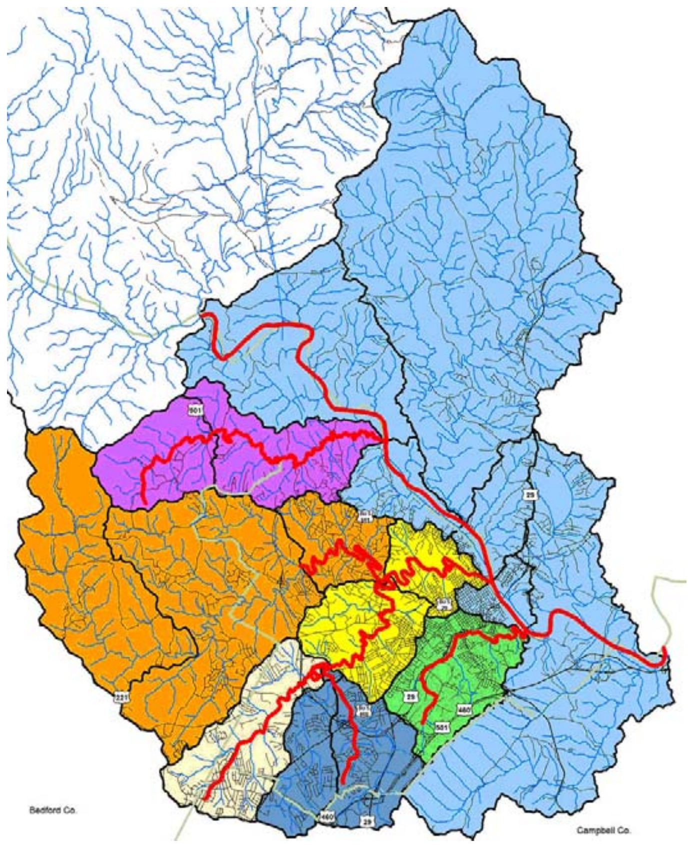
Bacteria Total Maximum Daily Load Development for the James River Basin



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Submitted: August 2007

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List of Acronyms

AVMA	American Veterinary Medical Association
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BMPs	Best Management Practices
BST	Bacterial Source Tracking
HSPF	Hydrologic Simulation Program – Fortran
LA	Load Allocation
MOS	Margin of Safety
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
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
SCS	Soil Conservation Service
SERCC	Southeast Regional Climate Center
SWCD	Soil and Water Conservation District
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
UAA	Use Attainability Analysis
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VADCR	Virginia Department of Conservation and Recreation
VADEQ	Virginia Department of Environmental Quality
VADGIF	Virginia Department of Game and Inland Fisheries
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	Wasteload Allocation
WQMP	Water Quality Management Plan

Executive Summary

Background

James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) were first listed as impaired streams in 1996 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2003a) indicating that the swimmable use goal was not being met. The stream segments were further listed 2004 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2003b, 2004) based on Virginia Department of Environmental Quality (VADEQ) monitoring data. Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) were initially listed as impaired stream on Virginia's 2004 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2003b) due to water quality violations of the bacteria standard.

Streams that are identified as not supporting a given use such as recreation (swimmable) or fish tissue (consumption) exhibit pollutant concentrations that exceed the applicable water quality standard. This implies that using these streams in this manner exposes the user to excessive risk of contracting an illness as a result of that use. It is advisable to avoid the non-supported use in the listed streams until such time that water quality improvements are demonstrated that allow their delisting.

The impaired portion of James River (VAC-H03R-04) delineated by VADEQ, beginning at the Holcomb Rock Dam and continuing downstream approximately 18.43 miles to the confluence of Archer Creek with the James River, is listed as impaired by fecal coliform bacteria on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of the bacteria standard at station 2-JMS258.54. James River is also listed on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of PCBs in Fish Tissue at station 2-JMS258.54.

The impaired portion of Ivy Creek (VAC-H03R-03) delineated by VADEQ, beginning at the mouth of Cheese Creek and continuing downstream approximately 5.37 miles to the confluence with Blackwater Creek, is listed as impaired by fecal coliform bacteria on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of the bacteria standard at station 2-IVA000.22.

The impaired portion of Fishing Creek (VAC-H03R-02) delineated by VADEQ, beginning at its headwaters and continuing downstream approximately 5.45 miles to the confluence with the James River, is listed as impaired by fecal coliform bacteria on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of the bacteria standard at station 2-FSG000.85.

The impaired portion of Blackwater Creek (VAC-H03R-01) delineated by VADEQ, beginning at the confluence of Tomahawk and Burton Creeks and continuing downstream approximately 10.24 miles to the confluence with the James River, is listed as impaired by fecal coliform bacteria on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of the bacteria standard at station 2BKW000.40.

The impaired portion of Tomahawk Creek (VAC-H03R-07) delineated by VADEQ, beginning at its headwaters and continuing downstream approximately 5.9 miles to the confluence with Burton Creek, is listed as impaired by E. coli bacteria on Virginia's 2006 list (VADEQ, 2006) due to water quality violations of the bacteria standard at station 2-THK002.33.

The impaired portion of Burton Creek (VAC-H03R-05) delineated by VADEQ, beginning at its headwaters and continuing downstream approximately 3.47 miles to the confluence with Tomahawk Creek, is listed as impaired by E. coli bacteria on Virginia's 2006 list (VADEQ, 2006) due to water quality violations of the bacteria standard at station 2-BUNN001.64.

The impaired portion of Judith Creek (VAC-H03R-06) delineated by VADEQ, beginning at its headwaters and continuing downstream approximately 10.55 miles to the confluence with the James River, is listed as impaired by fecal E. coli bacteria on Virginia's 2006 list (VADEQ, 2006) due to water quality violations of the bacteria standard at station 2-JTH001.52.

The James River (VAC-H03R-04) watershed area is approximately 64,269 acres consisting mainly of forest (74%) and pasture/cropland (16%), with the remaining area is split between residential/commercial (7%) and water/wetland (3%). The Ivy Creek (VAC-H03R-03) watershed is approximately 23,946 acres in size and is mainly a forested watershed (about 63%) with pasture/cropland, residential/commercial, and water/wetland comprising 29%, 7%, and 1% of the area, respectively. The Fishing Creek (VAC-H03R-02) watershed area of approximately 4,590 acres is comprised of residential/commercial (54%), forest (38%), pasture/cropland (7%), and water/wetland (1%). The 6,118 acres in the Blackwater Creek (VAC-H03R-01) watershed consists of approximately 48% forest, 45% residential/commercial, 6% pasture/cropland, and 1% water/wetland land uses. The approximately 5,231 acres of Tomahawk Creek (VAC-H03R-07) watershed consists of 45% forest, 28% residential/commercial, 27%, pasture/cropland, and 1% water/wetland land uses. The Burton Creek (VAC-H03R-05) watershed area of 6,615 acres is comprised of forest (46%), residential/commercial (39%), pasture/cropland (14%), and water/wetland (1%). The approximately 8,389 acres of the Judith Creek (VAC-H03R-06) watershed are mostly forested (about 78%) with 15%, 6%, and 1% of the remaining acreage consisting of pasture/ cropland, residential/commercial, and water/wetland land uses, respectively.

The James River begins in Botetourt County, Virginia at the confluence of the Jackson and Cowpasture Rivers. The river flows across the Commonwealth to the Chesapeake Bay.

VADEQ personnel monitored pollutant concentrations throughout the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds. Of the 49 water quality samples collected from January 1998 through December 2002 (the 2004 Section 303(d) 5-year listing period) at VADEQ station 2-JMS258.54, 30.6% of the samples exceeded the then-applicable instantaneous standard of 1,000 cfu/100 mL. Consequently, this segment of James River (VAC-H03R-04) was determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2004 Section 305(b) water quality assessment report and was included in the 2004 Section 303(d) list (VADEQ, 2004).

The instantaneous fecal coliform bacteria standard was exceeded in three of 19 (15.8%) samples collected during the 2004 Section 303(d) assessment period at station 2-IVA000.22. This segment of Ivy Creek (VAC-H03R-03) was assessed as not supporting of the Recreation Use goal and was included in the 2004 Section 303(d) list (VADEQ, 2004).

Of the 25 water quality samples collected from January 1998 through December 2002 (the 2004 Section 303(d) 5-year listing period) at VADEQ station 2-FSG000.85, 32.0% of the samples exceeded the then-applicable instantaneous standard of 1,000 cfu/100 mL. Consequently, this segment of Fishing Creek (VAC-H03R-02) was determined as not supporting of the Clean Water Act’s Recreation Use Goal for the 2004 Section 305(b) water quality assessment report and was included in the 2004 Section 303(d) list (VADEQ, 2004).

The instantaneous fecal coliform bacteria standard was exceeded in ten of 16 (62.5%) samples collected during the 2004 Section 303(d) assessment period at station 2BKW000.40. This segment of Blackwater Creek (VAC-H03R-01) was assessed as not supporting of the Recreation Use goal and was included in the 2004 Section 303(d) list (VADEQ, 2004).

Of the nine water quality samples collected from at VADEQ station 2-THK002.33, 22.2% of the samples exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Consequently, this segment of Tomahawk Creek (VAC-H03R-07) 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 (VADEQ, 2006).

The instantaneous *E. coli* bacteria standard of 235 cfu/100 mL was exceeded in four nine (44.4%) samples collected during the 2004 Section 303(d) assessment period at station 2-BUN001.64. This segment of Burton Creek (VAC-H03R-05) was assessed as not supporting of the Recreation Use goal and was included in the 2006 Section 303(d) list (VADEQ, 2004).

Of the 9 water quality samples collected from at VADEQ station 2-JTH001.52, 33.3% of the samples exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Consequently, this segment of Judith Creek (VAC-H03R-06) 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 (VADEQ, 2006).

In order to remedy the water quality impairment pertaining to fecal coliform, a Total Maximum Daily Load (TMDL) has been developed, taking into account all sources of bacteria and a margin of safety (MOS). The TMDL was developed for the new water quality standard for bacteria, which states that the calendar-month geometric mean concentration of E. coli shall not exceed 126 cfu/100 mL, and that no single sample can exceed a concentration of 235 cfu/100mL. The glossary lists terms used in the development of this TMDL.

Sources of Fecal Coliform

There are a variety of permits and special loading conditions present in the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds. Currently, there are one and six point discharges with a

VPDES permit located in the Judith Creek (VAC-H03R-06) and James River (VAC-H03R-04) watersheds, respectively. One of these VPDES permits has multiple combined sewer overflow (CSO) points associated with it. To date, 132 CSOs originally identified in 1989 have been reduced to 35 as of 2006. Active CSO discharge points are present in James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) watersheds. The City of Lynchburg and the Virginia Department of Transportation each have a MS4 permit whose limits are defined by the city boundary. These MS4 permits discharge within the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds.

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) and residential, with a significant load applied to 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.

Modeling

The Hydrologic Simulation Program – Fortran (HSPF) (Bicknell et al., 2000) was used to model fecal coliform transport and fate in the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds. To identify localized sources of fecal coliform, the watersheds were divided into subwatersheds. These subdivisions were based primarily on homogeneity of land use.

The James River model was calibrated using observed flow values from USGS station #02026000 at Bent Creek, VA, transferred to the outlet of James River model, for the period January 1, 1995 to December 31, 1999. 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 for the period January 1, 2000 to December 31, 2004. 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 2-JMS258.54, 2-IVA000.22, 2-FSG000.85, 2-BKW000.40, 2-THK002.33, 2-BUN001.64, and 2-JTH001.52 within the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) impairments, respectively, were used to calibrate the water quality component of HSPF between January 1, 1995 and December 31, 1999 (if data were available). The model was validated for period January 1, 2000 to December 31, 2004 (if data were available). For stations with limited data, water quality calibration was performed for January 1, 2000 to December 31, 2004 only. 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.

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 the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) TMDLs, 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.

Existing Conditions

Based on amounts of fecal coliform produced in different locations, daily fecal coliform loadings to different land use categories were calculated for each sub-watershed for input into the model. Fecal coliform content of stored waste was adjusted to account for die-off during storage prior to land application. Similarly, fecal coliform die-off on land was taken into account, as was the reduction in fecal coliform available for surface wash-off due to incorporation following waste application on cropland. Straight pipes produced a direct fecal coliform load to the stream. Direct seasonal fecal coliform loadings to streams by cattle were calculated for pastures adjacent to streams. Fecal coliform loadings to streams and land by wildlife were estimated for several species. Fecal coliform loadings to land from failing septic systems were estimated based on number and age of houses. Fecal coliform contribution from pet waste was also considered. Contributions from these various sources were represented in HSPF to establish existing conditions for a representative hydrologic period (January 1, 1995 and December 31, 1999).

TMDL Allocation Scenarios

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 for the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith

Creek (VAC-H03R-06) impairments needed to meet both the calendar-month geometric mean and single sample water quality goals are listed in Table E.1.

Table E.1. Reduction in fecal coliform loading from existing conditions for TMDL allocation scenario.

Impairment	Percent Reduction in Fecal Coliform Loading from Existing Conditions							
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest
James River (VAC-H03R-04)	100	100	80	80	80	80	0	0
Ivy Creek (VAC-H03R-03)	100	100	98	98	98	98	0	0
Fishing Creek (VAC-H03R-02)	100	100	80	90	80	80	0	0
Blackwater Creek (VAC-H03R-01)	100	100	91	91	91	91	0	0
Tomahawk Creek (VAC-H03R-07)	100	100	95	95	95	95	0	0
Burton Creek (VAC-H03R-05)	100	100	98	98	98	98	0	0
Judith Creek (VAC-H03R-06)	100	100	94	94	94	94	0	0

DD – direct deposition

Using equation [E.1], summaries of the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) bacteria TMDLs for the selected allocation scenario are shown in Tables E.2 through E.15, respectively.

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

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

Table E.2. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in James River (VAC-H03R-04) impairment.

Pollutant	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
E. coli	2.75E+14	3.76E+14	N/A	6.51E+14

N/A – not applicable because MOS was implicit.

Table E.3. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in James River (VAC-H03R-04) impairment.

Pollutant	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
E. coli	7.53E+11	6.23E+16	N/A	6.23E+16

N/A – not applicable because MOS was implicit.

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

Table E.4. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Ivy Creek (VAC-H03R-03) impairment.

Pollutant	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
E. coli	6.25E+11	7.07E+12	N/A	7.69E+12

N/A – not applicable because MOS was implicit.

Table E.5. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Ivy Creek (VAC-H03R-03) impairment.

Pollutant	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
E. coli	1.71E+09	5.42E+14	N/A	5.42E+14

N/A – not applicable because MOS was implicit.

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

Table E.6. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Fishing Creek (VAC-H03R-02) impairment.

Pollutant	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
E. coli	1.03E+12	3.45E+12	N/A	4.48E+12

N/A – not applicable because MOS was implicit.

Table E.7. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Fishing Creek (VAC-H03R-02) impairment.

Pollutant	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
E. coli	2.81E+09	1.87E+14	N/A	1.87E+14

N/A – not applicable because MOS was implicit.

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

Table E.8. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Blackwater Creek (VAC-H03R-01) impairment.

Pollutant	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
E. coli	3.06E+12	1.62E+13	N/A	1.93E+13

N/A – not applicable because MOS was implicit.

Table E.9. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Blackwater Creek (VAC-H03R-01) impairment.

Pollutant	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
E. coli	8.37E+09	1.23E+15	N/A	1.23E+15

N/A – not applicable because MOS was implicit.

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

Table E.10. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Tomahawk Creek (VAC-H03R-07) impairment.

Pollutant	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
E. coli	8.34E+11	1.82E+12	N/A	2.65E+12

N/A – not applicable because MOS was implicit.

Table E.11. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Tomahawk Creek (VAC-H03R-07) impairment.

Pollutant	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
E. coli	2.29E+09	1.81E+14	N/A	1.81E+14

N/A – not applicable because MOS was implicit.

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

Table E.12. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Burton Creek (VAC-H03R-05) impairment.

Pollutant	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
E. coli	7.37E+11	1.08E+12	N/A	1.82E+12

N/A – not applicable because MOS was implicit.

Table E.13. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Burton Creek (VAC-H03R-05) impairment.

Pollutant	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
E. coli	2.02E+09	2.69E+14	N/A	2.69E+14

N/A – not applicable because MOS was implicit.

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

Table E.14. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Judith Creek (VAC-H03R-06) impairment.

Pollutant	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
E. coli	8.31E+11	1.24E+12	N/A	2.07E+12

N/A – not applicable because MOS was implicit.

Table E.15. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Judith Creek (VAC-H03R-06) impairment.

Pollutant	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
E. coli	2.28E+09	1.82E+14	N/A	1.82E+14

N/A – not applicable because MOS was implicit.

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

Stage 1 Implementation

Staged implementation is a key component to restoring water quality in James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06). An alternative scenario was evaluated to establish goals for the first stage of the implementation of the 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 Stage 1 implementation goal was to reduce the bacteria loading reductions from controllable sources (excluding wildlife) such that exceedances of a potential future single sample maximum criterion (384 cfu/100ml) are less than 10 percent, and the potential future geometric mean standard (206 cfu/100 ml) is not exceeded. These conditions were met in the Stage 1 scenarios with no reduction from wildlife sources. The goal was met in all impairments. Stage 1 reduction scenarios are listed in Table E. 16.

Table E. 16. Stage 1 reduction scenarios.

Impairment	Percent Reduction in Fecal Coliform Loading from Existing Conditions							
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest
James River (VAC-H03R-04)	Note 1	100	10	0	10	10	0	0
Ivy Creek (VAC-H03R-03)	Note 1	100	56	96	56	56	0	0
Fishing Creek (VAC-H03R-02)	Note 1	100	0	17	0	0	0	0
Blackwater Creek (VAC-H03R-01)	Note 1	100	48	0	48	48	0	0
Tomahawk Creek (VAC-H03R-07)	Note 1	100	65	10	65	65	0	0
Burton Creek (VAC-H03R-05)	Note 1	100	72	0	72	72	0	0
Judith Creek (VAC-H03R-06)	Note 1	100	0	40	0	0	0	0

1 - CSO loads reflected current conditions with additional CSO point eliminations resulting from implementation of City project priorities 1-25.
DD – direct deposition

Public Participation

During development of the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) TMDLs, public participation was encouraged through two public meetings.

The first public meeting was held at Lynchburg College in Lynchburg, Virginia on July 17, 2006 to discuss the need for a TMDL, discuss the draft watershed source assessment, and review the approach for TMDL development. The second and final public meetings will be held at the Lynchburg Public Library in Lynchburg, Virginia on May 3, 2007 to discuss the source allocations and reductions required to meet the TMDL. Copies of the draft TMDL report will be available for public review and comment.

In addition to keeping the public apprised of progress in the development of the the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) TMDLs, a TMDL Technical Advisory Committee (TAC) was also established to help advise the TMDL developers. TAC meetings were held for this project on June 26, 2006, November 14, 2006, and February 26, 2007 at the Region 2000 Local Government Council office in Lynchburg, Virginia. The TAC membership for the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) TMDLs included representatives from the following agencies and organizations: Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation, Virginia Department of Health, Virginia Department of Forestry, Virginia Cooperative Extension, Region 2000 Local Government Council , Robert E. Lee and Peaks of Otter SWCDs, City of Lynchburg Government, Amherst County Government, Campbell County Government, Bedford County Government, City of Lynchburg Utilities, Amherst County Service Authority, Bedford County Public Service Authority, Campbell County Utilities and Service Authority, U.S. Department of Agriculture – Natural Resources Conservation Service, Lynchburg College, Liberty University, Sweet Briar College, James River Association, Greater Lynchburg Environmental Network.

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.

Project Personnel

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Acknowledgements

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Brian Watson, **Virginia Department of Game and Inland Fisheries**

Michael Fies, **Virginia Department of Game and Inland Fisheries**

Matt Knox, **Virginia Department of Game and Inland Fisheries**

Jim Bowman, **Virginia Department of Game and Inland Fisheries**

Virginia Cooperative Extension

Robert E. Lee and Peaks of Otter SWCDs

All members of the Technical Advisory Committee

Land owners and producers who provided data and access through their property.

Engineering Concepts, Inc. of Fincastle, Virginia supported this study as a contractor to Virginia's Region 2000 – Local Government Council through funding provided by the Virginia Department of Environmental Quality

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 violate 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 violating 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

James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) were first listed as impaired streams in 1996 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2003a) indicating that the swimmable use goal was not being met. The stream segments were further listed 2004 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2003b, 2004) based on Virginia Department of Environmental Quality (VADEQ) monitoring data. Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) were initially listed as impaired stream on Virginia's 2004 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2003b) due to water quality violations of the bacteria standard.

The impaired portion of James River (VAC-H03R-04) delineated by VADEQ, beginning at the Holcomb Rock Dam and continuing downstream approximately 18.43 miles to the confluence of Archer Creek with the James River, is listed as impaired by fecal coliform bacteria on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of the bacteria standard at station 2-JMS258.54. James River is also listed on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of PCBs in Fish Tissue at station 2-JMS258.54.

The impaired portion of Ivy Creek (VAC-H03R-03) delineated by VADEQ, beginning at the mouth of Cheese Creek and continuing downstream approximately 5.37 miles to the confluence with Blackwater Creek, is listed as impaired by fecal coliform bacteria on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of the bacteria standard at station 2-IVA000.22.

The impaired portion of Fishing Creek (VAC-H03R-02) delineated by VADEQ, beginning at its headwaters and continuing downstream approximately 5.45 miles to the confluence with the James River, is listed as impaired by fecal coliform bacteria on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of the bacteria standard at station 2-FSG000.85.

The impaired portion of Blackwater Creek (VAC-H03R-01) delineated by VADEQ, beginning at the confluence of Tomahawk and Burton Creeks and continuing downstream approximately 10.24 miles to the confluence with the James River, is listed as impaired by fecal coliform bacteria on Virginia's 2004 list (VADEQ, 2004) due to water quality violations of the bacteria standard at station 2BKW000.40.

The impaired portion of Tomahawk Creek (VAC-H03R-07) delineated by VADEQ, beginning at its headwaters and continuing downstream approximately 5.9 miles to the confluence with Burton Creek, is listed as impaired by E. coli bacteria on Virginia's 2006 list (VADEQ, 2006) due to water quality violations of the bacteria standard at station 2-THK002.33.

The impaired portion of Burton Creek (VAC-H03R-05) delineated by VADEQ, beginning at its headwaters and continuing downstream approximately 3.47 miles to the confluence with Tomahawk Creek, is listed as impaired by E. coli bacteria on Virginia's 2006 list (VADEQ, 2006) due to water quality violations of the bacteria standard at station 2-BUNN001.64.

The impaired portion of Judith Creek (VAC-H03R-06) delineated by VADEQ, beginning at its headwaters and continuing downstream approximately 10.55 miles to the confluence with the James River, is listed as impaired by fecal E. coli bacteria on Virginia's 2006 list (VADEQ, 2006) due to water quality violations of the bacteria standard at station 2-JTH001.52.

1.1.3 Watershed Location and Description

The James River impairment watershed is located in Amherst County, Bedford County, and Lynchburg, Virginia. Ivy Creek and Judith Creek impairment watersheds are located in Bedford County and Lynchburg, Virginia. The Burton Creek impairment watershed is located in Campbell County and Lynchburg, Virginia. Blackwater Creek and Fishing Creek impairment watersheds are located in Lynchburg, Virginia (Figure 1.1).

The James River (VAC-H03R-04) watershed area is approximately 64,269 acres consisting mainly of forest (74%) and pasture/cropland (16%), with the remaining area is split between residential/commercial (7%) and water/wetland (3%). The Ivy Creek (VAC-H03R-03) watershed is approximately 23,946 acres in size and is mainly a forested watershed (about 63%) with pasture/cropland, residential/commercial, and water/wetland comprising 29%, 7%, and 1% of the area, respectively. The Fishing Creek (VAC-H03R-02) watershed area of approximately 4,590 acres is comprised of residential/commercial (54%), forest (38%), pasture/cropland (7%), and water/wetland (1%). The 6,118 acres in the Blackwater Creek (VAC-H03R-01) watershed consists of approximately 48% forest, 45% residential/commercial, 6% pasture/cropland, and 1% water/wetland land uses. The approximately 5,231 acres of Tomahawk Creek (VAC-H03R-07) watershed consists of 45% forest, 28% residential/commercial, 27%, pasture/cropland, and 1% water/wetland land uses. The Burton Creek (VAC-H03R-05) watershed area of 6,615 acres is comprised of forest (46%), residential/commercial (39%), pasture/cropland (14%), and water/wetland (1%). The approximately 8,389 acres of the Judith Creek (VAC-H03R-06) watershed are mostly forested

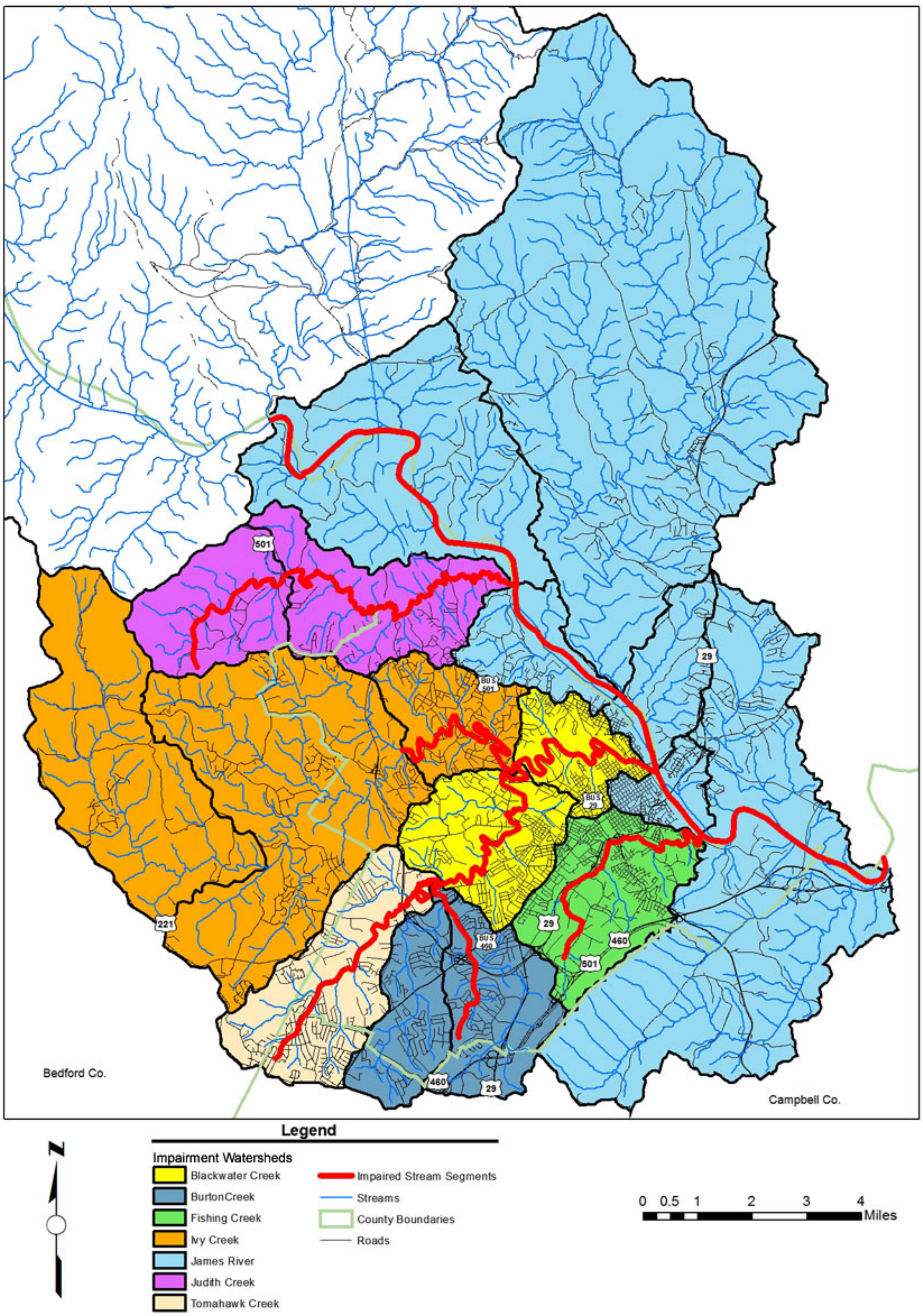

Figure 1.1. Location James River, Ivy Creek, Fishing Creek, Blackwater Creek, Tomahawk Creek, Blackwater Creek, Fishing Creek and James River watersheds.

(about 78%) with 15%, 6%, and 1% of the remaining acreage consisting of pasture/ cropland, residential/commercial, and water/wetland land uses, respectively.

The James River begins in Botetourt County, Virginia at the confluence of the Jackson and Cowpasture Rivers. The river flows across the Commonwealth to the Chesapeake Bay.

1.1.4 Pollutant of Concern

Pollution from both point and nonpoint sources can lead to fecal coliform and E. coli bacteria contamination of water bodies. Fecal coliform and *E. coli* bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform and *E. coli*. Even though most fecal coliform and *E. coli* 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 and *E. coli* 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 and *E. coli* counts. If the fecal coliform and *E. coli* concentration in a water body exceeds state water quality standards, the water body is listed for violation of the state fecal coliform and *E. coli* 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. This *E. coli* standard was used to list Burton Creek, Judith Creek, and Tomahawk Creek.

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)."

The goal of the Clean Water Act is that all streams should be suitable for recreational uses, including swimming and fishing. **Fecal coliform and *E. coli* bacteria** are used to indicate the presence of pathogens in streams supporting the **swimmable use goal**. Bacteria in James River, Ivy Creek, Fishing Creek, and Blackwater Creek exceed the fecal coliform criterion. Bacteria in Burton Creek, Judith Creek, and Tomahawk Creek exceeded the *E. coli* criterion.

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 any assessment period, if more than 10.5% of a station's samples exceed the applicable standard, 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 James River, Ivy Creek, Fishing Creek and Blackwater Creek was based on violations of an earlier fecal coliform standard that included a numeric single sample maximum limit of 1,000 cfu/100 mL. The bacteria TMDLs for these impaired segments were 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*. The same translator was used to convert *E. Coli* data collected for Burton Creek, Judith Creek, and Tomahawk Creek to fecal coliform concentrations for the purpose of modeling.

Chapter 2. Watershed Characterization

2.1 Water Resources

The James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds were subdivided into sub-watersheds for fecal coliform modeling purposes, as discussed in Section 4.2. The impaired segment of the main branch of James River runs for approximately 18.43 miles beginning at Holcomb Rock Dam and continuing downstream to the confluence with Archer Creek. The other streams included in this study are tributaries to this impaired segment of the James River. Judith Creek flows approximately 10.55 miles from its headwaters downstream to the confluence with the James River. The impaired portion of Ivy Creek flows about 5.37 miles beginning at the mouth of Cheese Creek and continuing downstream to the confluence with Blackwater Creek. The impaired portion of Tomahawk Creek flows approximately 5.9 miles beginning at its headwaters and continuing downstream to the confluence with Burton Creek. The impaired portion of Burton Creek flows about 3.47 miles beginning at its headwaters and continuing downstream to the confluence with Tomahawk Creek. Blackwater Creek flows about 10.24 miles beginning at the confluence of Tomahawk and Burton Creeks and continuing downstream to the confluence with the James River. Fishing Creek flows approximately 5.45 miles from its headwaters to the confluence with the James River. These are all perennial streams with a trapezoidal channel cross-section.

2.2 Ecoregion

The Ivy Creek (VAC-H03R-03), Judith Creek (VAC-H03R-06), and James River (VAC-H03R-04) watersheds partially lie within the Blue Ridge Mountains ecoregion. The balance of those three watersheds and the entirety of the Blackwater Creek (VAC-H03R-01), Fishing Creek (VAC-H03R-02), Burton Creek (VAC-H03R-05), and Tomahawk Creek (VAC-H03R-07) watershed lie within the Piedmont ecoregion.

The Piedmont ecoregion is predominantly wooded (i.e., successional pine and oak-hickory forests) and consists of irregular plains, low rounded hills and ridges, shallow valleys, and scattered monadnocks (Woods et al., 1999). This ecoregion is a transitional area between the mostly mountainous ecoregions of the Appalachians to the west and the lower and more level ecoregions of the coastal plain to the east (Woods et al., 1999). It is a complex mosaic of Precambrian and Paleozoic metamorphic and igneous rocks, with moderately dissected irregular plains and some hills. The soils tend to be finer-textured than in coastal plain regions. Once largely cultivated, much of this region has reverted to successional pine and hardwood woodlands, with an increasing conversion to an urban and suburban land cover.

The Blue Ridge Mountains ecoregion is a narrow strip of mountainous ridges that are forested and well dissected (Woods et al., 1999). Crestal elevations range from about 1,000 feet to over 5,700 feet (305-1,737 m) on Mt. Rogers and tend to rise southward (Woods et al., 1999). Local relief is high and both the side slopes and the channel gradients are steep. Streams are cool and clear and have many riffle sections; they support a different, less diverse fish assemblage than the streams of the valleys below, which are warmer, lower in gradient, and more turbid (Woods et al., 1999). The Blue Ridge Mountains are underlain by resistant and deformed metavolcanic, igneous, sedimentary, and metasedimentary rock (Woods et al., 1999). Inceptisols, Ultisols, and Alfisols have developed on the Cambrian, Paleozoic, and Precambrian rock (Woods et al., 1999).

2.3 Climate

The climate of the seven study watersheds is characterized based on the meteorological observations from 01/01/1930 to 09/30/2005 assembled by the Southeast Regional Climate Center for the Lynchburg WSO Airport, Virginia (445120) station. Average annual precipitation is 40.90 inches with 53.3% of the precipitation occurring during the crop-growing season (May-October) (SERCC, 2006). Average annual snowfall is 17.7 inches with the highest snowfall occurring during January (SERCC, 2004). Average annual daily temperature is 56.6°F. The highest average daily temperature of 86.7°F occurs in July while the lowest average daily temperature of 27.3°F occurs in January (SERCC, 2004).

2.4 Land Use

General depiction of land use draining to impairments is listed in Table 4.1. Details of landuse used in this study are described in Section 4.3 with landuse per subwatershed listed in Tables 4.2 through 4.5.

For purposes of this study, it was assumed that residential development in the James River (VAC-H03R-04) watershed will continue at its average annual rate of -0.40%, and the Ivy Creek (VAC-H03R-03) watershed will continue at its average annual rate of 1.75%. It was also assumed that residential development in the Fishing Creek (VAC-H03R-02) and Blackwater Creek (VAC-H03R-01) watersheds will continue at average annual rates of -0.67% and -0.53%, respectively. Residential development in the Tomahawk Creek (VAC-H03R-07) watershed was assumed to continue at a 1.67% annual rate. Likewise, it was assumed that residential development in Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds will continue at average annual rates of 0.74% and 0.87%, respectively.

2.5 Water Quality Data

2.5.1 Historic Data for Fecal Coliform

This section includes historical data relevant to four of the seven streams addressed in this report: James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01). This data is compiled from samples collected from January 1998 through December 2002 for the 2004 Section 303(d) 5-year listing period. The data are included in Figures 2.1 through 2.4. The other three streams were listed in 2006 under the *E. coli* standard and have no historical fecal coliform data, but are discussed in Section 2.5.2.

Of the 49 water quality samples collected from January 1998 through December 2002 (the 2004 Section 303(d) 5-year listing period) at VADEQ station 2-JMS258.54, 30.6% of the samples exceeded the then-applicable instantaneous standard of 1,000 cfu/100 mL. Consequently, this segment of James River (VAC-H03R-04) was determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2004 Section 305(b) water quality assessment report and was included in the 2004 Section 303(d) list (VADEQ, 2004).

The instantaneous fecal coliform bacteria standard was exceeded in three of 19 (15.8%) samples collected during the 2004 Section 303(d) assessment period at station 2-IVA000.22. This segment of Ivy Creek (VAC-H03R-03) was assessed as not supporting of the Recreation Use goal and was included in the 2004 Section 303(d) list (VADEQ, 2004).

Of the 25 water quality samples collected from January 1998 through December 2002 (the 2004 Section 303(d) 5-year listing period) at VADEQ station 2-FSG000.85, 32.0% of the samples exceeded the then-applicable instantaneous standard of 1,000 cfu/100 mL. Consequently, this segment of Fishing Creek (VAC-H03R-02) was determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2004 Section 305(b) water quality assessment report and was included in the 2004 Section 303(d) list (VADEQ, 2004).

The instantaneous fecal coliform bacteria standard was exceeded in ten of 16 (62.5%) samples collected during the 2004 Section 303(d) assessment period at station 2BKW000.40. This segment of Blackwater Creek (VAC-H03R-01) was assessed as not supporting of the Recreation Use goal and was included in the 2004 Section 303(d) list (VADEQ, 2004).

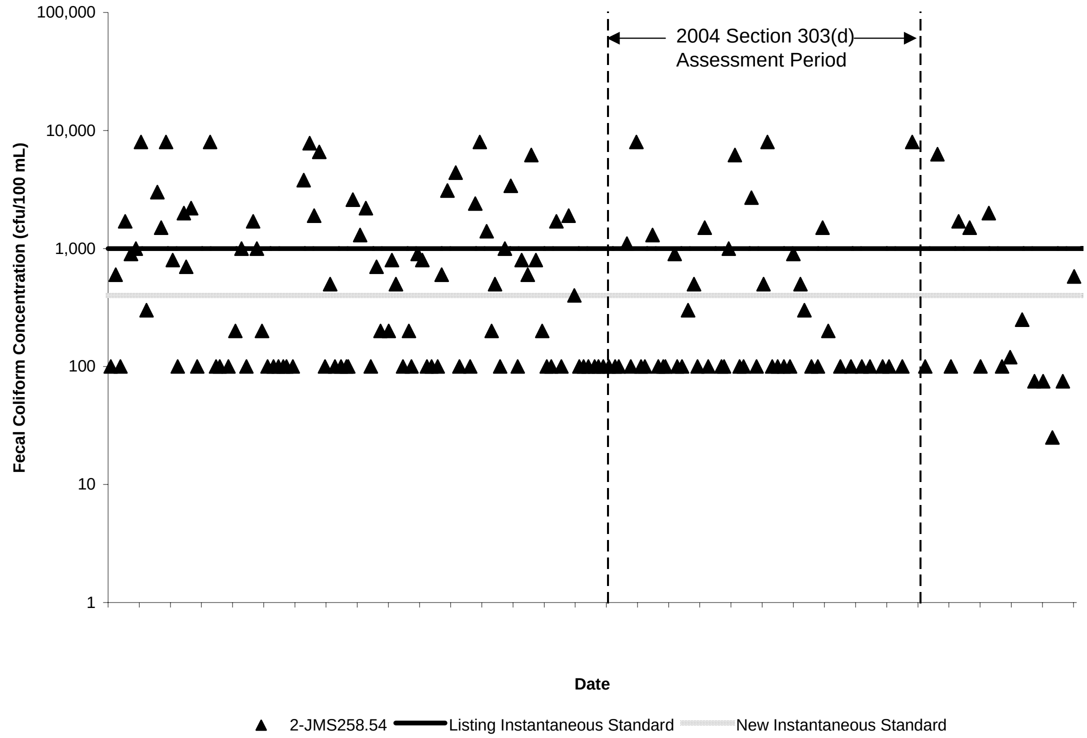

Figure 2.1. Fecal coliform concentrations VADEQ station 2-JMS258.54 in the James River (VAC-H03R-04) impairment.

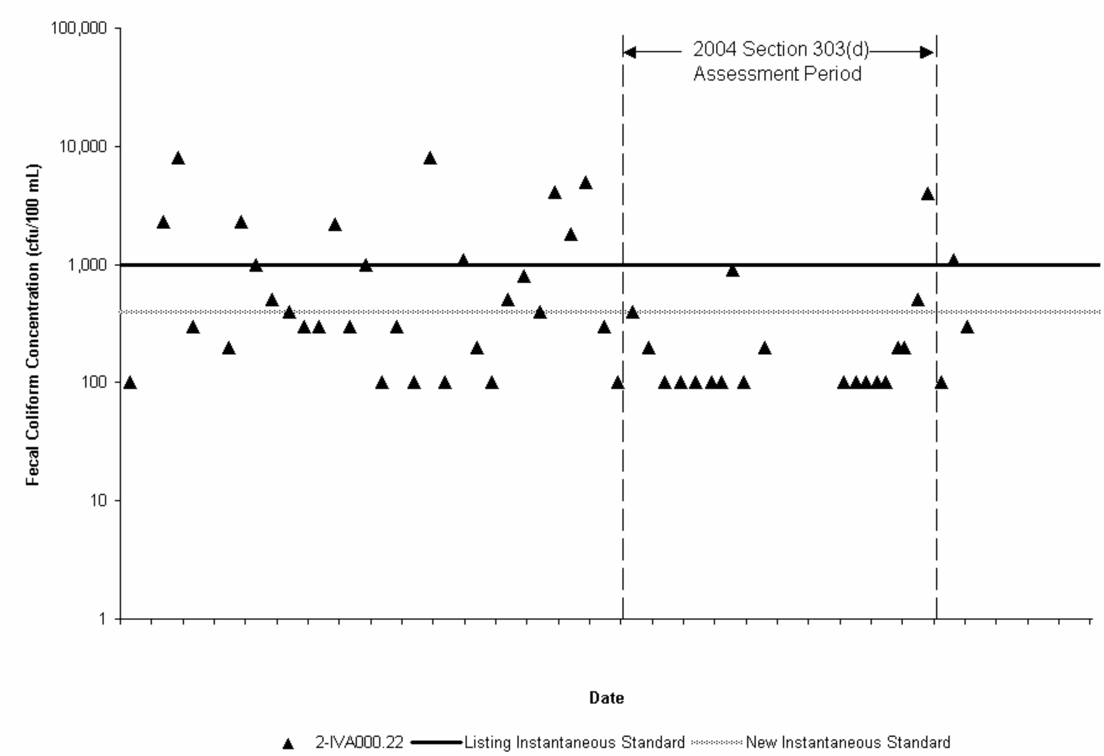

Figure 2.2. Fecal coliform concentrations VADEQ station 2-IVA000.22 in the Ivy Creek (VAC-H03R-03) impairment.

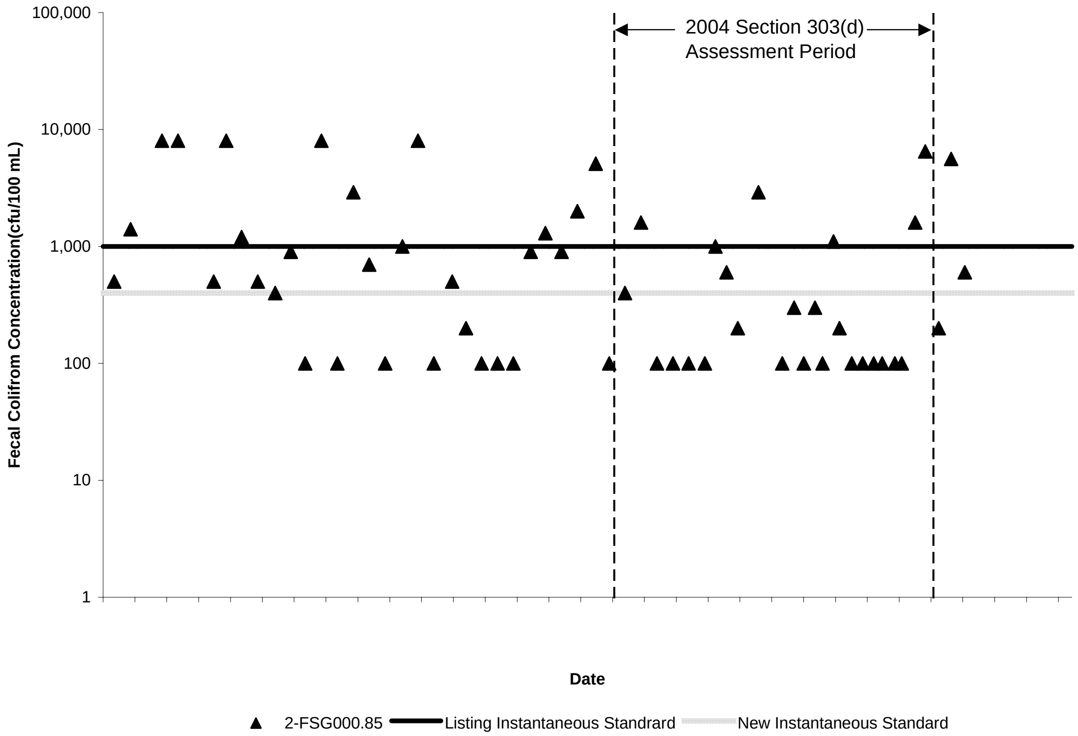

Figure 2.3. Fecal coliform concentrations VADEQ station 2-FSG000.85 in the Fishing Creek (VAC-H03R-02) impairment.

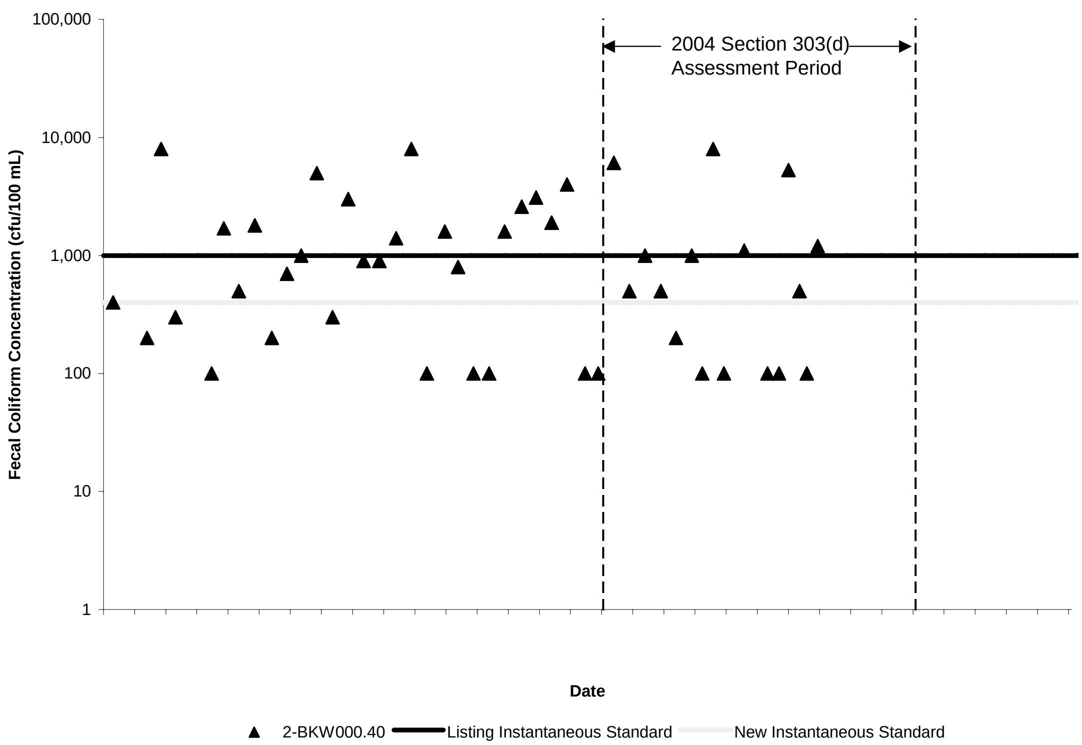

Figure 2.4. Fecal coliform concentrations VADEQ station 2-BKW000.40 in the Blackwater Creek (VAC-H03R-01) impairment.

Seasonal variability of fecal coliform concentration 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 the concentrations for samples collected in each month; the number of values varied according to the available number of samples for each month in the period of record (Table 2.1). The period of record for the 2-JMS258.54 station was 1970 – 2006, the period of record for the 2-FSG000.85, and 2-IVA000.22 stations was 1988 – 2003, and the period of record for the 2-BKW000.40 station was 1988 - 2001. Mean monthly fecal coliform bacteria concentrations were plotted for these four stations (Figures 2.5 - 2.8).

Every month at station 2-JMS258.54 had high mean fecal coliform concentrations with a peak average concentration in July (Figure 2.5). The highest mean concentrations occurred in the fall and winter, with February having the highest average concentration followed by December and November at station 2-IVA000.22 (Figure 2.6). At station 2-FSG000.85, mean fecal coliform bacteria concentrations were highest in the spring (March/April) and Fall (November/December) (Figure 2.7). Figure 2.8 illustrates that each season contained a month that the mean fecal coliform concentration was elevated, therefore a seasonal difference could not be determined at station 2-BKW000.40.

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) 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 2.5 – 2.8.

Table 2.1. Number of samples collected per month from 1970 to 2006 (2-JMS258.54), 1988 to 2003 (2-IVA000.22 and 2-FSG000.85) and 1988 to 2001 (2-BKW000.40) in the James River impairments.

Month	Samples Collected at			
	2-JMS258.54 (#)	2-IVA000.22 (#)	2-FSG000.85 (#)	2BKW000.40 (#)
January	28	2	2	0
February	32	3	1	4
March	27	8	11	6
April	36	3	3	2
May	29	1	1	0
June	32	9	12	9
July	32	3	2	1
August	30	1	2	2
September	27	12	11	10
October	31	1	2	2
November	29	2	2	0
December	29	12	13	13
TOTAL	362	57	62	49

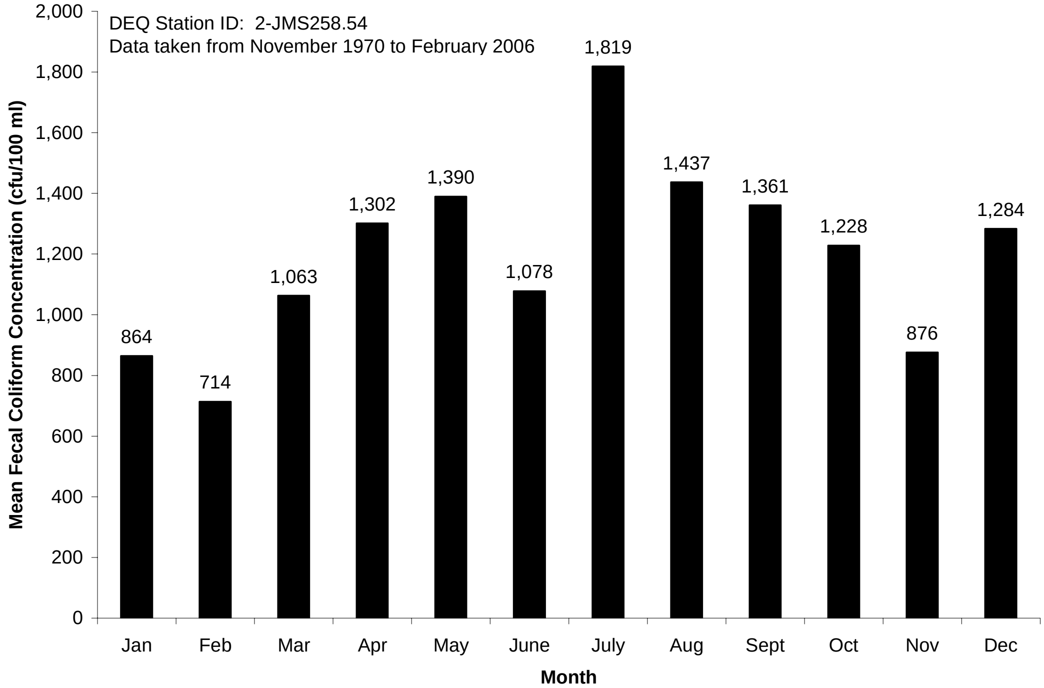

Figure 2.5. Impact of seasonality on fecal coliform concentrations (VADEQ station 2-JMS258.54 in the James River (VAC-H03R-04) impairment from November 1970 to February 2006.

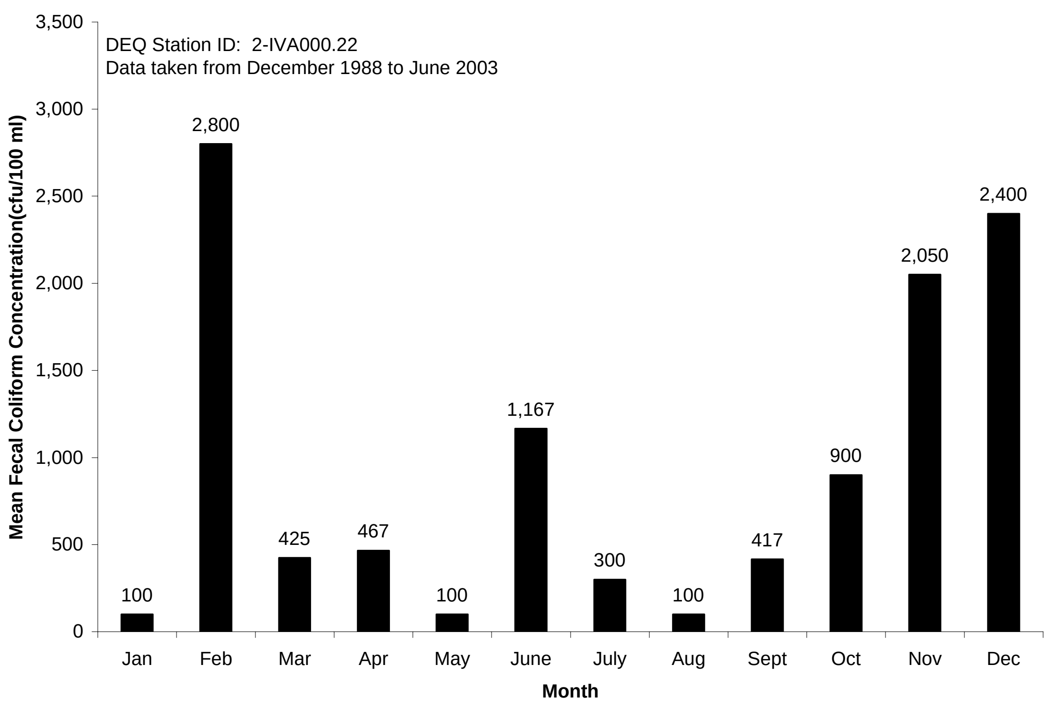

Figure 2.6. Impact of seasonality on fecal coliform concentrations (VADEQ station 2-IVA000.22 in the Ivy Creek (VAC-H03R-03) impairment from December 1998 to June 2003.

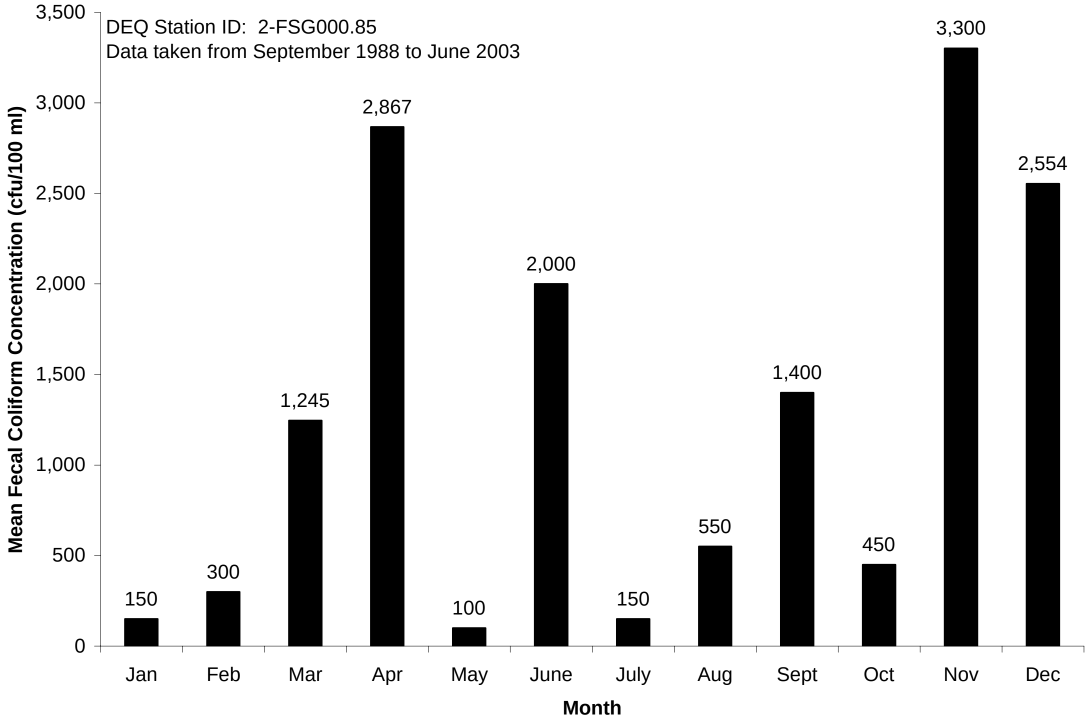

Figure 2.7. Impact of seasonality on fecal coliform concentrations (VADEQ station 2-FSG000.85 in the Fishing Creek (VAC-H03R-02) impairment from September 1998 to June 2003.

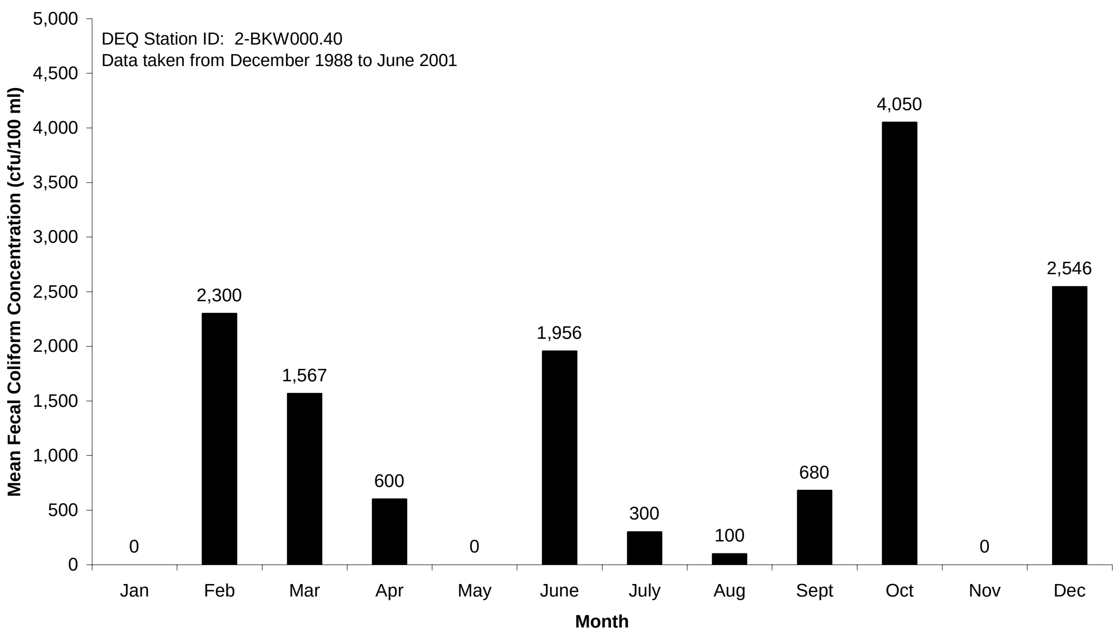

Figure 2.8. Impact of seasonality on fecal coliform concentrations (VADEQ station 2BKW000.40 in the Blackwater Creek (VAC-H03R-01) impairment from December 1988 to June 2001.

2.5.2 Historic Data for E. coli

This section includes historical data relevant to three of the seven streams addressed in this report: Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06). This data is compiled from samples collected from January 2000 through December 2004 (the 2006 Section 303(d) 5-year listing period) for the 2006 Section 303(d) 5-year listing period. The data are included in Figures 2.9 through 2.11.

Of the nine water quality samples collected from at VADEQ station 2-THK002.33, 22.2% of the samples exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Consequently, this segment of Tomahawk Creek (VAC-H03R-07) 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 (VADEQ, 2006).

The instantaneous *E. coli* bacteria standard of 235 cfu/100 mL was exceeded in four nine (44.4%) samples collected during the 2004 Section 303(d) assessment period at station 2-BUN001.64. This segment of Burton Creek (VAC-H03R-05) was assessed as not supporting of the Recreation Use goal and was included in the 2006 Section 303(d) list (VADEQ, 2004).

Of the 9 water quality samples collected from at VADEQ station 2-JTH001.52, 33.3% of the samples exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Consequently, this segment of Judith Creek (VAC-H03R-06) 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 (VADEQ, 2006).

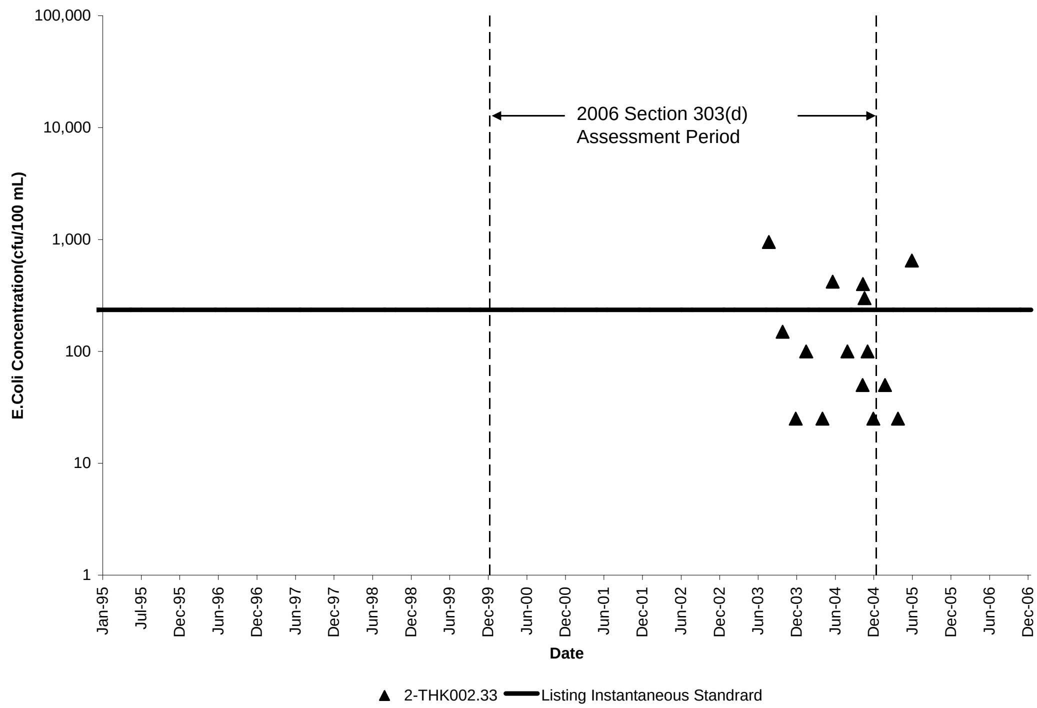

Figure 2.9. VADEQ station 2-THK002.33 in the Tomahawk Creek (VAC-H03R-07) impairment.

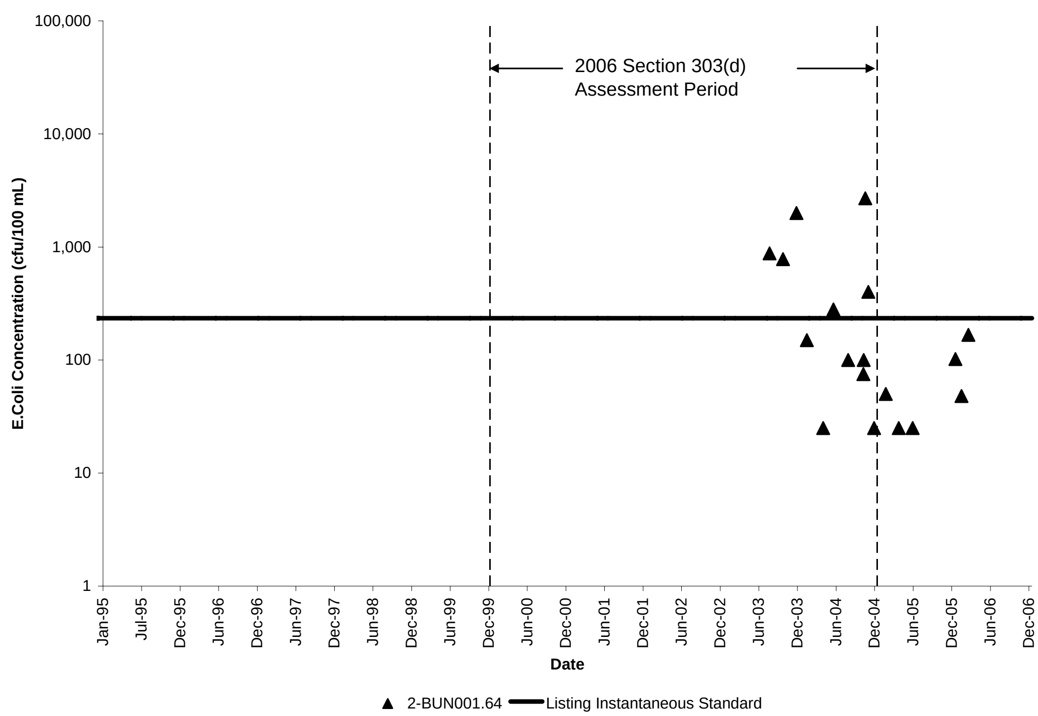

Figure 2.10. VADEQ station 2-BUN001.64 in the Burton Creek (VAC-H03R-05) impairment.

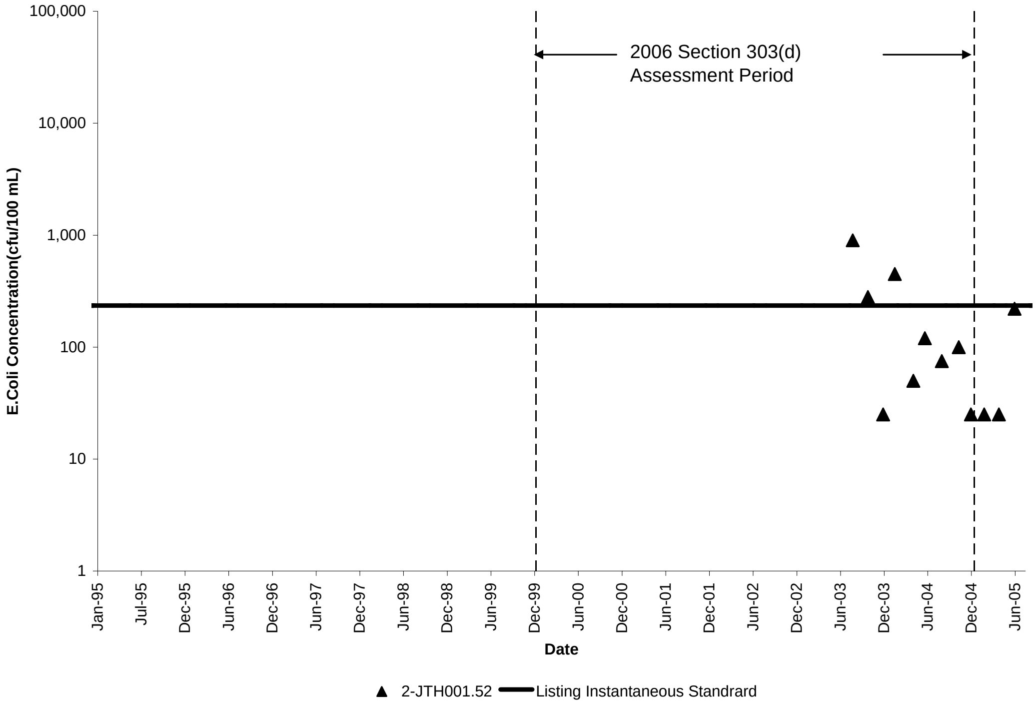

Figure 2.11. VADEQ station 2-JTH001.52 in the Judith Creek (VAC-H03R-06) impairment.

Seasonal variability of *E. coli* concentration in the stream network was evaluated by plotting the mean monthly *E. coli* concentration values. Mean monthly *E. coli* concentration values were determined as the average of the concentrations for samples collected in each month; the number of values varied according to the available number of samples for each month in the period of record (Table 2.2). The period of record for the 2-THK002.33 station was 2003 – 2005, and the period of record for the 2-BUN001.64 and 2-JTH001.52 stations was 2003 – 2006. Mean monthly *E. coli* bacteria concentrations were plotted for these four stations (Figures 2.12 - 2.14).

The summer months of June and August had the highest mean *E. coli* concentrations at station 2-THK002.33 (Figure 2.12). The highest mean concentrations occurred in the late summer and fall months, with November having the highest average concentration at station 2-BUN001.64 (Figure 2.13). At station 2-JTH001.52, mean *E. coli* bacteria concentrations were highest in August (Figure 2.14).

Table 2.2. Number of samples collected per month from 2003 to 2005 (2-THK002.33) and 2003 to 2006 (2-BUN001.64 and 2-JTH001.52) in the James River impairments.

Month	Samples Collected at		
	2-THK002.33 (#)	2-BUN001.64 (#)	2-JTH001.52 (#)
January	0	1	1
February	2	3	3
March	0	1	1
April	2	2	3
May	0	0	1
June	2	2	2
July	0	0	0
August	2	2	2
September	0	0	0
October	3	3	2
November	2	2	0
December	2	2	2
TOTAL	15	18	17

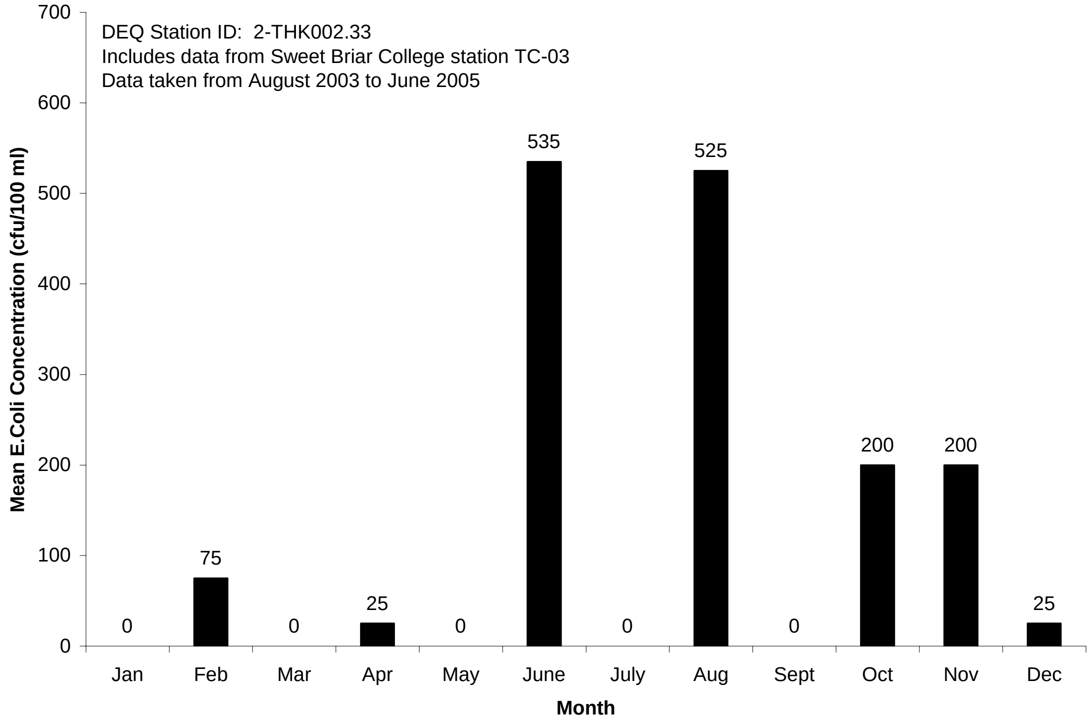

Figure 2.12. Impact of seasonality on fecal coliform concentrations (VADEQ station 2-THK002.33 in the Tomahawk Creek (VAC-H03R-07) impairment from August 2003 to June 2005.

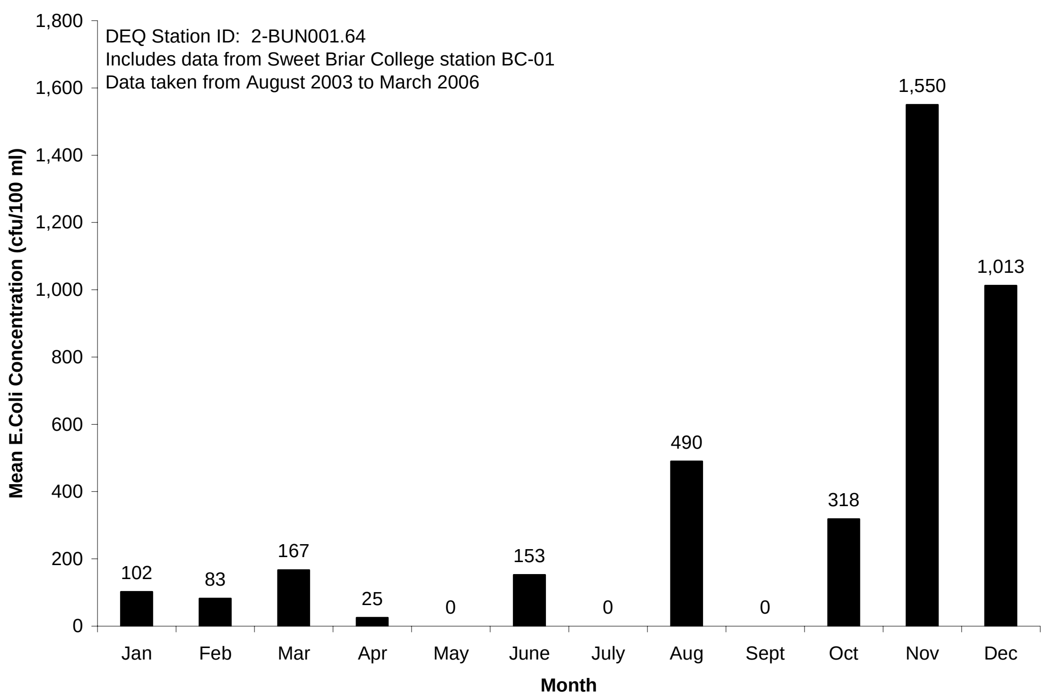

Figure 2.13. Impact of seasonality on fecal coliform concentrations (VADEQ station 2-BUN001.64 in the Burton Creek (VAC-H03R-05) impairment from August 2003 to March 2006.

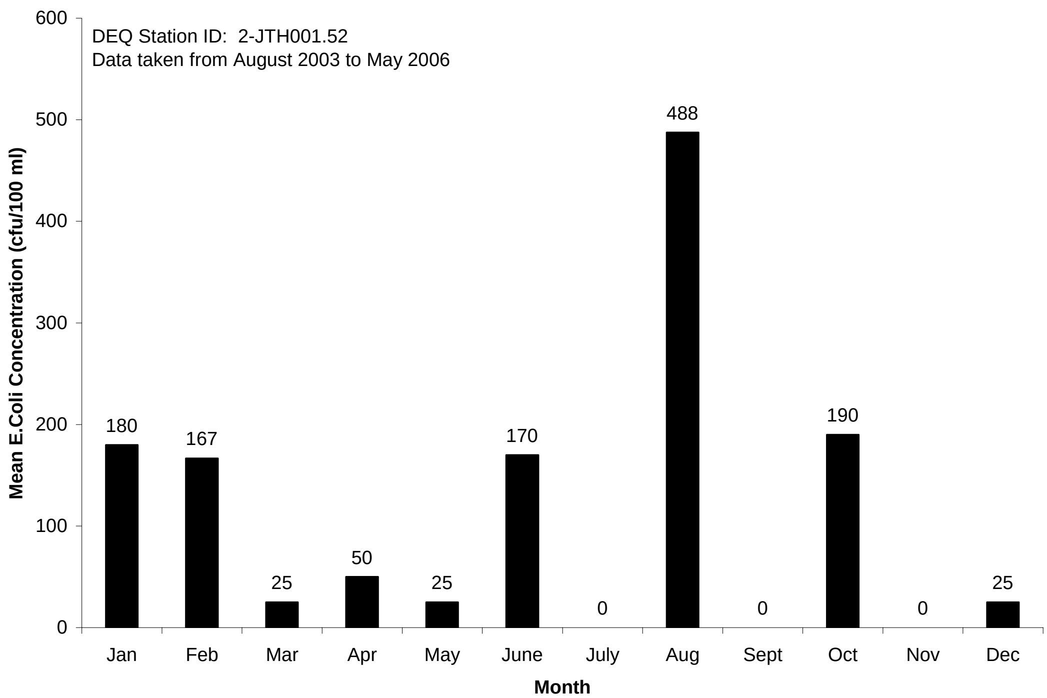

Figure 2.14. Impact of seasonality on fecal coliform concentrations (VADEQ station 2-JTH001.52 in the Judith Creek (VAC-H03R-06) impairment from August 2003 to May 2006.

2.5.3 Historic Data for Bacteria Source Tracking

The results from 12 monthly bacteria source tracking (BST) samples collected at stations 2-JMS258.54, 2-FSG000.85, 2-BKW000.40, 2-THK001.31, and 2-BUN001.64 and were received at the time this report was prepared. There were only 11 samples collected at station 2-IVA000.22. The BST analysis was performed by MapTech, Inc. 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 study watersheds, 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%. Tables 2.3 through 2.8 summarize the results of the presence/absence analysis of the BST data. The BST data were used to verify modeling methods and assumptions.

Table 2.3. Presence/absence analysis of bacteria sources at station 2-JMS258.54 in the James River (VAC-H03R-04) impairment watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standards[2] (%)
Wildlife	92%	100%
Human	50%	63%
Livestock	83%	88%
Pet	50%	38%

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., two) the source was present in samples that exceeded either the fecal coliform or *E. coli* instantaneous standard.

Table 2.4. Presence/absence analysis of bacteria sources at station 2-IVA000.22 in the Ivy Creek (VAC-H03R-03) impairment watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standards[2] (%)
Wildlife	64%	67%
Human	64%	67%
Livestock	9%	0%
Pet	64%	100%

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., three) the source was present in samples that exceeded either the fecal coliform or *E. coli* instantaneous standard.

Table 2.5. Presence/absence analysis of bacteria sources at station 2-FSG000.85 in the Fishing Creek (VAC-H03R-02) impairment watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standards[2] (%)
Wildlife	92%	100%
Human	25%	40%
Livestock	50%	60%
Pet	42%	40%

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.

Table 2.6. Presence/absence analysis of bacteria sources at station 2-BKW000.40 in the Blackwater Creek (VAC-H03R-01) impairment watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standards[2] (%)
Wildlife	92%	100%
Human	42%	75%
Livestock	50%	0%
Pet	42%	50%

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.

Table 2.7. Presence/absence analysis of bacteria sources at station 2-THK002.33 in the Tomahawk Creek (VAC-H03R-07) impairment watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standards[2] (%)
Wildlife	83%	75%
Human	33%	50%
Livestock	33%	25%
Pet	50%	25%

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.

Table 2.8. Presence/absence analysis of bacteria sources at station 2-BUN001.64 in the Burton Creek (VAC-H03R-05) impairment watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standards[2] (%)
Wildlife	75%	67%
Human	50%	50%
Livestock	67%	67%
Pet	67%	67%

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.

Fecal coliform and *E. coli* enumerations were also performed on the BST samples. These data are also referenced in Appendix B. At station 2-JMS258.54, 66.7% (eight of 12) of the samples exceeded the *E. coli* bacteria instantaneous standard. Three of 11 (27.3%) samples exceeded the *E. coli* bacteria instantaneous standard at station 2-IVA000.22. There were five violations (41.7%) of the *E. coli* bacteria instantaneous standard at station 2-FSG000.85. At stations 2-BKW000.40 and 2-THK002.33, 33.3% (4 of 12) of the samples exceeded the *E. coli* bacteria instantaneous standard. Half of the samples (50% or six of 12) collected at station 2-BUN001.64 exceeded the *E. coli* bacteria instantaneous standard.

Chapter 3. Bacteria Source Assessment

Potential bacteria sources in the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds 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 Lynchburg; Bedford County; Campbell County, Amherst County; Region 2000 Local Government Council; Natural Resources Conservation Service (NRCS); Virginia Department of Agricultural and Consumer Services (VDACS); Robert E. Lee and Peaks of Otter 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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds, 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 impaired watersheds.

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
	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 of fecal coliform bacteria in the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds include all municipal and industrial plants that treat human waste (individual permits), as well as private residences that fall under general permits (less than or equal to 1,000 gallons per day). Virginia issues Virginia Pollutant Discharge Elimination System (VPDES) permits for point sources of pollution. Point sources with an individual or general permit were 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 James River (VAC-H03R-04) and Judith Creek (VAC-H03R-06) watersheds. There are no permitted facilities discharging bacteria in the Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), or Burton Creek (VAC-H03R-05) watersheds.

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.

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

Impairment	Permit Number	Facility Name	Sub-shed	Design Flow (MGD)	FC Load (cfu/yr)	*E. coli* Load (cfu/yr)
Judith Creek (VAC-H03R-06)	VA0063657 [1]	Amherst Co Service Auth-Ivanhoe Forest	JR-4	0.0015	4.11E+09	2.59E+09
James River (VAC-H03R-04)	VA0027618 [1, 4]	US Department of Labor-Rescare	JR-4	0.04	0.00E+00	0.00E+00
James River (VAC-H03R-04)	VA0091162 [1]	Boonsboro Country Club	JC-2	0.015	4.14E+10	2.61E+10
James River (VAC-H03R-04)	VA0051888 [2]	Lynchburg City Abert Water	JR-2	0.265	0.00E+00	0.00E+00
James River (VAC-H03R-04)	VA0024970 [1, 3]	Lynchburg City Sewage	JR-7	22	6.08E+13	3.83E+13
James River (VAC-H03R-04)	VA0087114 [2]	American Electric Power - Reusens	JR-3	0.177	0.00E+00	0.00E+00
James River (VAC-H03R-04)	VA0002925 [2]	Griffin Pipe Products	JR-5	0.04	0.00E+00	0.00E+00

Notes:
1. These permits include either an explicite bacteria limit or a chlorine residual limit implying the discharge of bacteria and therefore will receive an allocation for their permitted load at the design flow.
2. These permits do not include a bacteria limit, either explicite or implicite. They will be modeled at the design flow, but no allocation will be made for them.
3. This permit also authorizes combined sewer overflow (CSO) discharge points.
4. This permit is not active, but is included for historical reference. It receives no allocation.

As noted in Table 3.2, VPDES permit # VA0024970 associated with the Lynchburg Waste Water Treatment Plant has associated with it authorization for discharges from combined sewer overflow (CSO) points. Since 1989, the City of Lynchburg has been working toward correcting its CSOs, pursuing an approach of separation. To date, 132 CSOs originally identified in 1989 have been reduced to 35 as of 2006. The bacteria load from these CSOs is precipitation event-dependent, and has been reduced from an estimated value of $9.02\text{x}10^{16}$ in 1989 to an estimated value of $1.07\text{x}10^{16}$ in 2002 The City continues to work toward eliminating these 35 CSOs, but estimates it will require another 30 years to completely eliminate them. Active CSO discharge points are present in James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01).

Phase II Municipal Separate Storm Sewer System (MS4) permits were also reviewed. The City of Lynchburg and the Virginia Department of Transportation each have a MS4 permit whose limits are defined by the city boundary. These MS4 permits discharge within the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds.

3.2 James River (VAC-H03R-04) Sources

3.2.1 Humans and Pets

There are 5,245 homes served by municipal sanitary sewer in the James River (VAC-H03R-04) watershed. Wastewater from 5,542 households within the watershed is treated on site by traditional sewage handling and disposal systems.

The James River (VAC-H03R-04) watershed has an estimated population of 25,326 people (10,893 households at an average of 2.32 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce $1.95x10^9$ cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of $4.94x10^{13}$ cfu/day ($1.80x10^{16}$ cfu/year) in James River (VAC-H03R-04) watershed.

Bacteria from humans and pets can be transported to streams from failing septic systems, straight pipes discharging directly into streams, biosolid applications to pasture and cropland, or deposition of pet waste on residential land.

3.2.1.1 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 and 2000 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). Originally, in accordance with estimates from Dr. Raymond B. Reneau, Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1984, a 20% 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 James River (VAC-H03R-04) 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). The application of Dr. Reneau's work reflects the implementation of the septic regulations combined with the consideration of data availability. Also, considering substantial input from members of the project Technical Advisory Committee, the rates applied using this method were adjusted to reflect local conditions. The 40% rate to reflect conditions prior to implementation was changed to 15%, the 20% failure rate that reflects conditions during the period following implementation and those systems reaching their design life (ranges from 10 to 20 years depending on the application and housing unit age data used) was changed to 7.5%, but the 3% failure rated used to reflect more modern systems that haven't approached design life was left unchanged. Our application of this method incorporates Census data to determine home age and reflects implementation of the septic regulations. The local VDH staff indicated that the regulations were implemented in 1982. The census data we used breaks at 1984, so we used 1984 as a breakpoint year and applied a 10-year interim period to arrive at 1994 for the other breakpoint year.

An average number of people per household and number of houses and people in each subwatershed in 2006 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB; 1990, 2000, and 2004). 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 2.32 persons/household was 4.53×10^9 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.

3.2.1.2 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-1967 age category. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1967, 1967 – 1987, post 1987), 10% of old houses (pre-1967) within 150 ft of streams and 2% of mid-age houses (1967 – 1987) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 106 houses that potentially could be classified as straight pipes in the James River (VAC-H03R-04) watershed (Table 3.4).

3.2.1.3 Biosolids

According to VDH records; 3,417, 5,589, 831, 4,598, 7,459, and 23,286 dry tons of Class B biosolids were applied in 2000, 2001, 2002, 2003, 2004, and 2005, respectively, in Bedford County. VDH records do not indicate application of biosolids in Amherst County, Campbell County, or Lynchburg. Comprehensive application rates, bacteria concentrations, and spatial distribution of application sites within the James River (VAC-H03R-04) watershed were not available. To estimate biosolids applications within each James River (VAC-H03R-04) subwatershed, records of biosolids applications within the county were obtained from VDH. The average monthly biosolids application total mass data for the county from 2000 to 2005 were divided by the total pasture and cropland acreage in the county. The resulting rates were distributed based on the crop and pasture areas in each subwatershed. Although Class B biosolids are permitted to contain fecal coliform concentrations of $2.0\text{x}10^6$ cfu/g (VDH, 1997), values reported by treatment plants are typically lower than this value. For this study, VDH records indicated that the primary source for biosolids was Synagro stabilized cake and pellets. The fecal coliform density of biosolids from this source is estimated to be less than 4 cfu/g (VDH, 2005). Therefore, an average fecal coliform density of 4 cfu/g was used for bacteria loading calculations. Table 3.3 shows the estimated average annual biosolids application amount for each subwatershed (See Figure 4.1 through 4.4 for location of subwatersheds).

Table 3.3. Estimated average annual biosolids application amount for each subwatershed in the James River (VAC-H03R-04) watershed.

Subwatershed	Biosolids Applied (dry tons / year)
JR-2	0
JR-3	6.21

Subwatershed	Biosolids Applied (dry tons / year)
JR-4	0
JR-5	0
JR-6	0
JR-7	0
Total	**6.21**

3.2.2 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 theses densities and number of households in each watershed, 5,773 dogs and 6,536 cats were projected to reside in the James River (VAC-H03R-04) 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 10,893 for James River (VAC-H03R-04) 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 James River (VAC-H03R-04) watershed is 4.9×10^{12} cfu/day (1.8×10^{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 James River (VAC-H03R-04) watershed.

Sub-shed	Human Population	Sewered Houses	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
			Pre-1984	1985 - 1995	Post-1995			
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
JR-2	747	12	216	63	31	38	12	334
JR-3	4,479	1,779	85	20	17	15	2	1,904
JR-4	5,851	255	1,503	409	382	268	72	2,620
JR-5	2,142	589	408	25	4	63	4	1,031
JR-6	4,082	1,794	108	2	0	16	2	1,906
JR-7	8,025	816	2,092	176	0	327	14	3,098
Total	25,326	5,245	4,412	695	434	727	11	10,893

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

3.2.3 Livestock Sources

In the James River (VAC-H03R-04) watershed, bacteria from livestock 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. Livestock populations in the James River (VAC-H03R-04) 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.

3.2.3.1 Cattle

Based on information obtained from VADCR and SWCDs, there is no dairy farm presently operating in the James River (VAC-H03R-04) watershed. Beef cattle in the James River (VAC-H03R-04) watershed (1,729 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 James River (VAC-H03R-04) watersheds.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
JR-2	0	0	153
JR-3	0	0	20
JR-4	0	0	1,204
JR-5	0	0	34
JR-6	0	0	9
JR-7	0	0	309
Total	**0**	**0**	**1,729**

[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 James River (VAC-H03R-04) 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 TAC 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 beef cattle.

Table 3.7. Distribution of the beef cattle population (pairs) in the James River (VAC-H03R-04) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*	Loafing
January	795.34	907.95	227.39	56.85	0.82	0.00
February	933.66	1065.86	266.93	66.73	0.97	0.00
March	0.00	1828.43	457.91	114.48	2.49	0.00
April	0.00	1880.40	470.92	117.73	3.42	0.00
May	0.00	1931.66	483.76	120.94	5.27	0.00
June	0.00	1978.73	495.55	123.89	12.63	0.00
July	0.00	2031.14	508.68	127.17	12.96	0.00
August	0.00	2083.56	521.80	130.45	13.30	0.00
September	0.00	2141.91	536.42	134.10	5.84	0.00
October	0.00	1314.96	329.32	82.33	2.39	0.00
November	0.00	1381.19	345.90	86.48	1.88	0.00
December	760.76	868.48	217.50	54.37	0.79	0.00

*Number of beef cattle defecating in stream.

3.2.3.2 Direct Manure Deposition in Streams

Direct manure loading to streams can be due to both dairy and beef cattle (Table 3.7) defecating in the stream. However, only cattle on pastures contiguous to streams which 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 James River (VAC-H03R-04) watersheds is 115,129 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 1.73×10^{11} cfu/day (6.33×10^{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.

3.2.3.3 Direct Manure Deposition on Pastures

Dairy and beef (Table 3.7) 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 James River (VAC-H03R-04) watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 6,079; 3,040; and 1,520 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 James River (VAC-H03R-04), averaged over the year, are 3.36×10^{12}, 1.69×10^{12}, and 8.54×10^{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.

3.2.3.4 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, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 3.9.

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 3.9). 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 3.9). Solid manure is applied at the rate of 12 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 3.8. Based on availability of land and solid manure, as well as the assumptions regarding application rate, 35.5 acres of the cropland,76.5 acres of the pasture 1, 25.6 acres of pasture 2, and 12.8 acres of pasture 3 in James River (VAC-H03R-04) received solid manure application.

Table 3.8. Schedule of cattle waste application in James River (VAC-H03R-04) 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.

Table 3.9. 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 James River (VAC-H03R-04) 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	0	1,400	115.0	2.17	5.50
Heifer	0	640	40.7	2.17	
Beef (pairs)	1,729	1,000	60.0	5.50	

[a]Source: BSE (2003)

3.2.4 Horses

The estimated number of horses in the James River (VAC-H03R-04) watershed is included in Table 3.10. 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 TAC.

The typical horse produces $4.2x10^8$ cfu/day (VADCR, 2003). Therefore, the daily fecal coliform production by horses in the James River (VAC-H03R-04) watershed is $9.16x10^{10}$ cfu/day ($3.34x10^{13}$ cfu/year).

Table 3.10. Horse population by subwatershed in the James River (VAC-H03R-04) watershed.

Subwatershed	Horses
JR-2	23
JR-3	3
JR-4	157
JR-5	4
JR-6	1
JR-7	30
Total	**218**

3.2.5 Other Livestock Sources

Other minor livestock-related sources of bacteria (e.g., goats) were present during watershed visits; however, a significant population was not identified within the James River (VAC-H03R-04) watershed. The potential bacteria load from these sources was accounted for during water quality calibration.

3.2.6 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 James River (VAC-H03R-04) watershed, is $6.89x10^{14}$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, and revised based on significant feedback from TAC members. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.11).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (3.11). 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 3.11, 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 3.12.

Table 3.11. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the James River (VAC-H03R-04) watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.021	
Raccoon	Primary: 600 feet buffer around streams and impoundments Secondary: 601 feet -7,920 feet buffer from streams and impoundments	0.070	
Muskrat	Primary: 66 feet buffer around streams and impoundments in forest and cropland Secondary: 67-300 feet buffer from same	0.037[a]	
Beaver	300 feet buffer around streams and impoundments in forest and pasture	0.015	
Geese	300 feet buffer around main streams	0.006[b]	
Wood Duck	300 feet buffer around main streams	0.002[b]	
Wild Turkey	Entire watershed except urban areas	0.005[c]	

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

Table 3.12. Distribution of wildlife among sub-watersheds in James River (VAC-H03R-04) watershed.

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
JR-2	569	444	177	43	63	22	131
JR-3	124	144	94	6	15	5	17
JR-4	1,767	1,326	1,772	96	185	65	256
JR-5	116	101	35	10	15	5	19
JR-6	35	39	12	2	8	3	5
JR-7	667	747	687	48	100	35	132
Total	**3,278**	**2,801**	**2,777**	**205**	**386**	**135**	**560**

3.2.7 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the James River (VAC-H03R-04) watershed along with average fecal coliform production rates are shown in Table 3.13. The total fecal coliform production by all sources in the James River (VAC-H03R-04) watershed is 3.21×10^{16} cfu/yr.

Table 3.13. Potential fecal coliform sources and daily fecal coliform production by source in James River (VAC-H03R-04) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times 10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times 10^6$ cfu/ day)[b]
Beef Cattle (pairs)	1,729	33,000	77,142,236
Horses	218	420	91,623
Humans	25,326	1,950	3,948,366
Pets	10,893	450	4,905,207
Deer	3,278	350	1,148,086
Raccoon	2,801	50	140,146
Muskrat	2,777	25	69,473
Beaver	205	0.2	41
Wild Turkey	386	93	52,116
Duck	135	2,400	245,581
Goose	560	800	231,984

[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 3.14. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.14.

From 3.14, it is clear in the James River (VAC-H03R-04) watershed that nonpoint source loadings to the land surface are more than 98 times as large as direct loadings to the streams, with pastures receiving about 87% 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 3.14. Annual fecal coliform loadings to the stream and the various land use categories in the James River (VAC-H03R-04) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	17,658	0.59%
Cattle in Stream	6,332	0.21%
Wildlife in Stream	5,942	0.20%
Loading to Land Surfaces		
Cropland	3,079	0.10%
Pasture 1	1,969,564	66.15%
Pasture 2	496,495	16.67%
Pasture 3	126,031	4.23%
Forest	46,978	1.58%
Residential*	305,497	10.26%
Total	**2,977,576**	**100.00%**

*Includes loads received from failed septic systems and pets.

3.3 Ivy Creek (VAC-H03R-03) Sources

3.3.1 Humans and Pets

There are 3,979 homes served by municipal sanitary sewer in the Ivy Creek (VAC-H03R-03) watershed. Wastewater from 2,580 households within the watershed is treated on site by traditional sewage handling and disposal systems.

The Ivy Creek (VAC-H03R-03) watershed has an estimated population of 16,892 people (6,572 households at an average of 2.57 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce $1.95x10^9$ cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of $3.29x10^{13}$ cfu/day ($1.20x10^{16}$ cfu/year) in Ivy Creek (VAC-H03R-03) watershed.

Bacteria from humans and pets can be transported to streams from failing septic systems, straight pipes discharging directly into streams, biosolid applications to pasture and cropland, or deposition of pet waste on residential land.

3.3.1.1 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 and 2000 U.S. Census Bureau demographics data

(UCSB, 1990 and 2000). Originally, in accordance with estimates from Dr. Raymond B. Reneau, Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1984, a 20% 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 James River (VAC-H03R-04) 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). The application of Dr. Reneau's work reflects the implementation of the septic regulations combined with the consideration of data availability. Also, considering substantial input from members of the project Technical Advisory Committee, the rates applied using this method were adjusted to reflect local conditions. The 40% rate to reflect conditions prior to implementation was changed to 15%, the 20% failure rate that reflects conditions during the period following implementation and those systems reaching their design life (ranges from 10 to 20 years depending on the application and housing unit age data used) was changed to 7.5%, but the 3% failure rated used to reflect more modern systems that haven't approached design life was left unchanged. Our application of this method incorporates Census data to determine home age and reflects implementation of the septic regulations. The local VDH staff indicated that the regulations were implemented in 1982. The census data we used breaks at 1984, so we used 1984 as a breakpoint year and applied a 10-year interim period to arrive at 1994 for the other breakpoint year.

An average number of people per household and number of houses and people in each subwatershed in 2006 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB; 1990, 2000, and 2004). 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 2.57 persons/household was 5.01×10^9 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 3.16.

3.3.1.2 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-1967 and 1967-1987 age categories. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1967, 1967 – 1987, post 1987), 10% of old houses (pre-1967) within 150 ft of streams and 2% of mid-age houses (1967 – 1987) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 13

houses that potentially could be classified as straight pipes in the Ivy Creek (VAC-H03R-03) watershed (Table 3.16).

3.3.1.3 Biosolids

According to VDH records; 3,417, 5,589, 831, 4,598, 7,459, and 23,286 dry tons of Class B biosolids were applied in 2000, 2001, 2002, 2003, 2004, and 2005, respectively, in Bedford County. VDH records do not indicate application of biosolids in Lynchburg. Comprehensive application rates, bacteria concentrations, and spatial distribution of application sites within the Ivy Creek (VAC-H03R-03) watershed were not available. To estimate biosolids applications within each Ivy Creek (VAC-H03R-03) subwatershed, records of biosolids applications within the county were obtained from VDH. The average monthly biosolids application total mass data for the county from 2000 to 2005 were divided by the total pasture and cropland acreage in the county. The resulting rates were distributed based on the crop and pasture areas in each subwatershed. Although Class B biosolids are permitted to contain fecal coliform concentrations of $2.0x10^6$ cfu/g (VDH, 1997), values reported by treatment plants are typically lower than this value. For this study, VDH records indicated that the primary source for biosolids was Synagro stabilized cake and pellets. The fecal coliform density of biosolids from this source is estimated to be less than 4 cfu/g (VDH, 2005). Therefore, an average fecal coliform density of 4 cfu/g was used for bacteria loading calculations. Table 3.15 shows the estimated average annual biosolids application amount for each subwatershed (See Figure 4.1 through 4.4 for location of subwatersheds).

Table 3.15. Estimated average annual biosolids application amount for each subwatershed in the Ivy Creek (VAC-H03R-03) watershed.

Subwatershed	Biosolids Applied (dry tons / year)
BW-1	124
BW-2	128
BW-3	0
Total	**252**

3.3.2 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 theses densities and number of households in each watershed, 3,483 dogs and 3,943 cats were projected to reside in the Ivy Creek (VAC-H03R-03) 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 6,572 for Ivy Creek (VAC-H03R-03) watershed. The maximum typical fecal coliform production for both dogs and cats is $5.0x10^9$ 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 Ivy Creek (VAC-H03R-03) watershed is $3.0x10^{12}$ cfu/day ($1.1x10^{15}$ cfu/yr). The pet population distribution among the subwatersheds is listed in Table

3.16. 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 3.16. 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 Ivy Creek (VAC-H03R-03) watershed.

Sub-shed	Human Population	Sewered Houses	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
			Pre-1984	1985 - 1995	Post-1995			
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
BW-1	2943	118	245	353	251	71	5	1100
BW-2	8269	1,455	1,115	448	41	202	8	3468
BW-3	5680	2,406	110	11	5	17	0	2862
Total	**16,892**	**3,979**	**1,471**	**812**	**297**	**290**	**13**	**7,430**

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

3.3.3 Livestock Sources

In the Ivy Creek (VAC-H03R-03) watershed, bacteria from livestock 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. Livestock populations in the Ivy Creek (VAC-H03R-03) 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.

3.3.3.1 Cattle

Based on information obtained from VADCR and SWCDs, there is one dairy farm presently operating in the Blue Run (VAN-E13R-03) watershed. Based on information provided, it was determined that there were 80 milk cows, 40 dry cows, and 40 heifers on one farm. The dairy cattle population was distributed among the sub-watersheds based on the location of the dairy farm (Table 3.17). Beef cattle in the Ivy Creek (VAC-H03R-03) watershed (749 pairs) included cow/calf and feeder operations (Table 3.17).

Table 3.17. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Ivy Creek (VAC-H03R-03) watersheds.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
BW-1	0	0	396
BW-2	160	1	353
BW-3	0	0	0
Total	**160**	**0**	**749**

[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 3.18.
- 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 3.18). 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 3.18. Time spent by cattle in confinement and in the stream in Ivy Creek (VAC-H03R-03) 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 TAC 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 3.19 for dairy cattle and in Table 3.20 for beef cattle.

Table 3.19. Distribution of the dairy cattle[a] population in the Ivy Creek (VAC-H03R-03) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream[b]	Loafing[c]
January	92.00	51.71	12.95	3.24	0.10	0.00
February	92.00	51.71	12.95	3.24	0.10	0.00
March	32.00	97.26	24.36	6.09	0.29	0.00
April	24.00	103.26	25.86	6.47	0.41	0.00
May	24.00	103.11	25.82	6.46	0.61	0.00
June	24.00	102.48	25.67	6.42	1.43	0.00
July	24.00	102.48	25.67	6.42	1.43	0.00
August	24.00	102.48	25.67	6.42	1.43	0.00
September	24.00	103.11	25.82	6.46	0.61	0.00
October	24.00	103.26	25.86	6.47	0.41	0.00
November	32.00	97.26	24.36	6.09	0.29	0.00
December	92.00	51.71	12.95	3.24	0.10	0.00

[a]Includes milk cows, dry cows, and heifers.
[b]Number of dairy cattle defecating in stream.
[c]Milk cows in loafing lot.

Table 3.20. Distribution of the beef cattle population (pairs) in the Ivy Creek (VAC-H03R-03) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*	Loafing
January	344.54	392.94	98.41	24.60	0.86	0.00
February	404.46	461.28	115.52	28.88	1.01	0.00
March	0.00	790.91	198.07	49.52	2.61	0.00
April	0.00	812.99	203.60	50.90	3.58	0.00
May	0.00	834.33	208.95	52.24	5.52	0.00
June	0.00	851.27	213.19	53.30	13.23	0.00
July	0.00	873.82	218.84	54.71	13.58	0.00
August	0.00	896.37	224.48	56.12	13.93	0.00
September	0.00	925.14	231.69	57.92	6.12	0.00
October	0.00	568.52	142.38	35.59	2.50	0.00
November	0.00	597.45	149.62	37.41	1.97	0.00
December	329.56	375.85	94.13	23.53	0.83	0.00

*Number of beef cattle defecating in stream.

3.3.3.2 Direct Manure Deposition in Streams

Direct manure loading to streams is due to both dairy (Table 3.19) and beef cattle (Table 3.20) defecating in the stream. However, only cattle on pastures contiguous to streams which 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 Ivy Creek (VAC-H03R-03) watersheds is 141,207 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 3.69×10^{13} cfu/day (1.35×10^{16} 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.

3.3.3.3 Direct Manure Deposition on Pastures

Dairy (Table 3.19) and beef (Table 3.20) 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 Ivy Creek (VAC-H03R-03) watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 4,884; 2,442; and 1,221 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 Ivy Creek (VAC-H03R-03), averaged over the year, are 2.44×10^{12}, 1.23×10^{12}, and 6.20×10^{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.

3.3.3.4 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 Ivy Creek (VAC-H03R-03) watershed is 212,551 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 32.2 acres of cropland and 0.0 acres of pasture 1 in the Ivy Creek (VAC-H03R-03) 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 3.21. Dry cows and heifers were assumed to produce only solid manure.

Table 3.21. Schedule of cattle waste application in Ivy Creek (VAC-H03R-03) 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.

3.3.3.5 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, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 3.22.

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 3.22). 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 3.22). Solid manure is applied at the rate of 12 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 3.21. Based on availability of land and solid manure, as well as the assumptions regarding application rate, 0.0 acres of the cropland and 90.1 acres of the pasture 1 in Ivy Creek (VAC-H03R-03) received solid manure application.

Table 3.22. 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 Ivy Creek (VAC-H03R-03) 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	40	1,400	115.0	2.17	5.09
Heifer	40	640	40.7	2.17	
Beef (pairs)	749	1,000	60.0	5.50	

[a]Source: BSE (2003)

3.3.4 Horses

The estimated number of horses in the Ivy Creek (VAC-H03R-03) watershed is included in Table 3.23. 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 TAC.

The typical horse produces $4.2x10^8$ cfu/day (VADCR, 2003). Therefore, the daily fecal coliform production by horses in the Ivy Creek (VAC-H03R-03) watershed is $6.05x10^{10}$ cfu/day ($2.21x10^{13}$ cfu/year).

Table 3.23. Horse population by subwatershed in the Ivy Creek (VAC-H03R-03) watershed.

Subwatershed	Horses
BW-1	76
BW-2	68
BW-3	0
Total	**144**

3.3.5 Other Livestock Sources

Other minor livestock-related sources of bacteria (e.g., goats) were present during watershed visits; however, a significant population was not identified within the Ivy Creek (VAC-H03R-03) watershed. The potential bacteria load from these sources was accounted for during water quality calibration.

3.3.6 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Table 3.26 The total wildlife fecal coliform production each year in the Ivy Creek (VAC-H03R-03) watershed, is $2.76x10^{14}$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, and revised based on significant feedback from TAC members. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.24).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.24). 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 3.24, 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 3.25.

Table 3.24. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Ivy Creek (VAC-H03R-03) watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.021	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	0.006[b]	0.25
Wood Duck	300 feet buffer around main streams	0.002[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 3.25. Distribution of wildlife among sub-watersheds in Ivy Creek (VAC-H03R-03) watershed.

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
BW-1	484	311	800	33	53	19	120
BW-2	678	550	804	46	73	26	136
BW-3	147	179	28	8	17	6	21
Total	**1,309**	**1,040**	**1,632**	**87**	**143**	**51**	**277**

3.3.7 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the Ivy Creek (VAC-H03R-03) watershed along with average fecal coliform production rates are shown in Table 3.26. The total fecal coliform production by all sources in the Ivy Creek (VAC-H03R-03) watershed is 1.54×10^{16} cfu/yr.

Table 3.26. Potential fecal coliform sources and daily fecal coliform production by source in Ivy Creek (VAC-H03R-03) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times10^7$ cfu/ day)[b]
Dairy Cattle			
Millk and Dry Cows	120	25,000	3,002,055
Heifers	40	8,800	457,456
Beef Cattle (pairs)	749	33,000	33,417,892
Horses	144	420	60,521
Humans	16,892	1,950	1,674,303
Pets	6,572	450	2,959,426
Deer	1,309	350	458,464
Raccoon	1,040	50	52,036
Muskrat	1,632	25	40,828
Beaver	87	0.2	17
Wild Turkey	143	93	25,779
Duck	51	2,400	92,237
Goose	277	800	86,248

[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 3.27. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.27.

From Table 3.27, it is clear in the Ivy Creek (VAC-H03R-03) watershed that nonpoint source loadings to the land surface are more than 115 times as large as direct loadings to the streams, with pastures receiving about 85% 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 3.27. Annual fecal coliform loadings to the stream and the various land use categories in the Ivy Creek (VAC-H03R-03) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	2,687	0.19%
Cattle in Stream	7,100	0.50%
Wildlife in Stream	2,368	0.17%
Loading to Land Surfaces		
Cropland	6,877	0.49%
Pasture 1	915,671	65.02%
Pasture 2	230,573	16.37%
Pasture 3	58,271	4.14%
Forest	18,345	1.30%
Residential*	166,444	11.82%
Total	**1,408,337**	**100.00%**

*Includes loads received from failed septic systems and pets.

3.4 Fishing Creek (VAC-H03R-02) Sources

3.4.1 Humans and Pets

There are 4,211 homes served by municipal sanitary sewer in the Fishing Creek (VAC-H03R-02) watershed. Wastewater from 87 households within the watershed is treated on site by traditional sewage handling and disposal systems.

The Fishing Creek (VAC-H03R-02) watershed has an estimated population of 9,006 people (4,298 households at an average of 2.10 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce $1.95x10^{9}$ cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of $1.76x10^{13}$ cfu/day ($6.41x10^{15}$ cfu/year) in Fishing Creek (VAC-H03R-02) watershed.

Bacteria from humans and pets can be transported to streams from failing septic systems, straight pipes discharging directly into streams, biosolid applications to pasture and cropland, or deposition of pet waste on residential land.

3.4.1.1 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 and 2000 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). Originally, in accordance with estimates from Dr. Raymond B. Reneau,

Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1984, a 20% 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 James River (VAC-H03R-04) 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). The application of Dr. Reneau's work reflects the implementation of the septic regulations combined with the consideration of data availability. Also, considering substantial input from members of the project Technical Advisory Committee, the rates applied using this method were adjusted to reflect local conditions. The 40% rate to reflect conditions prior to implementation was changed to 15%, the 20% failure rate that reflects conditions during the period following implementation and those systems reaching their design life (ranges from 10 to 20 years depending on the application and housing unit age data used) was changed to 7.5%, but the 3% failure rated used to reflect more modern systems that haven't approached design life was left unchanged. Our application of this method incorporates Census data to determine home age and reflects implementation of the septic regulations. The local VDH staff indicated that the regulations were implemented in 1982. The census data we used breaks at 1984, so we used 1984 as a breakpoint year and applied a 10-year interim period to arrive at 1994 for the other breakpoint year.

An average number of people per household and number of houses and people in each subwatershed in 2006 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB; 1990, 2000, and 2004). 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 2.10 persons/household was 4.09×10^9 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 3.28.

3.4.1.2 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-1967 and 1967-1987 age categories. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1967, 1967 – 1987, post 1987), 10% of old houses (pre-1967) within 150 ft of streams and 2% of mid-age houses (1967 – 1987) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 0

houses that potentially could be classified as straight pipes in the Fishing Creek (VAC-H03R-02) watershed (Table 3.28.

3.4.1.3 Biosolids

VDH records do not indicate application of biosolids in Lynchburg.

3.4.2 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 theses densities and number of households in each watershed, 2,278 dogs and 2,579 cats were projected to reside in the Fishing Creek (VAC-H03R-02) 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 4,298 for Fishing Creek (VAC-H03R-02) watershed. The maximum typical fecal coliform production for both dogs and cats is $5.0x10^9$ 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 Fishing Creek (VAC-H03R-02) watershed is $1.9x10^{12}$ cfu/day ($7.1x10^{14}$ cfu/yr). The pet population distribution among the subwatersheds is listed in Table 3.29. 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 3.28. 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 Fishing Creek (VAC-H03R-02) watershed.

Sub-shed	Human Population	Sewered Houses	Unsewered Houses in Each Age Category: Pre-1984	1985 - 1995	Post-1995	Failing Septic System	Straight Pipes	Pet Population[a]
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
FG-1	9,006	4,211	85	2	0	13	0	4,298
Total	9,006	4,211	85	2	0	13	0	4,298

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

3.4.3 Livestock Sources

In the Fishing Creek (VAC-H03R-02) watershed, bacteria from livestock 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. Livestock populations in the Fishing Creek (VAC-H03R-02) 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.

3.4.3.1 Cattle

Based on information obtained from VADCR and SWCDs, there are no dairy farms presently operating in the Fishing Creek (VAC-H03R-02) watershed. Beef cattle in the Fishing Creek (VAC-H03R-02) watershed (30 pairs) included cow/calf and feeder operations (Table 3.29).

Table 3.29. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Fishing Creek (VAC-H03R-02) watersheds.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
FG-1	0	0	30
Total	**0**	**0**	**30**

[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 3.30.
- 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 3.30). 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 3.30. Time spent by cattle in confinement and in the stream in Fishing Creek (VAC-H03R-02) 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 TAC 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 3.31 for beef cattle.

Table 3.31. Distribution of the beef cattle population (pairs) in the Fishing Creek (VAC-H03R-02) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*	Loafing
January	13.80	15.74	3.94	0.99	0.03	0.00
February	16.20	18.48	4.63	1.16	0.03	0.00
March	0.00	31.69	7.94	1.98	0.09	0.00
April	0.00	32.58	8.16	2.04	0.12	0.00
May	0.00	33.45	8.38	2.09	0.18	0.00
June	0.00	34.17	8.56	2.14	0.44	0.00
July	0.00	35.07	8.78	2.20	0.45	0.00
August	0.00	35.98	9.01	2.25	0.46	0.00
September	0.00	37.09	9.29	2.32	0.20	0.00
October	0.00	22.78	5.71	1.43	0.08	0.00
November	0.00	23.94	6.00	1.50	0.06	0.00
December	13.20	15.06	3.77	0.94	0.03	0.00

*Number of beef cattle defecating in stream.

3.4.3.2 Direct Manure Deposition in Streams

Direct manure loading to streams can be due to both dairy and beef cattle (Table 3.31) defecating in the stream. However, only cattle on pastures contiguous to streams which 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 Fishing Creek (VAC-H03R-02) watersheds is 3,976 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 5.99×10^{9} cfu/day (2.18×10^{12} 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.

3.4.3.3 Direct Manure Deposition on Pastures

Dairy and beef (Table 3.31) 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 Fishing Creek (VAC-H03R-02) watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 3,428; 1,714; and 857 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 Fishing Creek (VAC-H03R-02), averaged over the year, are 1.89×10^{12}, 9.50×10^{11}, and 4.79×10^{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.

3.4.3.4 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, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 3.33.

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 3.33). 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 3.33). Solid manure is applied at the rate of 12 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 3.32. Based on availability of land and solid manure, as well as the assumptions regarding application rate, 3.2 acres of the cropland and 0.0 acres of the pasture 1 in Fishing Creek (VAC-H03R-02) received solid manure application.

Table 3.32. Schedule of cattle waste application in Fishing Creek (VAC-H03R-02) 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.

Table 3.33. 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 Fishing Creek (VAC-H03R-02) 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	0	1,400	115.0	2.17	5.50
Heifer	0	640	40.7	2.17	
Beef (pairs)	30	1,000	60.0	5.50	

[a]Source: BSE (2003)

3.4.4 *Horses*

Based on information obtained from VADCR and SWCDs, there are no horses presently in the Fishing Creek (VAC-H03R-02) watershed.

3.4.5 *Other Livestock Sources*

Other minor livestock-related sources of bacteria (e.g., goats) were present during watershed visits; however, a significant population was not identified within the Fishing Creek (VAC-H03R-02) watershed. The potential bacteria load from these sources was accounted for during water quality calibration.

3.4.6 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Table 3.36. The total wildlife fecal coliform production each year in the Fishing Creek (VAC-H03R-02) watershed, is $6.55x10^{12}$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, and revised based on significant feedback from TAC members. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.34).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.34). 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 3.34, 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 3.35.

Table 3.34. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Fishing Creek (VAC-H03R-02) watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.020	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	0.009[b]	0.25
Wood Duck	300 feet buffer around main streams	0.002[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 3.35. Distribution of wildlife among sub-watersheds in Fishing Creek (VAC-H03R-02) watershed.

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
FG-1	145	167	47	5	28	10	19
Total	**145**	**167**	**47**	**5**	**28**	**10**	**19**

3.4.7 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the Fishing Creek (VAC-H03R-02) watershed along with average fecal coliform production rates are shown in Table 3.36. The total fecal coliform production by all sources in the Fishing Creek (VAC-H03R-02) watershed is 1.25×10^{15} cfu/yr.

Table 3.36. Potential fecal coliform sources and daily fecal coliform production by source in Fishing Creek (VAC-H03R-02) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times 10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times 10^6$ cfu/ day)[b]
Beef Cattle (pairs)	30	33,000	1,338,500
Humans	9,006	1,950	54,739
Pets	4,298	450	1,935,425
Deer	145	350	50,785
Raccoon	167	50	8,356
Muskrat	47	25	1,176
Beaver	5	0.2	1
Wild Turkey	28	93	1,768
Duck	10	2,400	17,967
Goose	19	800	16,769

[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 3.37. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.37.

From Table 3.37, it is clear in the Fishing Creek (VAC-H03R-02) watershed that nonpoint source loadings to the land surface are more than 199 times as large as direct loadings to the streams, with pastures receiving about 36% 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 3.37. Annual fecal coliform loadings to the stream and the various land use categories in the Fishing Creek (VAC-H03R-02) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	8	0.01%
Cattle in Stream	219	0.18%
Wildlife in Stream	377	0.31%
Loading to Land Surfaces		
Cropland	227	0.19%
Pasture 1	33,916	28.04%
Pasture 2	8,526	7.05%
Pasture 3	2,148	1.78%
Forest	2,923	2.42%
Residential*	72,633	60.04%
Total	**120,977**	**100.00%**

*Includes loads received from failed septic systems and pets.

3.5 Blackwater Creek (VAC-H03R-01) Sources

3.5.1 Humans and Pets

There are 8,941 homes served by municipal sanitary sewer in the Blackwater Creek (VAC-H03R-01) watershed. Wastewater from 586 households within the watershed is treated on site by traditional sewage handling and disposal systems.

The Blackwater Creek (VAC-H03R-01) watershed has an estimated population of 20,019 people (9,548 households at an average of 2.10 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce $1.95x10^{13}$ cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of $3.90x10^{13}$ cfu/day ($1.42x10^{16}$ cfu/year) in Blackwater Creek (VAC-H03R-01) watershed.

Bacteria from humans and pets can be transported to streams from failing septic systems, straight pipes discharging directly into streams, biosolid applications to pasture and cropland, or deposition of pet waste on residential land.

3.5.1.1 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 and 2000 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). Originally, in accordance with estimates from Dr. Raymond B. Reneau,

Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1984, a 20% 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 James River (VAC-H03R-04) 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). The application of Dr. Reneau's work reflects the implementation of the septic regulations combined with the consideration of data availability. Also, considering substantial input from members of the project Technical Advisory Committee, the rates applied using this method were adjusted to reflect local conditions. The 40% rate to reflect conditions prior to implementation was changed to 15%, the 20% failure rate that reflects conditions during the period following implementation and those systems reaching their design life (ranges from 10 to 20 years depending on the application and housing unit age data used) was changed to 7.5%, but the 3% failure rated used to reflect more modern systems that haven't approached design life was left unchanged. Our application of this method incorporates Census data to determine home age and reflects implementation of the septic regulations. The local VDH staff indicated that the regulations were implemented in 1982. The census data we used breaks at 1984, so we used 1984 as a breakpoint year and applied a 10-year interim period to arrive at 1994 for the other breakpoint year.

An average number of people per household and number of houses and people in each subwatershed in 2006 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB; 1990, 2000, and 2004). 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 2.10 persons/household was 4.09×10^9 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 3.38.

3.5.1.2 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-1967 and 1967-1987 age categories. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1967, 1967 – 1987, post 1987), 10% of old houses (pre-1967) within 150 ft of streams and 2% of mid-age houses (1967 – 1987) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 21

houses that potentially could be classified as straight pipes in the Blackwater Creek (VAC-H03R-01) watershed (Table 3.38).

3.5.1.3 Biosolids

VDH records do not indicate application of biosolids in Lynchburg.

3.5.2 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 theses densities and number of households in each watershed, 5,060 dogs and 5,729 cats were projected to reside in the Blackwater Creek (VAC-H03R-01) 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 9,548 for Blackwater Creek (VAC-H03R-01) 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 Blackwater Creek (VAC-H03R-01) watershed is 3.90×10^{13} cfu/day (1.42×10^{16} cfu/yr). The pet population distribution among the subwatersheds is listed in Table 3.38. 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 3.38. 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 Blackwater Creek (VAC-H03R-01) watershed.

Sub-shed	Human Population	Sewered Houses	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
			Pre-1984	1985 - 1995	Post-1995			
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
BW-8	13,046	5,438	529	44	0	83	8	6,018
BW-9	6,973	3,503	11	2	0	2	14	3,530
Total	20,019	8,941	540	46	0	85	21	9,548

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

3.5.3 Livestock Sources

Based on information obtained from VADCR, City of Lynchburg, TAC members, and SWCDs, there are no livestock presently in the Blackwater Creek (VAC-H03R-01) watershed. This is a very urbanized watershed.

3.5.4 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Table 3.41. The total wildlife fecal coliform production each year in the Blackwater Creek (VAC-H03R-01) watershed, is 5.40×10^{13}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, and revised based on significant feedback from TAC members. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.39).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.39). 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 3.39, 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 3.40.

Table 3.39. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Blackwater Creek (VAC-H03R-01) watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.019	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	0.021[b]	0.25
Wood Duck	300 feet buffer around main streams	0.003[b]	0.25
Wild Turkey	Entire watershed except urban areas	0.006[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 3.40. Distribution of wildlife among sub-watersheds in Blackwater Creek (VAC-H03R-01) watershed.

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
BW-8	149	195	57	7	24	8	20
BW-9	86	103	10	5	13	5	12
Total	**235**	**298**	**67**	**12**	**37**	**13**	**32**

3.5.5 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the Blackwater Creek (VAC-H03R-01) watershed along with average fecal coliform production rates are shown in Table 3.41. The total fecal coliform production by all sources in the Blackwater Creek (VAC-H03R-01) watershed is 1.79×10^{15} cfu/yr.

Table 3.41. Potential fecal coliform sources and daily fecal coliform production by source in Blackwater Creek (VAC-H03R-01) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times 10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times 10^6$ cfu/ day)[b]
Humans	20,019	1,950	449,223
Pets	9,548	450	4,299,543
Deer	235	350	82,306
Raccoon	298	50	14,910
Muskrat	67	25	1,676
Beaver	12	0.2	2
Wild Turkey	37	93	2,978
Duck	13	2,400	23,962
Goose	32	800	22,361

[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 3.42. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.42.

From Table 3.42, it is clear in the Blackwater Creek (VAC-H03R-01) watershed that nonpoint source loadings to the land surface are more than 48 times as large as direct loadings to the streams, with pastures receiving about 1% 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 3.42. Annual fecal coliform loadings to the stream and the various land use categories in the Blackwater Creek (VAC-H03R-01) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	3,123	1.75%
Cattle in Stream	0	0.00%
Wildlife in Stream	524	0.29%
Loading to Land Surfaces		
Cropland	8	0.00%
Pasture 1	715	0.40%
Pasture 2	358	0.20%
Pasture 3	179	0.10%
Forest	3,625	2.03%
Residential*	170,207	95.23%
Total	**178,739**	**100.00%**

*Includes loads received from failed septic systems and pets.

3.6 Tomahawk Creek (VAC-H03R-07) Sources

3.6.1 Humans and Pets

There are 910 homes served by municipal sanitary sewer in the Tomahawk Creek (VAC-H03R-07) watershed. Wastewater from 2,554 households within the watershed is treated on site by traditional sewage handling and disposal systems.

The Tomahawk Creek (VAC-H03R-07) watershed has an estimated population of 9,306 people (3,476 households at an average of 2.68 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce $1.95x10^9$ cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of $1.81x10^{13}$ cfu/day ($6.62x10^{15}$ cfu/year) in Tomahawk Creek (VAC-H03R-07) watershed.

Bacteria from humans and pets can be transported to streams from failing septic systems, straight pipes discharging directly into streams, biosolid applications to pasture and cropland, or deposition of pet waste on residential land.

3.6.1.1 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 and 2000 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). Originally, in accordance with estimates from Dr. Raymond B. Reneau,

Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1984, a 20% 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 James River (VAC-H03R-04) 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). The application of Dr. Reneau's work reflects the implementation of the septic regulations combined with the consideration of data availability. Also, considering substantial input from members of the project Technical Advisory Committee, the rates applied using this method were adjusted to reflect local conditions. The 40% rate to reflect conditions prior to implementation was changed to 15%, the 20% failure rate that reflects conditions during the period following implementation and those systems reaching their design life (ranges from 10 to 20 years depending on the application and housing unit age data used) was changed to 7.5%, but the 3% failure rated used to reflect more modern systems that haven't approached design life was left unchanged. Our application of this method incorporates Census data to determine home age and reflects implementation of the septic regulations. The local VDH staff indicated that the regulations were implemented in 1982. The census data we used breaks at 1984, so we used 1984 as a breakpoint year and applied a 10-year interim period to arrive at 1994 for the other breakpoint year.

An average number of people per household and number of houses and people in each subwatershed in 2006 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB; 1990, 2000, and 2004). 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 2.68 persons/household was 5.22×10^9 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 3.44.

3.6.1.2 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-1967 and 1967-1987 age categories. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1967, 1967 – 1987, post 1987), 10% of old houses (pre-1967) within 150 ft of streams and 2% of mid-age houses (1967 – 1987) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 12

houses that potentially could be classified as straight pipes in the Tomahawk Creek (VAC-H03R-07) watershed (Table 3.44).

3.6.1.3 Biosolids

According to VDH records; 3,417, 5,589, 831, 4,598, 7,459, and 23,286 dry tons of Class B biosolids were applied in 2000, 2001, 2002, 2003, 2004, and 2005, respectively, in Bedford County. VDH records do not indicate application of biosolids in Lynchburg. Comprehensive application rates, bacteria concentrations, and spatial distribution of application sites within the Tomahawk Creek (VAC-H03R-07) watershed were not available. To estimate biosolids applications within each Tomahawk Creek (VAC-H03R-07) subwatershed, records of biosolids applications within the county were obtained from VDH. The average monthly biosolids application total mass data for the county from 2000 to 2005 were divided by the total pasture and cropland acreage in the county. The resulting rates were distributed based on the crop and pasture areas in each subwatershed. Although Class B biosolids are permitted to contain fecal coliform concentrations of $2.0x10^6$ cfu/g (VDH, 1997), values reported by treatment plants are typically lower than this value. For this study, VDH records indicated that the primary source for biosolids was Synagro stabilized cake and pellets. The fecal coliform density of biosolids from this source is estimated to be less than 4 cfu/g (VDH, 2005). Therefore, an average fecal coliform density of 4 cfu/g was used for bacteria loading calculations. Table 3.43 shows the estimated average annual biosolids application amount for each subwatershed (See Figure 4.1 through 4.4 for location of subwatersheds).

Table 3.43. Estimated average annual biosolids application amount for each subwatershed in the Tomahawk Creek (VAC-H03R-07) watershed.

Subwatershed	Biosolids Applied (dry tons / year)
BW-7	23.5
Total	**23.5**

3.6.2 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 theses densities and number of households in each watershed, 1,842 dogs and 2,086 cats were projected to reside in the Tomahawk Creek (VAC-H03R-07) 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 3,476 for Tomahawk Creek (VAC-H03R-07) watershed. The maximum typical fecal coliform production for both dogs and cats is $5.0x10^9$ 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 Tomahawk Creek (VAC-H03R-07) watershed is $1.6x10^{12}$ cfu/day ($5.7x10^{14}$ cfu/yr). The pet population distribution among the subwatersheds is listed in Table 3.44. 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 3.44. 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 Tomahawk Creek (VAC-H03R-07) watershed.

Sub-shed	Human Population	Sewered Houses	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
			Pre-1984	1985 - 1995	Post-1995			
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
BW-7	9,306	910	2,064	376	114	341	12	3,476
Total	9,306	910	2,064	376	114	341	12	3,476

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

3.6.3 Livestock Sources

In the Tomahawk Creek (VAC-H03R-07) watershed, bacteria from livestock 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. Livestock populations in the Tomahawk Creek (VAC-H03R-07) 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.

3.6.3.1 Cattle

Based on information obtained from VADCR and SWCDs, there is no dairy farms presently operating in the Tomahawk Creek (VAC-H03R-07) watershed. Beef cattle in the Tomahawk Creek (VAC-H03R-07) watershed (95 pairs) included cow/calf and feeder operations (Table 3.45).

Table 3.45. Distribution of beef cattle among subwatersheds in Tomahawk Creek (VAC-H03R-07) watersheds.

Subwatershed	Beef Cattle (pairs)
BW-7	95
Total	**95**

Cattle spend varying amounts of time in streams and pasture depending on the time of year. 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:

- The beef cattle spend their time on pasture.

- 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 3.46). 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 3.46. Time spent by cattle in the stream in Tomahawk Creek (VAC-H03R-07) watershed.

Month	Time Spent in Stream (hours/day)*
January	0.50
February	0.50
March	0.75
April	1.00
May	1.50
June	3.50
July	3.50
August	3.50
September	1.50
October	1.00
November	0.75
December	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 TAC 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 3.47 for beef cattle.

Table 3.47. Distribution of the beef cattle population (pairs) in the Tomahawk Creek (VAC-H03R-07) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*	Loafing
January	43.70	49.86	12.49	3.12	0.08	0.00
February	51.30	58.53	14.66	3.66	0.10	0.00
March	0.00	100.38	25.14	6.28	0.25	0.00
April	0.00	103.20	25.85	6.46	0.34	0.00
May	0.00	105.96	26.54	6.63	0.52	0.00
June	0.00	108.30	27.12	6.78	1.25	0.00
July	0.00	111.17	27.84	6.96	1.28	0.00
August	0.00	114.04	28.56	7.14	1.32	0.00
September	0.00	117.49	29.42	7.36	0.58	0.00
October	0.00	72.17	18.07	4.52	0.24	0.00
November	0.00	75.83	18.99	4.75	0.19	0.00
December	41.80	47.69	11.94	2.99	0.08	0.00

*Number of beef cattle defecating in stream.

3.6.3.2 Direct Manure Deposition in Streams

Direct manure loading to streams can be due to dairy and beef cattle (Table 3.47) defecating in the stream. However, only cattle on pastures contiguous to streams which 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 Tomahawk Creek (VAC-H03R-07) watersheds is 4,565 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 1.72×10^{10} cfu/day (6.26×10^{12} 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.

3.6.3.3 Direct Manure Deposition on Pastures

Beef cattle that graze on pastures, but do not deposit in streams, contribute the majority of fecal coliform loading on pastures (Table 3.47). Manure loading on pasture was estimated by multiplying the total number of cattle 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 Tomahawk Creek (VAC-H03R-07) watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 841; 420; and 210 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 Tomahawk Creek (VAC-H03R-07), averaged over the year, are 1.48×10^{12}, 7.45×10^{11}, and 3.78×10^{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.

3.6.3.4 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, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 3.49.

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 3.49). 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 3.49). Solid manure is applied at the rate of 12 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 3.48. Based on availability of land and solid manure, as well as the assumptions regarding application rate, 10.2 acres of the cropland in Tomahawk Creek (VAC-H03R-07)received solid manure application.

Table 3.48. Schedule of cattle waste application in Tomahawk Creek (VAC-H03R-07) 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.

Table 3.49. 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 Tomahawk Creek (VAC-H03R-07) 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	0	1,400	115.0	2.17	5.50
Heifer	0	640	40.7	2.17	
Beef (pairs)	95	1,000	60.0	5.50	

[a]Source: BSE (2003)

3.6.4 Horses

The estimated number of horses in the Tomahawk Creek (VAC-H03R-07) watershed is included in Table 3.50. 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 TAC.

The typical horse produces 4.2×10^8 cfu/day (VADCR, 2003). Therefore, the daily fecal coliform production by horses in the Tomahawk Creek (VAC-H03R-07) watershed is 5.46×10^9 cfu/day (1.99×10^{12} cfu/year).

Table 3.50. Horse population by subwatershed in the Tomahawk Creek (VAC-H03R-07) watershed.

Subwatershed	Horses
BW-7	13
Total	**13**

3.6.5 Other Livestock Sources

Other minor livestock-related sources of bacteria (e.g., goats) were present during watershed visits; however, a significant population was not identified within the Tomahawk Creek (VAC-H03R-07) watershed. The potential bacteria load from these sources was accounted for during water quality calibration.

3.6.6 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Table 3.53. The total wildlife fecal coliform production each year in the Tomahawk Creek (VAC-H03R-07) watershed, is 4.95×10^{13}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, and revised based on significant feedback from TAC members. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.51).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.51). 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 3.51, 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 3.52.

Table 3.51. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Tomahawk Creek (VAC-H03R-07) watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.021	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	0.006[b]	0.25
Wood Duck	300 feet buffer around main streams	0.002[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 3.52. Distribution of wildlife among sub-watersheds in Tomahawk Creek (VAC-H03R-07) watershed.

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
BW-7	216	244	228	15	31	11	32
Total	216	244	228	15	31	11	32

3.6.7 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the Tomahawk Creek (VAC-H03R-07) watershed along with average fecal coliform production rates are shown in Table 3.53. The total fecal coliform production by all sources in the Tomahawk Creek (VAC-H03R-07) watershed is 2.86×10^{15} cfu/yr.

Table 3.53. Potential fecal coliform sources and daily fecal coliform production by source in Tomahawk Creek (VAC-H03R-07) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times 10^7$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times 10^6$ cfu/ day)[b]
Beef Cattle (pairs)	95	33,000	4,238,584
Horses	13	420	5,464
Humans	9,306	1,950	1,892,348
Pets	3,476	450	1,565,271
Deer	216	350	75,652
Raccoon	244	50	12,208
Muskrat	228	25	5,704
Beaver	15	0.2	3
Wild Turkey	31	93	2,978
Duck	11	2,400	20,369
Goose	32	800	18,768

[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 3.54. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.54.

From Table 3.54, it is clear in the Tomahawk Creek (VAC-H03R-07) watershed that nonpoint source loadings to the land surface are more than 77 times as large as direct loadings to the streams, with pastures receiving about 52% 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 3.54. Annual fecal coliform loadings to the stream and the various land use categories in the Tomahawk Creek (VAC-H03R-07) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	2,381	0.87%
Cattle in Stream	626	0.23%
Wildlife in Stream	482	0.18%
Loading to Land Surfaces		
Cropland	824	0.30%
Pasture 1	107,887	39.49%
Pasture 2	27,230	9.97%
Pasture 3	6,913	2.53%
Forest	3,063	1.12%
Residential*	123,822	45.32%
Total	**273,229**	**100.00%**

*Includes loads received from failed septic systems and pets.

3.7 Burton Creek (VAC-H03R-05) Sources

3.7.1 Humans and Pets

There are 2,285 homes served by municipal sanitary sewer in the Burton Creek (VAC-H03R-05) watershed. Wastewater from 2,430 households within the watershed is treated on site by traditional sewage handling and disposal systems.

The Burton Creek (VAC-H03R-05) watershed has an estimated population of 13,952 people (4,719 households at an average of 2.96 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce $1.95x10^{9}$ cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of $2.72x10^{13}$ cfu/day ($9.93x10^{15}$ cfu/year) in Burton Creek (VAC-H03R-05) watershed.

Bacteria from humans and pets can be transported to streams from failing septic systems, straight pipes discharging directly into streams, biosolid applications to pasture and cropland, or deposition of pet waste on residential land.

3.7.1.1 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 and 2000 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). Originally, in accordance with estimates from Dr. Raymond B. Reneau,

Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1984, a 20% 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 James River (VAC-H03R-04) 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). The application of Dr. Reneau's work reflects the implementation of the septic regulations combined with the consideration of data availability. Also, considering substantial input from members of the project Technical Advisory Committee, the rates applied using this method were adjusted to reflect local conditions. The 40% rate to reflect conditions prior to implementation was changed to 15%, the 20% failure rate that reflects conditions during the period following implementation and those systems reaching their design life (ranges from 10 to 20 years depending on the application and housing unit age data used) was changed to 7.5%, but the 3% failure rated used to reflect more modern systems that haven't approached design life was left unchanged. Our application of this method incorporates Census data to determine home age and reflects implementation of the septic regulations. The local VDH staff indicated that the regulations were implemented in 1982. The census data we used breaks at 1984, so we used 1984 as a breakpoint year and applied a 10-year interim period to arrive at 1994 for the other breakpoint year.

An average number of people per household and number of houses and people in each subwatershed in 2006 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB; 1990, 2000, and 2004). 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 2.96 persons/household was 5.77×10^9 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 3.55.

3.7.1.2 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-1967 and 1967-1987 age categories. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1967, 1967 – 1987, post 1987), 10% of old houses (pre-1967) within 150 ft of streams and 2% of mid-age houses (1967 – 1987) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 4

houses that potentially could be classified as straight pipes in the Burton Creek (VAC-H03R-05) watershed (Table 3.55).

3.7.1.3 Biosolids

VDH records do not indicate application of biosolids in Campbell County or Lynchburg.

3.7.2 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 theses densities and number of households in each watershed, 2,501 dogs and 2,831 cats were projected to reside in the Burton Creek (VAC-H03R-05) 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 4,719 for Burton Creek (VAC-H03R-05) 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 Burton Creek (VAC-H03R-05) watershed is 2.1×10^{12} cfu/day (7.8×10^{14} cfu/yr). The pet population distribution among the subwatersheds is listed in Table 3.55. 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 3.55. 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 Burton Creek (VAC-H03R-05) watershed.

Sub-shed	Human Population	Sewered Houses	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
			Pre-1984	1985 - 1995	Post-1995			
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
BW-4	5008	724	1,048	247	124	179	4	2,146
BW-5	8664	1,435	645	317	41	122	0	2,438
BW-6	280	127	6	2	1	1	0	135
Total	**13,952**	**2,285**	**1,699**	**565**	**165**	**302**	**4**	**4,719**

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

3.7.3 Livestock Sources

In the Burton Creek (VAC-H03R-05) watershed, bacteria from livestock 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. Livestock populations in the Burton Creek (VAC-H03R-05) 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.

3.7.3.1 Cattle

Based on information obtained from VADCR and SWCDs, there are no dairy farms presently operating in the Burton Creek (VAC-H03R-05) watershed. Beef cattle in the Burton Creek (VAC-H03R-05) watershed (30 pairs) included cow/calf and feeder operations (Table 3.56).

Table 3.56. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Burton Creek (VAC-H03R-05) watersheds.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
BW-4	0	0	17
BW-5	0	0	13
BW-6	0	0	0
Total	**0**	**0**	**30**

[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 3.57.
- 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 3.57). 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 3.57. Time spent by cattle in confinement and in the stream in Burton Creek (VAC-H03R-05) 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 TAC 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 3.58 for beef cattle.

Table 3.58. Distribution of the beef cattle population (pairs) in the Burton Creek (VAC-H03R-05) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*	Loafing
January	13.80	15.74	3.94	0.99	0.03	0.00
February	16.20	18.48	4.63	1.16	0.04	0.00
March	0.00	31.68	7.93	1.98	0.10	0.00
April	0.00	32.57	8.16	2.04	0.14	0.00
May	0.00	33.43	8.37	2.09	0.21	0.00
June	0.00	34.12	8.54	2.14	0.50	0.00
July	0.00	35.02	8.77	2.19	0.51	0.00
August	0.00	35.93	9.00	2.25	0.53	0.00
September	0.00	37.07	9.28	2.32	0.23	0.00
October	0.00	22.78	5.70	1.43	0.09	0.00
November	0.00	23.93	5.99	1.50	0.07	0.00
December	13.20	15.06	3.77	0.94	0.03	0.00

*Number of beef cattle defecating in stream.

3.7.3.2 Direct Manure Deposition in Streams

Direct manure loading to streams can be due to both dairy and beef cattle (Table 3.58) defecating in the stream. However, only cattle on pastures contiguous to streams which 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 Burton Creek (VAC-H03R-05) watersheds is 4,565 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 6.88×10^{9} cfu/day (2.51×10^{12} 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.

3.7.3.3 Direct Manure Deposition on Pastures

Dairy and beef (Table 3.58) 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 Burton Creek (VAC-H03R-05) watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 1,146; 573; and 286 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 Burton Creek (VAC-H03R-05), averaged over the year, are 6.42×10^{11}, 3.27×10^{11}, and 1.69×10^{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.

3.7.3.4 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, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 3.60.

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 3.60). 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 3.60). Solid manure is applied at the rate of 12 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 3.59. Based on availability of land and solid manure, as well as the assumptions regarding application rate, 0.0 acres of the cropland and 3.2 acres of the pasture 1 in Burton Creek (VAC-H03R-05) received solid manure application.

Table 3.59. Schedule of cattle waste application in Burton Creek (VAC-H03R-05) 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.

Table 3.60. 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 Burton Creek (VAC-H03R-05) 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	0	1,400	115.0	2.17	5.5
Heifer	0	640	40.7	2.17	
Beef (pairs)	466	1,000	60.0	5.50	

[a]Source: BSE (2003)

3.7.4 Horses

The estimated number of horses in the Burton Creek (VAC-H03R-05) watershed is included in Table 3.61. 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 TAC.

The typical horse produces 4.2×10^8 cfu/day (VADCR, 2003). Therefore, the daily fecal coliform production by horses in the Burton Creek (VAC-H03R-05) watershed is 8.41×10^8 cfu/day (3.06×10^{11} cfu/year).

Table 3.61. Horse population by subwatershed in the Burton Creek (VAC-H03R-05) watershed.

Subwatershed	Horses
BW-4	1
BW-5	1
BW-6	0
Total	**2**

3.7.5 Other Livestock Sources

Other minor livestock-related sources of bacteria (e.g., goats) were present during watershed visits; however, a significant population was not identified within the Burton Creek (VAC-H03R-05) watershed. The potential bacteria load from these sources was accounted for during water quality calibration.

3.7.6 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Table 3.64. The total wildlife fecal coliform production each year in the Burton Creek (VAC-H03R-05) watershed, is 5.83×10^{13}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, and revised based on significant feedback from TAC members. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.62).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.62). 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 3.62, 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 3.63.

Table 3.62. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Burton Creek (VAC-H03R-05) watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.020	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	0.012[b]	0.25
Wood Duck	300 feet buffer around main streams	0.002[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 3.63. Distribution of wildlife among sub-watersheds in Burton Creek (VAC-H03R-05) watershed.

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
BW-4	113	145	129	7	17	6	14
BW-5	128	171	71	7	22	8	19
BW-6	4	7	8	0	1	0	0
Total	**245**	**323**	**208**	**14**	**40**	**14**	**33**

3.7.7 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the Burton Creek (VAC-H03R-05) watershed along with average fecal coliform production rates are shown in Table 3.64. The total fecal coliform production by all sources in the Burton Creek (VAC-H03R-05) watershed is 1.95×10^{15} cfu/yr.

Table 3.64. Potential fecal coliform sources and daily fecal coliform production by source in Burton Creek (VAC-H03R-05) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times 10^7$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times 10^6$ cfu/ day)[b]
Beef Cattle (pairs)	30	33,000	1,338,500
Horses	2	420	841
Humans	13,952	1,950	1,730,120
Pets	4,719	450	2,125,004
Deer	245	350	85,809
Raccoon	323	50	16,161
Muskrat	208	25	5,204
Beaver	14	0.2	3
Wild Turkey	40	93	3,071
Duck	14	2,400	25,154
Goose	33	800	24,359

[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 3.65. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.65.

From Table 3.65, it is clear in the Burton Creek (VAC-H03R-05) watershed that nonpoint source loadings to the land surface are more than 128 times as large as direct loadings to the streams, with pastures receiving about 23% 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 3.65. Annual fecal coliform loadings to the stream and the various land use categories in the Burton Creek (VAC-H03R-05) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	642	0.34%
Cattle in Stream	251	0.13%
Wildlife in Stream	591	0.31%
Loading to Land Surfaces		
Cropland	0	0.00%
Pasture 1	34,685	18.12%
Pasture 2	8,772	4.58%
Pasture 3	2,272	1.19%
Forest	4,165	2.18%
Residential*	140,070	73.16%
Total	**191,447**	**100.00%**

*Includes loads received from failed septic systems and pets.

3.8 Judith Creek (VAC-H03R-06) Sources

3.8.1 Humans and Pets

There are 728 homes served by municipal sanitary sewer in the Judith Creek (VAC-H03R-06) watershed. Wastewater from 624 households within the watershed is treated on site by traditional sewage handling and disposal systems.

The Judith Creek (VAC-H03R-06) watershed has an estimated population of 3,648 people (1,366 households at an average of 2.67 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce $1.95x10^{9}$ cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of $7.11x10^{12}$ cfu/day ($2.60x10^{15}$ cfu/year) in Judith Creek (VAC-H03R-06) watershed.

Bacteria from humans and pets can be transported to streams from failing septic systems, straight pipes discharging directly into streams, biosolid applications to pasture and cropland, or deposition of pet waste on residential land.

3.8.1.1 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 and 2000 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). Originally, in accordance with estimates from Dr. Raymond B. Reneau,

Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1984, a 20% 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 James River (VAC-H03R-04) 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). The application of Dr. Reneau's work reflects the implementation of the septic regulations combined with the consideration of data availability. Also, considering substantial input from members of the project Technical Advisory Committee, the rates applied using this method were adjusted to reflect local conditions. The 40% rate to reflect conditions prior to implementation was changed to 15%, the 20% failure rate that reflects conditions during the period following implementation and those systems reaching their design life (ranges from 10 to 20 years depending on the application and housing unit age data used) was changed to 7.5%, but the 3% failure rated used to reflect more modern systems that haven't approached design life was left unchanged. Our application of this method incorporates Census data to determine home age and reflects implementation of the septic regulations. The local VDH staff indicated that the regulations were implemented in 1982. The census data we used breaks at 1984, so we used 1984 as a breakpoint year and applied a 10-year interim period to arrive at 1994 for the other breakpoint year.

An average number of people per household and number of houses and people in each subwatershed in 2006 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB; 1990, 2000, and 2004). 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 2.67 persons/household was 5.21×10^9 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 3.67.

3.8.1.2 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-1967 and 1967-1987 age categories. Any houses within 150 feet of streams are considered potential straight pipe dischargers. Using the age categories (pre-1967, 1967 – 1987, post 1987), 10% of old houses (pre-1967) within 150 feet of streams and 2% of mid-age houses (1967 – 1987) within 150 feet of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 14 houses that potentially could be classified as straight pipes in the Judith Creek (VAC-H03R-06) watershed (Table 3.67).

3.8.1.3 Biosolids

According to VDH records; 3,417, 5,589, 831, 4,598, 7,459, and 23,286 dry tons of Class B biosolids were applied in 2000, 2001, 2002, 2003, 2004, and 2005, respectively, in Bedford County. VDH records do not indicate application of biosolids in Lynchburg. Comprehensive application rates, bacteria concentrations, and spatial distribution of application sites within the Judith Creek (VAC-H03R-06) watershed were not available. To estimate biosolids applications within each Judith Creek (VAC-H03R-06) subwatershed, records of biosolids applications within the county were obtained from VDH. The average monthly biosolids application total mass data for the county from 2000 to 2005 were divided by the total pasture and cropland acreage in the county. The resulting rates were distributed based on the crop and pasture areas in each subwatershed. Although Class B biosolids are permitted to contain fecal coliform concentrations of $2.0x10^6$ cfu/g (VDH, 1997), values reported by treatment plants are typically lower than this value. For this study, VDH records indicated that the primary source for biosolids was Synagro stabilized cake and pellets. The fecal coliform density of biosolids from this source is estimated to be less than 4 cfu/g (VDH, 2005). Therefore, an average fecal coliform density of 4 cfu/g was used for bacteria loading calculations. Table 3.66 shows the estimated average annual biosolids application amount for each subwatershed (See Figure 4.1 through 4.4 for location of subwatersheds).

Table 3.66. Estimated average annual biosolids application amount for each subwatershed in the Judith Creek (VAC-H03R-06) watershed.

Subwatershed	Biosolids Applied (dry tons / year)
JC-1	34.0
JC-2	12.2
Total	**46.2**

3.8.2 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 theses densities and number of households in each watershed, 724 dogs and 820 cats were projected to reside in the Judith Creek (VAC-H03R-06) 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 1,366 for Judith Creek (VAC-H03R-06) watershed. The maximum typical fecal coliform production for both dogs and cats is $5.0x10^9$ 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 Judith Creek (VAC-H03R-06) watershed is $6.1x10^{11}$ cfu/day ($2.2x10^{14}$ cfu/yr). The pet population distribution among the subwatersheds is listed in Table

3.67. 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 3.67. 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 Judith Creek (VAC-H03R-06) watershed.

Sub-shed	Human Population	Sewered Houses	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
			Pre-1984	1985 - 1995	Post-1995			
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
JC-1	803	56	87	98	85	23	4	373
JC -2	2,845	673	310	44	0	50	10	1,172
Total	**3,648**	**728**	**396**	**142**	**85**	**73**	**14**	**1,545**

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

3.8.3 Livestock Sources

In the Judith Creek (VAC-H03R-06) watershed, bacteria from livestock 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. Livestock populations in the Judith Creek (VAC-H03R-06) 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.

3.8.3.1 Cattle

Based on information obtained from VADCR and SWCDs, there is no dairy farms presently operating in the Judith Creek (VAC-H03R-06) watershed. Beef cattle in the Judith Creek (VAC-H03R-06) watershed (147 pairs) included cow/calf and feeder operations (Table 3.68).

Table 3.68. Distribution of beef cattle among subwatersheds in Judith Creek (VAC-H03R-06) watersheds.

Subwatershed	Beef Cattle (pairs)
JC-1	109
JC -2	38
Total	**147**

Cattle spend varying amounts of time in streams and pasture depending on the time of year. 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:

- The beef cattle spend their time on pasture.

- 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 3.69). 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 3.69. Time spent by cattle in the stream in Judith Creek (VAC-H03R-06) watershed.

Month	Time Spent in Stream (hours/day)*
January	0.50
February	0.50
March	0.75
April	1.00
May	1.50
June	3.50
July	3.50
August	3.50
September	1.50
October	1.00
November	0.75
December	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 TAC 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 3.70 for beef cattle.

Table 3.70. Distribution of the beef cattle population (pairs) in the Judith Creek (VAC-H03R-06) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*	Loafing
January	67.62	77.19	19.33	4.83	0.08	0.00
February	79.38	90.61	22.69	5.67	0.09	0.00
March	0.00	155.43	38.93	9.73	0.24	0.00
April	0.00	159.84	40.03	10.01	0.33	0.00
May	0.00	164.18	41.12	10.28	0.51	0.00
June	0.00	168.11	42.10	10.53	1.23	0.00
July	0.00	172.57	43.22	10.80	1.26	0.00
August	0.00	177.02	44.33	11.08	1.29	0.00
September	0.00	182.05	45.59	11.40	0.57	0.00
October	0.00	111.78	27.99	7.00	0.23	0.00
November	0.00	117.41	29.40	7.35	0.18	0.00
December	64.68	73.83	18.49	4.62	0.08	0.00

*Number of beef cattle defecating in stream.

3.8.3.2 Direct Manure Deposition in Streams

Direct manure loading to streams is due to beef cattle (Table 3.70) defecating in the stream. However, only cattle on pastures contiguous to streams which 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 Judith Creek (VAC-H03R-06) watersheds is 11,208 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 1.69×10^{10} cfu/day (6.16×10^{12} 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.

3.8.3.3 Direct Manure Deposition on Pastures

Beef cattle that graze on pastures, but do not deposit in streams, contribute the majority of fecal coliform loading on pastures (Table 3.70). Manure loading on pasture was estimated by multiplying the total number of cattle 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 Judith Creek (VAC-H03R-06) watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 4,286; 2,143; and 1,072 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 Judith Creek (VAC-H03R-06), averaged over the year, are 2.38×10^{12}, 1.20×10^{12}, and 6.07×10^{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.

3.8.3.4 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, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 3.72.

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 3.72). 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 3.72). Solid manure is applied at the rate of 12 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 3.71. Based on availability of land and solid manure, as well as the assumptions regarding application rate, 7.1 acres of the cropland and 8.6 acres of pasture 1 in Judith Creek (VAC-H03R-06) received solid manure application.

Table 3.71. Schedule of cattle waste application in Judith Creek (VAC-H03R-06) 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.

Table 3.72. 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 Judith Creek (VAC-H03R-06) 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	0	1,400	115.0	2.17	5.50
Heifer	0	640	40.7	2.17	
Beef (pairs)	95	1,000	60.0	5.50	

[a]Source: BSE (2003)

3.8.4 Horses

The estimated number of horses in the Judith Creek (VAC-H03R-06) watershed is included in Table 3.73. 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 TAC.

The typical horse produces 4.2×10^8 cfu/day (VADCR, 2003). Therefore, the daily fecal coliform production by horses in the Judith Creek (VAC-H03R-06) watershed is 1.18×10^{10} cfu/day (4.29×10^{12} cfu/year).

Table 3.73. Horse population by subwatershed in the Judith Creek (VAC-H03R-06) watershed.

Subwatershed	Horses
JC-1	21
JC -2	7
Total	**28**

3.8.5 Other Livestock Sources

Other minor livestock-related sources of bacteria (e.g., goats) were present during watershed visits; however, a significant population was not identified within the Judith Creek (VAC-H03R-06) watershed. The potential bacteria load from these sources was accounted for during water quality calibration.

3.8.6 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Table 3.76. The total wildlife fecal coliform production each year in the Judith Creek (VAC-H03R-06) watershed, is 9.69×10^{13} 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, and revised based on significant feedback from TAC members. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.74).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.74). 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 3.74, 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 3.75.

Table 3.74. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Judith Creek (VAC-H03R-06) watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.021	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	0.014[b]	0.25
Wood Duck	300 feet buffer around main streams	0.003[b]	0.25
Wild Turkey	Entire watershed except urban areas	0.004[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 3.75. Distribution of wildlife among sub-watersheds in Judith Creek (VAC-H03R-06) watershed.

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
JC-1	197	142	326	16	22	8	57
JC-2	265	240	81	19	29	10	67
Total	**462**	**382**	**407**	**35**	**51**	**18**	**124**

3.8.7 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the Judith Creek (VAC-H03R-06) watershed along with average fecal coliform production rates are shown in Table 3.76. The total fecal coliform production by all sources in the Judith Creek (VAC-H03R-06) watershed is 2.89×10^{15} cfu/yr.

Table 3.76. Potential fecal coliform sources and daily fecal coliform production by source in Judith Creek (VAC-H03R-06) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times 10^7$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times 10^6$ cfu/ day)[b]
Beef Cattle (pairs)	147	33,000	6,558,652
Horses	28	420	11,768
Humans	3,648	1,950	457,512
Pets	1,366	450	615,121
Deer	462	350	161,811
Raccoon	382	50	19,113
Muskrat	407	25	10,182
Beaver	35	0.2	7
Wild Turkey	51	93	11,540
Duck	18	2,400	32,341
Goose	124	800	30,746

[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 3.77. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.77.

From Table 3.77, it is clear in the Judith Creek (VAC-H03R-06) watershed that nonpoint source loadings to the land surface are more than 63 times as large as direct loadings to the streams, with pastures receiving about 82% 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 3.77. Annual fecal coliform loadings to the stream and the various land use categories in the Judith Creek (VAC-H03R-06) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	2,781	1.03%
Cattle in Stream	616	0.23%
Wildlife in Stream	802	0.30%
Loading to Land Surfaces		
Cropland	523	0.19%
Pasture 1	167,948	62.43%
Pasture 2	42,183	15.68%
Pasture 3	10,704	3.98%
Forest	7,074	2.63%
Residential*	36,370	13.52%
Total	**269,002**	**100.00%**

*Includes loads received from failed septic systems and pets.

Chapter 4. Modeling Process for Fecal Coliform TMDL Development

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) 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 are discussed.

4.1 Model Description

Conducting a TMDL study requires the use of a watershed-based model that integrates both point and nonpoint 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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds. The ArcView 9.2 GIS program was used to display and analyze landscape information.

The HSPF model simulates nonpoint 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 models for the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds are discussed below in Sections 4.2 through 4.6. 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.

4.2 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 James River watershed is 250,503 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 19 subwatersheds as shown in Figure 4.1. The unimpaired segment JR-1 drains into the impaired segment JR-2 of James River (VAC-H03R-04).

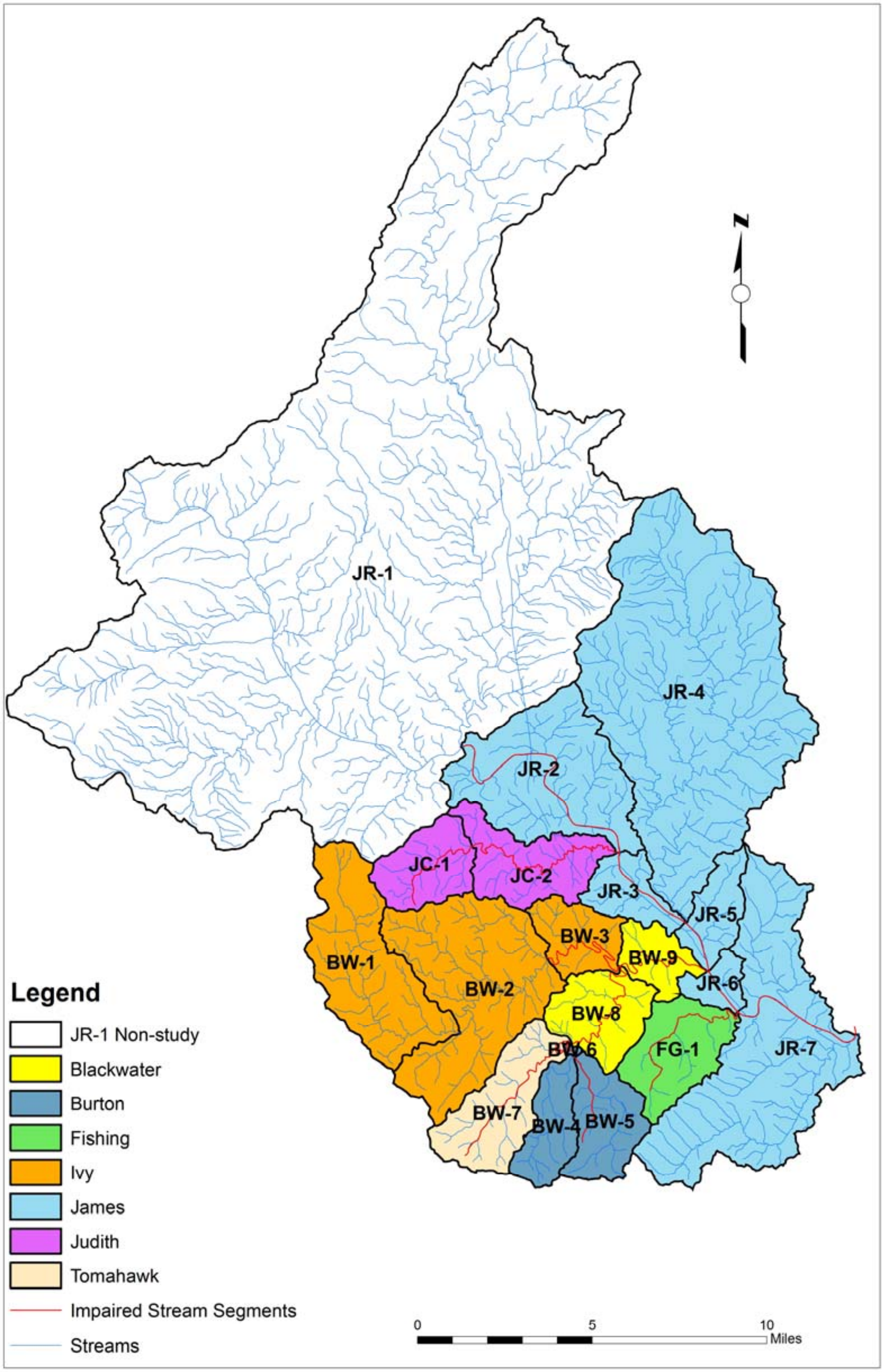

Figure 4.1. James River subwatersheds.

4.3 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), 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 4.1). 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.

Table 4.1. Consolidation of NLCD land use categories for James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds.

TMDL Land Use Categories	Pervious / Impervious* (%)	NLCD Land use Classification (Class No.)
Cropland	Pervious (100)	Row Crops (82) Small grains (83)
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)	Low Density Residential (21) High Intensity Residential (22) Commercial/Industrial/Transportation (23)
Water	Impervious (100)	Open Water (11)
Wetland	Pervious (100)	Woody Wetlands (91) Emergent Herbaceous Wetlands (92)
Forest	Pervious (100)	Transitional (33) Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)

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

As discussed in Section 4.2, subwatersheds in each impairment were defined to spatially analyze waste or fecal coliform distribution within the watershed (Figures 4.1 and 4.2). Land use distribution in the subwatersheds as well as in the entire James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds is presented in Tables 4.2 and 4.3.

Table 4.2. Land use distribution in James River watershed.

Sub-shed	Land Use (ac)							
	Cropland	Pasture1	Pasture2	Pasture3	Residential	Water/ Wetland	Forest	Commercial
BW-1	133.49	1617.57	810.2	405.1	484.5	92.98	5339.81	3.62
BW-2	165.79	2049.64	1026.62	513.31	1530.5	96.77	6771.06	68.93
BW-3	3.95	85.98	43.07	21.53	1264.5	4.1	1395.27	22.32
BW-4	0	314.91	157.73	78.87	1069.5	27.92	948.91	204.55
BW-5	0	210.05	105.21	52.6	1216.5	1.9	1443.48	695.18
BW-6	0	10.74	5.38	2.69	67.5	0	1.1	0
BW-7	129.32	730.16	365.72	182.86	1738.5	20.18	1790.86	273.53
BW-8	0.48	174.18	87.24	43.62	2972	43.89	389.62	221.53
BW-9	1.73	53.06	26.58	13.29	1738.5	0	204.81	142.18
JC-1	21.27	453.69	227.24	113.62	165	13.08	2589.05	0.44
JC-2	14.82	250.06	125.25	62.62	501	33.26	3811.78	6.28
FG-1	7.87	179.22	89.77	44.88	2078.5	4.87	1545.4	639.76
JR-1	531.01	5023.67	2516.24	1258.12	903	1377.71	119718.2	18.75
JR-2	24.91	519.81	260.36	130.18	166.5	587.09	8779.56	0.13
JR-3	3.1	190.3	95.32	47.66	955	245.52	896.19	24.41
JR-4	198.33	3682.35	1844.4	922.2	1305.5	113.41	22641.72	109.74
JR-5	9.21	118.3	59.26	29.63	517	145.39	1610.71	71.44
JR-6	4.32	51.08	25.59	12.79	891	98.58	99.85	138.42
JR-7	99.75	1276.47	639.35	319.68	1544	372.04	11891.02	500.19
Total	**1349.35**	**16991.24**	**8510.53**	**4255.25**	**21108.5**	**3278.69**	**191868.4**	**3141.4**

4.4 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. Information on stream geometry in each subwatershed is presented in Table 4.3.

Table 4.3. Stream channel characteristics used to calculate F-Tables in the James River watershed.

Sub-shed	Stream Length (mile)	Average Width (ft)	Average Depth (ft)	Stream Relief (ft/ft)	Channel Slope (ft/ft)	Channel Manning's n[a]	Flood Plain Manning's n[a]
BW-1	50,794	22.0	10.0	0.0116	1.0	0.035	22.0
BW-2	30,936	35.0	8.0	0.0018	4.0	0.032	35.0
BW-3	28,301	35.0	9.5	0.0014	4.0	0.032	35.0
BW-4	27,203	7.0	4.0	0.0090	3.0	0.030	7.0
BW-5	14,732	8.0	11.0	0.0140	2.0	0.032	8.0
BW-6	3,511	30.0	7.0	0.0065	2.0	0.040	30.0
BW-7	32,989	8.0	7.0	0.0072	2.0	0.034	8.0
BW-8	29,262	20.0	7.0	0.0022	2.0	0.040	20.0
BW-9	25,476	30.0	15	0.0030	2.0	0.030	30.0
JC-1	18,007	12.0	6.0	0.0113	2.0	0.030	12.0
JC-2	40,347	23.0	10.0	0.0054	1.5	0.041	23.0
FG-1	33,277	14.0	8.0	0.0121	3.0	0.038	14.0
JR-1	84,286	325.0	12.0	0.0015	3.0	0.032	325.0
JR-2	43,146	350.0	14.0	0.0007	3.0	0.032	350.0
JR-3	15,512	355.0	16	0.0021	3.0	0.032	355.0
JR-4	123,214	45.0	12.0	0.0070	3.0	0.032	45.0
JR-5	8,500	355.0	22.0	0.0008	3.0	0.032	355.0
JR-6	7,658	360.0	24.0	0.0009	3.0	0.032	360.0
JR-7	23,231	365.0	25.0	0.0010	3.0	0.032	365.0

[a] Dimensionless

4.5 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, 2005), part of the National Weather Service (NWS). Simulations performed for James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds used hourly weather data from the Lynchburg Regional Airport (440860) weather station.

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.

4.6 Accounting for Pollutant Sources

4.6.1 Overview

There are one and six permitted point discharges located in the Judith Creek (VAC-H03R-06) and James River (VAC-H03R-04) watersheds.

Fecal coliform loads that are directly deposited by straight pipes and cattle along with wildlife in streams 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 nonpoint 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 nonpoint 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 4.6.4. 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.

4.6.2 Modeling Fecal Coliform Die-off

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

$$C_t = C_0 10^{-kt} \qquad [4.1]$$

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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds (Table 4.4).

Table 4.4. First order decay rates for different animal waste storage as affected by storage/application conditions and their sources in the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01),

Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds.

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 [4.1]. 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.

4.6.3 Modeling Direct Nonpoint Sources

Fecal coliform loads from direct nonpoint 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 cfu/100mL. Based on TAC feedback, no instances of groundwater contamination were acknowledged and as a result it was assumed that the groundwater contained no bacteria. Loads from direct nonpoint sources in each watershed are described in detail in Chapter 3.

4.6.4 Modeling Land-based Nonpoint Sources

For modeling purposes, nonpoint 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.

4.6.5 Modeling Existing BMPs

Data describing existing best management practices (BMPs) were provided by staff from the VADCR. 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.

Due to a shortage of data describing bacteria removal efficiencies, some BMPs were accounted for during calibration. Grassed buffer strips between pasture or crop and stream edges is a good example of an identified BMP that was accounted for during calibration of the water quality model.

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.

4.7 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.

4.7.1 Hydrology

4.7.1.1 James River

The model was calibrated for the period January 1, 1995 to December 31, 1999. Two different gaging stations were utilized for the calibration comparison and inflow data. One major reason for this choice is that the downstream gage captures the higher storm peak flows resulting from the large impervious surface associated with the city.

USGS gaging station 02026000 (at Bent Creek, VA) was transferred to the outlet of JR-7 to use for calibration. The ratio of the drainage areas was used as a multiplier to transfer the gage data to the JR-7 outlet as shown below:

Drainage Area @ Station 02026000:	3683	sq. miles
Drainage Area @ Station 02025500:	3259	sq. miles
Drainage Area of JR-2 thru JR-7:	204	sq. miles
Drainage Area @ Outlet of JR-7:	3463	sq. miles
Multiplier to transfer station to outlet of JR-7:	0.940	

USGS gaging station 02025500 (Holcomb Rock, VA) was transferred from JR-2 to the inlet of JR-1 to account for flow coming into the system in the James River. This gage is located downstream of the confluence of the James River and Pedlar River. The City withdraws water from its reservoir in the Pedlar River watershed within JR-1. Therefore, the withdrawal is accounted for in the gage data. The gage data were transferred using a factor that represents the ratio of the drainage areas at the gage location and the inlet of JR-1 as shown below:

Drainage Area @ Station:	3259	sq. miles
Drainage Area of JR-1:	187	sq. miles
Drainage Area @ Top of JR-1:	3072	sq. miles
Multiplier to transfer station to top of JR-1:	0.943	

The model was validated for the period January 1, 2000 to December 31, 2004. 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 4.5 and 4.6, respectively. All criteria were within the recommended ranges. As shown in Figures 4.2 and 4.3, the simulated flow for both the calibration and validation matched the observed flow well. The agreement with observed flows is further illustrated in Figures 4.4 and 4.5 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 4.6 and 4.7). It is acknowledged that this close agreement between the observed and modeled flows is largely due to the magnitude of the flows relative to the contributing watersheds being modeled. Flows in the tributaries for which no gaging station was available for comparison were qualitatively reviewed to ensure they were reasonable hydrologic responses from watersheds of these areas and land use compositions.

Table 4.5. Summary statistics for the calibration period (1/1/95 to 12/31/99) in James River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume (in)	10	701.87	709.78	1.13%
Total of Highest 10% Flow Volume (in)	15	280.03	292.89	4.59%
Total of Lowest 50% Flow Volume (in)	10	122.55	117.25	-4.32%
Total Winter Flow Volume (in)	20	302.83	315.43	4.16%
Total Summer Flow Volume (in)	20	94.11	90.57	-3.77%
Total Storm Flow Volume (in)	20	568.45	576.50	1.42%
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.95			

Table 4.6. Summary statistics for the validation period (1/1/00 to 12/31/04) in James River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume (in)	20	642.2	650.7	1.32%
Total of Highest 10% Flow Volume (in)	25	242.1	237.2	-2.05%
Total of Lowest 50% Flow Volume (in)	20	113.1	115.8	2.37%
Total Winter Flow Volume (in)	30	167.0	163.6	-2.01%
Total Summer Flow Volume (in)	30	109.7	109.0	-0.71%
Total Storm Flow Volume (in)	30	543.7	542.9	-0.15%
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.96			

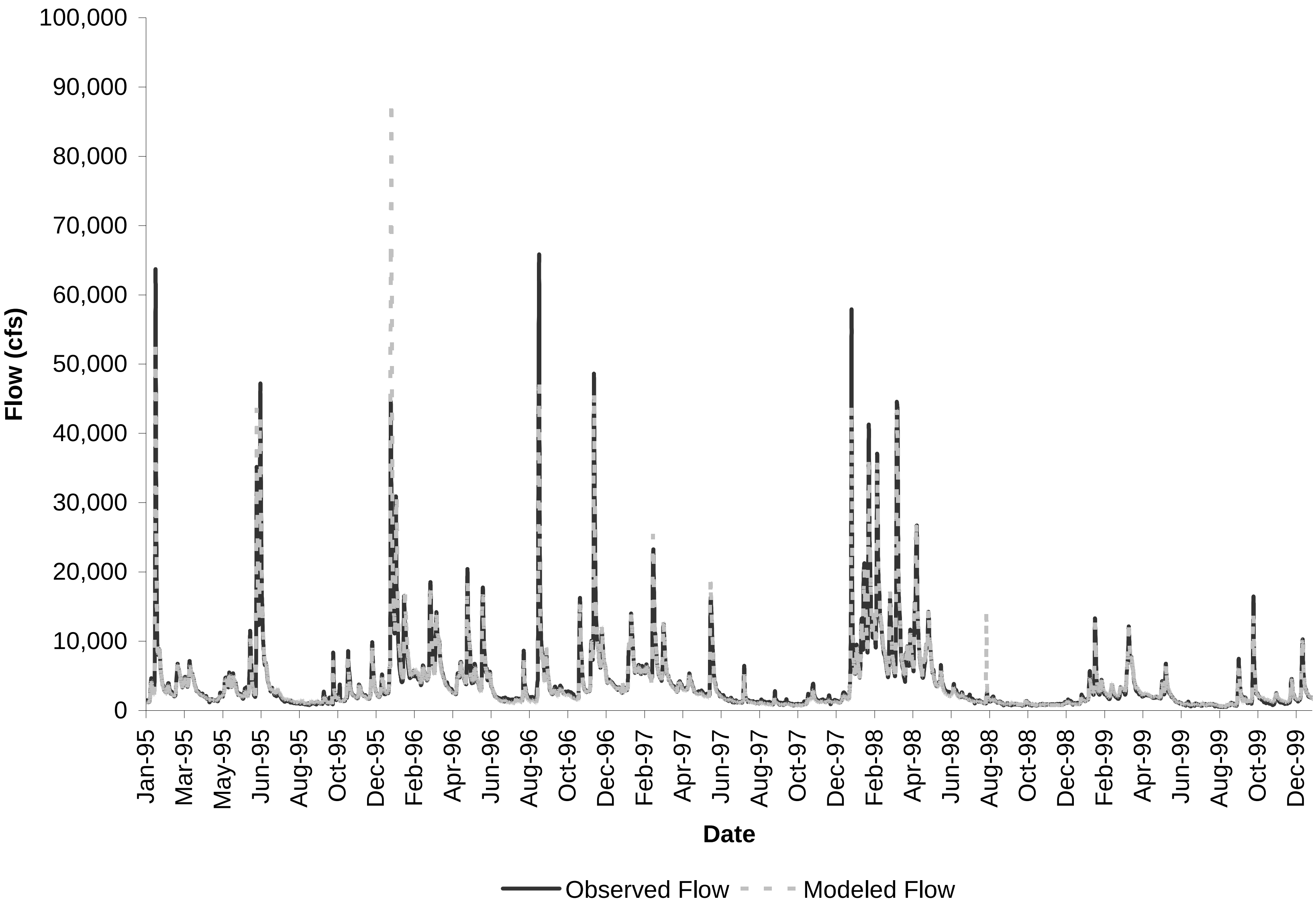

Figure 4.2. Observed and modeled flows for the calibration period (1/1/95 to 12/31/99) in James River watershed.

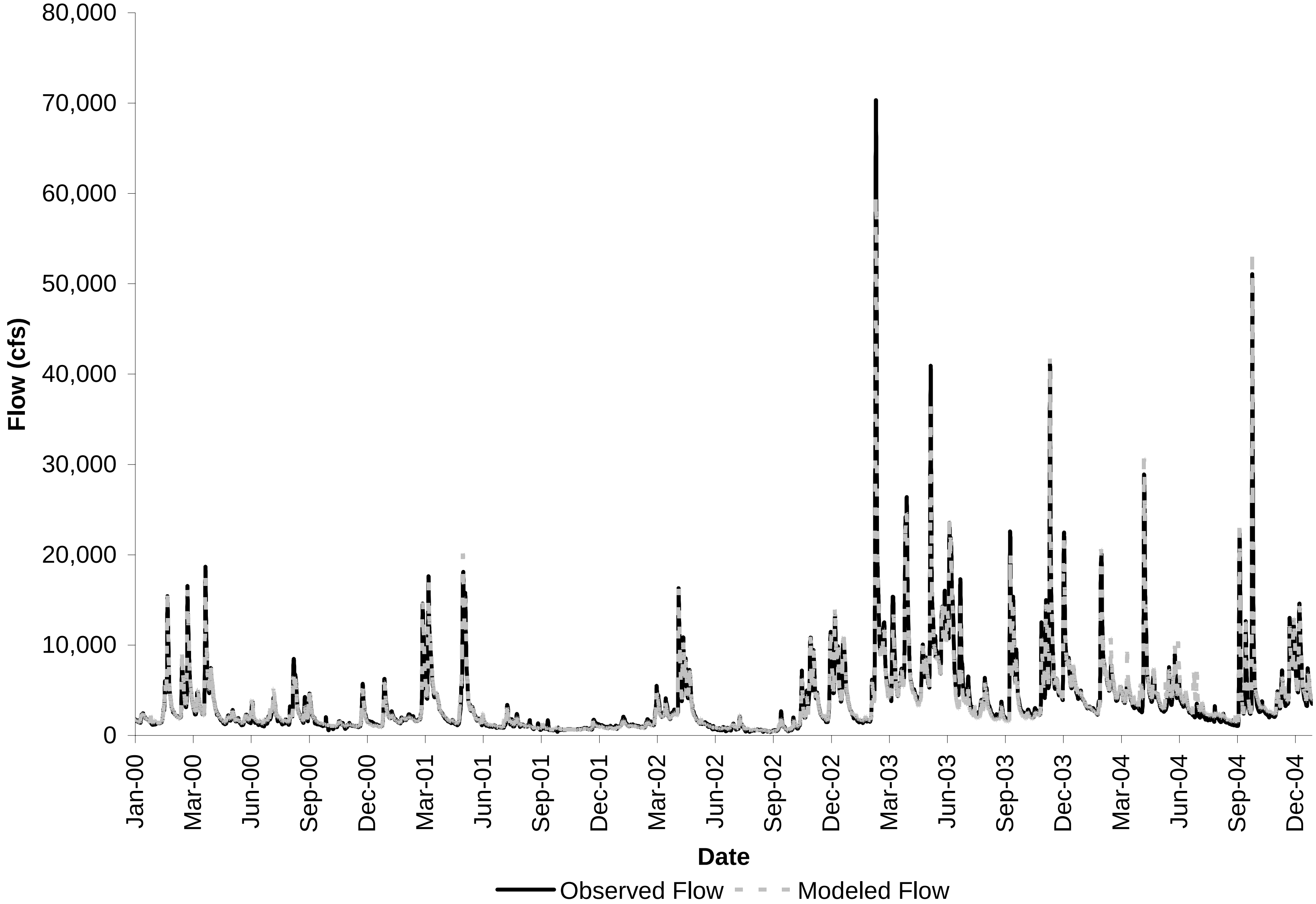

Figure 4.3. Observed and modeled flows for the validation period (1/1/00 to 12/31/04) in James River watershed.

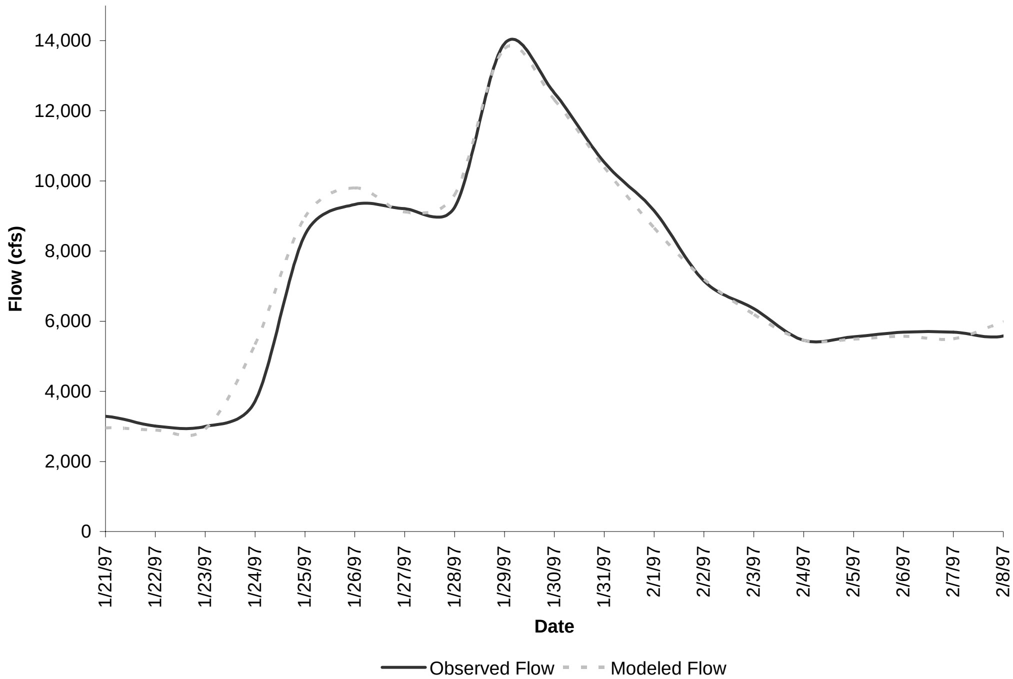

Figure 4.4. Observed and modeled flows for representative storms (1/21/97-2/8/97) during the calibration period in James River watershed.

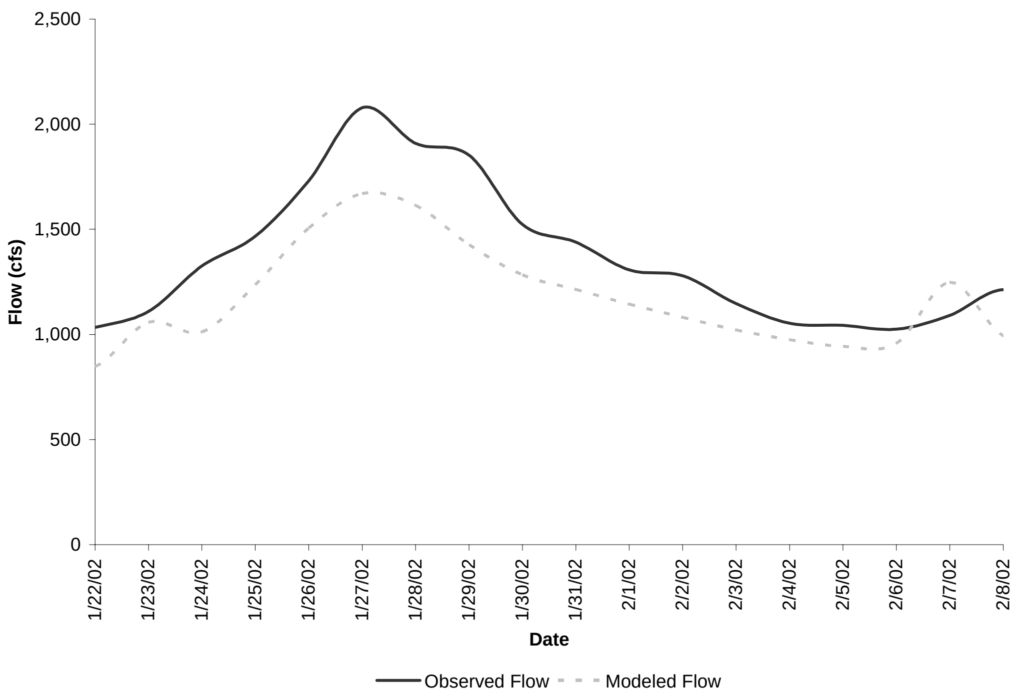

Figure 4.5. Observed and modeled flows for a representative storm (1/22/02-2/8/02) during the validation period in James River watershed.

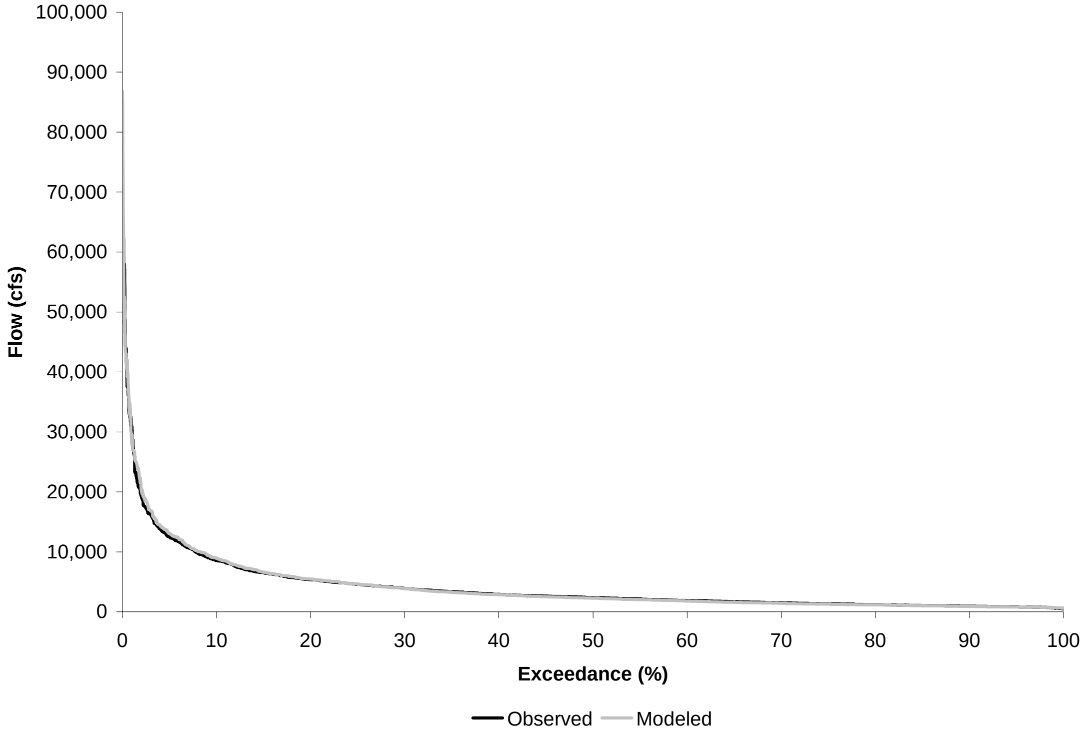

Figure 4.6. Cumulative frequency curves for the calibration period (1/1/95 to 12/31/99) in James River watershed.

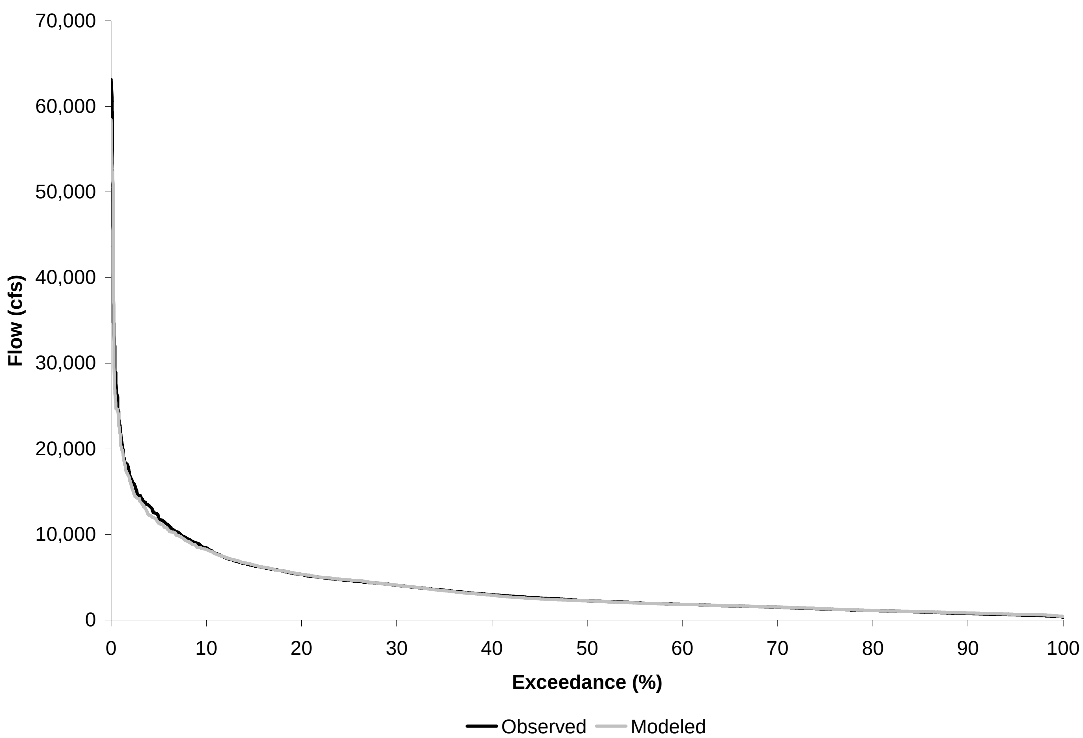

Figure 4.7. Cumulative frequency curves for the validation period (1/1/00 to 12/31/04) in James River watershed.

Flow partitioning for James River hydrologic model calibration and validation is shown in Table 4.7.

Table 4.7. Flow partitioning for the calibration and validation periods in James River watershed.

Average Annual Flow	Calibration	Validation
Total Runoff (in)	86.6	77.5
Surface Runoff (in)	14.6 (16.8%)	11.0 (14.2%)
Interflow (in)	9.5 (11.0%)	7.7 (9.9%)
Baseflow (in)	62.5 (72.2%)	58.8 (75.9%)

A list of final calibration parameters for the hydrology calibration can be found in Tables 4.8 and 4.9.

Table 4.8. Calibrated hydrology HSPF parameters (PERLND) for James 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	5.5	5.5	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.08 – 0.3	0.08 - 0.3	Soil and cover condition
LSUR	Length of overland flow	ft	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.046-0.212	0.046-0.212	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	0.96	0.98	Calibrate
PWAT-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
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 GW 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	0.03	0.02	Riparian vegetation
AGWETP	Fraction of remain ET from active W	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	.05-.25	0.01 – 0.17	Vegetation
UZSN	Upper zone nominal soil moisture storage	in	0.10	1	0.05	2	0.5	0.25	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	1.0	1.0	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.5	0.5	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	0.1-0.6	0.1 - 0.6	Vegetation

* USEPA, 2000.

Table 4.9. Calibrated hydrology HSPF parameters (IMPLND and RCHRES) for James 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	100	Topography
SLSUR	Slope of overland flow	none	0.01	0.15	0.001	0.3	0.046-0.212	0.046-0.212	Topography
NSUR	Manning's n (roughness)	none	0.15	0.35	0.1	0.5	0.1	0.1	Land use, surface condition
RETSC	Retention/interception storage capacity	in	0.03	0.2	0.01	0.4	0.065	0.065	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.

4.7.2 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, the period of January 1, 1995 through December 31, 1999 was chosen for water quality calibration and January 1, 2000 through December 31, 2004 for water quality validation.

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). Additionally, F-Tables were adjusted to account for additional assimilative capacity in the watershed not represented by channel volumes derived for the reach section. Added assimilation can be achieved through three additional pathways. First, only the main channel of the impairment streams and the major tributaries are explicitly represented in HSPF. Stream channels not represented add additional water volume available to dilute fecal coliform loads during low flow conditions and increase channel residence time, which increases settling and die-off of bacteria in transit. Second, dead water that occurs during minimal streamflow can provide added storage. Third, flow in the watershed drains through a multitude of farm ponds. Using GIS, ponds were estimated by separating water in the stream layer from water in the land use layer. Surface area of the ponds was multiplied by an estimated depth of four feet to calculate the total storage volume of all ponds in a subwatershed. To account for the three sources of additional storage, an additional storage volume was added to each line of the F-table. This storage has no effect on the functional relationship between volume of water stored in the channel and flow in the channel. 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.

In the course of calibrating JC-2, BW-5, BW-7, and JR-6, it appears that there are some outliers, or observed values are not represented in the model. This is indicated by an observed value with a corresponding modeled value is so much lower that it indicates that the cause of the observed value is not simulated by the model. Such an instance may have been caused by a slug of bacteria being captured by the sampling from an illicit discharge in this largely urbanized watershed. The outliers for JC-2, BW-5 and FG-1 all occurred during baseflow conditions, and all outliers for JR-6 occurred during storms. Rather than calibrating to these outliers, biasing the model to predict higher values, we decided to adjust the calibration and/or validation metrics by removing the outliers to evaluate model performance. One outlier was eliminated for the calibration of JC-2, two for the calibration of BW-5, one for the calibration of BW-7, three for the calibration of JR-6, and two for the validation of JR-6.

4.7.2.1 James River (VAC-H03R-04)

Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 2-JMS258.54 within the James River (VAC-H03R-04) impairment were used to calibrate the water quality component of HSPF. The final water calibration parameters are shown in Table 4.10. Observations from the VADEQ station, 2-JMS258.54, were graphically compared to corresponding modeled concentrations at subwatershed JR-6 (Figures 4.8 and 4.9). 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. As expected, differences between modeled and observed bacteria concentrations were greater during the validation period.

To provide a quantitative measure of the agreement between observed and modeled data, the geometric mean and violation 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 4.11 and 4.12 show the observed and modeled comparisons of the geometric mean and violation rates for the calibration and validation periods, respectively. The modeled versus observed geometric mean concentrations and violation 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 James River (VAC-H03R-04) watershed.

Table 4.10. Calibrated water quality HSPF parameters for James River (VAC-H03R-04) 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	13E06-01E10	13E06-01E10	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	1E08-12E10	1E08-3E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.25-2.4	0.25-2.4	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	20E08-33E08	20E08-33E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	02E10-03E10	02E10-03E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.02-0.1	0.02-0.1	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	2.0	0.05	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

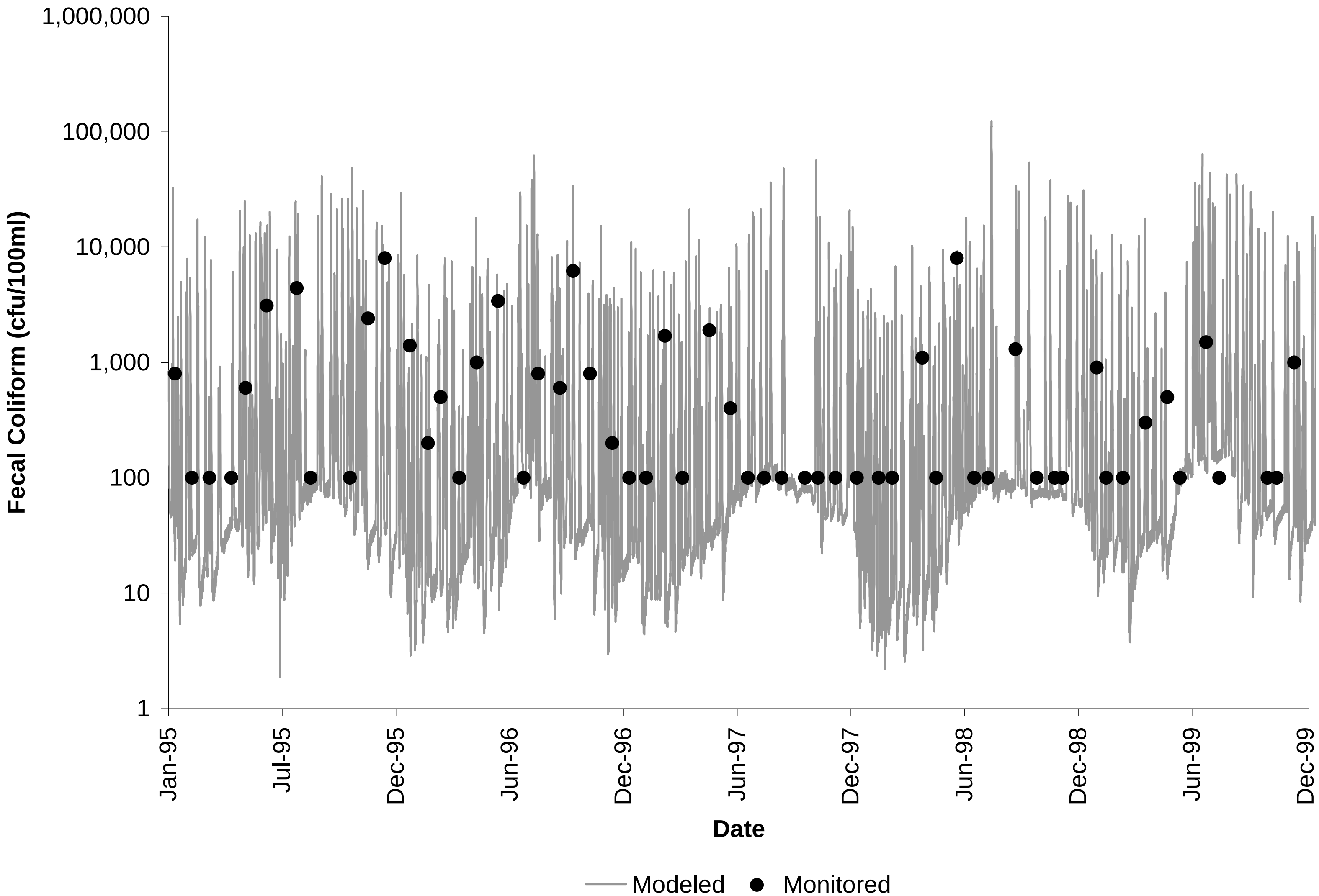

Figure 4.8. Water quality calibration results with observed and modeled fecal coliform concentrations for subwatershed JR-6 in James River (VAC-H03R-04) impairment.

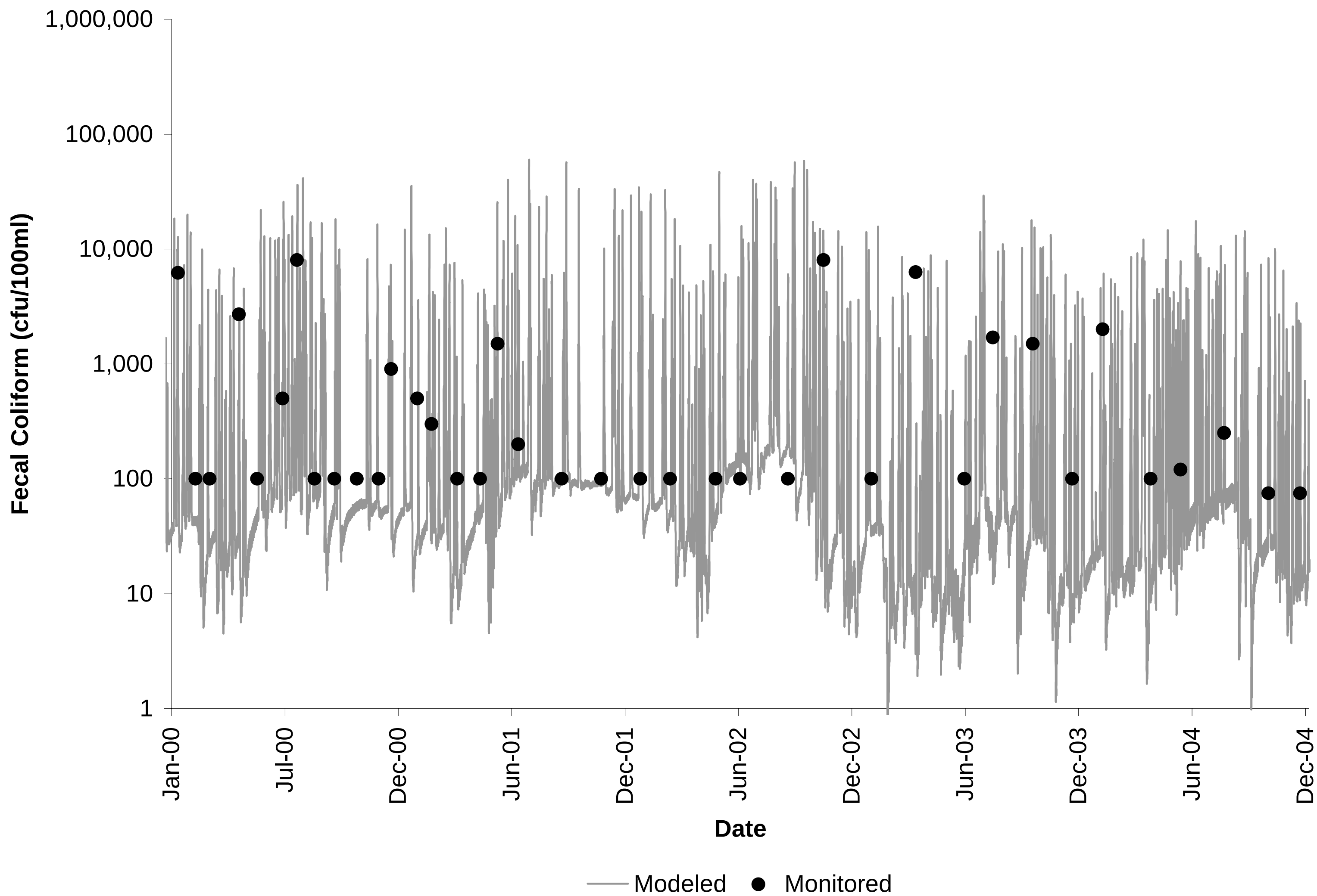

Figure 4.9. Water quality validation results with observed and modeled fecal coliform concentrations for subwatershed JR-6 in James River (VAC-H03R-04) impairment.

Table 4.11. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the calibration period in James River (VAC-H03R-04) watershed.

Parameter	Sub JR-6
Geometric Mean of Observed Values (cfu/100mL)	**279**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**256**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**17**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**19**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**34**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**33**

Table 4.12. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the validation period in James River (VAC-H03R-04) watershed.

Parameter	Sub JR-6
Geometric Mean of Observed Values (cfu/100mL)	**245**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**221**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**18**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**18**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**26**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**26**

4.7.2.2 Ivy Creek (VAC-H03R-03)

Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 2-IVA000.22 within the Ivy Creek (VAC-H03R-03) impairment were used to calibrate the water quality component of HSPF. The final water calibration parameters are shown in Table 4.13. Observations from the VADEQ station, 2-IVA000.22, were graphically compared to corresponding modeled concentrations at subwatershed BW-3 (Figures 4.10 and 4.11). 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. As expected, differences between modeled and observed bacteria concentrations were greater during the validation period.

To provide a quantitative measure of the agreement between observed and modeled data, the geometric mean and violation 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 4.14 and 4.15 show the observed and modeled comparisons of the geometric mean and violation rates for the calibration and validation periods, respectively. It should be noted that a limited number of observed values were available for comparison when determining violation rates in Tables 4.14 and 4.15. A difference of one violation could result in a difference of violation rate of 4-5%. The highest difference (15%) between observed and modeled geometric mean concentrations was recorded during the calibration period. The highest difference in the water quality standard violation rates (5%) was also recorded during the calibration period. Twenty-one observations were available for comparison during this period resulting in a 5% weighting when comparing the water quality standard violation rate. The modeled versus observed geometric mean concentrations and violation 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 Ivy Creek (VAC-H03R-03) watershed.

Table 4.13. Calibrated water quality HSPF parameters for Ivy Creek (VAC-H03R-03) 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	27E06-01E10	27E06-01E10	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	02E08-9E10	81E06-3E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.5	0.5	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	2E08-28E08	2E08-28E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	16E8-3E10	5E8-84E8	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.02	0.02	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	2.0	2.0	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

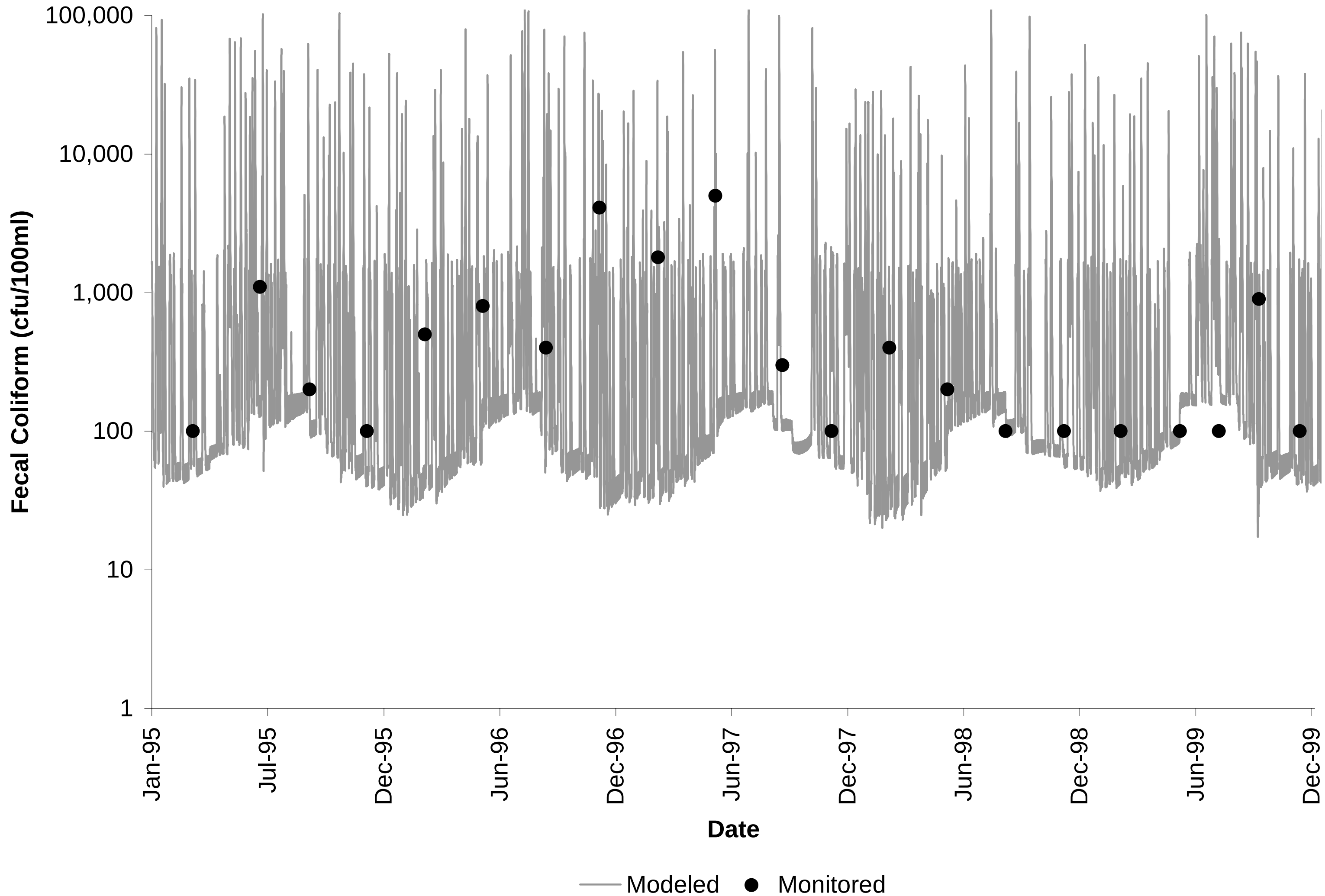

Figure 4.10. Water quality calibration results with observed and modeled fecal coliform concentrations for subwatershed BW-3 in Ivy Creek (VAC-H03R-03) impairment.

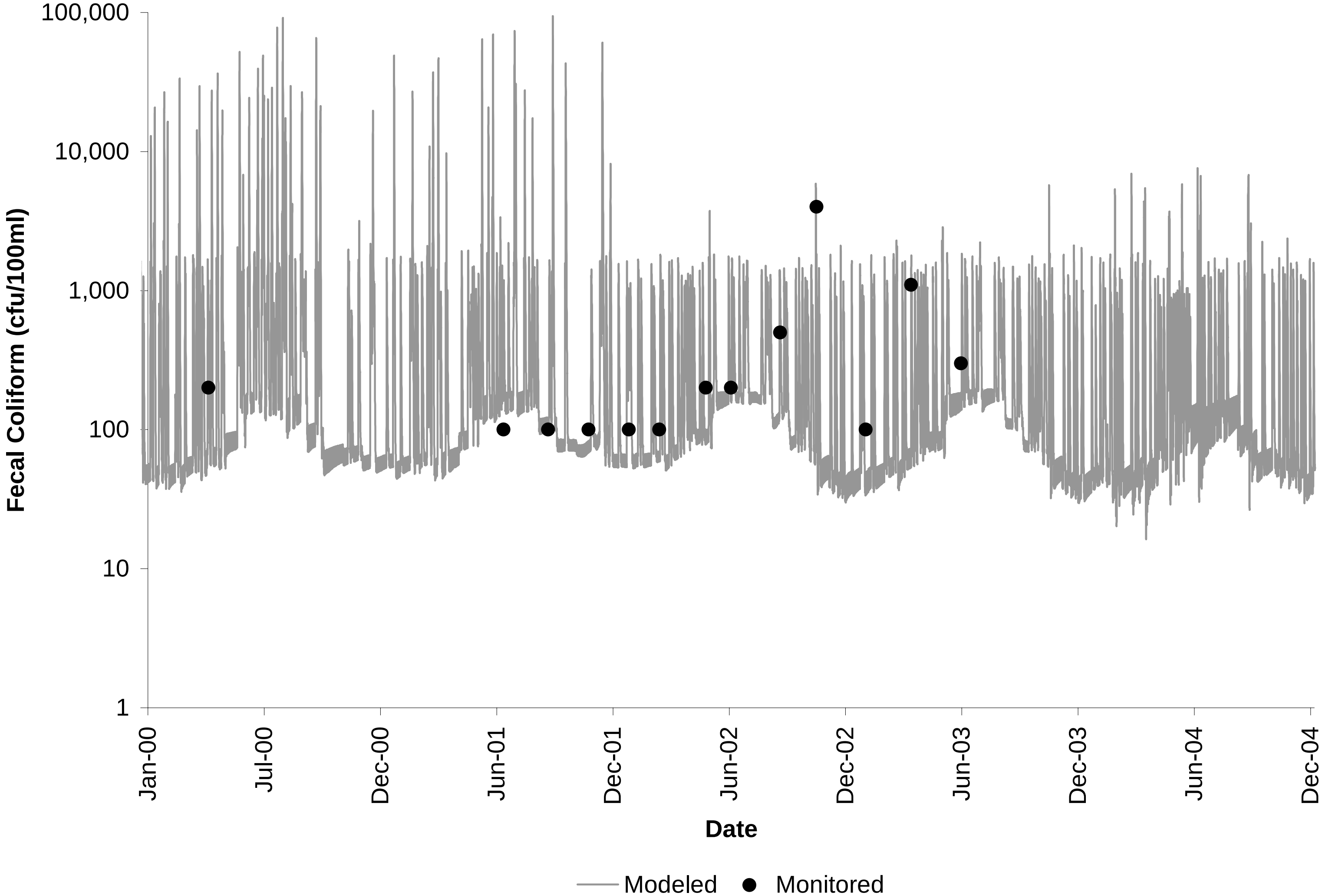

Figure 4.11. Water quality validation results with observed and modeled fecal coliform concentrations for subwatershed BW-3 in Ivy Creek (VAC-H03R-03) impairment.

Table 4.14. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the calibration period in Ivy Creek (VAC-H03R-03) watershed.

Parameter	Sub BW-3
Geometric Mean of Observed Values (cfu/100mL)	**314**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**273**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**19**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**14**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**33**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**33**

Table 4.15. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the validation period in Ivy Creek (VAC-H03R-03) watershed.

Parameter	Sub BW-3
Geometric Mean of Observed Values (cfu/100mL)	**231**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**211**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**14**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**14**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**21**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**21**

4.7.2.3 Fishing Creek (VAC-H03R-02)

Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 2-FSG000.85 within the Fishing Creek (VAC-H03R-02) impairment were used to calibrate the water quality component of HSPF. The final water calibration parameters are shown in Table 4.16. Observations from the VADEQ station, 2-FSG000.85, were graphically compared to corresponding modeled concentrations at subwatershed FG-1 (Figures 4.12 and 4.13). 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. As expected, differences between modeled and observed bacteria concentrations were greater during the validation period.

To provide a quantitative measure of the agreement between observed and modeled data, the geometric mean and violation 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 4.17 and 4.18 show the observed and modeled comparisons of the geometric mean and violation rates for the calibration and validation periods, respectively. It should be noted that a limited number of observed values were available for comparison when determining violation rates in Tables 4.17 and 4.18. A difference of one violation could result in a difference of violation rate of 6%. The highest difference (23%) between observed and modeled geometric mean concentrations was recorded during the validation period. The highest difference in the water quality standard violation rates (6%) was recorded during the validation period. This 6% difference in violation rate reflects one violation difference between observed and modeled conditions. The modeled versus observed geometric mean concentrations and violation 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 Fishing Creek (VAC-H03R-02) watershed.

Table 4.16. Calibrated water quality HSPF parameters for Fishing Creek (VAC-H03R-02) 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	27E06-68E8	27E06-68E8	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	2E08-6E10	3E08-8E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.25	0.25	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	75E06	75E06	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	7E08	9E08	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.02	0.02	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	2.0	0.5	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

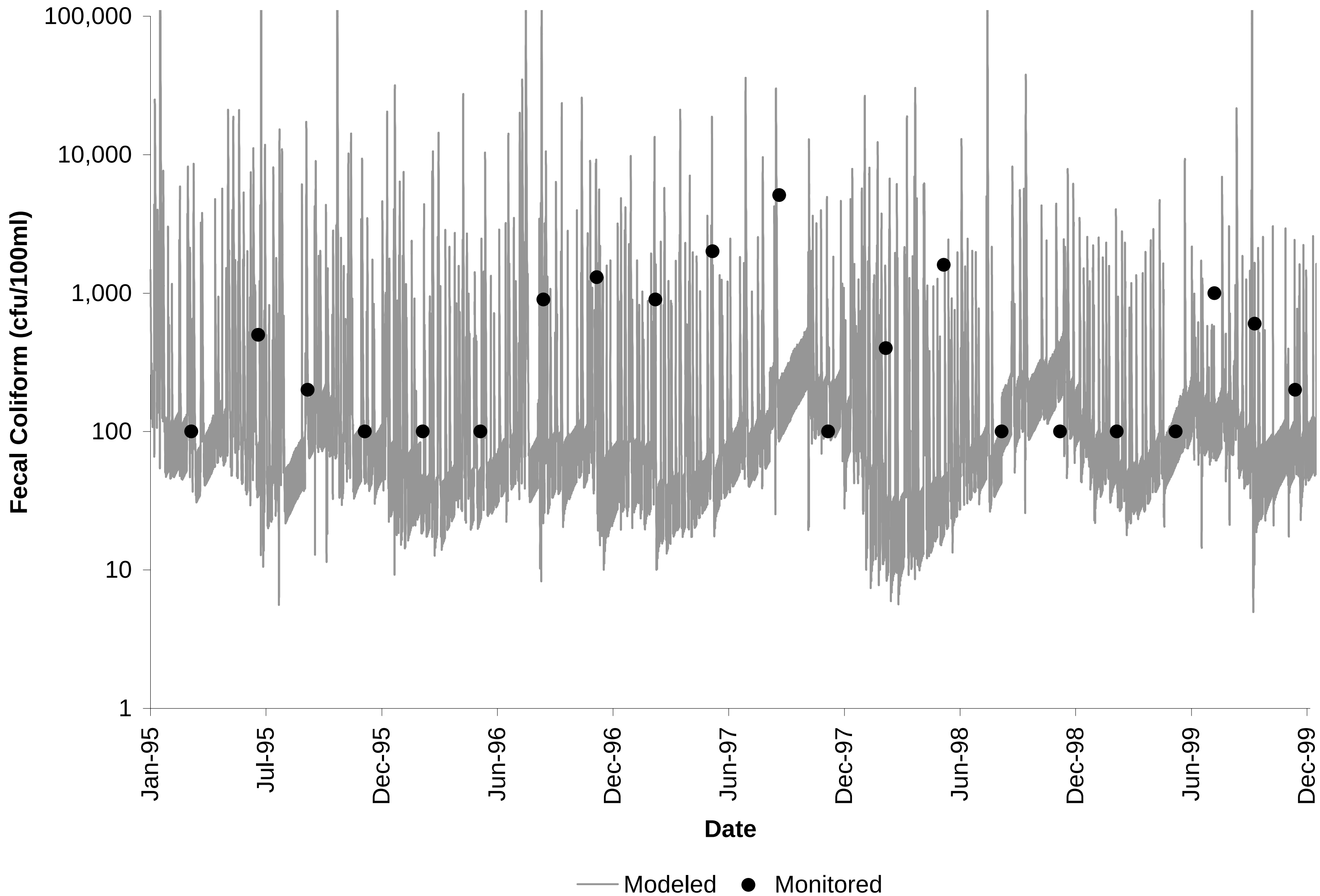

Figure 4.12. Water quality calibration results with observed and modeled fecal coliform concentrations for subwatershed FG-1 in Fishing Creek (VAC-H03R-02) impairment.

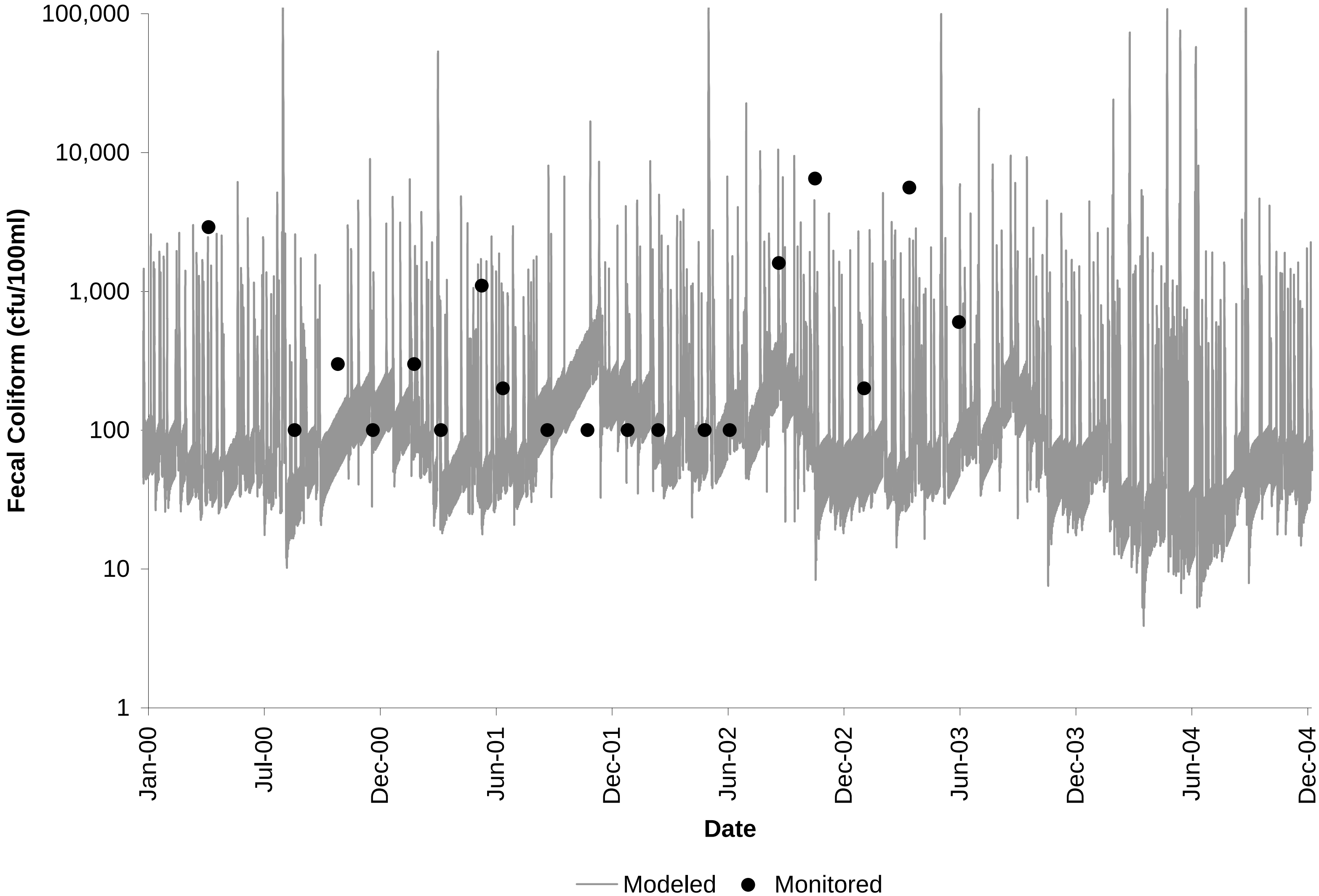

Figure 4.13. Water quality validation results with observed and modeled fecal coliform concentrations for subwatershed FG-1 in Fishing Creek (VAC-H03R-02) impairment.

Table 4.17. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the calibration period in Fishing Creek (VAC-H03R-02) watershed.

Parameter	Sub FG-1
Geometric Mean of Observed Values (cfu/100mL)	**331**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**308**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**19**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**19**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**43**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**43**

Table 4.18. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the validation period in Fishing Creek (VAC-H03R-02) watershed.

Parameter	Sub FG-1
Geometric Mean of Observed Values (cfu/100mL)	**320**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**261**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**26**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**26**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**32**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**26**

4.7.2.4 Blackwater Creek (VAC-H03R-01)

Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 2-BKW000.40 within the Blackwater Creek (VAC-H03R-01) impairment were used to calibrate the water quality component of HSPF. The final water calibration parameters are shown in Table 4.19. Observations from the VADEQ station, 2-BKW000.40, were graphically compared to corresponding modeled concentrations at subwatershed BW-9 (Figures 4.14 and 4.15). 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 violation rate of the previous 1,000 cfu/100mL fecal coliform instantaneous standard and the interim 400 cfu/100mL fecal coliform instantaneous standard were calculated. Table 4.20 shows the observed and modeled comparisons of the geometric mean and violation rates for the calibration period, and Table 4.21 shows the same comparisons for the validation period. It should be noted that a limited number of observed values were available for comparison when determining violation rates in Tables 4.20 and 4.21. A difference of one violation could result in a difference of violation rate of 5%. The highest difference (7%) between observed and modeled geometric mean concentrations was recorded during the validation period. The highest difference in the water quality standard violation rates (5%) was recorded during the calibration period. This 5% difference represents one difference in the number of violations in the modeled and observed conditions. The modeled versus observed geometric mean concentrations and violation rates comparison yielded acceptable results for the calibration period.

Based on the qualitative and quantitative analyses performed during hydrology and water quality calibration, it was established that the developed model adequately represented the processes and interactions associated with the production and transport of bacteria within the Blackwater Creek (VAC-H03R-01) watershed.

Table 4.19. Calibrated water quality HSPF parameters for Blackwater Creek (VAC-H03R-01) 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	19E06-4E8	19E06-4E8	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	02E08-32E8	02E08-32E8	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.25	0.25	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	19E06-4E08	19E06-4E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	2E8-32E8	2E8-32E8	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.02	0.02	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	2.0	0.05-2.0	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

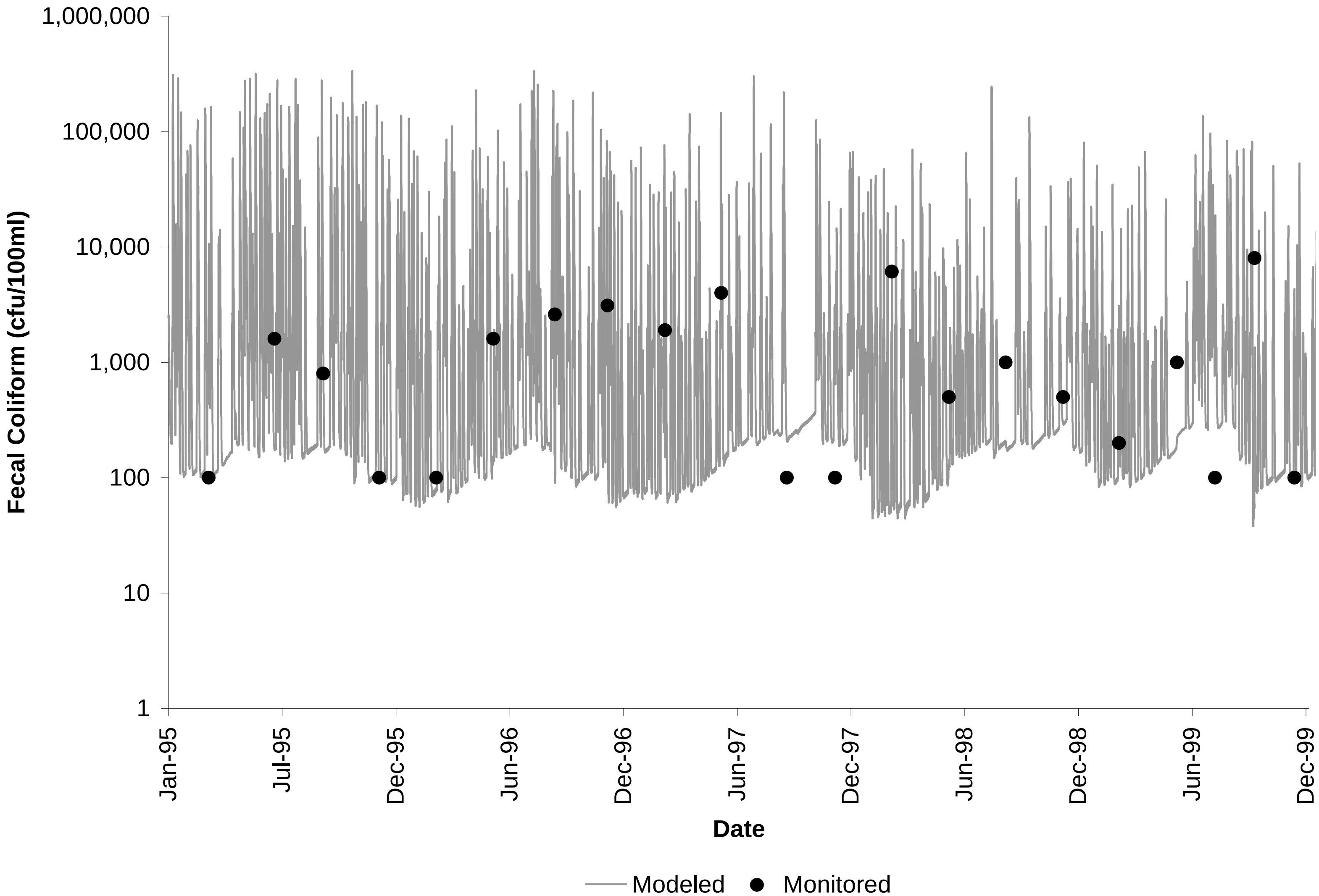

Figure 4.14. Water quality calibration results with observed and modeled fecal coliform concentrations for subwatershed BW-9 in Blackwater Creek (VAC-H03R-01) impairment.

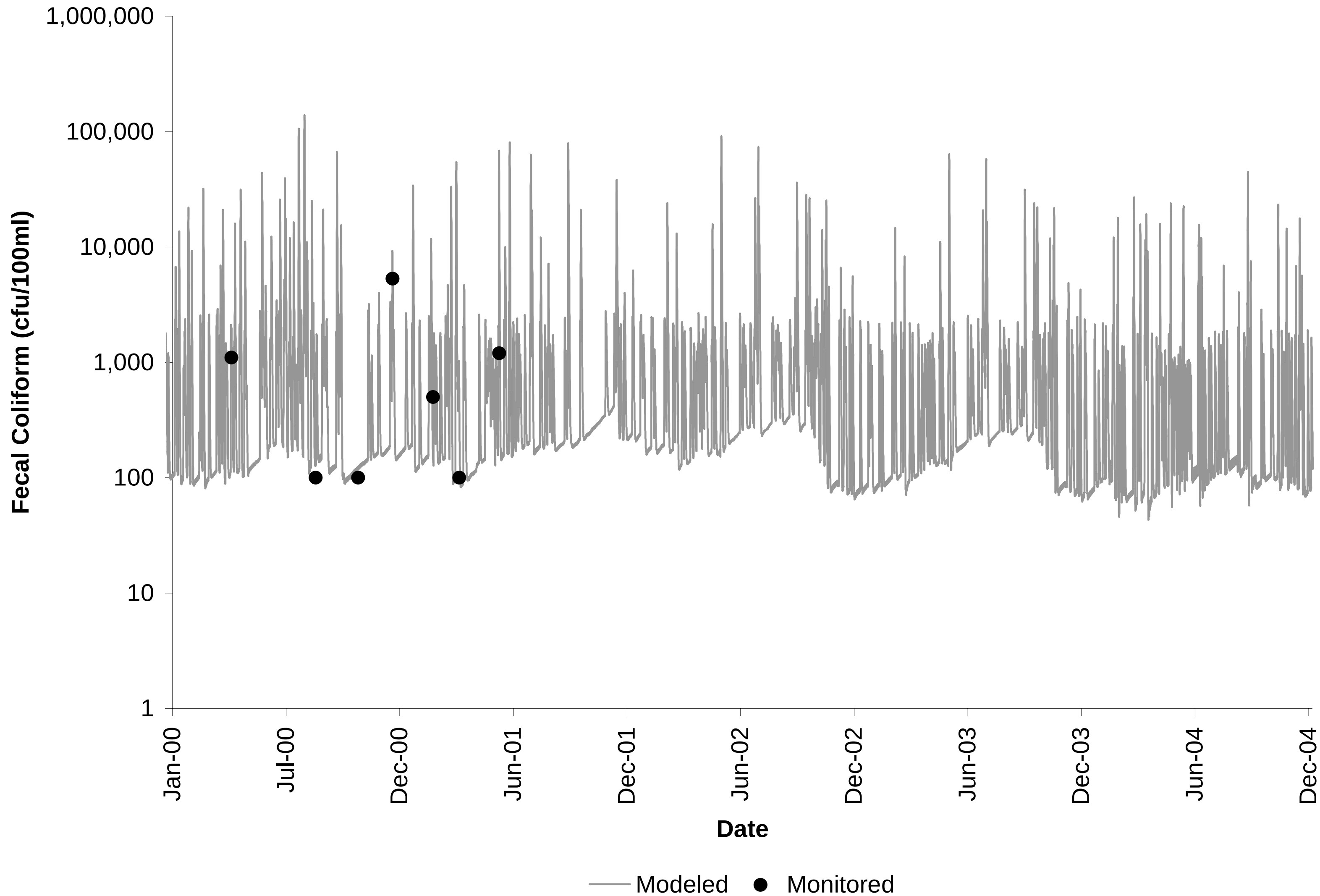

Figure 4.15. Water quality calibration results with observed and modeled fecal coliform concentrations for subwatershed BW-9 in Blackwater Creek (VAC-H03R-01) impairment.

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Table 4.20. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the calibration period in Blackwater Creek (VAC-H03R-01) watershed.

Parameter	Sub BW-9
Geometric Mean of Observed Values (cfu/100mL)	**610**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**618**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**38**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**33**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**62**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**62**

Table 4.21. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the calibration period in Blackwater Creek (VAC-H03R-01) watershed.

Parameter	Sub BW-9
Geometric Mean of Observed Values (cfu/100mL)	**446**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**480**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**43**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**43**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**57**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**57**

4.7.2.5 Tomahawk Creek (VAC-H03R-07)

Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 2-THK002.33 within the Tomahawk Creek (VAC-H03R-07) impairment were used to calibrate the water quality component of HSPF. The final water calibration parameters are shown in Table 4.22. Observations from the VADEQ station, 2-THK002.33, were graphically compared to corresponding modeled concentrations at subwatershed BW-7 (Figure 4.16). Observed data were not available for the designated calibration period (1/1/95 – 12/31/99) for bacteria station 2-THK002.33, so the calibration was performed for the designated validation period (1/1/00 – 12/31/04) and no validation was performed. 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

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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. As expected, differences between modeled and observed bacteria concentrations were greater during the validation period.

To provide a quantitative measure of the agreement between observed and modeled data, the geometric mean and violation rate of the previous 1,000 cfu/100mL fecal coliform instantaneous standard and the interim 400 cfu/100mL fecal coliform instantaneous standard were calculated. Table 4.23 shows the observed and modeled comparisons of the geometric mean and violation rates for the calibration period. It should be noted that a limited number of observed values were available for comparison when determining violation rates in Table 4.23. A difference of one violation could result in a difference of violation rate of 10%. The highest difference between observed and modeled geometric mean concentrations was 5%. The water quality standard violations rates were the same in the observed and modeled conditions. The modeled versus observed geometric mean concentrations and violation rates comparison yielded acceptable results for the calibration period.

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 Tomahawk Creek (VAC-H03R-07) watershed.

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Table 4.22. Calibrated water quality HSPF parameters for Tomahawk Creek (VAC-H03R-07) 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	27E06-53E8	27E06-53E8	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	2E08-5E10	81E6-2E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.5	0.5	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	29E08	29E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	3E10	87E8	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.02	0.02	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	2.0	2.5	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

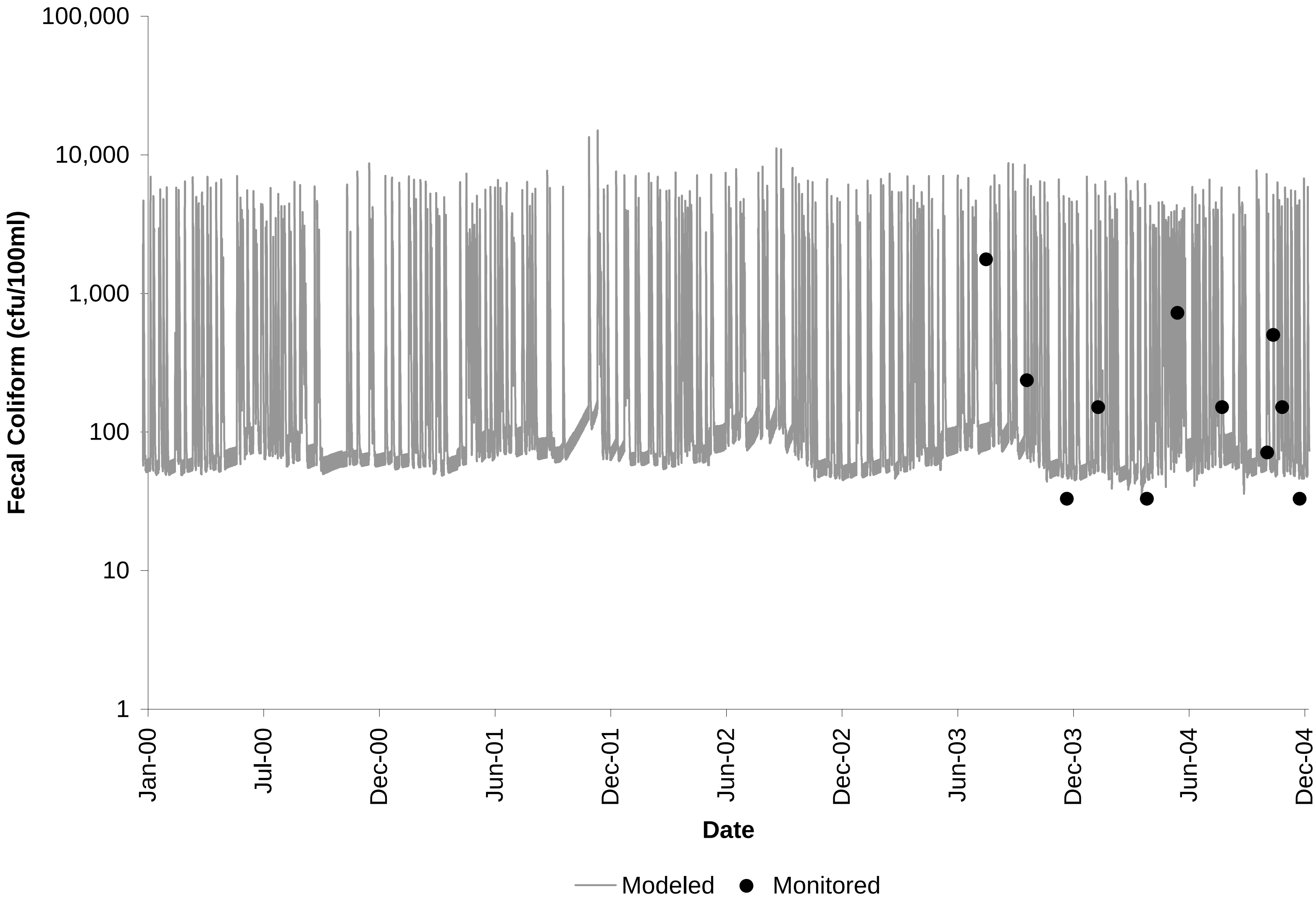

Figure 4.16. Water quality validation results with observed and modeled fecal coliform concentrations for subwatershed BW-7 in Tomahawk Creek (VAC-H03R-07) impairment.

Table 4.23. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the calibration period in Tomahawk Creek (VAC-H03R-07) watershed.

Parameter	Sub BW-7
Geometric Mean of Observed Values (cfu/100mL)	122
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	129
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	0
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	0
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	18
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	18

4.7.2.6 Burton Creek (VAC-H03R-05)

Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 2-BUN001.64 within the Burton Creek (VAC-H03R-05) impairment were used to calibrate the water quality component of HSPF. The final water calibration parameters are shown in Table 4.24. Observations from the VADEQ station, 2-BUN001.64, were graphically compared to corresponding modeled concentrations at subwatershed BW-5 (Figure 4.17). Observed data were not available for the designated calibration period (1/1/95 – 12/31/99) for bacteria station 2-BUN001.64, so the calibration was performed for the designated validation period (1/1/00 – 12/31/04) and no validation was performed. 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. As expected, differences between modeled and observed bacteria concentrations were greater during the validation period.

To provide a quantitative measure of the agreement between observed and modeled data, the geometric mean and violation rate of the previous 1,000 cfu/100mL fecal coliform instantaneous standard and the interim 400 cfu/100mL fecal coliform instantaneous standard were calculated. Table 4.25 shows the observed and modeled comparisons of the geometric mean and violation rates for the calibration period. It should be noted that a limited number of observed values were available for comparison when determining violation rates in Table 4.25. A difference of one violation could result in a difference of violation rate of 11%. The difference between observed and modeled geometric mean concentrations was 2.5% in the calibration period. The highest difference in the water quality standard violation rates was 11%. The modeled versus observed geometric mean concentrations and violation 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 Burton Creek (VAC-H03R-05) watershed.

Table 4.24. Calibrated water quality HSPF parameters for Burton Creek (VAC-H03R-05) 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	40E06-26E8	40E06-26E8	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	4E08-9E10	1E08-78E8	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.5	0.5	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	2E08-23E08	2E08-23E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	18E8-2E10	6E8-69E8	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.02	0.02	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	2.0	2.5	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

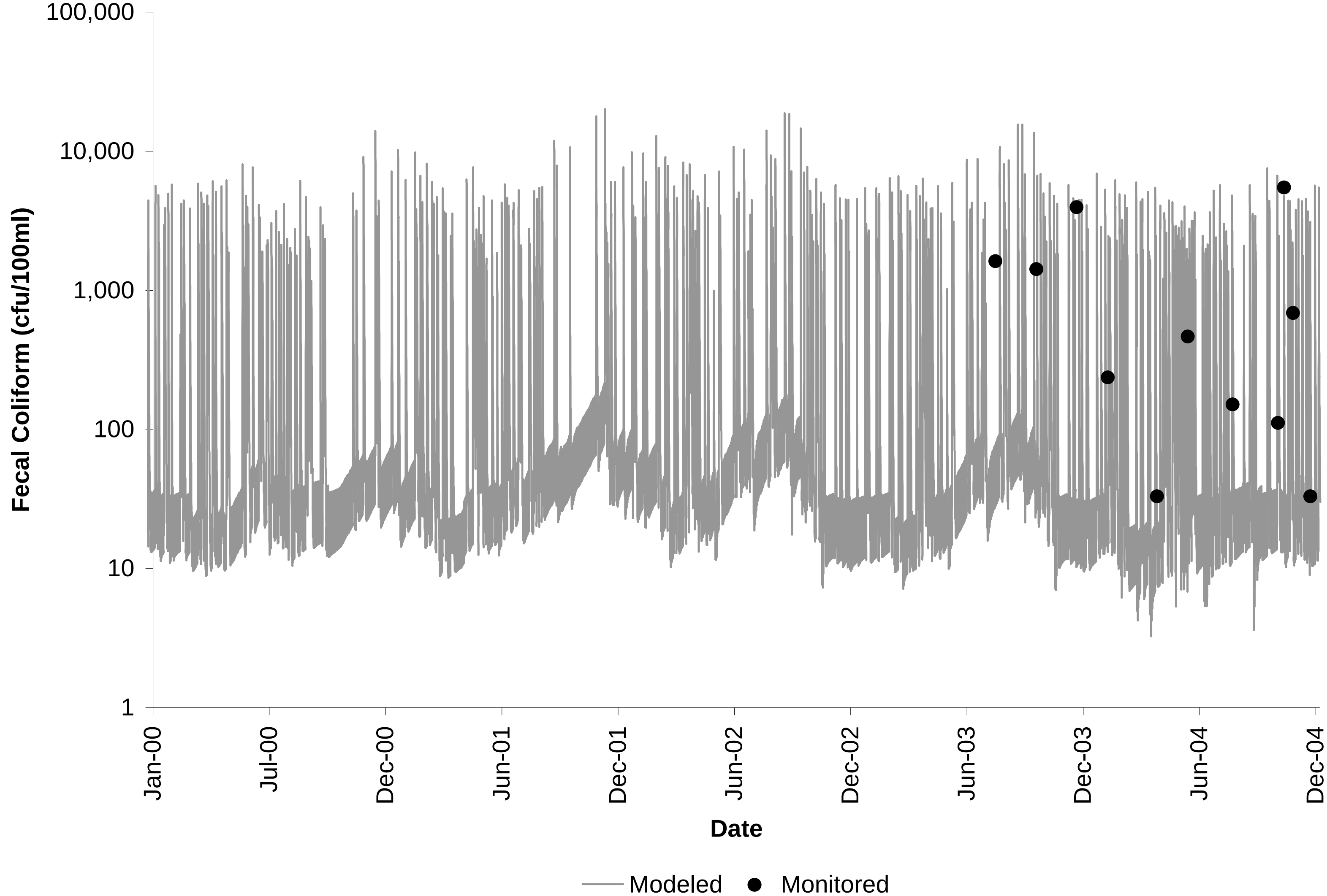

Figure 4.17. Water quality validation results with observed and modeled fecal coliform concentrations for subwatershed BW-5 in Burton Creek (VAC-H03R-05) impairment.

Table 4.25. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the calibration period in Burton Creek (VAC-H03R-05) watershed.

Parameter	Sub BW-5
Geometric Mean of Observed Values (cfu/100mL)	**280**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**288**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**22**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**22**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**44**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**33**

4.7.2.7 Judith Creek (VAC-H03R-06)

Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 2-JTH001.52 within Judith Creek (VAC-H03R-06) impairment were used to calibrate the water quality component of HSPF. The final water calibration parameters are shown in Table 4.26. Observations from the VADEQ station, 2-JTH001.52, were graphically compared to corresponding modeled concentrations at subwatershed BW-5 (Figure 4.18). Observed data were not available for the designated calibration period (1/1/95 – 12/31/99) for bacteria station 2-JTH001.52, so the calibration was performed for the designated validation period (1/1/00 – 12/31/04) and no validation was performed. 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. As expected, differences between modeled and observed bacteria concentrations were greater during the validation period.

To provide a quantitative measure of the agreement between observed and modeled data, the geometric mean and violation rate of the previous 1,000 cfu/100mL fecal coliform instantaneous standard and the interim 400 cfu/100mL fecal coliform instantaneous standard were calculated. Table 4.27 shows the observed and modeled comparisons of the geometric mean and violation rates for the calibration period. It should be noted that a limited number of observed values were available for comparison when determining violation rates in Table 4.27. A difference of one violation could result in a difference of violation rate of 12%. The difference between observed and modeled geometric mean concentrations was 5.2% in the calibration period. The highest difference in the water quality standard violation rates was 12%, which represents one violation difference between observed and modeled conditions. The modeled versus observed geometric mean concentrations and violation 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 Judith Creek (VAC-H03R-06) watershed.

Table 4.26. Calibrated water quality HSPF parameters for Judith Creek (VAC-H03R-06) 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	11E06-9E08	11E06-9E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	99E6-9E10	99E6-9E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	2.4	2.4	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	14E08-24E08	14E08-24E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	1E10-2E10	1E10-2E10	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	2.0	2.5	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

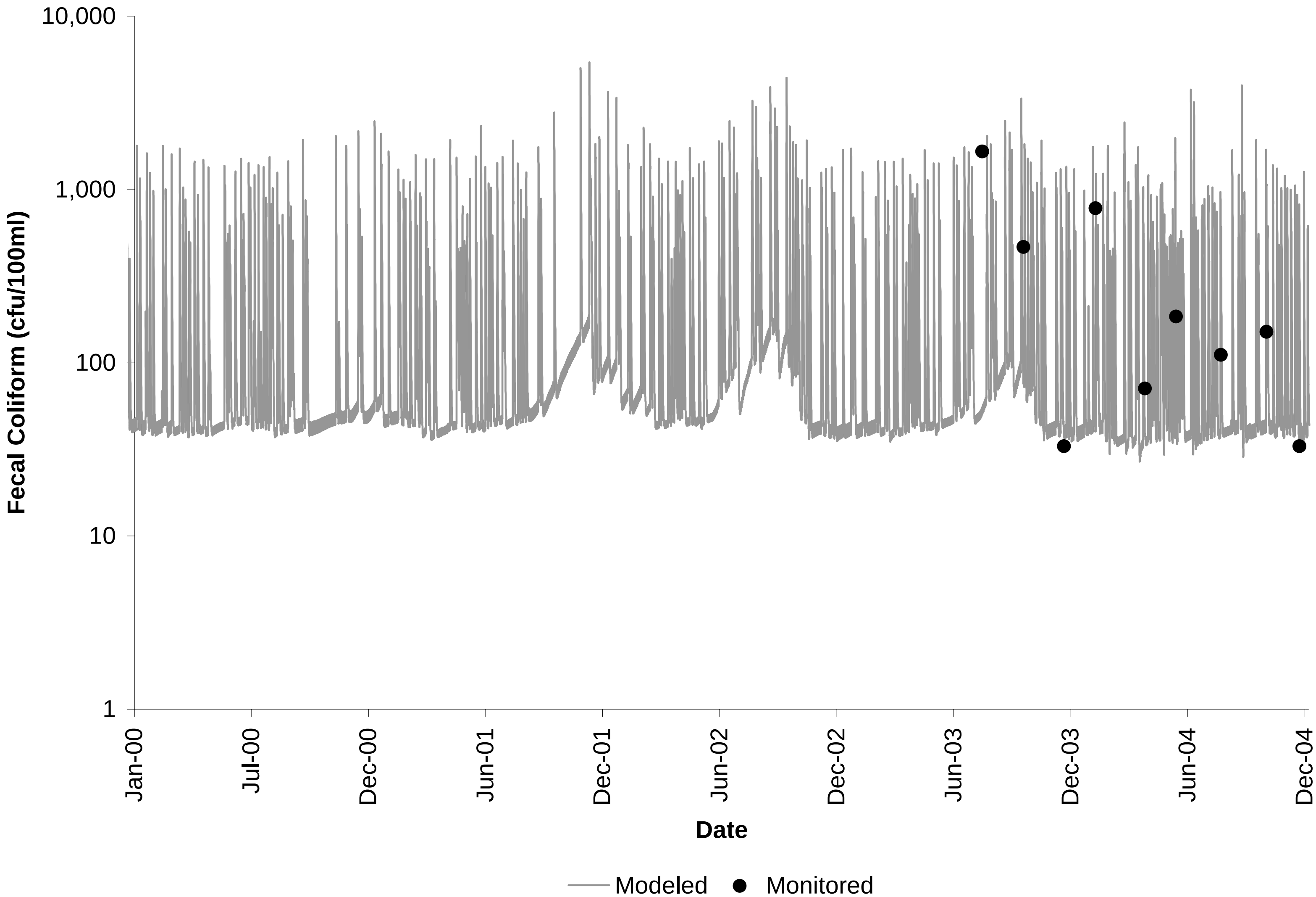

Figure 4.18. Water quality calibration results with observed and modeled fecal coliform concentrations for subwatershed JC-2 in Judith Creek (VAC-H03R-06) impairment

Table 4.27. Observed and modeled geometric mean concentrations and violation rates of instantaneous standards for the calibration period in Judith Creek (VAC-H03R-06) watershed.

Parameter	Sub JC-2
Geometric Mean of Observed Values (cfu/100mL)	**131**
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	**125**
Observed Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**0**
Modeled Fecal Coliform Instantaneous Standard, 1,000 cfu/100mL, Violation Rate (%)	**0**
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**25**
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Violation Rate (%)	**13**

Chapter 5. Load Allocations

1.1 Background

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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) TMDLs was to determine what reductions in bacteria loadings from point and nonpoint sources are required to meet state water quality standards. 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 TMDL considers all sources contributing *E. coli* to James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06). 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:

$$TMDL = WLA + LA + MOS \qquad [5.1]$$

where: WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

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 violations will occur if the TMDL plan is followed.

Bacteria loadings were updated to reflect 2006 conditions for the existing conditions and allocation runs. The simulation period selected for the load allocation study was January 1, 1995 to December 31, 1999. This period incorporates average rainfall, low rainfall, and high rainfall years allowing the representation of both low and high flow conditions.

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:

$$\log_2(EC) = -0.0172 + 0.91905*\log_2(FC) \qquad [5.2]$$

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.

5.1 Existing Conditions

Bacteria loadings for 2006 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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) impairments. Appendix C contains tables with monthly land-based and direct bacteria loadings for existing conditions.

5.1.1 James River (VAC-H03R-04)

Figure 5.1 shows the monthly geometric mean for each subwatershed within the impairment 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 5.2). The subwatershed outlet used for comparison of modeled concentrations to water quality standards for the James River (VAC-H03R-04) impairment was subwatershed JR-7.

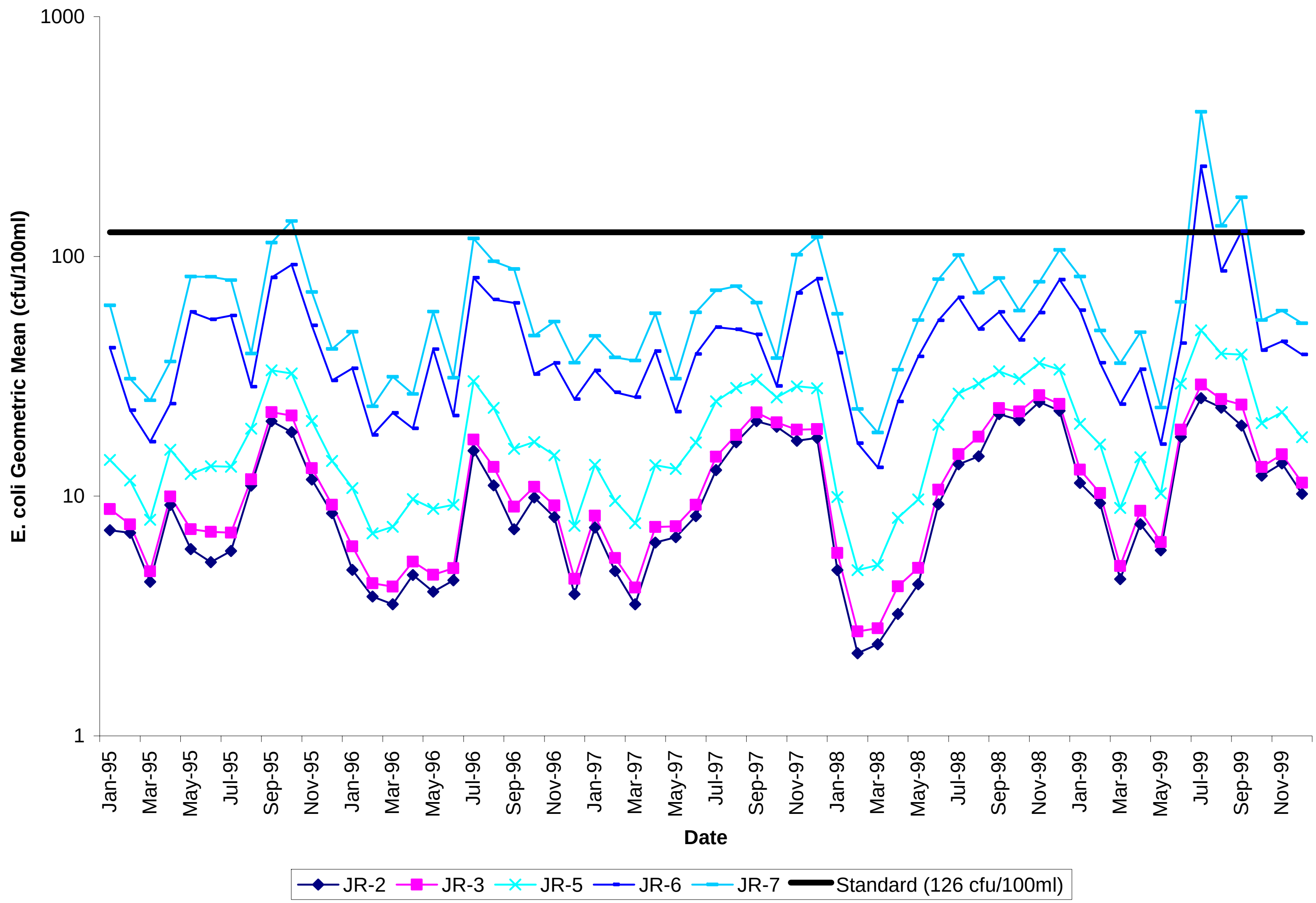

Figure 5.1. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds JR-2 to JR-7 in the James River (VAC-H03R-04) watershed.

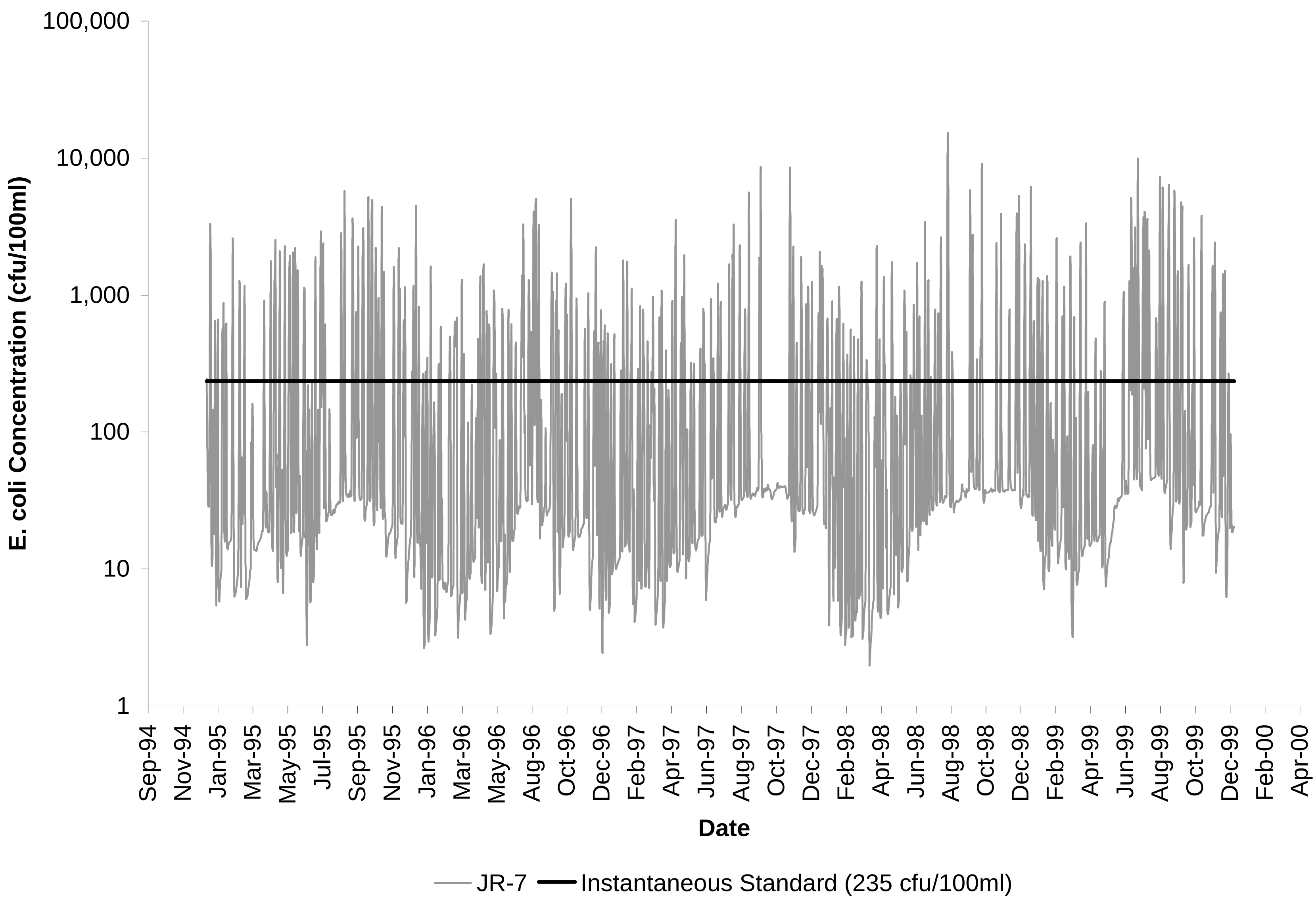

Figure 5.2. Daily average *E. coli* concentrations for subwatershed JR-7 in James River (VAC-H03R-04) watershed.

5.1.2 Ivy Creek (VAC-H03R-03)

Figure 5.3 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 5.4). The subwatershed outlet used for comparison of modeled concentrations to water quality standards for the Ivy Creek (VAC-H03R-03) impairment was subwatershed BW-3.

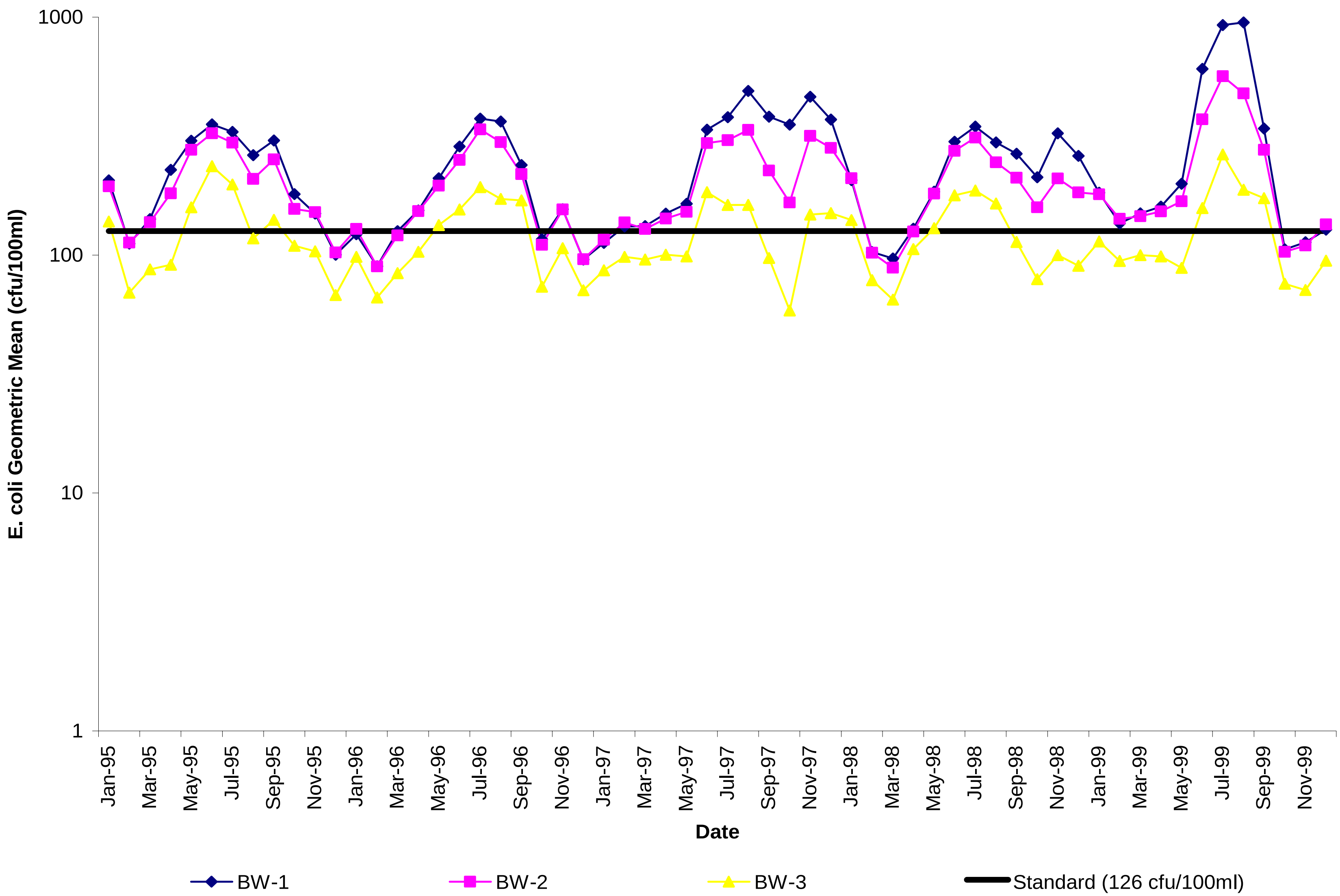

Figure 5.3. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds BW-1 to BW-3 in the Ivy Creek (VAC-H03R-03) watershed.

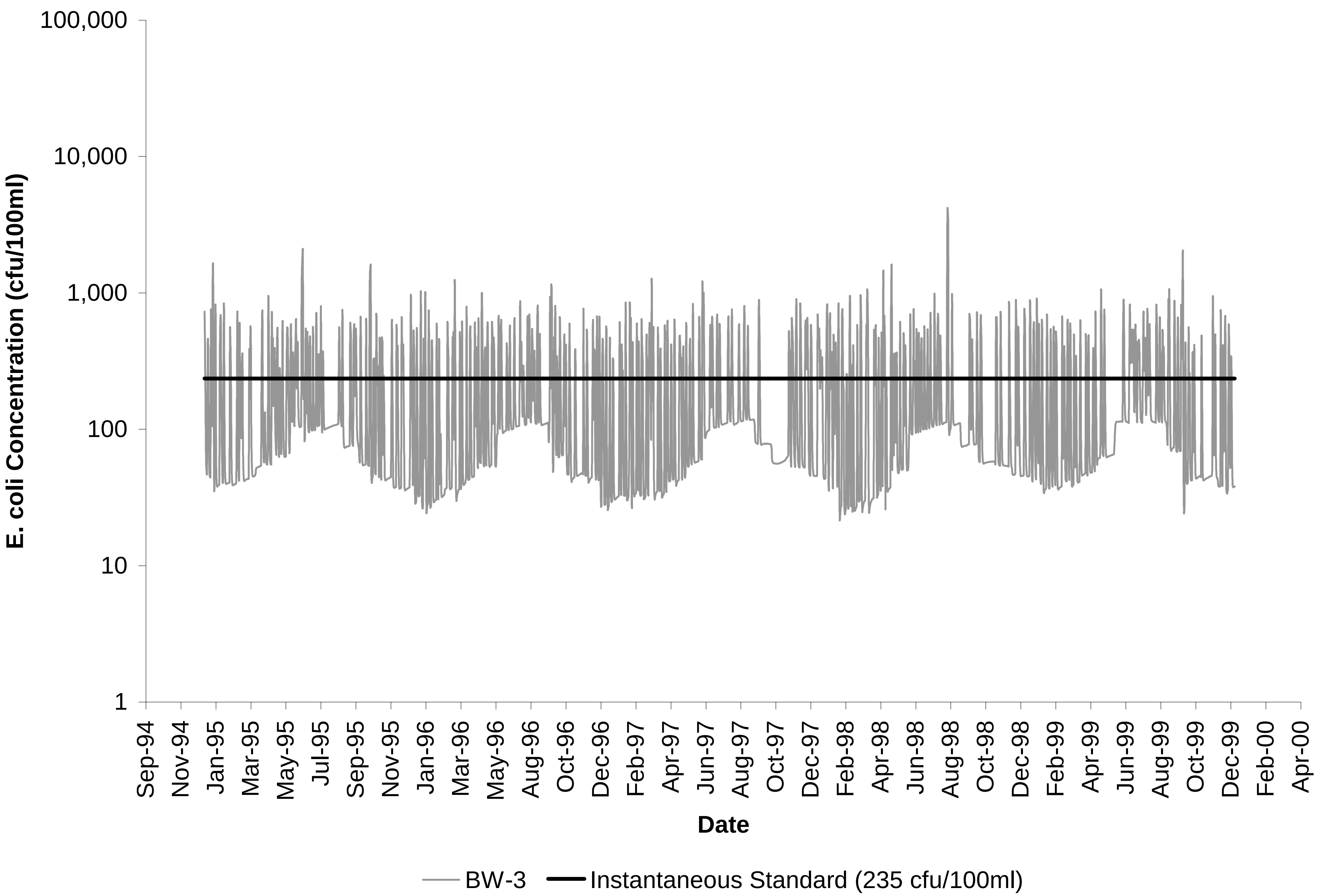

Figure 5.4. Daily average *E. coli* concentrations for subwatershed BW-3 in Ivy Creek (VAC-H03R-03) watershed.

5.1.3 Fishing Creek (VAC-H03R-02)

Figure 5.5 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 5.6). The subwatershed outlet used for comparison of modeled concentrations to water quality standards for the Fishing Creek (VAC-H03R-02) impairment was subwatershed FG-1.

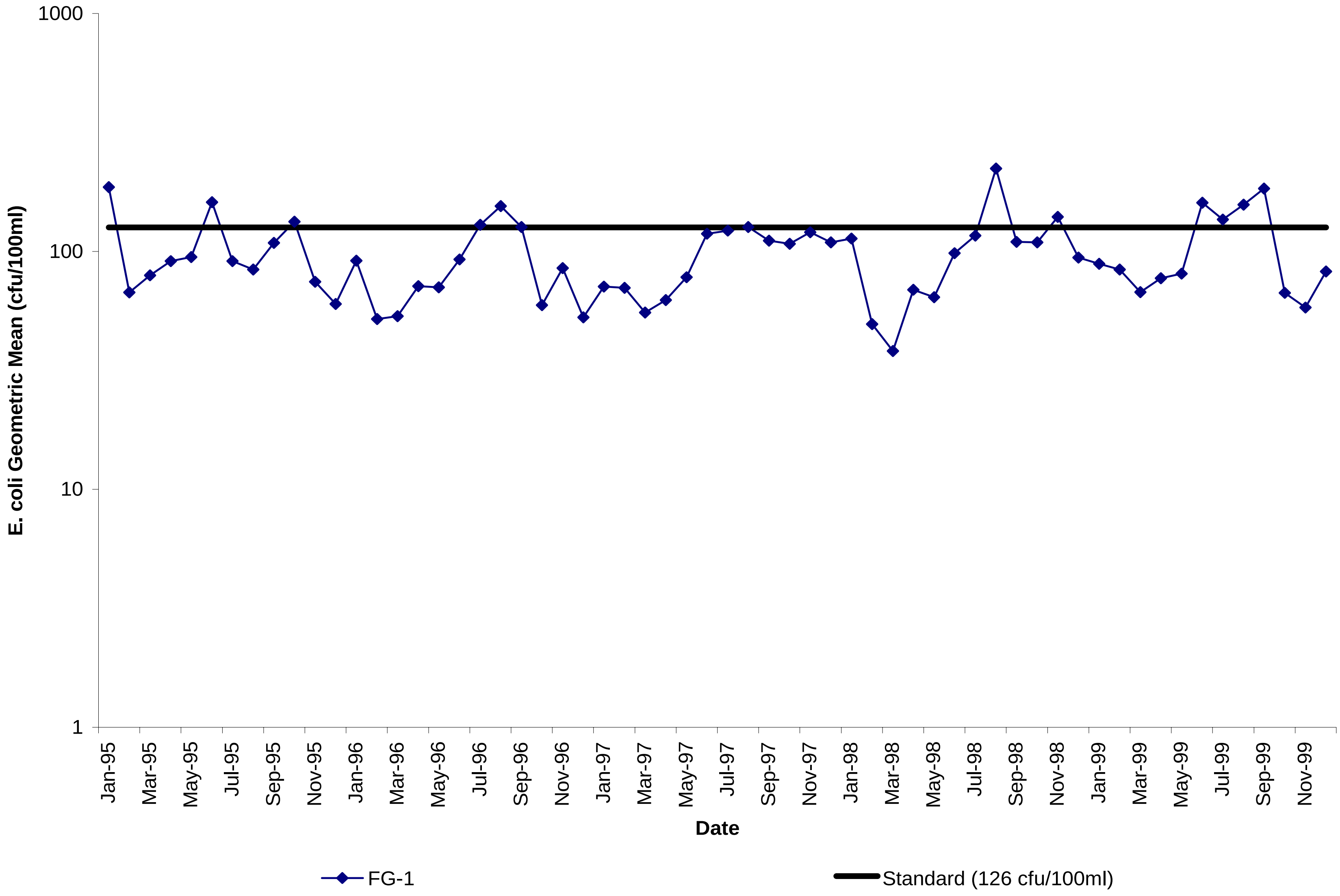

Figure 5.5. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatershed FG-1, in Fishing Creek (VAC-H03R-02) watershed.

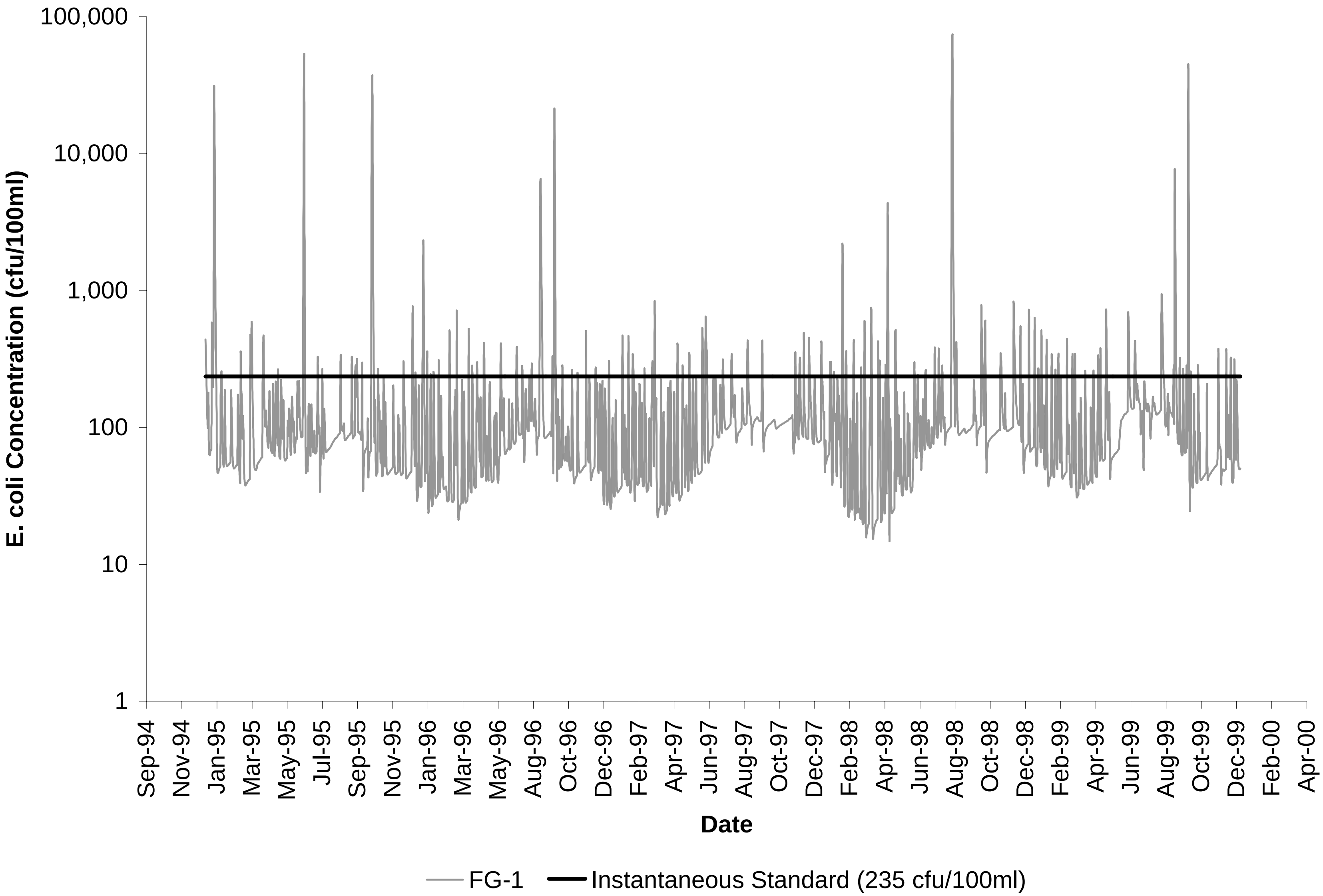

Figure 5.6. Daily average *E. coli* concentrations for subwatershed FG-1 in Fishing Creek (VAC-H03R-02) watershed.

5.1.4 Blackwater Creek (VAC-H03R-01)

Figure 5.7 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 5.8). The subwatershed outlet used for comparison of modeled concentrations to water quality standards for the Blackwater Creek (VAC-H03R-01) impairment was subwatershed BW-9.

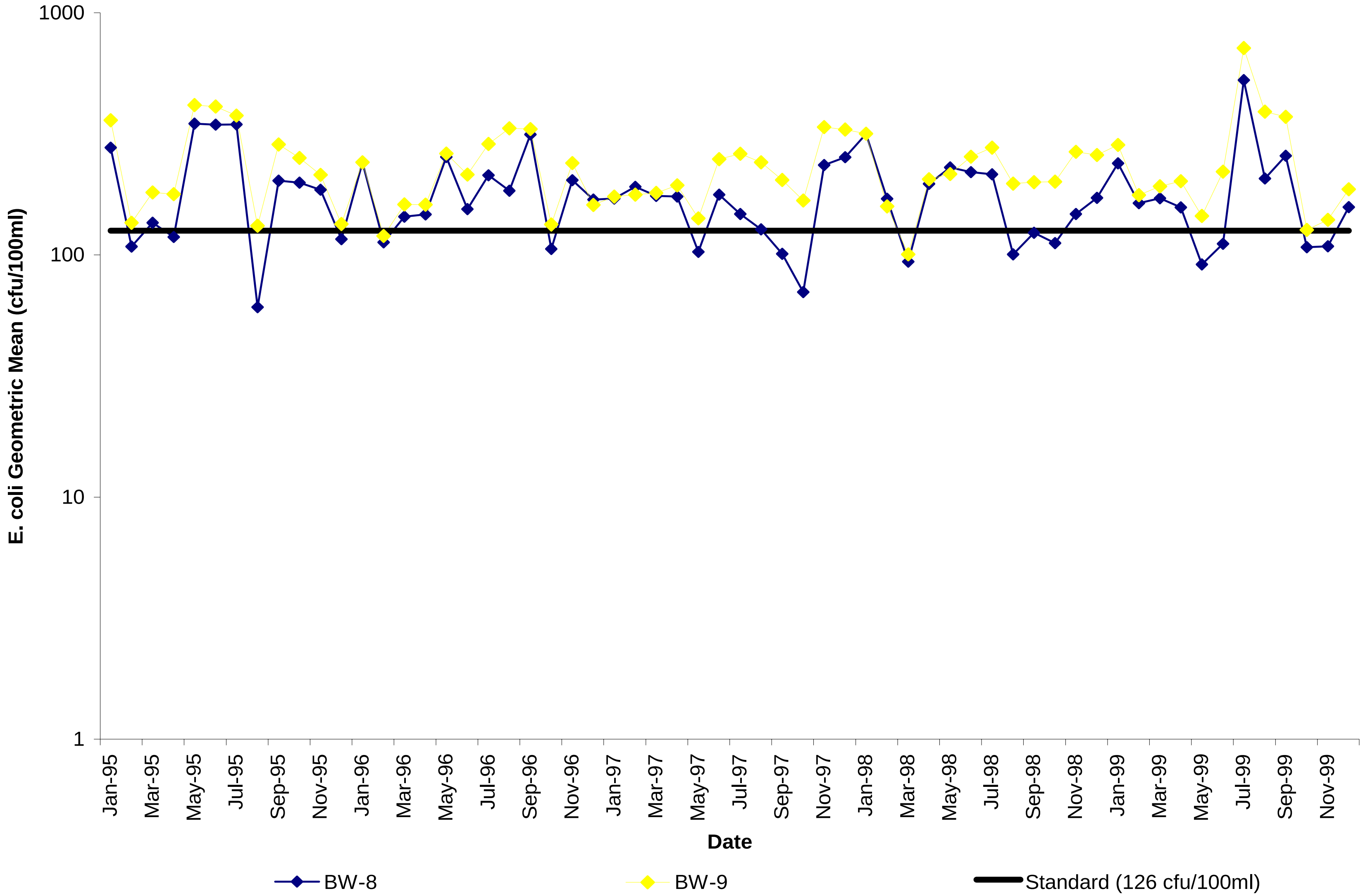

Figure 5.7. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds BW-8 and BW-9 in Blackwater Creek (VAC-H03R-01) watershed.

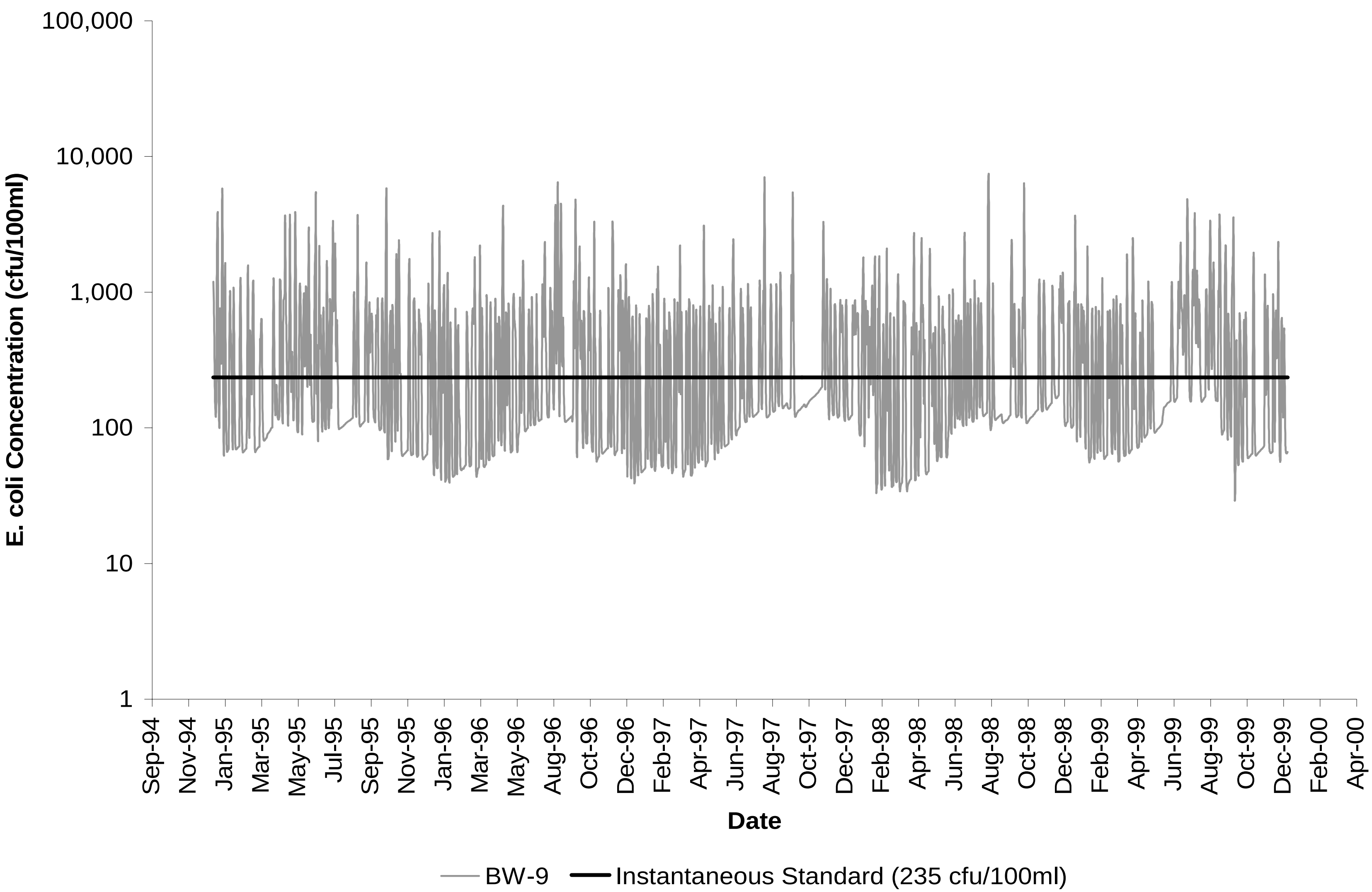

Figure 5.8. Daily average *E. coli* concentrations for subwatershed BW-9 in Blackwater Creek (VAC-H03R-01) watershed.

5.1.5 Tomahawk Creek (VAC-H03R-07)

Figure 5.9 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 5.10). The subwatershed outlet used for comparison of modeled concentrations to water quality standards for the Tomahawk Creek (VAC-H03R-07) impairment was subwatershed BW-7.

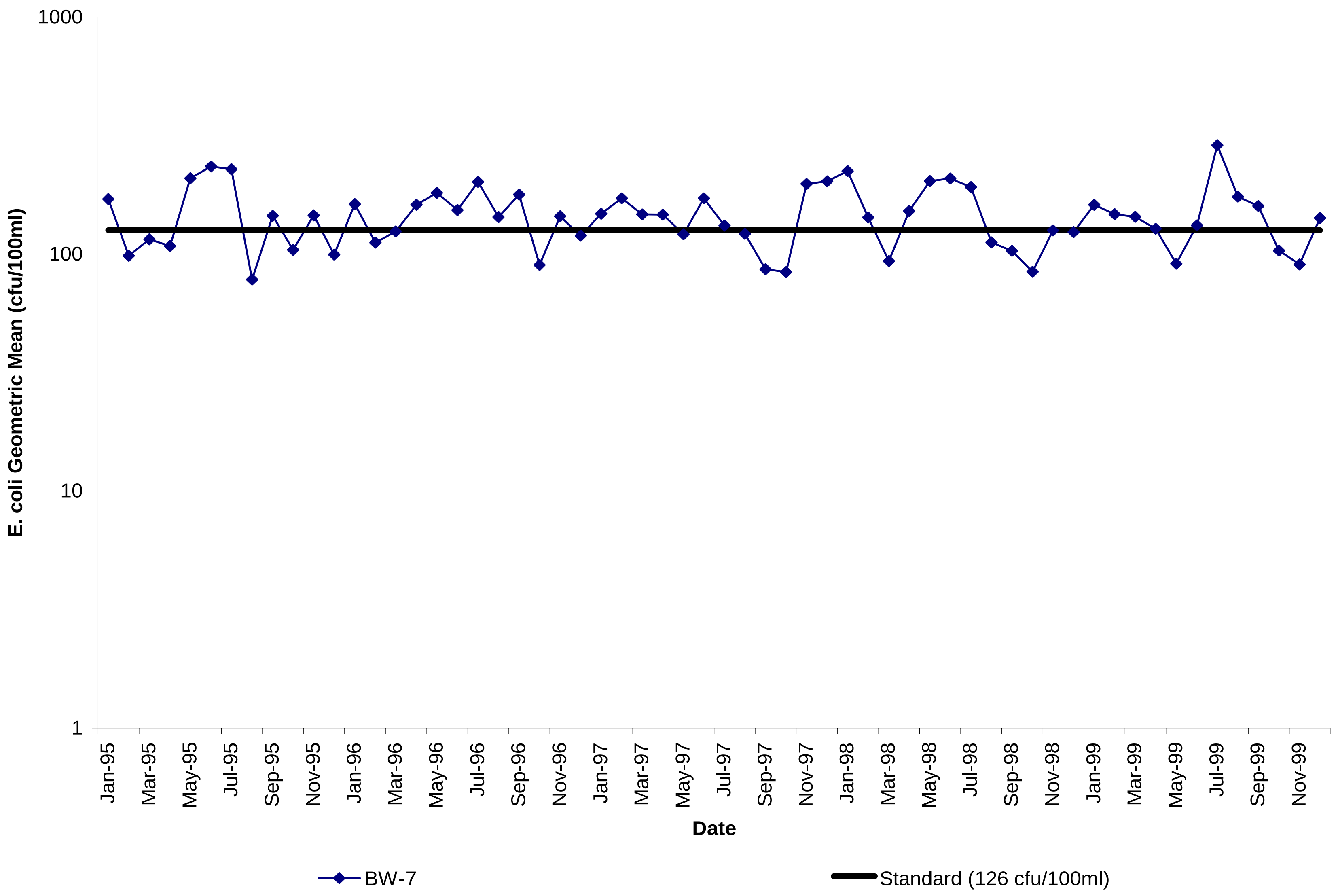

Figure 5.9. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatershed BW-7 in Tomahawk Creek (VAC-H03R-07) watershed.

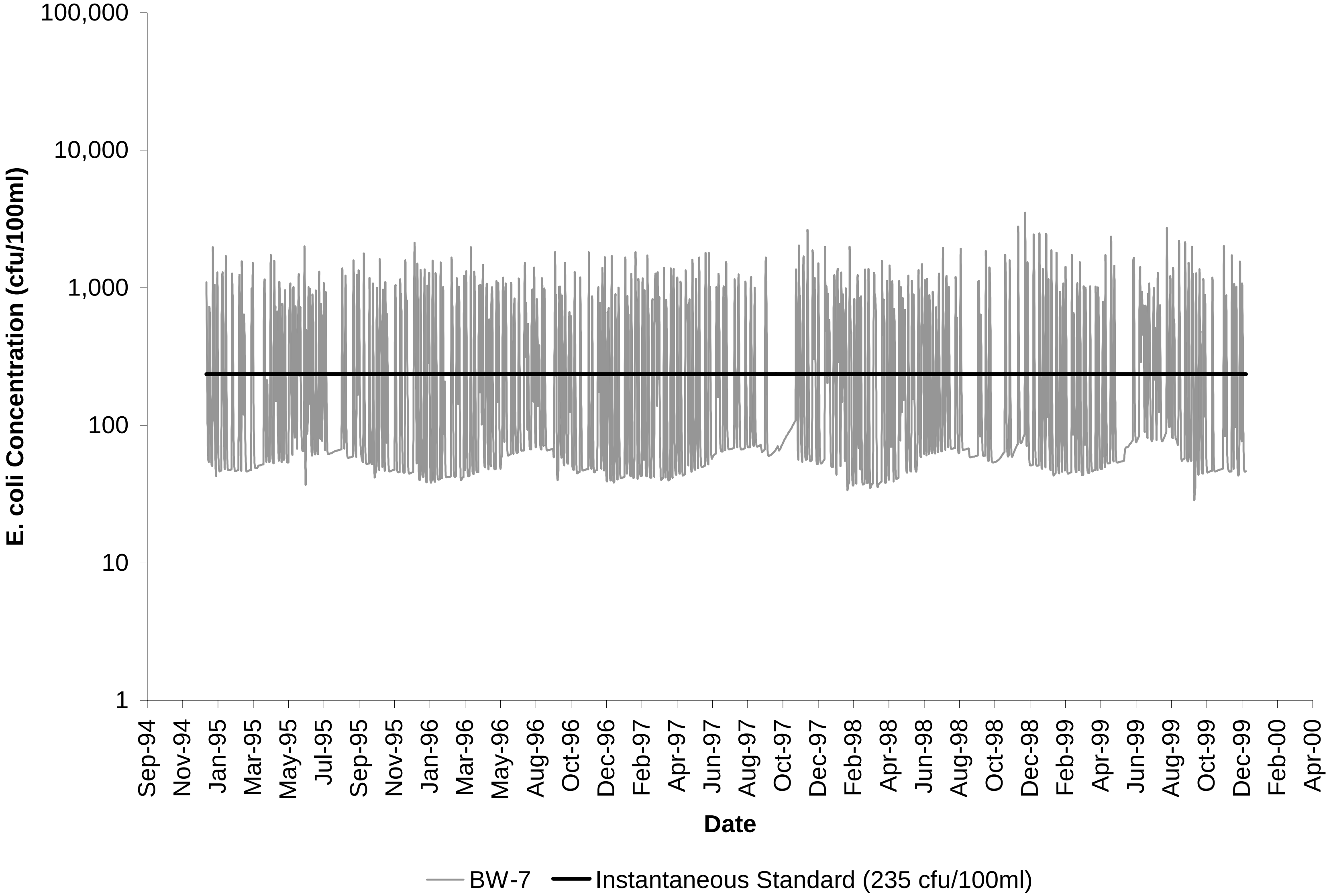

Figure 5.10. Daily average *E. coli* concentrations for subwatershed BW-7 in Tomahawk Creek (VAC-H03R-07) watershed.

5.1.6 Burton Creek (VAC-H03R-05)

Figure 5.11 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 5.12). The subwatershed outlet used for comparison of modeled concentrations to water quality standards for the Burton Creek (VAC-H03R-05) impairment was subwatershed BW-6.

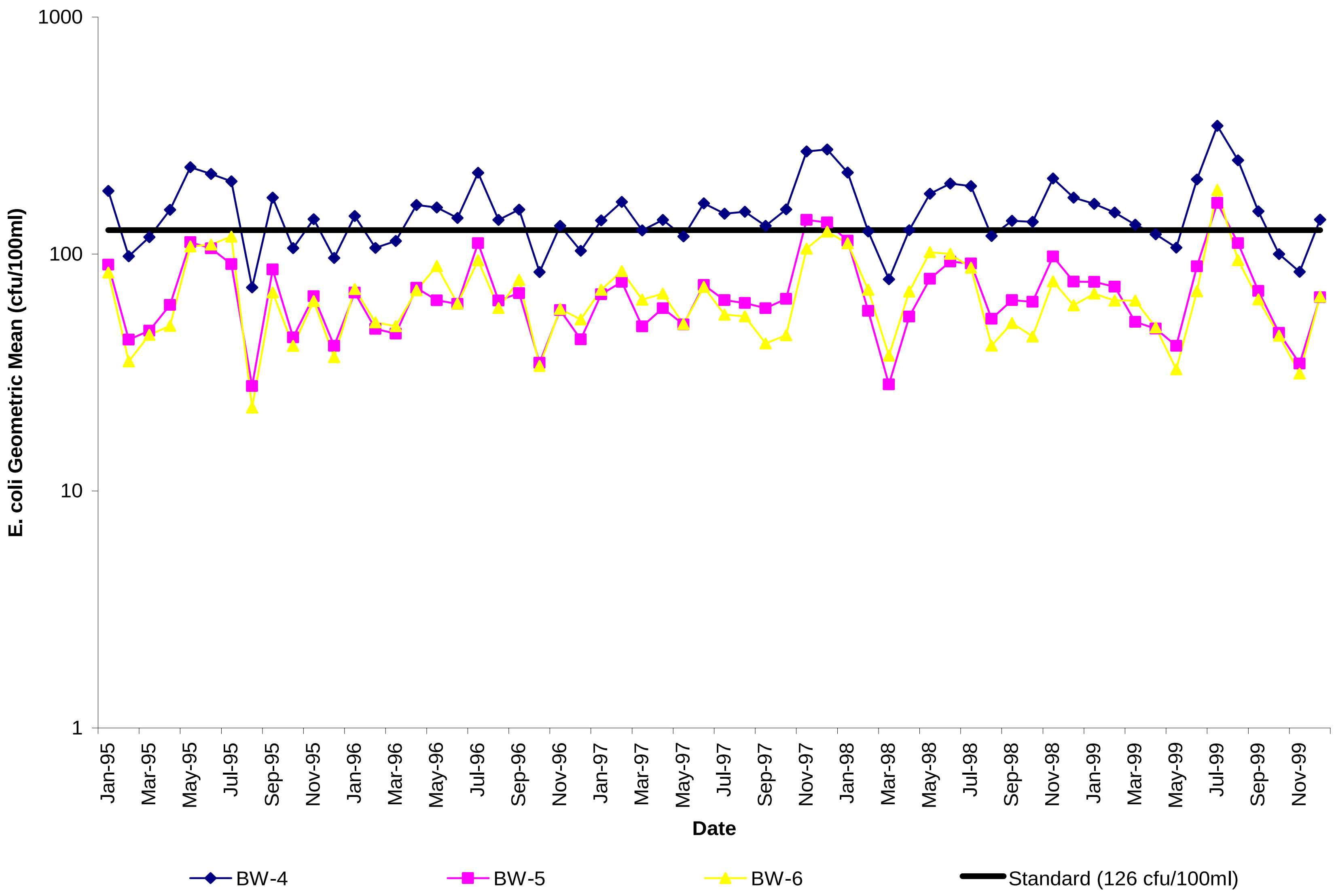

Figure 5.11. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds BW-4 to BW-6 in Burton Creek (VAC-H03R-05) watershed.

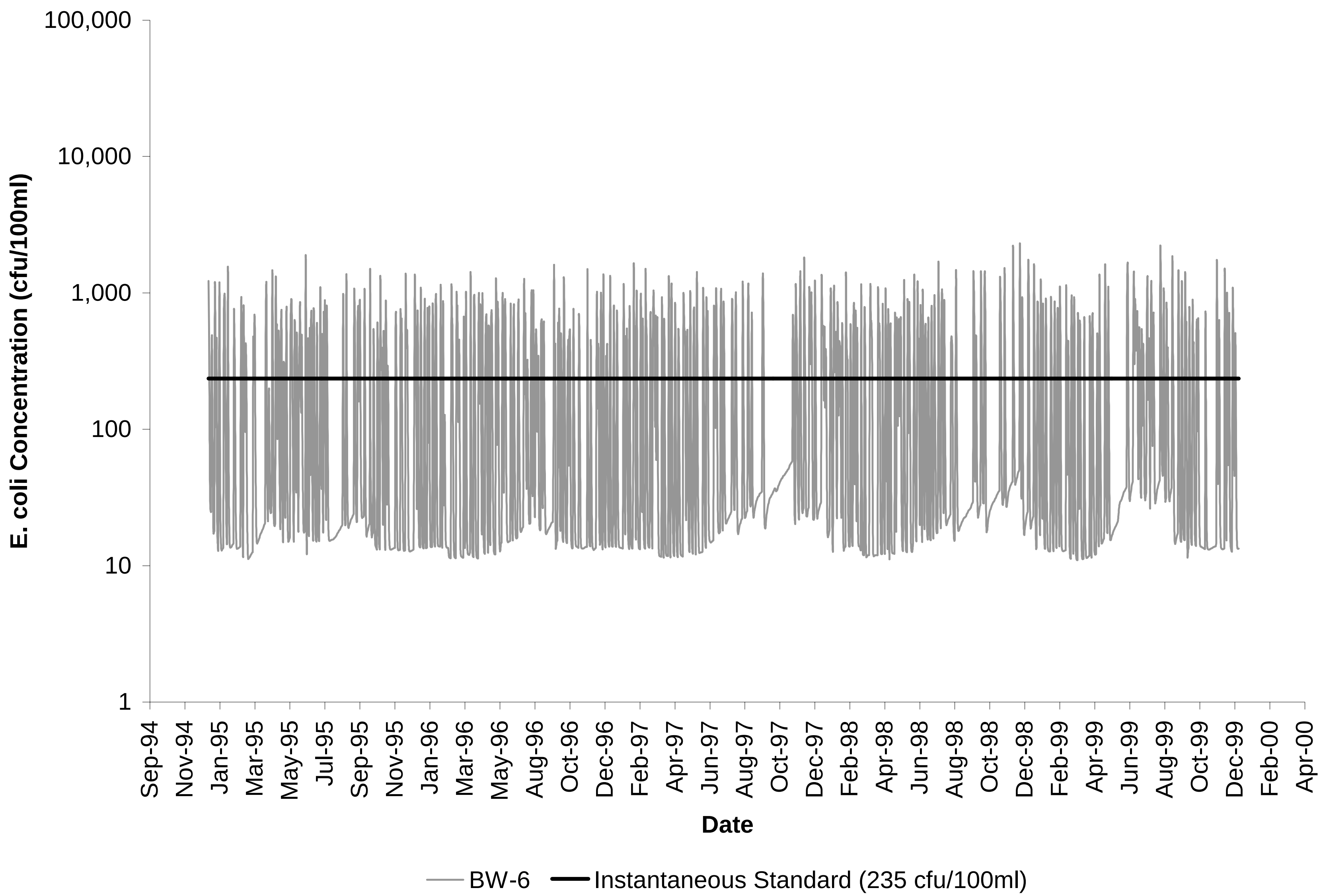

Figure 5.12. Daily average *E. coli* concentrations for subwatershed BW-6 in Burton Creek (VAC-H03R-05) watershed.

5.1.7 Judith Creek (VAC-H03R-06)

Figure 5.13 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 5.14). The subwatershed outlet used for comparison of modeled concentrations to water quality standards for the Judith Creek (VAC-H03R-06) impairment was subwatershed JC-2.

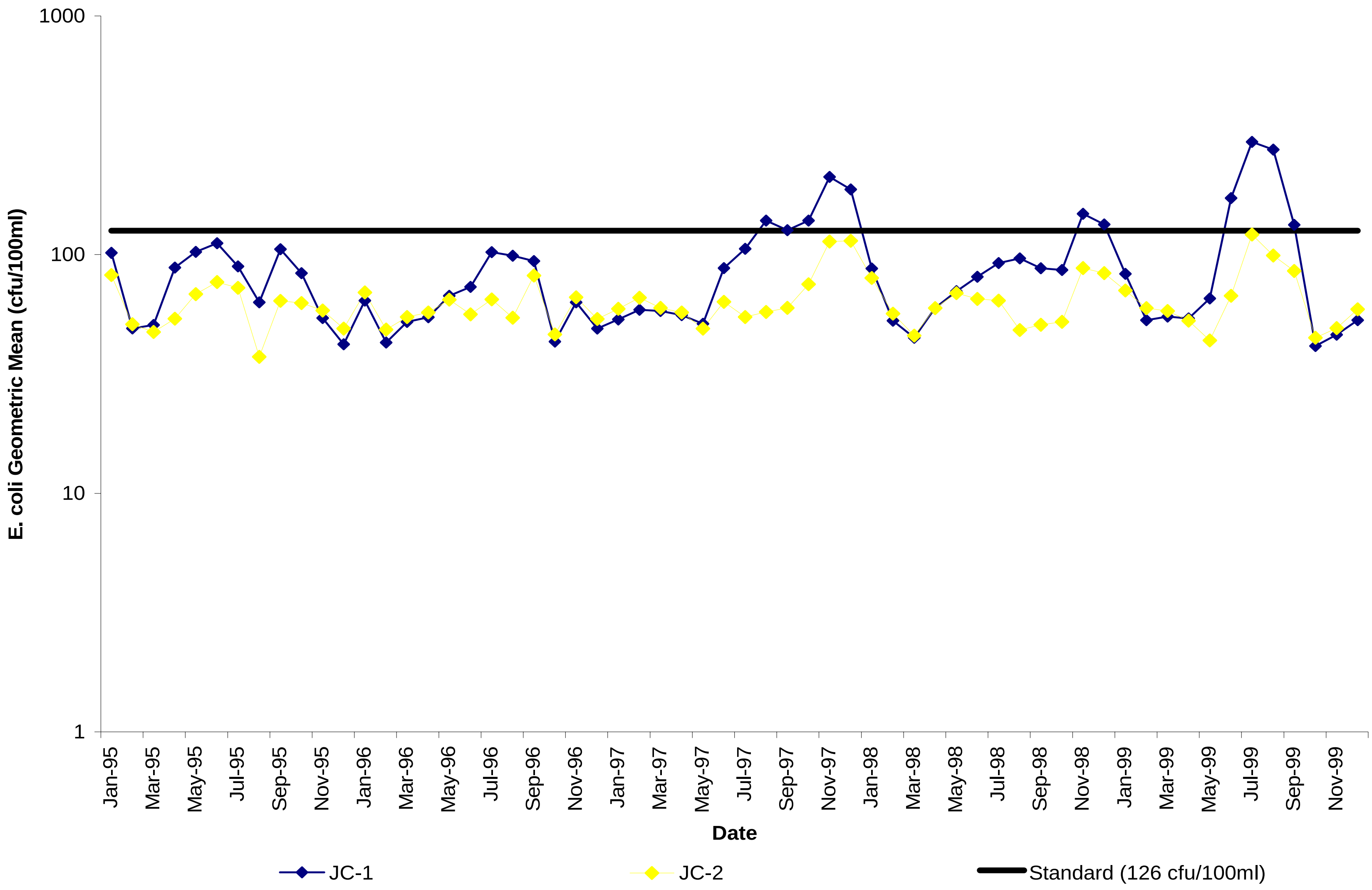

Figure 5.13. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds JC-1 and JC-2 in Judith Creek (VAC-H03R-06) watershed.

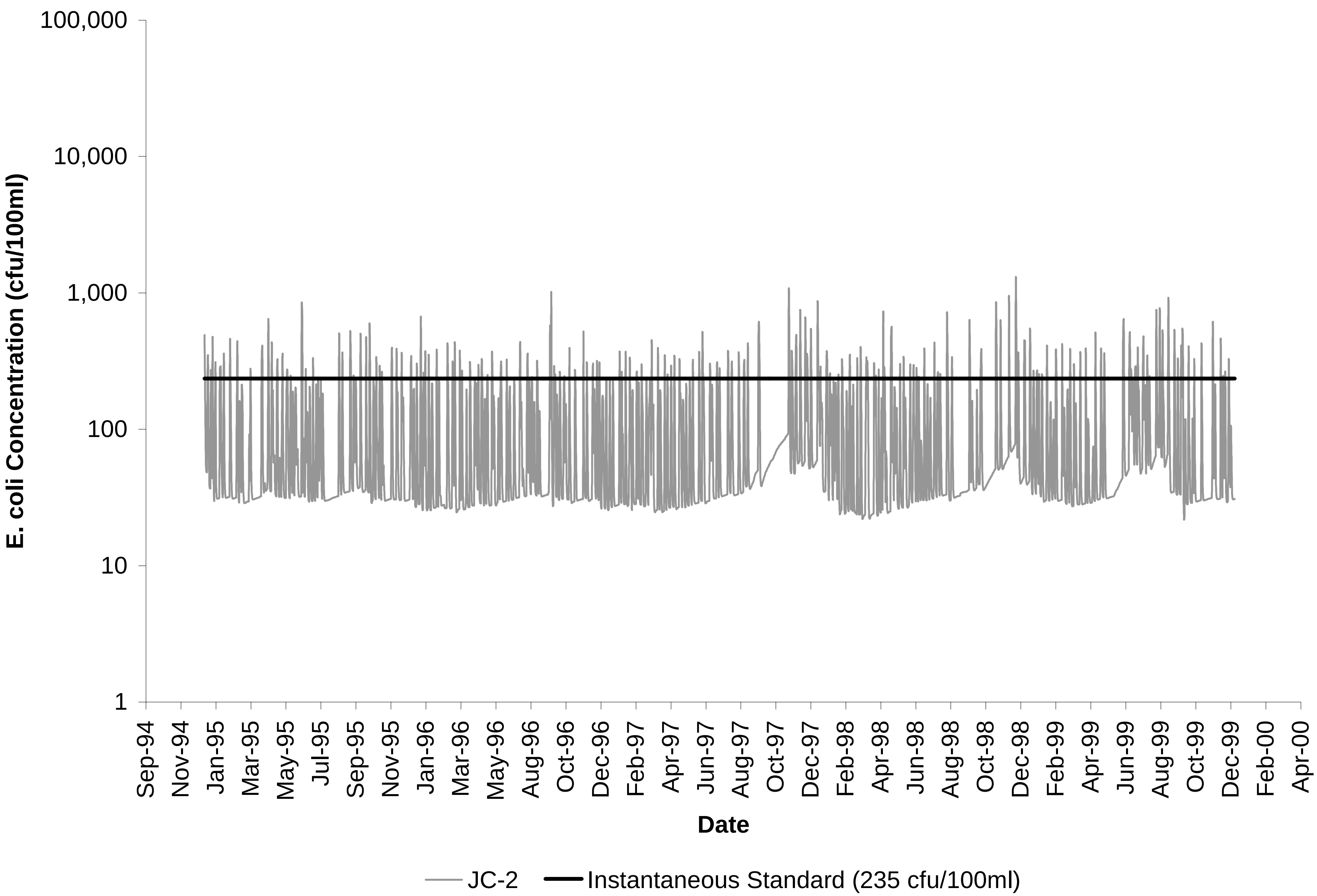

Figure 5.14. Daily average *E. coli* concentrations for subwatershed JC-2 in Judith Creek (VAC-H03R-06) watershed.

5.2 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 1, 1995 to December 31, 1999, 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.

5.2.1 James River (VAC-H03R-04)

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 5.15 and 5.16, respectively. Figures 5.17 and 5.18, 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 5.15 with Figure 5.16 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 5.17 to Figure 5.18 indicates that the maximum daily average *E. coli* concentrations are affected somewhat by increasing land-based loads and affected slightly more by increasing directly deposited loads during lower flow periods. It is also apparent that September 1997 was a very dry period that is most affected by directly deposited loads but not land-based loads.

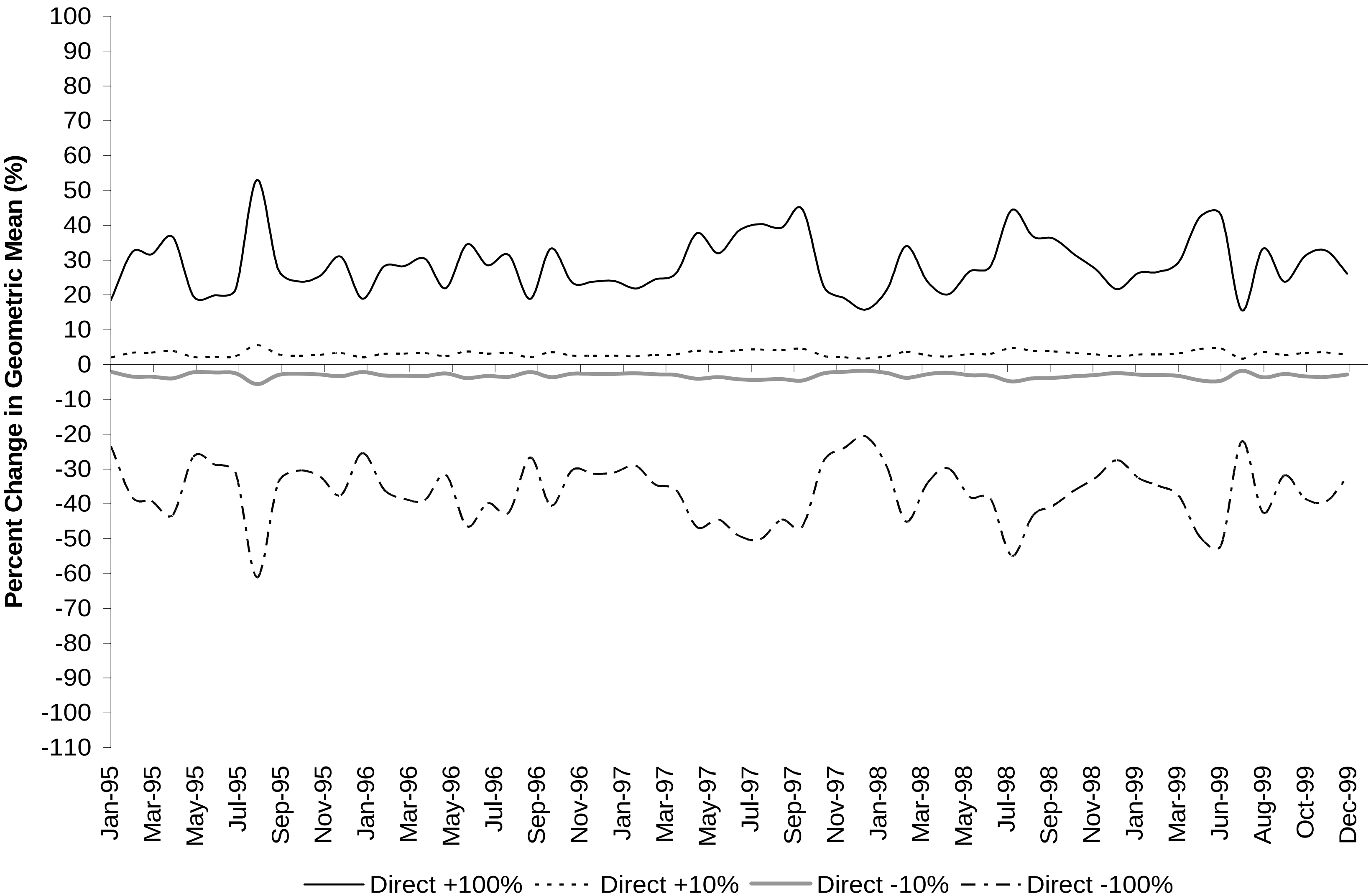

Figure 5.15. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed JR-7) of James River (VAC-H03R-04) watershed, as affected by direct load changes.

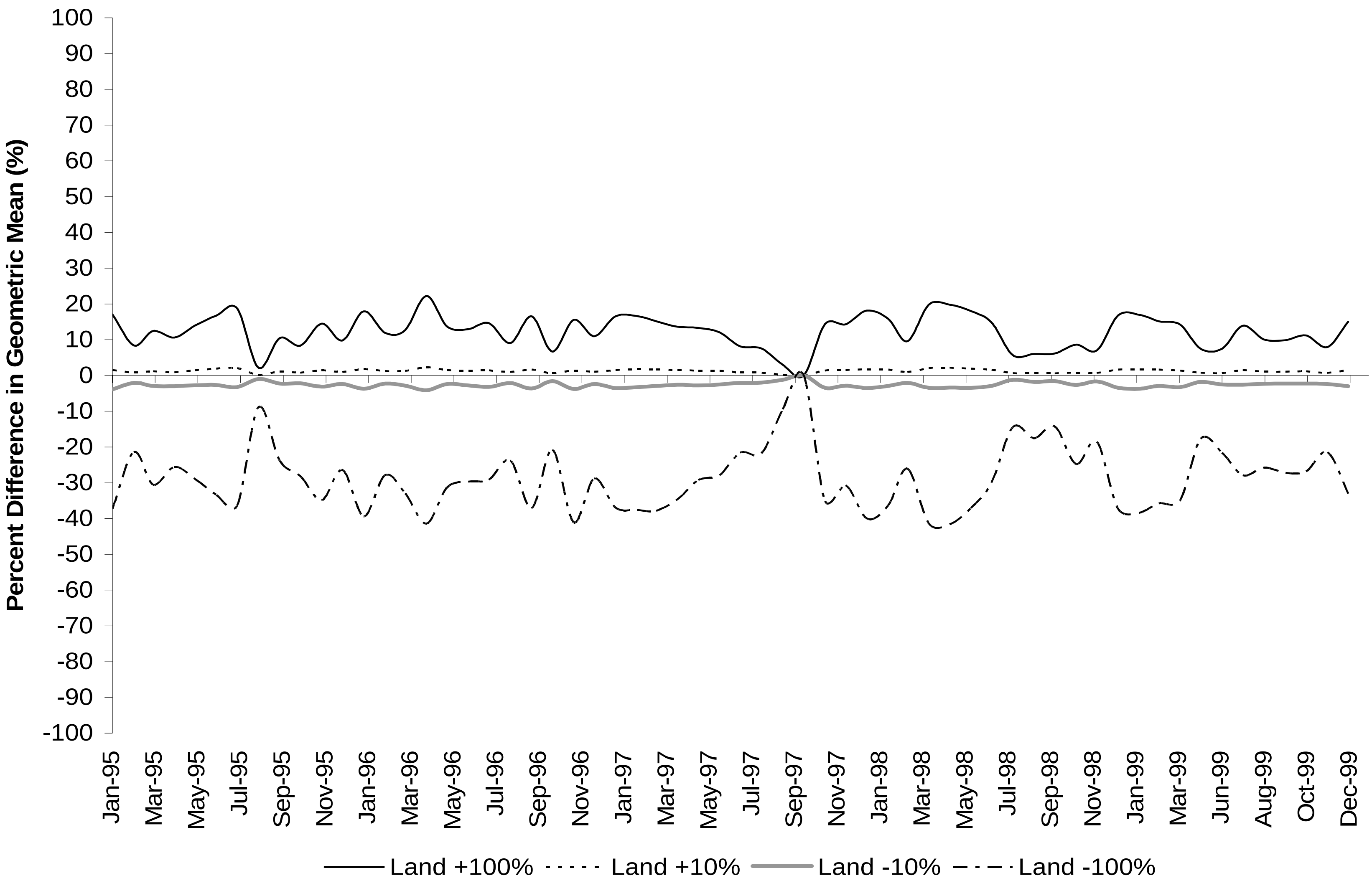

Figure 5.16. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed JR-7) of James River (VAC-H03R-04) watershed, as affected by land-based load changes.

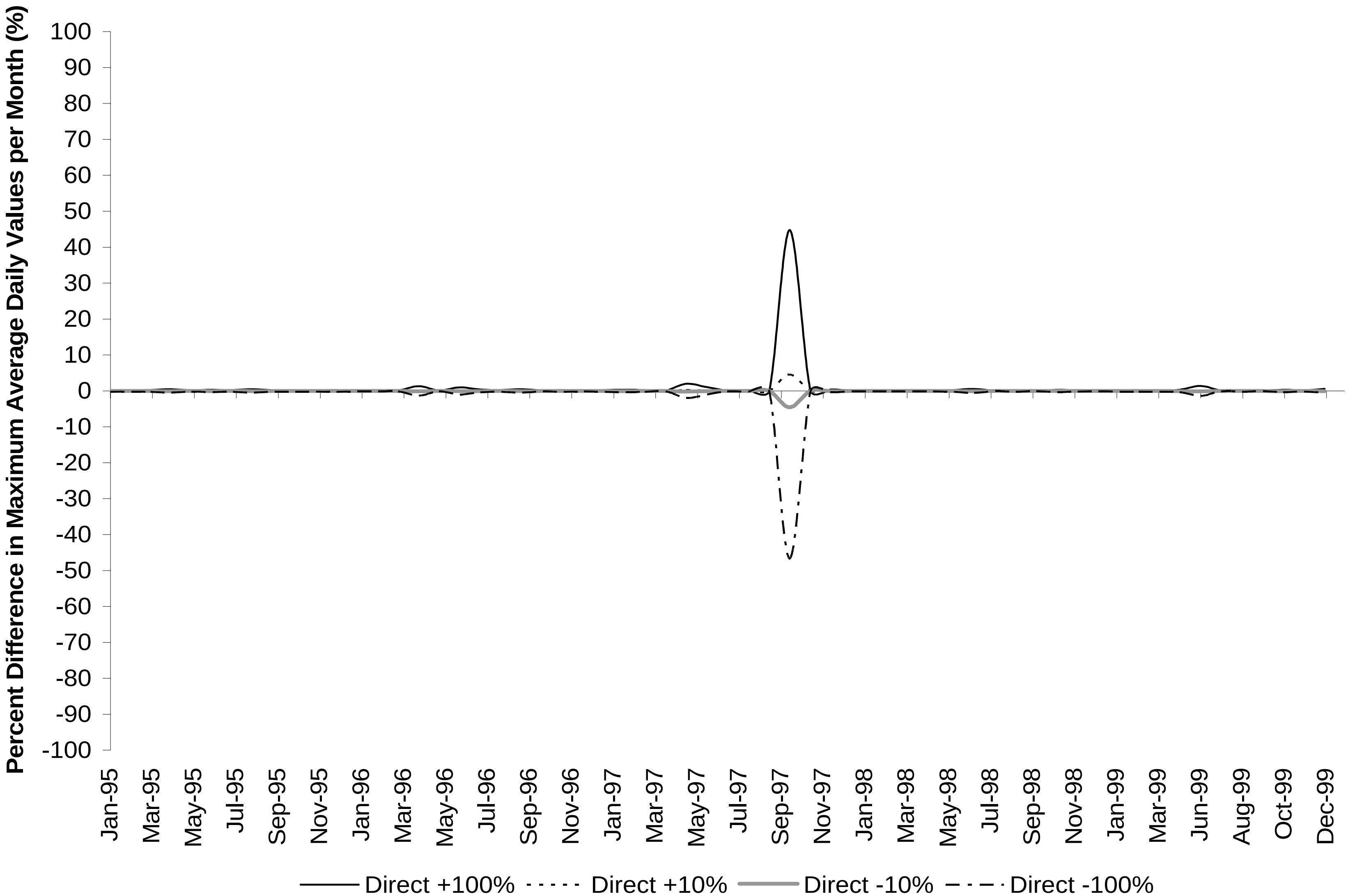

Figure 5.17. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed JR-7) of James River (VAC-H03R-04) watershed, as affected by direct load changes.

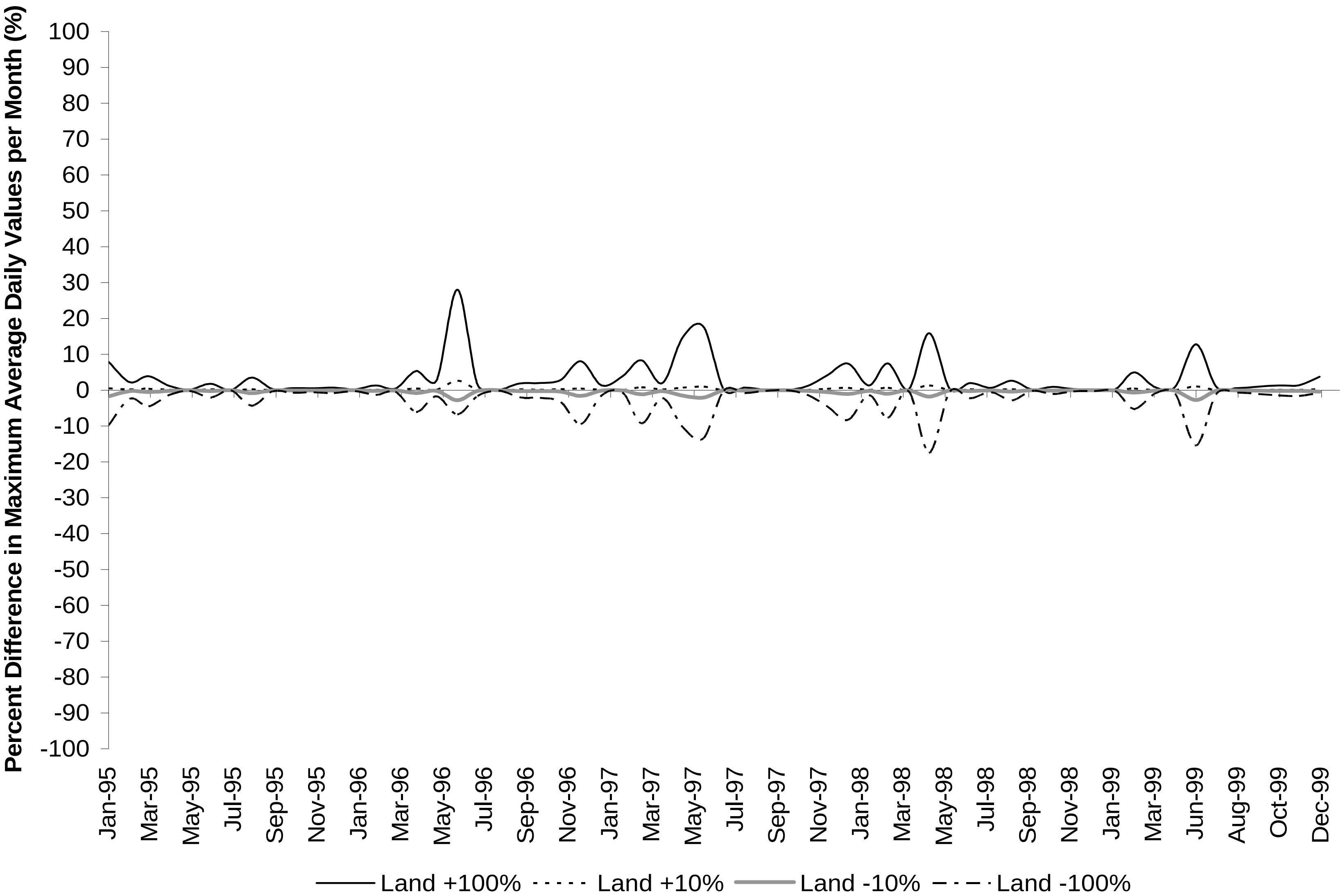

Figure 5.18. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed JR-7) of James River (VAC-H03R-04) watershed, as affected by land-based load changes.

5.2.2 Ivy Creek (VAC-H03R-03)

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 5.19 and 5.20, respectively. Figures 5.21 and 5.22, 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 5.19 with Figure 5.20 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 5.21 to Figure 5.22 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected to a lesser degree by increasing directly deposited loads during lower flow periods.

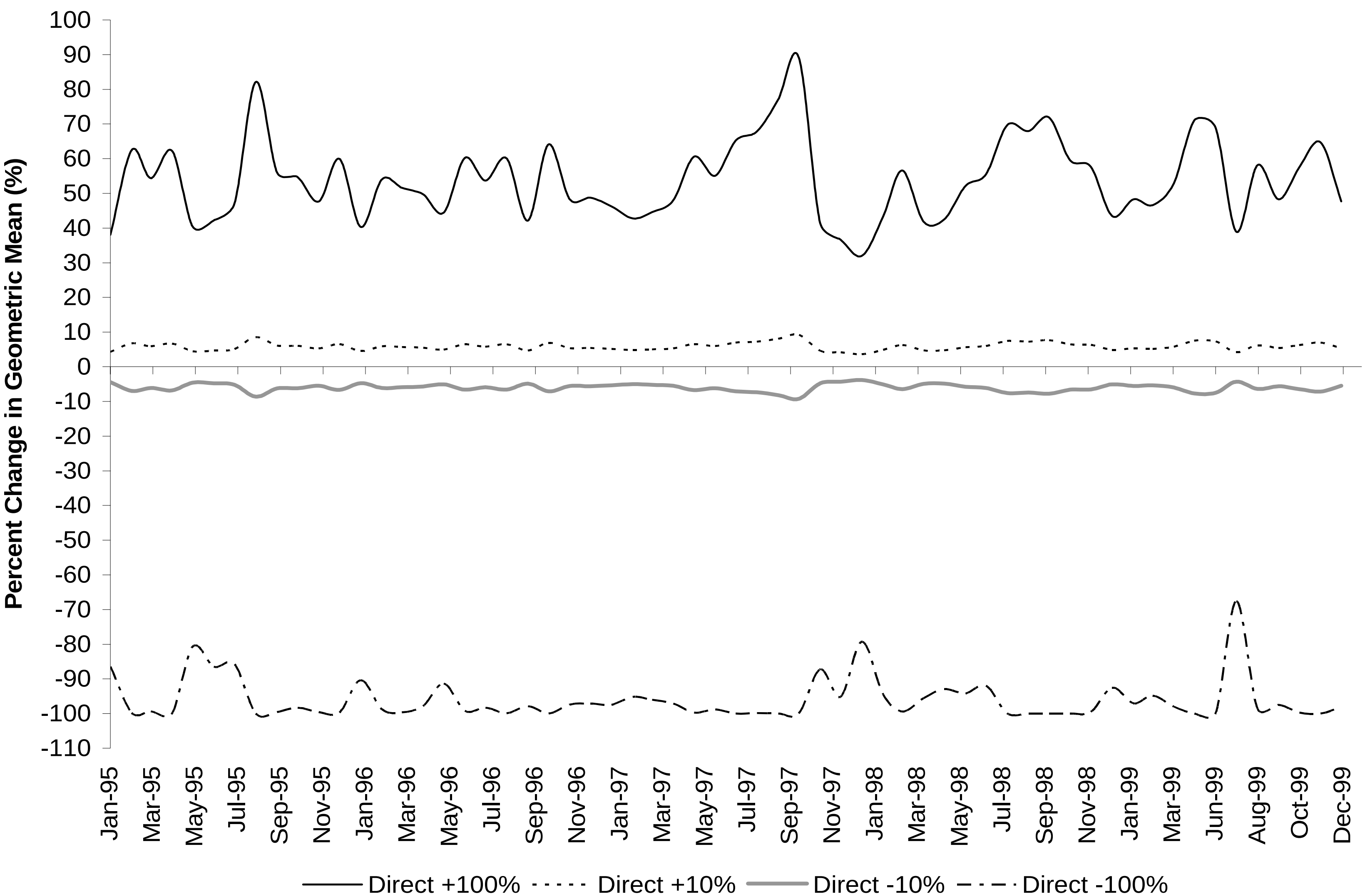

Figure 5.19. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed BW-3) of Ivy Creek (VAC-H03R-03) watershed, as affected by direct load changes.

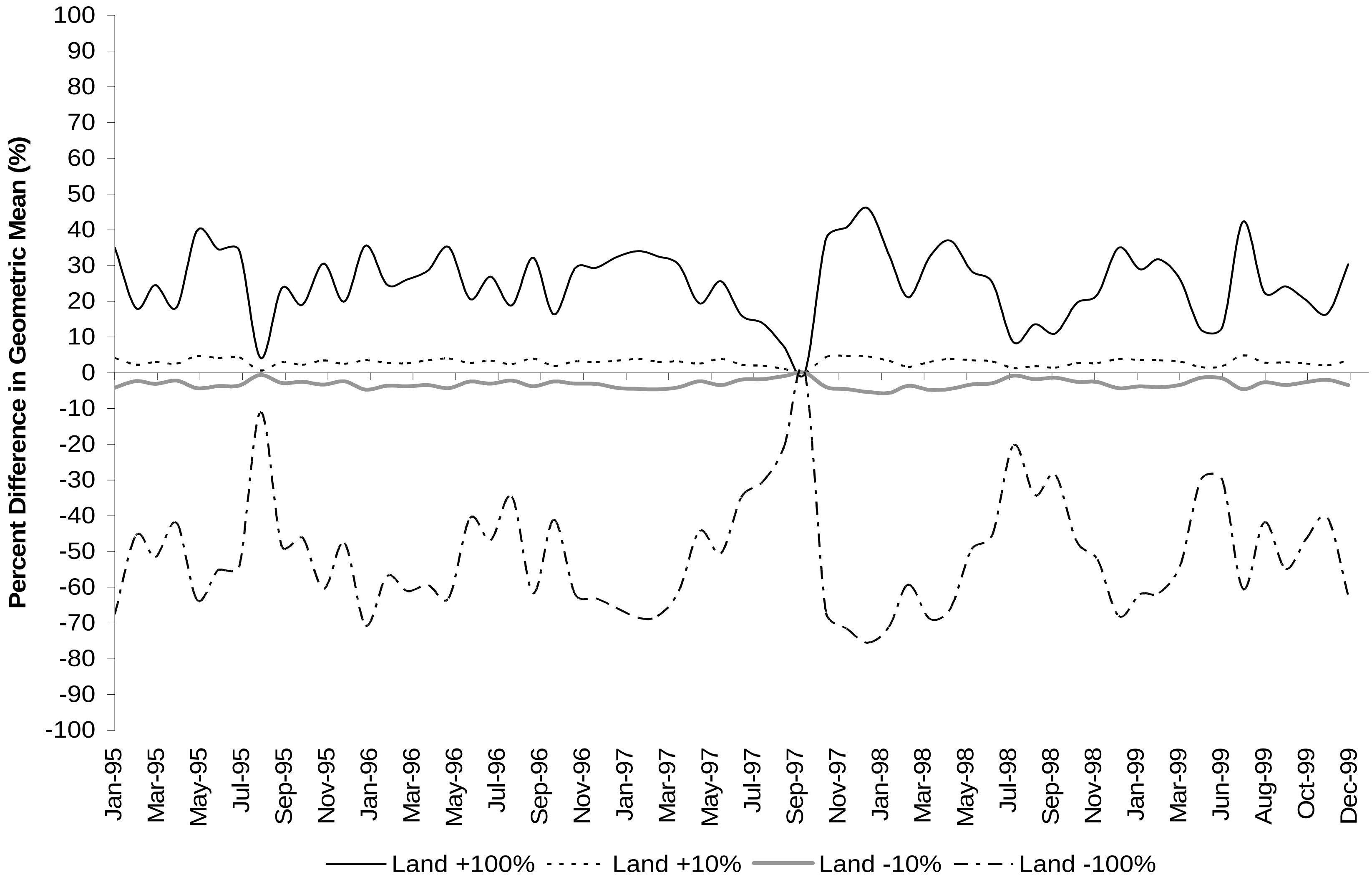

Figure 5.20. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed BW-3) of Ivy Creek (VAC-H03R-03) watershed, as affected by land-based load changes.

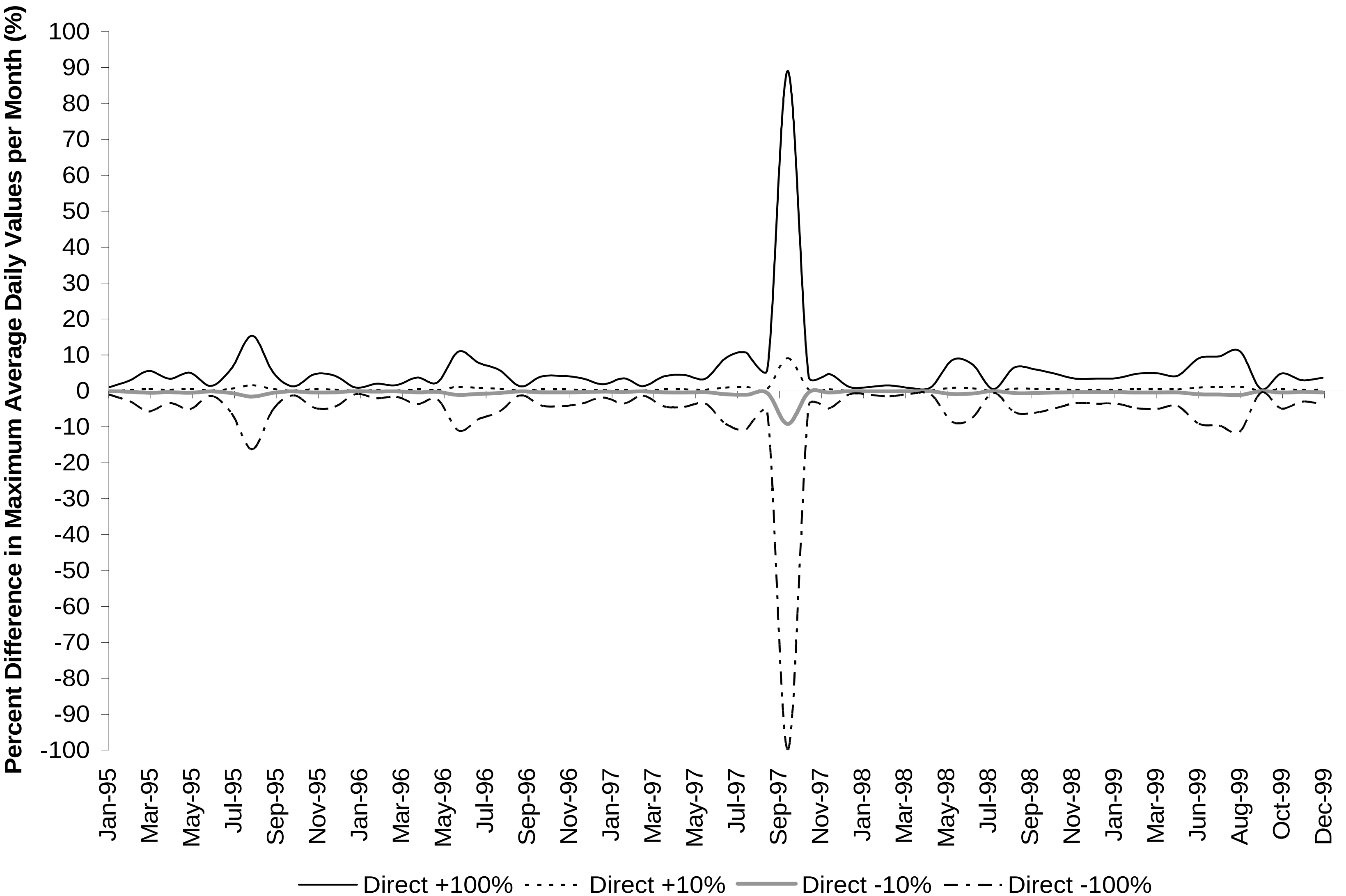

Figure 5.21. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed BW-3) of Ivy Creek (VAC-H03R-03) watershed, as affected by direct load changes.

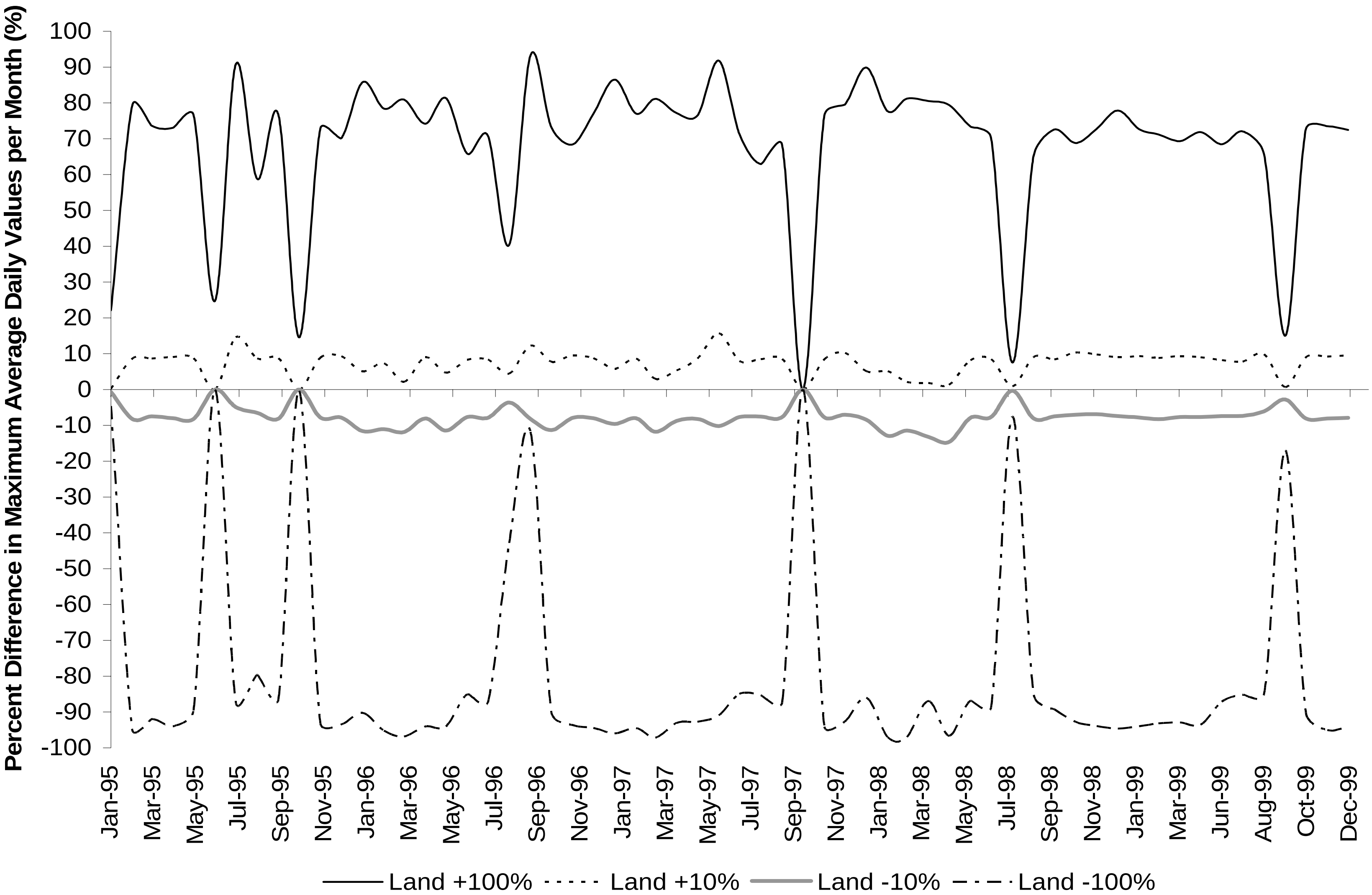

Figure 5.22. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed BW-3) of Ivy Creek (VAC-H03R-03) watershed, as affected by land-based load changes.

5.2.3 Fishing Creek (VAC-H03R-02)

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 5.23 and 5.24, respectively. Figures 5.25 and 5.26, 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 5.23 with Figure 5.24 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 5.25 to Figure 5.26 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected to a lesser degree by increasing directly deposited loads during lower flow periods.

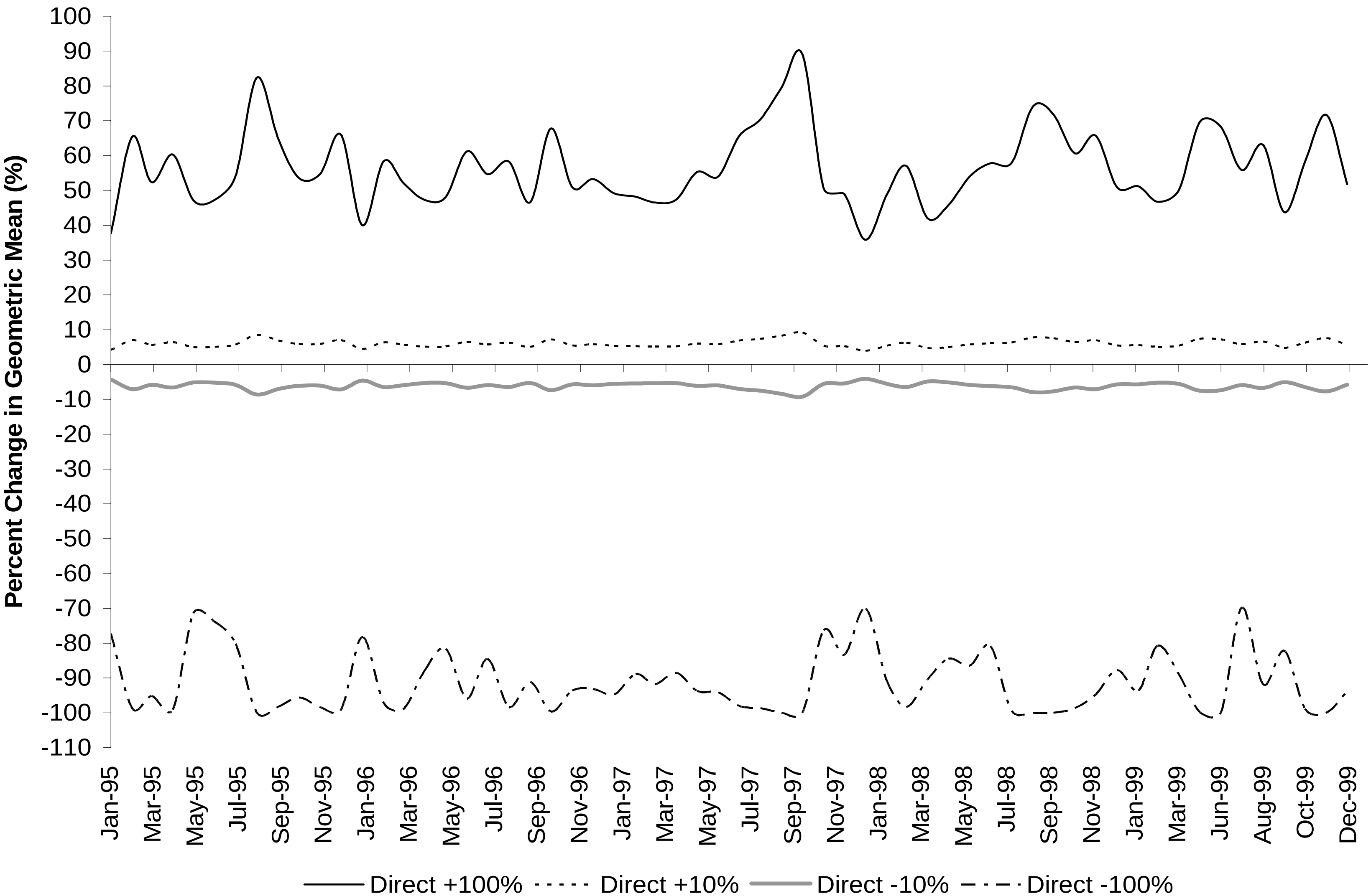

Figure 5.23. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed FG-1) of Fishing Creek (VAC-H03R-02) watershed, as affected by direct load changes.

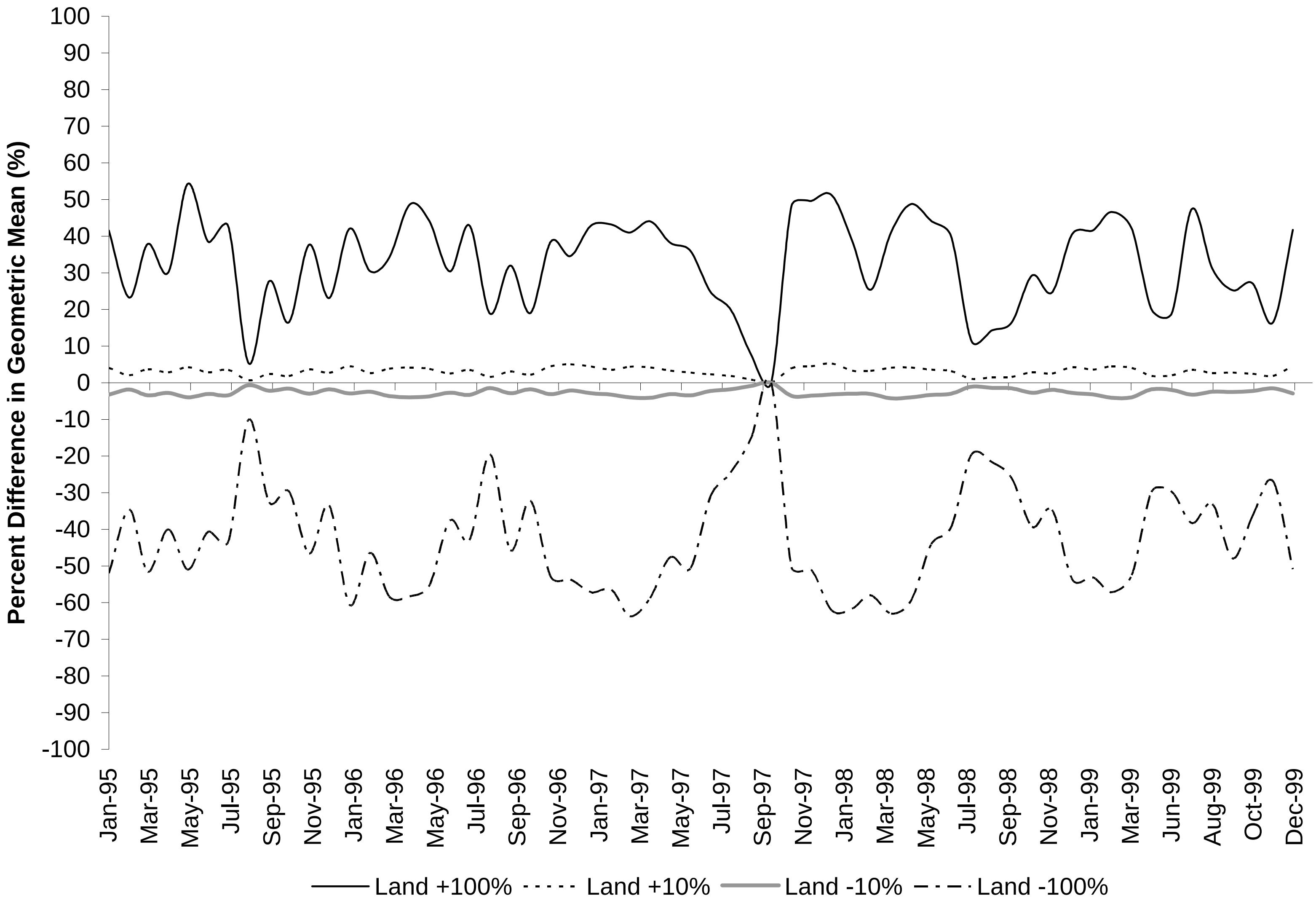

Figure 5.24. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed FG-1) of Fishing Creek (VAC-H03R-02) watershed, as affected by land-based load changes.

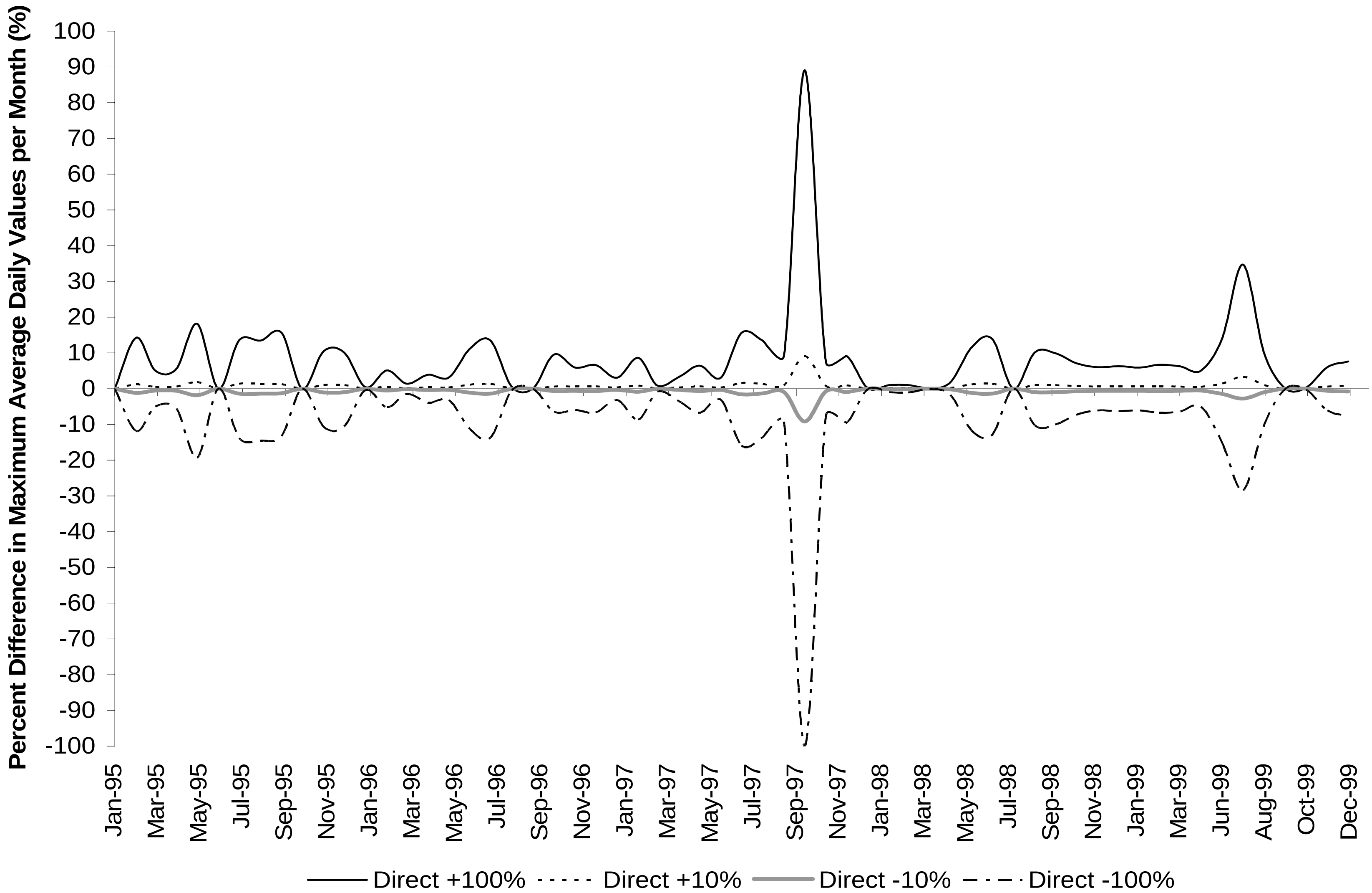

Figure 5.25. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed FG-1) of Fishing Creek (VAC-H03R-02) watershed, as affected by direct load changes.

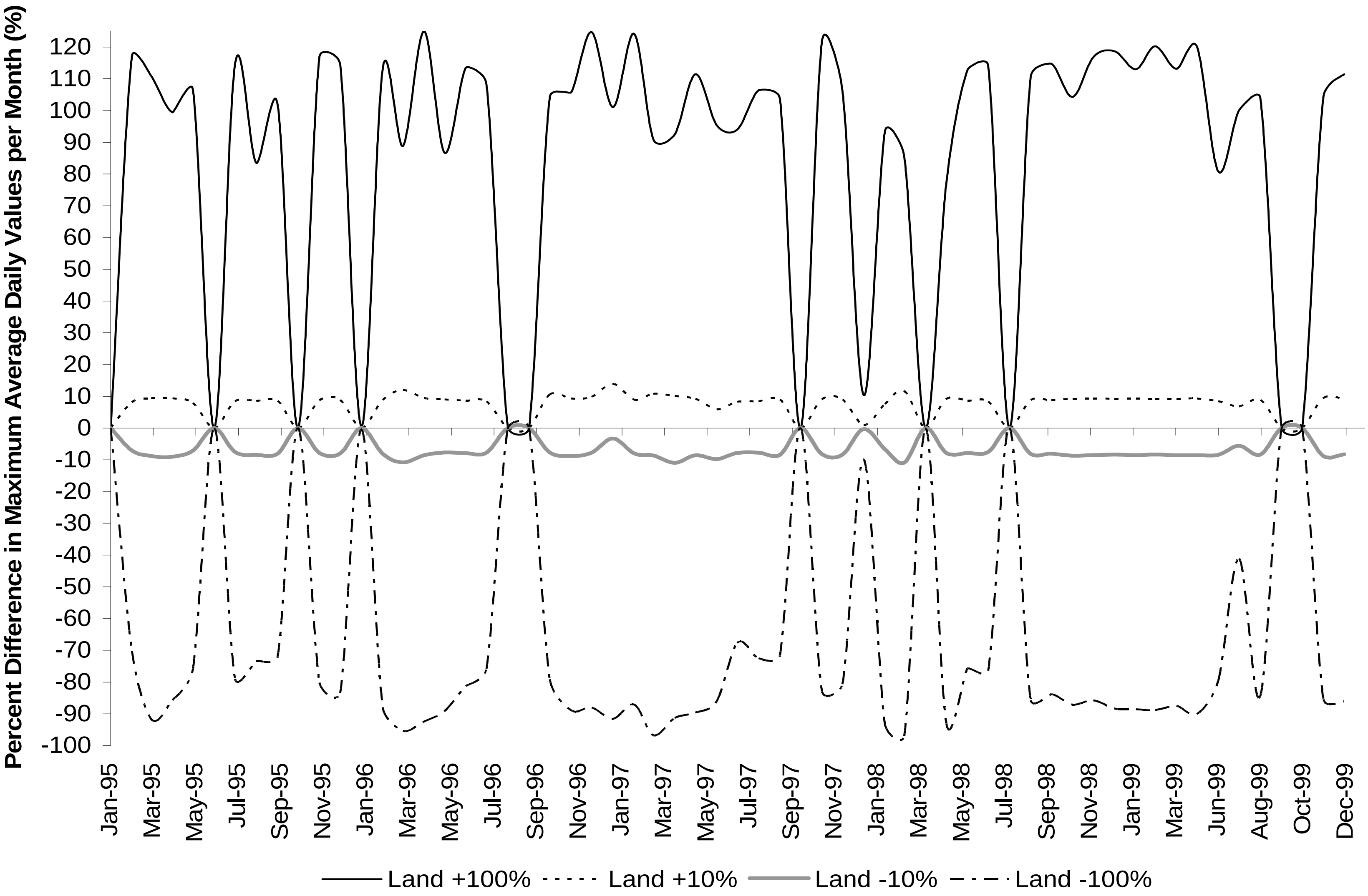

Figure 5.26. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed FG-1) of Fishing Creek (VAC-H03R-02) watershed, as affected by land-based load changes.

5.2.4 Blackwater Creek (VAC-H03R-01)

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 5.27 and 5.28, respectively. Figures 5.29 and 5.30, 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 5.27 with Figure 5.28 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 5.29 to Figure 5.30 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.

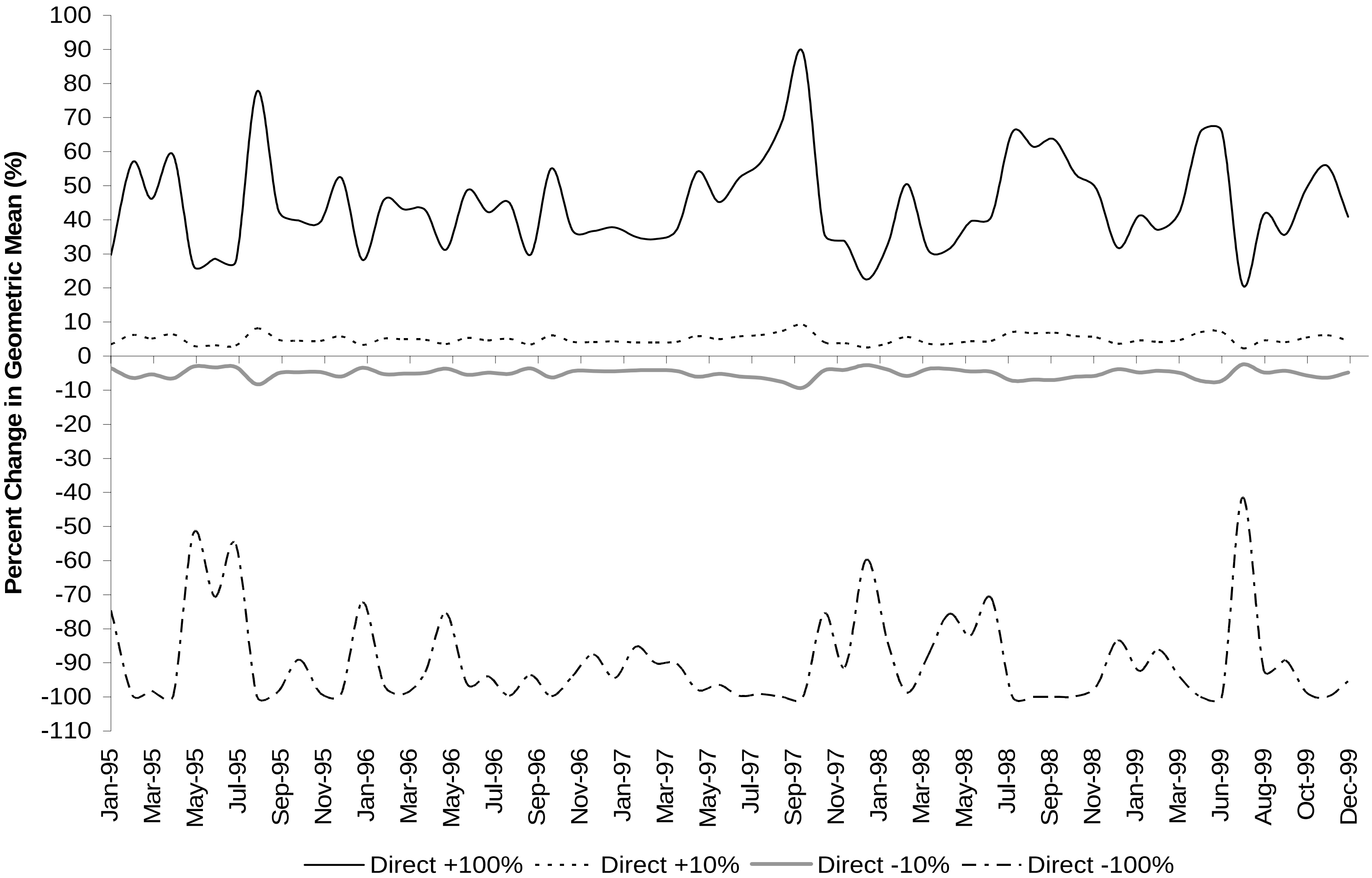

Figure 5.27. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed BW-9) of Blackwater Creek (VAC-H03R-01) watershed, as affected by direct load changes.

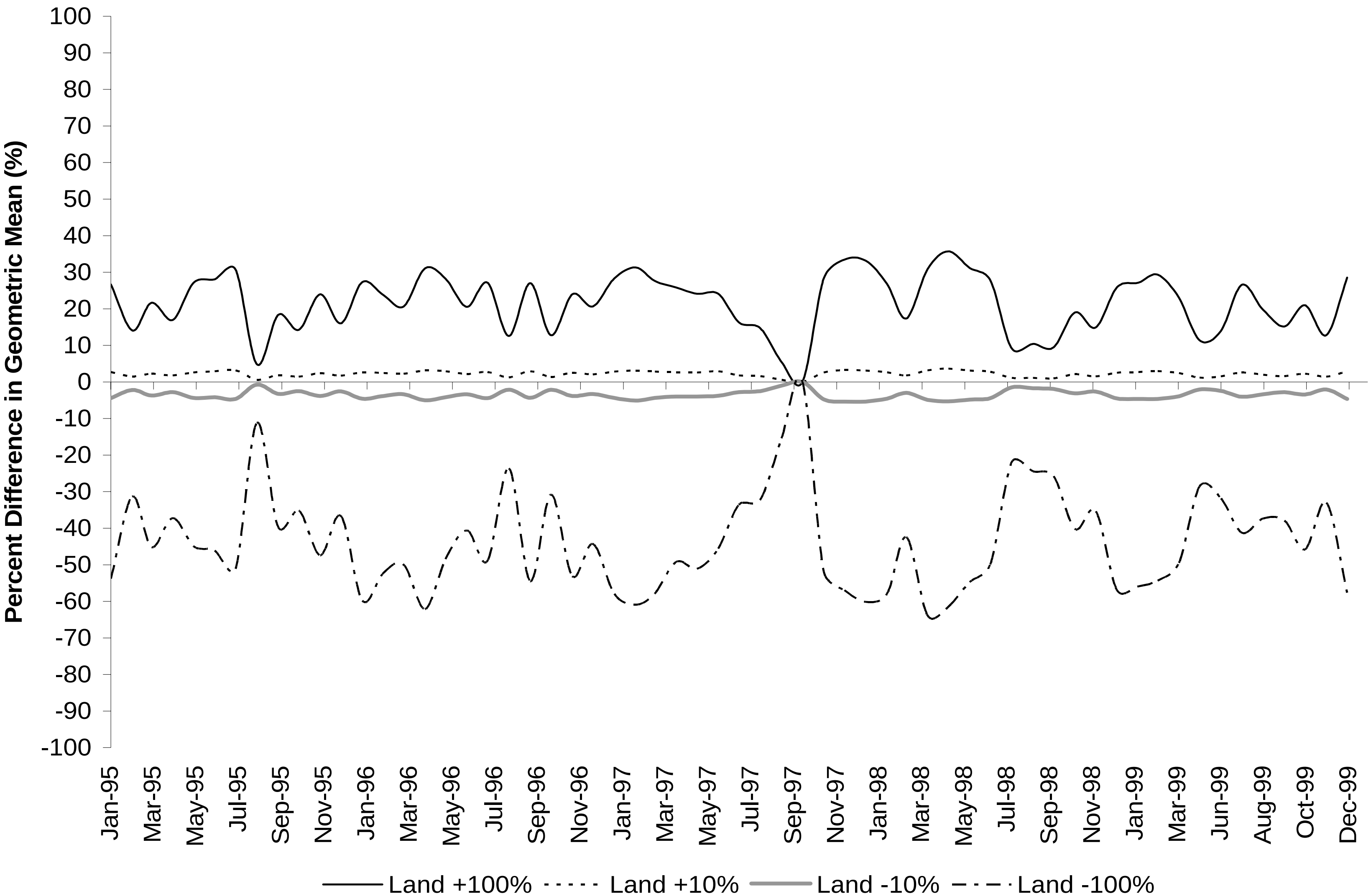

Figure 5.28. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed BW-9) of Blackwater Creek (VAC-H03R-01) watershed, as affected by land-based load changes.

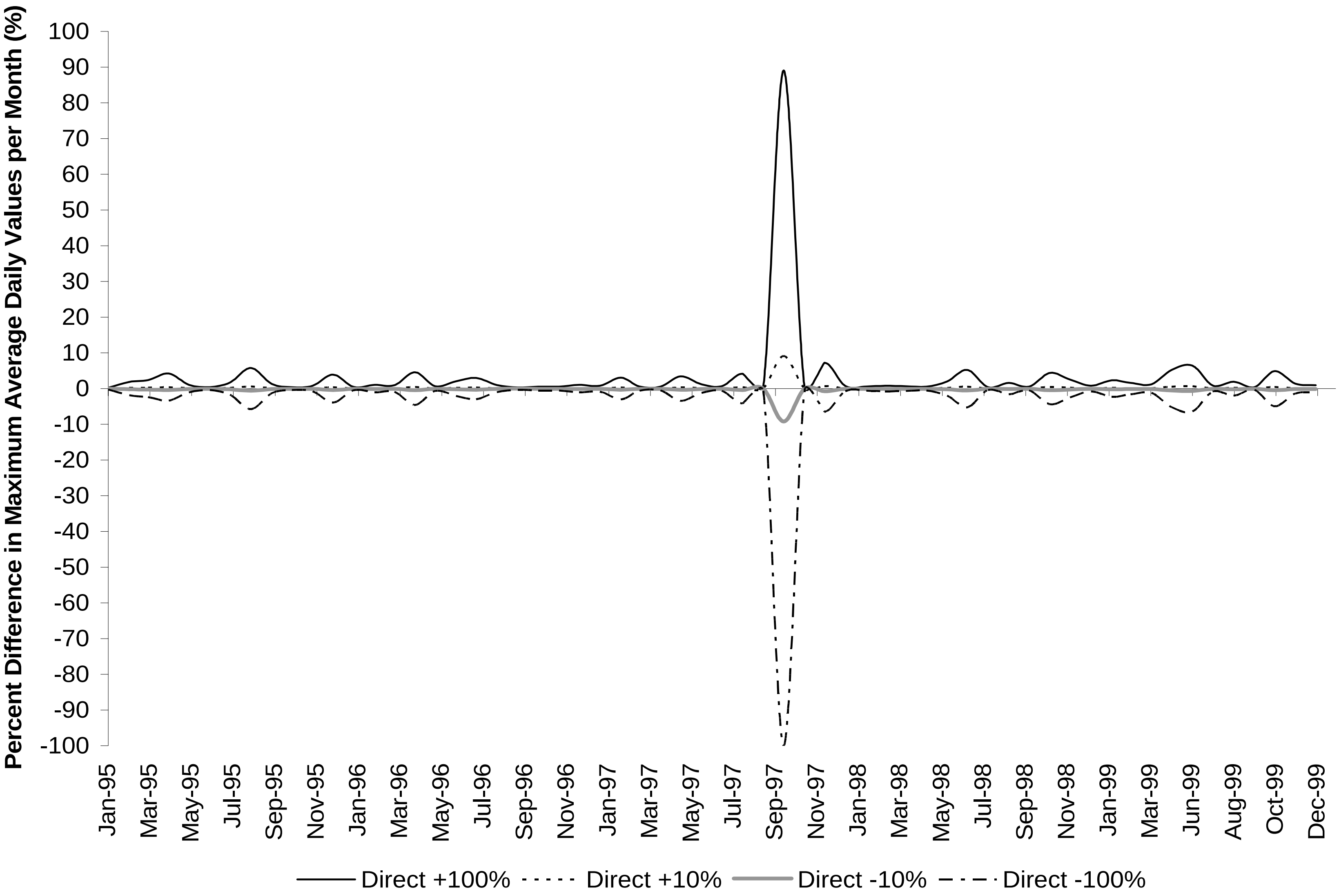

Figure 5.29. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed BW-9) of Blackwater Creek (VAC-H03R-01) watershed, as affected by direct load changes.

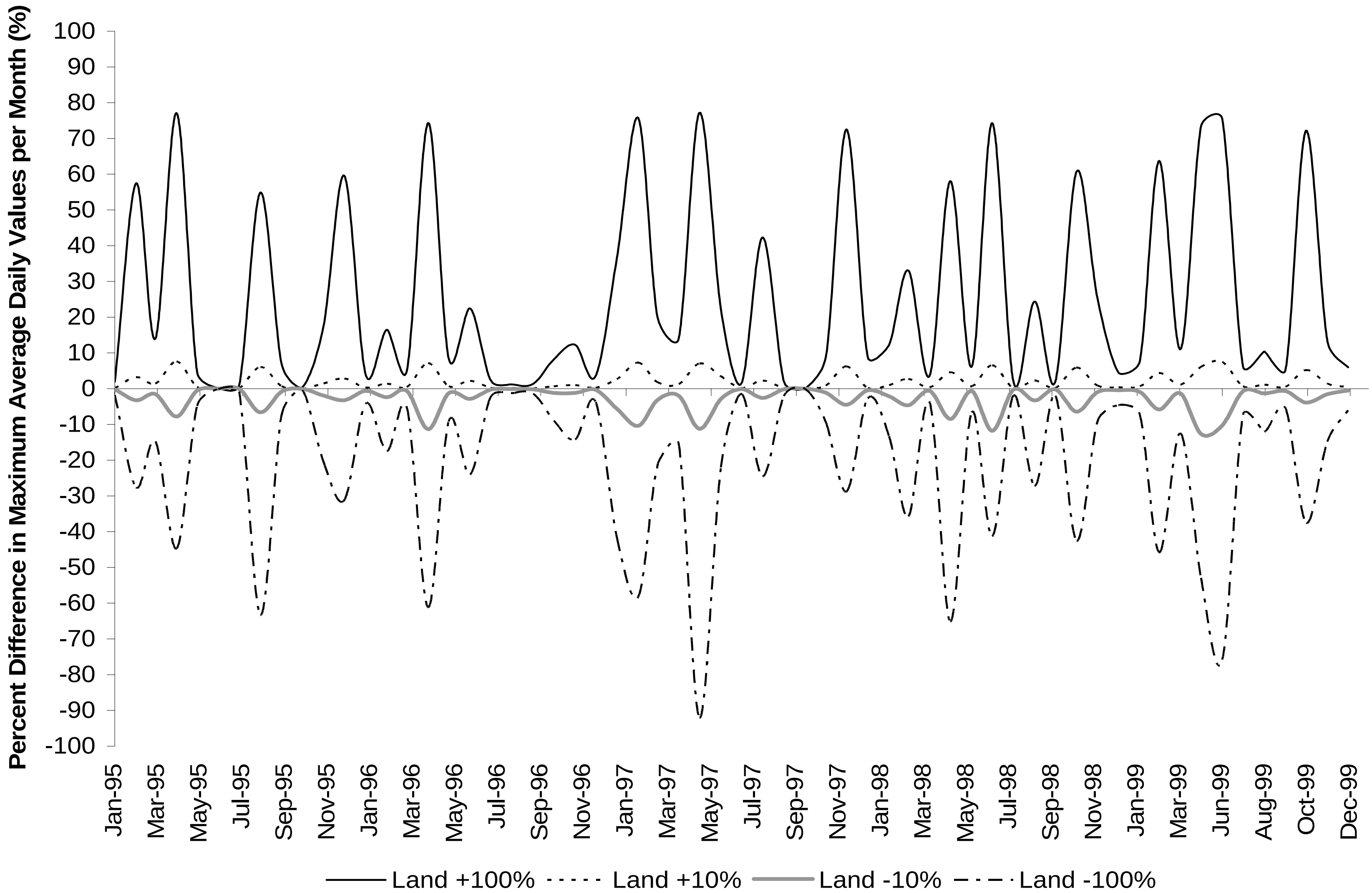

Figure 5.30. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed BW-9) of Blackwater Creek (VAC-H03R-01) watershed, as affected by land-based load changes.

5.2.5 Tomahawk Creek (VAC-H03R-07)

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 5.31 and 5.32, respectively. Figures 5.33 and 5.34, 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 5.31 with Figure 5.32 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations slightly more significantly than increasing land-based loads. Comparing Figure 5.33 to Figure 5.34 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.

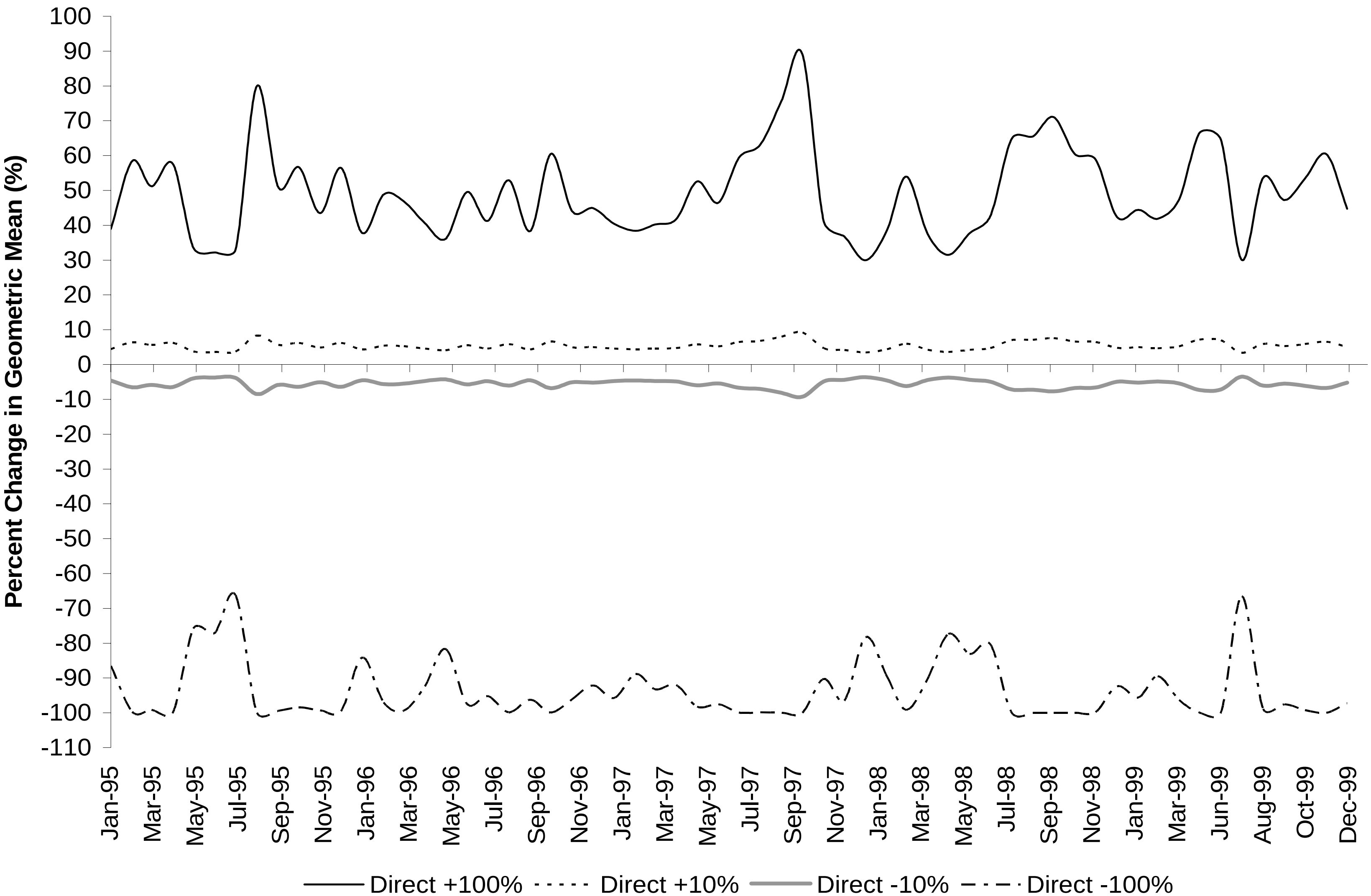

Figure 5.31. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed BW-7) of Tomahawk Creek (VAC-H03R-07) watershed, as affected by direct load changes.

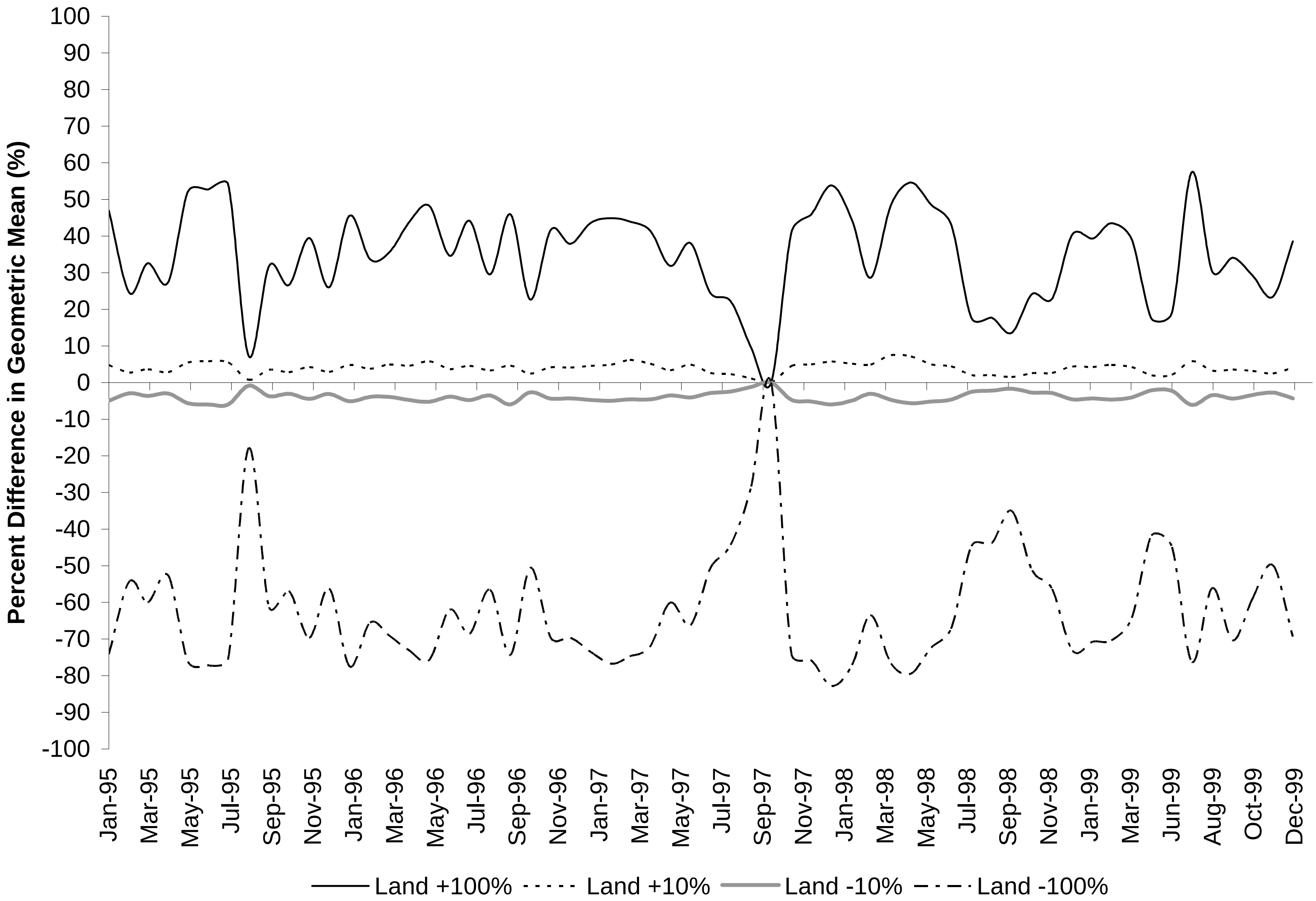

Figure 5.32. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed BW-7) of Tomahawk Creek (VAC-H03R-07) watershed, as affected by land-based load changes.

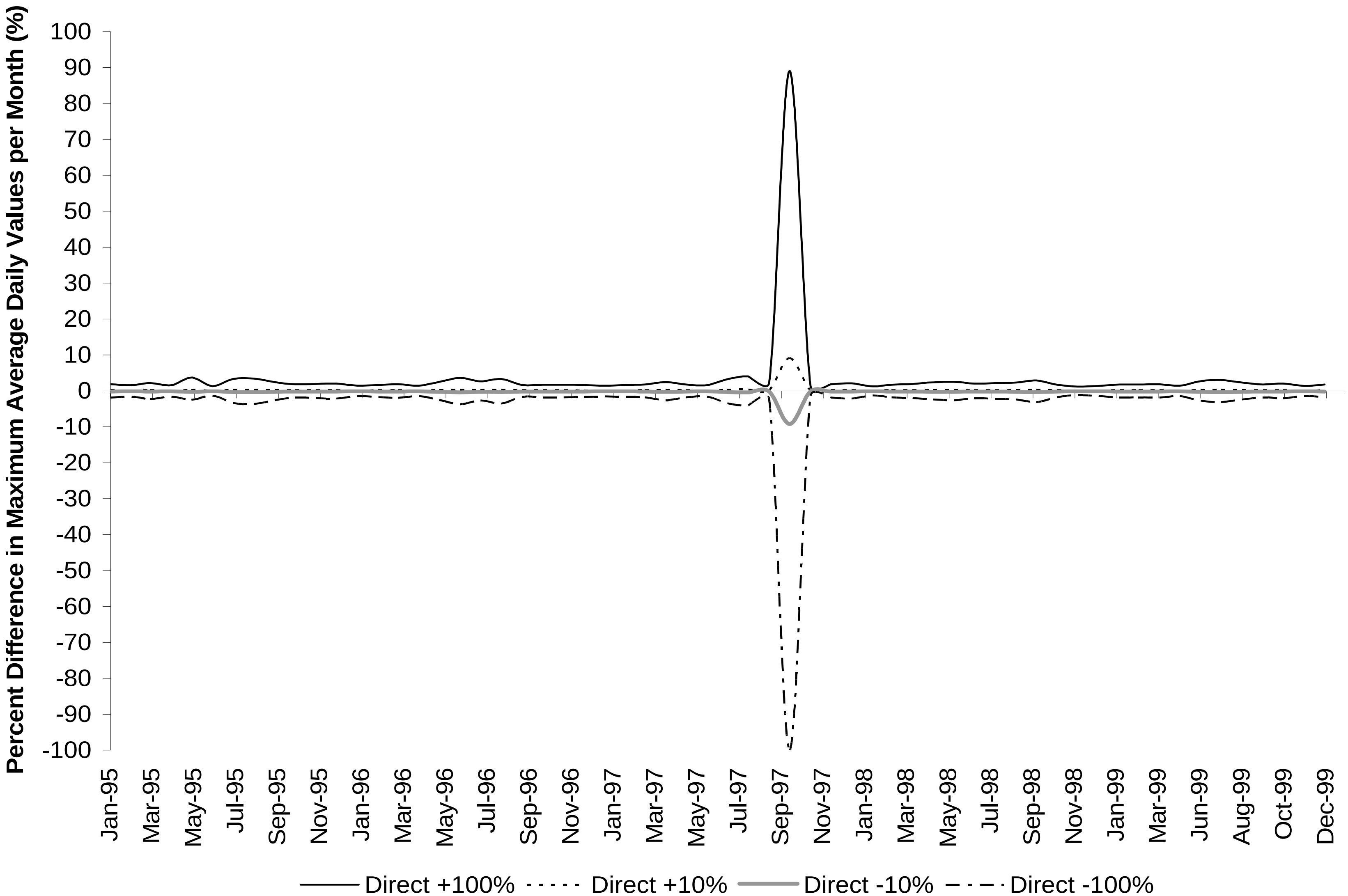

Figure 5.33. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed BW-7) of Tomahawk Creek (VAC-H03R-07) watershed, as affected by direct load changes.

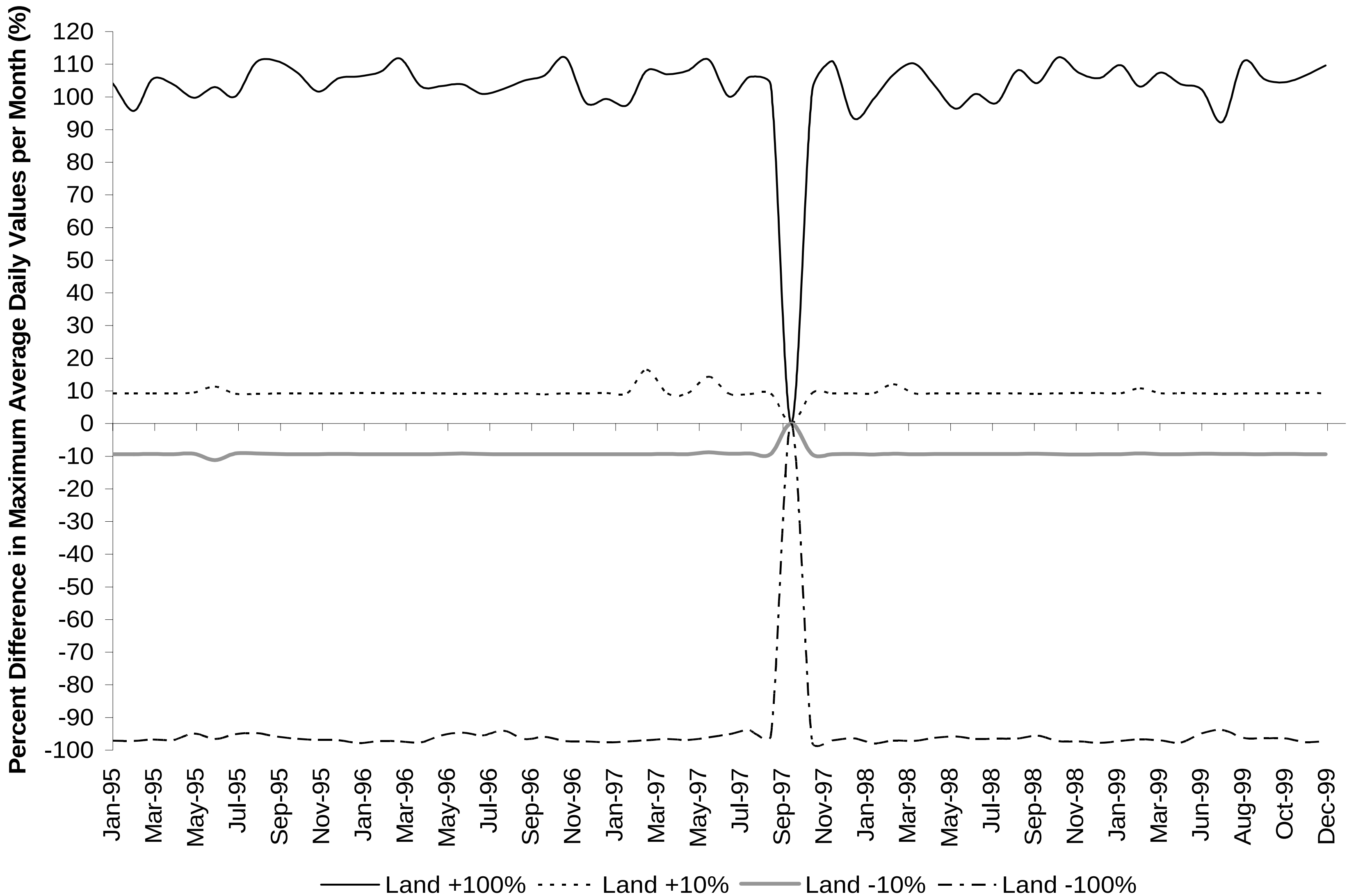

Figure 5.34. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed BW-7) of Tomahawk Creek (VAC-H03R-07) watershed, as affected by land-based load changes.

5.2.6 Burton Creek (VAC-H03R-05)

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 5.35 and 5.36, respectively. Figures 5.37 and 5.38, 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 5.35 with Figure 5.36 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations slightly more significantly than increasing land-based loads. Comparing Figure 5.37 to Figure 5.38 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. Little effect was noted other than the very dry period of September 1997.

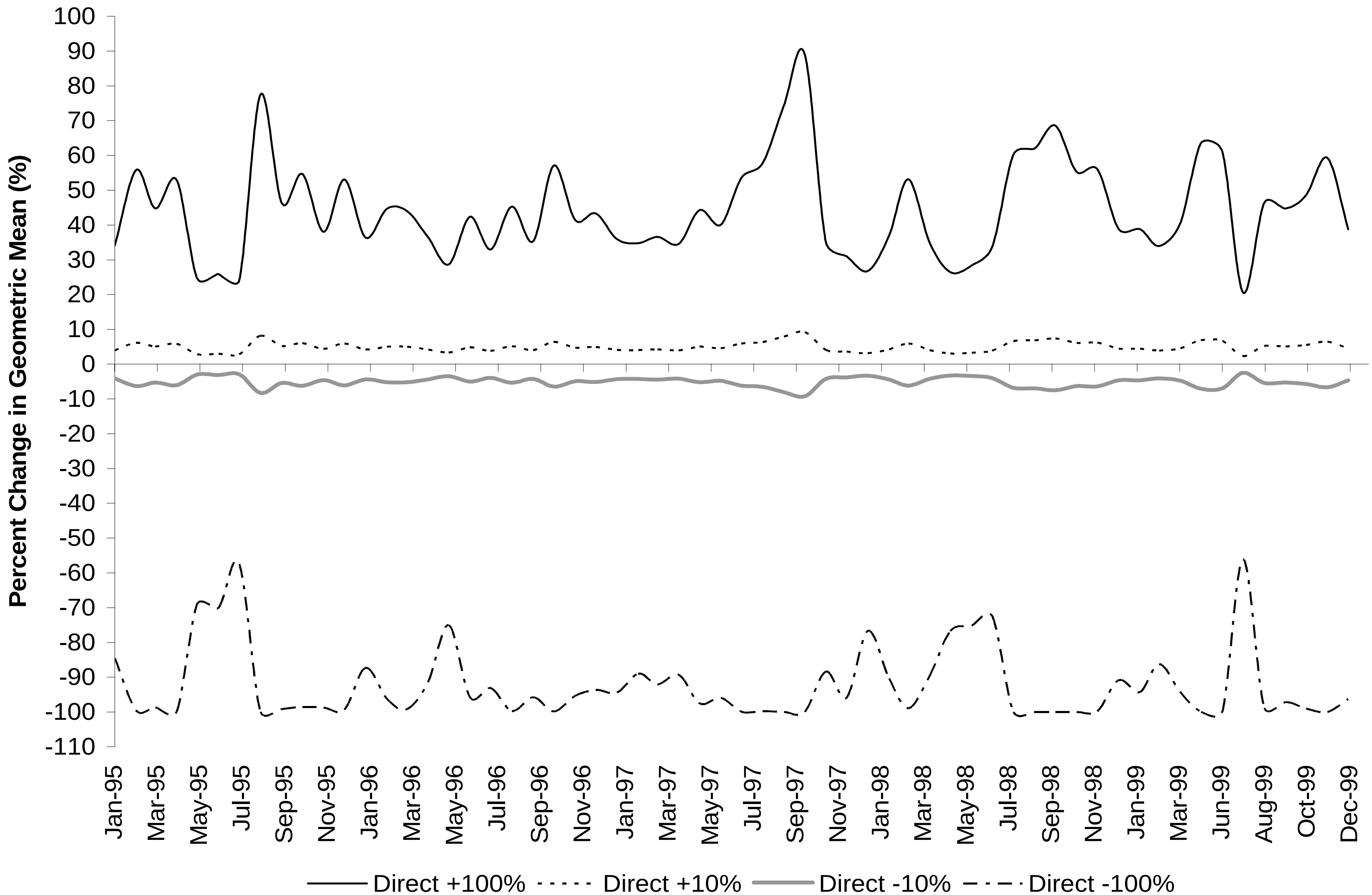

Figure 5.35. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed BW-6) of Burton Creek (VAC-H03R-05) watershed, as affected by direct load changes.

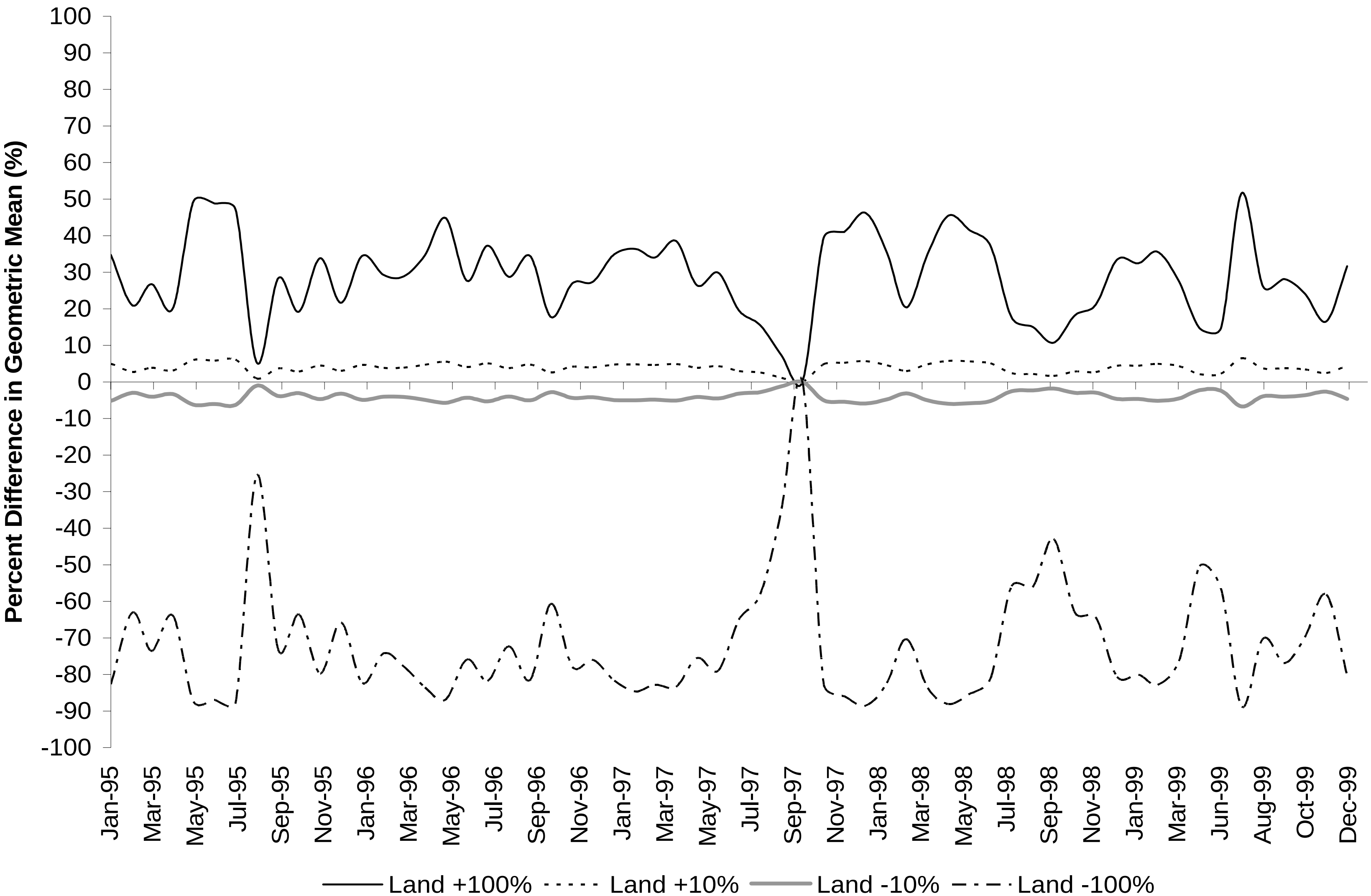

Figure 5.36. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed BW-6) of Burton Creek (VAC-H03R-05) watershed, as affected by land-based load changes.

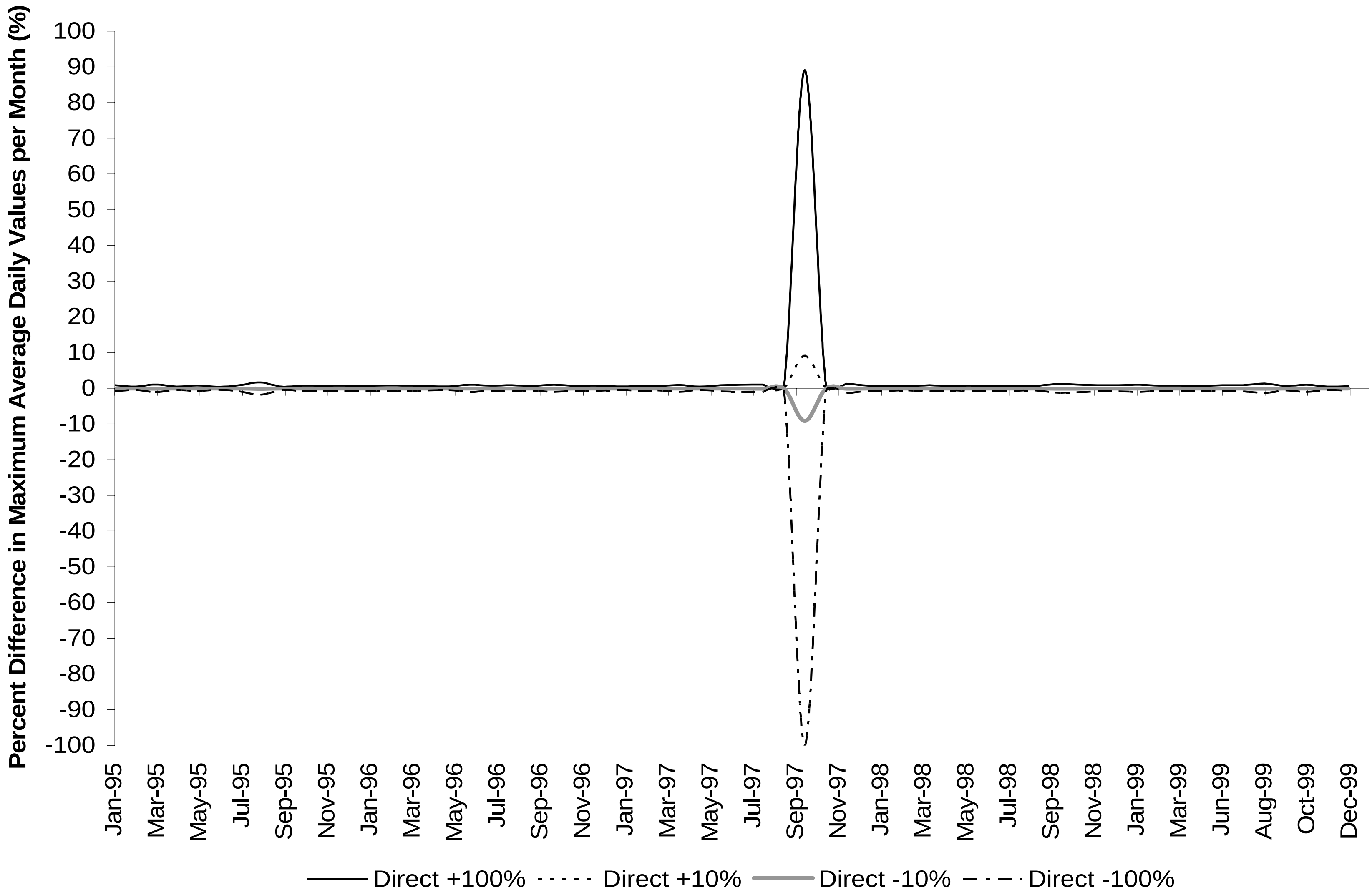

Figure 5.37. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed BW-6) of Burton Creek (VAC-H03R-05) watershed, as affected by direct load changes.

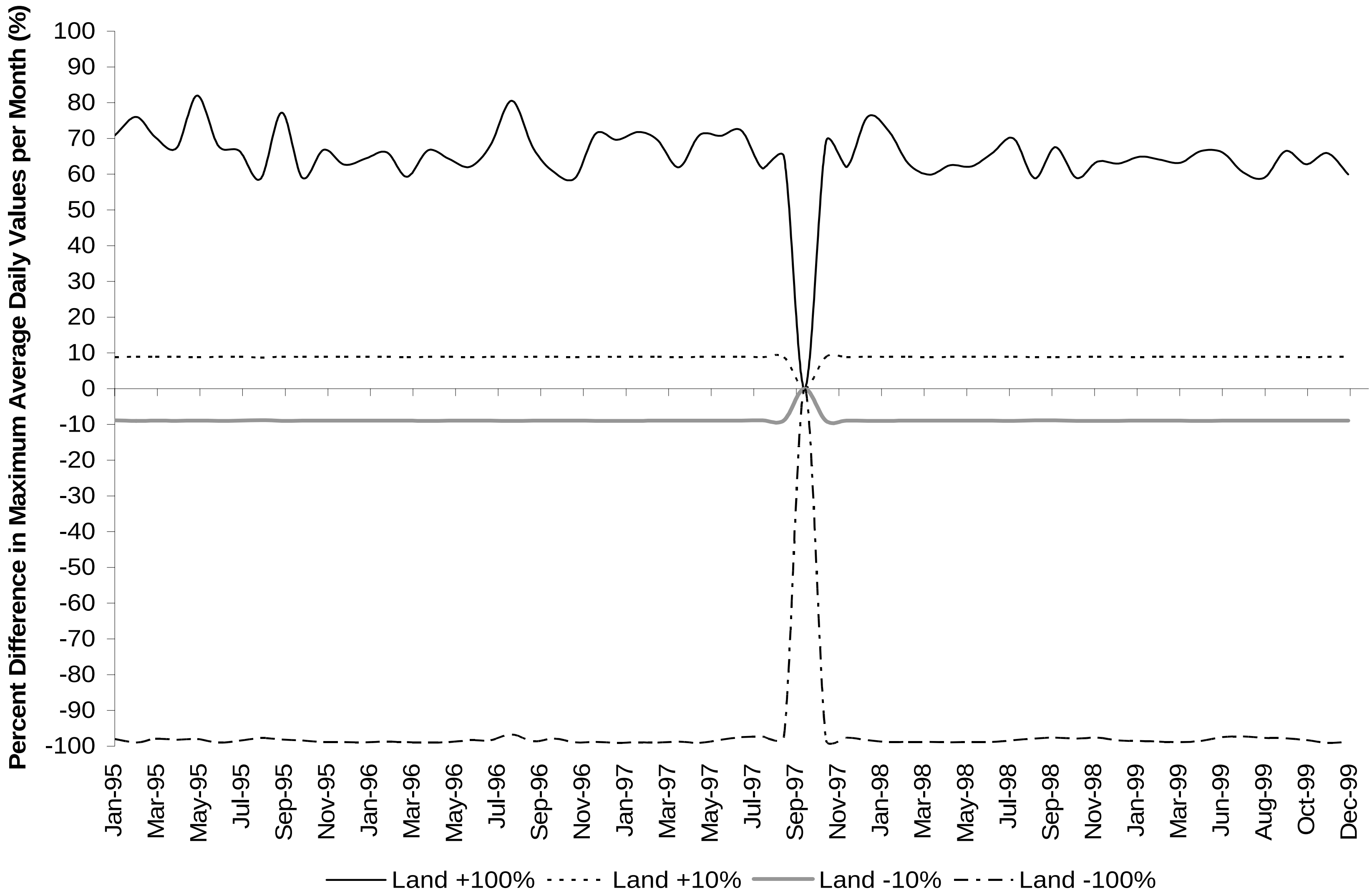

Figure 5.38. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed BW-6) of Burton Creek (VAC-H03R-05) watershed, as affected by land-based load changes.

5.2.7 Judith Creek (VAC-H03R-06)

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 5.39 and 5.40, respectively. Figures 5.41 and 5.42, 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 5.39 with Figure 5.40 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 5.41 to Figure 5.42 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.

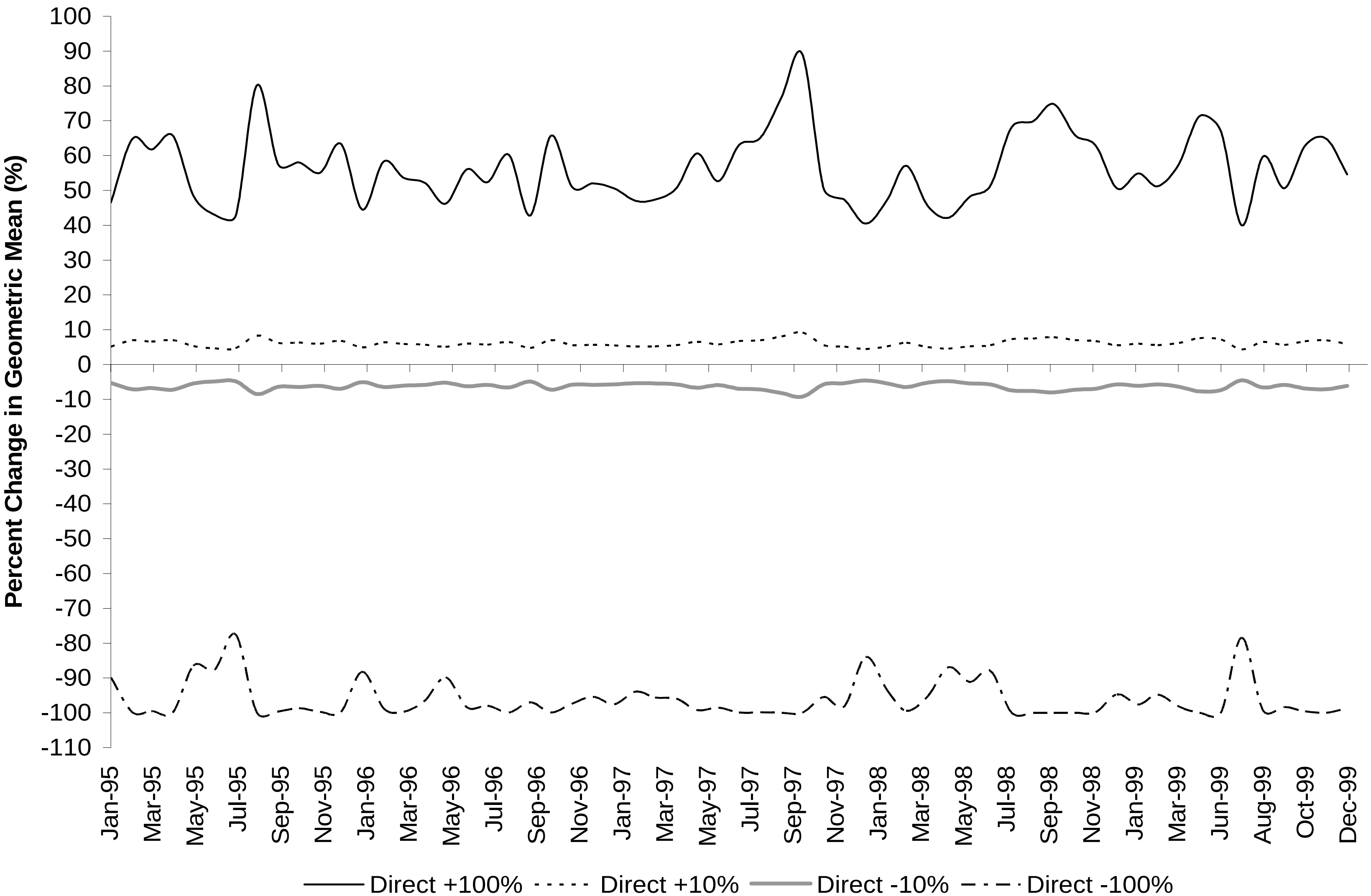

Figure 5.39. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed JC-2) of Judith Creek (VAC-H03R-06) watershed, as affected by direct load changes.

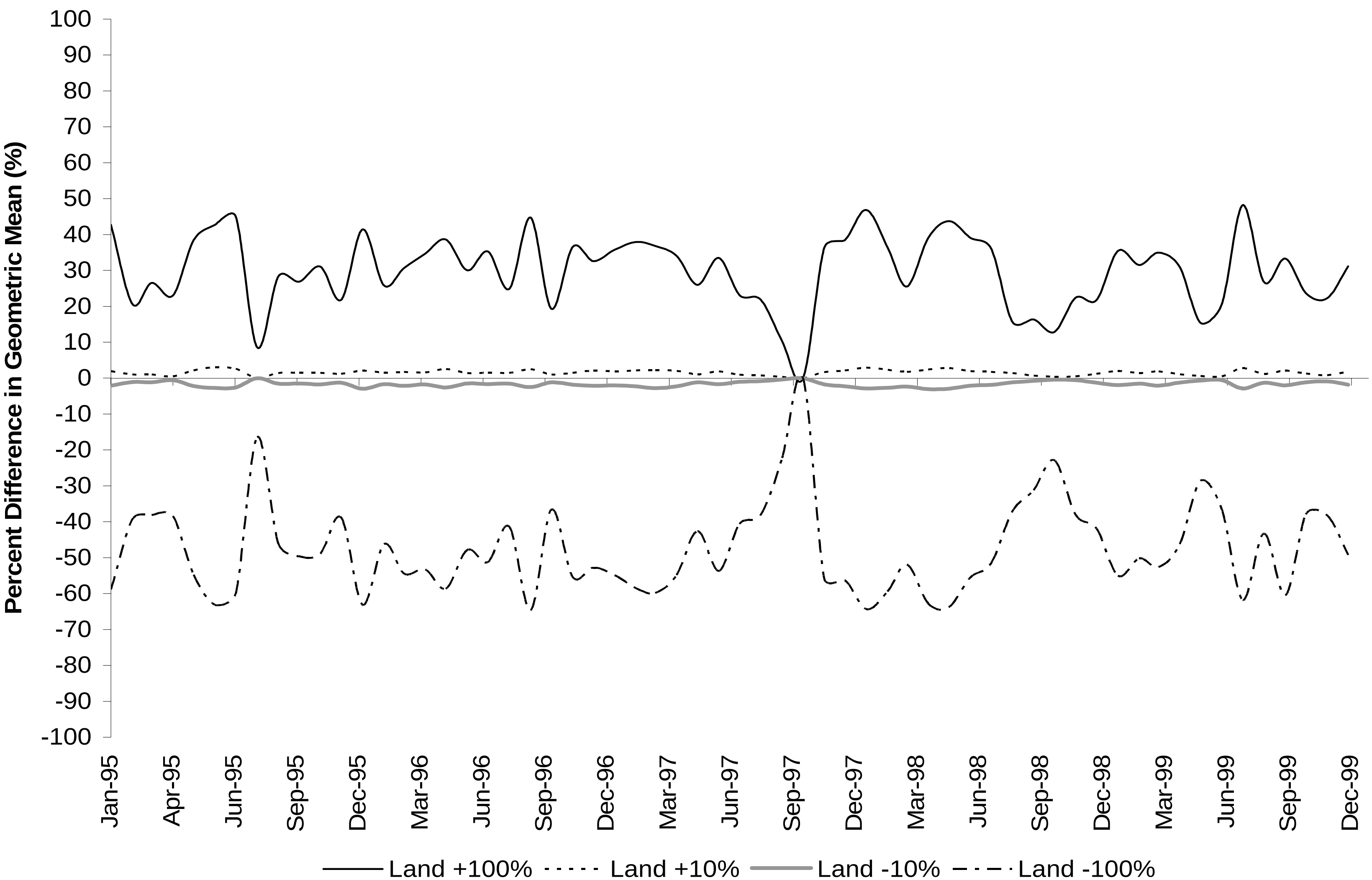

Figure 5.40. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed JC-2) of Judith Creek (VAC-H03R-06) watershed, as affected by land-based load changes.

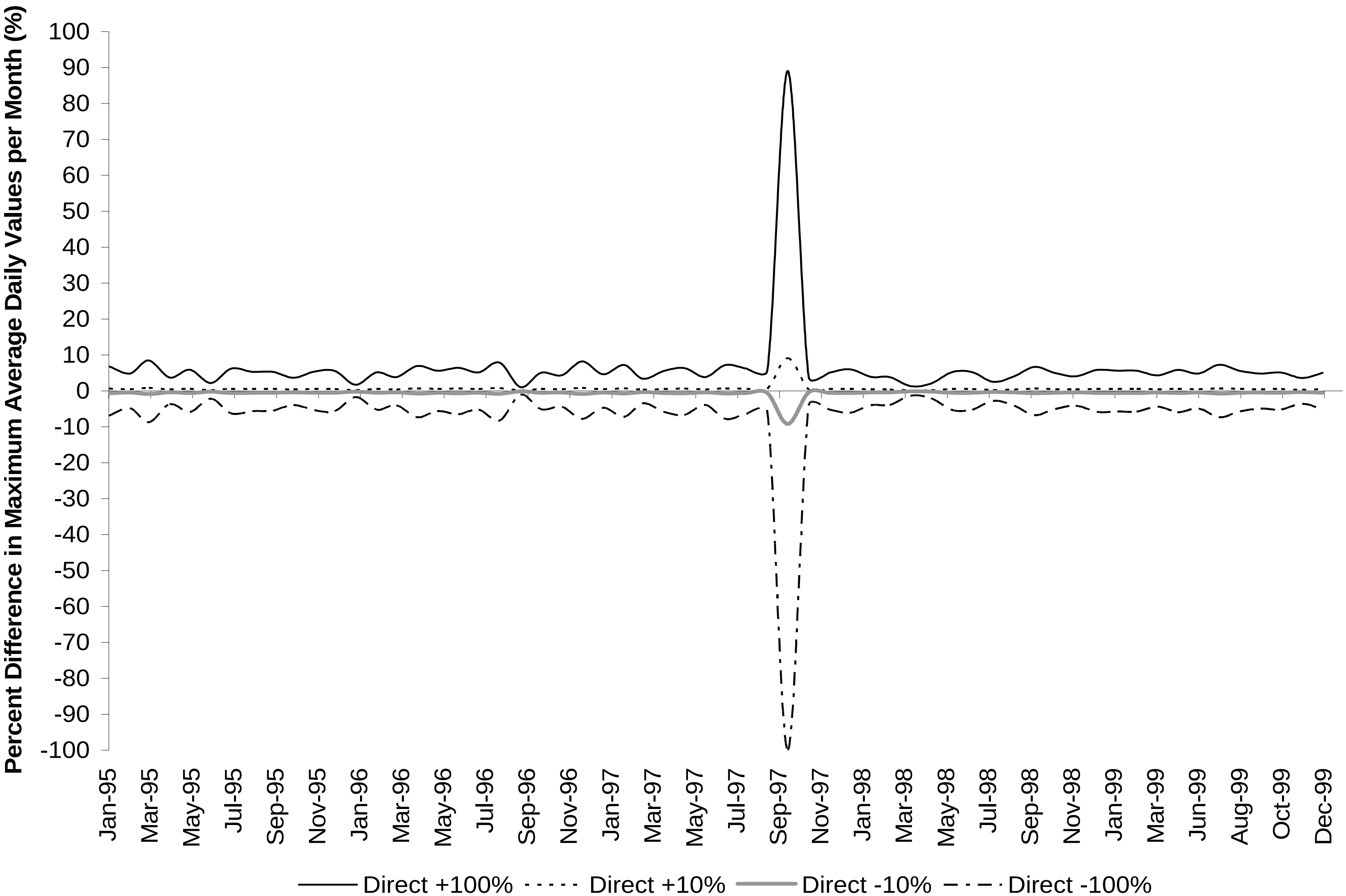

Figure 5.41. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed JC-2) of Judith Creek (VAC-H03R-06) watershed, as affected by direct load changes.

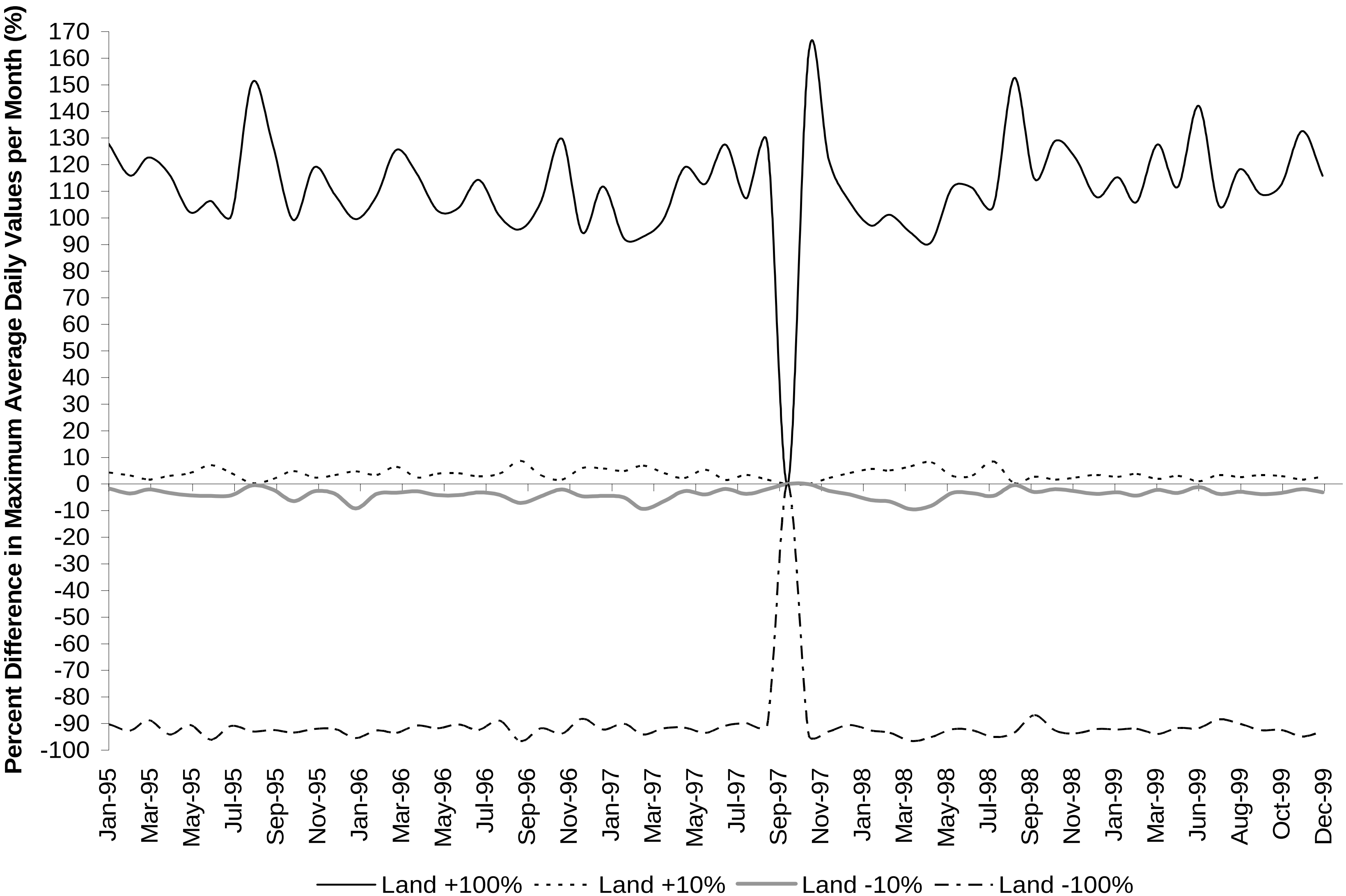

Figure 5.42. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed JC-2) of Judith Creek (VAC-H03R-06) watershed, as affected by land-based load changes.

5.3 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 1, 1995 through December 31, 1999. 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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) impairments to meet bacteria water quality standards. As each impairment met bacteria standards, the loads that allowed it to do so were adopted for those segments for subsequent runs. Due to similarities in the seven impairments, the final allocation scenarios for the seven segments were similar.

Currently, there are one and six permitted point discharges located in the Judith Creek (VAC-H03R-06) and James River (VAC-H03R-04) watersheds, respectively. The City of Lynchburg and the Virginia Department of Transportation each have a MS4 permit that whose limits are defined by the city boundary. These MS4 permits discharge within the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds. 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 3.2. The WLA associated with the MS4 permits was calculated by isolating the load coming from the impervious land segments of the residential land use in each impairment subwatershed that lies within the City limits.

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 2006 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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) impairments and their results are summarized in Sections 5.4.1 through 5.4.7.

The general approach used to determine the TMDL allocation was very similar among the seven watersheds. The first scenario represents existing conditions. Scenario number 1 eliminates all CSO discharges, which remain eliminated for all subsequent scenarios. Scenario 2 reduces straight pipes by 100%, which remain eliminated in subsequent scenarios since they are illegal. Scenario 3 reduces livestock directly deposited loads by 100%, keeping the remaining source reductions at 0%. Scenarios numbered 4 through 7 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 CSOs, straight pipes and livestock directly deposited loads were reduced 100%. The results of Scenarios 1 through 7 were then used to formulate additional scenarios that led to the TMDL allocation. These additional scenarios were designed to first determine non-anthropogenic source reductions required to meet bacteria water quality standards, if any. Subsequent scenarios were used to determine required reductions in anthropogenic sources (Sections 5.4.1 through 5.4.7).

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 James River (VAC-H03R-04) and Judith Creek (VAC-H03R-06) watersheds were increased by two and five times the existing permit levels to determine the effect of possible facility expansion, which is discussed in Sections 5.4.1 and 5.4.7 respectively. These increases did not result in violations of the water quality standard. The WLAs attributed to the MS4 permits held by the City of Lynchburg and VDOT were developed for current conditions and did not incorporate expansion. These WLAs did not result in violations of the water quality standard. From information provided by the Technical Advisory 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 declining slightly 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 5.3. 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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) impairments 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 James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) are seasonal. The TMDL accounts for these seasonal effects.

- The exceedance rates listed in the allocation scenario tables indicate exceedance rates for the watershed outlet only. Some scenarios resulted in bacteria water quality standard exceedances in subwatersheds upstream of the outlet but within the impaired reach watershed.

The TMDL allocations are presented in the subsequent sections in terms of average annual loads and daily loads in pairs of tables (e.g. Table 5.3 and Table 5.4 in Section 5.3.1). The average annual TMDL load represents the average annual in-stream load for the allocation period and is a function of modeled in-stream bacteria concentration and flow. The corresponding WLA was derived from the bacteria limit and design flows or in-stream municipal stormwater bacteria load as described previously in this section. The LA is calculated as the TMDL minus the WLA. The daily bacteria load TMDL represents the in-stream load during the 99th percentile daily flow with a bacteria concentration equal to the instantaneous water quality limit of 235 cfu/100 ml. The WLA presented in the daily bacteria load table is equal to the average annual WLA value divided by 365. The LA presented in the daily bacteria load table is calculated as the daily bacteria load TMDL minus the WLA.

5.3.1 James River (VAC-H03R-04)

Formulations of Scenarios 1 through 7 are discussed in Section 5.4. The results of those scenarios, and additional scenarios, are displayed in Table 5.1. Scenarios 8 through 9 are further reductions to the anthropogenic sources. 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 James River (VAC-H03R-04) watershed. Scenario 8 tested the land use load reductions at 90% with a 90% reduction in livestock directly deposited load. Table 5.1

shows that no exceedances are present under Scenario 8. Lesser reductions were tested. Scenario 9 tested the land use and livestock directly deposited loads at a 80% reduction rate. Scenario 9 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 5.43 for the final TMDL allocation (Scenario 9), along with the geometric mean and instantaneous standards. Table 5.2 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 5.3 presents the final allocated in-stream *E. coli* loads for the James River (VAC-H03R-04) impairment.

Increases in loads over the next five years must be considered to ensure the stated allocation will meet the water quality standards. Potential increases in all sources and the effect on the TMDLs for the study watersheds are discussed in Section 5.3. Table 5.4 presents the TMDL for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. Discharges from the permitted point sources in the James River (VAC-H03R-04) watershed were increased by two and five times the existing permit levels to determine the effect of possible facility expansion (Table 5.5). The increases did not result in additional violations of the water quality standards.

Table 5.1. TMDL allocation scenarios for James River (VAC-H03R-04) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions								% Violations of *E. coli* Standard		# Violations of the Instantaneous Standard
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Instantan-eous	
Existing Conditions	0	0	0	0	0	0	0	0	6.67	22.95	419
1	100	0	0	0	0	0	0	0	0	6.96	127
2	100	100	0	0	0	0	0	0	0	6.79	124
3	100	100	0	100	0	0	0	0	0	6.57	120
4	100	100	100	100	100	100	0	0	0	0	0
5	100	100	50	100	50	50	0	0	0	1.59	29
6	100	100	75	100	75	75	0	0	0	0.16	3
7	100	100	90	100	90	90	0	0	0	0	0
8	100	100	90	90	90	90	0	0	0	0	0
9	100	100	80	80	80	80	0	0	0	0	0

Table 5.2. Annual nonpoint source fecal coliform loads for existing conditions and final allocation along with corresponding reductions in James River (VAC-H03R-04) impairment.

Source	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	1.77E+14	0.00E+00	100
Livestock	6.33E+13	1.27E+13	80
Wildlife	5.94E+13	5.94E+13	0
Total	*2.99E+14*	*7.21E+13*	76
Land-based			
Residential	3.05E+15	6.11E+14	80
Cropland	3.08E+13	6.16E+12	80
Pasture	2.59E+16	5.18E+15	80
Forest	4.70E+14	4.70E+14	0
Total	*2.95E+16*	*6.27E+15*	79

Table 5.3. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in James River (VAC-H03R-04) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	2.75E+14	3.76E+14	N/A	6.51E+14

N/A – not applicable because MOS was implicit.

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 5.4. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in James River (VAC-H03R-04) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	7.53E+11	6.23E+16	N/A	6.23E+16

N/A – not applicable because MOS was implicit.

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.

Table 5.5. Expansion matrix for WLA in the James River (VAC-H03R-04) watershed.

Permit Number	Sub-shed	Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/d)
VA0063657	JR-4	0.0015	126	7.09E+06
VA0024970	JR-7	22	126	1.05E+11
Existing WLA		22.0015	126	1.05E+11
Expansion Scenario: 2 x Existing WLA		44.0030	126	2.10E+11
Expansion Scenario: 5 x Existing WLA		110.0075	126	5.25E+11
		Contributing Area (Acres)	**Average Runoff**	
Combined MS4 Permit Allocation (City & VDOT)		762.28	not available	2.28E+11

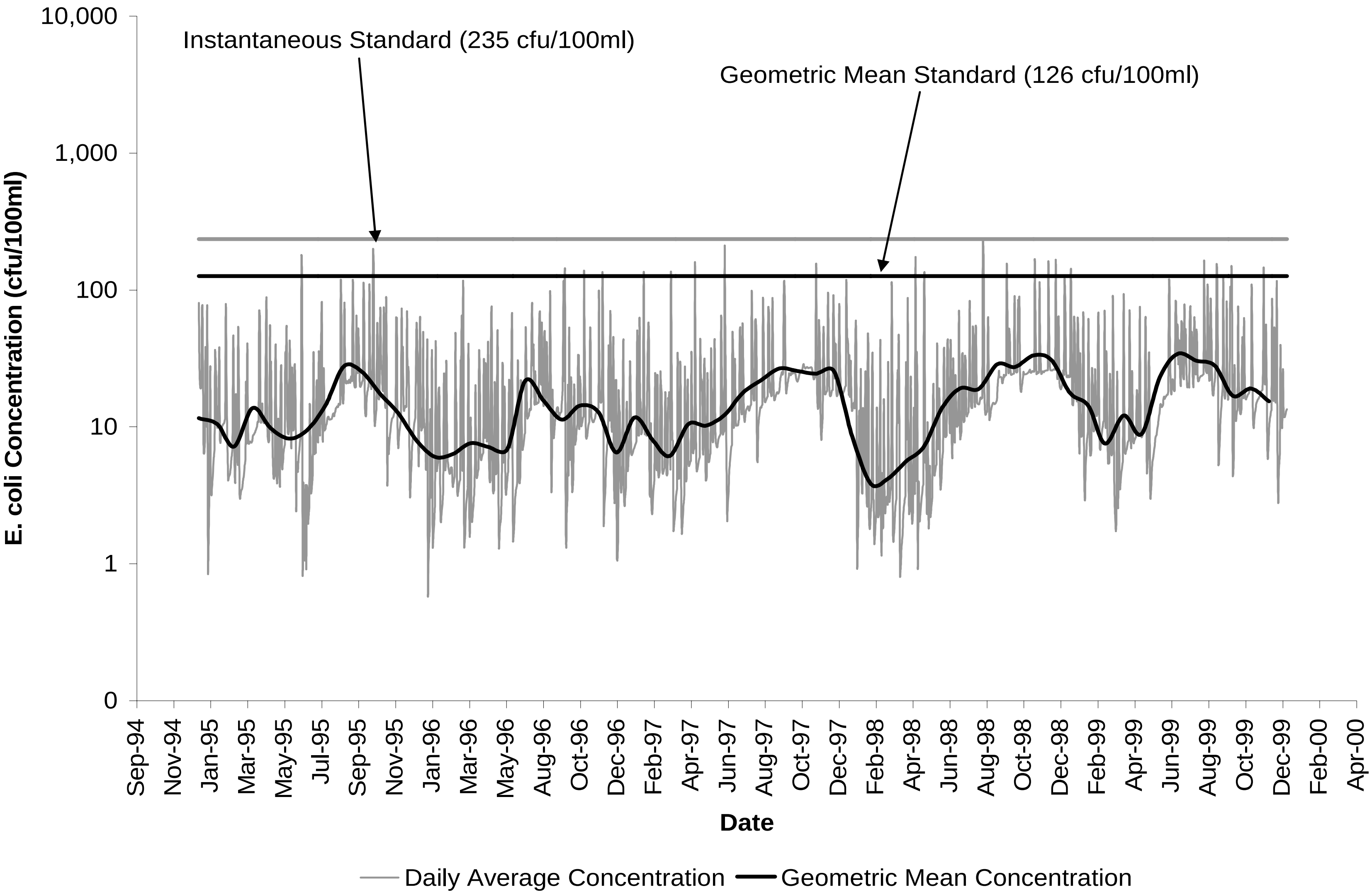

Figure 5.43. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 9 from Table 5.1) in James River (VAC-H03R-04) impairment.

5.3.2 Ivy Creek (VAC-H03R-03)

Formulations of Scenarios 1 through 7 are discussed in Section 5.4. The results of those scenarios, and additional scenarios, are displayed in Table 5.6. Scenarios 8 through 9 are further reductions to the anthropogenic sources. 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 Ivy Creek (VAC-H03R-03) watershed. Scenario 8 tested the anthropogenic land use load reductions at 97%. Table 5.6 does not directly show that exceedances are present when the anthropogenic sources are tested at a 97% reduction rate, but exceedances were observed upstream of the outlet. Scenario 9 tested the land use and livestock directly deposited loads at a 98% reduction rate. Scenario 8 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 5.44 for the final TMDL allocation (Scenario 9), along with the geometric mean and instantaneous standards. Table 5.7 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 5.8 presents the final allocated in-stream *E. coli* loads for the Ivy Creek (VAC-H03R-03) impairment. Table 5.9 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. Potential increases in all sources and the effect on the TMDLs for the six study watersheds are discussed in Section 5.3. While there are no permitted point sources in the Ivy Creek (VAC-H03R-03) watershed, Table 5.30 does describe the WLA associated with the existing MS4 permits.

Table 5.6. TMDL allocation scenarios for Ivy Creek (VAC-H03R-03) impairment.

Scenario Number		Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of *E. coli* Standard		# Violations of the Instantaneous Standard
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Instantan-eous	
Existing Conditions	0	0	0	0	0	0	0	0	40	26.78	489
1	100	0	0	0	0	0	0	0	38.33	26.45	483
2	100	100	0	0	0	0	0	0	28.33	25.85	472
3	100	100	0	100	0	0	0	0	1.67	24.1	440
4	100	100	100	100	100	100	0	0	0	0	0
5	100	100	50	100	50	50	0	0	0	12.65	231
6	100	100	75	100	75	75	0	0	0	1.64	30
7	100	100	90	100	90	90	0	0	0	0	0
8	100	100	97	100	97	97	0	0	0	0	0
9	100	100	98	98	98	98	0	0	0	0	0

Table 5.7. Annual nonpoint source fecal coliform loads for existing conditions and final allocation along with corresponding reductions in Ivy Creek (VAC-H03R-03) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	2.69E+13	0.00E+00	100
Livestock	7.10E+13	1.42E+12	98
Wildlife	2.37E+13	2.37E+13	0
Total	*1.22E+14*	*2.51E+13*	79
Land-based			
Residential	1.66E+15	3.33E+13	98
Cropland	6.88E+13	1.38E+12	98
Pasture	2.59E+16	5.18E+14	98
Forest	1.83E+14	1.83E+14	0
Total	*2.78E+16*	*7.37E+14*	97

Table 5.8. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Ivy Creek (VAC-H03R-03) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	6.25E+11	7.07E+12	N/A	7.69E+12

N/A – not applicable because MOS was implicit.

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 5.9. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Ivy Creek (VAC-H03R-03) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	1.71E+09	5.42E+14	N/A	5.42E+14

N/A – not applicable because MOS was implicit.

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.

Table 5.10. WLA in the Ivy Creek (VAC-H03R-03) watershed.

Permit Description	Contributing Area (Acres)	Average Runoff	Wasteload Allocation (cfu/d)
Combined MS4 Permit Allocation (City & VDOT)	779.78	not available	1.71E+09

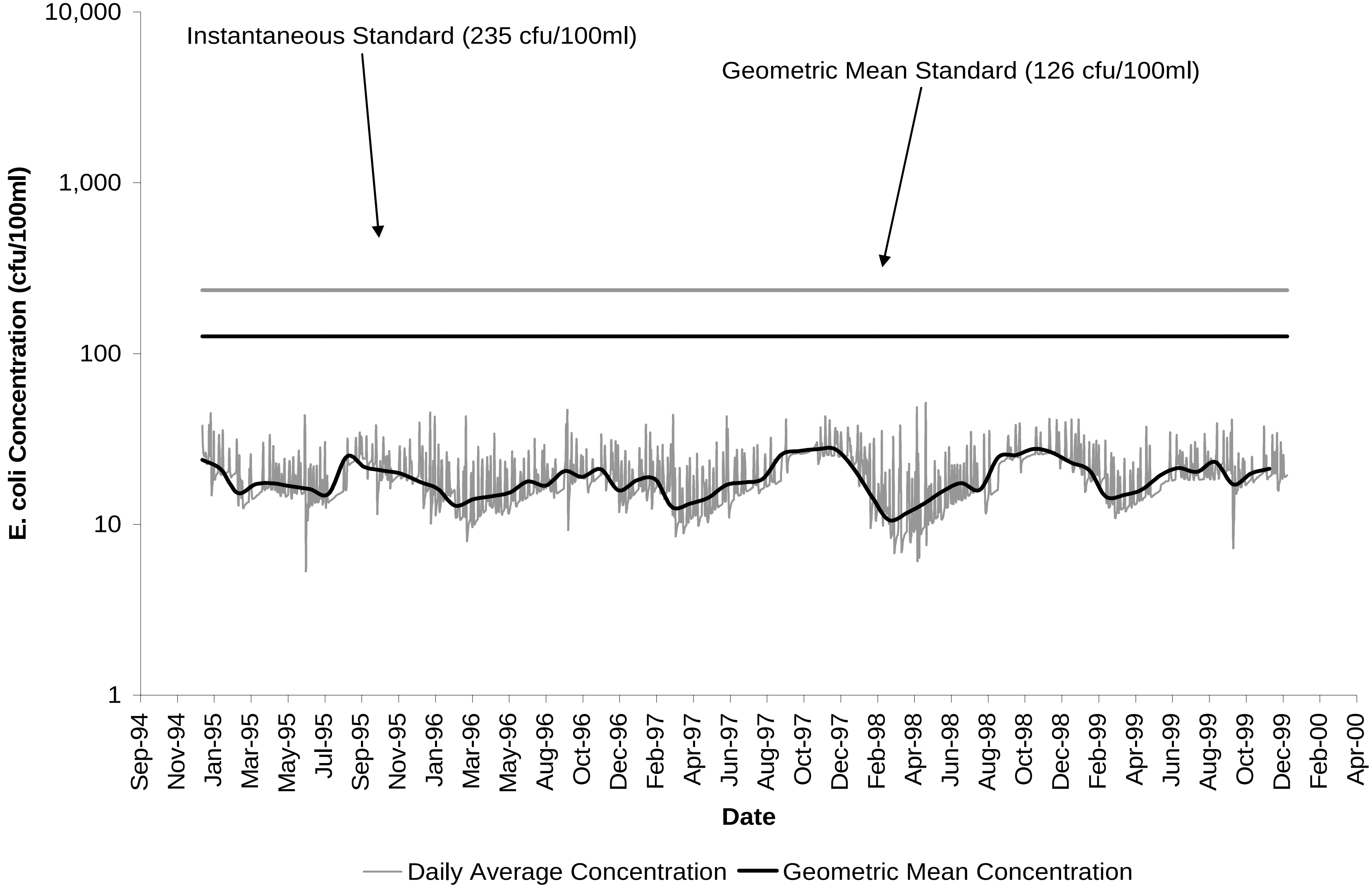

Figure 5.44. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 9 from Table 5.5) in Ivy Creek (VAC-H03R-03) impairment.

5.3.3 Fishing Creek (VAC-H03R-02)

Formulations of Scenarios 1 through 7 are discussed in Section 5.4. The results of those scenarios, and additional scenarios, are displayed in Table 5.11. Scenarios 8 through 9 are further reductions to the anthropogenic sources. 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 Fishing Creek (VAC-H03R-02) watershed. Scenario 8 tested the anthropogenic land use load reductions at 79%. Table 5.11 shows that exceedances are present when the anthropogenic sources are tested at a 79% reduction rate. Scenario 9 tested the cropland land-based, pasture land-based loads, and livestock directly deposited loads at a 80% reduction rate. Scenario 9 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 5.45 for the final TMDL allocation (Scenario 9), along with the geometric mean and instantaneous standards. Table 5.12 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 5.13 presents the final allocated in-stream *E. coli* loads for the Fishing Creek (VAC-H03R-02) impairment. Table 5.14 presents the TMDL for the 99^{th} 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. Potential increases in all sources and the effect on the TMDLs for the study watersheds are discussed in Section 5.3. While there are no permitted point sources in the Fishing Creek (VAC-H03R-02) watershed, Table 5.30 does describe the WLA associated with the existing MS4 permits.

Table 5.11. TMDL allocation scenarios for Fishing Creek (VAC-H03R-02) impairment.

Scenario Number		Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of *E. coli* Standard		# Violations of the Instantaneous Standard
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Instantan-eous	
Existing Conditions	0	0	0	0	0	0	0	0	21.67	10.79	197
1	100	0	0	0	0	0	0	0	10	8.98	164
2	100	100	0	0	0	0	0	0	8.33	8.87	162
3	100	100	0	100	0	0	0	0	0	8.11	148
4	100	100	100	100	100	100	0	0	0	0	0
5	100	100	50	100	50	50	0	0	0	2.63	48
6	100	100	75	100	75	75	0	0	0	0.27	5
7	100	100	90	100	90	90	0	0	0	0	0
8	100	100	79	100	79	79	0	0	0	0.05	1
9	100	100	80	90	80	80	0	0	0	0	0

Table 5.12. Annual nonpoint source fecal coliform loads for existing conditions and final allocation along with corresponding reductions in Fishing Creek (VAC-H03R-02) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	8.08E+10	0.00E+00	100
Livestock	2.19E+12	4.37E+11	80
Wildlife	3.77E+12	3.77E+12	0
Total	*6.04E+12*	*4.21E+12*	30
Land-based			
Residential	7.26E+14	1.45E+14	80
Cropland	2.27E+12	4.54E+11	80
Pasture	4.46E+14	8.92E+13	80
Forest	2.92E+13	2.92E+13	0
Total	*1.20E+15*	*2.64E+14*	78

Table 5.13. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Fishing Creek (VAC-H03R-02) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	1.03E+12	3.45E+12	N/A	4.48E+12

N/A – not applicable because MOS was implicit.

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 5.14. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Fishing Creek (VAC-H03R-02) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	2.81E+09	1.87E+14	N/A	1.87E+14

N/A – not applicable because MOS was implicit.

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.

Table 5.15. WLA in the Fishing Creek (VAC-H03R-02) watershed.

Permit Description	Contributing Area (Acres)	Average Runoff	Wasteload Allocation (cfu/d)
Combined MS4 Permit Allocation (City & VDOT)	830.85	not available	2.81E+09

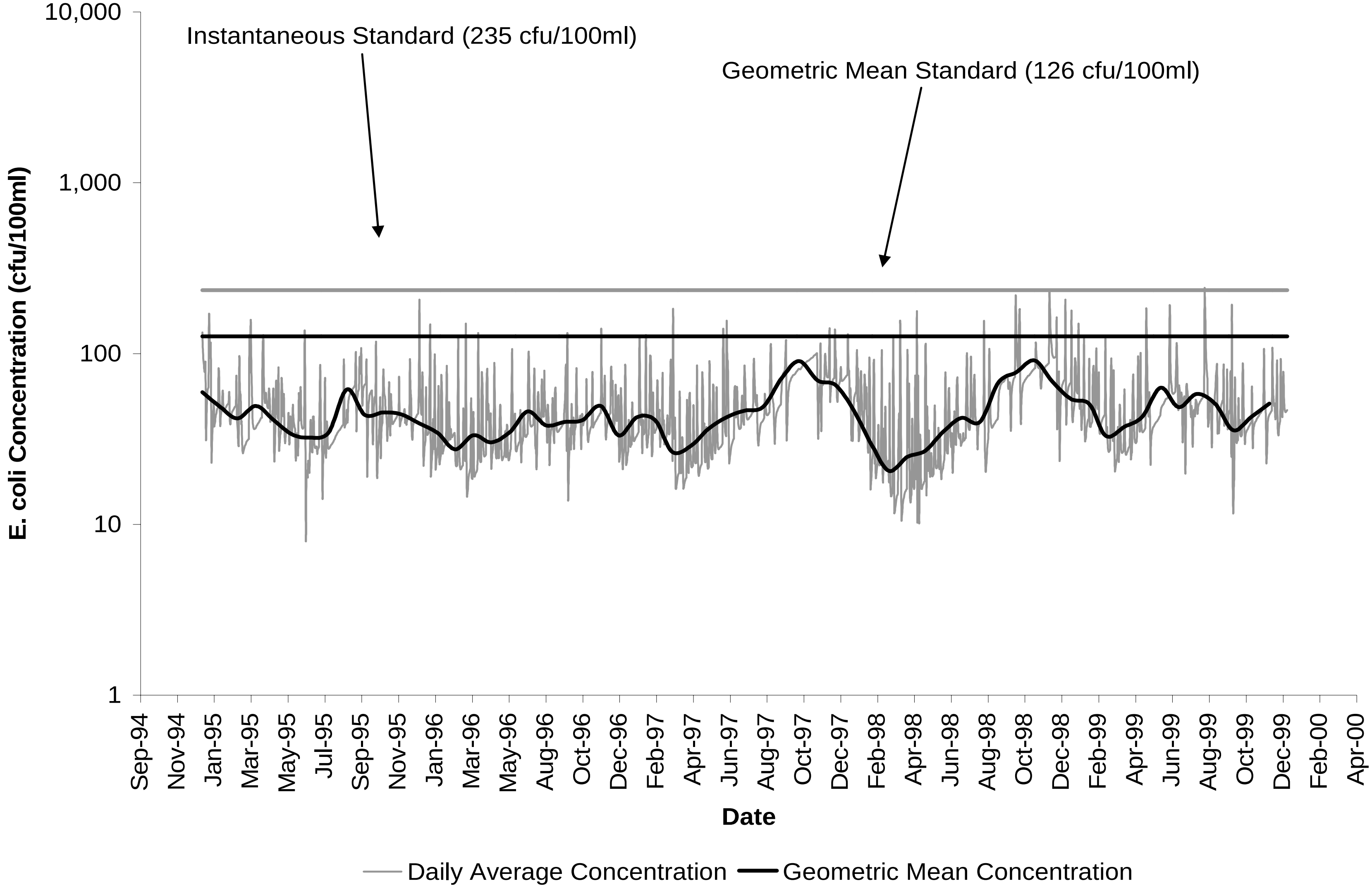

Figure 5.45. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 9 from Table 5.11) in Fishing Creek (VAC-H03R-02) impairment.

5.3.4 Blackwater Creek (VAC-H03R-01)

Formulations of Scenarios 1 through 7 are discussed in Section 5.4. The results of those scenarios, and additional scenarios, are displayed in Table 5.16. Scenarios 8 through 9 are further reductions to the anthropogenic sources. 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 Blackwater Creek (VAC-H03R-01) watershed. Scenario 8 tested the land based and directly deposited livestock load reductions at 92%. Table 5.16 does not show that exceedances are present when the land based sources are tested at a 92% reduction rate. Lesser load reductions were tested. Scenario 9 tested the land based and directly deposited livestock load reductions at 91%. Scenario 9 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 5.46 for the final TMDL allocation (Scenario 9), along with the geometric mean and instantaneous standards. Table 5.17 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 5.18 presents the final allocated in-stream *E. coli* loads for the Blackwater Creek (VAC-H03R-01) impairment. Table 5.19 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. Potential increases in all sources and the effect on the TMDLs for the study watersheds are discussed in Section 5.3. While there are no permitted point sources in the Blackwater Creek (VAC-H03R-01) watershed, Table 5.30 does describe the WLA associated with the existing MS4 permits.

Table 5.16. TMDL allocation scenarios for Blackwater Creek (VAC-H03R-01) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions								% Violations of *E. coli* Standard		# Violations of the Instantaneous Standard
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Instantan-eous	
Existing Conditions	0	0	0	0	0	0	0	0	96.67	42.55	777
1	100	0	0	0	0	0	0	0	83.33	33.41	610
2	100	100	0	0	0	0	0	0	33.33	30.45	556
3	100	100	0	100	0	0	0	0	6.67	29.41	537
4	100	100	100	100	100	100	0	0	0	0	0
5	100	100	50	100	50	50	0	0	1.67	19.28	352
6	100	100	75	100	75	75	0	0	0	3.61	66
7	100	100	90	100	90	90	0	0	0	0	0
8	100	100	92	92	92	92	0	0	0	0	0
9	100	100	91	91	91	91	0	0	0	0	0

Table 5.17. Annual nonpoint source fecal coliform loads for existing conditions and final allocation along with corresponding reductions in Blackwater Creek (VAC-H03R-01) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	3.12E+13	0.00E+00	100
Livestock	0.00E+00	0.00E+00	0
Wildlife	5.24E+12	5.24E+12	0
Total	*3.65E+13*	*5.24E+12*	86
Land-based			
Residential	1.70E+15	1.53E+14	91
Cropland	8.06E+10	7.26E+09	91
Pasture	1.25E+13	1.13E+12	91
Forest	3.62E+13	3.62E+13	0
Total	*1.75E+15*	*1.91E+14*	89

Table 5.18. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Blackwater Creek (VAC-H03R-01) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	3.06E+12	1.62E+13	N/A	1.93E+13

N/A – not applicable because MOS was implicit.

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 5.19. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Blackwater Creek (VAC-H03R-01) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	8.37E+09	1.23E+15	N/A	1.23E+15

N/A – not applicable because MOS was implicit.

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.

Table 5.20. WLA in the Blackwater Creek (VAC-H03R-01) watershed.

Permit Description	Contributing Area (Acres)	Average Runoff	Wasteload Allocation (cfu/d)
Combined MS4 Permit Allocation (City & VDOT)	1884.20	not available	8.37E+09

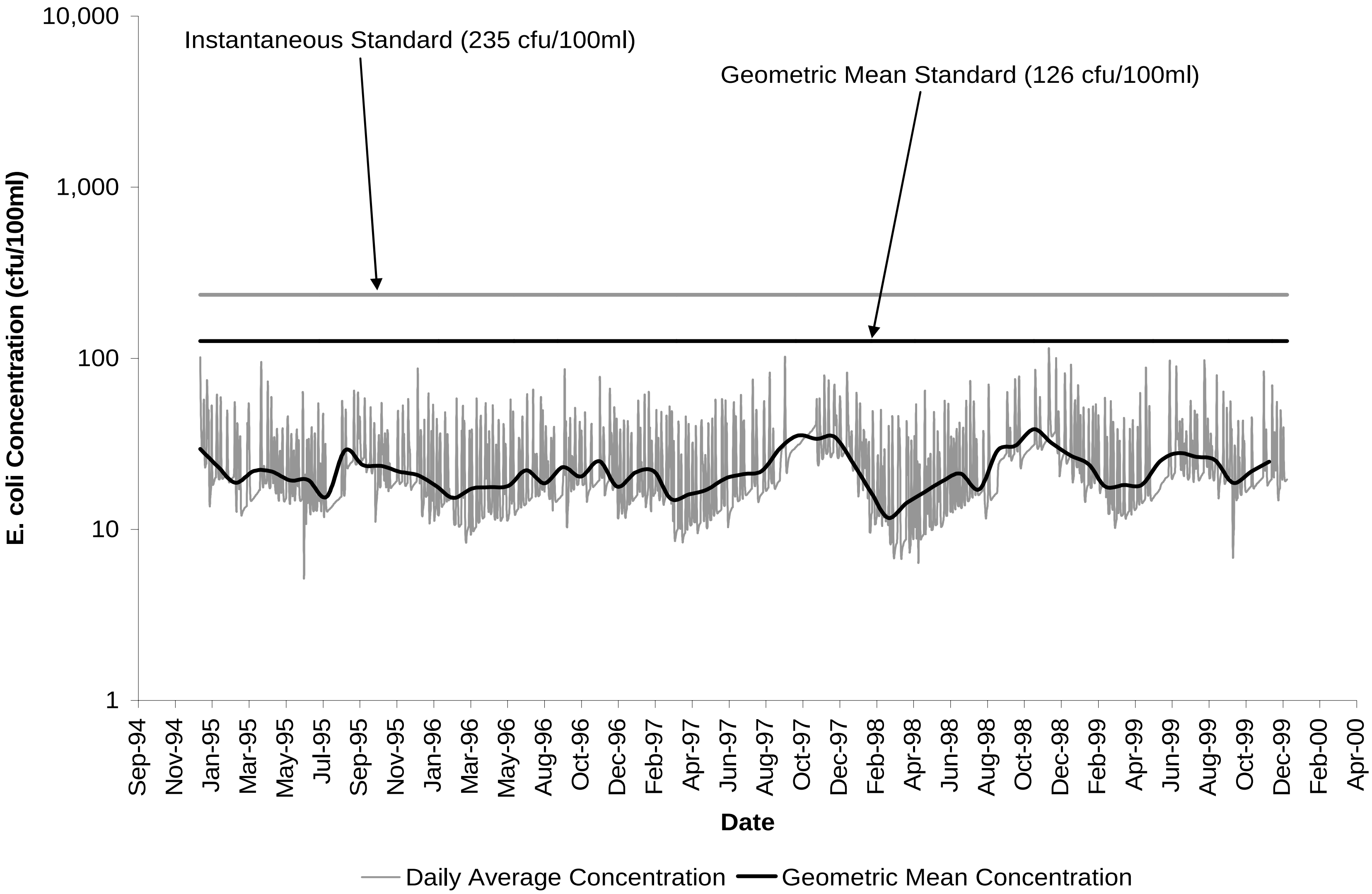

Figure 5.46. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 9 from Table 5.16) in Blackwater Creek (VAC-H03R-01) impairment.

5.3.5 Tomahawk Creek (VAC-H03R-07)

Formulations of Scenarios 1 through 7 are discussed in Section 5.4. The results of those scenarios, and additional scenarios, are displayed in Table 5.21. Scenarios 8 through 9 are further reductions to the anthropogenic sources. 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 Tomahawk Creek (VAC-H03R-07) watershed. Scenario 8 tested the land based and directly deposited livestock load reductions at 93%. Table 5.21 shows that exceedances are present when the land based sources are tested at a 92% reduction rate. Scenario 9 tested the land based and directly deposited livestock load reductions at 95%. Scenario 9 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 5.47 for the final TMDL allocation (Scenario 9), along with the geometric mean and instantaneous standards. Table 5.22 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 5.23 presents the final allocated in-stream *E. coli* loads for the Tomahawk Creek (VAC-H03R-07) impairment. Table 5.24 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. Potential increases in all sources and the effect on the TMDLs for the study watersheds are discussed in Section 5.3. While there are no permitted point sources in the Tomahawk Creek (VAC-H03R-07) watershed, Table 5.30 does describe the WLA associated with the existing MS4 permits.

Table 5.21. TMDL allocation scenarios for Tomahawk Creek (VAC-H03R-07) impairment

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions								% Violations of *E. coli* Standard		# Violations of the Instantaneous Standard
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Instantan-eous	
Existing Conditions	0	0	0	0	0	0	0	0	61.67	30.23	552
1	100	0	0	0	0	0	0	0	61.67	30.23	552
2	100	100	0	0	0	0	0	0	15	29.63	541
3	100	100	0	100	0	0	0	0	3.33	29.41	537
4	100	100	100	100	100	100	0	0	0	0	0
5	100	100	50	100	50	50	0	0	0	25.25	461
6	100	100	75	100	75	75	0	0	0	14.24	260
7	100	100	90	100	90	90	0	0	0	0.93	17
8	100	100	93	100	93	93	0	0	0	0.05	1
9	100	100	95	95	95	95	0	0	0	0	0

Table 5.22. Annual nonpoint source fecal coliform loads for existing conditions and final allocation along with corresponding reductions in Tomahawk Creek (VAC-H03R-07) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	2.38E+13	0.00E+00	100
Livestock	6.26E+12	3.13E+11	95
Wildlife	4.82E+12	4.82E+12	0
Total	*3.49E+13*	*5.14E+12*	85
Land-based			**95**
Residential	1.24E+15	6.19E+13	95
Cropland	8.24E+12	4.12E+11	95
Pasture	1.42E+15	7.10E+13	95
Forest	3.06E+13	3.06E+13	0
Total	*2.70E+15*	*1.64E+14*	94

Table 5.23. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Tomahawk Creek (VAC-H03R-07) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	8.34E+11	1.82E+12	N/A	2.65E+12

N/A – not applicable because MOS was implicit.

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 5.24. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Tomahawk Creek (VAC-H03R-07) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	2.29E+09	1.81E+14	N/A	1.81E+14

N/A – not applicable because MOS was implicit.

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.

Table 5.25. WLA in the Tomahawk Creek (VAC-H03R-07) watershed.

Permit Description	Contributing Area (Acres)	Average Runoff	Wasteload Allocation (cfu/d)
Combined MS4 Permit Allocation (City & VDOT)	300.46	not available	2.29E+09

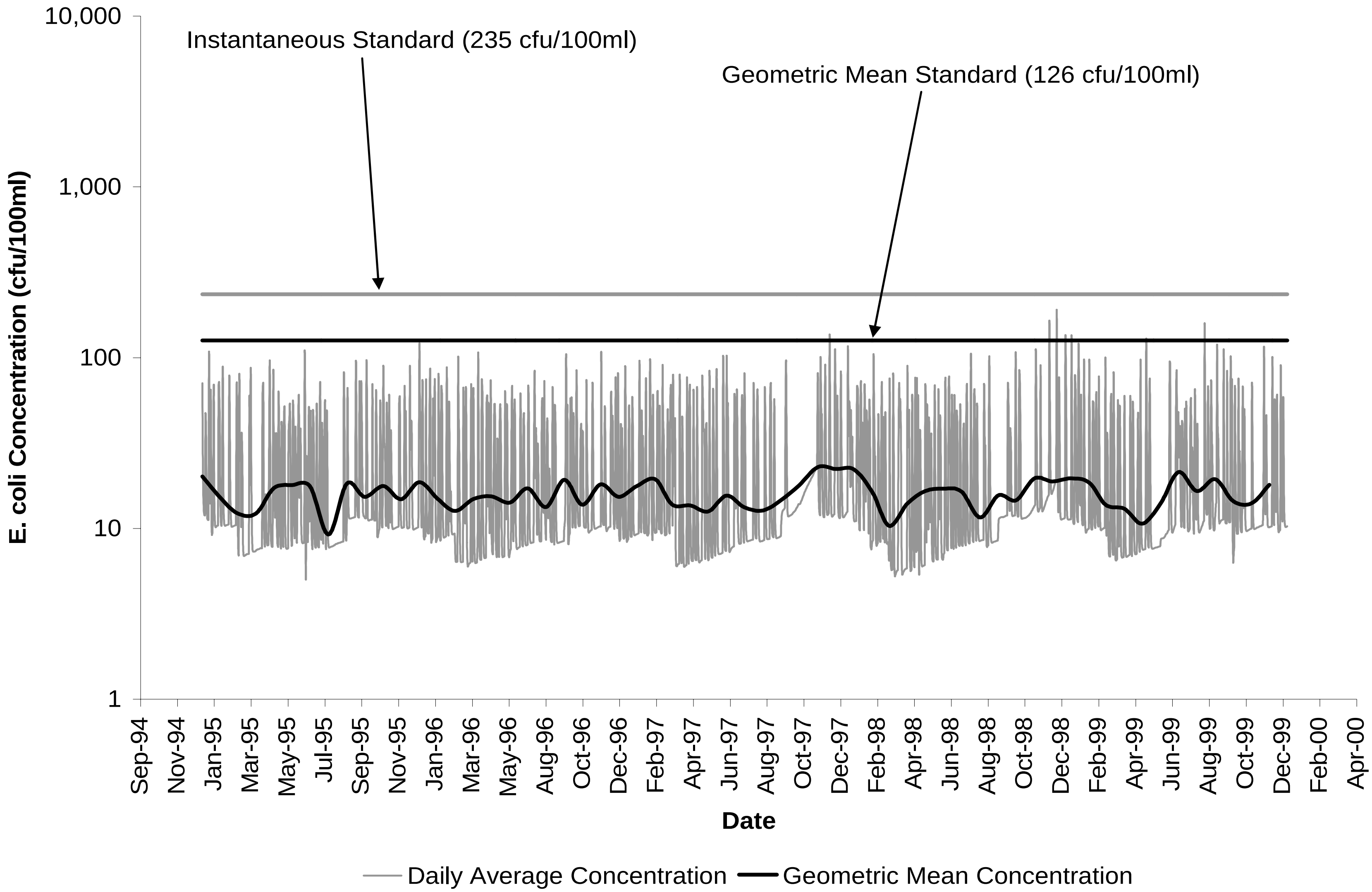

Figure 5.47. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 9 from Table 5.21) in Tomahawk Creek (VAC-H03R-07) impairment.

5.3.6 Burton Creek (VAC-H03R-05)

Formulations of Scenarios 1 through 7 are discussed in Section 5.4. The results of those scenarios, and additional scenarios, are displayed in Table 5.26. Scenarios 8 through 9 are further reductions to the anthropogenic sources. 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 Burton Creek (VAC-H03R-05) watershed. Scenario 8 tested the land-based load reductions at 97%. Though Table 5.26 does not indicate that exceedances are present when the land-based sources are tested at a 97% reduction rate, they were observed upstream of the outlet. Scenario 9 tested the land based and livestock directly deposited loads at a 98% reduction rate. Scenario 9 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 5.48 for the final TMDL allocation (Scenario 9), along with the geometric mean and instantaneous standards. Table 5.27 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 5.28 presents the final allocated in-stream *E. coli* loads for the Burton Creek (VAC-H03R-05) impairment. Table 5.29 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. Potential increases in all sources and the effect on the TMDLs for the study watersheds are discussed in Section 5.3. While there are no permitted point sources in the Burton Creek (VAC-H03R-05) watershed, Table 5.30 does describe the WLA associated with the existing MS4 permits.

Table 5.26. TMDL allocation scenarios for Burton Creek (VAC-H03R-05) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions								% Violations of *E. coli* Standard		# Violations of the Instantaneous Standard
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Instantan-eous	
Existing Conditions	0	0	0	0	0	0	0	0	1.67	27.6	504
1	100	0	0	0	0	0	0	0	1.67	27.6	504
2	100	100	0	0	0	0	0	0	1.67	27.55	503
3	100	100	0	100	0	0	0	0	1.67	27.49	502
4	100	100	100	100	100	100	0	0	0	0	0
5	100	100	50	100	50	50	0	0	0	20.65	377
6	100	100	75	100	75	75	0	0	0	8.21	150
7	100	100	90	100	90	90	0	0	0	0.16	3
8	100	100	97	100	97	97	0	0	0	0	0
9	100	100	98	98	98	98	0	0	0	0	0

Table 5.27. Annual nonpoint source fecal coliform loads for existing conditions and final allocation along with corresponding reductions in Burton Creek (VAC-H03R-05) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	6.42E+12	0.00E+00	100
Livestock	2.51E+12	5.02E+10	98
Wildlife	5.91E+12	5.91E+12	0
Total	*1.48E+13*	*5.96E+12*	60
Land-based			
Residential	1.40E+15	2.80E+13	98
Cropland	0.00E+00	0.00E+00	98
Pasture	4.57E+14	9.15E+12	98
Forest	4.17E+13	4.17E+13	0
Total	*1.90E+15*	*7.88E+13*	96

Table 5.28. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Burton Creek (VAC-H03R-05) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	7.37E+11	1.08E+12	N/A	1.82E+12

N/A – not applicable because MOS was implicit.

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 5.29. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Burton Creek (VAC-H03R-05) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	2.02E+09	2.69E+14	N/A	2.69E+14

N/A – not applicable because MOS was implicit.

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.

Table 5.30. Expansion matrix for WLA in the Burton Creek (VAC-H03R-05) watershed.

Permit Description	Contributing Area (Acres)	Average Runoff	Wasteload Allocation (cfu/d)
Combined MS4 Permit Allocation (City & VDOT)	784.74	not available	2.02E+09

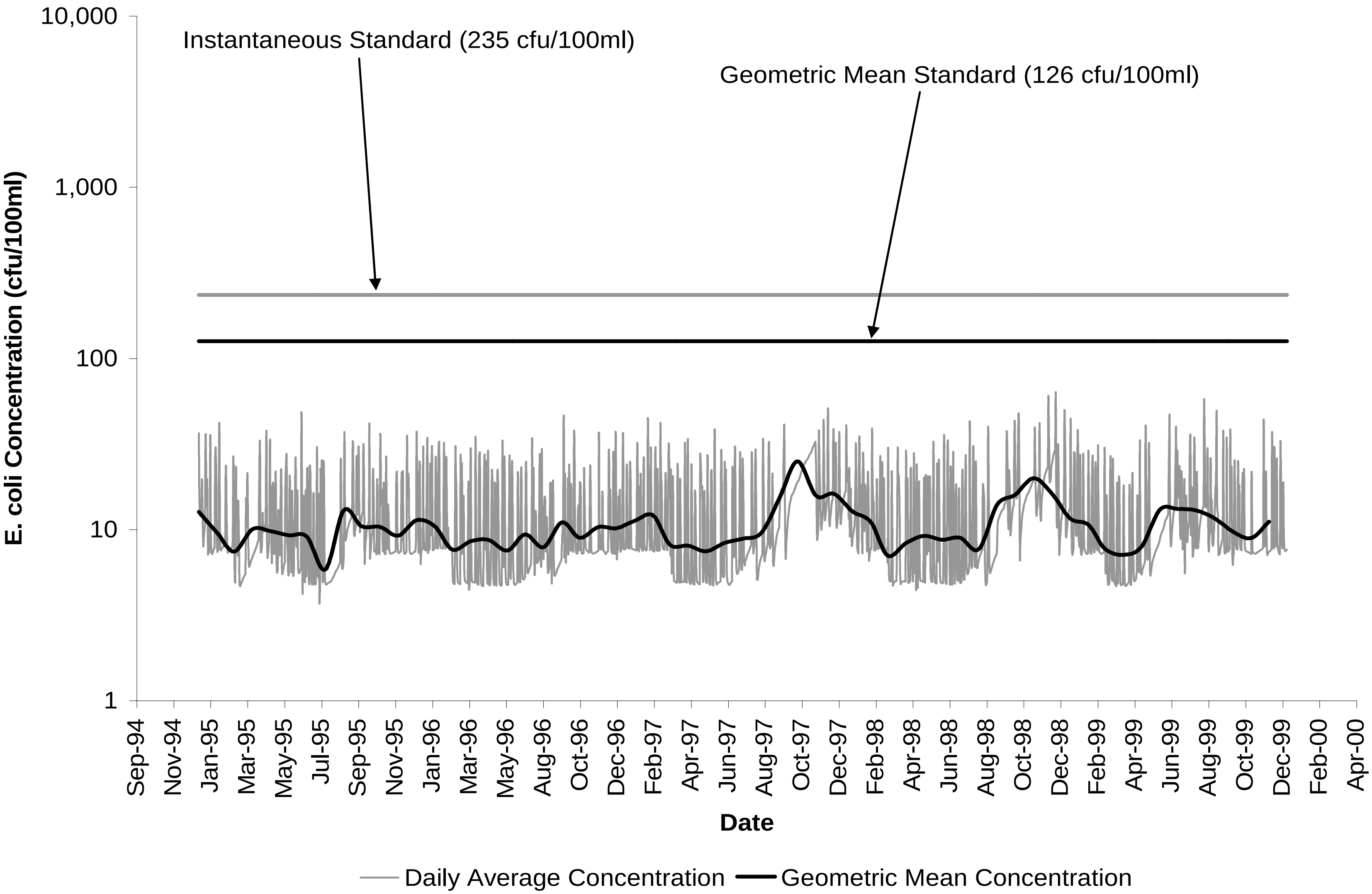

Figure 5.48. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 9 from Table 5.26) in Burton Creek (VAC-H03R-05) impairment.

5.3.7 Judith Creek (VAC-H03R-06)

Formulations of Scenarios 1 through 7 are discussed in Section 5.4. The results of those scenarios, and additional scenarios, are displayed in Table 5.31. Scenarios 8 through 9 are further reductions to the anthropogenic sources. 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 Judith Creek (VAC-H03R-06) watershed. Scenario 8 tested the land based load reductions at 93%. Table 5.31 does not indicate that exceedances are present when the anthropogenic land based loads are tested at a 93% reduction rate, but they were observed upstream of the outlet. Scenario 9 tested the land-based and livestock directly deposited loads at a 94% reduction rate. Scenario 9 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 5.49 for the final TMDL allocation (Scenario 9), along with the geometric mean and instantaneous standards. Table 5.32 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 5.33 presents the final allocated in-stream *E. coli* loads for the Judith Creek (VAC-H03R-06) impairment. Table 5.34 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. Potential increases in all sources and the effect on the TMDLs for the study watersheds are discussed in Section 5.3. Discharges from the permitted point source in the Judith Creek (VAC-H03R-06) watershed were increased by two and five times the existing permit levels to determine the effect of possible facility expansion (Table 5.35). The increases did not result in additional violations of the water quality standards.

Table 5.31. TMDL allocation scenarios for Judith Creek (VAC-H03R-06) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions								% Violations of *E. coli* Standard		# Violations of the Instantaneous Standard
	CSO	Straight Pipes	Urban & Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Instantan-eous	
Existing Conditions	0	0	0	0	0	0	0	0	0	12.1	221
1	100	0	0	0	0	0	0	0	0	12.1	221
2	100	100	0	0	0	0	0	0	0	10.84	198
3	100	100	0	100	0	0	0	0	0	10.73	196
4	100	100	100	100	100	100	0	0	0	0	0
5	100	100	50	100	50	50	0	0	0	3.07	56
6	100	100	75	100	75	75	0	0	0	0.55	10
7	100	100	90	100	90	90	0	0	0	0	0
8	100	100	93	100	93	93	0	0	0	0	0
9	100	100	94	94	94	94	0	0	0	0	0

Table 5.32. Annual nonpoint source fecal coliform loads for existing conditions and final allocation along with corresponding reductions in Judith Creek (VAC-H03R-06) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	2.78E+13	0.00E+00	100
Livestock	6.16E+12	3.70E+11	94
Wildlife	8.02E+12	8.02E+12	0
Total	*4.20E+13*	*8.39E+12*	80
Land-based			
Residential	3.64E+14	2.18E+13	94
Cropland	5.23E+12	3.14E+11	94
Pasture	2.21E+15	1.33E+14	94
Forest	7.07E+13	7.07E+13	0
Total	*2.65E+15*	*2.25E+14*	91

Table 5.33. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Judith Creek (VAC-H03R-06) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	8.31E+11	1.24E+12	N/A	2.07E+12

N/A – not applicable because MOS was implicit.

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 5.34. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Judith Creek (VAC-H03R-06) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	2.28E+09	1.82E+14	N/A	1.82E+14

N/A – not applicable because MOS was implicit.

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.

Table 5.35. Expansion matrix for WLA in the Judith Creek (VAC-H03R-06) watershed.

Permit Number	Sub-shed	Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/d)
VA0091162	JC-2	0.015	126	2.86E+08
Existing WLA		0.0150	126	2.86E+08
Expansion Scenario: 2 x Existing WLA		0.0300	126	5.72E+08
Expansion Scenario: 5 x Existing WLA		0.0750	126	1.43E+09
		Contributing Area (Acres)	**Average Runoff**	
Combined MS4 Permit Allocation (City & VDOT)		92.94	not available	8.48E+08

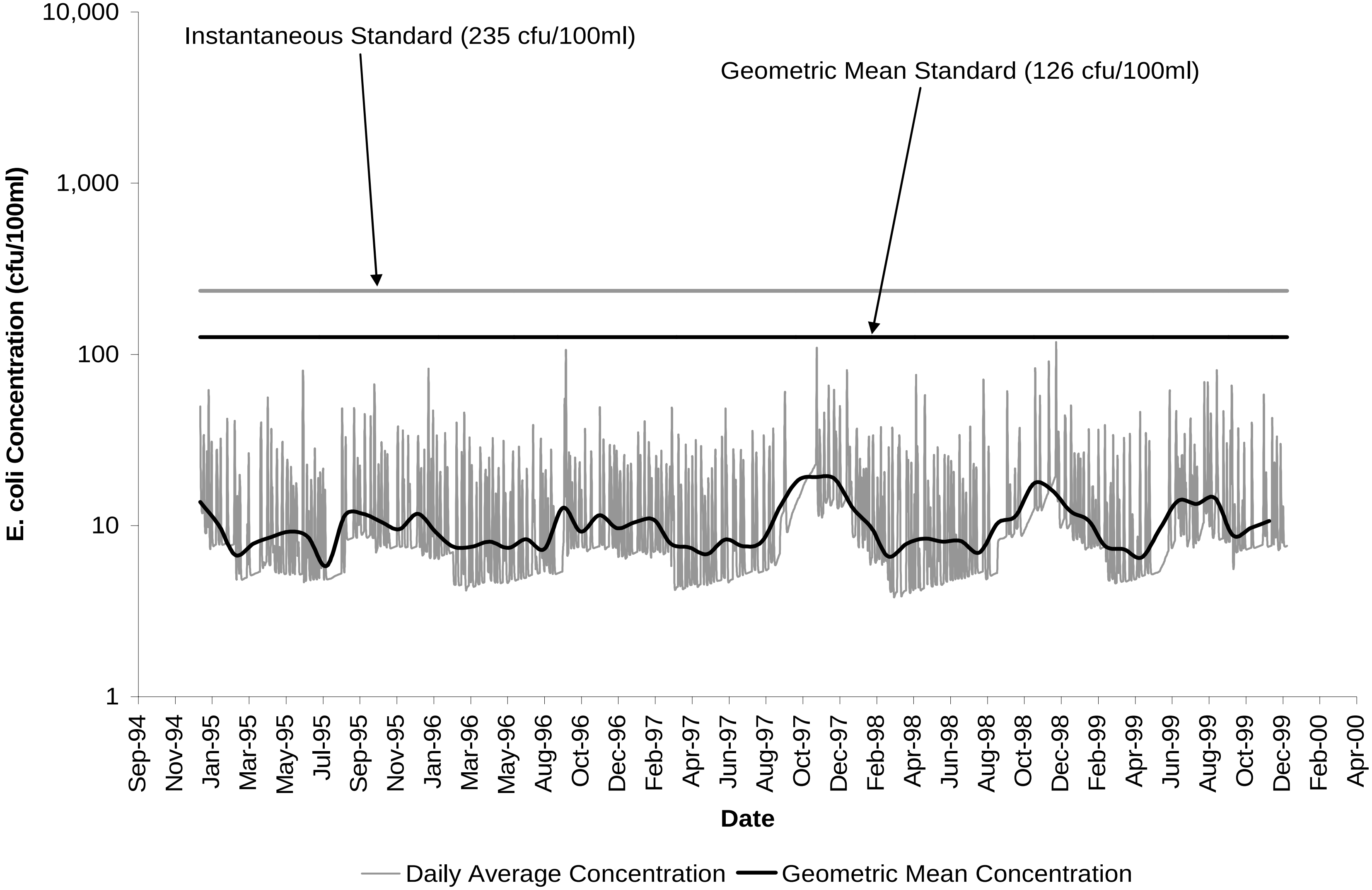

Figure 5.49. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 9 from Table 5.31) in Judith Creek (VAC-H03R-06) impairment.

Chapter 6. TMDL Implementation and Reasonable Assurance

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairments in the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) stream segments. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see section 7.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR '122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non point source reductions, 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 DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf With successful completion of implementation plans, local stakeholders 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.

6.1 Staged Implementation

In general, Virginia intends for the required bacteria 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.

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 incomputer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. 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.

6.2 Stage 1 Scenarios

The goal of the Stage 1 implementation scenarios is to reduce the bacteria loading reductions from controllable sources (excluding wildlife) such that exceedances of a potential future single sample maximum criterion (384 cfu/100ml) are less than 10 percent. 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. The Stage I scenarios were also developed to result in no violations of the potential geometric mean standard of 206 cfu/100 ml. It should be reiterated that the instantaneous and geometric mean standards used for evaluation of the Stage I scenarios are potential future Virginia bacteria instantaneous standards, and are not the current standards under which the allocation scenarios were developed. The current and potential standards are displayed in Figures 6.1 through 6.7. These scenarios include no reduction in loads from wildlife sources.

For the Stage I implementation scenarios, HSPF was run with a one-hour time step for the period January 1, 1995 to December 31, 1999, as with the TMDL allocation scenarios. The implicit MOS used in allocation scenarios was utilized in determining the Stage 1 implementation scenarios. Loadings from the CSO points were included for Stage I scenario development, and CSO correction priorities 1-25 were incorporated. This resulted in the elimination of CSO points 23, 57, and 59, but the others that are active underr current conditions were depicted as active. Several scenarios were run until the Stage 1 goal was met. Stage 1 allocation results are presented in Sections 6.2.1 through 6.2.7.

6.2.1 James River (VAC-H03R-04)

The Stage 1 allocation for the James River (VAC-H03R-04) impairment requires a 100% reduction in straight pipes, no reduction in livestock direct deposition, no reduction in wildlife direct deposition, a 10% reduction in nonpoint source loadings to residential land use, a 10% reduction in nonpoint source loadings to pasture land use, a 10% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.97% potential instantaneous standard (384 cfu/100 ml) exceedance rate and no violations of the potential geometric mean standard (206 cfu/100 ml). 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 6.1 for the James River (VAC-H03R-04) 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 6.1.

Table 6.1. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in James River (VAC-H03R-04) impairment.

Source	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	1.77E+14	0.00E+00	100
Livestock	6.33E+13	6.33E+13	0
Wildlife	5.94E+13	5.94E+13	0
Total	*2.99E+14*	*1.23E+14*	59%
Land-based			
Residential	3.05E+15	2.75E+15	10
Cropland	3.08E+13	2.77E+13	10
Pasture	2.59E+16	2.33E+16	10
Forest	4.70E+14	4.70E+14	0
Total	*2.95E+16*	*2.66E+16*	10%

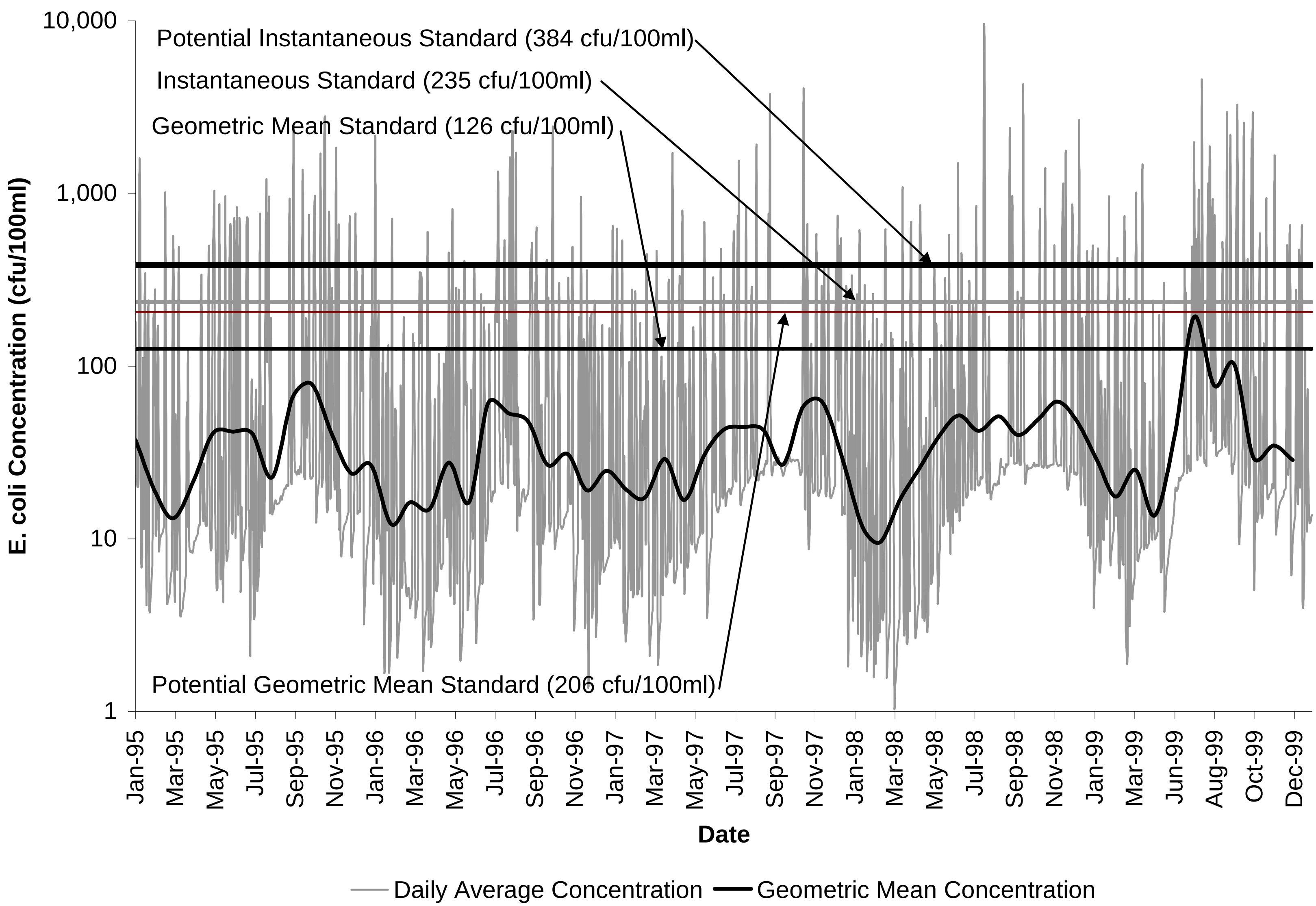

Figure 6.1. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in James River (VAC-H03R-04) impairment.

6.2.2 Ivy Creek (VAC-H03R-03)

The Stage 1 allocation for the Ivy Creek (VAC-H03R-03) impairment requires a 100% reduction in straight pipes, 96% reduction in livestock direct deposition, no reduction in wildlife direct deposition, a 56% reduction in nonpoint source loadings to residential, pasture, and cropland land uses, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.86% potential instantaneous standard (384 cfu/100 ml) exceedance rate and no violations of the potential geometric mean standard (206 cfu/100 ml). 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 6.2 for the Ivy Creek (VAC-H03R-03) 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 6.2.

Table 6.2. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Ivy Creek (VAC-H03R-03) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	2.69E+13	0.00E+00	100
Livestock	7.10E+13	2.84E+12	96
Wildlife	2.37E+13	2.37E+13	0
Total	*1.22E+14*	*2.65E+13*	78%
Land-based			
Residential	1.66E+15	7.32E+14	56
Cropland	6.88E+13	3.03E+13	56
Pasture	2.59E+16	1.14E+16	56
Forest	1.83E+14	1.83E+14	0
Total	*2.78E+16*	*1.24E+16*	56%

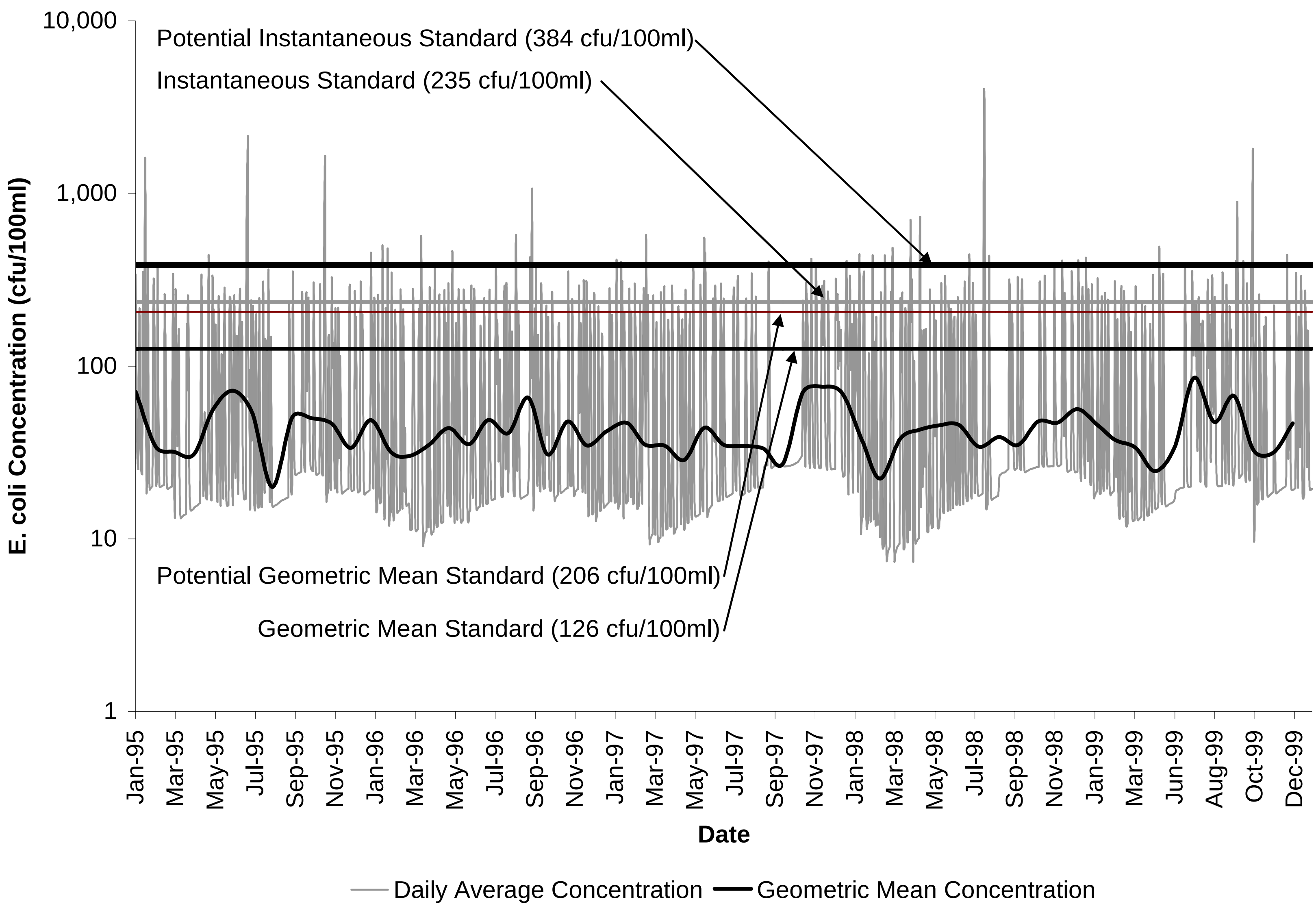

Figure 6.2. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Ivy Creek (VAC-H03R-03) impairment.

6.2.3 *Fishing Creek (VAC-H03R-03)*

The Stage 1 allocation for the Fishing Creek (VAC-H03R-03) impairment requires a 100% reduction in straight pipes, a 17% reduction in livestock direct deposition and no other reductions. This scenario resulted in a 4.82% potential instantaneous standard (384 cfu/100 ml) exceedance rate and no violations of the potential geometric mean standard (206 cfu/100 ml). This is largely a reflection of the potential instantaneous standard used for evaluation. 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 6.3 for the Fishing Creek (VAC-H03R-03) 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 6.3.

Table 6.3. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Fishing Creek (VAC-H03R-03) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	8.08E+10	0.00E+00	100
Livestock	2.19E+12	1.81E+12	17
Wildlife	3.77E+12	3.77E+12	0
Total	*6.04E+12*	*5.59E+12*	7%
Land-based			
Residential	7.26E+14	7.26E+14	0
Cropland	2.27E+12	2.27E+12	0
Pasture	4.46E+14	4.46E+14	0
Forest	2.92E+13	2.92E+13	0
Total	*1.20E+15*	*1.20E+15*	0%

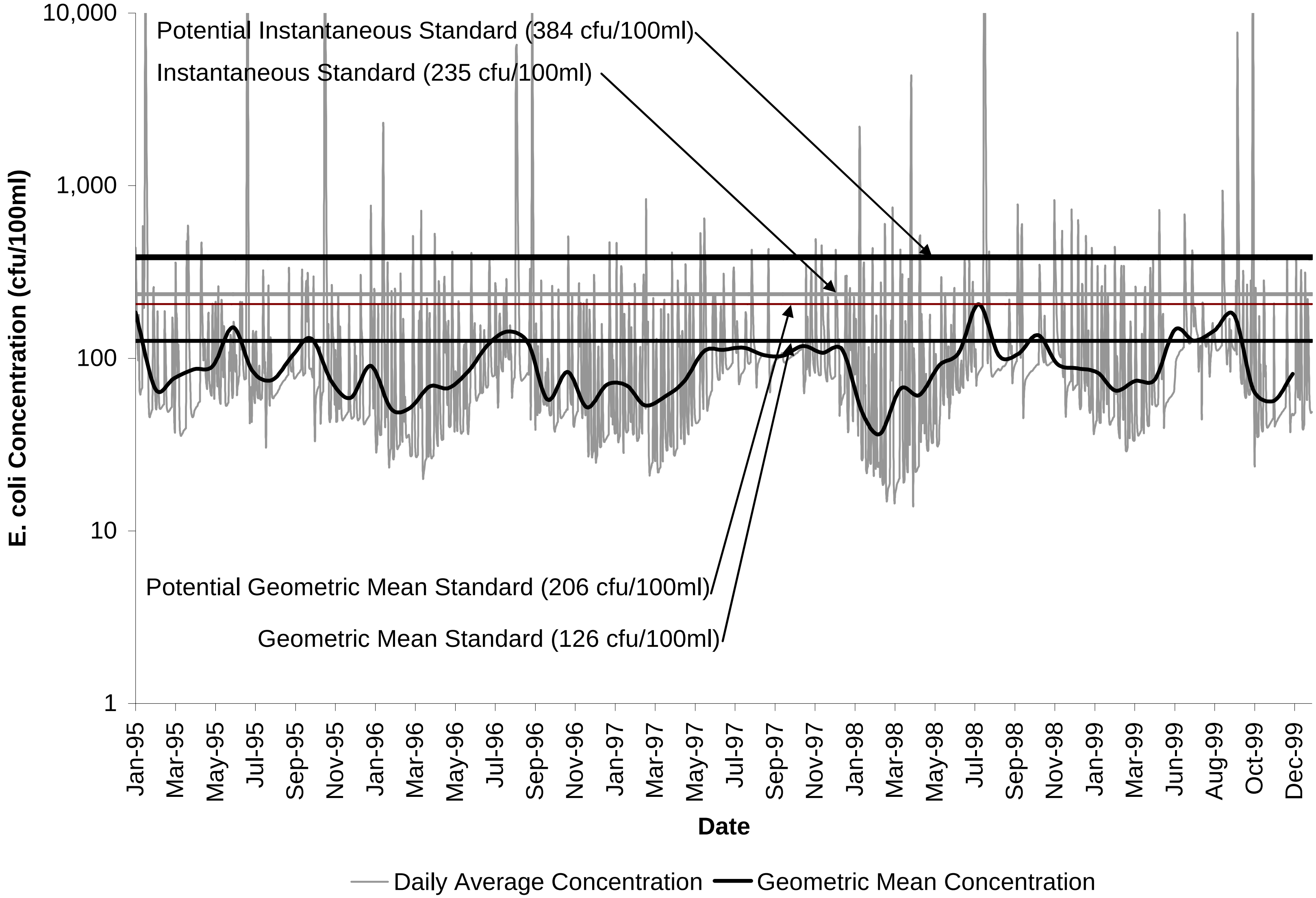

Figure 6.3. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Fishing Creek (VAC-H03R-03) impairment.

6.2.4 *Blackwater Creek (VAC-H03R-01)*

The Stage 1 allocation for the Blackwater Creek (VAC-H03R-01) impairment requires a 100% reduction in straight pipes, no reduction in livestock direct deposition since there is no load associated with this source, 0% reduction in wildlife direct deposition, a 48% reduction in nonpoint source loadings to residential, pasture and cropland land uses. It also requires no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.80% potential instantaneous standard (384 cfu/100 ml) exceedance rate and no violations of the potential geometric mean standard (206 cfu/100 ml). 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 6.4 for the Blackwater Creek (VAC-H03R-01) 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 6.4.

Table 6.4. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Blackwater Creek (VAC-H03R-01) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	3.12E+13	0.00E+00	100
Livestock	0.00E+00	0.00E+00	0
Wildlife	5.24E+12	5.24E+12	0
Total	*3.65E+13*	*5.24E+12*	86%
Land-based			
Residential	1.70E+15	8.85E+14	48
Cropland	8.06E+10	4.19E+10	48
Pasture	1.25E+13	6.52E+12	48
Forest	3.62E+13	3.62E+13	0
Total	*1.75E+15*	*9.28E+14*	47%

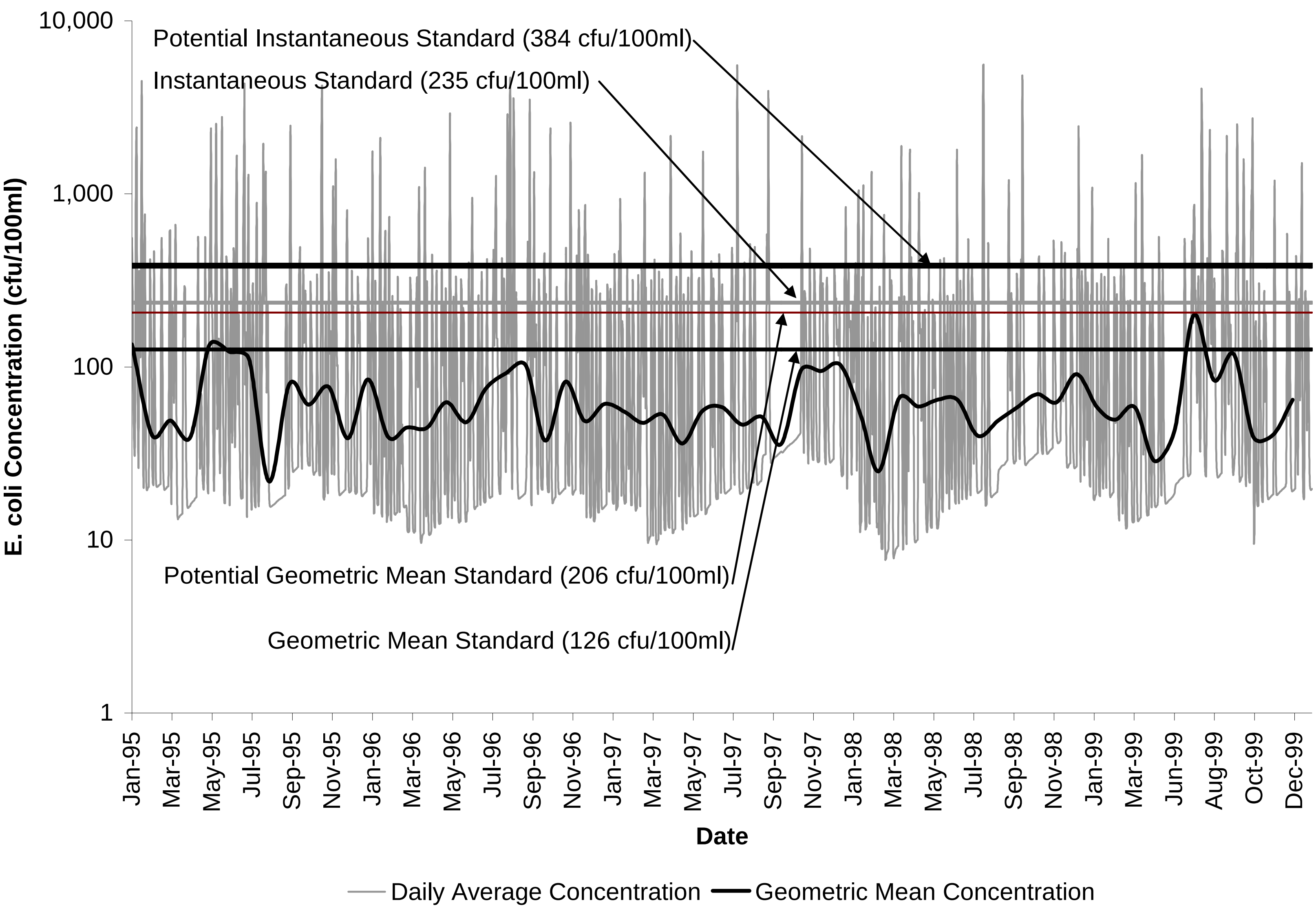

Figure 6.4. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Blackwater Creek (VAC-H03R-01) impairment.

6.2.5 Tomahawk Creek (VAC-H03R-07)

The Stage 1 allocation for the Tomahawk Creek (VAC-H03R-07) impairment requires a 100% reduction in straight pipes, 10% reduction in livestock direct deposition, no reduction in wildlife direct deposition, a 65% reduction in nonpoint source loadings to residential and pasture land uses, a 65% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.97% potential instantaneous standard (384 cfu/100 ml) exceedance rate and no violations of the potential geometric mean standard (206 cfu/100 ml). 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 6.5 for the Tomahawk Creek (VAC-H03R-07) 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 6.5.

Table 6.5. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Tomahawk Creek (VAC-H03R-07) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	2.38E+13	0.00E+00	100
Livestock	6.26E+12	5.64E+12	10
Wildlife	4.82E+12	4.82E+12	0
Total	*3.49E+13*	*1.05E+13*	70%
Land-based			
Residential	1.24E+15	4.33E+14	65
Cropland	8.24E+12	2.88E+12	65
Pasture	1.42E+15	4.97E+14	65
Forest	3.06E+13	3.06E+13	0
Total	*2.70E+15*	*9.64E+14*	64%

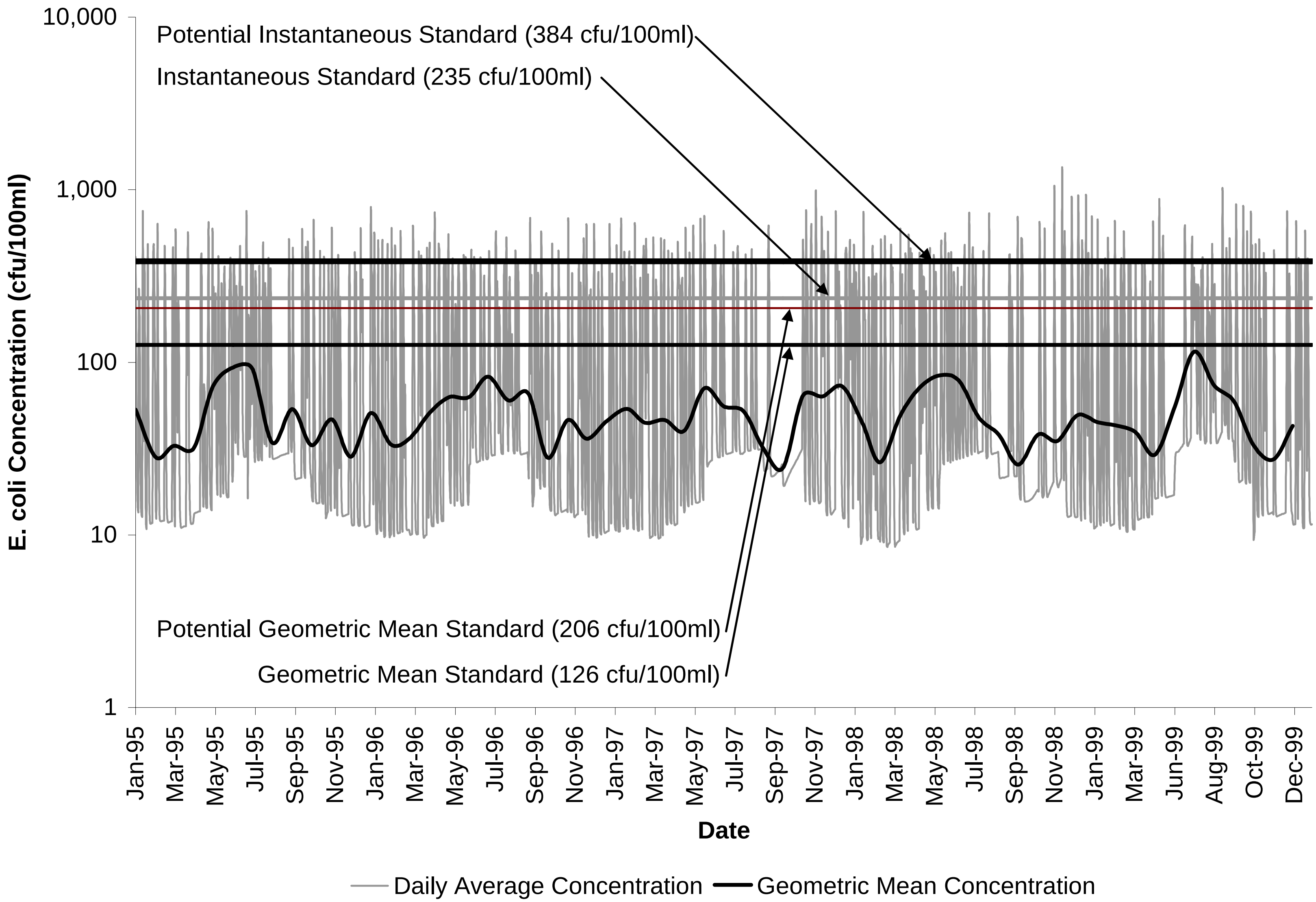

Figure 6.5. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Tomahawk Creek (VAC-H03R-07) impairment.

6.2.6 Burton Creek(VAC-H03R-05)

The Stage 1 allocation for the Burton Creek (VAC-H03R-05) impairment requires a 100% reduction in straight pipes, no reduction in livestock direct deposition, no reduction in wildlife direct deposition, a 72% reduction in nonpoint source loadings to residential, pasture, and cropland land uses, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 8.98% instantaneous standard exceedance rate and no violations of the potential geometric mean standard (206 cfu/100 ml). 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 6.6 for the Burton Creek (VAC-H03R-05) 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 6.6.

Table 6.6. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Burton Creek (VAC-H03R-05) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	6.42E+12	0.00E+00	100
Livestock	2.51E+12	2.51E+12	0
Wildlife	5.91E+12	5.91E+12	0
Total	*1.48E+13*	*8.42E+12*	43%
Land-based			
Residential	1.40E+15	3.92E+14	72
Cropland	0.00E+00	0.00E+00	72
Pasture	4.57E+14	1.28E+14	72
Forest	4.17E+13	4.17E+13	0
Total	*1.90E+15*	*5.62E+14*	70%

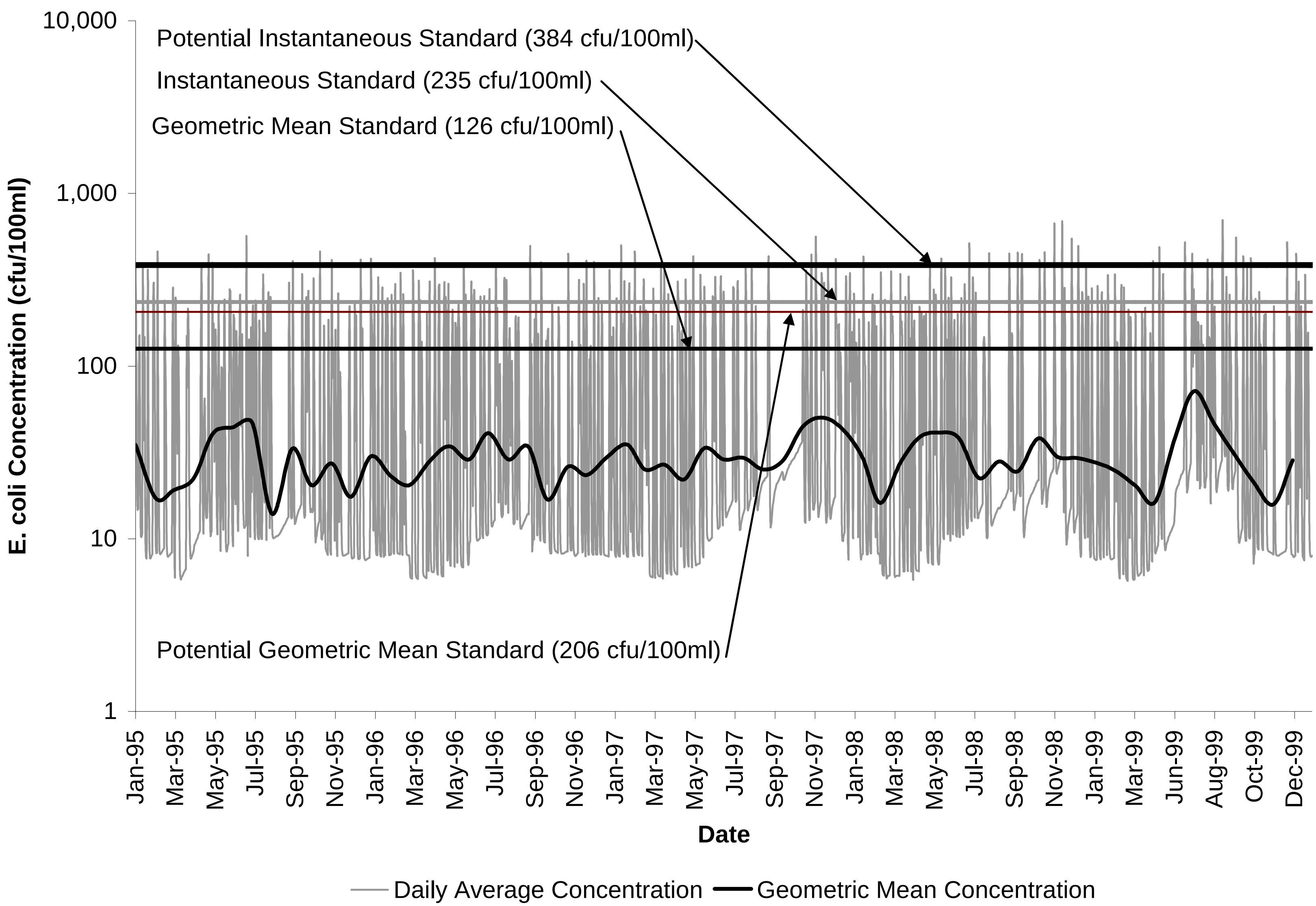

Figure 6.6. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Burton Creek(VAC-H03R-05) impairment.

6.2.7 Judith Creek(VAC-H03R-06)

The Stage 1 allocation for the Judith Creek (VAC-H03R-06) impairment requires a 100% reduction in straight pipes, 40% reduction in livestock direct deposition, and no other load reductions. This is largely a reflection of the potential instantaneous standard used to evaluate the Stage I scenarios. This scenario resulted in a 6.90% instantaneous standard exceedance rate and no violations of the potential geometric mean standard (206 cfu/100 ml). 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 6.7 for the Judith Creek (VAC-H03R-06) 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 6.7.

Table 6.7. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Judith Creek(VAC-H03R-06) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	2.78E+13	0.00E+00	100
Livestock	6.16E+12	3.70E+12	40
Wildlife	8.02E+12	8.02E+12	0
Total	*4.20E+13*	*1.17E+13*	72%
Land-based			
Residential	3.64E+14	3.64E+14	0
Cropland	5.23E+12	5.23E+12	0
Pasture	2.21E+15	2.21E+15	0
Forest	7.07E+13	7.07E+13	0
Total	*2.65E+15*	*2.65E+15*	0%

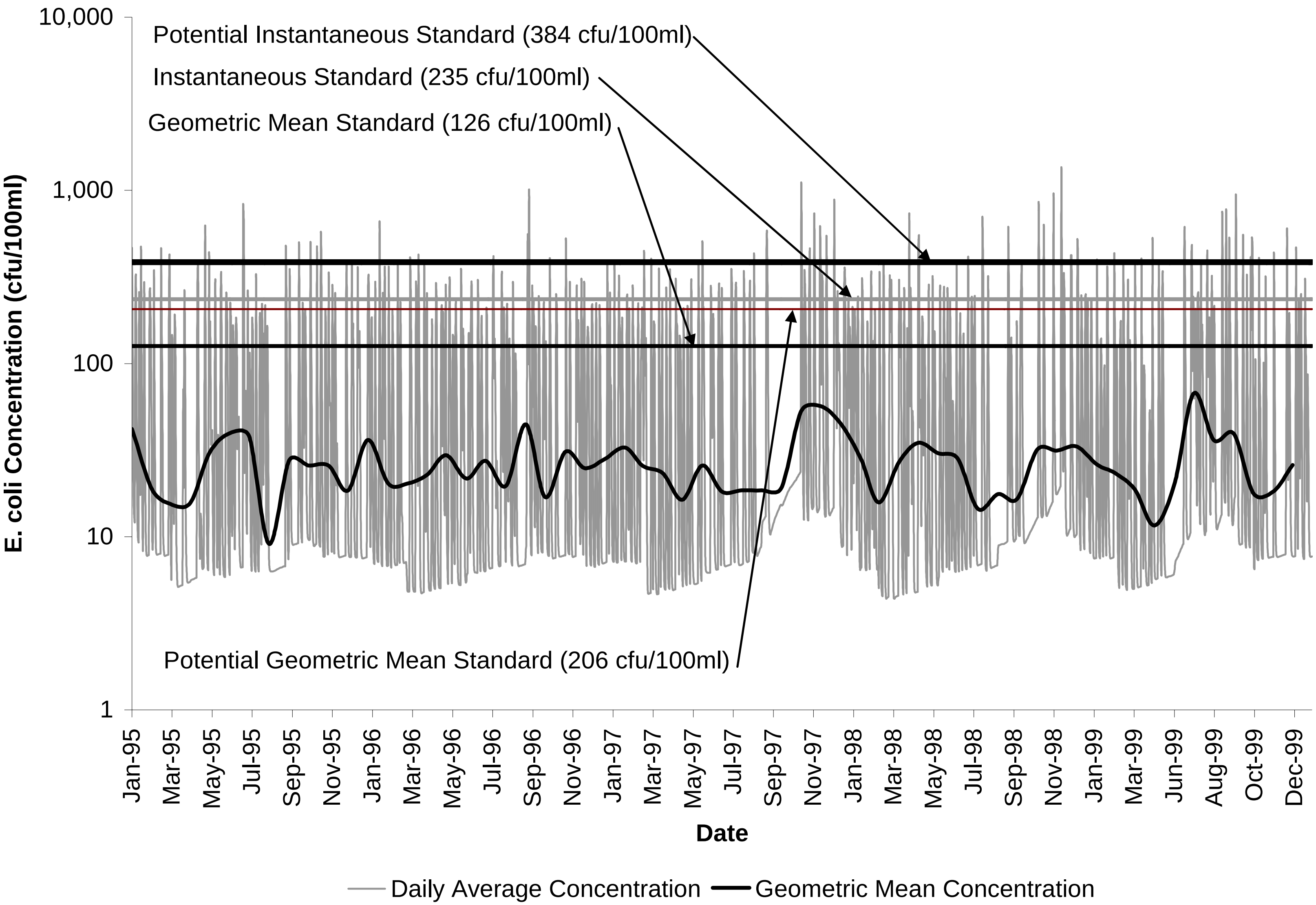

Figure 6.7. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Judith Creek (VAC-H03R-06) impairment.

6.3 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 Chesapeake Bay. Several BMPs known to be effective in controlling bacteria have also been identified for implementation as part of the 2004 Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the Judith Creek Basin. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of the strategy described under nonpoint source implementation mechanisms (2004 Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the James River Basin). Other programs being implemented to affect water quality in the impaired streams include:

- City of Lynchburg Combined Sewer Overflow (CSO) Program
- City of Lynchburg Municipal Separate Storm Sewer System (MS4) Permit
- City of Lynchburg Erosion & Sediment Control Program
- Robert E. Lee Soil and Water Conservation District Programs

6.3.1 CSO Program

The City of Lynchburg owns and operates a combined sanitary and stormwater sewer system which, during periods of rainfall discharges pollutants from permitted outfalls to the James River and certain tributaries of the James River. A Consent Special Order was signed by both the City of Lynchburg and DEQ on August 19, 1994. The Order directs the City to implement elements of the CSO Plan (submitted in December 1989) on a schedule that reflects the limits of its financial capability.

Per the Order, the City of Lynchburg submits an Annual CSO Program status report to the VA Department of Environmental Quality South Central Regional Office. The FY2006 report highlights implementation progress made throughout the year as well as a cumulative overview. Since 1993, $118,117,317 has been authorized for CSO projects, with $106,592,475 in expenditures. Phase 1 of the Citywide Rainleader Disconnect project has been completed. Phase 2 was implemented in September 2000. Of the 14,255,862 total square feet of connected area, 60% or 8,855,708 square feet of impervious area has been disconnected. Construction of all major combined Interceptor sewers, except for the James River Interceptor has been completed. To date, 32 separation construction projects have been completed, are under design or are under construction. As of December 2006, of the original 132 overflow points, 100 have been eliminated, leaving 32 overflow points to be closed in the future.

The VPDES permit authorizes the City's CSO discharges and requires the City to report annually on the progress of its nine minimum controls implementation. The nine minimum controls are as follows:

- Operation and Maintenance
- Use Collection System for Storage
- Pretreatment Program
- Maximize Flow to wastewater Treatment Plan
- Eliminate Dry Weather Overflows
- Control Solids and Floatable Materials in CSO's
- Pollution Control
- Public Notification
- Monitoring
- Biosurvey Monitoring (submit results within 60 days)
- Fecal Coliform Monitoring (significant rainfall events/reported with DMRs)

Upcoming CSO Projects for FY 2008 are:

- 8.1B Ongoing – Peakland Place off Boonsboro Road (James River TMDL Subshed)
- 8.1A Bidding – Opposite side of Boonsboro Road from 8.1B (Ivy Creek TMDL Subshed)
- Pending funds from 2007 GA 8.1C - Opposite side of Boonsboro Road from 8.1B (Ivy Creek TMDL Subshed)
- James River Interceptor Division I Bidding – Lower section from Business Rte 29 to STP (James River TMDL Subshed)
- James River Interceptor Divisions 4-6 Bidding- Blackwater Creek to Judith Creek (James River TMDL Subshed)

6.3.2 MS4 Permit

The City has had a permit to discharge stormwater from its MS4 system since March 27 2003. This current permit will expire on December 9, 2007. Prior to expiration, the City will apply for a new five-year permit.

Under the current permit, the City has taken numerous initiatives to reduce stormwater pollution. Some of the activities completed in accordance with this permit are:

- revised its Stormwater Ordinance to prohibit illicit discharges,
- created an illicit discharge detection and elimination (IDDE) program,
- mapped the stormwater collection system,
- created a database of existing stormwater best management practices (BMPs),
- created a BMP design manual, and
- published a booklet entitled “Living In Your Watershed” which is distributed annually to all fourth grade students in the City schools.

The City will be applying for a new permit by December 7, 2007. The requirements for this application have not yet been published by the Virginia Department of Conservation and Recreation (DCR). However, based on the previous permit, some anticipated activities include:

- implementing the IDDE program,
- expanding the BMP database,
- inspecting existing BMPs, and
- requiring maintenance of existing BMPs by private owners.

In general, for MS4/VSMP permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the iterative implementation of programmatic BMPs. BMP effectiveness would be determined through permittee implementation of an individual control strategy that includes a monitoring program that is sufficient to determine its BMP effectiveness. As stated in EPA’s Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002, “The NPDES permits must require the monitoring necessary to assure compliance under the permit limits.” Ambient in-stream monitoring would not be an appropriate means of determining permit compliance. Ambient monitoring would be appropriate to determine if the entire TMDL is being met by ALL attributed sources. This is in accordance with recent EPA guidance. If future monitoring indicates no improvement in the quality of the regulated discharge, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit.

Any changes to the TMDL resulting from water quality standards changes on the James River and certain tributaries would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed as a condition of the MS4 permit. An impairment control plan will identify types of corrective actions and strategies to obtain the load allocation for the pollutant causing the water quality impairment. Permittees will be required to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL. For example, MS4 permittees regulate erosion and sediment control programs that affect discharges that are not regulated by the MS4 permit.

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

6.3.3 Erosion & Sediment Control Program

The City has an Erosion and Sediment Control Ordinance that is actively enforced. The program is administered in two separate components, one devoted to public development that is administered by the Planning Division, and one devoted to public development projects that is administered by the Engineering Division.

The Planning Division program has one full time plan reviewer, one full time inspector, and one part time program administrator. The Engineering Division program has one part time plan reviewer, five part time inspectors, and two part time program administrators. Within the past year, 390 land disturbing activities were tracked under these combined programs.

6.3.4 District Programs

The Robert E. Lee Soil & Water Conservation District has hired a TMDL Agricultural Best Management Practice Technician through funding provided by the Department of Conservation and Recreation (DCR).

Amherst County Watershed Protection Program

Virginia Agricultural Best Management Practices Cost-Share Program

Virginia Agricultural BMP tax Credit Program

Educational Programs

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. DEQ’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, 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.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR 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 DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR 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 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 DEQ’s standard monitoring plan. Ancillary monitoring by citizens’, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ 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/.

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), DEQ 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.

6.4.2 Regulatory Framework

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

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (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. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the 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 with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

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 is the municipal separate storm sewer systems (MS4s) which are both covered by NPDES permits and expected to be included in TMDL implementation plans, as described in the stormwater permit section below.

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

In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ 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.

DEQ staff will present both EPA-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.

DEQ 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 DEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

6.4.3 Stormwater Permits

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 from municipal separate storm sewer systems (MS4s).

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

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

The City of Lynchburg and the Virginia Department of Transportation each have a MS4 permit that whose limits are defined by the city boundary. These MS4 permits discharge within the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), and Blackwater Creek (VAC-H03R-01) Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) watersheds. The permitted point source discharges are described in Table 3.2. For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the implementation of programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent USEPA guidance (USEPA Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered an exceedance of the permit. Current activities associated with the MS4 permits are described in Section 6.3.

VADEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacteria TMDLs (see section 6.4.5 below). At some future time, it may therefore become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis. Any changes to the TMDL resulting from water quality standards change on James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-03), Blackwater Creek(VAC-H03R-01), Tomahawk Creek(VAC-H03R-07), Burton Creek(VAC-H03R-05), Judith Creek (VAC-H03R-06) would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by the MS4 permits were included in the development of these TMDLs, and are quantified in Section2 5.4.1 through 5.4.7. An implementation plan will identify types of corrective actions and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Management program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/soil_&_water/stormwat.shtml

6.4.4 Implementation Funding Sources

The implementation of 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, the Virginia State

Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

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.

6.4.5 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. This condition was not observed in this study. 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.

6.4.6 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).

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

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate:

1. that the use is not an existing use;
2. that downstream uses are protected;
3. that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for non-point source control (9 VAC 25-260-10);
4. 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;
5. 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;
6. 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;
7. 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
8. 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.

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted primarily at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance populations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 8.2 above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

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 use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that “If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed.”

Chapter 7. Public Participation

The development of the the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) TMDLs would not have been possible without public participation.

The first public meeting was held at Lynchburg College in Lynchburg, Virginia on July 17, 2006 to discuss the need for a TMDL, discuss the draft watershed source assessment, and review the approach for TMDL development. Twenty four people attended the first public meeting. Copies of the presentation materials, watershed history results, source assessment per subwatershed, and various TMDL information handouts were available for public distribution. Public notice of the meetings was printed in the Virginia Register on July 10, 2006 and advertised on the VADEQ and Region 2000 Local Government Council websites. Notification regarding the meetings was sent to area appointed and elected officials and Technical Advisory Committee (TAC) members. Members of the TAC were encouraged to inform others of the meetings as appropriate. The general public was notified of the meeting through advertisements in the community calendar section of local newspapers, and through post card mailings, randomly distributed throughout the watershed. There was a 30-day public comment period for the public meeting (July 17, 2006 to August 23, 2006), however, no written comments were received.

The second and final public meetings will be held at the Lynchburg Public Library in Lynchburg, Virginia on May 3, 2007 to discuss the source allocations and reductions required to meet the TMDL. Copies of the draft TMDL report will be available for public review and comment. Public notice of the meeting was printed in the Virginia Register on April 2, 2007 and advertised on the VADEQ and Region 2000 Local Government Council websites. Notification regarding the meetings was sent to area appointed and elected officials, TAC members, and prior public meeting attendees. Members of the TAC were encouraged to inform others of the meetings as appropriate. The general public was notified of the meeting through advertisements in the community calendar section of local newspapers. There will be a 30-day public comment period for these meetings that extends from May 3, 2007 to June 4, 2007.

In addition to keeping the public apprised of progress in the development of the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) TMDLs, a TMDL TAC was also established to help advise the TMDL developers. TAC meetings were held prior to public meetings, with a third meeting added in the middle of the process to accommodate more detailed feedback on the TMDL development. TAC meetings were held for this project on June 26, 2006, November 14, 2006, and February 26, 2007 at the Region 2000 Local Government Council office in Lynchburg, Virginia. The TAC membership for the James River (VAC-H03R-04), Ivy Creek (VAC-H03R-03), Fishing Creek (VAC-H03R-02), Blackwater Creek (VAC-H03R-01), Tomahawk Creek (VAC-H03R-07), Burton Creek (VAC-H03R-05), and Judith Creek (VAC-H03R-06) TMDLs included representatives from the following agencies and organizations:

- Virginia Department of Environmental Quality
- Virginia Department of Conservation and Recreation
- Virginia Department of Health
- Virginia Department of Game & Inland Fisheries
- Virginia Department of Forestry
- Virginia Cooperative Extension
- Region 2000 Local Government Council
- Robert E. Lee and Peaks of Otter SWCDs
- City of Lynchburg Government
- Amherst County Government
- Campbell County Government
- Bedford County Government
- City of Lynchburg Utilities
- Amherst County Service Authority
- Bedford County Public Service Authority
- Campbell County Utilities and Service Authority
- U.S. Department of Agriculture – Natural Resources Conservation Service
- Lynchburg College
- Liberty University
- Sweet Briar College
- James River Association
- Greater Lynchburg Environmental Network

16, 19, and 16 people attended the June, November, and February meetings, respectively. TAC meetings were used as a forum to review data and assumptions used in the modeling, and to provide local government agencies 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 geomorphological 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.

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.

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

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 deposits of fecal material to streams from livestock and wildlife.

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.

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).

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.

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.

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.

References

ASAE Standards, 45th edition. 1998. D384.1 DEC93. Manure production and characteristics. St. Joseph, Mich.: ASAE. Census Bureau. 2000. Washington, D.C.:

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

BSE (Department of Biological Systems Engineering, Virginia Tech). 2003. Bacteria TMDLs for Abrams Creek and Upper and Lower Opequon Creek Located in Frederick and Clarke County, Virginia.

CTWS (Center for TMDL and Watershed Studies, Virginia Tech), 2004. Bacteria Source Load Calculator.

Bicknell, B., J. Imhoff, J. Kittle, Jr., and A. Donigian, Jr. 2000.Hydrological Simulation Program – Fortran (HSPF): User Manual for Release 12.

Geldreich, E.E. 1978. Bacterial populations and indicator concepts in feces, sewage, stormwater and solid wastes. In Indicators of Viruses in Water and Food, ed. G. Berg, ch. 4, 51-97. Ann Arbor, Mich.: Ann Arbor Science Publishers, Inc.

Keeling, W. 2003. Virginia Department of Conservation and Recreation. Compilation of bacteria source data.

NCDC (National Climatic Data Center). 2003. (http://www.ncaa.gov/oa/ncdc.html).

NRCS (Natural Resources Conservation Service). 2004. Official Soil Series Descriptions: USDA-NRCS Soil Survey Division. (http://ortho.ftw.nrcs.usda.gov/cgi-bin/osd/osdname.cgi).

Orange County, 1999. Orange County, Virginia Comprehensive Plan – Office of Planning and Community Development.

SAIC (Science Applications International Corporation). 2001. Fecal Coliform TMDL (Total Maximum Daily Load) Development for Holmans Creek, Virginia. Prepared for VADEQ and VADCR.

SCS (U.S. Department of Agricultural - Soil Conservation Service). 1974. Soil Survey of Stafford and King George Counties, Virginia. U.S. Government Printing Office, Washington, D.C.

SERCC (Southeast Regional Climate Center). 2006. South Carolina Department of Natural Resources, 1000 Assembly Street, Suite 230, Columbia, SC 29201. (http://www.sercc.com/climateinfo/historical/historical_va.html)

Swanson, C. 2006. Virginia Department of Health. Compilation of fecal coliform densities of biosolids applied in Virginia.

USCB (U.S. Census Bureau). 1990. 1990 U.S. Census Block Data. (http://www.census.gov)

USCB (U.S. Census Bureau). 2000. 2000 U.S. Census Block Data. (http://www.census.gov)

USEPA (U.S. Environmental Protection Agency). 1991. Guidance for Water Quality-based Decisions: The TMDL Process. EPA 440/4-91-001. Washington, D.C.: Office of Water, USEPA.

USEPA (U.S. Environmental Protection Agency). 2000. BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF. EPA Doc No: 823-R00-012. Washington, D.C. 29 - 32 pp.

USEPA (U.S. Environmental Protection Agency). 2001. Better Assessment Science Integrating Point and Nonpoint Sources (BASINS 3.0): User's Manual. EPA Doc No: 823-B-01-001. Washington D.C. 337 pp.

USGS (U.S. Geological Survey). 2004. Daily Streamflow for the Nation. (http://waterdata.usgs.gov/nwis/discharge).

VADEQ (Virginia Department of Environmental Quality). 2000. Fecal Coliform Bacteria; Other Waters (9VAC25-260-170). Richmond, VA.: VADEQ. (http://leg1.state.va.us/cgi-bin/legp504.exe?000+reg+9VAC25-260-170)

VADEQ (Virginia Department of Environmental Quality). 2003. 2002 Section 303(d) List of Impaired Waters. (http://www.deq.state.va.us/water/303d.html)

VADEQ (Virginia Department of Environmental Quality). 2004. 2004 Section 303(d) List of Impaired Waters. (http://www.deq.state.va.us/water/303d.html)

VADEQ (Virginia Department of Environmental Quality). 2006. 2006 Section 303(d) List of Impaired Waters. (http://www.deq.state.va.us/water/303d.html)

VASS (Virginia Agricultural Statistics Service). 2002. 2001 Virginia Equine Report. Virginia Agricultural Statistics Service. Richmond, Virginia.

VDH (Virginia Department of Health). 1997. Biosolids Use Regulations. 12 VAC 5-585. Virginia Department of Health, Richmond, Virginia.

VWCB (Virginia Water Control Board). 1985. Ground Water Map of Virginia, ed. P.J. Smith and R.P. Ellison. Richmond, VA.: Virginia Water Control Board (VWCB) Ground Water Program.

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

Woods, A.J., J.M. Omernik, D.D. Brown. 1999. Level III and IV Ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. Corvallis, Or.: USEPA. (ftp://ftp.epa.gov/wed/ecoregions/reg3/FinalFullRgnIIIText3).

Yagow, G. 2001. Fecal Coliform TMDL: Mountain Run Watershed, Culpeper County, Virginia. Available at: http://www.deq.state.va.us

Appendix A – Historic Water Quality Data

Table A.1. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	11/24/70	600		0.33
2-JMS258.54	12/14/70	1000		0.38
2-JMS258.54	1/19/71	300		0.13
2-JMS258.54	2/15/71	4200		0.84
2-JMS258.54	4/19/71	8000		0
2-JMS258.54	5/9/71	600		0.89
2-JMS258.54	6/17/71	500		1.04
2-JMS258.54	7/19/71	8000		0.29
2-JMS258.54	8/4/71	100		1.62
2-JMS258.54	9/29/71	100		0.01
2-JMS258.54	10/21/71	400		0.31
2-JMS258.54	11/16/71	500		0
2-JMS258.54	12/8/71	1600		0.82
2-JMS258.54	1/4/72	6000		0.7
2-JMS258.54	2/28/72	100		1.04
2-JMS258.54	3/14/72	10		0.3
2-JMS258.54	4/18/72	6000		0.49
2-JMS258.54	4/30/72	180		0
2-JMS258.54	6/7/72	1500		0.1
2-JMS258.54	7/17/72	100		2.08
2-JMS258.54	7/31/72	100		3.86
2-JMS258.54	9/13/72	200		0
2-JMS258.54	10/24/72	100		0.66
2-JMS258.54	11/9/72	100		0.84
2-JMS258.54	12/5/72	100		0.31
2-JMS258.54	1/24/73	1100		1.31
2-JMS258.54	2/12/73	100		0.35
2-JMS258.54	2/28/73	100		0.28

Table A.2. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	4/5/73	400		1.26
2-JMS258.54	4/30/73	200		2.53
2-JMS258.54	7/21/73	400		3.18
2-JMS258.54	10/4/73	600		1.31
2-JMS258.54	11/13/73	100		0.02
2-JMS258.54	1/14/74	100		0.67
2-JMS258.54	2/22/74	100		0.34
2-JMS258.54	4/17/74	100		0.12
2-JMS258.54	6/16/74	500		0.93
2-JMS258.54	7/25/74	100		0.28
2-JMS258.54	8/21/74	100		0.56
2-JMS258.54	9/26/74	200		0.01
2-JMS258.54	10/15/74	100		0
2-JMS258.54	11/20/74	100		0.38
2-JMS258.54	1/10/75	100		0.68
2-JMS258.54	2/24/75	200		0.37
2-JMS258.54	3/11/75	100		0.87
2-JMS258.54	4/10/75	100		0.11
2-JMS258.54	5/30/75	400		3
2-JMS258.54	6/10/75	100		0.61
2-JMS258.54	7/16/75	100		2.3
2-JMS258.54	7/31/75	100		0
2-JMS258.54	9/22/75	100		3.25
2-JMS258.54	10/7/75	100		0.01
2-JMS258.54	12/11/75	400		0.96
2-JMS258.54	1/9/76	200		0.38
2-JMS258.54	2/23/76	100		1.4
2-JMS258.54	3/9/76	6000		1.61

Table A.3. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	4/22/76	100		0.1
2-JMS258.54	5/7/76	200		0
2-JMS258.54	6/24/76	100		2.75
2-JMS258.54	7/16/76	100		0.19
2-JMS258.54	8/9/76	100		0.29
2-JMS258.54	9/21/76	100		0
2-JMS258.54	10/7/76	100		1.43
2-JMS258.54	11/19/76	100		0.02
2-JMS258.54	4/5/77	2200		2.73
2-JMS258.54	5/23/77	100		0
2-JMS258.54	6/7/77	100		0.25
2-JMS258.54	7/27/77	100		0.36
2-JMS258.54	8/19/77	100		1.91
2-JMS258.54	12/16/77	100		0.87
2-JMS258.54	2/23/78	100		0.15
2-JMS258.54	3/9/78	100		0.53
2-JMS258.54	5/9/78	400		3.53
2-JMS258.54	6/27/78	100		1.59
2-JMS258.54	7/18/78	100		1.32
2-JMS258.54	8/11/78	100		0.37
2-JMS258.54	9/25/78	100		0.02
2-JMS258.54	10/17/78	100		0.09
2-JMS258.54	11/16/78	100		0.81
2-JMS258.54	12/14/78	100		1.18
2-JMS258.54	3/19/79	100		0.12
2-JMS258.54	4/11/79	100		0.29
2-JMS258.54	5/3/79	100		0.01
2-JMS258.54	6/18/79	200		1.47

Table A.4. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	7/10/79	100		0.29
2-JMS258.54	8/13/79	100		1.4
2-JMS258.54	9/17/79	300		0.45
2-JMS258.54	10/22/79	200		0
2-JMS258.54	11/8/79	100		0.02
2-JMS258.54	2/14/80	100		0.29
2-JMS258.54	3/24/80	300		1.96
2-JMS258.54	4/10/80	2100		1.08
2-JMS258.54	5/8/80	100		0.23
2-JMS258.54	6/12/80	100		0.06
2-JMS258.54	8/1/80	100		0.43
2-JMS258.54	10/14/80	100		0
2-JMS258.54	11/12/80	100		0.17
2-JMS258.54	12/8/80	100		0.01
2-JMS258.54	1/15/81	1100		0.01
2-JMS258.54	2/11/81	300		1.46
2-JMS258.54	3/9/81	100		0.64
2-JMS258.54	4/2/81	100		0.59
2-JMS258.54	5/11/81	100		0.31
2-JMS258.54	6/26/81	200		0.33
2-JMS258.54	7/6/81	3100		3.18
2-JMS258.54	8/20/81	100		0.05
2-JMS258.54	9/14/81	200		0
2-JMS258.54	10/27/81	200		2.6
2-JMS258.54	11/13/81	100		0
2-JMS258.54	12/15/81	3600		1.73
2-JMS258.54	1/25/82	1500		0.74
2-JMS258.54	2/1/82	1700		0.23

Table A.5. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	3/10/82	1200		0.99
2-JMS258.54	4/13/82	200		0.33
2-JMS258.54	5/18/82	4000		0.91
2-JMS258.54	6/29/82	900		0
2-JMS258.54	7/13/82	2500		1.39
2-JMS258.54	8/11/82	5100		1.78
2-JMS258.54	9/7/82	200		0.28
2-JMS258.54	10/14/82	4100		1.55
2-JMS258.54	11/22/82	200		0.17
2-JMS258.54	12/13/82	400		0.8
2-JMS258.54	1/10/83	300		0.11
2-JMS258.54	2/9/83	1100		0.4
2-JMS258.54	3/9/83	1300		0.81
2-JMS258.54	4/20/83	400		1.13
2-JMS258.54	5/23/83	3000		1.55
2-JMS258.54	6/2/83	600		0.22
2-JMS258.54	7/19/83	100		0
2-JMS258.54	8/8/83	400		0
2-JMS258.54	9/15/83	8000		0.66
2-JMS258.54	10/13/83	8000		2.05
2-JMS258.54	11/14/83	700		1.19
2-JMS258.54	12/8/83	600		1.79
2-JMS258.54	1/31/84	200		0.21
2-JMS258.54	2/16/84	2200		2.94
2-JMS258.54	3/5/84	5300		0.46
2-JMS258.54	4/12/84	300		0.55
2-JMS258.54	5/16/84	100		0

Table A.6. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	6/14/84	700		0
2-JMS258.54	7/23/84	2600		6.21
2-JMS258.54	8/13/84	8000		4.4
2-JMS258.54	9/4/84	8000		1.07
2-JMS258.54	10/31/84	1100		0.04
2-JMS258.54	1/16/85	100		0
2-JMS258.54	2/14/85	500		1.26
2-JMS258.54	3/13/85	700		0.11
2-JMS258.54	4/8/85	100		0.07
2-JMS258.54	5/13/85	8000		1.51
2-JMS258.54	6/17/85	3500		0.16
2-JMS258.54	7/11/85	8000		0.21
2-JMS258.54	8/5/85	8000		0.49
2-JMS258.54	9/12/85	8000		0
2-JMS258.54	10/15/85	100		0.01
2-JMS258.54	11/19/85	200		0.14
2-JMS258.54	12/11/85	900		0.01
2-JMS258.54	1/13/86	100		0
2-JMS258.54	2/5/86	500		0.37
2-JMS258.54	3/5/86	400		0
2-JMS258.54	4/3/86	100		0.07
2-JMS258.54	5/15/86	4900		1.91
2-JMS258.54	6/16/86	2100		0.34
2-JMS258.54	7/2/86	8000		0.49
2-JMS258.54	8/4/86	100		0.61
2-JMS258.54	9/2/86	200		0.49
2-JMS258.54	10/14/86	8000		1.31
2-JMS258.54	11/13/86	700		0.5

Table A.7. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	12/10/86	4100		0.63
2-JMS258.54	1/15/87	300		0.22
2-JMS258.54	2/5/87	500		0.01
2-JMS258.54	3/10/87	100		0.13
2-JMS258.54	4/8/87	100		0.42
2-JMS258.54	5/5/87	1600		0.81
2-JMS258.54	7/20/87	500		0
2-JMS258.54	8/3/87	300		0.04
2-JMS258.54	9/1/87	100		0.01
2-JMS258.54	10/1/87	1600		0.45
2-JMS258.54	11/4/87	100		0
2-JMS258.54	12/2/87	1100		1.38
2-JMS258.54	1/5/88	100		0.16
2-JMS258.54	3/2/88	100		0
2-JMS258.54	4/4/88	8000		1.22
2-JMS258.54	5/2/88	200		0.15
2-JMS258.54	6/8/88	100		0.59
2-JMS258.54	7/6/88	100		0
2-JMS258.54	8/22/88	100		0.58
2-JMS258.54	9/8/88	200		0.71
2-JMS258.54	10/5/88	1300		0.84
2-JMS258.54	11/17/88	8000		1.16
2-JMS258.54	12/6/88	100		0
2-JMS258.54	1/10/89	100		0.45
2-JMS258.54	2/2/89	100		0.1
2-JMS258.54	3/22/89	100		0.82
2-JMS258.54	4/3/89	300		0.02
2-JMS258.54	4/11/89	100		0.89

Table A.8. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	5/9/89	1200		3.01
2-JMS258.54	6/13/89	3800		2.72
2-JMS258.54	7/12/89	100		0.29
2-JMS258.54	8/7/89	8000		0.16
2-JMS258.54	9/12/89	8000		2.26
2-JMS258.54	10/11/89	100		0
2-JMS258.54	11/7/89	100		0.35
2-JMS258.54	12/6/89	100		0.02
2-JMS258.54	1/17/90	100		0
2-JMS258.54	2/15/90	600		1.19
2-JMS258.54	3/14/90	100		0.04
2-JMS258.54	4/11/90	1700		1.07
2-JMS258.54	5/14/90	900		1.53
2-JMS258.54	6/12/90	1000		2.07
2-JMS258.54	7/12/90	8000		0.42
2-JMS258.54	8/13/90	300		0.05
2-JMS258.54	10/16/90	3000		3.63
2-JMS258.54	11/7/90	1500		0.1
2-JMS258.54	12/6/90	8000		2.05
2-JMS258.54	1/14/91	800		1.61
2-JMS258.54	2/12/91	100		0.08
2-JMS258.54	3/19/91	2000		1.35
2-JMS258.54	4/2/91	700		1.94
2-JMS258.54	5/1/91	2200		0.85
2-JMS258.54	6/6/91	100		0.06
2-JMS258.54	8/20/91	8000		0.08
2-JMS258.54	9/23/91	100		0.02
2-JMS258.54	10/15/91	100		0.07

Table A.9. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	12/5/91	100		3.18
2-JMS258.54	1/15/92	200		0.09
2-JMS258.54	2/19/92	1000		0.91
2-JMS258.54	3/19/92	100		0.23
2-JMS258.54	4/27/92	1700		0.11
2-JMS258.54	5/20/92	1000		0.98
2-JMS258.54	6/18/92	200		0.17
2-JMS258.54	7/21/92	100		0.59
2-JMS258.54	8/24/92	100		0
2-JMS258.54	9/22/92	100		0.23
2-JMS258.54	10/21/92	100		0
2-JMS258.54	11/9/92	100		1.03
2-JMS258.54	12/15/92	100		1.61
2-JMS258.54	2/17/93	3800		1.77
2-JMS258.54	3/23/93	7800		0.78
2-JMS258.54	4/19/93	1900		1.62
2-JMS258.54	5/19/93	6600		0.95
2-JMS258.54	6/21/93	100		0
2-JMS258.54	7/21/93	500		0.67
2-JMS258.54	8/18/93	100		0
2-JMS258.54	9/23/93	100		0.39
2-JMS258.54	10/25/93	100		0.24
2-JMS258.54	11/4/93	100		0.88
2-JMS258.54	12/1/93	2600		2.09
2-JMS258.54	1/13/94	1300		1.02
2-JMS258.54	2/15/94	2200		2.66
2-JMS258.54	3/16/94	100		0
2-JMS258.54	4/19/94	700		0.09

Table A.10. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	5/12/94	200		0.23
2-JMS258.54	6/29/94	200		2.26
2-JMS258.54	7/18/94	800		2.11
2-JMS258.54	8/10/94	500		0
2-JMS258.54	9/20/94	100		0.47
2-JMS258.54	10/25/94	200		0.32
2-JMS258.54	11/9/94	100		0
2-JMS258.54	12/15/94	900		0.94
2-JMS258.54	1/11/95	800		1.02
2-JMS258.54	2/7/95	100		0.36
2-JMS258.54	3/7/95	100		0.17
2-JMS258.54	4/11/95	100		0.01
2-JMS258.54	5/4/95	600		1.44
2-JMS258.54	6/7/95	3100		1.46
2-JMS258.54	7/25/95	4400		2.95
2-JMS258.54	8/16/95	100		0
2-JMS258.54	10/18/95	100		1.02
2-JMS258.54	11/16/95	2400		1.05
2-JMS258.54	12/13/95	8000		0.33
2-JMS258.54	1/22/96	1400		1.83
2-JMS258.54	2/20/96	200		0.79
2-JMS258.54	3/11/96	500		0.97
2-JMS258.54	4/10/96	100		0.1
2-JMS258.54	5/8/96	1000		1.65
2-JMS258.54	6/11/96	3400		1.42
2-JMS258.54	7/22/96	100		0.13
2-JMS258.54	8/14/96	800		1.74
2-JMS258.54	9/18/96	600		1.5

Table A.11. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	10/9/96	6200		1.92
2-JMS258.54	11/5/96	800		0.25
2-JMS258.54	12/11/96	200		0.7
2-JMS258.54	1/7/97	100		0.16
2-JMS258.54	2/3/97	100		0.01
2-JMS258.54	3/5/97	1700		2.27
2-JMS258.54	4/2/97	100		0.26
2-JMS258.54	5/15/97	1900		0.34
2-JMS258.54	6/18/97	400		0.58
2-JMS258.54	7/16/97	100		0.31
2-JMS258.54	8/11/97	100		0.05
2-JMS258.54	9/8/97	100		0.31
2-JMS258.54	10/15/97	100		0
2-JMS258.54	11/5/97	100		2.19
2-JMS258.54	12/3/97	100		0.7
2-JMS258.54	1/6/98	100		0.67
2-JMS258.54	2/10/98	100		0.58
2-JMS258.54	3/4/98	100		0.57
2-JMS258.54	4/21/98	1100		2.73
2-JMS258.54	5/13/98	100		0.55
2-JMS258.54	6/15/98	8000		0.9
2-JMS258.54	7/13/98	100		0.2
2-JMS258.54	8/4/98	100		0
2-JMS258.54	9/17/98	1300		0.79
2-JMS258.54	10/21/98	100		0
2-JMS258.54	11/19/98	100		0.04
2-JMS258.54	12/1/98	100		0.15
2-JMS258.54	1/25/99	900		1.67

Table A.12. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	2/9/99	100		100
2-JMS258.54	3/8/99	100		100
2-JMS258.54	4/13/99	300		300
2-JMS258.54	5/18/99	500		500
2-JMS258.54	6/7/99	100		100
2-JMS258.54	7/19/99	1500		1500
2-JMS258.54	8/9/99	100		100
2-JMS258.54	10/25/99	100		100
2-JMS258.54	11/9/99	100		100
2-JMS258.54	12/7/99	1000		1000
2-JMS258.54	1/11/00	6200		6200
2-JMS258.54	2/8/00	100		100
2-JMS258.54	3/2/00	100		100
2-JMS258.54	4/18/00	2700		2700
2-JMS258.54	5/17/00	100		100
2-JMS258.54	6/27/00	500		500
2-JMS258.54	7/20/00	8000		8000
2-JMS258.54	8/17/00	100		100
2-JMS258.54	9/18/00	100		100
2-JMS258.54	10/24/00	100		100
2-JMS258.54	11/28/00	100		100
2-JMS258.54	12/18/00	900		900
2-JMS258.54	1/29/01	500		500
2-JMS258.54	2/21/01	300		300
2-JMS258.54	4/3/01	100		100
2-JMS258.54	5/10/01	100		100
2-JMS258.54	6/7/01	1500		1500
2-JMS258.54	7/10/01	200		200

Table A.13. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS258.54 in James River (VAC-H03R-04) 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)
2-JMS258.54	9/18/01	100		0.01
2-JMS258.54	11/20/01	100		0
2-JMS258.54	1/22/02	100		0.91
2-JMS258.54	3/11/02	100		0.11
2-JMS258.54	5/23/02	100		0.31
2-JMS258.54	7/1/02	100		0.3
2-JMS258.54	9/16/02	100		0.29
2-JMS258.54	11/12/02	8000		2.77
2-JMS258.54	1/28/03	100		0.71
2-JMS258.54	4/9/03	6300		0.29
2-JMS258.54	6/26/03	100		0.07
2-JMS258.54	8/11/03	1700		0
2-JMS258.54	10/14/03	1500		1.05
2-JMS258.54	12/16/03	100		1.2
2-JMS258.54	2/3/04	2000		0.32
2-JMS258.54	4/20/04	100		0.29
2-JMS258.54	6/7/04	120		3.07
2-JMS258.54	8/16/04	250		0.77
2-JMS258.54	10/26/04	75		0.88
2-JMS258.54	12/16/04	75		1.19

Table A.14. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS260.46 in James River (VAC-H03R-04) 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)
2-JMS260.46	4/3/89	200		0.02

Table A.15. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JMS270.84 in James River (VAC-H03R-04) 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)
2-JMS270.84	11/20/74	100		0.38
2-JMS270.84	4/10/75	100		0.11
2-JMS270.84	8/18/93	100		0
2-JMS270.84	11/4/93	100		0.88
2-JMS270.84	2/15/94	200		2.66
2-JMS270.84	5/12/94	100		0.23
2-JMS270.84	7/10/01	100		0.46
2-JMS270.84	9/18/01	100		0.01
2-JMS270.84	11/20/01	100		0
2-JMS270.84	1/22/02	100		0.91
2-JMS270.84	3/11/02	100		0.11
2-JMS270.84	5/23/02	100		0.31
2-JMS270.84	7/1/02	100		0.3
2-JMS270.84	9/16/02	100		0.29
2-JMS270.84	11/12/02	1000		2.77
2-JMS270.84	1/28/03	100		0.71
2-JMS270.84	4/9/03	2800		0.29
2-JMS270.84	6/26/03	100		0.07
2-JMS270.84	8/11/03	1300		0
2-JMS270.84	10/14/03	25		1.05
2-JMS270.84	12/16/03	50		1.2
2-JMS270.84	2/3/04	1200		0.32
2-JMS270.84	4/20/04	75		0.29
2-JMS270.84	6/7/04	350		3.07
2-JMS270.84	8/16/04	25		0.77
2-JMS270.84	10/26/04	25		0.88
2-JMS270.84	12/16/04	100		1.19

Table A.16. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-IVA000.22 in Ivy Creek (VAC-H03R-03) 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)
2-IVA000.22	12/1/88	1400		1.55
2-IVA000.22	2/21/89	8000		1.42
2-IVA000.22	4/3/89	100		0.02
2-IVA000.22	7/18/89	600		2.04
2-IVA000.22	9/7/89	100		0.23
2-IVA000.22	12/4/89	3300		0
2-IVA000.22	2/26/90	100		0.38
2-IVA000.22	9/12/90	2300		0.15
2-IVA000.22	12/3/90	8000		2
2-IVA000.22	2/25/91	300		0.36
2-IVA000.22	9/25/91	200		0.1
2-IVA000.22	12/5/91	2300		3.18
2-IVA000.22	3/2/92	1000		0.78
2-IVA000.22	6/3/92	500		0.8
2-IVA000.22	9/10/92	400		2.48
2-IVA000.22	12/8/92	300		0
2-IVA000.22	3/1/93	300		0.34
2-IVA000.22	6/1/93	2200		0.47
2-IVA000.22	9/1/93	300		0.13
2-IVA000.22	12/1/93	1000		2.09
2-IVA000.22	3/1/94	100		0.69
2-IVA000.22	6/1/94	300		0
2-IVA000.22	9/7/94	100		0.01
2-IVA000.22	12/5/94	8000		0.56
2-IVA000.22	3/6/95	100		0.2
2-IVA000.22	6/19/95	1100		0.16
2-IVA000.22	9/5/95	200		0.97
2-IVA000.22	12/4/95	100		0.2

Table A.17. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-IVA000.22 in Ivy Creek (VAC-H03R-03) 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)
2-IVA000.22	3/4/96	500		0.05
2-IVA000.22	6/3/96	800		0.05
2-IVA000.22	9/10/96	400		4.14
2-IVA000.22	12/3/96	4100		2.32
2-IVA000.22	3/5/97	1800		2.27
2-IVA000.22	6/3/97	5000		2.44
2-IVA000.22	9/16/97	300		0.03
2-IVA000.22	12/2/97	100		0.48
2-IVA000.22	3/3/98	400		0.57
2-IVA000.22	6/2/98	200		0.01
2-IVA000.22	9/1/98	100		0.01
2-IVA000.22	12/2/98	100		0
2-IVA000.22	3/1/99	100		0.31
2-IVA000.22	6/2/99	100		0
2-IVA000.22	8/2/99	100		1.01
2-IVA000.22	10/4/99	900		3.93
2-IVA000.22	12/7/99	100		0.26
2-IVA000.22	4/4/00	200	60	0.47
2-IVA000.22	7/10/01	100	56	0.46
2-IVA000.22	9/18/01	100	18	0.01
2-IVA000.22	11/20/01	100	48	0
2-IVA000.22	1/22/02	100	48	0.91
2-IVA000.22	3/11/02	100		0.11
2-IVA000.22	5/23/02	200		0.31
2-IVA000.22	7/1/02	200		0.3
2-IVA000.22	9/16/02	500		0.29
2-IVA000.22	11/12/02	4000		2.77
2-IVA000.22	1/28/03	100		0.71

Table A.18. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-IVA000.22 in Ivy Creek (VAC-H03R-03) 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)
2-IVA000.22	4/9/03	1100		0.29
2-IVA000.22	6/26/03	300		0.07

Table A.19. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-FSG000.85 in Fishing Creek (VAC-H03R-02) 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)
2-FSG000.85	9/27/88	5400		0.24
2-FSG000.85	12/1/88	3300		1.55
2-FSG000.85	3/1/89	2700		0.32
2-FSG000.85	6/12/89	8000		3.38
2-FSG000.85	12/4/89	200		0
2-FSG000.85	3/5/90	500		0.55
2-FSG000.85	6/7/90	1400		0
2-FSG000.85	12/3/90	8000		2
2-FSG000.85	3/4/91	8000		1.95
2-FSG000.85	9/25/91	500		0.1
2-FSG000.85	12/5/91	8000		3.18
2-FSG000.85	3/2/92	1200		0.78
2-FSG000.85	6/3/92	500		0.8
2-FSG000.85	9/10/92	400		2.48
2-FSG000.85	12/8/92	900		0
2-FSG000.85	3/1/93	100		0.34
2-FSG000.85	6/1/93	8000		0.47
2-FSG000.85	9/1/93	100		0.13
2-FSG000.85	12/1/93	2900		2.09
2-FSG000.85	3/1/94	700		0.69
2-FSG000.85	6/1/94	100		0
2-FSG000.85	9/7/94	1000		0.01
2-FSG000.85	12/5/94	8000		0.56
2-FSG000.85	3/6/95	100		0.2
2-FSG000.85	6/19/95	500		0.16
2-FSG000.85	9/5/95	200		0.97
2-FSG000.85	12/4/95	100		0.2
2-FSG000.85	3/4/96	100		0.05

Table A.20. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-FSG000.85 in Fishing Creek (VAC-H03R-02) 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)
2-FSG000.85	6/3/96	100		0.05
2-FSG000.85	9/10/96	900		4.14
2-FSG000.85	12/3/96	1300		2.32
2-FSG000.85	3/5/97	900		2.27
2-FSG000.85	6/3/97	2000		2.44
2-FSG000.85	9/16/97	5100		0.03
2-FSG000.85	12/2/97	100		0.48
2-FSG000.85	3/3/98	400		0.57
2-FSG000.85	6/2/98	1600		0.01
2-FSG000.85	9/1/98	100		0.01
2-FSG000.85	12/2/98	100		0
2-FSG000.85	3/1/99	100		0.31
2-FSG000.85	6/2/99	100		0
2-FSG000.85	8/2/99	1000		1.01
2-FSG000.85	10/4/99	600		3.93
2-FSG000.85	12/7/99	200		0.26
2-FSG000.85	4/4/00	2900		0.47
2-FSG000.85	8/17/00	100		0.39
2-FSG000.85	10/24/00	300		0.01
2-FSG000.85	12/18/00	100		1.26
2-FSG000.85	2/21/01	300		0.86
2-FSG000.85	4/4/01	100		0.85
2-FSG000.85	6/7/01	1100		1.48
2-FSG000.85	7/10/01	200		0.46
2-FSG000.85	9/18/01	100		0.01
2-FSG000.85	11/20/01	100		0
2-FSG000.85	1/22/02	100		0.91
2-FSG000.85	3/11/02	100		0.11

Table A.21. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-FSG000.85 in Fishing Creek (VAC-H03R-02) 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)
2-FSG000.85	5/23/02	100		0.31
2-FSG000.85	7/1/02	100		0.3
2-FSG000.85	9/16/02	1600		0.29
2-FSG000.85	11/12/02	6500		2.77
2-FSG000.85	1/28/03	200		0.71
2-FSG000.85	4/9/03	5600		0.29
2-FSG000.85	6/26/03	600		0.07

Table A.22. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW000.40 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW000.40	12/1/88	2000		1.55
2-BKW000.40	2/21/89	8000		1.42
2-BKW000.40	7/18/89	300		2.04
2-BKW000.40	9/7/89	100		0.23
2-BKW000.40	12/4/89	500		0
2-BKW000.40	2/26/90	400		0.38
2-BKW000.40	9/12/90	200		0.15
2-BKW000.40	12/3/90	8000		2
2-BKW000.40	2/25/91	300		0.36
2-BKW000.40	9/25/91	100		0.1
2-BKW000.40	12/5/91	1700		3.18
2-BKW000.40	3/2/92	500		0.78
2-BKW000.40	6/3/92	1800		0.8
2-BKW000.40	9/10/92	200		2.48
2-BKW000.40	12/8/92	700		0
2-BKW000.40	3/1/93	1000		0.34
2-BKW000.40	6/1/93	5000		0.47
2-BKW000.40	9/1/93	300		0.13
2-BKW000.40	12/1/93	3000		2.09
2-BKW000.40	3/1/94	900		0.69
2-BKW000.40	6/1/94	900		0
2-BKW000.40	9/7/94	1400		0.01
2-BKW000.40	12/5/94	8000		0.56
2-BKW000.40	3/6/95	100		0.2
2-BKW000.40	6/19/95	1600		0.16
2-BKW000.40	9/5/95	800		0.97
2-BKW000.40	12/4/95	100		0.2
2-BKW000.40	3/4/96	100		0.05

Table A.23. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW000.40 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW000.40	6/3/96	1600		0.05
2-BKW000.40	9/10/96	2600		4.14
2-BKW000.40	12/3/96	3100		2.32
2-BKW000.40	3/5/97	1900		2.27
2-BKW000.40	6/3/97	4000		2.44
2-BKW000.40	9/16/97	100		0.03
2-BKW000.40	12/2/97	100		0.48
2-BKW000.40	3/3/98	6100		0.57
2-BKW000.40	6/2/98	500		0.01
2-BKW000.40	9/1/98	1000		0.01
2-BKW000.40	12/2/98	500		0
2-BKW000.40	3/1/99	200		0.31
2-BKW000.40	6/2/99	1000		0
2-BKW000.40	8/2/99	100		1.01
2-BKW000.40	10/4/99	8000		3.93
2-BKW000.40	12/7/99	100		0.26
2-BKW000.40	4/4/00	1100		0.47
2-BKW000.40	8/17/00	100		0.39
2-BKW000.40	10/24/00	100		0.01
2-BKW000.40	12/18/00	5300		1.26
2-BKW000.40	2/21/01	500		0.86
2-BKW000.40	4/4/01	100		0.85
2-BKW000.40	6/7/01	1200		1.48

Table A.24. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW005.57 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW005.57	5/9/71	3300		0.89
2-BKW005.57	6/17/71	8000		1.04
2-BKW005.57	7/19/71	4200		0.29
2-BKW005.57	8/4/71	400		1.62
2-BKW005.57	9/29/71	100		0.01
2-BKW005.57	10/21/71	600		0.31
2-BKW005.57	11/16/71	200		0
2-BKW005.57	12/8/71	1600		0.82
2-BKW005.57	1/4/72	6000		0.7
2-BKW005.57	2/28/72	100		1.04
2-BKW005.57	3/14/72	100		0.3
2-BKW005.57	4/30/72	1700		0
2-BKW005.57	6/7/72	2500		0.1
2-BKW005.57	7/17/72	100		2.08
2-BKW005.57	7/31/72	100		3.86
2-BKW005.57	9/13/72	100		0
2-BKW005.57	10/24/72	100		0.66
2-BKW005.57	2/28/73	1600		0.28
2-BKW005.57	4/5/73	2800		1.26
2-BKW005.57	4/30/73	400		2.53
2-BKW005.57	7/21/73	6000		3.18
2-BKW005.57	8/16/73	NULL		0.67
2-BKW005.57	10/4/73	6000		1.31
2-BKW005.57	11/13/73	6000		0.02
2-BKW005.57	1/14/74	4300		0.67
2-BKW005.57	2/22/74	400		0.34
2-BKW005.57	4/17/74	100		0.12
2-BKW005.57	7/25/74	2900		0.28

Table A.25. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW005.57 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW005.57	8/21/74	1800		0.56
2-BKW005.57	9/26/74	3700		0.01
2-BKW005.57	10/15/74	600		0
2-BKW005.57	11/20/74	6000		0.38
2-BKW005.57	12/9/74	6000		1.43
2-BKW005.57	1/10/75	6000		0.68
2-BKW005.57	2/24/75	6000		0.37
2-BKW005.57	3/11/75	6000		0.87
2-BKW005.57	4/10/75	100		0.11
2-BKW005.57	5/30/75	4500		3
2-BKW005.57	6/10/75	100		0.61
2-BKW005.57	7/16/75	1400		2.3
2-BKW005.57	7/31/75	100		0
2-BKW005.57	9/22/75	1100		3.25
2-BKW005.57	10/7/75	100		0.01
2-BKW005.57	12/11/75	100		0.96
2-BKW005.57	1/9/76	6000		0.38
2-BKW005.57	2/23/76	2100		1.4
2-BKW005.57	3/9/76	6000		1.61
2-BKW005.57	4/22/76	300		0.1
2-BKW005.57	5/7/76	300		0
2-BKW005.57	6/24/76	100		2.75
2-BKW005.57	7/16/76	200		0.19
2-BKW005.57	8/9/76	400		0.29
2-BKW005.57	9/21/76	500		0
2-BKW005.57	10/7/76	100		1.43
2-BKW005.57	11/19/76	100		0.02
2-BKW005.57	12/21/76	1100		0.44

Table A.26. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW005.57 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW005.57	3/14/77	2700		0.67
2-BKW005.57	4/5/77	5700		2.73
2-BKW005.57	5/23/77	200		0
2-BKW005.57	6/7/77	1100		0.25
2-BKW005.57	7/27/77	100		0.36
2-BKW005.57	8/19/77	300		1.91
2-BKW005.57	11/22/77	6000		1.13
2-BKW005.57	12/16/77	100		0.87
2-BKW005.57	1/12/78	200		2.09
2-BKW005.57	2/23/78	100		0.15
2-BKW005.57	3/9/78	100		0.53
2-BKW005.57	4/27/78	8000		4.71
2-BKW005.57	5/9/78	5600		3.53
2-BKW005.57	7/18/78	8000		1.32
2-BKW005.57	8/11/78	600		0.37
2-BKW005.57	9/25/78	3100		0.02
2-BKW005.57	10/17/78	8000		0.09
2-BKW005.57	11/16/78	400		0.81
2-BKW005.57	12/14/78	400		1.18
2-BKW005.57	3/19/79	8000		0.12
2-BKW005.57	4/11/79	8000		0.29
2-BKW005.57	5/3/79	8000		0.01
2-BKW005.57	6/18/79	8000		1.47
2-BKW005.57	7/10/79	8000		0.29
2-BKW005.57	8/13/79	8000		1.4
2-BKW005.57	9/17/79	4100		0.45
2-BKW005.57	10/22/79	1700		0
2-BKW005.57	11/8/79	8000		0.02

Table A.27. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW005.57 in Blackwater Creek(VAC-H03R-01)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)
2-BKW005.57	2/14/80	5800		0.29
2-BKW005.57	3/24/80	8000		1.96
2-BKW005.57	4/10/80	8000		1.08
2-BKW005.57	5/8/80	8000		0.23
2-BKW005.57	7/14/80	200		1.04
2-BKW005.57	10/14/80	200		0
2-BKW005.57	11/12/80	1500		0.17
2-BKW005.57	12/8/80	4000		0.01
2-BKW005.57	1/15/81	2700		0.01
2-BKW005.57	2/11/81	3800		1.46
2-BKW005.57	3/9/81	100		0.64
2-BKW005.57	4/2/81	100		0.59
2-BKW005.57	5/11/81	8000		0.31
2-BKW005.57	6/26/81	600		0.33
2-BKW005.57	7/6/81	8000		3.18
2-BKW005.57	8/20/81	300		0.05
2-BKW005.57	9/14/81	300		0
2-BKW005.57	10/27/81	8000		2.6
2-BKW005.57	11/13/81	4500		0
2-BKW005.57	12/15/81	8000		1.73
2-BKW005.57	1/25/82	3100		0.74
2-BKW005.57	2/1/82	8000		0.23
2-BKW005.57	3/10/82	400		0.99
2-BKW005.57	4/13/82	100		0.33
2-BKW005.57	5/18/82	8000		0.91
2-BKW005.57	6/29/82	5100		0
2-BKW005.57	7/13/82	1000		1.39
2-BKW005.57	8/11/82	2800		1.78

Table A.28. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW005.57 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW005.57	9/7/82	100		0.28
2-BKW005.57	11/22/82	1900		0.17
2-BKW005.57	12/13/82	300		0.8
2-BKW005.57	1/10/83	300		0.11
2-BKW005.57	2/9/83	8000		0.4
2-BKW005.57	3/9/83	2900		0.81
2-BKW005.57	4/20/83	3200		1.13
2-BKW005.57	5/23/83	8000		1.55
2-BKW005.57	6/2/83	8000		0.22
2-BKW005.57	8/8/83	100		0
2-BKW005.57	9/15/83	8000		0.66
2-BKW005.57	10/13/83	2300		2.05
2-BKW005.57	11/14/83	100		1.19
2-BKW005.57	12/8/83	8000		1.79
2-BKW005.57	1/31/84	1600		0.21
2-BKW005.57	2/16/84	7200		2.94
2-BKW005.57	3/5/84	1400		0.46
2-BKW005.57	4/12/84	1200		0.55
2-BKW005.57	5/16/84	3400		0
2-BKW005.57	6/14/84	400		0
2-BKW005.57	7/23/84	1600		6.21
2-BKW005.57	8/13/84	8000		4.4
2-BKW005.57	9/4/84	8000		1.07
2-BKW005.57	10/31/84	3100		0.04
2-BKW005.57	1/16/85	500		0
2-BKW005.57	2/14/85	2500		1.26
2-BKW005.57	3/13/85	100		0.11
2-BKW005.57	4/8/85	1200		0.07

Table A.29. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW005.57 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW005.57	5/13/85	8000		1.51
2-BKW005.57	6/17/85	3500		0.16
2-BKW005.57	7/11/85	2700		0.21
2-BKW005.57	8/5/85	400		0.49
2-BKW005.57	9/12/85	200		0
2-BKW005.57	10/15/85	100		0.01
2-BKW005.57	11/19/85	200		0.14
2-BKW005.57	12/11/85	100		0.01
2-BKW005.57	1/13/86	100		0
2-BKW005.57	2/5/86	400		0.37
2-BKW005.57	3/5/86	1000		0
2-BKW005.57	4/3/86	600		0.07
2-BKW005.57	5/15/86	2500		1.91
2-BKW005.57	6/16/86	300		0.34
2-BKW005.57	7/2/86	2600		0.49
2-BKW005.57	8/4/86	200		0.61
2-BKW005.57	9/2/86	800		0.49
2-BKW005.57	10/14/86	8000		1.31
2-BKW005.57	11/13/86	300		0.5
2-BKW005.57	12/10/86	1300		0.63
2-BKW005.57	1/15/87	600		0.22
2-BKW005.57	2/5/87	400		0.01
2-BKW005.57	3/10/87	1000		0.13
2-BKW005.57	4/8/87	100		0.42
2-BKW005.57	5/5/87	1000		0.81
2-BKW005.57	7/20/87	200		0
2-BKW005.57	8/3/87	100		0.04
2-BKW005.57	9/1/87	600		0.01

Table A.30. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW005.57 in Blackwater Creek(VAC-H03R-01)) 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)
2-BKW005.57	10/1/87	100		0.45
2-BKW005.57	11/4/87	100		0
2-BKW005.57	12/2/87	100		1.38
2-BKW005.57	1/5/88	1000		0.16
2-BKW005.57	3/2/88	1600		0
2-BKW005.57	4/4/88	2400		1.22
2-BKW005.57	5/2/88	3300		0.15
2-BKW005.57	6/8/88	200		0.59
2-BKW005.57	6/8/88	200		0.59
2-BKW005.57	10/1/87	100		0.45
2-BKW005.57	11/4/87	100		0
2-BKW005.57	12/2/87	100		1.38
2-BKW005.57	1/5/88	1000		0.16

Table A.31. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station S.B. COLLEGE STATION BW-02 in Blackwater Creek(VAC-H03R-01) 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)
S.B. COLLEGE STATION BW-02	11/5/04		700	1.58
S.B. COLLEGE STATION BW-02	11/12/04		400	0.42
S.B. COLLEGE STATION BW-02	11/19/04		100	1.17

Table A.32. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW005.95 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW005.95	8/11/03		1700	0.89
2-BKW005.95	10/14/03		230	1.04
2-BKW005.95	12/16/03		25	0.29
2-BKW005.95	2/3/04		500	1.62
2-BKW005.95	4/20/04		200	0.01
2-BKW005.95	6/7/04		50	0.31
2-BKW005.95	8/16/04		120	0
2-BKW005.95	10/26/04		25	0.82
2-BKW005.95	12/16/04		25	0.7
2-BKW005.95	2/9/05		25	1.04
2-BKW005.95	4/11/05		25	0.3
2-BKW005.95	6/16/05		50	0

Table A.33. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW007.19 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW007.19	8/4/71	100		0.56
2-BKW007.19	11/16/71	100		0.01
2-BKW007.19	12/8/71	2200		0
2-BKW007.19	1/4/72	6000		0.38
2-BKW007.19	2/28/72	100		1.43
2-BKW007.19	3/14/72	100		0.68
2-BKW007.19	4/30/72	500		0.37
2-BKW007.19	6/7/72	1200		0.87
2-BKW007.19	7/31/72	100		0.11
2-BKW007.19	9/13/72	200		3
2-BKW007.19	10/24/72	100		0.61
2-BKW007.19	11/9/72	100		2.3
2-BKW007.19	2/25/73	800		0
2-BKW007.19	4/5/73	3300		3.25
2-BKW007.19	4/30/73	1700		0.01
2-BKW007.19	6/10/73	6000		0.96
2-BKW007.19	10/4/73	2000		0.38
2-BKW007.19	11/13/73	100		1.4
2-BKW007.19	1/14/74	1100		1.61
2-BKW007.19	2/22/74	200		0.1
2-BKW007.19	3/27/74	100		0
2-BKW007.19	4/17/74	100		2.75
2-BKW007.19	7/25/74	700		0.19
2-BKW007.19	8/21/74	100		0.29
2-BKW007.19	9/26/74	100		0
2-BKW007.19	10/15/74	100		1.43
2-BKW007.19	11/20/74	100		0.02
2-BKW007.19	12/9/74	100		0.44

Table A.34. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW007.19 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW007.19	1/10/75	100		0.67
2-BKW007.19	2/24/75	200		2.73
2-BKW007.19	3/11/75	100		0
2-BKW007.19	4/10/75	100		0.25
2-BKW007.19	5/30/75	4200		0.36
2-BKW007.19	6/10/75	100		1.91
2-BKW007.19	7/16/75	200		1.13
2-BKW007.19	7/31/75	100		0.87
2-BKW007.19	9/22/75	1900		2.09
2-BKW007.19	10/7/75	100		0.15
2-BKW007.19	12/11/75	100		0.53
2-BKW007.19	1/9/76	100		4.71
2-BKW007.19	2/23/76	1700		3.53
2-BKW007.19	3/9/76	6000		1.32
2-BKW007.19	4/22/76	100		0.37
2-BKW007.19	5/7/76	800		0.02
2-BKW007.19	6/24/76	400		0.09
2-BKW007.19	7/16/76	100		0.81
2-BKW007.19	8/9/76	100		1.18
2-BKW007.19	9/21/76	100		0.12
2-BKW007.19	11/19/76	100		0.29
2-BKW007.19	12/21/76	100		0.01
2-BKW007.19	3/14/77	1900		1.47
2-BKW007.19	4/5/77	6000		0.29
2-BKW007.19	5/23/77	100		1.4
2-BKW007.19	6/7/77	500		0.45
2-BKW007.19	7/27/77	100		0
2-BKW007.19	8/19/77	400		0.02

Table A.35. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BKW007.19 in Blackwater Creek(VAC-H03R-01) 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)
2-BKW007.19	11/22/77	100		0.29
2-BKW007.19	12/6/77	300		1.96
2-BKW007.19	4/27/78	2500		1.08
2-BKW007.19	5/9/78	5500		0.23
2-BKW007.19	7/18/78	8000		1.04
2-BKW007.19	8/11/78	100		0
2-BKW007.19	9/25/78	100		0.17
2-BKW007.19	10/17/78	100		0.01
2-BKW007.19	11/16/78	100		0.01
2-BKW007.19	12/14/78	1400		1.46
2-BKW007.19	3/19/79	100		0.64
2-BKW007.19	4/11/79	100		0.59
2-BKW007.19	5/3/79	100		0.31
2-BKW007.19	6/18/79	5100		0.33
2-BKW007.19	1/4/06		267	3.18
2-BKW007.19	2/1/06		6	0.05
2-BKW007.19	3/6/06		20	0
2-BKW007.19	11/22/77	100		0.29
2-BKW007.19	12/6/77	300		1.96
2-BKW007.19	4/27/78	2500		1.08
2-BKW007.19	5/9/78	5500		0.23
2-BKW007.19	7/18/78	8000		1.04
2-BKW007.19	8/11/78	100		0
2-BKW007.19	9/25/78	100		0.17
2-BKW007.19	10/17/78	100		0.01
2-BKW007.19	11/16/78	100		0.01
2-BKW007.19	12/14/78	1400		1.46
2-BKW007.19	3/19/79	100		0.64

Table A.36. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station S.B. COLLEGE STATION BW-05 in Blackwater Creek(VAC-H03R-01) 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)
S.B. COLLEGE STATION BW-05	10/29/04		1100	0.28
S.B. COLLEGE STATION BW-05	11/5/04		2200	0.17
S.B. COLLEGE STATION BW-05	11/12/04		1400	0.8
S.B. COLLEGE STATION BW-05	11/19/04		400	0.11

Table A.37. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station S.B. COLLEGE STATION TC-02 in Tomahawk Creek (VAC-H03R-07) 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)
S.B. COLLEGE STATION TC-02	10/29/04		100	1.31
S.B. COLLEGE STATION TC-02	11/5/04		800	1.58
S.B. COLLEGE STATION TC-02	11/19/04		100	1.17

Table A.38. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-THK002.33 in Tomahawk Creek (VAC-H03R-07) 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)
2-THK002.33	8/11/03		950	0
2-THK002.33	10/14/03		150	1.05
2-THK002.33	12/16/03		25	1.2
2-THK002.33	2/3/04		100	0.32
2-THK002.33	4/20/04		25	0.29
2-THK002.33	6/7/04		420	3.07
2-THK002.33	8/16/04		100	0.77
2-THK002.33	10/26/04		50	0.88
2-THK002.33	12/16/04		25	1.19

Table A.39. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station S.B. COLLEGE STATION TC-03 in Tomahawk Creek (VAC-H03R-07) 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)
S.B. COLLEGE STATION TC-03	10/29/04		400	1.31
S.B. COLLEGE STATION TC-03	11/5/04		300	1.58
S.B. COLLEGE STATION TC-03	11/19/04		100	1.17

Table A.40. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-BUN001.64 in Burton Creek (VAC-H03R-05) 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)
2-BUN001.64	8/11/03		880	0
2-BUN001.64	10/14/03		780	1.05
2-BUN001.64	12/16/03		2000	1.2
2-BUN001.64	2/3/04		150	0.32
2-BUN001.64	4/20/04		25	0.29
2-BUN001.64	6/7/04		280	3.07
2-BUN001.64	8/16/04		100	0.77
2-BUN001.64	10/26/04		75	0.88
2-BUN001.64	12/16/04		25	1.19

Table A.41. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station S.B. COLLEGE STATION BC-01 in Burton Creek (VAC-H03R-05) 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)
S.B. COLLEGE STATION BC-01	10/29/04		100	1.31
S.B. COLLEGE STATION BC-01	11/5/04		2700	1.58
S.B. COLLEGE STATION BC-01	11/19/04		400	1.17
S.B. COLLEGE STATION BC-01	10/29/04		100	1.31
S.B. COLLEGE STATION BC-01	11/5/04		2700	1.58
S.B. COLLEGE STATION BC-01	11/19/04		400	1.17

Table A.42. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station S.B. COLLEGE STATION BC-03 in Burton Creek (VAC-H03R-05) 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)
S.B. COLLEGE STATION BC-03	10/29/04		200	1.31
S.B. COLLEGE STATION BC-03	11/5/04		500	1.58
S.B. COLLEGE STATION BC-03	11/19/04		300	1.17

Table A.43. Observed fecal coliform concentration, *E. coli* concentration, and antecedent rainfall for VADEQ station 2-JTH001.52 in Judith Creek (VAC-H03R-06) 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)
2-JTH001.52	8/11/03		900	0
2-JTH001.52	10/14/03		280	1.05
2-JTH001.52	12/16/03		25	1.2
2-JTH001.52	2/3/04		450	0.32
2-JTH001.52	4/20/04		50	0.29
2-JTH001.52	6/7/04		120	3.07
2-JTH001.52	8/16/04		75	0.77
2-JTH001.52	10/26/04		100	0.88
2-JTH001.52	12/16/04		25	1.19

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 stations 2-JMS258.54, 2-IVA000.22, 2-FSG000.85 , 2-BKW000.40, 2-THK002.33, 2-BUN001.64

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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/reports/bst05.pdf

and http://www.deq.virginia.gov/tmdl/reports/bst06.pdf

or contact VDEQ-NRO

Appendix C – Fecal Coliform Loading in Subwatersheds

Table C.1. Monthly nonpoint fecal coliform loadings in sub-watershed JR-2.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	2	8,270	2,086	529	888	993	0
Fe.	2	8,838	2,227	563	809	905	0
Mar.	2	16,590	4,169	1,049	769	993	0
Apr.	2	16,503	4,147	1,044	744	961	0
May.	2	17,502	4,398	1,107	769	993	0
Jun.	2	17,293	4,345	1,093	744	961	0
Jul.	2	18,341	4,608	1,159	769	993	0
Aug.	2	18,813	4,726	1,189	769	993	0
Sep.	2	18,775	4,716	1,186	859	961	0
Oct.	2	11,942	3,005	758	888	993	0
Nov.	2	12,141	3,055	771	859	961	0
Dec.	2	7,913	1,996	506	888	993	0
Total	23	172,919	43,475	10,954	9,756	11,698	0

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

Table C.2. Monthly nonpoint fecal coliform loadings in sub-watershed JR-3.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	1	1,089	276	71	198	2,889	0
Fe.	1	1,163	294	75	180	2,633	0
Mar.	1	2,180	549	139	173	2,889	0
Apr.	1	2,170	547	138	168	2,796	0
May.	1	2,304	581	147	173	2,889	0
Jun.	1	2,290	577	146	168	2,796	0
Jul.	1	2,429	612	155	173	2,889	0
Aug.	1	2,491	627	159	173	2,889	0
Sep.	1	2,471	622	157	191	2,796	0
Oct.	1	1,572	397	101	198	2,889	0
Nov.	1	1,597	403	103	191	2,796	0
Dec.	1	1,043	265	68	198	2,889	0
Total	11	22,799	5,751	1,459	2,184	34,044	0

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

Table C.3. Monthly nonpoint fecal coliform loadings in sub-watershed JR-4.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	49	65,383	16,548	4,224	1,908	7,352	0
Fe.	44	69,835	17,647	4,491	1,739	6,700	0
Mar.	49	130,975	32,975	8,330	1,559	7,352	0
Apr.	47	130,344	32,811	8,287	1,508	7,115	0
May.	49	138,362	34,825	8,793	1,559	7,352	0
Jun.	47	137,230	34,535	8,718	1,508	7,115	0
Jul.	49	145,542	36,623	9,242	1,559	7,352	0
Aug.	49	149,280	37,559	9,476	1,559	7,352	0
Sep.	47	148,400	37,333	9,417	1,847	7,115	0
Oct.	49	94,396	23,814	6,040	1,908	7,352	0
Nov.	47	95,911	24,188	6,131	1,847	7,115	0
Dec.	49	62,570	15,843	4,048	1,908	7,352	0
Total	574	1,368,229	344,701	87,197	20,408	86,620	0

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

Table C.4. Monthly nonpoint fecal coliform loadings in sub-watershed JR-5.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	1	1,843	466	118	179	2,250	0
Fe.	1	1,969	497	126	163	2,050	0
Mar.	1	3,696	930	234	154	2,250	0
Apr.	1	3,679	925	233	149	2,177	0
May.	1	3,907	982	248	154	2,250	0
Jun.	1	3,879	975	246	149	2,177	0
Jul.	1	4,114	1,034	261	154	2,250	0
Aug.	1	4,220	1,061	267	154	2,250	0
Sep.	1	4,191	1,053	265	173	2,177	0
Oct.	1	2,663	671	170	179	2,250	0
Nov.	1	2,706	681	172	173	2,177	0
Dec.	1	1,764	446	113	179	2,250	0
Total	12	38,631	9,721	2,454	1,960	26,507	0

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

Table C.5. Monthly nonpoint fecal coliform loadings in sub-watershed JR-6.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	0	489	124	32	67	2,871	0
Fe.	0	522	132	34	61	2,617	0
Mar.	0	977	246	62	54	2,871	0
Apr.	0	971	245	62	52	2,779	0
May.	0	1,028	259	66	54	2,871	0
Jun.	0	1,011	255	64	52	2,779	0
Jul.	0	1,072	270	68	54	2,871	0
Aug.	0	1,099	277	70	54	2,871	0
Sep.	0	1,103	278	70	65	2,779	0
Oct.	0	704	178	45	67	2,871	0
Nov.	0	716	181	46	65	2,779	0
Dec.	0	468	119	30	67	2,871	0
Total	3	10,159	2,563	650	709	33,831	0

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

Table C.6. Monthly nonpoint fecal coliform loadings in sub-watershed JR-7.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	4	16,713	4,215	1,068	1,110	9,573	0
Fe.	4	17,861	4,500	1,138	1,011	8,724	0
Mar.	4	33,534	8,427	2,122	922	9,573	0
Apr.	4	33,368	8,385	2,110	892	9,265	0
May.	4	35,409	8,897	2,239	922	9,573	0
Jun.	4	35,066	8,810	2,217	892	9,265	0
Jul.	4	37,192	9,344	2,351	922	9,573	0
Aug.	4	38,149	9,583	2,410	922	9,573	0
Sep.	4	37,984	9,541	2,399	1,074	9,265	0
Oct.	4	24,147	6,077	1,534	1,110	9,573	0
Nov.	4	24,542	6,175	1,558	1,074	9,265	0
Dec.	4	15,991	4,034	1,023	1,110	9,573	0
Total	49	349,956	87,987	22,169	11,960	112,797	0

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

Table C.7. Monthly nonpoint fecal coliform loadings in sub-watershed BW-1.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	11	21,439	5,417	1,378	604	2,689	0
Fe.	10	22,905	5,780	1,467	551	2,450	0
Mar.	11	42,958	10,806	2,725	506	2,689	0
Apr.	11	42,724	10,746	2,709	489	2,602	0
May.	11	45,295	11,391	2,872	506	2,689	0
Jun.	11	44,694	11,239	2,833	489	2,602	0
Jul.	11	47,402	11,919	3,003	506	2,689	0
Aug.	11	48,621	12,224	3,080	506	2,689	0
Sep.	11	48,585	12,214	3,076	585	2,602	0
Oct.	11	30,930	7,794	1,972	604	2,689	0
Nov.	11	31,448	7,922	2,003	585	2,602	0
Dec.	11	20,515	5,185	1,320	604	2,689	0
Total	130	447,518	112,635	28,439	6,534	31,680	0

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

Table C.8. Monthly nonpoint fecal coliform loadings in sub-watershed BW-2.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	14	22,413	5,670	1,446	851	7,655	0
Fe.	13	23,428	5,919	1,505	776	6,976	0
Mar.	14	44,626	11,233	2,836	712	7,655	0
Apr.	14	44,671	11,242	2,838	689	7,408	0
May.	14	47,186	11,874	2,997	712	7,655	0
Jun.	14	46,442	11,686	2,949	689	7,408	0
Jul.	14	49,079	12,348	3,115	712	7,655	0
Aug.	14	50,167	12,620	3,183	712	7,655	0
Sep.	14	49,903	12,552	3,165	824	7,408	0
Oct.	14	34,370	8,664	2,194	851	7,655	0
Nov.	14	34,158	8,609	2,180	824	7,408	0
Dec.	14	21,589	5,463	1,394	851	7,655	0
Total	167	468,035	117,879	29,802	9,199	90,198	0

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

Table C.9. Monthly nonpoint fecal coliform loadings in sub-watershed BW-3.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	0	10	5	3	238	3,782	0
Fe.	0	9	5	2	217	3,447	0
Mar.	0	10	5	3	206	3,782	0
Apr.	0	10	5	2	199	3,660	0
May.	0	10	5	3	206	3,782	0
Jun.	0	10	5	2	199	3,660	0
Jul.	0	10	5	3	206	3,782	0
Aug.	0	10	5	3	206	3,782	0
Sep.	0	10	5	2	230	3,660	0
Oct.	0	10	5	3	238	3,782	0
Nov.	0	10	5	2	230	3,660	0
Dec.	0	10	5	3	238	3,782	0
Total	5	118	59	30	2,612	44,566	0

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

Table C.10. Monthly nonpoint fecal coliform loadings in sub-watershed FG-1.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	1	1,621	409	104	275	6,165	0
Fe.	1	1,733	436	110	251	5,618	0
Mar.	1	3,253	817	206	221	6,165	0
Apr.	1	3,236	813	205	214	5,966	0
May.	1	3,433	862	217	221	6,165	0
Jun.	1	3,393	852	214	214	5,966	0
Jul.	1	3,599	904	227	221	6,165	0
Aug.	1	3,692	927	233	221	6,165	0
Sep.	1	3,682	925	233	266	5,966	0
Oct.	1	2,342	589	149	275	6,165	0
Nov.	1	2,381	599	151	266	5,966	0
Dec.	1	1,551	391	99	275	6,165	0
Total	8	33,916	8,526	2,148	2,923	72,633	0

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

Table C.11. Monthly nonpoint fecal coliform loadings in sub-watershed BW-8.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	0	43	22	11	209	9,497	0
Fe.	0	40	20	10	191	8,655	0
Mar.	0	43	22	11	165	9,497	0
Apr.	0	42	21	11	159	9,191	0
May.	0	43	22	11	165	9,497	0
Jun.	0	42	21	11	159	9,191	0
Jul.	0	43	22	11	165	9,497	0
Aug.	0	43	22	11	165	9,497	0
Sep.	0	42	21	11	203	9,191	0
Oct.	0	43	22	11	209	9,497	0
Nov.	0	42	21	11	203	9,191	0
Dec.	0	43	22	11	209	9,497	0
Total	1	512	256	128	2,202	111,899	0

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

Table C.12. Monthly nonpoint fecal coliform loadings in sub-watershed BW-9.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	1	17	9	4	132	4,949	0
Fe.	1	16	8	4	120	4,510	0
Mar.	1	17	9	4	110	4,949	0
Apr.	1	17	8	4	106	4,789	0
May.	1	17	9	4	110	4,949	0
Jun.	1	17	8	4	106	4,789	0
Jul.	1	17	9	4	110	4,949	0
Aug.	1	17	9	4	110	4,949	0
Sep.	1	17	8	4	128	4,789	0
Oct.	1	17	9	4	132	4,949	0
Nov.	1	17	8	4	128	4,789	0
Dec.	1	17	9	4	132	4,949	0
Total	7	204	102	51	1,422	58,309	0

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

Table C.13. Monthly nonpoint fecal coliform loadings in sub-watershed BW-7.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	11	5,172	1,313	337	288	10,509	0
Fe.	10	5,522	1,399	358	263	9,577	0
Mar.	11	10,340	2,608	661	232	10,509	0
Apr.	11	10,286	2,593	657	225	10,170	0
May.	11	10,911	2,750	697	232	10,509	0
Jun.	11	10,791	2,720	689	225	10,170	0
Jul.	11	11,444	2,884	730	232	10,509	0
Aug.	11	11,737	2,957	748	232	10,509	0
Sep.	11	11,701	2,948	746	279	10,170	0
Oct.	11	7,455	1,885	480	288	10,509	0
Nov.	11	7,576	1,915	487	279	10,170	0
Dec.	11	4,950	1,258	323	288	10,509	0
Total	129	107,887	27,230	6,913	3,063	123,822	0

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

Table C.14. Monthly nonpoint fecal coliform loadings in sub-watershed BW-4.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	0	944	244	65	165	5,598	0
Fe.	0	1,005	259	68	150	5,101	0
Mar.	0	1,868	476	123	133	5,598	0
Apr.	0	1,857	473	122	129	5,417	0
May.	0	1,968	501	129	133	5,598	0
Jun.	0	1,943	494	127	129	5,417	0
Jul.	0	2,060	524	135	133	5,598	0
Aug.	0	2,112	537	138	133	5,598	0
Sep.	0	2,109	536	138	159	5,417	0
Oct.	0	1,351	346	90	165	5,598	0
Nov.	0	1,373	351	92	159	5,417	0
Dec.	0	904	234	62	165	5,598	0
Total	0	19,493	4,974	1,290	1,752	65,957	0

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

Table C.15. Monthly nonpoint fecal coliform loadings in sub-watershed BW-5.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	0	718	185	49	223	6,089	0
Fe.	0	764	196	51	203	5,549	0
Mar.	0	1,425	362	93	181	6,089	0
Apr.	0	1,417	360	92	175	5,893	0
May.	0	1,502	381	98	181	6,089	0
Jun.	0	1,484	377	97	175	5,893	0
Jul.	0	1,574	399	102	181	6,089	0
Aug.	0	1,614	409	105	181	6,089	0
Sep.	0	1,610	408	104	216	5,893	0
Oct.	0	1,030	263	68	223	6,089	0
Nov.	0	1,046	267	69	216	5,893	0
Dec.	0	687	177	47	223	6,089	0
Total	0	14,871	3,782	975	2,377	71,743	0

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

Table C.16. Monthly nonpoint fecal coliform loadings in sub-watershed BW-6.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	0	3	1	1	3	201	0
Fe.	0	2	1	1	3	183	0
Mar.	0	3	1	1	3	201	0
Apr.	0	3	1	1	3	195	0
May.	0	3	1	1	3	201	0
Jun.	0	3	1	1	3	195	0
Jul.	0	3	1	1	3	201	0
Aug.	0	3	1	1	3	201	0
Sep.	0	3	1	1	3	195	0
Oct.	0	3	1	1	3	201	0
Nov.	0	3	1	1	3	195	0
Dec.	0	3	1	1	3	201	0
Total	0	30	15	8	36	2,370	0

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

Table C.17. Monthly nonpoint fecal coliform loadings in sub-watershed JC-1.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	1	5,915	1,497	382	271	807	0
Fe.	1	6,318	1,596	406	247	736	0
Mar.	1	11,847	2,982	753	228	807	0
Apr.	1	11,787	2,967	749	221	781	0
May.	1	12,505	3,147	795	228	807	0
Jun.	1	12,377	3,115	786	221	781	0
Jul.	1	13,127	3,303	833	228	807	0
Aug.	1	13,464	3,387	855	228	807	0
Sep.	1	13,413	3,374	851	262	781	0
Oct.	1	8,536	2,153	546	271	807	0
Nov.	1	8,675	2,187	554	262	781	0
Dec.	1	5,660	1,433	366	271	807	0
Total	9	123,623	31,141	7,876	2,940	9,512	0

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

Table C.18. Monthly nonpoint fecal coliform loadings in sub-watershed JC-2.

Month	Fecal Coliform loadings (x10^{10} cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]	Loafing Lot
Jan.	2	2,089	535	139	378	2,279	0
Fe.	2	2,227	568	147	345	2,077	0
Mar.	2	4,161	1,054	269	324	2,279	0
Apr.	2	4,141	1,048	268	314	2,206	0
May.	2	4,398	1,113	284	324	2,279	0
Jun.	2	4,370	1,106	282	314	2,206	0
Jul.	2	4,635	1,172	299	324	2,279	0
Aug.	2	4,753	1,202	306	324	2,279	0
Sep.	2	4,714	1,192	304	366	2,206	0
Oct.	2	3,007	764	197	378	2,279	0
Nov.	2	3,053	776	199	366	2,206	0
Dec.	2	2,000	512	134	378	2,279	0
Total	26	43,548	11,042	2,828	4,134	26,858	0

[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 nonpoint sources in sub-watershed JR-2 of James River (VAC-H03R-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	2,282	0%	456	80%
Pasture	22,734,832	91%	4,546,966	80%
Loafing Lots	0	0%	0	0%
Forest	975,646	4%	975,646	0%
Residential	1,169,808	5%	233,962	80%
Total	24,882,569	100%	5,757,031	77%

Table D.2. Required annual reductions in direct nonpoint sources in sub-watershed JR-2 of James River (VAC-H03R-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	121,147	30%	24,229	80%
Wildlife in Streams	90,566	22%	90,566	0%
Straight Pipes	196,714	48%	0	100%
Total	408,427	100%	114,796	72%

Table D.3. Required annual reductions in nonpoint sources in sub-watershed JR-3 of James River (VAC-H03R-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	1,094	0%	219	80%
Pasture	3,000,874	45%	600,175	80%
Loafing Lots	0	0%	0	0%
Forest	218,450	3%	218,450	0%
Residential	3,404,412	51%	680,882	80%
Total	6,624,830	100%	1,499,726	77%

Table D.4. Required annual reductions in direct nonpoint sources in sub-watershed JR-3 of James River (VAC-H03R-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	530	0.8%	106	80%
Wildlife in Streams	23,552	38%	23,552	0%
Straight Pipes	38,670	62%	0	100%
Total	62,752	100%	23,658	62%

Table D.5. Required annual reductions in nonpoint sources in sub-watershed JR-4 of James River (VAC-H03R-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	57,418	0%	11,484	80%
Pasture	180,012,664	94%	36,002,531	80%
Loafing Lots	0	0%	0	0%
Forest	2,040,771	1%	2,040,771	0%
Residential	8,662,021	5%	1,732,404	80%
Total	190,772,874	100%	39,787,189	79%

Table D.6. Required annual reductions in direct nonpoint sources in sub-watershed JR-4 of James River (VAC-H03R-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	343,042	19%	68,608	80%
Wildlife in Streams	296,567	16%	296,567	0%
Straight Pipes	1,172,754	65%	0	100%
Total	1,812,363	100%	365,175	80%

Table D.7. Required annual reductions in nonpoint sources in sub-watershed JR-5 of James River (VAC-H03R-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	1,177	0%	235	80%
Pasture	5,080,616	64%	1,016,123	80%
Loafing Lots	0	0%	0	0%
Forest	196,048	2%	196,048	0%
Residential	2,650,718	33%	530,143	80%
Total	7,928,558	100%	1,742,550	78%

Table D.8. Required annual reductions in direct nonpoint sources in sub-watershed JR-5 of James River (VAC-H03R-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	4,618	5%	924	80%
Wildlife in Streams	21,326	25%	21,326	0%
Straight Pipes	60,707	70%	0	100%
Total	86,651	100%	22,249	74%

Table D.9. Required annual reductions in nonpoint sources in sub-watershed JR-6 of James River (VAC-H03R-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	309	0%	62	80%
Pasture	1,337,163	28%	267,433	80%
Loafing Lots	0	0%	0	0%
Forest	70,899	1%	70,899	0%
Residential	3,383,066	71%	676,613	80%
Total	4,791,437	100%	1,015,007	79%

Table D.10. Required annual reductions in direct nonpoint sources in sub-watershed JR-6 of James River (VAC-H03R-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	13,388	24%	2,678	80%
Wildlife in Streams	11,294	20%	11,294	0%
Straight Pipes	31,290	56%	0	100%
Total	55,971	100%	13,971	75%

Table D.11. Required annual reductions in nonpoint sources in sub-watershed JR-7 of James River (VAC-H03R-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	4,895	0%	979	80%
Pasture	46,011,201	79%	9,202,240	80%
Loafing Lots	0	0%	0	0%
Forest	1,195,981	2%	1,195,981	0%
Residential	11,279,684	19%	2,255,937	80%
Total	58,491,761	100%	12,655,136	78%

Table D.12. Required annual reductions in direct nonpoint sources in sub-watershed JR-7 of James River (VAC-H03R-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	150,487	27%	30,097	80%
Wildlife in Streams	150,902	27%	150,902	0%
Straight Pipes	265,698	47%	0	100%
Total	567,087	100%	181,000	68%

Table D.13. Required annual reductions in nonpoint sources in sub-watershed BW-1 of Ivy Creek (VAC-H03R-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	12,958	0%	259	98%
Pasture	58,859,259	94%	1,177,184	98%
Loafing Lots	0	0%	0	0%
Forest	653,413	1%	653,413	0%
Residential	3,167,976	5%	63,359	98%
Total	62,693,606	100%	1,894,216	97%

Table D.14. Required annual reductions in direct nonpoint sources in sub BW-1 of Ivy Creek (VAC-H03R-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	381,778	65%	7,636	98%
Wildlife in Streams	91,400	16%	91,400	0%
Straight Pipes	110,590	19%	0	100%
Total	583,768	100%	99,036	83%

Table D.15. Required annual reductions in nonpoint sources in sub-watershed BW-2 of Ivy Creek (VAC-H03R-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	16,666	0%	333	98%
Pasture	61,571,599	86%	1,231,431	98%
Loafing Lots	0	0%	0	0%
Forest	919,901	1%	919,901	0%
Residential	9,019,766	13%	180,395	98%
Total	71,527,931	100%	2,332,060	97%

Table D.16. Required annual reductions in direct nonpoint sources in sub BW-2 of Ivy Creek (VAC-H03R-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	328,219	54%	6,564	98%
Wildlife in Streams	120,250	20%	120,250	0%
Straight Pipes	157,510	26%	0	100%
Total	605,979	100%	126,814	79%

Table D.17. Required annual reductions in nonpoint sources in sub-watershed BW-3 of Ivy Creek (VAC-H03R-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	542	0%	11	98%
Pasture	20,630	0.4%	413	98%
Loafing Lots	0	0%	0	0%
Forest	261,208	6%	261,208	0%
Residential	4,456,628	94%	89,132	98%
Total	4,739,008	100%	350,764	93%

Table D.18. Required annual reductions in direct nonpoint sources in sub BW-3 of Ivy Creek (VAC-H03R-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	0	0%	0	98%
Wildlife in Streams	25,173	98%	25,173	0%
Straight Pipes	640	2%	0	100%
Total	25,813	100%	25,173	2%

Table D.19. Required annual reductions in nonpoint sources in sub-watershed FG-1 of Fishing Creek (VAC-H03R-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	765	0%	153	80%
Pasture	4,459,041	37%	891,808	80%
Loafing Lots	0	0%	0	0%
Forest	292,280	2%	292,280	0%
Residential	7,263,289	60%	1,452,658	80%
Total	12,015,375	100%	2,636,899	78%

Table D.20. Required annual reductions in direct nonpoint sources in sub-watershed FG-1 of Fishing Creek (VAC-H03R-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	21,866	36%	4,373	80%
Wildlife in Streams	37,740	62%	37,740	0%
Straight Pipes	808	1%	0	100%
Total	60,414	100%	42,113	30%

Table D.21. Required annual reductions in nonpoint sources in sub-watershed BW-8 of Blackwater Creek (VAC-H03R-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	142	0%	13	91%
Pasture	89,600	0.8%	8,064	91%
Loafing Lots	0	0%	0	0%
Forest	220,211	2%	220,211	0%
Residential	11,189,887	97%	1,007,090	91%
Total	11,499,839	100%	1,235,377	89%

Table D.22. Required annual reductions in direct nonpoint sources in sub-watershed BW-8 of Blackwater Creek (VAC-H03R-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	0	0%	0	0%
Wildlife in Streams	33,070	23%	33,070	0%
Straight Pipes	110,234	77%	0	100%
Total	143,303	100%	33,070	77%

Table D.23. Required annual reductions in nonpoint sources in sub-watershed BW-9 of Blackwater Creek (VAC-H03R-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	665	0%	60	91%
Pasture	35,700	0.6%	3,213	91%
Loafing Lots	0	0%	0	0%
Forest	142,242	2%	142,242	0%
Residential	5,830,856	97%	524,777	91%
Total	6,009,462	100%	670,292	89%

Table D.24. Required annual reductions in direct nonpoint sources in sub-watershed BW-9 of Blackwater Creek (VAC-H03R-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	0	0%	0	0%
Wildlife in Streams	19,289	9%	19,289	0%
Straight Pipes	202,019	91%	0	100%
Total	221,309	100%	19,289	91%

Table D.25. Required annual reductions in nonpoint sources in sub-watershed BW-7 of Tomahawk Creek (VAC-H03R-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	12,920	0%	646	95%
Pasture	14,202,993	53%	710,150	95%
Loafing Lots	0	0%	0	0%
Forest	306,310	1%	306,310	0%
Residential	12,382,197	46%	619,110	95%
Total	26,904,420	100%	1,636,216	94%

Table D.26. Required annual reductions in direct nonpoint sources in sub-watershed BW-7 of Tomahawk Creek (VAC-H03R-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	62,632	18%	3,132	95%
Wildlife in Streams	48,248	14%	48,248	0%
Straight Pipes	238,112	68%	0	100%
Total	348,993	100%	51,380	85%

Table D.27. Required annual reductions in nonpoint sources in sub-watershed BW-4 of Burton Creek (VAC-H03R-05).

	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	0	0%	0	98%
Pasture	2,575,656	28%	51,513	98%
Loafing Lots	0	0%	0	0%
Forest	175,192	2%	175,192	0%
Residential	6,595,728	71%	131,914	98%
Total	9,346,575	100%	358,619	96%

Table D.28. Required annual reductions in direct nonpoint sources in sub-watershed BW-4 of Burton Creek (VAC-H03R-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	15,376	15%	308	98%
Wildlife in Streams	26,399	25%	26,399	0%
Straight Pipes	63,985	61%	0	100%
Total	105,760	100%	26,707	75%

Table D.29. Required annual reductions in nonpoint sources in sub-watershed BW-5 of Burton Creek (VAC-H03R-05).

	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	0	0%	0	98%
Pasture	1,962,786	21%	39,256	98%
Loafing Lots	0	0%	0	0%
Forest	237,714	3%	237,714	0%
Residential	7,174,280	77%	143,485	98%
Total	9,374,780	100%	420,455	96%

Table D.30. Required annual reductions in direct nonpoint sources in sub-watershed BW-5 of Burton Creek (VAC-H03R-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	9,734	23%	195	98%
Wildlife in Streams	31,586	76%	31,586	0%
Straight Pipes	170	0.4%	0	100%
Total	41,490	100%	31,781	23%

Table D.31. Required annual reductions in nonpoint sources in sub-watershed BW-6 of Burton Creek (VAC-H03R-05).

	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	0	0%	0	98%
Pasture	5,331	2%	107	98%
Loafing Lots	0	0%	0	0%
Forest	3,622	1%	3,622	0%
Residential	237,040	96%	4,741	98%
Total	245,993	100%	8,469	97%

Table D.32. Required annual reductions in direct nonpoint sources in sub-watershed BW-6 of Burton Creek (VAC-H03R-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	0	0%	0	98%
Wildlife in Streams	1,092	100%	1,092	0%
Straight Pipes	0	0%	0	100%
Total	1,092	100%	1,092	0%

Table D.33. Required annual reductions in nonpoint sources in sub-watershed JC-1 of Judith Creek (VAC-H03R-05).

	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	882	0%	53	94%
Pasture	16,264,003	93%	975,840	94%
Loafing Lots	0	0%	0	0%
Forest	293,977	2%	293,977	0%
Residential	951,233	5%	57,074	94%
Total	17,510,096	100%	1,326,945	92%

Table D.34. Required annual reductions in direct nonpoint sources in sub-watershed JC-1 of Judith Creek (VAC-H03R-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	61,390	35%	3,683	94%
Wildlife in Streams	37,892	21%	37,892	0%
Straight Pipes	77,511	44%	0	100%
Total	176,794	100%	41,576	76%

Table D.35. Required annual reductions in nonpoint sources in sub-watershed JC-2 of Judith Creek (VAC-H03R-05).

	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	2,589	0%	155	94%
Pasture	5,741,844	65%	344,511	94%
Loafing Lots	0	0%	0	0%
Forest	413,419	5%	413,419	0%
Residential	2,685,762	30%	161,146	94%
Total	8,843,615	100%	919,231	90%

Table D.36. Required annual reductions in direct nonpoint sources in sub-watershed JC-2 of Judith Creek (VAC-H03R-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	252	0.1%	15	94%
Wildlife in Streams	42,282	17%	42,282	0%
Straight Pipes	200,605	83%	0	100%
Total	243,139	100%	42,297	83%