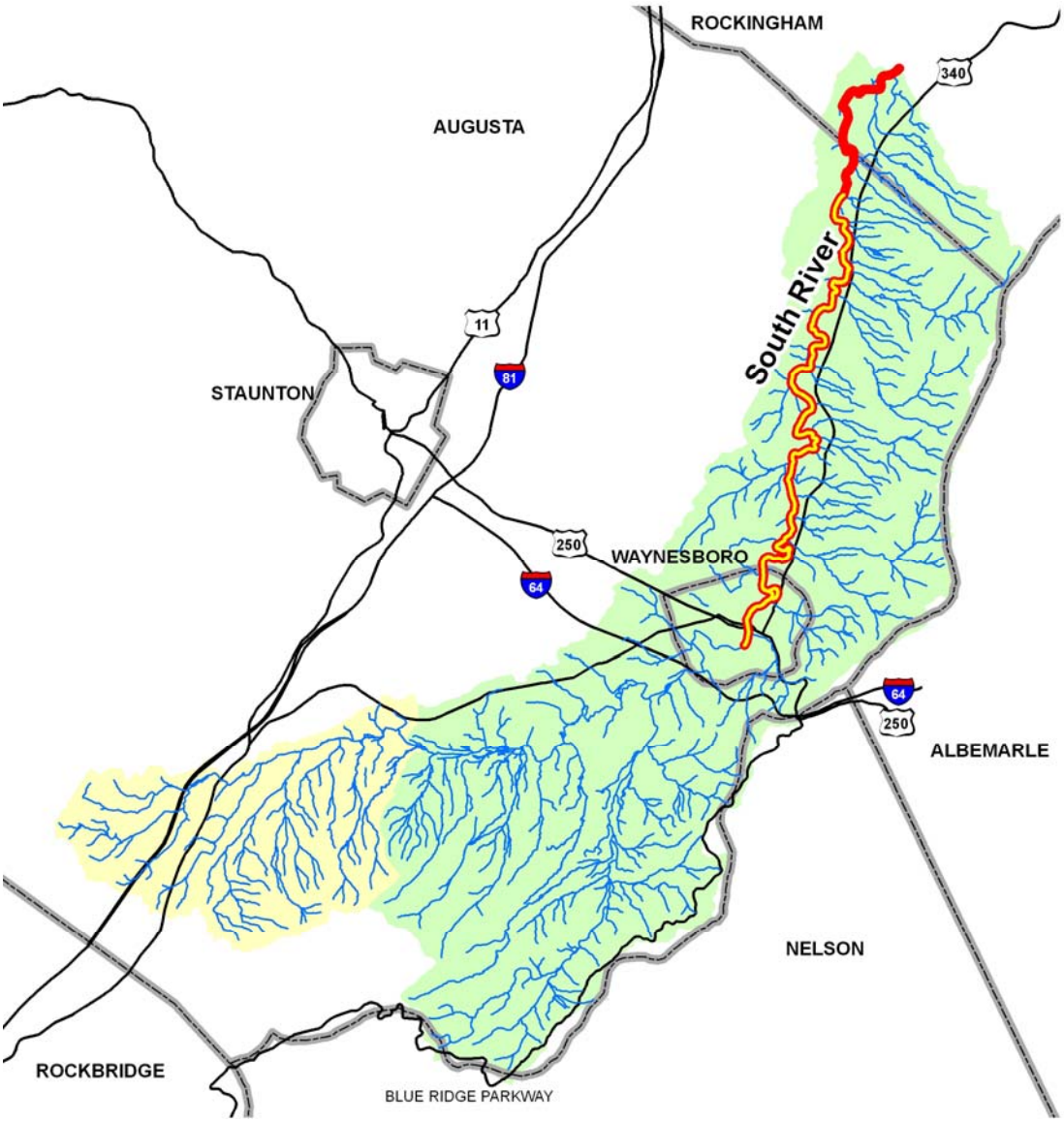
Bacteria and Benthic Total Maximum Daily Load Development for South River



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List of Acronyms

AVGWLF	ArcView Generalized Watershed Loading Functions
AVMA	American Veterinary Medical Association
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BMPs	Best Management Practices
BSE	Biological Systems Engineering
BST	Bacterial Source Tracking
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
E&S	Erosion and Sediment Control Program
GIS	Geographic Information Systems
GWLF	Generalized Watershed Loading Functions
HRU	Hydrologic Response Unit
HSPF	Hydrologic Simulation Program – Fortran
LA	Load Allocation
LSC	Local Steering Committee
MDL	Minimum Detection Limit
MFBI	Modified Family Biotic Index
MOS	Margin of Safety
MPID	Monitoring Point Identification Number
MPN	Most Probable Number
MRLC	Multi-Resolution Land Characterization
MS4	Phase II Municipal Separate Storm Sewer System
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NLCD	National Land Cover Data
NPDES	National Pollutant Discharge Elimination System
NPS	Non-Point Source
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PEC	Probable Effect Concentrations
RBP	Rapid Bioassessment Protocol
RBP II	Rapid Bioassessment Protocol II
SCS	Soil Conservation Service
SERCC	Southeast Regional Climate Center
SMC	Unsaturated Soil Moisture Capacity
SWCD	Soil and Water Conservation District
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load

TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation
VADCR	Virginia Department of Conservation and Recreation
VADEQ	Virginia Department of Environmental Quality
VADGIF	Virginia Department of Game and Inland Fisheries
VaSCI	Virginia Stream Condition Index
VASS	Virginia Agriculture Statistics Service
VCE	Virginia Cooperative Extension
VDACS	Virginia Department of Agricultural and Consumer Services
VDH	Virginia Department of Health
VPDES	Virginia Pollutant Discharge Elimination System
VWCB	Virginia Water Control Board
WLA	Waste Load Allocation
WQMP	Water Quality Management Plan

Executive Summary

Background

South River was first listed as an impaired stream in 1996 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report for not supporting the Aquatic Life (i.e., benthic-macroinvertebrate bioassessments) and Recreational (i.e., bacteria) Use goals (VADEQ, 1996). South River remained on the 1998, 2002, 2004, and 2006 Section 303(d) Total Maximum Daily Load Priority List and Report based on Virginia Department of Environmental Quality (VADEQ) benthic-macroinvertebrate bioassessments and bacteria (i.e., fecal coiform) monitoring data (VADEQ; 1998, 2002, 2004, 2006). The recent 2008 Section 303(d) Total Maximum Daily Load Priority List and Report listed South River as impaired caused by *E. coli*, fecal coliform, and benthic-macroinvertebrate bioassessments (VADEQ, 2008).

The impaired portion of South River (VAV-B32R-01) first listed in 1996 for benthic-macroinvertebrate bioassessments was delineated by VADEQ in the 2008 assesmment from the INVISTA discharge to its confluence with Sawmill Run, approximately 5.43 miles. A second impaired segment, delineated by VADEQ in the 2008 assemment, continues from Sawmill Run downstream to its confluence with Stull Run, approximately 13.91 miles. The two benthic impaired segments total approximately 19.34 miles. The impairment was listed for violations of the General Standard (Benthic) for not supporting Aquatic Life Use due to a moderately impaired benthic rating during the 2008 assessment period (VADEQ, 2008). The impaired portion of South River (VAV-B32R-02) first listed in 1996 for fecal coliform was delineated in the 2008 assessment beginning at the INVISTA disharge continuing downstream to its confluence with North River, approximately 24.63 miles. This section is listed as impaired by fecal coliform on Virginia's 2008 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2008). In addition to the fecal coliform impairtment listing, South River from its confluence with Sawmill Run downstream to its confluence with Stull Run, approximately 13.91 miles, was listed in Virginia's 2008 Section 303(d) Total Maximum Daily Load Priority List and Report due to water quality exceedances of the *E. coli* standard. *E.coli* values exceeded the standard at stations 1-BSTH007.80 (eight exceedances out of 27 samples), 1-BSTH014.49 (two exceedances out of 12 samples), and 1-BSTH019.52 (three exceedances out of 12 samples) during the 2008 assessment cycle (VADEQ, 2008).

The South River (VAV-B32R-01) is located in Waynesboro and Augusta County, Virginia. The second impairment for South River, (VAV-B32R-02), is located in Waynesboro and Augusta and Rockingham Counties, Virginia. South River flows northeast to the confluence with North River near Port Republic, VA. The South River watershed is approximately 150,000 acres, predominately forest, constituting approximately 59% of the total watershed area. The remaining land uses are divided between pasture (22%), residential (15%), and cropland (4%).

VADEQ personnel monitored pollutant concentrations throughout the South River watershed at stations 1-BSTH002.14, 1-BSTH007.80, 1-BSTH019.52, and 1-BSTH027.85. Of the 48 water quality samples collected from January 1998 through December 2004 (the 2006 Section 303(d) 5-year listing period) at VADEQ station 1-BSTH007.80, 20.8% of the samples

exceeded the then-applicable instantaneous fecal coliform water quality standard. Consequently, this segment of South River (VAV-B32R-02) was determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2006 Section 305(b) water quality assessment report and was included in the 2006 Section 303(d) List of Impaired Waters (VADEQ, 2006).

Data were considered from five benthic sampling stations. The Virginia Stream Condition Index (VaSCI) based on eight bio-monitoring metrics was utilized to assess samples collected at each station. Stream health scores, in the form of SCI values, range from 0-100. A maximum score of 100 represents the best benthic community sites. The threshold criterion defines "non-impaired" sites as those with a VaSCI of 60 or above, and "impaired" sites as those with a score below 60. Impaired conditions exist at all stations on the South River. The biological assessments conducted on the South River indicate that some pollutant(s) is interfering with attainment of the General Standard, as impaired invertebrate communities have been observed in the listed segment of this river. Although biological assessments are indicative of the impacts of pollution, the specific pollutant(s) and source(s) are not necessarily known based on biological assessments alone.

Stressor Analysis

TMDLs must be developed for a specific pollutant. Since the benthic impairment is based on a biological inventory, rather than on a physical or chemical water quality parameter, the pollutant is not explicitly identified in the assessment, as it is with physical and chemical parameters. The process outlined in USEPA's Stressor Identification Guidance Document (USEPA, 2000) was used to identify the critical stressor for South River. A list of candidate causes was developed from the listing information, biological data, published literature, and stakeholder input. Chemical and physical monitoring data from VADEQ monitoring provided additional evidence to support or eliminate the potential candidate causes. Biological metrics and habitat evaluations in aggregate provided the basis for the initial impairment listing, but individual metrics were also used to look for links with specific stressors, where possible. Logical pathways were explored between observed effects in the benthic community, potential stressors, and intermediate steps or interactions that would be consistent in establishing a cause and effect relationship with each candidate cause. Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed. Depending on the weight of evidence available, each potential stressor was placed into one of the following three categories:

<u>Non-stressor</u>: Stressor with data indicating normal conditions, without water quality standard exceedances, or without observable impacts usually associated with the stressor.

<u>Possible stressor</u>: Stressor with data indicating possible links to the benthic impairment, but without conclusive data to demonstrate direct impact on benthic community.

<u>Most probable stressor(s)</u>: Stressor with conclusive data linking it to the poor health of the benthic community, or the most plausible of the possible stressors. TMDL is developed for the most probable stressor(s).

The evaluation resulted in pH, temperature, dissolved oxygen, biochemical oxygen demand, ammonia, and sediment toxics being classified as non- stressors; nutrients and water column toxics were classified as possible stressors; and sediment and phosphorus were classified as the most probable stressors adversely affecting the benthic community in South River watershed.

Pollutant Sources

Currently, there are 17 active point source discharges with a VPDES permit to discharge bacteria within the South River watershed. However, the majority of the fecal coliform load originates from nonpoint sources. Nonpoint sources of fecal coliform are primarily agricultural (i.e., land-applied animal waste, manure deposited directly on pastures by livestock, and a significant fecal coliform load due to cattle directly depositing manure in streams) with a significant load applied to residential and forest land use categories. Non-agricultural anthropogenic nonpoint sources of fecal coliform loadings include straight pipes, leaking sanitary sewer, failing septic systems, and pet waste. Wildlife contributes to fecal coliform loadings on all land uses, according to the acceptable habitat range for each species. The amounts of fecal coliform produced in different locations (e.g., confinement, pasture, forest) were estimated on a monthly basis to account for seasonal variability in wildlife habitat and livestock production and practices. Livestock management and production factors, such as the fraction of time cattle spend in confinement or in streams, the amount of manure storage, and spreading schedules, were considered on a monthly basis.

Sediment and phosphorus can be delivered to the stream from point sources, non-point sources, and the processes of scour and deposition (primarily a function of stream flow) in the stream. Sediment and phosphorus loadings from permitted sources are attributable to the total suspended solids (TSS) and total phosphorus (TP), respectively, present in discharge effluent or stormwater runoff. There are 24 and 22 VPDES permitted facilities currently active or under application within the South River watershed discharging TSS and TP, respectively. Stormwater permits are divided between 15 industrial, one concrete plant, two mining, and 37 construction facilities. Sediment and phosphorus generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, mining, transportation, and residential land uses. During runoff events, sediment loading occurs from both pervious and impervious surfaces around the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. Vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, and land management practices influence this process. During periods without rainfall, dirt, dust and fine sediment build up on impervious areas through dry deposition, which is then subject to wash-off during rainfall events. Phosphorus is delivered to the stream through runoff, attachment to sediment particles, or seepage. Phosphorus loading is a function of land use, soils, and land use management practices. A total phosphorus delivery ratio is applied to sediment yield to determine the total phosphorus loadings to the stream. Nonpoint sources entering through seepage include dissolved inorganic and/or organic phosphorus forms and originate from agricultural phosphorus application and septic systems.

Modeling

The Hydrologic Simulation Program – Fortran (HSPF) was used to simulate the fate and transport of fecal coliform bacteria in the South River watershed. To identify localized sources of fecal coliform, the watersheds were divided into subwatersheds. These subdivisions were based primarily on homogeneity of land use. The South River model was calibrated using observed flow values from USGS station #01626000 on South River near Waynesboro, VA and USGS station #01627500 on South River at Harriston, VA for the period January 1, 1992 to December 31, 1996. The calibration period covered a wide range of hydrologic conditions, including low- and high-flow conditions, as well as seasonal variations. The calibrated HSPF data set was validated on a separate period from January 1, 1987 to December 31, 1991. Calibration parameters were adjusted within the recommended ranges until the model performance was deemed acceptable. Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring stations 1-BSTH002.14, 1-BSTH007.80, and 1-BSTH027.85 within the South River impairment were used to calibrate and validate the water quality component of HSPF. The period January 1, 1993 through December 31, 1997 was chosen for water quality calibration and January 1, 1998 through December 31, 2002 was chosen for water quality validation. Inputs to the model included fecal coliform loadings on land and in the stream along with simulated flow data. A comparison of simulated and observed fecal coliform loadings in the stream indicated that the model adequately simulated the fate and transport of fecal coliform in the watershed.

A modified reference watershed approach was used to establish the numeric sediment and phosphorus TMDL endpoints for South River. The Generalized Watershed Loading Function (GWLF) model was used to simulate sediment and phosphorus loads from potential sources in the impaired watershed. Several non-impaired watersheds were used to generate a load duration curve that establishes the TMDL endpoints. The load duration curve shows the sediment and phosphorus loadings in the unimpaired watersheds at different flow frequencies. Difference of loads at the various flow levels (i.e., high, moist, mid-range, dry, and low) signifies overall load reductions needed for sufficient recovery of benthic community. It is assumed that reduction of the sediment and phosphorus loads in South River to the average sediment and phosphorus load levels on the load duration curves derived from the reference watersheds will result in elimination of the benthic impairment.

Margin of Safety

A margin of safety (MOS) was included to account for any uncertainty in the TMDL development process. There are several different ways that the MOS could be incorporated into the TMDL (USEPA, 1991). For bacteria TMDL, the MOS was implicitly incorporated into the TMDL by conservatively estimating several factors affecting bacteria loadings, such as animal numbers, production rates, and contributions to streams. An explicit margin of safety of 10% of the reference load was used for the sediment and phosphorus TMDLs to account for uncertainties in the methodologies used to determine sediment and phosphorus loadings.

TMDL Allocation Scenarios

The wasteload allocated to permitted point sources in the watershed was based on the design flow or calculated runoff and the permitted concentration of *E. coli*, total suspended solids, or total phosphorus for each facility. No reduction in permitted source loads is required.

After calibrating to the existing water quality conditions, different scenarios were evaluated to identify implementable scenarios that meet both the calendar-month geometric mean *E. coli* criterion (126 cfu/100 mL) and the single sample maximum *E. coli* criterion (235 cfu/100 mL) with zero exceedances. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Required reductions in fecal coliform loading from existing conditions for the selected TMDL allocation include a 100% reduction in straight pipes, 95% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 95% reduction in nonpoint source loadings to residential land use, a 95% reduction in nonpoint source loadings to pasture land use, a 95% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land use.

Sediment and phosphorus load allocations for non-point sources not covered under the general wastewater permits were based on an equal percent reduction from controllable sources. Sediment and phosphorus loads from forest land use are considered to be representative of the natural condition and were not subject to reductions. Overall, the sediment and phosphorus load in the South River watershed must be reduced by 39% and 51% in order to meet the established TMDL endpoint, respectively. This translates to a 48% reduction in sediment from cropland, pasture, transitional, and residential land uses; along with sediment from channel erosion. Phosphorus must be reduced by 70% from cropland, pasture, transitional, and residential land uses; along with a 70% reduction of the phosphorus load from septic systems.

Using equation [E.1], summaries of the South River bacteria, sediment, and phosphorus TMDLs for the selected allocation scenario are shown in Tables E.1 through E.6.

$$TMDL = WLA + LA + MOS \qquad [E.1]$$

where: WLA = wasteload allocation (point source contributions);
LA = load allocation (nonpoint source contributions); and
MOS = margin of safety (implicit).

Table E.1. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in South River impairment.

WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
1.13E+14	2.71E+13	Implicit	1.40E+14

Table E.2. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in South River impairment.

WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
3.10E+11	1.62E+13	Implicit	1.65E+13

Table E.3. Yearly sediment loads (T/yr) modeled after TMDL allocation in South River impairment.

WLA (T/yr)	LA (T/yr)	MOS (T/yr)	TMDL (T/yr)
619.4	1,471.0	234.1	2,324.5

Table E.4. Daily sediment loads (T/d) modeled after TMDL allocation in South River impairment.

WLA (T/d)	LA (T/d)	MOS (T/d)	TMDL (T/d)
3.33	8.91	1.36	13.60

Table E.5. Yearly phosphorus loads (kg/yr) modeled after TMDL allocation in South River impairment.

WLA (kg/yr)	LA (kg/yr)	MOS (kg/yr)	TMDL (kg/yr)
6,929.9	5,926.1	1,435.5	14,291.5

Table E.6. Daily phosphorus loads (kg/d) modeled after TMDL allocation in South River impairment.

WLA (kg/d)	LA (kg/d)	MOS (kg/d)	TMDL (kg/d)
40.50	34.73	8.36	83.59

TMDL Implementation and Reasonable Assurance

The goal of the TMDL program is to establish a three-step process that will enable the 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 bacteria and benthic impairments on South River. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and monitor stream water quality to determine if water quality standards are being attained. Watershed stakeholders will have the 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.

Following the development of the TMDL, the VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. VADEQ staff, in cooperation with VADCR staff, the Implementation Plan 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 implementation plan, 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. Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the watershed.

Staged implementation is a key component to restoring water quality in South River. An alternative scenario was evaluated to establish goals for the first implementation stage of the bacteria TMDL. The implementation of such a transitional scenario, or Stage 1 implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through continued data collection. The bacteria Stage 1 implementation goal was to provide an instantaneous standard exceedance rate below 10%, a geometric mean standard exceedance rate of 0%, and 0% reduction in wildlife loads. These exceedance rate criteria mirror the new proposed bacteria standard meeting a 10% exceedance rate of the single sample maximum criterion (235 cfu/100ml) and a 0% exceedance rate of the geometric mean criterion (126 cfu/100 ml).The Stage 1 allocation for the South River bacteria impairment requires a 100% reduction in straight pipes, 75% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 39% reduction in nonpoint source loadings to residential land use, a 39% reduction in nonpoint source loadings to pasture land use, a 39% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.36% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate. After the proposed bacteria standard is adopted by the VWCB, the Stage I implementation scenario will become the TMDL allocation scenario, since it will meet the new revised standard.

Public Participation

During development of the South River Bacteria and Benthic TMDL, public participation was encouraged through two public meetings and two Local Steering Committee (LSC) meetings. The first public meeting was held at the Council Chambers in the Waynesboro Municipal Building in Waynesboro, VA on April 15, 2008, to discuss the need for a TMDL, discuss the draft watershed stressor analysis, and review the approach for TMDL development. The final public meeting was held at the Waynesboro City Council Chambers, Charles T.

Yancey Municipal Building in Waynesboro, VA on June 11, 2009, to discuss the source allocations and reductions required to meet the TMDL. Copies of the draft TMDL report were available for public review and comment.

In addition to keeping the public apprised of progress in the development of the South River Bacteria and Benthic TMDL, a TMDL Local Steering Committee (LSC) was also established to help advise the TMDL developers. LSC meetings were held for this project on April 30, 2008 and November 13, 2008 at the Waynesboro Public Library in Waynesboro, Virginia. The general public was solicited to participate on the LSC during the first public meeting in addition to agencies and groups already represented on the LSC. The LSC membership for the South River Bacteria and Benthic TMDL included representatives from the following agencies and organizations: Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation, Virginia Cooperative Extension, Central Shenandoah Planning District Commission, Shenandoah Valley Soil and Water Conservation District, City of Waynesboro, Augusta County, Rockingham County, Nelson County, Albemarle County, INVISTA, and DuPont.

The meetings were used as a forum to facilitate understanding of, and involvement in, the TMDL process. Data and assumptions used in the TMDL development were reviewed along with stakeholder concerns about the implications of the TMDL. Feedback from these meetings was used in the TMDL development and improved confidence in the allocation.

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Augusta County Government

Rockingham County Government

Nelson County Government

Albemarle County Government

City of Waynesboro

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Chapter 1. Introduction

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that exceed state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL represents the total load of a pollutant that a water body can receive without exceeding state water quality standards. The TMDL process establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the allowable load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

1.1.2 Impairments Listing

South River was first listed as an impaired stream in 1996 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report for not supporting the Aquatic Life (i.e., benthic-macroinvertebrate bioassessments) and Recreational (i.e., bacteria) Use goals (VADEQ, 1996). South River remained on the 1998, 2002, 2004, and 2006 Section 303(d) Total Maximum Daily Load Priority List and Report based on Virginia Department of Environmental Quality (VADEQ) benthic-macroinvertebrate bioassessments and bacteria (i.e., fecal coiform) monitoring data (VADEQ; 1998, 2002, 2004, 2006). The recent 2008 Section 303(d) Total Maximum Daily Load Priority List and Report listed South River as impaired caused by *E. coli*, fecal coliform, and benthic-macroinvertebrate bioassessments (VADEQ, 2008).

The impaired portion of South River (VAV-B32R-01) first listed in 1996 for benthic-macroinvertebrate bioassessments was delineated by VADEQ in the 2008 assesmment from the INVISTA discharge to its confluence with Sawmill Run, approximately 5.43 miles. A second impaired segment, delineated by VADEQ in the 2008 assemment, continues from Sawmill Run downstream to its confluence with Stull Run, approximately 13.91 miles. The two benthic impaired segments total approximately 19.34 miles. The impairment was listed for violations of the General Standard (Benthic) for not supporting Aquatic Life Use due to a moderately impaired benthic rating during the 2008 assessment period (VADEQ, 2008).

The impaired portion of South River (VAV-B32R-02) first listed in 1996 for fecal coliform was delineated in the 2008 assessment beginning at the INVISTA disharge continuing downstream to its confluence with North River, approximately 24.63 miles. This section is listed as impaired by fecal coliform on Virginia's 2008 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2008). In addition to the fecal coliform impairtment listing, South River from its confluence with Sawmill Run downstream to its confluence with Stull Run, approximately 13.91 miles, was listed in Virginia's 2008 Section 303(d) Total Maximum Daily Load Priority List and Report due to water quality exceedances of the *E. coli* standard.

1.1.3 Watershed Location and Description

The South River (VAV-B32R-01) is located in Waynesboro and Augusta County, Virginia. The second impairment for South River, (VAV-B32R-02), is located in Waynesboro and Augusta and Rockingham Counties, Virginia. South River flows northeast to the confluence with North River near Port Republic, VA. The South River watershed is approximately 150,000 acres, predominately forest, constituting approximately 59% of the total watershed area. The remaining land uses are divided between pasture (22%), residential (15%), and cropland (4%). A summary of the land use distribution is listed in Table 2.2.

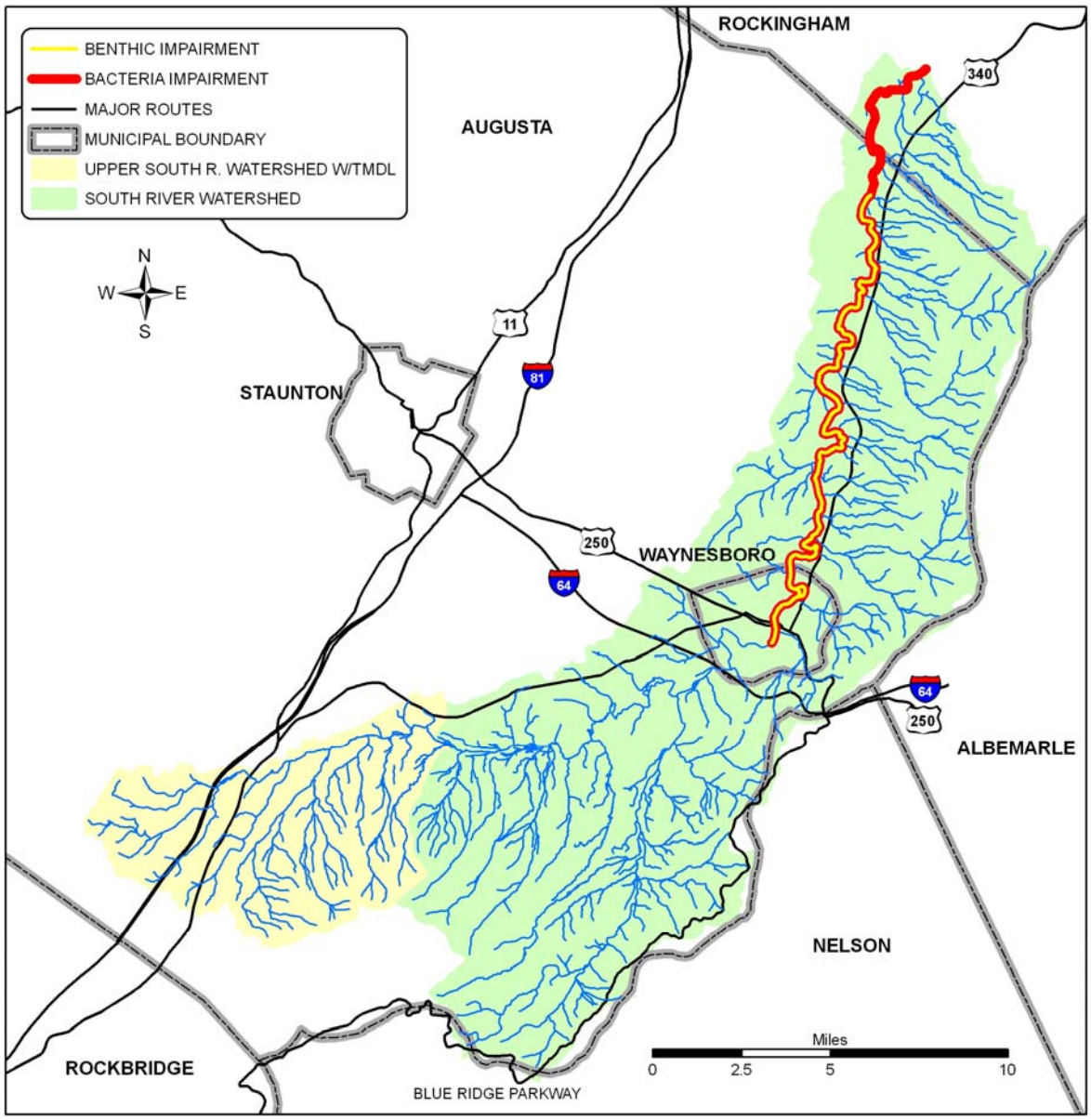

Figure 1.1. Location of South River watershed.

1.1.4 Pollutant of Concern

Pollution from both point and nonpoint sources can lead to fecal coliform bacteria contamination of water bodies. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform. Even though most fecal coliform are not pathogenic, some forms can be harmful to human health and their presence in water indicates recent contamination by fecal material. Because fecal material may contain pathogenic organisms, water bodies with fecal coliform counts may also contain pathogenic organisms. For recreational activities involving contact with water, such as boating and swimming, health risks increase with increasing fecal coliform counts. If the fecal coliform concentration in a water body exceeds state water quality standards, the water body is listed for an exceedance of the state fecal coliform standard for contact recreational uses. As discussed in Section 1.2.2, Virginia has adopted an Escherichia coli (*E. coli*) standard for water quality. The concentration of *E. coli* (a subset of the fecal coliform group) in water is considered to be a better indicator of pathogenic exposure than the concentration of the entire fecal coliform group in the water body.

Additionally, pollution from both point and nonpoint sources can lead to exceedance of the benthic standard, assessed based on measurements of the in-stream benthic macro-invertebrate community. Water bodies having a benthic impairment are not fully supportive of the aquatic life designated use for Virginia's waters.

1.2 Designated Uses and Applicable Water Quality Standards

1.2.1 Designation of Uses (9 VAC 25-260-10)

> "A. All state waters 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)." (SWCB, 2002)

1.2.2 Bacteria Standard (9 VAC 25-260-170)

USEPA has recommended that all states adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters, because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than there is with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals and are subsets of the fecal coliform and fecal streptococcus groups, respectively. In line with this recommendation, Virginia adopted and published revised bacteria criteria on June 17, 2002. The revised criteria became effective on January 15, 2003. As of that date, the *E. coli* standard described below applies to all freshwater streams in Virginia. Additionally, prior to June 30, 2008, the interim fecal coliform standard must be applied at any sampling station that has fewer than 12 samples of *E. coli*.

For a non-shellfish water body to be in compliance with Virginia's revised bacteria standards (as published in the Virginia Register Volume 18, Issue 20) the following criteria shall apply to protect primary contact recreational uses (VADEQ, 2000):

- **Interim Fecal Coliform Standard:** 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.
- **Escherichia coli Standard:** *E. coli* bacteria concentrations for freshwater shall not exceed a geometric mean of 126 counts per 100 mL for two or more samples taken during any calendar month and shall not exceed an instantaneous single sample maximum of 235 cfu/100mL.

During an assessment period, conventional parameters such as bacteria require at least two exceedences of the standard, and an exceedance of greater than 10.5% of the total samples before a water is listed as impaired (VADEQ Assessment Guidance, 2006). If these conditions are met, the stream segment associated with that station is classified as impaired and a TMDL must be developed and implemented to bring the segment into compliance with the water quality standard. The original impairment designation to South River was based on exceedances of an earlier fecal coliform standard that included a numeric single sample maximum limit of 1,000 cfu/100 mL. The bacteria TMDL for these impaired segments was developed to meet the *E. coli* standard. As recommended by VADEQ, the modeling was conducted with fecal coliform inputs, and then a translator equation developed by the VADEQ was used to convert the output of the model to *E. coli*.

1.2.3 General Standard (9 VAC 25-260-20)

The general standard for a water body in Virginia is stated as follows:

> "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.
>
> Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled." (SWCB, 2002)

The VADEQ conducts the biological monitoring program in Virginia used to evaluate compliance with the General standard. Evaluations of monitoring data to determine whether or not a stream segment has a benthic impairment focus on benthic macro-invertebrates (i.e., bottom-dwelling; visible to eyes; insects, mollusks, crustaceans, and annelid worms). Changes in water quality generally result in alterations to the quantity and diversity of the benthic organisms that live in streams and other water bodies. Besides being the major intermediate constituent of the aquatic food chain, benthic macro-invertebrates are "living recorders" of past

and present water quality conditions. This is due to their relative immobility and their variable resistance to the diverse contaminants that are introduced into streams. The community structure of these organisms provides the basis for the biological analysis of water quality. Qualitative and semi-quantitative biological monitoring has been conducted by VADEQ since the early 1970's.

From 1990 to 2006, the U.S. Environmental Protection Agency's (USEPA) Rapid Bioassessment Protocol II (RBP II) was the official protocol used to assess compliance with the general standard in Virginia (Barbour et al., 1999). The RBP II was employed beginning in the fall of 1990 to utilize standardized and repeatable assessment methodology. For any single sample, the RBP II produces water quality ratings of "non-impaired," "slightly impaired," "moderately impaired," or "severely impaired." In Virginia, benthic samples are typically collected and analyzed twice a year in the spring and in the fall. The RBP II procedure evaluates the benthic macro-invertebrate community by comparing ambient monitoring "network" stations to "reference" sites. Reference bio-monitoring stations have been identified by regional biologists that are both representative of regional physiographic and ecological conditions and have a healthy, non-impaired benthic community. The RBP II evaluation also accounts for the natural variation noted in streams in different ecoregions. One additional product of the RBP II evaluation is a habitat assessment. This is a stand alone assessment that describes bank condition and other stream and riparian corridor characteristics and serves as a measure of habitat suitability for the benthic community. Determination of the degree of support for the aquatic life designated use is based on biological monitoring data and the best professional judgment of the regional biologist, relying primarily on the most recent data collected during the current 5-year assessment period. In Virginia, any stream segment with an overall rating of "moderately impaired" or "severely impaired" is placed on the state's 303(d) list of impaired streams (DEQ, 2002).

Beginning with the 2008 Assessment, VADEQ upgraded its bio-monitoring and biological assessment methods to use the Virginia Stream Condition Index (VaSCI) for Virginia's non-coastal areas (Tetra Tech, 2002). Rather than being based on a paired reference site approach (like the RBPII method), the VaSCI is based on a regional condition. This multi-metric index is based on eight bio-monitoring metrics, with a scoring range of 0-100, that include some different metrics than those used in the RBP II, but are based on the same taxa inventory. A maximum score of 100 represents the best benthic community sites. The threshold criterion defines "non-impaired" sites as those with a VaSCI of 60 or above, and "impaired" sites as those with a score below 60 (VADEQ, 2006).

The biological assessments conducted on the South River indicate that some pollutant(s) is interfering with attainment of the General Standard, as impaired invertebrate communities have been observed in the listed segment of this river. Although biological assessments are indicative of the impacts of pollution, the specific pollutant(s) and source(s) are not necessarily known based on biological assessments alone.

Chapter 2. Watershed Characterization

2.1 Water Resources

South River runs for approximately 18 miles from the headwaters near Spotswood, VA to the confluence with Back Creek, south of the City of Waynesboro, VA. South River continues flowing northeast for approximately 35 miles to the confluence with North River near Port Republic, VA. South River is a perennial stream with a trapezoidal channel cross-section.

2.2 Ecoregion

The South River watershed is divided into two ecoregions. The eastern portion of the watershed lies within the Blue Ridge Mountains ecoregion and the western portion lies within the Central Appalachian Ridges and Valleys ecoregion.

The Blue Ridge Mountains vary from narrow ridges to hilly plateaus to more massive mountainous areas. The mostly forested slopes, high-gradient, cool, clear streams, and rugged terrain occur primarily on metamorphic rocks, with minor areas of igneous and sedimentary geology. Appalachian Oak Forests and northern hardwoods coupled with shrub, grass, heath balds, hemlock, cove hardwoods, and oak-pine communities illustrate the floristic diversity of this ecoregion (USEPA, 2002).

The Central Appalachians is primarily a high, dissected, rugged plateau, which is composed of sandstone, shale, conglomerate and coal. The land cover is mostly forested due to rugged terrain, cool climate and infertile soils, which limit agriculture. A mixed mesophytic forest with areas of Appalachian oak and northern hardwood forest cover the high hills and low mountains. The agricultural lands of the ecoregion are located in the valleys, where the main agricultural activities include livestock and dairy farming and Christmas trees growing on plantations. Bituminous coal mines that may cause siltation and acidification of streams are common in this region (USEPA, 2002).

2.3 Soils and Geology

The soils found in South River watershed are primarily in the Frederick, Alleghany, Cataska, Drall, Lew, Monongahela, and Sherando series. The components are on hills on uplands, on mountains on uplands, and on stream terraces on river valleys. The parent material consists of residuum or alluvium weathered from limestone, sandstone, shale, slate, siltstone, phyllite, and greenstone; derived from sandstone, quartzite, and shale. Depth to a root restrictive layer is 40 to 60 inches, bedrock (paralithic) is 4 to 20 inches, and fragipan is 20 to 30 inches. The natural drainage class is well drained to excessively Water movement in the most restrictive layer is moderately high to high. Available water to a depth of 60 inches is low to moderate. Shrink-swell potential is low to moderate. These soils are not flooded or ponded. There is no zone of

water saturation within a depth of 72 inches, except on stream terraces on river valleys, a seasonal zone of water saturation at 27 inches exists during January, February, March, April, and December. Organic matter content in the surface horizon varies between one and three percent. Non-irrigated land capability classifications are 2e, 3e, 4e, and 7s.The soils do not meet hydric criteria.

2.4 Climate

The climate of the South River watershed is characterized based on the meteorological observations from 01/01/1893 to 12/31/2007 assembled by the Southeast Regional Climate Center for the Staunton Sewage Treatment Plant, Virginia (448062) station. Average annual precipitation is 37.23 inches with 56.8% of the precipitation occurring during the crop-growing season (May-October) (SERCC, 2008). Average annual snowfall is 21.7 inches with the highest snowfall occurring during January (SERCC, 2004). Average annual daily temperature is 53.9°F. The highest average daily temperature of 85.0°F occurs in July while the lowest average daily temperature of 24.1°F occurs in January (SERCC, 2008).

2.5 Land Use

The National Land Cover Data (NLCD) produced by U.S. Geological Survey (USGS) in cooperation with the USEPA was used for this study. NLCD was developed from 30-meter Landsat 7 thematic mapper (TM) data between 1990 and 1994 and updated with data between 1999 and 2003 acquired by the Multi-resolution Land Characterization (MRLC) Consortium, a partnership between Unites States Geologic Survey (USGS), USEPA, U.S. Forest Service, National Oceanic and Atmospheric Administration (NOAA), Bureau of Land Management (BLM), Natural Resources Conservation Service (NRCS), National Park Service (NPS), National Aeronautics and Space Administration (NASA), and United States Fish and Wildlife Service (USFWS). NLCD is classified into 21 land use types. The NLCD land use types within the watershed were consolidated into 12 categories based on similarities in hydrologic and pollutant production features (Table 2.1). Land use distribution in the South River, watershed is presented in Table 2.2. For purposes of this study, it was assumed that residential development in the South River watershed will continue at the overall average rate of 1.8% annually.

Table 2.1. Consolidation of NLCD land use categories for South River watershed.

TMDL Land Use Categories	NLCD Land Use Classification (Class No.)
High Tillage Cropland	Cultivated Crops (82)
Low Tillage Cropland	Cultivated Crops (82)
Pasture 1[a]	Pasture/Hay (81)
Pasture 2[a]	Pasture/Hay (81)
Pasture 3[a]	Pasture/Hay (81)
Open Urban Grass	Developed, Open Space (21)
Low Intensity Residential	Developed, Low Intensity (22)
Medium Intensity Residential	Developed, Medium Intensity (23)
High Intensity Residential	Developed, High Intensity (24)
Forest	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43) Woody Wetlands (91) Emergent Herbaceous Wetlands (92)
Transitional	Barren Land, Rock, Sand, Clay (31)
Water	Open Water (11)

[a] Pasture 1 (improved pasture/hay land) stocks twice as many cows per unit area as pasture 2 (unimproved pasture/grazed woodlands), which stocks twice as many cows per unit area as pasture 3 (overgrazed pasture).

Table 2.2. Land use distribution in South River watershed.

TMDL Land Use Categories	Area (ac)	Portion of Total (%)
High Tillage Cropland	1,827.2	1.2
Low Tillage Cropland	4,265.3	2.8
Pasture 1	18,528.5	12.4
Pasture 2	9,280.5	6.2
Pasture 3	4,640.2	3.1
Open Urban Grass	12,163.2	8.1
Low Intensity Residential	8,018.9	5.3
Medium Intensity Residential	1,242.8	0.8
High Intensity Residential	686.8	0.5
Forest	88,923.7	59.2
Transitional	44.9	0.0
Water	530.1	0.4
TOTAL	150,152.1	100.0

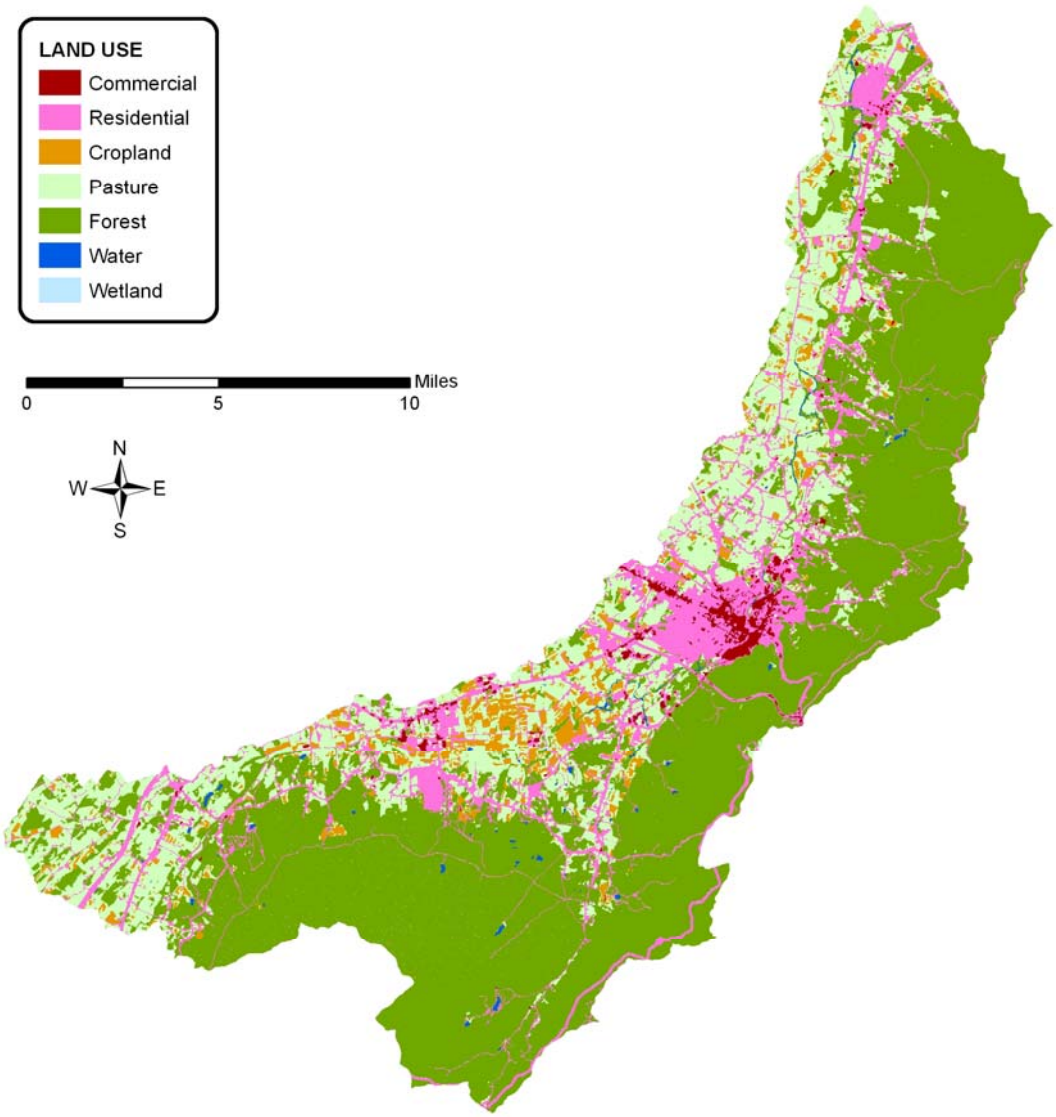

Figure 2.1. Land use distribution in South River watershed.

2.5 Bacteria Water Quality Data

2.5.1 Historic Data for Fecal Coliform

Of the 48 water quality samples collected from January 1998 through December 2004 (the 2006 Section 303(d) 5-year listing period) at VADEQ station 1-BSTH007.80, 20.8% of the samples exceeded the then-applicable instantaneous fecal coliform water quality standard. Consequently, this segment of South River (VAV-B32R-02) was determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2006 Section 305(b) water quality assessment report and was included in the 2006 Section 303(d) List of Impaired Waters (VADEQ, 2006).

VADEQ personnel monitored pollutant concentrations throughout the South River watershed. Monitoring data with corresponding 6-day antecedent precipitation used in assessment of the impairments, as well as in this study, are included in Appendix A. Time series data of fecal coliform concentration from 1990 through the most recent data collected at the time this report was written for stations 1-BSTH002.14, 1-BSTH007.80, 1-BSTH019.52, and 1-BSTH027.85 are plotted in Figures 2.2 – 2.5, respectively. The Most Probable Number (MPN) and membrane filtration methods were used for analyzing water samples for fecal coliform concentration.

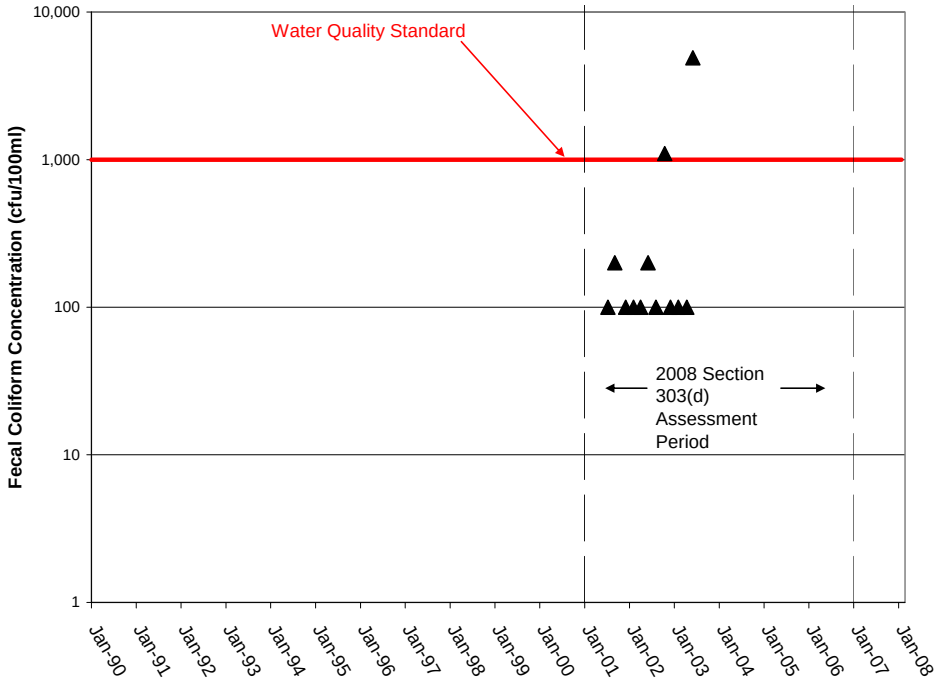

Figure 2.2. Fecal coliform concentrations (VADEQ station 1-BSTH002.14) in the South River impairment.

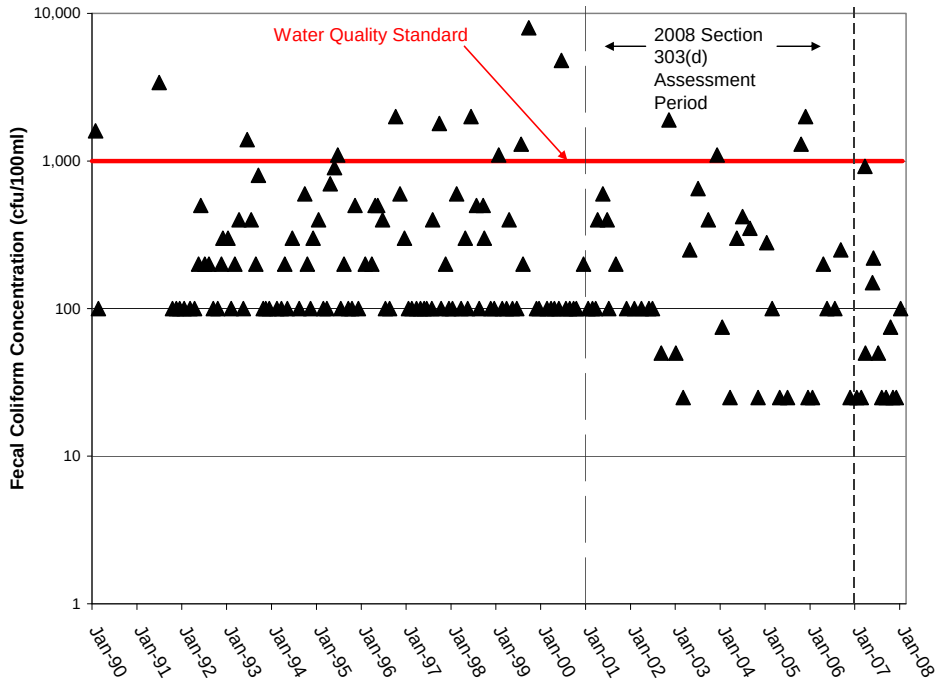

Figure 2.3. Fecal coliform concentrations (VADEQ station 1-BSTH007.80) in the South River impairment.

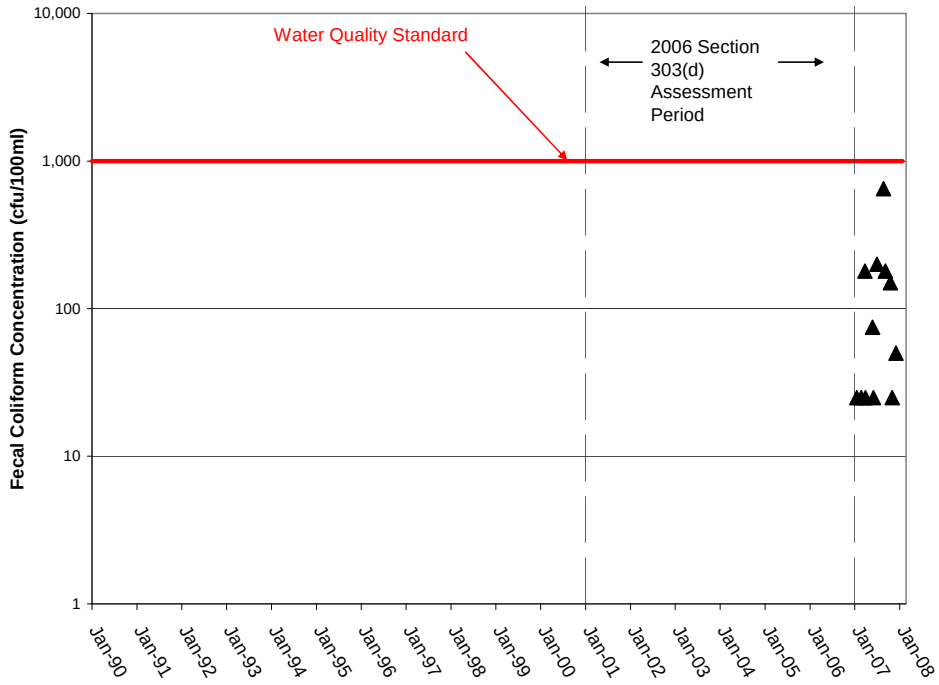

Figure 2.4. Fecal coliform concentrations (VADEQ station 1-BSTH019.52) in the South River impairment.

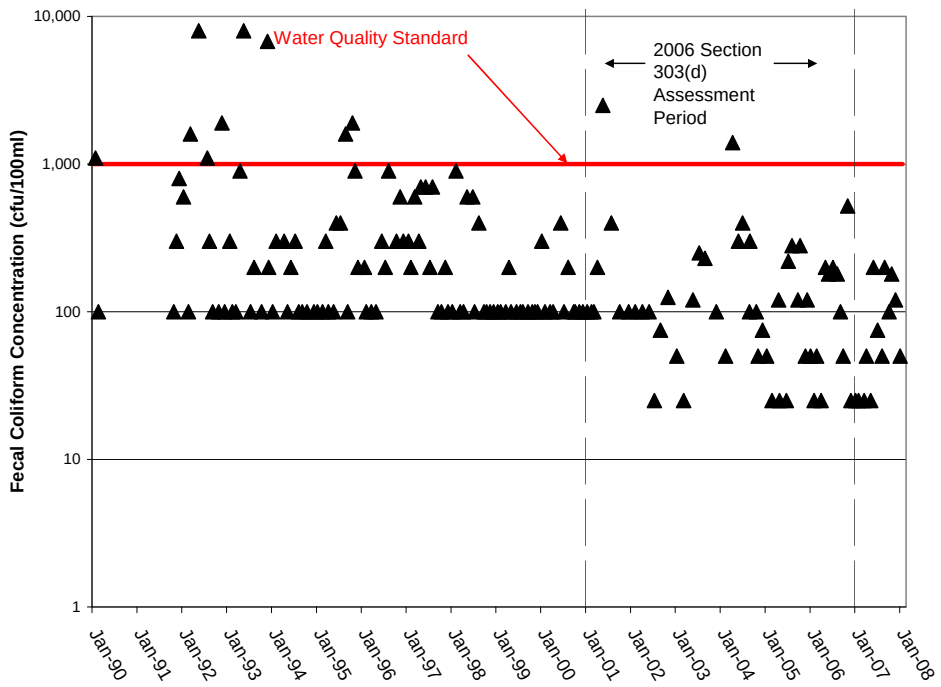

Figure 2.5. Fecal coliform concentrations (VADEQ station 1-BSTH027.85) in the South River impairment.

Seasonal variability of fecal coliform concentrations in the stream network was evaluated by plotting the mean monthly fecal coliform concentration values. Mean monthly fecal coliform concentration values were determined as the average of zero to 16 values for each month; the number of values varied according to the available number of samples for each month in the 1990 to 2007 period of record (Table 2.3). Mean monthly fecal coliform bacteria concentrations were plotted for stations 1-BSTH002.14, 1-BSTH007.80, 1-BSTH019.52, and 1-BSTH027.85 (Figures 2.6 – 2.9).

The highest mean concentration occurred in June and October with the remaining months having a uniform distribution at station 1-BSTH002.14 (Figure 2.6). At station 1-BSTH007.80, the highest in-stream fecal coliform concentrations occur in June and September (Figure 2.7). At station 1-BSTH019.52, the data indicate that higher in-stream fecal coliform concentrations occur during August (Figure 2.8). The highest mean concentration occurred in May and November with the remaining months having a uniform distribution at station 1-BSTH027.85 (Figure 2.9). It should be noted that due to the upper cap (8,000 cfu/100 mL or 16,000 cfu/100 mL) and lower cap (100 cfu/100ml or 18 cfu/100ml) imposed on the fecal coliform count, the actual counts could be higher or lower in cases where fecal coliform levels are equal to these level limits; therefore, changing the averages shown in Figure 2.6 – 2.9.

Table 2.3. Number of samples collected per month from 1/1/90 to 12/31/07 in the South River impairment.

Month	Samples Collected at			
	1-BSTH002.14 (#)	1-BSTH007.80 (#)	1-BSTH019.52 (#)	1-BSTH027.85 (#)
January	0	13	1	15
February	2	12	1	15
March	0	14	1	13
April	2	13	1	13
May	0	15	1	13
June	2	12	1	12
July	1	16	1	15
August	1	10	1	14
September	1	14	1	13
October	1	11	1	15
November	0	14	1	14
December	2	14	1	16
TOTAL	**12**	**158**	**12**	**168**

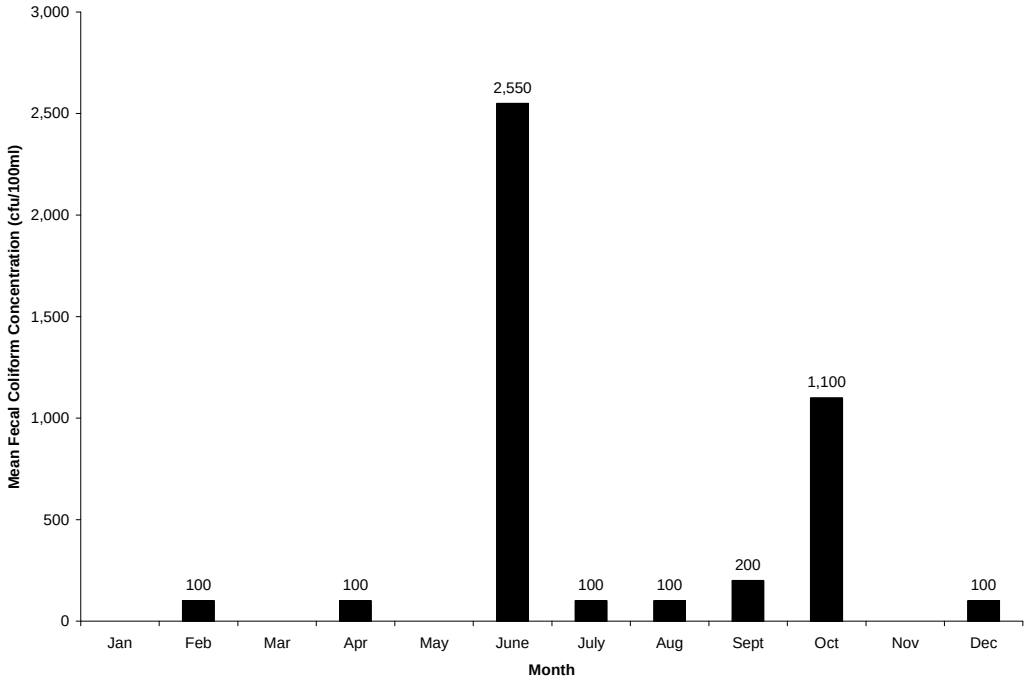

Figure 2.6. Impact of seasonality on fecal coliform concentrations (VADEQ station 1-BSTH02.14) in the South River impairment from January 1990 through December 2007.

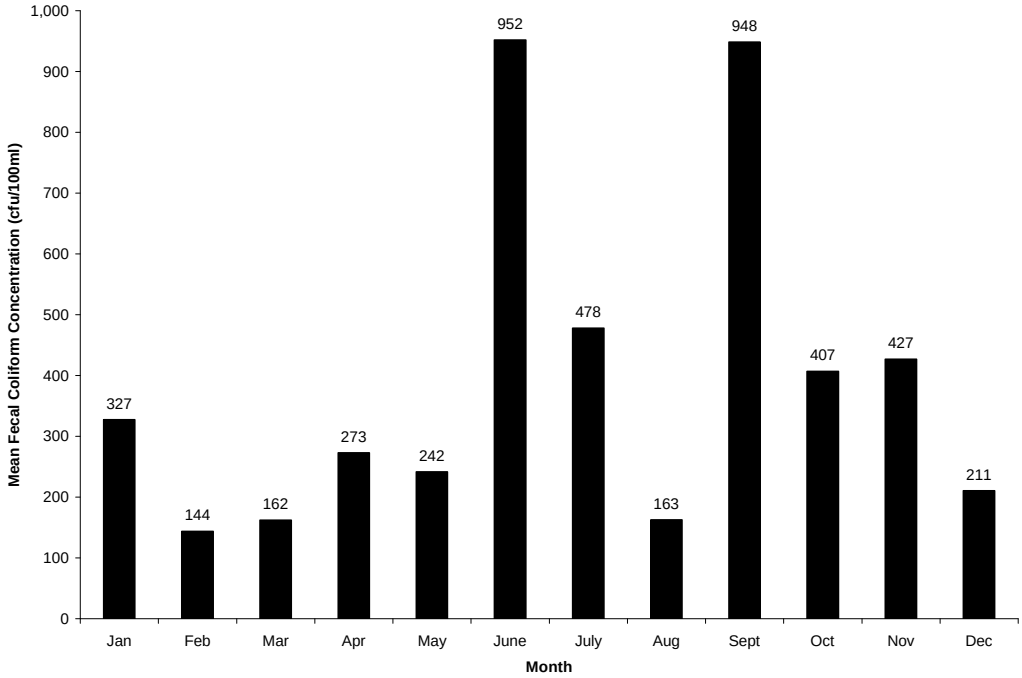

Figure 2.7. Impact of seasonality on fecal coliform concentrations (VADEQ station 1-BSTH007.80) in the South River impairment from January 1990 through December 2007.

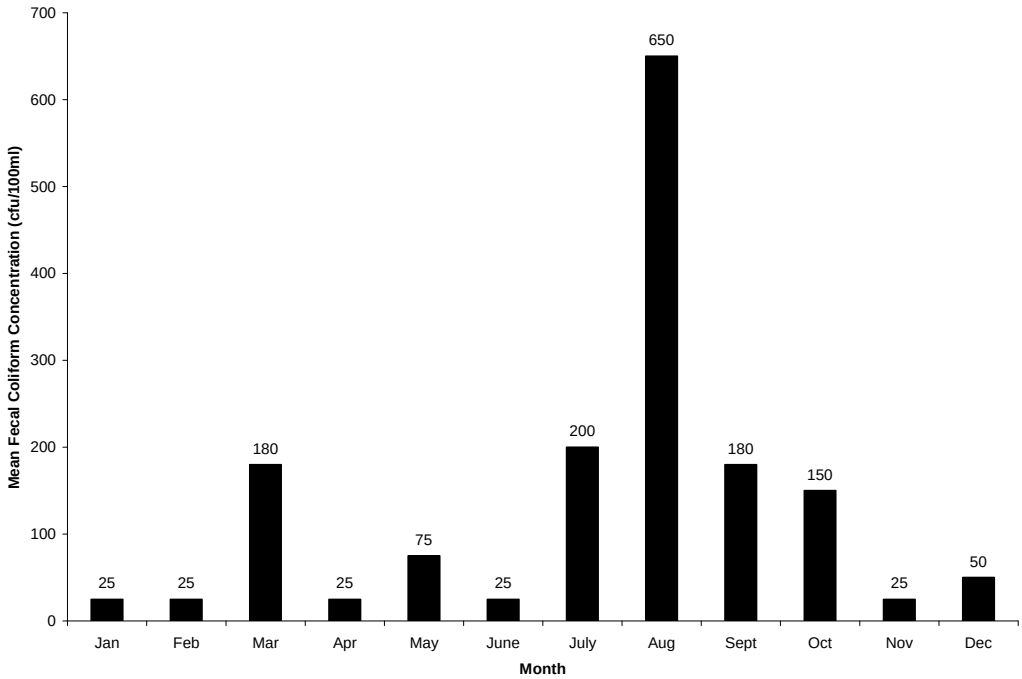

Figure 2.8. Impact of seasonality on fecal coliform concentrations (VADEQ station 1-BSTH019.52) in the South River impairment from January 1990 through December 2007.

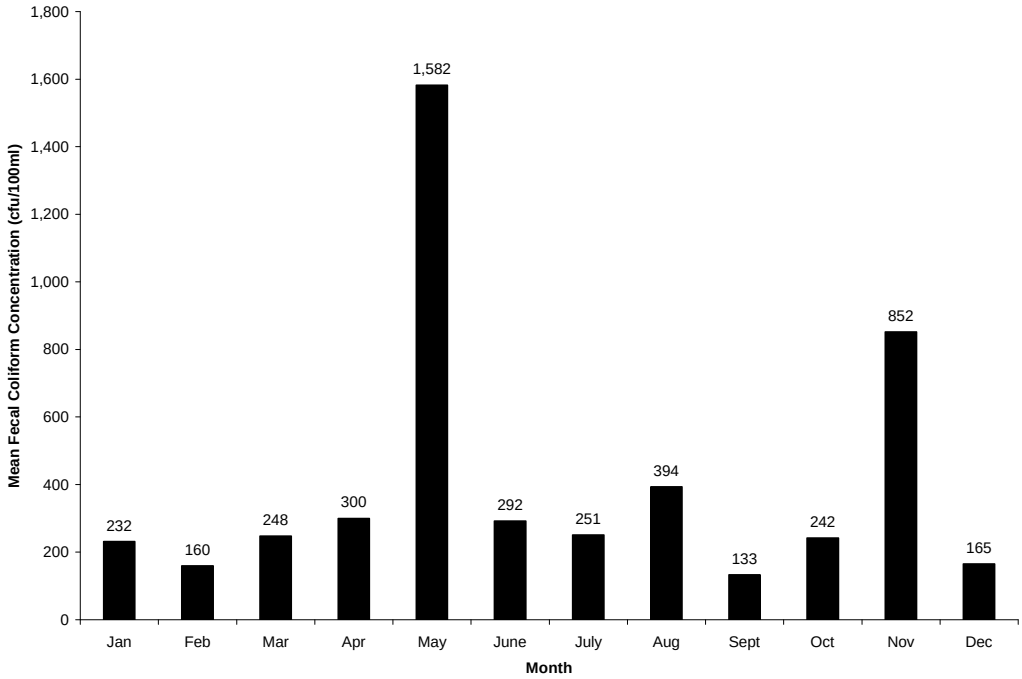

Figure 2.9. Impact of seasonality on fecal coliform concentrations (VADEQ station 1-BSTH027.85) in the South River impairment from January 1990 through December 2007.

2.5.2 Historic Data for E. coli

VADEQ staff examined water samples collected at stations 1-BSTH007.80, 1-BSTH014.49, 1-BSTH019.52, and 1-BSTH027.85 for their concentration of *E. coli* (Figures 2.10 and 2.11). This analysis was conducted concurrently with other monthly testing at the stations from April 2002 through December 2007. Eight of the 27 (30%) samples analyzed from station 1-BSTH007.80 exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Of the 12 water quality samples collected at station 1-BSTH014.49, two (16.6%) of the samples exceeded the instantaneous *E. coli* bacteria standard. At station 1-BSTH019.52, three of 12 (25%) samples violated the instantaneous *E. coli* bacteria standard. Of the 54 water quality samples collected at station 1-BSTH027.85, four (7.4%) of the samples exceeded the instantaneous *E. coli* bacteria standard.

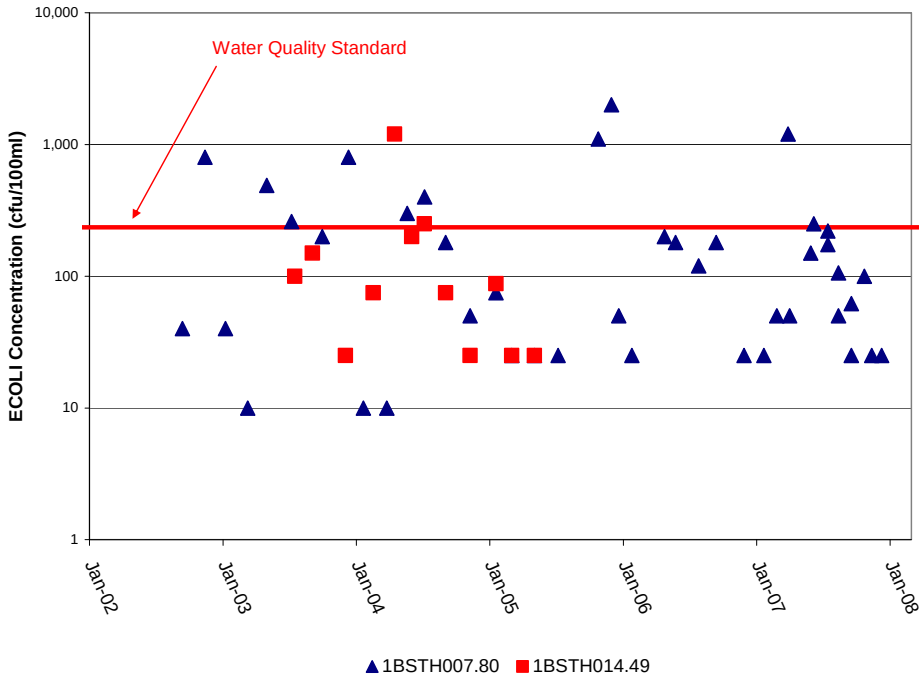

Figure 2.10. E. coli concentrations (1-BSTH007.80 and 1-BSTH014.49) in the South River impairment.

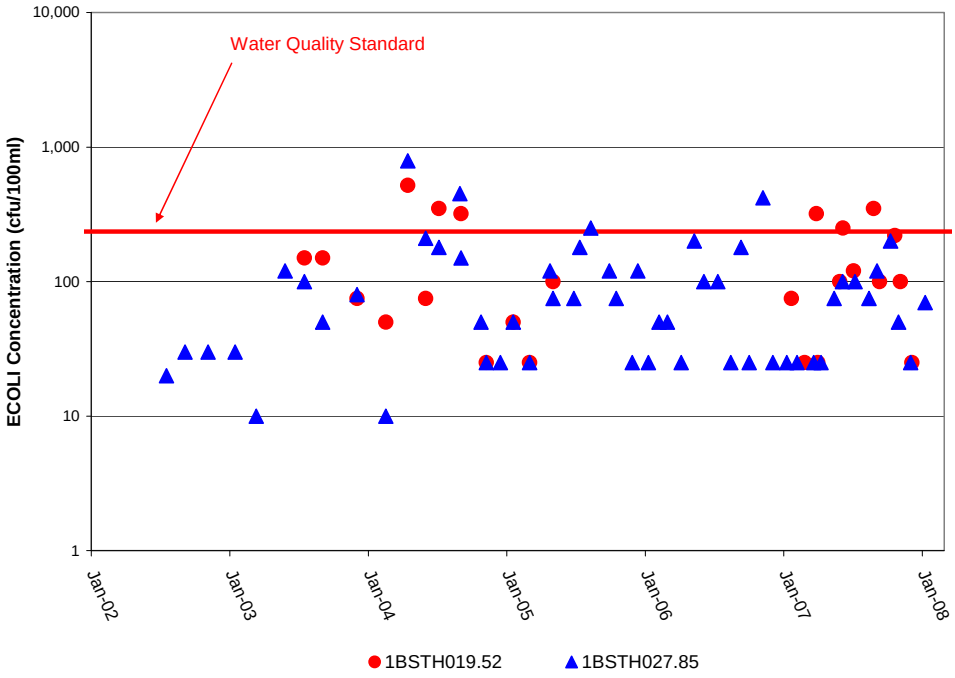

Figure 2.11. E. coli concentrations (1-BSTH019.52 and 1-BSTH027.85) in the South River impairment.

2.5.3 Historic Data for Bacterial Source Tracking

The results from 12 monthly bacteria source tracking (BST) samples collected at station 1-BSTH007.80 were received at the time this report was prepared. The BST analysis was performed by MapTech, Inc. and New River Highlands RC&D as a separate study. The results of the BST analysis provide a measure of the relative contribution of bacteria sources to the bacteria concentration found in the water samples. The bacteria sources were lumped into four categories: wildlife, human, livestock, and pet. Data resulting from the BST study are referenced in Appendix B. A discussion of the BST results provided by VADEQ indicates there is 90% confidence that the indicated proportions for each sample are within 15% of the sampled population (Appendix B). These data represent a brief glimpse of bacteria concentration in the South River and may not be representative of long-term conditions in the stream.

The analysis in the BST report also included a test of statistical significance, providing an indication of presence or absence of contribution from a particular source. The presence/absence use of these data is most appropriate for use in this study due to statistical confidence, with presence defined as any proportional contribution greater than 15%. Table 2.4 summarizes the results of the presence/absence analysis of the BST data. The BST data were used to verify modeling methods and assumptions.

Fecal coliform and *E. coli* enumerations were also performed on the BST samples. These data are referenced in Appendix B. At station 1-BSTH007.80, 8.33%

(one of 12) of the samples exceeded either the fecal coliform or E. coli bacteria instantaneous standard. The exceedance occurred in June of 2008.

Table 2.4. Presence/absence analysis of bacteria sources at station 1-BSTH007.80 in South River watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standards[2] (%)
Wildlife	83	100
Human	8	0
Livestock	92	100
Pet[3]	0	0

1 – This is a measure of the number of times the source is present in all 12 samples.

2 – This is a measure of the number of times (i.e., one) the source was present in samples that exceeded either the fecal coliform or *E. coli* instantaneous standard.

3 – Pet waste signature was identrified in the April 2008 sample; however, it was not at at a level sufficient for statistical significance.

2.6 Biological Monitoring Data

Data were considered from five benthic sampling stations (Table 2.5). Stream health scores in the form of SCI values are shown in Figures 2.12 - 2.14. Impaired conditions exist at all stations on the South River. The benthic scores included in Figures 2.12 through 2.14 are described in greater detail in Tables 2.6 through 2.10. Taxa data describing the quantities of the individual benthic macro-invertebrate organisms in each of the assessments previously described are included in Tables 2.12 through 2.15. The two dominant species in each sample are highlighted. The RBP II assessment ratings are included for reference.

Table 2.5. Stream name, monitoring station, and location of biological monitoring stations in South River watersheds.

Stream Name	Monitoring Station	Station Location
South River	1-BSTH012.71	VA Dept. of Forestry (VADOF) Pump House
South River	1-BSTH013.58	VADOF Farm Near Old Mill Race Outlet
South River	1-BSTH021.72	Downstream of Hopeman Parkway
South River	1-BSTH027.08	Route 664 Bridge
South River	1-BSTH029.45	Route 650 Bridge

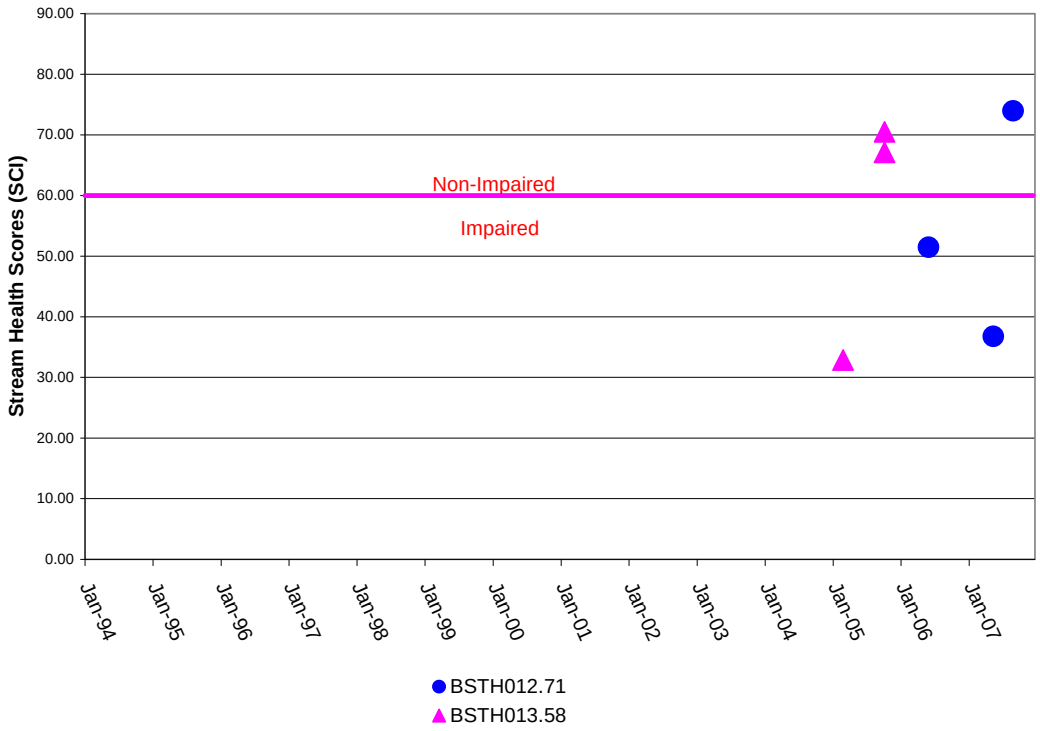

Figure 2.12. SCI scores from benthic monitoring stations 1-BSTH012.71 and 1-BSTH013.58.

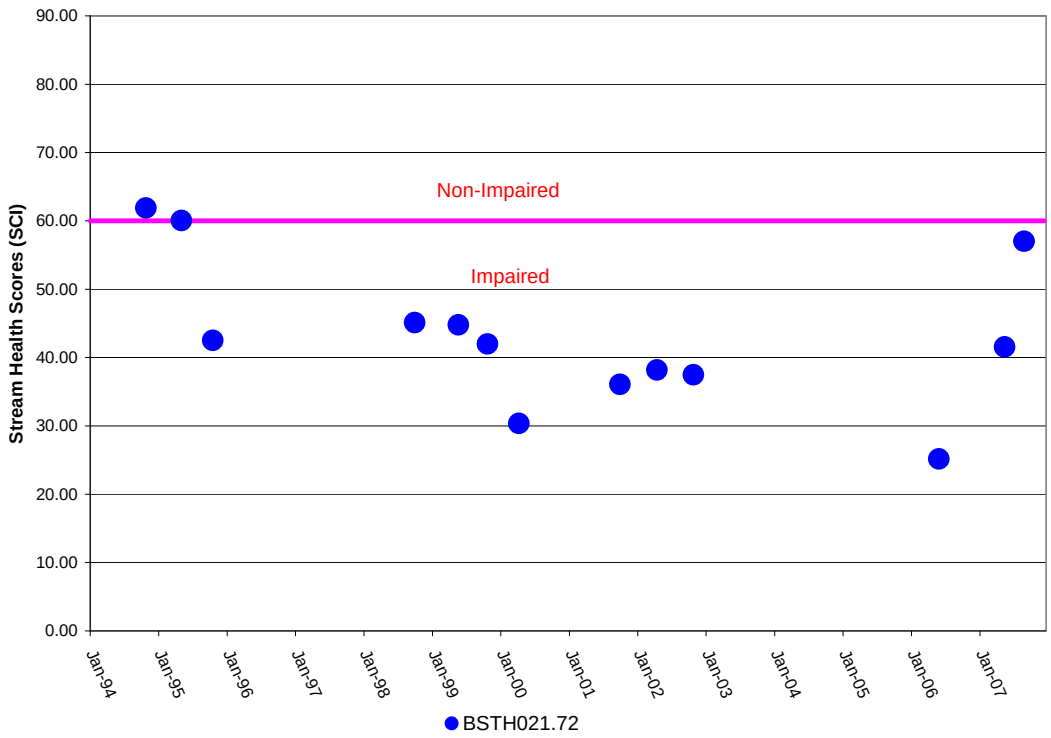

Figure 2.13. SCI scores from benthic monitoring station 1-BSTH 21.72.

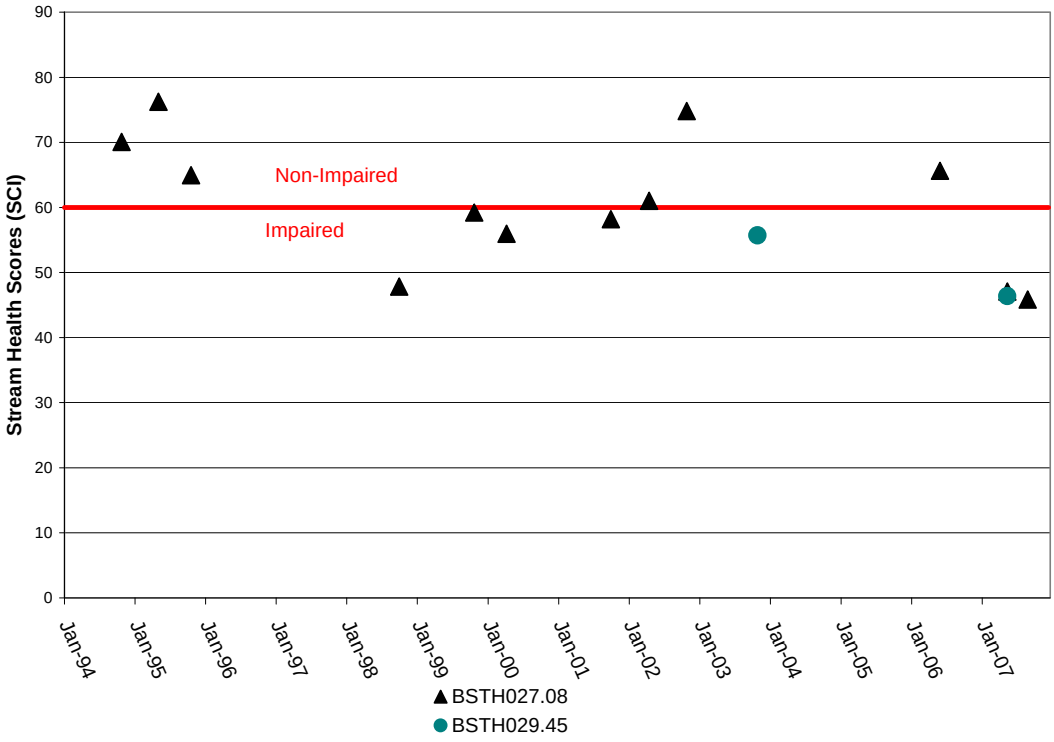

Figure 2.14. SCI scores from benthic monitoring stations 1-BSTH027.08 and 1-BSTH029.45.

Table 2.6. Benthic assessment scores for station 1-BSTH012.71.

	6/6/2006	5/21/2007	9/4/2007
RBP II Metric			
Total Taxa	14	11	
HBI	5.27	5.82	
SC/CF	0.90	0.15	
EPT/Chi Abund	2.60	0.79	
% Dominant	36.11	48.45	
EPT Index	6	3	
SH/Tot	0.93	0.00	
% of Reference			
RBP II Assessment	Moderate	Moderate	
MAIS Metric			
% Haptobenthos	75.93	73.20	92.23
SCI Scores	51.48	36.77	73.96
SCI Assessment	Impaired	Impaired	Non-Impaired

Table 2.7. Benthic assessment scores for station 1-BSTH013.58.

	3/3/2005	10/12/2005	10/12/2005
RBP II Metric			
Taxa Richness	10	16	15
HBI	5.31	4.92	4.68
SC/CF	8.78	3.78	4.64
EPT/Chi Abund	0.16	11.17	16.39
% Dominant	58.33	20.39	20.20
EPT Index	2	5	6
SH/Tot	1.04	0.97	1.01
% of Reference	56.5	90.5	100
RBP II Assessment	Slight	Non-Impaired	Non-Impaired
MAIS Metric			
% Haptobenthos	36.46	88.35	94.95
SCI Scores	32.86	67.10	70.52
SCI Assessment	Impaired	Non-Impaired	Non-Impaired

Table 2.8. Benthic assessment scores for station 1-BSTH021.72.

	10/25/1994	5/4/1995	10/19/1995	10/2/1998	5/24/1999	10/26/1999	4/11/2000	10/4/2001	4/20/2002	11/1/2002	6/6/2006	5/23/2007	9/4/2007
RBP II Metric						Metric Values							
Taxa Richness	24	21	11	11	14	10	11	16	19	12	5	15	
HBI	5.39	5.32	5.98	5.75	5.96	5.68	6.68	5.92	6.71	6.17	5.74	5.85	
SC/CF	1.55	0.55	0.42	0.53	1.13	1.15	1.10	0.51	0.89	0.68	0.00	0.16	
EPT/Chi Abund	2.92	1.05	22.22	5.86	0.14	0.77	0.11	0.63	0.12	0.54	1.09	1.08	
% Dominant	32.12	26.67	54.72	49.06	32.08	32.48	40.69	48.81	49.58	52.38	46.39	31.53	
EPT Index	7	8	2	4	4	1	3	3	5	4	2	5	
SH/Tot	2.42	1.90	0.00	0.94	0.00	0.00	0.00	0.60	0.84	0.00	0.00	0.90	
% of Reference	54.17	66.67	39.13	54.17	52.4	50	27.3	26.09	28.57	34.78			
RBP II Assessment	Slight	Slight	Moderate	Slight	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate			
MAIS Metric													
% Haptobenthos	68.48	63.81	80.19	79.25	32.08	n/a	14.71	44.64	15.13	30.16	51.55	54.05	85.19
SCI Scores	61.90	60.07	42.52	45.13	44.78	41.97	30.36	36.10	38.18	37.48	25.17	41.55	57.03
SCI Assessment	Non-Impaired	Non-Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired

Table 2.9. Benthic assessment scores for station 1-BSTH027.08.

	10/25/1994	5/4/1995	10/19/1995	10/2/1998	5/24/1999	10/26/1999	4/11/2000	10/4/2001	4/20/2002	11/1/2002	6/6/2006	5/23/2007	9/4/2007
RBP II Metric						Metric Values							
Taxa Richness	24	21	11	11	14	10	11	16	19	12	5	15	
HBI	5.39	5.32	5.98	5.75	5.96	5.68	6.68	5.92	6.71	6.17	5.74	5.85	
SC/CF	1.55	0.55	0.42	0.53	1.13	1.15	1.10	0.51	0.89	0.68	0.00	0.16	
EPT/Chi Abund	2.92	1.05	22.22	5.86	0.14	0.77	0.11	0.63	0.12	0.54	1.09	1.08	
% Dominant	32.12	26.67	54.72	49.06	32.08	32.48	40.69	48.81	49.58	52.38	46.39	31.53	
EPT Index	7	8	2	4	4	1	3	3	5	4	2	5	
SH/Tot	2.42	1.90	0.00	0.94	0.00	0.00	0.00	0.60	0.84	0.00	0.00	0.90	
% of Reference	54.17	66.67	39.13	54.17	52.4	50	27.3	26.09	28.57	34.78			
RBP II Assessment	Slight	Slight	Moderate	Slight	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate			
MAIS Metric													
% Haptobenthos	68.48	63.81	80.19	79.25	32.08	n/a	14.71	44.64	15.13	30.16	51.55	54.05	85.19
SCI Scores	61.90	60.07	42.52	45.13	44.78	41.97	30.36	36.10	38.18	37.48	25.17	41.55	57.03
SCI Assessment	Non-Impaired	Non-Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired

Table 2.10. Benthic assessment scores for station 1-BSTH029.45.

	11/3/2003	5/21/2007
RBP II Metric		
Taxa Richness	12	13
HBI	4.93	5.32
SC/CF	0.62	0.48
EPT/Chi Abund	2.80	0.56
% Dominant	30.77	51.43
EPT Index	7	9
SH/Tot	1.71	0.00
% of Reference	68.2	
RBP II Assessment	Slight	
MAIS Metric		
% Haptobenthos	75.93	73.20
SCI Scores	55.71	46.39
SCI Assessment	Impaired	Impaired

Table 2.11. Taxa data for station 1-BSTH012.71.

Final ID	Functional Feeding Group	Tolerance Value	11/3/2003	5/21/2007	Total Individuals
Elmidae	Scraper	4	3	3	6
Psephenidae	Scraper	4	2		2
Chironomidae (A)	Collector	6	27	54	81
Simuliidae	Filterer	6	1	15	16
Baetidae	Collector	4	3	4	7
Ephemerellidae	Collector	4	12	8	20
Heptageniidae	Scraper	4	18	4	22
Isonychiidae	Filterer	2	7		7
Leptophlebiidae	Collector	2		1	1
Tricorythidae	Collector	4		2	2
Pleuroceridae	Scraper	4	5		5
Asellidae	Collector	8		1	1
Plecoptera (unknown)				1	1
Taeniopterygidae	Shredder	2	2		2
Glossosomatidae	Scraper	0		4	4
Hydropsychidae	Filterer	6	36	7	43
Philopotamidae	Collector	3	1	1	2
Total Organisms			117	105	222
RBP II Rating			Slight	N/A	

Table 2.12. Taxa data for station 1-BSTH013.58.

Final ID	Functional Feeding Group	Tolerance Value	3/3/2005	10/12/2005	10/12/2005	Total Individuals
Gammaridae	Collector	6		2	4	6
Elmidae	Scraper	4	1	8	10	19
Hydrophilidae	Predator	5	1			1
Psephenidae	Scraper	4		4	11	15
Chironomidae (A)	Collector	6	56	3	2	61
Tipulidae	Shredder	3	1	1	1	3
Baetidae	Collector	4		2		2
Ephemerellidae	Collector	4	8	10	20	38
Heptageniidae	Scraper	4		21	19	40
Isonychiidae	Filterer	2		5	3	8
Pleuroceridae	Scraper	4	25	20	10	55
Hydracarina (unknown)	Predator	5		1		1
Lumbriculidae	Collector	8			1	1
Gomphidae	Predator	1		1		1
Coenagrionidae	Predator	9		12	10	22
Corbiculidae	Filterer	8	1	1	1	3
Brachycentridae	Filterer	1			2	2
Hydropsychidae	Filterer	6	1	7	4	12
Hydroptilidae	Scraper	6			1	1
Tricladida (unknown)	Collector	8	1	5		6
Naididae	Collector	8	1			1
Total Organisms			96	103	99	298
RBP II Rating			Slight	Non-Impaired	Non-Impaired	

Table 2.13. Taxa data for station 1-BSTH021.72.

Final ID	Functional Feeding Group	Tolerance Value	10/25/1994	5/4/1995	10/19/1995	10/2/1998	5/24/1999	10/26/1999	4/11/2000	10/4/2001	4/20/2002	11/1/2002	6/6/2006	5/23/2007	9/4/2007	Total Individuals
Gammaridae	Collector	6	9	6			1				1			1		18
Talitridae	Collector	8									1	1				2
Dryopidae	Shredder	5	2													2
Elmidae	Scraper	4	2	1	1	5	2	3			4			1		19
Hydrophilidae	Predator	5	1												1	2
Psephenidae	Scraper	4	3	1	2											6
Cambaridae	Shredder	5								1						1
Chironomidae (A)	Collector	6	11	17	2	9	34	26	83	82	59	66	45	35	11	480
Ephydridae	Collector	7						1				2				3
Muscidae	Predator	8								2						2
Simuliidae	Filterer	6	3	28	1					1	2			13		48
Tipulidae	Shredder	3	1	1		1								1		4
Baetidae	Collector	4		1		4	2			9	1	16	13	6	26	78
Caenidae	Collector	4		2			1									3
Ephemerellidae	Collector	4		5					3							8
Ephemeridae	Collector	4		1												1
Heptageniidae	Scraper	4	2	2	10	2	1		1							18
Tricorythidae	Collector	4	1			1					1			1		4
Lymnaeidae	Scraper	7					1									1
Physidae	Scraper	8								2	3					5
Planorbidae	Scraper	7	3	1			3									7
Pleuroceridae	Scraper	4	53	15	7	11	27	38	19	6	2	1		6	52	237
Corixidae	Predator	5					1									1
Hydracarina (unknowr	Predator	5	5	2								2	1		1	11
Hirudinidae		7								1						1
Ancylidae	Scraper	6	3		6	10		4	2	14				1		40
Lumbriculidae	Collector	8	6	10	7	3	2	5	1	2	4					40
Corydalidae	Predator	5	1							1						2
Sialidae	Predator	4						1								1
Gomphidae	Predator	1									1			1		2
Coenagrionidae	Predator	9	1								2					3
Corbiculidae	Filterer	8	11	2	2		28	17	13	1	4	1	1	4		84
Sphaeriidae	Filterer	8		1						1	1				1	4
Brachycentridae	Filterer	1	2	6			1							1		10
Glossosomatidae	Scraper	0	3	1												4
Helicopsychidae	Shredder	3	1	1							1					3
Hydropsychidae	Filterer	6	27		58	52		21	5	42	3	11	37	30	6	292
Hydroptilidae	Scraper	6								2	1	8			6	17
Leptoceridae	Collector	4	1									1		1		3
Tricladida (unknown)	Collector	8	13	1	10	8	2	1	2			7				44
Naididae	Collector	8							74	1	18			9		102
Tubificidae	Collector	10							1		10	10				21
Crangonyctidae	Collector	6													1	1
Diptera (unknown)															1	1
Ancylidae	Scraper	6													1	1
Total Organisms			165	105	106	106	106	117	204	168	119	126	97	111	107	1637
RBP II Rating			Slight	Slight	Moderate	Slight	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	N/A	N/A	N/A	

Table 2.14. Taxa data for station 1-BSTH027.08.

Final ID	Functional Feeding Group	Tolerance Value	10/25/1994	5/4/1995	10/19/1995	10/2/1998	10/26/1999	4/11/2000	10/4/2001	4/20/2002	11/1/2002	6/6/2006	5/21/2007	9/4/2007	Total Individuals
Gammaridae	Collector	6	3	1											4
Talitridae	Collector	8								1					1
Dryopidae	Shredder	5		1											1
Elmidae	Scraper	4	9	3	1	1					6	6	2	2	30
Hydrophilidae	Predator	5								1					1
Psephenidae	Scraper	4	2	1	1							1			5
Cambaridae	Shredder	5	1							1					2
Athericidae	Predator	2	1												1
Blephariceridae	Scraper	0		1				1							2
Ceratopogonidae	Predator	6									1				1
Chironomidae (A)	Collector	6	12	21	4	8	2	14	10	25	2	17	36	7	158
Chironomidae (B)	Collector	9	4	1											5
Empididae	Predator	6						1		1					2
Simuliidae	Filterer	6	1	2	2				1	5			3		14
Tipulidae	Shredder	3	1			1		2		2	2		2		10
Baetidae	Collector	4		1		3	1		2	10	1	2		7	27
Caenidae	Collector	4							1			4		2	7
Ephemerellidae	Collector	4	1	10		1	7	59	12	29	34	6	14	5	178
Heptageniidae	Scraper	4	5	5	7	3	8	3	17	3	24	1	2	5	83
Isonychiidae	Filterer	2	14	2	35	5	16	2	27	2	9	1	3		116
Leptophlebiidae	Collector	2			1										1
Polymitarcyidae	Collector	2										5			5
Tricorythidae	Collector	4	1	1								1	1		4
Hydrobiidae	Scraper	3											1		1
Physidae	Scraper	8			1										1
Planorbidae	Scraper	7	4												4
Pleuroceridae	Scraper	4	64	32	10	13	31	8	12	21	11	10	6	18	236
Hydracarina (unknown)	Predator	5	4	3	1										8
Asellidae	Collector	8	14	2	2										18
Ancylidae	Scraper	6	1			1									2
Lumbriculidae	Collector	8	3	3		1	9	1	1	3			2		23
Corydalidae	Predator	5				1					1				2
Aeshnidae	Predator	3	1	2											3
Gomphidae	Predator	1		1									1		2
Lumbricidae	Collector	10										3			3
Corbiculidae	Filterer	8			2		1			1					4
Sphaeriidae	Filterer	8	1												1
Capniidae	Shredder	1										1			1
Nemouridae	Shredder	2		1											1
Perlidae	Predator	1	1												1
Brachycentridae	Filterer	1	13	13	6		1	2		2		3	2	1	43
Glossosomatidae	Scraper	0	1	1	3						2	1			8
Helicopsychidae	Shredder	3		10											10
Hydropsychidae	Filterer	6	24		32	80	34	16	54	7	11	25	7	68	358
Hydroptilidae	Scraper	6				1	1		2	1	3	1			9
Lepidostomatidae	Shredder	1									5				5
Leptoceridae	Collector	4		1											1
Limnephilidae	Shredder	4		1											1
Philopotamidae	Collector	3	1	1	6	1		1				1			11
Psychomyiidae	Collector	2										1			1
Tricladida (unknown)	Collector	8				4	3		3		2				12
Naididae	Collector	8				4				2					6
Total Organisms			187	121	114	128	114	110	142	117	114	90	82	115	1434
RBP II Rating			Slight	Non-Impaired	Slight	Slight	Non-Impaired	Slight	Slight	Slight	Non-Impaired	N/A	N/A	N/A	

Table 2.15. Taxa data for station 1-BSTH029.45.

Final ID	Functional Feeding Group	Tolerance Value	11/3/2003	5/21/2007	Total Individuals
Elmidae	Scraper	4	3	3	6
Psephenidae	Scraper	4	2		2
Chironomidae (A)	Collector	6	27	54	81
Simuliidae	Filterer	6	1	15	16
Baetidae	Collector	4	3	4	7
Ephemerellidae	Collector	4	12	8	20
Heptageniidae	Scraper	4	18	4	22
Isonychiidae	Filterer	2	7		7
Leptophlebiidae	Collector	2		1	1
Tricorythidae	Collector	4		2	2
Pleuroceridae	Scraper	4	5		5
Asellidae	Collector	8		1	1
Plecoptera (unknown)				1	1
Taeniopterygidae	Shredder	2	2		2
Glossosomatidae	Scraper	0		4	4
Hydropsychidae	Filterer	6	36	7	43
Philopotamidae	Collector	3	1	1	2
Total Organisms			117	105	222
RBP II Rating			Slight	N/A	

Habitat data associated with each biological assessment were obtained and are summarized in Tables 2.16 through 2.20. Individual metric scores of 10 or below are considered poor or marginal. These scores are highlighted for easy identification. Habitat scores on South River at Stations 1-BSTH012.71, 1-BSTH013.58, 1-BSTH021.72, and 1-BSTH027.08 are generally low for riparian vegetation. Station 1-BSTH021.72 is also generally low for bank stability, embeddedness, graze, riffle stability, and substrate. Additionally, station 1-BSTH027.08 is generally low for bank vegetation, graze, and riffle stability.

Table 2.16. Habitat scores for stations 1-BSTH012.71.

Habitat Metrics	SAMPLING DATES		
	6/6/2006	5/21/2007	9/4/2007
Channel Alteration	19	15	15
Bank Stability	9	18	16
Bank Vegetation	13	18	16
Cover			
Embeddedness	13	17	15
Channel Flow Status	12	18	16
Graze			
Riffle Stability	13	16	15
Riparian Vegetation	10	3	7
Sediment Disposition	17	16	14
Substrate	15	17	16
Velocity	17	16	16
Total Habitat Score	**138**	**154**	**146**

Table 2.17. Habitat scores for station 1-BSTH013.58.

Habitat Metrics	SAMPLING DATES	
	3/3/2005	10/12/2005
Channel Alteration	19	19
Bank Stability	14	15
Bank Vegetation	14	14
Cover		
Embeddedness	11	14
Channel Flow Status	19	19
Graze		
Riffle Stability	19	18
Riparian Vegetation	4	10
Sediment Disposition	16	18
Substrate	17	16
Velocity	17	17
Total Habitat Score	**150**	**160**

Table 2.18. Habitat scores for station 1-BSTH021.72.

Habitat Metrics	SAMPLING DATES												
	10/25/1994	5/4/1995	10/19/1995	10/2/1998	5/24/1999	10/26/1999	4/11/2000	10/4/2001	4/29/2002	11/1/2002	6/6/2006	5/23/2007	9/4/2007
Channel Alteration	14	16	18	17	15	14	14	18	16	15	15	13	14
Bank Stability	16	14	16	10	13	11	16	16	14	10	8	14	13
Bank Vegetation	14	14	12	17	18	5	16	18	13	15	16	16	13
Cover	14	16	16	0									
Embeddedness	12	14	12	16	13	12	7	11	7	10	11	10	11
Channel Flow Status	20	20	20	15	19	20	20	14	17	19	7	16	15
Graze	16	20	20	0									
Riffle Stability	12	16	14	17	10	11	12	11	13	7	6	10	14
Riparian Vegetation	8	12	10	12	9	4	6	9	12	11	11	9	8
Sediment Disposition	12	14	14	13	16	14	14	13	11	14	15	15	14
Substrate	12	16	12	16	16	9	10	12	12	13	3	6	13
Velocity	16	16	16	17	14	16	18	16	16	16	16	13	12
Total Habitat Score	**166**	**188**	**180**	**150**	**143**	**116**	**133**	**138**	**131**	**130**	**108**	**122**	**127**

Table 2.19. Habitat scores for station 1-BSTH027.08.

Habitat Metrics	SAMPLING DATES											
	10/25/1994	5/4/1995	10/19/1995	10/2/1998	10/26/1999	4/11/2000	10/4/2001	4/29/2002	11/1/2002	6/6/2006	5/21/2007	9/4/2007
Channel Alteration	16	16	18	18	18	19	18	18	17	19	14	14
Bank Stability	16	18	16	13	16	13	17	15	18	14	16	17
Bank Vegetation	10	12	10	14	13	15	15	16	17	17	16	16
Cover	16	18	16	0								
Embeddedness	14	16	16	19	17	17	12	11	18	15	16	15
Channel Flow Status	20	20	20	15	20	20	14	18	19	8	18	15
Graze	6	10	4	0								
Riffle Stability	12	16	10	20	19	19	18	16	16	19	18	16
Riparian Vegetation	0	2	0	9	9	8	8	13	15	12	11	12
Sediment Disposition	14	16	16	19	18	18	13	12	16	16	16	15
Substrate	14	18	12	19	18	18	16	16	17	18	17	16
Velocity	14	16	14	16	15	19	18	18	17	18	18	17
Total Habitat Score	**152**	**178**	**152**	**162**	**163**	**166**	**149**	**153**	**170**	**156**	**160**	**153**

Table 2.20. Habitat scores for station 1-BSTH029.45.

Habitat Metrics	SAMPLING DATES
	5/21/2007
Channel Alteration	18
Bank Stability	14
Bank Vegetation	15
Cover	
Embeddedness	16
Channel Flow Status	18
Graze	
Riffle Stability	15
Riparian Vegetation	14
Sediment Disposition	13
Substrate	17
Velocity	18
Total Habitat Score	**158**

2.7 Water Quality Data

2.7.1 VADEQ Ambient Monitoring Data

Ambient water quality data were collected at various points along the South River. Data collected at two stations within and just upstream of the impaired reach were examined. These stations are located at river miles 7.80 and 27.85, respectively. Limited data were available from stations between these two stations (Figures 2.15 through 2.26). Where available; water quality standard, stressor screening criteria, minimum, or maximum values are shown for reference on the figures. The data temporal range varies significantly from parameter to parameter, and there is not always a good overlap between biological and ambient monitoring data.

Generally, most of the data appear to be within the expected ranges for each parameter.

- Measured values for pH, DO, Temperature, BOD, and COD are within expected ranges, and do not appear to be stressors to the benthic community.
- The majority of dissolved phosphorus concentrations recorded at stations 1-BSTH007.80 and 1-BSTH027.85 exceeded the stressor screening criteria and several exceeded VADEQ's "threatened waters" threshold for total phosphorus (TP).
- Nitrogen values were not generally elevated, with only two TKN values exceeding 1.0 mg/l.
- Average and maximum nitrate values at station 1-BSTH007.80 were 1.21 mg/l and 2.80 mg/l. Values at station 1-BSTH027.85 were less excessive, with an average of 0.72 mg/l and a maximum value of 1.69 mg/l.
- Nitrite values were not elevated, average values at stations 1-BSTH007.80 and 1-BSTH027.85 were 0.014 mg/l and 0.13 mg/l, respectively. Maximum values were 0.06 mg/l and 0.04 mg/l, respectively.
- Ammonia values at all stations are not elevated, with all values except one at or below 0.14 mg/l.
- TSS values at station 1-BSTH027.85 are not elevated, but this station is just above the impaired segment. TSS values at station 1-BSTH007.80 exhibit higher values, with three measurements over 150 mg/l, and appear to be trending higher.

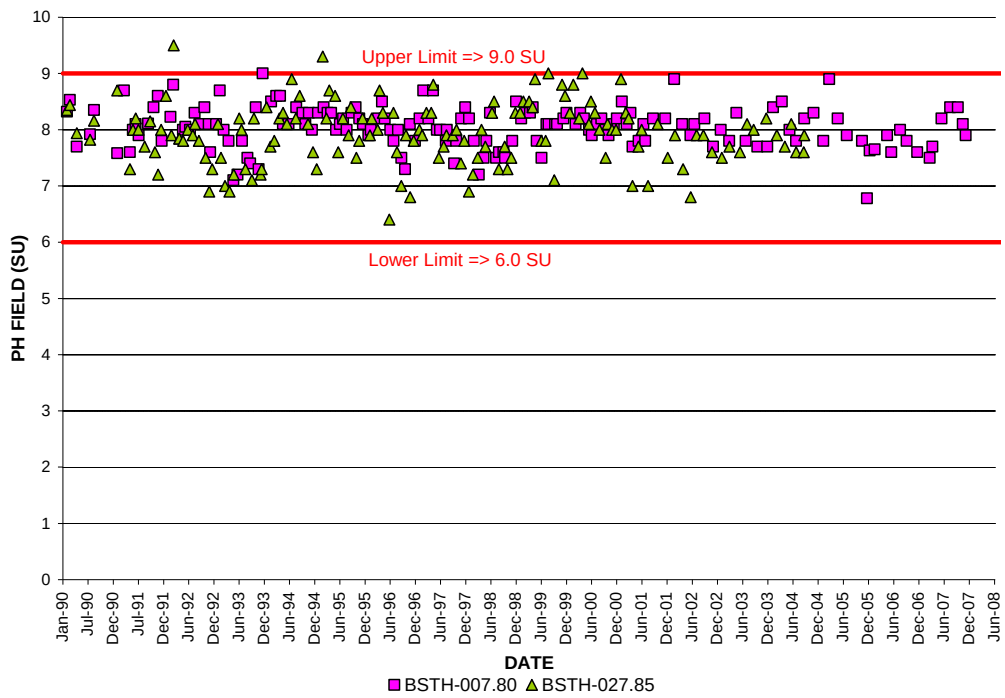

Figure 2.15. Field pH values at water quality monitoring stations in South River.

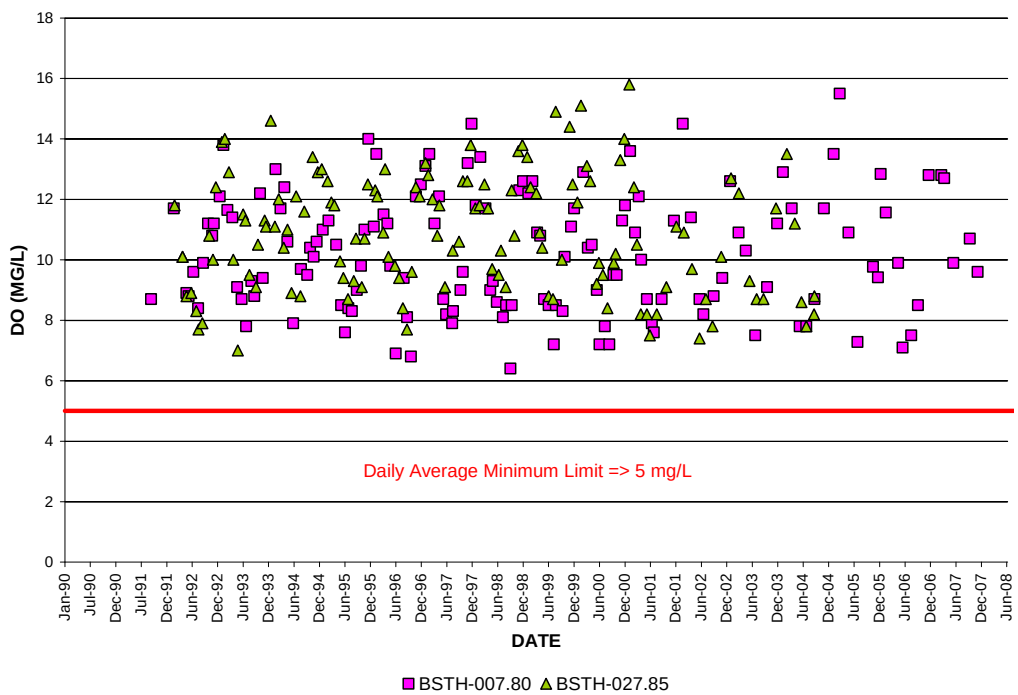

Figure 2.16. Dissolved oxygen values at water quality monitoring stations in South River.

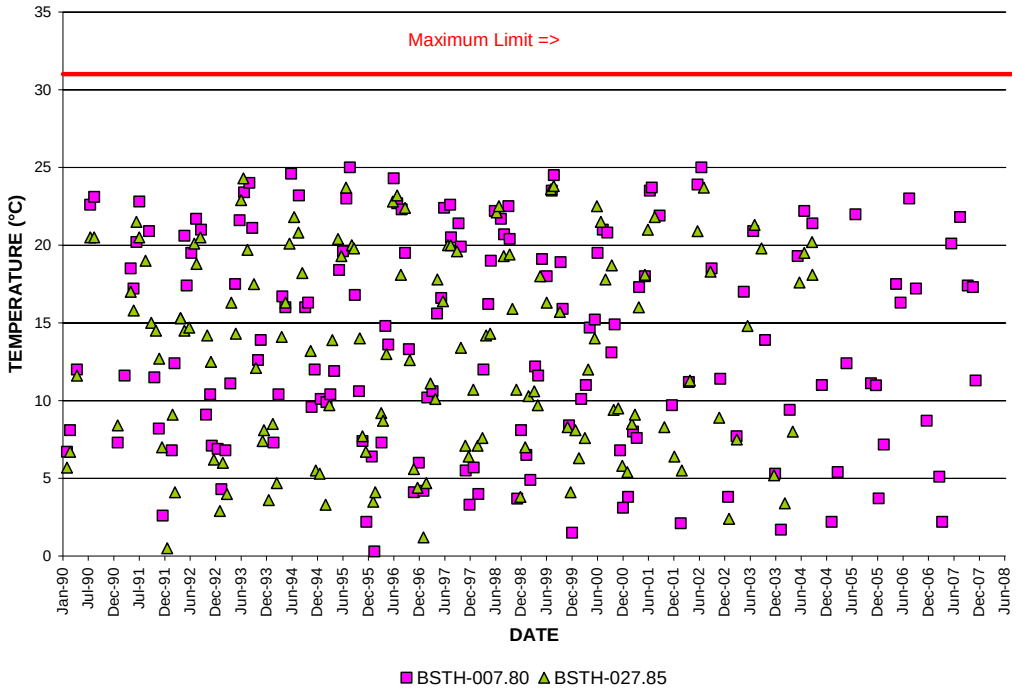

Figure 2.17. Temperature values at water quality monitoring stations in South River.

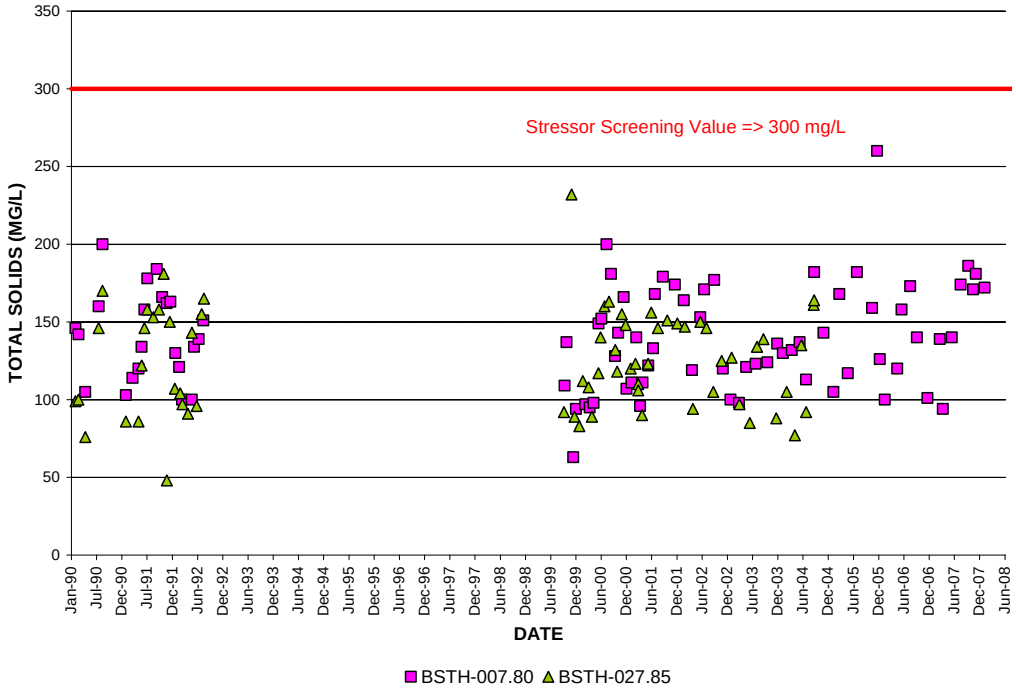

Figure 2.18. Total solids values at water quality monitoring stations in South River.

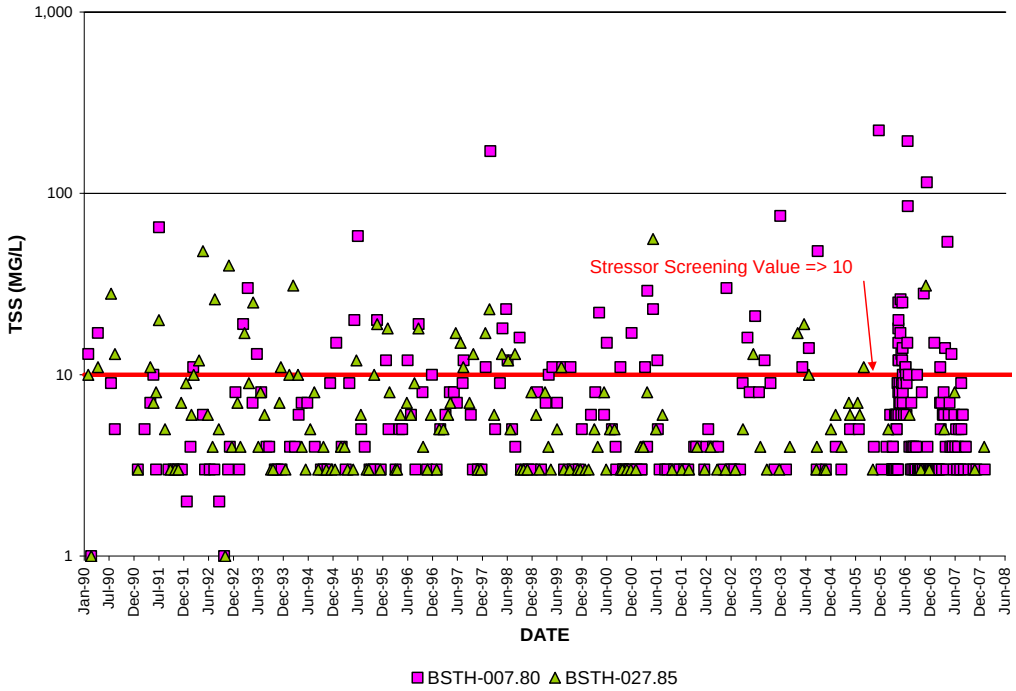

Figure 2.19. Total suspended solids at water quality monitoring stations in South River.

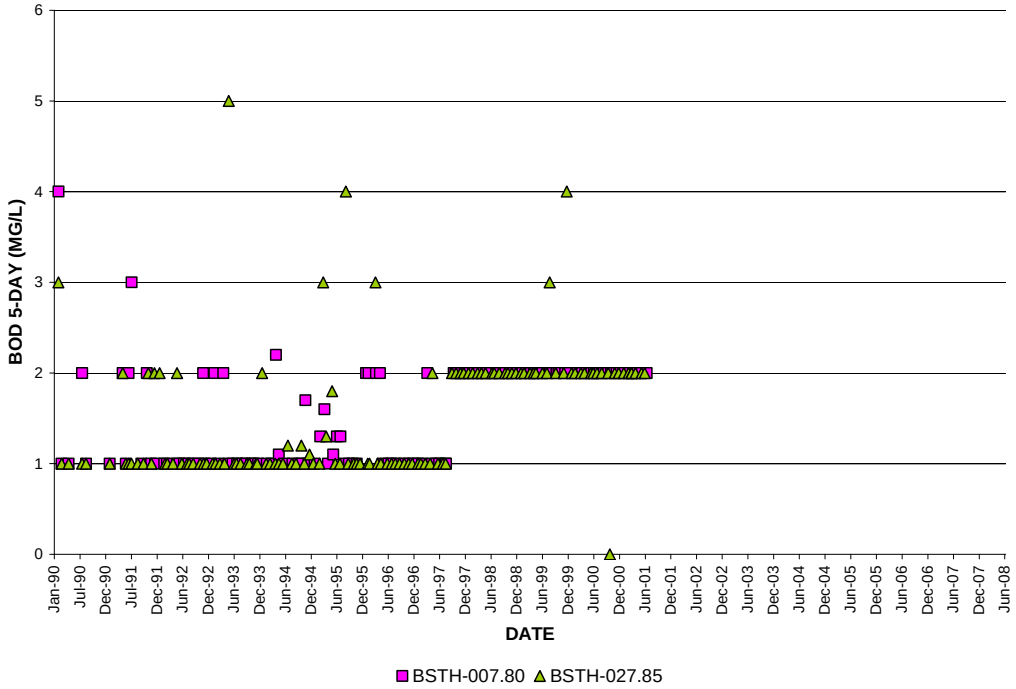

Figure 2.20. Biochemical oxygen demand (BOD_5) at water quality monitoring stations in South River.

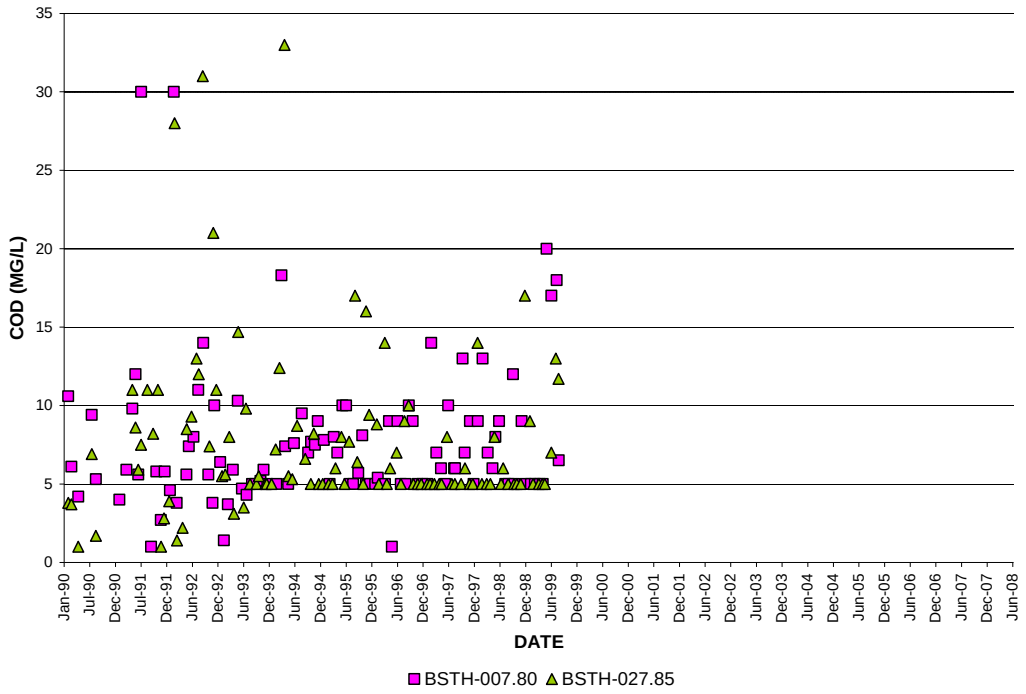

Figure 2.21. COD values at water quality monitoring stations in South River.

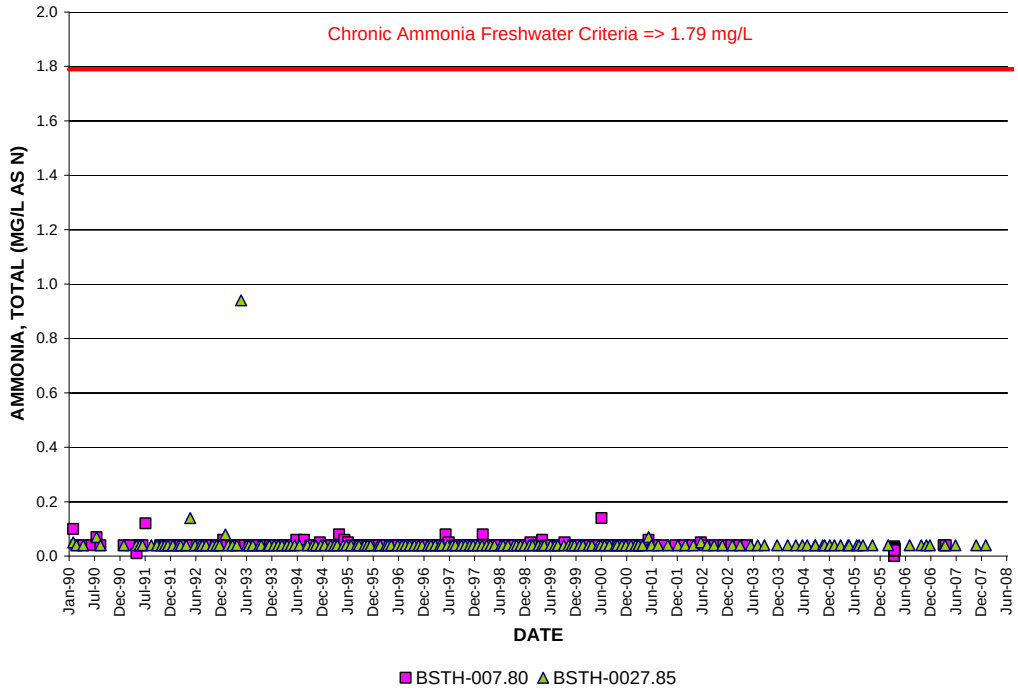

Figure 2.22. Ammonia values at water quality monitoring stations in South River.

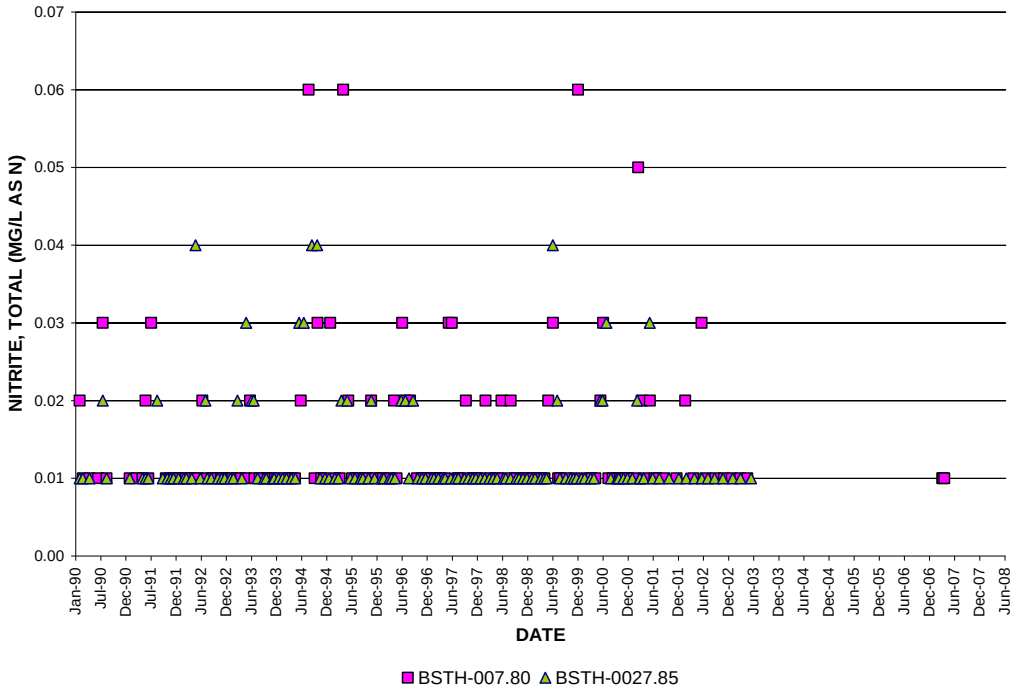

Figure 2.23. Nitrite values at water quality monitoring stations in South River.

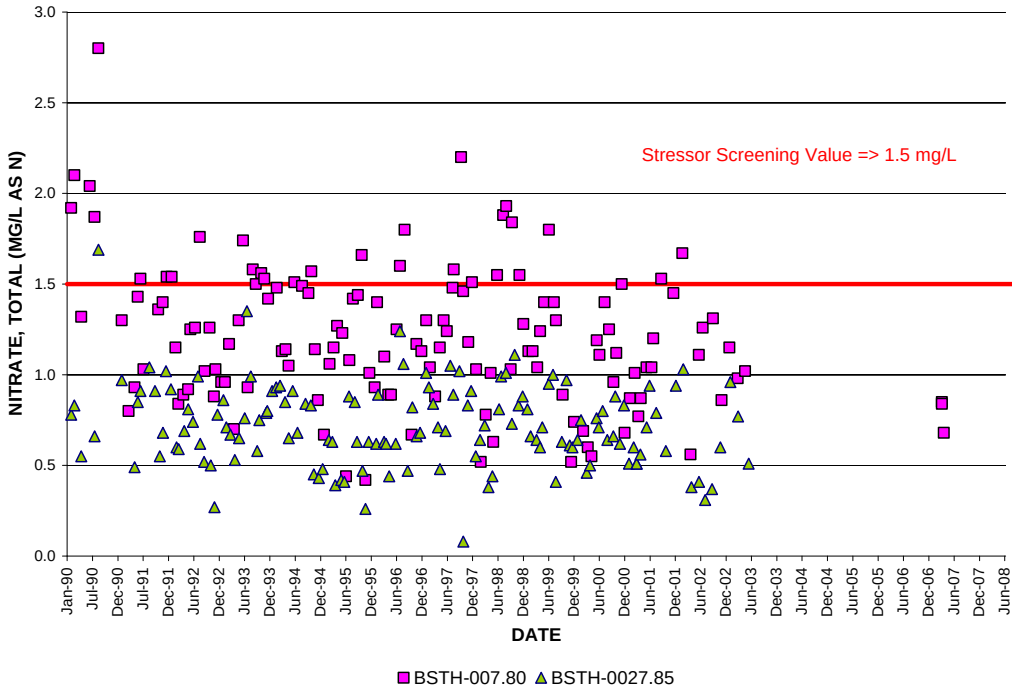

Figure 2.24. Nitrate values at water quality monitoring stations in South River.

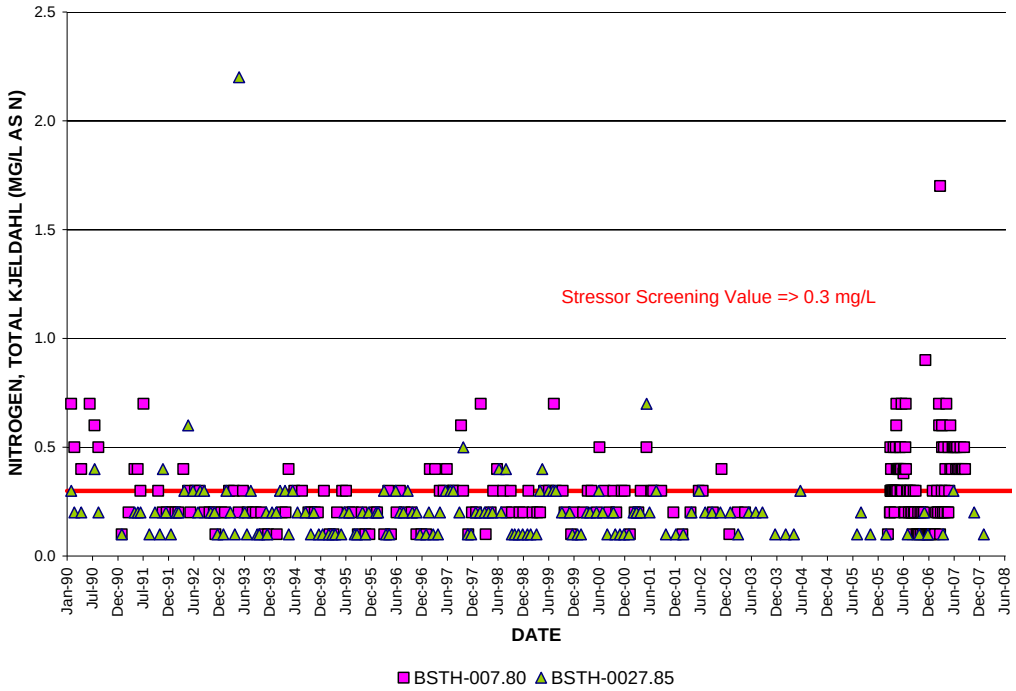

Figure 2.25. TKN values at water quality monitoring stations in South River.

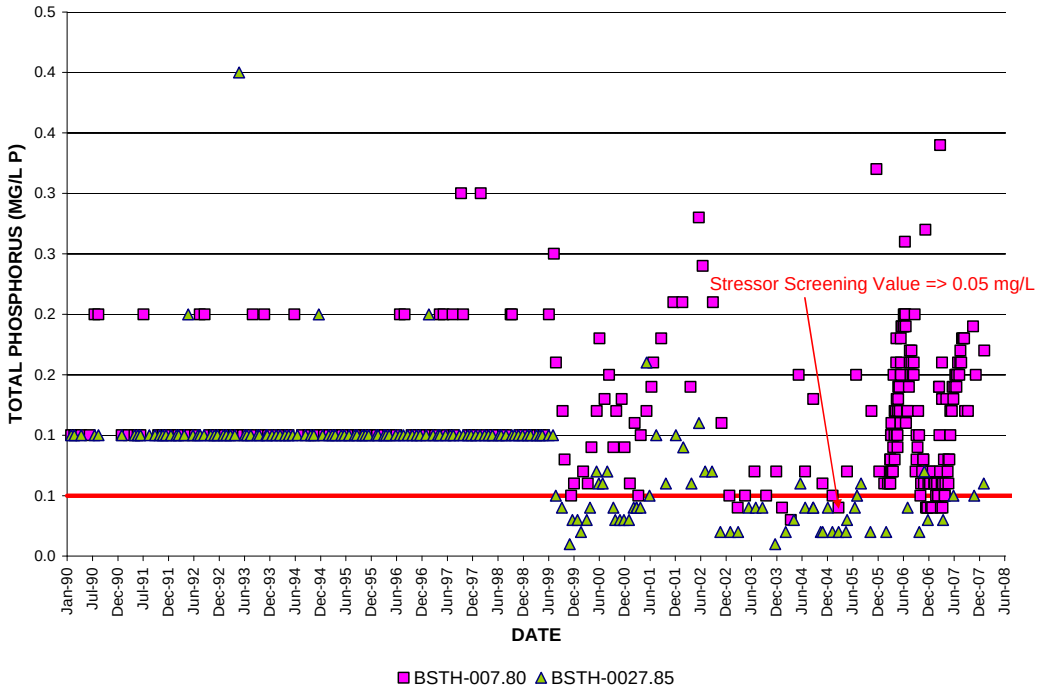

Figure 2.26. Total phosphorous values at water quality monitoring stations in South River.

2.7.2 VADEQ Stream Metals Data

Sediment samples were collected from one point along the South River at station 1-BSTH000.19 in May 1996 and August 2005. These sediment samples were analyzed for metals, PAHs, and PCBs. Tables 2.21 through 2.23 lists testing results. None of the measured concentrations exceeded established probable effect concentrations listed.

Table 2.21. Metal sampling results for station 1-BSTH000.19.

	Sampling Date	05/28/96			
	DEQ Station	1BSTH000.19			
	Stream Name / Description		NOAA'S Effects Range-Median	NOAA'S Effects Range-Low	Freshwater Consensus-Based Probable Effect Concentration
%	TOC	0.09			
	Al	0.17	**	**	
ppm (dry wgt. Basis)	Ag	0.029	3.7	1	NA
	As	1.2	70	8.2	33
	Cd	<0.01	9.6	1.2	4.98
	Cr	10	370	81	111
	Cu	9.3	270	34	149
	Hg	0.4	0.71	0.15	1.06
	Ni	0.1	51.6	20.9	48.6
	Pb	4.2	223	46.7	128
	Sb	<0.5	**	**	
	Se	<0.5	**	**	
	Tl	0.3	**	**	
	Zn	28	410	150	459

Table 2.22. PAH sampling results for station 1-BSTH000.19.

	Sampling Date	05/28/96			
	DEQ Station	1BSTH000.19			
	Stream Name / Description		NOAA'S Effects Range-Median	NOAA'S Effects Range-Low	Freshwater Consensus-Based Probable Effect Concentration
%	TOC	0.09	44792	4022	22800
ppb	Total PAH	25.41	9600	1700	NA
	High MW PAH	25.41	3160	552	NA
	Low MW PAH	0.00	2100	160	561
ppb (dry wgt. Basis)	NAP[a]		670	70	NA
	NAP 2-Me		**	**	
	NAP 1-Me		**	**	
	biphenyl		**	**	
	NAP d-Me		640	44	NA
	naphthylene ace~		500	16	NA
	naphthene ace~		**	**	
	NAP t-Me		540	19	536
	fluorene		1500	240	1170
	PHH		1100	85.3	845
	ATH		**	**	
	PHH 1-Me		5100	600	2230
	FTH	25.41	2600	665	1520
	pyrene		1600	261	1050
	ATH benz(a)		2800	384	1290
	chrysene		**	**	
	FTH benzo (b)		**	**	
	FTH benzo (k)		**	**	
	pyrene benzo (e)		1600	430	1450
	pyrene benzo (a)		**	**	
	perylene		**	**	
	pyrene IND		260	63.4	NA
	ATH db (a,h)		**	**	
	perylene benzo (ghi)				

Table 2.23. PCB sampling results for station 1-BSTH000.19.

	Sampling Date	05/28/96			
	DEQ Station	1BSTH000.19			
	Stream Name / Description		NOAA'S Effects Range-Median	NOAA'S Effects Range-Low	Freshwater Consensus-Based Probable Effect Concentration
%	TOC	0.09			
ppb (dry wgt. Basis)	Total PCB	0.12	180	22.7	676
	Total Chlordane	0.3	6	0.5	17.6
	Sum DDE		27	2.2	31.3
	Sum DDD		20	2	28
	Sum DDT		7	1	62.9
	Total DDT		46.1	1.58	572
	Total BDE		**	**	
	HCB		**	**	
	OCDD		**	**	

2.7.3 Diurnal Dissolved Oxygen Data

Diurnal dissolved oxygen testing was performed between April 2008 and May 2008 as part of the South River Ecological Study. Station name and location are listed in Table 2.24. Figures 2.27 through 2.32 contain dissolved oxygen concentrations for each station.

Table 2.24. Station name and sampling locations of dissolved oxygen diurnal sampling in South River.

Station Name	Location Description
RRM 1.6	Oxbow near confluence with Steele Run
RRM 4.6	South River at Brand Farm
RRM 5.2	Holsinger Farm Mill Race near confluence with South River
RRM 6.4	South River at Deep Meadow Farm
RRM 7.4	South River at RRM 7.4
RRM 8.7	South River at RRM 8.7

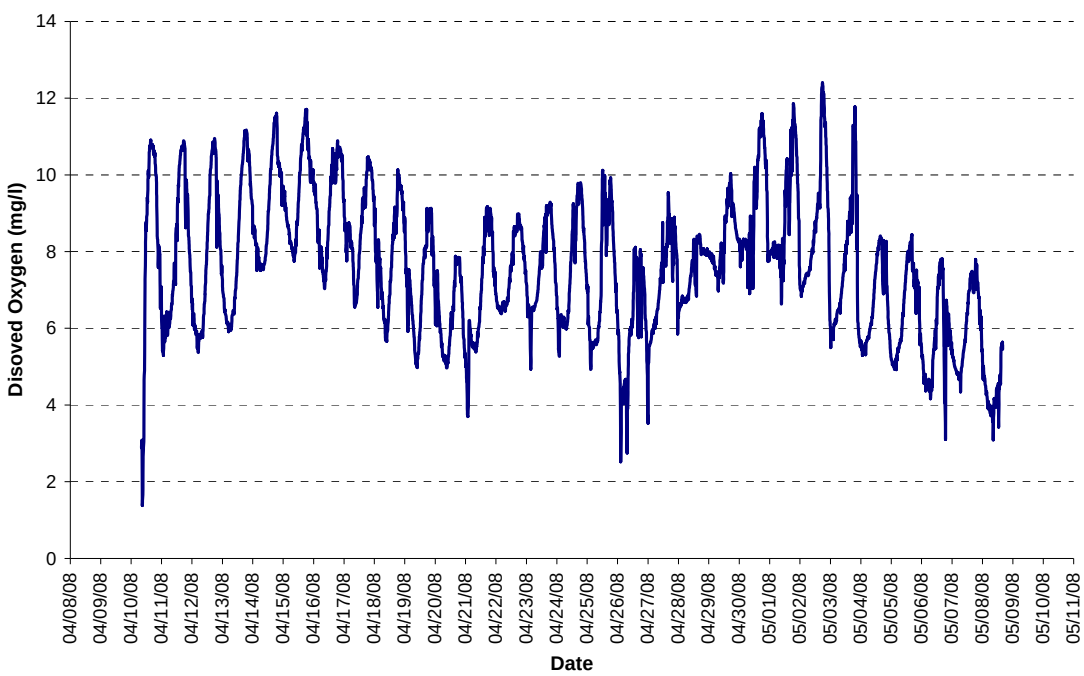

Figure 2.27. Dissolved oxygen sampling results at station RRM 1.6 in South River.

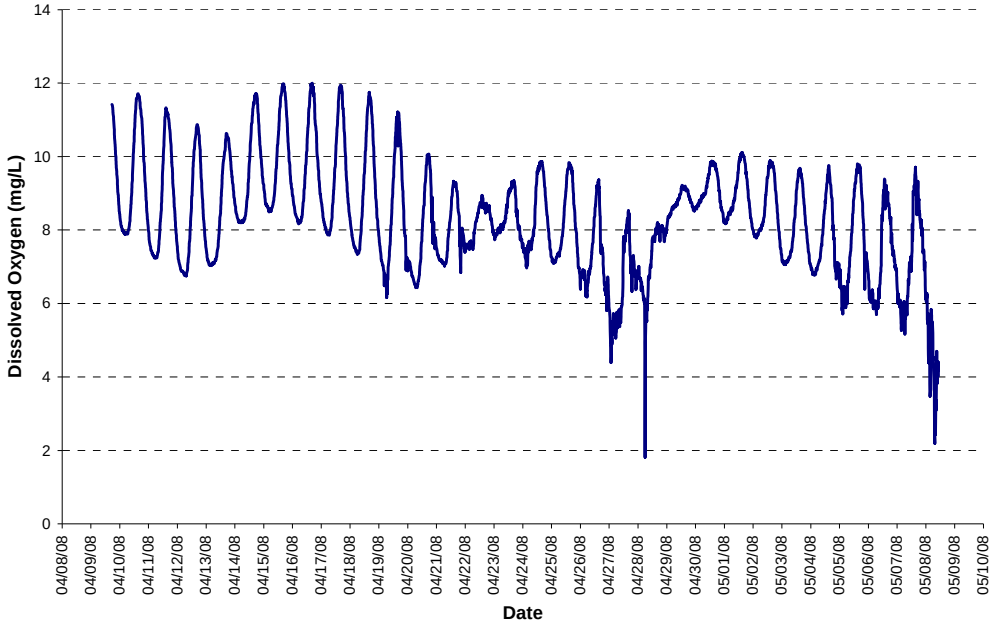

Figure 2.28. Dissolved oxygen sampling results at station RRM 4.6 in South River.

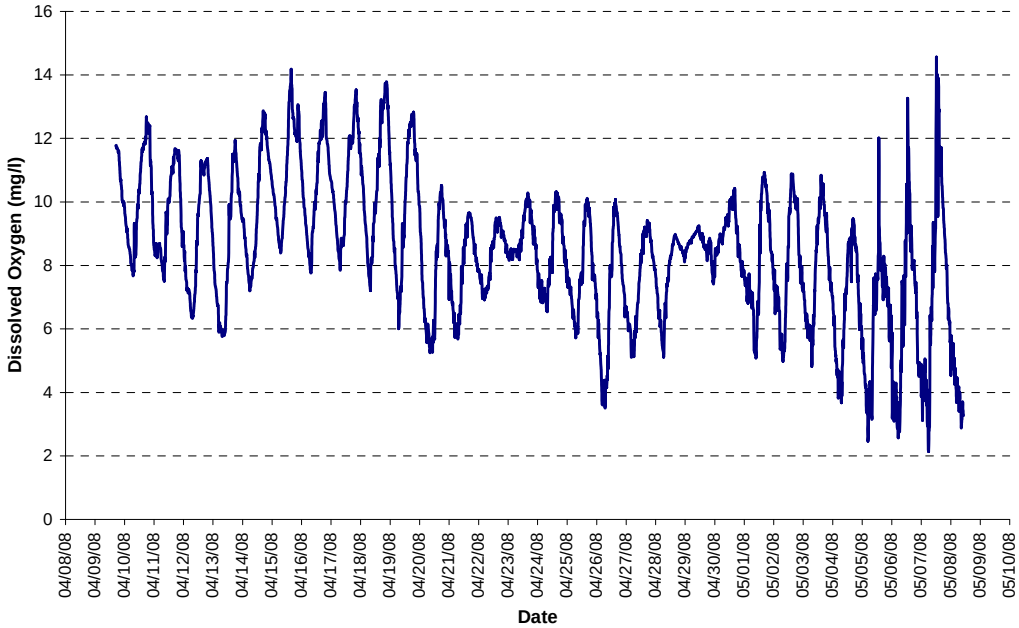

Figure 2.29. Dissolved oxygen sampling results at station RRM 5.2 in South River.

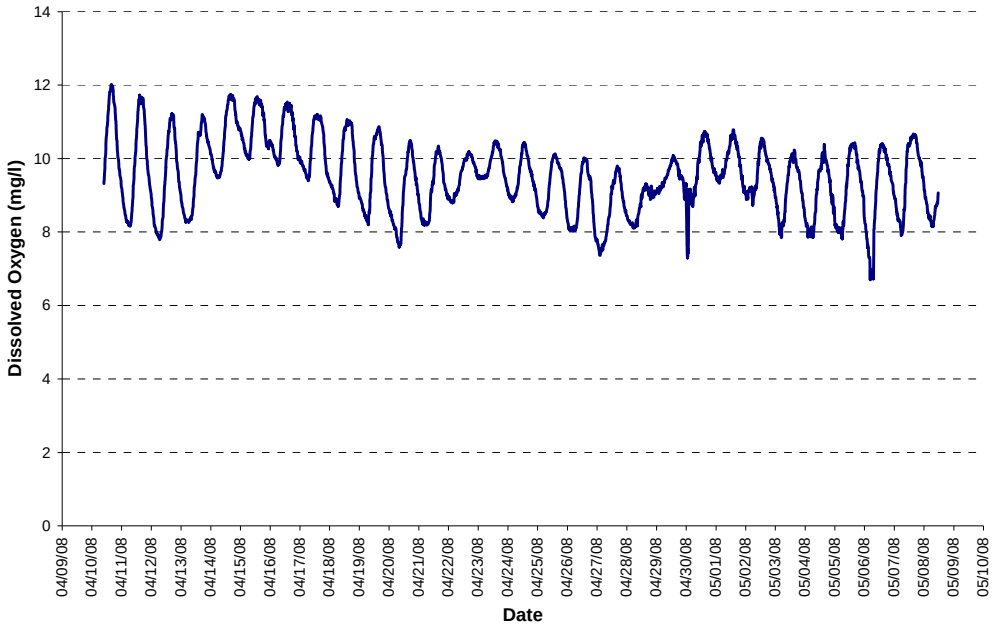

Figure 2.30. Dissolved oxygen sampling results at station RRM 6.4 in South River.

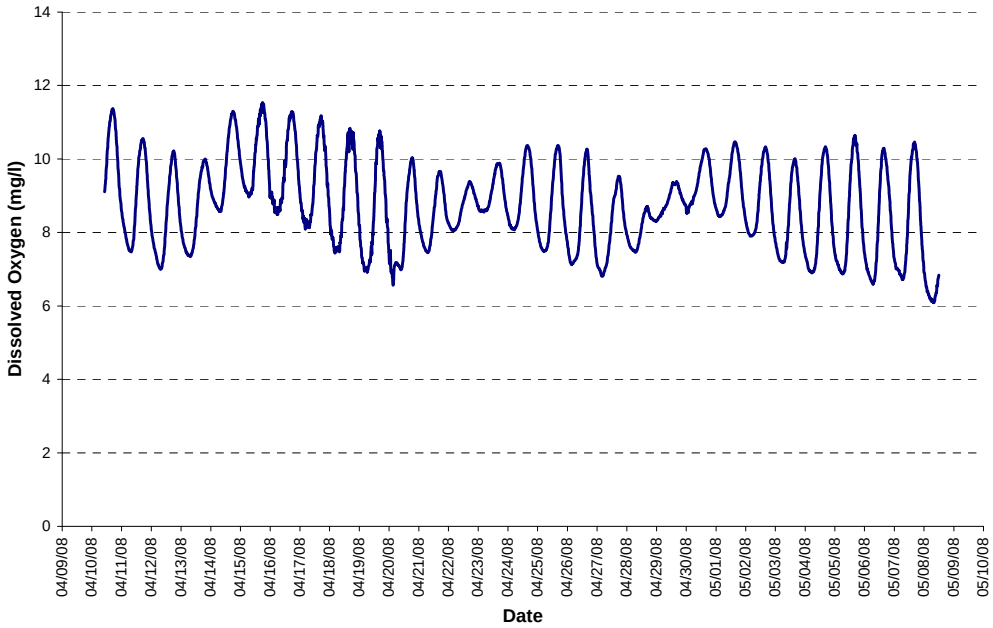

Figure 2.31. Dissolved oxygen sampling results at station RRM 7.4 in South River.

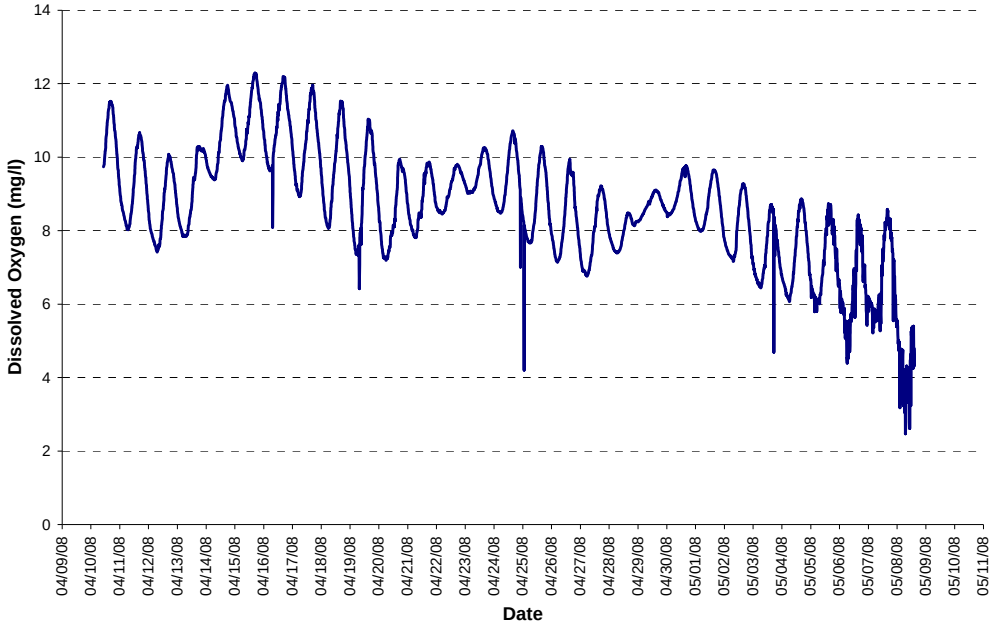

Figure 2.32. Dissolved oxygen sampling results at station RRM 8.7 in South River.

Chapter 3. Bacteria Source Assessment

Potential bacteria sources in the South River watershed were assessed using multiple approaches, including information from VADEQ; Virginia Department of Conservation (VADCR); Virginia Department of Game and Inland Fisheries (VADGIF); Virginia Cooperative Extension (VCE); Virginia Department of Health (VDH); City of Waynesboro and Augusta, Rockingham, Nelson and Albemarle County Planning Departments; Natural Resources Conservation Service (NRCS); Virginia Department of Agricultural and Consumer Services (VDACS); Headwaters and Shenandoah Valley SWCDs; public participation; watershed reconnaissance and monitoring; published information; and professional judgment. The gathered information was used to estimate source populations and their associated bacteria loads throughout the South River watershed, forming the basis for model development and analysis of allocation scenarios (Table 3.1). The following sections discuss available information and methods used to estimate bacteria loads for each modeling segment.

Table 3.1. Sources of bacteria in the South River watershed.

Source Category	Source / Animal Type	Applied To
Human and Pets	Permitted Discharges	Stream Reach
	Sanitary Sewer	Land
	Straight Pipes	Stream Reach
	Failing Septic Systems	Land
	Biosolids Applications	Land
	Dogs / Cats	Land
Agricultural	Dairy Cattle	Land, Stream Reach
	Beef Cattle	Land, Stream Reach
	Horses	Land
	Turkey	Land
	Chicken	Land
	Other Livestock	Land
Wildlife	Deer	Land, Stream Reach
	Bear	Land, Stream Reach
	Raccoon	Land, Stream Reach
	Muskrats	Land, Stream Reach
	Beavers	Land, Stream Reach
	Turkeys	Land, Stream Reach
	Geese	Land, Stream Reach
	Ducks	Land, Stream Reach

3.1 Permitted Discharges

Permitted point sources in the South River watershed include all individual Virginia Pollutant Discharge Elimination System municipal and industrial permitted facilities, as well as general permits issued for domestic sewage discharges of less than or equal to 1,000 gallons per day. The 2007 VPDES Permit Manual defines an individual municipal facility as:

"A treatment works, other than an industrial facility, whose primary function is to receive and treat wastewater from domestic sources or from indirect industrial sources (analogous to a Treatment Works Treating Domestic Sewage (TWTDS), which is a publicly owned treatment works or any other sewage sludge or waste water treatment devices or systems, regardless of ownership (including federal facilities), used in the storage, treatment, recycling, and reclamation of municipal or domestic sewage, including land dedicated for the disposal of sewage sludge. This definition does not include septic tanks or similar devices. For purposes of this definition, domestic sewage includes waste and waste water from humans or household operations that are discharged to or otherwise enter a treatment works." (VPDES Permit Manual – 2007)

The permit manual defines an industrial facility is defined as:

"Establishments with activity in which they are engaged as an economic unit, generally at a single location where business is conducted, services or industrial operations performed, or in which raw materials are changed into useful products." (VPDES Permit Manual 2007)

For this reason, permitted point sources of fecal coliform include only the individual municipal or general domestic sewage permits (permits classified as industrial do not discharge bacteria). The individual municipal and general domestic sewage permits are required to maintain a fecal coliform concentration of 200 cfu/100 mL or less (the 'interim standard'), and are required to meet the new *E. coli* standard of 126 cfu/100 mL or less in their effluent on permit renewal. Table 3.2 shows the point sources in the South River watershed.

In allocation scenarios, the entire allowable point source discharge concentration of 200 cfu/100 mL of fecal coliform (the 'interim standard') was used. The ultimate waste load allocation (WLA) was calculated using the *E. coli* limit of 126 cfu/100mL, and *E. coli* loads based on the facility design flow are presented in Table 3.2.

Phase II Municipal Separate Storm Sewer System (MS4) permits were also reviewed and found no facilities with MS4 permits discharge within the South River watershed.

Table 3.2. Active VPDES permitted bacteria point sources in the South River watershed.

Permit Number	Facility Name	Sub-shed	Design Flow (MGD)	FC Load (cfu/yr)	*E. coli* Load (cfu/yr)
VA0001767	Alcoa Packaging LLC	SOR-02	0.019	5.25E+10	3.31E+10
VAG401441	Residence	SOR-02	0.001	2.68E+09	1.69E+09
VA0066877	Stuarts Draft WWTP	SOR-04	4.000	1.11E+13	6.96E+12
VA0025151	Waynesboro STP	SOR-05	6.000	1.66E+13	1.04E+13
VA0027901	Harriston STP	SOR-05	0.100	2.76E+11	1.74E+11
VA0065374	Grottoes STP	SOR-06	0.400	1.11E+12	6.96E+11
VA0028037	Skyline Swannanoa	SOR-06	0.150	4.15E+11	2.61E+11
VAG408047	Residence	SOR-06	0.001	2.68E+09	1.69E+09
VAG408048	Residence	SOR-06	0.001	2.68E+09	1.69E+09
VAG408122	Residence	SOR-06	0.001	2.68E+09	1.69E+09
VA0088226	Hugh K Cassell Elementary School	SOR-07	0.011	3.04E+10	1.91E+10
VAG401199	Residence	SOR-07	0.001	2.68E+09	1.69E+09
VAG401576	Residence	SOR-07	0.001	2.68E+09	1.69E+09
VAG401940	Residence	SOR-07	0.001	2.68E+09	1.69E+09
VA0067962	Vesper View STP	SOR-08	0.100	2.76E+11	1.74E+11
VA0088943	Blue Ridge MHC LLC	SOR-08	0.024	6.63E+10	4.17E+10
VAG401110	Residence	SOR-08	0.001	2.68E+09	1.69E+09

3.2 Humans

There are 11,8471homes served by municipal sanitary sewer in the South River watershed. Wastewater from 8,895 households within the watershed is treated on site by traditional sewage handling and disposal systems.

The South River watershed has an estimated population of 45,093 people (20,741 households at an average of 2.17 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce 1.95×10^{9} cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of 8.79×10^{13} cfu/day (3.21×10^{16} cfu/year) in South River watershed.

Bacteria from humans can be transported to streams from failing septic systems, straight pipes discharging directly into streams, or biosolids applications to pasture and cropland.

3.2.1 Failing Septic Systems

Septic systems are designed to filter septic tank effluent through the soil allowing removal of bacteria and nutrients from the wastewater. Septic system failure is manifested by

the rise of effluent to the soil surface. It was assumed treatment of effluent ceased once effluent containing fecal coliform reached the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters.

Total septic systems were classified into one of three age categories (pre-1984, 1985-1994, and post-1994) based on 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB, 1990, 2000, and 2004). In accordance with estimates from Dr. Raymond B. Reneau, Jr. from Virginia Tech, a 15% failure rate for systems designed and installed prior to 1984, a 8% failure rate for systems designed and installed between 1985 and 1994, and a 3% failure rate on all systems designed and installed after 1994 was used in the development of the South River TMDL. The rates reported by Dr. Raymond B. Reneau, Jr. were a culmination of studies he performed throughout the state with numerous variables (e.g., soils) considered. These rates have been accepted by the Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation, and United States Environmental Protection Agency in TMDLs throughout Virginia. Estimates of these failure rates were also supported by the Holmans Creek Watershed Study which found that over 30% of all septic systems checked in the watershed were either failing or not functioning at all (SAIC, 2001).

An average number of people per household and number of houses and people in each subwatershed in 2008 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). The applicable failure rate was multiplied by each total and summed to get the total failed septic systems per subwatershed. Daily total fecal coliform load to the land from a failing septic system in a particular sub-watershed was determined by multiplying the average household occupancy rate for that subwatershed by the per capita fecal coliform production rate of 1.95×10^9 cfu/day (Geldreich et al., 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a subwatershed with an occupancy rate of 2.17 persons/household was 4.24×10^9 cfu/day. Transport of some portion of the fecal coliform to a stream by runoff may occur during storm events. The number of failing septic systems in the watershed is given in Table 3.4.

3.2.2 Straight Pipes

Houses that deliver a waste load directly to the stream, or straight pipes, were estimated by identifying those houses located within 150 feet of streams in the pre-1969 and 1970-1988 age categories. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1969, 1970 – 1988, post 1988), 10% of old houses (pre-1969) within 150 ft of streams and 2% of mid-age houses (1970 – 1988) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 197 houses that potentially could be classified as straight pipes in the South River watershed (Table 3.4).

3.2.3 Biosolids

VADEQ records were available for Class B biosolids applications in 2004, 2005, and 2006. Spatial distribution of application sites within the South River watershed, biosolids amount applied, and area biosolids applied to were available. Although Class B biosolids are permitted

to contain fecal coliform concentrations of 2.0×10^6 cfu/g (VDH, 1997), values reported by treatment plants are typically lower than this value. Blue Plains, a large wastewater treatment plant in the Washington D.C. metropolitan area was used to estimate the bacteria content in the biosolids. The fecal coliform density of Blue Plains biosolids from a sample collected and tested by VDH in 2006 was less than 2.0 cfu/g (Swanson, 2006). Therefore, an average fecal coliform density of 2.0 cfu/g was used for bacteria loading calculations. Table 3.3 shows the annual biosolids application amount and area for each subwatershed.

Table 3.3. Annual biosolids application amount for each subwatershed in the South River watershed.

Sub_shed	2004 Application Info		2005 Application Info		2006 Application Info	
	Dry Metric Tons Applied in 2004	Acreage Used in 2004	Dry Metric Tons Applied in 2005	Acreage Used in 2005	Dry Metric Tons Applied in 2006	Acreage Used in 2006
SOR-01	101.1	65.2	12.7	6.2	24.2	21.2
SOR-02	62.4	47.3	62.4	47.3	28.7	10.7
SOR-03	0	0	0	0	0	0
SOR-04	0	0	0	0	0	0
SOR-05	0	0	0	0	0	0
SOR-06	60.7	27.1	175.3	32.7	88.9	30.2
SOR-07	334.1	131.2	158.2	93.3	29.2	12.2

3.3 Pets

According to the American Veterinary Medical Association (AVMA), there are on average 0.53 dogs per household and 0.60 cats per household in the Unites States (AVMA, 1997). Based on these densities and number of households in each watershed, 12,445 dogs and 10,993 cats were projected to reside in the South River impairment. All pets were combined for modeling purposes into a standard ‘unit pet’ category. This ‘unit pet’ was assumed equivalent to one dog or several cats, and a rate of one ‘unit pet’ per household was used to calculate a total pet population of 20,741 for South River watershed. The maximum typical fecal coliform production for both dogs and cats is 5.0×10^9 cfu/day-animal (Keeling, 2003), and the typical ranges overlap significantly. The pet population was estimated to produce 4.5×10^8 cfu/day-animal based on these published values. The total bacteria production attributed to pets in the South River watershed is 9.3×10^{12} cfu/day (3.4×10^{15} cfu/yr). The pet population distribution among the subwatersheds is listed in Table 3.4. Pet waste is generated in the residential land use type. Bacteria loading to streams from pet waste can result from surface runoff transporting bacteria from residential areas.

Table 3.4. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the South River watershed.

Sub-shed	Human Population	Sewered Houses	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
			Pre-1984	1985 - 1994	Post-1994			
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
SOR-1	8,227	1,008	1,140	431	911	231	47	3,536
SOR-2	2,234	105	514	159	371	100	29	1,178
SOR-3	8,792	3,597	424	57	80	70	15	4,172
SOR-4	14,828	5,927	735	119	189	125	38	7,008
SOR-5	2,710	130	598	154	240	109	19	1,141
SOR-6	3,713	326	600	314	380	125	21	1,640
SOR-7	4,589	756	589	196	497	118	28	2,065
Total	**45,093**	**11,847**	**4,599**	**1,430**	**2,668**	**877**	**197**	**20,741**

[a]Calculated from average of 1.0 pet per household.

3.4 Domesticated Animal Sources

In the South River watershed, bacteria from domesticated animal waste can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animals depositing waste on pastures or from applying collected waste on crop and hay land. Domesticated animal populations in the South River watershed were estimated based on Virginia Agriculture Statistics Service (VASS) data and communication with staff from SWCDs, NRCS, VADCR, VCE, watershed residents, and local producers.

3.4.1 Cattle

Based on information obtained from VADCR and SWCDs, there is one dairy farm presently operating in the South River watershed. Based on information provided, it was determined that there were 250 milk cows, 125 dry cows, and 125 heifers at the farm. The dairy cattle population was distributed among the sub-watersheds based on the location of the dairy farm (Table 3.5). Beef cattle in the South River watershed (4,503 pairs) included cow/calf and feeder operations (Table 3.5).

Table 3.5. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in South River watershed.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
SOR-1	0	0	1413
SOR-2	0	0	284
SOR-3	0	0	204
SOR-4	0	0	309
SOR-5	0	0	777
SOR-6	0	0	762
SOR-7	500	1	754
Total	**500**	**1**	**4,503**

[a]Consists of the milking herd, dry cows, and heifers.

Cattle spend varying amounts of time in confinement, loafing lots, streams, and pasture depending on the time of year and type of cattle (i.e., milk cow versus heifer). Accordingly, the proportion of bacteria deposited in any given land area varies throughout the year. Based on discussions with SWCDs, NRCS, VADCR, VCE, and local producers, the following assumptions and procedures were used to estimate the distribution of cattle (and thus their manure) among different land use types and in the stream:

- Cows are confined according to the schedule given in Table 3.6.
- When cattle are not confined, they spend their time on pasture and in loafing lots, where applicable.
- Pasture 1 (improved pasture/hay land) stocks twice as many cows per unit area as pasture 2 (unimproved pasture/grazed woodlands), which stocks twice as many cows per unit area as pasture 3 (overgrazed pasture).
- Cows on pastures that are contiguous to streams have stream access.
- Cows with stream access spend varying amounts of time in the stream during different seasons (Table 3.6). Cows spend more time in the stream during the three summer months to protect their hooves from hornflies, among other things.
- Thirty percent of cows in and around streams directly deposit fecal coliform into the stream. The remaining 70% of the manure is deposited on pastures.

Table 3.6. Time spent by cattle in confinement and in the stream in South River watershed.

Month	Time Spent in Confinement (%)		Time Spent in Stream (hours/day)*
	Milking	Dry Cows, Heifers, and Beef Cattle	
January	75	40	0.50
February	75	40	0.50
March	40	0	0.75
April	30	0	1.00
May	30	0	1.50
June	30	0	3.50
July	30	0	3.50
August	30	0	3.50
September	30	0	1.50
October	30	0	1.00
November	40	0	0.75
December	75	40	0.50

* Time spent in and around the stream by cows that have stream access.

The time cattle spend each month in various land uses or a given stream reach was estimated based on typical agricultural practice, and adjusted to reflect feedback from LSC members and agricultural producers. Using these data describing where cattle spend their time, the cattle and their resulting bacteria loads were distributed among the land uses for modeling purposes. The resulting numbers of cattle in each land use type as well as in the stream for all subwatersheds are given in Table 3.7 for dairy cattle and in Table 3.8 for beef cattle. Table 3.8 reflects animal unit (i.e., 1,000 lb) per beef cow-calf pair variation throughout year.

Table 3.7. Distribution of the dairy cattle[a] population in the South River watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream[b]
January	287.50	161.79	40.52	10.13	0.07
February	287.50	161.79	40.52	10.13	0.07
March	100.00	304.49	76.26	19.06	0.19
April	75.00	323.47	81.01	20.25	0.27
May	75.00	323.37	80.98	20.25	0.40
June	75.00	322.97	80.88	20.22	0.93
July	75.00	322.97	80.88	20.22	0.93
August	75.00	322.97	80.88	20.22	0.93
September	75.00	323.37	80.98	20.25	0.40
October	75.00	323.47	81.01	20.25	0.27
November	100.00	304.49	76.26	19.06	0.19
December	287.50	161.79	40.52	10.13	0.07

[a]Includes milk cows, dry cows, and heifers.

[b]Number of dairy cattle defecating in stream.

Table 3.8. Distribution of the beef cattle population (pairs) in the South River watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*
January	2,071.38	2,365.57	592.43	148.11	0.97
February	2,431.62	2,776.97	695.46	173.86	1.14
March	0.00	4,764.67	1,193.25	298.31	2.93
April	0.00	4,901.02	1,227.40	306.85	4.02
May	0.00	5,036.53	1,261.34	315.33	6.21
June	0.00	5,167.11	1,294.04	323.51	14.87
July	0.00	5,303.98	1,328.32	332.08	15.27
August	0.00	5,440.86	1,362.60	340.65	15.66
September	0.00	5,584.73	1,398.63	349.66	6.88
October	0.00	3,427.28	858.32	214.58	2.81
November	0.00	3,599.21	901.38	225.34	2.22
December	1,981.32	2,262.71	566.67	141.67	0.93

*Number of beef cattle defecating in stream.

3.4.1.1 Direct Manure Deposition in Streams

Direct manure loading to streams is due to both dairy (Table 3.7) and beef cattle (Table 3.8) defecating in the stream. However, only cattle on pastures contiguous to streams that have not been fenced off have stream access. Manure loading increases during the warmer months when cattle spend more time in water, compared to the cooler months. Average annual manure loading directly deposited by cattle in the stream for the South River watershed is 148,945 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 2.13×10^{11} cfu/day (7.76×10^{13} cfu/year). Part of the fecal coliform deposited in the stream stays in the dissolved form while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that dissolved fecal coliform bacteria are the primary form transported with the flow. Sediment-bound bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. For this TMDL, the dissolved form of bacteria was modeled and re-suspension of sediment-bound bacteria was accounted for through calibration (see Chapter 4). Die-off of fecal coliform in the stream results from sunlight, predation, turbidity, and other environmental factors.

3.4.1.2 Direct Manure Deposition on Pastures

Dairy (Table 3.7) and beef (Table 3.8) cattle that graze on pastures, but do not deposit in streams, contribute the majority of fecal coliform loading on pastures. Manure loading on pasture was estimated by multiplying the total number of each type of cattle (milk cow, dry cow, heifer, and beef) on pasture by the amount of manure it produced per day. The total amount of manure produced by all types of cattle was divided by the pasture acreage to obtain manure loading (lb/ac-day) on pasture. Fecal coliform loading (cfu/ac-day) on pasture was calculated by multiplying the manure loading (lb/ac-day) by the fecal coliform content (cfu/lb) of the manure. Since the confinement and calving schedule of the cattle changes throughout the year, manure and fecal coliform loading on pasture also change with season.

In the South River watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 7,606; 3,819; and 1,875 lb/ac-year, respectively. The loadings vary because the stocking rate varies with pasture type, with improved pasture able to stock the most cattle. Fecal coliform loadings from cattle in South River, averaged over the year, are 4.42×10^{12}, 2.29×10^{12}, and 9.81×10^{11} cfu/ac-year for pastures 1, 2, and 3, respectively. Fecal coliform bacteria deposited on the pasture surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

3.4.1.3 Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 pounds and produces 17 gallons of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule and the number of milk cows, annual liquid dairy manure production in the South River watershed is 664,222 gallons. Based on per capita fecal coliform production of milk cows, the fecal coliform concentration in fresh liquid dairy manure is 3.88×10^{7} cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) in application to land. Liquid dairy manure application rates are 6,600 and 3,900 gal/ac-year to cropland and pasture land use categories (BSE, 2003), respectively, with cropland receiving priority in application. Based on availability of land and liquid dairy manure, as well as the assumptions regarding application rates and priority of application, it was estimated that liquid dairy manure was applied to 100.64 acres of cropland and 0.0 acres of pastures 1, 2, and 3 in the South River watershed.

The typical crop rotation in the watershed is a seven-year rotation with three years of corn-rye and four years of rotational hay (BSE, 2003). It was assumed that 50% of the corn acreage was under no-till cultivation. Liquid manure is applied to cropland during February through May (prior to planting) and in October-November (after the crops are harvested). For spring application to cropland, liquid manure is applied on the soil surface to rotational hay and no-till corn and is incorporated into the soil for corn in conventional tillage. In fall, liquid manure is incorporated into the soil for cropland under rye and surface-applied to cropland under rotational hay. It was assumed that only 10% of the subsurface-applied fecal coliform was available for removal in surface runoff based on local knowledge. The application schedule of liquid manure (BSE, 2003) is given in Table 3.9. Dry cows and heifers were assumed to produce only solid manure.

Table 3.9. Schedule of cattle waste application in South River watershed.

Month	Liquid Manure Applied (%)*	Solid Manure and Poultry Litter Applied (%)*
January	0	0
February	5	5
March	25	25
April	20	20
May	5	5
June	10	5
July	0	5
August	5	5
September	15	10
October	5	10
November	10	10
December	0	0

* As percent of annual production.

3.4.1.4 Land Application of Solid Manure

Solid manure produced by dry cows, heifers, and beef cattle during confinement is collected for land application. It was assumed that milk cows produce only liquid manure while in confinement. The number of cattle, their typical weights, amount of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 3.10.

Solid manure is last on the priority list for application to land (it falls behind liquid manure and poultry litter). The amount of solid manure produced in each sub-watershed was estimated based on the populations of dry cows, heifers, and beef cattle in the sub-watershed and their confinement schedules. Solid manure from dry cows, heifers, and beef cattle exhibits different fecal coliform concentrations (cfu/lb) (Table 3.10). Hence, a weighted average fecal coliform concentration in solid manure was calculated based on the relative manure contribution from dry cows, heifers, and beef cattle (Table 3.10). Solid manure is applied at the rate of12 tons/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid manure, solid manure is only applied to cropland during February through May and the months of October and November.

Solid manure can be applied to pasture during the whole year except during December and January. The method of application of solid manure to cropland or pasture is assumed to be identical to the method of application of liquid dairy manure. The application schedule for solid manure is given in Table 3.9. Based on availability of land and solid manure, as well as the assumptions regarding application rate, it was estimated that solid manure was applied to 322.3 acres of cropland; 3.1 acres of pasture 1; 189.8 acres of pasture 2; and 0.0 acres of pasture 3 in the South River watershed.

Table 3.10. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in South River watershed.

Type of Cattle	Population	Typical Weight (lb) [a]	Solid Manure Produced (lb/animal-day) [a]	Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb) [a]	Weighted Average Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb)
Dry Cow	125	1,400	115.0	2.17	5.28
Heifer	125	640	40.7	2.17	
Beef (pairs)	4,503	1,000	60.0	5.50	

[a]Source: BSE (2003)

3.4.2 Poultry

Based on permit information obtained from VADEQ, there are 10 turkey and no chicken facilities presently operating in the South River watershed. Based on information provided, it was determined that there were 407,400 turkeys distributed between the operations. The poultry population was distributed among the sub-watersheds based on the location of the poultry facility (Table 3.11).

Table 3.11. Distribution of poultry population among subwatersheds in South River watersheds.

Subwatershed	Turkeys Population (#)	Turkey Operations (#)
SOR-1	0	0
SOR-2	0	0
SOR-3	0	0
SOR-4	0	0
SOR-5	0	0
SOR-6	185,800	5
SOR-7	221,600	5
Total	**407,400**	**10**

3.4.2.1 Land Application of Poultry Litter

Poultry litter produced by chickens and turkeys during confinement is collected for land application. The main considerations for the poultry operations are the total number of birds produced in a given cycle, the number of cycles per year, and the amount of time between cycles during which the poultry house is empty. Based on these factors, the amount of poultry litter produced in each watershed was estimated along with the bacteria content of the litter. Poultry litter is applied at the rate of 6,000 lb/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid and solid manure, poultry litter is only applied to cropland during February through May and the months of October and November.

Poultry litter can be applied to pasture during the whole year except during December and January. The application schedule for poultry litter is given in Table 3.9. Based on availability of land and poultry litter, as well as the assumptions regarding application rate, it was estimated that 1,053.8 acres of cropland; 4,709.3 acres of pasture 1; 614.2 acres of pasture 2; and 0.0 acres of pasture 3 in the South River watershed received poultry litter application.

3.4.3 Horses

The estimated number of horses in the South River watershed is included in Table 3.12. The horse population in the watershed has risen in the last several years. Horse populations were estimated using data from the 2001 Virginia Equine Report produced by VASS (VASS, 2002).

The number of horses within the watershed was estimated by distributing the equine population evenly throughout all pasture in each county and determining the number of horses in the watershed based on pasture area in the watershed. The same method was used to determine the equine population in each subwatershed. The estimates were adjusted based on feedback from the LSC.

The typical horse produces 4.2×10^{8} cfu/day (VADCR, 2003). Therefore, the daily fecal coliform production by horses in the South River watershed is 2.79×10^{11} cfu/day (1.02×10^{14} cfu/year).

Table 3.12. Horse and sheep population by subwatershed in the South River watershed.

Subwatershed	Horses	Ewes
SOR-1	208	324
SOR-2	42	65
SOR-3	30	47
SOR-4	45	71
SOR-5	114	178
SOR-6	112	175
SOR-7	114	175
Total	**665**	**1,035**

3.4.4 Other Livestock Sources

Based on county sheep population data obtained from VASS and input from SWCDs, the sheep population was distributed to individual subwatersheds (Table 3.12). Based on information provided, it was determined that there were 1,035 ewes throughout the South River watershed. Other minor livestock-related sources of bacteria (e.g., goat) were present during watershed visits; however, a significant population was not identified within the South River watershed. The potential bacteria load from these sources was accounted for during water quality calibration.

3.5 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Table 3.13. The total wildlife fecal coliform production each year in the South River watershed is 1.03×10^{15}cfu/yr.

Wildlife fecal coliform contributions can be from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF, USF&WS, and watershed residents was used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, bear, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.13).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.13). Fecal matter produced by deer that is not directly deposited in streams is distributed among pastures and forest. Raccoons deposit their waste in streams and forests. Muskrats deposit their waste in streams and pastures.

Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among sub-watersheds based on habitat descriptions included in Table 3.13, and further details of the wildlife habitat were used to distribute the populations among the sub-watersheds. For example, the deer population was evenly distributed across the watershed, whereas the 66 feet buffer around streams and impoundments determined the muskrat population. Therefore, a sub-watershed with more stream length and impoundments would have more muskrats than a sub-watershed with shorter stream length and fewer impoundments. Distribution of wildlife among sub-watersheds is given in Table 3.14.

Table 3.13. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the South River watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.039	0.10
Raccoon	Primary: 600 feet buffer around streams and impoundments Secondary: 601 feet -7,920 feet buffer from streams and impoundments	0.070	0.10
Muskrat	Primary: 66 feet buffer around streams and impoundments in forest and cropland Secondary: 67-300 feet buffer from same	0.037[a]	0.25
Beaver	300 feet buffer around streams and impoundments in forest and pasture	0.015	0.50
Geese	300 feet buffer around main streams	0.003[b]	0.25
Wood Duck	300 feet buffer around main streams	0.004[b]	0.25
Wild Turkey	Entire watershed except urban areas	0.005[c]	0.00

[a] Muskrats per mile of stream through agricultural land.
[b] Animals per acres of all land uses.
[c] Animals per acres of forest.

Table 3.14. Distribution of wildlife among sub-watersheds in South River watershed.

Subwatershed	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Wood Duck (#)	Wild Turkey (#)
SOR-1	848	761	1,783	78	82	97	73
SOR-2	956	824	370	85	85	101	127
SOR-3	144	156	238	9	22	26	8
SOR-4	559	492	344	43	61	72	53
SOR-5	415	432	831	42	40	47	33
SOR-6	647	537	560	54	59	70	66
SOR-7	479	422	492	41	46	54	35
Total	**4,048**	**3,624**	**4,618**	**352**	**395**	**467**	**395**

3.6 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the South River watershed along with average fecal coliform production rates are shown in Table 3.15. The total fecal coliform production by all sources in the South River watershed is 1.09×10^{17} cfu/yr.

Table 3.15. Potential fecal coliform sources and daily fecal coliform production by source in South River watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times 10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times 10^7$ cfu/ day)[b]
Dairy Cattle			
Milk and Dry Cows	375	25,000	938,142
Heifers	125	8,800	142,955
Beef Cattle (pairs)	4,503	33,000	20,090,890
Horses	665	420	27,949
Poultry (Turkey)	407,400	93	3,791,415
Humans	45,093	1,950	1,063,976
Pets	20,741	450	934,119
Deer	4,048	350	141,777
Raccoon	3,624	50	18,132
Muskrat	4,618	25	11,553
Beaver	352	0.2	7
Wild Turkey	395	93	3,676
Duck	467	2,400	83,967
Goose	395	800	23,717

[a]Source: Keeling (2003) - Production per animal unit per species.

[b]Fecal coliform production adjusted to account for local animal weight. This may not equal the product of the other two columns.

Based on the inventory of fecal coliform sources, a summary of the contributions made by the nonpoint sources to annual fecal coliform loading directly to the stream and to various land use categories is given in Table 3.16. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.16.

From Table 3.16, it is clear in the South River watershed that nonpoint source loadings to the land surface are more than 172 times as large as direct loadings to the streams, with pastures receiving about 90% of the total fecal coliform load. It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily from pastures. However, other factors such as precipitation (amount and pattern), manure application activities (time and method), type of waste (solid versus liquid manure), proximity to streams and environmental factors also impact the amount of fecal coliform from upland areas that

reaches the stream. The HSPF model considers these factors when estimating fecal coliform loads to the receiving waters, as described in Chapter 4.

Table 3.16. Annual fecal coliform loadings to the stream and the various land use categories in the South River watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	31,533	0.36
Cattle in Stream	7,760	0.09
Wildlife in Stream	12,074	0.14
Loading to Land Surfaces		
Cropland	42,342	0.48
Pasture 1	6,090,651	68.62
Pasture 2	1,586,593	17.87
Pasture 3	334,178	3.76
Forest	73,445	0.83
Residential*	697,772	7.86
Total	**8,876,349**	**100.00**

*Includes loads received from failed septic systems and pets.

Chapter 4. Benthic Stressor Analysis

4.1 Introduction

TMDLs must be developed for a specific pollutant. Since the benthic impairment is based on a biological inventory, rather than on a physical or chemical water quality parameter, the pollutant is not explicitly identified in the assessment, as it is with physical and chemical parameters. The process outlined in USEPA's Stressor Identification Guidance Document (USEPA, 2000) was used to identify the critical stressor for South River. A list of candidate causes was developed from the listing information, biological data, published literature, and stakeholder input. Chemical and physical monitoring data from VADEQ monitoring provided additional evidence to support or eliminate the potential candidate causes. Biological metrics and habitat evaluations in aggregate provided the basis for the initial impairment listing, but individual metrics were also used to look for links with specific stressors, where possible.

Logical pathways were explored between observed effects in the benthic community, potential stressors, and intermediate steps or interactions that would be consistent in establishing a cause and effect relationship with each candidate cause.

The evaluation includes possible stressors such as dissolved oxygen, temperature, pH, metals, organic chemicals, nutrients, toxic compounds, and sediments. Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed. Depending on the weight of evidence available, each potential stressor was placed into one of the following three categories:

Non-stressor: Stressor with data indicating normal conditions, without water quality standard exceedances, or without observable impacts usually associated with the stressor.

Possible stressor: Stressor with data indicating possible links to the benthic impairment, but without conclusive data to demonstrate direct impact on benthic community.

Most probable stressor(s): Stressor with conclusive data linking it to the poor health of the benthic community, or the most plausible of the possible stressors. TMDL developed for the most probable stressor(s).

4.2 Non-Stressors

4.2.1 pH

Benthic macro-invertebrates require a specific pH range of 6.0 to 9.0 to thrive. Changes in pH may adversely affect the survival of benthic macro-invertebrates. Treated wastewater, mining discharge, and urban runoff can potentially alter in-stream levels of pH. No exceedance of the minimum and only two exceedances of the maximum pH standard (at VADEQ station 1-BSTH027.85) were reported at VADEQ stations on the impaired segment. Therefore, pH does not appear to be adversely impacting benthic communities in South River and is classified as a non-stressor.

4.2.2 Temperature

Elevated temperatures can stress benthic organisms and provide sub-optimal conditions for their survival. South River is classified as a Class IV mountain stream with a maximum temperature standard of 31°C. No exceedances of the temperature standard were recorded by VADEQ ambient monitoring, or by monitoring during collection of the biological samples. Therefore, no evidence supported temperature as a stressor, and it was classified as a non-stressor.

4.2.3 Dissolved Oxygen and Biochemical Oxygen Demand

Adequate dissolved oxygen (DO) levels are necessary for invertebrates and other aquatic organisms to survive in the benthic sediments of rivers or streams. Decreases in in-stream oxygen levels can result in oxygen depletion or anoxic sediments, which adversely impact the river's benthic community. The field DO samples complied with the DO criteria; therefore, dissolved oxygen is not considered to be impacting the benthic community and was classified as a non-stressor. Elevated biochemical oxygen demand (BOD) levels can contribute to low DO levels, adversely affecting the benthic community. Since observed BOD values were not elevated, aside from one value of 5 mg/l observed at station 1-BSTH027.85, BOD was classified as a non-stressor.

4.2.4 Ammonia

High values of ammonia are toxic to many fish species and may impact the benthic community as well. All the values except one recorded at VADEQ ambient monitoring stations were at or below 0.14 mg/L. A value of 0.94 mg/L was recorded 5/20/93 at station 1-BSTH027.85, still below the chronic ammonia freshwater criteria of 1.79 mg/L. No fish kills have been reported in this watershed and nothing in the ambient monitored data indicates ammonia as a stressor, therefore ammonia was classified as a non-stressor.

4.2.5 Sediment Toxics

Sediment samples were collected from one point along the South River at station 1-BSTH000.19 in May 1996 and August 2005. These sediment samples were analyzed for metals, PAHs, and PCBs. None of the measured concentrations exceeded established probable effect concentrations listed; therefore, sediment toxics was classified as a non-stressor.

4.3 Possible Stressors

4.3.1 Nutrients

Excessive nutrient inputs can lead to excessive algal growth, eutrophication, and low DO concentrations that may adversely affect the survival of benthic macro-invertebrates. In particular, DO levels may become low during overnight hours due to respiration. The majority of dissolved phosphorus concentrations recorded at stations 1-BSTH007.80 and 1-BSTH027.85 exceeded the stessor screening criteria and several exceeded VADEQ's "threatened waters"

threshold for total phosphorus (TP). Organic nitrogen values were elevated above the stressor screening value of 0.3 mg/L, with high TKN values of 1.7 mg/l and 2.2 mg/l recorded at stations 1-BSTH007.80 and 1-BSTH027.85, respectively. Ammonia values were not elevated, with all values except one at or below 0.14 mg/l. Average and maximum nitrate values at station 1-BSTH007.80 were 1.21 mg/l and 2.80 mg/l. Values at station 1-BSTH027.85 were less excessive , with an average of 0.72 mg/l and a maximum value of 1.69 mg/l. Nitrite values were not elevated, average values at stations 1-BSTH007.80 and 1-BSTH027.85 were 0.014 mg/l and 0.13 mg/l, respectively. Maximum values were 0.06 mg/l and 0.04 mg/l, respectively. While the benthic community in South River has occasional high populations of Chironomidae or Hydropsychidae – organisms associated with excessive nutrients, it has also contained high numbers of low pollution tolerant organisms. Several low riparian vegetation habitat metric scores have been recorded, which could promote increased nutrient transport through surface runoff. Nutrients were classified as a possible stressor.

4.3.2 Water Column Toxics

Toxic substances by definition are not well tolerated by living organisms. The presence of toxics as a stressor in a watershed may be supported by very low numbers of any type of organisms, low organism diversity, exceedances of freshwater aquatic life criteria or consensus-based probable effect concentrations (PEC) for metals or inorganic compounds, by low percentages of the shredder population, reports of fish kills, or by the presence of available sources.

Chronic toxicity testing was conducted on a water column sample collected at station 1-BSTH007.80 in June 2006, March 2007, and May 2007. The June 2006 test results showed there was not a toxic effect on the Ceriodaphnia dubia, also known as water fleas. However, based on results from the toxicity test, there was a biological effect on fathead minnow survival and biomass. The March 2007 and May 2007 samples had a statistically significant effect on the fathead minnow survival and biomass. Tests on Ceriodaphnia dubia were not performed for the March 2007 and May 2007 samples. It should be noted that these toxicity tests do not provide information on the source of the toxics that may be affecting the fish community. Because of the possibility of contributions from various sources discussed above and toxicity test results, toxics are considered to be a possible stressor.

4.4 Most Probable Stressors

4.4.1 Sediment

Sedimentation has been identified as a most probable stressor in the South River benthic impaired segment, based on the composition of the benthic community, benthic habitat data, and excessive TSS values from the stations along the impaired segment. In particular; bank stability, embeddedness, riparian vegetation, bank vegetation, and riffle stability habitat scores at these stations were sub-optimal. In addition, samples of the benthic community in South River have shown high populations of Chironomids and Hydropsychids, which thrive in sediment rich water. TSS values at station 1-BSTH027.85, located just above the impaired

segment, are not elevated. TSS values at station 1-BSTH007.80 exhibit higher values, with three measurements over 150 mg/l, and appear to be trending higher.

4.4.2 Phosphorus

Phosphorus has been identified as a most probable stressor in the South River benthic impaired segment based on the composition of the benthic community, benthic habitat data, magnitude of diurnal DO swings, evidence of algal blooms during the spring and summer, and in-stream phosphorus concentrations from the stations along the impaired segment. In particular; riparian vegetation and bank vegetation habitat scores at these stations were sub-optimal, which could promote increased nutrient transport through surface runoff. Samples of the benthic community in South River have shown high populations of Chironomids and Hydropsychids, which thrive in nutrient rich water. Significant diurnal DO swings violating the DO criteria and excessive algal production are strong indicators of nutrient enrichment, particulary phosphorus, the limiting nutrient in South River. Unacceptable DO levels were recorded in the non-daylight hours during testing perfomed between April 2008 and May 2008 as part of the South River Ecological Study and algal blooms have been observed throughout South River impairment. The majority of dissolved phosphorus concentrations recorded at stations 1-BSTH007.80 and 1-BSTH027.85 exceeded the stressor screening criteria and several exceeded VADEQ's "threatened waters" threshold for total phosphorus (TP).

Chapter 5. Modeling Process for Bacteria TMDL Development

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and non-point) and in-stream water quality conditions. Once this relationship has been developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutants and cause the impairment of the water body of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In this chapter, modeling process, input data requirements, model calibration procedure and results, and model validation results for the bacteria TMDL are discussed.

5.1 Model Description

Conducting a TMDL study requires the use of a watershed-based model that integrates both point and non-point sources and simulates in-stream water quality processes. The Hydrologic Simulation Program – Fortran (HSPF) (Bicknell et al., 2000) was used to model fecal coliform transport and fate in the South River watershed. The ArcView 9.2 GIS program was used to display and analyze landscape information.

The HSPF model simulates non-point source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes (Bicknell et al., 2000). HSPF estimates runoff from both pervious and impervious parts of the watershed and stream flow in the channel network. The sub-module PWATER within the module PERLND simulates runoff, and hence, estimates the water budget on pervious areas (e.g., agricultural land). Runoff from largely impervious areas is modeled using the IWATER sub-module within the IMPLND module. The simulation of flow through the stream network is performed using the sub-modules HYDR and ADCALC within the module RCHRES. While HYDR routes the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream. Fate of fecal coliform on pervious and impervious land segments is simulated using the PQUAL (PERLND module) and IQUAL (IMPLND module) sub-modules, respectively. Fate of fecal coliform in stream water is simulated using the GQUAL sub-module within RCHRES module. Fecal coliform bacteria are simulated as a dissolved pollutant using the general constituent pollutant model (GQUAL) in HSPF.

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the model for the South River watersheds are discussed below in Sections 5.2 through 5.6. This information is translated into model parameters. Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules are listed in BASINS Version 3.0 User's Manual 3.0 (USEPA, 2001). Water quality parameters required as inputs for PQUAL, IQUAL, and GQUAL are given in the BASINS Version 3.0 User's Manual (USEPA, 2001). Values for the hydrology and water quality parameters were estimated based on local conditions when possible; otherwise the default parameters provided within HSPF were used.

5.2 Selection of Sub-watersheds

The stream network was delineated based on the blue line stream network from USGS topographic maps with each subwatershed having at least one stream segment. Subwatershed delineation was based on potential fecal loadings, flow and water quality data availability, and HSPF model constraints. Because loadings of fecal coliform are believed to be associated with land use activities, subwatersheds were chosen based on uniformity of land use. HSPF outputs flow and fecal coliform concentration at subwatershed outlets; therefore, subwatershed outlets were chosen to correspond to flow and water quality station locations. An hourly model time-step was used requiring the time of concentration in each subwatershed to be greater than one hour.

The South River watershed is 150,150 acres and the model framework selected is suitable for this size. To account for the spatial distribution of fecal coliform sources, the watershed was divided into eight subwatersheds as shown in Figure 5.1. The impaired segment with a previously developed TMDL drains into unimpaired segment SOR-01 of South River. Segment SOR-01 joins Back Creek (SOR-02) and flow into the unimpaired segment SOR-03. Unimpaired segment SOR-03 drains to the impaired segments (SOR-04 through SOR-07) of South River.

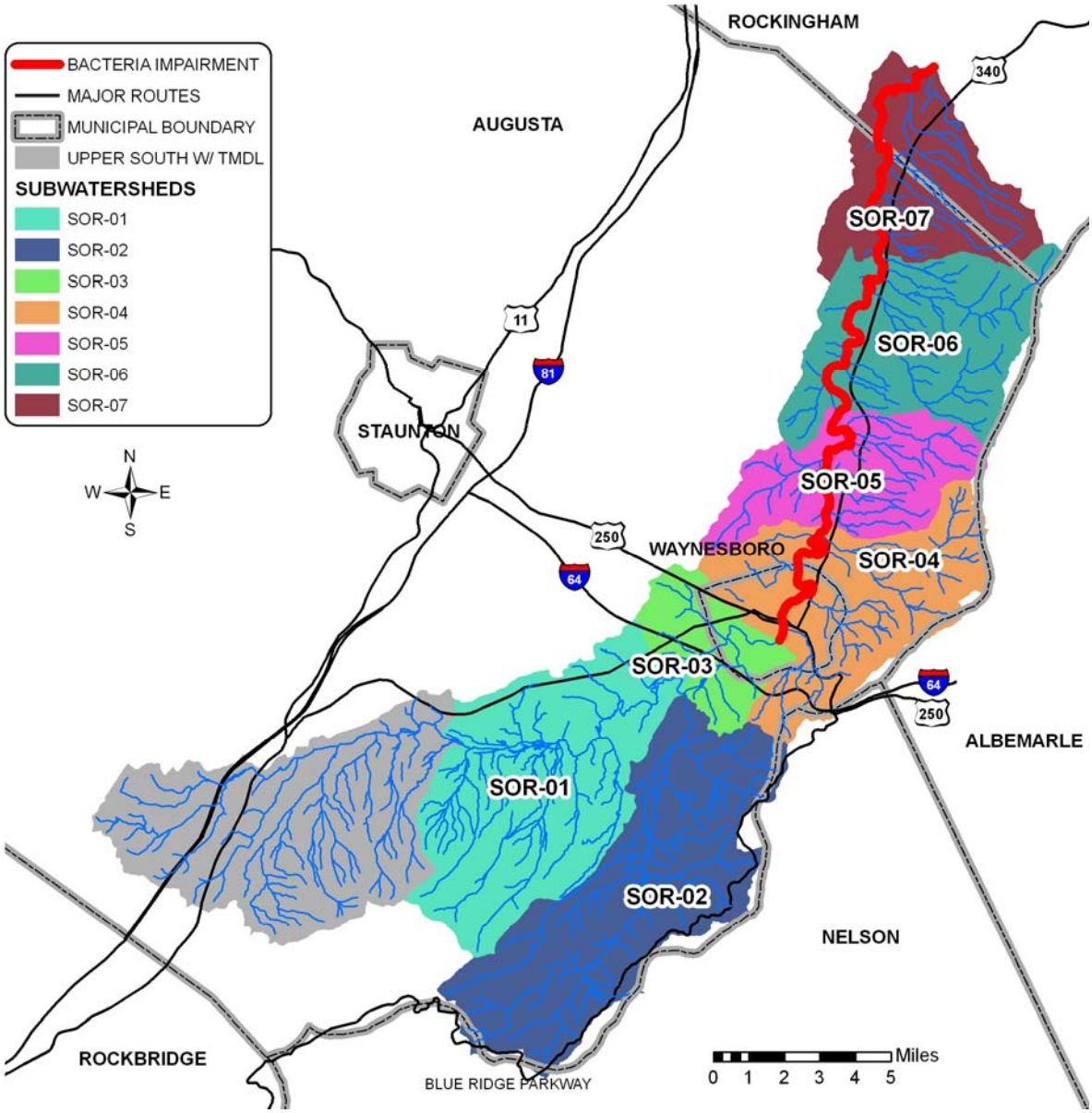

Figure 5.1. South River subwatersheds.

5.3 Land Use

The National Land Cover Data (NLCD) produced by U.S. Geological Survey (USGS) in cooperation with the USEPA was used for this study. NLCD was developed from 30-meter Landsat 7 thematic mapper (TM) data between 1990 and 1994 and updated with data between 1999 and 2003 acquired by the Multi-resolution Land Characterization (MRLC) Consortium, a partnership between USGS, USEPA, U.S. Forest Service, National Oceanic and Atmospheric Administration (NOAA), Bureau of Land Management (BLM), NRCS, National Park Service (NPS), National Aeronautics and Space Administration (NASA), and United States Fish and Wildlife Service (USFWS). NLCD is classified into 21 land use types. The NLCD land use types

within the watershed were consolidated into eight categories based on similarities in hydrologic and waste application/production features (Table 5.1). The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Some hydrology and water quality model parameters used in the PERLND and IMPLND modules are a function of land use.

As discussed in Section 5.2, subwatersheds were defined to spatially analyze waste or fecal coliform distribution within the watershed (Figure 5.1). Land use distribution in the subwatersheds as well as in the entire South River watershed is presented in Tables 5.2.

Table 5.1. Consolidation of NLCD land use categories for South River watershed.

TMDL Land Use Categories	Pervious / Impervious* (%)	NLCD Land Use Classification (Class No.)
Cropland	Pervious (100)	Cultivated Crops (82)
Pasture 1	Pervious (100)	Pasture/Hay (81)
Pasture 2	Pervious (100)	Pasture/Hay (81)
Pasture 3	Pervious (100)	Pasture/Hay (81)
Residential	Pervious (75), Impervious (25)	Developed, Open Space (21) Developed, Low Intensity (22) Developed, Medium Intensity (23) Developed, High Intensity (24)
Water	Impervious (100)	Open Water (11)
Wetland	Pervious (100)	Woody Wetlands (91) Emergent Herbaceous Wetlands (92)
Forest	Pervious (100)	Barren Land, Rock, Sand, Clay (31) Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)

*Percent pervious / impervious information was used in modeling (described in later sections).

Table 5.2. Land use distribution in South River watershed.

Sub-shed	Land Use (ac)							
	Cropland	Pasture1	Pasture2	Pasture3	Residential	Water/ Wetland	Forest	Total
Upper South	1,128.0	4,940.9	2,474.8	1,237.4	2,869.1	81.9	14,114.7	26,846.7
SOR-01	2,722.9	3,383.5	1,694.7	847.4	3,752.5	133.1	13,062.5	25,596.5
SOR-02	355.8	789.7	395.5	197.8	2,089.2	108.3	22,729.1	26,665.4
SOR-03	164.1	909.3	455.4	227.7	3,248.7	21.5	1,925.4	6,952.2
SOR-04	208.7	1,282.7	642.5	321.2	4,663.3	18.0	11,851.4	18,987.8
SOR-05	359.2	2,509.8	1,257.1	628.5	1,750.4	84.3	5,861.3	12,450.6
SOR-06	568.0	2,343.5	1,173.8	586.9	1,739.8	20.9	11,896.6	18,329.4
SOR-07	586.4	2,368.8	1,186.5	593.2	1,998.4	65.2	7,522.9	14,321.6
Total	6,093.1	18,528.1	9,280.3	4,640.1	22,111.3	533.2	88,963.8	150,150.0

5.4 Stream Channel Characteristics

For each stream reach, a function table (F-Table) is required to describe the relationship between water depth, surface area, volume, and discharge (Bicknell et al., 2000). These parameters were estimated by surveying representative channel cross-sections in each subwatershed. Trapezoidal channel geometry with pitch breaks at the beginning of the flood plain was developed for each reach.

5.5 Climatological Data

The climate data needed for model simulations conducted as a part of this study were obtained from the National Climatic Data Center (NCDC) (NCDC, 2008), part of the National Weather Service (NWS). Simulations performed for South River watershed used hourly weather data from the Staunton Water Treatment Plant (448062) and Stuarts Draft (448172) weather stations. Daily precipitation data from stations Staunton Water Treatment Plant (448062), Stuarts Draft (448172), Craigsville 2 S (442064), West Augusta (448975), and Waynesboro Sewage Plant (448941) was transformed to address discrepancies (i.e., missing data) between observed runoff and hourly precipitation records.

Using hourly precipitation data, frequency of precipitation events and precipitation amounts per hour were calculated. For daily precipitation amounts equal to or less than 0.3 inches, the daily amount was assigned to the hour with the highest likelihood of rainfall. For daily rainfall amounts greater than 0.3 inches, the daily amount was distributed over the day using the calculated hourly precipitation amount frequency distribution.

5.6 Accounting for Pollutant Sources

5.6.1 Overview

There are nine permitted point discharges of bacteria located in the South River watershed. This source was modeled using the permitted concentration and design discharge. Currently, MS4 permitted facilities do not exist in the South River watershed.

Fecal coliform loads that are directly deposited into the stream by straight pipes, or by cattle and wildlife in the stream, were treated as direct nonpoint sources in the model. Fecal coliform that is land-applied or deposited on land was treated as nonpoint source loading; all or part of that load may get transported to the stream as a result of surface runoff during rainfall events. Direct non-point source loading was applied to the stream in each sub-watershed as appropriate.

Nonpoint source loading was applied as fecal coliform counts to the pervious fraction of each land use category in a sub-watershed on a daily basis. Both direct non-point and nonpoint source loadings were varied by month to account for seasonal differences such as cattle and wildlife access to streams. Nonpoint source loading was applied as fecal coliform counts to the impervious fraction of each land use category in a subwatershed at a constant rate during the year. These constant application rates are a function of land use and are discussed in detail in

Section 5.6.4. Fecal coliform die-off was simulated during periods when manure is stored, while on the land between runoff generating precipitation events, and while in streams.

5.6.2 Modeling Fecal Coliform Die-off

Fecal coliform die-off was modeled using a first order die-off equation of the form:

$$C_t = C_0 10^{-kt} \qquad [5.1]$$

where: C_t = concentration or load at time t;

C_0 = starting concentration or load (cfu/ 100ml);

K = decay rate (day-1); and

t = time in days.

A review of literature provided estimates of decay rates that could be applied to waste storage and handling in the South River watershed (Table 5.3).

Table 5.3. First order decay rates for different animal waste storage as affected by storage/application conditions and their sources in the South River watershed.

Waste Type	Storage / Application	Decay Rate (1/day)	Reference
Dairy Manure	Pile (not covered)	0.066	Jones (1971)*
	Pile (covered)	0.028	
Beef Manure	Anaerobic Lagoon	0.375	Coles (1973)*

*Cited in Crane and Moore (1986).

Based on the values cited in the literature, the following decay rates were used in simulating fecal coliform die-off in stored waste.

- Liquid dairy manure: no decay rate for liquid dairy manure storage could be found in the literature, therefore the decay rate for beef manure in anaerobic lagoons (0.375 / day) was used.
- Solid cattle manure: based on the range of decay rates (0.028-0.066 / day) reported for solid dairy manure, a decay rate of 0.05 / day was used assuming that a majority of manure piles are not covered.

Based on these decay rates, die-off of fecal coliform in different storage capacities at the end of the respective storage period were calculated using Equation [5.1]. Depending on the duration of storage, type of storage, type of manure, and die-off factor, the fraction of fecal coliform surviving in the manure at the end of storage was calculated. While calculating survival fraction at the end of the storage period, the daily addition of manure and coliform die-off of each fresh manure addition was considered to arrive at an effective survival fraction over the entire storage period. By multiplying the survival fraction with total fecal coliform produced per year (in as-excreted manure), the amount of fecal coliform available for application to land per year was estimated. Monthly fecal coliform application to land was estimated by multiplying the amount of fecal coliform available for application to land per year by the fraction of manure applied to land during that month. The decay rate for fecal coliform on the land surface was

represented in HSPF by specifying a maximum surface buildup (i.e., MON-SQOLIM) based on the daily loading rate (i.e., MON-ACCUM). An in-stream decay rate for each reach segment (i.e., FSTDEC) was specified in HSPF.

5.6.3 Modeling Direct Non-point Sources

Fecal coliform loads from direct non-point sources included straight pipes, cattle in streams, and wildlife in streams. Also, contribution of fecal coliform from interflow was modeled as having a constant concentration of 4.0 cfu/100mL. Based on Local Steering Committee (LSC) feedback, no instances of groundwater contamination were acknowledged and as a result it was assumed that the groundwater contained no bacteria. Loads from direct non-point sources in each watershed are described in detail in Chapter 3.

5.6.4 Modeling Land-based Non-point Sources

For modeling purposes, non-point fecal coliform loads were those that were deposited or applied to land and, hence, required surface runoff events for transport to streams. Fecal coliform loading by land use for all sources in each sub-watershed is presented in Chapter 3. The existing condition fecal coliform loads are based on best estimates of existing wildlife, livestock, human, and pet populations along with fecal coliform production rates. Fecal coliform in stored waste was adjusted for die-off prior to the time of land application when calculating loadings to cropland and pasture. For a given period of storage, the total amount of fecal coliform present in the stored manure was adjusted for die-off on a daily basis. The sources of fecal coliform to different land use categories and how the model handled them are briefly discussed below.

- Cropland: Where applicable, liquid dairy manure, solid manure, and poultry litter are applied to cropland as described in Chapter 3. Fecal coliform loadings to cropland were adjusted to account for die-off during storage and partial incorporation during land-application. Wildlife contributions were also added to the cropland areas. For modeling, monthly fecal coliform loading assigned to cropland was distributed over as many acres within the subwatershed as were needed to utilize the generated manure. Thus, loading rate varied by month and sub-watershed.

- Pasture: Deposition of manure on pasture resulted from deposition from livestock and wildlife, as well as dairy manure, solid manure, and poultry litter applications as described in Chapter 3. For modeling, the monthly fecal coliform loading assigned to pasture was distributed over the entire pasture acreage within a sub-watershed. Thus, loading rate varied by month and sub-watershed.

- Residential: Fecal coliform loading on the pervious fraction of this land use category is described in Chapter 3. Residential land use loading came from failing septic systems and waste from pets. In the model simulations, fecal coliform loads produced by failing septic systems and pets in a sub-watershed were combined and assumed to be uniformly applied. Loading to the impervious fraction of this land use category was assumed constant throughout the year varying per subwatershed.

- Forest: Wildlife not defecating in streams or on cropland and pastures provided fecal coliform loading to the forested land use. Fecal coliform from wildlife was applied uniformly over the forest areas, except for the percentage considered as direct load to forested streams.

5.6.5 Modeling Existing BMPs

Data describing existing best management practices (BMPs) were provided by staff from the VADCR to VADEQ. Additional data were collected during windshield surveys in the watershed. These data were applied in multiple fashions when developing the model to represent the effects of BMPs on loads and load transport. BMPs were either accounted for directly in the development of loads associated with direct deposition and/or deposition on specific land uses, accounted for during calibration of the water quality model, or incorporated into the implicit margin of safety (MOS).

BMPs incorporated directly into the model, such as collection, storage, and spreading of confined animal waste were modeled as previously described. Die-off during storage was accounted for prior to spreading, as well as after spreading. Three grades of pasture were modeled to represent pasture management practices observed in the watershed. Reductions in stream access based on exclusion fencing were accounted for directly when developing the cattle distribution schedules listed in Chapter 3. Some BMPs were accounted for during calibration, such as grassed buffer strips between pasture or cropland and stream edges.

Identified BMPs that were not directly accounted for during load development or model calibration were incorporated into the implicit MOS. The MOS accounts for uncertainty in the model and helps ensure that the final TMDL allocation will enable the stream to meet water quality standards when implemented.

5.7 Model Calibration and Validation

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. Validation ensures that the calibrated parameters are appropriate for periods other than the calibration period. In this section, the procedures followed for calibrating the hydrology and water quality components of the HSPF model are discussed. The calibration and validation results of the hydrology and water quality components are presented.

5.7.1 Hydrology

The South River model was calibrated using observed flow values from USGS station #01626000 on South River near Waynesboro, VA and USGS station #01627500 on South River at Harriston, VA for the period January 1, 1992 to December 31, 1996. The model was validated for the period January 1, 1987 to December 31, 1991. The daily average flow data were used in the hydrologic calibration and validation. Output from the HSPF model for both calibration and validation was daily average flow in cubic feet per second (cfs). Calibration parameters were adjusted within the recommended ranges until the model performance was deemed acceptable.

The HSPEXP decision support system developed by USGS and tools developed by Engineering Concepts, Inc. were used to calibrate and validate the hydrologic portion of HSPF. Calibration and validation criteria as well as model performance are presented in Table 5.4 through 5.7. All criteria were within the recommended ranges. As shown in Figures 5.2 through 5.5, the simulated flow for both the calibration and validation matched the observed flow well. The agreement with observed flows is further illustrated in Figures 5.6 through 5.9 for a representative storm. The agreement of the simulated and observed time series can be further seen through the comparison of their cumulative frequency curves (Figures 5.10 and 5.13).

Table 5.4. Summary statistics for the calibration period (1/1/92 to 12/31/96) at USGS station #01626000 in South River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	10	103.6	98.6	-4.8
Total of Highest 10% Flow Volume (in)	15	48.1	42.3	-12.1
Total of Lowest 50% Flow Volume (in)	10	15.4	16.6	7.8
Total Winter Flow Volume (in)	20	42.7	39.1	-8.4
Total Summer Flow Volume (in)	20	13.1	12.7	-3.1
Total Storm Volume (in)	20	86.0	84.2	-2.1
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.85			

Table 5.5. Summary statistics for the calibration period (1/1/92 to 12/31/96) at USGS station #01627500 in South River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	10	103.4	103.4	0.0
Total of Highest 10% Flow Volume (in)	15	45.6	44.2	-3.1
Total of Lowest 50% Flow Volume (in)	10	17.4	17.4	0.0
Total Winter Flow Volume (in)	20	40.8	41.0	0.5
Total Summer Flow Volume (in)	20	14.6	13.4	-8.2
Total Storm Volume (in)	20	82.6	88.1	6.7
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.85			

Table 5.6. Summary statistics for the validation period (1/1/87 to 12/31/91) at USGS station #01626000 in South River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	20	84.8	85.8	1.2
Total of Highest 10% Flow Volume (in)	25	34.3	31.8	-7.3
Total of Lowest 50% Flow Volume (in)	20	15.5	17.0	9.7
Total Winter Flow Volume (in)	30	24.6	24.8	0.8
Total Summer Flow Volume (in)	30	13.9	14.4	3.6
Total Storm Volume (in)	30	69.4	70.5	1.6
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.79			

Table 5.7. Summary statistics for the validation period (1/1/87 to 12/31/91) at USGS station #01627500 in South River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	20	83.0	90.0	8.4
Total of Highest 10% Flow Volume (in)	25	31.7	33.4	5.4
Total of Lowest 50% Flow Volume (in)	20	17.0	17.7	4.1
Total Winter Flow Volume (in)	30	23.8	26.0	9.2
Total Summer Flow Volume (in)	30	14.6	15.2	4.1
Total Storm Volume (in)	30	61.2	73.2	19.6
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.76			

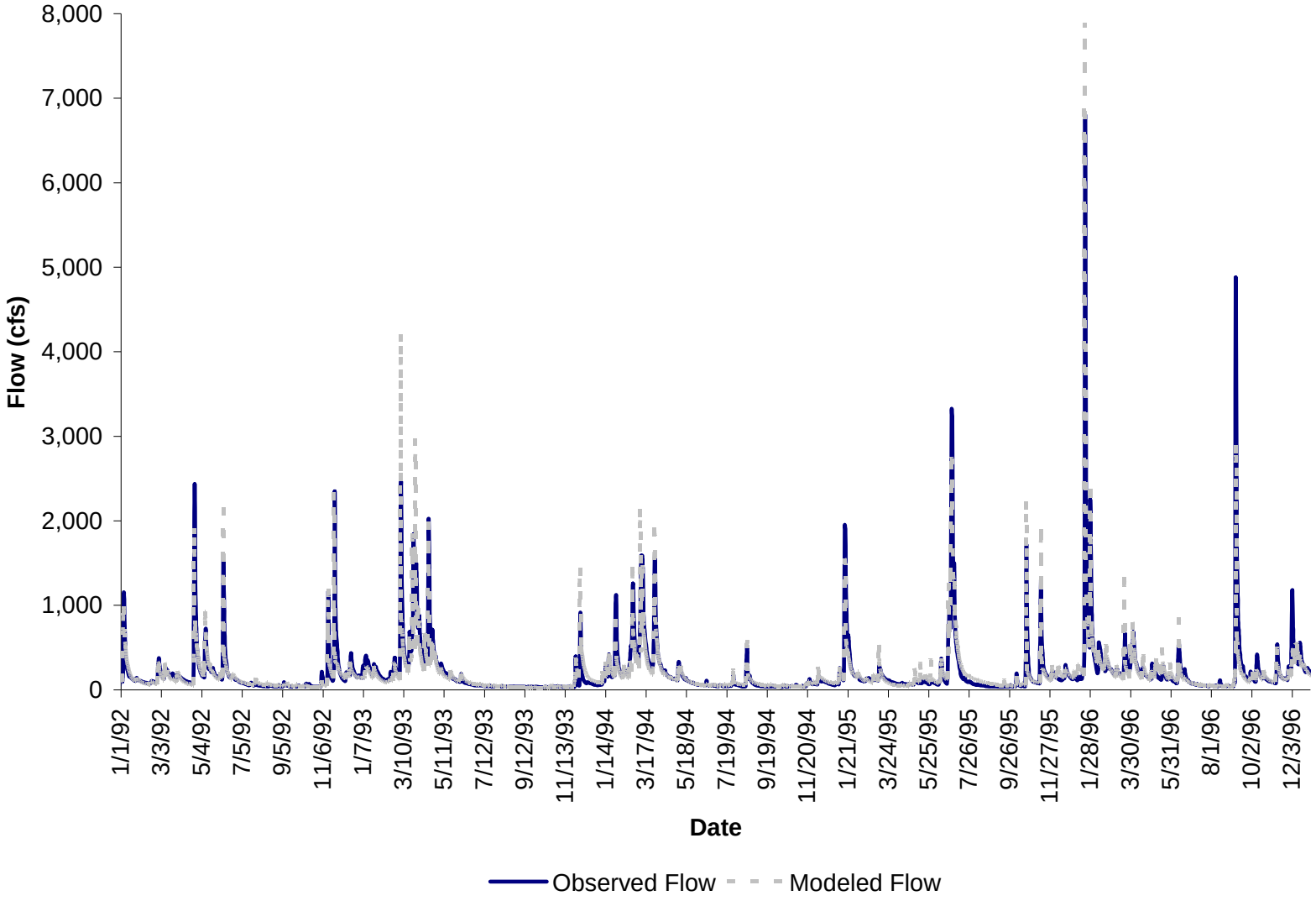

Figure 5.2. Observed and modeled flows for the calibration period 1/1/92 to 12/31/96 at USGS station #01626000 in South River watershed.

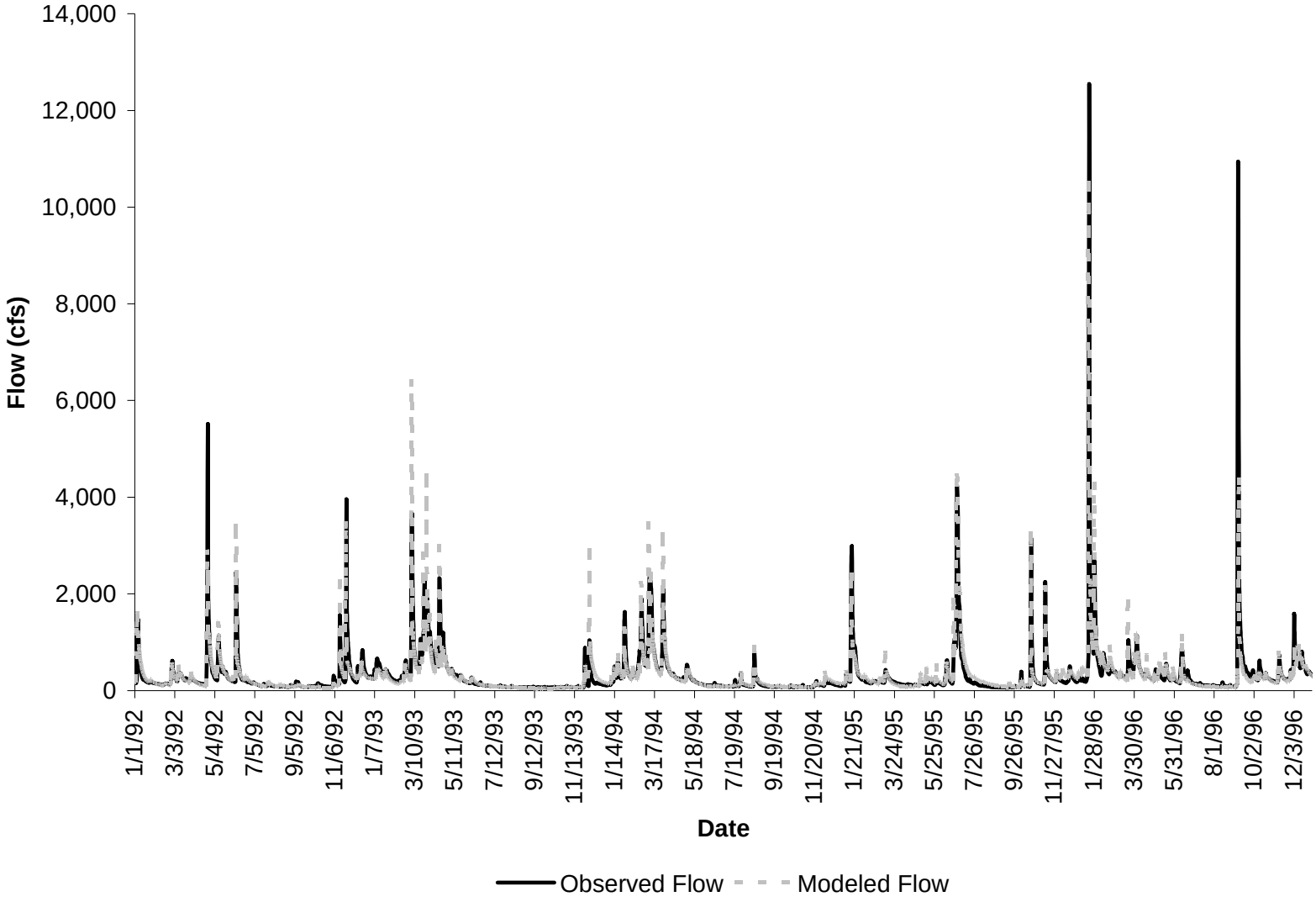

Figure 5.3. Observed and modeled flows for the calibration period 1/1/92 to 12/31/96 at USGS station #01627500 in South River watershed.

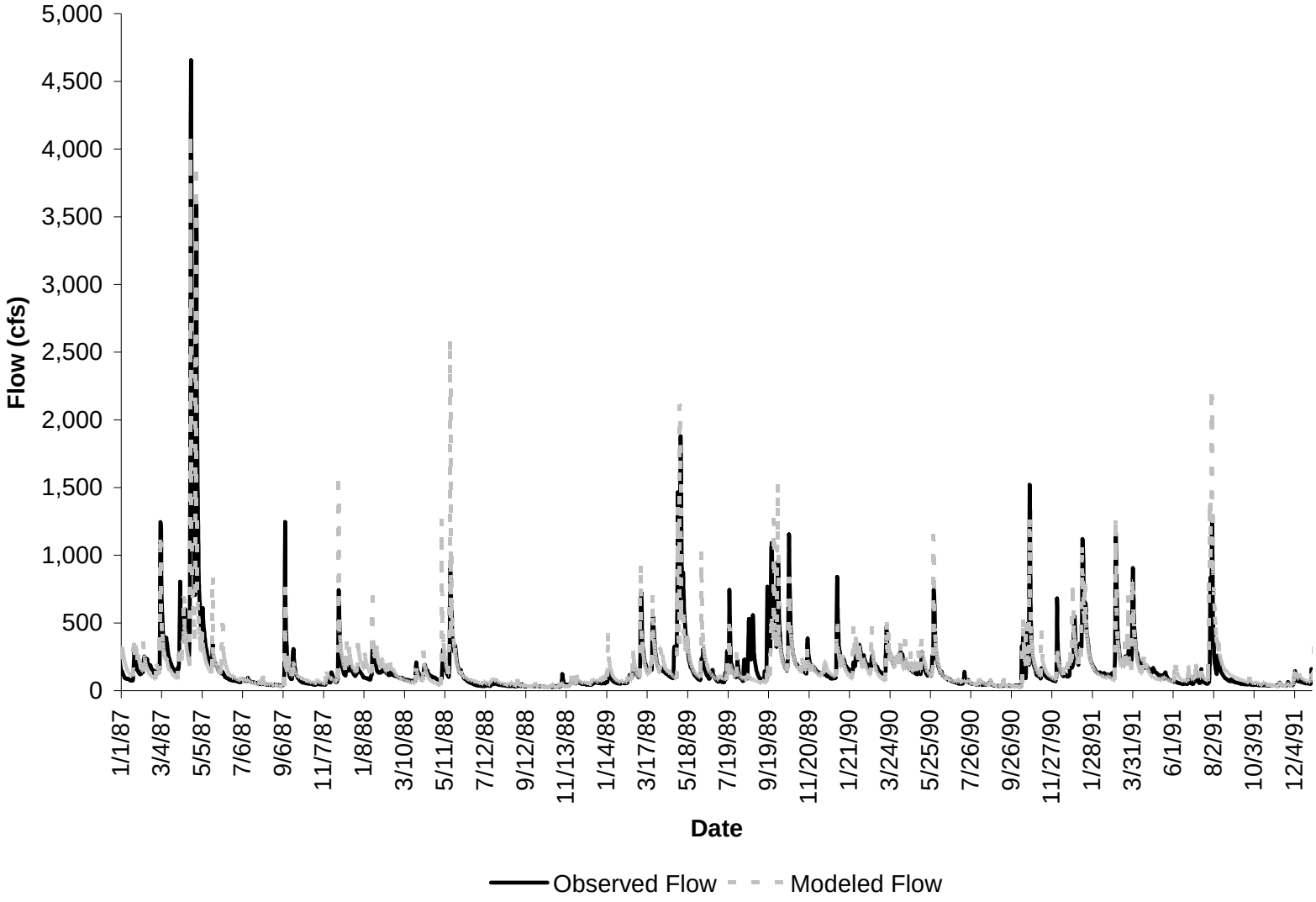

Figure 5.4. Observed and modeled flows for the validation period 1/1/87 to 12/31/91 at USGS station #01626000 in South River watershed.

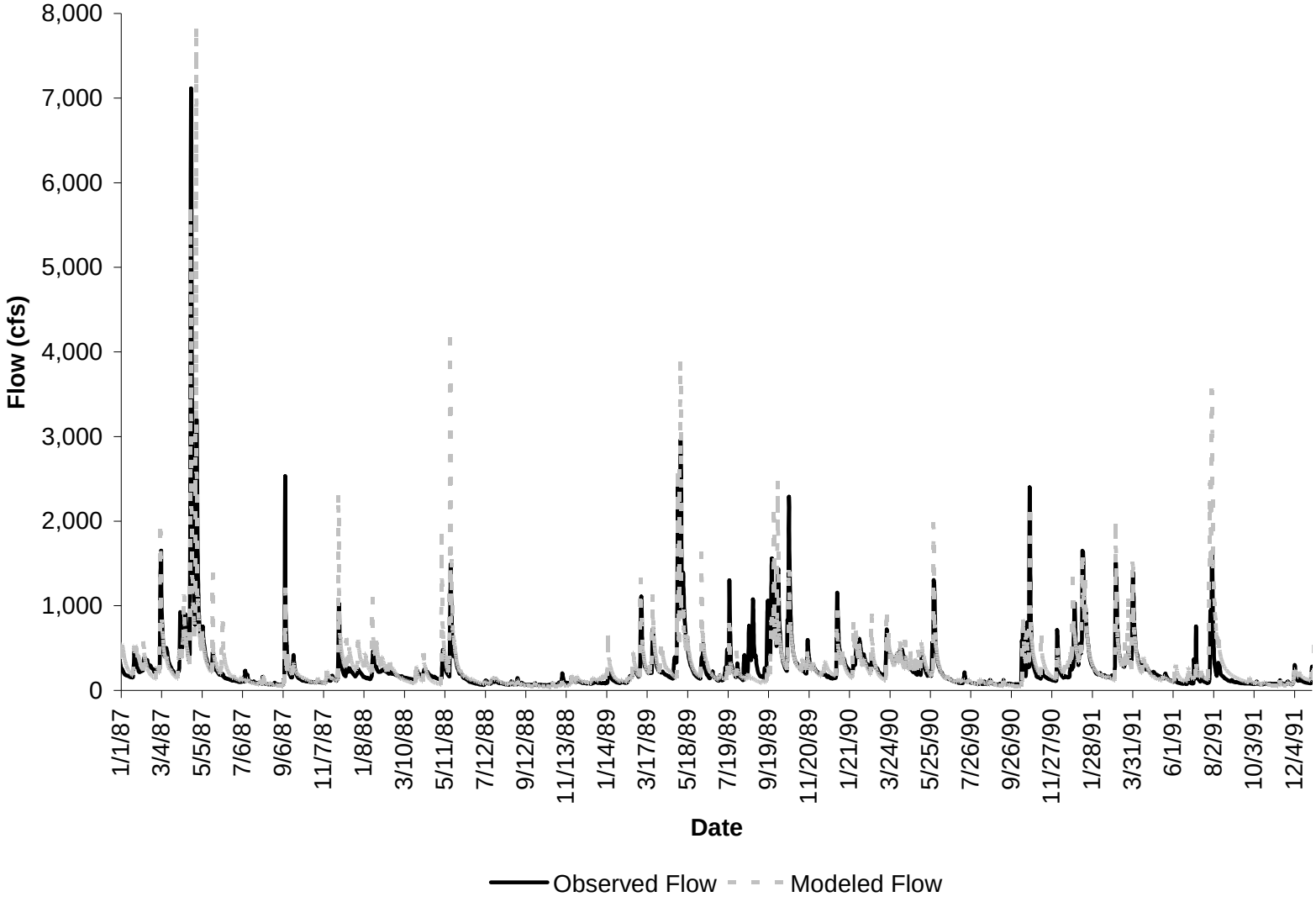

Figure 5.5. Observed and modeled flows for the validation period 1/1/87 to 12/31/91 at USGS station #01627500 in South River watershed.

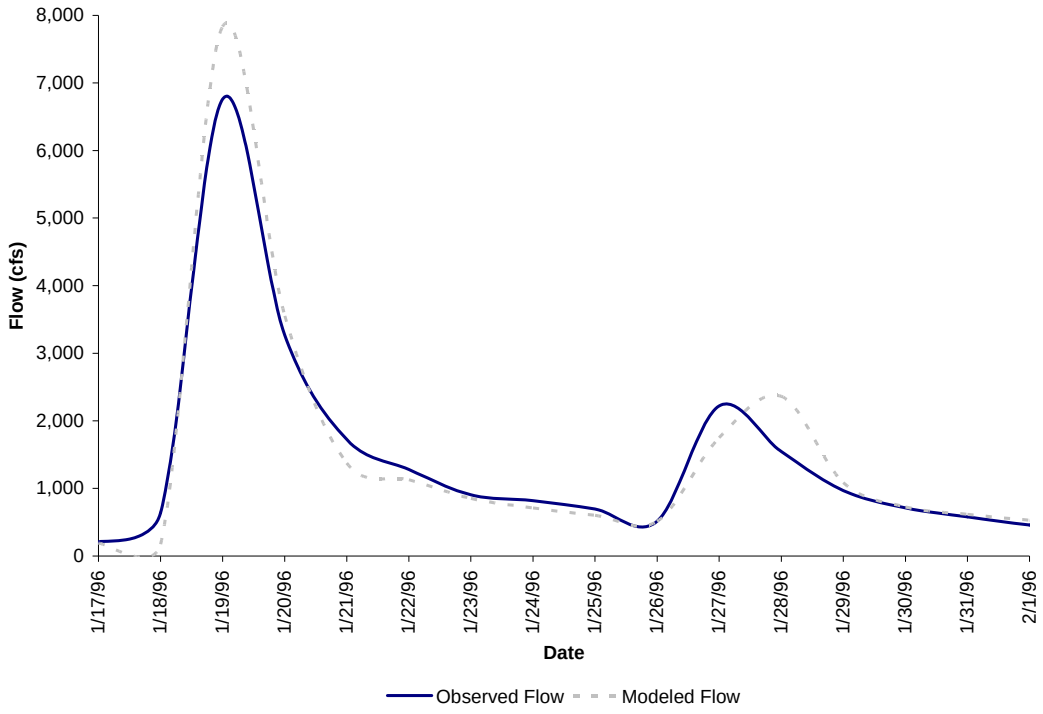

Figure 5.6. Observed and modeled flows for representative storms (1/17/96-2/1/96) during the calibration period at USGS station #01626000 in South River watershed.

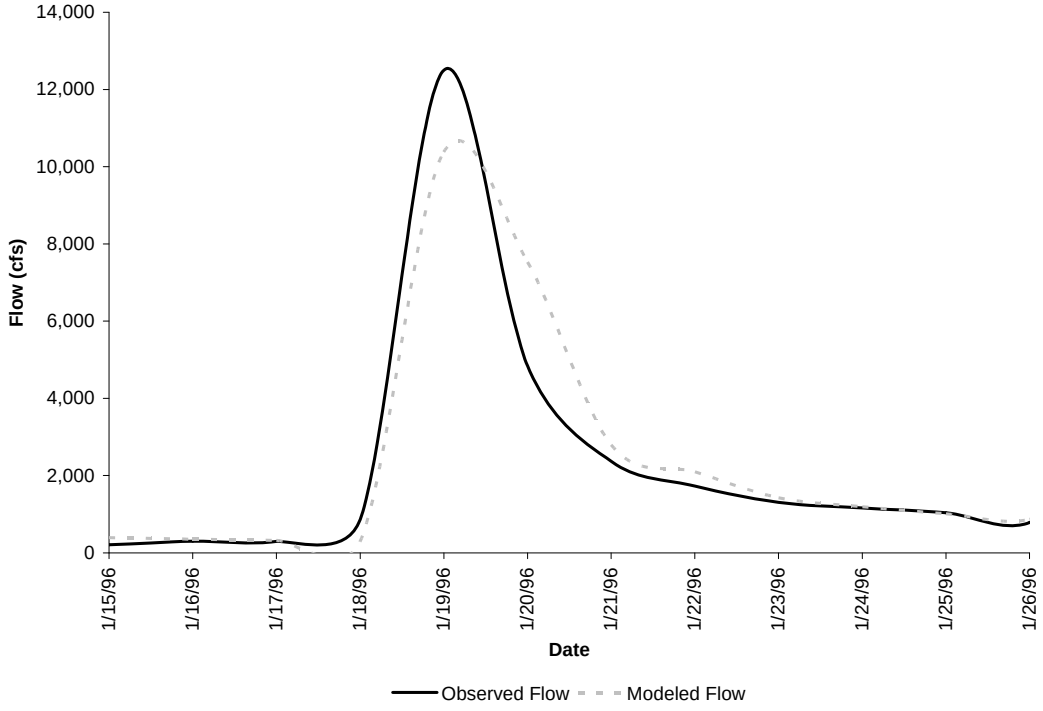

Figure 5.7. Observed and modeled flows for representative storms (1/15/96-1/26/96) during the calibration period at USGS station #01627500 in South River watershed.

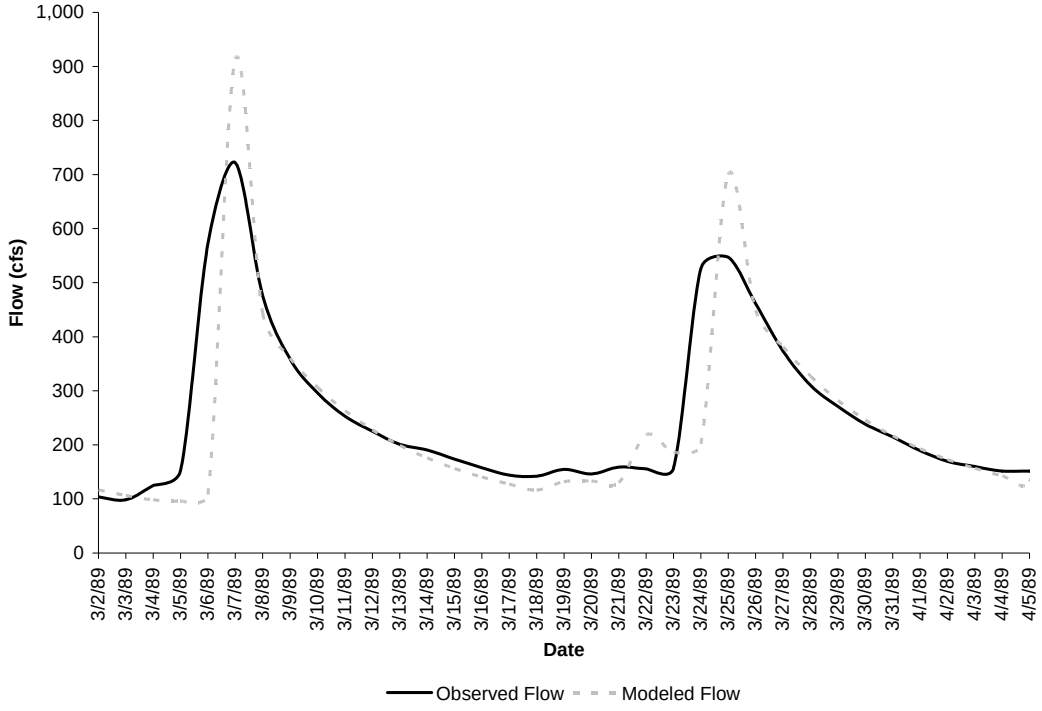

Figure 5.8. Observed and modeled flows for a representative storm (3/2/89-4/5/89) during the validation period at USGS station #01626000 in South River watershed.

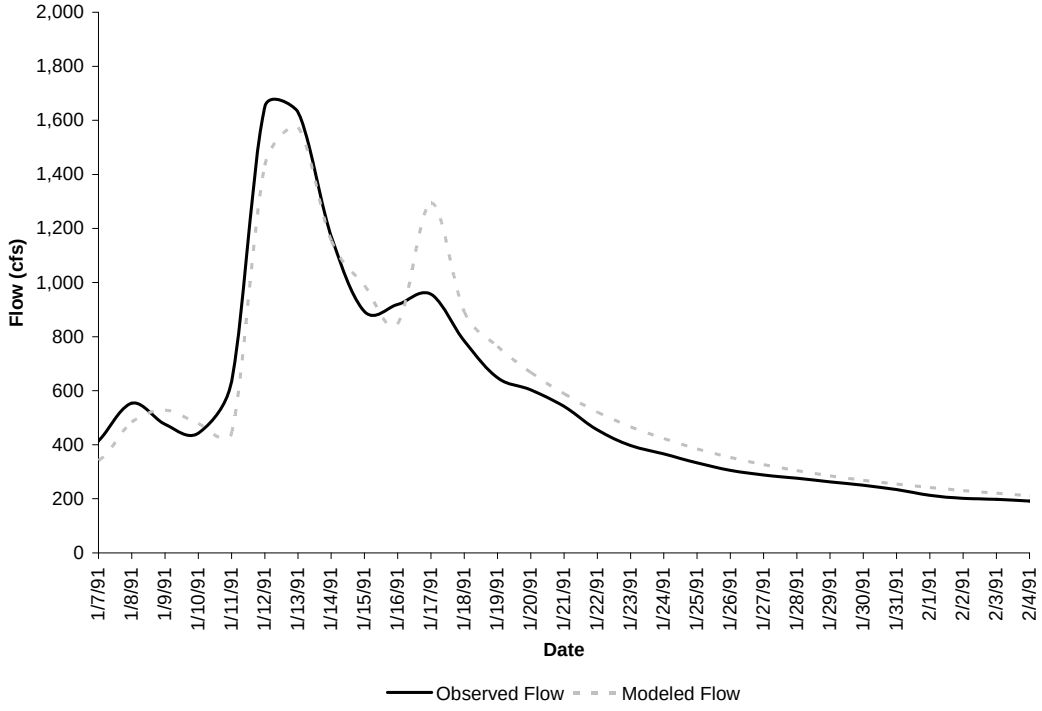

Figure 5.9. Observed and modeled flows for a representative storm (1/7/91-2/4/91) during the validation period at USGS station #01627500 in South River watershed.

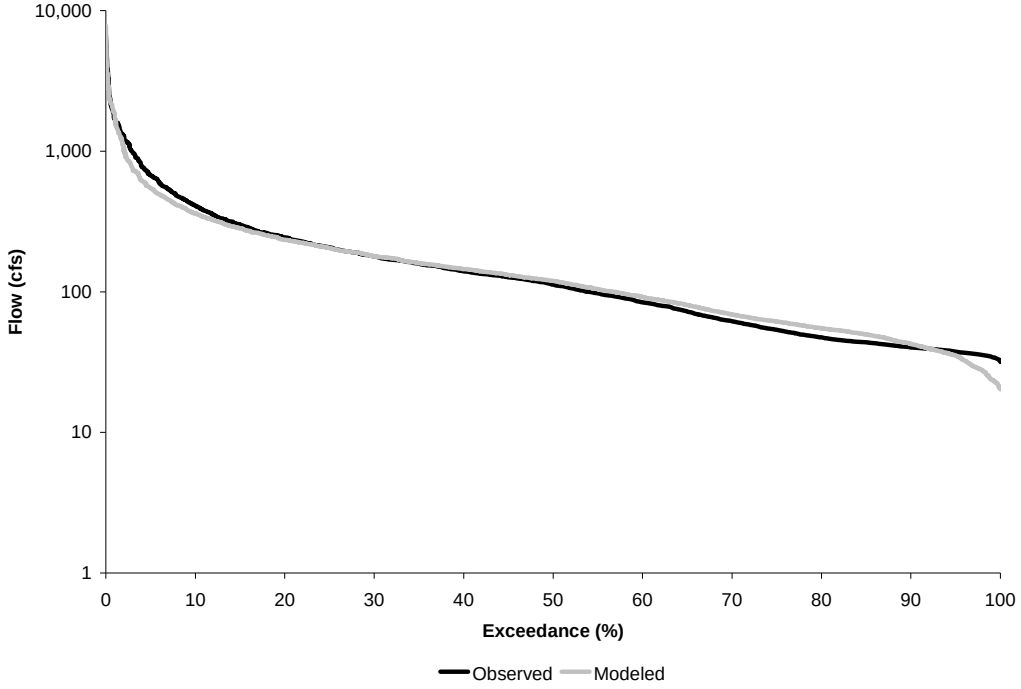

Figure 5.10. Cumulative frequency curves for the calibration period 1/1/92 to 12/31/96 at USGS station #01626000 in South River watershed.

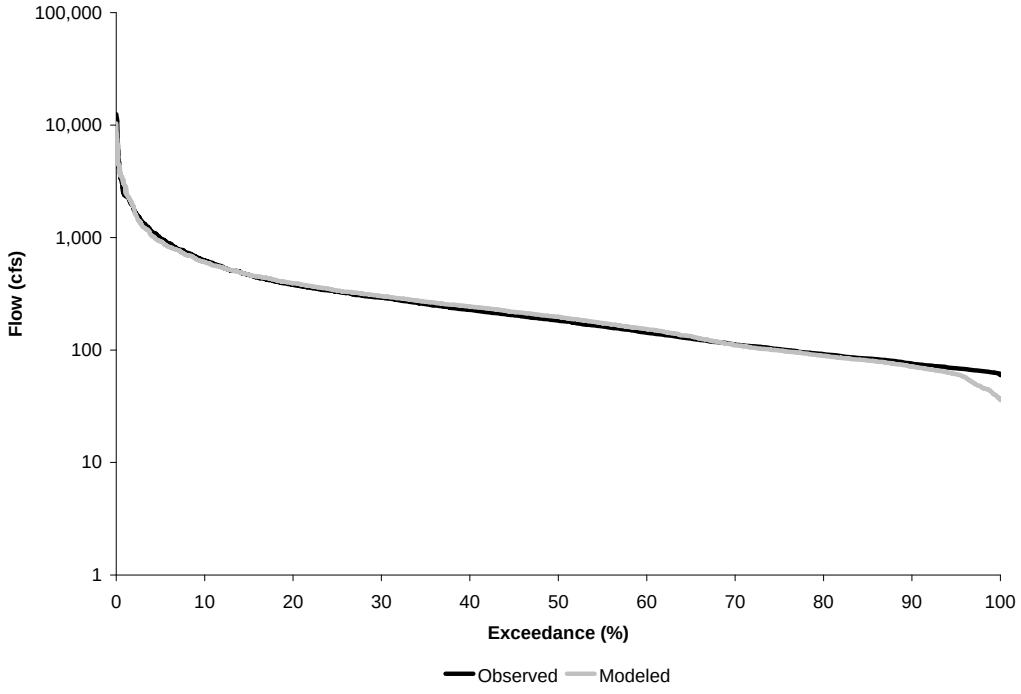

Figure 5.11. Cumulative frequency curves for the calibration period 1/1/92 to 12/31/96 at USGS station #01627500 in South River watershed.

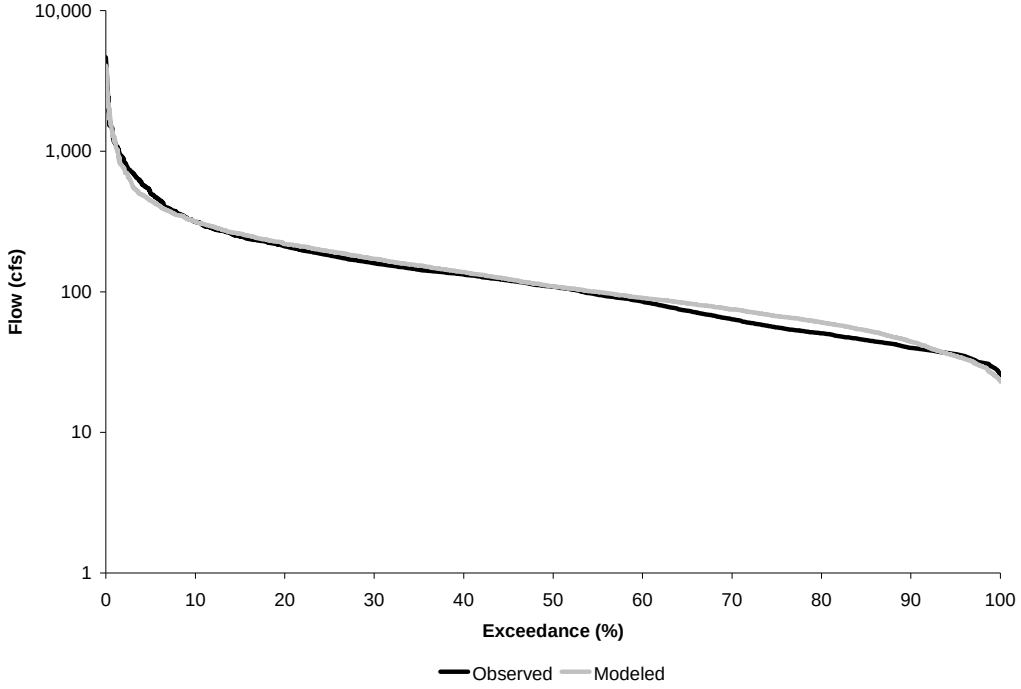

Figure 5.12. Cumulative frequency curves for the validation period 1/1/87 to 12/31/91 at USGS station #01626000 in South River watershed.

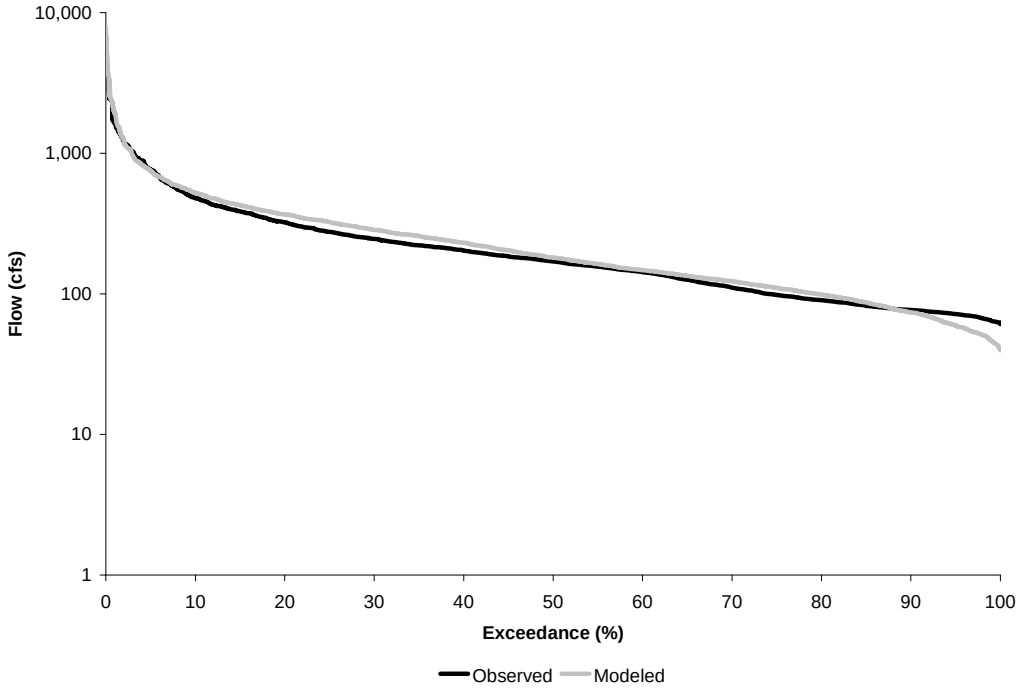

Figure 5.13. Cumulative frequency curves for the validation period 1/1/87 to 12/31/91 at USGS station #01627500 in South River watershed.

Flow partitioning for South River hydrologic model calibration and validation is shown in Table 5.8.

Table 5.8. Flow partitioning for the calibration and validation periods in South River watershed.

Average Annual Flow	Calibration	Validation
Total Runoff (in)	54.7	48.1
Surface Runoff (in)	12.6 (23.1%)	8.7 (18.1%)
Interflow (in)	19.0 (34.7%)	17.0 (35.3%)
Baseflow (in)	23.1 (42.2%)	22.4 (46.6%)

A list of final calibration parameters for the hydrology calibration can be found in Tables 5.9 and 5.10.

Table 5.9. Calibrated hydrology HSPF parameters (PERLND) for South River watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
PERLND									
PWAT-PARM2									
FOREST	Fraction forest cover	none	0.0	0.5	0.0	0.95	0.5	0.5	Forest cover
LZSN	Lower zone nominal soil moisture storage	in	3.0	8.0	2.0	15.0	3.5	3.6-5.6	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.10	0.001-0.094	Soil and cover condition
LSUR	Length of overland flow	ft	200	500	100	700	300	100-285	Topography
SLSUR	Slope of overland flow plane	none	0.01	0.15	0.001	0.3	0.033-0.280	0.055-0.300	Determined by GIS
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	0	Calibrate
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.975	0.959-0.983	Calibrate
PWAT-PARM3									
PETMAX	Temp below which evapotranspiration (ET) is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soil properties
DEEPFR	Fraction of groundwater inflow to deep recharge	none	0.0	0.2	0.0	0.5	0.0	0.0	Geology
BASETP	Fraction of remain ET from active baseflow	none	0.0	0.05	0.0	0.2	0.0	0.0	Riparian vegetation
AGWETP	Fraction of remain ET from active groundwater	none	0.0	0.05	0.0	0.2	0.0	0.0 – 0.7	Marsh/wetlands ET
PWAT-PARM4									
CEPSC	Interception storage capacity	in	0.03	0.2	0.01	0.4	0.1	0.01 – 0.224	Vegetation
UZSN	Upper zone nominal soil moisture storage	in	0.10	1	0.05	2	1.00	0.05-1.53	Soil properties
NSUR	Manning's n (roughness)	none	0.15	0.35	0.1	0.5	0.20 - 0.35	0.20 - 0.35	Land use, surface conditions
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	2.0	1.5-1.9	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.3	0.8	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	0.1-0.9	0.1 - 0.7	Vegetation

* USEPA, 2000.

Table 5.10. Calibrated hydrology HSPF parameters (IMPLND and RCHRES) for South River watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
IMPLND									
IWAT-PARM2									
LSUR	Length of overland flow	ft	200	500	100	700	100	88 - 131	Topography
SLSUR	Slope of overland flow	none	0.01	0.15	0.001	0.3	0.02 - 0.20	0.03 - 0.11	Topography
NSUR	Manning's n (roughness)	none	0.15	0.35	0.1	0.5	0.1	0.08	Land use, surface condition
RETSC	Retention/interception storage capacity	in	0.03	0.2	0.01	0.4	0.065	0.1	Land use, surface condition
IWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
RCHRES									
HYDR-PARM2									
KS	Weighting factor for hydraulic routing	none	0.3	0.7	0.0	0.9	0.5	0.5	Stream channel, topography

* USEPA, 2000.

5.7.2 Water Quality

The simulation of water quality concentrations (e.g., bacteria concentrations) is built on the hydrology simulation. The simulation runs at an hourly time step with average daily fecal coliform bacteria concentrations output at the stream reaches. Based on critical period analysis and availability of data, modeling periods were chosen for water quality calibration and validation for the impairment.

The PQUAL and IQUAL modules of HSPF were used to represent the build-up, die-off, and wash-off of fecal coliform bacteria from land surfaces. The modules are characterized by the following parameters: 1) Daily accumulation rate of bacteria on the soil surface (ACQOP); 2) Maximum bacteria build-up rate on the soil (SQOLIM); 3) Rate of surface runoff that removes 90% of the accumulated bacteria from the soil surface (WSQOP); and 4) Bacteria concentration in interflow, PQUAL only (IOQC). The GQUAL module in HSPF was used to represent the transport, settling, and die-off of dissolved bacteria in-stream. Settling and die-off were estimated using the first-order decay rate (FSTDEC). The listed model parameters were adjusted within reasonable limits until an acceptable match between measured and modeled bacteria concentrations was established.

A number of factors, not inclusive to description below, complicate the water quality calibration. The difficulty in measuring bacteria concentrations is attributed to variability in bacteria density in feces, variability in location and timing of fecal deposition, variability in

bacteria amount delivered to the stream, and environmental impacts on re-growth and die-off. The bacteria concentrations are highly dependent on flow conditions and variability associated with modeling stream flows compounds the variability in modeling the bacteria concentrations. The usually limited number of grab samples collected at each VADEQ station and the practice of censoring both high (over 8,000 cfu/100 ml or 16,000 cfu/100 ml) and low (under 100 cfu/100 ml or 18 cfu/100 ml) concentrations hinder the water quality calibration process.

The period January 1, 1993 through December 31, 1997 was chosen for water quality calibration and January 1, 1998 through December 31, 2002 was chosen for water quality validation. Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 1-BSTH002.14, 1-BSTH007.80, and 1-BSTH027.85 within the South River impairment were used to calibrate the water quality component of HSPF. The final water quality calibration parameters are shown in Table 5.11. Observations from VADEQ stations 1-BSTH027.85, 1-BSTH007.80, and 1-BSTH002.14; were graphically compared to corresponding modeled concentrations at subwatersheds SOR-04, SOR-07, and SOR-08; respectively (Figures 5.14 through 5.18). It should be noted that each observed bacteria concentration datum represents a “snapshot” resulting from the examination of one grab sample, while the modeled data represent a continuous time series of bacteria concentration. Uncertainty exists in the stream condition the grab sample represents. For example, was the sample taken as the bacteria concentration was increasing or decreasing in the stream? The short-period fluctuations in the modeled bacteria concentration represent the variability within daily concentrations associated with the wildlife, livestock, and straight pipe direct deposition distribution across each day. Careful inspection of graphical comparisons between continuous simulation results and limited observed points yielded acceptable results given the modeling constraints listed above. Seasonal variations are exhibited by the modeled concentrations, and most observed concentrations are simulated accurately for the calibration period.

To provide a quantitative measure of the agreement between observed and modeled data, the geometric mean and exceedance rate of the previous 1,000 cfu/100mL fecal coliform instantaneous standard and the interim 400 cfu/100mL fecal coliform instantaneous standard were calculated. Tables 5.12 and 5.13 show the observed and modeled comparisons of the geometric mean and exceedance rates for the calibration and validation periods, respectively. The highest difference (5%) between observed and modeled geometric mean concentrations was recorded during the validation period at subwatershed 8. It should be noted that a limited number of observed values were available for comparison when determining exceedance rates in Tables 5.12 and 5.13. A difference of one exceedance in subwatersheds 4, 7, and 8 results in a difference of exceedance rate of 2%, 2%, and 11%, respectively. Modeled exceedance rates matched all observed exceedance rates. The modeled versus observed geometric mean concentrations and exceedance rates comparison yielded acceptable results for the calibration and validation periods.

Based on the qualitative and quantitative analyses performed during hydrology and water quality calibration and validation, it was established that the developed model adequately represented the processes and interactions associated with the production and transport of bacteria within the South River watershed.

Table 5.11. Calibrated water quality HSPF parameters for South River watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
PERLND									
QUAL-INPUT									
SQO	Initial storage of constituent	#/ac	0	1E20	0	1E30	1E08	1E08	Land use
ACQOP	Rate of accumulation of constituent	#/day	0	1E20	0	1E30	16E06-02E10	16E06-02E10	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	01E08-17E10	01E08-17E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	2.0	2.0	Land use
IOQC	Constituent concentration in interflow	#/ft^3	0	1E6	0	1E10	1E03	1E03	Land use
AOQC	Constituent concentration in active groundwater	#/ft^3	0	1E6	0	1E10	0E00	0E00	Land use
IMPLND									
QUAL-INPUT									
SQO	Initial storage of constituent	#/ac	0	1E20	0	1E30	1E09	1E09	Land use
ACQOP	Rate of accumulation of constituent	#/day	0	1E20	0	1E30	05E08-17E08	05E08-17E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	41E08-02E10	41E08-02E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.1	0.1	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	1.5	2.5-4.3	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

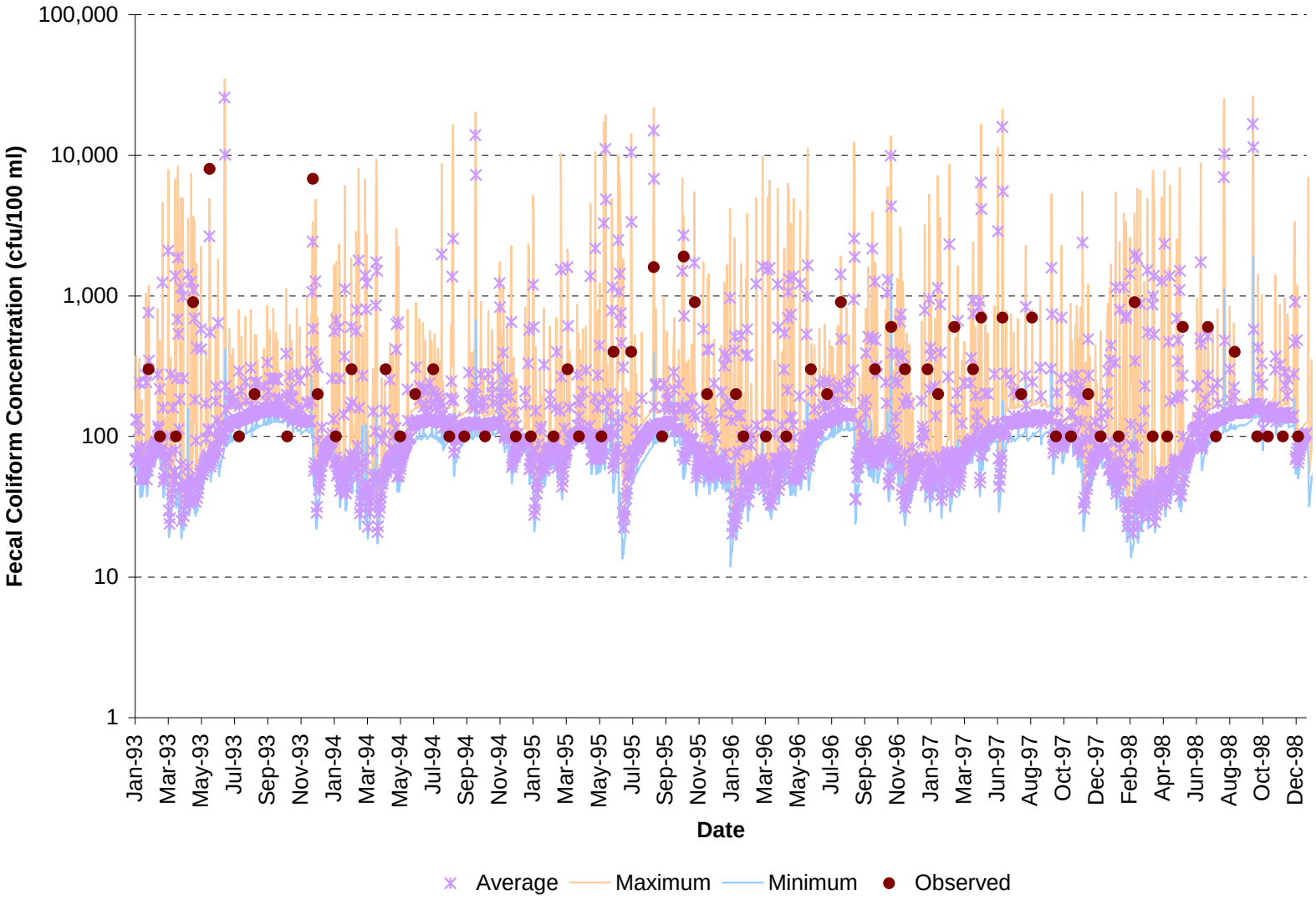

Figure 5.14. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed SOR-04 in South River watershed.

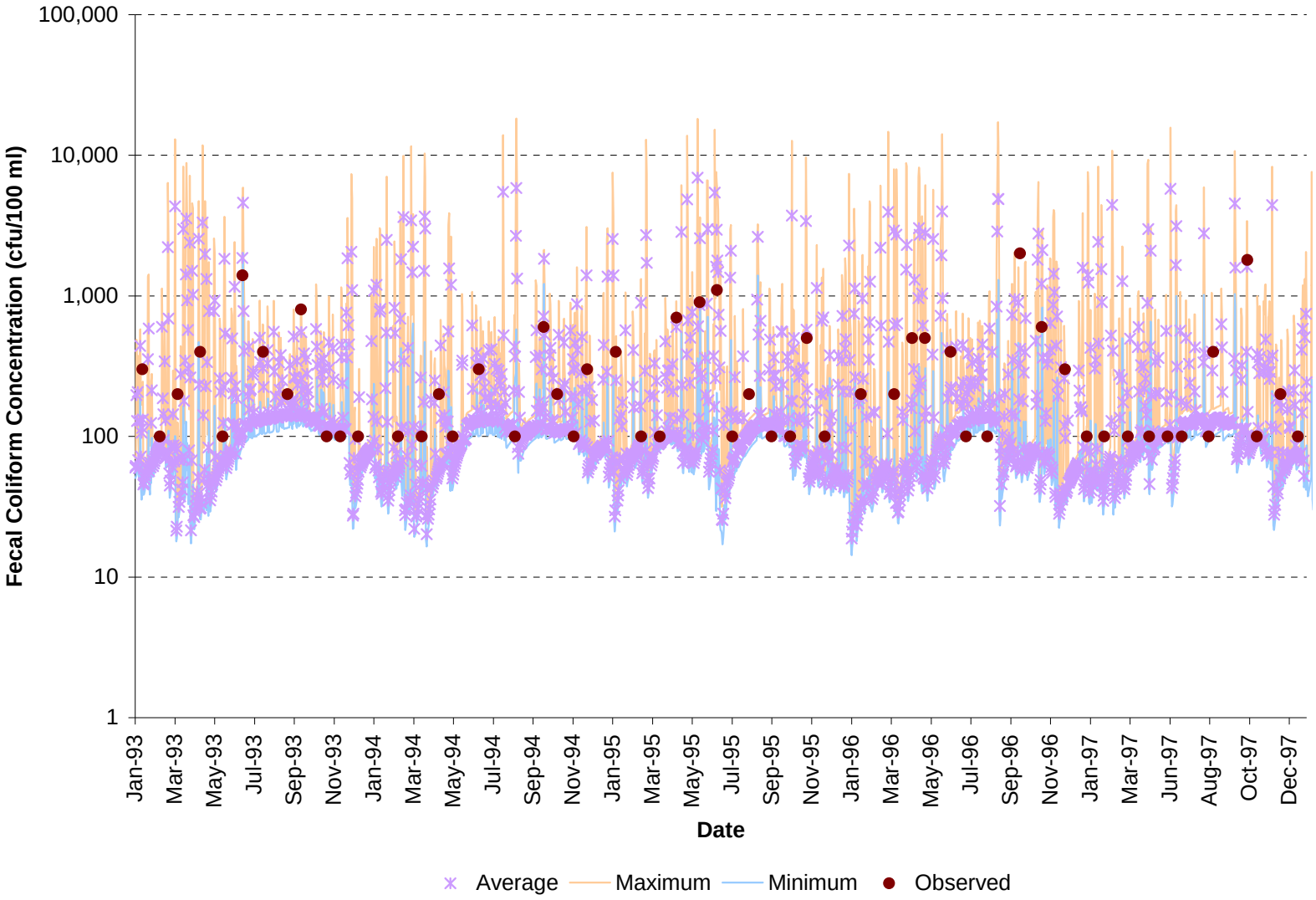

Figure 5.15. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed SOR-07 in South River watershed.

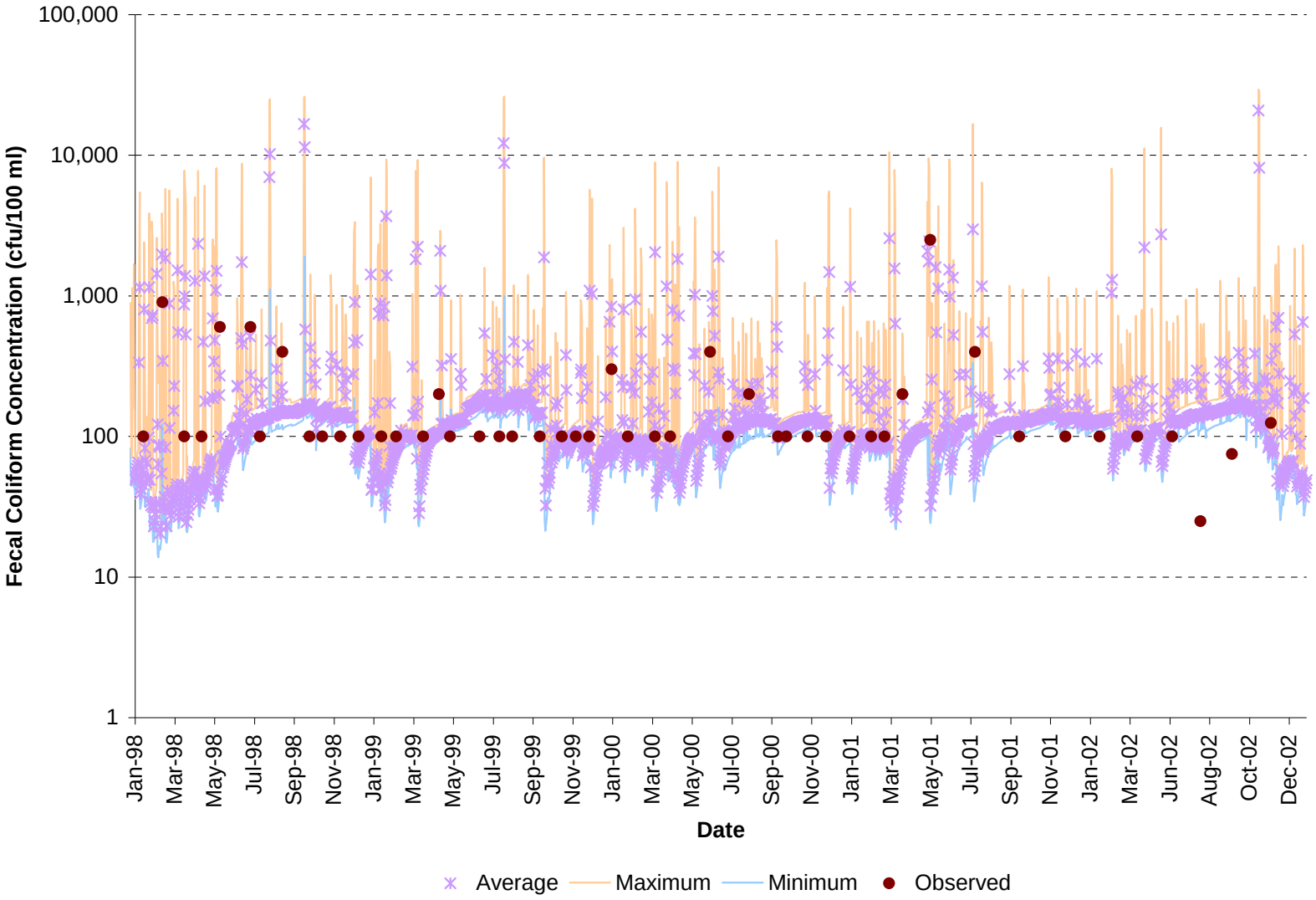

Figure 5.16. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed SOR-04 in South River watershed.

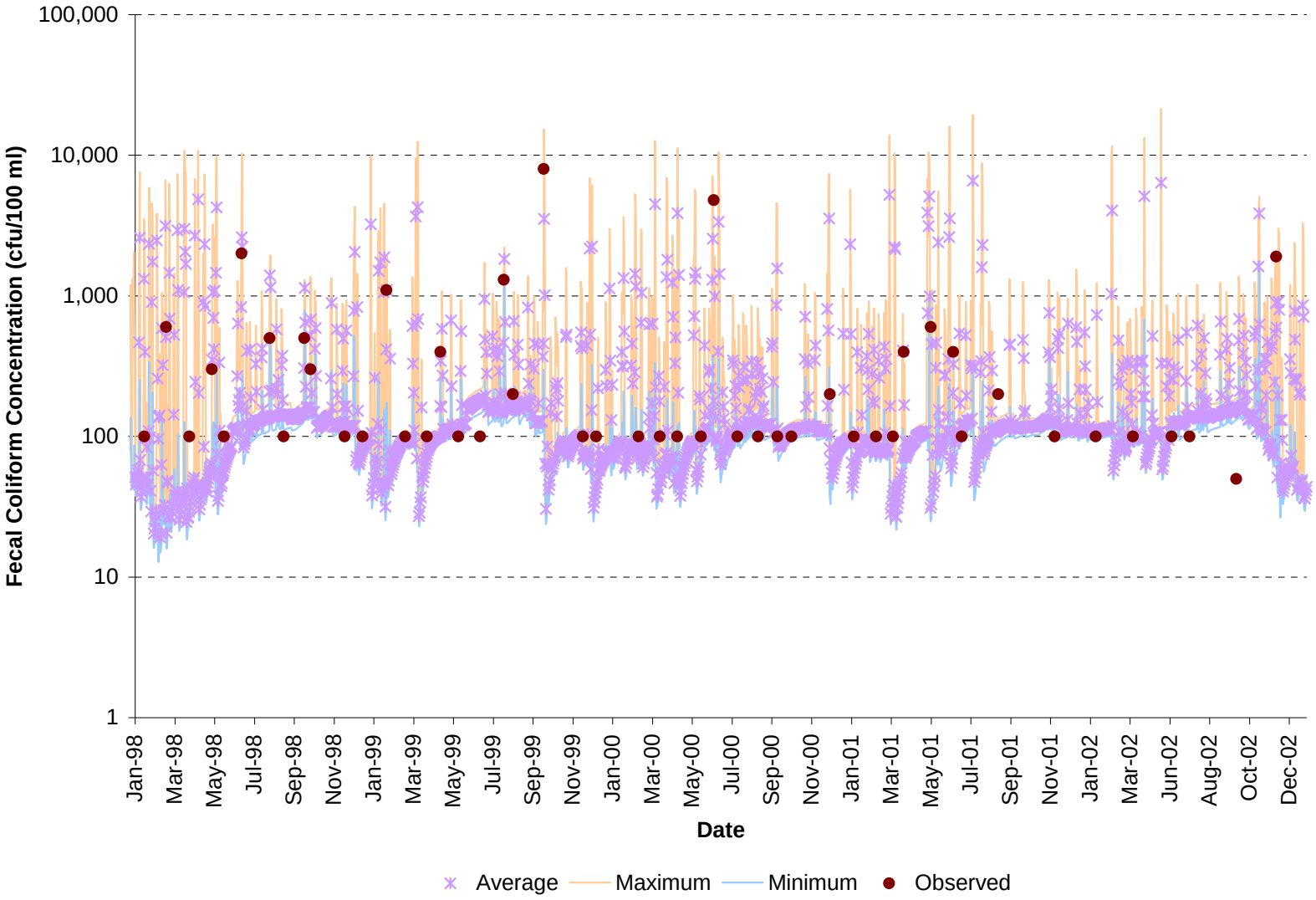

Figure 5.17. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed SOR-07 in South River watershed.

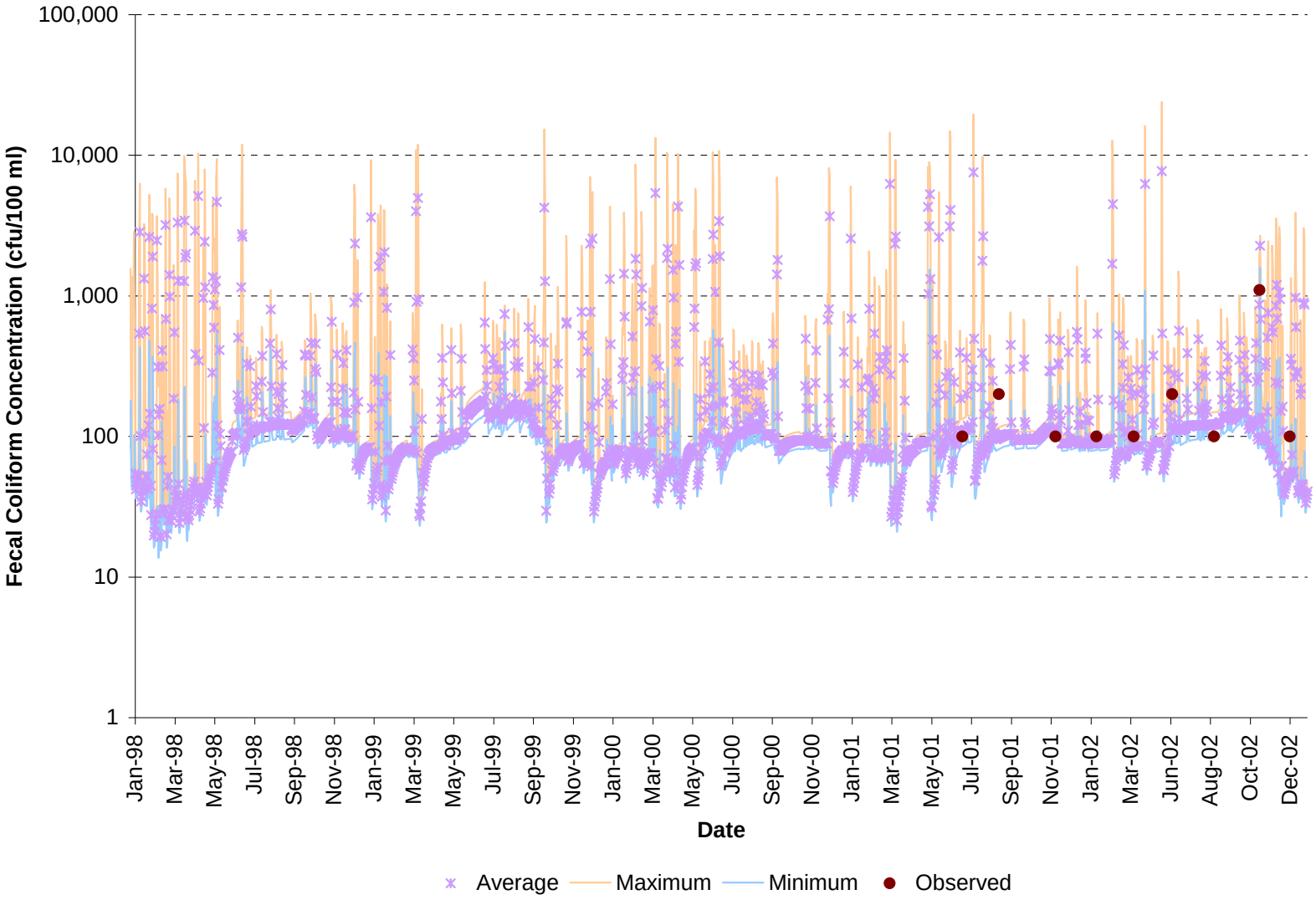

Figure 5.18. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed SOR-08 in South River watershed.

Table 5.12. Observed and modeled geometric mean concentrations and exceedance rates of instantaneous standards for the calibration period in South River watershed.

Parameter	Sub SOR-04	Sub SOR-07	Sub SOR-08
Geometric Mean of Observed Values (cfu/100mL)	254	213	N/D
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	246	205	N/D
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Exceedance Rate (%)	7	7	N/D
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Exceedance Rate (%)	7	7	N/D
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	22	21	N/D
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	22	21	N/D

N/D – no data available

Table 5.13. Observed and modeled geometric mean concentrations and exceedance rates of instantaneous standards for the validation period in South River watershed.

Parameter	Sub SOR-04	Sub SOR-07	Sub SOR-08
Geometric Mean of Observed Values (cfu/100mL)	135	202	152
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	137	193	145
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Exceedance Rate (%)	2	13	11
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Exceedance Rate (%)	2	13	11
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	8	21	11
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	8	21	11

Chapter 6. Modeling Process for Development of Sediment and Phosphorous TMDLs

For South River, the stressor analysis identified sediment and phosphorus as the most probable stressors impacting the benthic macro-invertebrate community (see Section 4.4). Virginia currently does not have numeric criteria for sediment and phosphorus. A modified reference watershed approach was used to establish the numeric sediment and phosphorus TMDL endpoints for South River. The Penn State Visual Basic™ version of Generalized Watershed Loading Function (GWLF) with modifications for use with ArcView watershed model (Evans et al., 2001) was used to simulate sediment and phosphorus loads from potential sources in the impaired watersheds. The model also included modifications made by Yagow et al., 2002 and BSE, 2003. Numeric endpoints were based on load duration curve calculated from the reference watersheds. The TMDLs were then developed for South River based on these endpoints and the results from load allocation scenarios.

6.1 Modified Reference Watershed Approach

The “modified reference watershed” approach involves assessment of the impaired reach and its watershed, identification of potential causes of impairment through a benthic stressor analysis, selection of appropriate reference watersheds, model parameterization and pollutant simulation within the TMDL watershed, definition of the TMDL endpoint, and development of alternative TMDL reduction (allocation) scenarios. TMDL endpoints were developed using a statistical measure of monitored pollutant concentrations from the reference watersheds.

Virginia has no numeric in-stream criteria for sediment or phosphorus. As a result, a “modified reference watershed” approach was used to set allowable loads for sediment and phosphorus in the impaired watershed. Under the reference watershed approach, two watersheds are paired – one whose streams are supportive of their designated uses and one whose streams are impaired. This approach is based on the assumption that reduction of the stressor loads in the impaired watershed to the level of the loads in the reference watershed will result in elimination of the benthic impairment.

In the case of the “modified reference watershed” approach, several non-impaired watersheds are used to generate a load duration curve that establishes the TMDL endpoint. The load duration curve shows the sediment and phosphorus loadings in the unimpaired watersheds at different flow frequencies. Difference of loads at the various flow levels (i.e., high, moist, mid-range, dry, and low) signifies overall load reductions needed for sufficient recovery of benthic community. It is assumed that reduction of the sediment and phosphorus loads in South River to the average sediment and phosphorus load levels on the load duration curves derived from the reference watersheds will result in elimination of the benthic impairment.

6.1.1 Selected Reference Watersheds

Reference watersheds were selected based on criteria of impairment status, stream order, and ecoregion similarity. These criteria help ensure comparable benthic communities

potentially inhabiting the streams and similar hydrologic responses that influence pollutant loadings to the stream.

Several VADEQ stations, located in non-impaired watersheds, were used as reference stations for the impaired South River watershed. The non-impaired reference stations included: the North Fork Shenandoah River (1-BNSF070.67), Calfpasture River (2-CFP004.67), Cowpasture River (2-CWP0002.58), Johns Creek (2-JOB000.39), North Fork Holston River (6-CNFH085.20), South Fork Holston River (6-CSFH097.42), Reed Creek (9-RDC009.00), and Wolf Creek (9-WFC000.20 and 9-WFC003.69). Each of these stations is located on a fourth order stream within close proximity to a USGS flow monitoring station. North Fork Shenandoah River is part of the Potomac River watershed. Calfpasture River, Cowpasture River, and Johns Creek are part of the James River watershed. North Fork Holston River and South Fork Holston River are part of the Tennessee River watershed Reed Creek and Wolf Creek are part of the New River watershed

The South River and the non-impaired watersheds are located primarily in the Blue Ridge and Central Appalachians ecoregions. The Blue Ridge ecoregion extends from southern Pennsylvania to northern Georgia and vary from narrow ridges to hilly plateaus to more massive mountainous areas. The Central Appalachians ecoregion is primarily a high, dissected, rugged plateau that is composed of sandstone, shale, conglomerate and coal.

6.1.2 Sediment and Phosphorus Rating Curves

The sediment and phosphorus rating curves were used to compare correlations of flow with sediment and phosphorous for the non-impaired reference stations and South River. The rating curves are derived through pairing the TSS or T-P sample collected at a VADEQ station with daily flow data collected at a nearby USGS station. A regression equation is computed for the data set, resulting in a rating curve. The rating curve is then used to generate a load duration curve (described in the following section). The reference sediment and phosphorous rating curves are the basis for the TMDLs (Figures 6.1 and 6.3). The sediment and phosphorus rating curves for South River are shown in Figures 6.2 and 6.4.

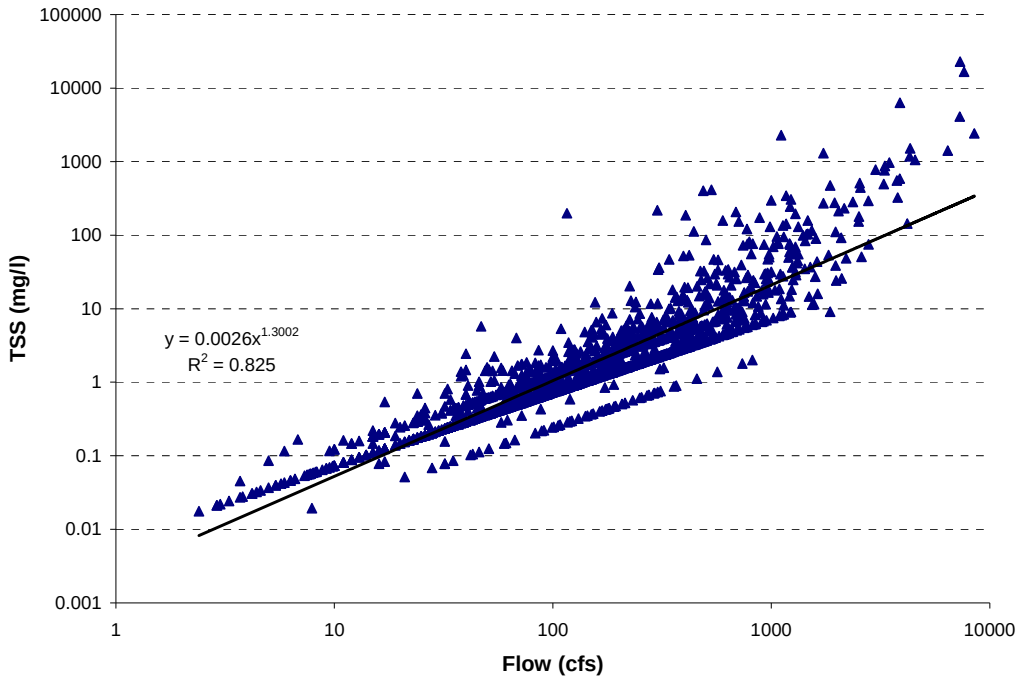

Figure 6.1. Sediment rating curve for reference watersheds.

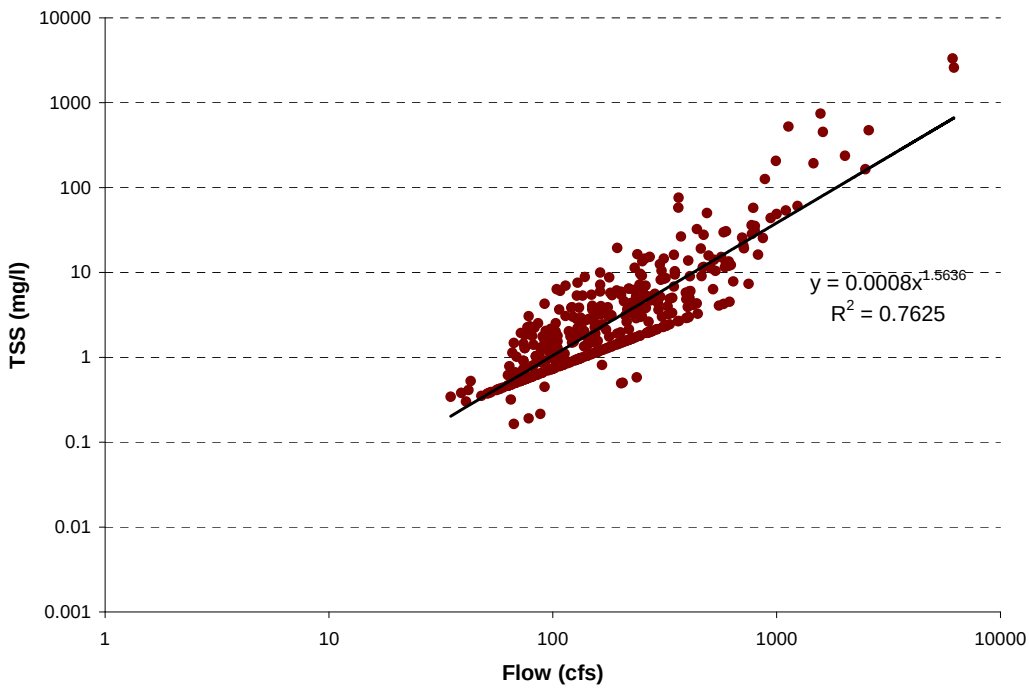

Figure 6.2. Sediment rating curve for South River watershed.

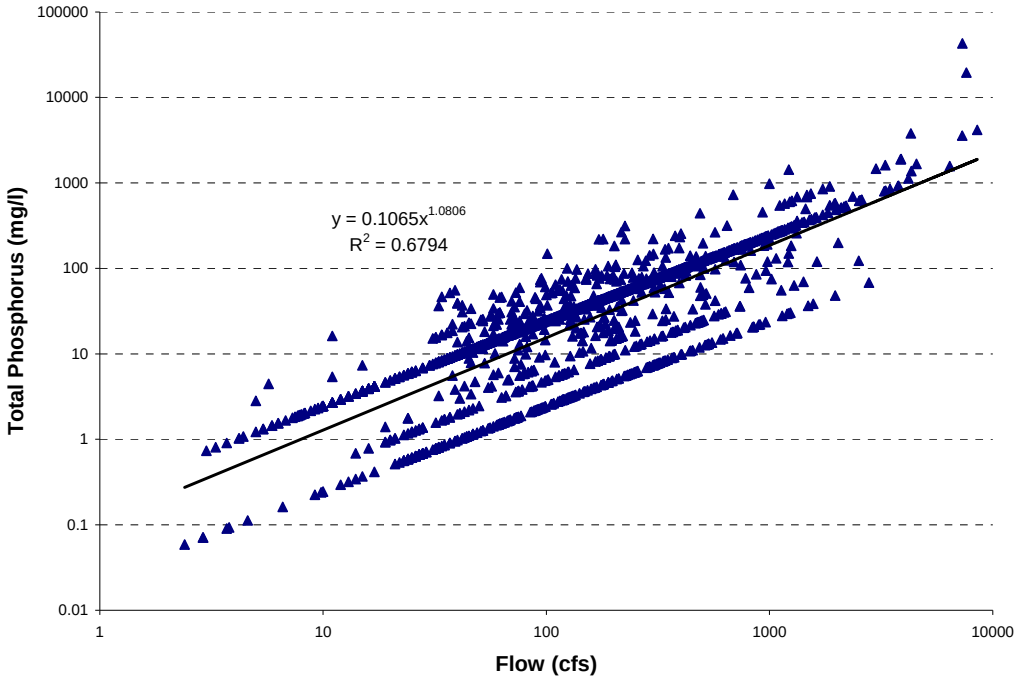

Figure 6.3. Phosphorus rating curve for reference watersheds.

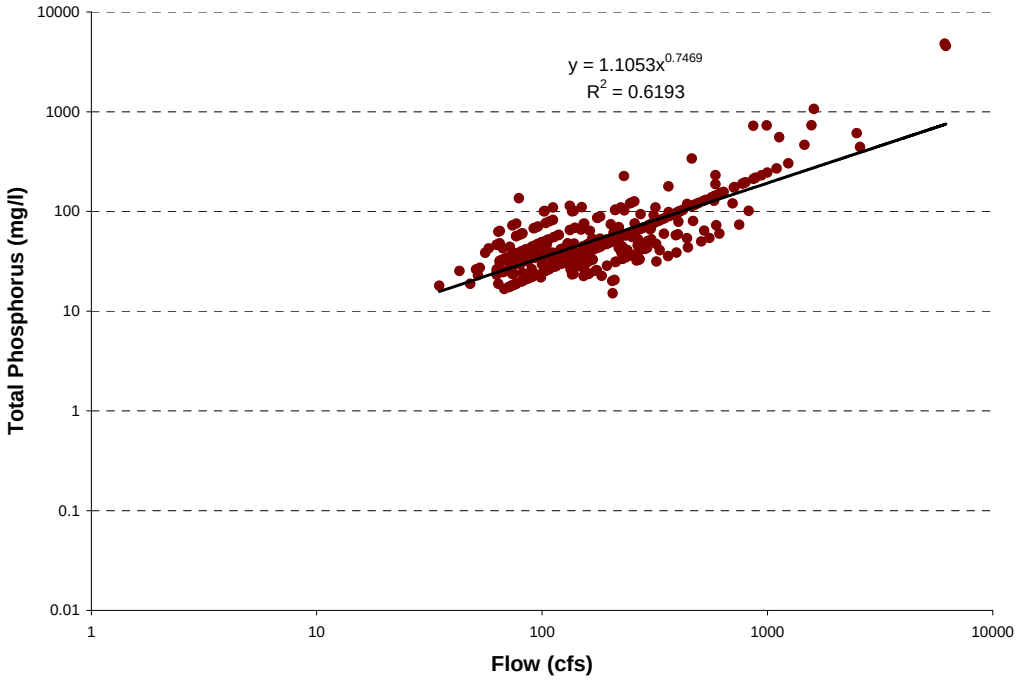

Figure 6.4. Phosphorus rating curve for South River watershed.

6.1.3 Sediment and Phosphorus Load Duration Curves

A load duration curve characterizes pollutant loads at different flow regimes and displays the relationship between stream flow and loading capacity (US EPA, 2007). Sediment load duration curves for the reference and South River stations were developed from the sediment rating curves depicted in Figures 6.1 and 6.2. Phosphorus load duration curves for the reference and South River stations were developed from the phosphorus rating curves depicted in Figures 6.3 and 6.4. Using the sediment and phosphorus rating curve equations, predicted reference and South River sediment and phosphorus loads were calculated for all flow conditions in the South River watershed. The load duration curves were used to assign loads to the flow regime in the reference and South River stations for comparison. The non-impaired load duration curves establish the TMDL endpoint. The load duration curve shows the sediment and phosphorus loadings in the unimpaired watersheds at different flow frequencies. Difference of loads at the various flow levels (i.e., high, moist, mid-range, dry, and low) signifies overall load reductions needed for sufficient recovery of benthic community. Figures 6.5 and 6.6 demonstrate a higher sediment load in the South River watershed versus the reference watershed for all flow regimes except low flow. At average flow conditions, a 25% reduction in the South River sediment load is needed. Higher phosphorus loads in the South River watershed versus the reference watershed are depicted in Figures 6.7 and 6.8 for all flow regimes except high flows. A 38% reduction in the South River phosphorus load is needed at average flow conditions.

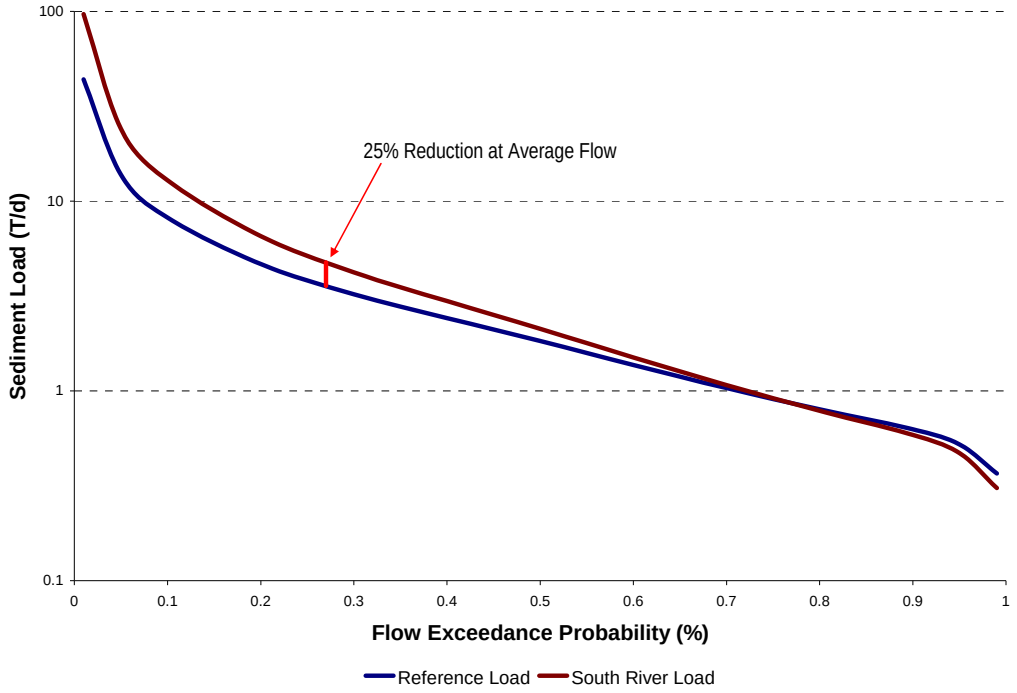

Figure 6.5. Sediment load duration curve for reference and South River watersheds.

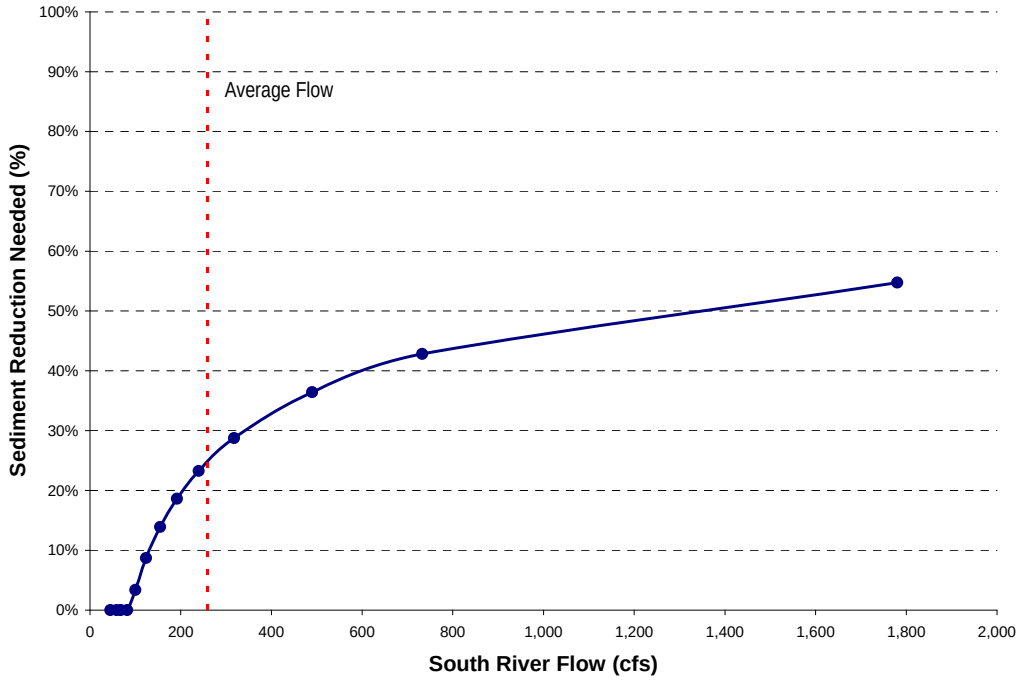

Figure 6.6. Sediment load reduction versus South River flow.

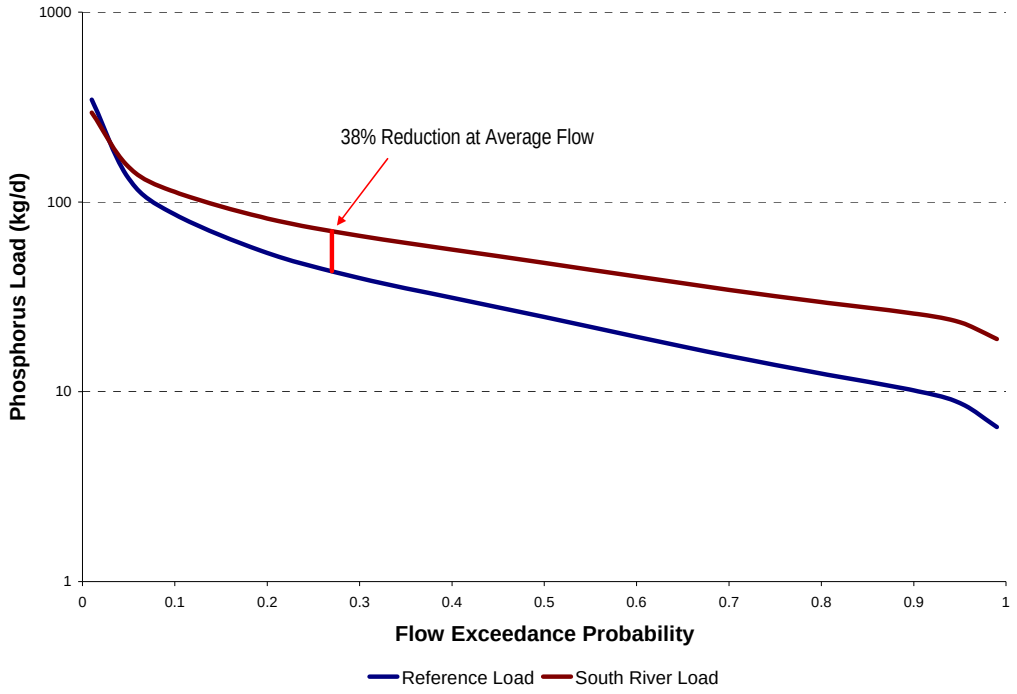

Figure 6.7. Phosphorus load duration curve for reference and South River watersheds.

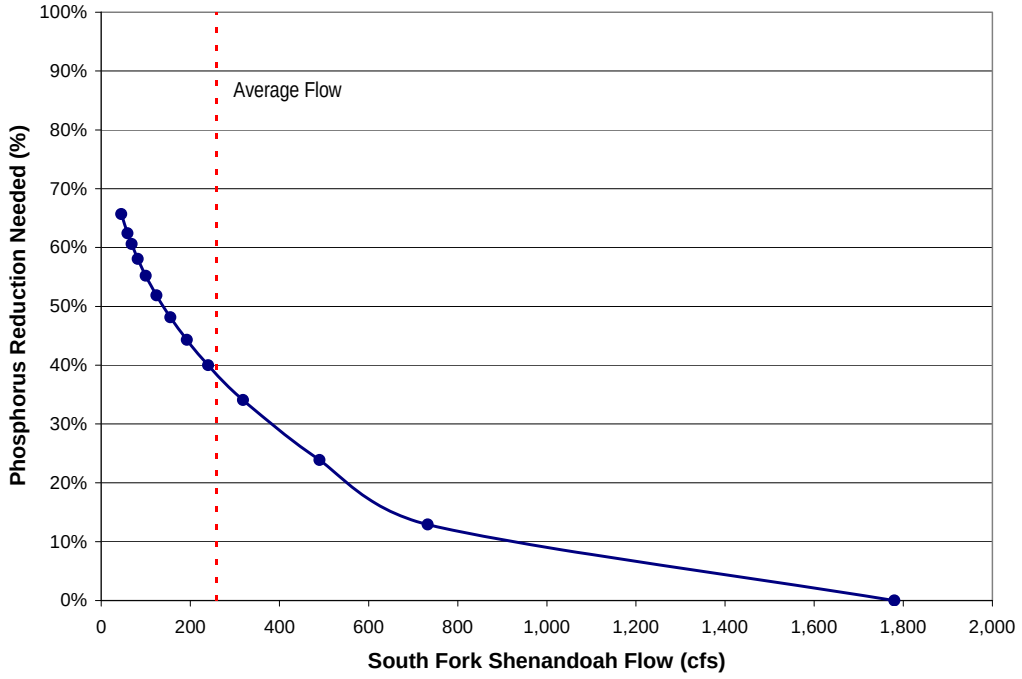

Figure 6.8. Phosphorus load reduction versus South River flow.

6.2 Sediment and Phosphorus Source Representation

Excessive sedimentation and phosphorus loads can adversely affect benthic invertebrate communities through a loss of habitat and degradation of water quality. Sediment and phosphorus can be delivered to the stream from point sources, non-point source runoff from urban and agricultural land areas, and seepage from groundwater in dissolved phosphorus forms. In addition, the processes of scour and deposition (primarily a function of stream flow) can generate sediment in the stream. During periods of high flow, increased erosion of the stream channel occurs. The eroded materials are deposited downstream as stream flow decreases.

6.2.1 Permitted Point Sources

6.2.1.1 Sediment

Sediment loadings from permitted sources are attributable to the total suspended solids (TSS) present in discharge effluent or stormwater runoff. There are 24 VPDES permitted facilities currently active or under application within the South River watershed discharging TSS (Table 6.1). Stormwater permits are divided between 15 industrial, one concrete plant, two mining, and 37 construction facilities (Tables 6.2 and 6.3).

Table 6.1. VPDES permitted facilities discharging sediment in the South River watershed.

Facility Name	Permit Number	VPDES Permit Category	Permit Type	Max Design Flow (MGD)	Average Flow (MGD)	TSS (mg/L)
Alcoa Packaging LLC	VA0001767	Individual	Industrial	0.019	0.005	28
Coyner Springs WTP	VA0092100	Individual	Industrial	0.060	0.060	30
INVISTA - Waynesboro	VA0002160	Individual	Industrial	1.440	0.710	40.403
Black Rock Mobile Home Park	VA0088986	Individual	Municipal	0.040	0.019	30
Blue Ridge MHC LLC	VA0088943	Individual	Municipal	0.024	0.007	78
DOC - Cold Springs Correctional Unit 10	VA0023400	Individual	Municipal	0.060	0.026	30
Grottoes STP	VA0065374	Individual	Municipal	0.400	0.230	30
Harriston STP	VA0027901	Individual	Municipal	0.100	0.040	30
Hugh K Cassell Elementary School	VA0088226	Individual	Municipal	0.011	0.004	30
Skyline Swannanoa	VA0028037	Individual	Municipal	0.150	0.009	15
Stuarts Draft WWTP	VA0066877	Individual	Municipal	4.000	1.100	30
Vesper View STP	VA0067962	Individual	Municipal	0.100	0.030	30
Waynesboro STP	VA0025151	Individual	Municipal	6.000	3.310	30
Residence	VAG408254	General	SFDS	0.001	0.001	30
Residence	VAG408047	General	SFDS	0.001	0.001	30
Residence	VAG401199	General	SFDS	0.001	0.001	30
Residence	VAG401441	General	SFDS	0.001	0.001	30
Residence	VAG401646	General	SFDS	0.001	0.001	30
Residence	VAG408048	General	SFDS	0.001	0.001	30
Residence	VAG401576	General	SFDS	0.001	0.001	30
Residence	VAG408122	General	SFDS	0.001	0.001	30
Residence	VAG401940	General	SFDS	0.001	0.001	30
Residence	VAG401110	General	SFDS	0.001	0.001	30

Table 6.2. Industrial, concrete plant, and mining stormwater permitted facilities contributing sediment in the South River watershed.

Facility	Permit Number	Type	Yearly Runoff (cm/acre)	Total Suspended Solids (mg/L)
ALCOA Home Exteriors	VAR050869	Industrial	65.52	100
Allied Pre-Cast	VAR050945	Industrial	65.52	100
Augusta Lumber LLC	VAR051667	Industrial	65.52	100
City of Waynesboro Sanitary Landfill	VAR051407	Industrial	65.52	100
Hershey Chocolate of Virginia Inc	VAR050792	Industrial	65.52	100
INVISTA Baugher Farms	VAR051598	Industrial	65.52	100
May Trucking LLC	VAR050791	Industrial	65.52	100
McKee Foods - Stuarts Draft	VAR050954	Industrial	65.52	100
Nibco of Virginia Inc	VAR050944	Industrial	65.52	100
Rexnord Corporation	VAR050934	Industrial	65.52	100
Target Distribution Center	VAR051472	Industrial	65.52	100
TB Pallets LLC	VAR051857	Industrial	65.52	100
UPS Freight	VAR050953	Industrial	65.52	100
Virginia Metalcrafters Inc	VAR051325	Industrial	65.52	100
Wayn-Tex LLC	VAR050783	Industrial	65.52	100
Allied Ready Mix Co - Waynesboro	VAG110072	Concrete Plant	65.52	30
Brett Aggregates Inc - Stuarts Draft Plant	VAG840040	Mining	65.52	30
Charles W Barger - Acres Sand and Stone LLC	VAG840041	Mining	65.52	30

Table 6.3. Construction stormwater permitted facilities contributing sediment in the South River watershed.

Facility	Permit Number	Yearly Runoff (cm/acre)	Total Suspended Solids (mg/L)
Crimora Land Company, LC	DCR01-05-100080	37.44	100
Gary Scrogham	DCR01-06-100467	37.44	100
Rutherford Construction, Inc.	DCR01-07-100121	37.44	100
Hill Group Development, LLC	DCR01-06-100835	37.44	100
Ron Oleyar	DCR01-08-101375	37.44	100
Hammond-Mitchell, Inc.	DCR01-08-101489	37.44	100
Michael Liberati, DuPont	DCR01-05-100527	37.44	100
Rutherford Construction, Inc.	DCR01-06-102384	37.44	100
Stoney Run, LLC	DCR01-07-101785	37.44	100
Nielsen Builders, Inc.	DCR01-06-101844	37.44	100
Mike Elzer	DCR01-06-100184	37.44	100
March Excavating Co.	DCR01-07-101308	37.44	100
Moffett Paving & Excavating	DCR01-08-100298	37.44	100
Lance Copperman	DCR01-07-101530	37.44	100
Beat G. C., Inc.	DCR01-07-100753	37.44	100
Dewitt Crossing, LLC	DCR01-07-102310	37.44	100
Massana Corp.	DCR01-08-100085	37.44	100
Mitch Lapin of Fortney & Weygandt	DCR01-08-100009	37.44	100
Moffett Paving & Excavating	DCR01-08-100098	37.44	100
Sheetz, Inc. c/o John Maxwell	DCR01-08-100572	37.44	100
Grand Home Furnishings, Inc./Engineering Concepts, Inc.	DCR01-08-101623	37.44	100
Hopeman Land Company, LC	DCR01-05-100072	37.44	100
Waynesboro Redevelopment and Housing Authority	DCR01-08-102321	37.44	100
P. J. Wright c/o BVL McMeans	DCR01-06-100180	37.44	100
W. Boutros and Company	DCR01-06-100290	37.44	100
Claybrook Associates, LLC	DCR01-06-100322	37.44	100
Grottoes Town of-Waste Collection Facility	VAR104279	37.44	100
Park Place Subdivision-end of 12th Street	VAR104844	37.44	100
Coyner Commercial Park - Lots 5 and 9	VAR102950	37.44	100
Triangle Services Retail Building - Waynesboro	VAR103915	37.44	100
Cracker Barrel Old Country Store	VAR103999	37.44	100
Home Depot - Waynesboro	VAR104063	37.44	100
Lowes-Waynesboro	VAR104485	37.44	100
Ana Marie Estates	VAR104743	37.44	100
Pratts Run Subdivision	VAR104463	37.44	100
VAR103788, DCR01-05-8-5-1	0610-007-P25, N501	37.44	100
VAR103788, DCR01-06-8-5-9	0608-007-397	37.44	100

6.2.1.2 Phosphorus

Phosphorus loadings from permitted sources are attributable to the total phosphorus (TP) present in discharge effluent. There are 22 VPDES permitted facilities currently active or under application within the South River watershed discharging TP (Table 6.4).

Table 6.4. VPDES permitted facilities discharging phosphorus in the South River watershed.

Facility Name	Permit Number	VPDES Permit Category	Permit Type	TP Design Flow (MGD)	TP (mg/L)
Alcoa Packaging LLC	VA0001767	Individual	Industrial	0.019	2.5
INVISTA - Waynesboro	VA0002160	Individual	Industrial	1.440	0.23
Black Rock Mobile Home Park	VA0088986	Individual	Municipal	0.040	2.5
Blue Ridge MHC LLC	VA0088943	Individual	Municipal	0.024	2.5
DOC - Cold Springs Correctional Unit 10	VA0023400	Individual	Municipal	0.060	2.5
Grottoes STP	VA0065374	Individual	Municipal	0.400	2.5
Harriston STP	VA0027901	Individual	Municipal	0.100	2.5
Hugh K Cassell Elementary School	VA0088226	Individual	Municipal	0.011	2.5
Skyline Swannanoa	VA0028037	Individual	Municipal	0.150	2.5
Stuarts Draft WWTP	VA0066877	Individual	Municipal	4.000	0.3
Vesper View STP	VA0067962	Individual	Municipal	0.100	2.5
Waynesboro STP	VA0025151	Individual	Municipal	4.000	0.3
Residence	VAG408254	General	SFDS	0.001	2.5
Residence	VAG408047	General	SFDS	0.001	2.5
Residence	VAG401199	General	SFDS	0.001	2.5
Residence	VAG401441	General	SFDS	0.001	2.5
Residence	VAG401646	General	SFDS	0.001	2.5
Residence	VAG408048	General	SFDS	0.001	2.5
Residence	VAG401576	General	SFDS	0.001	2.5
Residence	VAG408122	General	SFDS	0.001	2.5
Residence	VAG401940	General	SFDS	0.001	2.5
Residence	VAG401110	General	SFDS	0.001	2.5

6.2.2 Non-point Sources

Sediment and phosphorus generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, mining, transportation, and residential land uses. During runoff events, sediment loading occurs from both pervious and impervious surfaces around the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. This process is influenced by vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, and land management practices. During periods without rainfall, dirt, dust and fine sediment build up on impervious areas through dry deposition, which is then subject to wash-off during rainfall events. Sediment generated from impervious areas can be reduced through the use of management practices that reduce the surface load subject to wash-off. Phosphorus is delivered to the stream through runoff, attachment to sediment particles, or seepage. Phosphorus loading is a function of land use, soils, and landuse management practices. A total phosphorus delivery ratio is applied to sediment yield to determine the total phosphorus loadings to the stream. Nonpoint sources entering through seepage include dissolved inorganic and/or organic phosphorus forms and originate from agricultural phosphorus application and septic systems.

The land use types in the South River watershed were characterized from NLCD 2001. The South River watershed is predominately forest, constituting approximately 59% of the total

watershed area. The remaining land uses are divided between pasture (22%), residential (15%), and cropland (4%).

Sediment and phosphorous loads from forest land uses are generally lower. In addition to forest canopies intercepting and dampening the impact of rainfall, extensive root systems and vegetative cover assist in stabilizing the soil. Sediment and phosphorus loads from agricultural lands (i.e., pasture and cropland) tend to be elevated due to the exposure of soil and application on nutrients. Sediment and phosphorus loads from developed land uses tend to be high. Soil erosion occurs on the pervious land segments and solids build-up and wash-off occurs on the impervious land segments. Transitional land use (e.g., forest clear-cuts or construction sites) typically have sparse vegetative cover, exposing the soil, and resulting in high sediment loads.

6.2.3 Channel and Streambank Erosion

Sediment loading derived from instream bank erosion is dependent upon numerous watershed characteristics. These include soils, physiographic information, and land use. Land use types found in the watershed may affect hydrology. In particular, livestock with stream access can significantly alter the physical dimensions of streams through trampling and shearing, whereby; the bank full width increases, decreasing stream depth, increasing sediment, and adversely affecting aquatic habitat. An increase in impervious land without appropriate stormwater control, increases runoff volume and peaks and leads to greater channel erosion potential. Also, watersheds defined by steep topography may experience high levels of runoff that cause instream erosion. Conditions noted above have been observed in the South River Creek watersheds, therefore; overall amount of sediment generated by instream erosion would be expected to be high.

6.2.4 Septic Systems

Total septic systems were classified into one of three age categories (pre-1984, 1985-1994, and post-1994) based on 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB, 1990, 2000, and 2004). The septic systems were further classified into four different types of septic systems: normal, ponded, short-circuited, and direct discharge. A normal system is a properly functioning septic system. A ponded system is manifested by the rise of effluent to the soil surface. A short-circuited system is characterized by a failing system in close proximity to a stream. Direct discharges (e.g., straight pipes) are incomplete septic systems with partial or no treatment of effluent. Ponded systems and direct discharges were estimated based on methodology described in Section 3.2.1 and 3.2.2, respectively. An average number of people per septic system in 2008 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB, 1990 and 2000).

6.3 Model Development

The model selected for development of the sediment and phosphorus TMDLs was the Virginia Tech modified version (Yagow and Hession, 2007) of Generalized Watershed Loading Functions (GWLF) model, originally developed at Cornell University (Haith and Shoemaker, 1987; Haith, et al., 1992) for use in un-gaged watersheds. GWLF is a continuous simulation

spatially-lumped parameter model that operates on a daily time step. The model estimates runoff, sediment, and dissolved and attached nitrogen and phosphorus loads delivered to streams from complex watersheds with a combination of point and non-point sources of pollution. The model considers flow inputs from both surface runoff and groundwater.

The hydrology in the model is simulated with a daily water balance procedure that takes into consideration types of storages within the system. Runoff is generated based on the Soil Conservation Service's Curve Number method as presented in Technical Release 55 (SCS, 1986). Erosion is calculated from a modification of the Universal Soil Loss Equation (USLE) (Schwab et al., 1983; Wischmeier and Smith, 1978). Sediment estimates uses a delivery ratio as a function of watershed area coupled with erosion estimates. The sediment transported depends on the transport capacity of runoff. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Manured areas and septic systems are considered in the nutrient loading. Urban nutrient inputs are all assumed to be solid-phase, and GWLF uses an exponential accumulation and wash-off function for these loadings. Sub-surface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads, and the sub-surface sub-model only considers a single, lumped-parameter contributing area.

GWLF uses three input files for weather, transport, and nutrient data. The weather file contains daily temperature and precipitation for the period of simulation. The transport file contains input data primarily related to hydrology and sediment transport, while the nutrient file contains primarily nutrient values for the various land uses, point sources, and septic system types.

6.3.1 Climate Data

The climate in South River watershed was characterized by meteorological observations from the National Weather Service Cooperative Staunton Water Treatment Plant (448062) and Stuarts Draft (448172) stations located in Augusta County, Virginia. The period of record used for modeling was from January 1987 through December 2003.

6.3.2 Land use

Landuse for the South River watersheds was derived from the NLCD 2001 landuse – land cover digital data, as discussed in Section 2.5. The NLCD land use types within the watershed were consolidated into 12 categories based on similarities in hydrologic and pollutant production features (Table 2.1). The pasture/hay category was subdivided into three categories based on percentages assessed during the 2002 Statewide NPS Pollution Assessment study (Yagow et al., 2002). Cropland was divided into high-tillage cropland and low-tillage cropland based on input from the local steering committee and field observations. Land use distribution in the South River watershed is presented in Table 2.2.

6.3.3 Model Input Parameters

In addition to weather data, GWLF requires specification of input parameters relating to hydrology, erosion, sediment yield, and nutrient loads. All parameters were evaluated in a consistent manner between the reference and impaired watersheds, in order to ensure their comparability for the modified reference watershed approach. All GWLF parameter values were evaluated from a combination of GWLF user manual guidance (Haith et al., 1992), AVGWLF procedures (Evans et al., 2001), procedures developed during the 2002 State-wide NPS pollution assessment (Yagow et al., 2002), and best professional judgment. Generally, Appendix B of the GWLF manual (Haith et al., 1992) served as the primary source of guidance in developing input parameters. Hydrologic and sediment parameters are all included in GWLF's transport input file, with the exception of urban sediment buildup rates, which are in the nutrient input file with other nutrient parameters. Descriptions of each of the hydrologic, sediment, and nutrient parameters are listed below according to whether the parameters were related to the overall watershed, to the month of the year, or to individual land uses (adapted from Bull Creek TMDL report).

Hydrology Parameters

<u>Watershed-Related Parameter Descriptions</u>

- *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-1)*: The recession coefficient is a measure of the rate at which stream flow recedes following the cessation of a storm, and is approximated by averaging the ratios of stream flow 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. This parameter was evaluated using the following relationship from Lee et al. (2000): RecCoeff = 0.045+1.13/(0.306+Area in square kilometers).
- *Seepage coefficient (day-1)*: The seepage coefficient represents the amount of flow lost as seepage to deep storage (initially set to zero).

The following parameters were initialized by running the model for a 1-year period prior to the period used for load calculation:

- *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 file.

<u>Month-Related Parameter Descriptions</u>

- *Month*: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model and its assumption that all annual detached sediment is flushed from the system at the end of each Apr-Mar cycle.
- *ET_CV*: Composite evapotranspiration 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 is a regional coefficient used in Richardson's equation for calculating daily rainfall erosivity. Each region is assigned separate coefficients for the months October-March, and for April- September.

Land Use-Related Parameter Descriptions

- *Curve Number*: The SCS curve number (CN) is used in calculating runoff associated with a daily rainfall event, evaluated using SCS TR-55 guidance.

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 an inverse function of watershed size (Evans et al., 2001).

Land Use-Related Parameter Descriptions

- *USLE K-factor*: 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 measurements by land use. Slope is evaluated by GIS analysis, and slope length is calculated as an inverse function of slope.
- *USLE C-factor*: The vegetative cover factor for each land use was evaluated following GWLF manual guidance, Wischmeier and Smith (1978), and Hession et al. (1997); and then adjusted after consultation with local NRCS personnel.
- *Daily sediment buildup 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 et al., 2003)

- *% 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 the watershed area in acres.
- *Curve Number*: area-weighted average value for the watershed.
- *K Factor*: area-weighted USLE soil erodibility factor for the watershed.
- *Slope*: mean percent slope for the watershed.
- *Stream length*: calculated as the total stream length of natural perennial stream channels, in meters. Excludes any non-erosive hardened and piped sections of the stream.
- *Mean channel depth (m)*: calculated from relationships developed either by the Chesapeake Bay Program or by USDA-NRCS by physiographic region, of the general form – $y = a * Ab$, where y = mean channel depth in ft, and A = drainage area in square miles (USDA-NRCS, 2005).

Nutrient Parameters

Watershed-Related Parameter Descriptions

- Background N/P concentrations in GW
- Population on septic systems
- Per capita septic system loads (N/P)

- N and P point source loads

Land Use-Related Parameter Descriptions

- Dissolved N in runoff by land cover type
- Dissolved P in runoff by land cover type
- N/P buildup in urban areas
- Background P concentrations in soil
- Background N concentrations in soil
- Months of manure spreading
- N/P concentrations in manure runoff

6.3.4 Model Calibration

GWLF was originally developed as a planning tool for estimating nutrient and sediment loadings on non-gaged watersheds, not requiring calibration. To ensure the general validity of the model, simulations were performed from 1987 to 2003 to account for both seasonal and annual variations in hydrology as well as sediment and phosphorus loadings. The simulated flow from GWLF was calibrated based on USGS station #01627500 on South River at Harriston, VA. The groundwater seepage coefficient and unsaturated zone available water capacity were adjusted to obtain a best fit with observed data. All other GWLF hydrologic parameters were calibrated using GWLF user manual guidance and professional judgment.

Flow from USGS station #01627500 was input into the South River sediment and phosphorus loading curves to derive sediment and phosphorus loads for the period 1987 to 2003. This timeseries was compared to GWLF output for the same period. Overall sediment and phosphorus loads were underestimated by 0.4% and 0.3%, respectively.

6.4 Sediment and Phosphorus Load Estimates

The GWLF model was used to estimate sediment and phosphorus loading contributions from each land use, channel erosion, and nutrient concentrations from septic systems. Point source and non-point source loads for sediment and phosphorus are presented in Tables 6.5 and 6.6, respectively**.** Point source sediment and phosphorus loads were based on design flow or calculated runoff and the permitted concentration of total suspended solids or total phosphorus for each facility (Tables 6.1 through 6.4).

Table 6.5. Sediment sources and loads calculated for South River watershed.

Sediment Sources	Existing Load (t/yr)	Portion of Total Load (%)
Hi till cropland	777.6	25.0
Low-till cropland	788.9	25.4
Pasture 1	108.3	3.5
Pasture 2	136.4	4.4
Pasture 3	370.5	11.9
Transitional	17.4	0.6
Forest	43.0	1.4
Open urban grass	44.4	1.4
Low density residential	114.2	3.7
Medium density residential	34.0	1.1
High density residential	46.7	1.5
Channel erosion	307.8	9.9
Point Sources	319.9	10.3
TOTAL	3,109.0	100.0

Table 6.6. Phosphorus sources and loads calculated for South River watershed.

Phosphorus Sources	Existing Load (kg/yr)	Portion of Total Load (%)
Hi till cropland	1,705.1	7.4
Low-till cropland	2,786.5	12.1
Pasture 1	2,738.6	11.8
Pasture 2	2,711.0	11.7
Pasture 3	3,464.1	15.0
Transitional	16.8	0.1
Forest	123.5	0.5
Open urban grass	596.0	2.6
Low density residential	514.0	2.2
Medium density residential	381.3	1.6
High density residential	522.6	2.3
Groundwater	1,934.8	8.4
Septic systems	1,971.1	8.5
Point Sources	3,645.5	15.8
TOTAL	23,110.9	100.0

6.5 Accounting for Critical Conditions and Seasonal Variations

6.5.1 Selection of Representative Modeling Period

Selection of the modeling period was based on the availability of daily weather data and the need to represent variability in weather patterns over time in the watershed. A long period of weather inputs was selected to represent long-term variability in the watershed. The model was run using a weather time series from April 1987 through December 2003. The remaining period was used to calculate average annual sediment and phosphorus loads in the South River watershed.

6.5.2 Critical Conditions

The GWLF model is a continuous simulation model that uses daily time steps for weather data and water balance calculations. The period of rainfall selected for modeling was chosen as a multi-year period that was representative of typical weather conditions for the area, and included “dry”, “normal” and “wet” years. The model, therefore, incorporated the variable inputs needed to represent critical conditions during low flow – generally associated with point source loads – and critical conditions during high flow – generally associated with nonpoint source loads.

6.5.3 Seasonal Variability

The GWLF model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model also allows for monthly-variable parameter inputs for evapotranspiration cover coefficients, daylight hours/day, and rainfall erosivity coefficients for user-specified growing season months.

Chapter 7. TMDL Allocations

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The goal for the South River Bacteria and Benthic TMDL was to determine what reductions in pollutant loadings from point and nonpoint sources are required to meet state water quality standards. The TMDL considers all sources contributing bacteria, sediment, and phosphorus to South River. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL is defined in the following equation:

$$TMDL = WLA + LA + MOS \qquad [7.1]$$

where:

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

7.1 Bacteria TMDL

7.1.1 Background

While developing allocation scenarios to implement the bacteria TMDL, an implicit MOS was used by formulating conservative estimates of all factors that would affect the bacteria loadings in the watershed (e.g., animal numbers, production rates, and contributions to streams). These factors were estimated in such a way as to represent the worst-case scenario; i.e., these factors would describe the highest in-stream bacteria conditions that could exist in the watershed. Creating a TMDL with these conservative estimates ensures that the worst-case scenario has been considered and that no water quality standard exceedances will occur if the TMDL plan is followed.

Bacteria loadings were updated to reflect 2008 conditions for the existing conditions and allocation runs. The simulation period selected for the load allocation study was January 1993 to December 1997. This period incorporates average rainfall, low rainfall, and high rainfall years allowing the representation of both low and high flow conditions.

The state water quality standards for *E. coli* used in the development of the TMDL were 126 cfu/100mL (calendar-month geometric mean) and 235 cfu/100mL (single sample maximum). The calendar-month geometric mean values used in this report are geometric means of the daily concentrations. Because HSPF was operated with a one-hour time step in this study, 24 hourly concentrations were generated each day. To estimate the calendar-month geometric mean from the hourly HSPF output, the arithmetic mean of the hourly values was computed on a daily basis, and then the geometric mean was calculated from these average daily values.

The guidance for developing an *E. coli* TMDL put forth by the VADEQ is to develop input for the model using fecal coliform loadings as the bacteria source in the watershed. Then, the model output of average fecal coliform concentrations is converted to daily average *E. coli* concentrations through the use of the following translator equation derived by the VADEQ:

$$\log_2(EC) = -0.0172 + 0.91905*\log_2(FC) \qquad [7.2]$$

where: EC = *E. coli* concentration (cfu/100mL); and
FC = fecal coliform concentration (cfu/100mL)

Daily *E. coli* loads were obtained by using the *E. coli* concentrations calculated from the translator equation and multiplying them by the average daily flow. Average annual loads were obtained by summing the daily loads and dividing by the number of years in the allocation period.

7.1.2 Existing Conditions

Bacteria loadings for 2008 conditions were inserted into the model and simulated for the period January 1993 to December 1997. Model output was translated to average daily *E. coli* concentrations and the monthly geometric mean was calculated. Average daily *E. coli* concentrations at the impairment outlets were compared to the single sample maximum standard of 235 cfu/100 mL. Subwatershed outlets were used for comparison of modeled concentrations to water quality standards for the South River impairment. Appendix C contains tables with monthly land-based and direct bacteria loadings for existing conditions.

Figure 7.1 shows the monthly geometric mean for each subwatershed in relation to the monthly geometric mean (126 cfu/100mL) standard. Average daily *E. coli* concentrations at the impairment outlet were compared to the single sample maximum standard of 235 cfu/100 mL (Figure 7.2). Subwatershed 6 was used for comparison of modeled concentrations to water quality standards for the South River impairment.

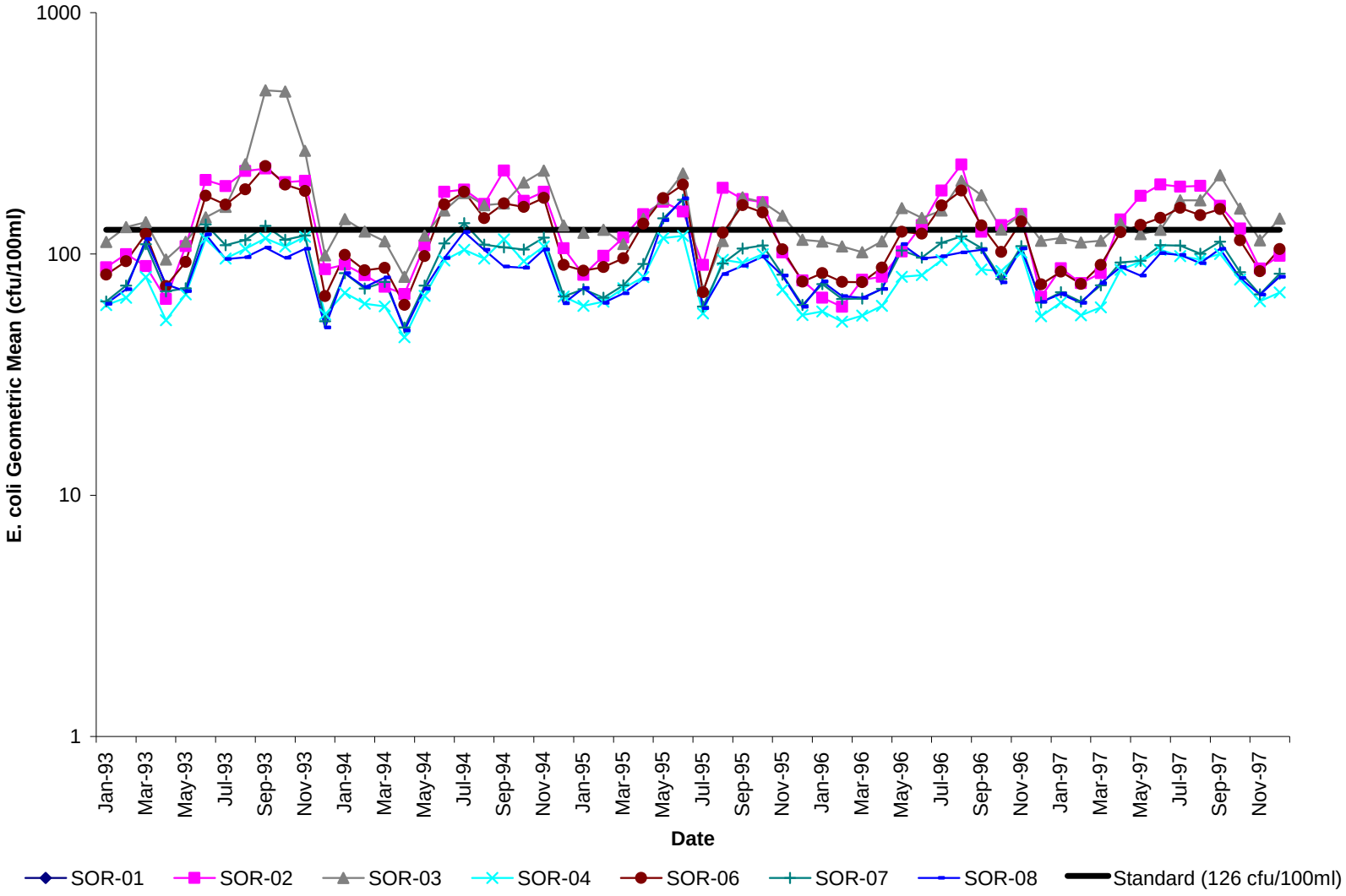

Figure 7.1. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds SOR-01 to SOR-08 in the South River watershed.

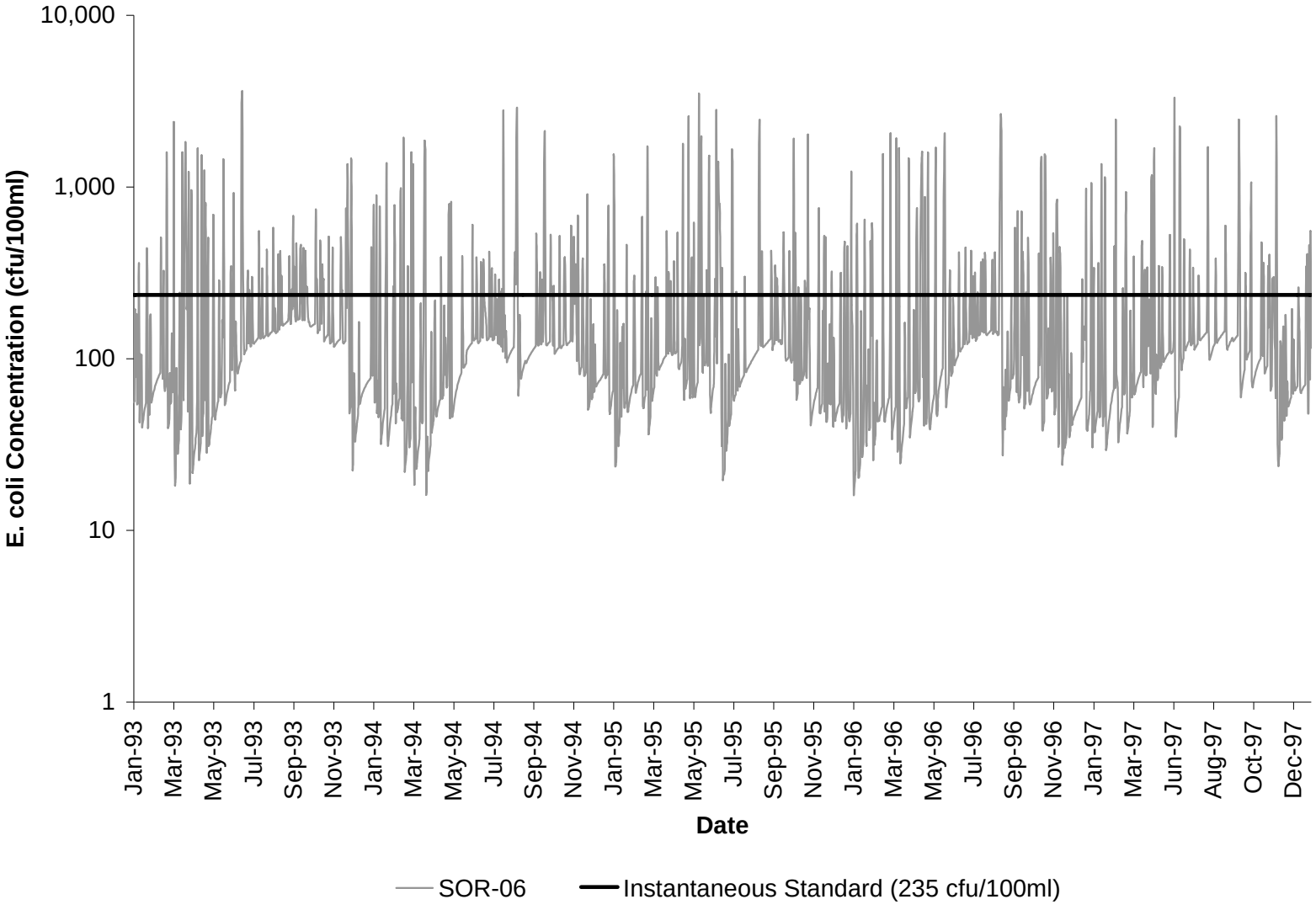

Figure 7.2. Daily average *E. coli* concentrations for subwatershed SOR-06 in South River watershed.

7.1.3 Impact Analysis

Analyses were conducted to assess the impact of unknown variability in source allocations on changes in direct and land-based loads. Model output from existing conditions was set as the comparative base to adjustments in direct and land-based loads of +100%, +10%, -10%, and -100% of the base value. Model simulations were made for the period January 1993 to December 1997, corresponding with the period used in the allocation scenarios. Percent difference in monthly geometric mean *E. coli* concentration and maximum daily average *E. coli* concentration per month for each direct and land-based load change to base value was calculated and plotted. Analysis results were used to assess the affects of future growth on the rate of water quality standards exceedance.

Percent difference in monthly geometric mean *E. coli* concentration for each direct and land-based load change to base value was calculated and plotted in Figures 7.3 and 7.4, respectively. Figures 7.5 and 7.6, respectively, show the percent difference in the maximum daily average *E. coli* concentration per month for each direct load and land load change to base value. It is apparent by comparing Figure 7.3 with Figure 7.4 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 7.5 to Figure 7.6 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected by increasing directly deposited loads during lower flow periods.

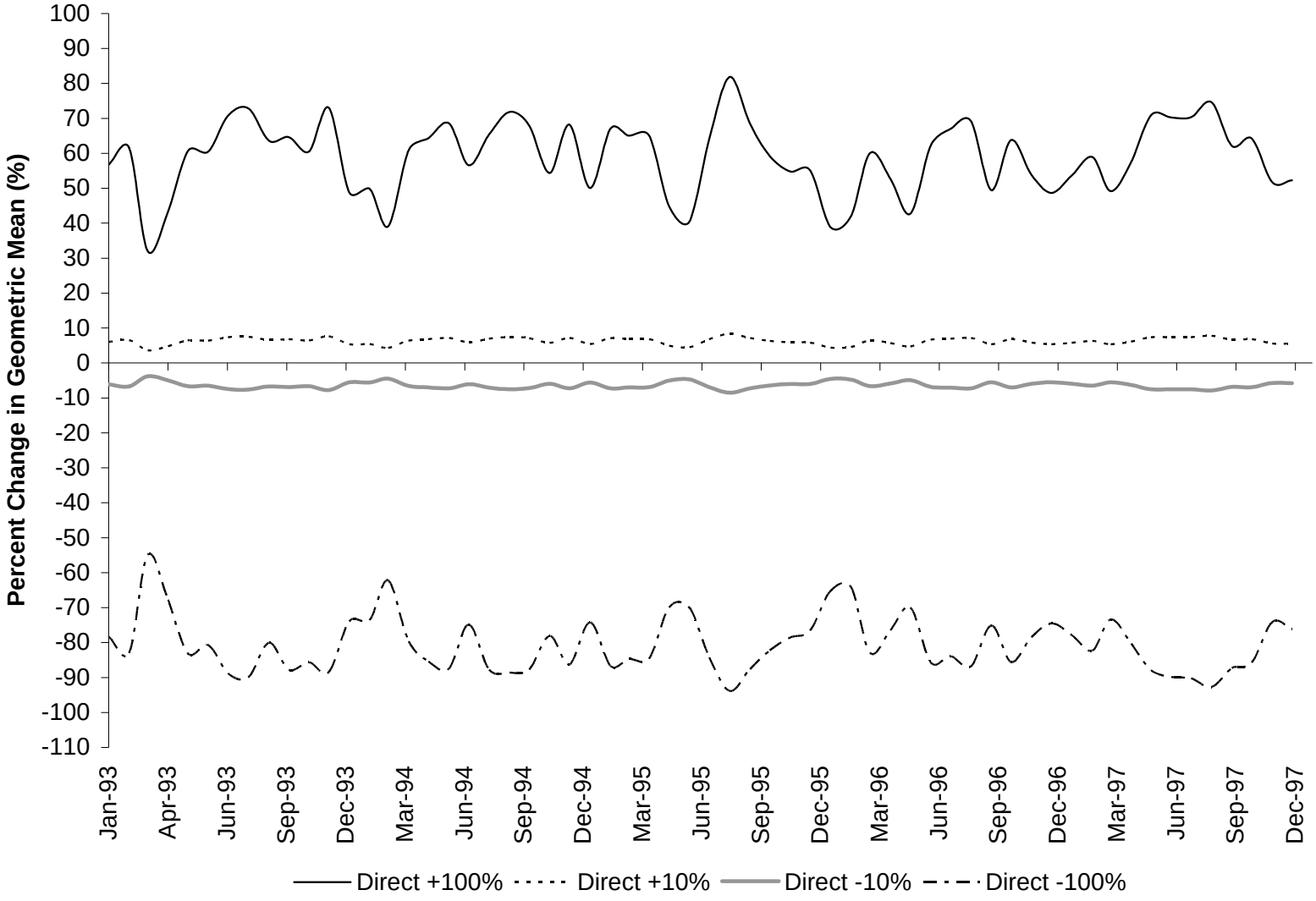

Figure 7.3. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed SOR-08) of South River watershed, as affected by direct load changes.

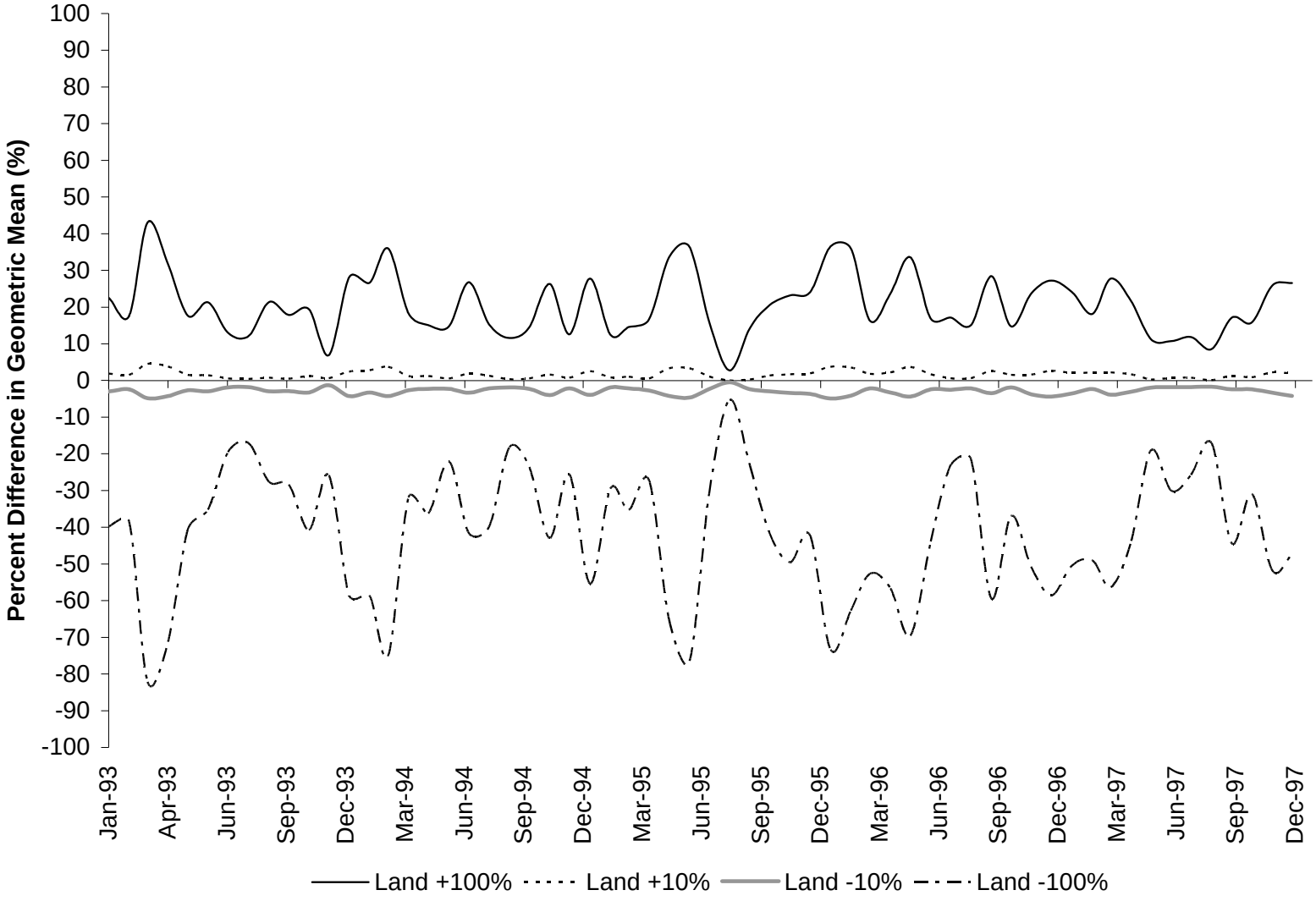

Figure 7.4. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed SOR-08) of South River watershed, as affected by land-based load changes.

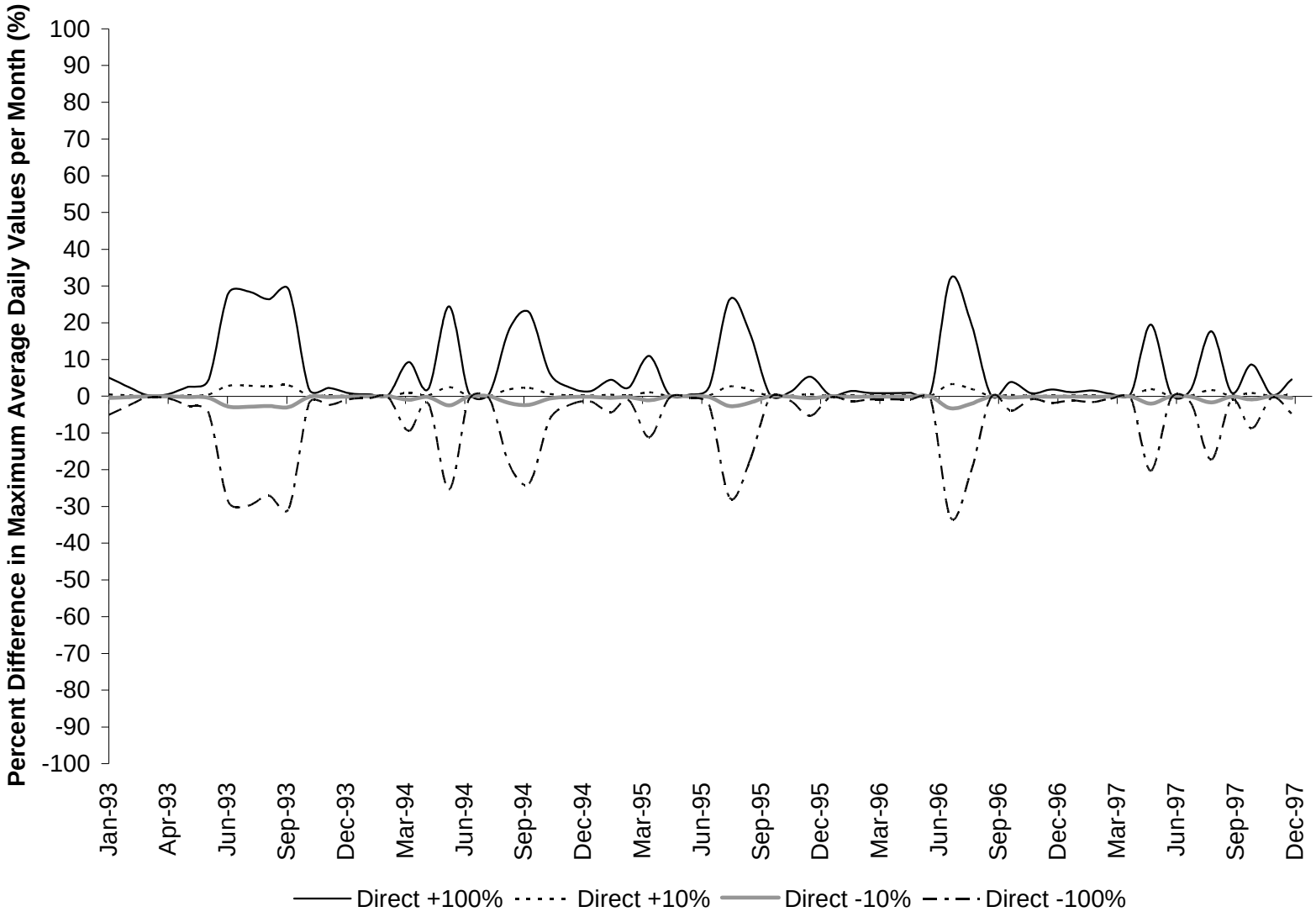

Figure 7.5. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed SOR-08) of South River watershed, as affected by direct load changes.

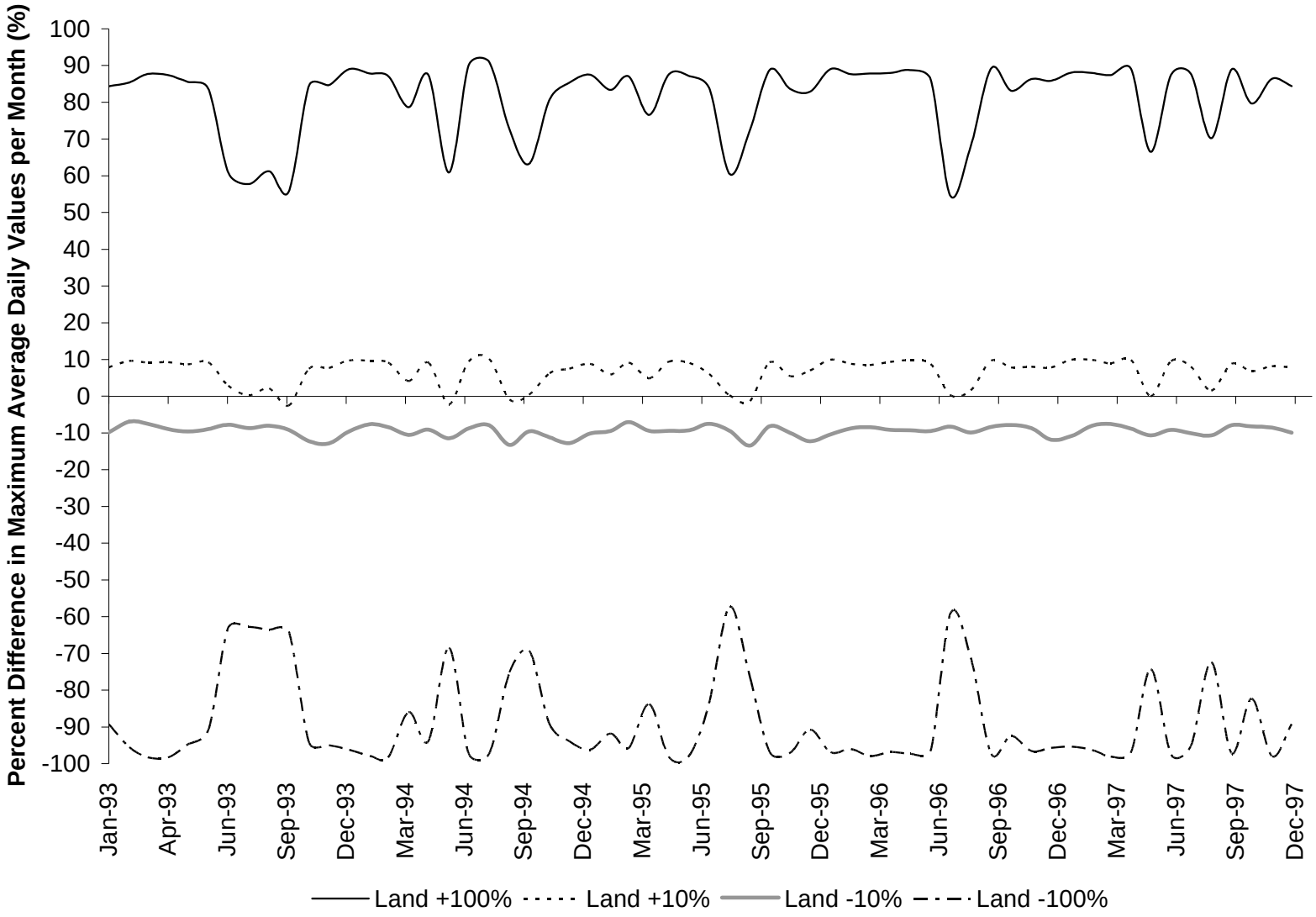

Figure 7.6. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed SOR-08) of South River watershed, as affected by land-based load changes.

7.1.4 TMDL Allocation Scenarios

Direct and land-based loads representing existing conditions were reduced in a variety of allocation scenarios (addressing anthropogenic sources first) until the *E. coli* TMDL goals of a calendar-month geometric mean of 126 cfu/100mL and the single sample maximum limit of 235 cfu/100mL were met. The representative modeling period selected for allocation scenarios was January 1993 through December 1997. This period incorporates average rainfall, low rainfall, and high rainfall years allowing the representation of both low and high flow conditions. The general approach to allocation scenario development was to develop a scenario that allowed the South River impairment to meet bacteria water quality standards.

Seventeen active point discharges in the South River watershed currently have VPDES permits. No municipalities with MS4 permits were identified within the South River watershed. The permitted point source discharges are described in Table 3.2. During allocation development, these permitted point sources were modeled with effluent fecal coliform concentrations of 200 cfu/100 mL and flows equal to their design flows as listed in Table 3.2. The ultimate waste load allocation (WLA) was calculated using the *E. coli* limit of 126 cfu/100mL, and *E. coli* loads based on the facility design flow are presented in Table 7.3.

Scenarios to address the load allocations to non-point sources were divided between direct and land-based loadings affected by both high and low stream flow conditions. Bacterial source tracking results from samples taken during 2007-2008 confirmed the presence of human, pet, livestock, and wildlife contamination. As a result, scenarios were formulated to address reductions from all sources and delivery mechanisms (See Section 6.5.4 for discussion of wildlife bacteria). In general, direct loads modeled as consistent loadings independent of the flow regime heavily influenced low flow concentrations, whereas land-applied loads reached the stream through runoff producing events during high flow conditions. Representative allocation reduction scenarios developed for the South River impairment and corresponding results are summarized in Table 7.1.

In Table 7.1, the first scenario represents existing conditions. Scenario number 1 reduces straight pipes and livestock directly deposited loads by 100%, keeping the remaining source reductions at 0%. Scenarios numbered 2 through 4 represent a stepwise reduction of the following anthropogenic sources: residential land-based, cropland land-based, and pasture land-based. In these scenarios, wildlife loads (directly deposited and forest land-based) were not reduced and straight pipes and livestock directly deposited loads were reduced 100%. Load from straight pipes was reduced by 100% in all reduction scenarios since they are illegal. Utilizing results of Scenarios 1 through 4, subsequent scenarios were used to determine required reductions in anthropogenic sources. Scenario 5 tested the land-based load reductions at 94%. Table 7.1 shows that exceedances are present when the anthropogenic sources are tested at an 94% reduction rate. Scenario 6 tested the land-based load reductions at 95% and met the 0% exceedance rate criterion for both standards, but an attempt to reduce the livestock direct deposition was performed to match the land-based anthropogenic source reductions. Scenario 7 tested the land-based and livestock directly deposited loads at a 95% reduction rate.

Scenario 7 met the 0% exceedance rate criterion for both standards and was selected as the final TMDL allocation. It was determined that no reductions were required in wildlife loads (directly deposited and forest land-based) to meet the bacteria water quality standards in the South River watershed. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 7.7 for the final TMDL allocation (Scenario 7), along with the geometric mean and instantaneous standards. Table 7.2 presents the existing and allocated direct and land-applied fecal coliform loads that result in in-stream *E. coli* concentrations to meet the applicable *E. coli* water quality standards after application of the VADEQ translator for fecal coliform to *E. coli* concentration. Table 7.3 presents the final allocated in-stream *E. coli* loads for the South River impairment. Table 7.4 presents the TMDL for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Increases in loads over the next five years must be considered to ensure the stated allocation will meet the water quality standards. Discharge from the permitted point sources in the South River watershed was increased by two and five times the existing permit levels to determine the effect of possible facility expansion. The allocated load from permitted point sources was set assuming that they were operating at five times their design flow at their permitted maximum average concentration. These increases did not result in exceedances of the water quality standard. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but it will be allocated to both new and existing permits as determined by the VADEQ Virginia Pollutant Discharge Elimination System program. All current permit limits remain in effect and can only be altered through the VADEQ permitting process. From information provided by the Local Steering Committee, it is our understanding that no major zoning changes are planned by counties in the watersheds that would result in accelerated development of the watershed. For purposes of this study, it was assumed that residential development in the study watersheds will continue at the current rates. New housing development is expected to produce no direct deposition, and a minimal land-based load increase based on the 3% failure rate associated with new septic systems and the number of pets added by this development. Data from the VASS indicated that beef cattle populations are decreasing by approximately 12% per year and there is no evidence that any new dairy or poultry operations are planned. Wildlife populations are expected to remain relatively constant over the next five years. Based on these observations and the TMDL allocations, it is anticipated that the increase in directly deposited and land-based loads in the study watersheds will be negligible over the next five years. The effects of changes in loads on the in-stream bacteria concentration is examined in the impact analysis in Section 7.3. These changes are adequately accounted for in the implicit MOS. This implies that the final TMDL allocation is valid for the next five years, accounting for the anticipated growth during that time period.

The selected *E. coli* TMDL allocation for the South River impairment that meets both the calendar-month geometric mean and single sample maximum water quality goals addresses the following issues:

- The TMDL was developed to meet the calendar-month geometric mean and single sample water quality standards.

- Because *E. coli* loading data were not available to quantify point or nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations on which the bacteria TMDL was based.
- The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
- An implicit MOS was incorporated by utilizing professional judgment and conservative estimates of model parameters.
- Both high- and low-flow stream conditions were considered while developing the TMDL.
- Both the flow regime and bacteria loading to South River are seasonal. The TMDL accounts for these seasonal effects.
- The exceedance rates listed in the allocation scenario table indicate the highest exceedance rate observed at a subwatershed outlet within the impaired segment (i.e., subwatershed 6). Some scenarios resulted in bacteria water quality standard exceedances in subwatersheds upstream of the outlet but not within the impaired reach subwatersheds.
- The TMDL was developed to account for future growth in the South River watershed.

Table 7.1. Bacteria TMDL allocation scenarios for South River impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of E. coli Standard	
	Straight Pipes	Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean*	Instantaneous*
Existing Conditions	0	0	0	0	0	0	0	43.3	19.1
1	100	0	100	0	0	0	0	3.3	14.1
2	100	50	100	50	50	0	0	0.0	7.6
3	100	75	100	75	75	0	0	0.0	3.8
4	100	90	100	90	90	0	0	0.0	0.9
5	100	94	100	94	94	0	0	0.0	0.2
6	100	95	100	95	95	0	0	0.0	0.0
7	100	95	95	95	95	0	0	0.0	0.0

Table 7.2. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in South River impairment.

Source	Fecal Coliform		*E. coli*[1]		Scenario Reduction
	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	(%)
Direct					
Straight Pipes	3.15E+14	0.00E+00	2.09E+13	0.00E+00	100
Livestock	7.76E+13	3.88E+12	5.76E+12	3.67E+11	95
Wildlife	1.21E+14	1.21E+14	8.66E+12	8.66E+12	0
Total	*5.14E+14*	*1.25E+14*	*3.53E+13*	*9.03E+12*	*76*
Land-based					
Residential	6.98E+15	3.49E+14	3.60E+14	2.29E+13	95
Cropland	4.23E+14	2.12E+13	2.74E+13	1.75E+12	95
Pasture	8.01E+16	4.01E+15	3.39E+15	2.16E+14	95
Forest	7.34E+14	7.34E+14	4.54E+13	4.54E+13	0
Total	*8.82E+16*	*5.11E+15*	*3.82E+15*	*2.86E+14*	*94*

[1] Loads derived from fecal coliform loads using equation 7.1

Table 7.3. Expansion matrix for bacteria WLA in the South River watershed.

Permit No	Facility Name	Max Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/yr)
VA0001767	Alcoa Packaging LLC	0.019	126	3.31E+10
VA0066877	Stuarts Draft WWTP	4	126	6.96E+12
VA0025151	Waynesboro STP	6	126	1.04E+13
VA0027901	Harriston STP	0.1	126	1.74E+11
VA0028037	Skyline Swannanoa	0.15	126	2.61E+11
VA0065374	Grottoes STP	0.4	126	6.96E+11
VA0088226	Hugh K Cassell Elementary School	0.011	126	1.91E+10
VA0067962	Vesper View STP	0.1	126	1.74E+11
VA0088943	Blue Ridge MHC LLC	0.024	126	4.18E+10
8 Domestic Sewage General Permits		0.008	126	1.39E+10
Point Source Future Growth Allocation (5x)		54.06	126	9.41E+13
			Total	1.13E+14

Table 7.4. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in South River impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	1.13E+14	2.71E+13	Implicit	1.40E+14

1 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

2 – The LA is calculated as the TMDL minus the WLA.

3 – The TMDL is presented as the average annual load for the allocation period.

Table 7.5. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in South River impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	3.10E+11	1.62E+13	Implicit	1.65E+13

1 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe. The WLA is calculated as the average annual load divided by 365.

2 – The LA is calculated as the TMDL minus the WLA.

3 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

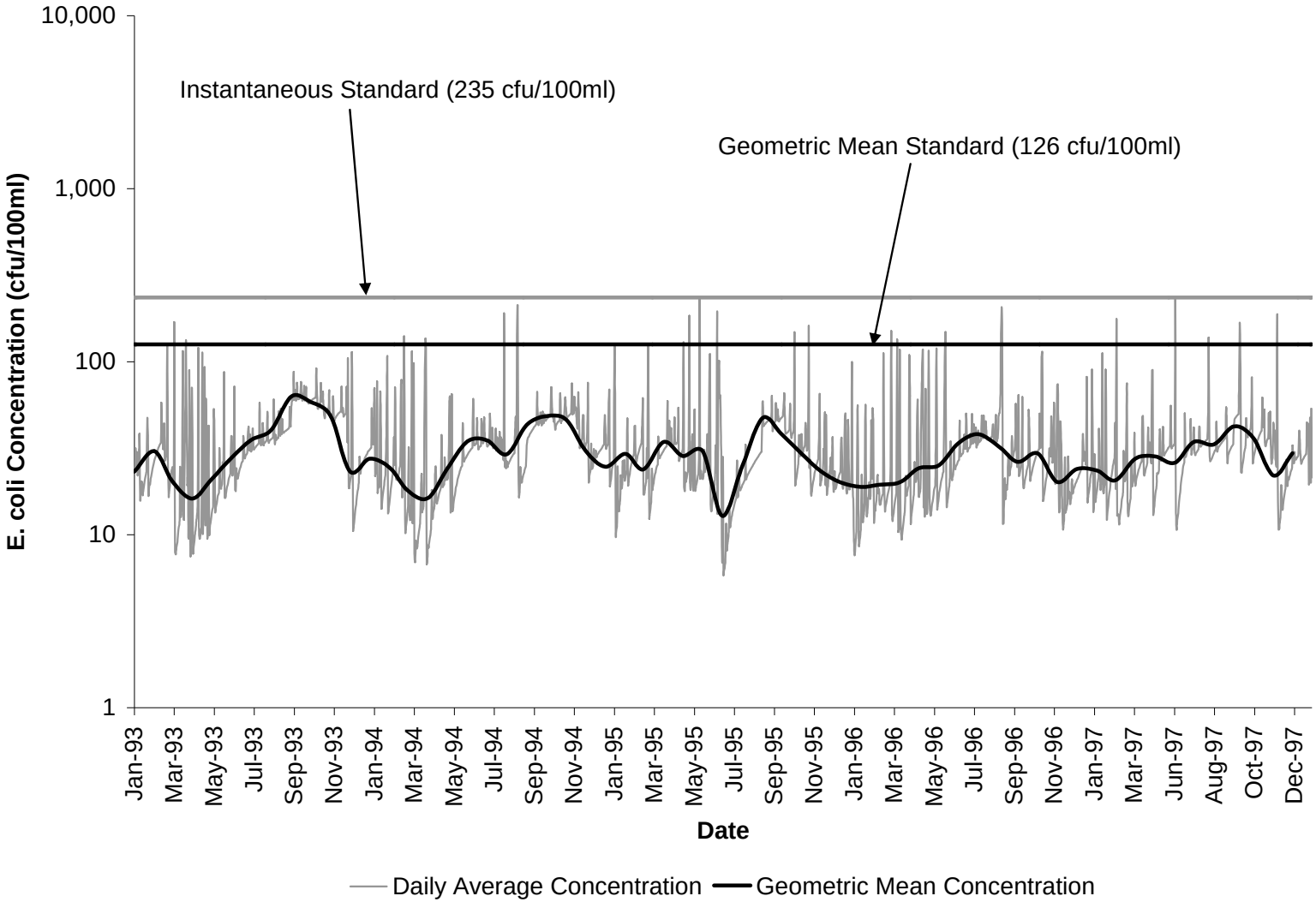

Figure 7.7. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations from successful TMDL allocation (Allocation Scenario 7 from Table 5.1) in South River impairment.

7.2 Sediment TMDL

7.2.1 Point Source Wasteload Allocation

The wasteload allocated to point sources in the watershed was based on the design flow or calculated runoff and the permitted concentration of total suspended solids for each facility (Table 7.6).

Table 7.6. Sediment waste load allocations for permitted point sources in the South River watershed.

Facility Name	Permit No.	Outfall	Design Flow (MGD)	Permitted TSS Conc.		Daily WLA (T/d)	Annual WLA (T/yr)
				Max. (mg/L)	Avg. (mg/L)		
Alcoa Packaging LLC	VA0001767	101	0.019	48	28	0.003	0.7
		102	NA	50	50	<0.001	<0.1
INVISTA - Waynesboro	VA0002160	101	1.44	130.154	40.403	0.709	80.4
		999	N/A	N/A	30	0.447	7.6
Stuarts Draft WWTP	VA0066877	1	4	45	30	0.681	165.8
Harriston STP	VA0027901	1	0.1	45	30	0.017	4.1
Vesper View STP	VA0067962	1	0.1	45	30	0.017	4.1
Waynesboro STP	VA0025151	2	6	45	30	1.022	248.7
Skyline Swannanoa	VA0028037	1	0.15	22	15	0.012	3.1
Grottoes STP	VA0065374	1	0.4	45	30	0.068	16.6
Hugh K Cassell Elementary School	VA0088226	1	0.011	45	30	0.002	0.5
Coyner Springs WTP	VA0092100	1	0.06	60	30	0.014	2.5
Blue Ridge MHC LLC	VA0088943	1	0.024	117	78	0.011	2.6
DOC-Cold Springs Correctional Unit 10	VA0023400	1	0.06	45	30	0.010	2.5
Black Rock Mobile Home Park	VA0088986	1	0.04	45	30	0.007	1.7
10 Single Family Domestic Sewage Facilities			0.01	45	30	0.002	0.4
15 Industrial Stormwater Facilities					100	0.054	19.9
1 Concrete Plant Stormwater Facility					30	0.001	0.4
2 Mining Stormwater Facilities					30	0.002	0.8
37 Construction Stormwater Facilities					100	0.156	57.1
					Total	**3.236**	**619.4**

7.2.2 Nonpoint Source Load Allocation

Load allocations for non-point sources not covered under the general wastewater permits were based on an equal percent reduction from controllable sources. Sediment loads from forest land use are considered to be representative of the natural condition and were not subject to reductions. The existing and allocated sediment loads for each non-point source in the South River impaired watershed are presented in Table 7.7. In addition, the necessary percent reduction is shown for each source.

Table 7.7. Load allocation summary with existing sediment load, sediment source reduction, and sediment allocation load for South River impairment.

Sediment Sources	Existing / Design Load (t/yr)	Sediment Source Reduction (%)	Allocation Load (t/yr)
Hi till cropland	777.6	48	404.3
Low-till cropland	788.9	48	410.2
Pasture 1	108.3	48	56.3
Pasture 2	136.4	48	70.9
Pasture 3	370.5	48	192.6
Transitional	17.4	48	9.0
Forest	43.0	0	43.0
Open urban grass	44.4	48	23.1
Low density residential	114.2	48	59.4
Medium density residential	34.0	48	17.7
High density residential	46.7	48	24.3
Channel erosion	307.8	48	160.1
Point source	619.4	0	619.4
TOTAL	3,408.5		2,090.4

7.2.3 Margin of Safety

An explicit margin of safety of 10% was used for the South River impairment to account for uncertainties in the methodologies used to determine sediment loadings (Tables 7.8 and 7.9).

7.2.4 TMDL Allocations

The sediment TMDL in South River is designed to restore aquatic life uses by reducing sedimentation and improving benthic habitat. While sediment loadings are very dynamic, the accumulation of sediment in the stream is reflective of conditions over extended time periods, ranging from seasonal to annual. Consequently, the most relevant expression of sediment loadings in the South River TMDL is the annual average loading. Table 7.8 shows the total load, wasteload allocations, and margin of safety for South River expressed as an average annual load. No sediment reductions to the point sources in South River are required. The recommended allocations for each non-point source are provided in Table 7.7. Overall, the sediment load in the South River watershed must be reduced by 39% in order to meet the established TMDL endpoint.

Table 7.8. Yearly sediment loads (T/yr) modeled after TMDL allocation in South River impairment.

WLA (T/yr)	LA (T/yr)	MOS (T/yr)	TMDL (T/yr)
619.4	1,471.0	234.1	2,324.5

In order to comply with current USEPA guidance (USEPA, 2007), the South River sediment TMDL was also expressed as a daily load by evaluating the variability and distribution of simulated loads (Table 7.9). The following formula from USEPA's *Technical Support Document for Water Quality-Based Toxics Control* (USEPA, 1991) and USEPA's draft *Options for Expressing Daily Loads in TMDLs* (USEPA, 2007) was used to calculate the daily expression of the TMDL:

$$MDL = LTA * \exp(Z_p \sigma_y - 0.5\sigma_y^{\ 2}) \qquad [7.3]$$

where,

MDL = maximum daily load,

LTA = long term average, which in this case is the average daily load calculated as the average annual load divided by 365,

Z_p = p^{th} percentage point of the standard normal distribution (95th percentile was used),

$\sigma_y = \sqrt{\ln(CV^2 + 1)}$, and

CV = coefficient of variation (estimated at 0.6).

The total maximum daily load was determined from Equation 7.2 using a 95th percentile, a CV of 0.6, and a long term average of 6.37 T/d. It should be noted that the maximum daily load expression represents extreme conditions (with a 5% frequency of occurrence), and routine loadings of this level would not meet average annual loadings that are necessary to restore aquatic life health.

Table 7.9. Daily sediment loads (T/d) modeled after TMDL allocation in South River impairment.

WLA (T/d)	LA (T/d)	MOS (T/d)	TMDL (T/d)
3.33	8.91	1.36	13.60

7.3 Phosphorus TMDL

7.3.1 Point Source Wasteload Allocation

The wasteload allocated to point sources in the watershed was based on the design flow or calculated runoff and the permitted concentration of total phosphorus for each facility (Table 7.10).

Table 7.10. Phosphorus waste load allocations for permitted point sources in the South River watershed.

Facility Name	Permit No.	Outfall	Design Flow (MGD)	TP conc. (mg/L)	Daily WLA (kg/d)	Annual WLA (kg/yr)
Alcoa Packaging LLC	VA0001767	101	0.019	2.5	0.4	65.6
INVISTA - Waynesboro	VA0002160	101	1.44	0.23	2.7	457.7
Stuarts Draft WWTP[1]	VA0066877	1	4	0.3	13.7	2,348.3
Harriston STP[1]	VA0027901	1	0.1	2.5		
Vesper View STP[1]	VA0067962	1	0.1	2.5		
Waynesboro STP	VA0025151	2	4	0.3	9.7	1,657.9
Skyline Swannanoa	VA0028037	1	0.15	2.5	3.0	518.1
Grottoes STP	VA0065374	1	0.4	2.5	8.1	1,381.5
Hugh K Cassell Elementary School	VA0088226	1	0.011	2.5	0.2	38.0
Blue Ridge MHC LLC	VA0088943	1	0.024	2.5	0.5	82.9
DOC - Cold Springs Correctional Unit 10	VA0023400	1	0.06	2.5	1.2	207.2
Black Rock Mobile Home Park	VA0088986	1	0.04	2.5	0.8	138.2
10 Single Family Domestic Sewage Facilities			0.01	2.5	0.2	34.5
				Total	**40.5**	**6,929.9**

[1] Stuarts Draft WWTP, Harriston STP, and Vesper View STP are operated by Augusta County Service Authority and have been assigned a lumped total phosphorus allocation that cannot be exceeded by the three facilities combined.

7.3.2 Nonpoint Source Load Allocation

Load allocations for non-point sources not covered under the general wastewater permits were based on an equal percent reduction from controllable sources. Phosphorus loads from forest land use are considered to be representative of the natural condition and were not subject to reductions. The existing and allocated phosphorus loads for each non-point source in the South River impaired watershed are presented in Table 7.11. In addition, the necessary percent reduction is shown for each source.

Table 7.11. Load allocation summary with existing phosphorus load, phosphorus source reduction, and phosphorus allocation load for South River impairment.

Phosphorus Sources	Existing / Design Load (kg/yr)	Phosphorus Source Reduction (%)	Allocation Load (kg/yr)
Hi till cropland	1,705.1	70	511.5
Low-till cropland	2,786.5	70	836.0
Pasture 1	2,738.6	70	821.6
Pasture 2	2,711.0	70	813.3
Pasture 3	3,464.1	70	1039.2
Transitional	16.8	70	5.0
Forest	123.5	0	123.5
Open urban grass	596.0	70	178.8
Low density residential	514.0	70	154.2
Medium density residential	381.3	70	114.4
High density residential	522.6	70	156.8
Groundwater	1,934.8	70	580.4
Septic systems	1,971.1	70	591.3
Point Sources	6,929.9	0	6,929.9
TOTAL	26,395.3		12,856.0

7.3.3 Margin of Safety

An explicit margin of safety of 10% was used for the South River impairment to account for uncertainties in the methodologies used to determine sediment loadings (Tables 7.12 and 7.13).

7.3.4 TMDL Allocations

The phosphorus TMDL in South River is designed to restore aquatic life uses by reducing phosphorous and improving benthic habitat. While phosphorus loadings are very dynamic, the accumulation of phosphorus in the stream is reflective of conditions over extended time periods, ranging from seasonal to annual. Consequently, the most relevant expression of phosphorus loadings in the South River TMDL is the annual average loading. Table 7.12 shows the total load, wasteload allocations, and margin of safety for South River expressed as an average annual load. No phosphorus reductions to the point sources in South River are required. The recommended allocations for each non-point source are provided in Table 7.11. Overall, the phosphorus load in the South River watershed must be reduced by 51% in order to meet the established TMDL endpoint.

Table 7.12. Yearly phosphorus loads (kg/yr) modeled after TMDL allocation in South River impairment.

WLA (kg/yr)	LA (kg/yr)	MOS (kg/yr)	TMDL (kg/yr)
6,929.9	5,926.1	1,435.5	14,291.5

In order to comply with current USEPA guidance (USEPA, 2007), the South River phosphorus TMDL was also expressed as a daily load by evaluating the variability and distribution of simulated loads (Table 7.13). The following formula from USEPA's *Technical Support Document for Water Quality-Based Toxics Control* (USEPA, 1991) and USEPA's draft *Options for Expressing Daily Loads in TMDLs* (USEPA, 2007) was used to calculate the daily expression of the TMDL:

$$MDL = LTA * \exp(Z_p \sigma_y - 0.5\sigma_y^{\ 2}) \qquad [7.4]$$

where,

MDL = maximum daily load,

LTA = long term average, which in this case is the average daily load calculated as the average annual load divided by 365,

Z_p = p^{th} percentage point of the standard normal distribution (95th percentile was used),

$\sigma_y = \sqrt{\ln(CV^2 + 1)}$, and

CV = coefficient of variation (estimated at 0.6).

The total maximum daily load was determined from Equation 7.3 using a 95th percentile, a CV of 0.6, and a long term average of 39.15 kg/d. It should be noted that the maximum daily load expression represents extreme conditions (with a 5% frequency of occurrence), and routine loadings of this level would not meet average annual loadings that are necessary to restore aquatic life health.

Table 7.13. Daily phosphorus loads (kg/d) modeled after TMDL allocation in South River impairment.

WLA (kg/d)	LA (kg/d)	MOS (kg/d)	TMDL (kg/d)
40.50	34.73	8.36	83.59

Chapter 8. TMDL Implementation and Reasonable Assurance

The goal of the TMDL program is to establish a three-step process that will enable the 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 bacteria and benthic impairment on South River. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by USEPA 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. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation. VADCR and VADEQ will work closely with watershed stakeholders, interested state agencies, and support groups to develop an acceptable implementation plan that will result in meeting the water quality target.

8.1 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, 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 urban wash-off from parking lots and roads and 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. Among the sediment sources identified in the impairment, promising management practices include streambank stabilization, riparian buffers, establishing vegetative cover on barren areas, street sweeping, and improved erosion and sediment control.

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 the opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following Stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

8.2 Bacteria Stage I Scenarios

The goal of the Stage 1 implementation scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) to enable no exceedance of the geometric mean criterion (126 cfu/100 ml) and less than 10 percent exceedance of the single sample maximum criterion (235 cfu/100ml), with no reduction from wildlife sources. The less than 10 percent exceedance rate is a conservative estimate of the extent of implementation needed to have each impaired segment de-listed, currently; a less than 10.5% exceedance rate is required. In addition, the 10 percent exceedance rate criteria mirrors the new proposed bacteria standard meeting a 10% exceedance rate of the single sample maximum criterion (235 cfu/100ml) and a 0% exceedance rate of the geometric mean criterion (126 cfu/100 ml). After the proposed bacteria standard is adopted by the VWCB, the Stage I implementation scenario will become the TMDL allocation scenario, since it will meet the new revised standard.

HSPF was run with a one-hour time step for the period January 1993 to December 1997, as with the TMDL allocation scenarios. The implicit MOS used in allocation scenarios was utilized in determining the Stage 1 implementation scenarios. Several scenarios were run until the Stage 1 goal was met. The Stage 1 allocation for the South River impairment requires a 100% reduction in straight pipes, 75% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 39% reduction in nonpoint source loadings to residential land use, a 39% reduction in nonpoint source loadings to pasture land use, a 39% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.36% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate. Fecal coliform loadings for the existing allocation and Stage 1 allocation scenario for nonpoint sources by land use and direct nonpoint sources are presented in Table 8.1 for the South River impairment. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the fecal coliform loads from the Stage 1 scenario are presented graphically in Figure 8.1.

Table 8.1. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in South River impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	3.15E+14	0.00E+00	100
Livestock	7.76E+13	1.94E+13	75
Wildlife	1.21E+14	1.21E+14	0
Total	*5.14E+14*	*1.40E+14*	73
Land-based			
Residential	6.98E+15	4.26E+15	39
Cropland	4.23E+14	2.58E+14	39
Pasture	8.01E+16	4.89E+16	39
Forest	7.34E+14	7.34E+14	0
Total	*8.82E+16*	*5.41E+16*	39

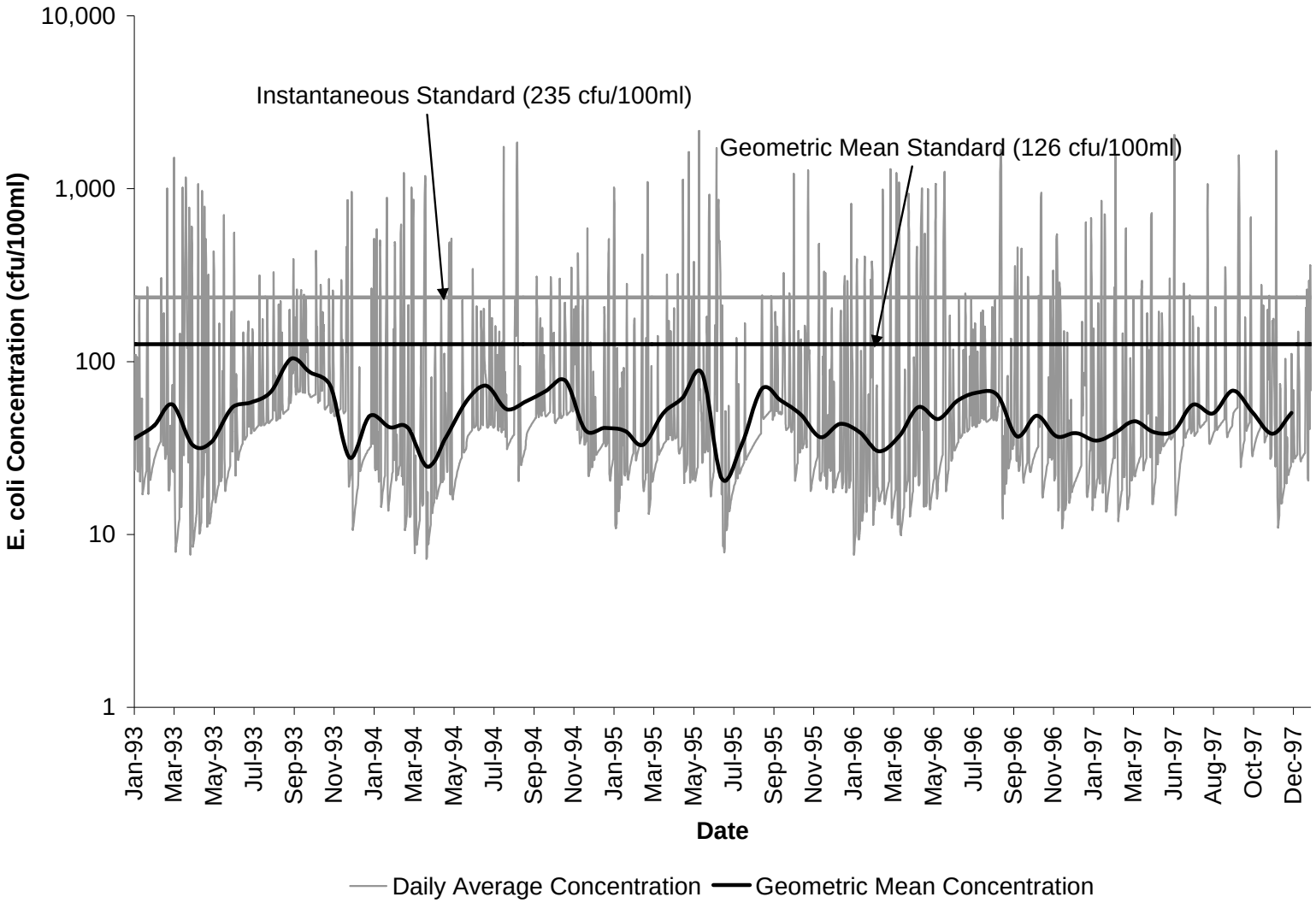

Figure 8.1. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in South River impairment.

8.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the watershed. Several BMPs known to be effective in controlling bacteria, sediment, and nutrients have also been identified for implementation as part of the 2004 Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the Potomac River Basin.

8.4 Reasonable Assurance for Implementation

8.4.1 Follow-up Monitoring

Following the development of the TMDL, the 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 DEQ Guidance Memo No. 03-2004 (http://www.deq.virginia.gov/waterguidance/pdf/032004.pdf), 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 where 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 have to occur in 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 Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. 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 30 of each year.

VADEQ staff, in cooperation with VADCR staff, the Implementation Plan 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 Implementation Plan (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' or 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 quality assurance/quality control (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 of the monitoring managers in each regional office an increase in 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 on 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/.

In order to demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan 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 (bacteria, 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.

8.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current USEPA 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 wasteload allocations can and will be implemented. USEPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to USEPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act 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. USEPA 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 utilizes the Virginia NPDES (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 IP development, especially those implemented through the water quality based effluent limitations. However, those requirements that are considered

BMPs may be enhanced by inclusion in the TMDL IP, and their connection to the targeted impairment. New permitted point source discharges will be allowed under the waste load allocation provided they implement applicable VPDES requirements (including any BMP, offset, trading, or payment-in-lieu conditions established to meet any future reduction requirements). Permits issued for facilities with wasteload allocations developed as part of a TMDL must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per USEPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, USEPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on VADEQ's web site at http://www.deq.virginia.gov/waterguidance/.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed. An exception are the municipal separate storm sewer systems (MS4s) that are both covered by NPDES permits and expected to be included in TMDL implementation plans. It is the intent of the Commonwealth that the TMDL will be implemented using existing regulations and programs. VADEQ and VADCR coordinate separate State programs that regulate the management of pollutants carried by storm water runoff. VADEQ regulates storm water discharges associated with "industrial activities", while VADCR regulates storm water discharges from construction sites and MS4s. USEPA 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 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. 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/soil_&_water/stormwat.shtml. As there are no MS4s permitted in the South River watershed at the time of this TMDL, they are not included in this study.

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 USEPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to USEPA in which VADEQ commits to regularly updating the WQMPs. Thus, 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 USEPA-approved TMDLs and TMDL implementation plans to the State Water Control Board for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act'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

8.4.3 Implementation Funding Sources

The implementation on pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, USEPA Section 319 funds Virginia's Nonpoint Source Management Program, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, and the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution). With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding stream for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/bay/wqif.html and at http://www.dcr.virginia.gov/soil_&_water/wqia.shtml.

8.4.4 Addressing Wildlife Contributions

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. Virginia and USEPA are not proposing the elimination of natural wildlife to allow for the attainment of water quality standards. However, managing overpopulations of wildlife remains an option available to local stakeholders. Should during the implementation plan development phase of a TMDL process, and in consultation with a local government or land owner, the Department of Game and Inland Fisheries (VDGIF) determine that a population of resident geese, deer or other wildlife is a at "nuisance" levels, measures to reduce such populations may be deemed acceptable if undertaken under the supervision, or issued permit, of the VDGIF or the U.S. Fish and Wildlife Service as appropriate.

Additional information on VDGIF's wildlife programs can be found at http://www.dgif.virginia.gov/hunting/va_game_wildlife/.

Based on the above, USEPA and Virginia have developed a process to address the wildlife issue. First in this process 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 only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the Stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described 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, a use attainability analysis (UAA) may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

8.4.5 Attainability of Designated Use

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;
2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or

6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the USEPA, will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/pdf/WQS05A_1.pdf.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E. provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a UAA according to the criteria listed above and a schedule established by the Board. The amendment further states “If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed.”

Chapter 9. Public Participation

The development of the South River Bacteria and Benthic TMDL would not have been possible without public participation.

The first public meeting was held at the Council Chambers in Waynesboro, VA on April 15, 2008, to discuss the need for a TMDL, discuss the draft watershed stressor analysis, and review the approach for TMDL development. Thirty people attended the meeting. Copies of the presentation materials and various TMDL information handouts were available for public distribution. Public notice of the meetings was printed in the Virginia Register and advertised on the VADEQ and Central Shenandoah Planning District Commission websites. Notification regarding the meetings was sent to area appointed and elected officials and Local Steering Committee (LSC) members. Members of the LSC were encouraged to distribute fliers advertising the meetings as appropriate. The general public was notified of the meetings through advertisements in the community calendar section of local newspapers. There was a 30-day public comment period for the public meeting; however, no written comments were received.

The final public meeting was held at the Waynesboro City Council Chambers, Charles T. Yancey Municipal Building in Waynesboro, VA on June 11, 2009, to discuss the source allocations and reductions required to meet the TMDL. Copies of the draft TMDL report were available for public review and comment. Public notice of the meetings was printed in the Virginia Register and advertised on the VADEQ and Central Shenandoah Planning District Commission websites. Notification regarding the meeting was sent to area appointed and elected officials, LSC members, and prior public meeting attendees. Members of the LSC were encouraged to distribute fliers advertising the meetings as appropriate. The general public was notified of the meeting through advertisements in the community calendar section of local newspaper. There was a 30-day public comment period for this meeting that extended from June 11, 2009 to July 11, 2009. One written comment was received and responsed to.

In addition to keeping the public apprised of progress in the development of the South River Bacteria and Benthic TMDL, a TMDL LSC was also established to help advise the TMDL developers. LSC meetings were held for this project on April 30, 2008 and November 13, 2008 at the Waynesboro Public Library in Waynesboro, Virginia. The LSC meetings were also advertised on the VADEQ and Central Shenandoah Planning District Commission websites. Notification regarding the meeting was sent to area appointed and elected officials and LSC members. The general public was solicited to participate on the LSC during the first public meeting in addition to agencies and groups already represented on the LSC. The LSC membership for the South River Bacteria and Benthic TMDL included representatives from the following agencies and organizations:

- Virginia Department of Environmental Quality
- Virginia Department of Conservation and Recreation
- Virginia Cooperative Extension

- Central Shenandoah Planning District Commission
- Shenandoah Valley Soil and Water Conservation District
- City of Waynesboro
- Augusta County
- Rockingham County
- Nelson County
- Albemarle County
- INVISTA
- DuPont

Thirteen and four people attended the April and November meetings, respectively. LSC meetings were used as a forum to review data and assumptions used in the modeling, and to provide local government agencies and stakeholders an opportunity to raise concerns about the implications of the TMDL for their jurisdictions. The generous assistance of the staff of these agencies is gratefully acknowledged.

Glossary

Allocation
That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario
A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Background levels
Levels representing the chemical, physical, and biological conditions that would result from natural geomorphologic processes such as weathering and dissolution. A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Bacterial Source Tracking (BST)
A collection of scientific methods used to track sources of fecal coliform.

Best Management Practices (BMP)
Methods, measures, or practices that are determined to be reasonable and cost- effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

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

Die-off (of fecal coliform)
Reduction in the fecal coliform population due to predation by other bacteria as well as by adverse environmental conditions (e.g., UV radiation, pH).

Direct Nonpoint Sources
Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: Direct loads from straight pipes to streams.

E-911 digital data
Emergency response database prepared by the county that contains graphical data on road centerlines and buildings. The database contains approximate outlines of buildings, including dwellings and poultry houses.

Failing septic system
Septic systems in which drain fields have failed such that effluent (wastewater) that is supposed to percolate into the soil, now rises to the surface and ponds on the surface where it can flow over the soil surface to streams or contribute pollutants to the surface where they can be lost during storm runoff events.

Fecal coliform
A type of bacteria found in the feces of various warm-blooded animals that is used as indicator of the possible presence of pathogenic (disease causing) organisms.

Geometric mean
The geometric mean is simply the nth root of the product of n values. Using the geometric mean lessens the significance of a few extreme values (extremely high or low values). In practical terms, this means that if you have just a few bad samples, their weight is lessened.

Mathematically the geometric mean, $\bar{x}_g$, is expressed as: $\bar{x}_g = \sqrt[n]{x_1 \cdot x_2 \cdot x_3 \ldots \cdot x_n}$ where n is the number of samples, and x_i is the value of sample i.

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.

HSPF (Hydrological Simulation Program-Fortran)
A computer-based model that calculates runoff, sediment yield, and fate and transport of various pollutants to the stream. The model was developed under the direction of the U.S. Environmental Protection Agency (EPA).

Instantaneous criterion
The instantaneous criterion or instantaneous water quality standard is the value of the water quality standard that should not be exceeded at any time. For example, the Virginia instantaneous water quality standard for fecal coliform is 1,000 cfu/100 mL. If this value is exceeded at any time, the water body is in exceedance of the state water quality standard.

Load Allocation (LA)
The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

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. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

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

Nonpoint Source
Pollution that is not released through pipes but rather 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.

Pathogen
Disease-causing agent, especially microorganisms such as certain bacteria, protozoa, and viruses.

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.

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.

Reach
Segment of a stream or river.

Runoff
That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system
An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives liquid and solid wastes from a residence or business and a drainfield or subsurface absorption system consisting of a series of tile or percolation lines for disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

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.

Straight Pipe
Delivers wastewater directly from a building, e.g., house or milking parlor, to a stream, pond, lake, or river.

Total Maximum Daily Load (TMDL)
The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) 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.

Urban Runoff
Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.1

Validation (of a model)
Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.

Wasteload Allocation (WLA)
The portion of a receiving water's 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.

Water Quality Standard
Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation 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.

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Appendix A – Historic Water Quality Data

Table A.1. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH002.14 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH002.14	07/11/2001	100	N/A	0.2
1-BSTH002.14	09/06/2001	200	N/A	0
1-BSTH002.14	12/03/2001	100	N/A	0.2
1-BSTH002.14	02/05/2002	100	N/A	0
1-BSTH002.14	04/04/2002	100	N/A	0.6
1-BSTH002.14	06/03/2002	200	N/A	0.3
1-BSTH002.14	08/07/2002	100	N/A	0
1-BSTH002.14	10/17/2002	1100	N/A	2.82
1-BSTH002.14	12/03/2002	100	N/A	#N/A
1-BSTH002.14	02/05/2003	100	N/A	0.1
1-BSTH002.14	04/16/2003	100	N/A	0.14
1-BSTH002.14	06/04/2003	4900	N/A	0.58

N/A – Data not available

Table A.2. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH007.80 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH007.80	01/30/1990	1600	N/A	2.1
1-BSTH007.80	02/21/1990	100	N/A	0.3
1-BSTH007.80	07/02/1991	3400	N/A	0.8
1-BSTH007.80	10/17/1991	100	N/A	1
1-BSTH007.80	11/18/1991	100	N/A	0.1
1-BSTH007.80	12/16/1991	100	N/A	0.1
1-BSTH007.80	01/21/1992	100	N/A	0
1-BSTH007.80	03/09/1992	100	N/A	1.08
1-BSTH007.80	04/14/1992	100	N/A	0.1
1-BSTH007.80	05/18/1992	200	N/A	1.2
1-BSTH007.80	06/04/1992	500	N/A	1.8
1-BSTH007.80	07/07/1992	200	N/A	0.6
1-BSTH007.80	08/10/1992	200	N/A	0.2
1-BSTH007.80	09/14/1992	100	N/A	0.9
1-BSTH007.80	10/20/1992	100	N/A	0.1
1-BSTH007.80	11/19/1992	200	N/A	0.1
1-BSTH007.80	12/01/1992	300	N/A	0.6
1-BSTH007.80	01/12/1993	300	N/A	1.146
1-BSTH007.80	02/08/1993	100	N/A	0
1-BSTH007.80	03/08/1993	200	N/A	3.9
1-BSTH007.80	04/12/1993	400	N/A	1.6
1-BSTH007.80	05/17/1993	100	N/A	0.512
1-BSTH007.80	06/17/1993	1400	N/A	0
1-BSTH007.80	07/19/1993	400	N/A	1.2
1-BSTH007.80	08/26/1993	200	N/A	0.12
1-BSTH007.80	09/16/1993	800	N/A	0.2
1-BSTH007.80	10/26/1993	100	N/A	0.9
1-BSTH007.80	11/16/1993	100	N/A	0.18

N/A – Data not available

Table A.3. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH007.80 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH007.80	12/14/1993	100	N/A	0
1-BSTH007.80	02/14/1994	100	N/A	0.974
1-BSTH007.80	03/23/1994	100	N/A	0.561
1-BSTH007.80	04/19/1994	200	N/A	0
1-BSTH007.80	05/10/1994	100	N/A	0.6
1-BSTH007.80	06/20/1994	300	N/A	0.86
1-BSTH007.80	08/15/1994	100	N/A	0.375
1-BSTH007.80	09/29/1994	600	N/A	0.68
1-BSTH007.80	10/20/1994	200	N/A	0
1-BSTH007.80	11/15/1994	100	N/A	0.58
1-BSTH007.80	12/06/1994	300	N/A	1.26
1-BSTH007.80	01/19/1995	400	N/A	3.1
1-BSTH007.80	02/28/1995	100	N/A	0.8
1-BSTH007.80	03/29/1995	100	N/A	0.1
1-BSTH007.80	04/24/1995	700	N/A	0.714
1-BSTH007.80	05/30/1995	900	N/A	1.502
1-BSTH007.80	06/26/1995	1100	N/A	5.95
1-BSTH007.80	07/20/1995	100	N/A	0.1
1-BSTH007.80	08/15/1995	200	N/A	0
1-BSTH007.80	09/19/1995	100	N/A	1.8
1-BSTH007.80	10/18/1995	100	N/A	0.781
1-BSTH007.80	11/13/1995	500	N/A	2.197
1-BSTH007.80	12/11/1995	100	N/A	0.92
1-BSTH007.80	02/05/1996	200	N/A	0.57
1-BSTH007.80	03/28/1996	200	N/A	1.3
1-BSTH007.80	04/25/1996	500	N/A	0.2
1-BSTH007.80	05/15/1996	500	N/A	1.1
1-BSTH007.80	06/24/1996	400	N/A	1.3

N/A – Data not available

Table A.4. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH007.80 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH007.80	07/18/1996	100	N/A	0.66
1-BSTH007.80	08/20/1996	100	N/A	0
1-BSTH007.80	10/10/1996	2000	N/A	1.4
1-BSTH007.80	11/13/1996	600	N/A	0.6
1-BSTH007.80	12/19/1996	300	N/A	0.5
1-BSTH007.80	01/22/1997	100	N/A	0.1
1-BSTH007.80	02/18/1997	100	N/A	1.2
1-BSTH007.80	03/27/1997	100	N/A	0.2
1-BSTH007.80	04/29/1997	100	N/A	1.3
1-BSTH007.80	05/28/1997	100	N/A	0.5
1-BSTH007.80	06/19/1997	100	N/A	0.3
1-BSTH007.80	07/31/1997	100	N/A	0
1-BSTH007.80	08/07/1997	400	N/A	0.9
1-BSTH007.80	09/29/1997	1800	N/A	2
1-BSTH007.80	10/14/1997	100	N/A	0
1-BSTH007.80	11/20/1997	200	N/A	0
1-BSTH007.80	12/17/1997	100	N/A	0.2
1-BSTH007.80	01/15/1998	100	N/A	1.1
1-BSTH007.80	02/18/1998	600	N/A	2.6
1-BSTH007.80	03/26/1998	100	N/A	0.42
1-BSTH007.80	04/30/1998	300	N/A	0
1-BSTH007.80	05/19/1998	100	N/A	0.1
1-BSTH007.80	06/15/1998	2000	N/A	1.6
1-BSTH007.80	07/29/1998	500	N/A	0
1-BSTH007.80	08/20/1998	100	N/A	1.3
1-BSTH007.80	09/21/1998	500	N/A	0.1
1-BSTH007.80	10/01/1998	300	N/A	0.19
1-BSTH007.80	11/23/1998	100	N/A	0.2

N/A – Data not available

Table A.5. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH007.80 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH007.80	12/21/1998	100	N/A	0
1-BSTH007.80	01/27/1999	1100	N/A	1.81
1-BSTH007.80	02/25/1999	100	N/A	0
1-BSTH007.80	03/31/1999	100	N/A	0
1-BSTH007.80	04/21/1999	400	N/A	0
1-BSTH007.80	05/19/1999	100	N/A	0
1-BSTH007.80	06/22/1999	100	N/A	0.11
1-BSTH007.80	07/29/1999	1300	N/A	0.51
1-BSTH007.80	08/12/1999	200	N/A	0
1-BSTH007.80	09/29/1999	8000	N/A	1.74
1-BSTH007.80	11/29/1999	100	N/A	1.65
1-BSTH007.80	12/20/1999	100	N/A	0
1-BSTH007.80	02/24/2000	100	N/A	0.31
1-BSTH007.80	03/28/2000	100	N/A	0.8
1-BSTH007.80	04/24/2000	100	N/A	0.6
1-BSTH007.80	05/31/2000	100	N/A	0.3
1-BSTH007.80	06/20/2000	4800	N/A	2.1
1-BSTH007.80	07/27/2000	100	N/A	0.78
1-BSTH007.80	08/28/2000	100	N/A	0.85
1-BSTH007.80	09/27/2000	100	N/A	1.679
1-BSTH007.80	10/19/2000	100	N/A	0.1
1-BSTH007.80	12/18/2000	200	N/A	2.9
1-BSTH007.80	01/24/2001	100	N/A	1.7
1-BSTH007.80	02/28/2001	100	N/A	0.3
1-BSTH007.80	03/26/2001	100	N/A	2.1
1-BSTH007.80	04/12/2001	400	N/A	0.4
1-BSTH007.80	05/24/2001	600	N/A	4
1-BSTH007.80	06/28/2001	400	N/A	0

N/A – Data not available

Table A.6. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH007.80 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH007.80	07/11/2001	100	N/A	0.2
1-BSTH007.80	09/06/2001	200	N/A	0
1-BSTH007.80	12/03/2001	100	N/A	0.2
1-BSTH007.80	02/05/2002	100	N/A	0
1-BSTH007.80	04/04/2002	100	N/A	0.6
1-BSTH007.80	06/03/2002	100	N/A	0.3
1-BSTH007.80	07/01/2002	100	N/A	0.4
1-BSTH007.80	09/12/2002	50	40	0
1-BSTH007.80	11/13/2002	1900	800	1.87
1-BSTH007.80	01/08/2003	50	40	2.08
1-BSTH007.80	03/10/2003	25	10	1.44
1-BSTH007.80	05/01/2003	250	490	1.25
1-BSTH007.80	07/08/2003	650	260	4.28
1-BSTH007.80	09/30/2003	400	200	0.73
1-BSTH007.80	12/11/2003	1100	800	1.94
1-BSTH007.80	01/21/2004	75	10	0.32
1-BSTH007.80	03/25/2004	25	10	0.01
1-BSTH007.80	05/20/2004	300	300	1.26
1-BSTH007.80	07/06/2004	420	400	2.47
1-BSTH007.80	09/02/2004	350	180	0.08
1-BSTH007.80	11/08/2004	25	50	1.11
1-BSTH007.80	01/18/2005	280	75	2.84
1-BSTH007.80	03/02/2005	100	25	0.74
1-BSTH007.80	05/03/2005	25	25	0.96
1-BSTH007.80	07/07/2005	25	25	0
1-BSTH007.80	10/25/2005	1300	1100	1.61
1-BSTH007.80	11/30/2005	2000	2000	1.06
1-BSTH007.80	12/20/2005	25	50	1.12

N/A – Data not available

Table A.7. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH007.80 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH007.80	01/25/2006	25	N/A	0.57
1-BSTH007.80	04/24/2006	200	N/A	#N/A
1-BSTH007.80	05/25/2006	100	N/A	#N/A
1-BSTH007.80	07/27/2006	100	N/A	#N/A
1-BSTH007.80	09/13/2006	250	N/A	#N/A
1-BSTH007.80	11/28/2006	25	N/A	#N/A
1-BSTH007.80	01/22/2007	25	N/A	#N/A
1-BSTH007.80	02/26/2007	25	N/A	#N/A
1-BSTH007.80	03/29/2007	920	N/A	#N/A
1-BSTH007.80	04/02/2007	50	N/A	#N/A
1-BSTH007.80	05/30/2007	150	N/A	#N/A
1-BSTH007.80	06/07/2007	220	N/A	#N/A
1-BSTH007.80	07/16/2007	50	N/A	#N/A
1-BSTH007.80	08/14/2007	25	N/A	
1-BSTH007.80	09/18/2007	25	N/A	#N/A
1-BSTH007.80	10/24/2007	75	N/A	#N/A
1-BSTH007.80	11/13/2007	25	N/A	#N/A
1-BSTH007.80	12/10/2007	25	N/A	#N/A
1-BSTH007.80	01/14/2008	100	N/A	#N/A
1-BSTH007.80	01/25/2006	25	N/A	0.57
1-BSTH007.80	04/24/2006	200	N/A	#N/A
1-BSTH007.80	05/25/2006	100	N/A	#N/A
1-BSTH007.80	07/27/2006	100	N/A	#N/A
1-BSTH007.80	09/13/2006	250	N/A	#N/A
1-BSTH007.80	11/28/2006	25	N/A	#N/A
1-BSTH007.80	01/22/2007	25	N/A	#N/A
1-BSTH007.80	02/26/2007	25	N/A	#N/A
1-BSTH007.80	03/29/2007	920	N/A	#N/A

N/A – Data not available

Table A.8. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH014.49 South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH014.49	07/17/2003	N/A	100	0.02
1-BSTH014.49	09/03/2003	N/A	150	2.41
1-BSTH014.49	12/03/2003	N/A	25	0
1-BSTH014.49	02/17/2004	N/A	75	0
1-BSTH014.49	04/15/2004	N/A	1200	2.5
1-BSTH014.49	06/01/2004	N/A	200	0.96
1-BSTH014.49	07/06/2004	N/A	250	2.47
1-BSTH014.49	09/02/2004	N/A	75	0.08
1-BSTH014.49	11/08/2004	N/A	25	1.11
1-BSTH014.49	01/18/2005	N/A	88	2.84
1-BSTH014.49	03/02/2005	N/A	25	0.74
1-BSTH014.49	05/03/2005	N/A	25	0.96

N/A – Data not available

Table A.9. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH019.52 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH019.52	07/17/2003	N/A	150	0.02
1-BSTH019.52	09/03/2003	N/A	150	2.41
1-BSTH019.52	12/03/2003	N/A	75	0
1-BSTH019.52	02/17/2004	N/A	50	0
1-BSTH019.52	04/15/2004	N/A	520	2.5
1-BSTH019.52	06/01/2004	N/A	75	0.96
1-BSTH019.52	07/06/2004	N/A	350	2.47
1-BSTH019.52	09/02/2004	N/A	320	0.08
1-BSTH019.52	11/08/2004	N/A	25	1.11
1-BSTH019.52	01/18/2005	N/A	50	2.84
1-BSTH019.52	03/02/2005	N/A	25	0.74
1-BSTH019.52	05/03/2005	N/A	100	0.96
1-BSTH019.52	01/22/2007	25	75	#N/A
1-BSTH019.52	02/26/2007	25	25	#N/A
1-BSTH019.52	03/29/2007	180	320	#N/A
1-BSTH019.52	04/02/2007	25	25	#N/A
1-BSTH019.52	05/30/2007	75	100	#N/A
1-BSTH019.52	06/07/2007	25	250	#N/A
1-BSTH019.52	07/05/2007	200	120	#N/A
1-BSTH019.52	08/27/2007	650	350	#N/A
1-BSTH019.52	09/12/2007	180	100	#N/A
1-BSTH019.52	10/22/2007	150	220	#N/A
1-BSTH019.52	11/06/2007	25	100	#N/A
1-BSTH019.52	12/06/2007	50	25	#N/A
1-BSTH019.52	07/17/2003	N/A	150	0.02
1-BSTH019.52	09/03/2003	N/A	150	2.41
1-BSTH019.52	12/03/2003	N/A	75	0
1-BSTH019.52	02/17/2004	N/A	50	0

N/A – Data not available

Table A.10. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH027.85 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH027.85	01/30/1990	1100	N/A	2.1
1-BSTH027.85	02/21/1990	100	N/A	0.3
1-BSTH027.85	10/28/1991	100	N/A	0.1
1-BSTH027.85	11/20/1991	300	N/A	0
1-BSTH027.85	12/11/1991	800	N/A	0.5
1-BSTH027.85	01/16/1992	600	N/A	0.1
1-BSTH027.85	02/24/1992	100	N/A	0.4
1-BSTH027.85	03/12/1992	1600	N/A	0.873
1-BSTH027.85	05/19/1992	8000	N/A	1.52
1-BSTH027.85	07/28/1992	1100	N/A	2.5
1-BSTH027.85	08/13/1992	300	N/A	1.8
1-BSTH027.85	09/10/1992	100	N/A	2.1
1-BSTH027.85	10/28/1992	100	N/A	0
1-BSTH027.85	11/24/1992	1900	N/A	2.9
1-BSTH027.85	12/15/1992	100	N/A	1.12
1-BSTH027.85	01/26/1993	300	N/A	0.9
1-BSTH027.85	02/16/1993	100	N/A	0.87
1-BSTH027.85	03/18/1993	100	N/A	1.629
1-BSTH027.85	04/19/1993	900	N/A	1.7
1-BSTH027.85	05/20/1993	8000	N/A	0.92
1-BSTH027.85	07/14/1993	100	N/A	0.4
1-BSTH027.85	08/12/1993	200	N/A	0.4
1-BSTH027.85	10/12/1993	100	N/A	1.1
1-BSTH027.85	11/29/1993	6800	N/A	2.86
1-BSTH027.85	12/08/1993	200	N/A	3.02
1-BSTH027.85	01/11/1994	100	N/A	0.6
1-BSTH027.85	02/09/1994	300	N/A	0.992
1-BSTH027.85	04/14/1994	300	N/A	0.779

N/A – Data not available

Table A.11. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH027.85 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH027.85	05/11/1994	100	N/A	0.44
1-BSTH027.85	06/08/1994	200	N/A	0
1-BSTH027.85	07/12/1994	300	N/A	0.8
1-BSTH027.85	08/11/1994	100	N/A	0
1-BSTH027.85	09/08/1994	100	N/A	0
1-BSTH027.85	10/17/1994	100	N/A	0.66
1-BSTH027.85	12/13/1994	100	N/A	0.4
1-BSTH027.85	01/10/1995	100	N/A	0.86
1-BSTH027.85	02/22/1995	100	N/A	0
1-BSTH027.85	03/20/1995	300	N/A	0
1-BSTH027.85	04/10/1995	100	N/A	0.4
1-BSTH027.85	05/22/1995	100	N/A	0.659
1-BSTH027.85	06/14/1995	400	N/A	2.02
1-BSTH027.85	07/17/1995	400	N/A	0.16
1-BSTH027.85	08/28/1995	1600	N/A	0
1-BSTH027.85	09/13/1995	100	N/A	0.1
1-BSTH027.85	10/23/1995	1900	N/A	2.52
1-BSTH027.85	11/13/1995	900	N/A	2.197
1-BSTH027.85	12/06/1995	200	N/A	0.3
1-BSTH027.85	01/29/1996	200	N/A	3.37
1-BSTH027.85	02/12/1996	100	N/A	0.98
1-BSTH027.85	03/25/1996	100	N/A	0
1-BSTH027.85	05/02/1996	100	N/A	1.09
1-BSTH027.85	06/17/1996	300	N/A	0
1-BSTH027.85	07/17/1996	200	N/A	0.6
1-BSTH027.85	08/12/1996	900	N/A	0.98
1-BSTH027.85	10/15/1996	300	N/A	0
1-BSTH027.85	11/14/1996	600	N/A	0

N/A – Data not available

Table A.12. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH027.85 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH027.85	12/10/1996	300	N/A	2.08
1-BSTH027.85	01/21/1997	300	N/A	0.5
1-BSTH027.85	02/10/1997	200	N/A	0.8
1-BSTH027.85	03/12/1997	600	N/A	0
1-BSTH027.85	04/16/1997	300	N/A	0.7
1-BSTH027.85	05/01/1997	700	N/A	1
1-BSTH027.85	06/10/1997	700	N/A	0
1-BSTH027.85	07/15/1997	200	N/A	0.1
1-BSTH027.85	08/04/1997	700	N/A	0.1
1-BSTH027.85	09/18/1997	100	N/A	0
1-BSTH027.85	10/16/1997	100	N/A	0.18
1-BSTH027.85	11/17/1997	200	N/A	0.7
1-BSTH027.85	12/10/1997	100	N/A	0
1-BSTH027.85	01/13/1998	100	N/A	1.1
1-BSTH027.85	02/12/1998	900	N/A	1.1
1-BSTH027.85	03/18/1998	100	N/A	1.11
1-BSTH027.85	04/14/1998	100	N/A	1.7
1-BSTH027.85	05/13/1998	600	N/A	1.5
1-BSTH027.85	06/29/1998	600	N/A	0.5
1-BSTH027.85	07/14/1998	100	N/A	0
1-BSTH027.85	08/18/1998	400	N/A	1.4
1-BSTH027.85	09/29/1998	100	N/A	0
1-BSTH027.85	10/19/1998	100	N/A	0
1-BSTH027.85	11/16/1998	100	N/A	0.3
1-BSTH027.85	12/15/1998	100	N/A	0.9
1-BSTH027.85	01/19/1999	100	N/A	1.81
1-BSTH027.85	02/11/1999	100	N/A	0
1-BSTH027.85	03/25/1999	100	N/A	0.2

N/A – Data not available

Table A.13. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH027.85 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH027.85	04/19/1999	200	N/A	0
1-BSTH027.85	05/06/1999	100	N/A	0
1-BSTH027.85	06/21/1999	100	N/A	0
1-BSTH027.85	07/22/1999	100	N/A	0.75
1-BSTH027.85	08/11/1999	100	N/A	0
1-BSTH027.85	09/23/1999	100	N/A	0.4
1-BSTH027.85	10/27/1999	100	N/A	0.03
1-BSTH027.85	11/18/1999	100	N/A	0
1-BSTH027.85	12/09/1999	100	N/A	0.5
1-BSTH027.85	01/13/2000	300	N/A	0.6
1-BSTH027.85	02/07/2000	100	N/A	0
1-BSTH027.85	03/20/2000	100	N/A	0.7
1-BSTH027.85	04/13/2000	100	N/A	1
1-BSTH027.85	06/14/2000	400	N/A	0.4
1-BSTH027.85	07/12/2000	100	N/A	0
1-BSTH027.85	08/14/2000	200	N/A	0.29
1-BSTH027.85	09/28/2000	100	N/A	1.679
1-BSTH027.85	10/11/2000	100	N/A	0.1
1-BSTH027.85	11/13/2000	100	N/A	0.5
1-BSTH027.85	12/12/2000	100	N/A	0
1-BSTH027.85	01/17/2001	100	N/A	0
1-BSTH027.85	02/20/2001	100	N/A	0.6
1-BSTH027.85	03/13/2001	100	N/A	0.2
1-BSTH027.85	04/10/2001	200	N/A	0.3
1-BSTH027.85	05/23/2001	2500	N/A	4.1
1-BSTH027.85	08/01/2001	400	N/A	4.3
1-BSTH027.85	10/09/2001	100	N/A	0.1
1-BSTH027.85	12/20/2001	100	N/A	0.1

N/A – Data not available

Table A.14. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH027.85 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH027.85	02/11/2002	100	N/A	0.5
1-BSTH027.85	04/11/2002	100	N/A	0.4
1-BSTH027.85	06/04/2002	100	N/A	0.4
1-BSTH027.85	07/18/2002	25	20	1.6
1-BSTH027.85	09/05/2002	75	30	0.16
1-BSTH027.85	11/05/2002	125	30	0.28
1-BSTH027.85	01/15/2003	50	30	0
1-BSTH027.85	03/12/2003	25	10	1.4
1-BSTH027.85	05/27/2003	120	120	2.53
1-BSTH027.85	07/17/2003	250	100	0.02
1-BSTH027.85	09/03/2003	230	50	2.41
1-BSTH027.85	12/03/2003	100	80	0
1-BSTH027.85	02/17/2004	50	10	0
1-BSTH027.85	04/15/2004	1400	790	2.5
1-BSTH027.85	06/01/2004	300	210	0.96
1-BSTH027.85	07/06/2004	400	180	2.47
1-BSTH027.85	08/30/2004	100	450	0
1-BSTH027.85	09/02/2004	300	150	0.08
1-BSTH027.85	10/25/2004	100	50	0.42
1-BSTH027.85	11/08/2004	50	25	1.11
1-BSTH027.85	12/15/2004	75	25	1.01
1-BSTH027.85	01/18/2005	50	50	2.84
1-BSTH027.85	03/02/2005	25	25	0.74
1-BSTH027.85	04/25/2005	120	120	0.66
1-BSTH027.85	05/03/2005	25	75	0.96
1-BSTH027.85	06/27/2005	25	75	0
1-BSTH027.85	07/13/2005	220	180	1.75
1-BSTH027.85	08/11/2005	280	250	1.12

N/A – Data not available

Table A.15. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 1-BSTH027.85 in South River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Observed E. coli Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
1-BSTH027.85	09/29/2005	120	120	0.34
1-BSTH027.85	10/17/2005	280	75	0.06
1-BSTH027.85	11/28/2005	50	25	0.35
1-BSTH027.85	12/13/2005	120	120	0
1-BSTH027.85	01/10/2006	50	25	0
1-BSTH027.85	02/07/2006	25	50	#N/A
1-BSTH027.85	03/01/2006	50	50	#N/A
1-BSTH027.85	04/06/2006	25	25	#N/A
1-BSTH027.85	05/11/2006	200	200	#N/A
1-BSTH027.85	06/05/2006	180	100	#N/A
1-BSTH027.85	07/12/2006	200	100	#N/A
1-BSTH027.85	08/15/2006	180	25	#N/A
1-BSTH027.85	09/11/2006	100	180	#N/A
1-BSTH027.85	10/03/2006	50	25	#N/A
1-BSTH027.85	11/08/2006	520	420	#N/A
1-BSTH027.85	12/04/2006	25	25	#N/A
1-BSTH027.85	01/10/2007	25	25	#N/A
1-BSTH027.85	02/06/2007	25	25	#N/A
1-BSTH027.85	03/22/2007	25	25	#N/A
1-BSTH027.85	04/10/2007	50	25	#N/A
1-BSTH027.85	05/15/2007	25	75	#N/A
1-BSTH027.85	06/06/2007	200	100	#N/A
1-BSTH027.85	07/09/2007	75	100	#N/A
1-BSTH027.85	08/15/2007	50	75	#N/A
1-BSTH027.85	09/05/2007	200	120	#N/A
1-BSTH027.85	10/11/2007	100	200	#N/A
1-BSTH027.85	11/01/2007	180	50	#N/A
1-BSTH027.85	12/03/2007	120	25	#N/A
1-BSTH027.85	01/10/2008	50	70	#N/A

N/A – Data not available

Appendix B – Bacteria Source Tracking Report

The bacterial source tracking (BST) data were generated in a separate study for VADEQ performed by MapTech, Inc. and New River Highlands RC&D. The reader should refer to data and analyses for station 1-BSTH007.80.

Bacterial Source Tracking Analyses to Support Virginia's TMDLs: *Non-Shellfish Stations*

Incorporated by Reference

Please refer to full document posted at:

http://www.deq.virginia.gov/tmdl/pdf/bstreports/directoryListing/082008bst.pdf

or contact VADEQ-VRO

Appendix C – Fecal Coliform Loading in Subwatersheds

Table C.1. Monthly nonpoint fecal coliform loadings in sub-watershed SOR-01.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	149	94,464	25,145	4,801	1,361	13,154
Fe.	872	98,119	25,928	5,128	1,240	11,987
Mar.	3,830	171,478	44,432	9,623	1,011	13,154
Apr.	3,089	170,182	44,059	9,577	978	12,730
May.	886	180,205	46,617	10,169	1,011	13,154
Jun.	145	178,448	46,129	10,095	978	12,730
Jul.	149	188,790	48,767	10,707	1,011	13,154
Aug.	149	193,184	49,868	10,982	1,011	13,154
Sep.	145	191,421	49,378	10,907	1,317	12,730
Oct.	1,270	128,546	33,680	6,935	1,361	13,154
Nov.	1,265	129,741	33,931	7,045	1,317	12,730
Dec.	149	91,163	24,318	4,594	1,361	13,154
Total	12,099	1,815,740	472,254	100,563	13,955	154,983

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.2. Monthly nonpoint fecal coliform loadings in sub-watershed SOR-02.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	20	18,987	5,055	967	1,824	4,577
Fe.	166	19,721	5,212	1,032	1,662	4,171
Mar.	760	34,466	8,931	1,936	1,467	4,577
Apr.	611	34,205	8,857	1,927	1,420	4,429
May.	168	36,220	9,371	2,046	1,467	4,577
Jun.	19	35,867	9,273	2,031	1,420	4,429
Jul.	20	37,945	9,803	2,154	1,467	4,577
Aug.	20	38,828	10,024	2,209	1,467	4,577
Sep.	19	38,474	9,926	2,194	1,765	4,429
Oct.	245	25,837	6,771	1,396	1,824	4,577
Nov.	244	26,077	6,821	1,418	1,765	4,429
Dec.	20	18,323	4,889	925	1,824	4,577
Total	2,312	364,950	94,932	20,232	19,374	53,922

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.3. Monthly nonpoint fecal coliform loadings in sub-watershed SOR-03.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	8	13,670	3,644	698	290	8,215
Fe.	114	14,195	3,756	745	264	7,487
Mar.	540	24,788	6,428	1,394	197	8,215
Apr.	433	24,600	6,374	1,387	190	7,950
May.	115	26,048	6,744	1,473	197	8,215
Jun.	8	25,794	6,673	1,462	190	7,950
Jul.	8	27,288	7,054	1,551	197	8,215
Aug.	8	27,922	7,213	1,590	197	8,215
Sep.	8	27,667	7,142	1,579	280	7,950
Oct.	170	18,590	4,876	1,006	290	8,215
Nov.	170	18,762	4,912	1,022	280	7,950
Dec.	8	13,193	3,525	668	290	8,215
Total	1,590	262,516	68,343	14,575	2,863	96,795

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.4. Monthly nonpoint fecal coliform loadings in sub-watershed SOR-04.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	11	20,690	5,514	1,056	1,094	14,035
Fe.	171	21,487	5,684	1,127	997	12,790
Mar.	816	37,532	9,732	2,111	837	14,035
Apr.	654	37,247	9,650	2,100	810	13,582
May.	172	39,440	10,210	2,230	837	14,035
Jun.	10	39,055	10,103	2,214	810	13,582
Jul.	11	41,318	10,680	2,348	837	14,035
Aug.	11	42,279	10,921	2,408	837	14,035
Sep.	10	41,892	10,813	2,391	1,059	13,582
Oct.	256	28,144	7,381	1,523	1,094	14,035
Nov.	255	28,404	7,435	1,547	1,059	13,582
Dec.	11	19,968	5,333	1,011	1,094	14,035
Total	2,386	397,456	103,454	22,065	11,364	165,362

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.5. Monthly nonpoint fecal coliform loadings in sub-watershed SOR-05.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	19	51,967	13,839	2,648	648	5,679
Fe.	422	53,975	14,269	2,827	591	5,175
Mar.	2,043	94,316	24,445	5,299	483	5,679
Apr.	1,638	93,602	24,240	5,274	467	5,496
May.	424	99,115	25,647	5,600	483	5,679
Jun.	18	98,148	25,378	5,559	467	5,496
Jul.	19	103,836	26,829	5,895	483	5,679
Aug.	19	106,252	27,434	6,046	483	5,679
Sep.	18	105,282	27,165	6,005	627	5,496
Oct.	635	70,708	18,533	3,821	648	5,679
Nov.	634	71,364	18,671	3,882	627	5,496
Dec.	19	50,151	13,385	2,534	648	5,679
Total	5,909	998,715	259,836	55,390	6,655	66,913

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.6. Monthly nonpoint fecal coliform loadings in sub-watershed SOR-06.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	28	50,975	13,574	2,593	1,088	6,689
Fe.	594	55,131	14,350	2,770	991	6,096
Mar.	2,868	103,448	25,751	5,194	839	6,689
Apr.	2,299	100,560	25,194	5,169	812	6,473
May.	596	99,401	25,509	5,488	839	6,689
Jun.	28	98,453	25,245	5,448	812	6,473
Jul.	28	104,031	26,668	5,778	839	6,689
Aug.	28	106,400	27,261	5,926	839	6,689
Sep.	28	107,637	27,352	5,886	1,053	6,473
Oct.	892	73,731	18,887	3,744	1,088	6,689
Nov.	892	74,374	19,022	3,804	1,053	6,473
Dec.	28	49,194	13,128	2,482	1,088	6,689
Total	8,309	1,023,335	261,941	54,282	11,337	78,811

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.7. Monthly nonpoint fecal coliform loadings in sub-watershed SOR-07.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	**Pasture 1**	**Pasture 2**	**Pasture 3**	**Forest**	**Residential[1]**
Jan.	29	60,682	16,004	3,201	768	6,874
Fe.	706	63,922	17,184	3,319	700	6,264
Mar.	3,428	122,241	33,623	6,366	574	6,874
Apr.	2,747	120,136	32,629	6,391	556	6,652
May.	709	119,559	31,189	6,749	574	6,874
Jun.	28	117,912	30,751	6,665	556	6,652
Jul.	29	124,114	32,330	7,034	574	6,874
Aug.	29	126,459	32,917	7,181	574	6,874
Sep.	28	127,062	33,483	7,100	743	6,652
Oct.	915	94,201	25,279	5,024	768	6,874
Nov.	1,062	92,730	24,885	4,951	743	6,652
Dec.	29	58,920	15,562	3,090	768	6,874
Total	9,737	1,227,938	325,835	67,071	7,897	80,987

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Appendix D – Required Reductions in Fecal Coliform Loads by Subwatershed – Allocation Scenario

Table D.1. Required annual reductions in non-point sources in sub-watershed SOR-01.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	1,209,866	0.5%	60,493	95%
Pasture	238,855,679	93%	11,942,787	95%
Forest	1,395,463	0.5%	1,395,463	0%
Residential	15,498,251	6%	774,913	95%
Total	256,959,260	100%	14,173,656	94%

Table D.2. Required annual reductions in direct non-point sources in sub-watershed SOR-01.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	234,064	18%	11,703	95%
Wildlife in Streams	269,010	21%	269,010	0%
Straight Pipes	799,971	61%	0	100%
Total	1,303,045	100%	280,713	78%

Table D.3. Required annual reductions in non-point sources in sub-watershed SOR-02.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	231,174	0.4%	11,559	95%
Pasture	48,011,401	86%	2,400,571	95%
Forest	1,937,398	3%	1,937,398	0%
Residential	5,392,186	10%	269,609	95%
Total	55,572,159	100%	4,619,137	92%

Table D.4. Required annual reductions in direct non-point sources in sub-watershed SOR-02.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	47,045	7%	2,352	95%
Wildlife in Streams	248,956	36%	248,956	0%
Straight Pipes	402,506	58%	0	100%
Total	698,507	100%	251,309	64%

Table D.5. Required annual reductions in non-point sources in sub-watershed SOR-03.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	159,013	0.4%	7,951	95%
Pasture	34,543,393	77%	1,727,170	95%
Forest	286,301	0.6%	286,301	0%
Residential	9,679,527	22%	483,976	95%
Total	44,668,234	100%	2,505,398	94%

Table D.6. Required annual reductions in direct non-point sources in sub-watershed SOR-03.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	33,793	10%	1,690	95%
Wildlife in Streams	64,803	20%	64,803	0%
Straight Pipes	231,203	70%	0	100%
Total	329,799	100%	66,493	80%

Table D.7. Required annual reductions in non-point sources in sub-watershed SOR-04.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	238,647	0.3%	11,932	95%
Pasture	52,297,551	74%	2,614,878	95%
Forest	1,136,400	2%	1,136,400	0%
Residential	16,536,182	24%	826,809	95%
Total	70,208,780	100%	4,590,020	93%

Table D.8. Required annual reductions in direct non-point sources in sub-watershed SOR-04.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	51,186	6%	2,559	95%
Wildlife in Streams	175,744	22%	175,744	0%
Straight Pipes	588,491	72%	0	100%
Total	815,421	100%	178,304	78%

Table D.9. Required annual reductions in non-point sources in sub-watershed SOR-05.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	590,893	0.4%	29,545	95%
Pasture	131,394,077	94%	6,569,705	95%
Forest	665,541	0.5%	665,541	0%
Residential	6,691,270	5%	334,564	95%
Total	139,341,782	100%	7,599,355	95%

Table D.10. Required annual reductions in direct non-point sources in sub-watershed SOR-05.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	128,710	22%	6,436	95%
Wildlife in Streams	131,761	22%	131,761	0%
Straight Pipes	330,332	56%	0	100%
Total	590,803	100%	138,196	77%

Table D.11. Required annual reductions in non-point sources in sub-watershed SOR-06.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	830,920	0.6%	41,546	95%
Pasture	133,955,783	93%	6,697,791	95%
Forest	1,133,731	0.8%	1,133,731	0%
Residential	7,881,109	5%	394,056	95%
Total	143,801,543	100%	8,267,123	94%

Table D.12. Required annual reductions in direct non-point sources in sub-watershed SOR-06.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	126,226	19%	6,311	95%
Wildlife in Streams	178,298	27%	178,298	0%
Straight Pipes	346,695	53%	0	100%
Total	651,219	100%	184,609	72%

Table D.13. Required annual reductions in non-point sources in sub-watershed SOR-07.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	973,722	0.6%	48,686	95%
Pasture	162,084,340	94%	8,104,219	95%
Forest	789,663	0.5%	789,663	0%
Residential	8,098,688	5%	404,935	95%
Total	171,946,413	100%	9,347,503	95%

Table D.14. Required annual reductions in direct non-point sources in sub-watershed SOR-07.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	154,965	21%	7,748	95%
Wildlife in Streams	138,867	19%	138,867	0%
Straight Pipes	454,079	61%	0	100%
Total	747,911	100%	146,616	80%