Bacteria TMDLs for Wilson Creek, Ore Branch and Roanoke River Watersheds, Virginia

Submitted by

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Executive Summary

This report presents the development of Bacteria TMDLs for the Wilson Creek, Ore Branch and Roanoke River watersheds, located in the Upper Roanoke River Basin. Segments of Wilson Creek, Ore Branch and the Roanoke River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform bacteria. These segments were also included on Virginia's 2002 303(d) Report on Impaired Waters and 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The impaired segments are located in the Upper Roanoke River Basin in southwestern Virginia.

Description of the Study Area

Wilson Creek is a tributary to the North Fork Roanoke River and is located in Montgomery County, while Ore Branch is a tributary to the Roanoke River and flows from Roanoke County into Roanoke City. The impaired segment of the Roanoke River begins in Salem City and flows through Roanoke City into Roanoke County. All three streams are located in the Upper Roanoke River Basin (USGS Cataloging Unit 03010101). The watershed is approximately 371,658 acres (580 square miles) and drains portions of Floyd, Montgomery, Roanoke, Botetourt, Bedford and Franklin Counties and all of Salem and Roanoke Cities.

Bacteria TMDLs have already been approved for five impaired streams in the watershed: Carvin Creek, Glade Creek, Laymantown Creek, Lick Run and Tinker Creek. The first four impairments all flow into Tinker Creek, which then flows into the Roanoke River just upstream of the Roanoke City/Roanoke County line near Vinton, Virginia. The results of the bacteria TMDLs developed for the Tinker Creek watershed were input into the model developed for this study.

Approximately 40 percent of the drainage basin is located in Roanoke County, 32 percent in Montgomery County and 12 percent in Botetourt County; the remainder of the watershed is divided among Floyd, Franklin and Bedford Counties (six, two and one percent, respectively) and the Cities of Roanoke and Salem (six and two percent, respectively). The watershed makes up 100 percent of the land area in the Cities of Roanoke and Salem, 90 percent of Roanoke County, 48 percent of Montgomery County, 13 percent of Botetourt County, eight percent of Floyd County and one percent each of Bedford and Franklin Counties. Interstate Route 81 (I-81) and U.S. Route 11 (US-11) run the entire length of the watershed from the northeast near Troutville to the southwest near Christiansburg. U.S. Route 221 (US-221) and the Blue Ridge Parkway pass through the lower section of the watershed in a northeast to southwest direction. U.S. Route 220 (US-220) runs the lower half of the watershed from the north near Trinity to the south near Boones Mill.

Impairment Description

The impaired segment of Wilson Creek (VAW-L02R-02) begins just east of Route 460, off Route 723 near Christiansburg and ends at the mouth of Wilson Creek on the North Fork of the Roanoke River just upstream of Route 603. The segment includes an unnamed tributary 1.65 mi. long that flows into Wilson Creek from the north. Fourteen of 27 samples (52%) collected at the listing station (4AWLN000.40) between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100 ml, while two of three samples (67%) collected during the same period exceeded the *Escherichia coli* (*E. coli*) instantaneous criterion of 235 cfu/100 ml.

The entire length of Ore Branch is impaired (VAW-L04R-04), from the headwaters to the mouth of Ore Branch on the Roanoke River. Three of six samples (50%) collected at the listing station (4AORE000.19) between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100 ml. In addition to the impaired segments on Wilson Creek and Ore Branch, this report also addresses two impairments on the Roanoke River. The first impaired segment (VAW-L04R-01) begins at the confluence of Mason Creek with the Roanoke River at river mile 210.47 and ends at the outfall of the Roanoke Regional STP at river mile 200.60. This impairment is based on two listing stations: 4AROA212.17 and 4AROA202.20. Eight of 41 samples (20%) collected at 4AROA212.17 and 17 of 58 samples (29%) collected at

4AROA202.20 between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100 ml. The second impaired segment (VAW-L04R-02) begins at the Roanoke Regional STP outfall and ends at the Niagara Dam at river mile 198.36. The total length of these four segments is 23.09 miles.

Applicable Water Quality Standards

At the time of the Wilson Creek, Ore Branch and Roanoke River listings, the Virginia Bacteria Water Quality Standard was expressed in fecal coliform bacteria; however, the bacteria water quality standard has been recently changed and is now expressed in E. coli. Virginia's bacteria water quality standard currently states that E. coli bacteria shall not exceed a geometric mean of 126 E. coli counts per 100 ml of water for two or more samples over a 30-day period or an E. coli concentration of 235 counts per 100 ml of water at anytime. However, the loading rates for watershed-based modeling are available only in terms of the previous standard, fecal coliform bacteria. Therefore, the TMDL was expressed in E. coli by converting modeled daily fecal coliform concentrations to daily E. coli concentrations using an in-stream translator. This TMDL was required to meet both the geometric mean and instantaneous E. coli water quality standard.

Watershed Characterization

Land use characterization was based on National Land Cover Data (NLCD) developed by USGS. The watershed is predominantly forested, with some agricultural lands clustered in the northeastern portion of the watershed. Urban and residential areas are clustered around the Cities of Roanoke and Salem in the eastern half of the watershed, with some smaller clusters located on the western edge of the watershed near Christianburg. Forested and agricultural lands consist of 73.2 and 15.4 percent respectively of the total drainage area Urban lands consists of 10 percent of total drainage area.

The potential sources of fecal coliform include run-off from livestock grazing, manure applications, industrial processes, residential, and domestic pets waste. Some of these sources are driven by dry weather and others are driven by wet weather. The potential sources of fecal coliform in the watershed were identified and characterized. These sources include permitted point sources, failed septic systems and straight pipes, livestock, wildlife, and pets.

An inventory of the livestock residing in the Wilson Creek, Ore Branch and Roanoke River watershed was conducted using county-specific data obtained from the United State Department of Agriculture (USDA) National Agricultural Statistics Service. The data and information indicate the following:

- beef and dairy cattle exist on the pasture areas of the watershed
- no poultry operations exist in the watershed
- no swine operations exist in the watershed
- no feedlots are located in the watershed
- alternative water has been implemented in the watershed to minimize livestock activity in the streams

There are 18 individually permitted facilities and 15 domestic sewage general permits located in the Wilson Creek, Ore Branch, and Roanoke River watersheds. For TMDL development, mean flow values were considered representative of flow conditions at each permitted facility, and were used in the model set-up and calibration. For TMDL allocation development, permitted facilities were represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

Bacteria Source Tracking

In the Wilson Creek, watershed, bacteria source tracking (BST) was conducted monthly at one monitoring station (4AWLN000.40) from November 2002 through October 2003. A total of 12 sampling events were collected at this station. The human signature in samples ranged from 0 to 38 percent, the wildlife signature ranged from 0 to 71 percent, the livestock signature ranged from 8 to 59 percent, and the pet signature ranged from 8 to 87 percent.

In the Ore Branch, watershed, bacteria source tracking (BST) was conducted monthly at one monitoring station (4AORE000.19) from July 2003 through June 2004. A total of 12 sampling events were collected at this station. The human signature in samples ranged from 0 to 84 percent, the wildlife signature ranged from 0 to 33 percent, the livestock signature ranged from 0 to 38 percent, and the pet signature ranged from 0 to 80 percent.

In the Roanoke River watershed, bacteria source tracking (BST) was conducted monthly at 5 monitoring station (AROA202.20, 4AROA205.73, 4AROA212.17, 4AROA192.94, and 4AROA199.20) from July 2003 through July 2004. A total of 60 sampling events were collected at these stations. The human signature in samples ranged from 0 to 84 percent, the wildlife signature ranged from 0 to 100 percent, the livestock signature ranged from 0 to 100 percent, and the pet signature ranged from 0 to 96 percent.

TMDL Technical Approach

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the in-stream water quality conditions of delineated watershed under varying scenarios of rainfall and fecal coliform loading. The results from the developed model were used to develop the TMDL allocations based on the existing fecal coliform load. HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

For this TMDL, the Roanoke River watershed including the Wilson Creek and Ore Branch watersheds were delineated into 85 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. The Roanoke River watershed was delineated into 62 subwatersheds, Wilson Creek watershed was delineated into 5 subwatersheds, and Ore Branch watershed was delineated into 1 subwatershed. Tinker Creek was delineated into 17 subwatersheds. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data.

Stream flow data were available from severable stations and utilized in the hydrology calibrations and TMDLs development. Weather data for the Roanoke, VA WSO Airport and the Pulaski precipitation gages were obtained from the National Climatic Data Center (NCDC). The data include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). The Roanoke Airport recorded data from 1952 present and the Pulaski recorded data from 1987 to the present. For this TMDL, the recorded data at Roanoke and Pulaski were combined based on their proximity to Wilson Creek, Ore Branch, and Roanoke River watershed.

The period of January 1996 to December 1999 was used for HSPF hydraulic calibration and January 2003 to December 2004 was used to validate the HSPF model. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization is representative of the hydrologic characteristics of the study areas. The model results closely matched the observed flows during low flow conditions, base flow recession and storm peaks.

Instream water quality data for this station was retrieved from STORET and DEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. The time period of January 1997 to December 1998 was used for water quality calibration of the model, and the period of January 2002 to December 2003 was used for model validation.

The existing fecal coliform loading was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of January 1995 to December 2004. Virginia has recently changed its bacteria standard from fecal coliform to E. coli; therefore, modeled fecal coliform concentrations were changed to E. coli concentrations using a translator. Water quality standards for both fecal coliform and E. coli were exceeded for the most part during this time period.

TMDL Calculations

The TMDL represents the maximum amount of a pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$\text{TMDL} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was implicitly incorporated in this TMDL. Implicitly incorporating the MOS required that allocation scenarios be designed to meet a 30-day geometric mean E. coli standard of 126 cfu/100 ml and the instantaneous E. coli standard of 235 cfu/100 ml with 0% exceedance.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

For the hydrologic period from January 1995 to December 2004, fecal coliform loading and instream fecal coliform concentrations were estimated for the various scenarios using the developed HSPF model of the Wilson Creek, Ore Branch, and Roanoke River watersheds. Because Virginia has recently changed its bacteria standard from fecal coliform to E. coli, modeled fecal coliform concentrations were translated to E. coli concentrations, and the TMDL allocation plan was developed to meet geometric mean and instantaneous E. coli standards. Based on the load-allocation scenario analyses, the TMDL allocation plans that will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous E. coli water quality standard of 235 cfu/100 ml are presented in Table E-1:

Table E-1: Allocation Plan Loads for E. coli for Wilson Creek, Ore Branch, and Roanoke River

Watershed	Human Sources (failed septic systems and straight pipes) (% reduction)	Livestock (Direct Instream Loading) (% reduction)	Agricultural and urban non-point sources (% reduction)	Wildlife (% reduction)
Wilson Creek	100	100	99.5	90
Ore Branch	100	100	99.5	93
Roanoke River	100	100	98.8	68

The summaries of the bacteria TMDL allocation plan loads for Wilson Creek, Ore Branch, and Roanoke River are presented in Table E-2.

Table E-2: Wilson Creek, Ore Branch, and Roanoke River TMDL Allocation Plan Loads for E. coli (cfu/year)

Watershed	Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
Wilson Creek	6.65E+9	3.64E+11	Implicit	3.70E+11
Ore Branch	2.17E+10	8.15E+10	Implicit	1.03E+11
Roanoke River	1.10E+14	3.02E+13	Implicit	1.40E+14

Tables E-3, E-4, and E-5 show the waste load allocations in Wilson Creek, Ore Branch and the Roanoke River respectively. Similarly, Tables E-6, E-7, and E-8 show the breakdown of the load allocations in Wilson Creek, Ore Branch and the Roanoke River respectively.

Table E-3: Wilson Creek Wasteload Allocation for E. coli

Point Source	Name	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VAR040019*	Town of Blacksburg	6.29E+11	3.15E+09	99.5%
VAR040025*	Town of Christianburg	4.65E+11	2.33E+09	99.5%
VAR040016*	VDOT Montgomery County Urban Area	2.34E+11	1.17E+09	99.5%
	Total	**1.33E+12**	**6.65E+09**	**99.5%**

(*) MS4 permit loads based on each share of the MS4 contributing urbanized area of the impairment. Appendix F outlines the steps used in the development of the MS4 E. coli allocations.

Table E-4: Ore Branch Wasteload Allocation for E. coli

Point Source	Name	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VAR040004*	City of Roanoke	4.04E+12	2.02E+10	99.5%
VAR040017*	VDOT Roanoke Urban Area	8.70E+10	4.35E+08	99.5%
VAR040022*	Roanoke County	2.13E+11	1.07E+09	99.5%
	Total	**4.35E+12**	**2.17E+10**	**99.5%**

(*) MS4 permit loads based on each share of the MS4 contributing urbanized area of the impairment. Appendix F outlines the steps used in the development of the MS4 E. coli allocations.

Table E-5: Roanoke River Wasteload Allocation for E. coli

Point Source	Name	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VA0077895	Roanoke Moose Lodge	8.18E+09	8.18E+09	0%
VA0027481	Blacksburg Country Club Sewage Treatment Plant	6.10E+10	6.10E+10	0%
VA0062219	Montgomery County PSA – Elliston-Lafayette WWTP	4.34E+11	4.34E+11	0%
VA0024031	Shawsville Town – Sewage Treatment Plant	3.48E+11	3.48E+11	0%
VA0025020	Western Virginia Water Authority Water Pollution Control Plant	1.08E+14	1.08E+14	0%
VA0028711	Suncrest Heights	3.48E+10	3.48E+10	0%
VAR040022*	Roanoke County	2.37E+13	2.84E+11	98.8%
VAR040004*	City of Roanoke	1.61E+13	1.93E+11	98.8%
VAR040026*	Town of Vinton	2.77E+12	3.32E+10	98.8%
VAR040010*	City of Salem	1.91E+13	2.29E+11	98.8%
VAR040017*	VDOT Roanoke Urban Area	8.94E+11	1.07E+10	98.8%
VAR040030*	Virginia Western Community College	1.44E+11	1.73E+09	98.8%
VAR040050*	Virginia Medical Center	6.56E+11	7.87E+09	98.8%
	Total	**1.72E+14**	**1.10E+14**	**36.0%**

(*) MS4 permit loads based on each share of the MS4 contributing urbanized area of the impairment. Appendix F outlines the steps used in the development of the MS4 E. coli allocations.

Table E-6: Wilson Creek Load Allocation for E. coli

Land Use/Source	Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	8.31E+10	4.15E+08	99.50%
Cropland	1.36E+11	6.81E+08	99.50%
Pasture	2.21E+12	1.11E+10	99.50%
Low Density Residential	1.27E+12	6.37E+09	99.50%
Commercial/Industrial/Transportation	1.43E+10	7.16E+07	99.50%
Water/Wetland	4.83E+07	2.42E+05	99.50%
Other Urban	1.41E+09	7.03E+06	99.50%
High Density Residential	1.62E+10	8.08E+07	99.50%
Failed Septic	9.39E+11	0.00E+00	100.00%
Cattle direct	2.44E+11	0.00E+00	100.00%
Wildlife	3.45E+12	3.45E+11	90.00%
Point Source + MS4s	1.33E+12	6.65E+09	99.5%
Total loads /Overall reduction	**9.70E+12**	**3.70E+11**	**96.18%**

Table E-7: Ore Branch Load Allocation for E. coli

Land Use/Source	Annual Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	2.44E+10	1.22E+08	99.50%
Cropland	0.00E+00	0.00E+00	0.00%
Pasture	1.83E+11	9.17E+08	99.50%
Low Density Residential	0.00E+00	0.00E+00	0.00%
Commercial/Industrial/Transportation	0.00E+00	0.00E+00	0.00%
Water/Wetland	5.82E+06	2.91E+04	99.50%
Other Urban	7.74E+08	3.87E+06	99.50%
High Density Residential	0.00E+00	0.00E+00	0.00%
Failed Septic	4.33E+11	0.00E+00	100.00%
Cattle direct	9.83E+09	0.00E+00	100.00%
Wildlife	1.15E+12	8.05E+10	93.00%
Point Source (MS4s)	4.35E+12	2.17E+10	99.50%
Total loads /Overall reduction	**6.16E+12**	**1.03E+11**	**98.32%**

TableE-8: Roanoke River Load Allocation for E. coli

Land Use/Source	Annual Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	2.48E+12	2.98E+10	98.8%
Cropland	3.21E+12	3.86E+10	98.8%
Pasture	4.03E+13	4.84E+11	98.8%
Low Density Residential	2.54E+13	3.05E+11	98.8%
Commercial/Industrial/Transportation	9.66E+10	1.16E+09	98.8%
Water/Wetland	3.70E+09	4.44E+07	98.8%
Other Urban	6.13E+09	7.35E+07	98.8%
High Density Residential	2.92E+11	3.51E+09	98.8%
Failed Septic	4.03E+14	0.00E+00	100%
Cattle direct	4.18E+12	0.00E+00	100%
Wildlife	9.18E+13	2.94E+13	68%
Point Source + MS4s	1.72E+14	1.10E+14	36%
Total loads /Overall reduction	**7.43E+14**	**1.40E+14**	**81.12%**

TMDL Implementation

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are: 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially, and 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

Three allocation scenarios are presented in Tables E-9, E-10, and E-11 for the Wilson Creek, Ore Branch, and the Roanoke River respectively. Scenario 1 represents the required load reduction that will not exceed the instantaneous standard by more than 10% violation. Scenarios 2 and 3 represent the implementation of BMPs and management strategies such as livestock exclusion from streams, alternative water, manure storage, riparian buffers, and pet waste control that can be readily put in place in the watershed.

TableE-9: Wilson Creek Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	99.5%	99.5%	89%	0%	6%
2	100%	50%	50%	50%	0%	55%	100%
3	100%	75%	75%	75%	0%	55%	100%

Table E-10: Ore Branch Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	99.5%	99.5%	92%	8%	3%
2	100%	50%	50%	50%	0%	48%	100%
3	100%	75%	75%	75%	0%	48%	100%

Table E-11: Roanoke River Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	98.8%	98.8%	61%	9%	0%
2	100%	50%	50%	50%	0%	53%	100%
3	100%	75%	75%	75%	0%	49%	100%

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. 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.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). 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.

Public Participation

The development of the Wilson Creek, Ore Branch, and Roanoke Rivers TMDLs would not have been possible without public participation. The first public meeting was held at the DEQ regional office in Roanoke VA on October 7, 2004 with 41 people attending the event. Copies of the presentation were available for public distribution. The meeting was public-noticed in *The Virginia Register of Regulations*. During the 30-day comment period, no written comments were received. The following information was presented during the meeting:

- listed segments in Wilson Creek, Ore Branch and the Roanoke River
- the data that caused the segments to be on the 303(d) list,
- review the TMDL process;
- the livestock, wildlife, and pet inventories;
- the fecal coliform sources assessment
- the calculation used to estimate the total available fecal coliform load;

- explanation of the assumptions used in the calculations; and presentation of the HSPF model.

The second public meeting was held was held in Shawsville, Virginia on August 4, 2005 to discuss the sources assessment, present the HSPF model calibration and the goodness of fit, and to discuss the Draft TMDL. Eleven people attended the August 4 public meeting. Copies of the presentation and the draft TMDL report executive summary were available for public distribution. The third public meeting was held at the DEQ regional office in Roanoke, VA on August 9, 2005 to discuss the topics from the August 4 public meeting. Twenty-two people attended the August 9 public meeting. In addition, several comments were received and are submitted with this report.

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1.0 Introduction

1.1 Background

1.1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a water body can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to develop and regulate a more effective TMDL process. DEQ is the lead agency for the development of TMDLs statewide and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. DEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA, passed by the Virginia General Assembly in 1997), and coordinates public participation throughout the TMDL development process. The role of DCR is to initiate non-point source pollution control programs statewide through the use of federal grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of bacterial contamination (DEQ, 2001).

As required by the Clean Water Act and WQMIRA, DEQ develops and maintains a listing of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the 303(d) List of Impaired Waters. In addition to 303(d) List development, WQMIRA directs DEQ to develop and implement TMDLs for listed waters (DEQ, 2001a). Once TMDLs have been developed, they are distributed for public comment and then submitted to the EPA for approval.

1.2 Impairment Listing

Segments of Wilson Creek, Ore Branch and the Roanoke River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform bacteria. These segments were also included on Virginia's 2002 303(d) Report on Impaired Waters and 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The impaired segments are located in the Upper Roanoke River Basin in southwestern Virginia (Figure 1-1). The watershed is located in the hydrologic unit (HUC) 03010101. The impaired watersheds include portions of Floyd, Montgomery, Roanoke and Botetourt Counties and Salem and Roanoke Cities.

The impaired segment of Wilson Creek (VAW-L02R-02) begins just east of Route 460, off Route 723 near Christiansburg and ends at the mouth of Wilson Creek on the North Fork of the Roanoke River just upstream of Route 603. The segment includes an unnamed tributary 1.65 mi. long that flows into Wilson Creek from the north. Fourteen of 27 samples (52%) collected at the listing station (4AWLN000.40) between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100 ml, while two of three samples (67%) collected during the same period exceeded the *Escherichia coli* (*E. coli*) instantaneous criterion of 235 cfu/100 ml.

The entire length of Ore Branch is impaired (VAW-L04R-04), from the headwaters to the mouth of Ore Branch on the Roanoke River. Three of six samples (50%) collected at the listing station (4AORE000.19) between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100 ml.

In addition to the impaired segments on Wilson Creek and Ore Branch, this report also addresses two impairments on the Roanoke River. The first impaired segment (VAW-L04R-01) begins at the confluence of Mason Creek with the Roanoke River at river mile 210.47 and ends at the outfall of the Roanoke Regional STP at river mile 200.60. This impairment is based on two listing stations: 4AROA212.17 and 4AROA202.20. Eight of 41 samples (20%) collected at 4AROA212.17 and 17 of 58 samples (29%) collected at 4AROA202.20 between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100 ml. The second impaired segment (VAW-L04R-02) begins at the Roanoke Regional STP outfall and ends at the Niagara Dam at river mile 198.36.

The total length of these four segments is 23.09 miles. Table 1-1 summarizes the details of the Wilson Creek, Ore Branch and Roanoke River impaired segments and Figure 1-2 presents their location.

Table 1-1: Details of the Wilson Creek, Ore Branch and Roanoke River Bacteria Impairments

Segment ID	Segment Name	Upstream Boundary	Downstream Boundary	Length (Miles)	Years Listed
VAW-L02R-02	Wilson Creek (and UT to Wilson Cr.)	East of Rt. 460, off Rt. 723, Christiansburg	Wilson Cr. Mouth on N.F. Roanoke R.	6.91 (1.65)	1996, 1998, 2002, 2004
VAW-L04R-04	Ore Branch	Headwaters in Hunting Hills	Ore Br. Mouth on Roanoke R.	2.42	1996, 1998, 2002, 2004
VAW-L04R-01*	Roanoke River	Confluence of Mason Cr. on the Roanoke R.	Roanoke Regional STP Outfall on the Roanoke R.	9.87	1996, 1998, 2002, 2004
VAW-L04R-02*	Roanoke River	Roanoke Regional STP Outfall on the Roanoke R.	Niagara Dam	2.24	1996, 1998, 2002, 2004
VAW-L12L-04* (in L07)	Smith Mountain Lake – Roanoke River	Back Cr. Mouth on Roanoke R. (795 ft. pool elevation)	Falling Cr. Mouth on Roanoke R. SML	6.26 (378 acres)	1998, 2002, 2004

* Portions of these segments also do not support the Aquatic Life and Fish Consumption Uses; TMDLs for these impairments are being developed separately.
Source: Virginia 2004 Water Quality Assessment 305(b)/303(d) Integrated Report.

Figure 1-1: Location of the Wilson Creek, Ore Branch and Roanoke River Watersheds

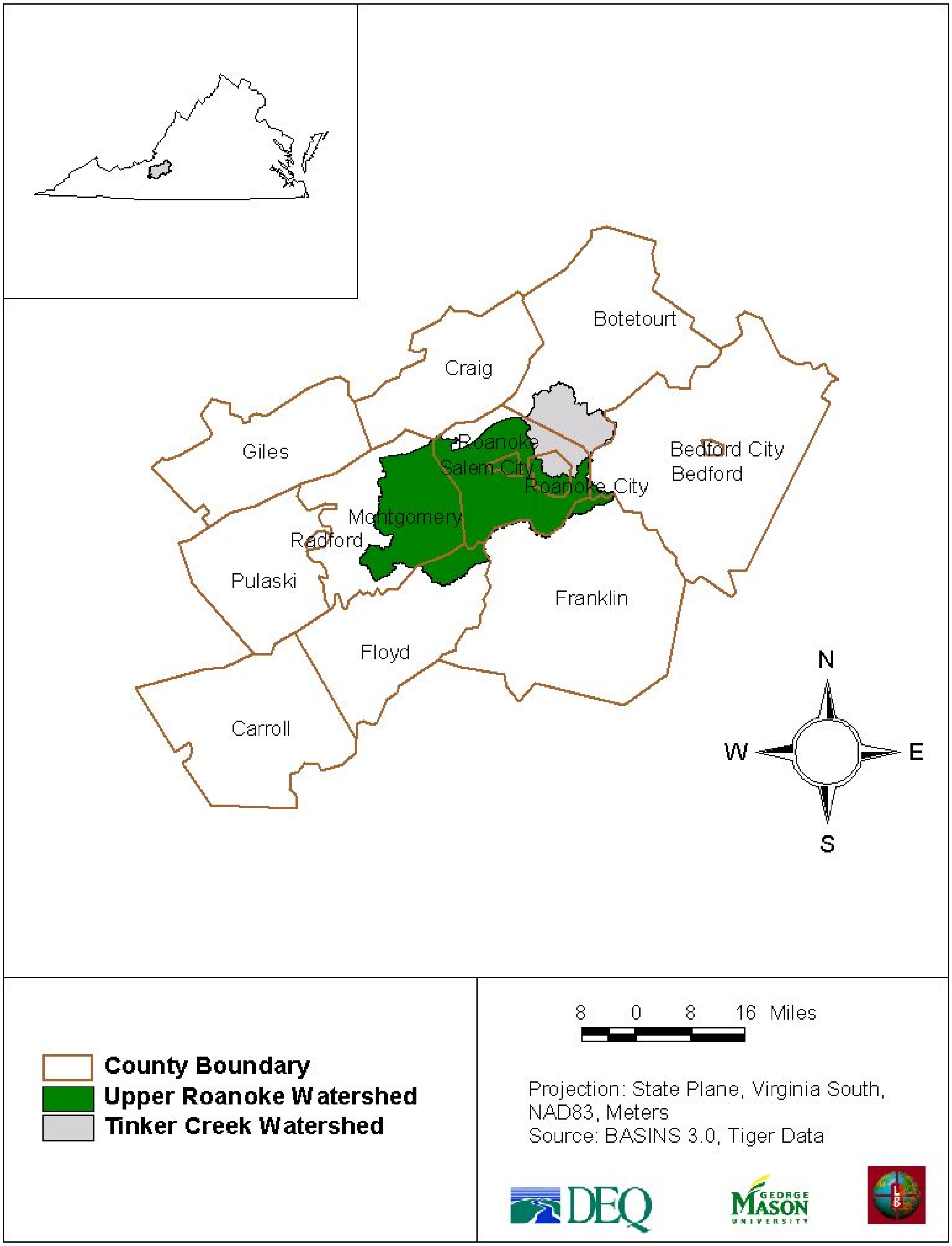
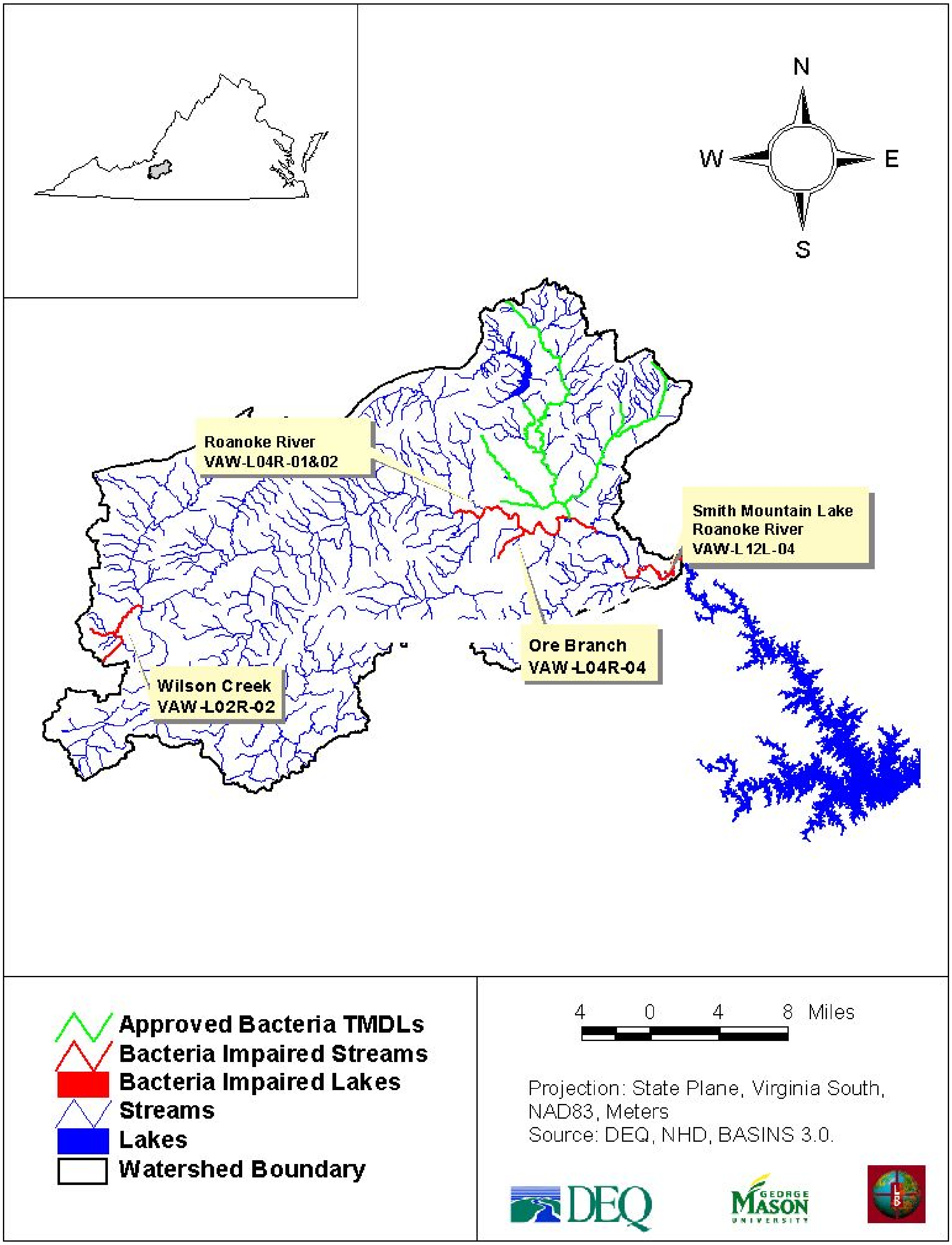


Figure 1-2: Wilson Creek, Ore Branch and Roanoke River Listed Segments



Virginia's 2004 305(b)/303(d) Water Quality Assessment Integrated Report identifies 14 of other bacteria impairments in the study watershed in addition to the four impairments addressed in this report. These additional impairments are summarized in Table 1-2 and are included in Figure 1-2. The approved TMDLs for Tinker Creek, Carvin Creek, Glade Creek, Lick Run and Laymantown Creek were included in developing the TMDLs presented in this report.

Table 1-2: Details of Additional Impairments in the Upper Portion of the Roanoke River Watershed

Segment ID	Segment Name	Cause(s) of Impairment (Years Listed)	Length (Miles)
VAW-L01R-01	Roanoke River, South Fork	Bacteria (2004) Temperature (2004)	12.65
VAW-L02R-01	Roanoke River, North Fork	Bacteria (2002, 2004)	6.56
VAW-L03R-01	Roanoke River	Bacteria (2004) Temperature (2002, 2004)	3.63
VAW-L03R-02	Roanoke River	Bacteria (1998, 2002, 2004) Temperature (2004) Fish Tissue – PCBs (2002, 2004)	11.68
VAW-L03R-04	Roanoke River	Bacteria (2002, 2004) Fish Tissue - PCBs (2002, 2004)	1.20
VAW-L04R-03	Roanoke River	Bacteria (2002, 2004) Fish Tissue - PCBs (2002, 2004)	3.35
VAW-L04R-05	Mason Creek	Bacteria (2002, 2004)	7.61
VAW-L04R-06	Peters Creek	Bacteria (2002, 2004) Fish Tissue - PCBs (2004)	7.17 2.52
VAW-L04R-07	Murray Run	Bacteria (2004)	3.23
VAW-L05R-01	Tinker Creek	Bacteria (1996, 1998, 2002, 2004) Temperature (1998, 2002, 2004)	19.38 11.90
VAW-L05R-02	Carvin Creek	Bacteria (2002, 2004)	5.35
VAW-L05R-03	Glade Creek	Bacteria (1998, 2002, 2004), Temperature (2002, 2004)	12.61 6.86
VAW-L05R-04	Lick Run	Bacteria (1996, 1998, 2002, 2004)	8.51
VAW-L05R-05	Laymantown Creek	Bacteria (2002, 2004)	2.08

Source: Virginia 2004 Water Quality Assessment 305(b)/303(d) Integrated Report

1.3 Applicable Water Quality Standard

Water quality standards consist of designated uses for a water body and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"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 be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

1.3.2 Applicable Water Quality Criteria

Effective January 15, 2003, DEQ specified a new bacteria standard in 9 VAC 25-260-170.A, and also revised the disinfection policy in 9 VAC 25-260-170.B. These standards replaced the existing fecal coliform standard and disinfection policy of 9 VAC 25-260-170. For a non-shellfish supporting waterbody to be in compliance with Virginia bacteria standards for primary contact recreation, the current criteria are as follows:

> *"Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples taken over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the [E. coli] bacterial indicators have a minimum of 12 data points or after June 30, 2008, whichever comes first."*

"E. coli bacteria shall not exceed a geometric mean of 126 bacteria per 100 ml of water for two or more samples taken during any calendar month nor should it exceed 235 counts per 100 ml of water for a single sample maximum value. No single sample maximum for E. coli shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater. Values shown are based on a log standard deviation of 0.4 in freshwater."

These criteria were adopted because there is a stronger correlation between the concentration of *E. coli* and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* are bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

For bacteria TMDL development after January 15, 2003, *E. coli* has become the primary applicable water quality target. However, the loading rates for watershed-based modeling are available only in terms of fecal coliform. Therefore, during the transition from fecal coliform to *E. coli* criteria, DCR, DEQ and EPA have agreed to apply a translator to in-stream fecal coliform data to determine whether reductions applied to the fecal coliform load would result in meeting in-stream *E. coli* criteria. The fecal coliform model and in-stream translator are used to calculate *E. coli* TMDLs. The following regression based in-stream translator is used to calculate *E. coli* concentrations from fecal coliform concentrations:

$$E.\ coli\ conc.\ (cfu/100\ ml) = 2^{-0.0172} \times [fecal\ coliform\ conc.\ (cfu/100ml)]^{0.91905}$$

For Wilson Creek, Ore Branch and the Roanoke River, the TMDL is required to meet both the geometric mean and instantaneous criteria. The modeled daily fecal coliform concentrations are converted to daily *E. coli* concentrations using the in-stream translator. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

2.0 TMDL Endpoint Identification

2.1 Selection of TMDL Endpoint and Water Quality Targets

Four stream segments on Wilson Creek, Ore Branch and the Roanoke River, located within Montgomery and Roanoke Counties and Salem and Roanoke Cities in west-central Virginia, were initially placed on the 1996 303(d) list for violations of the fecal coliform standards for primary contact recreation. These four segments, along with an unnamed tributary to Wilson Creek, were also included on the 1998, 2002 and 2004 303(d) lists. The impaired segments comprise approximately 23.1 river miles.

One of the first steps in TMDL development is determining the numeric endpoints, or water quality targets, for each impaired segment. Water quality targets compare the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the Wilson Creek, Ore Branch and Roanoke River TMDLs are established in Virginia Water Quality Standards (9 VAC 25-260), which state that all waters in Virginia should be free from any substances that can cause the water to violate the state numeric standards, interfere with its designated uses, or adversely affect human health and aquatic life. Therefore, the current water quality target for these four impairments, as stated in nine VAC 25-260-170, is an *E. coli* geometric mean not greater than 126 colony-forming units (cfu) per 100 ml for two or more water quality samples taken during any calendar month, and a single sample maximum of 235 cfu per 100 ml at all times.

2.2 Critical Condition

The critical condition is considered the “worst case scenario” of environmental conditions in Wilson Creek, Ore Branch, and the Roanoke River. If the TMDL is developed such that the water quality targets are met under the critical condition, then the targets would also be met under all other conditions.

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

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.

The Wilson Creek, Ore Branch and Roanoke River watershed flows through a predominantly rural setting, with forested and agricultural lands comprising the dominant land uses in the basin. Potential sources of fecal coliform include run-off from livestock grazing, manure applications, industrial processes, and residential waste. The TMDL critical condition will need to consider the location of large outfalls and contributions made from those outfalls during dry conditions, when there is little stream flow to dilute bacteria. If there are no significant dry weather flows (contributions from the outfalls), then the levels of fecal coliform may be attributed to direct deposition from livestock, wildlife, failed septic systems and straight pipes. Fecal coliform loadings resulted from sources contributing during wet weather and dry weather. Due to the recent adoption of *E. coli* as the indicator species for bacteria, bacteria data were expressed as *E. coli* and not as fecal coliform. For this TMDL, fecal coliform concentrations were modeled and then translated to *E. coli* concentrations.

2.2.1 Wilson Creek

The relationship of the coliform standard violations and stream flow in Wilson Creek was determined from the available in-stream water quality data and bacteria source tracking (BST) data collected by DEQ at monitoring station 4AWLN000.40. Flow data were obtained from USGS gauging station #2054500, located on the mainstem Roanoke River at Lafayette, VA, downstream of the confluence with Wilson Creek. Plotting bacteria water quality data from August 1988 to September 2004 along with stream flow data revealed that there was no apparent trend for the occurrence of fecal coliform standard exceedances. In fact, Figure 2-1 shows that the fecal coliform violations are uniformly distributed during all flow conditions. Bacteria source-tracking data at this station collected from November 2002 to October 2002 were also plotted to examine seasonal trends related to hydrologic conditions. However, BST *E. coli* concentrations plotted in

Figure 2-2 for at the same location shows that violations occurred primarily during low flow conditions.

2.2.2 Ore Branch

The relationship of the coliform standard exceedances and stream flow in Ore Branch was determined from the available in-stream water quality data and BST data collected by DEQ at monitoring station 4AORE000.19 located on Ore Branch. Flow data was obtained from USGS gauging station #2055000, located on the mainstem Roanoke River near the confluence with Ore Branch. Figure 2-3 depicts fecal coliform violations from November 1988 to September 2004 on Ore Branch as having a relatively uniform distribution throughout all flow conditions. However, the BST data shown in Figure 2-4 shows that the standard violations occurred mostly during mid-range to moist flow conditions. BST data was collected from July 2003 to June 2004.

2.2.3 Roanoke River

The relationship of the coliform standard exceedances and stream flow in the Roanoke River was determined from the available in-stream water quality data and BST monitoring data at several water quality stations along the mainstem Roanoke River including AROA202.20, 4AROA205.73, 4AROA212.17, 4AROA192.94, and 4AROA199.20. Flow data was obtained from USGS gauging station #2055000, located on the Roanoke River at Roanoke, VA. Figure 2-5 depicts the fecal coliform concentrations from January 1990 to September 2004 during different flow conditions. This graph indicates that most of the fecal coliform violations occurred during the high to mid-range flow conditions. The BST data collected from July 2003 to June 2004 and the flow data recorded along the Roanoke River monitoring stations are plotted in Figure 2-6. These results are similar to the water quality data since the majority of violations occurred during higher flow conditions.

Mid range to high flow periods were considered in the critical condition because many of the observed violations for all four watersheds occurred under these conditions. Violations under these conditions would occur from indirect sources of bacteria, and would most likely violate the geometric mean standard. However, this TMDL is required to meet both the geometric mean and instantaneous bacteria standards. Violations of the instantaneous standard would occur in wet weather, high flow conditions, when large amounts of bacteria can enter the stream from indirect non-point sources. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both the instantaneous and geometric mean bacteria standards.

2.3 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality because of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporates the seasonal variations of rainfall, runoff and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed the consideration of temporal variability in fecal coliform loading within the watershed.

Figure 2-1: Flow and Fecal Coliform Concentrations at Wilson Creek Monitoring Station 4AWLN000.40

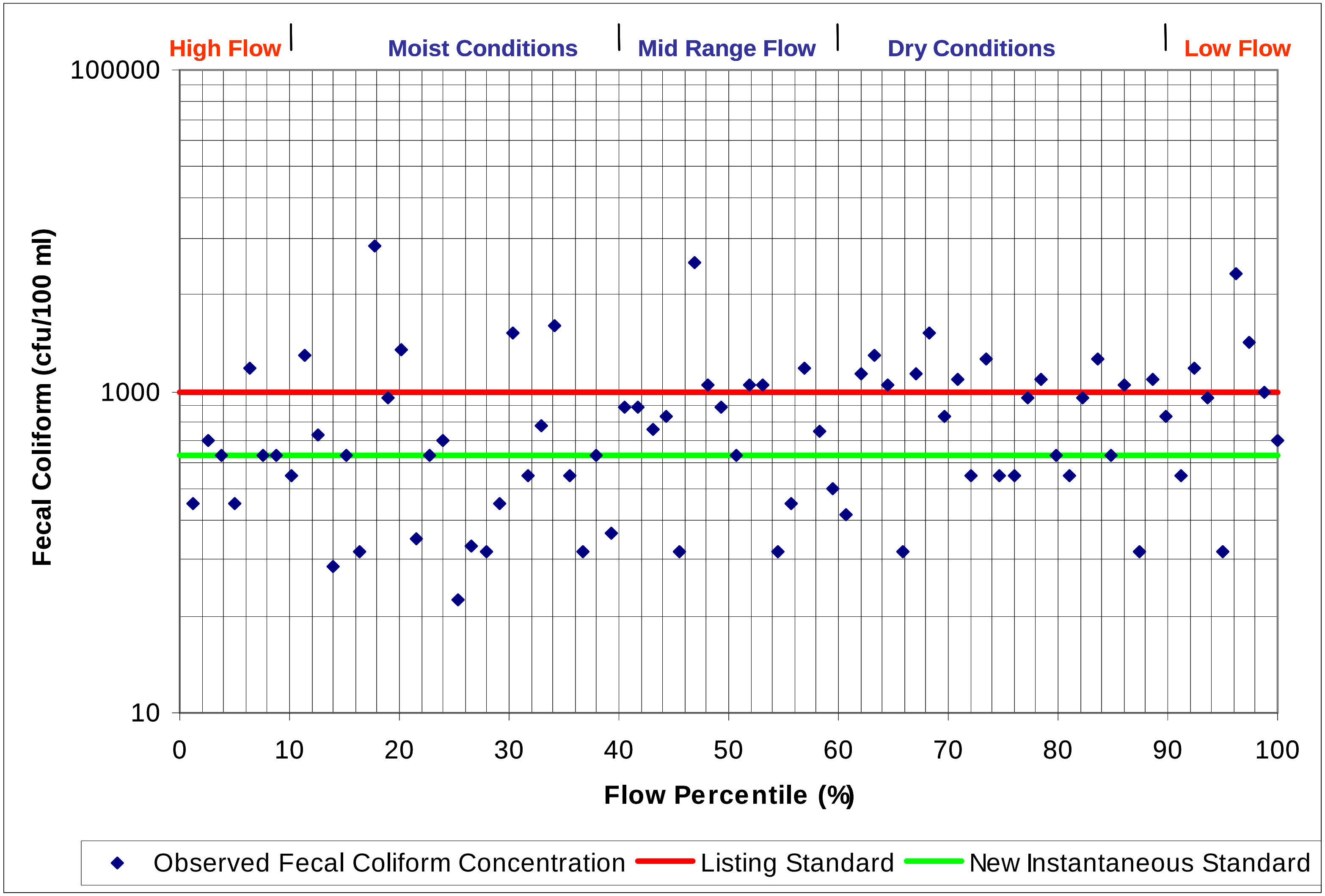


Figure 2-2: Flow and *E. coli* Concentrations from Bacteria Source Tracking Conducted at Wilson Creek Monitoring Station 4AWLN000.40

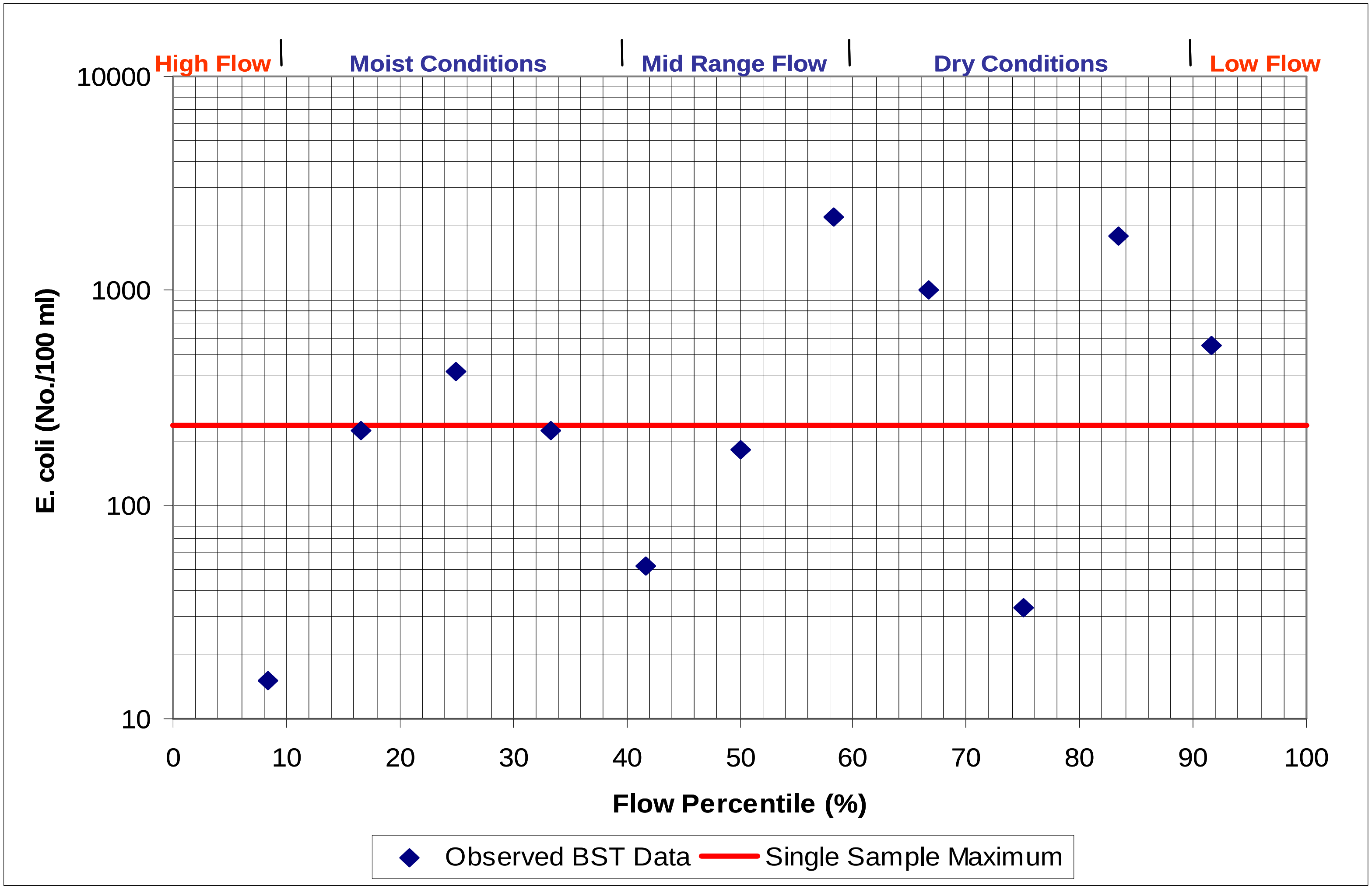


Figure 2-3: Flow and Fecal Coliform Concentrations at Ore Branch Monitoring Stations Ore Branch Monitoring Station 4AORE000.19

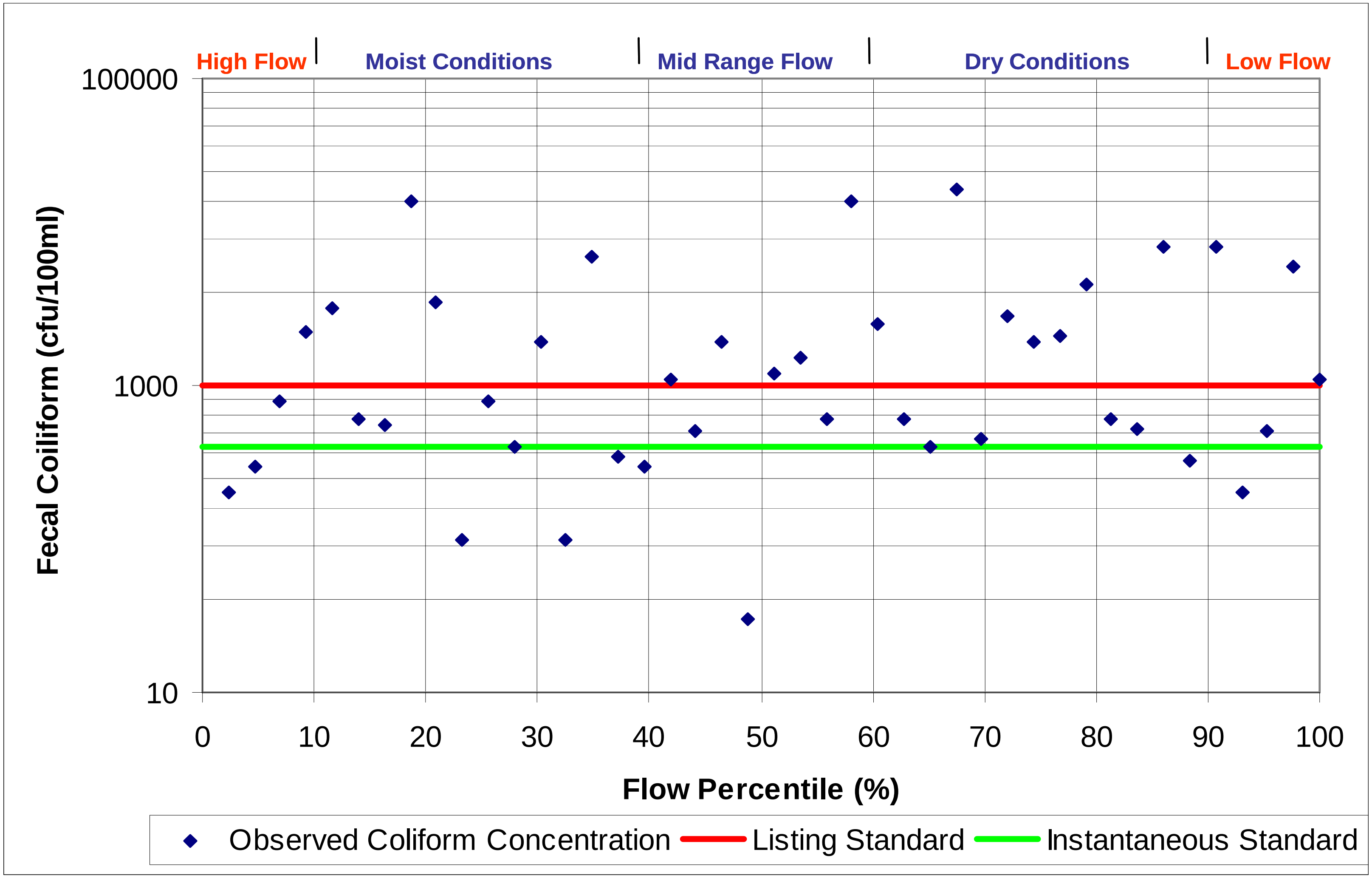


Figure 2-4: Flow and *E. coli* Concentrations from Bacteria Source Tracking Conducted at Ore Branch Monitoring Station 4AORE000.19

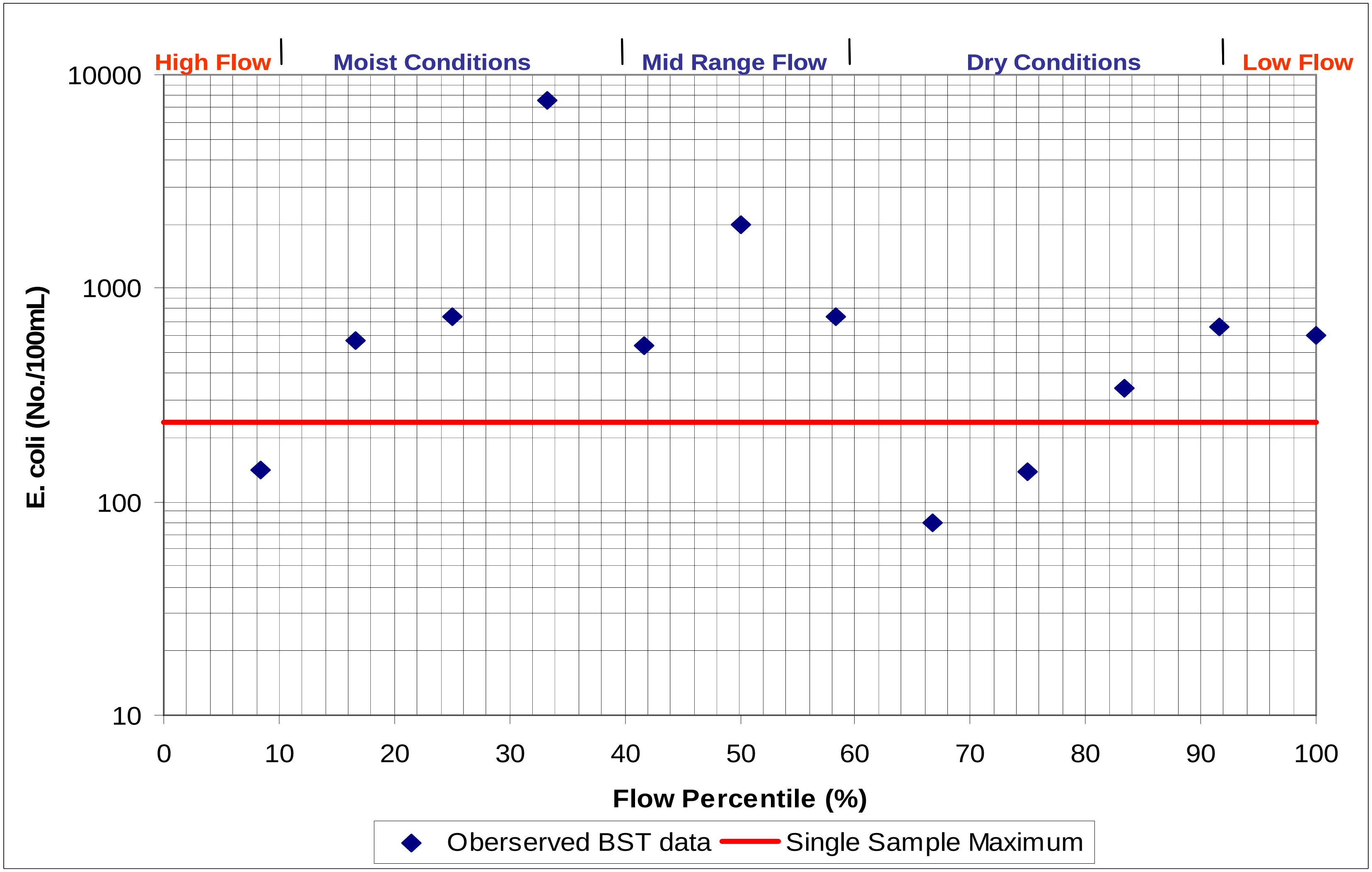


Figure 2-5: Flow and Fecal Coliform Concentrations at Roanoke River Monitoring Station 4AROA202.20

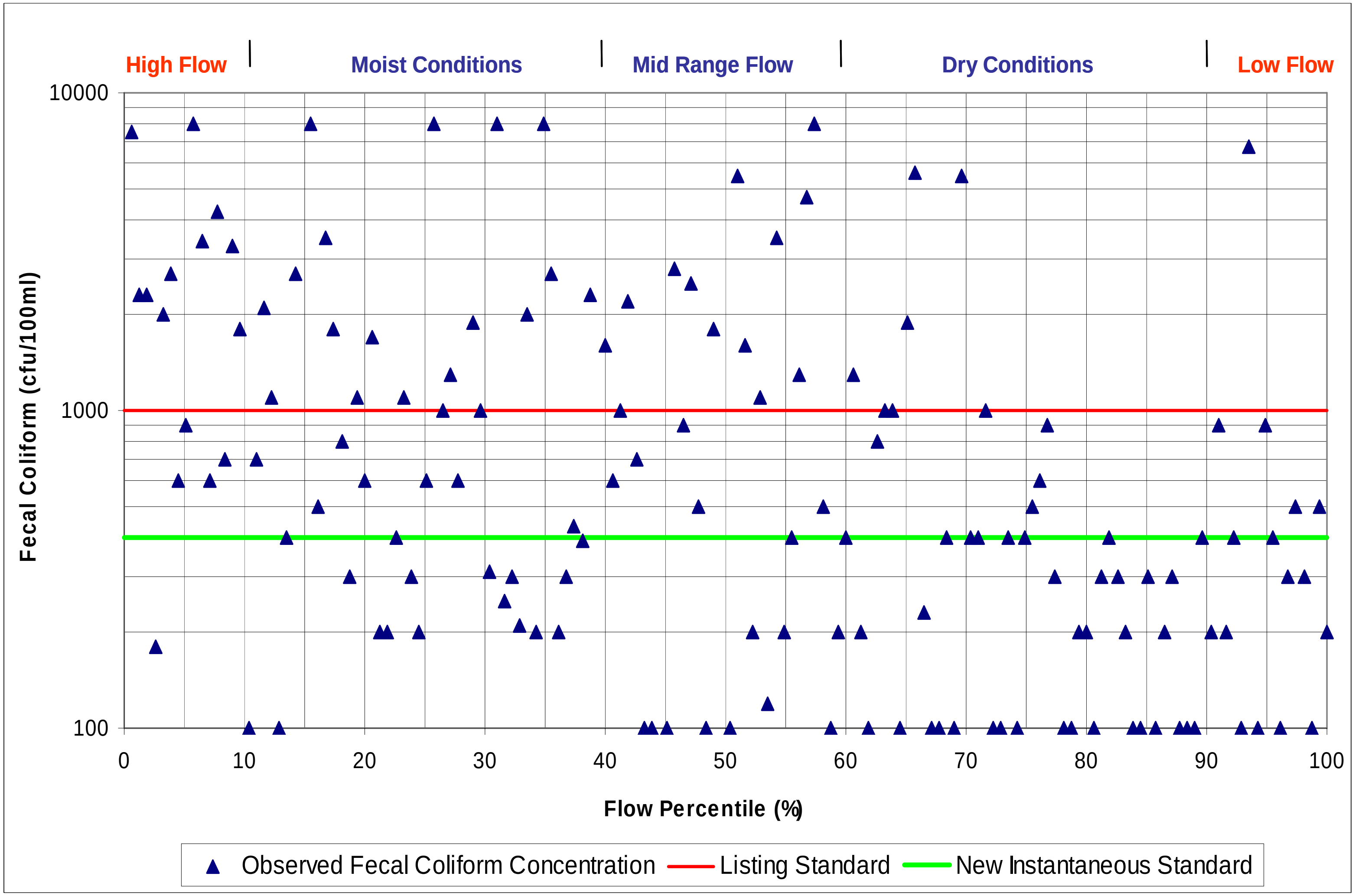
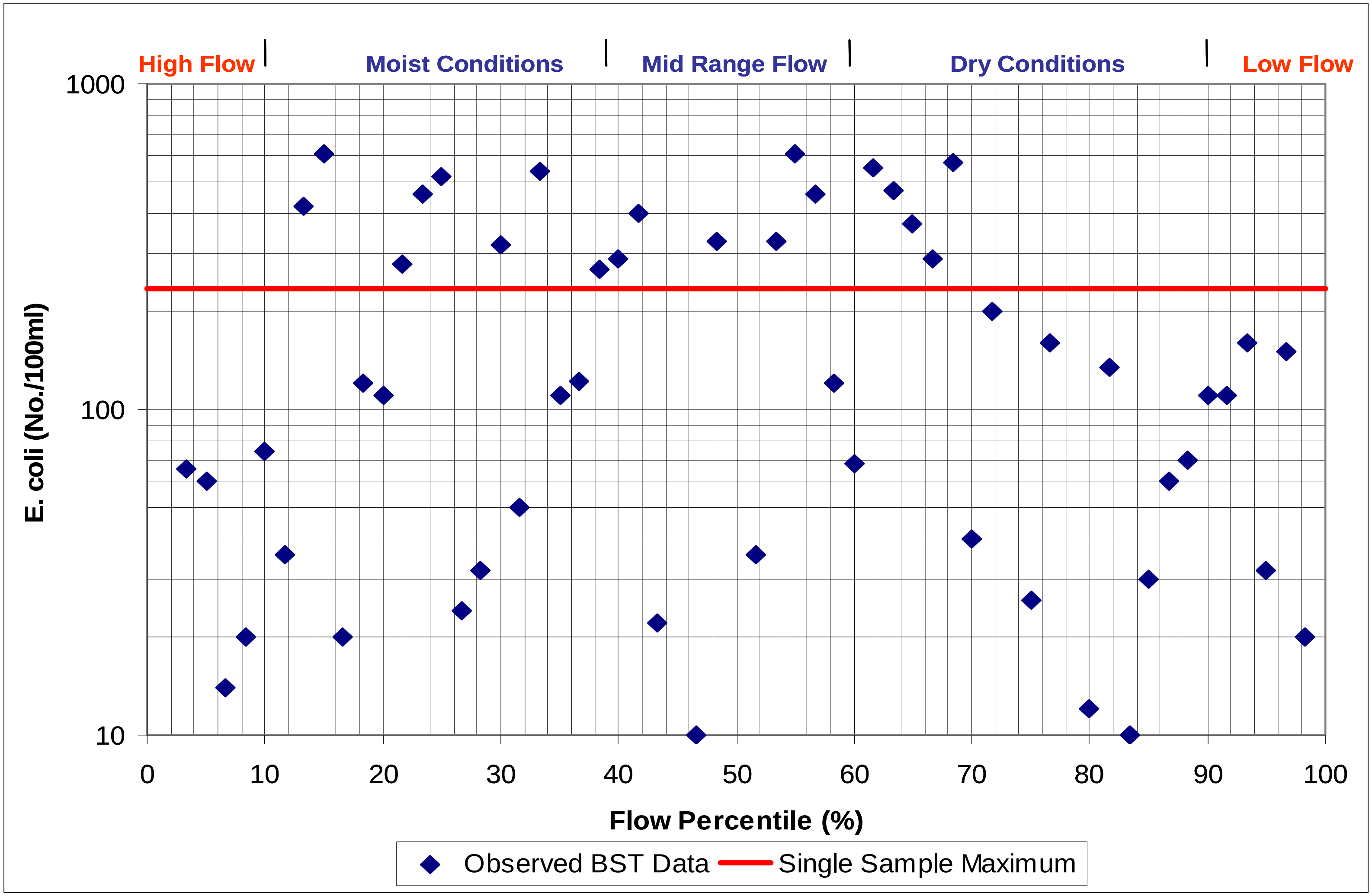


Figure 2-6: Flow and *E. coli* Concentrations from Bacteria Source Tracking Conducted at Roanoke River Monitoring Stations including AROA202.20, 4AROA205.73, 4AROA212.17, 4AROA192.94, and 4AROA199.20



3.0 Watershed Description and Source Assessment

In this section, the types of data available and information collected for the development of the Wilson Creek, Ore Branch and the Roanoke River TMDLs are presented. This information was used to characterize each stream and its watershed and to inventory and characterize the potential point and non-point sources of fecal coliform in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. Categories of data that were used include the following:

(1) Physiographic data that describe physical conditions (i.e., topography, soils, and land use) within the watershed

(2) Hydrographic data that describe physical conditions within the stream, such as the stream reach network and connectivity, and the stream channel depth, width, slope, and elevation

(3) Data related to uses of the watershed and other activities in the basin that can be used in the identification of potential fecal coliform sources

(4) Environmental monitoring data that describe stream flow and water quality conditions in the stream

Table 3-1 shows the various data types and the data sources used in the Wilson Creek, Ore Branch and the Roanoke River TMDLs.

Table 3-1: Inventory of Data and Information Used in the Wilson Creek, Ore Branch and Roanoke River TMDL Development

Data Category	Description	Potential Source(s)
Watershed physiographic data	Watershed boundary	USGS, DEQ
	Land use/land cover	NLCD
	Soil data (SSURGO, STATSGO)	NRCS, BASINS
	Topographic data (USGS-30 meter DEM, USGS Quads)	USGS, DCR
Hydrographic data	Stream network and reaches (RF3)	BASINS, NHD, Field surveys
	Stream morphology	
Weather data	Hourly meteorological conditions	NCDC, Earth Info
Watershed activities/ uses data and information related to fecal coliform production	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	State, county, and city governments, local groups and stakeholders
	Livestock inventory, grazing, stream access, and manure management	DCR, local SWCDs, NRCS
	Wildlife inventory	DGIF
	Septic systems inventory and failure rates	Local Departments of Health, Utilities, U.S. Census Bureau
	Straight pipes	DEQ
	Best management practices (BMPs)	DCR, NRCS, local SWCDs
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMRs)	EPA Permit Compliance System (PCS), VPDES, DEQ
Environmental monitoring data	Ambient in-stream monitoring data	DEQ
	Stream flow data	USGS, DEQ

Notes
DCR: Virginia Department of Conservation and Recreation
DEQ: Virginia Department of Environmental Quality
DGIF: Virginia Department of Game and Inland Fisheries
EPA: Environmental Protection Agency
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Coverage Data
NRCS: Natural Resources Conservation Service
SWCD: Soil and Water Conservation District
USGS: U.S. Geological Survey
VPDES: Virginia Pollutant Discharge Elimination System

3.2 Watershed Description and Identification

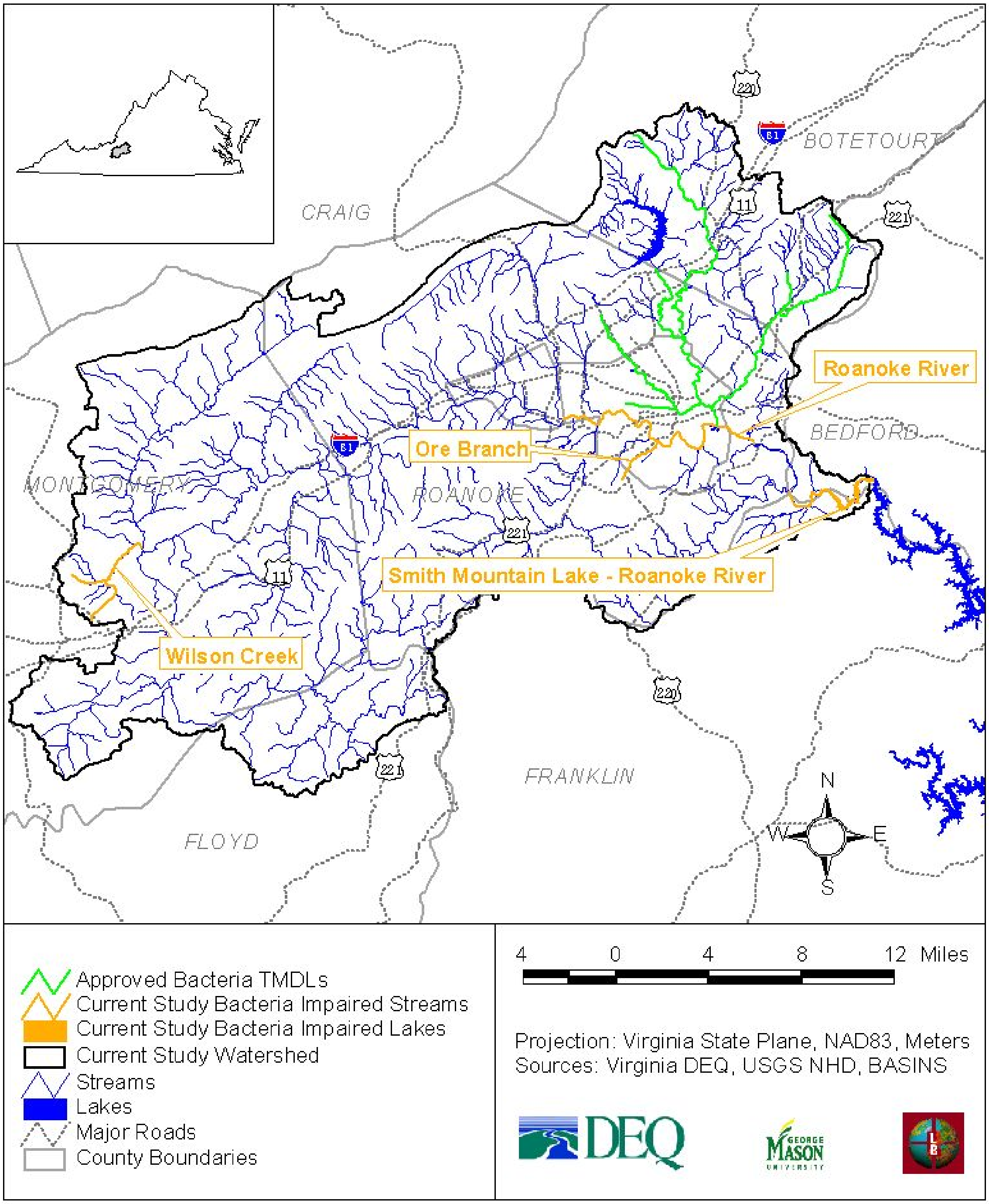
3.2.1 Watershed Boundaries

Wilson Creek is a tributary to the North Fork Roanoke River and is located in Montgomery County, while Ore Branch is a tributary to the Roanoke River and flows from Roanoke County into Roanoke City. The impaired segment of the Roanoke River begins in Salem City and flows through Roanoke City into Roanoke County. All three streams are located in the Upper Roanoke River Basin (USGS Cataloging Unit 03010101). The watershed that encompasses the Wilson Creek, Ore Branch and Roanoke River bacteria impairments is approximately 371,658 acres or 580 square miles. The watershed drains portions of Floyd, Montgomery, Roanoke, Botetourt, Bedford and Franklin Counties and all of Salem and Roanoke Cities.

Bacteria TMDLs have already been approved for five impaired streams in the watershed: Carvin Creek, Glade Creek, Laymantown Creek, Lick Run and Tinker Creek. The first four impairments all flow into Tinker Creek, which then flows into the Roanoke River just upstream of the Roanoke City/Roanoke County line near Vinton, Virginia. The results of the bacteria TMDLs developed for the Tinker Creek watershed will be input into the model developed for this study.

Approximately 40 percent of the drainage basin is located in Roanoke County, 32 percent in Montgomery County and 12 percent in Botetourt County; the remainder of the watershed is divided among Floyd, Franklin and Bedford Counties (six, two and one percent, respectively) and the Cities of Roanoke and Salem (six and two percent, respectively). The watershed makes up 100 percent of the land area in the Cities of Roanoke and Salem, 90 percent of Roanoke County, 48 percent of Montgomery County, 13 percent of Botetourt County, eight percent of Floyd County and one percent each of Bedford and Franklin Counties. Interstate Route 81 (I-81) and U.S. Route 11 (US-11) run the entire length of the watershed from the northeast near Troutville to the southwest near Christiansburg. U.S. Route 221 (US-221) and the Blue Ridge Parkway pass through the lower section of the watershed in a northeast to southwest direction. U.S. Route 220 (US-220) runs the lower half of the watershed from the north near Trinity to the south near Boones Mill. The majority of the remaining major roadways are concentrated in and around the Cities of Roanoke and Salem. Figure 3-1 is a map showing the location and boundary of the watershed.

Figure 3-1: Location and Boundary of Wilson Creek, Ore Branch and Roanoke River Watershed



3.2.2 Topography

A digital elevation model (DEM) based on USGS National Elevation Dataset (NED) was used to characterize topography in the watershed. NED data were obtained from The National Map Seamless Data Distribution System maintained by the USGS Eros Data Center. Elevation in the watershed ranges from 241 to 1,196 meters (791 to 3,924 feet) above mean sea level.

3.2.3 Soils

The Wilson Creek, Ore Branch and Roanoke River watershed soil characterization was based on data obtained from BASINS. There are ten general soil associations located in the watershed (see Table 3-2). The four dominant soil types in the watershed are the Hayesville-Parker-Peaks (VA007), Groseclose-Litz-Shottower (VA017), Carbo-Chilhowie-Frederick (VA002) and Berks-Weikert-Laidig (VA001) soil associations. Hayesville-Parker-Peaks soils are gravelly sandy loam soils with slopes ranging from 15 to 25 percent. Groseclose-Litz-Shottower soils are silt loam soils with slopes ranging from 25 to 35 percent. Carbo-Chilhowie-Frederick soils are silty clay loam soils with slopes ranging from 15 to 60 percent. Berks-Weikert-Laidig soils are channery silt loam soils with slopes ranging from 7 to 15 percent. The distribution of soils in the Wilson Creek, Ore Branch and Roanoke River watershed is presented in Table 3-2.

Table 3-2: Soil Types and Characteristics in the Wilson Creek, Ore Branch and Roanoke River Watershed

Map Unit ID	Soil Association	Hydrologic Soil Group	Percent Area
VA001	Berks-Weikert-Laidig	B/D	15.5%
VA002	Carbo-Chilhowie-Frederick	C	16.9%
VA003	Frederick-Carbo-Timberville	C	9.8%
VA004	Moomaw-Jefferson-Alonzville	B	6.8%
VA005	Wallen-Dekalb-Drypond	B	6.8%
VA007	Hayesville-Parker-Peaks	C	20.1%
VA016	Shottower-Laidig-Weikert	B	4.8%
VA017	Groseclose-Litz-Shottower	C	17.7%
VA020	Rubble Land-Porters-Hayesville	C	1.5%
VA031	Cullen-Wilkes-Iredell	D	0.2%
		Total	100.0%

Source: STASGO

The hydrologic soil group linked with each soil association is also presented in Table 3-2. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group "A", soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in Table 3-3.

Table 3-3: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover

3.2.4 Land Use

Land use characterization was based on National Land Cover Data (NLCD) developed by USGS. The distribution of land uses in Wilson Creek, Ore Branch and Roanoke River watershed, by land area and percentage, is presented in Table 3-4. Dominant land uses in the watershed are forested land (73.2%) and agricultural land (15.4%), which account for a combined 88.6% of the total land area in the watershed. Brief descriptions of land use classifications are presented in Table 3-5.

Table 3-4: Land Use Distribution in the Wilson Creek, Ore Branch and Roanoke River Watershed

Land Use Category	NLCD Land Use Type	Acres		Percent of Watershed's Land Area	
Water/ Wetlands	Water	1,787	1,974	0.5%	0.5%
	Woody Wetlands	101		0.0%	
	Emergent/Herbaceous Wetlands	87		0.0%	
Urban	Low Intensity Residential	28,060	37,104	7.6%	10.0%
	High Intensity Residential	391		0.1%	
	Commercial/Industrial/Transportation	8,652		2.3%	
Agriculture	Pasture/Hay	52,075	57,203	14.0%	15.4%
	Row Crops	5,128		1.4%	
Forest	Deciduous Forest	200,914	271,905	54.1%	73.2%
	Evergreen Forest	21,920		5.9%	
	Mixed Forest	49,071		13.2%	
Other	Quarries/Mines	1,227	3,473	0.3%	0.9%
	Transitional	1,319		0.4%	
	Urban/Recreational Grasses	927		0.2%	
Total		**371,658**		**100.0%**	

Source: Multi-Resolution Land Characteristics Consortium NLCD

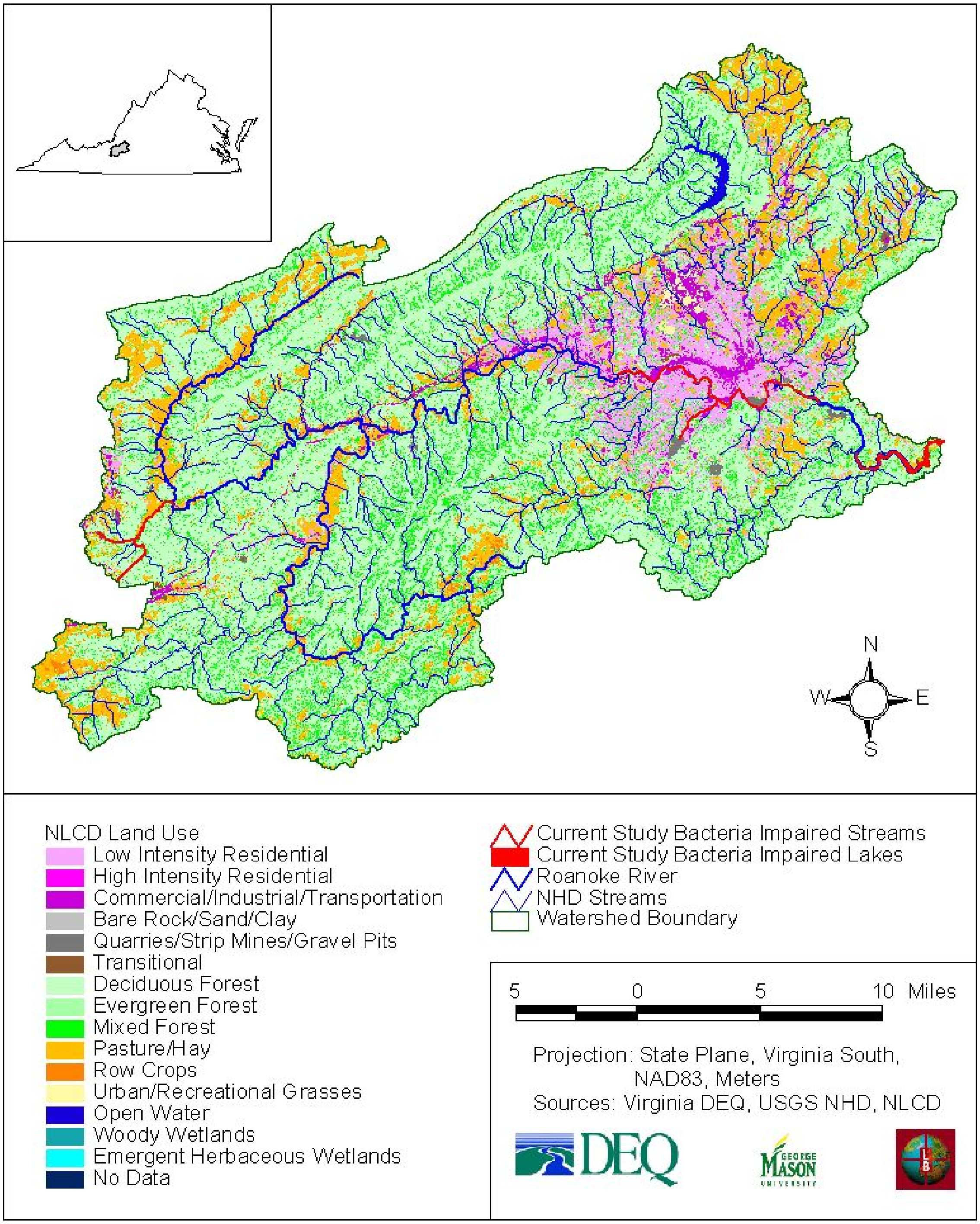
Table 3-5: Descriptions of Land Use Types

Land Use Type	Description
Open Water	Areas of open water, generally with less than 25 percent or greater cover of water.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
High Intensity Residential	Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.
Commercial/ Industrial/ Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crop	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Transitional	Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Source: Multi-Resolution Land Characteristics Consortium NLCD

Figure 3-2 depicts the land use distribution within the Wilson Creek, Ore Branch and Roanoke River watershed. The watershed is predominantly forested, with some agricultural lands clustered in the northeastern portion of the watershed (in the Tinker Creek drainage) and along the mainstem Roanoke River and its North and South Forks. Urban and residential areas are clustered around the Cities of Roanoke and Salem in the eastern half of the watershed, with some smaller clusters located on the western edge of the watershed near Christiansburg.

Figure 3-2: Land Use in the Wilson Creek, Ore Branch and Roanoke River Watershed



3.3 Stream Flow Data

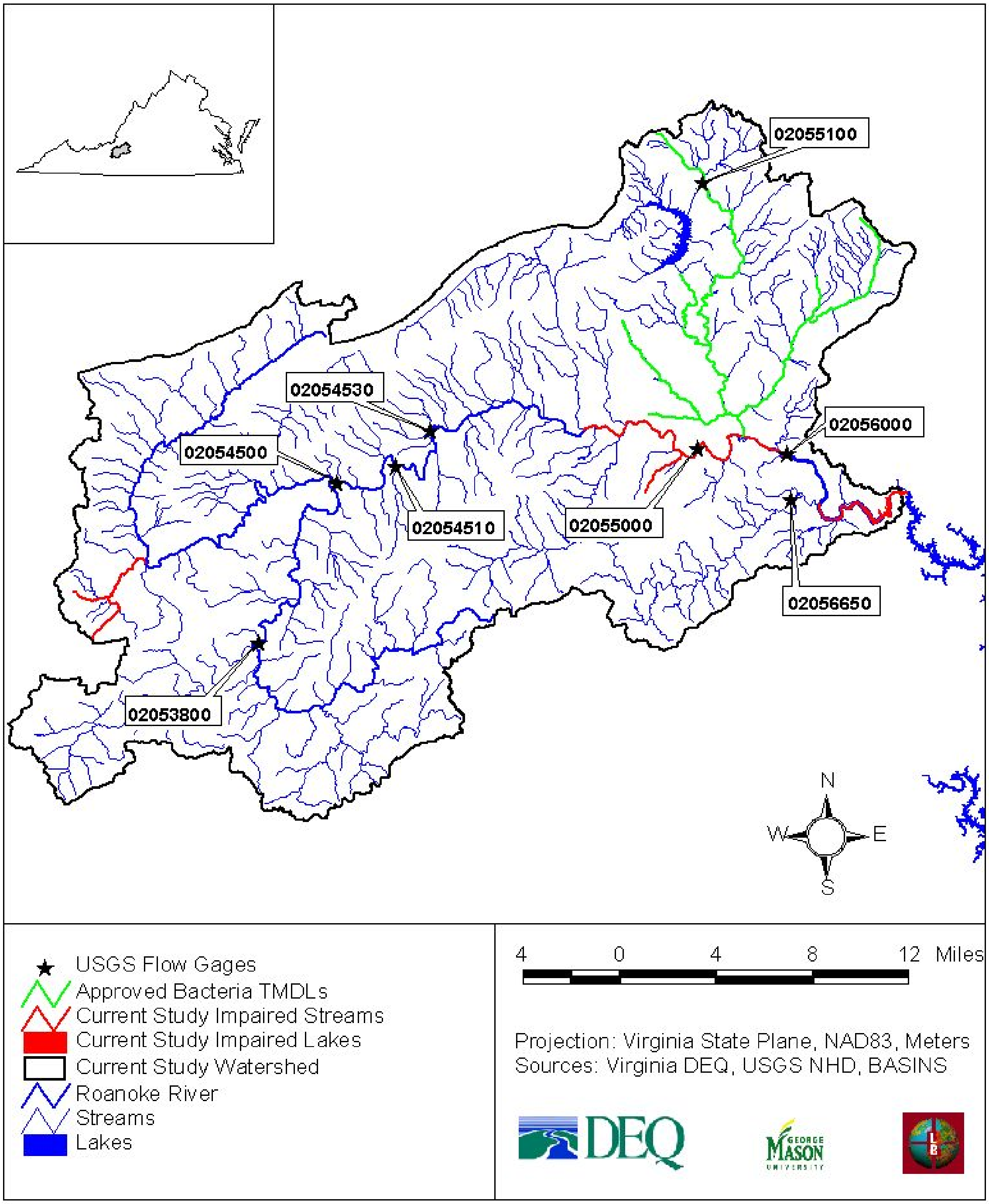
Stream flow data for the Wilson Creek, Ore Branch and Roanoke River watershed were retrieved from eight USGS stream flow-gauging stations and are summarized in Table 3-6. The location of these flow-gauging stations is presented in Figure 3-3. Stream flow data obtained from these stations were used in the set-up, hydrological calibration, and validation of the model.

Table 3-6: USGS Stream Flow Gauging Stations in the Wilson Creek, Ore Branch and Roanoke River Watershed

Station ID	Station Name	Area (mi^2)	Begin Date	End Date	No. of Records
02053800	S F Roanoke River near Shawsville, VA	110.0	10/01/1960	04/30/2005	16,283
02054500	Roanoke River at Lafayette, VA	257.0	10/01/1943	04/30/2005	22,493
02054510	Roanoke River near Wabun, VA	273.0	05/03/1993	09/30/1999	2,052
02054530	Roanoke River at Glenvar, VA	284.0	12/12/1991	04/30/2005	4,889
02055000	Roanoke River at Roanoke, VA	395.0	02/13/1899	04/30/2005	37,955
02055100	Tinker Creek near Daleville, VA	11.7	05/01/1956	04/30/2005	17,897
02056000	Roanoke River at Niagara, VA	512.0	10/01/1926	04/30/2005	28,702
02056650	Back Creek near Dundee, VA	56.8	07/01/1974	04/30/2005	11,262

Source: USGS Daily Stream flow for the Nation

Figure 3-3: Flow Monitoring Stations in the Wilson Creek, Ore Branch and Roanoke River Watershed



3.4 In-Stream Water Quality Conditions

Water quality data for the Wilson Creek, Ore Branch and Roanoke River watershed were obtained from DEQ, which conducted sampling at 51 water quality-monitoring stations located within the watershed boundary. Locations of these stations are summarized in Table 3-7. Figure 3-4 depicts the locations of these monitoring stations.

Table 3-7: DEQ In-Stream Water Quality Monitoring Stations Located in the Wilson Creek, Ore Branch and Roanoke River Watershed

No.	Watershed Code	Station ID	Station Description	Stream Name	County
1	VAW-L01R	4ARSF000.88	Rt. 460/11 Br. below Green Hill, Inc.	South Fork Roanoke River	Montgomery
2	VAW-L01R	4ARSF002.20	Private Br. upstream from Green Hill	South Fork Roanoke River	Montgomery
3	VAW-L01R	4ARSF002.53	Rt. 460/11 Br. at Elliston above Green Hill	South Fork Roanoke River	Montgomery
4	VAW-L01R	4ARSF011.73	Rt. 637 Br. at Gage	South Fork Roanoke River	Montgomery
5	VAW-L02R	4ABDC002.36	Rt. 629 Br.	Bradshaw Creek	Roanoke
6	VAW-L02R	4ACDN000.01	Confluence of Cedar Run and Wilson Cr.	Cedar Run	Montgomery
7	VAW-L02R	4ACDN001.12	Rt. 723 Br.	Cedar Run	Montgomery
8	VAW-L02R	4ACDN002.53	Rt. 603 Br. below Blacksburg	Cedar Run	Montgomery
9	VAW-L02R	4ARNF002.97	Rt. 603 Br.	North Fork Roanoke River	Montgomery
10	VAW-L02R	4ARNF009.01	Sisson & Ryan Property off Rt. 687	North Fork Roanoke River	Montgomery
11	VAW-L02R	4ARNF013.66	Rt. 603 Br. near Ellett - Montgomery	North Fork Roanoke River	Montgomery
12	VAW-L02R	4ARNF015.50	Above Rt. 603 and behind Church	North Fork Roanoke River	Montgomery
13	VAW-L02R	4AWLN000.40	Rt. 603 Br. - Montgomery County	Wilson Creek	Montgomery
14	VAW-L03R	4ADRR000.21	Rt. 612/639 Br.	Dry Branch	Roanoke
15	VAW-L03R	4AROA212.17	Rt. 11 Br. below Eaton, Inc.	Roanoke River	Salem (city)
16	VAW-L03R	4AROA212.99	Rt. 11 Br. above Eaton, Inc.	Roanoke River	Salem (city)
17	VAW-L03R	4AROA215.13	Mill Lane Br., Salem, VA	Roanoke River	Salem (city)
18	VAW-L03R	4AROA219.99	Rt. 612 Br. above Salem at Wabum	Roanoke River	Roanoke
19	VAW-L03R	4AROA220.94	Rt. 639 Br. south of Wabun	Roanoke River	Montgomery
20	VAW-L03R	4AROA221.95	Above Rt. 639 Br. near Wabun	Roanoke River	Roanoke
21	VAW-L03R	4AROA224.54	Rt. 639 Br. near Dixie Caverns	Roanoke River	Roanoke
22	VAW-L03R	4AROA227.42	Rt. 773 at Gaging Sta. in Lafayeette	Roanoke River	Montgomery
23	VAW-L03R	4AXDH000.63	Below Dixie Caverns Landfill	UT to Roanoke River	Roanoke
24	VAW-L04R	4AMDL000.34	Downstream of Brambleton Ave.	Mud Lick Creek	Roanoke (city)
25	VAW-L04R	4AMSN000.67	Roanoke Boulevard Br.	Mason Creek	Salem (city)

No.	Watershed Code	Station ID	Station Description	Stream Name	County
26	VAW-L04R	4AMSN007.25	Sta #16 Rt. 419 Br.	Mason Creek	Roanoke
27	VAW-L04R	4AMUR001.63	Fishburn Park off Rt. 221	Murray Run	Roanoke (city)
28	VAW-L04R	4AORE000.19	Wiley Drive (Greenway)	Ore Branch	Roanoke (city)
29	VAW-L04R	4APEE000.00	10 yards above confluence	Peters Creek	Roanoke (city)
30	VAW-L04R	4APEE001.04	Shenandoah Ave. Br.	Peters Creek	Roanoke (city)
31	VAW-L04R	4APEE004.98	Rt. 628 Br.	Peters Creek	Roanoke
32	VAW-L04R	4AROA199.20	Blue Ridge Parkway Br. below Roanoke	Roanoke River	Roanoke
33	VAW-L04R	4AROA202.20	13th. St. Br. above Roanoke STP	Roanoke River	Roanoke (city)
34	VAW-L04R	4AROA202.32	Upstream of 14th St. Br.	Roanoke River	Roanoke (city)
35	VAW-L04R	4AROA205.73	Franklin Road Br., Roanoke, VA	Roanoke River	Roanoke (city)
36	VAW-L05L	4ACRV006.19	Carvin Cove Reservoir Station at Dam	Carvin Creek	Botetourt
37	VAW-L05R	4ABPA002.71	Intersection of Rt. 652 & Rt. 11	Buffalo Creek	Botetourt
38	VAW-L05R	4ACRV001.88	Brookside Park off Rt. 623	Carvin Creek	Roanoke
39	VAW-L05R	4ACRV005.58	Sta. #9, Rt 115 Br.	Carvin Creek	Roanoke
40	VAW-L05R	4AGLA000.20	Walnut Ave. Br.	Glade Creek	Roanoke
41	VAW-L05R	4AGLA004.39	Layman Rd. (Rt. 606)	Glade Creek	Roanoke
42	VAW-L05R	4ALCK000.38	N & W Parking Lot Br.	Lick Run	Roanoke (city)
43	VAW-L05R	4ALCK002.17	Orange Ave. Br.	Lick Run	Roanoke (city)
44	VAW-L05R	4ATKR000.69	Rt. 24 Br. above Town of Vinton	Tinker Creek	Roanoke (city)
45	VAW-L05R	4ATKR009.30	Rt. 11 Br. at Hollins	Tinker Creek	Roanoke
46	VAW-L05R	4ATKR015.88	Off Rt. 779 intersect Rt. 675 at gauging	Tinker Creek	Botetourt
47	VAW-L06R	4ABAA000.03	End Rt. 618 confluence with Roanoke River	Back Creek	Franklin
48	VAW-L06R	4ABAA002.61	Gage near Dundee, Rt. 660 Br.	Back Creek	Roanoke
49	VAW-L07R	4AROA192.55	Smith Mtn. Lake, Hardys Ford	Roanoke River	Franklin
50	VAW-L12L	4AROA192.94	Smith Mtn Lake #2a-Top-Hardys Ford #2c-B	Roanoke River	Franklin
51	VAW-L12L	4AROA196.05	Smith Mtn. Lake, McVeigh Ford	Roanoke River	Franklin

Source: DEQ

Figure 3-4: Wilson Creek, Ore Branch and Roanoke River Watershed DEQ Water Quality Monitoring Stations

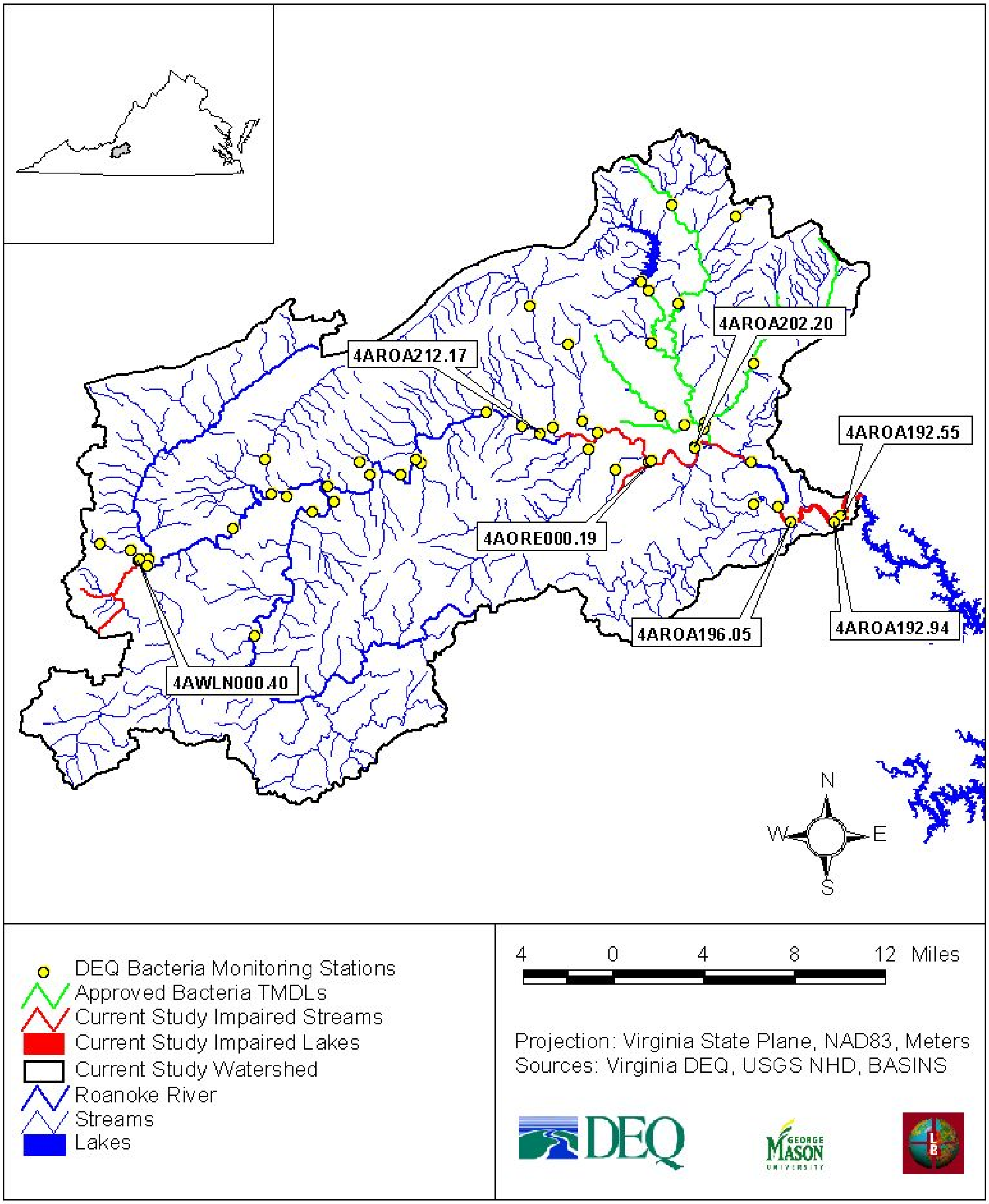


Table 3-8 lists the water quality sampling period of record, the number of samples collected, the minimum, maximum and average concentrations observed, and the number and percentage of samples violating the water quality standard. Water quality data collected from the Wilson Creek, Ore Branch and Roanoke River listing stations (highlighted in yellow in Table 3-8) indicate that violations of the fecal coliform standard ranged from 13 to 62 percent for the instantaneous maximum criterion of 400 cfu/100 ml, and from 6 to 75 percent for the geometric mean criterion of 200 cfu/100 ml.

Table 3-8: Summary of DEQ Fecal Coliform Bacteria Sampling Events in the Wilson Creek, Ore Branch and Roanoke River Watershed

No.	Station ID	Sample Date		No. of Sampl-es	Sample Value (cfu/100ml)			Exceedances of WQS			
								Inst. Max.[1]		Geo. Mean[2]	
		First	Last		Min	Max	Avg	No.	%	No.	%
1	4ARSF000.88	04/05/1973	11/06/1989	172	0	8,000	1,004	72	42	2	67
2	4ARSF002.20	02/12/1990	06/06/2001	47	100	8,000	643	9	19	--	--
3	4ARSF002.53	11/29/1970	06/25/1979	94	100	8,000	609	21	22	0	0
4	4ARSF011.73	07/22/1999	06/06/2001	12	100	3,000	442	3	25	--	--
5	4ABDC002.36	07/05/2001	05/28/2003	11	100	200	109	0	0	0	0
6	4ACDN000.01	01/20/2004	05/18/2004	6	25	400	175	0	0	1	33
7	4ACDN001.12	07/05/2001	05/28/2003	13	100	100	100	0	0	0	0
8	4ACDN002.53	05/10/1973	06/25/1979	68	100	8,000	646	10	15	0	0
9	4ARNF002.97	02/06/1989	04/14/1999	37	100	8,000	538	11	30	--	--
10	4ARNF009.01	11/08/2001	11/08/2001	1	800	800	800	1	100	--	--
11	4ARNF013.66	11/29/1970	07/15/2004	211	0	8,000	736	80	38	3	43
12	4ARNF015.50	11/08/2001	11/08/2001	1	100	100	100	0	0	--	--
13	4AWLN000.40	08/09/1988	07/15/2004	67	50	8,000	751	29	43	1	25
14	4ADRR000.21	03/24/2004	05/04/2004	4	25	200	113	0	0	0	0
15	4AROA212.17	11/29/1970	07/13/2004	227	0	80,000	916	51	22	1	17
16	4AROA212.99	11/29/1970	06/08/1979	96	0	80,000	1,357	20	21	1	25
17	4AROA215.13	01/29/2004	07/13/2004	7	25	1,300	282	1	14	0	0
18	4AROA219.99	11/29/1970	06/08/1979	97	100	6,000	480	20	21	1	33
19	4AROA220.94	01/29/2004	07/13/2004	7	25	1,200	336	2	29	1	33
20	4AROA221.95	04/25/2002	04/25/2002	1	130	130	130	0	0	--	--
21	4AROA224.54	10/24/1988	07/13/2004	13	25	8,000	846	2	15	0	0
22	4AROA227.42	11/29/1970	07/13/2004	373	0	8,000	637	101	27	3	25
23	4AXDH000.63	05/22/1989	05/22/1989	1	100	100	100	0	0	--	--
24	4AMDL000.34	01/29/2004	07/13/2004	7	100	5,200	1,293	3	43	2	67
25	4AMSN000.67	11/24/2003	07/13/2004	13	1	4,800	497	1	8	0	0
26	4AMSN007.25	08/26/1992	08/26/1992	1	300	300	300	0	0	--	--
27	4AMUR001.63	07/18/2000	05/01/2001	6	100	8,000	1,567	2	33	--	--
28	4AORE000.19	08/09/1988	07/06/2004	39	30	8,000	1,428	24	62	3	75
29	4APEE000.00	11/15/1974	08/26/1992	7	100	1,600	514	2	29	--	--
30	4APEE001.04	07/26/1994	07/13/2004	43	1	16,000	841	14	33	1	33
31	4APEE004.98	01/02/1975	06/08/1979	41	100	8,000	712	9	22	0	0
32	4AROA199.20	11/29/1970	04/26/2004	38	0	80,000	3,666	11	29	--	--

No.	Station ID	Sample Date		No. of Sampl-es	Sample Value (cfu/100ml)			Exceedances of WQS			
								Inst. Max.[1]		Geo. Mean[2]	
		First	Last		Min	Max	Avg	No.	%	No.	%
33	4AROA202.20	11/29/1970	07/19/2004	384	10	80,000	1,271	139	36	6	43
34	4AROA202.32	05/03/2004	05/03/2004	1	280	280	280	0	0	--	--
35	4AROA205.73	11/24/2003	07/06/2004	14	1	550	206	1	7	2	50
36	4ACRV006.19	06/30/1977	10/19/2000	15	100	100	100	0	0	0	0
37	4ABPA002.71	10/31/1974	06/07/1979	48	100	8,000	1,092	22	46	5	100
38	4ACRV001.88	10/25/2001	06/09/2003	10	100	1,100	390	3	30	--	--
39	4ACRV005.58	08/26/1992	08/08/2001	2	600	1,000	800	2	100	--	--
40	4AGLA000.20	08/02/1988	07/06/2004	35	100	10,000	1,427	21	60	4	100
41	4AGLA004.39	08/08/2001	07/06/2004	14	50	900	405	5	36	3	75
42	4ALCK000.38	11/17/1988	07/06/2004	73	100	16,000	2,277	47	64	4	80
43	4ALCK002.17	01/22/2004	07/06/2004	8	130	1,400	504	2	25	3	75
44	4ATKR000.69	11/29/1970	07/06/2004	344	100	220,000	3,102	210	61	8	89
45	4ATKR009.30	04/03/1973	07/06/2004	87	75	8,000	1,142	41	47	5	83
46	4ATKR015.88	11/29/1970	07/06/2004	109	6	80,000	1,742	46	42	8	100
47	4ABAA000.03	06/06/1974	08/26/1992	19	100	6,000	563	2	11	2	40
48	4ABAA002.61	07/18/1979	06/04/2001	123	100	8,000	383	17	14	0	0
49	4AROA192.55	07/07/1971	07/19/2004	305	25	8,000	571	58	19	1	6
50	4AROA192.94	04/24/1990	04/26/2004	48	1	1,800	220	6	13	--	--
51	4AROA196.05	07/07/1971	09/12/2002	80	10	16,000	979	17	21	5	45

[1] Instantaneous maximum fecal coliform bacteria concentration of 400 cfu/100 ml
[2] Geometric mean fecal coliform bacteria concentration of 200 cfu/100 ml, calculated only when two or more samples are collected in a calendar month
Note: Rows highlighted in yellow are listing stations for the Wilson Creek, Ore Branch and Roanoke River bacteria impairments.
Source: DEQ

3.4.1 Bacteria Source Tracking

As part of the TMDL development, Bacteria Source Tracking (BST) sampling was conducted at 10 locations throughout the watershed. The objective of the BST study was to identify the sources of fecal coliform in the listed segments of Wilson Creek, Ore Branch and the Roanoke River. After identifying these sources, this information was used in the model set-up, and in the distribution of fecal coliform loadings among the various sources.

There are various methodologies used to perform BST, which fall into three major categories: molecular, biochemical and chemical. Molecular (genotype) methods are referred to as "DNA fingerprinting," and are based on the unique genetic makeup of different strains, or subspecies, of fecal coliform bacteria. Biochemical (phenotype) methods are based on detecting biochemical substances produced by bacteria. The type and quantity of these substances are measured to identify the bacteria source. Chemical methods are based on testing for chemical compounds that are associated with human wastewaters, and are restricted to determining if sources of pollution are human or non-human.

For the Wilson Creek, Ore Branch and Roanoke River TMDLs, the Antibiotic Resistance Analysis (ARA) method of BST was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. Advantages of ARA include low cost per sample, and fast turnaround times for analyzing samples. The method can also be performed on large numbers of isolates; typically, 48 isolates per unknown source such as an in-stream water quality sample.

In the Wilson Creek, Ore Branch and Roanoke River watershed, BST was conducted monthly at 10 monitoring stations from July 2003 through June 2004 (except for the station on Wilson Creek, which was sampled from November 2002 through October 2003.) A total of 12 sampling events were collected at each station. The location of each BST station is presented in Table 3-9. Figure 3-5 depicts the locations of the monitoring stations in the Wilson Creek, Ore Branch and Roanoke River watershed.

Table 3-9: DEQ BST Stations Located in the Wilson Creek, Ore Branch and Roanoke River Watershed

No.	Watershed Code	Station ID	Station Description	Stream Name	County
1	VAW-L02R	4AWLN000.40	Rt. 603 Br. - Montgomery County	Wilson Creek	Montgomery
2	VAW-L02R	4ARNF013.66	Rt. 603 Br. near Ellett - Montgomery	North Fork Roanoke River	Montgomery
3	VAW-L03R	4AROA212.17	Rt. 11 Br. below Eaton, Inc.	Roanoke River	Salem (city)
4	VAW-L04R	4AMSN000.67	Roanoke Boulevard Br.	Mason Creek	Salem (city)
5	VAW-L04R	4APEE001.04	Shenandoah Ave. Br.	Peters Creek	Roanoke (city)
6	VAW-L04R	4AORE000.19	Wiley Drive (Greenway)	Ore Branch	Roanoke (city)
7	VAW-L04R	4AROA205.73	Franklin Road Br., Roanoke, VA	Roanoke River	Roanoke (city)
8	VAW-L04R	4AROA202.20	13th. St. Br. above Roanoke STP	Roanoke River	Roanoke (city)
9	VAW-L04R	4AROA199.20	Blue Ridge Parkway Br. below Roanoke	Roanoke River	Roanoke
10	VAW-L12L	4AROA192.94	Smith Mtn Lake #2a-Top-Hardys Ford #2c-B	Roanoke River	Franklin

Source: DEQ

Four categories of fecal bacteria sources were identified in the BST; wildlife, human, livestock and pet. Table 3-10 presents the complete BST data collected at the 10 stations listed in Table 3-10 and mapped in Figure 3-6. Some of the data presented in Table 3-10 is depicted in Figures 3-6 through 3-8 for representative stations on Wilson Creek (AWLN000.40), Ore Branch (4AORE000.19), and the Roanoke River (4AROA202.20).

Figure 3-5: Wilson Creek, Ore Branch and Roanoke River Watershed Bacteria Source Tracking Sampling Stations

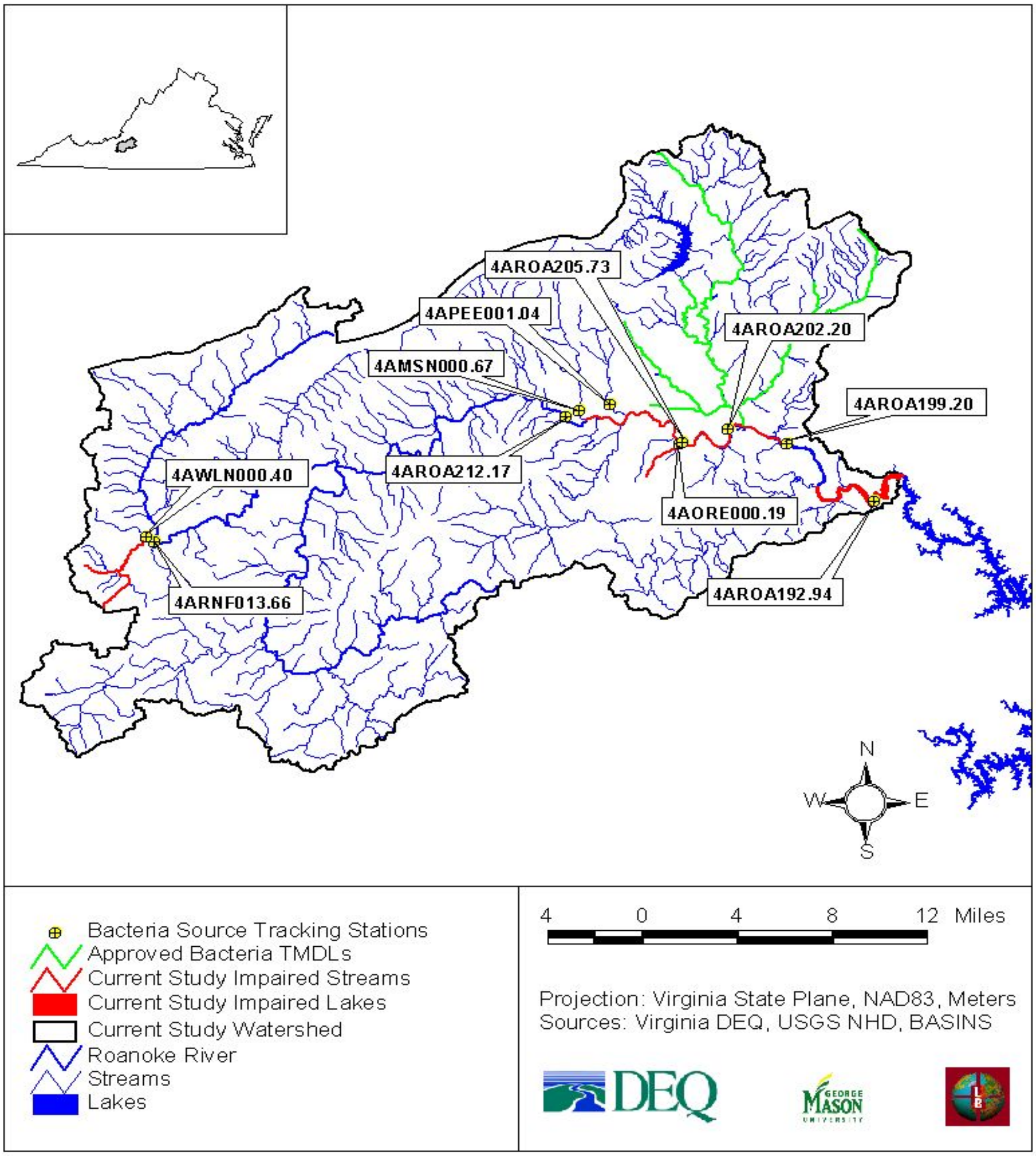


Table 3-10: Results of BST Analysis Conducted in the Wilson Creek, Ore Branch and Roanoke River Watershed

Station ID	Sample Date	No. of Isolates	E. coli (cfu/100 ml)	Wildlife	Human	Live-stock	Pets
4AWLN000.40	11/25/2002	22	33	18%	18%	59%	5%
	12/17/2002	14	52	29%	36%	14%	21%
	01/29/2003	0	<1	--	--	--	--
	02/25/2003	8	15	0%	13%	25%	62%
	03/31/2003	24	420	25%	21%	41%	13%
5 of 12 (42%) samples exceed 235 cfu/100ml	04/29/2003	24	180	0%	0%	13%	87%
	05/28/2003	24	220	13%	33%	29%	25%
	06/26/2003	24	220	33%	33%	25%	9%
	07/22/2003	24	1,000	33%	13%	25%	29%
	08/27/2003	24	1,800	71%	0%	8%	21%
	09/22/2003	24	2,200	50%	12%	21%	17%
	10/22/2003	24	550	47%	33%	12%	8%
	Weighted Average			**41%**	**15%**	**22%**	**22%**
4ARNF013.66	07/22/2003	24	610	8%	67%	21%	4%
	08/27/2003	24	900	21%	4%	21%	54%
	09/22/2003	24	800	21%	0%	46%	33%
	10/22/2003	24	420	25%	8%	63%	4%
	11/24/2003	24	178	38%	33%	25%	4%
7 of 12 (58%) samples exceed 235 cfu/100ml	12/22/2003	24	134	25%	0%	67%	8%
	01/28/2004	1	2	100%	0%	0%	0%
	02/23/2004	24	56	42%	29%	29%	0%
	03/29/2004	24	44	25%	38%	29%	8%
	04/26/2004	24	790	21%	50%	25%	4%
	05/17/2004	24	330	21%	59%	12%	8%
	06/28/2004	24	530	33%	55%	0%	12%
	Weighted Average			**23%**	**34%**	**28%**	**16%**
4AROA212.17	07/22/2003	24	68	12%	17%	12%	59%
	08/27/2003	24	160	22%	12%	33%	33%
	09/22/2003	24	610	54%	0%	46%	0%
	10/22/2003	2	20	100%	0%	0%	0%
	11/24/2003	24	122	71%	29%	0%	0%
3 of 12 (25%) samples exceed 235 cfu/100ml	12/22/2003	24	32	54%	0%	17%	29%
	01/28/2004	17	26	12%	53%	6%	29%
	02/23/2004	9	14	33%	11%	45%	11%
	03/29/2004	8	12	38%	25%	12%	25%
	04/26/2004	24	400	12%	25%	42%	21%
	05/17/2004	21	70	57%	38%	0%	5%
	06/28/2004	24	290	12%	21%	25%	42%
	Weighted Average			**34%**	**15%**	**34%**	**17%**

Station ID	Sample Date	No. of Isolates	E. coli (cfu/100 ml)	Wildlife	Human	Live-stock	Pets
4AMSN000.67	07/22/2003	24	210	21%	4%	8%	67%
	08/27/2003	24	160	17%	0%	12%	71%
	09/22/2003	24	330	21%	12%	12%	55%
	10/22/2003	16	120	56%	0%	6%	38%
	11/24/2003	24	76	50%	46%	0%	4%
3 of 12 (25%) samples exceed 235 cfu/100ml	12/22/2003	24	74	46%	0%	0%	54%
	01/28/2004	2	4	0%	0%	100%	0%
	02/23/2004	24	86	8%	67%	4%	21%
	03/29/2004	13	18	47%	23%	15%	15%
	04/26/2004	24	700	17%	46%	29%	8%
	05/17/2004	24	230	63%	25%	0%	12%
	06/28/2004	24	400	46%	0%	4%	50%
	Weighted Average			**28%**	**26%**	**14%**	**32%**
4APEE001.04	07/22/2003	24	530	17%	21%	62%	0%
	08/27/2003	24	280	63%	4%	21%	12%
	09/22/2003	24	380	4%	0%	0%	96%
	10/22/2003	8	110	0%	62%	38%	0%
	11/24/2003	24	92	88%	4%	4%	4%
6 of 12 (50%) samples exceed 235 cfu/100ml	12/22/2003	24	150	29%	8%	12%	51%
	01/28/2004	18	30	44%	56%	0%	0%
	02/23/2004	24	58	63%	25%	8%	4%
	03/29/2004	24	50	0%	0%	0%	100%
	04/26/2004	24	720	75%	17%	8%	0%
	05/17/2004	24	1,700	71%	17%	0%	12%
	06/28/2004	24	480	17%	8%	17%	58%
	Weighted Average			**49%**	**14%**	**14%**	**23%**
4AORE000.19	07/22/2003	24	2,000	8%	84%	0%	8%
	08/27/2003	24	660	0%	25%	4%	71%
	09/22/2003	24	540	33%	0%	25%	42%
	10/22/2003	24	600	29%	0%	38%	33%
	11/24/2003	24	740	17%	41%	21%	21%
9 of 12 (75%) samples exceed 235 cfu/100ml	12/22/2003	24	570	8%	12%	29%	51%
	01/28/2004	24	80	12%	51%	12%	25%
	02/23/2004	24	142	4%	51%	33%	12%
	03/29/2004	24	138	17%	71%	8%	4%
	04/26/2004	24	7,600	8%	4%	8%	80%
	05/17/2004	24	340	12%	80%	8%	0%
	06/28/2004	24	740	17%	33%	4%	46%
	Weighted Average			**10%**	**22%**	**10%**	**58%**

Station ID	Sample Date	No. of Isolates	E. coli (cfu/100 ml)	Wildlife	Human	Live-stock	Pets
4AROA205.73	07/22/2003	24	110	8%	12%	8%	72%
	08/27/2003	24	320	4%	0%	12%	84%
	09/22/2003	24	460	29%	4%	38%	29%
	10/22/2003	24	270	21%	0%	8%	71%
	11/24/2003	24	134	38%	29%	33%	0%
5 of 12 (42%) samples exceed 235 cfu/100ml	12/22/2003	24	32	46%	8%	0%	46%
	01/28/2004	1	1	0%	100%	0%	0%
	02/23/2004	13	20	38%	16%	38%	8%
	03/29/2004	14	22	29%	42%	0%	29%
	04/26/2004	24	550	4%	0%	0%	96%
	05/17/2004	24	160	51%	29%	8%	12%
	06/28/2004	24	570	8%	17%	4%	71%
	Weighted Average			**24%**	**14%**	**15%**	**47%**
4AROA202.20	07/22/2003	24	120	34%	33%	0%	33%
	08/27/2003	24	110	17%	4%	0%	79%
	09/22/2003	24	330	71%	0%	8%	21%
	10/22/2003	16	150	6%	0%	12%	82%
	11/24/2003	24	110	55%	4%	33%	8%
3 of 12 (25%) samples exceed 235 cfu/100ml	12/22/2003	16	24	44%	0%	0%	56%
	01/28/2004	0	0	0%	0%	0%	0%
	02/23/2004	24	60	21%	71%	8%	0%
	03/29/2004	4	6	0%	100%	0%	0%
	04/26/2004	24	290	8%	88%	4%	0%
	05/17/2004	7	60	57%	43%	0%	0%
	06/28/2004	24	370	29%	17%	12%	42%
	Weighted Average			**35%**	**32%**	**9%**	**24%**
4AROA199.20	07/22/2003	24	280	17%	29%	0%	54%
	08/27/2003	24	200	21%	0%	25%	54%
	09/22/2003	24	520	33%	0%	67%	0%
	10/22/2003	3	30	0%	0%	100%	0%
	11/24/2003	24	610	17%	0%	17%	66%
6 of 12 (50%) samples exceed 235 cfu/100ml	12/22/2003	24	36	58%	0%	21%	21%
	02/23/2004	24	66	4%	96%	0%	0%
	03/29/2004	24	36	0%	0%	21%	79%
	04/26/2004	15	120	53%	0%	7%	40%
	05/17/2004	24	330	72%	12%	12%	4%
	06/28/2004	24	540	8%	4%	42%	46%
	07/20/2004	24	470	8%	4%	17%	71%
	Weighted Average			**23%**	**8%**	**27%**	**42%**

Station ID	Sample Date	No. of Isolates	E. coli (cfu/100 ml)	Wildlife	Human	Live-stock	Pets
4AROA192.94	07/22/2003	24	110	42%	0%	25%	33%
	08/27/2003	24	40	59%	4%	12%	25%
	09/22/2003	24	460	58%	0%	42%	0%
	10/22/2003	2	10	100%	0%	0%	0%
	11/24/2003	24	420	20%	4%	38%	38%
2 of 12 (17%) samples exceed 235 cfu/100ml	12/22/2003	11	74	64%	0%	0%	36%
	01/28/2004	0	0	0%	0%	0%	0%
	02/23/2004	3	6	33%	67%	0%	0%
	03/29/2004	3	6	0%	100%	0%	0%
	04/26/2004	2	20	50%	50%	0%	0%
	05/17/2004	1	10	100%	0%	0%	0%
	06/28/2004	8	50	0%	88%	12%	0%
	Weighted Average			39%	3%	36%	22%

Source: DEQ

Figure 3-6: BST Source Distributions at Wilson Creek Station AWLN000.40

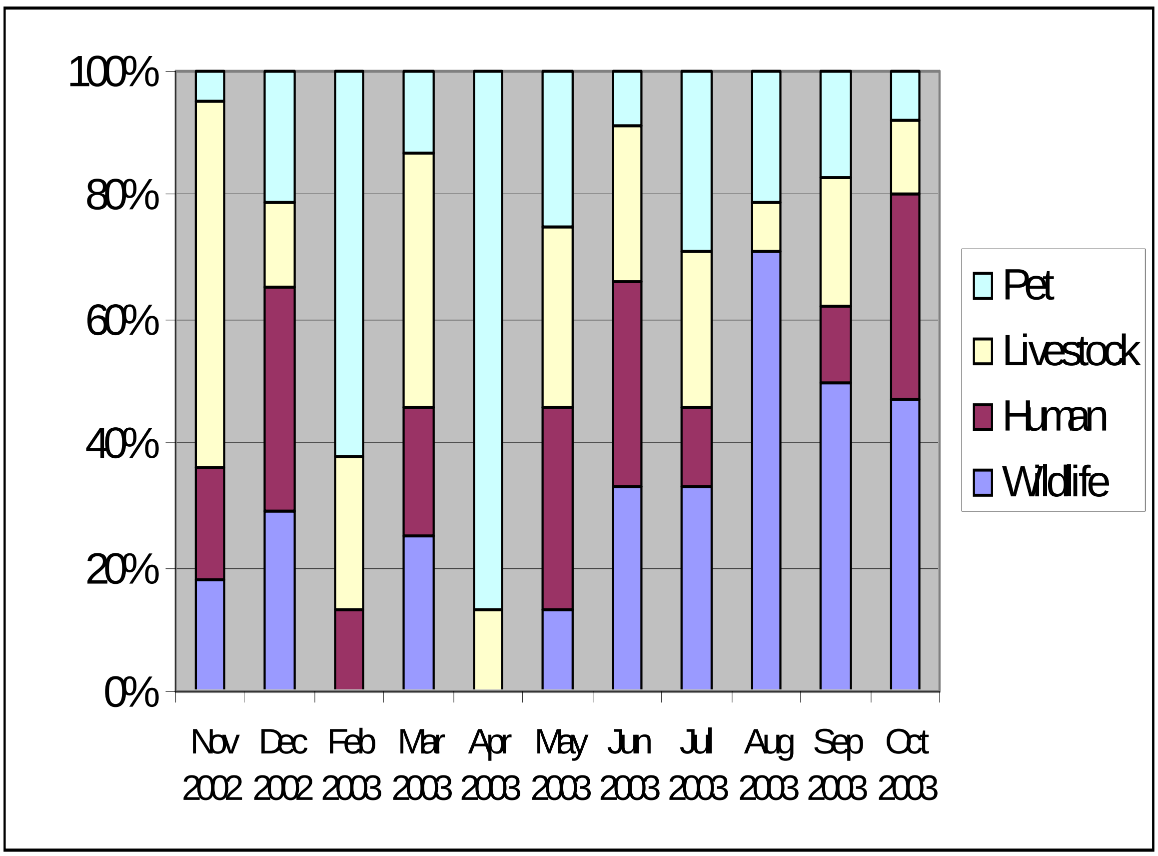


Figure 3-7: BST Source Distributions at Ore Branch Station 4AORE000.19

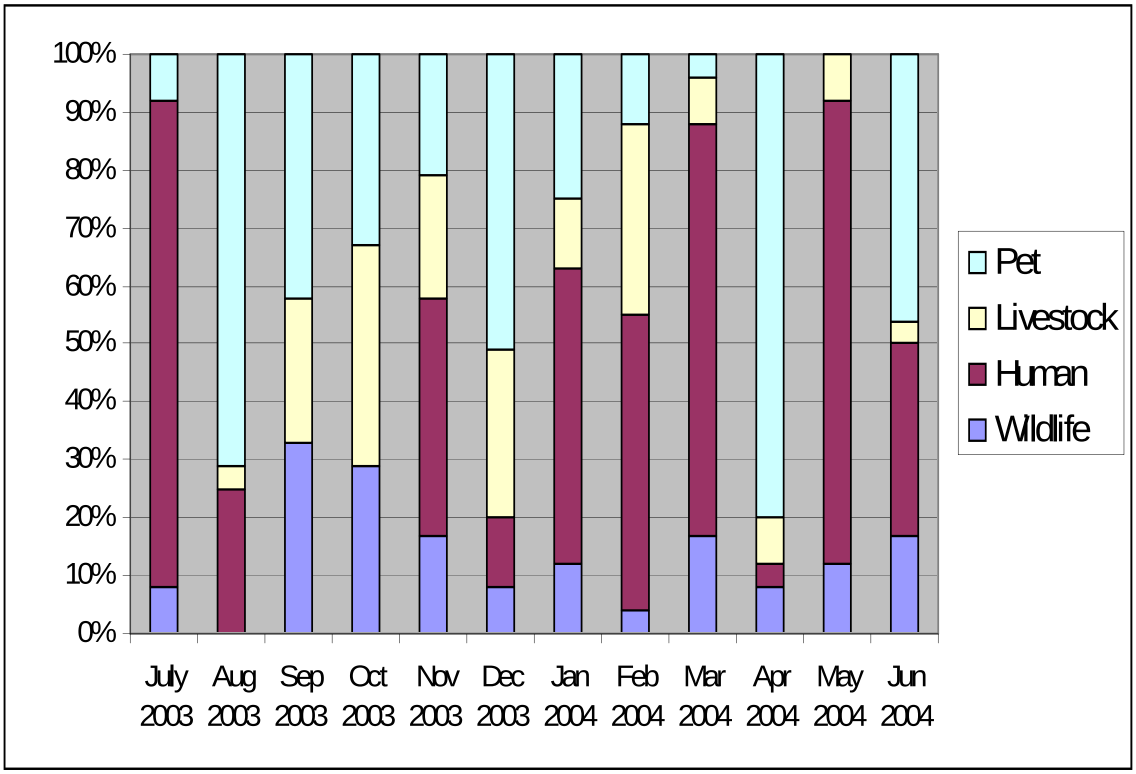
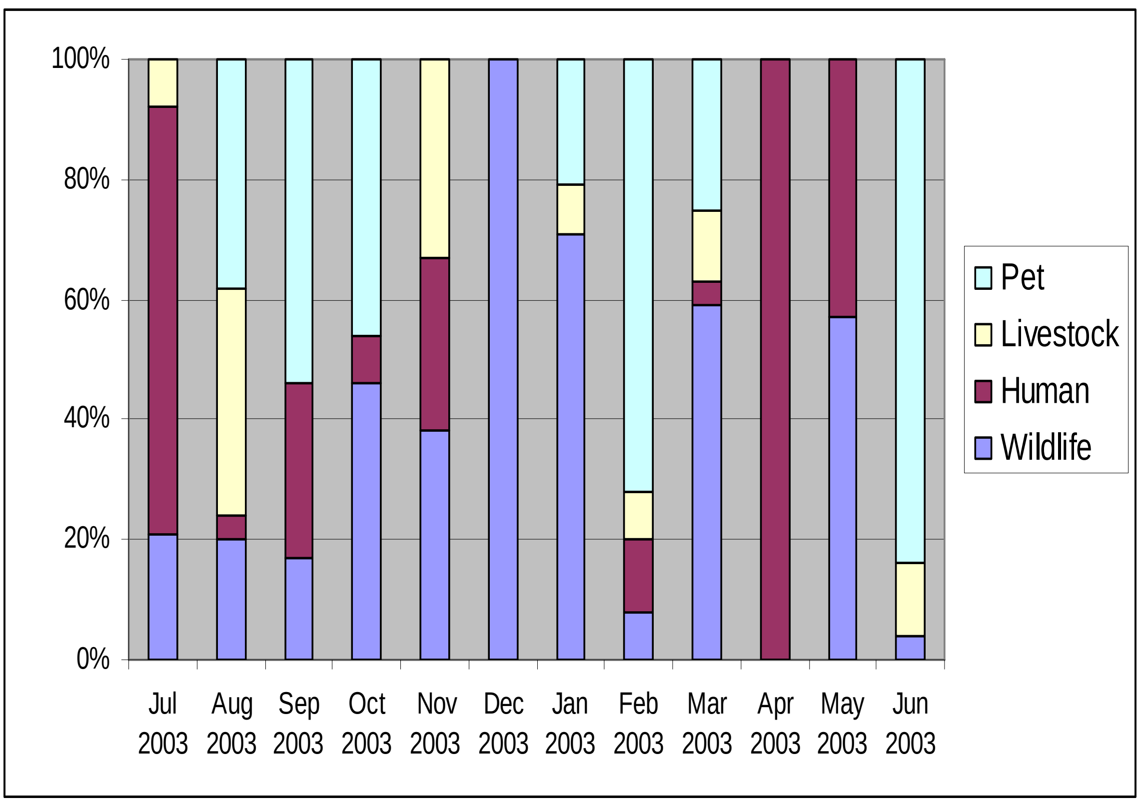


Figure 3-8: BST Source Distributions at Roanoke Monitoring Station 4AROA202.20



3.5 Fecal Coliform Source Assessment

This section focuses on characterizing the sources that potentially contribute to the fecal coliform loading in the Wilson Creek, Ore Branch and Roanoke River watershed. These sources include permitted facilities, sanitary sewer systems and septic systems, livestock, wildlife, pets, and land application of manure and biosolids. Chapter 4 includes a detailed presentation of how these sources are incorporated and represented in the model.

3.5.1 Permitted Facilities

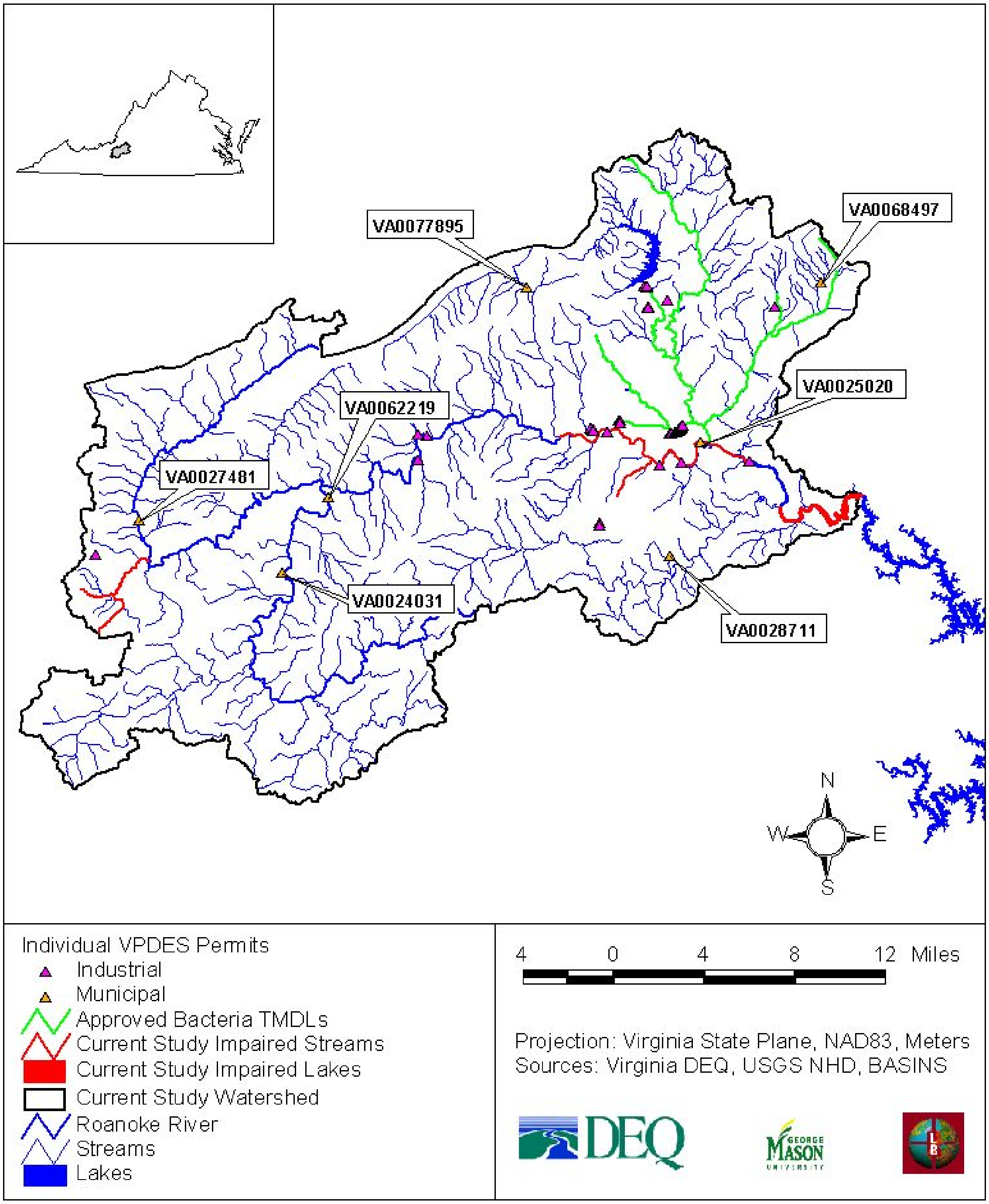
Data obtained from the DEQ's West Central Regional Office indicate that there are 18 individually permitted facilities and 15 domestic sewage general permits located in the Wilson Creek, Ore Branch and Roanoke River watershed. The permit number, design flow, and status for each permit are presented in Table 3-11. The locations of the individual permits are presented in Figure 3-9 (latitudes and longitudes were not consistently available for the general permits and they could not be mapped). The flow from all permitted dischargers will be considered in model setup and calibration.

Table 3-11: Permitted Discharges in the Wilson Creek, Ore Branch and Roanoke River Watershed

Permit Number	Facility Name	Facility Type	Design Flow (gpd)[1]	Receiving Waterbody	Status
VA0001252	Associated Asphalt Inc	Industrial	54,000	Roanoke River	Active
VA0001333	Koppers Inc	Industrial	600,000	Roanoke River	Active
VA0001431	Motiva Enterprises LLC - Roanoke	Industrial	5,320,000	Back Creek, UT	Active
VA0001473	Roanoke City - Carvins Cove Water Filtration Plant	Industrial	474,000	Carvin Creek, UT	Active
VA0001589	Roanoke Electric Steel (RES) Corporation	Industrial	39,000	Peters Creek	Active
VA0001597	Norfolk Southern Railway Co - Shaffers Crossing	Industrial	50,000	Hortons Branch; Lick Run, UT	Active
VA0024031	Shawsville Town - Sewage Treatment Plant	Municipal	200,000	South Fork Roanoke River	Active
VA0025020	Western Virginia Water Authority	Municipal	62,000,000	Roanoke River	Active
VA0027481	Blacksburg Country Club Sewage Treatment Plant	Municipal	35,000	North Fork Roanoke River	Active
VA0028711	Suncrest Heights	Municipal	20,000	Back Creek, UT	History
VA0062219	Montgomery County PSA - Elliston-Lafayette WWTP	Municipal	250,000	South Fork Roanoke River	Active
VA0077895	Roanoke Moose Lodge	Municipal	4,700	Mason Creek	Active
VA0086541	Marathon Ashland - Roanoke Terminal	Industrial	1,470,000	Back Creek, UT	Active
VA0087092	American Electric Power - Niagara Hydro Plant	Industrial	143,000	Roanoke River	Active
VA0088358	Fred Whitaker Co	Industrial	151,000	Roanoke River	Active
VA0089702	Safety Kleen Systems Inc.	Industrial	NA[2]	NA[2]	History
VA0089991	Federal Mogul Corp - Blacksburg	Industrial	65,000	Wilson Creek, UT	Active
VA0091065	Crystal Springs WTP	Industrial	92,000	Roanoke River	Active
VAG402002	Domestic Sewage Discharge	Residence	250	Mason Creek, UT	Active
VAG402003	Domestic Sewage Discharge	Residence	500	North Fork Roanoke River, UT	Active
VAG402004	Domestic Sewage Discharge	Residence	500	North Fork Roanoke River, UT	Active
VAG402008	Domestic Sewage Discharge	Residence	600	Roanoke River/ Smith Mountain Lake	Active
VAG402012	Domestic Sewage Discharge	Residence	500	Gish Branch	Active
VAG402019	Domestic Sewage Discharge	Residence	500	Cedar Run	Active
VAG402021	Domestic Sewage Discharge	Residence	500	Cedar Run Branch	Active
VAG402041	Domestic Sewage Discharge	Commercial	300	Crush Run	Active
VAG402046	Domestic Sewage Discharge	Residence	990	Wilson Creek	Active
VAG402054	Domestic Sewage Discharge	Residence	450	Wilson Creek	Active
VAG402059	Domestic Sewage Discharge	Residence	500	Glade Creek, UT	Active
VAG402061	Domestic Sewage Discharge	Residence	500	Glade Creek, UT	Active
VAG402063	Domestic Sewage Discharge	Commercial	500	Glade Creek, UT	Active
VAG402082	Domestic Sewage Discharge	Residence	50	Plum Creek	Active
VAG402091	Domestic Sewage Discharge	Residence	900	Flatwoods Branch, UT	Active

[1] Gallons per Day
[2] Connecting to Roanoke County Sewer System

Figure 3-9: Location of Permitted Facilities in the Wilson Creek, Ore Branch and Roanoke River Watershed



The available flow data for the permitted facilities was retrieved and analyzed. Table 3-12 shows the design flow, average flow, permitted bacteria concentration, and average bacteria concentrations recorded for the permitted facilities within the watershed. Appendix A shows the average and maximum monthly flows for the facilities for which flow data were available. Average flows for the permitted facilities were used in the HSPF model set-up and calibration.

Fecal coliform data were available only for the Shawsville Town - Sewage Treatment Plant and the Western Virginia Water Authority Water Pollution Control Plant (Appendix A), and were not available for other permitted facilities. The waste treatment plants use chlorine for disinfection, and measure total contact chlorine as an indication of fecal coliform levels. Appendix A also shows total contact chlorine levels for facilities where data were available. The available data indicate that adequate disinfection was achieved at the plants, and that these facilities were not a large source of fecal coliform loading.

Table 3-12: Inventory and Characterization of Facilities within the Wilson Creek, Roanoke River and Ore Branch Watersheds

Permit Number	Facility Name	Type	Design Flow (mgpd)	Permitted Bacteria Conc. (cfu/100mL)	Ave Flow (gpd)	Ave. Bacteria Conc. (cfu/100mL)
VA0001252	Associated Asphalt Inc	Ind.	54,000	N/A	12,938	N/A
VA0001333	Koppers Inc	Ind.	600,000	N/A	138,563	N/A
VA0001431	Motiva Enterprises LLC - Roanoke	Ind.	5,320,000	N/A	52,962	N/A
VA0001473	Roanoke City - Carvins Cove Water Filtration Plant	Ind.	474,000	N/A	384,405	N/A
VA0001589	Roanoke Electric Steel (RES) Corporation	Ind.	39,000	N/A	50,927	N/A
VA0001597	Norfolk Southern Railway Co - Shaffers Crossing	Ind.	50,000	N/A	40,049	N/A
VA0024031	Shawsville Town - STP	Mun.	200,000	126 (E. coli, Ave)	79,000	25.3
VA0025020	Western Virginia Water Authority	Mun.	62,000,000	126 (E. coli, Ave)	38,631,625	Below permitted limits
VA0027481	Blacksburg Country Club STP	Mun.	35,000	N/A	31,416	N/A
VA0028711	Suncrest Heights	Mun.	20,000	N/A	8,523	N/A
VA0062219	Montgomery County PSA - Elliston-Lafayette WWTP	Mun.	250,000	126 (E. coli, Ave)	76,758	N/A
VA0077895	Roanoke Moose Lodge	Mun.	4,700	N/A	1,311	N/A
VA0086541	Marathon Ashland - Roanoke Terminal	Ind.	1,470,000	N/A	81,958	N/A
VA0087092	American Electric Power - Niagara Hydro Plant	Ind.	143,000	N/A	12,723	N/A
VA0088358	Fred Whitaker Co	Ind.	151,000	N/A	22,490	N/A
VA0089702	Safety Kleen Systems Inc.	Ind.	N/A	N/A	N/A	N/A
VA0089991	Federal Mogul Corp - Blacksburg	Ind.	65,000	N/A	NL	N/A
VA0091065	Crystal Springs WTP	Ind.	92,000	N/A	193,150	N/A

N/A: Data not available or not applicable
NL: No permitted limit, facility does not monitor

Within the Wilson Creek, Ore Branch and Roanoke River Watersheds there are ten Municipal Separate Storm Sewer System (MS4) permits requiring TMDL allocations. Table 3-13 lists the MS4 discharges with the corresponding receiving streams.

Table 3-13: MS4 Permits in the Wilson Creek, Ore Branch and Roanoke River Watersheds

MS4 Permit Holder	Permit Number	Receiving Streams
Roanoke County	VAR040022	Ore Branch & Roanoke River
City of Roanoke	VAR040004	Ore Branch & Roanoke River
Town of Vinton	VAR040026	Roanoke River
City of Salem	VAR040010	Roanoke River
VDOT Roanoke Urban Area	VAR040017	Ore Branch & Roanoke River
Virginia Western Community College	VAR040030	Roanoke River
Virginia Medical Center	VAR040050	Roanoke River
VDOT Montgomery County Urban Area	VAR040016	Wilson Creek
Town of Blacksburg	VAR040019	Wilson Creek
Town of Christianburg	VAR040025	Wilson Creek

3.5.2 Extent of Sanitary Sewer Network

Houses can be connected to a public sanitary sewer, a septic tank, or the sewage can be disposed by other means. Estimates of the total number of households using each type of waste disposal are presented in the next section.

3.5.2.1 Septic Systems

There are no data available for the total number of septic systems in the watershed. Estimates of the total number of housing units located in the watershed and the identification of whether these housing units are connected to a public sewer or on septic systems were based on two sources of data:

- USGS 7.5 minute quadrangle maps
- U.S. Census Bureau data

The U.S. Census Bureau 2000 data for Bedford, Franklin, Montgomery, and Roanoke counties, as well as the Cities of Roanoke and Salem, were reviewed to establish the population growth rates in the counties and to validate the housing units' calculation. A summary of the census data and population estimates used for the Wilson Creek, Roanoke River and Ore Branch watershed as well as the estimates from the Tinker Creek TMDL report are presented in Table 3-14.

Table 3-14: 2000 Census Data Summary for Wilson Creek, Ore Branch and Roanoke River Watersheds

County		Population	# Households	# Housing Units
Wilson Creek, Roanoke River, and Ore Branch Watershed	Bedford	1,042	422	446
	Floyd	102	43	49
	Franklin	922	366	407
	Montgomery	14,860	6,078	6,439
	Roanoke	60,097	24,439	25,490
	Roanoke City	55,634	25,146	26,854
	Salem City	24,747	9,954	10,403
Tinker Creek Watershed[1]	Roanoke/Botetourt Counties	82,460	---	36,296

Source: U.S. Census Data, USGS Quad Maps
[1]Tinker Creek estimates based on TMDL Report (2004)

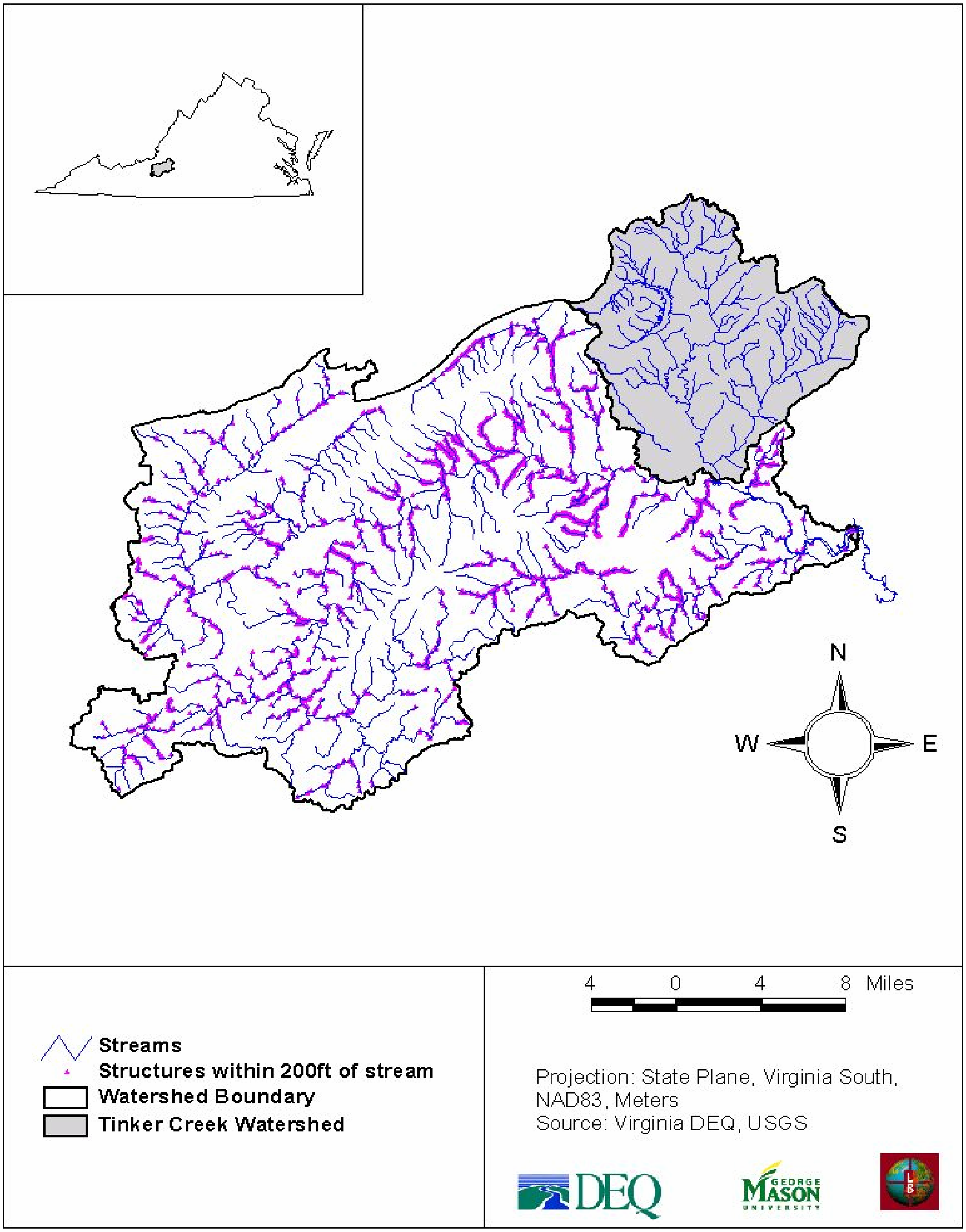
The 1990 U.S Census Report presents the percent of houses on each sewage disposal type as shown in Table 3-15. The 1990 U.S Census Report category “Other Means” includes the houses that dispose of sewage in other ways than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewer directly via straight pipes if located within 200 feet of a stream (Figure 3-39).

Table 3-15: Percent of Houses within Each County on Public Sewers, Septic Systems, and Other Means

County	% Public Sewer	% Septic Tank	% Other Means
Bedford County	6.75%	90.17%	3.09%
Floyd County	7.45%	83.96%	8.59%
Franklin County	15.04%	81.40%	3.55%
Montgomery County	65.50%	32.73%	1.78%
Roanoke County	66.46%	32.95%	0.60%
Roanoke City	95.96%	4.00%	0.04%
Salem City	93.10%	6.86%	0.04%

Source: U.S. Census Data

Figure 3-10: USGS Structures within 200ft of Stream in the Wilson Creek, Ore Branch and Roanoke River Watershed



3.5.2.2 Failed Septic Systems

In order to determine the amount of fecal coliform contributed by human sources, the failure rates of septic systems must be estimated. Septic system failures are generally attributed to the age of a system. For this TMDL model, the failure rate was assumed to be 3 percent of the total septic systems in the watershed. In order to determine the load of bacteria from these sources, it was assumed that the septic system design flow is 75 gallons per person per day. In addition, it was estimated that typical fecal coliform concentrations from a failed septic system is 10,000 cfu/100mL and from a straight pipe is 1,040,000 cfu/100 mL (Tinker Creek TMDL Report, 2004). Table 3-16 shows the estimates of the population on septic systems and straight pipes, the amount of failing systems, and the flow and fecal coliform load produced daily.

Table 3-16: Estimates of the Number of Septic Systems and Straight Pipes in the Wilson Creek, Roanoke River, and Ore Branch Watershed

Category	Total # of People on Septics	# People per Household	# Failing Septics or Pipes	People Served	Flow (gal/day)	Daily Load (#/day)
Septic Systems	51,504	2.49	620	1,545.1	115,884	4.39E+10
Straight Pipes	162	2.58	63	162.5	12184	4.61E+14

3.5.3 Livestock

An inventory of the livestock residing in the Wilson Creek, Ore Branch and Roanoke River watershed was conducted using data and information provided by DCR, Peaks of Otter Soil and Water Conservation District (SWCD) in Bedford County, Mountain Castles SWCD in Botetourt and Craig Counties, Skyline SWCD in Floyd and Montgomery Counties, Blue Ridge SWCD in Franklin and Roanoke Counties, NRCS, and the Virginia Agricultural Statistics Service (2002), as well as field surveys. Table 3-17 summarizes the livestock inventory in the watershed.

Table 3-17: Wilson Creek, Ore Branch and Roanoke River Watershed Livestock Inventory

Livestock Type	Number of Animals
Beef Cows	6,313
Dairy Cows	728
Hogs & Pigs	8
Sheep & Lambs	1,014
Horses & Ponies	2,161

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. Table 3-18 shows the average fecal coliform production per animal per day contributed by each type of livestock.

Table 3-18: Daily Fecal Coliform Production of Livestock

Livestock Type	Daily Fecal Coliform Production (millions of cfu/day)	Reference
Cattle and calves	5,400	Metcalf and Eddy, 1991
Beef Cows	100,000	ASAE, 1998
Dairy Cows	100,000	ASAE, 1998
Hogs & Pigs	8,900	Metcalf and Eddy, 1991
	11,000	ASAE, 1998
Sheep & Lambs	18,000	Metcalf and Eddy, 1991
	12,000	ASAE, 1998
Horses & Ponies	420	ASAE, 1998

Source: USEPA Protocol for Developing Pathogen TMDLs, 2001

The impact of fecal coliform loading from livestock is dependent upon whether loadings are directly deposited into the stream, or indirectly delivered to the stream via surface runoff. For this TMDL, fecal coliform deposited while livestock were in confinement or grazing was considered indirect deposit, and fecal coliform deposited when livestock directly defecate into the stream was considered direct deposit. The distribution of daily fecal coliform loading between direct and indirect deposits was based on livestock daily schedules.

For the Wilson Creek, Ore Branch and Roanoke River TMDLs, the initial estimates of the beef cattle daily schedule were based on the Dodd Creek TMDL. The amount of time beef cattle spend in the pasture and stream was also presented during the TAC meetings where local stakeholders provided comments. The monthly schedule was adjusted to reflect the conditions in the watershed.

The daily schedule for beef cattle that was accepted by the stakeholders is presented in Table 3-19. The daily schedule for dairy cows that was accepted by the stakeholders is presented in Table 3-20. The time beef cattle and dairy cows spend in the pasture or loafing was used to determine the fecal coliform load deposited indirectly. The directly deposited fecal coliform load from livestock was based on the amount of time they spend in the stream.

Table 3-19: Daily Schedule for Beef Cattle

Month	Time Spent in		
	Pasture	Stream	Loafing Lot
	(Hour)	(Hour)	(Hour)
January	23.50	0.50	0
February	23.50	0.50	0
March	23.25	0.75	0
April	23.00	1.00	0
May	23.00	1.00	0
June	22.75	1.25	0
July	22.75	1.25	0
August	22.75	1.25	0
September	23.00	1.00	0
October	23.25	0.75	0
November	23.25	0.75	0
December	23.50	0.50	0

Source: Dodd Creek TMDL Report, DCR 2002.

Table 3-20: Daily Schedule for Dairy Cows

Month	Time Spent in		
	Pasture	Stream	Loafing Lot
	(Hour)	(Hour)	(Hour)
January	7.45	0.25	16.30
February	7.45	0.25	16.30
March	8.10	0.50	15.40
April	9.35	0.75	13.90
May	10.05	0.75	13.20
June	10.30	1.00	12.70
July	10.80	1.00	12.20
August	10.80	1.00	12.20
September	11.05	0.75	12.20
October	11.00	0.50	12.50
November	10.30	0.50	13.20
December	9.15	0.25	14.60

Source: Dodd Creek TMDL Report, DCR 2002.

3.5.4 Land Application of Manure

Land application of the manure that cattle produce while in confinement is a typical agricultural practice. Both diary operations and beef cattle are present in the watershed. Because there are no recorded feedlots, or a significant number of manure storage facilities present in the watershed, the manure produced by confined livestock was directly applied on the pasturelands, and was treated as an indirect source in the development of the Wilson Creek, Ore Branch and Roanoke River TMDL.

3.5.5 Land Application of Biosolids

Non-point human sources of fecal coliform can be associated with the spreading of biosolids. Discussions with Virginia DOH indicated that there has been some biosolids land application in Bedford and Franklin Counties and no spreading of biosolids occurred in Floyd, Montgomery, and Roanoke Counties within the TMDL study area. Recorded biosolids application conducted in 2003 and 2004 is presented in Table 3-21. The biosolids loads were averaged and applied to crop and pasture land areas of the watershed in each corresponding county.

Table 3-21: Biosolids Application (dry ton/year) in the Wilson Creek, Ore Branch and Roanoke River Watershed

Year	County				
	Bedford	Floyd	Franklin	Montgomery	Roanoke
2003	4,505	0	1,395	0	0
2004	6,220	0	4,851	0	0

Source: VADOH

3.5.6 Wildlife

Similar to livestock contributions, wildlife contributions of fecal coliform can be both indirect and direct. Indirect sources are those that are carried to the stream from the surrounding land via rain and runoff events, whereas direct sources are those that are directly deposited into the stream.

The wildlife inventory for this TMDL was developed based on a number of information and data sources, including: (1) habitat availability, (2) Department of Game and Inland Fisheries (DGIF) harvest data and population estimates, and (3) stakeholder comments and observations.

A wildlife inventory was conducted based on habitat availability within the watershed. The number of animals in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. Typical wildlife densities are presented in Table 3-22.

Table 3-22: Wildlife Densities

Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire watershed
Raccoon	0.07 animals/habitat acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/habitat acre	Within 66 feet of streams and ponds
Beaver	4.8 animals/mile of stream	Within 66 feet of streams and ponds
Goose	0.0032 animals/watershed acre	Within 66 feet of streams and ponds
Duck	0.0065 animals/watershed acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding urban land uses

Source: Map Tech, Inc., 2001.

The wildlife inventory presented in Table 3-23 was then confirmed with DGIF and DCR, and was presented to stakeholders and local residents for approval.

Table 3-23: Wilson Creek, Ore Branch and Roanoke River Watershed Wildlife Inventory

Wildlife Type	Number of Animals
Deer	16,514
Raccoon	7,701
Muskrat	34,154
Beaver	3,647
Goose	1,189
Duck	2,416
Wild Turkey	3,291

The wildlife inventory was used to determine the fecal coliform loading by wildlife within the watershed. Table 3-24 shows the average fecal coliform production per animal, per day, contributed by each type of wildlife. Separation of the wildlife daily fecal coliform load into direct and indirect deposits was based on estimates of the amount of time each type of wildlife spends on land versus time spent in the stream. Table 3-24 also shows the percent of time each type of wildlife spends in the stream on a daily basis.

Table 3-24: Fecal Coliform Production from Wildlife

Wildlife	Daily Fecal Production (in millions of cfu/day)	Portion of the Day in Stream (%)
Deer	347	1
Raccoon	113	10
Muskrat	25	50
Goose	799	50
Beaver	0.2	90
Duck	2,430	75
Wild Turkey	93	5

Source: ASAE, 1998; Map Tech, Inc., 2000; EPA, 2001.

3.5.7 Pets

The contribution of fecal coliform loading from pets was also examined in the assessment of fecal coliform loading to Wilson Creek, Ore Branch and Roanoke River. The primary types of pets considered in this TMDL are cats and dogs. The number of pets residing in the Wilson Creek, Ore Branch and Roanoke River watershed was estimated based on the number of households in the watershed, assuming an average of 1.7 dogs and 2.2 cats per household. Using the estimates of the total number of households in the watershed, it was estimated that a total of 167,890 cats and 132,343 dogs were present in the watershed.

Fecal coliform loading from pets occurs primarily in residential areas. The load was estimated based on daily fecal coliform production rate of 504 cfu/day per cat and 4.09 $x10^9$ cfu/day per dog.

4.0 Modeling Approach

This section describes the modeling approach used in the Wilson Creek, Ore Branch and Roanoke River TMDL development. The primary focus is on the sources represented in the model, assumptions used, model set-up, calibration, and validation, and the existing load.

4.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the water body that can:

- represent the watershed characteristics
- represent the point and non-point sources of fecal coliform and their respective contribution
- use input time series data (rainfall and flow) and kinetic data (die-off rates of fecal coliform)
- estimate the in-stream pollutant concentrations and loadings under the various hydrologic conditions
- allow for direct comparisons between the in-stream conditions and the water quality standard

4.2 Model Selection

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict in-stream water quality conditions of Wilson Creek, Ore Branch, and Roanoke River under varying scenarios of rainfall and fecal coliform loading. The results from the developed Wilson Creek, Ore Branch, and Roanoke River model were used to develop the TMDL allocations for the existing fecal coliform loading conditions.

HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment

- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

These steps are discussed in the next few sections.

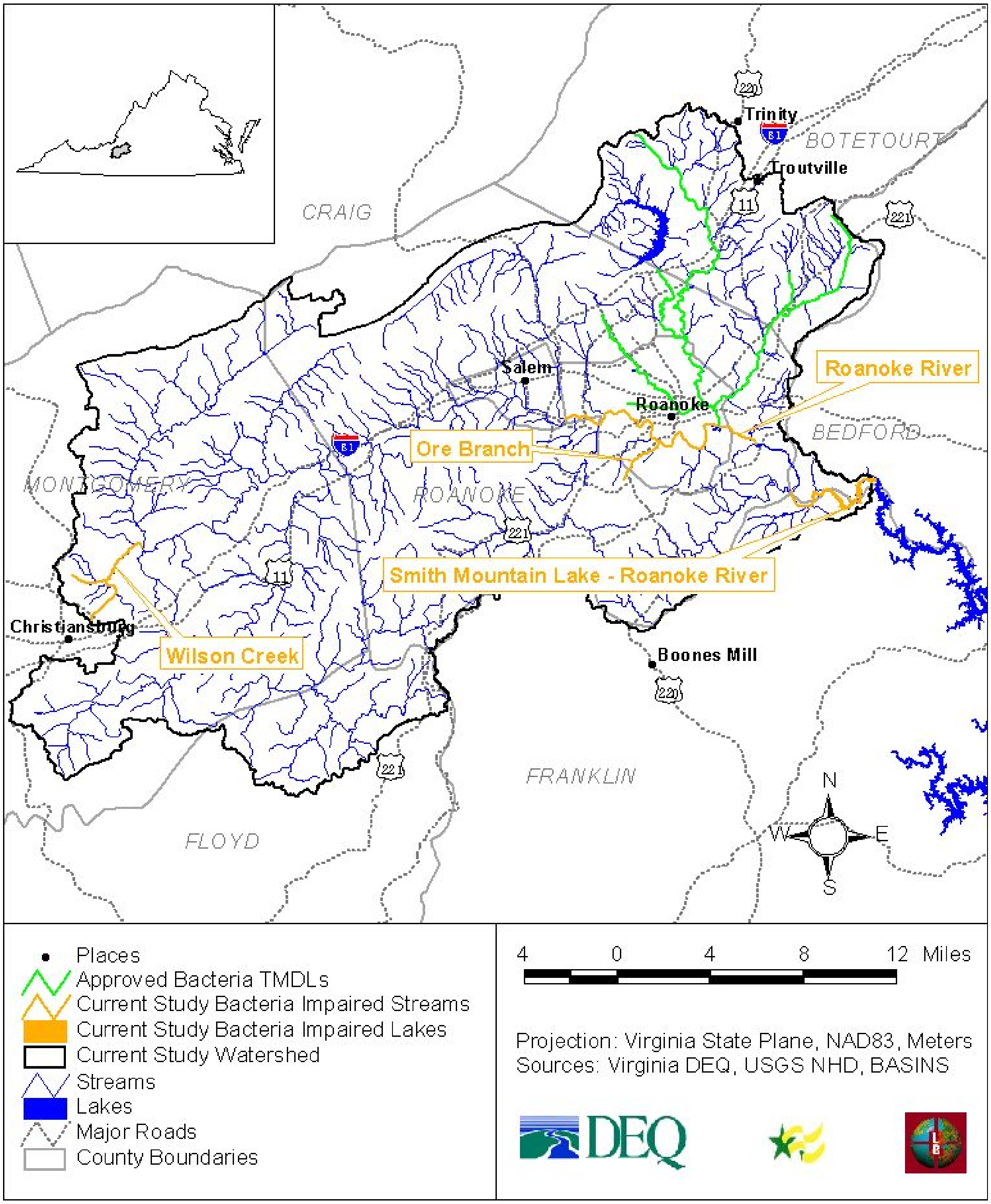
4.3 Watershed Boundaries

Wilson Creek is a tributary to the North Fork Roanoke River and is located in Montgomery County, while Ore Branch is a tributary to the Roanoke River and flows from Roanoke County into Roanoke City. The impaired segment of the Roanoke River begins in Salem City and flows through Roanoke City into Roanoke County. All three streams are located in the Roanoke River Basin (USGS Cataloging Unit 03010101). The watershed that encompasses the Wilson Creek, Ore Branch and Roanoke River bacteria impairments is approximately 371,658 acres or 580 square miles. The watershed drains portions of Floyd, Montgomery, Roanoke, Botetourt, Bedford and Franklin Counties and all of Salem and Roanoke Cities.

Bacteria TMDLs have already been approved for five impaired streams in the watershed: Carvin Creek, Glade Creek, Laymantown Creek, Lick Run and Tinker Creek. The first four impaired streams all flow into Tinker Creek, which then flows into the Roanoke River just upstream of the Roanoke City/Roanoke County line near Vinton, Virginia. The results of the bacteria TMDLs developed for the Tinker Creek watershed will be input into the model developed for this study.

Approximately 40 percent of the drainage basin is located in Roanoke County, 32 percent in Montgomery County and 12 percent in Botetourt County; the remainder of the watershed is divided among Floyd, Franklin and Bedford Counties (six, two and one percent, respectively) and the Cities of Roanoke and Salem (six and two percent, respectively). The watershed makes up 100 percent of the land area in the Cities of Roanoke and Salem, 90 percent of Roanoke County, 48 percent of Montgomery County, 13 percent of Botetourt County, eight percent of Floyd County and one percent each of Bedford and Franklin Counties. Interstate Route 81 (I-81) and U.S. Route 11 (US-11) run the entire length of the watershed from the northeast near Troutville to the southwest near Christiansburg. U.S. Route 221 (US-221) and the Blue Ridge Parkway pass through the lower section of the watershed in a northeast to southwest direction. U.S. Route 220 (US-220) runs the lower half of the watershed from the north near Trinity to the south near Boones Mill. The majority of the remaining major roadways are concentrated in and around the Cities of Roanoke and Salem. Figure 4-1 is a map showing the Wilson Creek, Ore Branch and Roanoke River watersheds boundaries.

Figure 4-1: Wilson Creek, Ore Branch and the Roanoke River Watershed Boundary



4.4 Watershed Delineation

For this TMDL, the Roanoke River watershed, including the Wilson Creek and Ore Branch watersheds, was delineated into 85 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. Figure 4-2 shows these 85 delineated subwatersheds. The Roanoke River watershed was delineated into 62 subwatersheds, Wilson Creek watershed was delineated into 5 subwatersheds and Ore Branch watershed was delineated into 1 subwatershed. Tinker Creek was delineated into 17 subwatersheds. The Wilson Creek, Roanoke River, Ore branch, and Tinker Creek subwatersheds as well as the total drainage area for each watershed are shown in Table 4-1. The location of these subwatersheds for these four watersheds is shown in Figure 4-3. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data.

Table 4-1: The Subwatershed IDs, and Drainage Areas for the Roanoke River, Tinker Creek, Wilson Creek, and Ore Branch Watersheds

Watershed	Subwatershed ID #	Drainage Area (acres)
Roanoke River	1-7; 25-56; 62-76; 78-85	289,076.47
Tinker Creek	8-24	71,387.82
Wilson Creek	57-61	8,255.16
Ore Branch	77	2,608.69
Total	-	371,328.14

Figure 4-2: Wilson Creek, Ore Branch and Roanoke River Subwatersheds Delineation

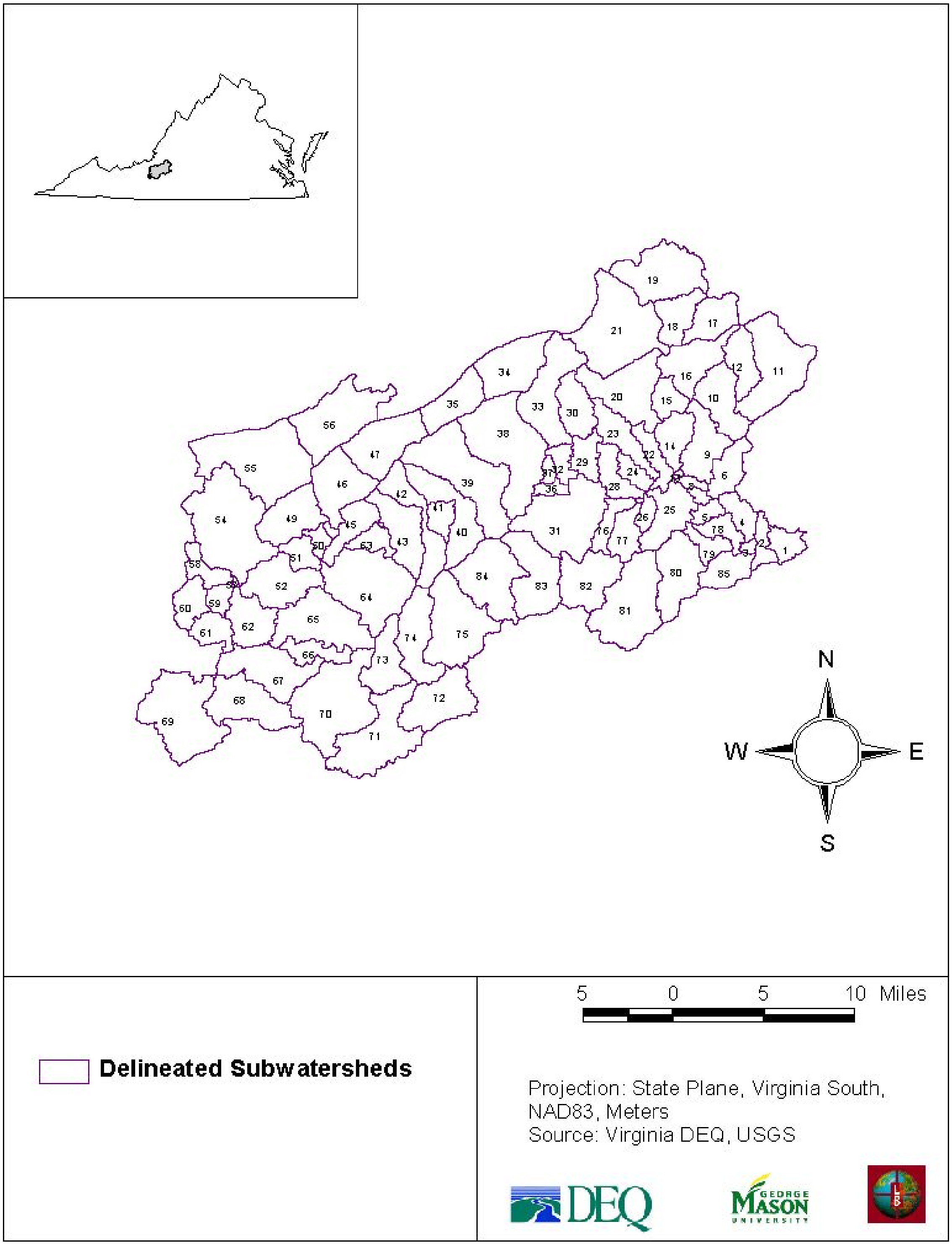
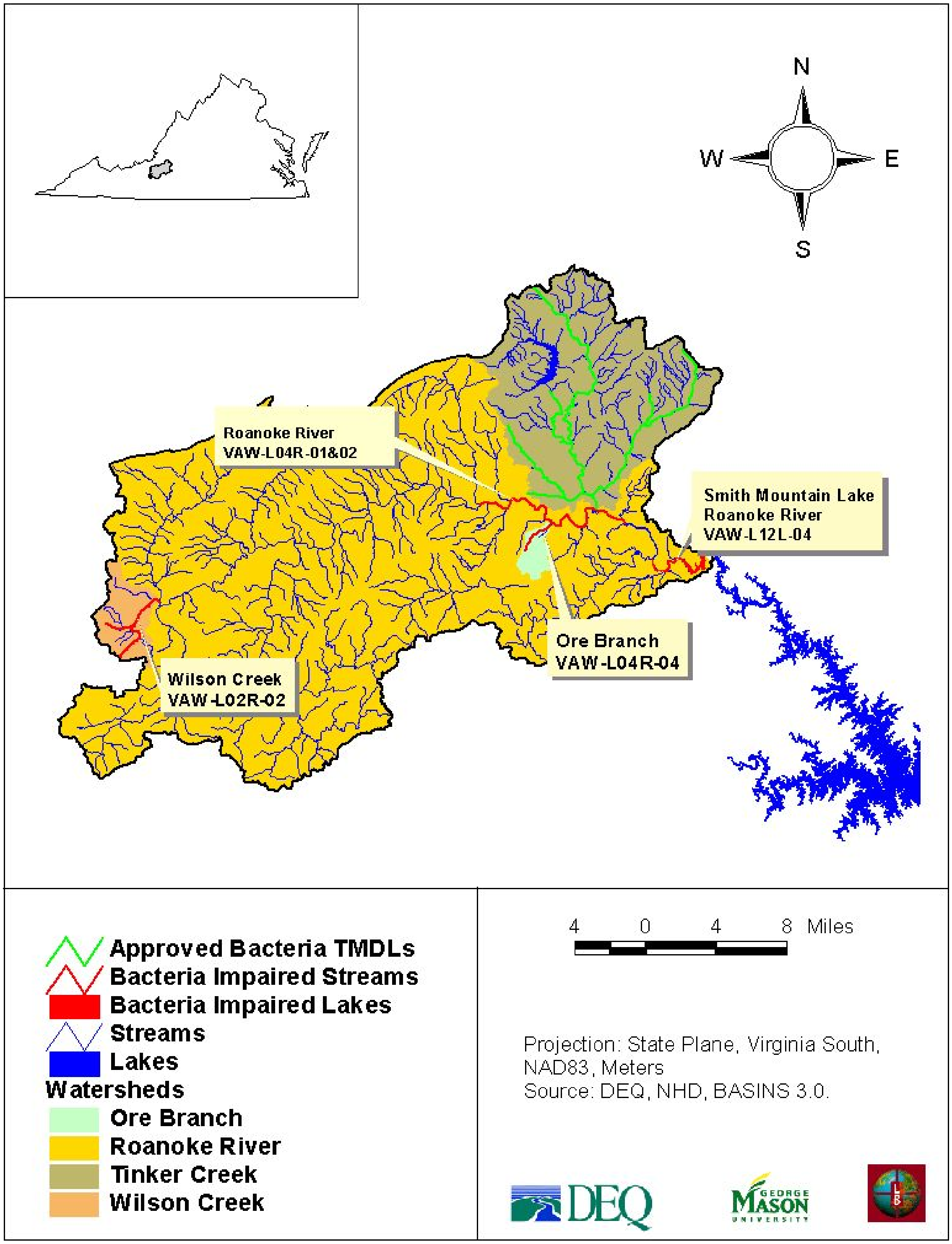


Figure 4-3: The Location of the Wilson Creek, Roanoke River, Ore Branch and Tinker Creek Watersheds and Impaired Segments



4.5 Land Use Reclassification

As previously mentioned, land use distribution in the Wilson Creek, Ore Branch, and Roanoke River Watersheds was determined using USGS NLCD data. The land use data and distribution of land uses in the impaired watershed were presented in Chapter 3. There are 5 land use categories present in the Wilson Creek, Ore Branch, and Roanoke River watershed; the dominant land uses are forested land (73.2%) and agricultural land (15.4%). The original 14 land use types were consolidated into 5 land-use categories to meet modeling goals, facilitate model parameterization, and reduce modeling complexity. This reclassification reduced the 14 land use types to a representative number of categories that best describe conditions and the dominant fecal coliform source categories in the Wilson Creek, Ore Branch, and Roanoke River watershed. Land use reclassification was based on similarities in hydrologic characteristics and potential fecal coliform production characteristics. The Wilson Creek, Ore Branch and Roanoke River watershed land use reclassification is presented in Table 4-2.

Table 4-2: Wilson Creek, Ore Branch, and Roanoke River Watershed Land Use Reclassification

Land Use Category	NLCD Land Use Type	Acres		Percent of Watershed's Land Area	
Water/ Wetlands	Water	1,787	1,974	0.5%	0.5%
	Woody Wetlands	101		0.0%	
	Emergent/Herbaceous Wetlands	87		0.0%	
Urban	Low Intensity Residential	28,060	37,104	7.6%	10.0%
	High Intensity Residential	391		0.1%	
	Commercial/Industrial/Transportation	8,652		2.3%	
Agriculture	Pasture/Hay	52,075	57,203	14.0%	15.4%
	Row Crops	5,128		1.4%	
Forest	Deciduous Forest	200,914	271,905	54.1%	73.2%
	Evergreen Forest	21,920		5.9%	
	Mixed Forest	49,071		13.2%	
Other	Quarries/Mines	1,227	3,473	0.3%	0.9%
	Transitional	1,319		0.4%	
	Urban/Recreational Grasses	927		0.2%	
Total		**371,658**		**100.0%**	

Source: Multi-Resolution Land Characteristics Consortium NLCD

4.6 Hydrographic Data

Hydrographic data describing the stream network of the Wilson Creek, Ore Branch, and Roanoke River watershed were obtained from the National Hydrography Dataset (NHD) and the Reach File Version 3 (RF3) dataset contained in BASINS. These data were used for HSPF model development and TMDL development. Information regarding the reach number, reach name, and length of each stream segment of Wilson Creek, Ore Branch, and the Roanoke River are included in the RF3 database. Reach information for stream segments comprising the mainstem Wilson Creek, Ore Branch, and Roanoke River are provided in Table 4-3. Due to the size of this basin, reach information for the entire Wilson Creek, Ore Branch, and Roanoke River drainage is not presented in this report.

Table 4-3: Mainstem Wilson Creek, Ore Branch, and Roanoke River RF3 Reach Information

Reach Number	Reach Name	Length (meters)
3010101 28 5.77	Roanoke River	5,951.99
3010101 28 5.77	Roanoke River	2,019.04
3010101 28 7.09	Roanoke River	1,762.15
3010101 29 0.00	Roanoke River	5,018.61
3010101 29 3.03	Roanoke River	974.75
3010101 133 0.00	Wolf Creek	7,414.14
3010101 29 3.90	Roanoke River	2,505.16
3010101 32 0.00	Tinker Creek	1,361.50
3010101 30 0.00	Tinker Creek	5,680.24
3010101 30 6.71	Tinker Creek	3,834.22
3010101 30 6.91	Tinker Creek	10,794.97
3010101 107 0.00	Tinker Creek	7,223.28
3010101 32 0.71	Tinker Creek	920.94
3010101 32 0.71	Tinker Creek	6,301.60
3010101 32 4.51	Tinker Creek	6,411.53
3010101 32 4.51	Tinker Creek	5,020.28
30101011041 0.00	Tinker Creek	5,889.48
3010101 32 4.51	Tinker Creek	5,604.22
3010101 32 4.51	Tinker Creek	5,354.83
3010101 81 0.00	Tinker Creek	9,493.37
3010101 81 0.00	Tinker Creek	6,204.04
3010101 198 0.00	Tinker Creek	2,072.11
3010101 198 0.00	Tinker Creek	9,443.48
3010101 198 0.00	Tinker Creek	3,586.08
3010101 33 1.29	Roanoke River	5,360.01
3010101 33 1.29	Roanoke River	1,587.21
3010101 33 3.56	Roanoke River	604.85
3010101 33 3.87	Roanoke River	5,329.73
30101011090 0.00	Peters Creek	5,279.17
30101011090 3.55	Peters Creek	6,220.01
3010101 33 6.60	Roanoke River	3,575.00
3010101 34 0.00	Mason Creek	4,150.56

Reach Number	Reach Name	Length (meters)
3010101 34 6.61	Mason Creek	8,042.17
3010101 34 7.26	Mason Creek	7,072.93
3010101 3411.44	Mason Creek	7,706.61
3010101 35 0.00	Roanoke River	1,950.38
3010101 35 0.00	Roanoke River	1,112.26
3010101 35 2.01	Roanoke River	3,934.90
3010101 35 8.03	Roanoke River	5,973.26
3010101 35 8.03	Roanoke River	1,517.98
3010101 35 8.85	Roanoke River	5,118.73
3010101 3512.51	Roanoke River	1,276.22
3010101 3513.42	Roanoke River	5,271.55
3010101 3517.18	Roanoke River	467.80
3010101 36 0.00	Roanoke River, North Fork	4,304.78
3010101 37 0.00	Bradshaw Creek	8,108.75
3010101 37 4.73	Bradshaw Creek	5,742.47
3010101 38 0.00	Roanoke River, North Fork	2,156.63
3010101 86 0.00	Craig Branch	6,379.85
3010101 38 0.53	Roanoke River, North Fork	4,239.16
3010101 38 1.59	Roanoke River, North Fork	4,195.15
3010101 38 2.63	Roanoke River, North Fork	6,177.20
3010101 38 4.16	Roanoke River, North Fork	259.92
3010101 38 4.22	Roanoke River, North Fork	10,363.12
3010101 38 6.80	Roanoke River, North Fork	8,701.33
3010101 3811.39	Roanoke River, North Fork	7,644.89
30101011171 0.00	Wilson Creek	680.98
30101011172 0.00	Cedar Run	5,170.01
30101011171 0.42	Wilson Creek	3,782.73
30101011171 2.77	Wilson Creek	2,681.16
30101011175 0.00	Wilson Creek	4,015.36
30101011179 0.00	Den Creek	7,537.20
3010101 39 0.00	Roanoke River, South Fork	5,391.31
3010101 39 1.43	Roanoke River, South Fork	6,712.64
3010101 39 3.21	Roanoke River, South Fork	5,987.06
3010101 39 5.34	Roanoke River, South Fork	2,253.08
3010101 40 0.00	Elliot Creek	8,031.17
3010101 40 4.00	Elliot Creek	7,573.25
3010101 40 8.82	Elliot Creek	6,110.49
3010101 41 0.00	Roanoke River, South Fork	7,368.64
3010101 44 0.00	Roanoke River, South Fork	5,661.45
3010101 44 2.74	Roanoke River, South Fork	12,103.59
3010101 45 0.00	Roanoke River, South Fork	4,954.62
3010101 45 4.10	Roanoke River, South Fork	3,811.63
3010101 45 5.09	Roanoke River, South Fork	10,428.24
30101011278 0.00	Murray Run	5,207.63
30101011279 0.00	Ore Branch	3,923.96
3010101 46 0.00	Back Creek	4,068.18
3010101 46 0.00	Back Creek	4,507.69
3010101 46 0.00	Back Creek	7,621.19
3010101 46 0.00	Back Creek	7,611.75
3010101 46 0.00	Back Creek	7,478.88
3010101 46 0.00	Back Creek	3,146.93
3010101 46 0.00	Back Creek	7,083.17
3010101 28 7.08	Roanoke River	5,306.48

The stage-flow relationships required by HSPF were developed using existing USGS rating curves data for Wilson Creek, Ore Branch, and the Roanoke River. Wilson Creek, Ore Branch, and the Roanoke River were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using Manning's equation of a 0.05 roughness coefficient. Model representation of the Wilson Creek, Ore Branch, and Roanoke River stream reach segments is presented in Appendix B.

4.7 Fecal Coliform Sources Representation

This section demonstrates how the fecal coliform sources identified in Chapter 3 were included or represented in the model. Permitted facilities, humans (through failed septic systems and straight pipes), livestock, wildlife, pets, and land application of manure and biosolids were the sources of fecal coliform included in the model.

4.7.1 Permitted Facilities

There are 18 individually permitted facilities and 15 domestic sewage general permits located in the Wilson Creek, Ore Branch, and Roanoke River watersheds. Table 4-4 shows identification number, the receiving waterbody, facility design flow, and the status of the permitted facilities in the Wilson Creek, Ore Branch, and Roanoke River watersheds. The locations of the individual permits are presented in Figure 4-4 (latitudes and longitudes were not consistently available for the general permits and they could not be mapped).

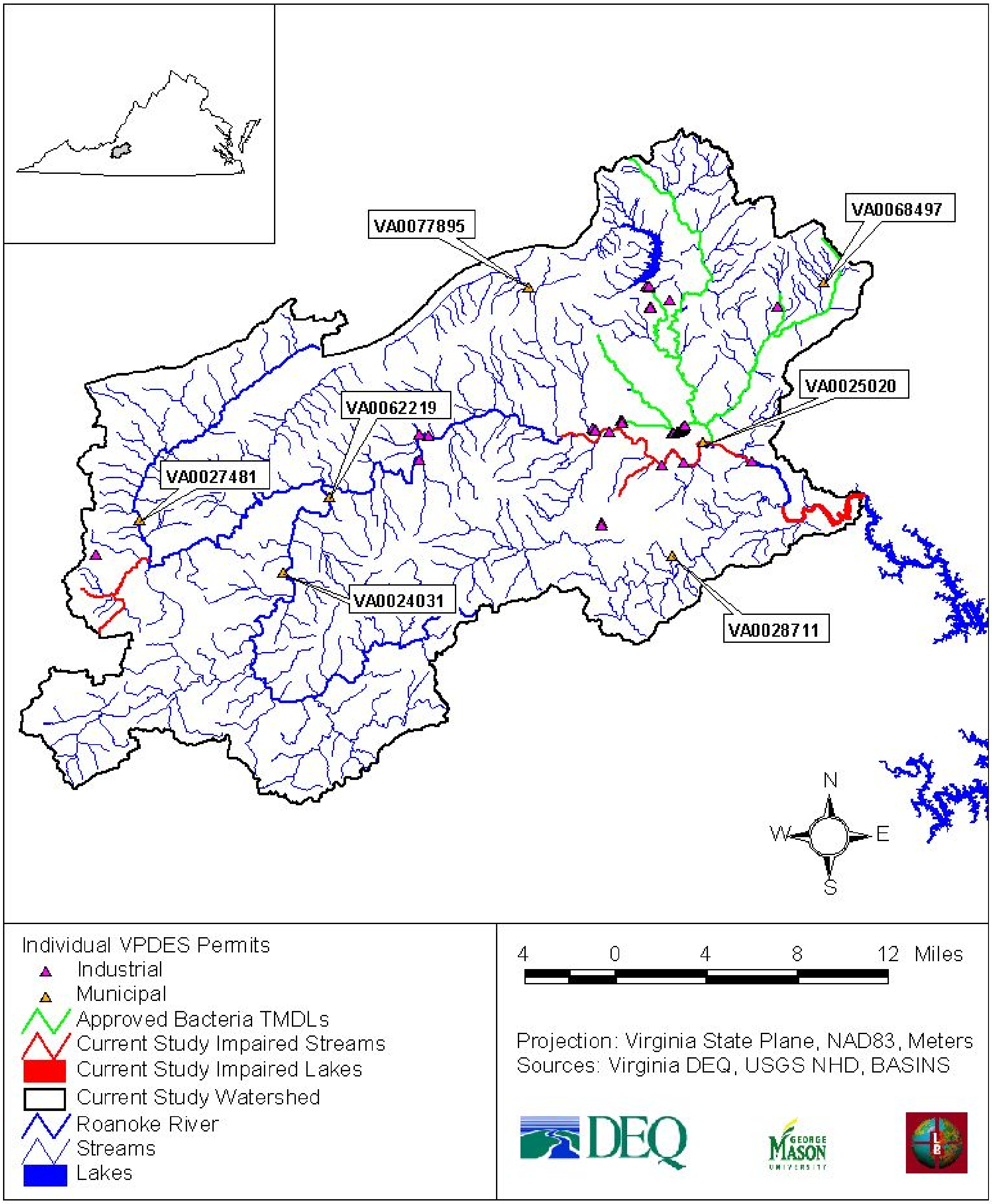
For TMDL development, mean flow values were considered representative of flow conditions at each permitted facility, and were used in the HSPF model hydrology set-up and calibration. However, for TMDL allocation development, only facilities permitted for bacteria are used and represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

Table 4-4: Permitted Dischargers in the Wilson Creek, Ore Branch, and Roanoke River Watersheds

Permit Number	Facility Name	Facility Type	Design Flow (mgd)	Receiving Waterbody	Ave. Bacteria Conc. (cfu/100 mL)	Status
VA0001252	Associated Asphalt Inc	I	0.054	Roanoke River	N/A	Active
VA0001333	Koppers Inc	I	0.6	Roanoke River	N/A	Active
VA0001431	Motiva Enterprises LLC - Roanoke	I	5.32	Back Creek, UT	N/A	Active
VA0001473	Roanoke City - Carvins Cove Water Filtration Plant	I	0.474	Carvin Creek, UT	N/A	Active
VA0001589	Roanoke Electric Steel (RES) Corporation	I	0.039	Peters Creek	N/A	Active
VA0001597	Norfolk Southern Railway Co - Shaffers Crossing	I	0.050	Hortons Branch; Lick Run, UT	N/A	Active
VA0024031	Shawsville Town - Sewage Treatment Plant	M	0.2	South Fork Roanoke River	25.3	Active
VA0025020	Western Virginia Water Authority	M	62	Roanoke River	Below permitted limits	Active
VA0027481	Blacksburg Country Club Sewage Treatment Plant	M	0.035	North Fork Roanoke River	N/A	Active
VA0028711	Suncrest Heights	M	0.020	Back Creek, UT	N/A	History
VA0062219	Montgomery County PSA - Elliston-Lafayette WWTP	M	0.25	South Fork Roanoke River	N/A	Active
VA0077895	Roanoke Moose Lodge	M	0.0047	Mason Creek	N/A	Active
VA0086541	Marathon Ashland - Roanoke Terminal	I	1.47	Back Creek, UT	N/A	Active
VA0087092	American Electric Power - Niagara Hydro Plant	I	0.143	Roanoke River	N/A	Active
VA0088358	Fred Whitaker Co	I	0.151	Roanoke River	N/A	Active
VA0089702	Safety Kleen Systems Inc.	I	NA	NA	N/A	History
VA0089991	Federal Mogul Corp - Blacksburg	I	0.065	Wilson Creek, UT	N/A	Active
VA0091065	Crystal Springs WTP	I	0.092	Roanoke River	N/A	Active

mgd: Million Gallons per Day
N/A: Data not available or not applicable
I: Industrial; M: Municipal

Figure 4-4: Location of Permitted Facilities in the Wilson Creek, Ore Branch and Roanoke River Watersheds



4.7.2 Failed Septic Systems

Failed septic system loading to Wilson Creek, Ore Branch, and the Roanoke River can be direct (point) or land-based (indirect or non-point), depending on the proximity of the septic system to the stream. The failing septic systems located within the 20-foot buffer were represented in the model as a constant source (similar to a permitted facility). For modeling purposes, the failed septic system load was considered as a land-based load in the Wilson Creek, Ore Branch, and Roanoke River watershed.

For TMDL development, it was assumed that a 3% failure rate for septic systems would be representative of conditions in the watershed. This corresponds to a total of 620 failed septic systems in the watershed. To account for uncontrolled dischargers in the watershed and failed septic systems within the stream buffer, a total of 63 straight pipes were included in the model. This estimate was based on digitized USGS Quad maps, discussions with DCR and DEQ, stakeholder comments, evaluation of the BST results, and 1990 Census data which indicated that approximately 0.45% of households in the Wilson Creek, Roanoke River, Ore Branch watershed are on “other” treatment systems.

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The following assumptions were used in the fecal load calculations: the design flow of a septic system is 75 gallons per person per day, the discharge of fecal coliform concentrations is 10,000 cfu/100mL from a failed septic system, and the discharge of fecal coliform from a straight pipe is 1,040,000 cfu/100 mL (Tinker Creek TMDL Report, 2004). Table 4-5 shows the distribution of the septic systems and the straight pipes in the Wilson Creek, Ore Branch, and Roanoke River watersheds.

Table 4-5: Failed Septic Systems and Straight Pipes Assumed in Model Development

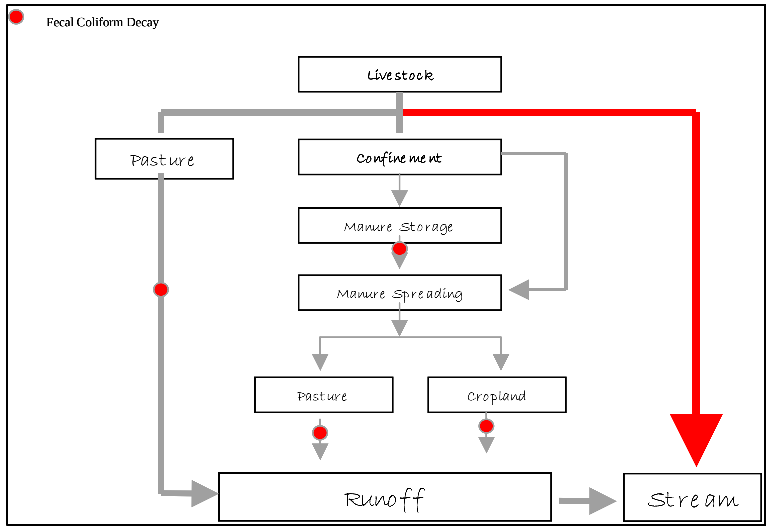
Subwatershed ID	Number of septic systems	Number of Failed Septic Systems	Number of straight pipes
1	169	5	0
2	92	3	0
3	0	0	0
4	158	5	0
5	65	2	0
6	822	25	1
7	69	2	0
8	226	7	1
9	911	27	2
10	294	9	1
11	319	10	1
12	143	4	0
13	56	2	0
14	813	24	2
15	306	9	1
16	524	16	1
17	190	6	0
18	195	6	0
19	69	2	0
20	1,568	47	4
21	1	0	0
22	1,083	32	3
23	737	22	2
24	788	24	2
25	309	9	0
26	68	2	0
27	7	0	0
28	252	8	0
29	154	5	0
30	523	16	0
31	2,708	81	2
32	95	3	0
33	220	7	1
34	158	5	0
35	1	0	0
36	79	2	0
37	51	2	0
38	677	20	1
39	635	19	1
40	58	2	0
41	6	0	0
42	6	0	1
43	20	1	0
44	0	0	0
45	20	1	0
46	1	0	0
47	10	0	0
48	1	0	0
49	102	3	1
50	71	2	0
51	93	3	1

Subwatershed ID	Number of septic systems	Number of Failed Septic Systems	Number of straight pipes
52	26	1	1
53	0	0	0
54	280	8	1
55	8	0	1
56	3	0	0
57	0	0	0
58	476	14	1
59	1	0	0
60	77	2	1
61	51	2	1
62	58	2	1
63	12	0	1
64	316	9	3
65	252	8	2
66	25	1	1
67	50	1	1
68	0	0	1
69	45	1	2
70	22	1	2
71	16	0	3
72	15	0	2
73	0	0	1
74	3	0	0
75	15	0	0
76	688	21	0
77	245	7	0
78	58	2	0
79	70	2	0
80	246	7	1
81	401	12	1
82	712	21	1
83	187	6	1
84	114	3	1
85	270	8	1
Total	**20,669**	**620**	**63**

4.7.3 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in Figure 4-5. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto the crop and pasture lands in the watershed (land application of manure), and finally, land-based fecal coliform deposited by livestock while grazing.

Figure 4-5: Livestock Contribution to Wilson Creek, Ore Branch. and Roanoke River Watersheds



Based on the inventory of livestock in the Wilson Creek, Ore Branch, and Roanoke River watersheds, it was determined that beef cattle are the predominant type of livestock. In addition, three dairy operations are present in the watershed. The inventory also indicated that there are horses, pigs, and sheep in the watershed. However, there was no record of any feedlots, poultry operations, or swine operations within the watershed. The survey also indicated that alternative water has been implemented in the Wilson Creek, Ore Branch, and Roanoke River watersheds to minimize livestock activity in the stream.

The distribution of the daily fecal coliform load between direct in-stream and indirect (land-based) loading was based on livestock daily schedules. The direct deposition load from livestock was estimated from the number of livestock in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spent in the stream, which is presented in Chapter 3.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends in pasture. The monthly loading rates are presented in Appendix C.

4.7.4 Land Application of Manure

Beef cattle, as well as several dairy operations, are present in the Wilson Creek, Ore Branch, and Roanoke River watersheds. Because there are no feedlots or large manure storage facilities present in the watershed, the manure produced daily is applied to pastureland in the watershed, and was treated as an indirect source in the development of the Wilson Creek, Roanoke River and Ore Branch TMDLs. Beef cattle spend the majority of their time on pastureland and are not confined. Thus, fecal coliform loading from beef cattle was accounted for via the methods described above. Dairy cattle do spend time in confinement, and their fecal coliform load was included in the calculation of land application of manure. Fecal coliform loading from land application of manure was estimated based on the total number of dairy cows in the watershed, the fecal coliform production per animal per day, and the percent of time dairy cows were in confinement.

4.7.5 Land Application of Biosolids

Because biosolids are spread on land areas within the Wilson Creek, Ore Branch, and Roanoke River watershed, this source was considered in thr TMDLs development. However, since biosolids have a fecal content less than that of average soil, it is expected that biosolids application will have a negligible impact on the total fecal coliform load. Land application of biosolids has occurred in Bedford and Franklin Counties; no spreading of biosolids occurred in the areas of Floyd, Montgomery, and Roanoke Counties that are within the TMDL study area according the VADOH records. The biosolids application by county is presented in chapter 3.

4.7.6 Wildlife

Fecal loading from wildlife was estimated in the same way as loading from livestock. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. The distribution between direct and indirect loading was based on estimates of the amount of time each type of wildlife spends on the surrounding land versus in the stream.

Daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented previously in the wildlife inventory (Chapter 3). The direct fecal coliform load from wildlife was calculated by multiplying the number of each type of wildlife in the watershed by the fecal coliform production per animal per day, and by the percentage of time each animal spends in the stream. Indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the number of each type of wildlife in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on land within the Wilson Creek, Ore Branch, and Roanoke River watersheds. The resulting fecal coliform load was then distributed to the forest and pasture land use categories, which represent the most likely areas in the watershed where wildlife would be present. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre), then multiplying the unit loading by the total area of forest and pasture in each subwatershed. Fecal coliform loading from wildlife is presented in Appendix C.

4.7.7 Pets

For the Wilson Creek, Ore Branch, and Roanoke River TMDLs, pet fecal coliform loading was considered a land-based load that was primarily deposited in residential areas of the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production for cats and dogs described in Chapter 3. The fecal coliform loading from pets is presented in Appendix C.

4.8 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the Wilson Creek, Ore Branch, and Roanoke River watersheds. Three fecal coliform die-off rates required by the model to accurately represent watershed conditions included:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure is in storage facilities.

2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.

3. **In-stream fecal coliform die-off**. Fecal coliform directly deposited into the stream, as well as fecal coliform entering the stream from indirect sources, will also undergo decay.

In the Wilson Creek, Ore Branch, and Roanoke River TMDLs, in-storage die-off was not included in the model because there is no manure storage facility located in the watershed. Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for on-surface and in-stream fecal coliform, respectively (EPA, 1985).

4.9 Model Set-up, Calibration, and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) and to make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process compares the model results with observed data to ensure the model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process compares the model output to the observed data set, which is different from the one used in the calibration process, and estimates the model's prediction accuracy. Water quality processes were calibrated following calibration of the hydrologic processes of the model.

4.9.1 Model Set-Up

The HSPF model was set up and calibrated based on Roanoke River flow data taken at USGS station #02056000, where daily flow data is available.

4.9.1.1 Stream Flow Data

Stream flow data for Upper Roanoke River watershed was available from the USGS stations presented in Chapter 3. The data from 7 of those stations, which have the most recent daily stream flow data were used in the TMDL development. Average flow data for the period of 1990 to 2005 were retrieved, and are plotted in Figures 4-6 through Figure 4-12. All of these stations reported a similar flow trend. Therefore, stream flow data the most downstream on the Roanoke River, USGS station #02056000, was used to set-up and calibrate the hydrological processes of the HSPF model. A 4-year period (1996-2000) was selected as the calibration period for the Wilson Creek, Ore Branch, and Roanoke River model.

Figure 4-6: Daily Mean Flow (cfs) at USGS Gauging Station #02053800

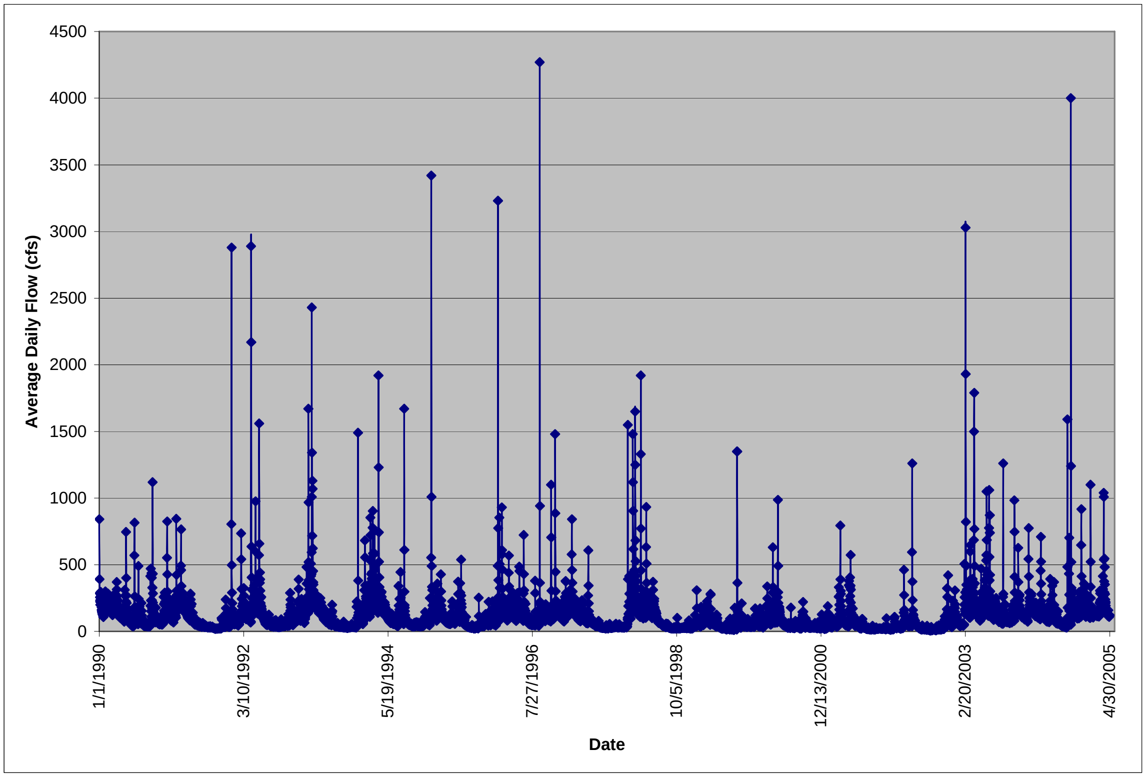


Figure 4-7: Daily Mean Flow (cfs) at USGS Gauging Station #02054500

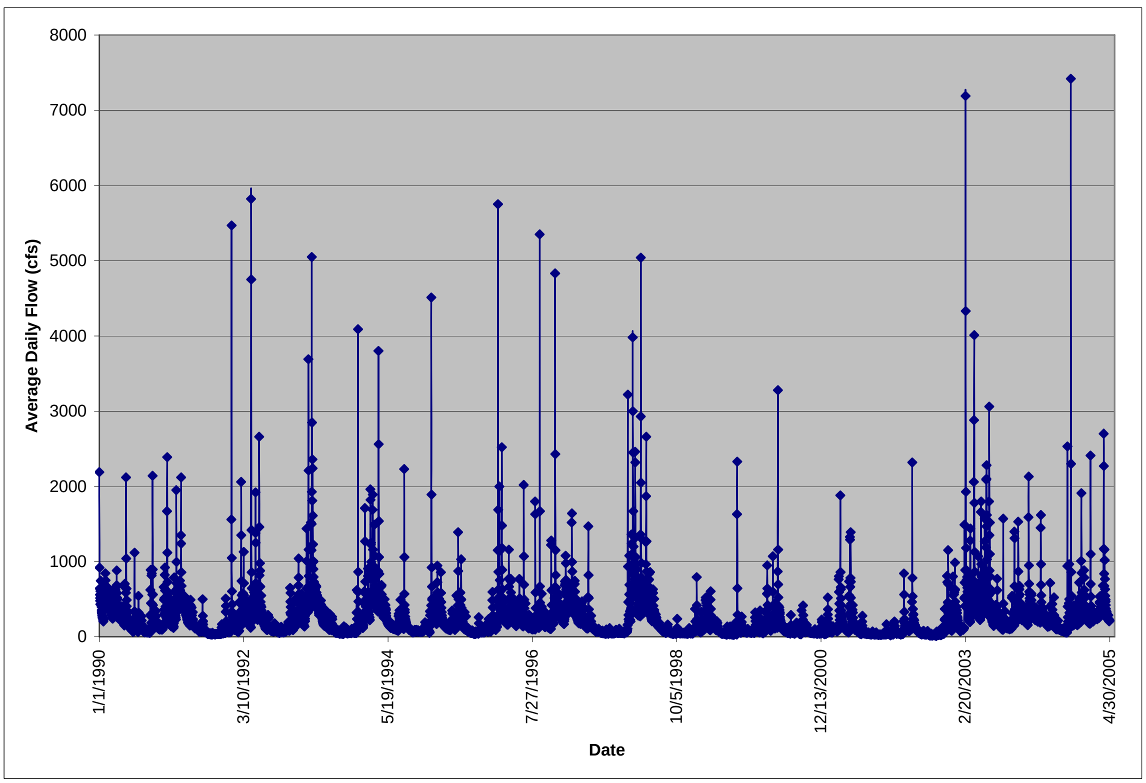


Figure 4-8: Daily Mean Flow (cfs) at USGS Gauging Station #02054530

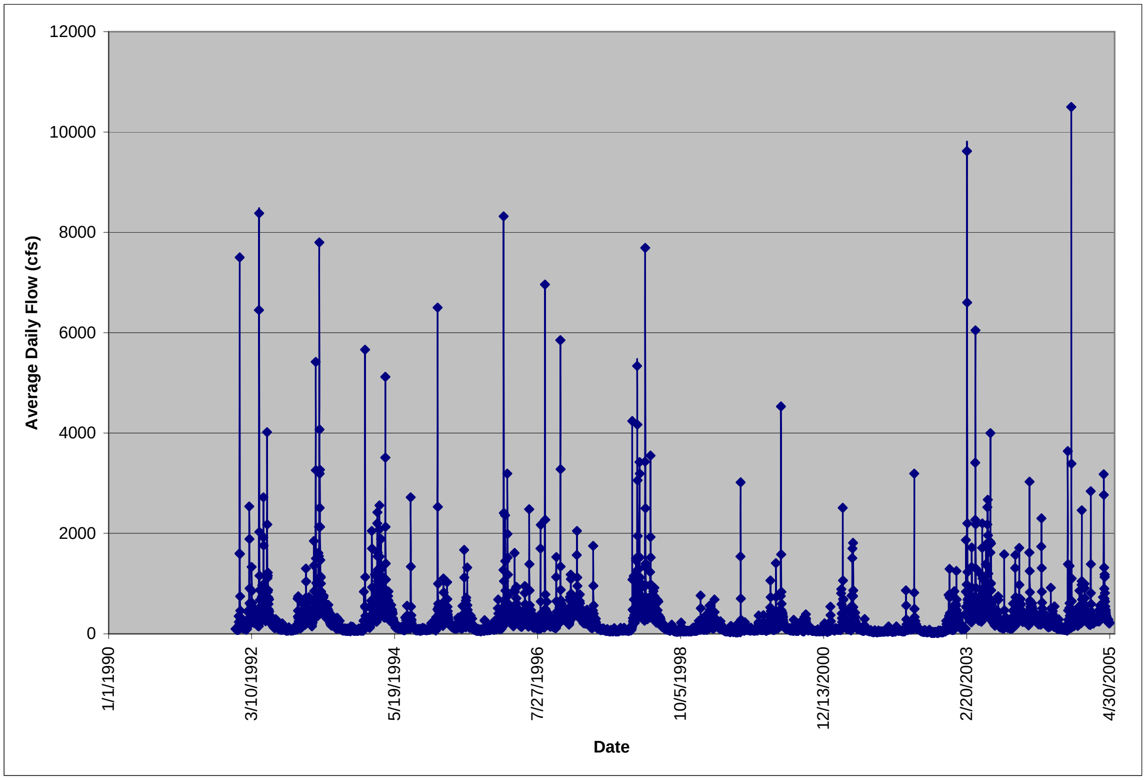


Figure 4-9: Daily Mean Flow (cfs) at USGS Gauging Station #02055000

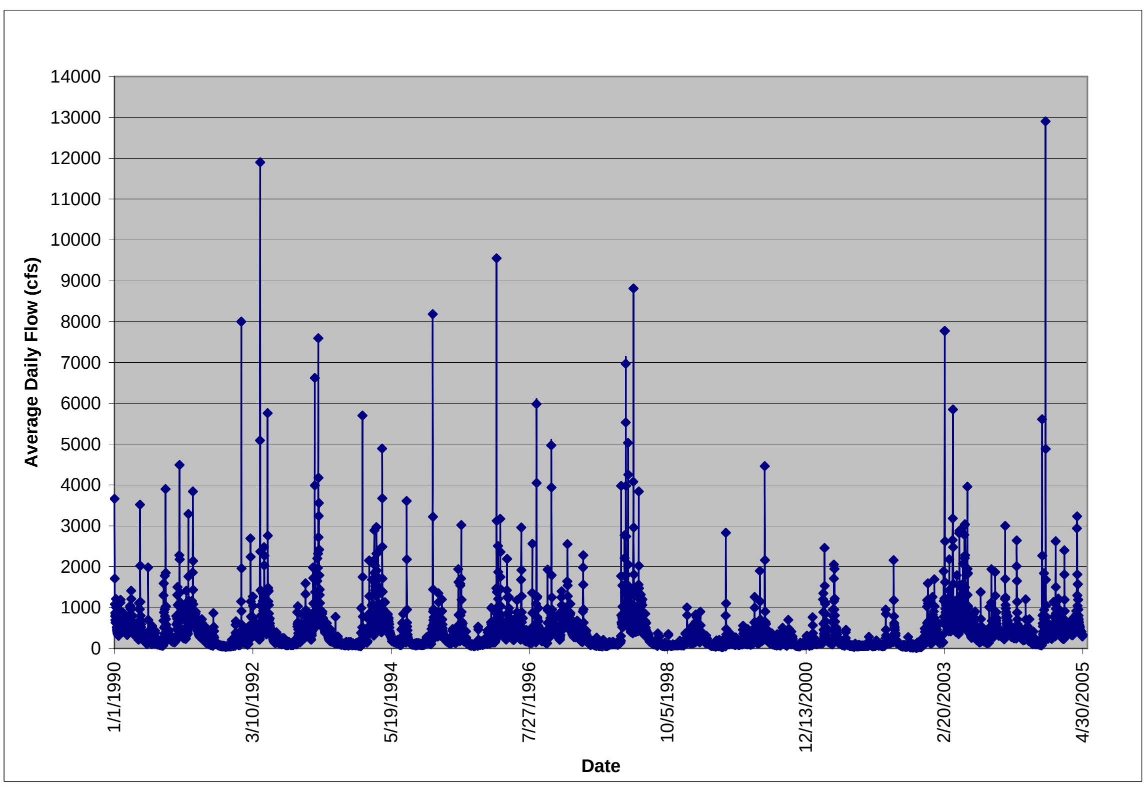


Figure 4-10: Daily Mean Flow (cfs) at USGS Gauging Station #02055100

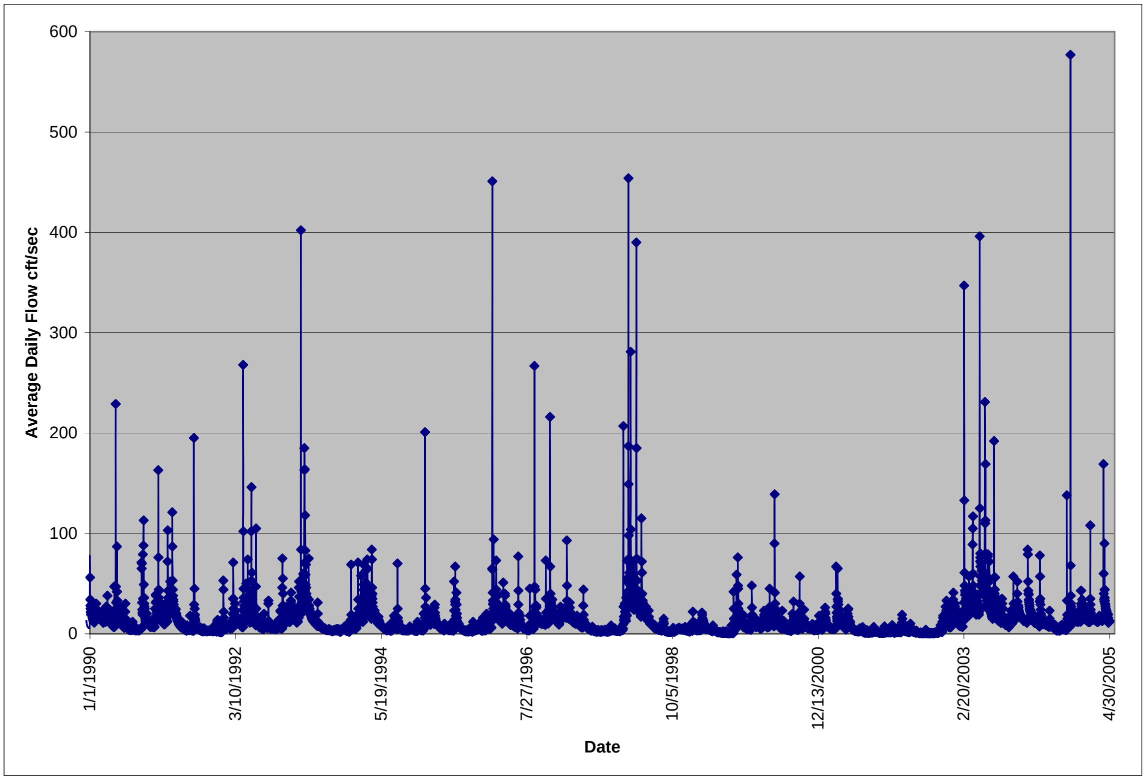


Figure 4-11: Daily Mean Flow (cfs) at USGS Gauging Station #02056000

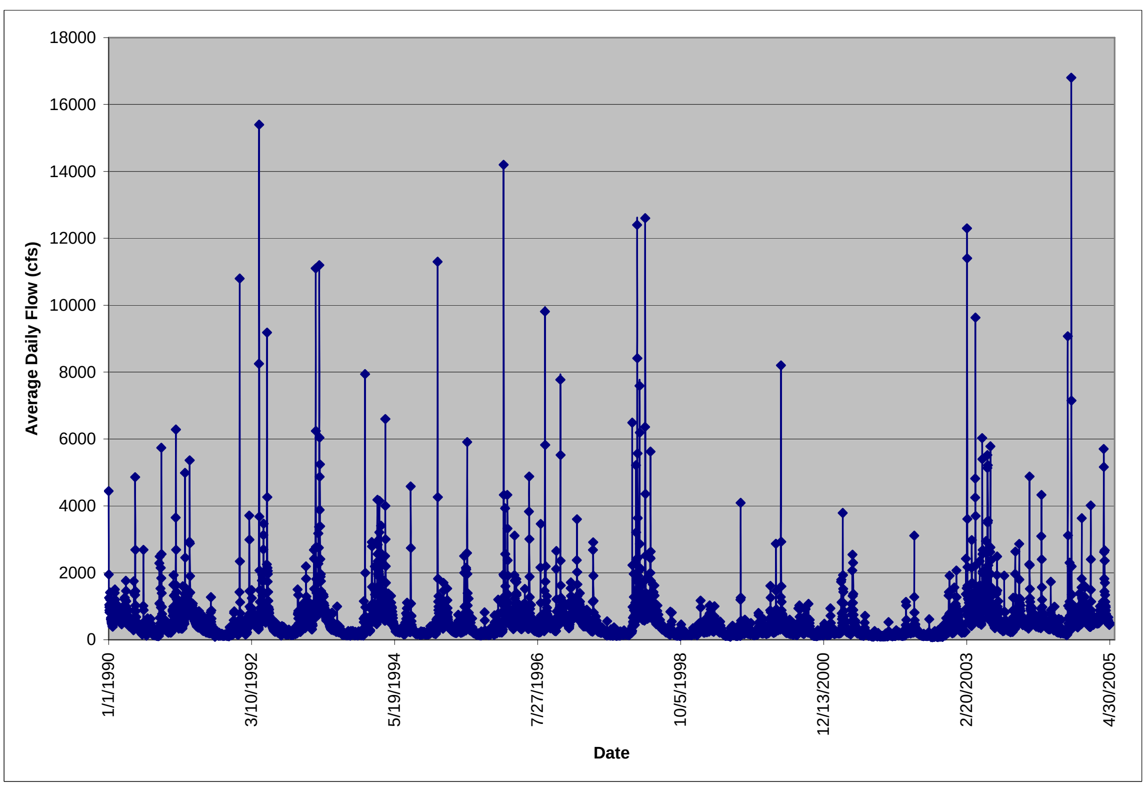
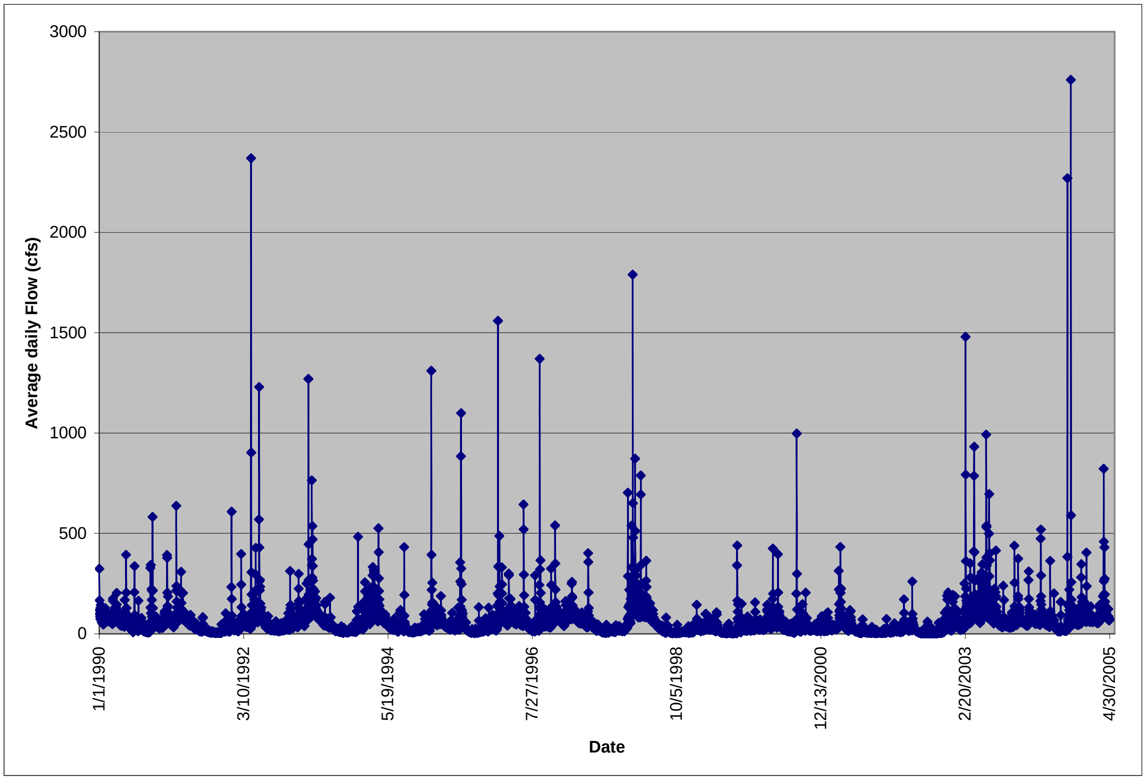


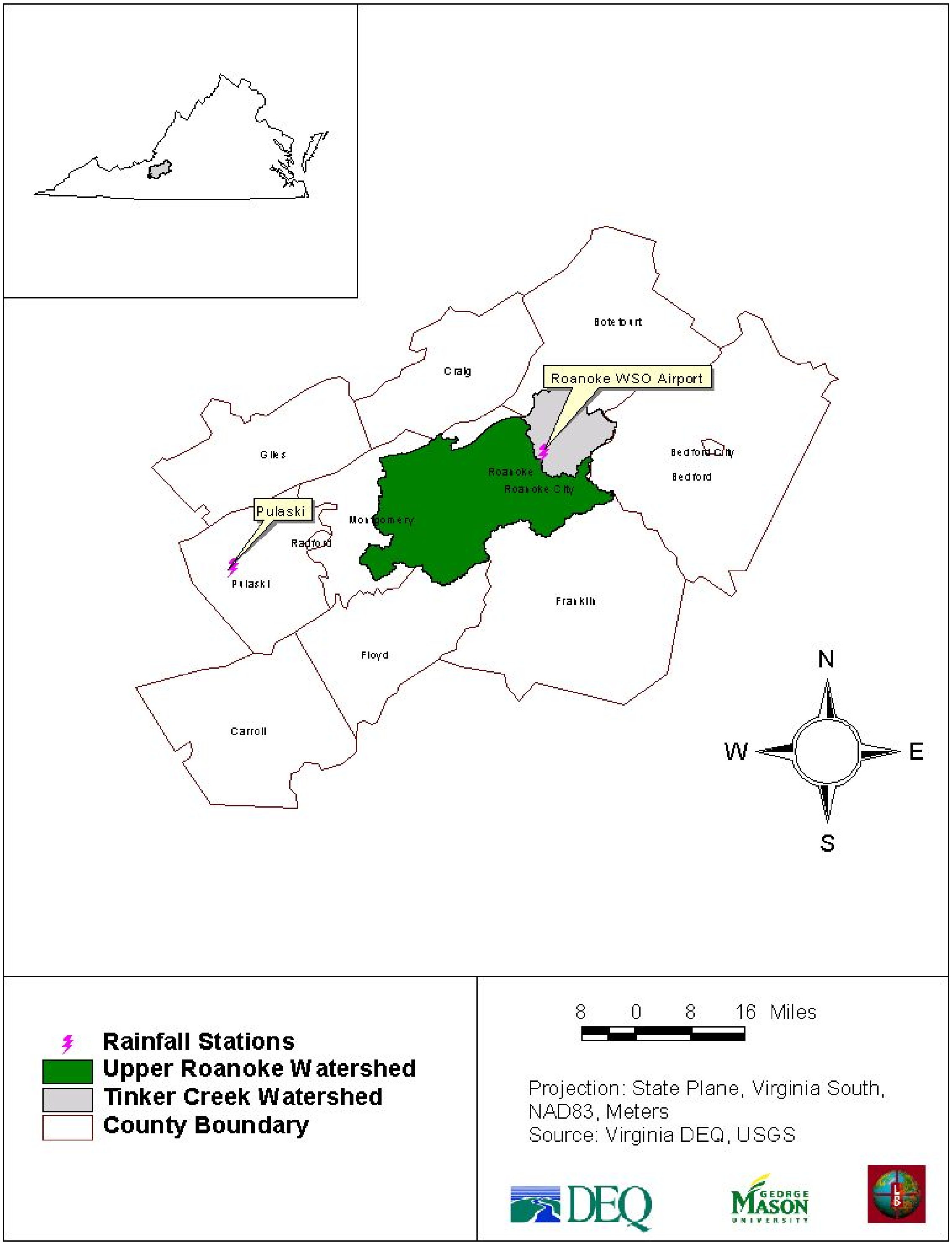
Figure 4-12: Daily Mean Flow (cfs) at USGS Gauging Station #02056650



4.9.1.2 Rainfall and Climate Data

Weather data for the Roanoke, VA WSO Airport and the Pulaski precipitation gages were obtained from NCDC. The data collected include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). The Roanoke Airport gage recorded data from 1952 to the present and the Pulaski gage recorded data from 1987 to the present. For this TMDL, the recorded data at the Roanoke Airport gage and Pulaski gage were combined based on their proximity to the Wilson Creek, Ore Branch, and Roanoke River watershed. The combined record consisted of 75 percent of the weather data from the Roanoke Airport gage and 25 percent of the weather data from the Pulaski gage. Figure 4-13 depicts the location of the weather stations.

Figure 4-13: Location of Rainfall Stations in the Wilson Creek, Ore Branch and Roanoke River Watershed



4.9.2 Model Hydrologic Calibration Results

HSPEXP software was used to calibrate the Wilson Creek, Ore Branch, and Roanoke River watersheds. After each iteration of the model, summary statistics were calculated to compare model results with observed values, in order to provide guidance on parameter adjustment according to built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb et. al, 1994).

Using the recommended default criteria as target values for an acceptable hydrologic calibration, the Wilson Creek, Ore Branch, and Roanoke River watershed model was calibrated for January 1996 to December 1999. Calibration results are presented in Table 4-6, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is presented in Table 4-7. The breakdown of the overall percent base, storm and interflow contribution is presented in Table 4-8. The model results and the observed daily average flow at USGS station #02056000 are plotted in Figure 4-14.

Table 4-6: Wilson, Roanoke, and Ore Model Calibration Results

Category	Simulated	Observed
Total simulated in-stream flow (cfs)	63.36	61.02
Total of highest 10% flows, in inches	29.09	26.16
Total of lowest 50% flows, in inches	10.74	10.53
Total storm volume, in inches	38.46	40.04
Average of storm peaks, in cfs	5047.65	5134.29
Baseflow recession rate	0.97	0.97
Summer flow volume, in inches	10.85	9.57
Winter flow volume, in inches	25.75	22.71
Summer storm volume, in inches	3.79	4.58

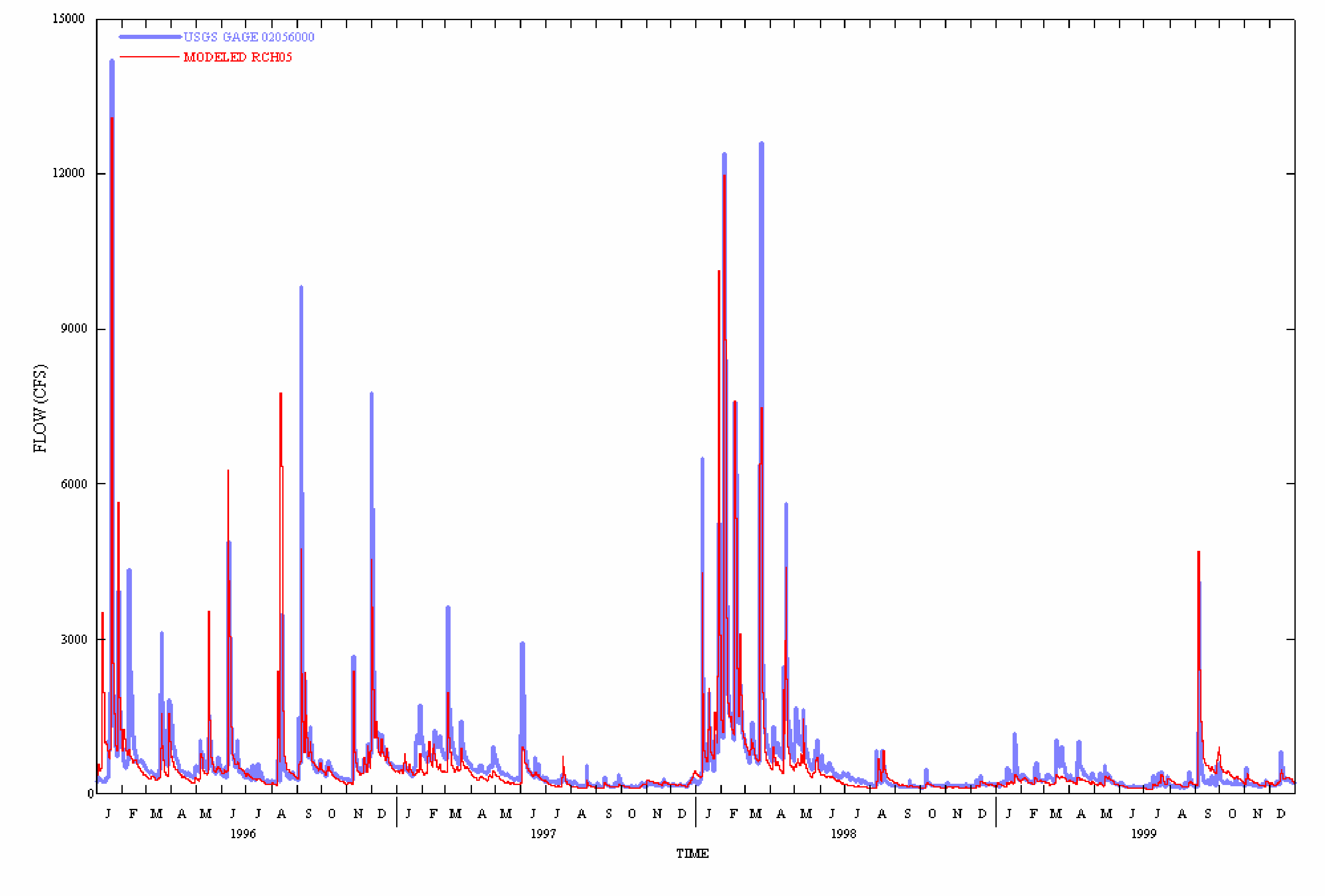
Table 4-7: Wilson, Ore, and Roanoke Model Calibration Error Statistics

Category	Current	Criterion
Error in total volume	3.8	10
Error in low flow recession	0	0.01
Error in 50% lowest flows	2	10
Error in 10% highest flows	11.2	15
Error in storm volumes	-1.7	15
Seasonal volume error	0.1	10
Summer storm volume error	-13.4	15

Table 4-8: Wilson, Ore, and Roanoke Simulation Water Budget

Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
1996	2.51	6.12	10.3	13.3%	32.3%	54.4%
1997	0.329	0.765	5.4	5.1%	11.8%	83.2%
1998	2.02	6.23	8.7	11.9%	36.8%	51.3%
1999	0.418	0.836	4.5	7.3%	14.5%	78.2%
Average	**1.32**	**3.49**	**7.23**	**9.4%**	**23.8%**	**66.8%**

Figure 4-14: Wilson, Ore, and Roanoke HSPF Model Hydrologic Calibration Results



4.9.3 Model Hydrologic Validation Results

The period of January 2003 to December 2004 was used to validate the HSPF model. The validation results are presented in Figure 4-15 and the summary statistics from HSPF are presented in Table 4-9 and Table 4-10. The error statistics indicate that the validation results were within the recommended ranges in HSPF. The breakdown of the overall percent base, storm and interflow contribution is presented in Table 4-11.

Table 4-9: Wilson, Ore , and Roanoke Model Validation Results

Category	Simulated	Observed
Total simulated in-stream flow, in (cfs)	43.61	45.04
Total of lowest 50% flows, in inches	19.46	17.94
Total of highest 10% flows, in inches	8.86	9.49
Total storm volume, in inches	11.46	10.89
Average of storm peaks, in cfs	7230.41	6296.25
Base flow recession rate	0.96	0.96
Summer flow volume, in inches	10.23	10.65
Winter flow volume, in inches	9.72	11.22
Summer storm volume, in inches	2.89	2.61

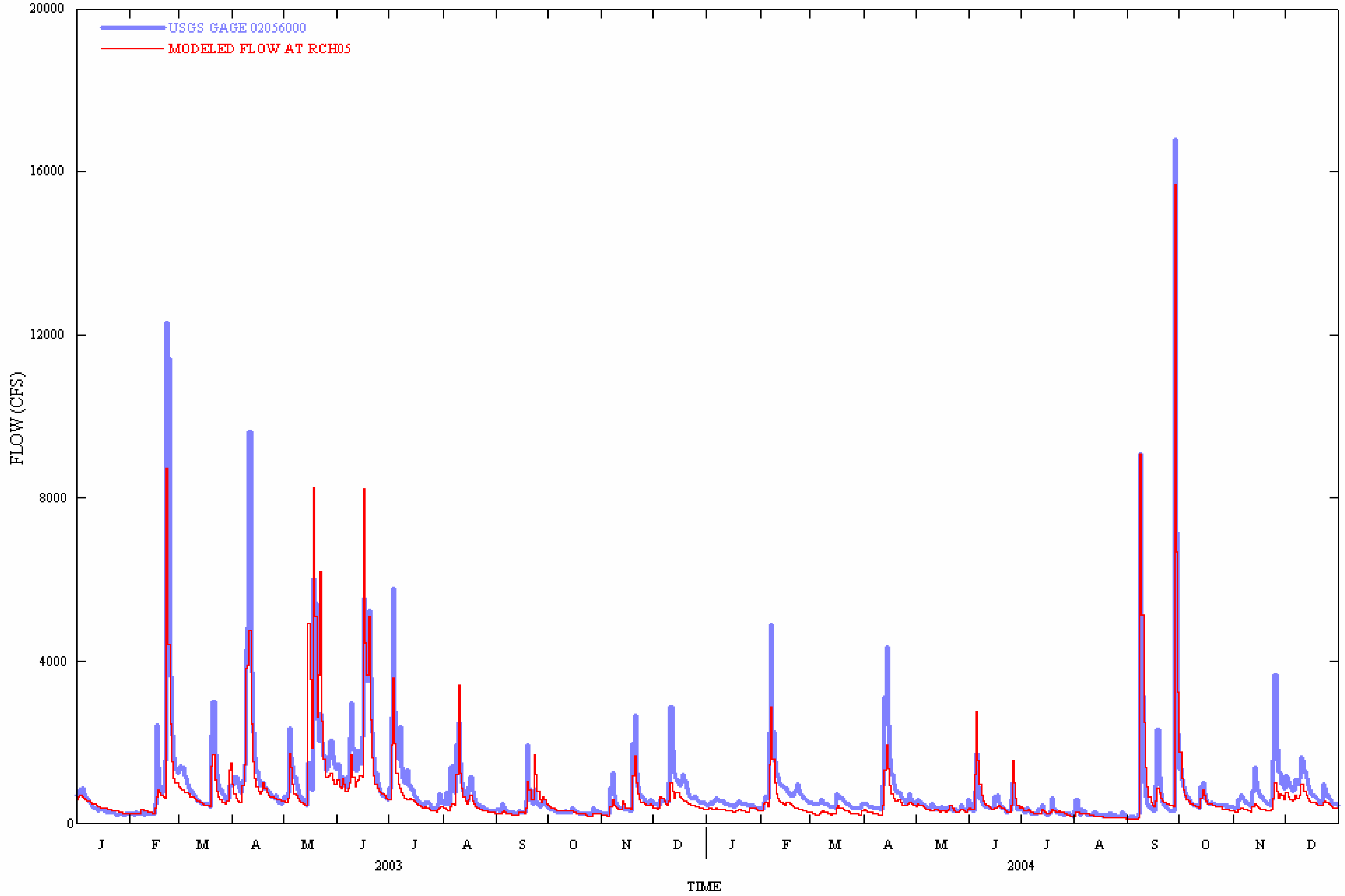
Table 4-10: Wilson, Ore, and Roanoke Model Validation Error Statistics

Category	Current (%)	Criteria (%)
Error in total volume	-3.2	10
Error in low flow recession	0	0.01
Error in 50% lowest flows	-6.7	10
Error in 10% highest flows	8.5	15
Error in storm volumes	14.8	15
Seasonal volume error	9.4	10
Summer storm volume error	5.3	15

Table 4-11: Wilson, Ore, and Roanoke Watershed Validation Water Budget

Water Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
2003	2.94	6.02	11.3	14.5%	29.7%	55.8%
2004	1.64	3.34	7.8	12.8%	26.1%	61.0%
Average	**2.29**	**4.68**	**9.55**	**13.7%**	**27.9%**	**58.4%**

Figure 4-15: Wilson and Ore and Roanoke - HSPF Model Hydrologic Validation Results



There is good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. Model results closely match the observed flows during low flow conditions, base flow recession, and storm peaks. The final parameter values of the calibrated model are listed in Table 4-12.

Table 4-12: Wilson, Ore, and Roanoke Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Wilson, Ore, and Roanoke
			Min	Max	Min	Max	
FOREST	Fraction forest cover	None	0	0.5	0	1.0	0.0-1
LZSN	Lower zone nominal soils moisture	Inch	3	8	2	15	4.0
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.001	0.5	0.06-0.07
LSUR	Length of overland flow	Ft	200	500	100	700	200
SLSUR	Slope of overland flowplane	None	0.01	0.15	0.001	0.3	0.0949
KVARY	Groundwater recession variable	1/inch	0	3	0	5	0
AGWRC	Basic groundwater recession	None	0.92	0.99	0.85	0.999	0.95
PETMAX	Air temp below which ET is reduced	Deg F	35	45	32	48	40
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	30	40	35
INFEXP	Exponent in infiltration equation	None	2	2	1	3	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	3	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	0.5	0.1
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	0.2	0.02

Parameter	Definition	Units	Typical		Possible		Wilson, Ore, and Roanoke
			Min	Max	Min	Max	
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	0.2	0
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.01	0.4	0.03-0.11, Monthly
UZSN	Upper zone nominal soils moisture	Inch	0.1	1	0.05	2	0.5
NSUR	Manning's n	None	0.15	0.35	0.1	0.5	0.25
INTFW	Interflow/surface runoff partition parameter	None	1	3	1	10	2.2
IRC	Interflow recession parameter	None	0.5	0.7	0.3	0.85	0.4
LZETP	Lower zone ET parameter	None	0.2	0.7	0.1	0.9	0.2
RETSC	Retention storage capacity of the surface	Inch					
ACQOP	Rate of accumulation of constituent	#/ac-day					5.8E5-2.47E10
SQOLIM	Maximum accumulation of constituent	#					1.04E6 – 4.45E10
WSQOP	Wash-off rate	Inch/hour					0.8-1.2
IOQC	Constituent concentration in interflow	#/CF					1416
AOQC	Constituent concentration in active groundwater	#/CF					283
KS	Weighing factor for hydraulic routing						0.5
FSTDEC	First order decay rate of the constituent	1/day					1.152
THFST	Temperature correction coefficient for FSTDEC	none					1.07

4.9.4 Water Quality Calibration

The calibration of the water quality component of the HSPF model involves setting up the build-up, wash-off, and kinetic rates for fecal coliform that best describe fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available in-stream fecal coliform data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated in-stream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The availability of water quality data is a major factor in determining calibration and validation periods for the model. In Chapter 3, in-stream monitoring stations were listed and sampling events conducted within the Wilson Creek, Roanoke River, and Ore branch watershed were summarized and presented. Of all the monitoring stations within the watershed, the stations located closest to the endpoint were used to calibrate the three models.

Station 4WLN000.40 was used to calibrate the model for Wilson Creek, station, station 4AORE000.19 was used to calibrate the model for Ore Branch, and 4AROA202.20 was used to calibrate the model for the Roanoke River Station 4AWLN000.40, 4AORE000.19 and 4AROA202.20 were sampled 44, 20 and 113 times respectively from January 1995 through December 2004. Water quality data for these stations were retrieved from STORET and DEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. The time period from January 1997 to December 1998 was used for water quality calibration of the model, and the time period from January 2002 to December 2003 was used for model validation.

It important to keep in mind that the observed fecal coliform concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. The model-simulated fecal coliform concentrations represent the average daily values. Model-simulated results and observed fecal coliform values are plotted and presented in Figure 4-16 and Figure 4-17. The goodness of fit for the water quality calibration was evaluated visually. Analysis of the model results indicated that the model was capable of predicting the range of fecal coliform concentrations under both wet and dry weather conditions, and therefore was well calibrated. Table 4-13 shows the observed and simulated geometric mean fecal coliform concentration over the simulation period. Table 4-14 shows the observed and simulated exceedance rates of the 400 cfu/100 ml instantaneous fecal coliform standard.

Table 4-13: Wilson, Ore, and Roanoke Observed and Simulated Geometric Mean Fecal Coliform Concentration over the Simulation Period (1995-2004).

Impaired Segment (s)	Watershed	Geometric Mean (cfu/100ml)	
		Observed	Simulated
VAW-L02R-02	Wilson Creek	417	346
VAW-L04R-04	Ore Branch	562	577
VAW-L04R-01, VAW-L04R-02, VAW-L12L-04	Roanoke River	239	242

Table 4-14: Wilson, Ore, and Roanoke Observed and Simulated Exceedance Rates of the 400 cfu/100ml Instantaneous Fecal Coliform Standard (1995-2004)

Impaired Segment (s)	Watershed	Rate of Exceedance	
		Observed	Simulated
VAW-L02R-02	Wilson Creek	45.5%	53.1%
VAW-L04R-04	Ore Branch	60%	73%
VAW-L04R-01, VAW-L04R-02, VAW-L12L-04	Roanoke River	24.8%	31.2%

Figure 4-16: Wilson, Ore, and Roanoke Water Quality Calibration at Reach 25 (VADEQ Station 4ARA202.20)

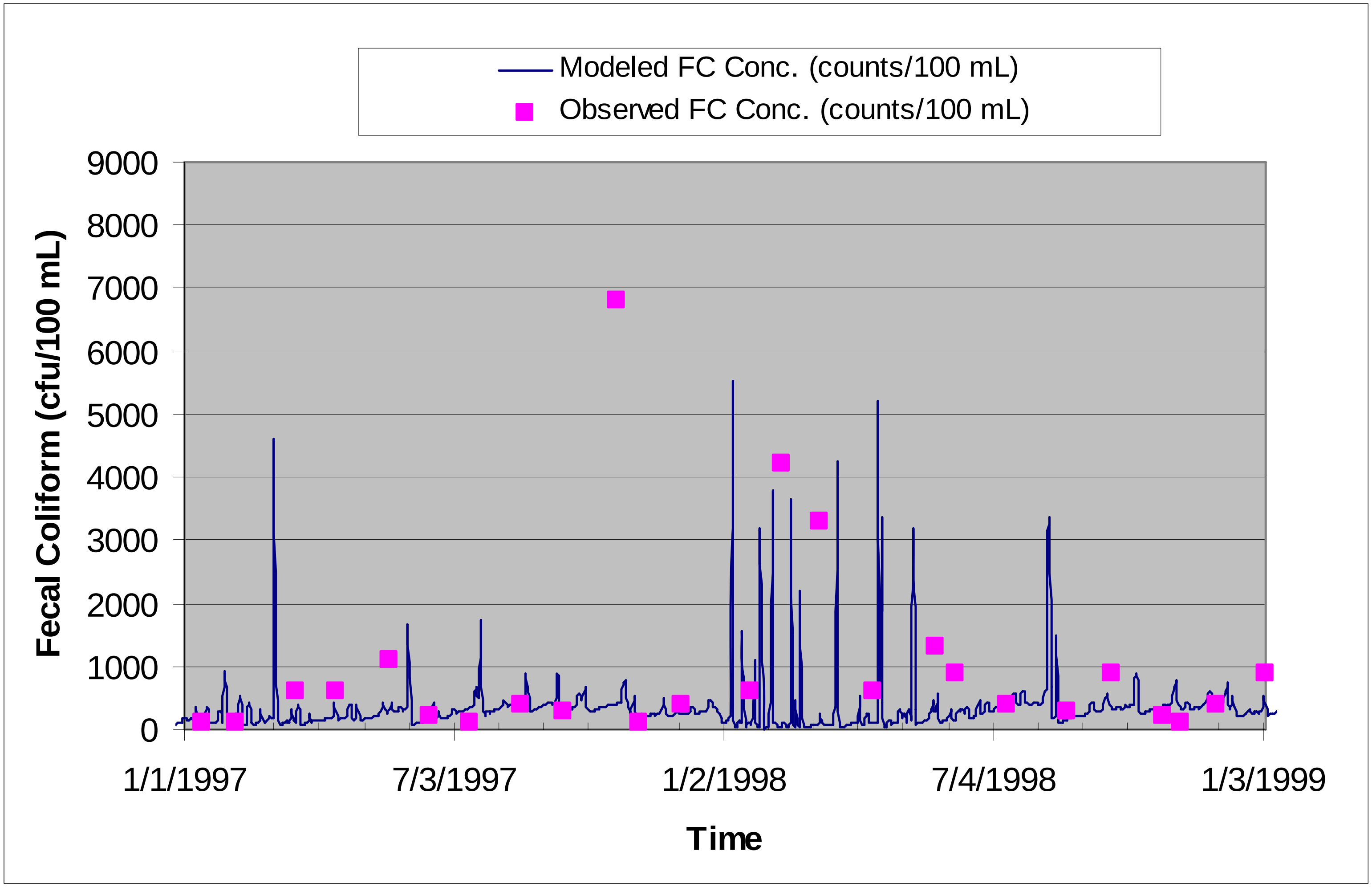
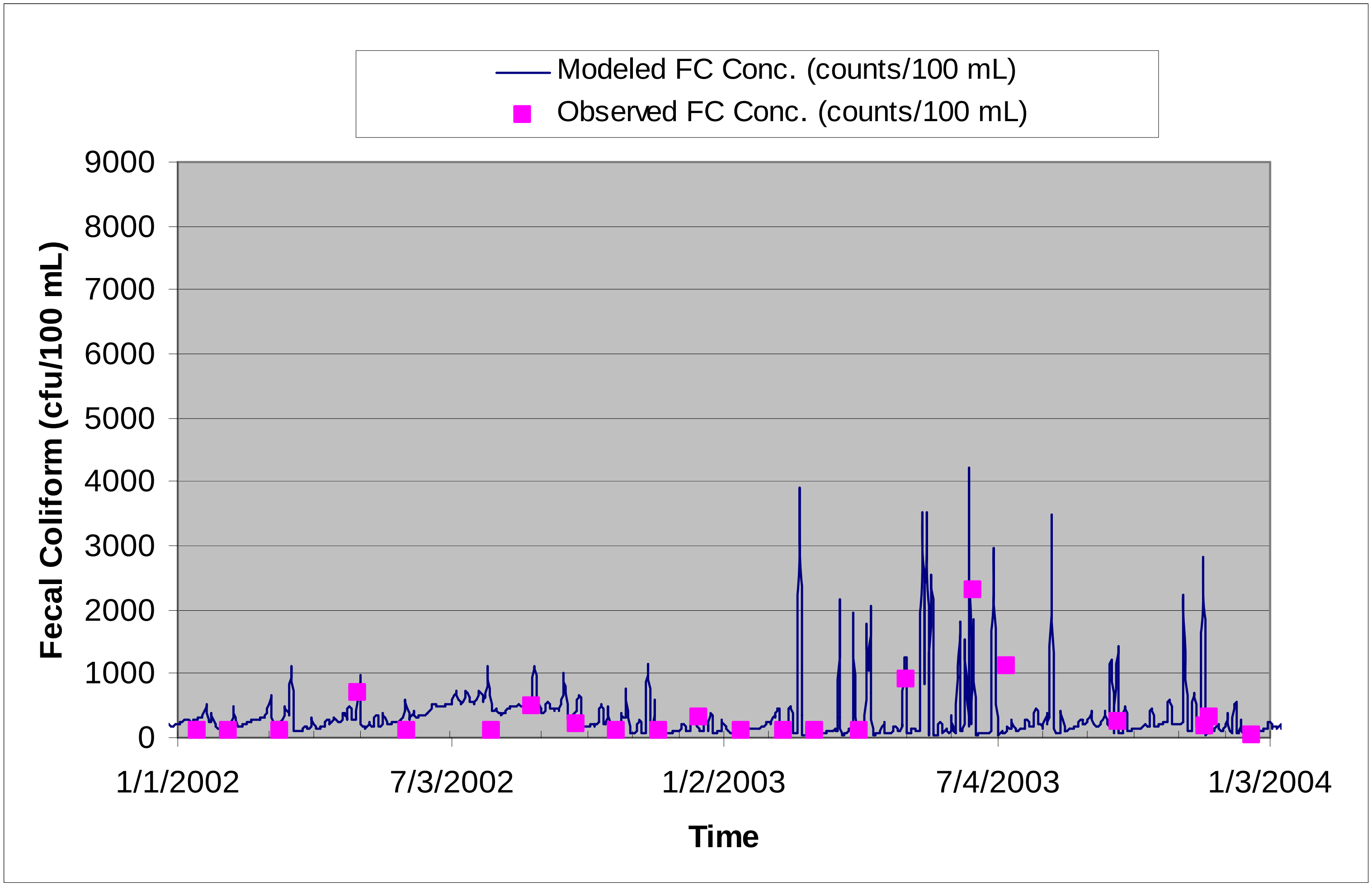


Figure 4-17: Wilson, Ore, and Roanoke Water Quality Validation at Reach 25 (VADEQ Station 4ARA202.20)



4.10 Existing Bacteria Loading

The existing fecal coliform loading for each watershed was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of 1995 to 2004. The standards used for fecal coliform concentrations were a geometric mean standard of 200 cfu/100 ml and an instantaneous standard of 400 cfu/100 ml. For E. coli concentrations, the standards used were a geometric mean of 126 cfu/100ml and an instantaneous standard of 235 cfu/100ml. E. coli concentrations in the impaired Wilson Creek (Reach 57), Ore Branch (Reach 77). Roanoke River (Reach 1) segments were calculated from fecal coliform concentrations using a regression based instream translator, which is presented below:

E. coli concentration (cfu/100 ml) $= 2^{-0.0172} \times$ *(FC concentration (cfu/100ml))* $^{0.91905}$

4.10.1 Wilson Creek

The instream concentration of bacteria under existing conditions in Wilson Creek is above both the fecal coliform and E. coli geometric mean and instantaneous standards for the majority of the time period. Figure 4-18 shows the fecal coliform geometric mean existing conditions and Figure 4-19 shows the E. coli geometric mean concentrations under existing conditions. Figure 4-20 shows the fecal coliform instantaneous concentrations under existing conditions and Figure 4-21 shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing fecal coliform load by source in Wilson Creek is presented in Table 4-15. The corresponding E. coli loading is presented in Table 4-16. E. coli concentrations in the impaired Wilson Creek (Reach 57) segment were calculated from fecal coliform concentrations using the instream translator. Table 4-15 and Table 4-16 show that loading from the failed septic systems and straight pipes, pasture, wildlife, and low density residential areas are the predominant sources of bacteria in the Wilson Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from wildlife, failed septic systems, and straight pipes will dominate. Under wet weather conditions, the non-point source loads from low-density residential and pasture areas will dominate.

Figure 4-18: Wilson Creek Fecal Coliform Geometric Mean Existing Conditions

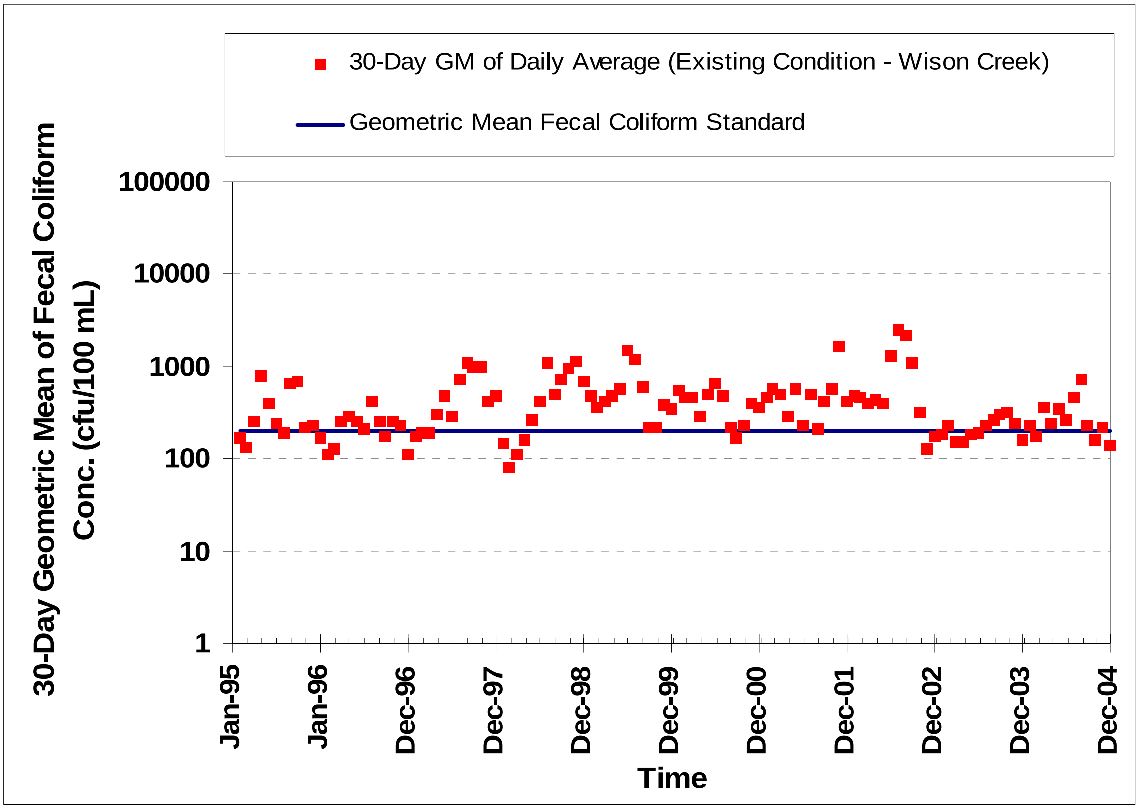


Figure 4-19: Wilson Creek E. Coli Geometric Mean Existing Conditions

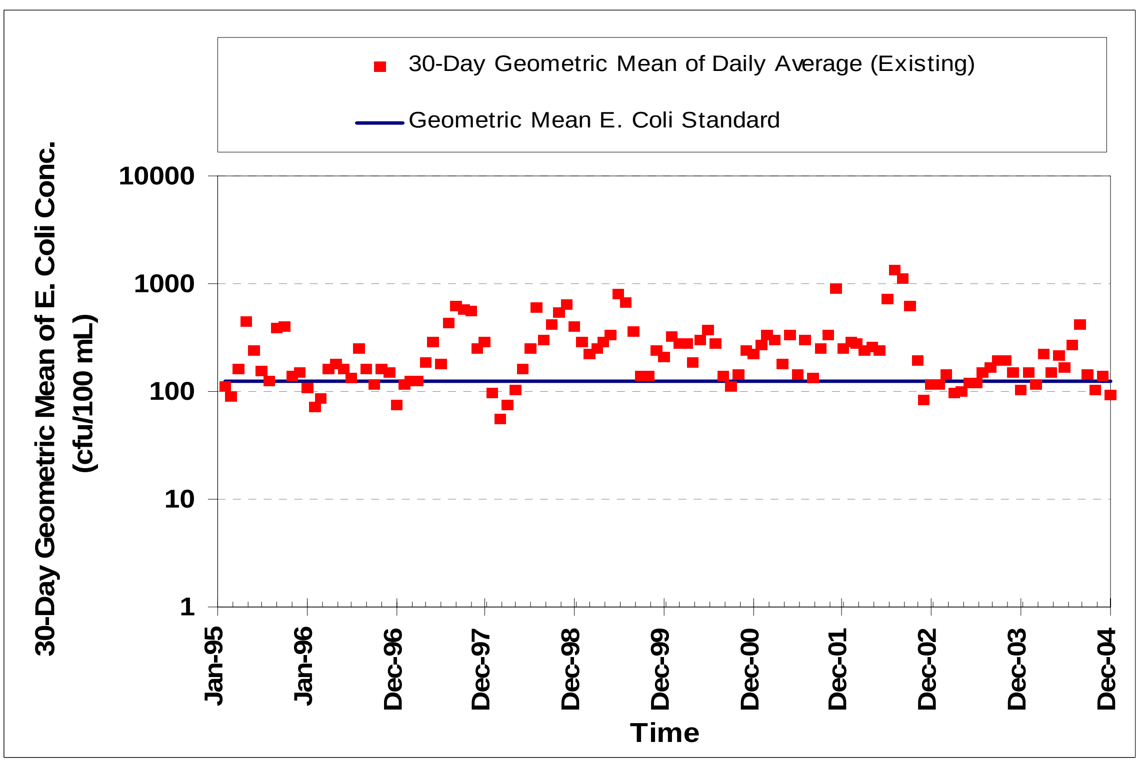


Figure 4-20: Wilson Creek Fecal Coliform Instantaneous Existing Conditions

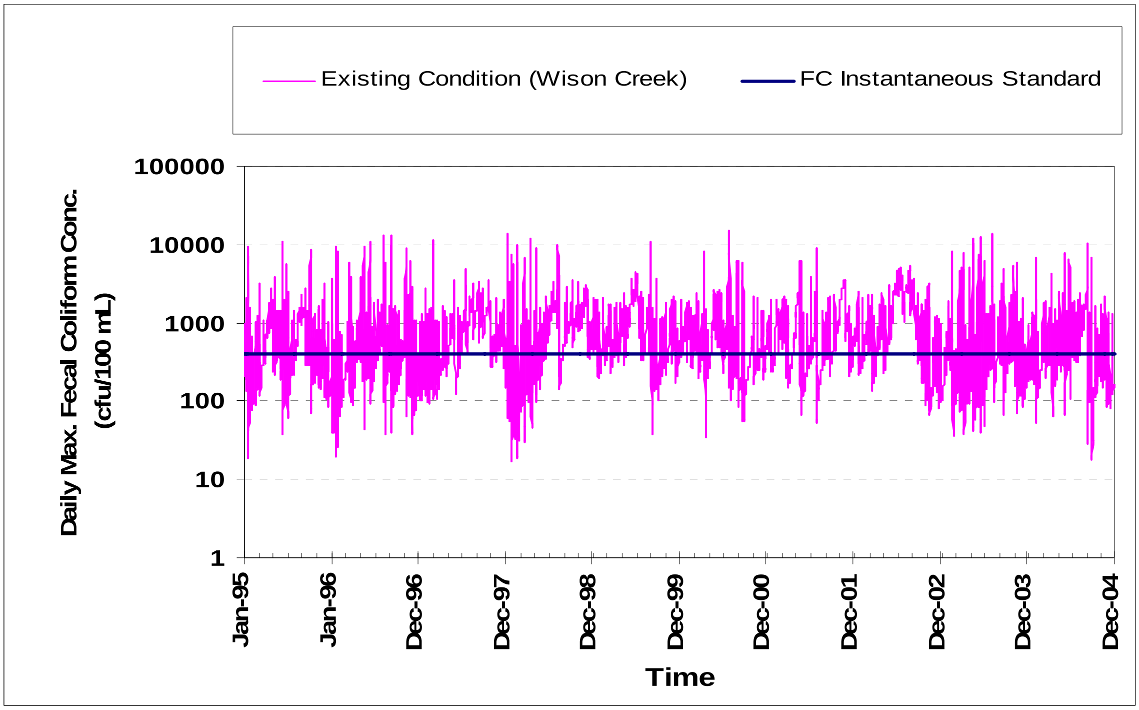


Figure 4-21: Wilson Creek E. coli Instantaneous Existing Conditions

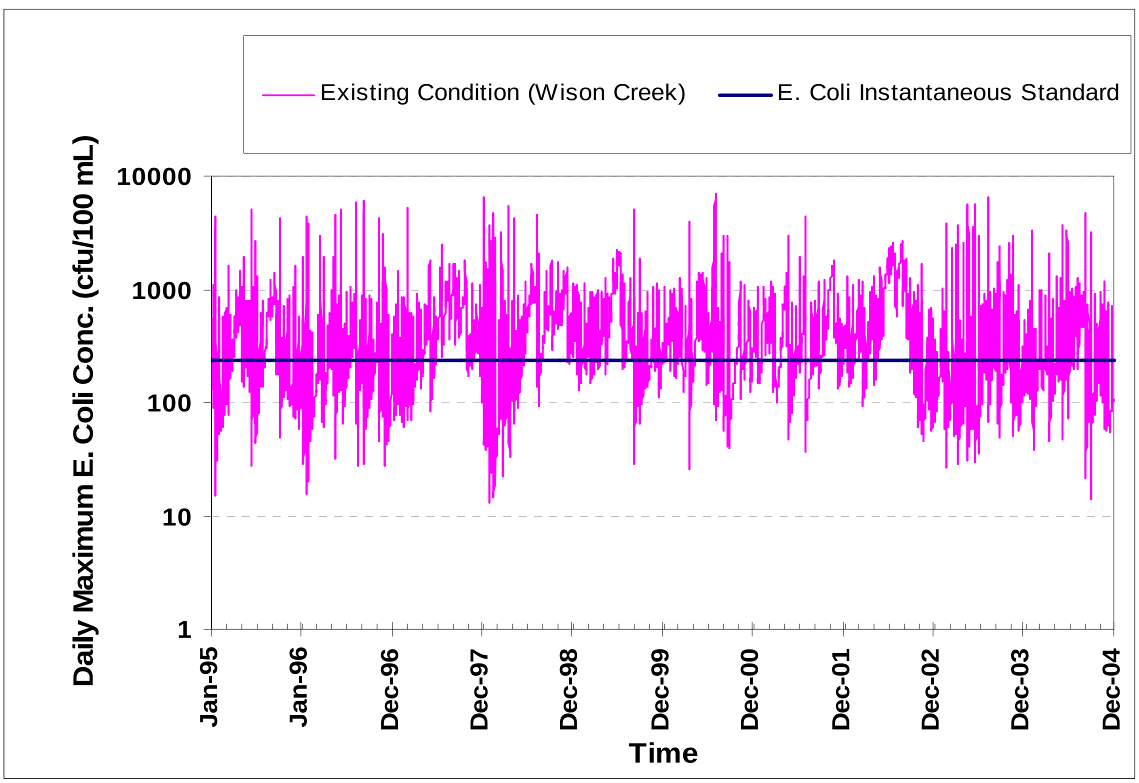


Table 4-15: Wilson Creek Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent (%)
Forest	7.71E+11	0.6%
Cropland	1.32E+12	1.1%
Pasture	2.74E+13	22.8%
Low Residential	3.23E+13	26.8%
Commercial/Industrial	2.45E+11	0.2%
Water/Wetland	2.33E+08	0.0%
Other	9.10E+09	0.0%
High Density Residential	2.78E+11	0.2%
Failed Septic and Straight Pipes	1.08E+13	9.0%
Cattle direct	2.49E+12	2.1%
Wildlife	4.45E+13	37.0%
Point Source	0.00E+00	0.0%
Total	1.20E+14	100%

Table 4-16: Wilson Creek E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	Percent (%)
Forest	8.31E+10	0.86%
Cropland	1.36E+11	1.4%
Pasture	2.21E+12	22.8%
Low Residential	2.57E+12	26.5%
Commercial/Industrial	2.89E+10	0.3%
Water/Wetland	4.83E+07	0.0%
Other	1.41E+09	0.01%
High Density Residential	3.26E+10	0.34%
Failed Septic and Straight Pipes	9.39E+11	9.69%
Cattle direct	2.44E+11	2.52%
Wildlife	3.45E+12	35.6%
Point Source	0.00E+00	0%
Total	9.70E+12	100%

4.10.2 Ore Branch

The instream bacteria concentration for the existing conditions in Ore Branch is above both the fecal coliform and E. coli geometric mean and instantaneous standards for the majority of the time period. Figure 4-22 shows the fecal coliform geometric mean under existing conditions and Figure 4-23 shows the E. coli geometric mean concentration under existing conditions. Figure 4-24 shows the fecal coliform instantaneous concentrations under existing conditions and Figure 4-25 shows the E. coli instantaneous concentration under existing conditions.

Distribution of the existing fecal coliform load by source in Ore Branch is presented in Table 4-17. The corresponding E. coli loading is presented in Table 4-18. E. coli concentrations in the impaired Ore Branch (Reach 77) segment were calculated from fecal coliform concentrations using the instream translator. Table 4-17 and Table 4-18 show that loading from wildlife, failing septic systems and straight pipes, and low density residential areas are the predominant sources of bacteria in the Ore Branch watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from wildlife and straight pipes will dominate. Under wet weather conditions, the non-point source loads from low-density residential areas will dominate.

Figure 4-22: Ore Branch Fecal Coliform Geometric Mean Existing Conditions

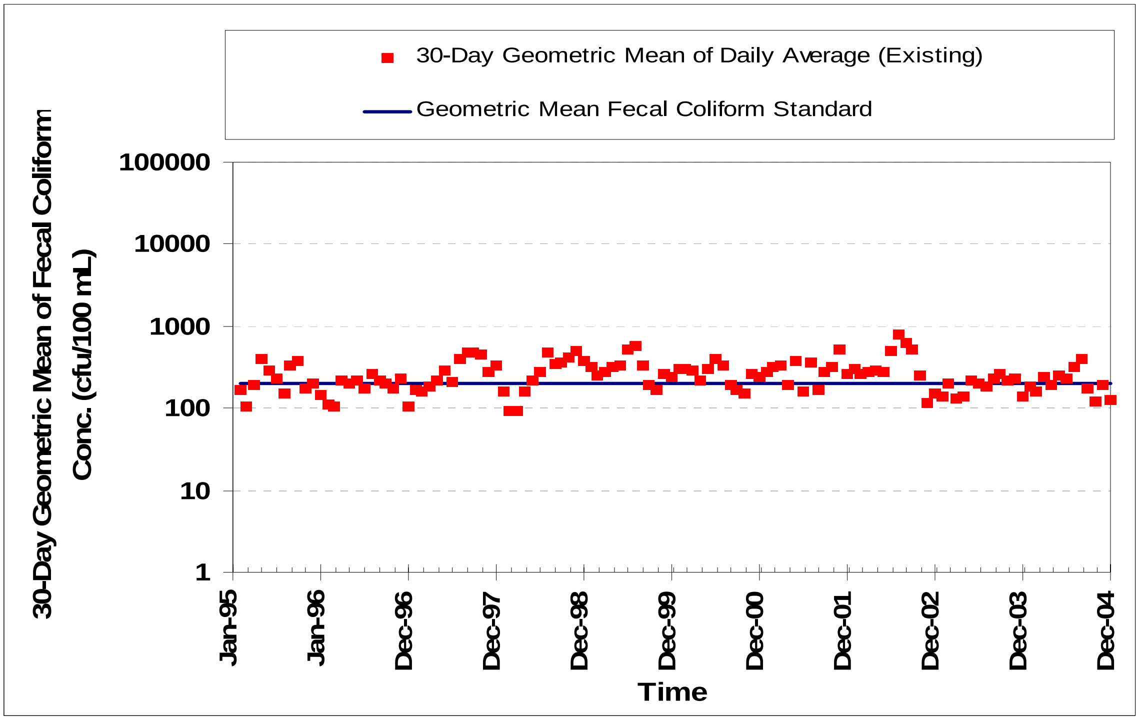


Figure 4-23: Ore Branch E. Coli Geometric Mean Existing Conditions

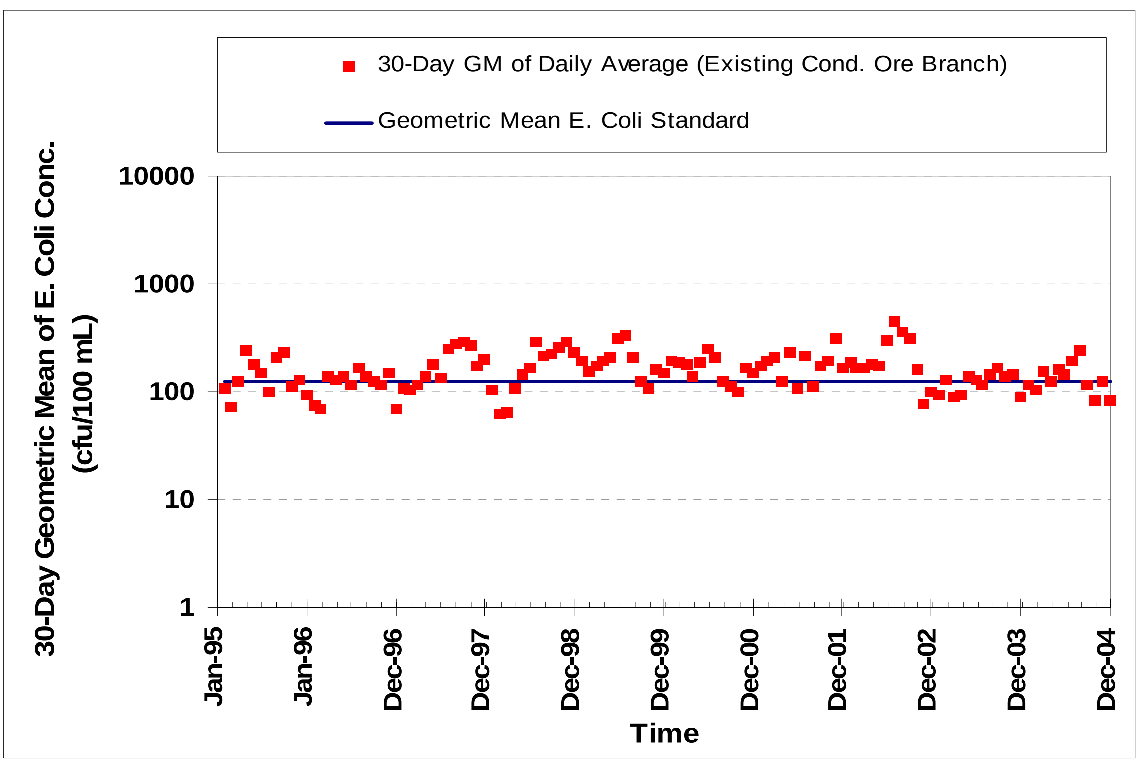


Figure 4-24: Ore Branch Fecal Coliform Instantaneous Existing Conditions

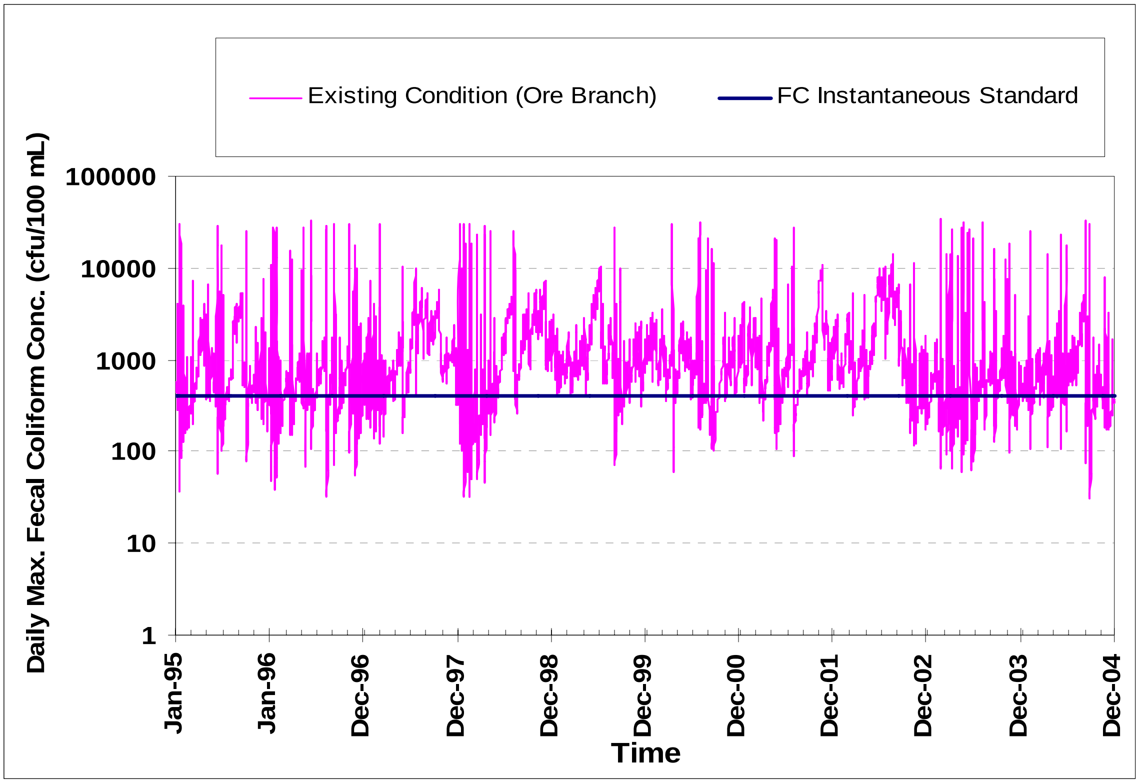


Figure 4-25: Ore Branch E. coli Instantaneous Existing Conditions

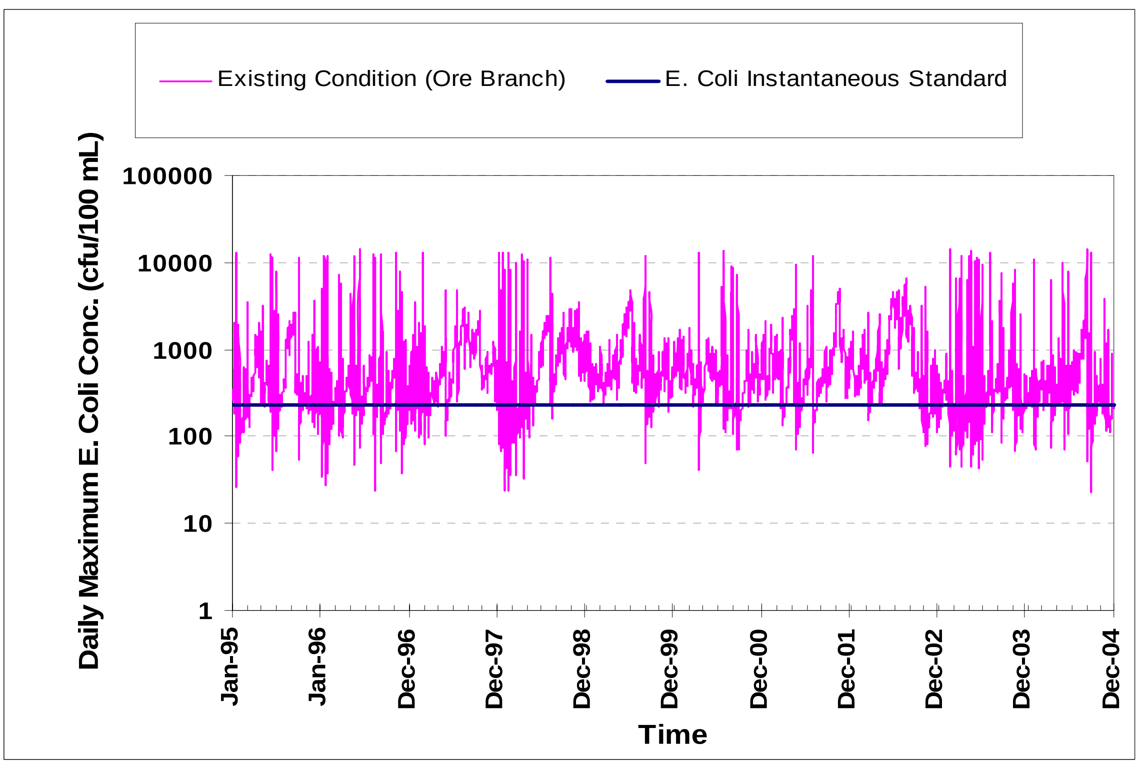


Table 4-17: Ore Branch Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent (%)
Forest	2.04E+11	0.3%
Cropland	0.00E+00	0.0%
Pasture	1.82E+12	2.4%
Low Residential	5.70E+13	73.7%
Commercial/Industrial	1.54E+11	0.2%
Water/Wetland	2.33E+07	0.0%
Other	4.75E+09	0.0%
High Density Residential	0.00E+00	0.0%
Failed Septic and Straight Pipes	4.65E+12	6.0%
Cattle direct	7.56E+10	0.1%
Wildlife	1.35E+13	17.4%
Point Source	0.00E+00	0.0%
Total	7.73E+13	100%

Table 4-18: Ore Branch E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	cfu/year
Forest	2.44E+10	0.4%
Cropland	0.00E+00	0.0%
Pasture	1.83E+11	3.0%
Low Residential	4.33E+12	70.4%
Commercial/Industrial	1.89E+10	0.3%
Water/Wetland	5.82E+06	0.0%
Other	7.74E+08	0.0%
High Density Residential	0.00E+00	0.0%
Failed Septic and Straight Pipes	4.33E+11	7.0%
Cattle direct	9.83E+09	0.2%
Wildlife	1.15E+12	18.7%
Point Source	0.00E+00	0.0%
Total	6.16E+12	100%

4.10.3 Roanoke River

The instream bacteria concentration under existing conditions in the Roanoke River is above both the fecal coliform and E. coli geometric mean and instantaneous standards for the majority of the time period. Figure 4-26 shows the fecal coliform geometric mean concentration under existing conditions and Figure 4-27 shows the E. coli geometric mean concentration under existing conditions. Figure 4-28 shows the fecal coliform instantaneous concentration under existing conditions and Figure 4-29 shows the E. coli instantaneous concentration under existing conditions.

Distribution of the existing fecal coliform load by source in the Roanoke River is presented in Table 4-19. The corresponding E. coli loading is presented in Table 4-20. E. coli concentrations in the impaired Roanoke River (Reach 1) segment were calculated from fecal coliform concentrations using the instream translator. Table 4-19 and Table 4-20 show that loading from the failed septic systems and straight pipes, pasture, wildlife, and low density residential areas are the predominant sources of bacteria in the Roanoke River watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from failed septic systems, straight pipes, and wildlife will dominate. Under wet weather conditions, the non-point source loads from low-density residential and pasture areas will dominate.

Figure 4-26: Roanoke River Fecal Coliform Geometric Mean Existing Conditions

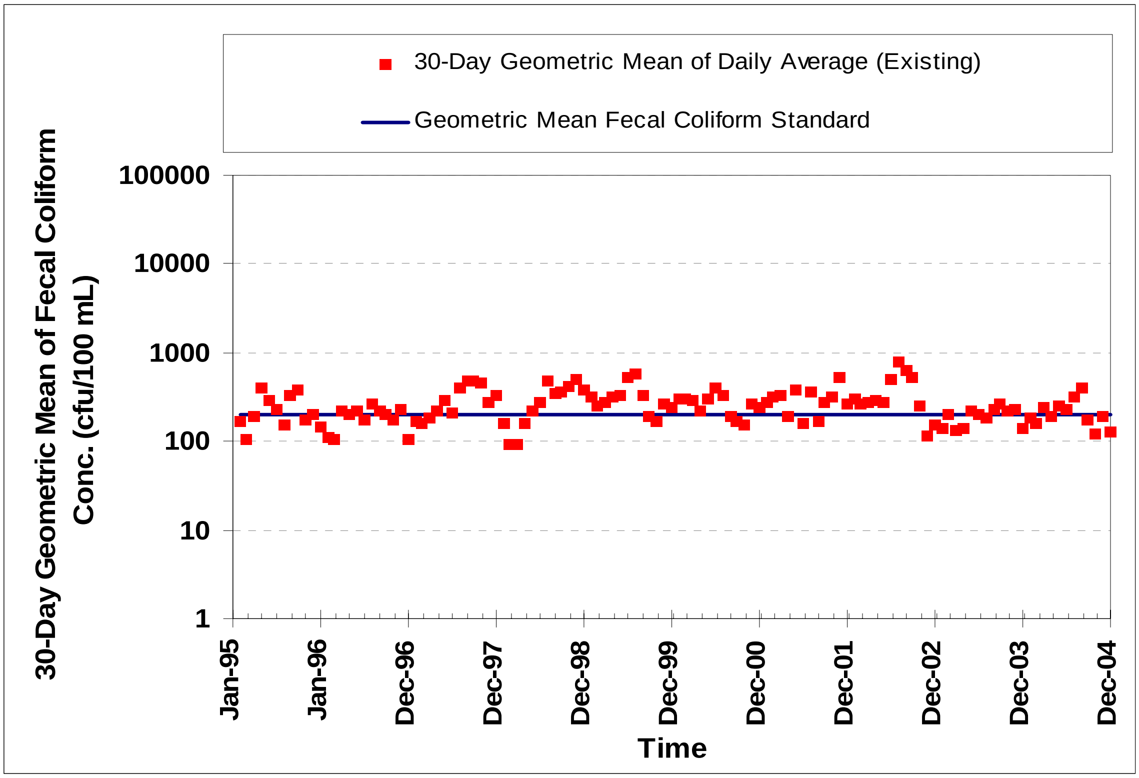


Figure 4-27: Roanoke River E. coli Geometric Mean Existing Conditions

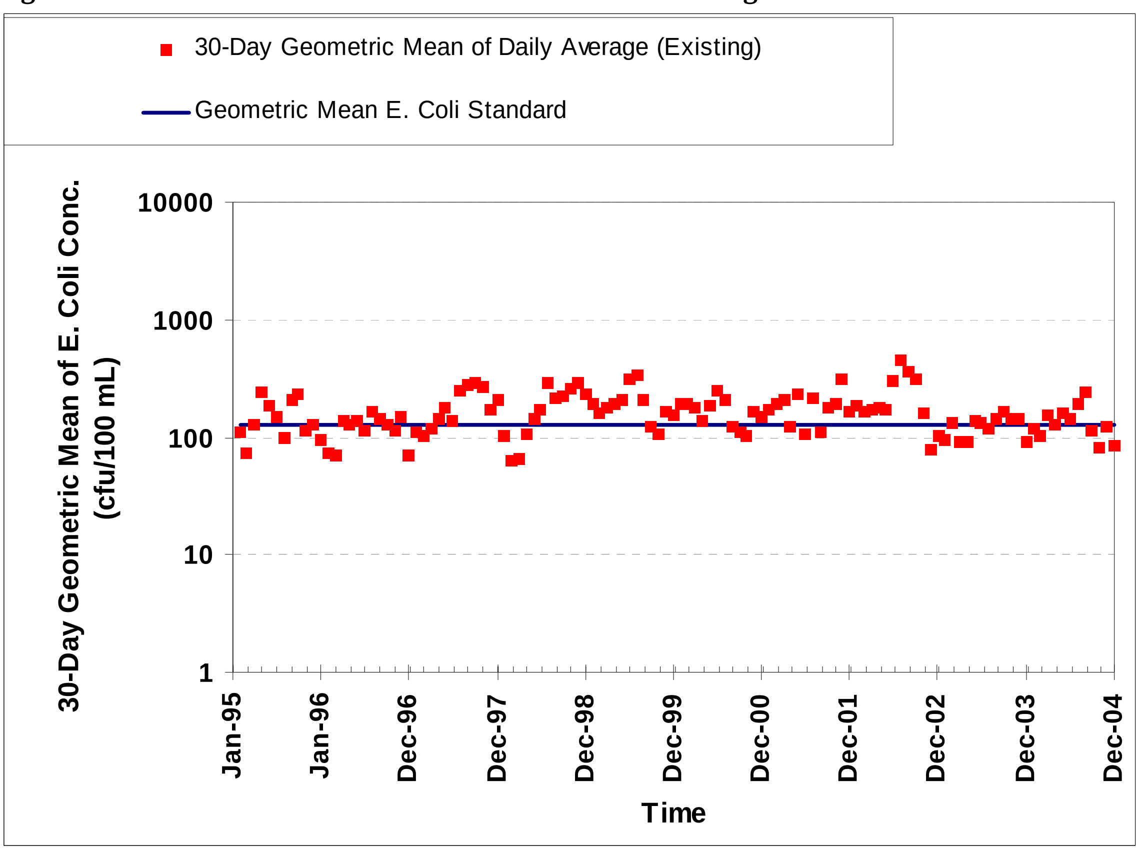


Figure 4-28: Roanoke River Fecal Coliform Instantaneous Existing Conditions

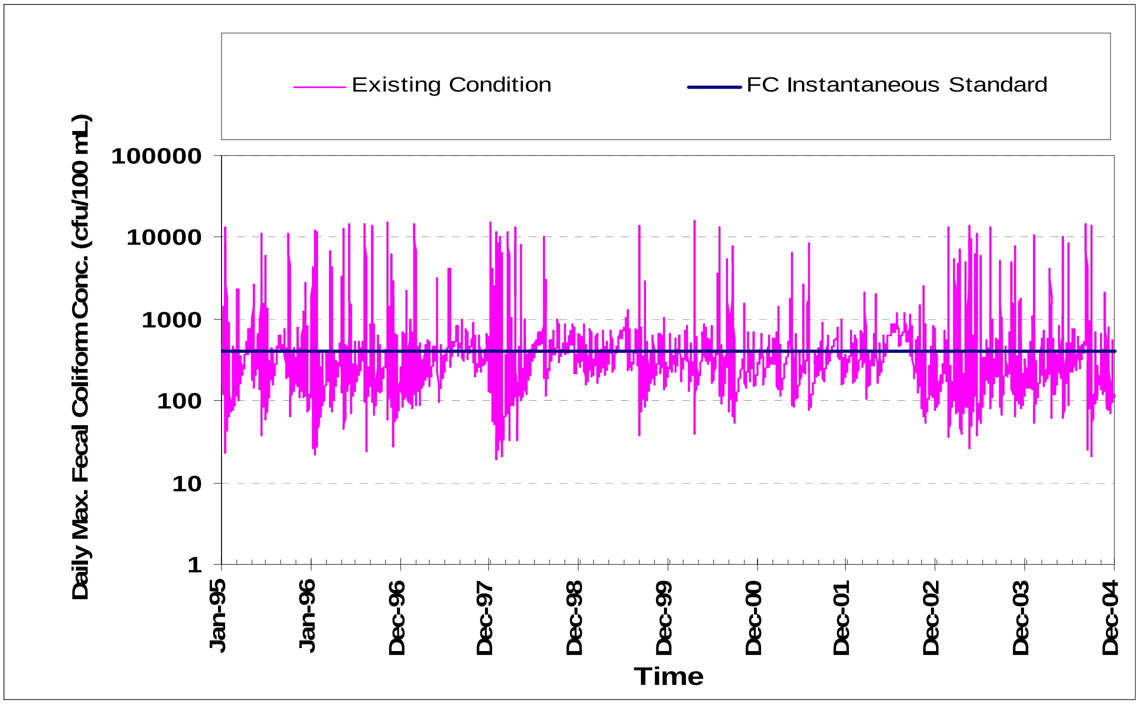


Figure 4-29: Roanoke River E. coli Instantaneous Existing Conditions

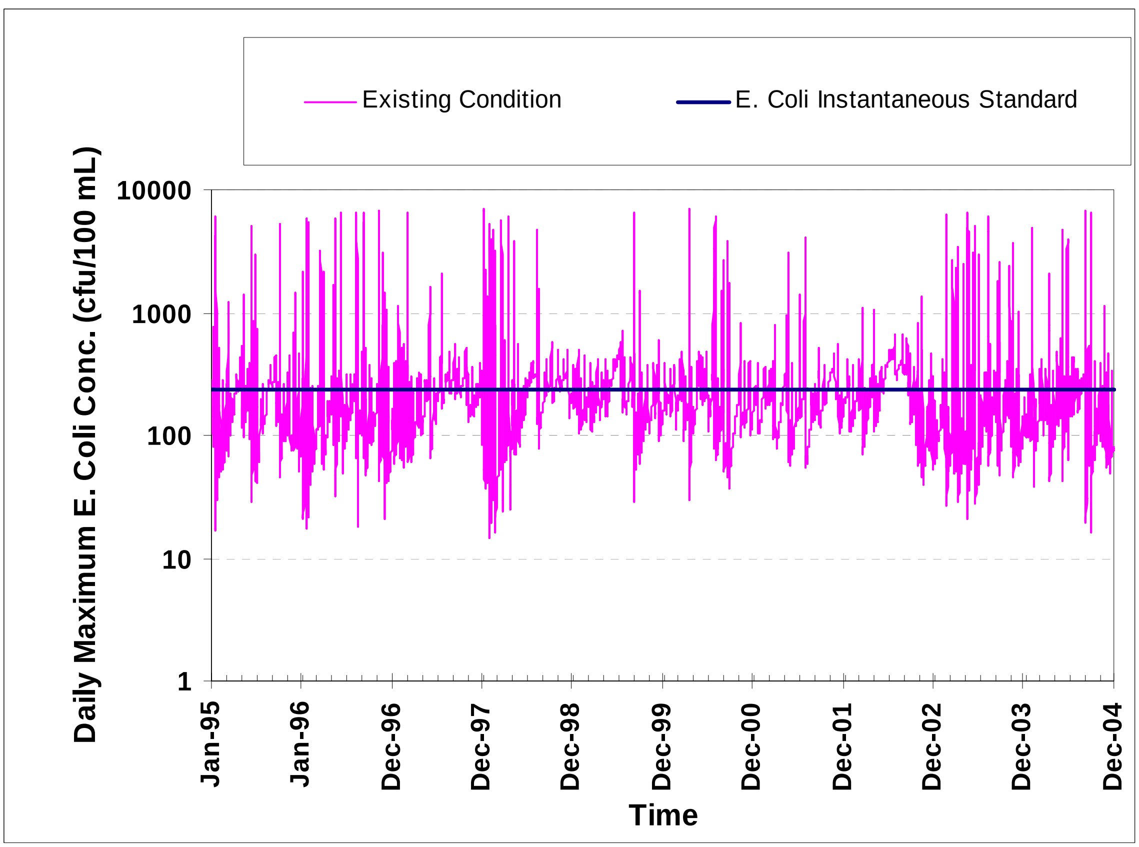


Table 4-19: Roanoke River Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent (%)
Forest	3.10E+13	0.3%
Cropland	4.11E+13	0.3%
Pasture	6.45E+14	5.4%
Low Residential	1.51E+15	12.6%
Commercial/Industrial	3.51E+12	0.0%
Water/Wetland	2.61E+10	0.0%
Other	4.52E+10	0.0%
High Density Residential	1.17E+13	0.1%
Failed Septic	7.90E+15	66.3%
Cattle direct	5.47E+13	0.5%
Wildlife	1.58E+15	13.3%
Point Source	1.39E+14	1.2%
Total	1.19E+16	100%

Table 4-20: Roanoke River E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	Percent (%)
Forest	2.48E+12	0.3%
Cropland	3.21E+12	0.4%
Pasture	4.03E+13	5.6%
Low Residential	8.79E+13	12.2%
Commercial/Industrial	3.34E+11	0.0%
Water/Wetland	3.70E+09	0.0%
Other	6.13E+09	0.0%
High Density Residential	1.01E+12	0.1%
Failed Septic	4.03E+14	55.8%
Cattle direct	4.18E+12	0.6%
Wildlife	9.18E+13	12.7%
Point Source	1.09E+14	12.1%
Total	7.43E+14	100%

5.0 Allocation

For the Wilson Creek, Roanoke River and Ore Branch bacteria TMDLs, allocation analysis was the third stage in development. Its purpose was to develop the framework for reducing bacteria loading under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocations for the selected scenarios were calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

5.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly fecal coliform geometric mean standard of 200 cfu/100 ml and the instantaneous fecal coliform standard of 400 cfu/100 ml with 0% exceedance. In terms of E. coli, incorporating an implicit MOS will require that the allocation scenario be designed to meet the monthly geometric mean standard of 126 cfu/100 ml and the instantaneous standard of 235 cfu/100 ml with 0 violations.

5.2 Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violations, and provides insight and direction in developing the TMDL allocations and implementation. Based on the sensitivity analysis, several allocation scenarios were developed. For each scenario developed, the percent of days water quality conditions violate the monthly geometric mean standard and instantaneous standard for E. coli were calculated. The results of the sensitivity analysis are presented in Appendix E.

5.3 Allocation Scenario Development

Allocation scenarios were modeled using the calibrated HSPF model to adjust the existing conditions until the water quality standard was attained. The TMDLs developed for the Wilson Creek, Roanoke River, and Ore Branch watershed were based on the Virginia State Standard for *E. coli*. As detailed in Section 1.2, the *E. coli* standard states that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml, and that a maximum single sample concentration of *E.coli* not exceed 235 cfu/100 ml. According to the guidelines put forth by the DEQ (DEQ, 2003) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform, and then the model output was converted to concentrations of *E. coli* with the following equation:

$$\log_2 (C_{ec}) = -0.0172+0.91905*\log2(c_{fc})$$

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

The pollutant concentrations were simulated over the entire duration of a representative modeling period, and pollutant loads were adjusted until the standard was met. The development of the allocation scenarios was an iterative process requiring numerous runs where each run was followed by an assessment of source reduction against the water quality target. The following sections present the waste load allocation (WLA) and load allocations (LA) for the Wilson Creek, Roanoke River, and Ore Branch Watershed.

5.3.1 Wasteload Allocation

5.3.1.1. Wilson Creek Wasteload Allocation

In the Wilson Creek watershed, there are no facilities permitted to discharge bacteria. Within Wilson Creek there are three Municipal Separate Storm Sewer System (MS4) permits requiring TMDL allocations. Table 5-1 shows the waste load allocations for each MS4. The waste load allocations were based on each municipality's share of the contributing urbanized area of the impairment. Appendix F outlines the steps used in the development of the MS4 E-coli allocations.

Table 5-1: Wilson Creek MS4s Wasteload Allocation for E. coli

MS4	Name	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VAR040019	Town of Blacksburg	6.29E+11	3.15E+9	99.5%
VAR040025	Town of Christianburg	4.65E+11	2.33E+9	99.5%
VAR040016	VDOT Montgomery County Urban Area	2.34E+11	1.17E+9	99.5%
	Total	**1.33E+12**	**6.65E+9**	**99.5%**

5.3.1.2. Ore Branch Waste Load Allocation

There are no industrial or municipal permitted facilities currently discharging into the Ore Branch watershed (see Chapter 4). However, the Ore Branch watershed is a complete part of the City of Roanoke urban area and the VODT of the City of Roanoke. Table 5-2 shows the waste load allocations for the two MS4s. In allocating the TMDLs, their loads were based on each share of the MS4' contributing urbanized area of the impairment. Appendix F outlines the steps used in the development of the MS4 E-coli allocations.

Table 5-2: Ore Branch MS4s Wasteload Allocation for E. coli

Point Source	Name	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VAR040004*	City of Roanoke	4.04E+12	2.02E+10	99.5%
VAR040017*	VDOT Roanoke Urban Area	8.70E+10	4.35E+08	99.5%
VAR040022*	Roanoke County	2.13E+11	1.07E+09	99.5%
	Total	**4.35E+12**	**2.17E+10**	**99.5%**

5.3.1.3. Roanoke River Waste Load Allocation

There are 6 industrial and municipal permitted facilities in the Roanoke River watershed permitted to discharge bacteria (see Chapter 4). For this TMDL, the wasteload allocation for permitted facilities is to maintain discharge at the design flow limits and bacteria concentrations at their permitted levels of 126 cfu/100mL. Table 5-3 shows the loading from the industrial and municipal permitted facilities in the watershed.

Table 5-3: Roanoke River Wasteload Allocation for E. coli

Point Source	Name	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VA0077895	Roanoke Moose Lodge	8.18E+09	8.18E+09	0%
VA0027481	Blacksburg Country Club Sewage Treatment Plant	6.10E+10	6.10E+10	0%
VA0062219	Montgomery County PSA – Elliston-Lafayette WWTP	4.34E+11	4.34E+11	0%
VA0024031	Shawsville Town – Sewage Treatment Plant	3.48E+11	3.48E+11	0%
VA0025020	Western Virginia Water Authority WPC	1.08E+14	1.08E+14	0%
VA0028711	Suncrest Heights	3.48E+10	3.48E+10	0%
Total		**1.09E+14**	**1.09E+14**	**0%**

Within Wilson Creek there are seven MS4s permits requiring TMDL allocations. Table 5-4 shows the waste load allocations for each MS4. The waste load allocations were based on each municipality's share of the contributing urbanized area of the impairment. Appendix F outlines the steps used in the development of the MS4 E-coli allocations.

Table 5-4: Roanoke River MS4s Wasteload Allocation for E. coli

MS4 Permit Holder	Permit Number	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
Roanoke County	VAR040022	2.37E+13	2.84E+11	98.8%
City of Roanoke	VAR040004	1.61E+13	1.93E+11	98.8%
Town of Vinton	VAR040026	2.77E+12	3.32E+10	98.8%
City of Salem	VAR040010	1.91E+13	2.29E+11	98.8%
VDOT Roanoke Urban Area	VAR040017	8.94E+11	1.07E+10	98.8%
Virginia Western Community College	VAR040030	1.44E+11	1.73E+09	98.8%
Virginia Medical Center	VAR040050	6.56E+11	7.87E+09	98.8%
	Total	**6.34E+13**	7.60E+11	**98.8%**

5.3.2 Load Allocation

The reduction of loading from non-point sources, including livestock and wildlife direct deposition, is incorporated into the load allocation. A number of load allocation scenarios were developed in order to determine the final TMDL load allocation. Fecal coliform loading and instream fecal coliform concentrations were estimated for each potential scenario using the HSPF model for the hydrologic period of January 1995 to December 2004. Table 5-5 shows the typical load allocation scenarios that were run to arrive at the final TMDL allocations. The following is a brief summary of the key scenarios:

- Scenario 0 is the existing load, no reduction of any of the sources.
- Scenario 1 represents elimination of human sources (septic systems and straight pipes).
- Scenario 3 represents elimination of the human sources (septic systems and straight pipes) as well as the direct instream loading from livestock.
- Scenario 4 represents the direct instream loading from wildlife (all other sources are eliminated).

Table 5-5: Wilson, Ore and Roanoke TMDL Load Allocation Scenarios

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agriculture)	NPS (Urban)	Direct Wildlife
0	0%	0%	0%	0%	0%
1	100%	0%	0%	0%	0%
2	100%	50%	0%	0%	0%
3	100%	100%	0%	0%	0%
4	100%	100%	100%	100%	0%
5	100%	100%	0%	0%	50%
6	100%	100%	0%	0%	75%
7	100%	100%	96%	96%	75%

The estimated load reductions for the Wilson Creek, Roanoke River, and Ore Branch from these allocation scenarios are presented separately in the next section. In addition, the percent of days the 126 cfu/100ml E. coli geometric mean water quality standard and the 235 cfu/100ml E. coli instantaneous water quality standard were violated under each scenario are presented.

5.3.2.1. Wilson Creek Load Allocation

The scenarios considered for Wilson Creek load allocation are presented in Table 5-6. The following conclusions can be made:

1. In Scenario 0 (existing conditions), the water quality standard was violated most of the time.
2. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 48 percent violation of the E. coli geometric mean standard.
3. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 43 percent violation of the E. coli geometric mean standard.
4. No violations of the E. coli geometric mean standard occurred in Wilson Creek under Scenario 9.

Therefore, scenario 9 was chosen as the final TMDL load allocation scenario for Wilson Creek. Under this scenario, complete elimination of the human sources (failed septic systems and straight pipes), livestock direct deposition, and a 99.5 percent reduction of urban and agricultural non-point sources, and a 90 percent reduction of direct loading by wildlife are required.

Table 5-6: Wilson Creek Load Reductions under 30-Day Geometric Mean and Instantaneous Standards for E. coli

Scenario	Failed Septic & Pipes	Direct Livestock	NPS Agri-cultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0	0%	0%	0%	0%	0%	76%	100%
1	100%	0%	0%	0%	0%	69%	100%
2	100%	50%	0%	0%	0%	57%	100%
3	100%	100%	0%	0%	0%	48%	100%
4	100%	100%	100%	100%	0%	43%	100%
5	100%	100%	0%	0%	50%	18%	97%
6	100%	100%	0%	0%	75%	4%	65%
7	100%	100%	96%	96%	75%	4%	65%

Scenario	Failed Septic & Pipes	Direct Livestock	NPS Agri-cultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
8	100%	100%	100%	100%	50%	15%	97%
9	100%	100%	99.5%	99.5%	90%	0%	0%

5.3.2.2. Ore Branch Load Allocation

The scenarios considered for Ore Branch load allocation are presented in Table 5-7. The following conclusions can be made:

1. In Scenario 0 (existing conditions), the water quality standard was violated most of the time.
2. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 48 percent violation of the E. coli geometric mean standard.
3. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 42 percent violation of the E. coli geometric mean standard.
4. No violations of either the E. coli geometric mean standard or the instantaneous E. coli standards occurred in the Ore Branch under Scenario 9.

Therefore, Scenario 9 was chosen as the final TMDL load allocation scenario for Ore Branch. Under this scenario, complete elimination of the human sources (failed septic systems and straight pipes), livestock direct deposition, and 99.5 percent reduction of urban and agricultural non-point sources, and a 93 percent reduction of direct loading by wildlife are required.

Table 5-7: Ore Branch Load Reductions under 30-Day Geometric Mean and Instantaneous Standards for E. coli

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agricul-tural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0	0%	0%	0%	0%	0%	76%	100%
1	100%	0%	0%	0%	0%	52%	100%
2	100%	50%	0%	0%	0%	50%	100%
3	100%	100%	0%	0%	0%	48%	100%
4	100%	100%	100%	100%	0%	42%	100%
5	100%	100%	0%	0%	50%	17%	100%
6	100%	100%	0%	0%	75%	4%	77%
7	100%	100%	96%	96%	75%	4%	77%
8	100%	100%	100%	100%	50%	13%	97%
9	100%	100%	99.5%	99.5%	93%	0%	0%

5.3.2.3. Roanoke River Load Allocation

The scenarios considered for Roanoke River load allocation are presented in Table 5-8. The following conclusions can be made:

1. In Scenario 0 (existing conditions), the water quality standard was violated most of the time in the Roanoke River.
2. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 23 percent violation of this standard in the Roanoke River.
3. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 15 percent violation of this standard in the Roanoke River.
4. No violations of either the E. coli geometric mean standard or the instantaneous E. coli standard occurred in the Roanoke River under Scenario 8.

Therefore, Scenario 8 was chosen as the final TMDL load allocation scenario for the Roanoke River. Under this scenario, complete elimination of the human sources (failed septic systems and straight pipes), livestock direct deposition, and 98.8 percent reduction of urban and agricultural non-point sources, and a 68 percent reduction of direct loading by wildlife are required.

Table 5-8: Roanoke River Load Reductions under 30-Day Geometric Mean and Instantaneous Standards for E. coli

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agric-ultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0	0%	0%	0%	0%	0%	76%	100%
1	100%	0%	0%	0%	0%	53%	100%
2	100%	50%	0%	0%	0%	36%	100%
3	100%	100%	0%	0%	0%	23%	100%
4	100%	100%	100%	100%	0%	15%	100%
5	100%	100%	0%	0%	50%	0%	47%
6	100%	100%	0%	0%	75%	0%	40%
7	100%	100%	96%	96%	75%	0%	7%
8	100%	100%	98.8%	98.8%	68%	0%	0%

5.4 TMDL Summary

Based on the load allocation scenario analyses, the TMDL allocation plans are summarized below:

5.4.1 Wilson Creek Allocation Plan

As shown in Table 5-6, scenario 9 will meet 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml for Wilson Creek. The requirements for this scenario are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 99.5% reduction of bacteria loading from agricultural and urban non-point sources.
- 90% reduction of the direct instream loading from wildlife.

Table 5-9 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix D.

Table 5-9: Wilson Creek Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	8.31E+10	4.15E+08	99.50%
Cropland	1.36E+11	6.81E+08	99.50%
Pasture	2.21E+12	1.11E+10	99.50%
Low Density Residential	1.27E+12	6.37E+09	99.50%
Commercial/Industrial/Transportation	1.43E+10	7.16E+07	99.50%
Water/Wetland	4.83E+07	2.42E+05	99.50%
Other Urban	1.41E+09	7.03E+06	99.50%
High Density Residential	1.62E+10	8.08E+07	99.50%
Failed Septic	9.39E+11	0.00E+00	100.00%
Cattle direct	2.44E+11	0.00E+00	100.00%
Wildlife	3.45E+12	3.45E+11	90.00%
Point Source + MS4s	1.33E+12	6.65E+9	99.5%
Total loads /Overall reduction	**9.70E+12**	**3.70E+11**	**96.18%**

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan are presented in Figure 5-1 and Figure 5-2. Figure 5-1 shows the 30-day geometric mean E. coli loading after applying the allocations of Scenario 9, as well as geometric mean loading under existing conditions. For Wilson Creek, allocation Scenario 9 results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for E. coli. A summary of the TMDL allocation plan loads for Wilson Creek is presented in Table 5-10.

Table 5-10: Wilson Creek TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
6.65E+9	3.64E+11	Implicit	3.70E+11

Figure 5-1: Wilson Creek Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 9

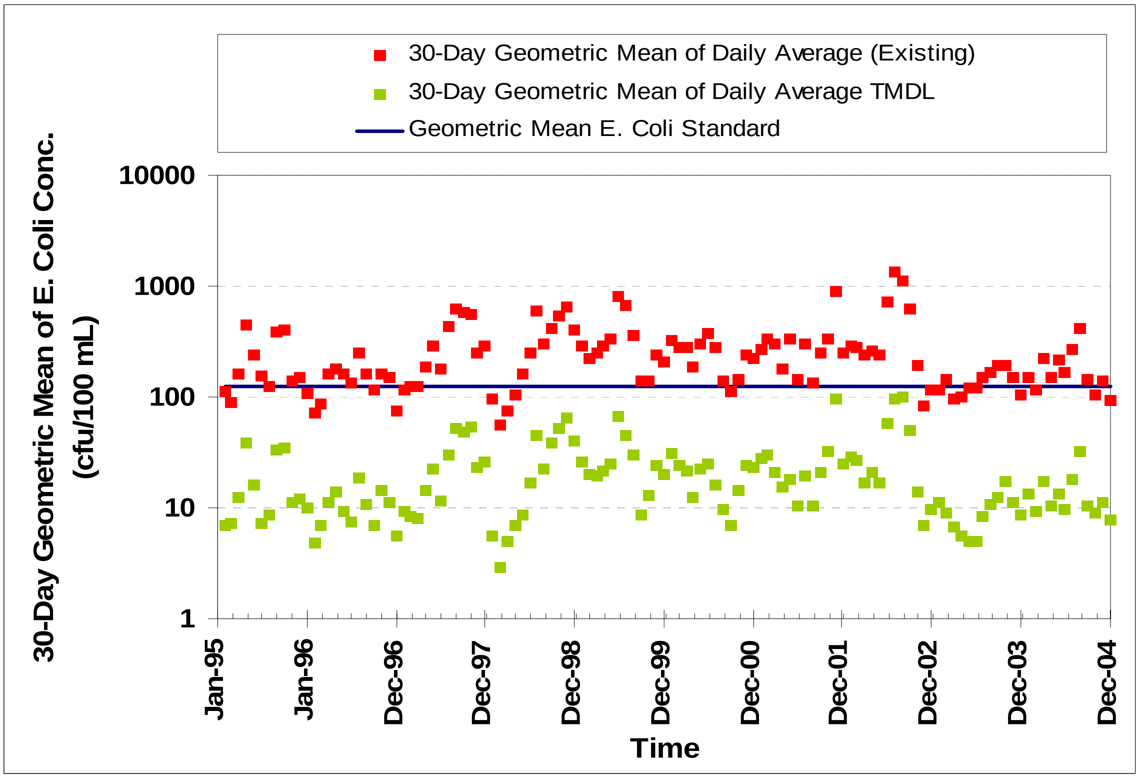
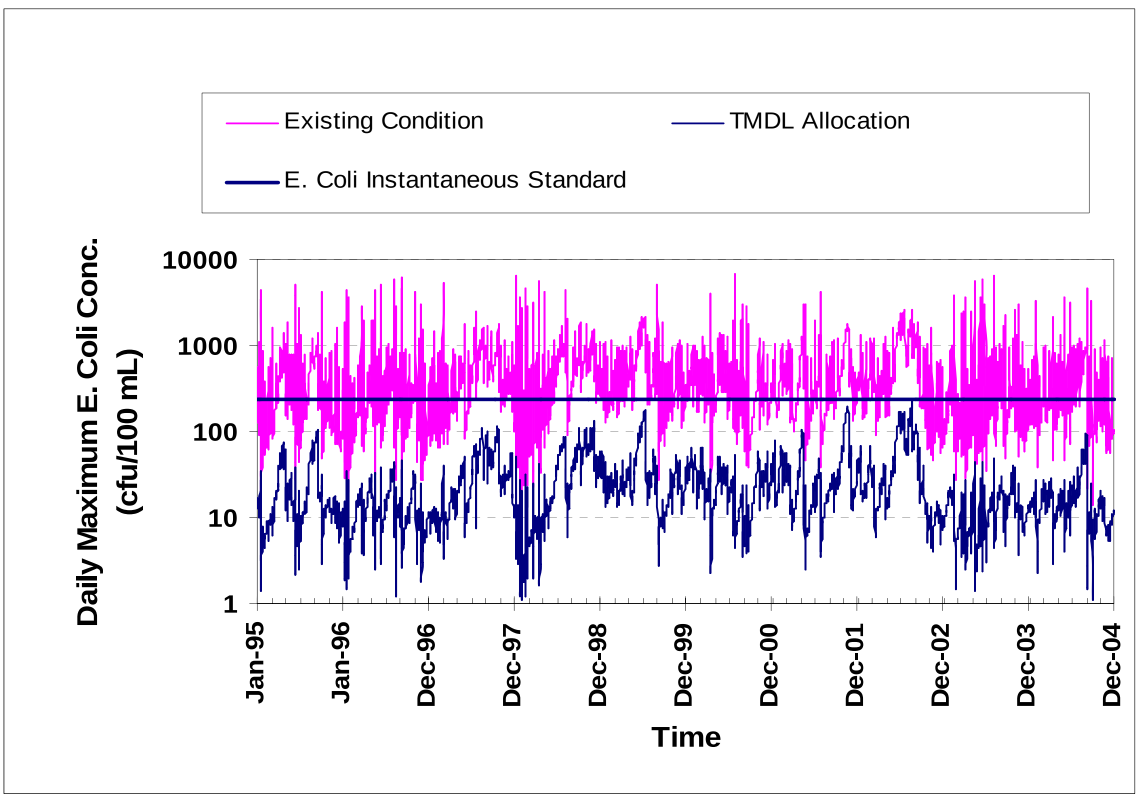


Figure 5-2: Wilson Creek Instantaneous E. coli Loadings under Allocation Scenario 9



5.4.2 Ore Branch Allocation Plan

For Ore Branch, as shown in table 5-7, Scenario 9 will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml. The requirements for this scenario include:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 99.5 percent reduction of bacteria loading from agricultural
- 93 percent reduction of the direct instream loading from wildlife.

Table 5-11 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. It should be noted that in Table 5-11, the urban areas E-coli allocations (low density residential, commercial/industrial/transportation, and the high density residential) have a zero E-coli loads, because all these urban areas are included in the urban MS4s allocations. In other words, the Ore Branch impaired watershed is mostly comprised within MS4 urban areas.

Table 5-11: Ore Branch Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	2.44E+10	1.22E+08	99.50%
Cropland	0.00E+00	0.00E+00	0.00%
Pasture	1.83E+11	9.17E+08	99.50%
Low Density Residential	0.00E+00	0.00E+00	0.00%
Commercial/Industrial/Transportation	0.00E+00	0.00E+00	0.00%
Water/Wetland	5.82E+06	2.91E+04	99.50%
Other Urban	7.74E+08	3.87E+06	99.50%
High Density Residential	0.00E+00	0.00E+00	0.00%
Failed Septic	4.33E+11	0.00E+00	100.00%
Cattle direct	9.83E+09	0.00E+00	100.00%
Wildlife	1.15E+12	8.05E+10	93.00%
Point Source (MS4s)	4.35E+12	2.17E+10	99.50%
Total loads /Overall reduction	**6.16E+12**	**1.03E+11**	**98.32%**

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan for the Ore Branch are presented in Figure 5-3 and Figure 5-4. Figure 5-3 shows the 30-day geometric mean E. coli loading after applying allocation Scenario 9, as well as geometric mean loading under existing conditions. Figure 5-4 shows the instantaneous E. coli loading after applying allocation Scenario 9. A summary of the TMDL allocation plan loads for the Ore Branch is presented in Table 5-12.

Table 5-12: Ore Branch TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
2.17E+10	8.15E+10	Implicit	1.03E+11

Figure 5-3: Ore Branch Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 9

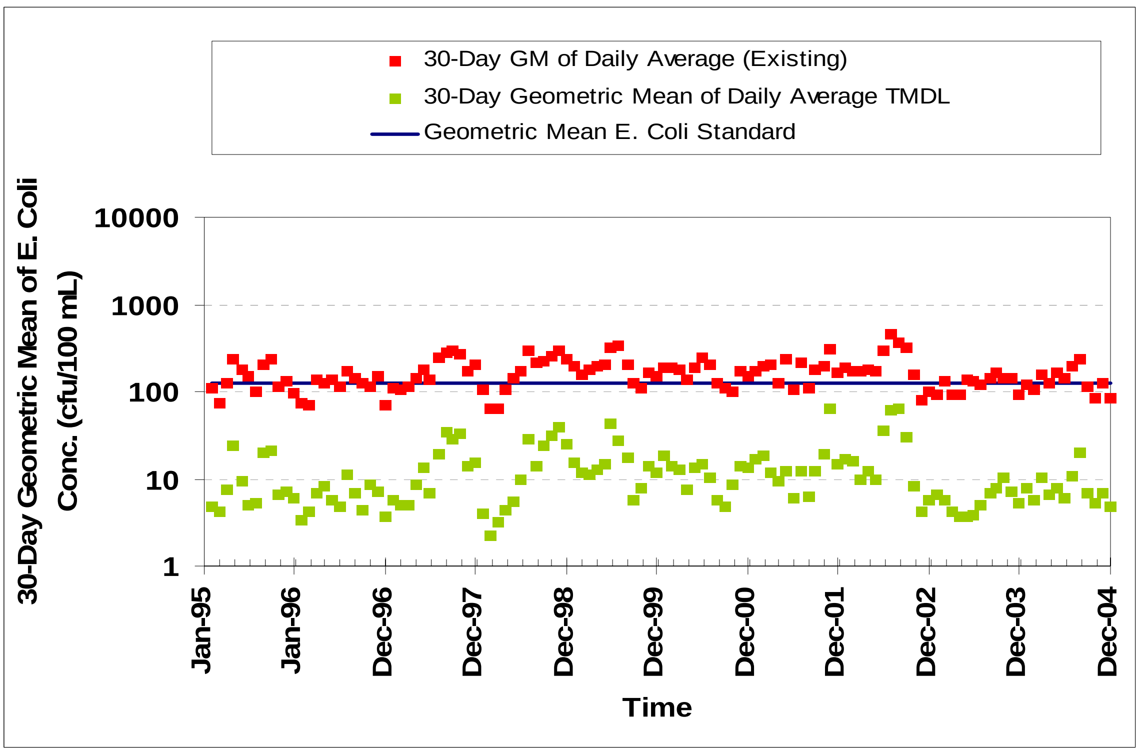
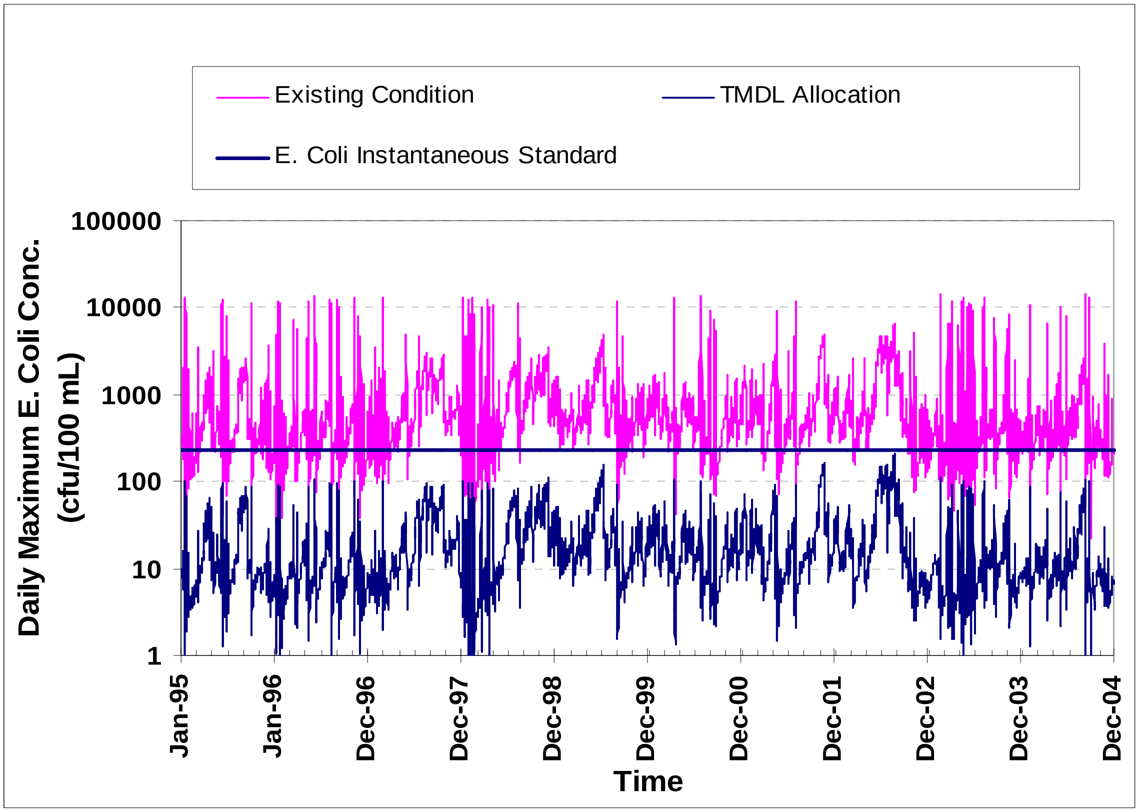


Figure 5-4: Ore Branch Instantaneous E. coli Loadings under Allocation Scenario 9



5.4.3 Roanoke River Allocation Plan

As shown in Table 5-8, Scenario 8 for the Roanoke River, will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml. The requirements necessary to met scenario 8 include:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 98.8 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 68 percent reduction of the direct instream loading from wildlife.

Table 5-13 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix D.

Table 5-13: Roanoke River Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	2.48E+12	2.98E+10	98.8%
Cropland	3.21E+12	3.86E+10	98.8%
Pasture	4.03E+13	4.84E+11	98.8%
Low Density Residential	2.54E+13	3.05E+11	98.8%
Commercial/Industrial/Transportation	9.66E+10	1.16E+09	98.8%
Water/Wetland	3.70E+09	4.44E+07	98.8%
Other Urban	6.13E+09	7.35E+07	98.8%
High Density Residential	2.92E+11	3.51E+09	98.8%
Failed Septic	4.03E+14	0.00E+00	100%
Cattle direct	4.18E+12	0.00E+00	100%
Wildlife	9.18E+13	2.94E+13	68%
Point Source + MS4s	1.72E+14	1.10E+14	0%
Total loads /Overall reduction	**7.43E+14**	**1.40E+14**	**81.12%**

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan are presented in Figure 5-5 and Figure 5-6. Figure 5-5 shows the 30-day geometric mean E. coli loading after applying allocation Scenario 8, as well as geometric mean loading under existing conditions. Figure 5-6 shows the instantaneous E. coli loading after applying allocation Scenario 8. A summary of the TMDL allocation plan loads for the Roanoke River is presented in Table 5-14.

Table 5-14: Roanoke River TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
1.10E+14	3.02E+13	Implicit	1.40E+14

Figure 5-5: Roanoke River Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 8

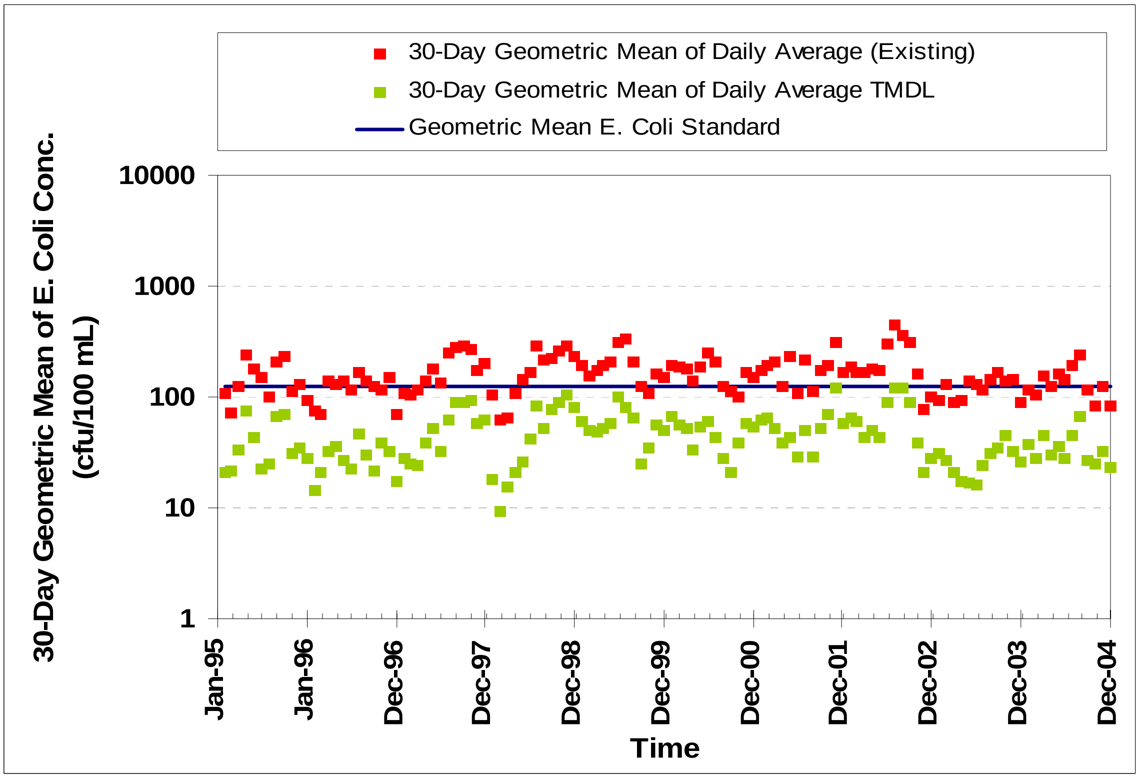
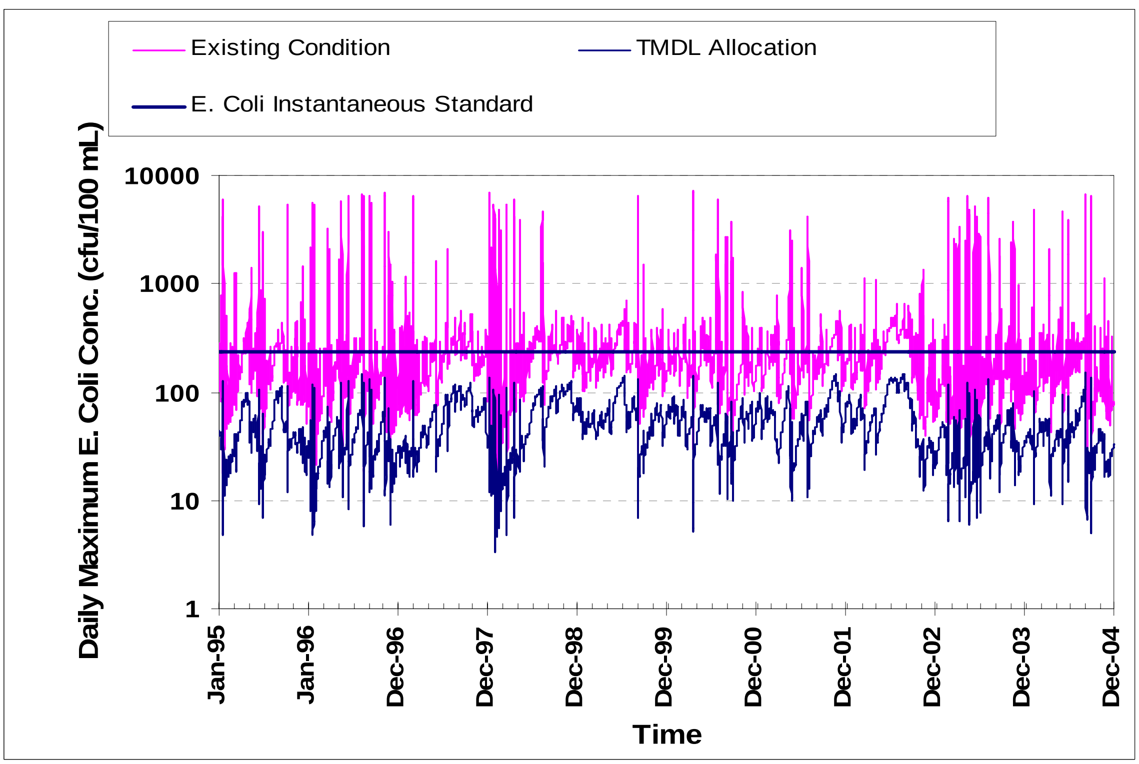


Figure 5-6: Roanoke River Instantaneous E. coli Loadings under Allocation Scenario 8



6.0 TMDL Implementation

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 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 in computer simulation modeling.
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements.
4. It helps ensure that the most cost effective practices are implemented first.
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 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. A margin of safety was not used in determining the stage 1 scenarios. It was estimated for modeling purposes that there are 63 straight pipes in the watershed. Should any be found during the implementation process, they should be eliminated as soon as possible since they would be illegally discharging fecal bacteria into Wilson Creek, Ore Branch and Roanoke River and its tributaries.

Three allocation scenarios are presented in Tables 6-1, 6-2, and 6-3 for the Wilson Creek, Ore Branch, and the Roanoke River respectively. Scenario 1 represents the required load reduction that will not exceed the instantaneous standard by more than 10% violation. Scenarios 2 and 3 represent the implementation of BMPs and management strategies such as livestock exclusion from streams, alternative water, manure storage, riparian buffers, and pet waste control that can be readily put in place in the watershed.

Table 6-1: Wilson Creek Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	99.5%	99.5%	89%	0%	6%
2	100%	50%	50%	50%	0%	55%	100%
3	100%	75%	75%	75%	0%	55%	100%

Table 6-2: Ore Branch Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	99.5%	99.5%	92%	8%	3%
2	100%	50%	50%	50%	0%	48%	100%
3	100%	75%	75%	75%	0%	48%	100%

Table 6-3: Roanoke River Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	98.8%	98.8%	61%	9%	0%
2	100%	50%	50%	50%	0%	53%	100%
3	100%	75%	75%	75%	0%	49%	100%

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 Wilson Creek, Ore Branch and Roanoke River watershed.

- Pick Up the Poop Project – A joint partnership between city of Roanoke, Roanoke County, Western Virginia Water Authority, and the Upper Roanoke River Roundtable. Information can be found at the following website: http://www.upperroanokeriver.org/projects.html

- The City of Roanoke has been participating in a feral cat sterilization program and deer culling program. In addition, the city of Roanoke has recently promulgated new unauthorized discharge ordinance into stormwater pipes. More information can be found at the following website: http://www.roanokeva.gov/WebMgmt/ywbase61b.nsf/vwContentByKey/N25NSHFJ240CDATEN

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 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. 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 are 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

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is the Virginia Pollutant Discharge Elimination System (VPDES) Permit Regulation (9 VAC 25-31-10 et seq.). Section 9 VAC 25-31-120 describes the requirements for storm water 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,…".

Part of the Roanoke River watershed is covered by Phase II VPDES permits for Municipal Separate Storm Sewer Systems (MS4s). Table 6-4 lists the MS4 permit holders within the Wilson Creek, Ore Branch, and Roanoke River Watershed.

Table 6-4: MS4 Permits in the Wilson Creek, Ore Branch, and Roanoke River Watersheds

MS4 Permit Holder	Permit Number
Roanoke County	VAR040022
City of Roanoke	VAR040004
Town of Vinton	VAR040026
City of Salem	VAR040010
VDOT Roanoke Urban Area	VAR040017
Virginia Western Community College	VAR040030
Virginia Medical Center	VAR040050
VDOT Montgomery County Urban Area	VAR040016
Town of Blacksburg	VAR040019
Town of Christianburg	VAR040025

These permits state, under Part II.A., that the "permittee must develop, implement, and enforce a storm water management program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP), to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act and the State Water Control Law."

The permits also contain a TMDL clause that states: "If a TMDL is approved for any waterbody into which the MS4 discharges, the Board will review the TMDL to determine whether the TMDL includes requirements for control of storm water discharges. If discharges from the MS4 are not meeting the TMDL allocations, the Board will notify the permittee of that finding and may require that the Storm Water Management Program required in Part II be modified to implement the TMDL within a timeframe consistent with the TMDL."

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 EPA guidance

(EPA 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 a violation of the permit. DEQ 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 7.4.5 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 Wilson Creek, Ore Branch or the Roanoke River would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL implementation plans. 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/sw/stormwat.htm.

6.4.4 Implementation Funding Sources

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". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan

Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

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. These streams may not be able to attain standards without some reduction in wildlife load. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. Additionally, other factors may prevent the stream from attaining the primary contact recreation use.

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

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

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance 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 in 6.2 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.

7.0 Public Participation

The development of the TMDLs for Wilson Creek, Ore Branch and Roanoke River would not have been possible without public participation. Public meetings were held in the Wilson Creek, Ore Branch, and Roanoke River watersheds, the following is a summary of the meeting objectives and attendance.

TAC Meeting. The TAC meeting was held at DEQ headquarters in the afternoon of October 7, 2004 to discuss the process for TMDL development, present the listed segments on the Upper Roanoke River, Wilson Creek, and Ore Branch, and present the data that caused the segment to be on the 303(d) list, identify review the data and information needed in the TMDL development, and officially request data and information. Copies of the presentation materials were available for public distribution. The meeting participants were contacted by DEQ via email and phone.

Public Meeting No. 1. The first public meeting was held at DEQ headquarters in the evening of October 7, 2004 to present the following:

- listed segments of the Roanoke River, Wilson Creek, and Ore Branch
- the data that caused the segments to be on the 303(d) list
- review of the TMDL process
- water quality standards
- address the need for pet and livestock inventories
- the calculation used to estimate the total available fecal coliform load;
- the assumptions used in the calculations; and present the HSPF model.

Forty-one people attended this public meeting. Copies of the presentation were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations*. During the 30-day comment period, no written comments were received.

Public Meeting No. 2. The second public meeting was held in Shawsville, Virginia at East Montgomery High School in the evening of August 4, 2005 to discuss the sources assessment, present the HSPF model calibration and the goodness of fit, and discuss the Draft TMDL. Eleven people attended this public meeting. Copies of the presentation and the draft TMDL report executive summary were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations.*

Public Meeting No. 3. The third public meeting was held in Roanoke, Virginia at at the DEQ regional office on August 9, 2005 to discuss the sources assessment, present the HSPF model calibration and the goodness of fit, and discuss the Draft TMDL. Twenty-two people attended this public meeting. Copies of the presentation and the draft TMDL report executive summary were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations.*

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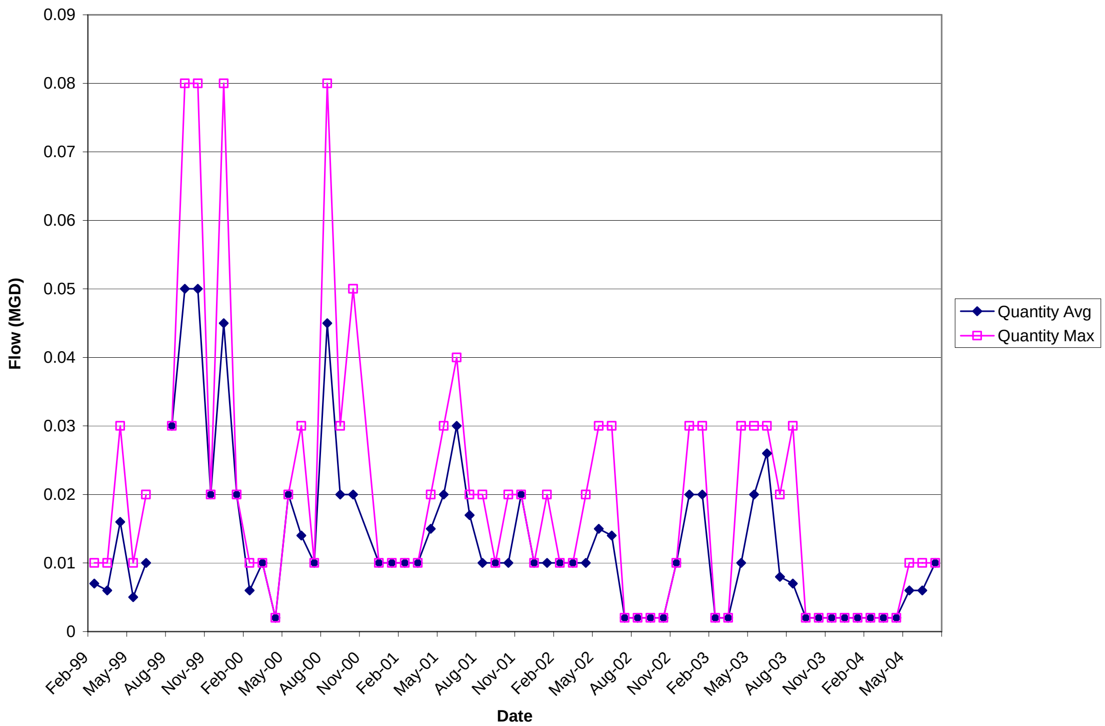
Appendix A

Discharge Monitoring Report Data

Figure A-1 : Associated Asphalt Inc. (VA0001252) Average and Maximum Monthly Flow



FigureA-2: Koppers Inc. (VA0001333 Outfall 1) Average and Maximum Monthly Flow

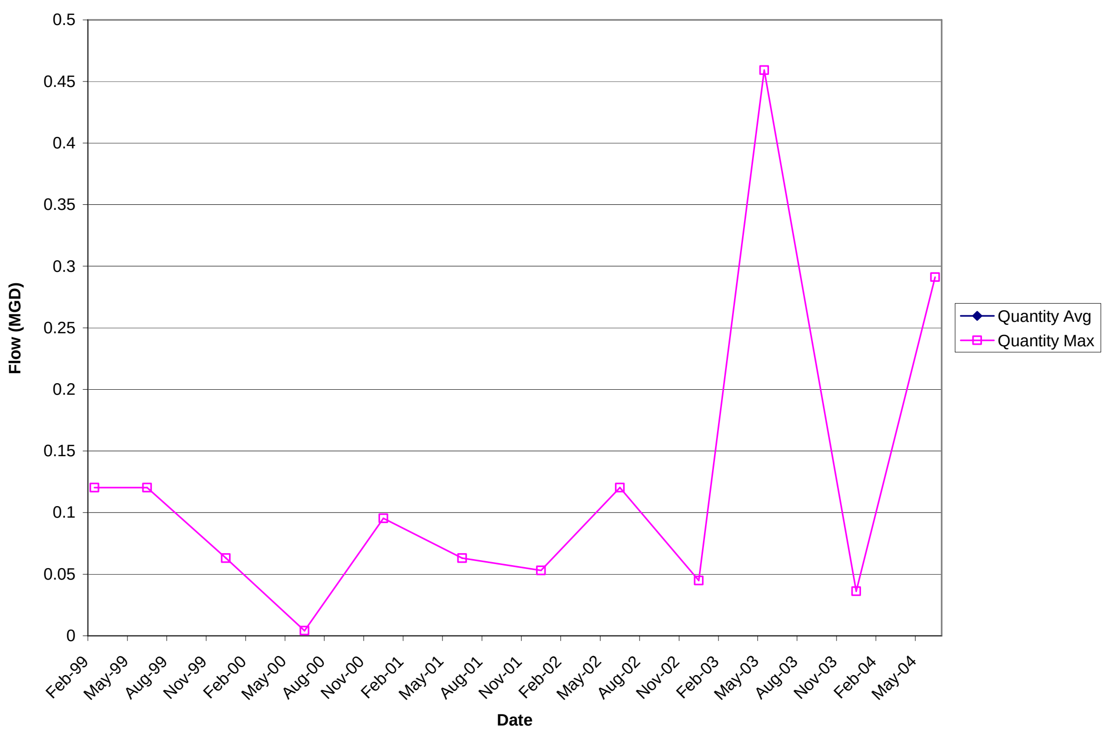


Figure A-3: Koppers Inc. (VA0001333 Outfall 2) Average and Maximum Monthly Flow

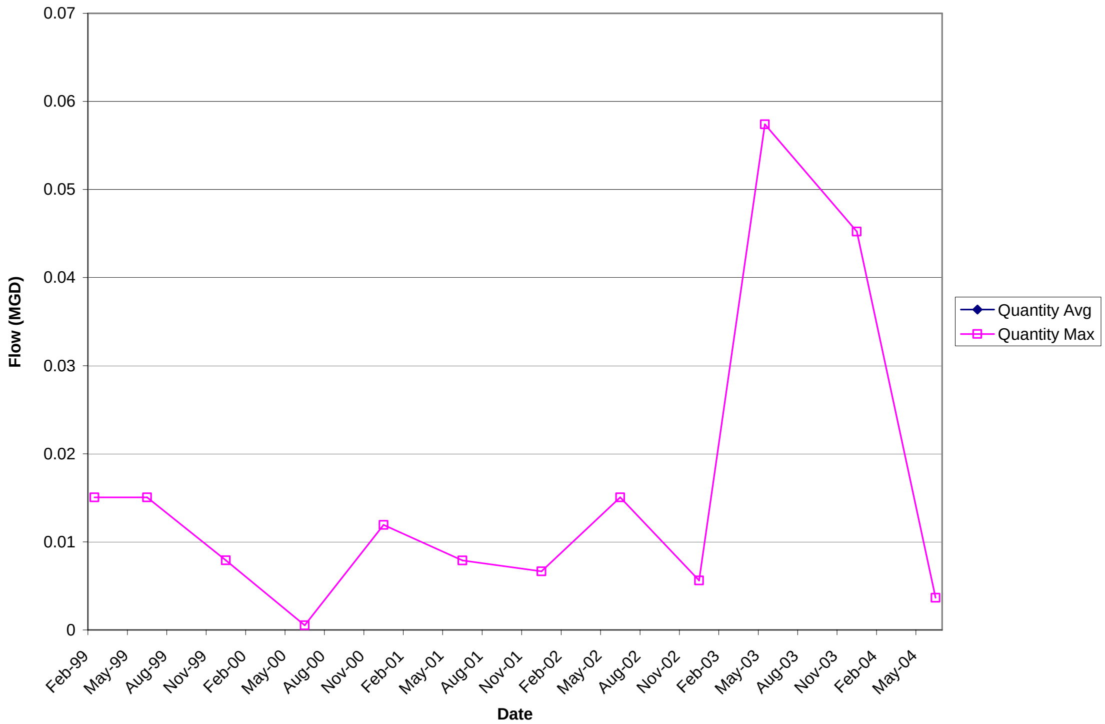


Figure A-4: Motiva Enterprises LLC - Roanoke (VA0001431) Average and Maximum Monthly Flow

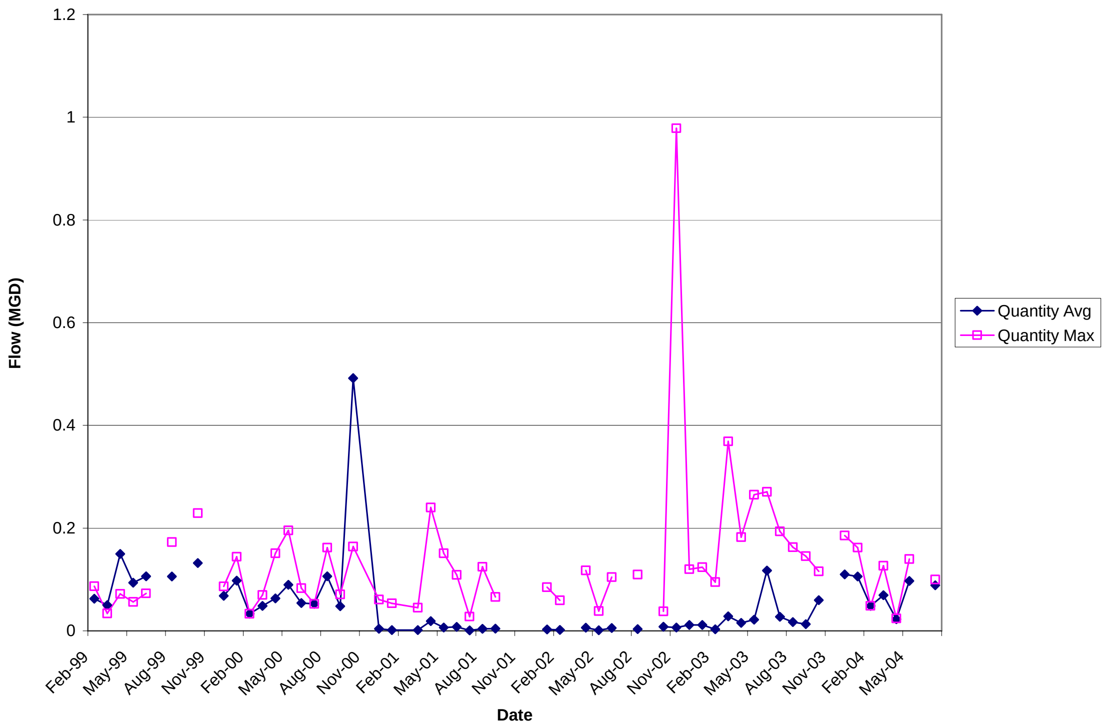


Figure A-5: Roanoke City - Carvins Cove Water Filtration Plant (VA0001473 Outfall 1) Average and Maximum Monthly Flow

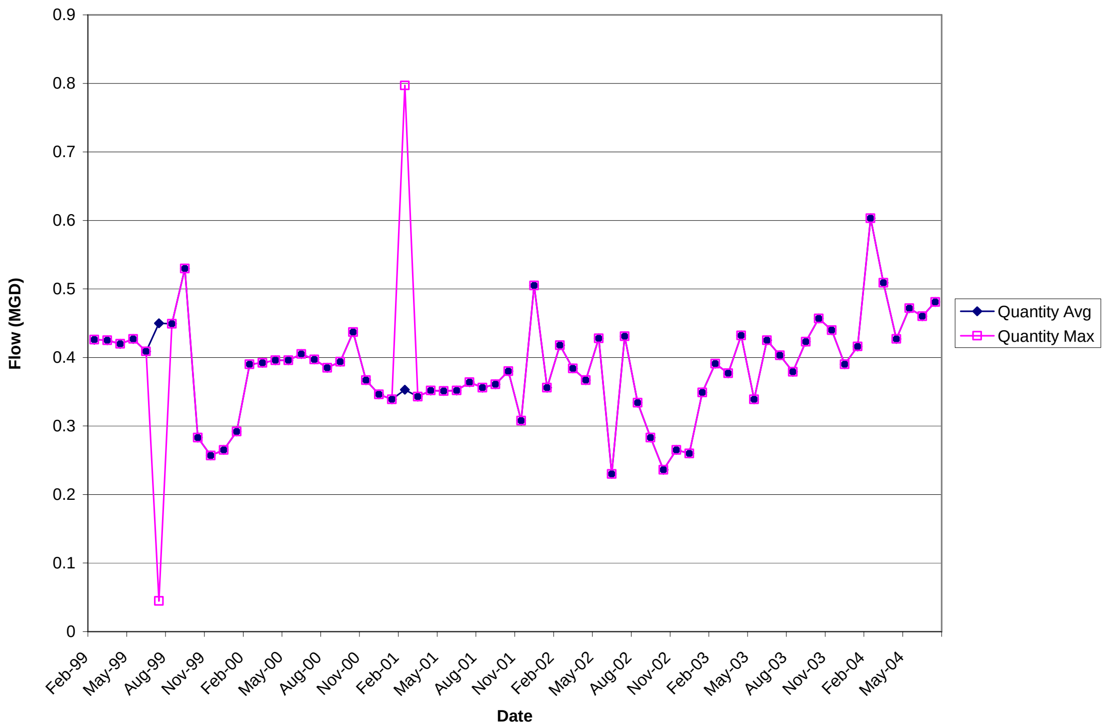


Figure A-6: Roanoke City - Carvins Cove Water Filtration Plant (VA0001473 Outfall 2) Average and Maximum Monthly Flow

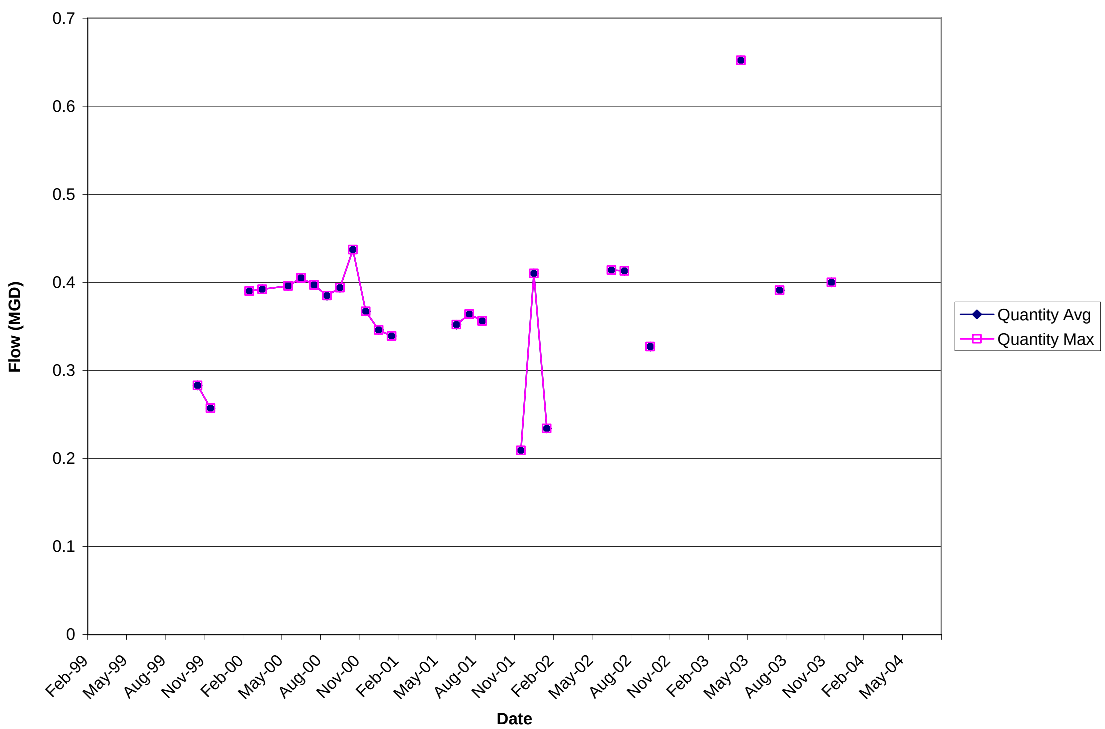


Figure A-7: Norfolk Southern Railway Co - East End Shops (VA0001511 Outfall 2) Average and Maximum Monthly Flow

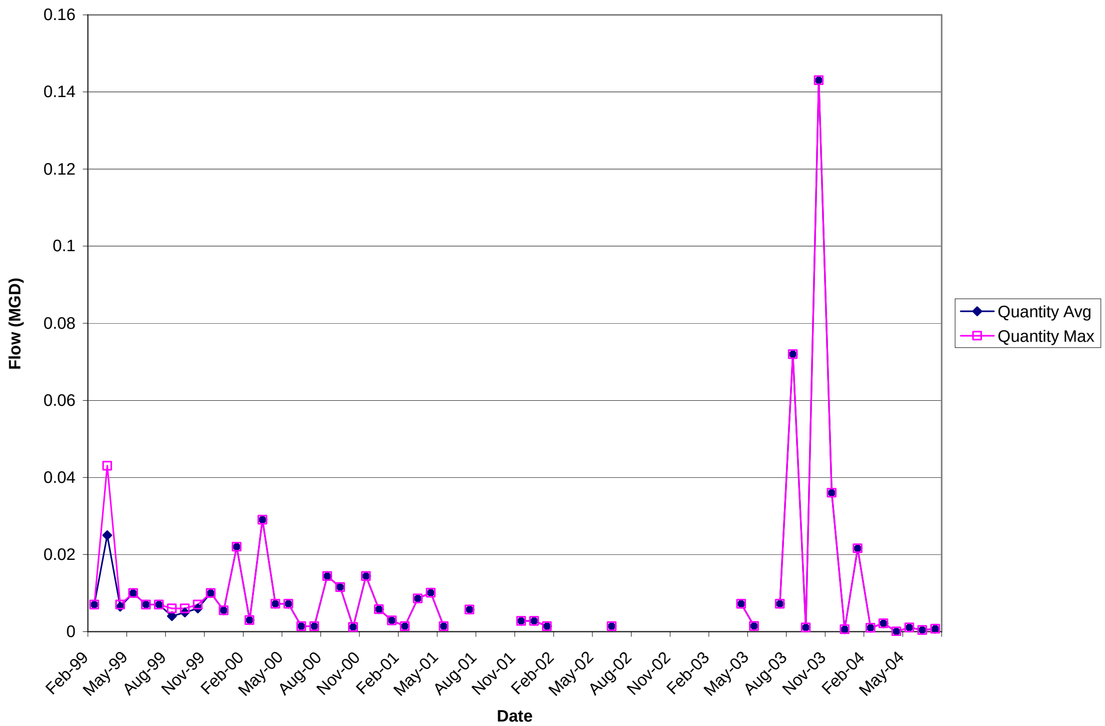


Figure A-8: Norfolk Southern Railway Co - East End Shops (VA0001511 Outfall 3) Average and Maximum Monthly Flow

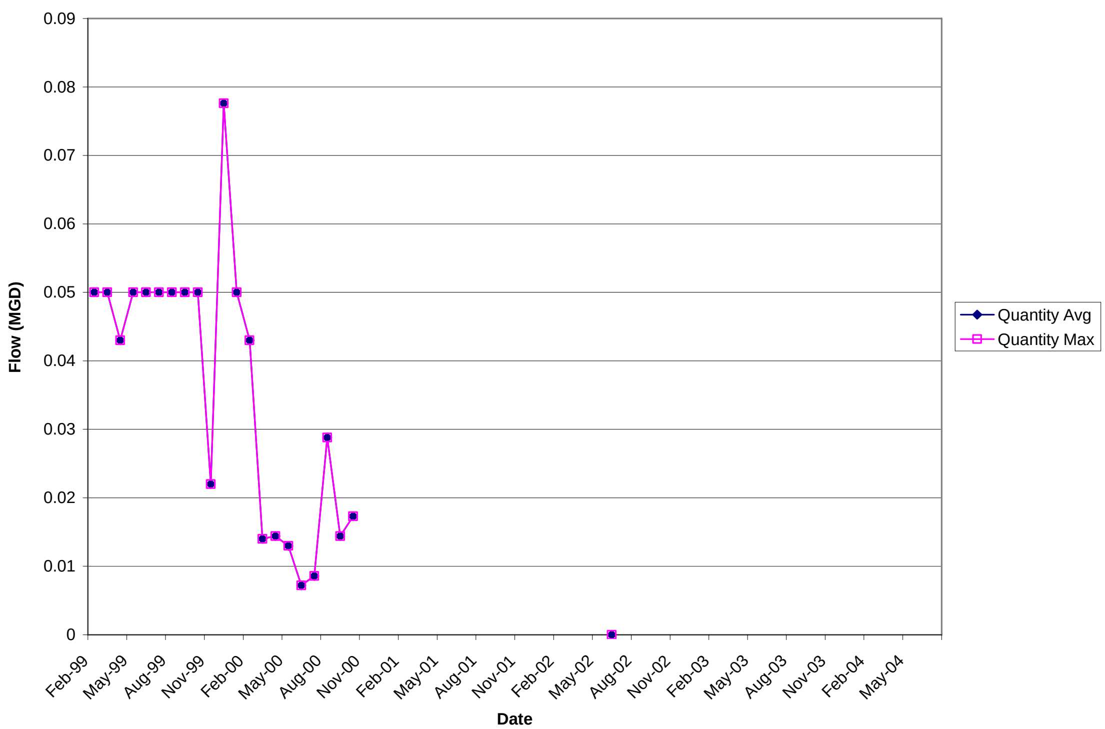


Figure A-9: Roanoke Electric Steel (RES) Corporation (VA0001589 Outfall 5) Average and Maximum Monthly Flow

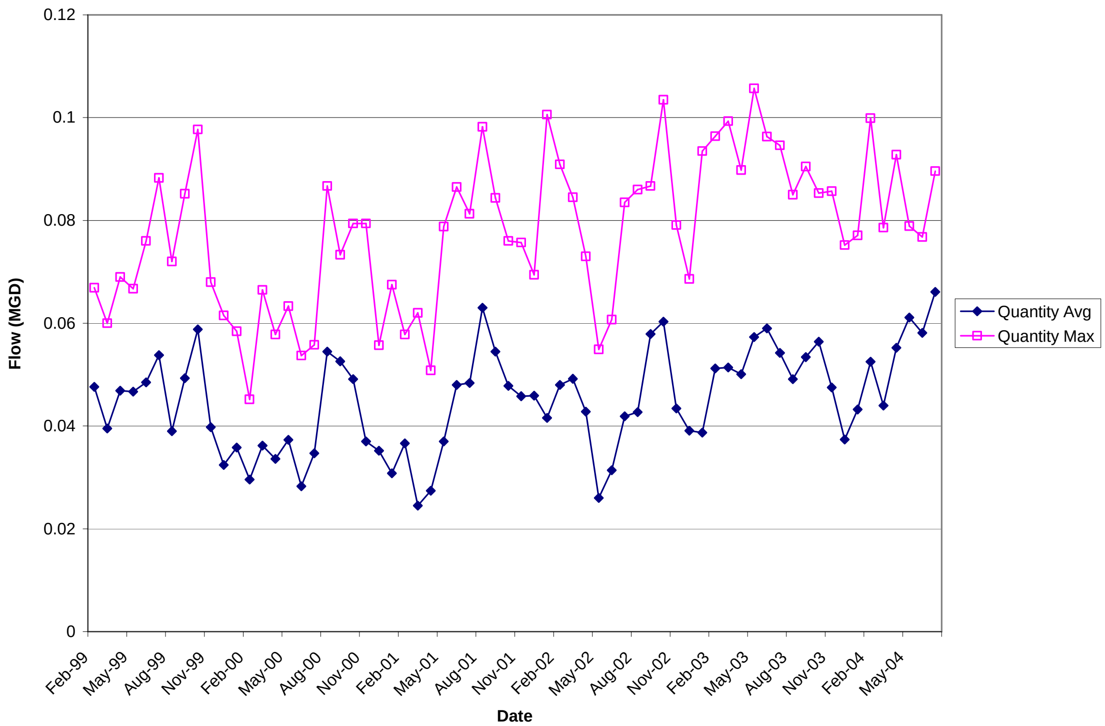


Figure A-10: Norfolk Southern Railway Co - Shaffers Crossing (VA0001597 Outfall 2) Average and Maximum Monthly Flow

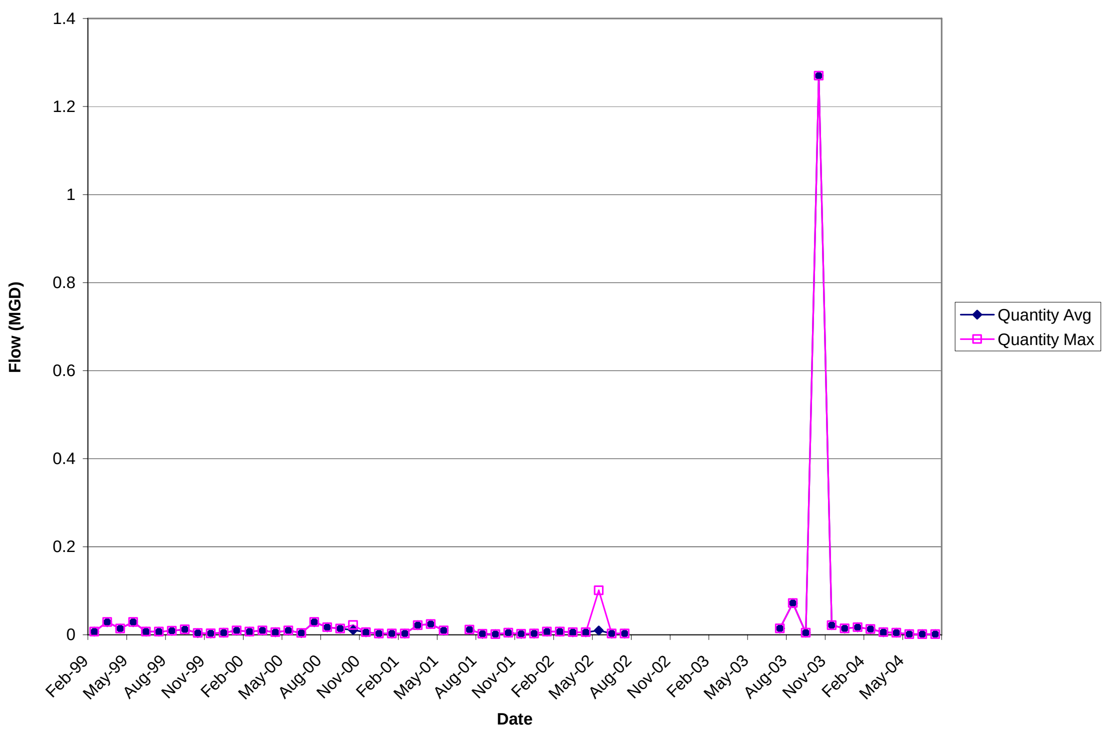
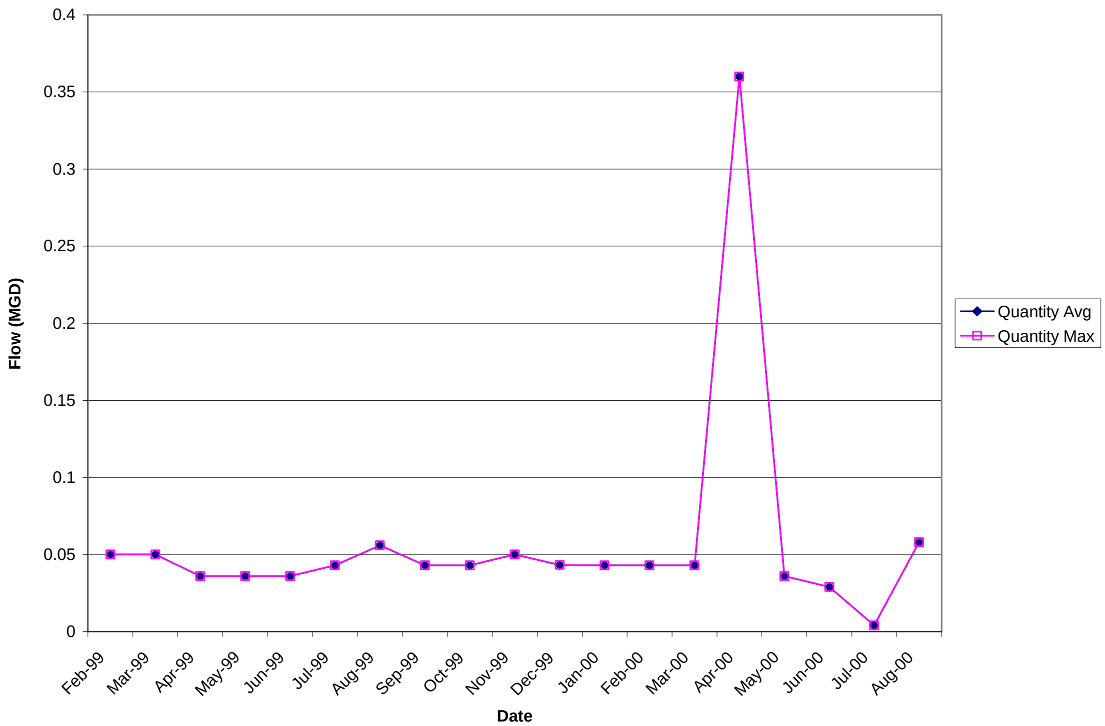


Figure A-11: Norfolk Southern Railway Co - Shaffers Crossing (VA0001597 Outfall 3) Average and Maximum Monthly Flow



FigureA-12: Shawsville Town - Sewage Treatment Plant (VA0024031) Average and Maximum Monthly Flow

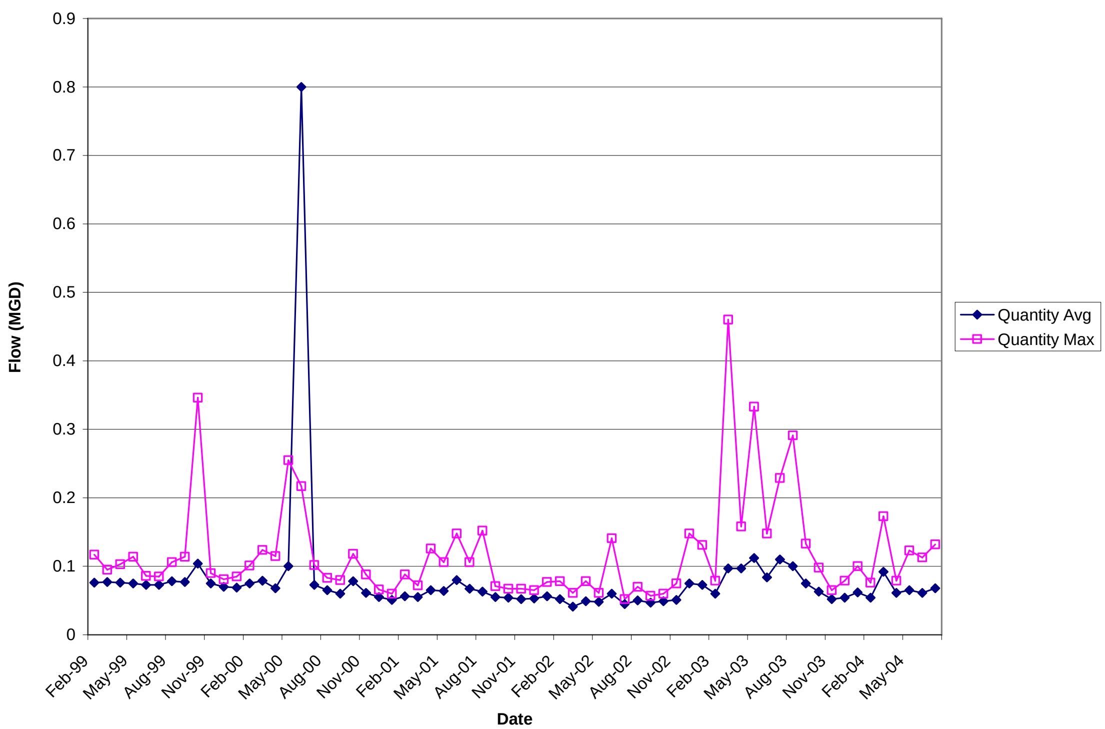


Figure A-13: Western Virginia Water Authority Water Pollution Control Plant (VA0025020) Average and Maximum Monthly Flow

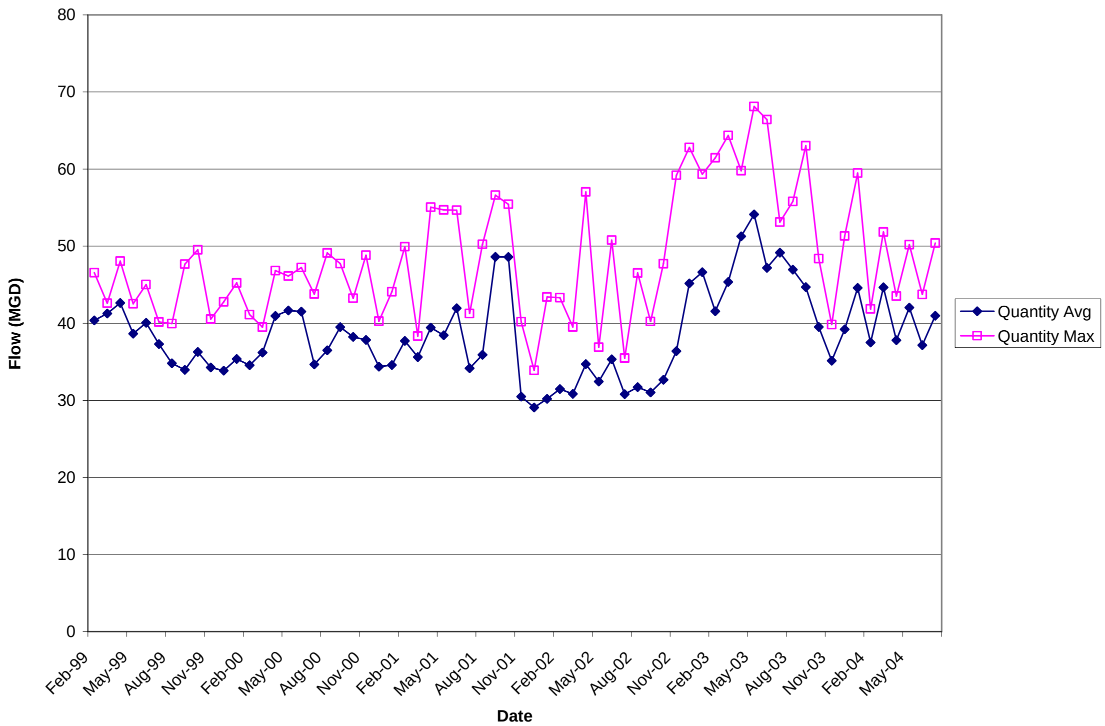
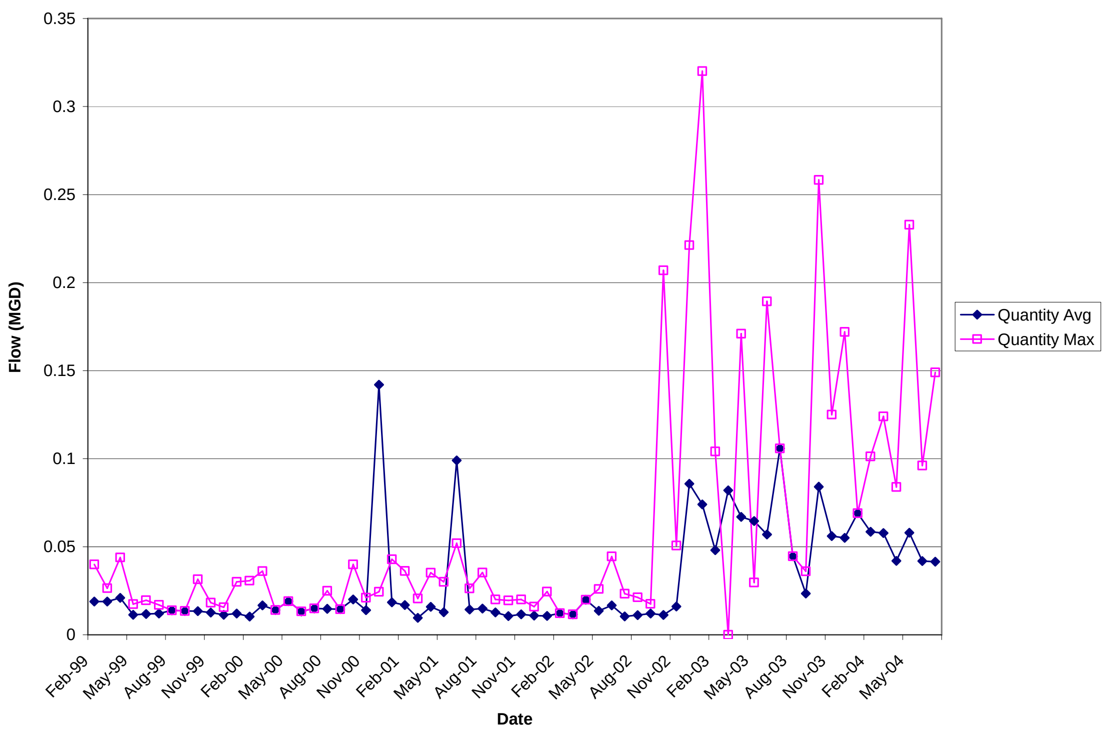


Figure A-14: Blacksburg Country Club Sewage Treatment Plant (VA0027481) Average and Maximum Monthly Flow



FigureA-15: Suncrest Heights (VA0028711) Average and Maximum Monthly Flow

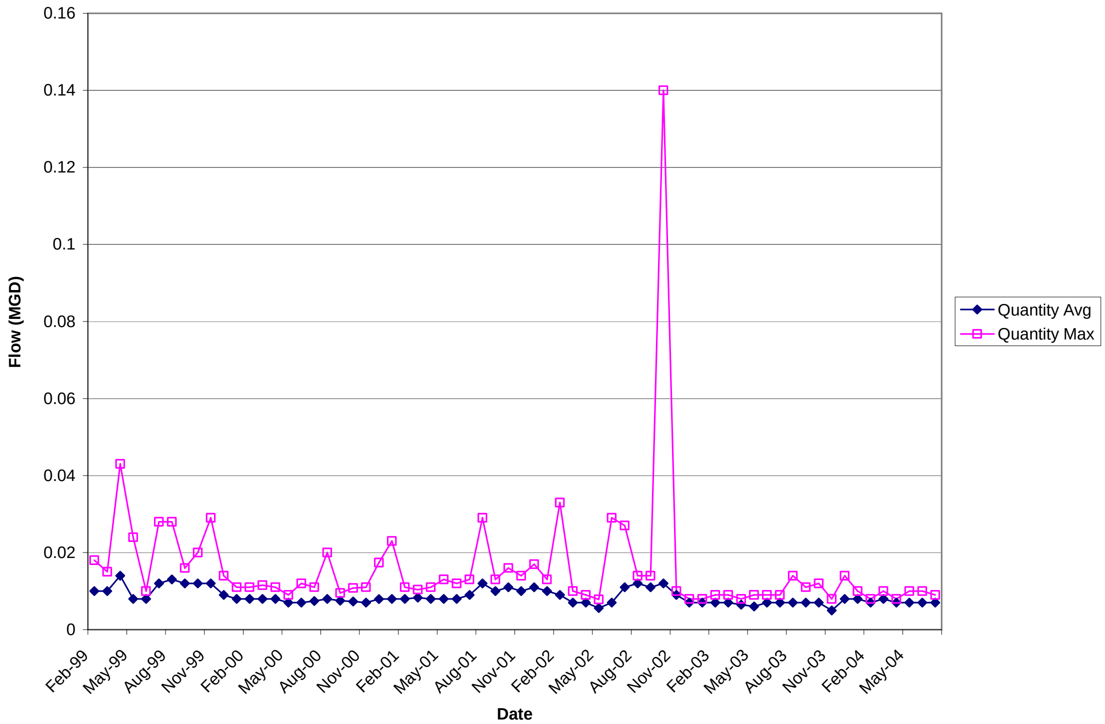


Figure A-16: Montgomery County PSA - Elliston-Lafayette WWTP (VA0062219) Average and Maximum Monthly Flow

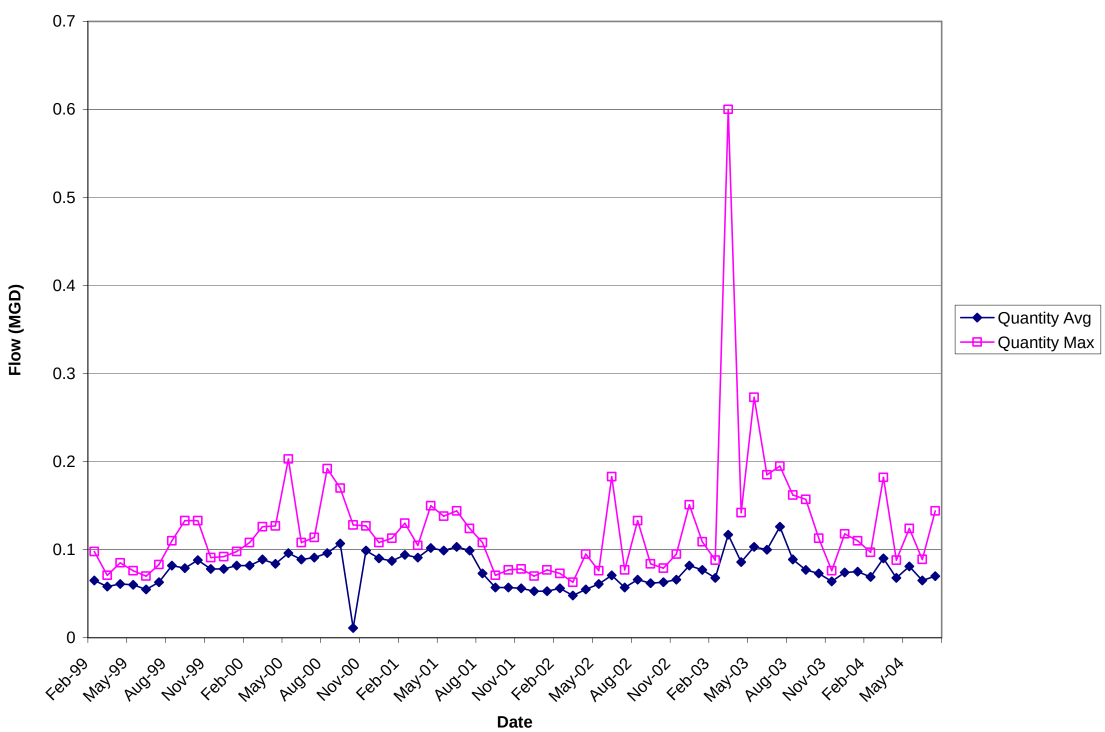


Figure A-17: Roanoke Moose Lodge (VA0077895) Average and Maximum Monthly Flow

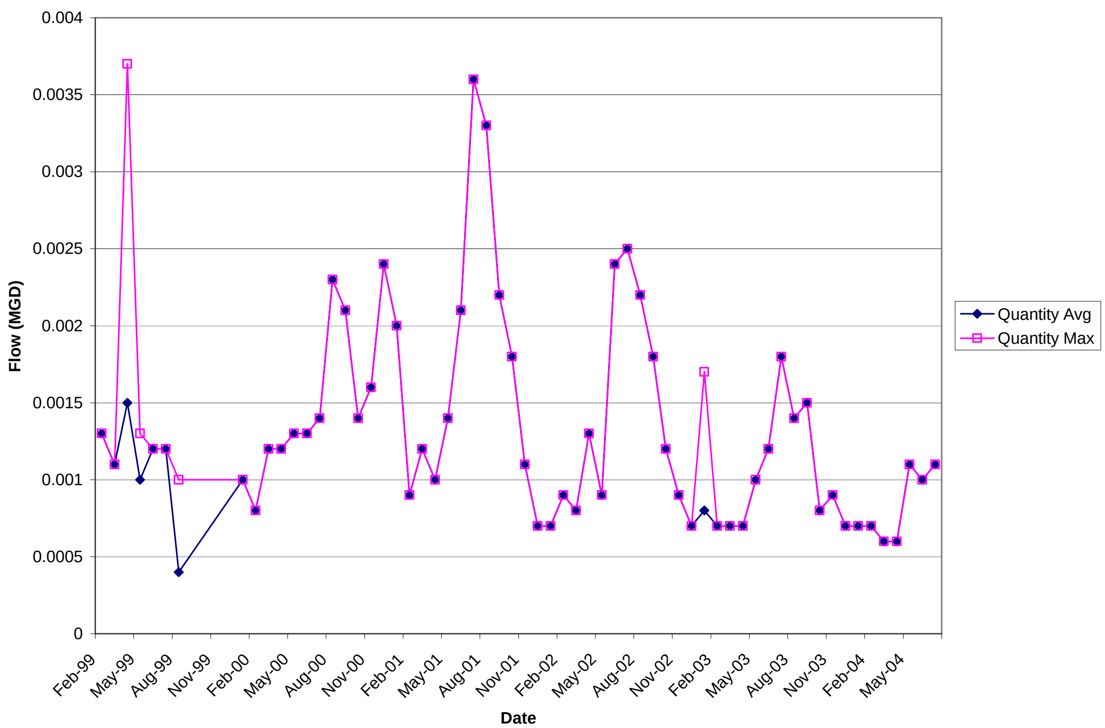


Figure A-18: Marathon Ashland - Roanoke Terminal (VA0086541) Average and Maximum Monthly Flow

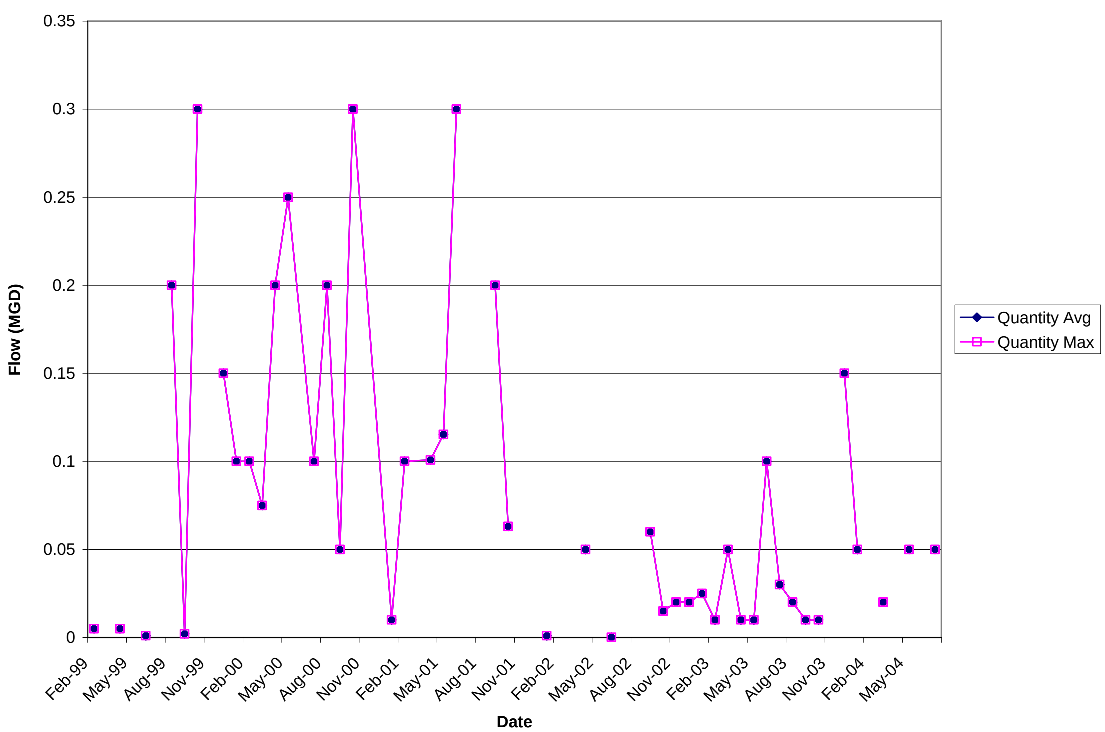


Figure A-19: American Electric Power - Niagara Hydro Plant (VA0087092 Outfall 1) Average and Maximum Monthly Flow

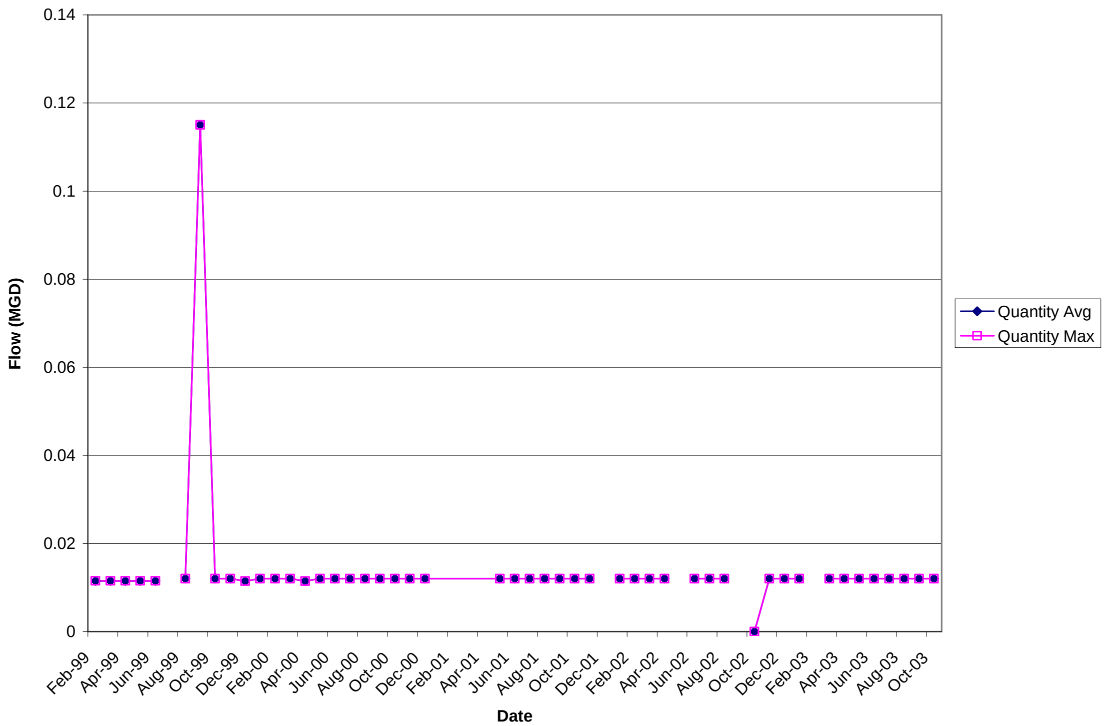


Figure A-20: American Electric Power - Niagara Hydro Plant (VA0087092 Outfall 2) Average and Maximum Monthly Flow

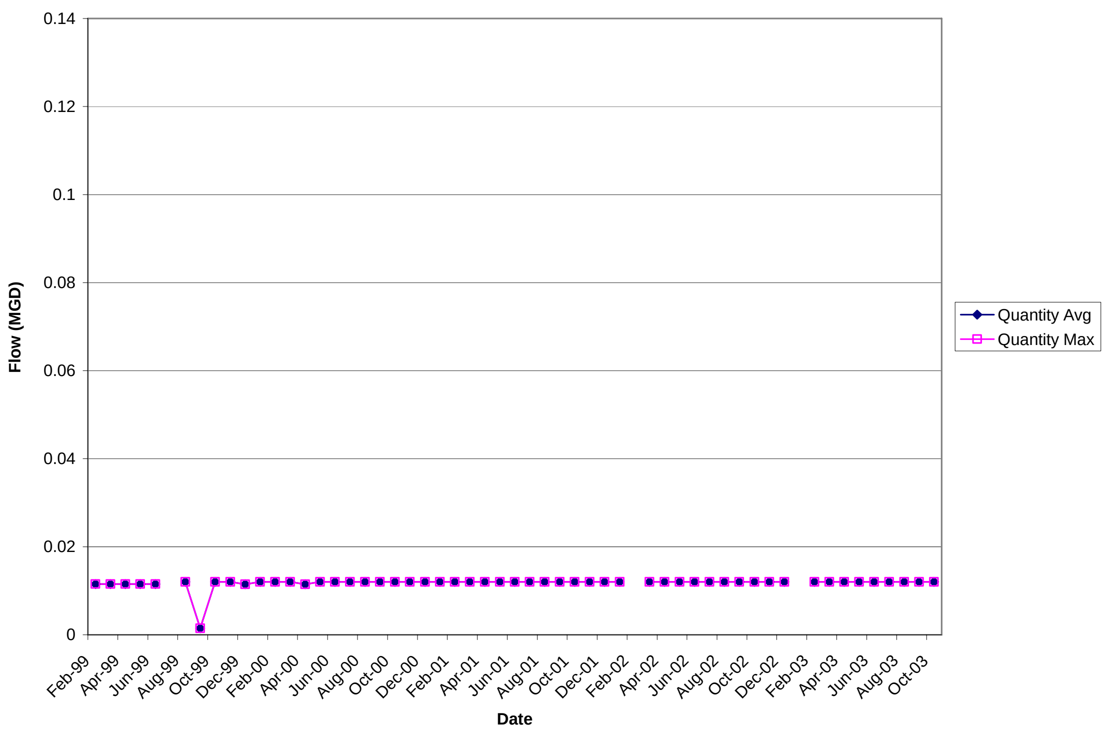


Figure A-21: Fred Whitaker Co (VA0088358) Average and Maximum Monthly Flow

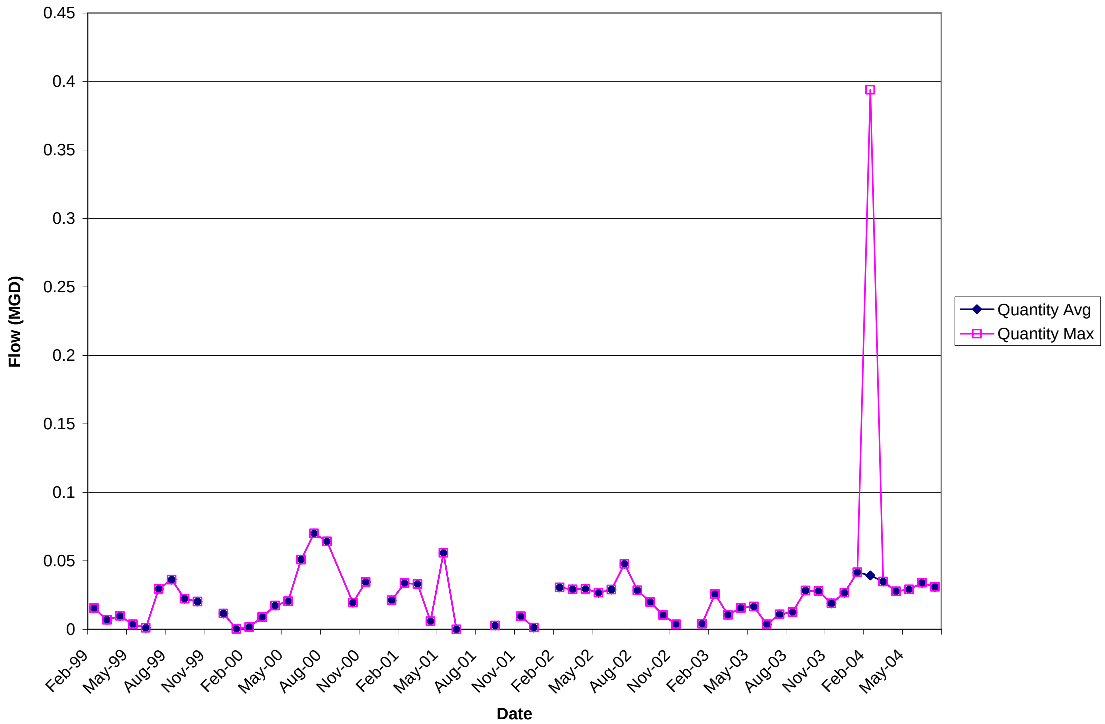


Figure A-22: Crystal Springs WTP (VA0091065) Average and Maximum Monthly Flow

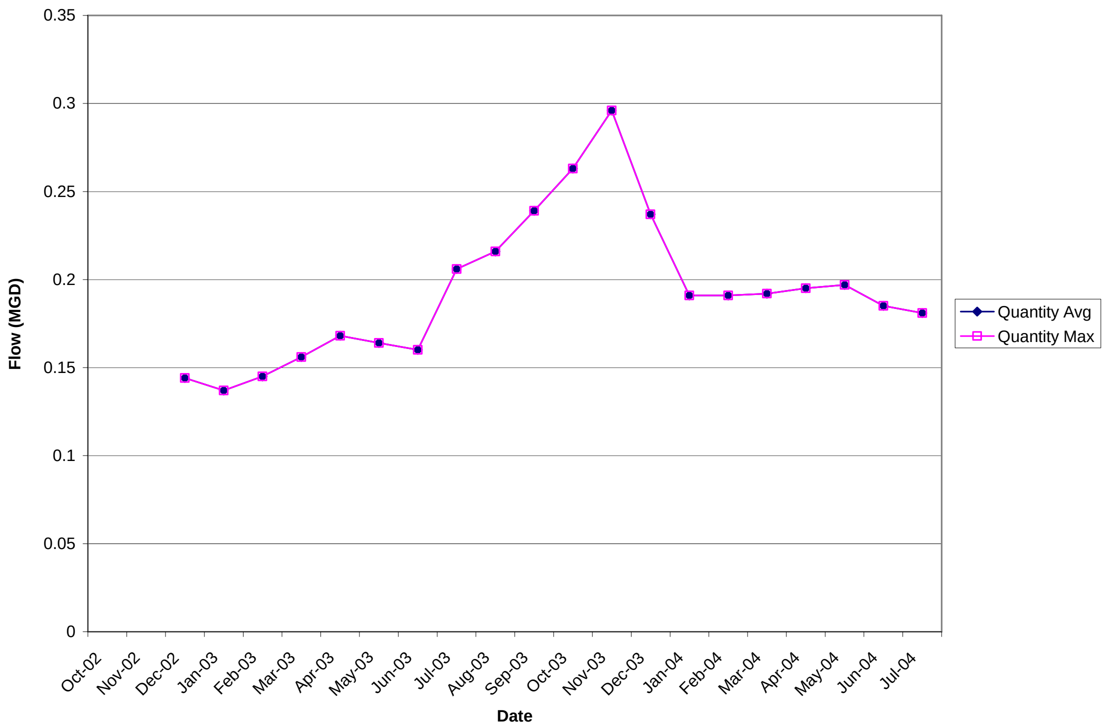


Figure A-23: Shawsville Town - Sewage Treatment Plant (VA0024031) Average Monthly Fecal Coliform Concentration

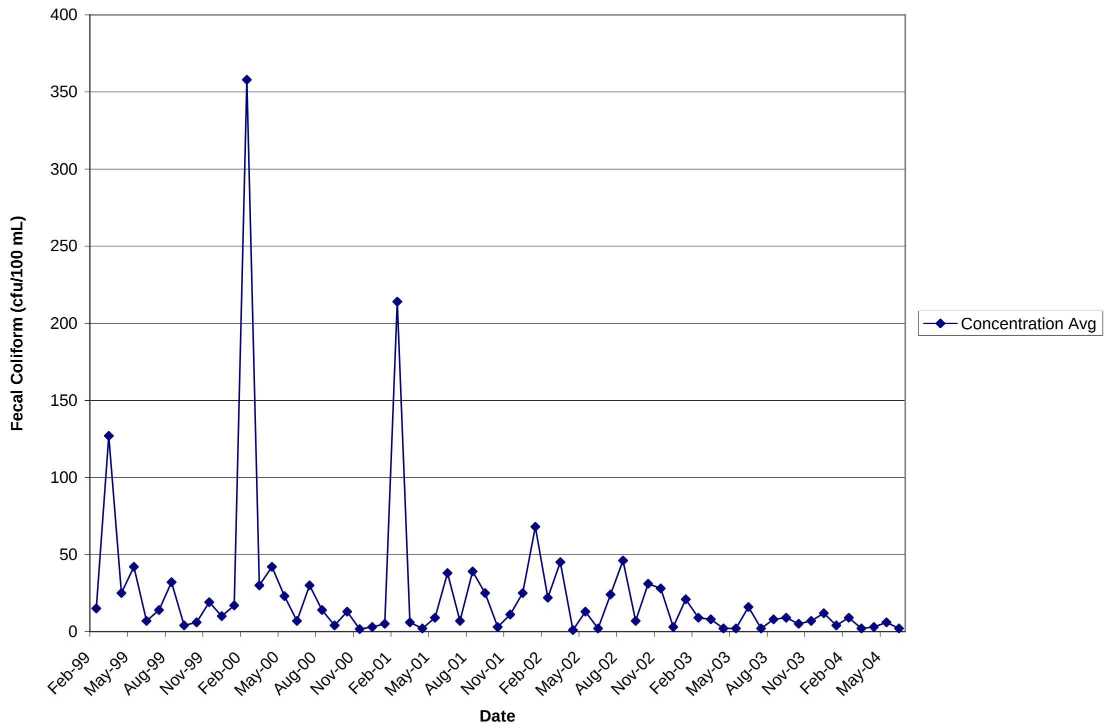


Figure A-24: Western Virginia Water Authority Water Pollution Control Plant (VA0025020) Average Monthly Fecal Coliform Concentration

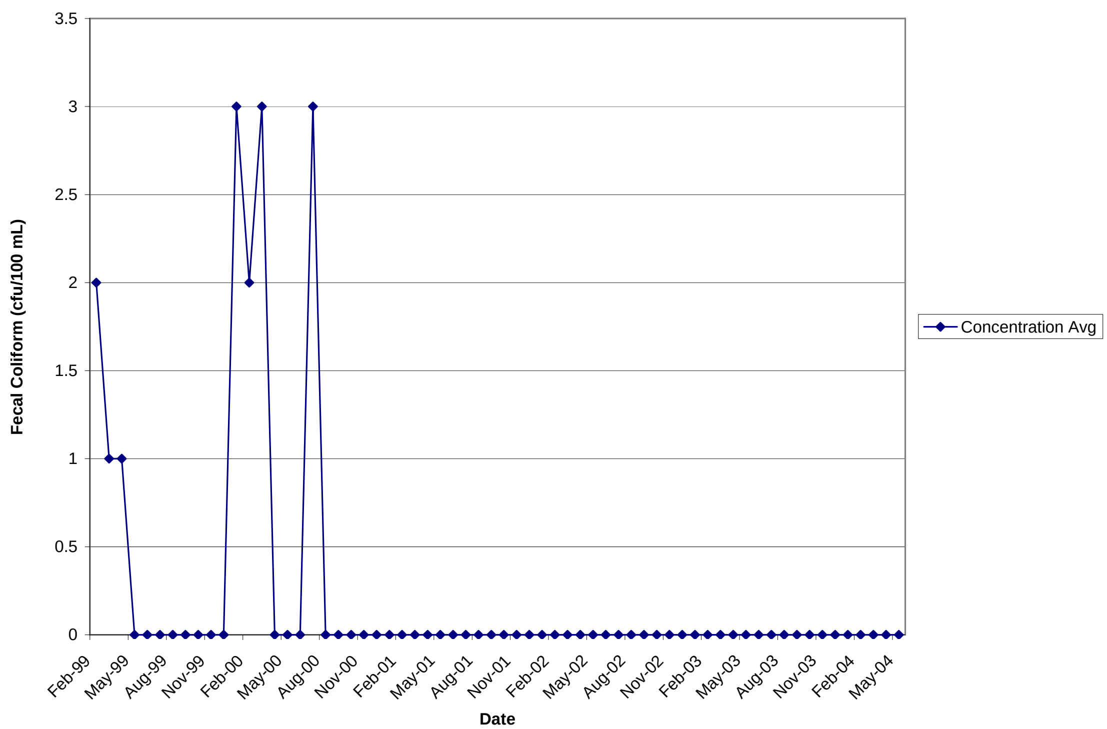


Figure A-25: Western Virginia Water Authority Water Pollution Control Plant (VA0025020) Minimum Monthly Total Contact Chlorine Concentration

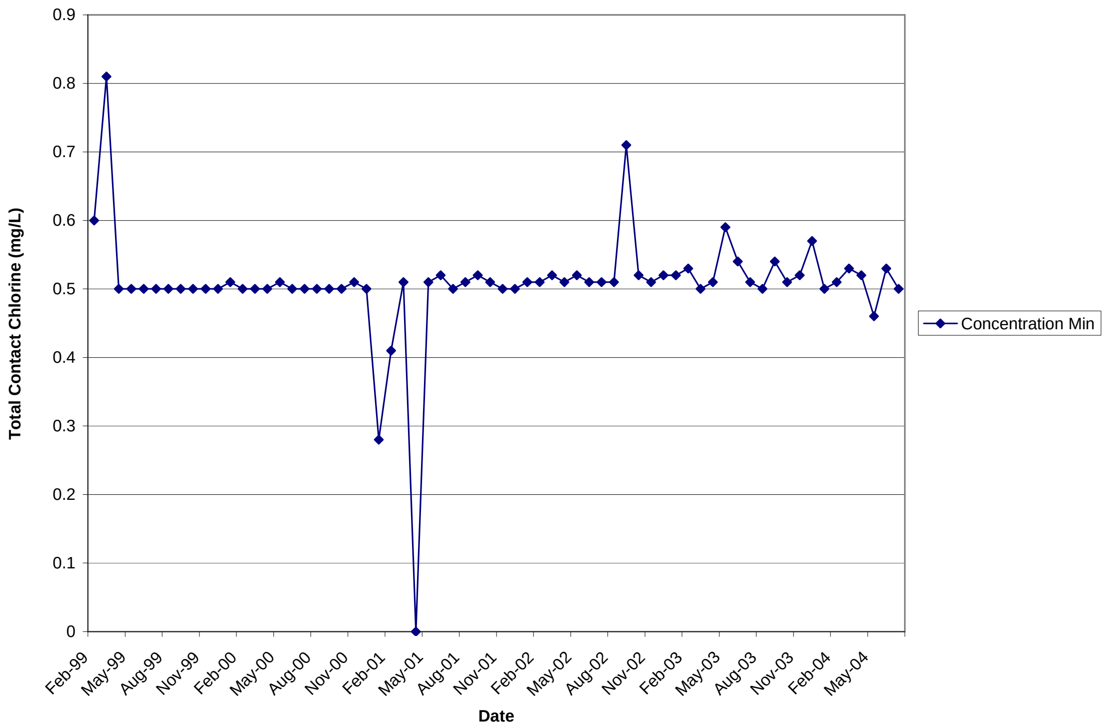


Figure A-26: Blacksburg Country Club Sewage Treatment Plant (VA0027481) Minimum Monthly Total Contact Chlorine Concentration

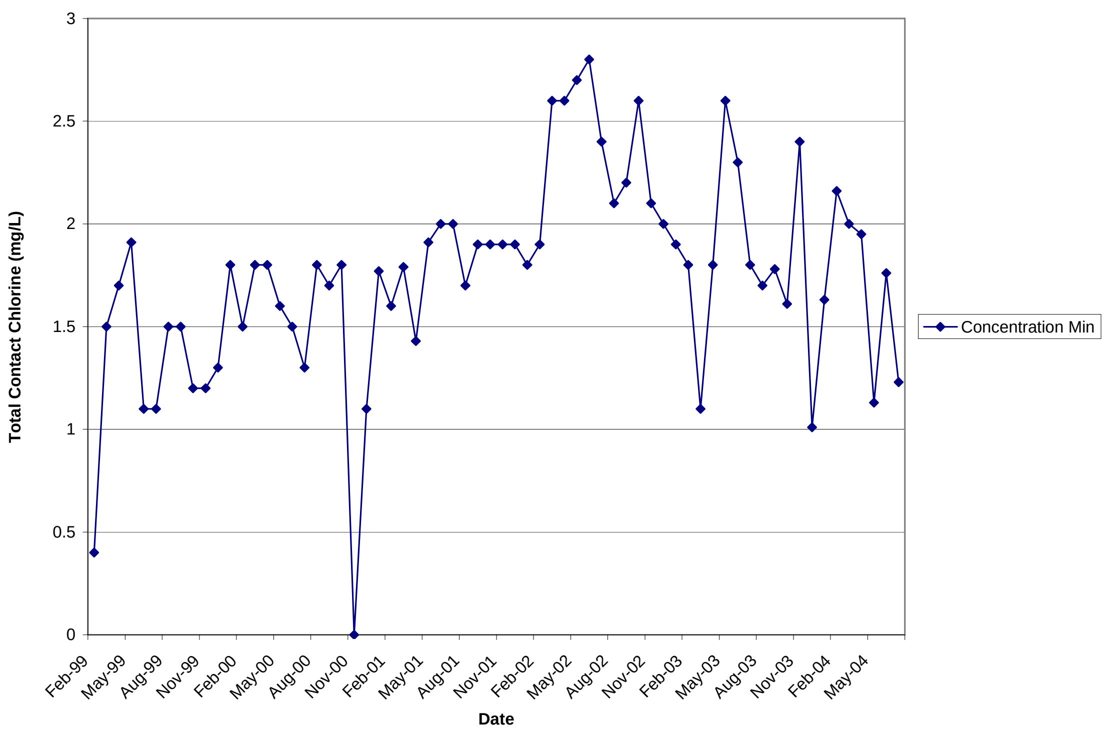


Figure A-27: Suncrest Heights (VA0028711) Minimum Monthly Total Contact Chlorine Concentration

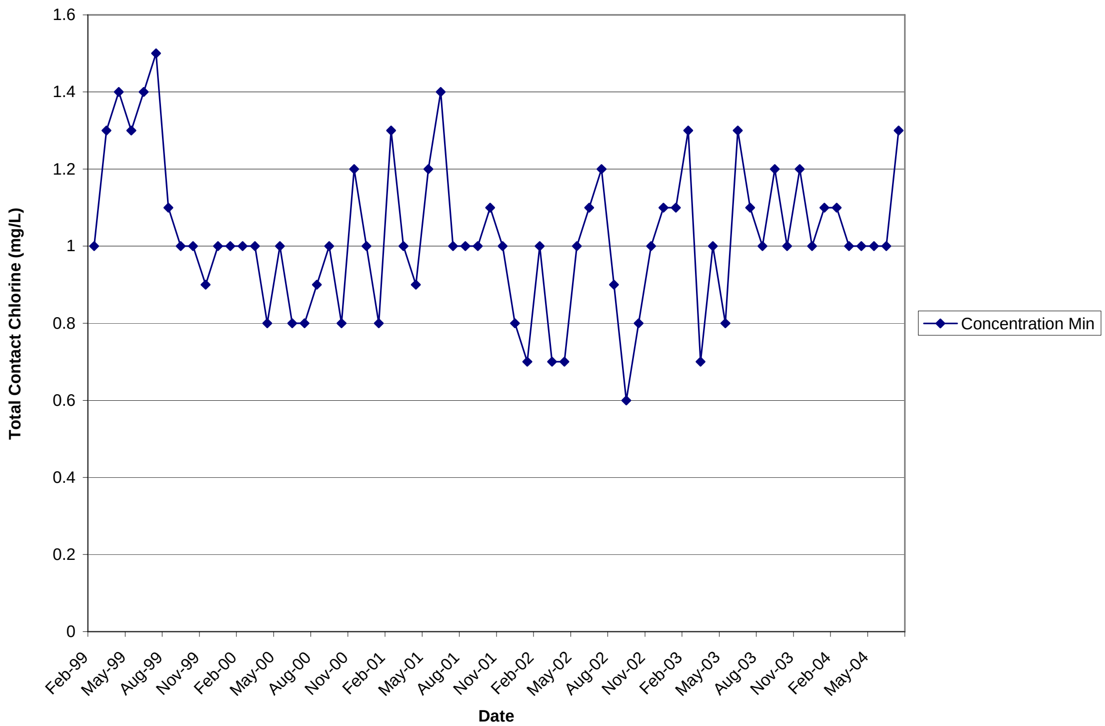


Figure A-28: Montgomery County PSA - Elliston-Lafayette WWTP (VA0062219) Minimum Monthly Total Contact Chlorine Concentration

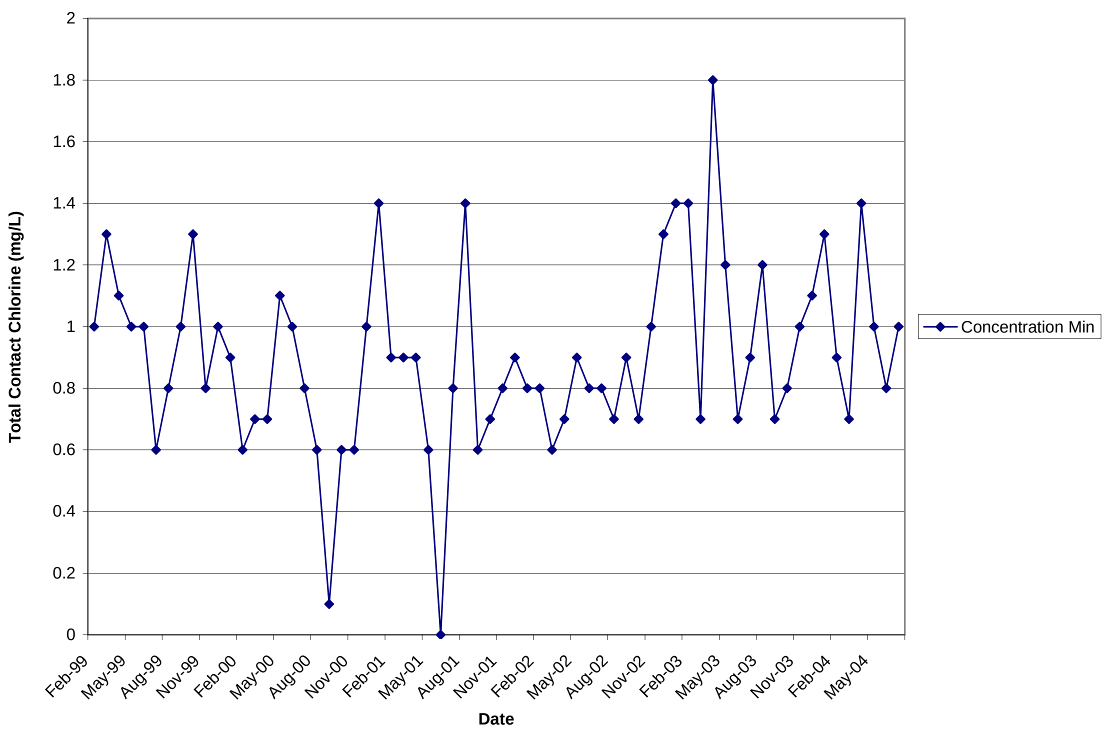
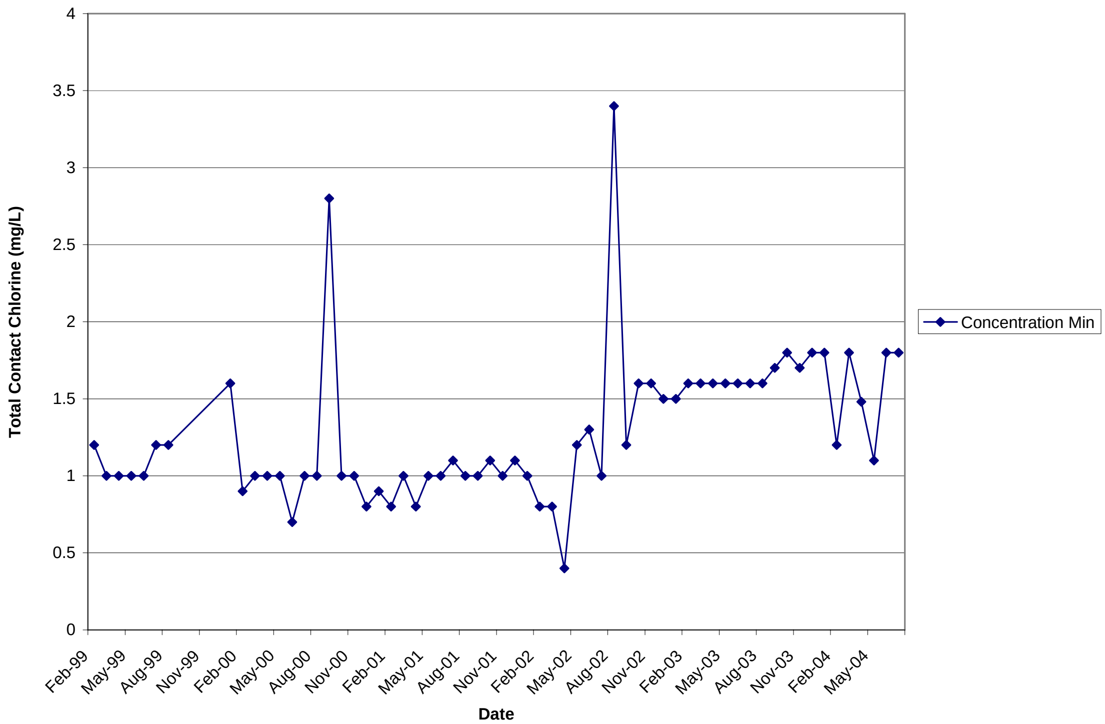
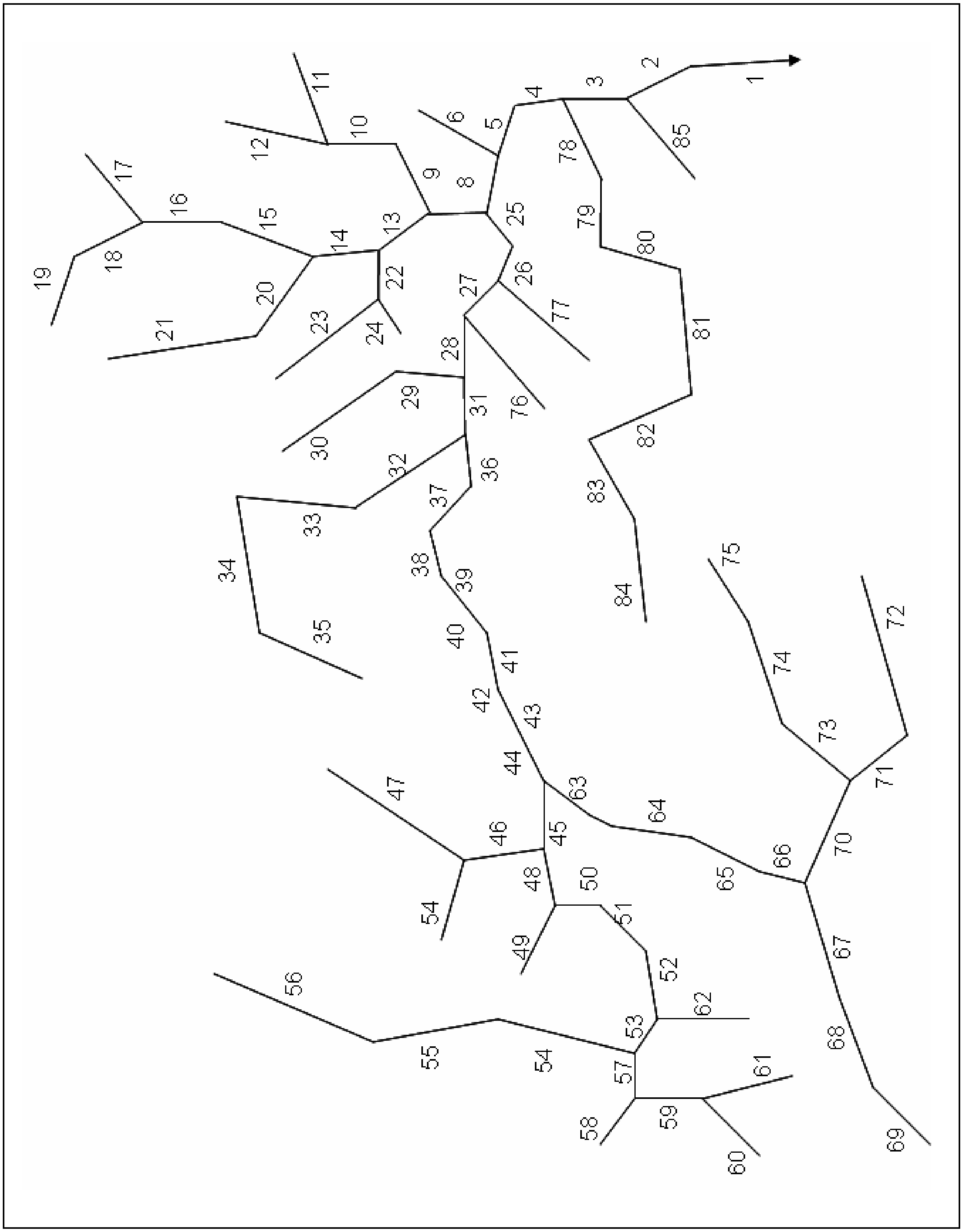


Figure A-29: Roanoke Moose Lodge (VA0077895) Minimum Monthly Total Contact Chlorine Concentration



Appendix B

Model Representation of Stream Reach Networks



Model Representation of Roanoke River
Model Stream Network

Appendix C

Monthly Fecal Coliform Build-up Rates

Table C-1: Roanoke River Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	4.47E+07	4.47E+07	4.47E+07	4.47E+07	4.47E+07	4.47E+07
Cropland	4.20E+07	2.60E+09	2.40E+09	4.90E+09	1.60E+09	4.20E+09
Pasture	5.30E+09	5.40E+09	5.40E+09	5.50E+09	5.40E+09	5.50E+09
Low Intensity Residential	2.47E+10	2.47E+10	2.47E+10	2.47E+10	2.47E+10	2.47E+10
Comm/Ind/Trnsprt	2.43E+08	4.38E+08	2.43E+08	2.43E+08	2.43E+08	2.43E+08
Other	5.80E+05	1.04E+06	5.80E+05	5.80E+05	5.80E+05	5.80E+05

Table C-2: Roanoke River Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	4.47E+07	4.47E+07	4.47E+07	4.47E+07	4.47E+07	4.47E+07
Cropland	1.60E+09	4.20E+09	2.40E+09	4.90E+09	2.60E+09	4.20E+07
Pasture	5.40E+09	5.50E+09	5.40E+09	5.60E+09	5.50E+09	5.30E+09
Low Intensity Residential	2.47E+10	2.47E+10	2.47E+10	2.47E+10	2.47E+10	2.47E+10
Comm/Ind/Trnsprt	2.43E+08	2.43E+08	2.43E+08	2.43E+08	2.43E+08	2.43E+08
Other	5.80E+05	5.80E+05	5.80E+05	5.80E+05	5.80E+05	5.80E+05

Table C-3: Wilson Creek Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	4.47E+07	4.47E+07	4.47E+07	4.47E+07	4.47E+07	4.47E+07
Cropland	4.20E+07	2.60E+09	2.40E+09	4.90E+09	1.60E+09	4.20E+09
Pasture	5.30E+09	5.40E+09	5.40E+09	5.50E+09	5.40E+09	5.50E+09
Low Intensity Residential	2.47E+10	2.47E+10	2.47E+10	2.47E+10	2.47E+10	2.47E+10
Comm/Ind/Trnsprt	2.43E+08	4.38E+08	2.43E+08	2.43E+08	2.43E+08	2.43E+08
Other	5.80E+05	1.04E+06	5.80E+05	5.80E+05	5.80E+05	5.80E+05

Table C-4: Wilson Creek Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	4.47E+07	4.47E+07	4.47E+07	4.47E+07	4.47E+07	4.47E+07
Cropland	1.60E+09	4.20E+09	2.40E+09	4.90E+09	2.60E+09	4.20E+07
Pasture	5.40E+09	5.50E+09	5.40E+09	5.60E+09	5.50E+09	5.30E+09
Low Intensity Residential	2.47E+10	2.47E+10	2.47E+10	2.47E+10	2.47E+10	2.47E+10
Comm/Ind/Trnsprt	2.43E+08	2.43E+08	2.43E+08	2.43E+08	2.43E+08	2.43E+08
Other	5.80E+05	5.80E+05	5.80E+05	5.80E+05	5.80E+05	5.80E+05

Table C-5: Ore Branch Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	2.34E+07	2.34E+07	2.34E+07	2.34E+07	2.34E+07	2.34E+07
Cropland	2.33E+07	1.08E+09	9.68E+08	2.02E+09	6.53E+08	1.70E+09
Pasture	4.07E+09	4.40E+09	4.38E+09	4.72E+09	4.31E+09	4.64E+09
Low Intensity Resid.	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10
Comm/Ind/Trnsprt	8.61E+07	8.61E+07	8.61E+07	8.61E+07	8.61E+07	8.61E+07
High Intensity Resid.	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10

Table C-6: Ore Branch Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	2.34E+07	2.34E+07	2.34E+07	2.34E+07	2.34E+07	2.34E+07
Cropland	6.53E+08	1.70E+09	9.68E+08	2.02E+09	1.06E+09	2.33E+07
Pasture	4.32E+09	4.65E+09	4.42E+09	4.74E+09	4.44E+09	4.10E+09
Low Intensity Resid.	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10
Comm/Ind/Trnsprt	8.61E+07	8.61E+07	8.61E+07	8.61E+07	8.61E+07	8.61E+07
High Intensity Resid.	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10

Table C-7 Roanoke River Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	2.32E+13	1.34E+14	1.31E+13
2	2.32E+13	1.21E+14	1.31E+13
3	3.52E+13	1.34E+14	1.31E+13
4	4.71E+13	1.30E+14	1.31E+13
5	4.71E+13	1.34E+14	1.31E+13
6	5.90E+13	1.30E+14	1.31E+13
7	5.90E+13	1.34E+14	1.31E+13
8	5.90E+13	1.34E+14	1.31E+13
9	4.71E+13	1.30E+14	1.31E+13
10	3.52E+13	1.34E+14	1.31E+13
11	3.52E+13	1.30E+14	1.31E+13
12	2.32E+13	1.34E+14	1.31E+13

Table C-8 Wilson Creek Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	1.06E+12	3.78E+12	9.15E+11
2	1.06E+12	3.41E+12	9.15E+11
3	1.62E+12	3.78E+12	9.15E+11
4	2.19E+12	3.66E+12	9.15E+11
5	2.19E+12	3.78E+12	9.15E+11
6	2.75E+12	3.66E+12	9.15E+11
7	2.75E+12	3.78E+12	9.15E+11
8	2.75E+12	3.78E+12	9.15E+11
9	2.19E+12	3.66E+12	9.15E+11
10	1.62E+12	3.78E+12	9.15E+11
11	1.62E+12	3.66E+12	9.15E+11
12	1.06E+12	3.78E+12	9.15E+11

Table C-9 Ore Branch Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	3.20E+10	1.14E+12	2.29E+11
2	3.20E+10	1.03E+12	2.29E+11
3	4.84E+10	1.14E+12	2.29E+11
4	6.47E+10	1.10E+12	2.29E+11
5	6.47E+10	1.14E+12	2.29E+11
6	8.11E+10	1.10E+12	2.29E+11
7	8.11E+10	1.14E+12	2.29E+11
8	8.11E+10	1.14E+12	2.29E+11
9	6.47E+10	1.10E+12	2.29E+11
10	4.84E+10	1.14E+12	2.29E+11
11	4.84E+10	1.10E+12	2.29E+11
12	3.20E+10	1.14E+12	2.29E+11

Appendix D

Monthly Distribution of Fecal Coliform Loading Under Existing and Allocated Conditions

Table D-1: Roanoke River Fecal Coliform Load: Existing Condition (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/ Industrial	Water/ Wetland	Other	High Density Residential
1	4.81E12	3.45E12	1.02E14	2.37E14	5.50E11	3.82E09	6.66E09	1.8411E12
2	3.64E12	4.16E12	7.32E13	1.69E14	3.94E11	3.26E09	5.60E09	1.313E12
3	1.91E12	3.03E12	3.78E13	9.00E13	2.12E11	2.00E09	3.40E09	6.98926E11
4	2.53E12	4.12E12	5.18E13	1.21E14	2.82E11	2.30E09	3.96E09	9.37586E11
5	3.70E12	5.15E12	7.96E13	1.85E14	4.29E11	2.59E09	4.58E09	1.43843E12
6	4.41E12	6.66E12	9.60E13	2.20E14	5.08E11	2.79E09	4.98E09	1.70691E12
7	1.21E12	1.89E12	2.58E13	6.17E13	1.45E11	1.10E09	1.89E09	4.79129E11
8	2.33E12	3.95E12	5.07E13	1.17E14	2.70E11	1.50E09	2.68E09	9.05596E11
9	4.86E12	7.64E12	1.02E14	2.34E14	5.42E11	3.09E09	5.49E09	1.82002E12
10	3.56E11	5.13E11	4.94E12	1.47E13	3.69E10	8.64E08	1.41E09	1.14377E11
11	8.20E11	5.72E11	1.58E13	4.34E13	1.03E11	1.24E09	2.07E09	3.36935E11
12	4.72E11	1.42E10	4.98E12	1.30E13	3.56E10	1.53E09	2.45E09	1.0064E11

Table D-2: Wilson Creek Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/ Industrial	Water/ Wetland	Other	High Density Residential
1	5.77E+10	4.13E+10	1.22E+12	2.85E+12	6.60E+09	4.59E+07	7.99E+07	2.21E+10
2	4.37E+10	4.99E+10	8.79E+11	2.03E+12	4.73E+09	3.91E+07	6.72E+07	1.58E+10
3	2.29E+10	3.64E+10	4.54E+11	1.08E+12	2.54E+09	2.40E+07	4.08E+07	8.39E+09
4	3.03E+10	4.94E+10	6.22E+11	1.45E+12	3.38E+09	2.76E+07	4.75E+07	1.13E+10
5	4.44E+10	6.18E+10	9.55E+11	2.22E+12	5.15E+09	3.11E+07	5.50E+07	1.73E+10
6	5.29E+10	7.99E+10	1.15E+12	2.64E+12	6.10E+09	3.35E+07	5.98E+07	2.05E+10
7	1.45E+10	2.27E+10	3.10E+11	7.40E+11	1.74E+09	1.32E+07	2.27E+07	5.75E+09
8	2.80E+10	4.74E+10	6.08E+11	1.40E+12	3.24E+09	1.80E+07	3.21E+07	1.09E+10
9	5.83E+10	9.17E+10	1.22E+12	2.81E+12	6.50E+09	3.70E+07	6.58E+07	2.18E+10
10	4.27E+09	6.16E+09	5.93E+10	1.77E+11	4.43E+08	1.04E+07	1.69E+07	1.37E+09
11	9.84E+09	6.86E+09	1.89E+11	5.21E+11	1.24E+09	1.49E+07	2.49E+07	4.04E+09
12	5.66E+09	1.71E+08	5.97E+10	1.55E+11	4.27E+08	1.83E+07	2.94E+07	1.21E+09

Table D-3: Wilson Creek Fecal Coliform Load: Existing Condition (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/ Industrial	Water/ Wetland	Other	High Density Residential
1	1.03E+11	9.87E+10	3.71E+12	4.34E+12	3.28E+10	2.94E+07	1.16E+09	3.75E+10
2	9.05E+10	1.33E+11	3.11E+12	3.63E+12	2.75E+10	2.91E+07	1.13E+09	3.13E+10
3	4.73E+10	9.72E+10	1.61E+12	1.93E+12	1.48E+10	1.79E+07	6.86E+08	1.66E+10
4	6.27E+10	1.32E+11	2.20E+12	2.59E+12	1.97E+10	2.05E+07	7.97E+08	2.23E+10
5	9.19E+10	1.65E+11	3.39E+12	3.97E+12	2.99E+10	2.31E+07	9.23E+08	3.42E+10
6	1.09E+11	2.14E+11	4.08E+12	4.71E+12	3.54E+10	2.49E+07	1.00E+09	4.06E+10
7	3.00E+10	6.07E+10	1.10E+12	1.32E+12	1.01E+10	9.77E+06	3.82E+08	1.14E+10
8	5.79E+10	1.27E+11	2.16E+12	2.50E+12	1.88E+10	1.34E+07	5.40E+08	2.16E+10
9	1.21E+11	2.45E+11	4.34E+12	5.03E+12	3.78E+10	2.75E+07	1.11E+09	4.33E+10
10	8.84E+09	1.65E+10	2.10E+11	3.16E+11	2.57E+09	7.70E+06	2.83E+08	2.72E+09
11	2.03E+10	1.83E+10	6.71E+11	9.30E+11	7.22E+09	1.11E+07	4.18E+08	8.02E+09
12	1.17E+10	4.56E+08	2.12E+11	2.78E+11	2.48E+09	1.36E+07	4.94E+08	2.40E+09

Table D-4: Wilson Creek Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/ Industrial	Water/ Wetland	Other	High Density Residential
1	5.15E+08	4.94E+08	1.86E+10	2.17E+10	1.64E+08	1.47E+05	5.78E+06	1.87E+08
2	4.52E+08	6.67E+08	1.56E+10	1.81E+10	1.38E+08	1.45E+05	5.64E+06	1.56E+08
3	2.37E+08	4.86E+08	8.05E+09	9.65E+09	7.38E+07	8.93E+04	3.43E+06	8.32E+07
4	3.14E+08	6.60E+08	1.10E+10	1.29E+10	9.83E+07	1.03E+05	3.99E+06	1.12E+08
5	4.59E+08	8.25E+08	1.69E+10	1.99E+10	1.50E+08	1.16E+05	4.62E+06	1.71E+08
6	5.47E+08	1.07E+09	2.04E+10	2.36E+10	1.77E+08	1.24E+05	5.02E+06	2.03E+08
7	1.50E+08	3.03E+08	5.49E+09	6.62E+09	5.04E+07	4.89E+04	1.91E+06	5.70E+07
8	2.90E+08	6.33E+08	1.08E+10	1.25E+10	9.40E+07	6.70E+04	2.70E+06	1.08E+08
9	6.03E+08	1.23E+09	2.17E+10	2.51E+10	1.89E+08	1.38E+05	5.53E+06	2.17E+08
10	4.42E+07	8.23E+07	1.05E+09	1.58E+09	1.29E+07	3.85E+04	1.42E+06	1.36E+07
11	1.02E+08	9.17E+07	3.36E+09	4.65E+09	3.61E+07	5.53E+04	2.09E+06	4.01E+07
12	5.86E+07	2.28E+06	1.06E+09	1.39E+09	1.24E+07	6.80E+04	2.47E+06	1.20E+07

Table D-5: Ore Branch Fecal Coliform Load: Existing Condition (counts/ month)

Month	Forest	Pasture	Low Density Residential	Commercial/ Industrial	Water/ Wetland	Other
1	3.15E+10	2.89E+11	8.97E+12	2.42E+10	3.41E+06	7.01E+08
2	2.39E+10	2.07E+11	6.40E+12	1.73E+10	2.91E+06	5.89E+08
3	1.25E+10	1.07E+11	3.41E+12	9.31E+09	1.79E+06	3.58E+08
4	1.66E+10	1.47E+11	4.57E+12	1.24E+10	2.05E+06	4.16E+08
5	2.43E+10	2.25E+11	7.01E+12	1.89E+10	2.31E+06	4.82E+08
6	2.89E+10	2.72E+11	8.32E+12	2.23E+10	2.49E+06	5.25E+08
7	7.93E+09	7.30E+10	2.33E+12	6.36E+09	9.77E+05	1.99E+08
8	1.53E+10	1.43E+11	4.41E+12	1.19E+10	1.34E+06	2.82E+08
9	3.19E+10	2.89E+11	8.87E+12	2.38E+10	2.75E+06	5.77E+08
10	2.33E+09	1.40E+10	5.57E+11	1.62E+09	7.70E+05	1.48E+08
11	5.37E+09	4.47E+10	1.64E+12	4.55E+09	1.11E+06	2.18E+08
12	3.09E+09	1.41E+10	4.90E+11	1.56E+09	1.36E+06	2.58E+08

Table D-6: Ore Branch Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Pasture	Low Density Residential	Commercial/ Industrial	Water/ Wetland	Other
1	1.58E+08	1.44E+09	4.49E+10	1.21E+08	1.70E+04	3.51E+06
2	1.19E+08	1.04E+09	3.20E+10	8.67E+07	1.45E+04	2.95E+06
3	6.25E+07	5.35E+08	1.70E+10	4.65E+07	8.93E+03	1.79E+06
4	8.28E+07	7.33E+08	2.28E+10	6.20E+07	1.03E+04	2.08E+06
5	1.21E+08	1.13E+09	3.50E+10	9.44E+07	1.16E+04	2.41E+06
6	1.44E+08	1.36E+09	4.16E+10	1.12E+08	1.24E+04	2.62E+06
7	3.97E+07	3.65E+08	1.17E+10	3.18E+07	4.89E+03	9.97E+05
8	7.65E+07	7.17E+08	2.21E+10	5.93E+07	6.70E+03	1.41E+06
9	1.59E+08	1.44E+09	4.43E+10	1.19E+08	1.38E+04	2.89E+06
10	1.17E+07	6.99E+07	2.79E+09	8.12E+06	3.85E+03	7.40E+05
11	2.69E+07	2.23E+08	8.21E+09	2.28E+07	5.53E+03	1.09E+06
12	1.55E+07	7.04E+07	2.45E+09	7.81E+06	6.80E+03	1.29E+06

Appendix E

Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Potential sources of fecal coliform include non-point (land-based) sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven.

The objective of the sensitivity analysis was to assess the impacts of variation of model calibration parameters on the simulation of flow and the violation of the fecal coliform standard in Roanoke River. For the January 1995 to December 2004 period, the model was run with 110 percent and 90 percent of calibrated values of the parameters. The scenarios that were analyzed include the following:

- 10 percent increase in LZSN
- 10 percent decrease in LZSN
- 10 percent increase in INFILT
- 10 percent decrease in INFILT
- 10 percent increase in AGWRC
- 10 percent decrease in AGWRC
- 10 percent increase in UZSN
- 10 percent decrease in UZSN
- 10 percent increase in INTFW
- 10 percent decrease in INTFW
- 10 percent increase in IRC
- 10 percent decrease in IRC
- 10 percent increase in LZETP
- 10 percent decrease in LZETP

The modeled flows for different sensitivity runs were compared with observed flows at the gage and the coefficients of determination of the hydrologic sensitivity analysis are presented in Table D-1. Based on these tables it can be seen that the calibration parameters affect the coefficient of determination in the decreasing order of UZSN, INTFW, LZSN, INFILT, AGWRC, IRC and LZETP.

The sensitivity analysis was also performed for two water quality parameters, WSQOP and FSTDEC, by simulating the fecal coliform concentrations for 120 percent and 80 percent of their calibrated values. The rate of violation of the Monthly Geometric Mean Water Quality Standard was determined for each scenario and compared with the rate of violation under the water quality calibration run. The changes in the rate of violation are presented in Table D-2. The results of the sensitivity analysis show that WSQOP has a more pronounced effect on the violation of the water quality standards than FSTDEC.

Table E-1: Sensitivity Analysis: Variation in Coefficient of Determination With Respect to Variation in Parameters For Simulation Period 1995-2004

Parameter	Coefficient of Determination	
	+10% change in parameter	-10% change in parameter
LZSN	0.855	0.855
INFILT	0.857	0.852
AGWRC	0.818	0.852*
UZSN	0.855	0.854
INTFW	0.857	0.850
IRC	0.855	0.854
LZETP	0.856	0.854
Calibrated Parameters 0.858		

* Used 0.999 instead of 1.045 because the valid range for the parameter is 0-0.999

Table E-2: Sensitivity Analysis: Change in Violation Rate From 20% Change in Calibration Parameter Values

Segment #	WSQOP		FSTDEC	
	+20%	-20%	+20%	-20%
Roanoke River (Seg. No. 1)	0.0%	0.0%	0.0%	0.0%
Wilson Creek (Seg. No. 57)	0.0%	0.0%	0.0%	0.0%
Ore Branch (Seg. No. 77)	0.0%	1.4%	0.0%	0.0%

Appendix F

Estimation of E. coli Load Allocations For MS4 Permits

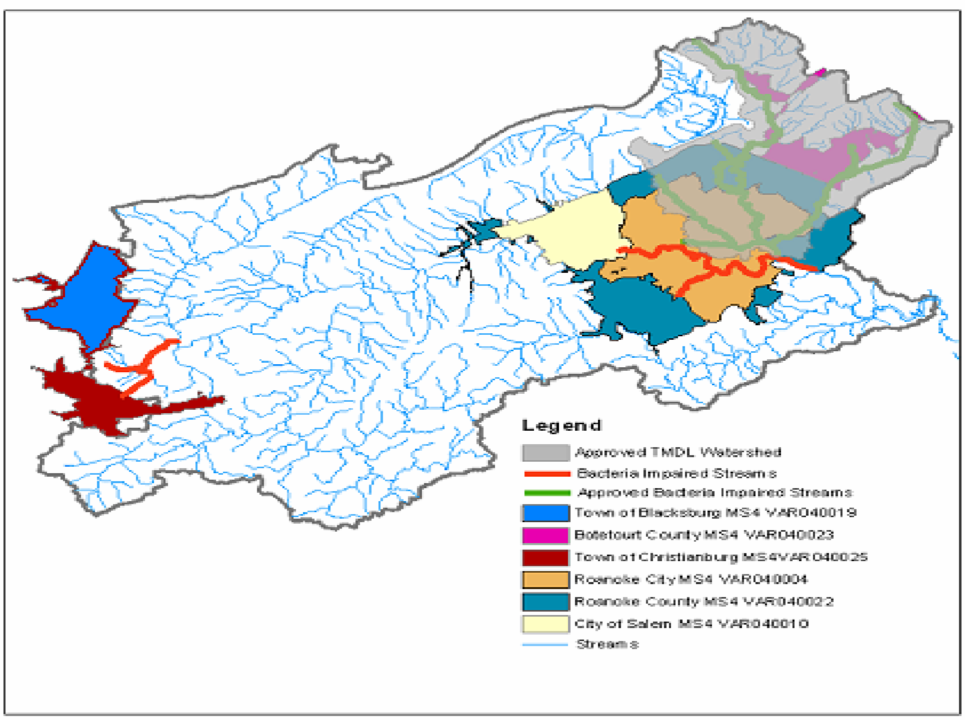
Introduction

This appendix outlines the steps used in the development of the MS4 E. coli allocations for the Wilson Creek, Ore Branch, and the Roanoke River impaired segments. Ten Municipal Separate Storm Sewer (MS4) permits have been issued to Cities, Towns, Counties, and other facilities within the Wilson Creek, Ore Branch, and Roanoke River Watersheds. Table F-1 lists the major MS4 permit holders including the area covered by each individual MS4. Figure F-1 depicts the major MS4 permits as well as the approved TMDLs within the Roanoke River basin.

Table F-1: MS4 Permits Within the Wilson Creek, Ore Branch, and Roanoke River Impairments

MS4 Permit Holder	Permit Number	Area (Acres)
Roanoke County	VAR040022	28,907
City of Roanoke	VAR040004	23,577
Town of Vinton	VAR040026	2,024
City of Salem	VAR040010	9,332
VDOT Roanoke Urban Area	VAR040017	436
Virginia Western Community College	VAR040030	35
Virginia Medical Center	VAR040050	160
VDOT Montgomery County Urban Area	VAR040016	60
Town of Blacksburg	VAR040019	1,613
Town of Christianburg	VAR040025	1,193

Figure F-1: Location of Major MS4 permit Holders



Estimation of the proportion of the MS4 Contributing Urbanized area of the Impairment

Since each MS4 permit drains a particular area, the MS4 acreage specific to each bacteria-impaired stream included in this study (Wilson Creek, Ore Branch, and the Roanoke River) is estimated using GIS. It should be noted that these acreages do not include areas from previously accepted TMDLs (shaded area in Figure F-1). Consequently, these acreages represent the MS4 contributions to each impairment. Tables F-2, F-3, and F-4 depict the specific MS4-acres within the Wilson Creek, Ore Branch, and Roanoke River impairments.

Table F-2: MS4 Acres by Permit Holder within the Wilson Creek Impairment

MS4 Permit Holder	Permit Number	MS4 Acres within the Wilson Creek Impairment
VDOT Montgomery County	VAR040016	60
Town of Blacksburg	VAR040019	161
Town of Christianburg	VAR040025	119

Table F-3: MS4 Acres by Permit Holder within the Ore Branch Impairment

MS4 Permit Holder	Permit Number	MS4 Acres within the Ore Branch Impairment
City of Roanoke	VAR040004	778
VDOT Roanoke Urban Area	VAR040017	16
Roanoke County	VAR040004	41

Table F-4: MS4 Acres by Permit Holder within the Roanoke River Impairment

MS4 Permit Holder	Permit Number	MS4 Acres within the Roanoke River Impairment
Roanoke County	VAR040022	5781
City of Roanoke	VAR040004	3930
Town of Vinton	VAR040026	675
City of Salem	VAR040010	4666
VDOT Roanoke Urban Area	VAR040017	218
Virginia Western Community College	VAR040030	35
Virginia Medical Center	VAR040050	160

Estimation of the Urban E. coli Loading Rate for each impaired stream

Using the modeling results, the E. coli loading rate (cfu/acre-yr) for each impaired segment is estimated using the MS4 acreages and the average E. coli loading rate from the urban land-use categories (low density residential, high density residential, commercial, industrial, and transportation land use categories). This weighted rate represents the E. coli loading rate from each urbanized area of the impairment (Table F-5).

Table F-5: Average Urban NPS E. coli Loading Rates

Impaired segment	Urban NPS E. coli Loading Rate (cfu/acre)
Wilson Creek	3.9E+9
Ore Branch	5.2E+9
Roanoke River	4.1E+9

Calculation of the Existing Conditions Loads for each MS4

The MS4 acreages presented in Tables F-2, F-3, and F-4 and the average urban NPS E. coli loading rates presented in Table F-5 are used to derive the E. coli existing-conditions loads for each MS4 (Tables F-6, F7, and F-8).

Table F-6: Wilson Creek MS4 Existing Conditions E. coli Loads

MS4 Permit Holder	Acres[1]	Average E. coli load (cfu/acre-yr)[2]	Existing Condition Loads (cfu/yr)
Town of Blacksburg	161	3.9E+09	6.29E+11
Town of Christianburg	119	3.9E+09	4.65E+11
VDOT Montgomery County	60	3.9E+09	2.34E+11
		Total	**1.33E+12**

[1] from Table F-2
[2] from Table F-5

Table F-7: Ore Branch MS4 Existing Conditions E. coli Loads

MS4 Permit Holder	Acres[1]	Average E. coli load (cfu/acre-yr)[2]	Existing Condition Loads (cfu/yr)
City of Roanoke	778	5.2E+09	4.04E+12
VDOT Roanoke Urban Area	17	5.2E+09	8.70E+10
Roanoke County	41	5.2E+09	2.13E+11
		Total	**4.35E+12**

[1] from Table F-3
[2] from Table F-5

Table F-8: Roanoke River MS4 Existing Conditions E. coli Loads

MS4 Permit Holder	Acres[1]	Average E. coli load (cfu/acre-yr)[2]	Existing Condition Loads (cfu/yr)
Roanoke County	5781	4.1E+09	2.37E+13
City of Roanoke	3930	4.1E+09	1.61E+13
Town of Vinton	675	4.1E+09	2.77E+12
City of Salem	4666	4.1E+09	1.91E+13
VDOT Roanoke Urban Area	218	4.1E+09	8.94E+11
Virginia Western Community College	35	4.1E+09	1.44E+11
Virginia Medical Center	160	4.1E+09	6.56+11
		Total	**6.34 E+13**

[1] from Table F-4
[2] from Table F-5

Calculation of the Allocations Loads for each MS4

The modeling of the fate and transport of E. coli in each impaired area indicated the reduction from each source and land-use category required to achieve zero percent violations of the standards (Table F-9).

Table F-9: E. coli Load Reductions by Source and Land-Use Category

Watershed	Failed Septic & Pipes	Direct Livestock	NPS (Agri-cultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E. coli Percent violation of Inst. standard 235 #/100ml
Wilson Creek	100%	100%	99.5%	99.5%	90%	0%	0%
Ore Branch	100%	100%	99.5%	99.5%	93%	0%	0%
Roanoke River	100%	100%	98.8%	98.8%	68%	0%	0%

The load reductions for the NPS-urban land-use category (shaded column in Table F-9) are applied to the MS4s existing conditions loads to derive the E. coli load allocations. These are presented in Tables F-10, F-11, and F-12 for the Wilson Creek, Ore Branch and Roanoke River respectively.

Table F-10: Wilson Creek MS4' E. coli Load Allocations

MS4 Permit Holder	Percent Reduction	Existing Condition Loads (cfu/yr)	Allocated Loads (cfu/yr)
Town of Blacksburg	99.5%	6.29E+11	3.15E+09
Town of Christianburg	99.5%	4.65E+11	2.33E+09
VDOT Montgomery County	99.5%	2.34E+11	1.17E+09
	Total	**1.33E+12**	**6.65E+09**

Table F-11: Ore Branch MS4' E. coli Load Allocations

MS4 Permit Holder	Percent Reduction	Existing Condition Loads (cfu/yr)	Allocated Loads (cfu/yr)
City of Roanoke	99.5%	4.04E+12	2.02E+10
VDOT Roanoke Urban Area	99.5%	8.70E+10	4.35E+08
Roanoke County	99.5%	2.13E+11	1.07E+09
	Total	**4.35E+12**	**2.17E+10**

Table F-12: Roanoke River MS4' E. coli Load Allocations

MS4 Permit Holder	Percent Reduction	Existing Condition Loads (cfu/yr)	Allocated Loads (cfu/yr)
Roanoke County	98.8%	2.37E+13	2.84E+11
City of Roanoke	98.8%	1.61E+13	1.93E+11
Town of Vinton	98.8%	2.77E+12	3.32E+10
City of Salem	98.8%	1.91E+13	229E+11
VDOT Roanoke Urban Area	98.8%	8.94E+11	1.07E+10
Virginia Western Community College	98.8%	1.44E+11	1.73E+09
Virginia Medical Center	98.8%	6.56+11	7.87E+09
	Total	**6.34 E+13**	**7.6E+11**