	66.01
Water	0.00	0	0.00	0	0.00	0	0.00
Reclaimed	212.56	0	212.56	0	212.56	0	212.56
Wetlands	0.26	0	0.26	0	0.26	0	0.26
Impervious Area:	0.00	0	0.00	0	0.00	0	0.00
Commercial	12.36	0	12.36	0	12.36	0	12.36
Residential	2.21	0	2.21	0	2.21	0	2.21
Streambank Erosion	67.94	27	49.59	0	67.94	28	48.91
Straight pipes	4.63	100	0.00	100	0.00	100	0.00
Point Sources:	0.00	0	0.00	0	0.00	0	0.00
Private residence	0.04	0	0.04	0	0.04	0	0.04
Northern Tazewell County WWTF	20.73	0	20.73	0	20.73	0	20.73
Watershed Total	**2,793**	**33.7**	**1,851**	**33.7**	**1,851**	**33.7**	**1,851**

The sediment TMDL for Laurel Fork (Table 10.3) includes three components – WLA, LA, and the 10% MOS. The WLA was calculated as the sum of the permitted point source discharges. The LA was calculated as the target TMDL load minus the WLA load minus the MOS.

Table 10.3 TMDL targets in metric tons per year (Mg/yr) for the impaired watershed.

Impairment	WLA (Mg/yr)	LA (Mg/yr)	MOS (Mg/yr)	TMDL (Mg/yr)
Laurel Fork	21	1,830	206	2,057

The reductions required to meet the TMDLs were based on the future growth scenario. The final overall sediment load reduction required for Laurel Fork is 33.7% (Table 10.4).

Table 10.4 Required reductions for the impaired watershed.

Load Summary	Laurel Fork	Reductions Required	
	(Mg/yr)	(Mg/yr)	(% of existing load)
Future Sediment Loads	2,793	942	33.7
Target Modeling Load	1,851		

PART IV: DISSOLVED OXYGEN TMDL

11. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

11.1 Applicable Criteria for Dissolved Oxygen Impairments

Virginia state law 9VAC25-260-50 defines the numerical criteria for dissolved oxygen in mountainous zones waters as a minimum of 4.0 mg/L and a daily average of 5.0 mg/L. These criteria were used in initially listing Laurel Fork on the 1998 *303(d) Total Maximum Daily Load Priority List and Report* for violations of DO. Laurel Fork remained on the 2002 *303(d) Report on Impaired Waters* and the 2004 *305(b)/303(d) Water Quality Assessment Integrated Report* for violations of the DO water quality standard.

11.2 Assessment of the Dissolved Oxygen Violations

Tables 6.8 through 6.17 and section 7.4.2 provide a detailed summary of the DO concentrations measured at the seven monitoring stations on Laurel Fork. Fifteen of the 61 DO concentrations measured at monitoring station 9-LRR001.39 were below the VADEQ minimum WQS. Upstream monitoring stations 9-LRR004.03 and 9-LRR006.43 each had one violation of the DO standard.

Low DO in a free-flowing stream may be associated with excessive nutrients and high BOD loads. Total phosphorus values measured at station 9-LRR001.39 are not elevated and therefore not likely responsible for low DO in Laurel Fork. The high nitrate-nitrogen concentrations are considered to be from organic compounds (section 7.3.2). Also, from section 7.3.1, the parameters that are indicative of high organic matter reveal that it is elevated in Laurel Fork. Therefore, low DO levels observed in Laurel Fork are most likely due to a high content of organic matter.

Less than 3% of the Laurel Fork watershed is agriculture and there is a small population of livestock (section 3.3.3), therefore it is not likely that livestock is a significant contributor of organic matter to the stream. The Pocahontas STP has a history of operational problems and violations of their discharge limits. Also, comments from attendees at the first public meeting and conversation with the local VDH officials indicated that there are a high number of uncontrolled discharges and failing septic systems within the Laurel Fork watershed. Human sewage is the likely source of organic matter in Laurel Fork.

The fourteen low DO concentrations measured before June 1999 at station 9-LRR001.39, 0.69 miles downstream from the Pocahontas STP, have been attributed to sewer collection system failure and improper maintenance and operation of the Pocahontas STP (section 6.4.3). VADEQ reports that the problems found in the inspections at the STP were corrected and it has been in compliance with its VPDES permit limits over the past several years.

The most recent measurement of low DO at station 9-LRR001.39 occurred on August 5, 2003. The violation of the DO standard at the upstream monitoring station 9-LRR006.43, near the Boissevain sewer collection pump station, also occurred on the same date. Bacteria counts were extremely high on this date. The fecal coliform enumeration from the water sample collected at station 9-LRR001.39 on August 5, 2003 was 56,000 cfu/100mL; the *E. coli* enumeration was 39,000 cfu/100mL. BST results from the water sample collected this day showed that 88% of the isolates classified as human source (Table 2.3).

While no overflows of the sewer collection system were reported for this day, overflows have been reported throughout the Pocahontas collection system since the correction of the Pocahontas STP (Table 11.1). VADEQ recognizes that not all overflows are necessarily reported. The high bacteria concentrations along with the BST results indicating a highly significant contribution from human source suggests that a large amount of human sewage, possibly associated with an overflow within the sewer collection system, is the most likely cause of the DO violations at the two monitoring stations. Corrections to the sewer collection system and elimination of non-regulated discharges will insure that bacteria concentrations remain below WQS and that DO levels will be above the standard.

Table 11.1 Pocahontas Overflow Summary for April 2002 – January 2005.

Date	Location	Total Gallons	Cause
1/14/2005	Boissevain Pump Station	Unknown	Grease Blockage
7/21/2004	Interceptor above STP	Unknown	Unknown
11/19/2004	Main Pump Station	Unknown	Flooding
2/24/2003	Main Pump Station	Unknown	Flooding
2/18/2003	Main Pump Station	Unknown	Dry well flooded-Pumping out
11/13/2002	Main Pump Station	Unknown	Flooding
5/2/2002	Main Pump Station	Unknown	Flooding

The violation of the DO standard at monitoring station 9-LRR004.03 occurred on November 4, 2003. Nutrient concentrations were not measured at this station, but total phosphorus measurements at station 9-LRR001.39 have consistently been very low (average = 0.09 mg/L). The fecal coliform and *E. coli* concentrations measured at station 9-LRR004.03 on November 4, 2003 were above the maximum detection levels. The source of the high bacteria concentrations is considered to be exfiltration and overflows from the Pocahontas sewer system in addition to non-regulated sewage discharges. The presence of high bacteria concentrations at station9-LRR004.03 is an indicator of a high content of organic matter in the stream.

11.3 Selection of a TMDL Endpoint

The objective of a TMDL is to provide an allocated load from a pollutant source(s) to meet the WQS. Dissolved oxygen itself is not a pollutant source and from section 11.2 it has been determined that the pollutant source affecting the DO levels in Laurel Fork is the high content of organic matter from human waste. The fecal bacteria TMDL that was developed for Laurel Fork (Table 5.3) requires a 100% reduction of all non-permitted direct sources of human bacteria (*i.e.*, straight pipes, failing septic systems, sewage overflows, exfiltration) deposited to Laurel Fork. Given that the episodic events of low DO correspond to high bacteria concentrations in Laurel Fork, the fecal bacteria TMDL developed for Laurel Fork will provide the reductions of organic matter that are responsible for the low DO.

While the organic solids that enter Laurel Fork through runoff are not as predominant as the organic matter entering the stream directly through non-regulated discharges, the sediment TMDL that was developed for Laurel Fork (Table 10.3) will reduce the sources of organic matter entering the stream through runoff and therefore contribute to keeping the DO level in Laurel Fork above the WQS.

PART V: IMPLEMENTATION AND PUBLIC PARTICIPATION

12. IMPLEMENTATION

Once a TMDL has been approved by the EPA and then the State Water Control Board (SWCB), measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the Implementation Plan (IP). The process for developing an implementation plan has been described in the *Guidance Manual for Total Maximum Daily Load Implementation Plans,* published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

12.1 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses the sources with the largest impact on water quality. The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

12.1.1 Staged Implementation - Bacteria

In agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling the bacteria in urban runoff that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

12.1.1.1 Stage 1 Scenario - Bacteria

The goal of the Stage 1 scenario is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The Stage 1 scenario was generated with the same model setup as was used for the TMDL allocation scenarios (Table 12.1). Table 12.2 details the load reductions required for meeting the Stage 1 Implementation for Laurel Fork.

Table 12.1 Allocation scenarios for bacterial concentration with current loading estimates in the Laurel Fork impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	Direct Human Loads	NPS Residential Land	Geometric Mean > 126 cfu/100mL	Single Sample > 235 cfu/100mL
1[1]	0	0	70	78	100	78	0.00	9.97
2[2]	36	86	70	99	100	99	0.00	0.00

[1]Stage1 implementation scenario.
[2]Final TMDL allocation.

Table 12.2 Fecal coliform land-based loads deposited on all land uses and direct loads in the Laurel Fork watershed for existing conditions and for the Stage 1 implementation management scenario.

Source		Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based				
	AML	8.25E+12	8.25E+12	0
	Commercial	4.24E+11	9.33E+10	78
	Crops	2.08E+12	4.58E+11	78
	Forest	1.10E+14	1.10E+14	0
	Pasture	8.18E+13	1.80E+13	78
	Reclaimed	1.11E+12	1.11E+12	0
	Residential	6.40E+14	1.41E+14	78
	Wetlands	1.20E+12	1.20E+12	0
Direct				
	Human	3.52E+12	0.00E+00	100
	Livestock	3.08E+11	9.24E+10	70
	Wildlife	6.38E+12	6.38E+12	0

12.1.2 Staged Implementation – Benthic

Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

12.1.2.1 Stage 1 Scenario – Benthic

It is anticipated that reclamation of abandoned mine land and the correction of straight pipes will be initial targets of implementation. Table 12.3 shows a 41% reduction from abandoned mine land and a 100% reduction in straight pipes resulting in a 23.8% reduction in the sediment load, which is over half of the required overall reduction. Erosion and sediment deposition from disturbed land generally abate over time as new growth emerges. One practice that has been successful on some sites involves regrading and vegetating disturbed areas, and constructing diversion ditches to direct water away from the disturbed area. The goal of the Stage 1 scenario in Table 12.3 was to reduce the sediment in Laurel Fork to half of the TMDL goal.

Table 12.3 Sediment Stage 1 scenario for the Laurel Fork impairment.

Sediment Source	Laurel Fork Existing Loads	Scenario 1 Reductions (Stage I)	Scenario 1 Stage I Loads
	Mg/yr	(%)	Mg/yr
Pervious Area:			
AML	1,610.58	41	950.24
Commercial	0.51	0	0.51
Forest-disturbed	48.01	0	48.01
Forest	113.40	0	113.40
Pasture - Hay	30.70	0	30.70
LAX	21.63	0	21.63
Residential	6.16	0	6.16
High Tillage	574.98	0	574.98
Low Tillage	66.01	0	66.01
Water	0.00	0	0.00
Reclaimed	212.56	0	212.56
Wetlands	0.26	0	0.26
Impervious Area:			
Commercial	12.36	0	12.36
Residential	2.21	0	2.21
Streambank Erosion	67.94	0	67.94
Straight pipes	4.63	100	0.00
Point Sources:	0.00	0	0.00
Private residence	0.04	0	0.04
Northern Tazewell County WWTF	20.73	0	20.73
Watershed Total	2,793	23.8	2,128

One way to accelerate reclamation of AML is through remining. As noted on the Virginia Department of Mines, Minerals and Energy's website (DMME, 2006):

> *"DMME, The Nature Conservancy, Virginia Tech/Powell River Project, and the U. S. Office of Surface Mining combined resources to develop proposals for incentives that will promote economically viable, environmentally beneficial remining operations that reclaim AML sites. Initial meetings led to the development of a Remining Ad Hoc Work Group that includes representatives from industry, other governmental agencies, special interest groups, and citizens of Southwest Virginia. The Ad Hoc Group has identified existing incentives and continues to propose new ones".*

One of the most important existing incentives is the alternative effluent limitations assigned to remining operations with pre-existing pollutant discharges. These regulations (known as the Rahall Amendment) were the result of a 1987 revision to the Federal Clean Water Act (CWA). Alternate effluent discharge limits are allowed in coal mining areas with pre-existing effluent problems. Operators document effluent conditions prior to remining. Upon completion of the remining operation and prior to reclamation bond and permit release, the operator would need to demonstrate that the pollution load from the site is equal to or less than pre-mining pollution load. Because the remining revisions were promulgated after the original TMDL provisions of the CWA, pollution load allocations and implementation plans should be designed to preserve the incentives implicit in the Rahall Amendment. Potential remining site include all abandoned mine land (AML).

12.2 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to ongoing water quality improvement efforts aimed at restoring water quality in Virginia's streams. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of the strategy described under nonpoint source implementation mechanisms.

12.3 Reasonable Assurance for Implementation

12.3.1 Follow-Up Monitoring

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with Guidance Memo No. 03-2004 (VADEQ, 2003b), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or when deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not be required during the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with VADCR staff, the IP Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station(s). At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30th of each year.

VADEQ staff, in cooperation with VADCR staff, the IP Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request that the monitoring managers in each regional office increase the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent upon staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that water quality standards are being met in watersheds where corrective actions have been installed (whether or not a TMDL or IP has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (total suspended solids, dissolved oxygen, etc.) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one-year period.

12.3.2 Regulatory Framework

While Section 303(d) of the CWA and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and waste load allocations can and will be implemented. EPA also requires that all new or revised NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the SWCB to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 *Guidance for Water Quality-Based Decisions: The TMDL Process*. The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the VPDES program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and permitted sources are not usually addressed during the development of a TMDL implementation plan. However, the NPDES permits which cover the municipal separate storm sewer systems (MS4s) are expected to be included in TMDL implementation plans. For the implementation of the TMDL's LA component, a TMDL implementation plan addressing the WQMIRA requirements, at a minimum, will be developed.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the state's Water Quality Management Plans (WQMPs).

The WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin. VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the SWCB for inclusion in the appropriate WQMP, in accordance with the CWA's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on VADEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf.

12.3.3 Stormwater Permits

VADEQ and VADCR coordinate separate State programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates stormwater discharges associated with "industrial activities", while VADCR regulates stormwater discharges from construction sites and from MS4s.

EPA approved VADCR's VPDES stormwater program on December 30, 2004. VADCR's regulations became effective on January 29, 2005. VADEQ is no longer the regulatory agency responsible for administration and enforcement of the VPDES, MS4, and construction stormwater permitting programs. More information is available on VADCR's web site through the following link: http://www.dcr.virginia.gov/sw/vsmp.

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is VADCR's Virginia Stormwater Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq). Section 4VAC 50-60-380 describes the requirements for stormwater discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when: (2) Numeric effluent limitations are infeasible…"

For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL waste load allocations for stormwater through the implementation of programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Office of Water, 2002).

If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL waste load allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit. VADEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacterial TMDLs (see section 11.3.5 below.) At some future time, it may therefore become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis (UAA). Any changes to the TMDL resulting from water quality standards change on Laurel Fork would be reflected in the permit.

Waste load allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL implementation plans. An IP will identify types of corrective actions and strategies to obtain the waste load allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL IPs since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Management program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/vsmp.htm.

12.3.4 Implementation Funding Sources

Cooperating agencies, organizations, and stakeholders must identify potential funding sources available for implementation during the development of the IP in accordance with the *Guidance Manual for Total Maximum Daily Load Implementation Plans*. Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits, and landowner contributions. The *Guidance Manual for Total Maximum Daily Load Implementation Plans* contains additional information on funding sources as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Because sediment load from AML needs to be reduced to meet the benthic TMDL, DMME will be involved with identify funding sources for implementations. According to DMME's website, "Over 71,000 acres of land in Virginia have been affected by coal mining. It is estimated that it would take approximately 55 years at the present rate of funding and reclamation construction to reclaim just the high priority Abandoned Mine Land (AML) sites" (DMME, 2006). In addition, it would cost more than $300 million to reclaim the AML sites causing environmental degradation. One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration. Additional funding sources may be available through the U. S. Office of Surface Mining.

12.3.5 Attainability of Designated Uses

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load.

With respect to these potential reductions in bacteria loads attributed to wildlife, Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. However, if bacteria levels remain high and localized overabundant populations of wildlife are identified as the source, then measures to reduce such populations may be an option if undertaken in consultation with the Department of Game and Inland Fisheries (DGIF) or the United States Fish and Wildlife Service (USFWS). Additional information on DGIF's wildlife programs can be found at http://www.dgif.virginia.gov/hunting/va_game_wildlife/. While managing such overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address the overall issue of attainability of the primary contact criteria, Virginia proposed during its latest triennial water quality standards review a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective on February 12, 2004 and can be found at http://www.deq.virginia.gov/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/WQS03AUG.pdf

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a Stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the Stage 1 scenario are targeted primarily at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance populations. During the implementation of the Stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 11.1 above. VADEQ will re-assess water quality in the stream during and subsequent to the implementation of the Stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

13. PUBLIC PARTICIPATION

The development of the Laurel Fork TMDL greatly benefited from public involvement. Table 13.1 details the public participation throughout the project. The government kickoff meeting for Laurel Fork took place on June 13, 2005 at the Pocahontas Presbyterian Church in Pocahontas, Virginia with 9 people in attendance. The agencies represented at the meeting included VADCR, Virginia Department of Forestry (VDOF), VADEQ, Tazewell SWCD, the Town of Pocahontas and MapTech. The kickoff meeting was publicized through direct mailing to local agencies and the local government.

The first public meeting for Laurel Fork was held at the Pocahontas Presbyterian Church in Pocahontas, Virginia on July 13, 2005 to discuss the process for TMDL development; 34 people (29 citizens, 2 consultants, and 2 agency representatives) were present. To publicize the meeting mailings were sent out, signs were posted and a notice was placed in the Virginia Register.

Table 13.1 Public participation during TMDL development for the Laurel Fork Watershed.

Date	Location	Attendance[1]	Type	Format
7/13/05	Pocahontas Presbyterian Church 134 Moore Street Pocahontas, VA	9	Kickoff Meeting	Publicized to government agencies
7/13/05	Pocahontas Presbyterian Church 134 Moore Street Pocahontas, VA	34	1st public	Open to public at large
2/13/06	Pocahontas Presbyterian Church 134 Moore Street Pocahontas, VA	11	Final public	Open to public at large

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

The final public meeting was held on February 13, 2006 at the Pocahontas Presbyterian Church in Pocahontas, Virginia. The meeting was publicized in the *Virginia Register,* the local newspaper, by placing signs throughout the watershed and through personal mailings. There were 11 people in attendance. Topics discussed included TMDL allocations for bacteria and sediment. There was a 30-day public comment period.

Public participation during the implementation plan development process will include the formation of stakeholders' committee and open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders' committee will have the expressed purpose of formulating the TMDL implementation plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from the Department of Environmental Quality, Department of Conservation and Recreation, Department of Health, local agricultural community, local urban community, and local governments. This committee will have responsibility for identifying corrective actions that are founded in practicality, establish a time line to insure expeditious implementation, and set measurable goals and milestones for attaining water quality standards.

REFERENCES

American Veterinary Medical Association – Center for Information Management. 1997 U.S. Pet Ownership and Demographics Sourcebook.

Armour, C.L., D.A. Duff and W. Elmore. 1991. AFS Position Statement. Fisheries, Jan/Feb 1991, p. 7-11.

ASAE Standards, 45th Edition. 1998. D384.1 DEC93. Manure Production and Characteristics. St. Joseph, Mich.: ASAE.

Bidrowski, T. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication. January 29, 2003.

Bidrowski, T. 2004. Virginia Department of Game and Inland Fisheries. Personal telecommunication. July 16, 2004 and August 9, 2004.

Black, Peter E. 1991. Watershed Hydrology. Prentice Hall, Inc. New Jersey.

BSE. 2003. Benthic TMDL for Stroubles Creek in Montgomery County, Virginia. Department of Biological Systems Engineering, Virginia Tech.

Chow, V.T. 1959. Open Channel Hydraulics. McGraw-Hill Book Company. NY.

Clary, W.P. and B.F. Webster. 1989. Managing grazing of riparian areas in the Intermountain Region. USDA, Forest Service, Intermountain Research Station, General Technical Report INT-263, Ogden, UT.

Costanzo, G. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication. January 29, 2003.

Cowan, W.L. 1956. Estimating hydraulic roughness coefficients. *Agricultural Engineering*, 37(7): 473-475.

DMME. 2006. DMME website. http://www.mme.state.va.us/dmlr/Remining/Remining New Page2.htm

England, C.B. 1970. Land Capability: A Hydrologic Response Unit in Agricultural Watersheds. Agricultural Research Service, USDA, ARS: 41-172.

EPA. 1991. Guidance for Water-Quality-Based Decisions: The TMDL Process. EPAA440-4-91-001.

EPA. 1992. Multi-Resolution Land Cover (MRLC) Data for Virginia, a Component of the National Land Cover Dataset (NLCD). U.S. Environmental Protection Agency and the U.S. Geological Survey. Reston, VA.

EPA. 1999. Guidance for Water Quality-Based Decisions: The TMDL Process. http://www.epa.gov/OWOW/tmdl/decisions/dec1c.html

EPA. 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. December 2000. EPA 822-B-00-025.

EPA. 2003. Total Maximum Daily Load (TMDL) Program and Individual Water Quality-Based Effluent Limitations. 40 CFR 130.7 (c)(1).

Evans, Barry M., Scott A. Sheeder, Kenneth J. Corradini, and Will w. Brown. 2001. AVGWLF version 3.2 Users Guide. Environmental Resources Research Institute, Pennsylvania State University and Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation.

Evans, B.M. 2002. Personal communications. August 6, 2003.

Farrar, R. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication. January 15, 2003.

Fire Effects Information System. 1999. http://www.huntana.com/feis/animals/mammals.

Fies, M. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. August 11, 2004, August 12, 2004 and August 24, 2004.

Geldreich, E. E. 1978. Bacterial Populations and Indictor Concepts in Feces, Sewage, Stormwater, and Solid Wastes. In *Indicators of Viruses in Water and Food*, ed. G. Berg. Ann Arbor, Mich.: Ann Arbor Science Publishers, Inc.

Haith, D.A. and L.L. Shoemaker, 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients. Water Resources Bulletin, 23(3), pp. 471-478.

Haith, D.A., R. Mandel, and R.S. Wu. 1992. GWLF. Generalized Watershed Loading Functions, version 2.0 User's Manual. Department of Agricultural and Biological Engineering, Cornell University, Ithaca, New York.

Kaufman, J.B. and W.C. Krueger. 1984. Livestock impacts on riparian plant communities, and streamside management implications. A review. *Journal of Range Management* 37(3): 430-437.

Kennedy, A.J. 2002. An Ecotoxicological Assessment of a Treated Coal-mining Effluent in the Leading Creek Watershed, Meigs County, Ohio. MS thesis. Blacksburg, VA: Virginia Polytechnic Institute and State University. Department of Biology.

Kleene, J. Wesley. 1995, Watershed Nonpoint Source Management System: A Geographic Information System Approach, Ph.D. Dissertation, Virginia Polytechnic Institute and University.

Knox, W. M. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. August 03, 2004, August 05, 2004, and August 25, 2004.

Lloyd, K. 2004. Virginia Department of Environmental Quality. Personal telecommunication. September 28, 2004.

Li, E.A. 1975. A model to define hydrologic response units based on characteristics of the soil-vegetative complex within a drainage basin. M.S. Thesis, Department of Agricultural Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus Based Sediment Quality Guidelines For Freshwater Ecosystems, Arch. *Environ. Contam. Toxicol.* 39: 20-31.

MapTech. 2002. Modeling Cattle Stream Access. Submitted to: VADCR, in cooperation with Biological Systems Engineering Department, Virginia Tech.

Norman, G.W. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication.

Norman, G. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. July 12, 2004.

Novotny, V., and G. Chesters. 1981. Handbook of Nonpoint Pollution. Van Nostrand Reinhold, New York, NY.

NRCS. 2004a. SSURGO website. http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/

NRCS. 2004b. STATSGO website. http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/

Pond, G. J. 2004. Effects of surface mining and residential land use on headwater stream biotic integrity. Kentucky Department of Environmental Protection Division of Water. July, 2004. p. 33.

Reneau, R.B., Jr. 2000. Department of Crop and Soil Environmental Sciences, Virginia Tech. Personal communication. January 7, 2000.

Rose, R.K., Cranford, J.A. 1987. Handbook of Virginia Mammals. Final Report, Project No. 567460. VA Dept. Game & Inland Fisheries, Richmond, VA: 121.

SERCC. 2005 Southeast Regional Climate Center. http://water.dnr.state.sc.us/climate/sercc/

Soil Conservation Service. 1963. National Engineering Handbook. 3rd ed. Washington, D.C.: Government Printing Office.

SCS. 1986. Urban Hydrology for Small Watersheds, USDA Soil Conservation Service, Engineering Division, Technical Release 55.

SCS. 2004. SSURGO website. www.ncgc.nrcs.usda.gov/branch/ssb/products/ssurgo/

Shanholtz, V.O., C.D. Heatwole, E.R. Yagow, J.M. Flagg, R.K. Byler, S. Mostaghimi, T.A. Collins and E.R. Collins, Jr. 1988. Agricultural Pollution Potential Database for Headwaters Soil and Water Conservation District. Interim Report VirGIS 88-10, Department of Conservation and Historic Resources, Division of Soil and Water Conservation, Richmond, Virginia.

Schwab, G. O., R. K. Frevert, T. W. Edminster, and K.K. Barnes. 1981. Soil and Water Conservation Engineering. 3rd ed. New York: John Wiley & Sons.

Spencer, J. 2006. Tazewell County Administrator. Personal telecommunication. January 6, 2006.

Stressor Identification Guidance Document. USEPA Office of Water. EPA-822-B-00-025. December 2000.

Tazewell County Planning Commission. 1996. Tazewell County Comprehensive Plan. County of Tazewell, Virginia.

Tetra Tech, Inc. 2002. Total Maximum Daily Load (TMDL) development for Blacks Run and Cooks Creek. Prepared for EPA Region III, Virginia Department of Environmental Quality and Virginia Department of Conservation and Recreation. Available at //www.deq.virginia.gov/tmdl/apptmdls/shenrvr/cooksbd2.pdf.

USCB. 1990. *1990 Census*. United States Census Bureau. Washington D.C.

USCB. 2000. *2000 Census*. United States Census Bureau. Washington D.C.

USDI, Bureau of Land Management. 1996. Riparian area management: process for assessing proper functioning conditions. Technical Reference 1737-9, National Applied Science Center, Denver, CO.

VADCR and VADEQ. 2003. Guidance Manual for Total Maximum Daily Load Implementation Plans. http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf.

VADEQ. 1996. Section 303(d) Total Maximum Daily Load Priority List.

VADEQ. 2002. Section 303(d) Report on Impaired Waters (DRAFT).

VADEQ. 2004. Section 303(d) Water Quality Assessment Integrated Report (DRAFT.).

VADEQ and VADCR. 1998. Section 303(d) Total Maximum Daily Load Priority List and Report (DRAFT).

VADEQ and VADCR. 2000. Total Maximum Daily Load (TMDL) Development for Middle Blackwater River. Prepared for EPA Region III, VADEQ, and VADCR by Map Tech, Inc. Available at / http://www.deq.virginia.gov/tmdl/apptmdls/roankrvr/mdblwtr.pdf

VADEQ and VADCR. 2002. Total Maximum Daily Load (TMDL) Development for Blacks Run and Cooks Creek: Aquatic Life Use (Benthic) Impairment. Prepared for EPA Region III, VADEQ, and VADCR by Tetra Tech, Inc. Available at //www.deq.virginia.gov/tmdl/apptmdls/shenrvr/cooksbd2.pdf

VASS. 1995. Virginia Agricultural Statistics Bulletin 1994. Virginia Agricultural Statistics Service. Richmond, VA.

VASS. 2005. Virginia Agricultural Statistics Bulletin 2003. Virginia Agricultural Statistics Service. Richmond, VA.

VDGIF. 1999. http://www.dgif.state.va.us The Virginia Fish and Wildlife Information Service.

VDGIF 2005. Virginia Fish and Wildlife Information Service Species List. http://vafwis.org/WIS/visitor/speciesList.asp?ln=V&sID=71244&nav=speciesList Accessed March 2, 2005.

Virginia's State Water Control Board. 1997a. Water quality standard 9 VAC 25-260-20. General Standard.

Virginia's State Water Control Board. 1997b. Water quality standard 9 VAC 25-260-170. Fecal Coliform Standard.

Virginia's State Water Control Board. 2003. Water Quality Standards 9 VAC 25-260-5.

Weiskel. P.A., B.L. Howes, and G.R. Heufelder. 1996. Coliform contamination of a coastal embayment: sources and transport pathways. *Environ. Sci. Technol.* 30:1872-1881.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting Rainfall Erosion Losses – A Guide to Conservation Planning. U.S. Department of Agriculture, Agriculture Handbook No. 537.

Yagow, E. 1999. Unpublished monitoring data. Mountain Run TMDL Study.

Yagow, G., S. Mostaghimi, and T.A. Dillaha. 2002. GWLF model calibration for statewide NPS assessment. Virginia NPS pollutant load assessment methodology for 2002 and 2004 statewide NPS pollutant assessments. January 1 - March 31, 2002 Quarterly Report. Submitted to Virginia Department Conservation and Recreation, Division of Soil and Water Conservation, Richmond, Virginia.

GLOSSARY

Note: All entries in italics are taken from USEPA (1998).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A waste load allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies*. Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity*. The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota. **(2)**

Biochemical Oxygen Demand (BOD). Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biological Integrity. A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Cause. 1. That which produces an effect (a general definition).
2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition).[2]

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Concentration-response model. A quantitative (usually statistical) model of the relationship between the concentration of a chemical to which a population or community of organisms is exposed and the frequency or magnitude of a biological response. (2)

Conductivity. An indirect measure of the presence of dissolved substances within water.

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition. *Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration.***

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES). *A permit issued by the EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion. *The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Dissolved Oxygen (DO). The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DMME. Virginia Department of Mines, Minerals, and Energy.

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Erosion. The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

***Fate of pollutants**. Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

***Feedlot.** A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

***Flux.** Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

General Standard. A narrative standard that ensures the general health of state waters. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (4)

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

***Ground water.** The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

***Hydrograph**. A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Impairment. A detrimental effect on the biological integrity of a water body that prevents attainment of the designated use.

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause.

Indirect effects. Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor.

Infiltration capacity. *The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by the EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mass balance. *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

Mass loading. *The quantity of a pollutant transported to a waterbody.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

Metric ton (Mg or t). A unit of mass equivalent to 1,000 kilograms. An annual load of a pollutant is typically reported in metric tons per year (t.yr).

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

Model. Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Narrative criteria*. Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nitrogen. An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets*. A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

Peak runoff*. The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (*e.g., pasture*, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by the EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased/staged approach. *Under the phased approach to TMDL development, load allocations and waste load allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Phosphorus. An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works*. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period*. The time allowed for the public to express its views and concerns regarding action by the EPA or states (e.g., a* Federal Register *notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25^{th}, 50^{th}, and 75^{th} percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50^{th} quartile is also known as the median. The 25^{th} and 75^{th} quartiles are referred to as the lower and upper quartiles, respectively.

Rapid Bioassessment Protocol II (RBP II). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP II scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach. Segment of a stream or river.

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reference Conditions. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Re-mining. Extracting resources from land previously mined. This method is often used to reclaim abandoned mine areas.

Reserve capacity*. Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration*. Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone*. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient. *A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles. (Gilbert, 1987)

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquate systems as a result of erosion.

Septic system. *An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Simulation. *The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Source. An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor.

Spatial segmentation. *A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Staged Implementation. A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 mL geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (*i.e.,* a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Storm runoff*. Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream Reach. A straight portion of a stream.

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Stressor. Any physical, chemical, or biological entity that can induce an adverse response. [2]

Surface area*. The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water*. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Suspended Solids. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

Technology-based standards*. Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Ton (T). A unit of measure of mass equivalent to 2,200 English lbs.

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Dissolved Solids (TDS). A measure of the concentration of dissolved inorganic chemicals in water.

Total Maximum Daily Load (TMDL). *The sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

TMDL Implementation Plan. A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

TRC. Total Residual Chlorine. A measure of the effectiveness of chlorinating treated wastewater effluent.

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Urban Runoff. Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under* *investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

DMLR. Virginia Department of mine Land Reclamation.

DMME. Virginia Department of Mines, Minerals, and Energy.

VDH. Virginia Department of Health.

Waste load allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

Wastewater treatment*. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality*. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based permit*. A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria*. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by the EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are* *necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

APPENDIX A

FREQUENCY ANALYSIS OF WATER QUALITY SAMPLING DATA

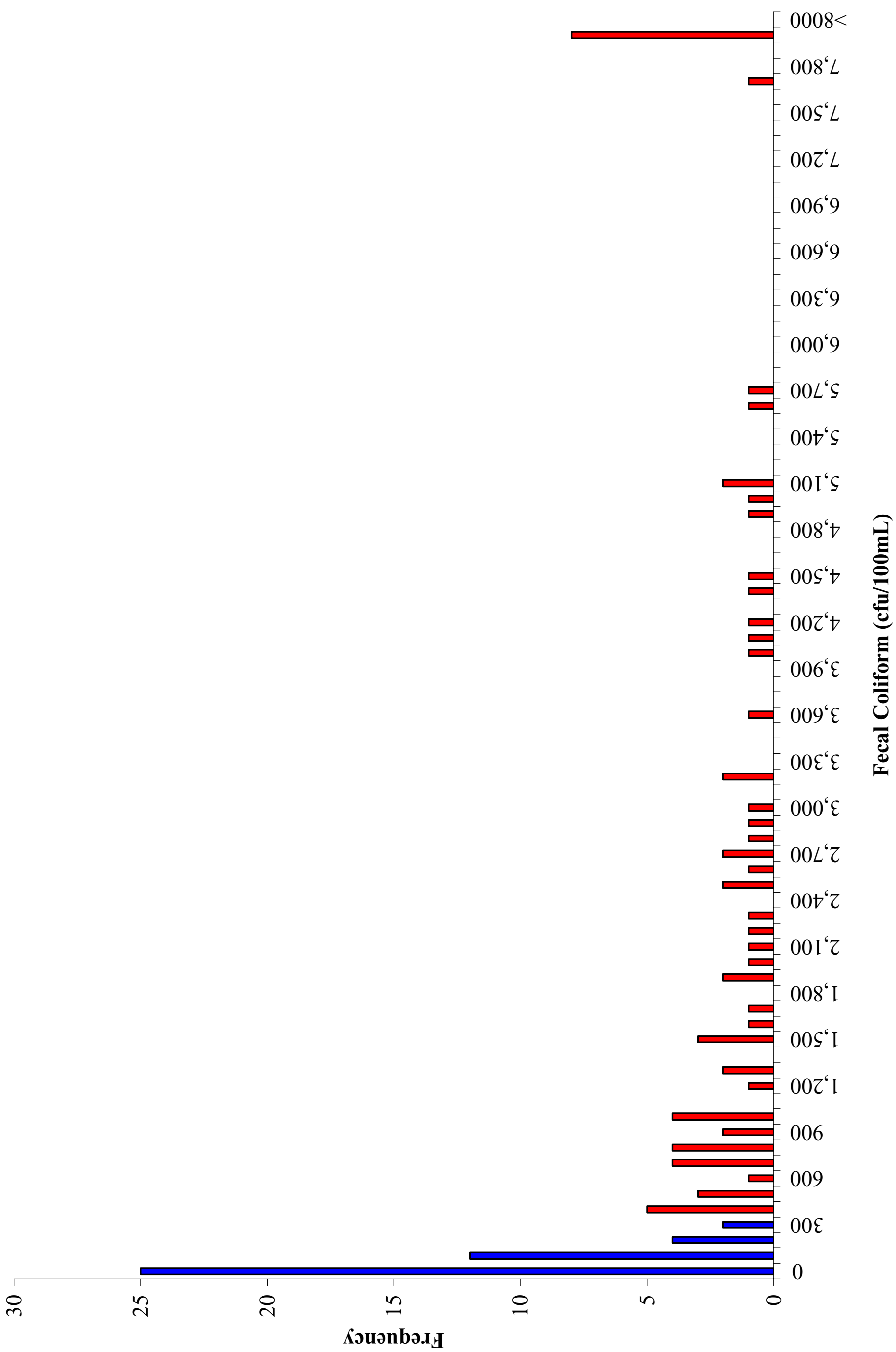

Figure A.1 Frequency analysis of fecal coliform concentrations at station 9LRR001.39 in the Laurel Fork impairment for the period January 1980 to June 2004.

*Red indicates a value which violates the listing standard of 400 cfu/100 mL.

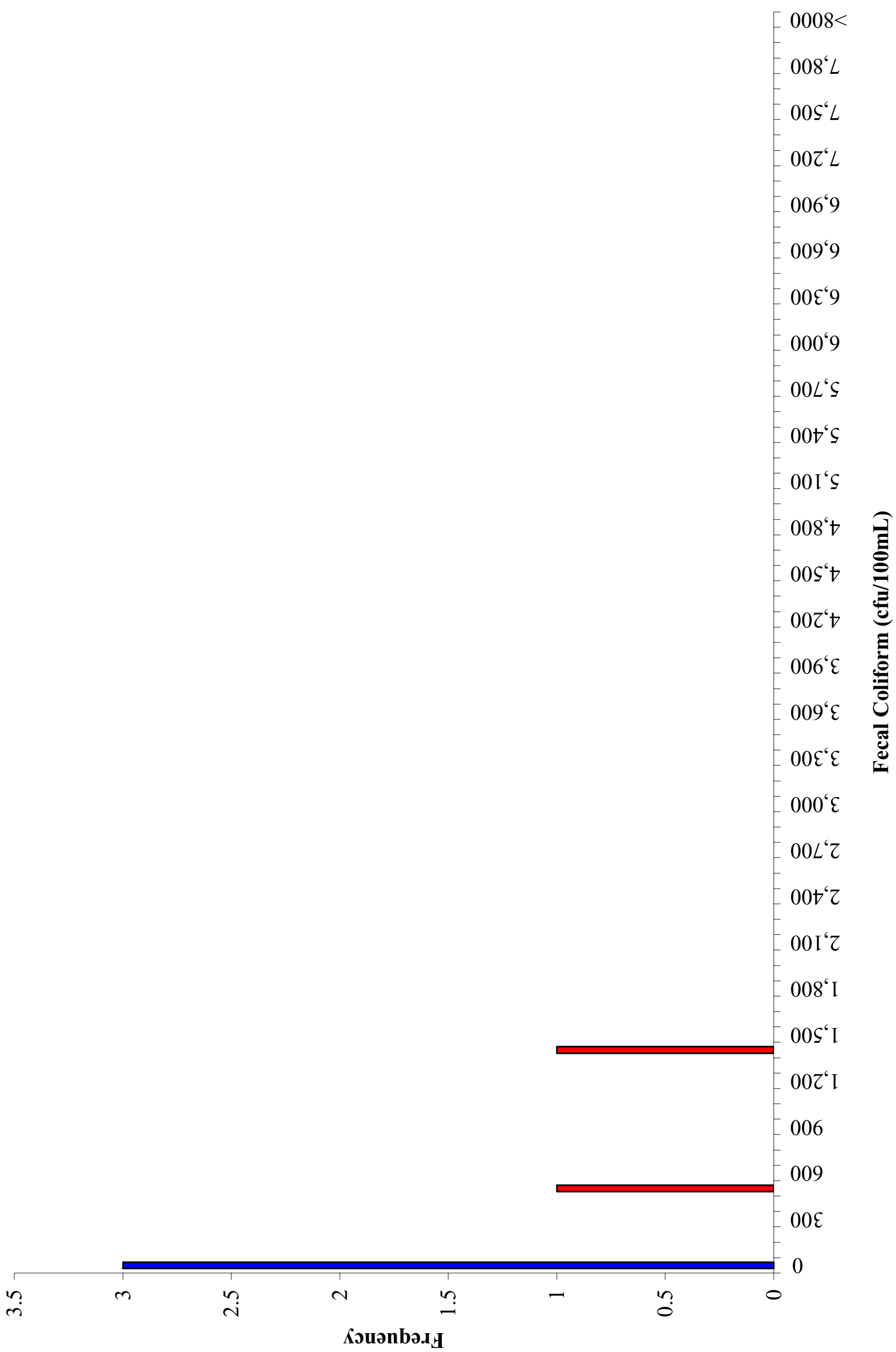

Figure A.2 Frequency analysis of fecal coliform concentrations at station 9LRR001.73 in the Laurel Fork impairment for the period August 2003 to June 2004.

*Red indicates a value which violates the listing standard of 400 cfu/100 mL.

Figure A.3 Frequency analysis of fecal coliform concentrations at station 9LRR002.59 in the Laurel Fork impairment for the period July 2003 to June 2004.

*Red indicates a value which violates the listing standard of 400 cfu/100 mL.

Figure A.4 Frequency analysis of fecal coliform concentrations at station 9LRR004.03 in the Laurel Fork impairment for the period July 2003 to June 2004.

*Red indicates a value which violates the listing standard of 400 cfu/100 mL.

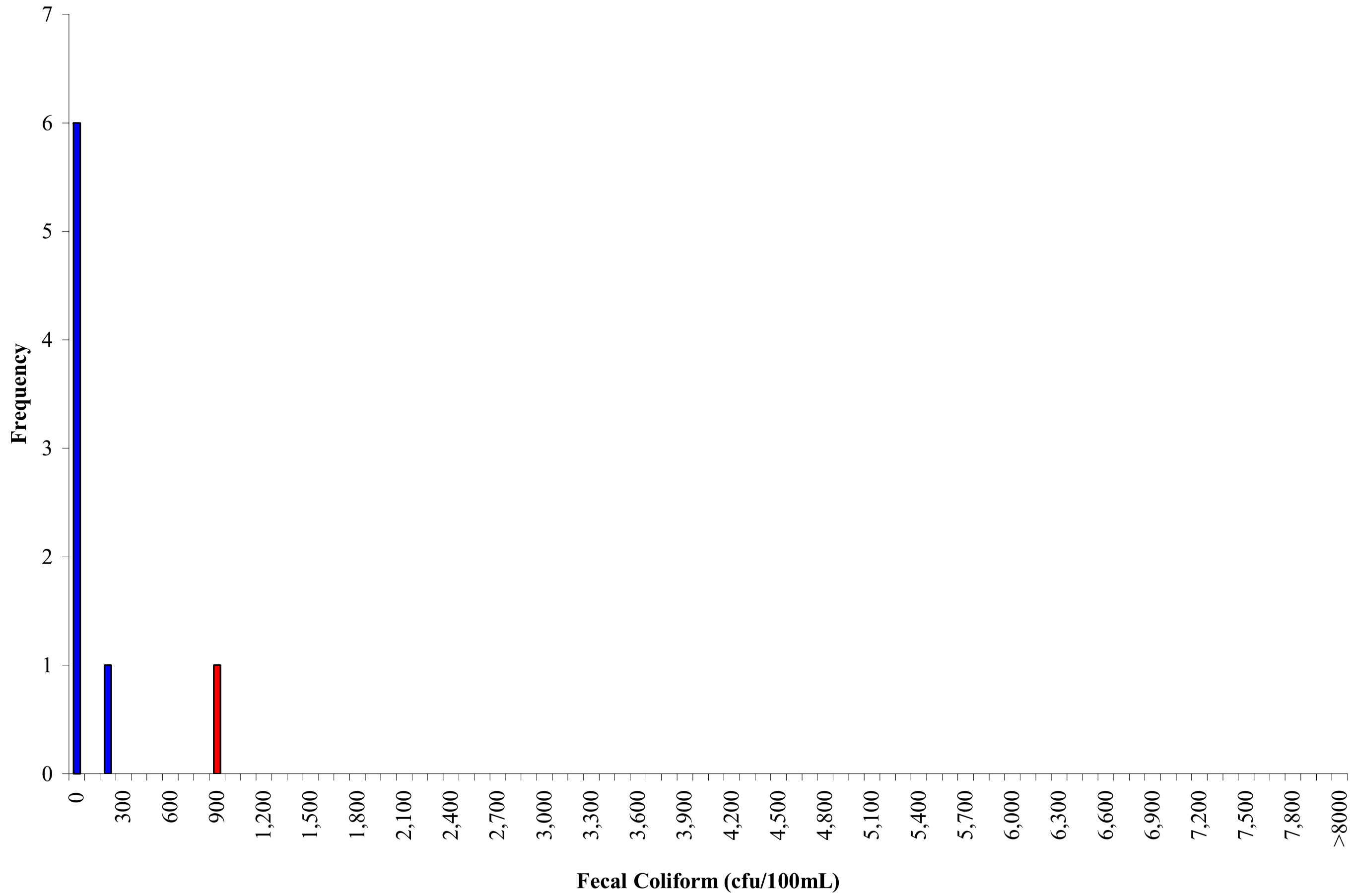

Figure A.5 Frequency analysis of fecal coliform concentrations at station 9LRR005.59 in the Laurel Fork impairment for the period September 2003 to June 2004.

*Red indicates a value which violates the listing standard of 400 cfu/100 mL.

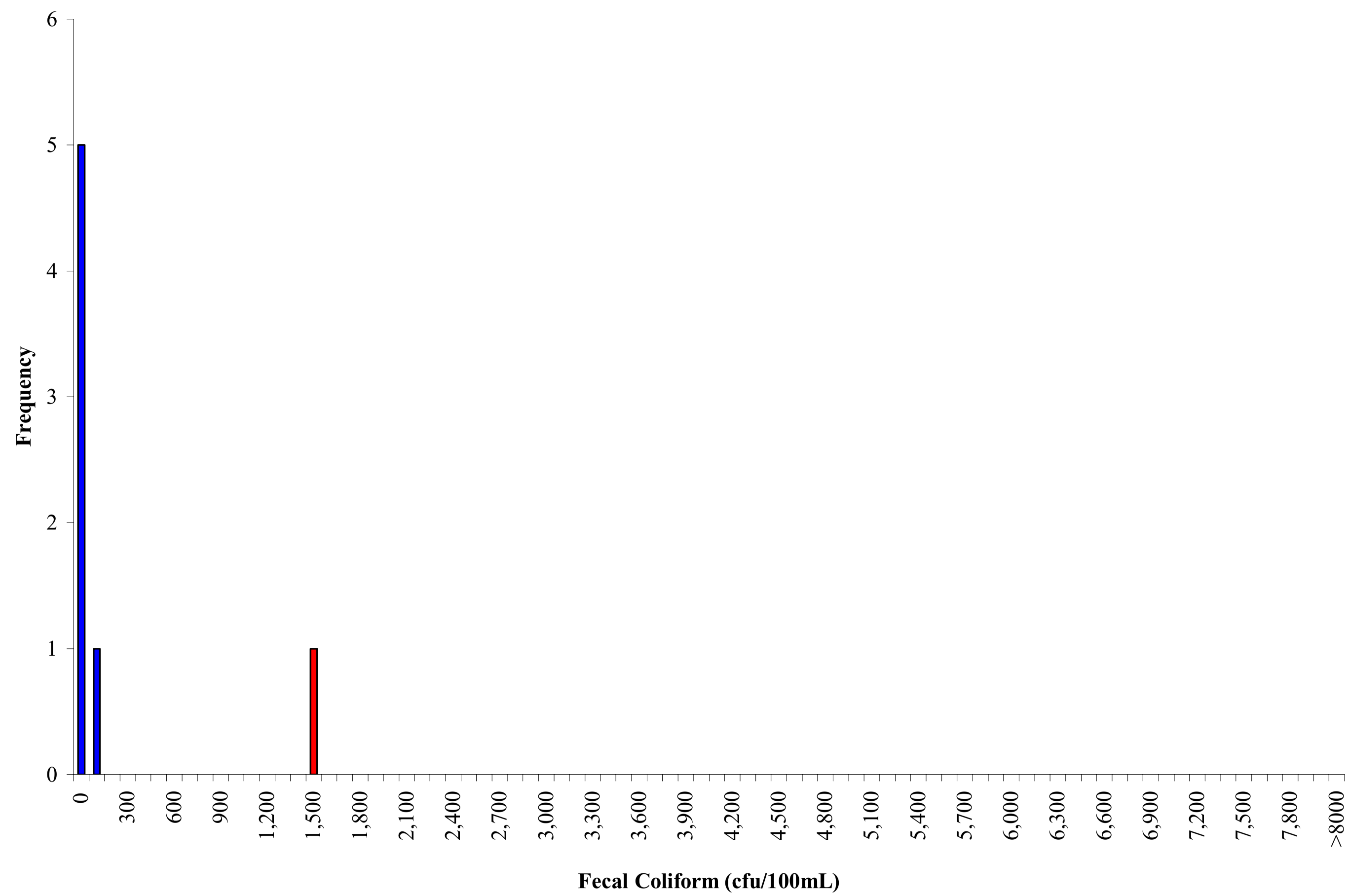

Figure A.6 Frequency analysis of fecal coliform concentrations at station 9LRR006.43 in the Laurel Fork impairment for the period July 2003 to June 2004.

*Red indicates a value which violates the listing standard of 400 cfu/100 mL.

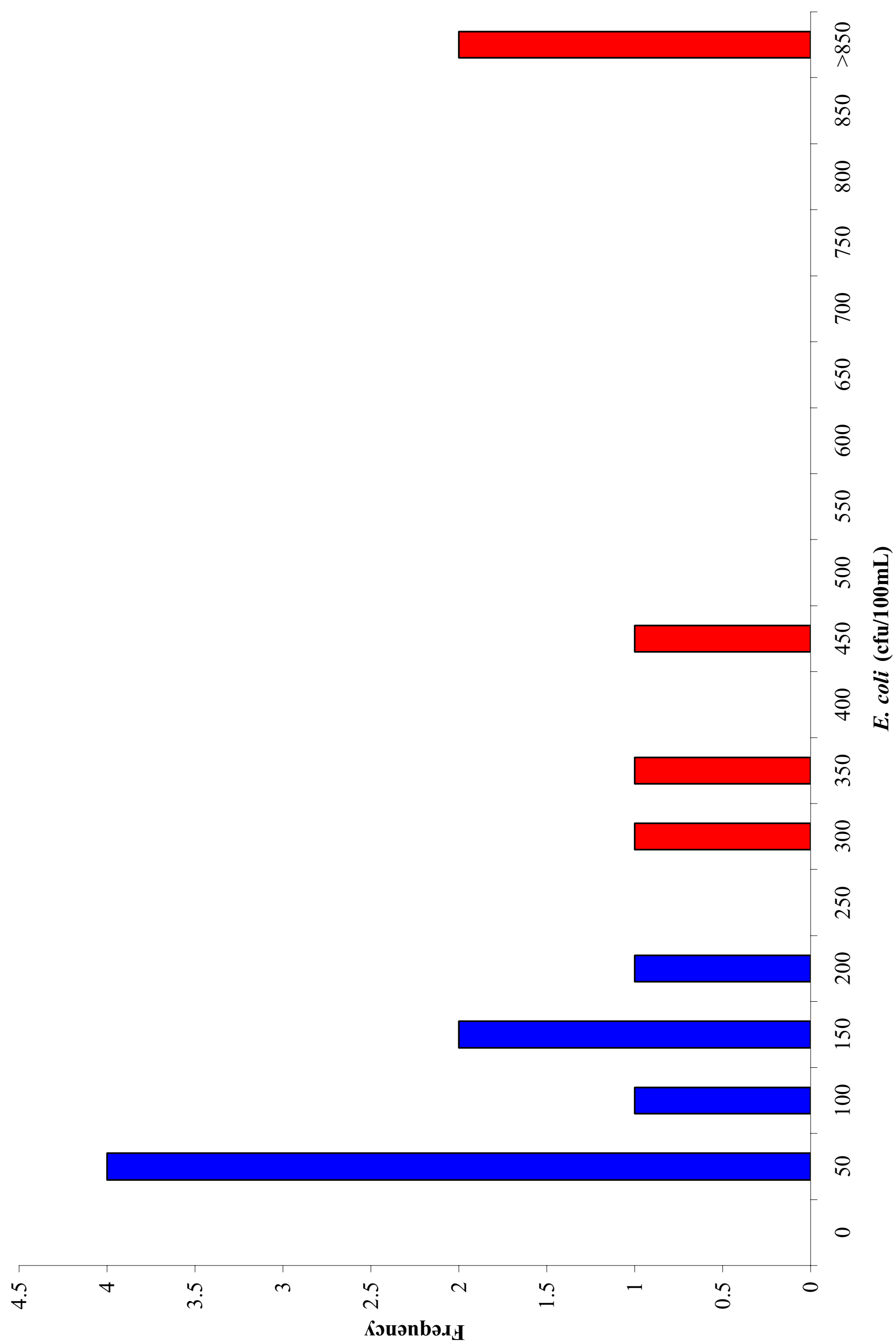

Figure A.7 Frequency analysis of E. coli concentrations at station 9LRR001.39 in the Laurel Fork impairment for the period July 2003 to June 2004.

*Red indicates a value which violates the listing standard of 235 cfu/100mL.

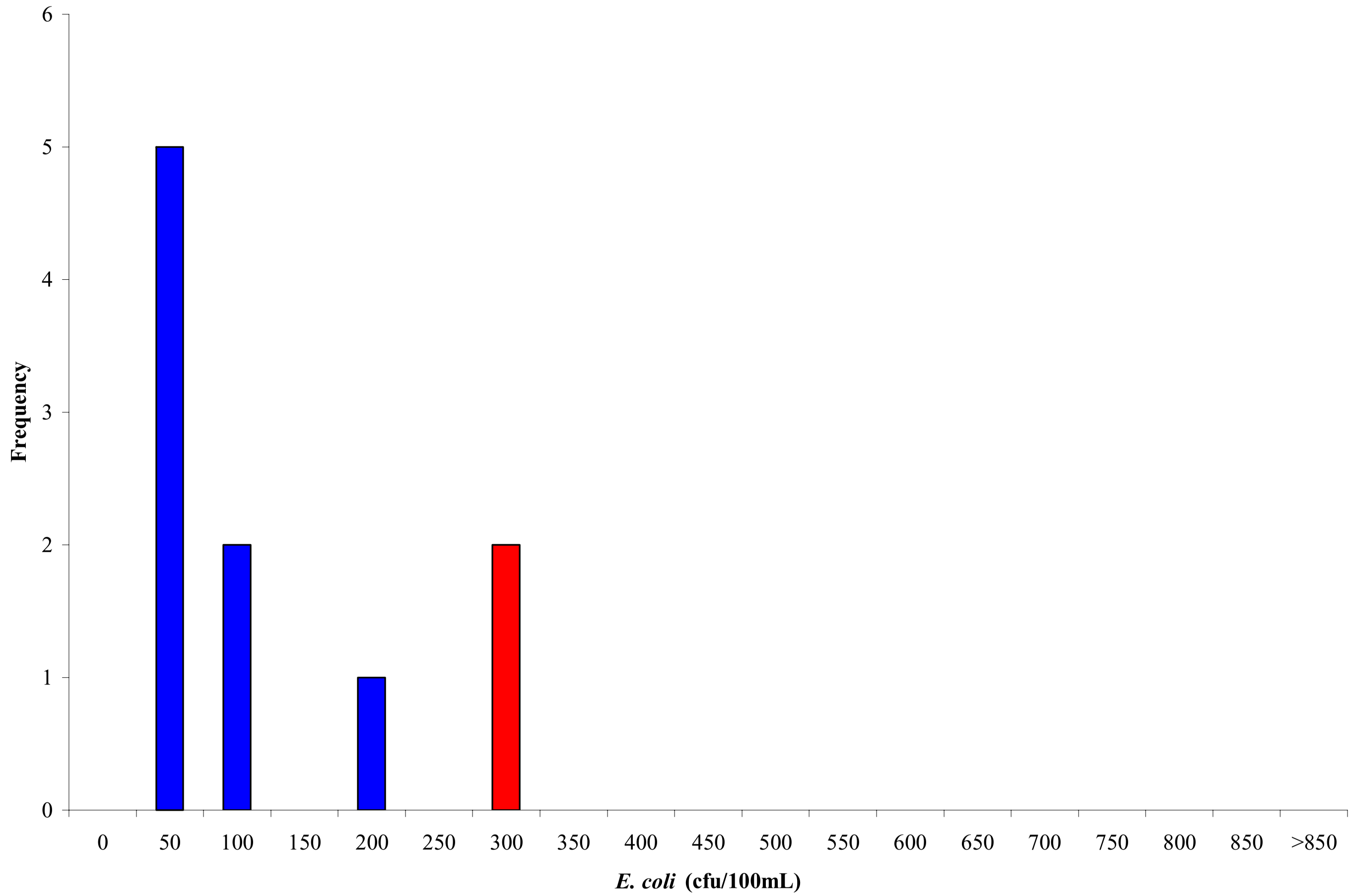

Figure A.8 Frequency analysis of E. coli concentrations at station 9LRR002.59 in the Laurel Fork impairment for the period July 2003 to June 2004.

*Red indicates a value which violates the listing standard of 235 cfu/100mL.

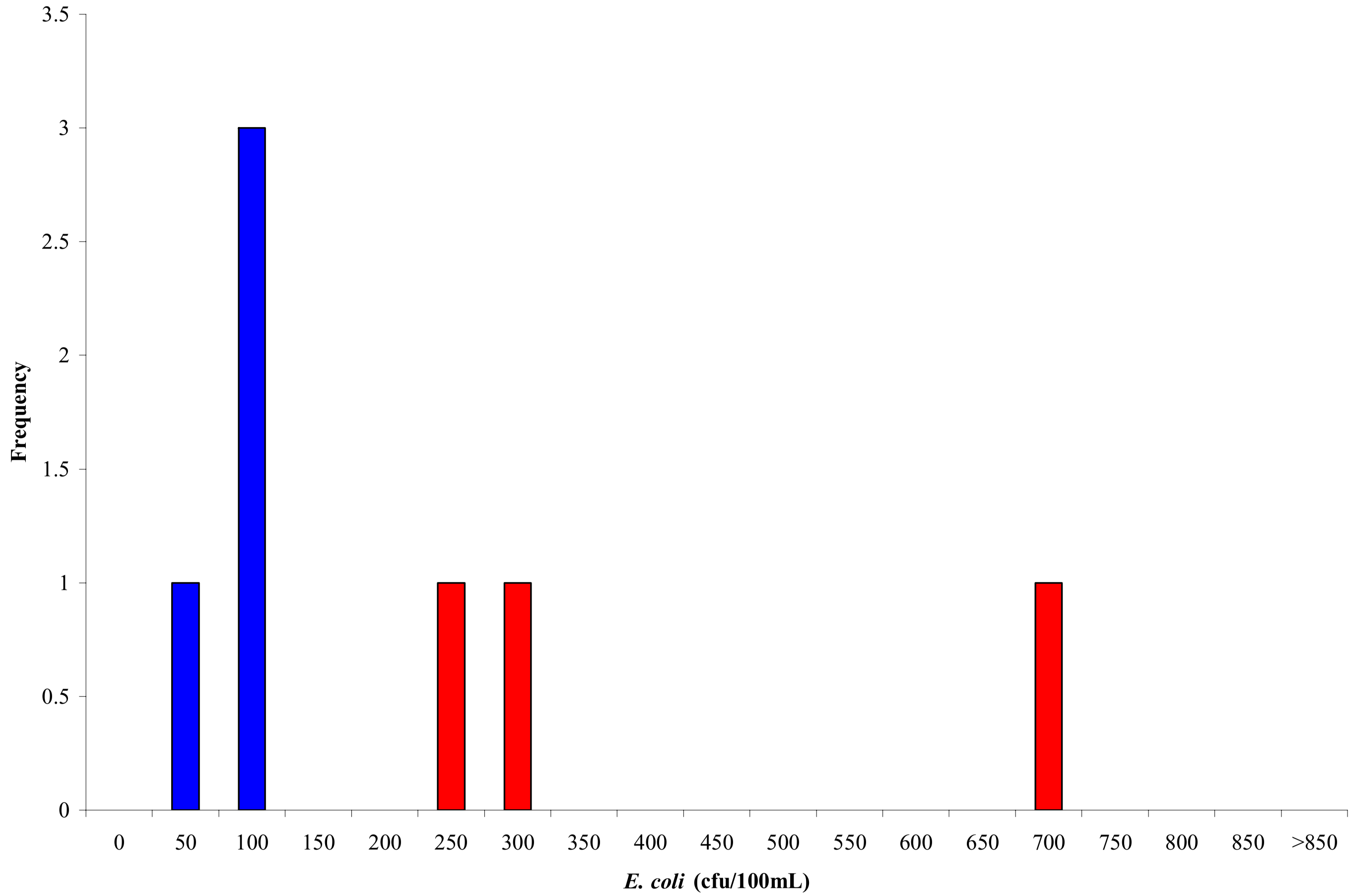

Figure A.9 Frequency analysis of E. coli concentrations at station 9LRR004.03 in the Laurel Fork impairment for the period July 2003 to June 2004.

*Red indicates a value which violates the listing standard of 235 cfu/100mL.

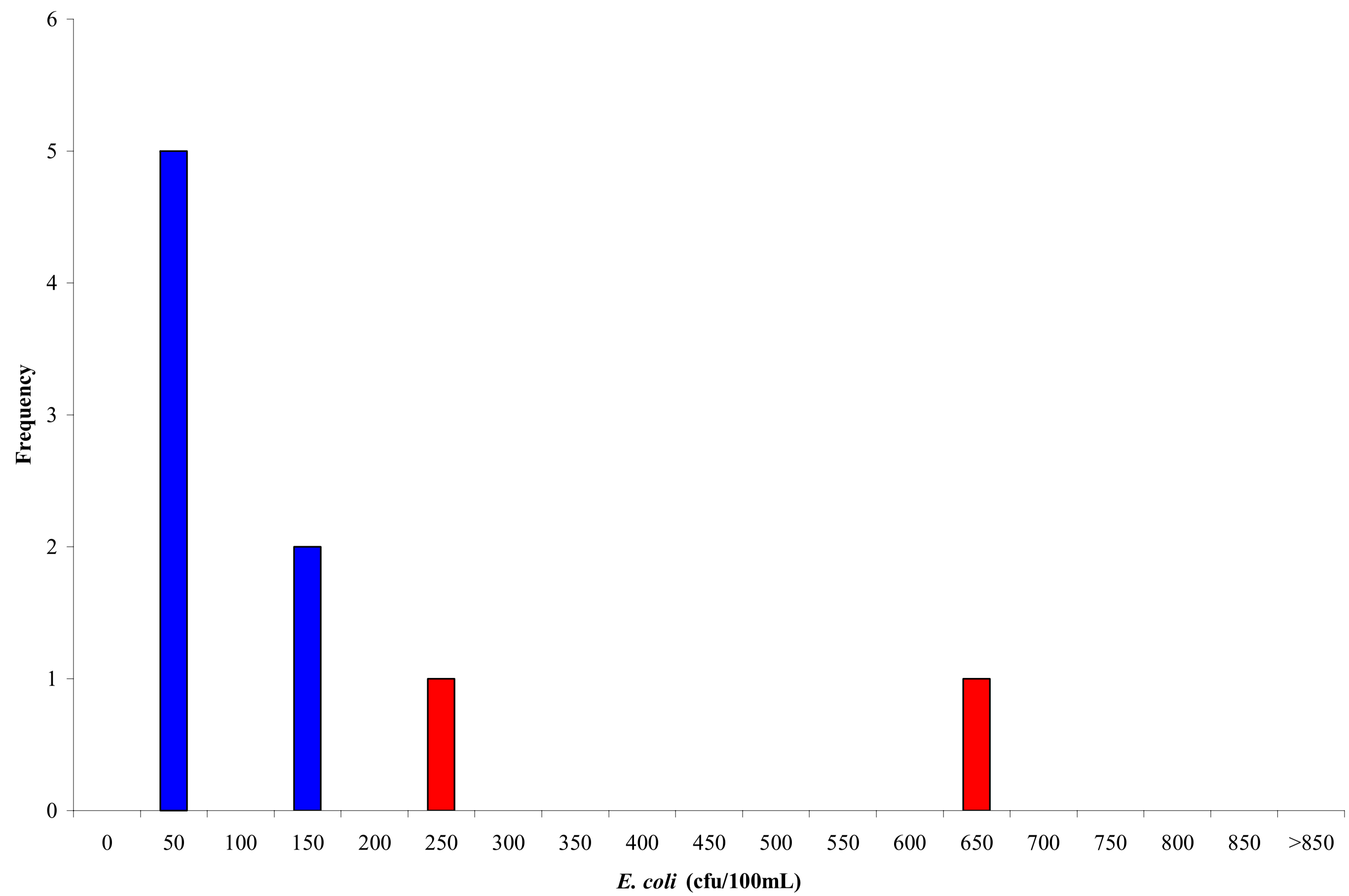

Figure A.10 Frequency analysis of E. coli concentrations at station 9LRR005.59 in the Laurel Fork impairment for the period August 2003 to June 2004.

*Red indicates a value which violates the listing standard of 235 cfu/100mL.

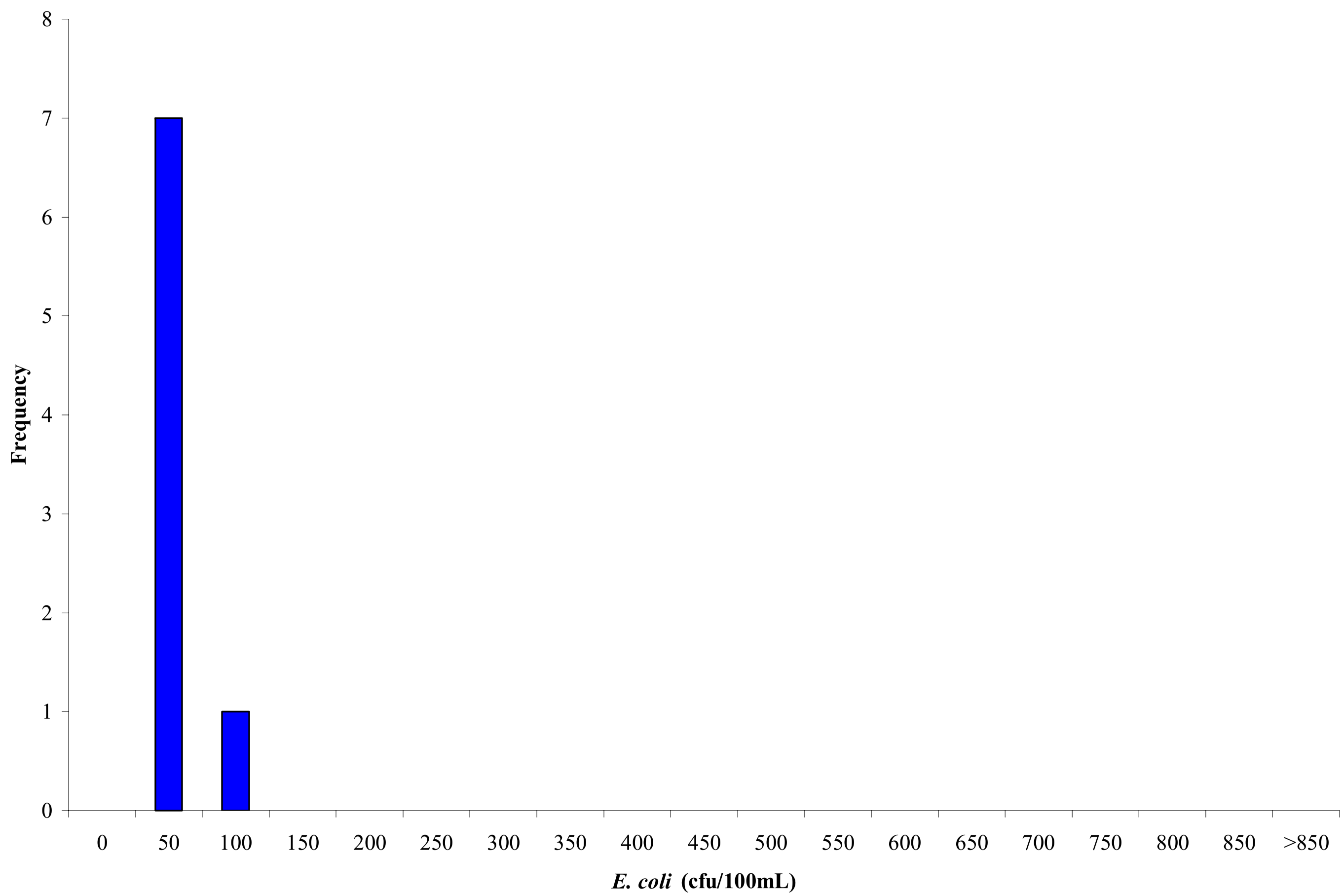

Figure A.11 Frequency analysis of E. coli concentrations at station 9LRR006.43 in the Laurel Fork impairment for the period August 2003 to June 2004.

*Red indicates a value which violates the listing standard of 235 cfu/100mL.

APPENDIX B

FECAL COLIFORM LOADS IN EXISTING CONDITIONS

Table B.1 Current conditions of land applied fecal coliform load for Laurel Fork by land use (Subwatersheds 1,2,3,4,5).

Land-use	AML	Commercial	Crops	Forest	LAX	Pasture	Reclaimed	Residential	Wetlands
January	7.15E+11	3.67E+10	1.80E+11	9.52E+12	1.58E+11	6.81E+12	9.64E+10	5.44E+13	1.04E+11
February	6.45E+11	3.32E+10	1.63E+11	8.60E+12	1.43E+11	6.15E+12	8.70E+10	4.91E+13	9.39E+10
March	7.06E+11	3.63E+10	1.78E+11	9.41E+12	2.18E+11	6.74E+12	9.52E+10	5.44E+13	1.03E+11
April	6.73E+11	3.46E+10	1.70E+11	8.96E+12	2.84E+11	6.44E+12	9.08E+10	5.26E+13	9.79E+10
May	6.95E+11	3.58E+10	1.76E+11	9.26E+12	2.94E+11	6.65E+12	9.38E+10	5.43E+13	1.01E+11
June	6.65E+11	3.42E+10	1.68E+11	8.86E+12	3.42E+11	6.37E+12	8.97E+10	5.26E+13	9.67E+10
July	6.87E+11	3.53E+10	1.73E+11	9.15E+12	3.54E+11	6.58E+12	9.26E+10	5.43E+13	1.00E+11
August	6.87E+11	3.53E+10	1.73E+11	9.15E+12	3.54E+11	6.58E+12	9.26E+10	5.43E+13	1.00E+11
September	6.73E+11	3.46E+10	1.70E+11	8.96E+12	2.84E+11	6.44E+12	9.08E+10	5.26E+13	9.79E+10
October	7.06E+11	3.63E+10	1.78E+11	9.41E+12	2.18E+11	6.74E+12	9.52E+10	5.44E+13	1.03E+11
November	6.83E+11	3.51E+10	1.73E+11	9.10E+12	2.11E+11	6.52E+12	9.22E+10	5.26E+13	9.94E+10
December	7.15E+11	3.67E+10	1.80E+11	9.52E+12	1.58E+11	6.81E+12	9.64E+10	5.44E+13	1.04E+11
Annual Total Loads (cfu/yr)	8.25E+12	4.24E+11	2.08E+12	1.10E+14	3.02E+12	7.88E+13	1.11E+12	6.40E+14	1.20E+12

Table B.2 Monthly, directly deposited fecal coliform loads in each reach of the Laurel Fork watershed (Reaches: 1,2,3,4,5,).

Source Type	Reach ID	January	February	March	April	May	June
Human/Pet	1	2.38E+10	2.15E+10	2.38E+10	2.31E+10	2.38E+10	2.31E+10
Livestock	1	5.08E+09	4.59E+09	6.78E+09	9.84E+09	1.02E+10	1.15E+10
Wildlife	1	1.09E+11	9.80E+10	1.56E+11	2.10E+11	2.17E+11	2.56E+11
Human/Pet	2	6.43E+10	5.81E+10	6.43E+10	6.23E+10	6.43E+10	6.23E+10
Livestock	2	4.42E+09	3.99E+09	5.89E+09	8.55E+09	8.83E+09	9.97E+09
Wildlife	2	9.10E+10	8.22E+10	1.31E+11	1.76E+11	1.82E+11	2.15E+11
Human/Pet	3	1.98E+10	1.78E+10	1.98E+10	1.91E+10	1.98E+10	1.91E+10
Livestock	3	7.96E+08	7.19E+08	1.06E+09	1.54E+09	1.59E+09	1.80E+09
Wildlife	3	3.13E+10	2.83E+10	4.51E+10	6.06E+10	6.26E+10	7.39E+10
Human/Pet	4	1.83E+11	1.65E+11	1.83E+11	1.77E+11	1.83E+11	1.77E+11
Livestock	4	4.34E+09	3.92E+09	5.79E+09	8.41E+09	8.69E+09	9.81E+09
Wildlife	4	5.14E+10	4.64E+10	7.39E+10	9.94E+10	1.03E+11	1.21E+11
Human/Pet	5	7.91E+09	7.14E+09	7.91E+09	7.65E+09	7.91E+09	7.65E+09
Livestock	5	1.01E+09	9.15E+08	1.35E+09	1.96E+09	2.03E+09	2.29E+09
Wildlife	5	3.27E+10	2.95E+10	4.71E+10	6.33E+10	6.54E+10	7.72E+10

Table B.2 Monthly, directly deposited fecal coliform loads in each reach of the Laurel Fork watershed (Reaches: 1,2,3,4,5,) (cont.).

Source Type	Reach ID	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	1	2.38E+10	2.38E+10	2.31E+10	2.38E+10	2.31E+10	2.38E+10	2.81E+11
Livestock	1	1.19E+10	1.19E+10	9.84E+09	6.78E+09	6.56E+09	5.08E+09	9.99E+10
Wildlife	1	2.65E+11	2.65E+11	2.10E+11	1.56E+11	1.51E+11	1.09E+11	2.20E+12
Human/Pet	2	6.43E+10	6.43E+10	6.23E+10	6.43E+10	6.23E+10	6.43E+10	7.57E+11
Livestock	2	1.03E+10	1.03E+10	8.55E+09	5.89E+09	5.70E+09	4.42E+09	8.68E+10
Wildlife	2	2.22E+11	2.22E+11	1.76E+11	1.31E+11	1.27E+11	9.10E+10	1.85E+12
Human/Pet	3	1.98E+10	1.98E+10	1.91E+10	1.98E+10	1.91E+10	1.98E+10	2.33E+11
Livestock	3	1.86E+09	1.86E+09	1.54E+09	1.06E+09	1.03E+09	7.96E+08	1.57E+10
Wildlife	3	7.64E+10	7.64E+10	6.06E+10	4.51E+10	4.36E+10	3.13E+10	6.35E+11
Human/Pet	4	1.83E+11	1.83E+11	1.77E+11	1.83E+11	1.77E+11	1.83E+11	2.15E+12
Livestock	4	1.01E+10	1.01E+10	8.41E+09	5.79E+09	5.60E+09	4.34E+09	8.54E+10
Wildlife	4	1.25E+11	1.25E+11	9.94E+10	7.39E+10	7.15E+10	5.14E+10	1.04E+12
Human/Pet	5	7.91E+09	7.91E+09	7.65E+09	7.91E+09	7.65E+09	7.91E+09	9.31E+10
Livestock	5	2.36E+09	2.36E+09	1.96E+09	1.35E+09	1.31E+09	1.01E+09	1.99E+10
Wildlife	5	7.97E+10	7.97E+10	6.33E+10	4.71E+10	4.56E+10	3.27E+10	6.63E+11

Table B.3 Existing annual loads from land-based sources for Laurel Fork (Subwatersheds 1,2,3,4,5).

Source	AML	Residential	Water	Wetlands
Beaver	0.00E+00	0.00E+00	4.02E+09	0.00E+00
Beef - calf	0.00E+00	0.00E+00	1.33E+11	0.00E+00
Beef - stocker	0.00E+00	0.00E+00	1.75E+11	0.00E+00
Cats	0.00E+00	1.74E+07	0.00E+00	0.00E+00
Deer	3.86E+11	5.45E+10	0.00E+00	4.60E+10
Dogs	0.00E+00	1.94E+13	0.00E+00	0.00E+00
Duck	2.70E+08	1.10E+08	0.00E+00	6.37E+07
Failing Septic Density	0.00E+00	6.18E+14	0.00E+00	0.00E+00
Goose	3.71E+11	1.51E+11	0.00E+00	8.76E+10
Hog	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Muskrat	3.76E+12	1.53E+12	0.00E+00	8.88E+11
Raccoon	3.73E+12	7.65E+11	0.00E+00	1.79E+11
Sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Straight Pipes	0.00E+00	0.00E+00	3.52E+12	0.00E+00
Turkey	2.01E+08	0.00E+00	0.00E+00	2.39E+07

Table B.4 Existing annual loads from direct-deposition sources for the Laurel Fork (Reaches 1,2,3,4,5).

Source	Annual Total Loads (cfu/yr)
Beaver	4.02E+09
Beef - calf	1.33E+11
Beef - stocker	1.75E+11
Deer	1.29E+12
Duck	1.74E+08
Goose	2.39E+11
Hog	0.00E+00
Horse	0.00E+00
Muskrat	2.43E+12
Raccoon	2.42E+12
Sheep	0.00E+00
Straight Pipes	3.52E+12
Turkey	6.55E+08

APPENDIX C

E. Coli TMDL FOR FUTURE CONDITIONS

Table C.1 Average annual *E. coli* loads (cfu/year) modeled for the Laurel Fork watershed impairment after TMDL allocation with permitted point source loads increased four times.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Laurel Fork	3.49E+12	4.93E+11	Implicit	3.98E+12
VA0091588	*2.61E+12*			
VAG400522	*2.61E+09*			