

***Bacteria TMDL Development for the  
Middle Clinch River and Tributaries  
in Virginia***



**Prepared for:**  
**Virginia Department of Environmental Quality**

**Submitted by:**  
**MapTech, Inc.**  
**Modified:**  
**December 2013**



MapTech, Inc.  
3154 State Street  
Blacksburg, VA 24060  
(540) 961-7864



New River Highlands RC&D  
325 East Main St., Suite-E2  
Wytheville, VA 24382

Page intentionally blank

## **ACKNOWLEDGEMENTS**

Virginia Department of Environmental Quality (VADEQ)

VADEQ, Southwest Regional Office

Virginia Department of Conservation and Recreation (VADCR)

Natural Resources Conservation Service

Tazewell Soil & Water Conservation District

Clinch Valley Soil & Water Conservation District

Virginia Department of Health

New River Highlands RC&D

Page intentionally blank

**TABLE OF CONTENTS**

ACKNOWLEDGEMENTS ..... ii

TABLE OF CONTENTS..... iii

FIGURES ..... vii

TABLES ..... xiii

EXECUTIVE SUMMARY ..... xix

1. INTRODUCTION ..... 1-1

    1.1 Regulations Background ..... 1-1

    1.2 Middle Clinch River and Tributaries Watershed Characteristics ..... 1-2

        1.2.1 Nested TMDL Units as Modeling Groups ..... 1-3

    1.3 Middle Clinch River Watershed Recreation Use Impairments..... 1-4

        1.3.1 Clinch River (VAS-P07R\_CLN01A00) ..... 1-5

        1.3.2 Indian Creek (VAS-P05R\_IDN01A04) ..... 1-6

        1.3.3 Weaver Creek (VAS-P07R\_WEA01A06)..... 1-6

        1.3.4 Thompson Creek (VAS-P07R\_TMP01A06) ..... 1-6

        1.3.5 Lewis Creek (VAS-P04R\_LWS01A98) ..... 1-7

        1.3.6 Lewis Creek (VAS-P04R\_LWS01A10) ..... 1-7

        1.3.7 Hess Creek (VAS-P04R\_HES01A10) ..... 1-7

        1.3.8 Swords Creek (VAS-P04R\_SWD01A00) ..... 1-7

        1.3.9 Little River (VAS-P05R\_LTR02A00)..... 1-8

        1.3.10 Little River (VAS-P05R\_LTR02A02)..... 1-8

        1.3.11 Big Cedar Creek (VAS-P06R\_BCD01A98)..... 1-8

        1.3.12 Big Cedar Creek (VAS-P06R\_BCD02A02)..... 1-8

        1.3.13 Big Cedar Creek (VAS-P06R\_BCD02A00)..... 1-9

        1.3.14 Big Cedar Creek (VAS-P06R\_BCD03A00)..... 1-9

        1.3.15 Maiden Spring Creek (VAS-P05R\_MSC01A02)..... 1-9

- 1.3.16 Maiden Spring Creek (VAS-P05R\_MSC01C04) ..... 1-9
- 1.3.17 Loop Creek (VAS-P06R\_LOO01A06)..... 1-9
- 1.3.18 Burgess Creek (VAS-P06R\_BUG01A06) ..... 1-10
- 1.3.19 Elk Garden Creek (VAS-P06R\_EKG01A06)..... 1-10
- 1.3.20 Dumps Creek (VAS-P08R\_DUM01A94) ..... 1-10
- 2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT ..... 2-1
  - 2.1 Applicable Water Quality Standards ..... 2-1
  - 2.2 Selection of a TMDL Endpoint..... 2-2
  - 2.3 Discussion of In-stream Water Quality..... 2-3
- 3. BACTERIA SOURCE ASSESSMENT ..... 3-1
  - 3.1 Assessment of Permitted Sources ..... 3-1
  - 3.2 Assessment of Nonpoint Sources..... 3-5
    - 3.2.1 Private Residential Sewage Treatment ..... 3-6
    - 3.2.2 Biosolids ..... 3-9
    - 3.2.3 Pets..... 3-9
    - 3.2.4 Livestock..... 3-10
    - 3.2.5 Wildlife ..... 3-12
- 4. BACTERIA MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT ..... 4-1
- 5. BACTERIAL ALLOCATION ..... 5-1
  - 5.1 Margin of Safety (MOS)..... 5-2
  - 5.2 Waste Load Allocations (WLAs)..... 5-2
  - 5.3 Load Allocations (LAs) ..... 5-3
  - 5.4 Final Total Maximum Daily Loads (TMDLs) ..... 5-3
- 6. TMDL IMPLEMENTATION AND REASONABLE ASSURANCE..... 6-1
  - 6.1 Continuing Planning Process and Water Quality Management Planning ..... 6-1
  - 6.2 Staged Implementation ..... 6-1

6.3 Implementation of Waste Load Allocations ..... 6-2

    6.3.1 Stormwater..... 6-2

    6.3.2 TMDL Modifications for New or Expanding Discharges ..... 6-3

6.4 Implementation of Load Allocations ..... 6-3

    6.4.1 Implementation Plan Development..... 6-3

    6.4.2 Staged Implementation Scenarios..... 6-4

    6.4.3 Link to Ongoing Restoration Efforts ..... 6-5

    6.4.4 Implementation Funding Sources ..... 6-5

6.5 Follow-Up Monitoring..... 6-6

6.6 Attainability of Designated Uses ..... 6-8

7. PUBLIC PARTICIPATION ..... 7-1

REFERENCES ..... R-1

GLOSSARY ..... G-1

APPENDIX A: FREQUENCY ANALYSIS OF BACTERIA DATA ..... A-1

APPENDIX B CURRENT CONDITIONS OF FECAL COLIFORM LOADS ..... B-1

APPENDIX C BACTERIA MODELING PROCEDURE: LINKING THE  
    SOURCES TO THE ENDPOINT ..... C-1

Page intentionally blank

**FIGURES**

Figure 1.1	Location of the Middle Clinch River watershed.....	1-2
Figure 1.2	The impaired segments, sub-watershed numbers, and NTUs in the Middle Clinch River watershed. ....	1-12
Figure 2.1	Location of VADEQ water quality monitoring stations in the Middle Clinch River Watershed. ....	2-4
Figure 3.1	Permitted Sources in the Middle Clinch River watershed. ....	3-2
Figure 5.1	Existing and allocated monthly geometric mean in-stream <i>E. coli</i> concentrations in the Middle Clinch River Modeling Group .....	5-6
Figure 5.2	Existing and allocated monthly geometric mean in-stream <i>E. coli</i> concentrations in the Big Cedar/Burgess Creek Modeling Group .....	5-13
Figure 5.3	Existing and allocated monthly geometric mean in-stream <i>E. coli</i> concentrations in the Elk Garden/Loop Creek Modeling Group .....	5-19
Figure 5.4	Existing and allocated monthly geometric mean in-stream <i>E. coli</i> concentrations in the Lewis Creek Modeling Group .....	5-25
Figure 5.5	Existing and allocated monthly geometric mean in-stream <i>E. coli</i> concentrations in the Swords/Hess Creek Modeling Group .....	5-30
Figure 5.6	Existing and allocated monthly geometric mean in-stream <i>E. coli</i> concentrations in the Dumps Creek Modeling Group .....	5-36
Figure A. 1	Frequency analysis of <i>E. coli</i> concentrations at station 6BBCD001.89 in Big Cedar Creek for the period from July 2003 to December 2010.....	A-2
Figure A. 2	Frequency analysis of <i>E. coli</i> concentrations at station 6BBCD006.66 in Big Cedar Creek for the period from July 2003 to December 2010.....	A-3
Figure A. 3	Frequency analysis of <i>E. coli</i> concentrations at station 6BBCD009.83 in the Big Cedar Creek for the period from July 2003 to December 2010.....	A-4
Figure A. 4	Frequency analysis of <i>E. coli</i> concentrations at station 6BIDN000.69 in the Indian Creek for the period from January 2007 to January 2011.....	A-5
Figure A. 5	Frequency analysis of <i>E. coli</i> concentrations at station 6BLTR000.75 in the Little River for the period from January 2007 to November 2008.....	A-6

Figure A. 6	Frequency analysis of <i>E. coli</i> concentrations at station 6BLTR018.19 in the Little River for the period from January 2007 to January 2011.	A-7
Figure A. 7	Frequency analysis of <i>E. coli</i> concentrations at station 6BLTR025.45 in the Little River for the period from January 2007 to November 2008.	A-8
Figure A. 8	Frequency analysis of <i>E. coli</i> concentrations at station 6BLWS000.06 in the Lewis Creek for the period from February 2007 to January 2011.	A-9
Figure A. 9	Frequency analysis of <i>E. coli</i> concentrations at station 6BLWS004.84 in the Lewis Creek for the period from February 2007 to January 2011.	A-10
Figure A. 10	Frequency analysis of <i>E. coli</i> concentrations at station 6BMSC001.53 in Maiden Spring Creek for the period from January 2007 to April 2010.	A-11
Figure A. 11	Frequency analysis of <i>E. coli</i> concentrations at station 6BMSC008.98 in Maiden Spring Creek for the period from January 2007 to January 2011.	A-12
Figure A. 12	Frequency analysis of <i>E. coli</i> concentrations at station 6BSWO000.11 in the Swords Creek for the period from April 2009 to January 2011.	A-13
Figure A. 13	Frequency analysis of <i>E. coli</i> concentrations at station 6BSWO001.81 in the Swords Creek for the period from February 2007 to December 2008.	A-14
Figure A. 14	Frequency analysis of <i>E. coli</i> concentrations at station 6BWEA000.02 in the Weaver Creek for the period from August 2003 to December 2010.	A-15
Figure A. 15	Frequency analysis of <i>E. coli</i> concentrations at station 6BWEA004.32 in the Weaver Creek for the period from August 2003 to December 2010.	A-16
Figure A. 16	Frequency analysis of Fecal Coliform concentrations at station 6BBCD004.18 in Big Cedar Creek for the period from May 1994 to March 2001.	A-17
Figure A. 17	Frequency analysis of Fecal Coliform concentrations at station 6BIDN000.69 in Indian Creek for the period from August 2001 to June 2003.	A-18
Figure A. 18	Frequency analysis of Fecal Coliform concentrations at station 6BLTR000.75 in the Little River for the period from September 1995 to June 2003.	A-19

Figure A. 19 Frequency analysis of Fecal Coliform concentrations at station 6BLTR003.00 in the Little River for the period from January 1990 to March 1994. .... A-20

Figure A. 20 Frequency analysis of Fecal Coliform concentrations at station 6BLTR018.19 in the Little River for the period from August 2001 to June 2003. .... A-21

Figure A. 21 Frequency analysis of Fecal Coliform concentrations at station 6BWS000.06 in Lewis Creek for the period from August 2001 to June 2003. .... A-22

Figure A. 22 Frequency analysis of Fecal Coliform concentrations at station 6BMSC001.53 in Maiden Spring Creek for the period from August 2001 to June 2003. .... A-23

Figure A. 23 Frequency analysis of Fecal Coliform concentrations at station 6BMSC008.98 in Maiden Spring Creek for the period from August 2001 to March 2007. .... A-24

Figure C. 1 All subwatersheds delineated for modeling in the Middle Clinch River watershed study area. .... C-4

Figure C. 2 Land uses in the Middle Clinch River watershed study area. .... C-7

Figure C. 3 Stream profile representation in HSPF. .... C-10

Figure C. 4 Fecal and *E. coli* bacteria concentrations at 6BCLN271.50 on the Middle Clinch River versus discharge at USGS Gaging Station # 03524000. .... C-12

Figure C. 5 Fecal and *E. coli* bacteria concentrations at 6BIDN000.69 on Indian Creek versus discharge at USGS Gaging Station # 03524000. .... C-12

Figure C. 6 Fecal and *E. coli* bacteria concentrations at 6BLTR000.75 on Little River versus discharge at USGS Gaging Station # 03524000. .... C-13

Figure C. 7 Fecal and *E. coli* bacteria concentrations at 6BLWS000.06 on Lewis Creek versus discharge at USGS Gaging Station # 03524000. .... C-13

Figure C. 8 Fecal and *E. coli* bacteria concentrations at 6BMSC008.98 on Maiden Springs Creek versus discharge at USGS Gaging Station # 03524000. .... C-14

Figure C. 9 Fecal and *E. coli* bacteria concentrations at 6BLTR018.19 on Little River versus discharge at USGS Gaging Station # 03524000. .... C-14

Figure C. 10 *E. coli* bacteria concentrations at 6BBCD001.89 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000. .... C-15

Figure C. 11 *E. coli* bacteria concentrations at 6BBCD006.66 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000. .... C-15

Figure C. 12 Fecal bacteria concentrations at 6BBCD004.18 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000. .... C-16

Figure C. 13 *E. coli* bacteria concentrations at 6BBCD009.83 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000. .... C-16

Figure C. 14 *E. coli* bacteria concentrations at 6BDUM000.04 on the Dumps Creek versus discharge at USGS Gaging Station # 03524000. .... C-17

Figure C. 15 *E. coli* bacteria concentrations at 6BEKG004.18 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000. .... C-17

Figure C. 16 *E. coli* bacteria concentrations at 6BEKG008.48 on Elk Garden Creek versus discharge at USGS Gaging Station # 03524000. .... C-18

Figure C. 17 *E. coli* bacteria concentrations at 6BLOO004.25 on Loop Creek versus discharge at USGS Gaging Station # 03524000..... C-18

Figure C. 18 *E. coli* bacteria concentrations at 6BLOO006.03 on Loop Creek watershed versus discharge at USGS Gaging Station # 03524000..... C-19

Figure C. 19 *E. coli* bacteria concentrations at 6BLTR025.45 on Little River versus discharge at USGS Gaging Station # 03524000..... C-19

Figure C. 20 *E. coli* bacteria concentrations at 6BLWS004.84 on the Lewis Creek versus discharge at USGS Gaging Station # 03524000. .... C-20

Figure C. 21 *E. coli* bacteria concentrations at 6BSWO000.11 on Swords Creek versus discharge at USGS Gaging Station # 03524000. .... C-20

Figure C. 22 *E. coli* bacteria concentrations at 6BSWO001.81 on Swords Creek versus discharge at USGS Gaging Station # 03524000. .... C-21

Figure C. 23 *E. coli* bacteria concentrations at 6BTMP003.58 on Thompson Creek versus discharge at USGS Gaging Station # 03524000. .... C-21

Figure C. 24 *E. coli* bacteria concentrations at 6BWEA000.02 on the Weaver Creek versus discharge at USGS Gaging Station # 03524000. .... C-22

Figure C. 25 *E. coli* bacteria concentrations at 6BWEA004.32 on Weaver Creek versus discharge at USGS Gaging Station # 03524000. .... C-22

Figure C. 26 Modeling time periods, annual historical flow (USGS Station 03524000), and precipitation (Station 447174/444777/440021) data..... C-24

Figure C. 27 Modeling time periods, seasonal historical flow (USGS Station 03524000), and precipitation (Station 447174/444777/440021) data..... C-24

Figure C. 28 Example of raccoon habitat layer in the Middle Clinch River watershed study area, as developed by MapTech..... C-31

Figure C. 29 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the in-stream first-order decay rate (FSTDEC)..... C-38

Figure C. 30 Results of sensitivity analysis on monthly mean concentrations as affected by changes in maximum fecal accumulation on land (MON-SQOLIM)..... C-39

Figure C. 31 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the wash-off rate from land surfaces (WSQOP)..... C-40

Figure C. 32 Results of total loading sensitivity analysis for outlet of the Middle Clinch River and Tributaries Watershed study area..... C-41

Figure C. 33 Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle Clinch River and Tributaries Watershed study area, as affected by changes in land-based loadings. .... C-42

Figure C. 34 Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle Clinch River and Tributaries Watershed study area, as affected by changes in loadings from direct nonpoint sources. .... C-43

Figure C. 35 Clinch River modeled flow duration versus USGS Gaging Station #03524000 data from 10/1/1988 to 9/30/1991 (subwatershed 19)..... C-46

Figure C. 36 Clinch River modeled results versus USGS Gaging Station # 03524000 data from 10/1/1988 to 9/30/1991 (subwatershed 19)..... C-47

Figure C. 37 Clinch River modeled flow duration versus USGS Gaging Station #03524000 data from 10/1/2000 through 9/30/2003 at (subwatershed 19)..... C-49

Figure C. 38 Clinch River validation modeled results versus USGS Gaging Station #03524000 data from 10/1/2000 through 9/30/2003 at (subwatershed 19)..... C-50

Figure C. 39 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BSWO001.81 in subwatershed 16 on Swords Creek..... C-53

Figure C. 40 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BLWS000.06 in subwatershed 16 on Lewis Creek..... C-53

Figure C. 41 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BDUM000.04 in subwatershed 7 on Dumps Creek..... C-54

Figure C. 42 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BEKG004.18 in subwatershed 10 on Elk Garden Creek..... C-54

Figure C. 43 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BBCD001.89 in subwatershed 9 on Big Cedar Creek. .... C-55

Figure C. 44 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BCLN271.50 in subwatershed 19 on Clinch River..... C-55

Figure C. 45 E. coli validation for 10/1/2007 – 8/31/2010 for VADEQ station 6BSWO001.81 in subwatershed 16 on Swords Creek..... C-57

Figure C. 46 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BLWS000.06 in subwatershed 16 on Lewis Creek. .... C-58

Figure C. 47 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BDUM000.04 in subwatershed 7 on Dumps Creek..... C-58

Figure C. 48 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BEKG004.18 in subwatershed 10 on Elk Garden Creek..... C-59

Figure C. 49 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BBCD001.89 in subwatershed 9 on Big Cedar Creek..... C-59

Figure C. 50 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BCLN271.50 in subwatershed 19 on Clinch River. .... C-60

**TABLES**

Table ES 1 Impairments within the Middle Clinch River watershed included in this study. .... xx

Table ES.1 Impairments within the Middle Clinch River watershed included in this study (cont.)..... xxi

Table ES.2 Impairments within the Middle Clinch River and Tributaries watershed and the NTU groups used for modeling. .... xxv

Table ES.3 Average annual in-stream cumulative pollutant loads modeled after allocation for each NTU of the Middle Clinch River watershed..... xxvi

Table ES.4 Average daily in-stream cumulative pollutant loads modeled after allocation for each NTU of the Middle Clinch River watershed..... xxvi

Table 1.1 Impairments within the Middle Clinch River and Tributaries watershed and the NTU groups used for modeling. .... 1-5

Table 1.2 Impairments within the Middle Clinch River watershed included in this study. .... 1-13

Table 1.2 Impairments within the Middle Clinch River watershed included in this study (cont.). .... 1-14

Table 2.1 Summary of fecal coliform (cfu/100mL) data collected by VADEQ from January 1990 – February 2012..... 2-5

Table 2.2 Summary of *E. coli* (cfu/100mL) data collected by VADEQ from August 2003 – February 2012..... 2-6

Table 3.1 Summary of VPDES permitted point sources permitted for fecal bacteria control in the Middle Clinch River watershed study area. .... 3-3

Table 3.2 Single family home permits in the Middle Clinch River watershed study area. .... 3-4

Table 3.2 Single family home permits in the Middle Clinch River watershed study area (cont.)..... 3-5

Table 3.3 Human population, housing units, houses on sanitary sewer, septic systems, and other sewage disposal systems for areas contributing to impaired segments in the Middle Clinch River watershed study area..... 3-7

Table 3.4 Domestic animal population density, waste load, and fecal coliform density. .... 3-9

Table 3.5 Estimated domestic animal populations in areas contributing to impaired segments in the Middle Clinch River watershed study area..... 3-10

Table 3.6 Livestock populations in areas contributing to impaired segments in the Middle Clinch River watershed study area..... 3-10

Table 3.7 Average fecal coliform densities and waste loads associated with livestock..... 3-11

Table 3.8 Average percentage of collected dairy waste applied throughout year. 3-11

Table 3.9 Average time beef cows, dry cows, and replacement heifers spend in different areas per day..... 3-12

Table 3.10 Wildlife population densities for the Middle Clinch River watershed study area. .... 3-13

Table 3.11 Estimated wildlife populations in the Middle Clinch River watershed study area. .... 3-13

Table 3.12 Average fecal coliform densities and fecal production rates.. .... 3-14

Table 3.13 Wildlife habitat and percentage of time spent in stream access areas. 3-15

Table 5.1 Allocation scenarios for reducing current bacteria loads in subwatershed 8 of the Middle Clinch River Modeling Group. .... 5-5

Table 5.2 Estimated existing and allocated *E. coli* in-stream loads in the Middle Clinch River Modeling Group watershed. .... 5-7

Table 5.3 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Middle Clinch River Modeling Group ..... 5-8

Table 5.4 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Middle Clinch River Modeling Group ..... 5-10

Table 5.5 Allocation scenarios for reducing current bacteria loads in subwatershed 9 of the Big Cedar/Burgess Creek Modeling Group. .... 5-12

Table 5.6 Estimated existing and allocated *E. coli* in-stream loads in the Big Cedar/Burgess Creek Modeling Group watershed. .... 5-14

Table 5.7 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Big Cedar/Burgess Creek Modeling Group ..... 5-15

Table 5.8 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Big Cedar/Burgess Creek Modeling Group ..... 5-16

Table 5.9 Allocation scenarios for reducing current bacteria loads in subwatershed 10 of the Elk Garden/Loop Creek Modeling Group. .... 5-18

Table 5.10 Estimated existing and allocated *E. coli* in-stream loads in the Elk Garden/Loop Creek Modeling Group watershed. .... 5-20

Table 5.11 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Elk Garden/Loop Creek Modeling Group ..... 5-21

Table 5.12 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Elk Garden/Loop Creek Modeling Group ..... 5-22

Table 5.13 Allocation scenarios for reducing current bacteria loads in subwatershed 16 of the Lewis Creek Modeling Group. .... 5-24

Table 5.14 Estimated existing and allocated *E. coli* in-stream loads in the Lewis Creek Modeling Group watershed. .... 5-26

Table 5.15 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Lewis Creek Modeling Group ..... 5-27

Table 5.16 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Lewis Creek Modeling Group ..... 5-27

Table 5.17 Allocation scenarios for reducing current bacteria loads in subwatershed 17 of the Swords/Hess Creek Modeling Group. .... 5-29

Table 5.18 Estimated existing and allocated *E. coli* in-stream loads in the Swords/Hess Creek Modeling Group watershed. .... 5-31

Table 5.19 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Swords/Hess Creek Modeling Group ..... 5-32

Table 5.20 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Swords/Hess Creek Modeling Group ..... 5-33

Table 5.21 Allocation scenarios for reducing current bacteria loads in subwatershed 7 of the Dumps Creek Modeling Group..... 5-35

Table 5.22 Estimated existing and allocated *E. coli* in-stream loads in the Dumps Creek Modeling Group watershed. .... 5-37

Table 5.23 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Dumps Creek Modeling Group ..... 5-38

Table 5.24 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Dumps Creek Modeling Group ..... 5-39

Table 7.1 Public participation during TMDL development for the Middle Clinch River watershed..... 7-1

Table B.1 Current conditions for land applied fecal coliform load for the Middle Clinch River by land use. .... B-2

Table B.2 Monthly, directly deposited, fecal coliform loads in the Middle Clinch River modeling group..... B-3

Table B.3 Existing annual fecal coliform loads from land-based sources for the Middle Clinch River modeling group by land use..... B-4

Table B.4 Existing annual loads from direct-deposition sources for the Middle Clinch River modeling group. .... B-5

Table B.5 Current conditions of land applied fecal coliform load for the Dumps Creek modeling group, by land-use. .... B-6

Table B.6 Monthly, directly deposited fecal coliform loads in the Dumps Creek modeling group..... B-7

Table B.7 Existing annual loads from land-based sources for the Dumps Creek modeling group by land-use. .... B-8

Table B.8 Existing annual loads from direct-deposition sources for the Dumps Creek modeling group. .... B-9

Table B.9 Current conditions of land applied fecal coliform load for the Big Cedar/Burgess modeling group, by land-use. .... B-10

Table B.10 Monthly, directly deposited fecal coliform loads in the Big Cedar/Burgess modeling group..... B-11

Table B.11 Existing annual loads from land-based sources for the Big Cedar/Burgess modeling group by land-use. .... B-12

Table B.12 Existing annual loads from direct-deposition sources for the Big Cedar/Burgess modeling group..... B-13

Table B.13 Current conditions of land applied fecal coliform load for the Elk Garden/Loop modeling group, by land-use..... B-14

Table B.14 Monthly, directly deposited fecal coliform loads in the Elk Garden/Loop modeling group..... B-15

Table B.15 Existing annual loads from land-based sources for the Elk Garden/Loop modeling group by land-use. .... B-16

Table B.16 Existing annual loads from direct-deposition sources for the Elk Garden/Loop modeling group..... B-17

Table B.17 Current conditions of land applied fecal coliform load for the Lewis Creek modeling group, by land-use. .... B-18

Table B.18 Monthly, directly deposited fecal coliform loads in the Lewis Creek modeling group..... B-19

Table B.19 Existing annual loads from land-based sources for the Lewis Creek modeling group by land-use. .... B-20

Table B.20 Existing annual loads from direct-deposition sources for the Lewis Creek modeling group..... B-21

Table B.21 Current conditions of land applied fecal coliform load for the Swords/Hess Creek modeling group, by land-use. .... B-22

Table B.22 Monthly, directly deposited fecal coliform loads in the Swords/Hess Creek modeling group..... B-23

Table B.23 Existing annual loads from land-based sources for the Swords/Hess Creek modeling group by land-use. .... B-24

Table B.24 Existing annual loads from direct-deposition sources for the Swords/Hess Creek modeling group..... B-25

Table C. 1 Impairments and subwatersheds within the Middle Clinch River watershed study area. .... C-5

Table C. 2 Consolidated land use categories for the Middle Clinch River watershed drainage area used in HSPF modeling..... C-7

Table C. 3 Spatial distribution of land use types in acres in the Middle Clinch River watershed study area. .... C-8

Table C. 4 Example of an F-table calculated for an HSPF model..... C-10

Table C. 5 Comparison of modeled period to historical records for the Clinch River..... C-25

Table C. 6 Flow rates and bacteria loads used to model VADEQ active permits in the Middle Clinch River watershed study area..... C-27

Table C. 7 Estimated failing septic systems and straight pipes for 2011 in the Middle Clinch River watershed study area. .... C-28

Table C. 8 HSPF base parameter values used to determine hydrologic model response..... C-33

Table C. 9 HSPF Sensitivity analysis results for hydrologic model parameters for the Middle Clinch River and Tributaries Watershed..... C-34

Table C. 9 HSPF Sensitivity analysis results for hydrologic model parameters for the Middle Clinch River and Tributaries Watershed (cont.) ..... C-35

Table C. 10 Base parameter values used to determine water quality model response. .... C-36

Table C. 11 Percent change in average monthly *E.coli* mean for the years 2007-2010..... C-37

Table C. 12 Initial hydrologic parameters estimated for the Middle Clinch River watershed TMDL study area, and resulting final values after calibration. .... C-44

Table C. 13 Hydrology calibration model performance from 10/1/1988 through 9/30/1991 at USGS Gaging Station # 03524000 on the Clinch River (subwatershed 19). .... C-45

Table C. 14 Hydrology validation model performance from 10/1/2000 through 9/30/2003 at USGS Gaging Station #03524000 on the Clinch River (subwatershed 19). .... C-48

Table C. 15 Model parameters utilized for water quality calibration..... C-51

Table C. 16 Bacteria calibration periods, subwatersheds and streams containing stations, and type of bacteria used in the Clinch River watershed study area. .... C-52

Table C. 17 Monitored and simulated maximum value, geometric mean,  
and single sample violation percentage for the calibration period. .... C-56

Table C. 18 Bacteria validation periods, subwatersheds and streams  
containing stations, and type of bacteria used in the Clinch River  
watershed study area. .... C-57

Table C. 19 Monitored and simulated maximum value, geometric mean,  
and single sample violation percentage for the validation period..... C-61

## **EXECUTIVE SUMMARY**

### ***Background and Applicable Standards***

There are fourteen (14) different impaired streams in this study area including Clinch River, Indian Creek, Weaver Creek, Thompson Creek, Lewis Creek, Hess Creek, Swords Creek, Little River, Big Cedar Creek, Burgess Creek, Dumps Creek, Elk Garden Creek, Loop Creek and Maiden Spring Creek. A total of twenty (20) separate impaired segments exist within the current project.

All 20 impaired segments are bacterial impairments. Table ES.1 shows the details of these impairments.

In Virginia, once a water body violates a given standard, the water body is assessed, and a watershed management plan such as a Total Maximum Daily Load (TMDL) must be developed. The TMDL is a pollution budget that determines the amount of pollutant the water body can receive in a given period of time and still meet the intended standard.

**Table ES 1 Impairments within the Middle Clinch River watershed included in this study.**

Stream Name Impairment ID	Impairment(s) Contracted	Initial Listing Year	2010 River Miles	2010 Listing Violation%	Impairment Location Description
<b>Indian Creek</b> VAS-P05R_IDN01A04	<i>E. coli</i>	2004	3.98	16 EC	From the highway 19 crossing to the Little River confluence at Wardell.
<b>Clinch River</b> VAS-P07R_CLN01A00	<i>E. coli</i>	2002	13.95	18 EC	From its confluence with Big Cedar Creek near Pinnacles downstream to its confluence with Dumps Creek at Carbo.
<b>Big Cedar Creek</b> VAS-P06R_BCD01A98	<i>E. coli</i>	2006	4.11	33 EC	From the vicinity of Daughertys Cave downstream to confluence with Clinch River.
<b>Big Cedar Creek</b> VAS-P06R_BCD02A02	<i>E. coli</i>	2008	1.12	33 EC	From the confluence with Little Cedar Creek downstream to the vicinity of Daughertys Cave.
<b>Big Cedar Creek</b> VAS-P06R_BCD02A00	<i>E. coli</i>	2006	2.75	25 EC	From the Lebanon raw water intake downstream to the confluence with Little Cedar Creek.
<b>Big Cedar Creek</b> VAS-P06R_BCD03A00	<i>E. coli</i>	2006	3.23	67 EC	From its headwaters downstream to the Lebanon raw water intake.
<b>Loop Creek</b> VAS-P06R_LOO01A06	<i>E. coli</i>	2006	2.87	50 EC	From route 80 downstream to the Elk Garden Creek confluence.
<b>Burgess Creek</b> VAS-P06R_BUG01A06	<i>E. coli</i>	2006	1.50	67 EC	From its confluence with Campbell Branch to its confluence with Big Cedar Creek.
<b>Elk Garden Creek</b> VAS-P06R_EKG01A06	<i>E. coli</i>	2006	3.28	75 EC	From Elk Garden to its confluence with Big Cedar Creek.
<b>Weaver Creek</b> VAS-P07R_WEA01A06	<i>E. coli</i>	2006	9.14	50 EC	From its confluence with Hart Creek to its confluence with the Clinch River near Artrip
<b>Thompson Creek</b> VAS-P07R_TMP01A06	<i>E. coli</i>	2006	4.26	50 EC	From Coulwood to its confluence with the Clinch River.

Note: Bacteria impairments are based on the instantaneous *E. coli* WQS of 235 cfu/100mL when violations exceed 10% for samples collected during the most recent data period assessment unless otherwise noted.

**Table ES.1 Impairments within the Middle Clinch River watershed included in this study (cont.).**

Stream Name Impairment ID	Impairment(s) Contracted	Initial Listing Year	2010 River Miles	2010 Listing Violation%	Impairment Location Description
<b>Lewis Creek</b> VAS-P04R_LWS01A98	<i>E. coli</i>	2006	4.83	33 EC	From its confluence with Stone Branch at Flat Rock downstream to the Clinch River confluence.
<b>Lewis Creek</b> VAS-P04R_LWS01A10	<i>E. coli</i>	2010	3.43	33 EC	From its confluence with Grassy Creek downstream to the Stone Branch confluence at Flat Rock.
<b>Hess Creek</b> VAS-P04R_HES01A10	<i>E. coli</i>	2010	1.04	41 EC	From groundhog hollow downstream to just south of Dye.
<b>Swords Creek</b> VAS-P04R_HES01A10	<i>E. coli</i>	2010	2.88	25 EC	Sulfur Spring Branch at Dye confluence downstream to the Clinch River confluence.
<b>Little River</b> VAS-P05R_LTR02A00	<i>E. coli</i>	2004	5.18	50 EC	From the Claypool Hill STP downstream to Laurel Creek confluence near Wardell.
<b>Little River</b> VAS-P05R_LTR02A02	<i>E. coli</i>	2008	4.11	50 EC	From the Laurel Creek confluence near Wardell downstream to Grays Branch confluence at Russell/Tazewell County line.
<b>Dumps Creek</b> VAS-P08R_DUM01A94	<i>E. coli</i>	2006	3.41	16 EC	From the Hurricane Creek confluence downstream to Clinch River confluence at Carbo.
<b>Maiden Spring Creek</b> VAS-P05R_MSC01A02	<i>E. coli</i>	2004	6.51	25 EC	From the Little River confluence upstream to foot of Morris Knob north of Robbins Gap.
<b>Maiden Spring Creek</b> VAS-P05R_MSC01C04	<i>E. coli</i>	2004	8.57	42 EC	From an unnamed tributary with Buchanan Cemetery downstream through Thompson Valley to Morris Knob.

Note: Bacteria impairments are based on the instantaneous *E. coli* WQS of 235 cfu/100mL when violations exceed 10% for samples collected during the most recent data period assessment unless otherwise noted.

***TMDL Endpoint and Water Quality Assessment***

Fecal bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard. Whereas the Instantaneous Maximum Standard of 235 cfu/100mL with no greater than 10% violations is used to assess waters based on monthly or bimonthly samples, for TMDL development, the in-stream *E. coli* target is a geometric mean not exceeding 126 cfu/100 mL.

***Source Assessment***

Sources of bacteria were identified and quantified in the Middle Clinch River watershed. Sources included point sources as well as non-point sources. The quantification of sources is important to determine the baseline of current conditions that is causing the impairment. Sources of bacteria included human, livestock, wildlife, and pets, as well as permitted point sources.

***Modeling Procedures***

Computer modeling is used to relate the sources on the ground to the water quality in the streams and rivers. This is important since not every colony of bacteria in the Middle Clinch River watershed ends up in the streams and rivers. The computer models help quantify the portion of bacteria within the Middle Clinch River watershed that ends up in the stream and the impact of die-off.

The computer modeling process consists of several steps. First, the characteristics of the drainage area including land use, slopes, stream network, and soil properties, are entered into the model. Bacteria loads and parameters influencing bacteria are also entered into the corresponding model. A process known as calibration is then conducted by comparing model simulations with monitored field data. Model parameters are adjusted during calibration to minimize the error between simulated and monitored values. This process is conducted for hydrology (flow) as well as water quality. Once the model is calibrated, it is then used to determine the existing water quality conditions in the study area and may be used to determine the reductions necessary to meet the water quality standard or endpoint.

**Hydrology**

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and fecal coliform loads. For purposes of modeling the Middle Clinch River watershed, inputs to streamflow and in-stream fecal bacteria, the drainage area was divided into twenty-one (21) subwatersheds. The subdivision of the entire area into smaller contributing areas allows for the placement of sources at the proper geographic location and better resemblance of actual connectivity of streams as observed in the real world.

Daily precipitation data was available within the watershed at the Richlands NCDC Coop station #447174. Missing values were filled using daily precipitation from the Lebanon NCDC Coop station #444777, and then from the Abingdon NCDC Coop station #440021 as needed. The final filled daily precipitation was disaggregated using the hourly station data from Bristol Tri City Airport NCDC Coop station #401094.

The model was calibrated for hydrologic accuracy using daily flow data for the period October 1988 through September 1991. The modeled output from subwatershed 19 was compared against the Clinch River USGS Gaging Station #03524000 data. The modeled output was validated for the period of October 2000 to September 2003. The calibration and validation time-periods were selected to include critical conditions, or the combination of environmental factors (e.g., rainfall, temperature, etc.) that yield high and low flows of an acceptably low frequency of occurrence. The inclusion of critical conditions ensures that the water quality is protected during times when it is most vulnerable.

Wildlife populations, the rate of failure of septic systems, domestic pet populations, and numbers of livestock are examples of land-based nonpoint sources used to calculate fecal coliform loads. Also represented in the model were direct sources of uncontrolled discharges, direct deposition by wildlife, and direct deposition by livestock. Contributions from all of these sources were updated to current conditions to establish existing conditions for the watershed.

***Load Allocation Scenarios***

Once the model was calibrated, the next step in the TMDL processes was to simulate reducing the various source loads to levels that would result in attainment of the water quality standards or endpoints. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality.

The impaired segments of this TMDL project are grouped by their location within geographic areas called Nested TMDL Units (NTUs). Modeling is done on an NTU-wide basis and therefore results of the TMDL development are summarized by NTU. A description of NTUs can be found in Section 1.2.1. Based on the NTU approach, the 20 impairments were grouped into six NTUs shown in Table ES.2.

**Table ES.2 Impairments within the Middle Clinch River and Tributaries watershed and the NTU groups used for modeling.**

NTU #	NTU Name	Stream Name	Impairment ID
250	<b>Middle Clinch River</b>	Clinch River	VAS-P07R_CLN01A00
		Indian Creek	VAS-P05R_IDN01A04
		Little River	VAS-P05R_LTR02A00
		Little River	VAS-P05R_LTR02A02
		Maiden Spring Creek	VAS-P05R_MSC01A02
		Maiden Spring Creek	VAS-P05R_MSC01C04
		Thompson Creek	VAS-P07R_TMP01A06
		Weaver Creek	VAS-P07R_WEA01A06
251	<b>Dumps Creek</b>	Dumps Creek	VAS-P08R_DUM01A94
252	<b>Big Cedar/Burgess</b>	Big Cedar Creek	VAS-P06R_BCD01A98
		Big Cedar Creek	VAS-P06R_BCD02A00
		Big Cedar Creek	VAS-P06R_BCD02A02
		Big Cedar Creek	VAS-P06R_BCD03A00
		Burgess Creek	VAS-P06R_BUG01A06
253	<b>Elk Garden/Loop</b>	Elk Garden Creek	VAS-P06R_EKG01A06
		Loop Creek	VAS-P06R_LOO01A06
298	<b>Lewis Creek</b>	Lewis Creek	VAS-P04R_LWS01A10
		Lewis Creek	VAS-P04R_LWS01A98
421	<b>Swords/Hess Creek</b>	Swords Creek, lower	VAS-P04R_SWD01A00
		Hess Creek	VAS-P04R_HES01A10

The final TMDL information is shown in Tables ES.3 and ES.4. Average annual in-stream cumulative bacteria pollutant loads modeled after allocation for each NTU are shown in Table ES.3. Average daily in-stream cumulative bacteria pollutant loads modeled after allocation for each NTU are shown in Table ES.4. These tables contain summaries of the required pollutant allocations needed to meet pollution standards, and contain the following components: Waste Load Allocation (WLA) which contains a

component for future growth, Load Allocation (LA), Margin of Safety (MOS), and Total Maximum Daily Load (TMDL). More information on these components is in Chapter 5.

**Table ES.3 Average annual in-stream cumulative pollutant loads modeled after allocation for each NTU of the Middle Clinch River watershed.**

Pollutant	Units	NTU Name	WLA <sup>1,2</sup>	LA	MOS	TMDL
<i>E. coli</i>	cfu/yr	Swords/Hess Creek	7.04E+12	6.94E+14	<i>Implicit</i>	7.01E+14
<i>E. coli</i>	cfu/yr	Lewis Creek	1.53E+13	4.88E+14		5.03E+14
<i>E. coli</i>	cfu/yr	Dumps Creek	9.91E+12	9.80E+14		9.90E+14
<i>E. coli</i>	cfu/yr	Elk Garden/Loop	6.36E+12	6.29E+14		6.35E+14
<i>E. coli</i>	cfu/yr	Big Cedar/Burgess	1.34E+13	1.17E+15		1.18E+15
<i>E. coli</i>	cfu/yr	Clinch River	1.64E+13	1.51E+15		1.53E+15

<sup>1</sup> Waste Load Allocation (WLA) by permit can be found in the corresponding allocation chapters.

<sup>2</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

**Table ES.4 Average daily in-stream cumulative pollutant loads modeled after allocation for each NTU of the Middle Clinch River watershed.**

Pollutant	Units	NTU Name	WLA <sup>1,2</sup>	LA	MOS	TMDL
<i>E. coli</i>	cfu/d	Swords/Hess Creek	1.93E+10	1.30E+12	<i>Implicit</i>	1.32E+12
<i>E. coli</i>	cfu/d	Lewis Creek	4.18E+10	1.22E+12		1.26E+12
<i>E. coli</i>	cfu/d	Dumps Creek	2.71E+10	1.78E+12		1.81E+12
<i>E. coli</i>	cfu/d	Elk Garden/Loop	1.74E+10	1.83E+12		1.84E+12
<i>E. coli</i>	cfu/d	Big Cedar/Burgess	3.66E+10	4.23E+12		4.26E+12
<i>E. coli</i>	cfu/d	Clinch River	4.51E+10	2.24E+13		2.25E+13

<sup>1</sup> Waste Load Allocation (WLA) by permit can be found in the corresponding allocation chapters.

<sup>2</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

### **Implementation**

The goal of the TMDL program is to establish a path that will lead to attainment of water quality standards. The first step in this process is to develop TMDLs that will result in meeting water quality standards. This report represents the first phase of that effort for the impairments in the Middle Clinch River watershed. The next step will be development of a TMDL implementation plan (IP), required by Virginia's 1997 Water

Quality Monitoring, Information and Restoration Act (WQMIRA). The final step is to implement the TMDL IPs and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource.

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. The state must also demonstrate that attaining the designated use is not feasible. Information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens as well as EPA will be able to provide comment during this process.

### ***Public Participation***

During development of the TMDL for the impairments in the Middle Clinch River watershed study area, public involvement was encouraged through a first public meeting (05/26/2011), and a final public meeting (05/24/2012). An introduction of the agencies involved, an overview of the TMDL process, details of the pollutant sources, and the specific approach to developing the Middle Clinch River watershed TMDLs were presented at the first of the public meeting. Public understanding of, and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting.

Page intentionally blank

## 1. INTRODUCTION

### 1.1 Regulations Background

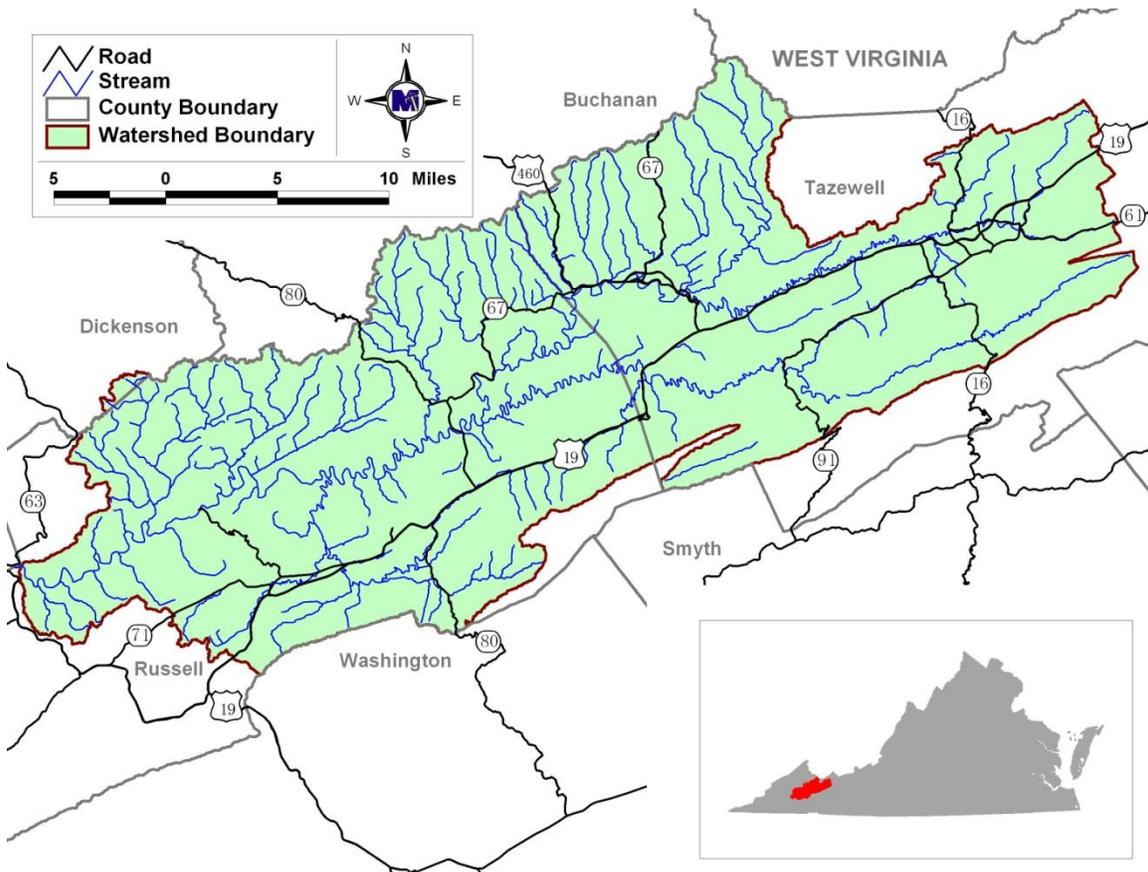
The Clean Water Act (CWA) that became law in 1972 requires that all U.S. streams, rivers, and lakes meet certain water quality standards. The CWA also requires that states conduct monitoring to identify waters that are polluted or do not otherwise meet standards. Through this required program, the state of Virginia has found that many stream segments do not meet state water quality standards for protection of the six designated uses: recreation/swimming, aquatic life, wildlife, fish consumption, shellfish consumption, and public water supply (drinking).

When streams fail to meet standards, the stream is “listed” in the current Section 303(d) report as requiring a Total Maximum Daily Load (TMDL). Section 303(d) of the CWA and the U.S. Environmental Protection Agency’s (EPA) Water Quality Management and Planning Regulation (40 CFR Part 130) both require that states develop a Total Maximum Daily Load (TMDL) for each pollutant. A TMDL is a “pollution budget” for a stream; that is, it sets limits on the amount of pollution that a stream can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and nonpoint source loadings are considered. A TMDL accounts for seasonal variations and must include a margin of safety (MOS).

Once a TMDL is developed and approved by EPA, measures must be taken to reduce pollution levels in the stream. Virginia’s 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the “*Board shall develop and implement a plan to achieve fully supporting status for impaired waters*”. The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), which should be implemented in a staged process. Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

**1.2 Middle Clinch River and Tributaries Watershed Characteristics**

The Middle Clinch River watershed (USGS Hydrologic Unit Code 06010205) is located in Russell and Tazewell Counties of Virginia. This watershed is a part of the Tennessee/Big Sandy River basin, which drains via the Mississippi River to the Gulf of Mexico. The location of the watershed is shown in Figure 1.1. The drainage area flowing into the most downstream impairment in this project is approximately 384,180 acres.



**Figure 1.1 Location of the Middle Clinch River watershed.**

The Middle Clinch River watershed is located within the level III Central Appalachian (69) and Ridge and Valley (67) ecoregions. The Central Appalachian ecoregion is a high rugged plateau consisting of sandstones, shale, conglomerate and coal. Some valleys contain limestone. Elevations range from 1,200 to 4,600 feet.

The Ridge and Valley ecoregion has elevations from 500 to 4,300 feet. The geology is primarily sedimentary sandstones, shale and limestone. ([http://www.eoearth.org/article/Ecoregions\\_of\\_Delaware%2C\\_Maryland%2C\\_Pennsylvania%2C\\_Virginia%2C\\_and\\_West\\_Virginia\\_%28EPA%29](http://www.eoearth.org/article/Ecoregions_of_Delaware%2C_Maryland%2C_Pennsylvania%2C_Virginia%2C_and_West_Virginia_%28EPA%29)).

As for the climatic conditions in the Middle Clinch River watershed, during the period from 1896 to 2010 Burkes Garden, Virginia (NCDC station# 441209) received an average annual precipitation of 45.14 inches, with 52% of the precipitation occurring during the May through October growing season (SERCC, 2011). Average annual snowfall is 42 inches, with the highest snowfall occurring during January (SERCC, 2011). The highest average daily temperature of 78.6 °F occurs in July, while the lowest average daily temperature of 21.6 °F occurs in January (SERCC, 2011).

Land use in the study area was characterized using the National Land Cover Database 2001 (NLCD). The drainage area is predominantly forest with woodlands covering approximately 59% of the area. Pasture and hay land covers account for roughly 30% of the drainage area. Developed, grassland, cropland, and water land uses account for the remainder of the study area.

### 1.2.1 Nested TMDL Units as Modeling Groups

The Virginia Department of Environmental Quality has recently moved towards a more cost effective approach to conducting TMDLs. The new approach is called a Nested TMDL, where the TMDL is developed for a "larger" geographic area that may contain several impaired stream segments. These large geographic units are herein called "nested TMDL units" (NTUs) because they consist of smaller sub-watershed areas that formerly were the basis of TMDL projects.

The building blocks for the NTUs are U. S. Geological Survey (USGS) 12-digit hydrologic units (HUCs). The HUCs were attributed with land cover and use values through GIS-extraction of information from the National Land Classification Dataset (2001), hydrologic connectivity from the USGS National Watershed Boundary dataset, and U. S. Environmental Protection Agency Ecoregion Level III features. NTUs

were generated by aggregating HUCs in an upstream fashion if they had similar attributes and their properties indicated the likelihood of similar TMDL conclusions. Aggregation continued until a HUC was encountered that had a substantially different potential TMDL conclusion, was a headwater, or had exceeded the cluster size limit.

NTUs are designed to provide TMDLs that are cost effective, while being scientifically defensible. For additional information about the generation of NTUs and their purpose, please refer to the document titled “*Virginia TMDL Coordination Planning; Nested TMDL Units*”.

The Middle Clinch River watershed consists of nine (9) NTUs: six (6) of which correlate to a TMDL equation, as well as three (3) upstream NTUs which represent the completed Upper Clinch TMDL project. Each of the six (6) NTUs within the watershed containing un-addressed impairments (which have not been addressed in a completed TMDL) have an associated TDML equation and an allocated load. Refer to Figure 1.2 for a map showing the NTU boundaries and the impairments they contain. Refer to Table ES.2 for a listing of the impairments included in each NTU modeling group.

### **1.3 Middle Clinch River Watershed Recreation Use Impairments**

There are twenty (20) different impairment segments in this study area. The impaired segments are on the following fourteen (14) streams: Clinch River, Indian Creek, Weaver Creek, Thompson Creek, Lewis Creek, Hess Creek, Swords Creek, Little River, Big Cedar Creek, Burgess Creek, Dumps Creek, Elk Garden Creek, Loop Creek and Maiden Spring Creek. In the sections below each impaired segment is described.

The Virginia Department of Environmental Quality has recently moved towards a more cost effective approach to conducting TMDLs. The new approach is called Nested TMDL where the TMDL is developed for a "larger" geographic area that contains smaller sub-areas with impaired segments that formerly were the basis of TMDL projects. Based on this approach, the 20 impairments were grouped into six groups, or nested TMDL units (NTUs) shown in Table 1.1.

**Table 1.1** Impairments within the Middle Clinch River and Tributaries watershed and the NTU groups used for modeling.

NTU #	NTU Name	Stream Name	Impairment ID
250	Middle Clinch River	Clinch River	VAS-P07R_CLN01A00
		Indian Creek	VAS-P05R_IDN01A04
		Little River	VAS-P05R_LTR02A00
		Little River	VAS-P05R_LTR02A02
		Maiden Spring Creek	VAS-P05R_MSC01A02
		Maiden Spring Creek	VAS-P05R_MSC01C04
		Thompson Creek	VAS-P07R_TMP01A06
		Weaver Creek	VAS-P07R_WEA01A06
251	Dumps Creek	Dumps Creek	VAS-P08R_DUM01A94
252	Big Cedar/Burgess	Big Cedar Creek	VAS-P06R_BCD01A98
		Big Cedar Creek	VAS-P06R_BCD02A00
		Big Cedar Creek	VAS-P06R_BCD02A02
		Big Cedar Creek	VAS-P06R_BCD03A00
		Burgess Creek	VAS-P06R_BUG01A06
253	Elk Garden/Loop	Elk Garden Creek	VAS-P06R_EKG01A06
		Loop Creek	VAS-P06R_LOO01A06
298	Lewis Creek	Lewis Creek	VAS-P04R_LWS01A10
		Lewis Creek	VAS-P04R_LWS01A98
421	Swords/Hess Creek	Swords Creek, lower	VAS-P04R_SWD01A00
		Hess Creek	VAS-P04R_HES01A10

### 1.3.1 Clinch River (VAS-P07R\_CLN01A00)

The Clinch River in Russell County flows southwest before it reaches the Virginia/Tennessee state line.

The Clinch River from its confluence with Big Cedar Creek near Pinnacles downstream to its confluence with Dumps Creek at Carbo (13.95 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ

monitoring station 6BCLN271.50 showed an 18% *E. coli* bacteria standard violation rate in the 2010 assessment.

### 1.3.2 Indian Creek (VAS-P05R\_IDN01A04)

Indian Creek in Russell County, VA flows northeast into the Little River at Wardell.

Indian Creek is listed as impaired from the route 19 bridge downstream to its confluence with the Little River (3.98 stream miles) on the 2010 303(d) list as impaired for not supporting the recreation/swimming use. VADEQ monitoring at station 6BIDN000.69 showed a 16% *E. coli* bacteria standard violation rate in the 2010 assessment.

### 1.3.3 Weaver Creek (VAS-P07R\_WEA01A06)

Weaver Creek, in Russell County, VA flows southwest before its confluence with the Clinch River.

Weaver Creek from its confluence with Hart Creek to its confluence with the Clinch River near Artrip (9.14 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring stations 6BWEA000.02 and 6BWEA004.32 both had a 50% violation rate in the 2010 assessment.

### 1.3.4 Thompson Creek (VAS-P07R\_TMP01A06)

Thompson Creek, in Russell County, VA flows southwest before its confluence with the Clinch River at Artrip.

Thompson Creek from Coulwood to its mouth (4.26 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BTMP003.58 had a 50% violation rate in the 2010 assessment.

### 1.3.5 Lewis Creek (VAS-P04R\_LWS01A98)

Lewis Creek, in Russell County, VA flows south before its confluence with the Clinch River.

Lewis Creek from its confluence with Stone Branch at Flat Rock downstream to the Clinch River confluence (4.83 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BLWS000.06 had a 33% violation rate in the 2010 assessment.

### 1.3.6 Lewis Creek (VAS-P04R\_LWS01A10)

Lewis Creek from its confluence with Grassy Creek downstream to the Stone Branch confluence at Flat Rock (3.43 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BLWS004.84 had a 33% violation rate in the 2010 assessment.

### 1.3.7 Hess Creek (VAS-P04R\_HES01A10)

Hess Creek, in Russell County, VA flows southeast before its confluence with the Swords Creek.

Hess Creek from groundhog hollow downstream to just south of Dye (1.04 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BHES000.05 had a 41% violation rate in the 2010 assessment.

### 1.3.8 Swords Creek (VAS-P04R\_SWD01A00)

Swords Creek, in Russell County, VA flows south before its confluence with the Clinch River.

Swords Creek from the Sulfur Spring Branch at Dye confluence downstream to the Clinch River confluence (2.88 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BSWO001.81 had a 25% violation rate in the 2010 assessment.

### 1.3.9 Little River (VAS-P05R\_LTR02A00)

Little River, in Russell and Tazewell Counties, VA flows southwest before its confluence with the Clinch River.

The Little River from the Claypool Hill STP downstream to Laurel Creek confluence near Wardell (5.18 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BLTR018.19 had a 50% violation rate in the 2010 assessment.

### 1.3.10 Little River (VAS-P05R\_LTR02A02)

The Little River from the Laurel Creek confluence near Wardell downstream to Grays Branch confluence at Russell/Tazewell County line (4.11 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BLTR018.19 had a 50% violation rate in the 2010 assessment.

### 1.3.11 Big Cedar Creek (VAS-P06R\_BCD01A98)

Big Cedar Creek, in Russell County, VA flows northwest before its confluence with the Clinch River.

Big Cedar Creek from the vicinity of Daughertys Cave downstream to confluence with Clinch River (4.11 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBCD001.89, had an *E. coli* bacteria standard violation rate of 33% in the 2010 assessment.

### 1.3.12 Big Cedar Creek (VAS-P06R\_BCD02A02)

Big Cedar Creek from its confluence with Little Cedar Creek downstream to the vicinity of Daughertys Cave (1.12 miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBCD001.89, had an *E. coli* bacteria violation rate of 33% in the 2010 assessment.

### 1.3.13 Big Cedar Creek (VAS-P06R\_BCD02A00)

Big Cedar Creek from the Lebanon raw water intake downstream to the confluence with Little Cedar Creek (2.75 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBCD006.66 had a violation rate of 25% in the 2010 assessment.

### 1.3.14 Big Cedar Creek (VAS-P06R\_BCD03A00)

Big Cedar Creek from its headwaters downstream to the Lebanon raw water intake (3.23 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBCD009.83 had a violation rate of 67% in the 2010 assessment.

### 1.3.15 Maiden Spring Creek (VAS-P05R\_MSC01A02)

Maiden Spring Creek, in Tazewell County, VA flows southwest before its confluence with the Little River.

Maiden Spring Creek from the Little River confluence upstream to foot of Morris Knob north of Robbins Gap (6.51 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BMSC001.53 had a 25% violation rate in the 2010 assessment.

### 1.3.16 Maiden Spring Creek (VAS-P05R\_MSC01C04)

Maiden Spring Creek from an unnamed tributary with Buchanan Cemetery downstream through Thompson Valley to Morris Knob (8.57 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BMSC008.98 had a 42% violation rate in the 2010 assessment.

### 1.3.17 Loop Creek (VAS-P06R\_LOO01A06)

Loop Creek, in Russell County, VA flows southwest before it's confluence with Elk Garden Creek.

This impaired segment was listed on the 2010 303(d) list of impaired waters for not supporting the recreation/swimming use. This impaired segment extends from the Route

80 bridge downstream the Elk Garden Creek confluence (2.87 stream miles). VADEQ monitoring station 6BLOO004.25 had a bacteria standard violation rate of 50% in the 2010 assessment.

#### 1.3.18 Burgess Creek (VAS-P06R\_BUG01A06)

Burgess Creek, in Russell County, VA flows northeast before its confluence with Big Cedar Creek.

Burgess Creek from its confluence with Campbell Branch to its mouth (1.50 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BBUG000.10 had a 67% violation rate in the 2010 assessment.

#### 1.3.19 Elk Garden Creek (VAS-P06R\_EKG01A06)

Elk Garden Creek, in Russell County, VA flows northeast before its confluence with Loop Creek (headwaters of Big Cedar Creek).

Elk Garden Creek from Elk Garden to its mouth (3.28 stream miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BEKG004.18 had a 75% violation rate in the 2010 assessment.

#### 1.3.20 Dumps Creek (VAS-P08R\_DUM01A94)

Dumps Creek, in Russell County, VA flows south before its confluence with the Clinch River.

Dumps Creek from the Hurricane Creek confluence downstream to the Clinch River confluence at Carbo (3.41 miles) was listed as impaired on the 2010 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 6BDUM000.04 had a 16% violation rate in the 2010 assessment.

Figure 1.2 shows the location of the impairments, sub-watersheds, and Nested TMDL Units (NTUs) in the Middle Clinch River Watershed. Each NTU within the watershed correlates to a TDML equation and an allocated load (with the exception of the NTUs

that make up the upstream watershed from the completed Upper Clinch TMDL). Table 1.2 details the impairments in the Middle Clinch River watershed included in this study.

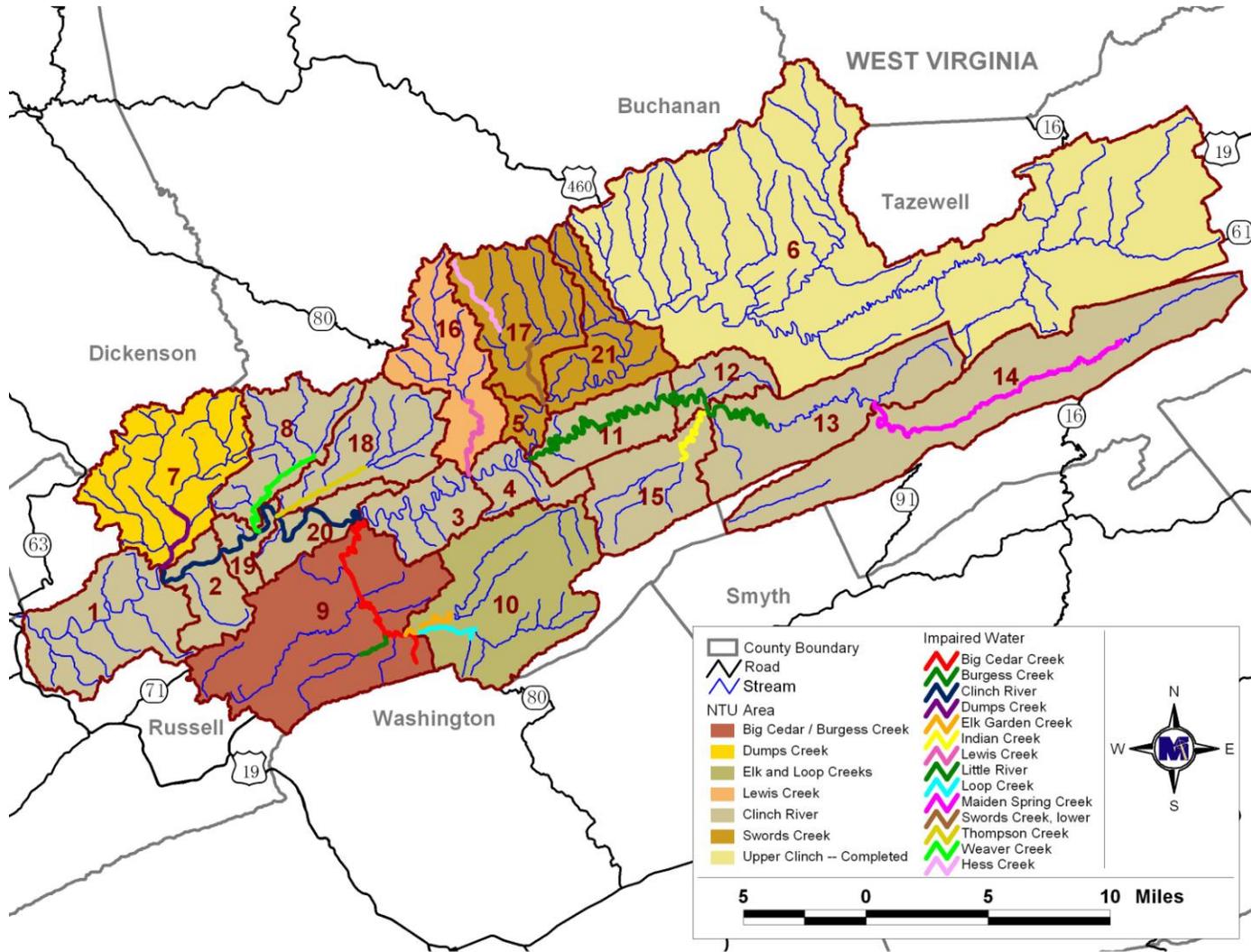


Figure 1.2 The impaired segments, sub-watershed numbers, and NTUs in the Middle Clinch River watershed.

**Table 1.2 Impairments within the Middle Clinch River watershed included in this study.**

Stream Name Impairment ID	Impairment(s) Contracted	Initial Listing Year	2010 River Miles	2010 Listing Violation%	Impairment Location Description
<b>Indian Creek</b> VAS-P05R_IDN01A04	<i>E. coli</i>	2004	3.98	16 EC	From the highway 19 crossing to the Little River confluence at Wardell.
<b>Clinch River</b> VAS-P07R_CLN01A00	<i>E. coli</i>	2002	13.95	18 EC	From its confluence with Big Cedar Creek near Pinnacles downstream to its confluence with Dumps Creek at Carbo.
<b>Big Cedar Creek</b> VAS-P06R_BCD01A98	<i>E. coli</i>	2006	4.11	33 EC	From the vicinity of Daughertys Cave downstream to confluence with Clinch River.
<b>Big Cedar Creek</b> VAS-P06R_BCD02A02	<i>E. coli</i>	2008	1.12	33 EC	From the confluence with Little Cedar Creek downstream to the vicinity of Daughertys Cave.
<b>Big Cedar Creek</b> VAS-P06R_BCD02A00	<i>E. coli</i>	2006	2.75	25 EC	From the Lebanon raw water intake downstream to the confluence with Little Cedar Creek.
<b>Big Cedar Creek</b> VAS-P06R_BCD03A00	<i>E. coli</i>	2006	3.23	67 EC	From its headwaters downstream to the Lebanon raw water intake.
<b>Loop Creek</b> VAS-P06R_LOO01A06	<i>E. coli</i>	2006	2.87	50 EC	From route 80 downstream to the Elk Garden Creek confluence.
<b>Burgess Creek</b> VAS-P06R_BUG01A06	<i>E. coli</i>	2006	1.50	67 EC	From its confluence with Campbell Branch to its confluence with Big Cedar Creek.
<b>Elk Garden Creek</b> VAS-P06R_EKG01A06	<i>E. coli</i>	2006	3.28	75 EC	From Elk Garden to its confluence with Big Cedar Creek.
<b>Weaver Creek</b> VAS-P07R_WEA01A06	<i>E. coli</i>	2006	9.14	50 EC	From it's confluence with Hart Creek to its confluence with the Clinch River near Artrip
<b>Thompson Creek</b> VAS-P07R_TMP01A06	<i>E. coli</i>	2006	4.26	50 EC	From Coulwood to its confluence with the Clinch River.

Bacteria impairments are based on the instantaneous *E. coli* WQS of 235 cfu/100mL when violations exceed 10% for samples collected during the most recent data period assessment unless otherwise noted.

**Table 1.2 Impairments within the Middle Clinch River watershed included in this study (cont.).**

Stream Name Impairment ID	Impairment(s) Contracted	Initial Listing Year	2010 River Miles	2010 Listing Violation%	Impairment Location Description
<b>Lewis Creek</b> VAS-P04R_LWS01A98	<i>E. coli</i>	2006	4.83	33 EC	From it's confluence with Stone Branch at Flat Rock downstream to the Clinch River confluence.
<b>Lewis Creek</b> VAS-P04R_LWS01A10	<i>E. coli</i>	2010	3.43	33 EC	From it's confluence with Grassy Creek downstream to the Stone Branch confluence at Flat Rock.
<b>Hess Creek</b> VAS-P04R_HES01A10	<i>E. coli</i>	2010	1.04	41 EC	From groundhog hollow downstream to just south of Dye.
<b>Swords Creek</b> VAS-P04R_SWD01A00	<i>E. coli</i>	2010	2.88	25 EC	Sulfur Spring Branch at Dye confluence downstream to the Clinch River confluence.
<b>Little River</b> VAS-P05R_LTR02A00	<i>E. coli</i>	2004	5.18	50 EC	From the Claypool Hill STP downstream to Laurel Creek confluence near Wardell.
<b>Little River</b> VAS-P05R_LTR02A02	<i>E. coli</i>	2008	4.11	50 EC	From the Laurel Creek confluence near Wardell downstream to Grays Branch confluence at Russell/Tazewell County line.
<b>Dumps Creek</b> VAS-P08R_DUM01A94	<i>E. coli</i>	2006	3.41	16 EC	From the Hurricane Creek confluence downstream to Clinch River confluence at Carbo.
<b>Maiden Spring Creek</b> VAS-P05R_MSC01A02	<i>E. coli</i>	2004	6.51	25 EC	From the Little River confluence upstream to foot of Morris Knob north of Robbins Gap.
<b>Maiden Spring Creek</b> VAS-P05R_MSC01C04	<i>E. coli</i>	2004	8.57	42 EC	From an unnamed tributary with Buchanan Cemetery downstream through Thompson Valley to Morris Knob.

Bacteria impairments are based on the instantaneous *E. coli* WQS of 235 cfu/100mL when violations exceed 10% for samples collected during the most recent data period assessment unless otherwise noted.

## 2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

### 2.1 Applicable Water Quality Standards

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

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

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

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

Virginia adopted its current *E. coli* and *enterococci* standard in January 2003. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals; there is a strong correlation between these and the incidence of gastrointestinal illness. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. . Prior to January 2003, Virginia water quality standard in fresh water for swimming/recreational use was based on fecal coliform rather than *E.coli*. The move was based on EPA recommendation that all states adopt an *E. coli* or *enterococci* standard for fresh water and *enterococci* criteria for marine waters by 2003. The EPA pursued the states' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and *enterococci*) and the incidence of gastrointestinal illness than with fecal coliform.

The criteria which were used in developing the bacteria TMDL in this study are outlined in Section 9 VAC 25-260-170 and read as follows:

*A. The following bacteria criteria (colony forming units (CFU)/100 ml) shall apply to protect primary contact recreational uses in surface waters, except waters identified in subsection B of this section:*

*E.coli bacteria shall not exceed a monthly geometric mean of 126 CFU/100 ml in freshwater.*

*Enterococci bacteria shall not exceed a monthly geometric mean of 35 CFU/100 ml in transition and saltwater.*

- 1. See 9VAC25-260-140 C for boundary delineations for freshwater, transition and saltwater.*
- 2. Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples.*
- 3. If there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E.coli CFU/100 ml .*
- 4. If there are insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 104 CFU/100 ml.*
- 5. For beach advisories or closures, a single sample maximum of 235 E.coli CFU/100 ml in freshwater and a single sample maximum of 104 enterococci CFU/100 ml in saltwater and transition zones shall apply.*

## **2.2 Selection of a TMDL Endpoint**

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the bacteria impairments in the Middle Clinch River Watershed, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations. In order to remove a waterbody from a state's list of impaired waters, the Clean Water Act requires compliance with that state's water quality standard.

Since modeling provided simulated output of *E. coli* concentrations at 1-hour intervals, assessment of TMDLs was made using the geometric mean standard. Therefore, the in-

stream *E. coli* target for the TMDLs in this study was a monthly geometric mean not exceeding 126 cfu/100 ml.

### **2.3 Discussion of In-stream Water Quality**

This section provides an inventory and analysis of available observed in-stream fecal bacteria monitoring data in the Middle Clinch River Watershed. An examination of data from water quality stations used in the 303(d) assessment was performed. The primary sources of available water quality information are bacteria enumerations from twenty nine (29) VADEQ in-stream monitoring stations with data from January 1990 to February 2012,

Data from in-stream water samples, collected at VADEQ monitoring stations (Figure 2.1), were analyzed for fecal coliform (Table 2.1) and *E.coli* (Table 2.2). Samples were taken for the express purpose of determining compliance with the state instantaneous bacteria standards. Until recent years, and as a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 mL or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) were not analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported values of 100 cfu/100 mL most likely represent concentrations below 100 cfu/100 mL, and reported concentrations of 8,000 or 16,000 cfu/100 mL most likely represent concentrations in excess of these values. *E. coli* concentrations have minimum and maximum laboratory detection concentrations of 25 and 2,000 cfu/100 mL respectively. Information in the tables is arranged in alphabetical order by stream name then from downstream to upstream station location.



**Table 2.1 Summary of fecal coliform (cfu/100mL) data collected by VADEQ from January 1990 – February 2012.**

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard	
								Deviation	Violation <sup>1</sup> %
Big Cedar Creek	6BBCD004.18	5/1994 - 3/2001	31	0	900	222	170	235	19.4
Clinch River	6BCLN271.50	1/2005 – 2/2012	38	25	2,000	222	120	366	5.3
Indian Creek	6BIDN000.69	8/2001 - 6/2003	12	100	2,600	608	400	727	50.0
Little River	6BLTR000.75	9/95 - 6/2003	37	0	1,400	183	100	253	10.8
Little River	6BLTR003.00	1/1990 - 3/1994	27	10	4,300	311	100	811	7.4
Little River	6BLTR018.19	8/2001 - 6/2003	12	100	2,200	400	150	612	16.7
Little River	6BLTR019.45	3/2008 - 5/2009	2	25	25	25	25	0	0.0
Little River	6BLTR025.03	4/2005	1	75	75	75	NA	NA	0.0
Lewis Creek	6BLWS000.06	8/2001 - 6/2003	11	100	2,100	427	100	629	18.2
Lewis Creek	6BLWS003.88	10/2001	1	100	100	100	NA	NA	0.0
Maiden Spring Creek	6BMSC001.53	8/2001 - 6/2003	8	100	1,000	300	100	374	25.0
Maiden Spring Creek	6BMSC008.98	8/2001 - 3/2007	13	25	8,000	1,463	100	2,834	38.5

NA – Not applicable

<sup>1</sup> Based on an instantaneous fecal coliform standard of 400 cfu/100mL.

**Table 2.2 Summary of *E. coli* (cfu/100mL) data collected by VADEQ from August 2003 – February 2012.**

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation <sup>1</sup> %
Big Cedar Creek	6BBCD001.89	7/2003 - 12/2010	24	25	2,000	369	88	595	33.3
Big Cedar Creek	6BBCD006.66	7/2003 - 12/2010	24	25	2,000	352	200	530	33.3
Big Cedar Creek	6BBCD009.83	7/2003 - 12/2010	24	25	2,000	534	380	526	70.8
Burgess Creek	6BBUG000.10	1/2009 – 12/2010	12	75	2,000	735	615	675	66.7
Clinch River	6BCLN271.50	1/2005 – 2/2012	52	25	2,000	225	100	395	25.0
Dumps Creek	6BDUM000.04	1/2005 - 12/2010	16	25	320	76	50	85	12.5
Elk Garden Creek	6BEKG004.18	1/2005 - 12/2010	15	50	2,000	784	600	672	86.7
Elk Garden Creek	6BEKG008.48	1/2009 - 12/2010	12	100	2,000	600	300	675	75.0
Hess Creek	6BHES000.05	2/2007 – 4/2011	24	25	2,000	451	125	693	37.5
Indian Creek	6BIDN000.69	1/2007 - 1/2011	22	25	1,100	225	25	352	22.7
Little River	6BLTR000.75	1/2007 - 11/2008	11	25	750	114	25	216	9.1
Little River	6BLTR018.19	1/2007 - 1/2011	22	25	2,000	390	265	557	54.5
Little River	6BLTR019.45	3/2008 - 5/2009	2	20	20	20	NA	0	0.0
Little River	6BLTR025.03	4/2005	1	90	90	90	NA	NA	0.0
Little River	6BLTR025.45	1/2007 - 11/2008	12	25	400	97	63	105	8.3
Lewis Creek	6BLWS000.06	2/2007 - 1/2011	22	25	2,000	364	63	533	40.9
Lewis Creek	6BLWS004.84	2/2007 - 1/2011	21	25	1,600	263	75	392	33.3
Loop Creek	6BLOO004.25	1/2005 - 12/2010	15	25	1,300	339	220	396	46.7
Loop Creek	6BLOO006.03	1/2009 - 12/2010	12	25	2,000	441	265	546	50.0
Maiden Spring Creek	6BMSC001.53	1/2007 - 4/2010	5	25	950	225	50	406	20.0
Maiden Spring Creek	6BMSC008.98	1/2007 - 1/2011	21	25	2,000	345	120	571	38.1
Swords Creek	6BSWO000.11	4/2009 - 1/2011	21	25	1,800	386	150	501	38.1
Swords Creek	6BSWO001.81	2/2007 - 12/2008	12	25	1,400	289	98	448	25.0
Thompson Creek	6BTMP003.58	8/2003 - 12/2010	24	25	2,000	609	340	626	58.3
Weaver Creek	6BWEA000.02	8/2003 - 12/2010	24	25	2,000	643	350	677	58.3
Weaver Creek	6BWEA004.32	8/2003 - 12/2010	24	25	2,000	636	235	731	50.0

NA – Not applicable

<sup>1</sup>Based on the current instantaneous *E. coli* standard of 235 cfu/100mL.

### 3. BACTERIA SOURCE ASSESSMENT

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

#### 3.1 Assessment of Permitted Sources

Six point sources are permitted to discharge to surface water bodies in the Middle Clinch River watershed study area through the Virginia Pollutant Discharge Elimination System (VPDES). These are listed in Table 3.1. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain an *E. coli* concentration below 126 cfu/100mL, the current standard. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill pathogens. The monitoring method for ensuring the goal is to measure the concentration of total residual chlorine (TRC) in the effluent. Typically, if minimum TRC levels are met, bacteria concentrations are reduced to levels well below the standard.

Table 3.2 shows the 62 single family home permits within the Middle Clinch River watershed study area. The use of “UT” in this table refers to Unnamed Tributaries. These permits allow treated residential wastewater to be discharged to surface waters. All of these housing units discharge water and bacteria to the streams. One permit (VAG400177) listed in Table 3.2, is located in an upstream contributing watershed which was accounted for in a separate TMDL study. Although that permit and its bacteria load are accounted for in this TMDL, the permit is not reflected in the TMDL tables for the NTUs in this TMDL. A map of all the permitted sources is shown in Figure 3.1. Further information on the domestic permits can be found in Table 3.2

Watershed, VA

There are no VPDES Animal Feeding Operations (AFOs) or Virginia Pollution Abatement (VPA) facilities in the study area.

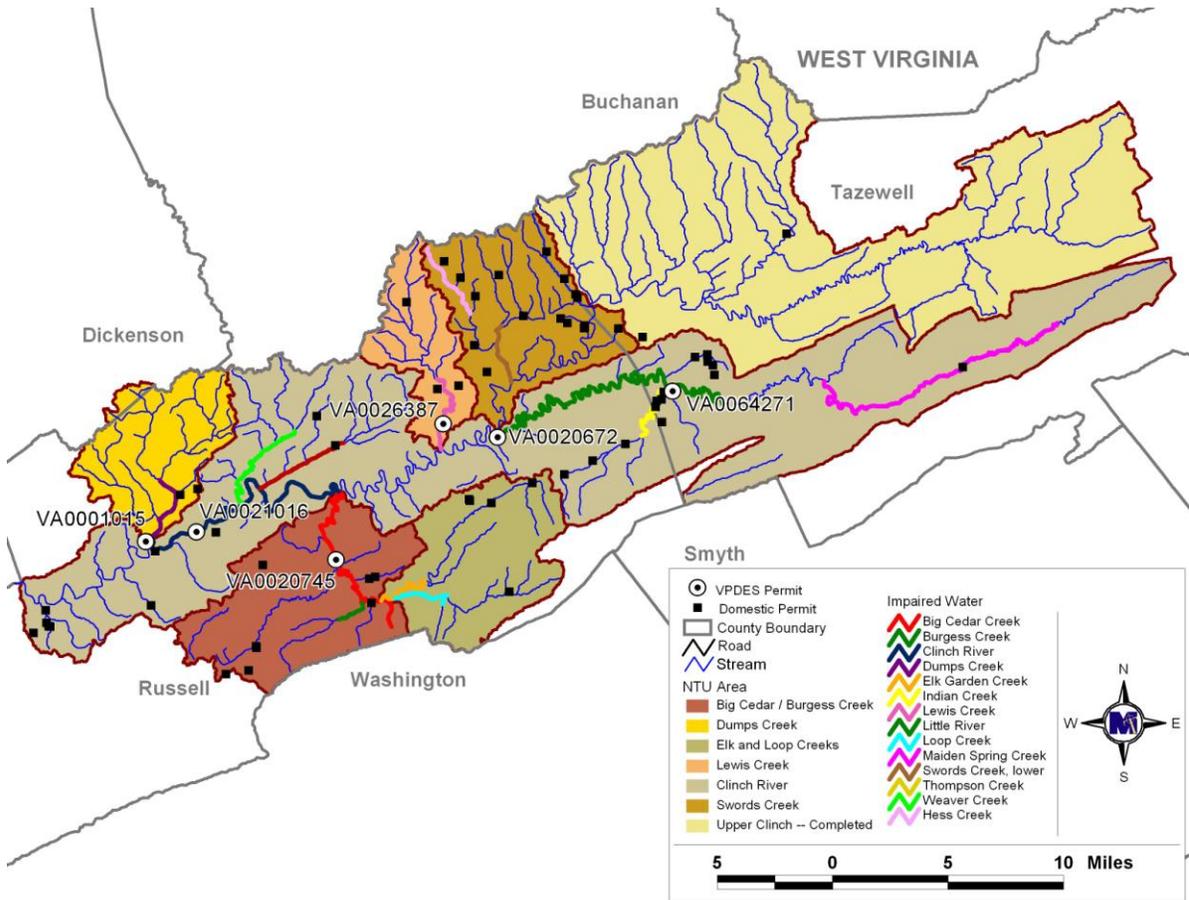


Figure 3.1 Permitted Sources in the Middle Clinch River watershed.

**Table 3.1 Summary of VPDES permitted point sources permitted for fecal bacteria control in the Middle Clinch River watershed study area.**

Permit	Receiving Stream(s)	Facility Name	Permitted for <i>E. coli</i> Control	Average Discharge Concentrations (cfu/100mL)
VA0020672	Casey Branch	DOC - Appalachian Detention Center 29	Y	4.25
VA0020745	Big Cedar Creek	Lebanon WWTP	Y	5.75
VA0026387	Lewis Creek	Honaker STP	Y	6.82
VA0064271	Little River	Claypool Hill STP	Y	3.95
VA0001015	Middle Clinch River	American Electric Power Clinch River Plant 008	Y	9.40
VA0021016	Middle Clinch River	Cleveland STP	Y	39.76

**Table 3.2 Single family home permits in the Middle Clinch River watershed study area.**

Permit	Receiving Stream	NTU	Facility Type
VAG400058	Indian Creek	250	Domestic
VAG400094	Katie Branch, UT	250	Domestic
VAG400114	Katie Branch	250	Domestic
VAG400279	Indian Creek	250	Domestic
VAG400542	Indian Creek, UT	250	Domestic
VAG400551	Indian Creek	250	Domestic
VAG400598	Indian Creek	250	Domestic
VAG400600	Indian Creek	250	Domestic
VAG400605	Katie Branch	250	Domestic
VAG400638	Indian Creek	250	Domestic
VAG400760	Katie Branch, UT	250	Domestic
VAG400832	Indian Creek, UT	250	Domestic
VAG400872	Maiden Spring Creek UT	250	Domestic
VAG400143	Clinch River	250	Domestic
VAG400692	Breezers Branch	250	Domestic
VAG400795	Clinch River, UT	250	Domestic
VAG400874	Big Spring Branch	250	Domestic
VAG400873	Big Spring Branch	250	Domestic
VAG400845	Big Spring Branch	250	Domestic
VAG400828	Big Spring Branch	250	Domestic
VAG400714	Meade Branch	250	Domestic
VAG400625	Big Spring Branch	250	Domestic
VAG400781	Katie Branch, UT	250	Domestic
VAG400335	Little River, UT	250	Domestic
VAG400952	Thompson Creek UT	250	Domestic
VAG400976	Millstone Branch, UT	251	Domestic
VAG400836	Millstone Branch	251	Domestic
VAG400133	UT	252	Domestic
VAG400186	Willis Branch	252	Domestic
VAG400411	Little Cedar Creek	252	Domestic
VAG400615	Roaring Spring Branch	252	Domestic
VAG400624	Roaring Spring Branch, UT	252	Domestic
VAG400777	Mountain Branch	252	Domestic
VAG400971	Little Cedar Creek	252	Domestic
VAG400972	Little Cedar Creek UT	252	Domestic
VAG400280	Elk Garden Creek	253	Domestic
VAG400754	Boardwine Branch, UT	253	Domestic

**Table 3.2 Single family home permits in the Middle Clinch River watershed study area (cont.).**

	Receiving Stream	NTU	Facility Type
VAG400844	Elk Garden Creek	253	Domestic
VAG400862	Elk Garden Creek UT	253	Domestic
VAG400866	Elk Garden Creek UT	253	Domestic
VAG400521	Lewis Creek, UT	298	Domestic
VAG400614	Lewis Creek, UT	298	Domestic
VAG400811	Lewis Creek, UT	298	Domestic
VAG400175	Sugar Run, UT	421	Domestic
VAG400278	UT	421	Domestic
VAG400421	Right Fork Mill Creek	421	Domestic
VAG400434	Sulfur Spring UT	421	Domestic
VAG400444	Long Branch	421	Domestic
VAG400492	Long Branch Creek	421	Domestic
VAG400511	Sugar Run Creek	421	Domestic
VAG400513	Groundhog Hollow, UT	421	Domestic
VAG400587	Strow Creek	421	Domestic
VAG400622	Long Branch	421	Domestic
VAG400628	Pine Creek	421	Domestic
VAG400647	Long Branch	421	Domestic
VAG400835	Mill Creek	421	Domestic
VAG400968	Hess Creek UT	421	Domestic
VAG400940	Long Branch UT	421	Domestic
VAG400937	Right Fork of Mill Creek	421	Domestic
VAG400563	Mill Creek	421	Domestic
VAG400900	Clinch River UT	*	Domestic
VAG400177	Indian Creek	*	Domestic

\* These 2 permits are located in upstream NTUs which are part of the completed Upper Clinch TMDL

### 3.2 Assessment of Nonpoint Sources

In the Middle Clinch River watershed study area, both residential and agricultural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage disposal systems, land application of waste (livestock), livestock, wildlife, and pets.

### 3.2.1 Private Residential Sewage Treatment

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

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

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

MapTech previously sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml (MapTech, 2001). An average fecal

coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

**Table 3.3 Human population, housing units, houses on sanitary sewer, septic systems, and other sewage disposal systems for areas contributing to impaired segments in the Middle Clinch River watershed study area.**

<b>NTU - Impairment Grouping</b>	<b>Human Population</b>	<b>Housing Units</b>	<b>Homes with Sewer</b>	<b>Homes with Septic</b>	<b>Estimated Homes with Straight Pipes</b>
Big Cedar/Burgess	7,276	3,420	1,739	1,640	3
Elk Garden/Loop	2,025	912	9	890	1
Lewis Creek	2,577	1,364	502	810	4
Middle Clinch River	13,275	5,672	856	4,531	22
Swords/Hess	4,157	2,201	580	1,462	13
Dumps Creek	341	182	25	139	1
<b>Total</b>	<b>29,651</b>	<b>13,751</b>	<b>3,711</b>	<b>9,472</b>	<b>44</b>

### 3.2.1.1 Virginia Department of Health Failing Septic System Procedures

The Emergency Regulations for Alternative Onsite Sewage Systems, adopted in April, 2010, require that all alternative onsite sewage treatment systems in Virginia be visited at least annually by a licensed operator. However, the Virginia Department of Health (VDH) does not currently have the authority, the mandate or the resources to require or conduct similar surveillance of all conventional onsite sewage treatment (septic) systems in the Commonwealth. (Note that, as resources allow, VDH may conduct or assist with such surveys that target localized areas of specific concern.)

Given the above limitations, VDH generally learns of failed septic systems directly or indirectly from the owners of those systems or through complaints from neighbors or other government agencies. Reports of straight pipes are less-frequently received from either source, since they are generally located in less-populated areas and are typically sited/intended to avoid detection.

When VDH receives a report of a non-compliant system, it performs a site inspection, if necessary, to verify the report. VDH then works with the homeowner to address the issue in an effective, timely and regulatory-compliant manner, generally through installation of

a septic or alternative onsite system, repair or replacement of an existing system and/or failed components of that system, connection to a central collection/treatment system, or other appropriate measure(s). In the case of non-cooperative homeowners, VDH initially attempts to achieve compliance through internal enforcement actions and, ultimately, through the court system.

An impasse may be reached when a homeowner is willing, but financially unable to correct the non-compliance. In such situations, VDH assists in attempting to locate funding for the needed corrections, with the knowledge that many of the existing funding sources (State Revolving Loan Fund, Water Quality Improvement Fund, etc.) have significant shortcomings with regard to the onsite wastewater treatment arena. VDH, DEQ, and DCR have discussed those shortcomings and have agreed to collaborate in an effort to identify sources of financial assistance for owners of onsite wastewater systems located in the watersheds of impaired waters.

Further, onsite sewage disposal system's that were permitted in accordance with prior regulations may also have an impact on bacteriological impairments. Some of these system's may have been permitted and installed in less favorable site and soil conditions than are required under current regulations, such as being installed too close to a water table or stream. For example, under prior regulations, an onsite system could discharge septic tank effluent within 2" of the water table in sandy soil and within 12" of the water table in clay type soils. Under the current regulations, septic tank effluent cannot be discharged within 18" of the water table in any soil type to adequately protect groundwater resources.

The current regulations state that, for the purpose of requiring correction of a malfunctioning sewage disposal system, the presence of raw or partially treated sewage on the ground's surface or in adjacent ditches or waterways or exposure to insects, animals or humans is evidence of system failure and is deemed a violation of the regulations. The regulations also state that pollution of the groundwater or backup of sewage into plumbing fixtures may also indicate system failure. VDH does not have a specific standard for what constitutes the "pollution of groundwater," but the current

regulations reflect the minimum standards necessary to adequately protect groundwater supplies and public health. However, unless an existing system malfunctions in accordance with the current regulations, VDH does not have a mandate to require repairs of that system.

**3.2.2 Biosolids**

Biosolids have not been applied in the Middle Clinch River watershed study area.

**3.2.3 Pets**

Among pets, cats and dogs are the predominant contributors of fecal coliform in the Middle Clinch River watershed study area watershed and were the only pets considered in this analysis. Cat and dog populations were derived from American Veterinary Medical Association Center for Information Management demographics in 1997. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was previously measured by MapTech. Fecal coliform density for dogs and cats was previously measured from samples collected by MapTech (MapTech, 1999). A summary of the data collected is given in Table 3.4. Table 3.5 lists the domestic animal populations for impairments in the Middle Clinch River watershed study area.

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

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

**Table 3.5** Estimated domestic animal populations in areas contributing to impaired segments in the Middle Clinch River watershed study area.

NTU - Impairment Grouping	Dogs	Cats
Big Cedar/Burgess	1,724	1,930
Elk Garden/Loop	451	505
Lewis Creek	676	757
Middle Clinch River	2,792	3,125
Swords Creek	1,090	1,220
Dumps Creek	83	92
<b>Total</b>	<b>6,816</b>	<b>7,629</b>

### 3.2.4 Livestock

The predominant type of livestock in the Middle Clinch River watershed study area is beef cattle, although other types of livestock identified were considered in modeling the watershed. Table 3.6 gives a summary of livestock populations in the Middle Clinch River watershed study area. Animal populations were based on communication with VADEQ, Clinch Valley Soil and Water Conservation District (CVSWCD), Tazewell Soil and Water Conservation District (TSWCD), watershed visits, and verbal communication with citizens at the first public meeting.

**Table 3.6** Livestock populations in areas contributing to impaired segments in the Middle Clinch River watershed study area.

NTU - Impairment Grouping	Beef	Beef Calves	Dairy	Dairy Calves	Dairy (Dry)	Horse	Sheep
Big Cedar/Burgess	2,840	1,420	47	24	24	379	331
Elk Garden/Loop	1,802	901	30	15	15	240	210
Lewis Creek	10,004	5,002	167	83	83	1,334	1,167
Middle Clinch River	16,908	8,453	693	345	345	2,680	3,327
Swords Creek	14,723	7,362	245	123	123	1,963	1,718
Dumps Creek	888	444	15	7	7	118	104
<b>Total</b>	<b>47,165</b>	<b>23,582</b>	<b>1,197</b>	<b>597</b>	<b>597</b>	<b>6,714</b>	<b>6,857</b>

Values of fecal coliform density of livestock sources were based on sampling previously performed by MapTech (MapTech, 1999). Reported manure production rates for livestock were taken from American Society of Agricultural Engineers (1998). A summary of fecal coliform density values and manure production rates is presented in Table 3.7.

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

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)	Waste Storage Die-off factor
Beef stocker (850 lb)	51.0	101,000	NA
Beef calf (350 lb)	21.0	101,000	NA
Dairy milker (1,400 lb)	120.4	271,329	0.5
Dairy heifer (850 lb)	70.0	271,329	0.25
Dairy calf (350 lb)	29.0	271,329	0.5
Hog (135 lb)	11.3	400,000	0.8
Horse (1,000 lb)	51.0	94,000	NA
Sheep (60 lb)	2.4	43,000	NA

<sup>1</sup>units are cfu/100mL

Fecal bacteria produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (*e.g.*, pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Dairy cows were considered confined at all times, and therefore dairy waste was modeled as being collected and applied throughout the year. Table 3.8 shows the average percentage of collected dairy waste that is applied throughout the year. Second, grazing livestock deposit manure directly on the land where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities may have drainage systems that divert wash-water and waste directly to drainage ways or streams.

**Table 3.8 Average percentage of collected dairy waste applied throughout year.**

Month	Applied % of Total	
	Dairy	Land use
January	1.50	Cropland
February	1.75	Cropland
March	17.00	Cropland
April	17.00	Cropland
May	17.00	Cropland
June	1.75	Pasture
July	1.75	Pasture
August	1.75	Pasture
September	5.00	Cropland

October	17.00	Cropland
November	17.00	Cropland
December	1.50	Cropland

Some livestock were expected to deposit a portion of waste on land areas. The percentage of time spent on pasture for livestock was estimated based on projects in other areas of southwest Virginia. All livestock, with the exception of actively milked dairy cows, were assumed to be in pasture 100% of the time.

It was assumed that beef cattle were expected to make a significant contribution through direct deposition with access to flowing water. For areas where direct deposition by cattle is assumed, the average amount of time that beef cattle, dry cows, and replacement heifers spend in stream access areas for each month is given in Table 3.9.

**Table 3.9 Average time beef cows, dry cows, and replacement heifers spend in different areas per day.**

<b>Month</b>	<b>Pasture (hr)</b>	<b>Stream Access (hr)</b>	<b>Loafing Lot (hr)</b>
January	23.3	0.7	0
February	23.3	0.7	0
March	23.0	1.0	0
April	22.6	1.4	0
May	22.6	1.4	0
June	22.3	1.7	0
July	22.3	1.7	0
August	22.3	1.7	0
September	22.6	1.4	0
October	23.0	1.0	0
November	23.0	1.0	0
December	23.3	0.7	0

**3.2.5 Wildlife**

The predominant wildlife species in the Middle Clinch River watershed study area were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), United States Fish and Wildlife Service (FWS), citizens from the watershed, and source sampling. Population densities were calculated

from data provided by VDGIF and FWS, and are listed in Table 3.10 (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; Raftovich, 2004; Rose and Cranford, 1987).

**Table 3.10 Wildlife population densities for the Middle Clinch River watershed study area.**

<b>Deer (an/ac of habitat)</b>	<b>Turkey (an/ac of habitat)</b>	<b>Goose (an/ac of habitat)</b>	<b>Duck (an/ac of habitat)</b>	<b>Muskrat (an/ac of habitat)</b>	<b>Raccoon (an/ac of habitat)</b>	<b>Beaver (an/mi of stream)</b>
0.0349	0.00907	0.0032	0.006522	0.31254	0.07034	0.25

The numbers of animals estimated to be in the Middle Clinch River watershed study area are reported in Table 3.11. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996, and Yagow, 1999b).

**Table 3.11 Estimated wildlife populations in the Middle Clinch River watershed study area.**

<b>NTU - Impairment Grouping</b>	<b>Deer</b>	<b>Duck</b>	<b>Goose</b>	<b>Raccoon</b>	<b>Turkey</b>	<b>Muskrat</b>	<b>Beaver</b>
Big Cedar/Burgess	1,115	69	34	2,288	263	3,330	566
Elk Garden/Loop	865	51	25	1,773	220	2,460	504
Lewis Creek	481	24	12	985	114	1,139	235
Middle Clinch River	5,103	215	105	10,474	1,275	10,308	2,035
Swords Creek	979	51	25	2,020	233	2,427	494
Dumps Creek	670	33	16	1,430	165	1,567	302
<b>Total</b>	<b>9,213</b>	<b>443</b>	<b>217</b>	<b>18,970</b>	<b>2,270</b>	<b>21,231</b>	<b>4,136</b>

Fecal coliform densities and fecal production information are reported in Table 3.12. Where available, fecal coliform densities were based on sampling of wildlife scat performed by MapTech (MapTech, 1999). The only value that was not obtained from MapTech sampling in the watershed was for beaver.

**Table 3.12 Average fecal coliform densities and fecal production rates..**

<b>Animal Type</b>	<b>Fecal Coliform Density (cfu/g)</b>	<b>Waste Load (g/an-day)</b>
Raccoon	2,100,000	450
Muskrat	1,900,000	100
Beaver <sup>1</sup>	1,000	200
Deer	380,000	772
Turkey <sup>2</sup>	1,332	320
Goose <sup>3</sup>	250,000	225
Duck	3,500	150

<sup>1</sup> Beaver waste load was calculated as twice that of muskrat, based on field observations.

<sup>2</sup> Waste load for domestic turkey (ASAE, 1998).

<sup>3</sup> Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2003)

Percentage of time spent in stream access areas and percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Table 3.13 summarizes the wildlife habitat and estimated percentages of time spent in stream access areas (i.e., within 100 feet of stream).

**Table 3.13 Wildlife habitat and percentage of time spent in stream access areas.**

Animal	Portion of Day in Stream Access Areas	Habitat
	(%)	
Raccoon	5	<b>Primary</b> = region within 600 ft of perennial streams <b>Secondary</b> = region between 601 and 7,920 ft from perennial streams <b>Infrequent/Seldom</b> = rest of watershed area including waterbodies (lakes, ponds)
Muskrat	90	<b>Primary</b> = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies <b>Secondary</b> = region between 67 and 308 ft from perennial streams, and waterbodies <b>Infrequent/Seldom</b> = rest of the watershed area
Beaver	100	<b>Primary</b> = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) <b>Infrequent/Seldom</b> = rest of the watershed area
Deer	5	<b>Primary</b> = forested, harvested forest land, orchards, grazed woodland, urban grassland, cropland, pasture, wetlands, transitional land <b>Secondary</b> = low density residential, medium density residential <b>Infrequent/Seldom</b> = remaining land use areas
Turkey	5	<b>Primary</b> = forested, harvested forest land, grazed woodland, orchards, wetlands, transitional land <b>Secondary</b> = cropland, pasture <b>Infrequent/Seldom</b> = remaining land use areas
Goose	50	<b>Primary</b> = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies <b>Secondary</b> = region between 67 and 308 ft from perennial streams, and waterbodies <b>Infrequent/Seldom</b> = rest of the watershed area
Mallard (Duck)	75	<b>Primary</b> = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies <b>Secondary</b> = region between 67 and 308 ft from perennial streams, and waterbodies <b>Infrequent/Seldom</b> = rest of the watershed area

Page intentionally blank

#### 4. BACTERIA MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Computer modeling is used in this study as a tool that allows simulating the interaction between the land surface and subsurface and the quantities of various bacteria sources by location. The model allows the climatological factors and in particular, precipitation, to drive this interaction. By modeling the watershed conditions and bacteria sources, the model allows quantifying the relationship between sources as they exist throughout the watershed to bacteria concentrations within the watershed. The model used in the analysis was the USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources.

To adequately represent the spatial variation in the watershed parameters and pollutant quantification, the Middle Clinch River Watershed drainage area was divided into twenty one (21) subwatersheds (Figure C.1). Hydrologic parameters collected for the watershed were used to calibrate and validate the simulated flow. Flow was calibrated by comparing model output to observed flow within the Middle Clinch River and making the proper adjustments to obtain the best match between simulated and observed flow. Once the flow component was built, the bacteria concentration was calibrated by comparing model simulations of bacteria to observed bacteria values collected by VADEQ at two locations. Finally the bacteria concentration was validated using a different time period from the calibration period.

Critical conditions were considered directly during model development. Critical conditions for waters impacted by land-based non-point sources of bacteria generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context, include non-point sources that are not precipitation driven (*e.g.*, fecal deposition to stream).

Graphical analyses of fecal bacteria concentrations and flow duration intervals showed that water quality standard violations occurred at nearly every flow interval at all VADEQ monitoring stations in the Middle Clinch River watershed study area. Therefore, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons in order to capture a wide range of hydrologic circumstances for all impaired streams in this study area.

In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. For example, modeling periods extended across high and low flow seasons over a period of several years. The use of HSPF allowed consideration of seasonal aspects of precipitation and stream flow patterns within the watershed. It also simulates the change in land-based nonpoint sources based on land use type and season, and the seasonal distribution of septic loads. Finally, the bacteria models were run at a 1-hour time-step across a fine scale of temporal and seasonal conditions.

Existing conditions of bacteria were then entered into the model to simulate the baseline conditions. This stage gives an indication of the current, predicted, violation rates of the geometric mean standard. At this point, the model was used in the allocation process where reductions are simulated for various sources until the bacteria geometric mean standard was met. A complete description of the modeling approach is presented in Appendix C.

## 5. BACTERIAL ALLOCATION

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

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

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

Allocation scenarios were modeled using the HSPF model. Scenarios were created by reducing direct and land-based bacteria until the water quality standards were attained. The TMDLs developed for the impairments in the Middle Clinch River watershed study area were based on the *E. coli* riverine Virginia State standards. As detailed in Section 2.1, the VADEQ riverine primary contact recreational use *E. coli* standards state that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml.

According to the guidelines put forth by the VADEQ (VADEQ, 2003) for modeling bacteria with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation (developed from a data set containing 493 paired data points):

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

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

Pollutant concentrations were modeled over the entire duration of a representative modeling period and pollutant loads were adjusted until the standards were met. The Upper Clinch River watershed (subwatershed 6) was set to its allocated load for the

modeling runs because it has a previously approved bacteria TMDL. The development of the allocation scenarios was an iterative process that required numerous runs with each followed by an assessment of source reduction against the applicable water quality standards.

### **5.1 Margin of Safety (MOS)**

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

- Allocating permitted point sources at the maximum allowable fecal coliform concentration, and
- Selecting a modeling period that represented the critical hydrologic conditions in the watershed.

### **5.2 Waste Load Allocations (WLAs)**

There are 68 point sources currently permitted to discharge into the Middle Clinch River watershed study area. The allocation for the sources permitted for *E. coli* control is equivalent to their current permit levels (design discharge and 126 cfu/100 ml). In order to account for growth in permitted discharges or creation of new ones, future growth in each watershed was calculated as the greater value of the following two scenarios: 1% of the TMDL, or a five-fold increase to the combined permitted source load from non-residential waste-water treatment plants and sewage treatment plants. The value representing 1% of the TMDL was the greater of the two values for each watershed

except the Lewis Creek modeling group (NTU 298), in which case the five-fold increase to permitted sources was used for future growth. There are currently no Municipal Separate Storm Sewer System (MS4) permits in the Middle Clinch River watershed study area.

### **5.3 Load Allocations (LAs)**

Load allocations to nonpoint sources are divided into land-based loadings from land uses (nonpoint source, NPS) and directly applied loads in the stream (livestock, wildlife, straight pipes). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads most significantly impact bacteria concentrations during high-flow conditions, while direct deposition NPS most significantly impact low flow bacteria concentrations. Nonpoint source load reductions were performed by land use, as opposed to reducing sources, as it is considered that the majority of BMPs will be implemented by land use. Appendix B shows tables of the breakdown of the annual fecal coliform per animal per land use for contributing subwatersheds to each impairment.

### **5.4 Final Total Maximum Daily Loads (TMDLs)**

Allocation scenarios were run sequentially, beginning with headwater impairments, and then continuing with downstream impairments until all impairments were allocated to 0% exceedances of all applicable standards. The first table in each of the following sections represents the scenarios developed to determine the TMDLs. The first scenario was run for all impairments simultaneously; subsequent runs were made after upstream impairments were allocated. Scenario 1 in each table describes a baseline scenario that corresponds to the existing conditions in the watershed.

Reduction scenarios exploring the role of anthropogenic sources in standards violations were explored first to determine the feasibility of meeting standards without wildlife reductions. In each table, a scenario reflects the impact of eliminating direct human sources from straight pipes. Further scenarios in each table explore a range of management scenarios, leading to the final allocation scenario that contains the predicted reductions needed to meet 0% exceedance of all applicable water quality standards. The

graphs in the following sections depict the existing and allocated 30-day geometric mean in-stream bacteria concentrations.

The second table in each of the following sections shows the existing and allocated *E. coli* loads that are output from the HSPF model. The third table shows the final in-stream allocated loads for the appropriate bacteria species. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. The final table is an estimation of the in-stream daily load of bacteria. The tables and graphs in the following sections all depict values at the most limiting subwatershed for each Nested TMDL Unit.

#### *5.4.1.1 Middle Clinch River Modeling Group – NTU 250*

Table 5.1 shows allocation scenarios used to determine the final TMDL for the Middle Clinch River watershed impairments (VAS-P07R\_CLN01A00, VAS-P05R\_IDN01A04, VAS-P07R\_WEA01A06, VAS-P07R\_TMP01A06, VAS-P05R\_LTR02A00, VAS-P05R\_LTR02A02, VAS-P05R\_MSC01A02, and VAS-P05R\_MSC01C04). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 31.43% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenario 4 is an intermediate scenario. Scenario 5 requires an 8% reduction to residential sources and eliminating straight pipes and direct inputs from livestock. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 5 will be the target goal during the implementation of best management practices (BMPs).

**Table 5.1 Allocation scenarios for reducing current bacteria loads in subwatershed 8 of the Middle Clinch River Modeling Group.**

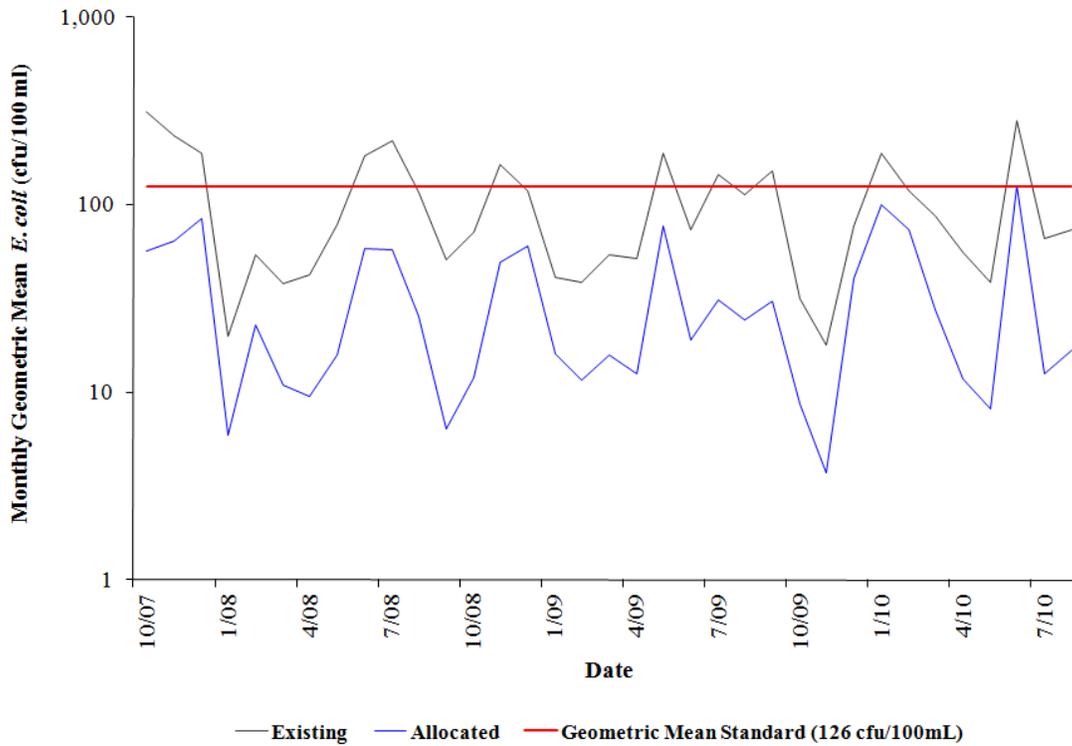
Percent Reductions to Existing Bacteria Loads								VADEQ <i>E. coli</i> Standard percent violations
Scenario	Wildlife Land Based			Agricultural Land Based	Human Direct	Human and Pet Land Based	% >126 GM	
	Wildlife Direct	Barren <sup>1</sup> , Forest, Gas well, Reclaimed Mine	Livestock Direct	Cropland, Pasture, LAX <sup>2</sup>	Straight Pipes	Developed, Commercial		
1	0	0	0	0	0	0	31.43%	
2	0	0	0	0	100	0	26.12%	
3	0	0	100	0	100	0	14.29%	
4	0	0	100	0	100	5	2.86%	
5 <sup>3</sup>	0	0	100	0	100	8	0.00%	

<sup>1</sup>Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

<sup>2</sup>LAX - livestock pasture access near flowing streams.

<sup>3</sup>Final TMDL Scenario

Figure 5.1 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Middle Clinch River modeling group (subwatershed 8). Subwatershed 8 is shown because it was the most limiting subwatershed out of this modeling group. The graph shows existing conditions in black, with allocated conditions overlaid in blue.



**Figure 5.1 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Middle Clinch River Modeling Group**

Table 5.2 contains estimates of existing and allocated in-stream *E. coli* loads at the Middle Clinch Holston River watershed impairments outlet reported as average annual cfu per year. The estimates in Table 5.2 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

Appendix B includes the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation.

**Table 5.2 Estimated existing and allocated *E. coli* in-stream loads in the Middle Clinch River Modeling Group watershed.**

Source	Source Type	Total Annual Existing Load (cfu/yr)	Total Annual Allocated Load (cfu/yr)	Required Percent Reduction
<b>Land Based</b>				
Developed	LA	6.24E+14	5.74E+14	8.0%
Commercial	LA	9.62E+13	8.85E+13	8.0%
Barren*	LA	4.96E+10	4.96E+10	0.0%
Forest	LA	3.06E+14	3.06E+14	0.0%
Pasture	LA	9.64E+13	9.64E+13	0.0%
Cropland	LA	8.26E+13	8.26E+13	0.0%
Gas Well	LA	8.11E+13	8.11E+13	0.0%
LAX**	LA	8.08E+13	8.08E+13	0.0%
Reclaimed	LA	1.21E+14	1.21E+14	0.0%
<b>Direct to Water</b>				
Human	LA	8.10E+13	0.00E+00	100.0%
Livestock	LA	8.11E+13	0.00E+00	100.0%
Wildlife	LA	8.09E+13	8.09E+13	0.0%
Permitted Sources	WLA	1.17E+12	1.17E+12	0%
Future Growth	WLA	0.00E+00	1.53E+13	NA
<b>Total Loads</b>		1.73E+15	1.53E+15	11.8%

\*Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

\*\*LAX - livestock pasture access near flowing streams.

Table 5.3 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

**Table 5.3 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Middle Clinch River Modeling Group**

NTU Group	WLA <sup>1</sup>	LA	MOS	TMDL
<b>Clinch River</b>	<b>1.64E+13</b>	<b>1.51E+15</b>		<b>1.53E+15</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	
VA0020672	2.09E+10	0.012	126	
VA0064271	6.55E+11	0.376	126	
VA0001015	6.27E+10	0.036	126	
VA0021016	3.92E+11	0.225	126	
VAG400143	1.74E+09	0.001	126	
VAG400795	1.74E+09	0.001	126	
VAG400094	1.74E+09	0.001	126	
VAG400114	1.74E+09	0.001	126	
VAG400605	1.74E+09	0.001	126	
VAG400760	1.74E+09	0.001	126	
VAG400872	1.74E+09	0.001	126	
VAG400058	1.74E+09	0.001	126	
VAG400279	1.74E+09	0.001	126	
VAG400542	1.74E+09	0.001	126	
VAG400551	1.74E+09	0.001	126	
VAG400598	1.74E+09	0.001	126	
VAG400600	1.74E+09	0.001	126	
VAG400638	1.74E+09	0.001	126	
VAG400832	1.74E+09	0.001	126	
VAG400692	1.74E+09	0.001	126	
VAG400874	1.74E+09	0.001	126	
VAG400873	1.74E+09	0.001	126	
VAG400845	1.74E+09	0.001	126	
VAG400828	1.74E+09	0.001	126	
VAG400714	1.74E+09	0.001	126	
VAG400625	1.74E+09	0.001	126	
VAG400781	1.74E+09	0.001	126	
VAG400335	1.74E+09	0.001	126	
VAG400952	1.74E+09	0.001	126	
<i>Future Load</i>	<i>1.53E+13</i>			

*Implicit*

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.4. The daily TMDL was calculated using the 99<sup>th</sup> percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100mL. This calculation of the daily TMDL does not account for varying stream flow conditions.

**Table 5.4 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Middle Clinch River Modeling Group**

NTU Group	WLA <sup>1</sup>	LA	MOS	TMDL <sup>2</sup>
Clinch River	4.51E+10	2.24E+13		2.25E+13
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	
VA0020672	5.73E+07	0.012	126	
VA0064271	1.79E+09	0.376	126	
VA0001015	1.72E+08	0.036	126	
VA0021016	1.07E+09	0.225	126	
VAG400143	4.77E+06	0.001	126	
VAG400795	4.77E+06	0.001	126	
VAG400094	4.77E+06	0.001	126	
VAG400114	4.77E+06	0.001	126	
VAG400605	4.77E+06	0.001	126	
VAG400760	4.77E+06	0.001	126	
VAG400872	4.77E+06	0.001	126	
VAG400058	4.77E+06	0.001	126	
VAG400279	4.77E+06	0.001	126	
VAG400542	4.77E+06	0.001	126	
VAG400551	4.77E+06	0.001	126	
VAG400598	4.77E+06	0.001	126	
VAG400600	4.77E+06	0.001	126	
VAG400638	4.77E+06	0.001	126	
VAG400832	4.77E+06	0.001	126	
VAG400692	4.77E+06	0.001	126	
VAG400874	4.77E+06	0.001	126	
VAG400873	4.77E+06	0.001	126	
VAG400845	4.77E+06	0.001	126	
VAG400828	4.77E+06	0.001	126	
VAG400714	4.77E+06	0.001	126	
VAG400625	4.77E+06	0.001	126	
VAG400781	4.77E+06	0.001	126	
VAG400335	4.77E+06	0.001	126	
VAG400952	4.77E+06	0.001	126	
Future Load	4.18E+10			

*Implicit*

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

<sup>2</sup> The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100mL. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

*5.4.1.2 Big Cedar/Burgess Creek Modeling Group – NTU 252*

Table 5.5 shows allocation scenarios used to determine the final TMDL for the Big Cedar/Burgess Creek Modeling Group impairments (VAS-P06R\_BCD01A98, VAS-P06R\_BCD02A02, VAS-P06R\_BCD02A00, P06R\_BCD03A00, and VAS-P06R\_BUG01A06). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 65.71% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, an 86% reduction to agricultural land based loads, and a 90% reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

**Table 5.5 Allocation scenarios for reducing current bacteria loads in subwatershed 9 of the Big Cedar/Burgess Creek Modeling Group.**

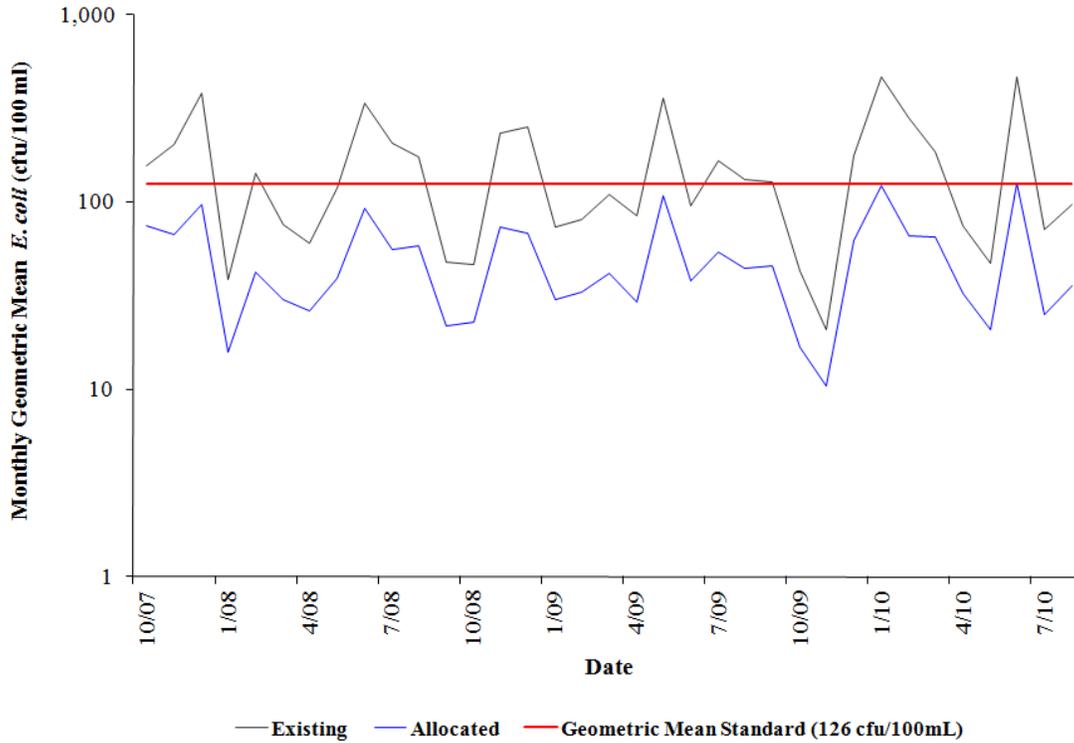
Percent Reductions to Existing Bacteria Loads							
	Wildlife Land Based		Agricultural Land Based		Human Direct	Human and Pet Land Based	VADEQ <i>E. coli</i> Standard percent violations
Scenario	Wildlife Direct	Barren <sup>1</sup> , Forest, Gas well, Reclaimed Mine	Livestock Direct	Cropland, Pasture, LAX <sup>2</sup>	Straight Pipes	Developed, Commercial	% >126 GM
1	0	0	0	0	0	0	65.71%
2	0	0	0	0	100	0	57.92%
3	0	0	100	0	100	0	42.86%
4	0	0	100	50	100	50	25.71%
5	0	0	100	75	100	75	14.29%
6 <sup>3</sup>	0	0	100	86	100	90	0.00%

<sup>1</sup>Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

<sup>2</sup>LAX - livestock pasture access near flowing streams.

<sup>3</sup>Final TMDL Scenario

Figure 5.2 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Big Cedar/Burgess Creek Modeling Group (subwatershed 9). The graph shows existing conditions in black, with allocated conditions overlaid in blue.



**Figure 5.2 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Big Cedar/Burgess Creek Modeling Group**

Table 5.6 contains estimates of existing and allocated in-stream *E. coli* loads at the Big Cedar/Burgess Creek watershed impairments outlet reported as average annual cfu per year. The estimates in Table 5.6 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

Appendix B includes the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation.

**Table 5.6 Estimated existing and allocated *E. coli* in-stream loads in the Big Cedar/Burgess Creek Modeling Group watershed.**

Source	Source Type	Total Annual Existing Load (cfu/yr)	Total Annual Allocated Load (cfu/yr)	Required Percent Reduction
<b>Land Based</b>				
Developed	LA	2.09E+15	2.09E+14	90.0%
Commercial	LA	4.40E+13	4.40E+12	90.0%
Barren*	LA	2.09E+12	2.09E+12	0.0%
Forest	LA	5.05E+14	5.05E+14	0.0%
Pasture	LA	4.46E+14	4.46E+14	0.0%
Cropland	LA	3.03E+12	4.24E+11	86.0%
Gas Well	LA	3.92E+11	3.92E+11	0.0%
LAX**	LA	7.48E+12	1.05E+12	86.0%
Reclaimed	LA	3.92E+11	3.92E+11	0.0%
<b>Direct to Water</b>				
Human	LA	7.08E+11	0.00E+00	100.0%
Livestock	LA	1.84E+12	0.00E+00	100.0%
Wildlife	LA	1.80E+12	1.80E+12	0.0%
Permitted Sources	WLA	1.52E+12	1.52E+12	0.0%
Future Growth	WLA	0.00E+00	1.18E+13	NA
<b>Total Loads</b>		3.10E+15	1.18E+15	61.9%

\*Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

\*\*LAX - livestock pasture access near flowing streams.

Table 5.7 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

**Table 5.7 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Big Cedar/Burgess Creek Modeling Group**

NTU Group	WLA <sup>1</sup>		LA	MOS	TMDL
<b>Big Cedar/Burgess</b>	<b>1.34E+13</b>		<b>1.17E+15</b>		<b>1.18E+15</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)		
VA0020745	1.50E+12	0.8636	126	<i>Implicit</i>	
VAG400133	1.74E+09	0.001	126		
VAG400186	1.74E+09	0.001	126		
VAG400411	1.74E+09	0.001	126		
VAG400615	1.74E+09	0.001	126		
VAG400624	1.74E+09	0.001	126		
VAG400777	1.74E+09	0.001	126		
VAG400971	1.74E+09	0.001	126		
VAG400972	1.74E+09	0.001	126		
<i>Future Load</i>	<i>1.18E+13</i>				

<sup>1</sup>The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.8. The daily TMDL was calculated using the 99<sup>th</sup> percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100mL. This calculation of the daily TMDL does not account for varying stream flow conditions.

**Table 5.8 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Big Cedar/Burgess Creek Modeling Group**

NTU Group	WLA <sup>1</sup>		LA	MOS	TMDL <sup>2</sup>
<b>Big Cedar/Burgess</b>	<b>3.66E+10</b>		<b>4.23E+12</b>		<b>4.26E+12</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)		
VA0020745	4.12E+09	0.8636	126	<i>Implicit</i>	
VAG400133	4.77E+06	0.001	126		
VAG400186	4.77E+06	0.001	126		
VAG400411	4.77E+06	0.001	126		
VAG400615	4.77E+06	0.001	126		
VAG400624	4.77E+06	0.001	126		
VAG400777	4.77E+06	0.001	126		
VAG400971	4.77E+06	0.001	126		
VAG400972	4.77E+06	0.001	126		
Future Load	3.24E+10				

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

<sup>2</sup> The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100mL. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

**5.4.1.3 Elk Garden/Loop Creek Modeling Group – NTU 253**

Table 5.9 shows allocation scenarios used to determine the final TMDL for the Elk Garden/Loop Creek Modeling Group impairments (VAS-P06R\_LOO01A06, and VAS-P06R\_EKG01A06). Because Virginia’s water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 48.57% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and

direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, an 83% reduction to agricultural land based loads, and a 89% reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

**Table 5.9 Allocation scenarios for reducing current bacteria loads in subwatershed 10 of the Elk Garden/Loop Creek Modeling Group.**

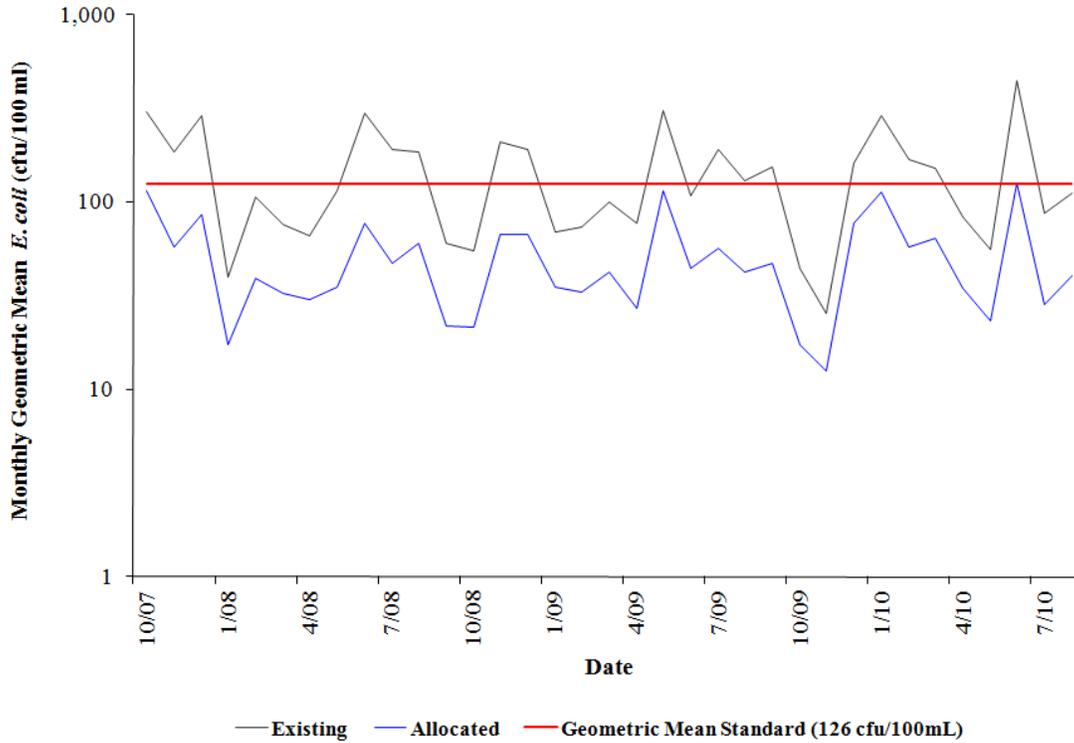
Percent Reductions to Existing Bacteria Loads								VADEQ <i>E. coli</i> Standard percent violations
Wildlife Land Based		Agricultural Land Based		Human Direct	Human and Pet Land Based		% >126 GM	
Scenario	Wildlife Direct	Barren <sup>1</sup> , Forest, Gas well, Reclaimed Mine	Livestock Direct	Cropland, Pasture, LAX <sup>2</sup>	Straight Pipes	Developed, Commercial		
1	0	0	0	0	0	0	48.57%	
2	0	0	0	0	100	0	42.37%	
3	0	0	100	0	100	0	34.29%	
4	0	0	100	50	100	50	17.14%	
5	0	0	100	75	100	75	11.43%	
6 <sup>3</sup>	0	0	100	83	100	89	0.00%	

<sup>1</sup>Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

<sup>2</sup>LAX - livestock pasture access near flowing streams.

<sup>3</sup>Final TMDL Scenario

Figure 5.3 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Elk Garden/Loop Creek modeling group (subwatershed 10). The graph shows existing conditions in black, with allocated conditions overlaid in blue.



**Figure 5.3 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Elk Garden/Loop Creek Modeling Group**

Table 5.10 contains estimates of existing and allocated in-stream *E. coli* loads at the Elk Garden/Loop Creek watershed impairments outlet reported as average annual cfu per year. The estimates in Table 5.10 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

Appendix B includes the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation.

**Table 5.10 Estimated existing and allocated *E. coli* in-stream loads in the Elk Garden/Loop Creek Modeling Group watershed.**

Source	Source Type	Total Annual Existing Load (cfu/yr)	Total Annual Allocated Load (cfu/yr)	Required Percent Reduction
<b>Land Based</b>				
Developed	LA	4.09E+14	4.50E+13	89.0%
Commercial	LA	5.54E+11	6.10E+10	89.0%
Barren*	LA	8.07E+11	8.07E+11	0.0%
Forest	LA	5.36E+14	5.36E+14	0.0%
Pasture	LA	2.47E+14	4.21E+13	83.0%
Cropland	LA	2.27E+12	3.87E+11	83.0%
Gas Well	LA	3.05E+11	3.05E+11	0.0%
LAX**	LA	6.74E+12	1.15E+12	83.0%
Reclaimed	LA	3.05E+11	3.05E+11	0.0%
<b>Direct to Water</b>				
Human	LA	6.96E+11	0.00E+00	100.0%
Livestock	LA	2.79E+12	0.00E+00	100.0%
Wildlife	LA	2.89E+12	2.89E+12	0.0%
Permitted Sources	WLA	8.71E+09	8.71E+09	0%
Future Growth	WLA	0.00E+00	6.35E+12	NA
<b>Total Loads</b>		1.21E+15	6.35E+14	47.5%

\*Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

\*\*LAX - livestock pasture access near flowing streams.

Table 5.11 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

**Table 5.11 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Elk Garden/Loop Creek Modeling Group**

NTU Group	WLA <sup>1</sup>		LA	MOS	TMDL
<b>Elk Garden/Loop</b>	<b>6.36E+12</b>		<b>6.29E+14</b>		<b>6.35E+14</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	<i>Implicit</i>	
VAG400280	1.74E+09	0.001	126		
VAG400754	1.74E+09	0.001	126		
VAG400844	1.74E+09	0.001	126		
VAG400862	1.74E+09	0.001	126		
VAG400866	1.74E+09	0.001	126		
<i>Future Load</i>	6.35E+12				

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.12. The daily TMDL was calculated using the 99<sup>th</sup> percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100mL. This calculation of the daily TMDL does not account for varying stream flow conditions.

**Table 5.12 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Elk Garden/Loop Creek Modeling Group**

NTU Group	WLA <sup>1</sup>	LA	MOS	TMDL <sup>2</sup>
<b>Elk Garden/Loop</b>	<b>1.74E+10</b>	<b>1.83E+12</b>		<b>1.84E+12</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	<i>Implicit</i>
VAG400280	4.77E+06	0.001	126	
VAG400754	4.77E+06	0.001	126	
VAG400844	4.77E+06	0.001	126	
VAG400862	4.77E+06	0.001	126	
VAG400866	4.77E+06	0.001	126	
Future Load	1.74E+10			

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

<sup>2</sup> The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100mL. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

**5.4.1.4 Lewis Creek Modeling Group – NTU 298**

Table 5.13 shows allocation scenarios used to determine the final TMDL for the Lewis Creek Modeling Group impairments (VAS-P04R\_LWS01A98 and VAS-P04R\_LWS01A10). Because Virginia’s water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 48.57% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, an 79% reduction to agricultural land based loads, and a 83% reduction to residential loads. This scenario meets the geometric mean standard of 126

cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

**Table 5.13 Allocation scenarios for reducing current bacteria loads in subwatershed 16 of the Lewis Creek Modeling Group.**

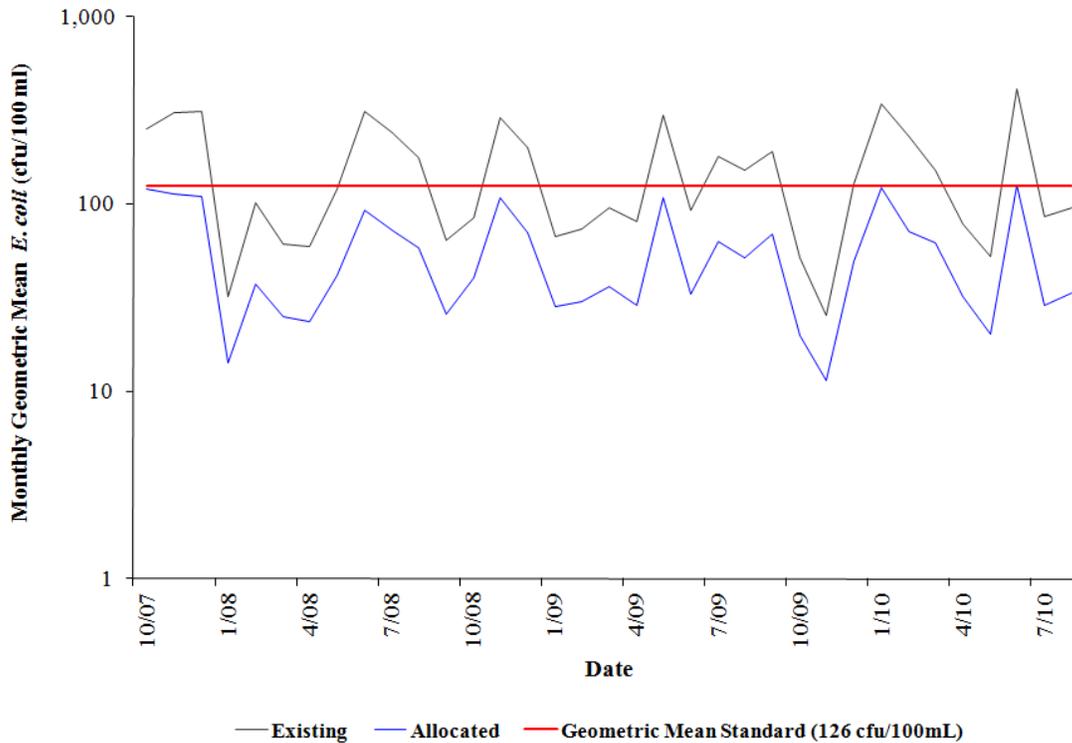
Percent Reductions to Existing Bacteria Loads								VADEQ <i>E. coli</i> Standard percent violations
Scenario	Wildlife Land Based			Agricultural Land Based		Human Direct	Human and Pet Land Based	% >126 GM
	Wildlife Direct	Barren <sup>1</sup> , Forest, Gas well, Reclaimed Mine	Livestock Direct	Cropland, Pasture, LAX <sup>2</sup>	Straight Pipes	Developed, Commercial		
1	0	0	0	0	0	0	48.57%	
2	0	0	0	0	100	0	44.38%	
3	0	0	100	0	100	0	31.43%	
4	0	0	100	50	100	50	27.71%	
5	0	0	100	75	100	75	14.29%	
6 <sup>3</sup>	0	0	100	79	100	83	0.00%	

<sup>1</sup>Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

<sup>2</sup>LAX - livestock pasture access near flowing streams.

<sup>3</sup>Final TMDL Scenario

Figure 5.4 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Lewis Creek modeling group (subwatershed 16). The graph shows existing conditions in black, with allocated conditions overlaid in blue.



**Figure 5.4 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Lewis Creek Modeling Group**

Table 5.14 contains estimates of existing and allocated in-stream *E. coli* loads at the Lewis Creek watershed impairments outlet reported as average annual cfu per year. The estimates in Table 5.14 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

Appendix B includes the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation.

**Table 5.14 Estimated existing and allocated *E. coli* in-stream loads in the Lewis Creek Modeling Group watershed.**

Source	Source Type	Total Annual Existing Load (cfu/yr)	Total Annual Allocated Load (cfu/yr)	Required Percent Reduction
<b>Land Based</b>				
Developed	LA	2.16E+14	3.68E+13	83.0%
Commercial	LA	6.97E+13	1.18E+13	83.0%
Barren*	LA	6.19E+13	6.19E+13	0.0%
Forest	LA	1.30E+14	1.30E+14	0.0%
Pasture	LA	1.53E+14	3.21E+13	79.0%
Cropland	LA	6.28E+13	1.32E+13	79.0%
Gas Well	LA	6.19E+13	6.19E+13	0.0%
LAX**	LA	6.38E+13	1.34E+13	79.0%
Reclaimed	LA	6.48E+13	6.48E+13	0.0%
<b>Direct to Water</b>				
Human	LA	6.19E+13	0.00E+00	100.0%
Livestock	LA	6.23E+13	0.00E+00	100.0%
Wildlife	LA	6.19E+13	6.19E+13	0.0%
Permitted Sources	WLA	2.55E+12	2.55E+12	0%
Future Growth	WLA	0.00E+00	1.27E+13	NA
<b>Total Loads</b>		1.07E+15	5.03E+14	53.1%

\*Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

\*\*LAX - livestock pasture access near flowing streams.

Table 5.15 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, a five-fold increase to the combined permitted source load from non-residential waste-water treatment plants and sewage treatment plants was set aside for future growth in the WLA portion.

**Table 5.15 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Lewis Creek Modeling Group**

NTU Group	WLA <sup>1</sup>	LA	MOS	TMDL
<b>Lewis Creek</b>	<b>1.53E+13</b>	<b>4.88E+14</b>		<b>5.03E+14</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	<i>Implicit</i>
VA0026387	2.54E+12	1.46	126	
VAG400521	1.74E+09	0.001	126	
VAG400614	1.74E+09	0.001	126	
VAG400811	1.74E+09	0.001	126	
<i>Future Load</i>	1.27E+13			

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.16. The daily TMDL was calculated using the 99<sup>th</sup> percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100mL. This calculation of the daily TMDL does not account for varying stream flow conditions.

**Table 5.16 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Lewis Creek Modeling Group**

NTU Group	WLA <sup>1</sup>	LA	MOS	TMDL <sup>2</sup>
<b>Lewis Creek</b>	<b>4.18E+10</b>	<b>1.22E+12</b>		<b>1.26E+12</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	<i>Implicit</i>
VA0026387	6.97E+09	1.46	126	
VAG400521	4.77E+06	0.001	126	
VAG400614	4.77E+06	0.001	126	
VAG400811	4.77E+06	0.001	126	
<i>Future Load</i>	3.48E+10			

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

<sup>2</sup> The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100mL. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

#### *5.4.1.5 Swords/Hess Creek Modeling Group – NTU 421*

Table 5.17 shows allocation scenarios used to determine the final TMDL for the Swords/Hess Creek Modeling Group impairments (VAS-P04R\_HES01A10 and VAS-P04R\_SWD01A00). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 31.43% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, and a 63% reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

**Table 5.17 Allocation scenarios for reducing current bacteria loads in subwatershed 17 of the Swords/Hess Creek Modeling Group.**

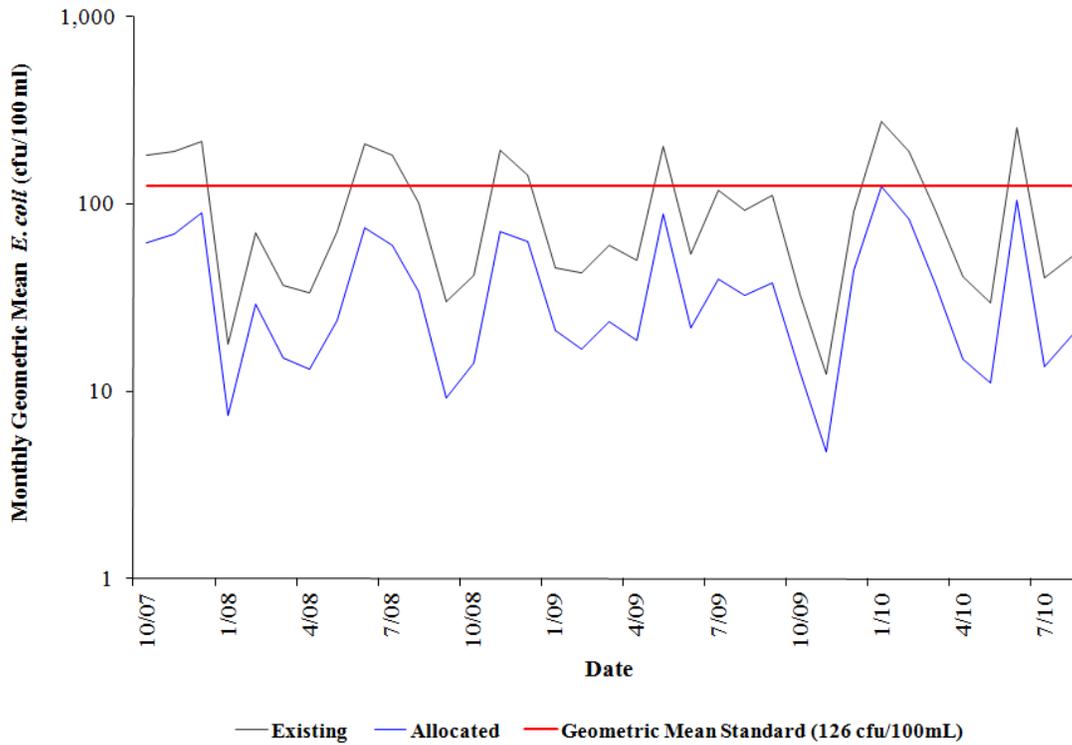
Percent Reductions to Existing Bacteria Loads								VADEQ <i>E. coli</i> Standard percent violations
Scenario	Wildlife Land Based		Agricultural Land Based		Human Direct	Human and Pet Land Based	% >126 GM	
	Wildlife Direct	Barren <sup>1</sup> , Forest, Gas well, Reclaimed Mine	Livestock Direct	Cropland, Pasture, LAX <sup>2</sup>	Straight Pipes	Developed, Commercial		
1	0	0	0	0	0	0	31.43%	
2	0	0	0	0	100	0	27.38%	
3	0	0	100	0	100	0	17.14%	
4	0	0	100	50	100	50	2.86%	
5	0	0	100	60	100	60	2.86%	
6 <sup>3</sup>	0	0	100	0	100	63	0.00%	

<sup>1</sup>Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

<sup>2</sup>LAX - livestock pasture access near flowing streams.

<sup>3</sup>Final TMDL Scenario

Figure 5.5 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Swords/Hess Creek modeling group (subwatershed 17). The graph shows existing conditions in black, with allocated conditions overlaid in blue.



**Figure 5.5 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Swords/Hess Creek Modeling Group**

Table 5.18 contains estimates of existing and allocated in-stream *E. coli* loads at the Swords/Hess Creek watershed impairments outlet reported as average annual cfu per year. The estimates in Table 5.18 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

Appendix B includes the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation.

**Table 5.18** Estimated existing and allocated *E. coli* in-stream loads in the Swords/Hess Creek Modeling Group watershed.

Source	Source Type	Total Annual Existing Load (cfu/yr)	Total Annual Allocated Load (cfu/yr)	Required Percent Reduction
<b>Land Based</b>				
Developed	LA	2.56E+14	9.47E+13	63.0%
Commercial	LA	6.49E+13	2.40E+13	63.0%
Barren*	LA	5.95E+13	5.95E+13	0.0%
Forest	LA	1.40E+14	1.40E+14	0.0%
Pasture	LA	6.43E+13	6.43E+13	0.0%
Cropland	LA	6.00E+13	6.00E+13	0.0%
Gas Well	LA	5.95E+13	5.95E+13	0.0%
LAX**	LA	5.94E+13	5.94E+13	0.0%
Reclaimed	LA	7.26E+13	7.26E+13	0.0%
<b>Direct to Water</b>				
Human	LA	5.95E+13	0.00E+00	100.0%
Livestock	LA	5.95E+13	0.00E+00	100.0%
Wildlife	LA	5.95E+13	5.95E+13	0.0%
Permitted Sources	WLA	2.96E+10	2.96E+10	0%
Future Growth	WLA	0.00E+00	7.01E+12	NA
<b>Total Loads</b>		1.01E+15	7.01E+14	31.0%

\*Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

\*\*LAX - livestock pasture access near flowing streams.

Table 5.19 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

**Table 5.19 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Swords/Hess Creek Modeling Group**

NTU Group	WLA <sup>1</sup>		LA	MOS	TMDL
<b>Swords/Hess Creek</b>	<b>7.04E+12</b>		<b>6.94E+14</b>		<b>7.01E+14</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)		
VAG400175	1.74E+09	0.001	126	<i>Implicit</i>	
VAG400421	1.74E+09	0.001	126		
VAG400492	1.74E+09	0.001	126		
VAG400511	1.74E+09	0.001	126		
VAG400622	1.74E+09	0.001	126		
VAG400647	1.74E+09	0.001	126		
VAG400835	1.74E+09	0.001	126		
VAG400278	1.74E+09	0.001	126		
VAG400434	1.74E+09	0.001	126		
VAG400444	1.74E+09	0.001	126		
VAG400513	1.74E+09	0.001	126		
VAG400587	1.74E+09	0.001	126		
VAG400628	1.74E+09	0.001	126		
VAG400940	1.74E+09	0.001	126		
VAG400937	1.74E+09	0.001	126		
VAG400563	1.74E+09	0.001	126		
VAG400968	1.74E+09	0.001	126		
<i>Future Load</i>	7.01E+12				

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.20. The daily TMDL was calculated using the 99<sup>th</sup> percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100mL. This calculation of the daily TMDL does not account for varying stream flow conditions.

**Table 5.20 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Swords/Hess Creek Modeling Group**

NTU Group	WLA <sup>1</sup>		LA	MOS	TMDL <sup>2</sup>
Swords/Hess Creek	1.93E+10		1.30E+12		1.32E+12
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	<i>Implicit</i>	
VAG400175	4.77E+06	0.001	126		
VAG400421	4.77E+06	0.001	126		
VAG400492	4.77E+06	0.001	126		
VAG400511	4.77E+06	0.001	126		
VAG400622	4.77E+06	0.001	126		
VAG400647	4.77E+06	0.001	126		
VAG400835	4.77E+06	0.001	126		
VAG400278	4.77E+06	0.001	126		
VAG400434	4.77E+06	0.001	126		
VAG400444	4.77E+06	0.001	126		
VAG400513	4.77E+06	0.001	126		
VAG400587	4.77E+06	0.001	126		
VAG400628	4.77E+06	0.001	126		
VAG400940	4.77E+06	0.001	126		
VAG400937	4.77E+06	0.001	126		
VAG400563	4.77E+06	0.001	126		
VAG400968	4.77E+06	0.001	126		
Future Load	1.92E+10				

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

<sup>2</sup> The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100mL. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.1.6 Dumps Creek Modeling Group – NTU 251

Table 5.21 shows allocation scenarios used to determine the final TMDL for the Dumps Creek Modeling Group impairment (VAS-P08R\_DUM01A94). Because Virginia’s water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use

(swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 17.14% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenarios 4 and 5 are intermediate scenarios. Scenario 6 requires eliminating straight pipes and direct inputs from livestock, and a 60% reduction to residential loads. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 6 will be the target goal during the implementation of best management practices (BMPs).

**Table 5.21 Allocation scenarios for reducing current bacteria loads in subwatershed 7 of the Dumps Creek Modeling Group.**

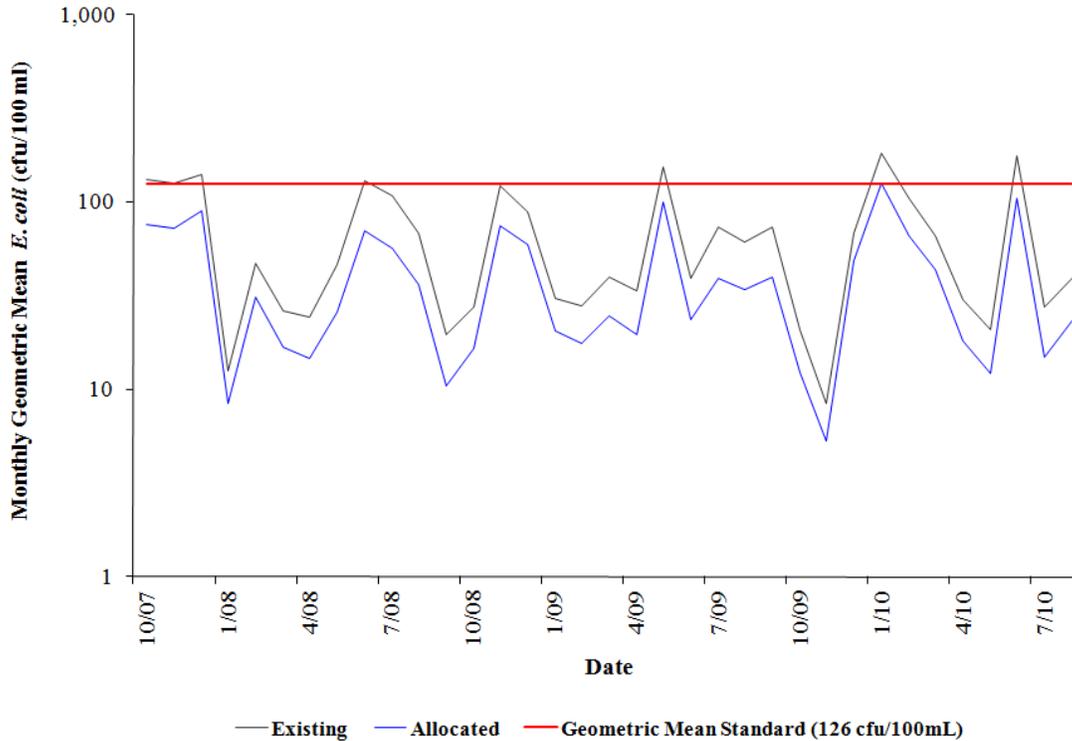
Percent Reductions to Existing Bacteria Loads								VADEQ <i>E. coli</i> Standard percent violations
Scenario	Wildlife Land Based		Agricultural Land Based		Human Direct	Human and Pet Land Based	% >126 GM	
	Wildlife Direct	Barren <sup>1</sup> , Forest, Gas well, Reclaimed Mine	Livestock Direct	Cropland, Pasture, LAX <sup>2</sup>	Straight Pipes	Developed, Commercial		
1	0	0	0	0	0	0	17.14%	
2	0	0	0	0	100	0	14.38%	
3	0	0	100	0	100	0	8.57%	
4	0	0	100	25	100	25	5.71%	
5	0	0	100	50	100	50	2.86%	
6 <sup>3</sup>	0	0	100	0	100	60	0.00%	

<sup>1</sup>Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

<sup>2</sup>LAX - livestock pasture access near flowing streams.

<sup>3</sup>Final TMDL Scenario

Figure 5.6 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Dumps Creek modeling group (subwatershed 7). The graph shows existing conditions in black, with allocated conditions overlaid in blue.



**Figure 5.6 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in the Dumps Creek Modeling Group**

Table 5.22 contains estimates of existing and allocated in-stream *E. coli* loads at the Dumps Creek watershed impairments outlet reported as average annual cfu per year. The estimates in Table 5.22 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

Appendix B includes the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation.

**Table 5.22 Estimated existing and allocated *E. coli* in-stream loads in the Dumps Creek Modeling Group watershed.**

Source	Source Type	Total Annual Existing Load (cfu/yr)	Total Annual Allocated Load (cfu/yr)	Required Percent Reduction
<b>Land Based</b>				
Developed	LA	1.99E+14	7.95E+13	60.0%
Commercial	LA	9.60E+13	3.84E+13	60.0%
Barren*	LA	1.08E+14	1.08E+14	0.0%
Forest	LA	2.79E+14	2.79E+14	0.0%
Pasture	LA	8.77E+13	8.77E+13	0.0%
Cropland	LA	8.59E+13	8.59E+13	0.0%
Gas Well	LA	2.92E+13	2.92E+13	0.0%
LAX**	LA	8.59E+13	8.59E+13	0.0%
Reclaimed	LA	1.00E+14	1.00E+14	0.0%
<b>Direct to Water</b>				
Human	LA	8.59E+13	0.00E+00	100.0%
Livestock	LA	8.60E+13	0.00E+00	100.0%
Wildlife	LA	8.61E+13	8.61E+13	0.0%
Permitted Sources	WLA	3.48E+09	3.48E+09	0.0%
Future Growth	WLA	0.00E+00	9.90E+12	NA
<b>Total Loads</b>		1.33E+15	9.90E+14	25.5%

\* Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

\*\* LAX - livestock pasture access near flowing streams.

Table 5.23 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

**Table 5.23 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Dumps Creek Modeling Group**

NTU Group	WLA <sup>1</sup>	LA	MOS	TMDL
<b>Dumps Creek</b>	<b>9.91E+12</b>	<b>9.80E+14</b>		<b>9.90E+14</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	<i>Implicit</i>
VAG400976	1.74E+09	0.001	126	
VAG400836	1.74E+09	0.001	126	
<i>Future Load</i>	<i>9.90E+12</i>			

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the Middle Clinch River watershed are shown in Table 5.24. The daily TMDL was calculated using the 99<sup>th</sup> percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100mL. This calculation of the daily TMDL does not account for varying stream flow conditions.

**Table 5.24 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Dumps Creek Modeling Group**

NTU Group	WLA <sup>1</sup>		LA	MOS	TMDL <sup>2</sup>
<b>Dumps Creek</b>	<b>2.71E+10</b>		<b>1.78E+12</b>		<b>1.81E+12</b>
Permitted Source	Allocated Load	Design Flow (MGD)	Permitted Concentration (cfu/100mL)	<i>Implicit</i>	
VAG400976	4.77E+06	0.001	126		
VAG400836	4.77E+06	0.001	126		
<i>Future Load</i>	<i>2.71E+10</i>				

<sup>1</sup> The WLA includes a future load for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

<sup>2</sup> The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100mL. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

Page intentionally blank

## **6. TMDL IMPLEMENTATION AND REASONABLE ASSURANCE**

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. EPA requires that there is reasonable assurance that TMDLs can be implemented. TMDLs represent an attempt to quantify the pollutant load that might be present in a waterbody and still ensure attainment and maintenance of water quality standards. The Commonwealth intends to use existing programs in order to attain water quality goals.

The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

### **6.1 Continuing Planning Process and Water Quality Management Planning**

As part of the Continuing Planning Process, VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in 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 the VADEQ web site under <http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ppp.pdf>.

### **6.2 Staged Implementation**

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those

sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following 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 implementation levels and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

### **6.3 Implementation of Waste Load Allocations**

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

#### **6.3.1 Stormwater**

VADEQ and VADCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while VADCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. Stormwater discharges from coal mining operations are permitted through NPDES permits by the Department of Mines, Minerals and Energy (DMME). As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented. More information regarding these programs can be found at [http://www.dcr.virginia.gov/stormwater\\_management/index.shtml](http://www.dcr.virginia.gov/stormwater_management/index.shtml).

### 6.3.2 TMDL Modifications for New or Expanding Discharges

Permits issued for facilities with wasteload allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on VADEQ's web site at

<http://www.deq.virginia.gov/Programs/Water/LawsRegulationsGuidance/Guidance/TMDLGuidance.aspx>.

## **6.4 Implementation of Load Allocations**

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. 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 TMDL implementation plan.

### 6.4.1 Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19:7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". 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.

In order to qualify for other funding sources, such as EPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003. It is available upon request from the VADEQ and VADCR TMDL project staff or at

<http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/TMDLImplementation/TMDLImplementationPlanGuidanceManual.aspx>.

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

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.

#### 6.4.2 Staged Implementation Scenarios

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control. Among the most efficient bacterial BMPs for both urban and rural watersheds are stream side fencing for cattle farms, pet waste clean-up programs, and government or grant programs available to homeowners with failing septic systems and installation of treatment systems for homeowners currently using straight pipes.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effective and reasonable BMPs, a Use Attainability Analysis (UAA) may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and §306 of Clean Water Act, and by implementing cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in Section 6.6.

Stage I scenarios are discussed in Chapter 5. Correcting 50% of straight pipes will benefit the water quality significantly for all the impairments.

#### 6.4.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality within, and downstream of, in the Middle Clinch River watershed, including the completed TMDL titled "*E. coli Total Maximum Daily Loads in the Upper Clinch River Watershed of Tazewell County, Virginia*". There are additional TDMLs scheduled for the Lower Clinch River as well.

#### 6.4.4 Implementation Funding Sources

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

efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding source for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at

<http://www.deq.virginia.gov/Programs/Water/CleanWaterFinancingAssistance/WaterQualityImprovementFund.aspx> and at

[http://www.dcr.virginia.gov/stormwater\\_management/wqia.shtml](http://www.dcr.virginia.gov/stormwater_management/wqia.shtml).

### **6.5 Follow-Up Monitoring**

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired streams in accordance with its ambient monitoring programs. The DEQ Office of Water Quality Monitoring and Assessment (WQMA) operates an ambient network of monitoring stations known as "trend stations," designed to measure long term water quality trends. The design of the trend network is such that key water quality variables are measured at targeted locations approximately every month. This monitoring station network and potentially other monitoring stations will be utilized in monitoring water quality throughout and following implementation.

VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with *DEQ Guidance Memo No. 04-2005* (<http://www.deq.virginia.gov/Portals/0/DEQ/Water/Guidance/042005b.pdf>), during

periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. The details of the follow-up ambient monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office.

VADEQ staff, in cooperation with 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 VADEQ’s standard monitoring plans. Ancillary monitoring by citizens’ or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens’ monitoring data are 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 to 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 VADEQ’s citizen monitoring in Virginia and QA/QC guidelines is available at

<http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring.aspx>.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), VADEQ must meet the minimum data requirements from the

original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years.

### **6.6 Attainability of Designated Uses**

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

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

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

1. Naturally occurring pollutant concentration prevents the attainment of the use;
2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;
5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or
6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment. Additional information can be obtained at <http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityStandards/DesignatedUses.aspx>.

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation is that all controllable sources would be reduced to the maximum extent possible using the implementation approaches described above. VADEQ will continue to monitor water quality in the stream during and subsequent to the implementation of these measures to determine if the water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E. provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed".

Page intentionally blank

## 7. PUBLIC PARTICIPATION

Public participation during TMDL development for the Middle Clinch River watershed was encouraged; a summary of the meetings is presented in Table 7.1. The first public meeting took place on May 26, 2011 at the Lebanon Town Hall in Lebanon, Virginia. 5 people attended the meeting. The second public meeting was held on May 24, 2012 and 5 people attended. The meetings were publicized by placing notices in the Virginia Register, signs in the watershed, and emailing notices to local stakeholders and representatives. During the 30-day public comment period on the final document, no written comments were received.

**Table 7.1 Public participation during TMDL development for the Middle Clinch River watershed.**

<b>Date</b>	<b>Location</b>	<b>Attendance<sup>1</sup></b>	<b>Type</b>
5/26/2011	Lebanon Town Hall Lebanon, VA	5	1 <sup>st</sup> public
5/24/2012	Lebanon Town Hall Lebanon, VA	5	2 <sup>nd</sup> public

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

Public participation during the implementation plan development process will include the formation of stakeholders’ committees, with committee and public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. Stakeholder committees will have the express purpose of formulating the TMDL Implementation Plan. The committees will consist of, but not be limited to, representatives from VADEQ, VADCR and local governments. These committees will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

Page intentionally blank

**REFERENCES**

- American Veterinary Medical Association – Center for Information Management. 1997. U.S. Pet Ownership and Demographics Sourcebook.
- American Society of Agricultural Engineers (ASAE). 1998. ASAE Standards, 45<sup>th</sup> Edition. D384.1 DEC93. Manure Production and Characteristics. St. Joseph, Mich.: ASAE.
- Bidrowski, T. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication, 01/29/03.
- Bidrowski, T. 2004. Virginia Department of Game and Inland Fisheries. Personal telecommunication. July 16, 2004 and August 9, 2004.
- Costanzo, G. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication, 01/29/03.
- EPA. 1991. Guidance for Water-Quality-Based Decisions: The TMDL Process. USEPAA440-4-91-001.
- EPA. 1992. Multi-Resolution Land Cover (MRLC) Data for Virginia, a Component of the National Land Cover Dataset (NLCD). U.S. Environmental Protection Agency and the U.S. Geological Survey, Reston, VA.
- EPA. 1999. Guidance for Water Quality-Based Decisions: The TMDL Process. <http://www.epa.gov/OWOW/tmdl/decisions/dec1c.html>
- EPA. 2000a. USEPA BASINS Technical note 6: Estimating hydrology and hydraulic parameters for HSPF. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. USEPA 823-R00-012. July 2000.
- Farrar, R. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication.
- Fies, M. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. 08/11/04, 08/12/04, and 08/24/04.
- Geldreich, E. E. 1978. Bacterial Populations and Indicator Concepts in Feces, Sewage, Stormwater, and Solid Wastes. In Indicators of Viruses in Water and Food, ed. G. Berg. Ann Arbor, Mich.: Ann Arbor Science Publishers, Inc.
- Knox, W. M. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. August 03, 2004, August 05, 2004, and August 25, 2004.
- MapTech. 1999. Unpublished source sampling data. Blackwater River TMDL Study.

- MapTech. 2011. Virginia TMDL Coordination Planning; Nested TMDL Units. January 4, 2011.
- Norman, G.W. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication.
- Norman, G. W. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. July 12, 2004.
- NRCS. Regional Hydraulic Geometry Curves. Available: 2010 <http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/index.html>
- Raftovich, R. V. 2004. Atlantic Flyway Breeding Waterfowl Plot Survey: Breeding Pair and Population Size Estimates 2004. U.S. Fish and Wildlife Service. Division of Migratory Bird Management. July 28, 2004.
- Rose, R.K., Cranford, J.A. 1987. Handbook of Virginia Mammals. Final Report, Project No. 567460. VA Dept. Game & Inland Fisheries, Richmond, VA: 121.
- SERCC. 2011. Southeast Regional Climate Center. <http://www.sercc.com/>
- USCB. 1990. *1990 Census*. United States Census Bureau. Washington D.C.
- USCB. 2000. *2000 Census*. United States Census Bureau. Washington D.C.
- USDA. 1999. Forest Service. Fire Effects Information System. [www.fs.fed.us/database/feis/plants/](http://www.fs.fed.us/database/feis/plants/)
- VADCR and VADEQ. 2003. Guidance Manual for Total Maximum Daily Load Implementation Plans. <http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf>.
- VADEQ. 1996. 303(d) Total Maximum Daily Load Priority List and Report.
- VADEQ. 2002. Section 303(d) Report on Impaired Waters .
- VADEQ. 2006. 305(b)/303(d) Integrated Report.
- VADEQ. 2008. 305(b)/303(d) Integrated Report.
- VADEQ. 2004. Section 303(d) Water Quality Assessment Integrated Report.
- VADEQ and VADCR. 1998. Section 303(d) Total Maximum Daily Load Priority List and Report.
- VASS. 2000. Virginia Agricultural Statistics Bulletin 1999. Virginia Agricultural Statistics Service. Richmond, VA.
- VASS. 2008. Virginia Agricultural Statistics Bulletin 2007. Virginia Agricultural Statistics Service. Richmond, VA.

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

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

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

Page intentionally blank

## GLOSSARY

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

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

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

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

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

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

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

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

***Biosolids.*** *Biologically treated solids originating from municipal wastewater treatment plants. Also known as "sludge". Applications to farmland are permitted by VADEQ.*

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

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

***Clean Water Act (CWA).*** *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to*

restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

*conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Privately owned treatment works.** Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.

**Public comment period.** The time allowed for the public to express its views and concerns regarding action by the USEPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

**Publicly owned treatment works (POTW).** Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

**Quartile.** The 25<sup>th</sup>, 50<sup>th</sup>, and 75<sup>th</sup> percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50<sup>th</sup> quartile is also known as the median. The 25<sup>th</sup> and 75<sup>th</sup> quartiles are referred to as the lower and upper quartiles, respectively.

**Reach.** Segment of a stream or river.

**Receiving waters.** Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.

**Reference Conditions.** The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

**Residence time.** Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.

**Restoration.** Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.

**Riparian areas.** Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.

**Riparian zone.** The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.

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

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

**Sewer.** A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.

**Simulation.** The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

**Slope.** *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

**Source.** An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor.

**Staged Implementation.** A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

**Stakeholder.** Any person with a vested interest in the TMDL development.

**Standard deviation.** A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

**Standard error.** The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

**Statistical significance.** An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

**Storm runoff.** *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

**Streamflow.** *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

**Stream restoration.** *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

**Surface area.** *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

**Surface runoff.** *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

**Surface water.** *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

**Timestep.** An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

**Topography.** *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

**Total Maximum Daily Load (TMDL).** *The sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

**TMDL Implementation Plan.** A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

**Transport of pollutants (in water).** *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

**TRC.** Total Residual Chlorine. A measure of the effectiveness of chlorinating treated waste water effluent.

**Tributary.** *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

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

**Validation (of a model).** *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

**Variance.** A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

**VADACS.** Virginia Department of Agriculture and Consumer Services.

**VADCR.** Virginia Department of Conservation and Recreation.

**VADEQ.** Virginia Department of Environmental Quality.

**VDH.** Virginia Department of Health.

**Waste load allocation (WLA).** *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

**Wastewater.** *Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

**Wastewater treatment.** *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

**Water quality.** *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

**Water quality-based permit.** *A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

**Water quality criteria.** *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by the USEPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

**Water quality standard.** *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

**Watershed.** *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

**WQIA.** Water Quality Improvement Act.

Page intentionally blank

**APPENDIX A: FREQUENCY ANALYSIS OF BACTERIA DATA**

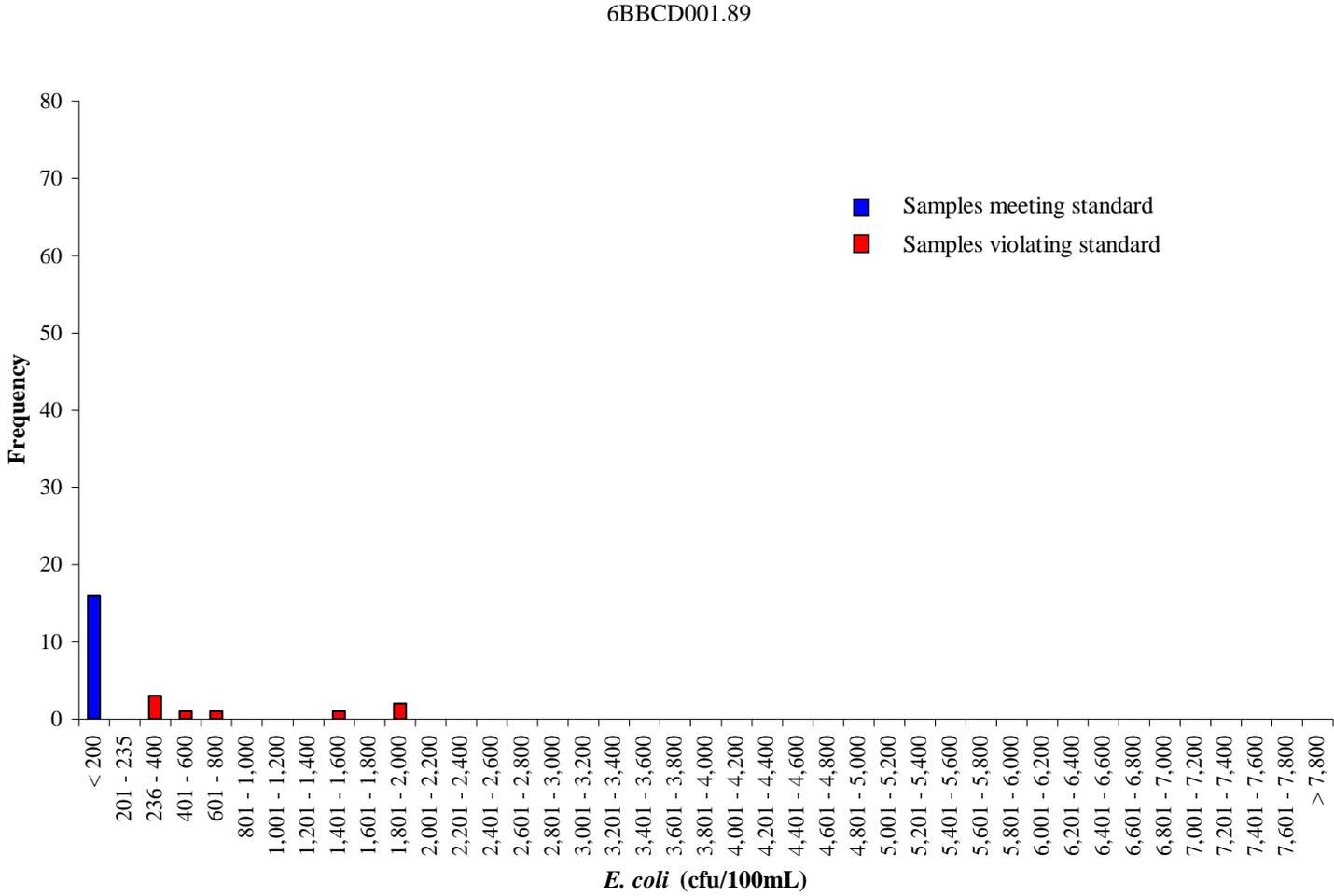
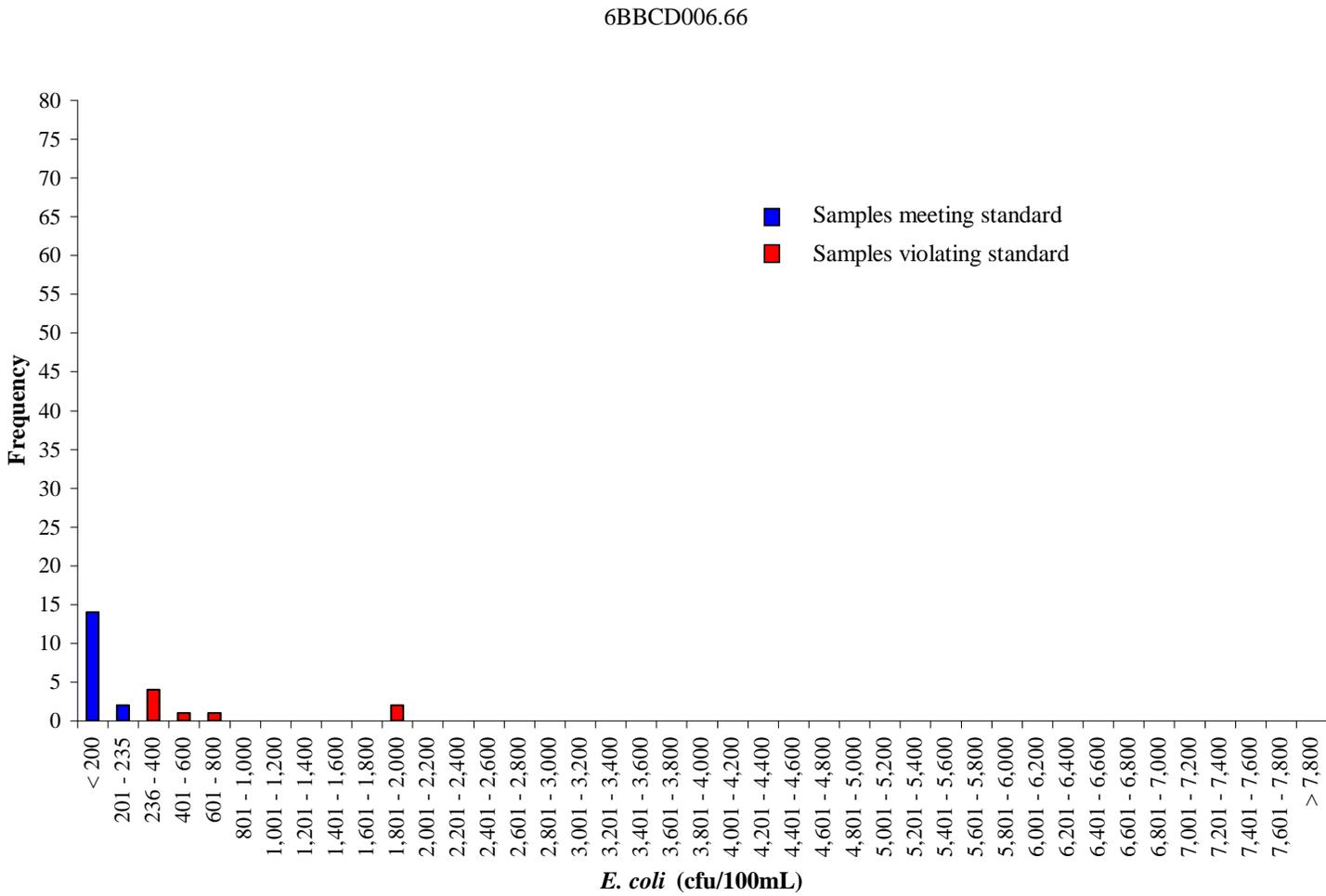


Figure A. 1 Frequency analysis of *E. coli* concentrations at station 6BBCD001.89 in Big Cedar Creek for the period from July 2003 to December 2010.



**Figure A. 2** Frequency analysis of *E. coli* concentrations at station 6BBCD006.66 in Big Cedar Creek for the period from July 2003 to December 2010.

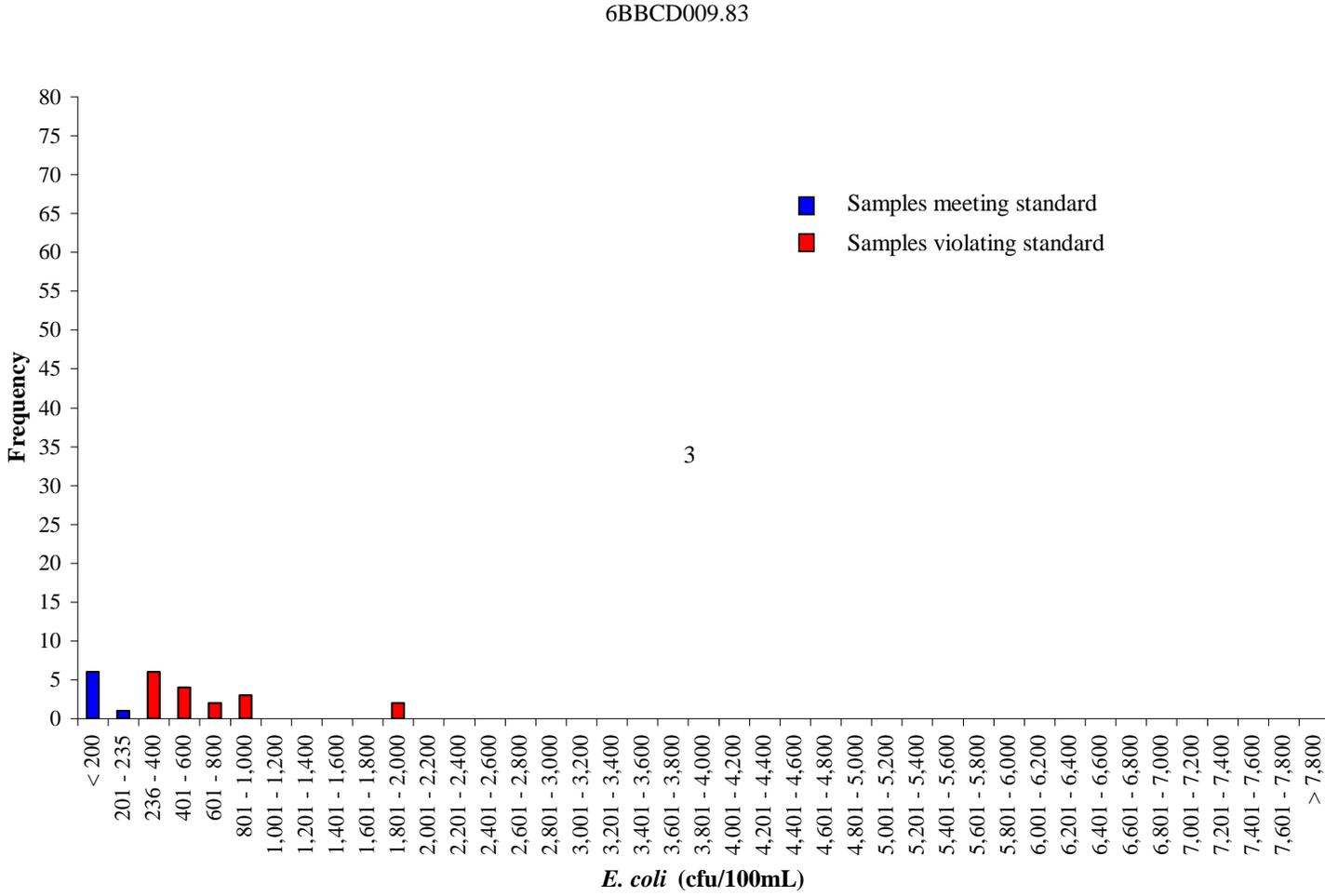
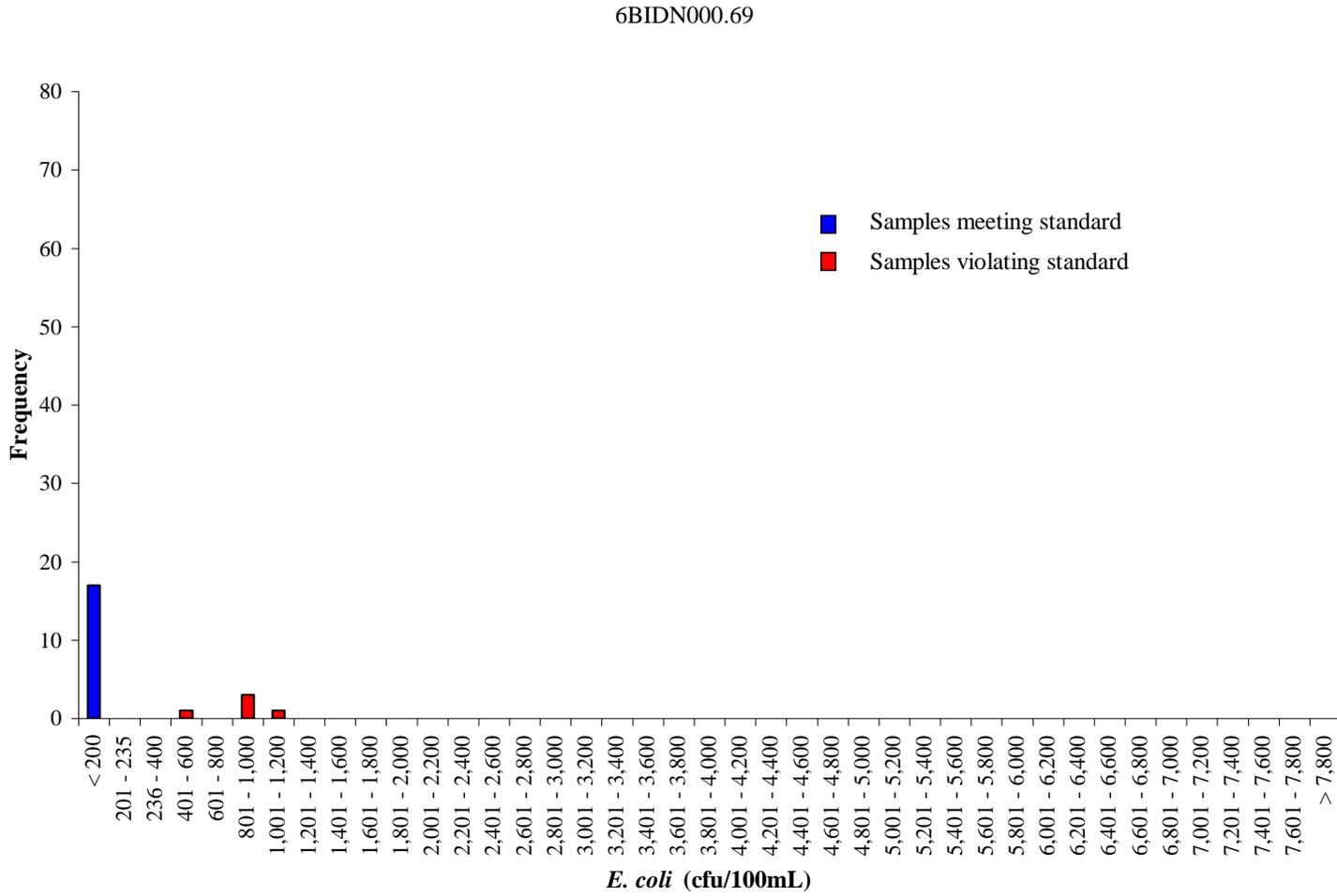
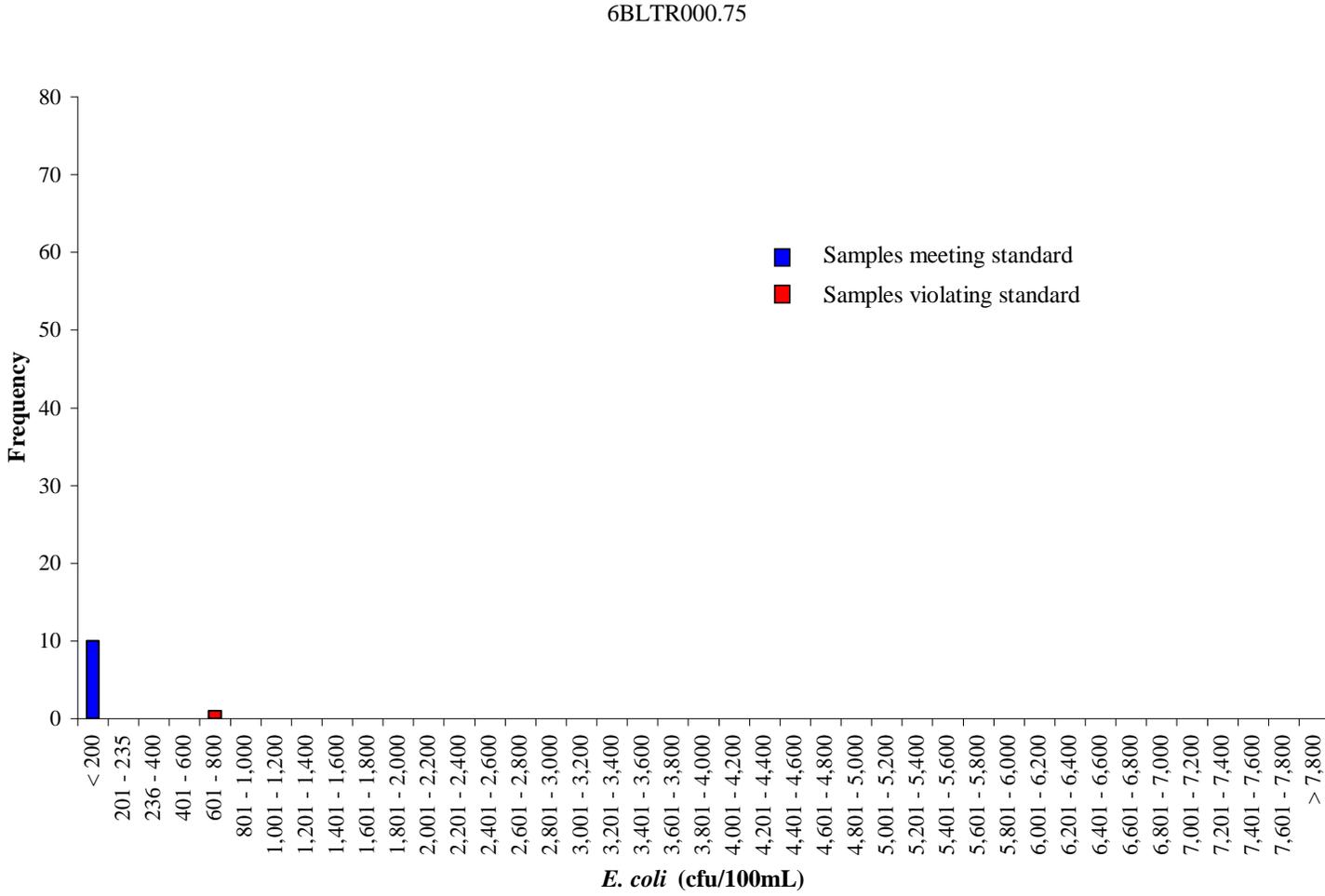


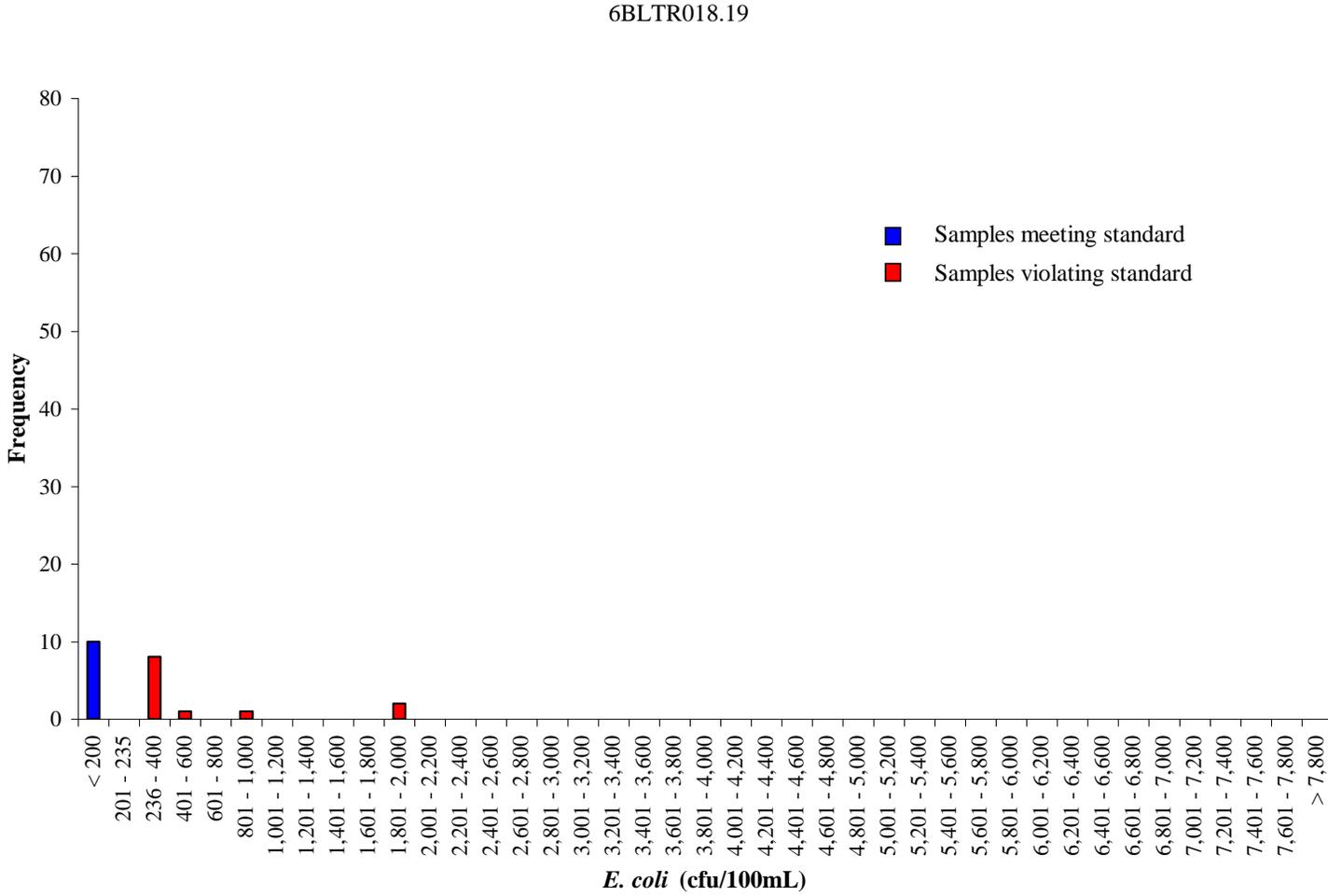
Figure A. 3 Frequency analysis of *E. coli* concentrations at station 6BBCD009.83 in the Big Cedar Creek for the period from July 2003 to December 2010.



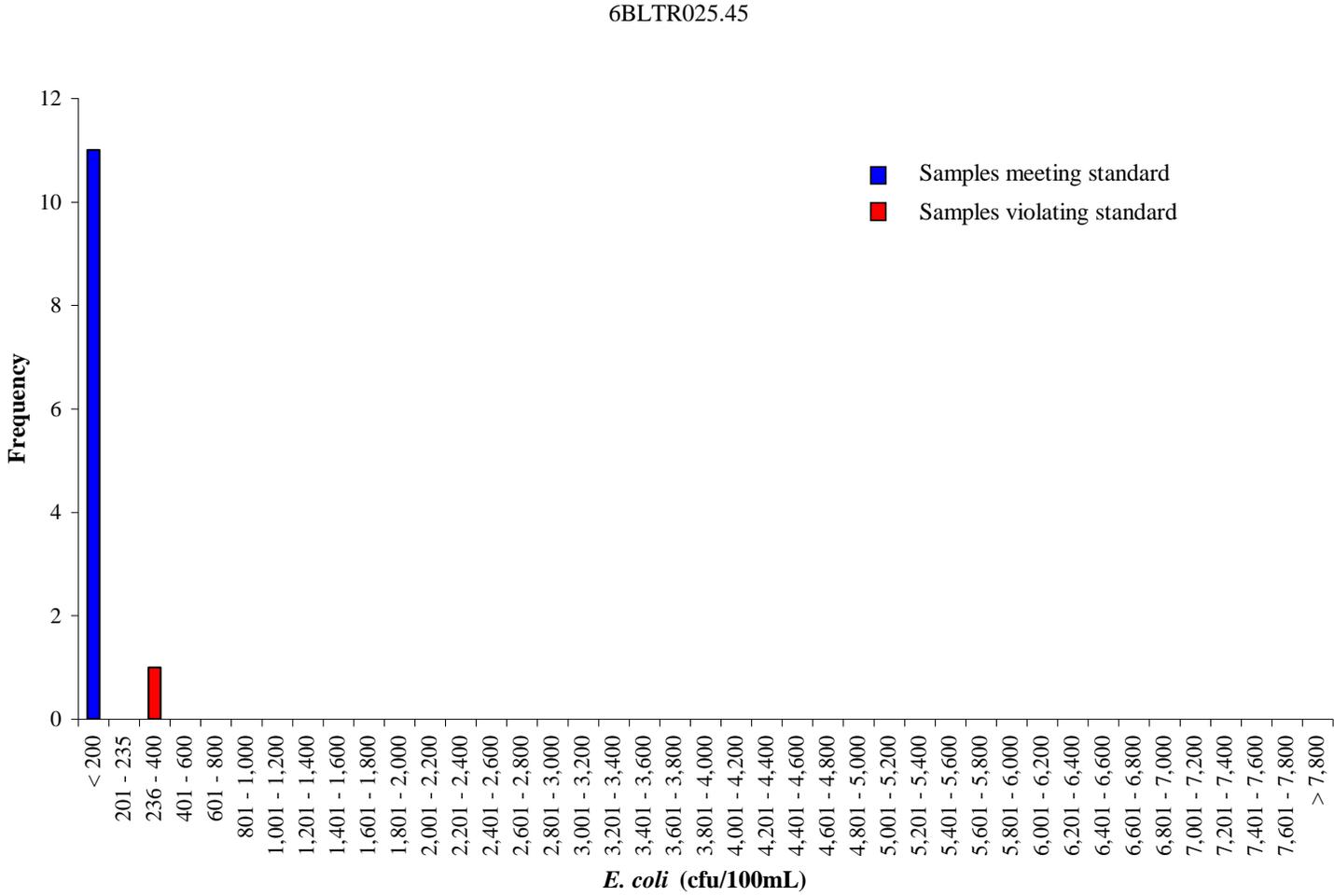
**Figure A. 4** Frequency analysis of *E. coli* concentrations at station 6BIDN000.69 in the Indian Creek for the period from January 2007 to January 2011.



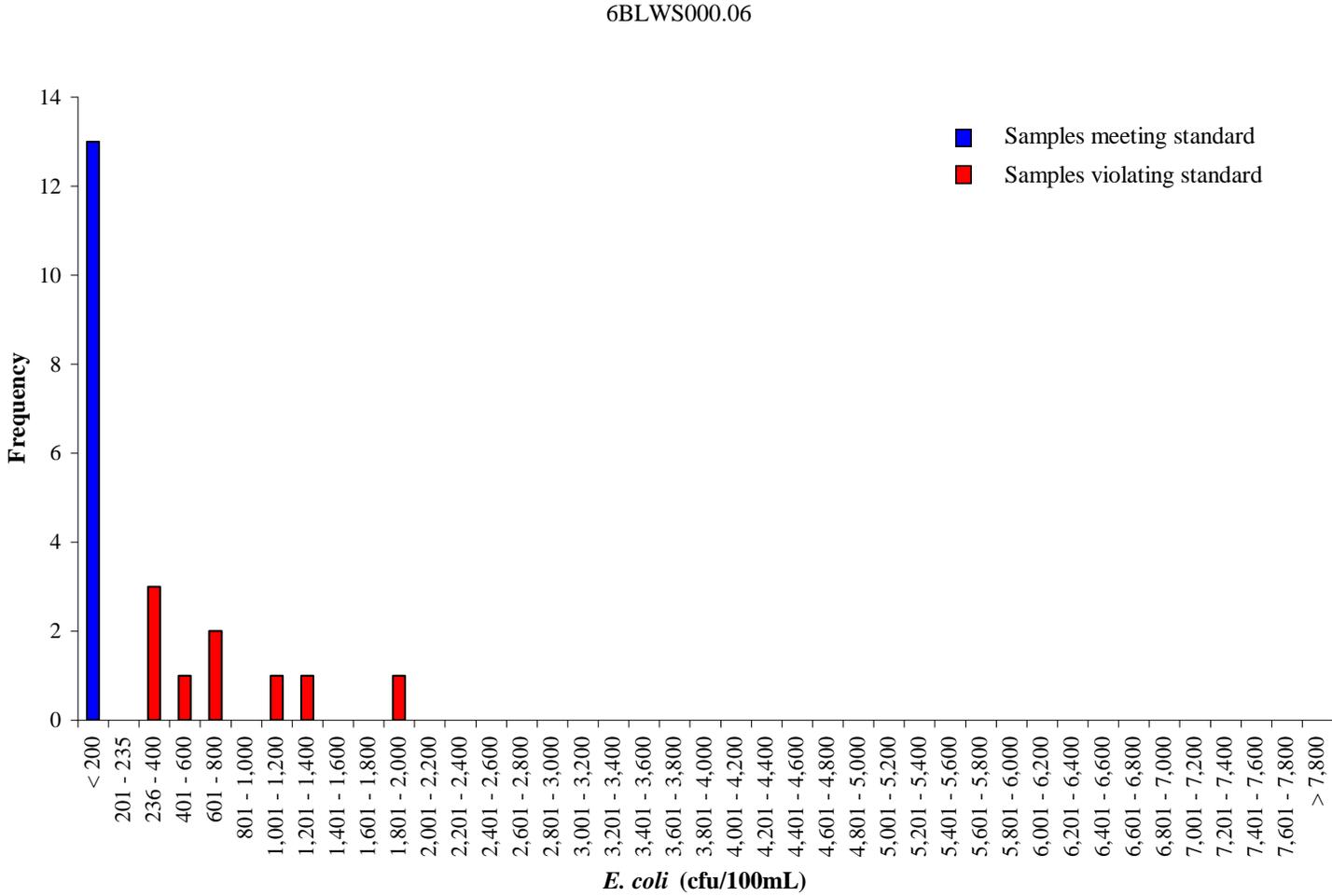
**Figure A. 5** Frequency analysis of *E. coli* concentrations at station 6BLTR000.75 in the Little River for the period from January 2007 to November 2008.



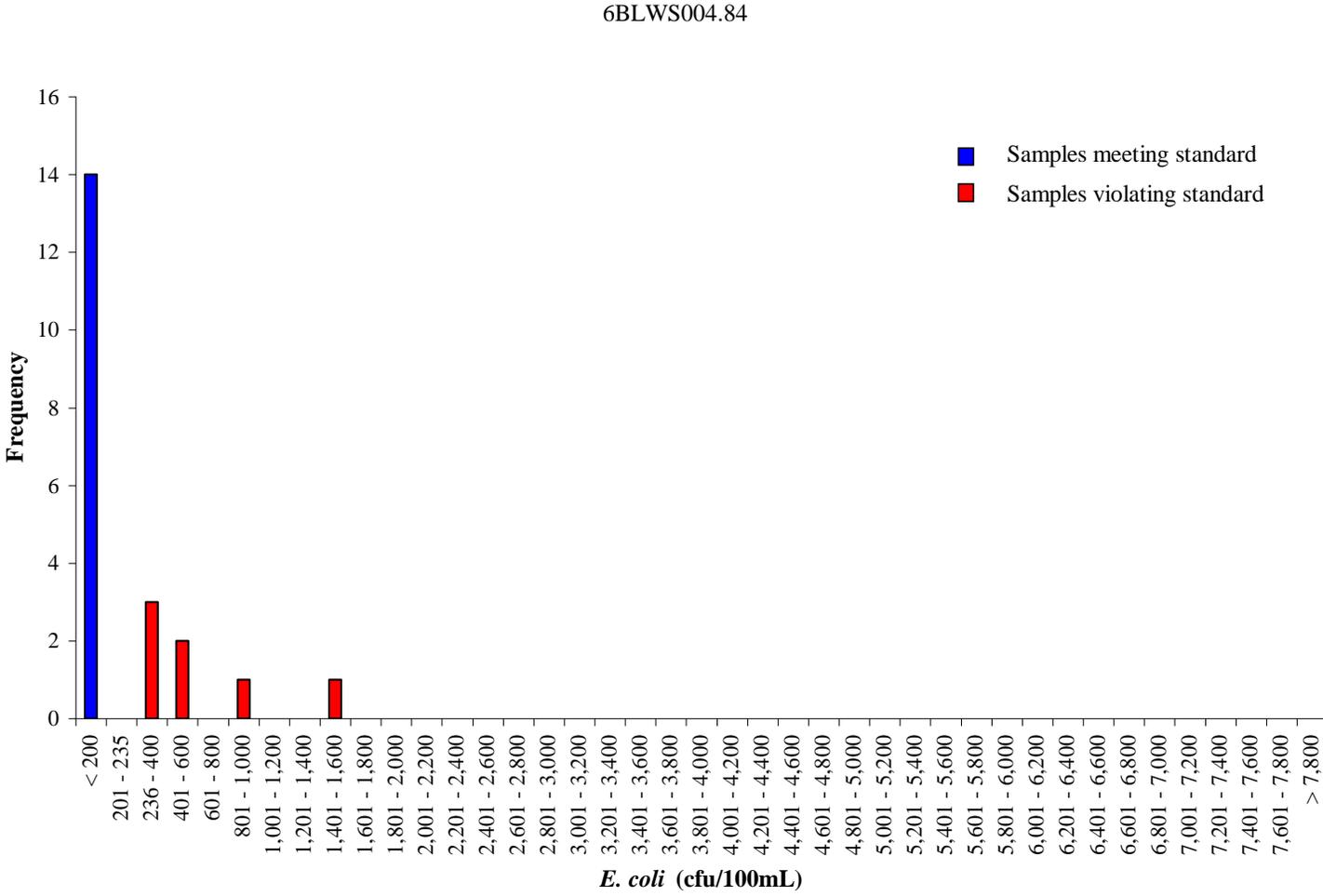
**Figure A. 6** Frequency analysis of *E. coli* concentrations at station 6BLTR018.19 in the Little River for the period from January 2007 to January 2011.



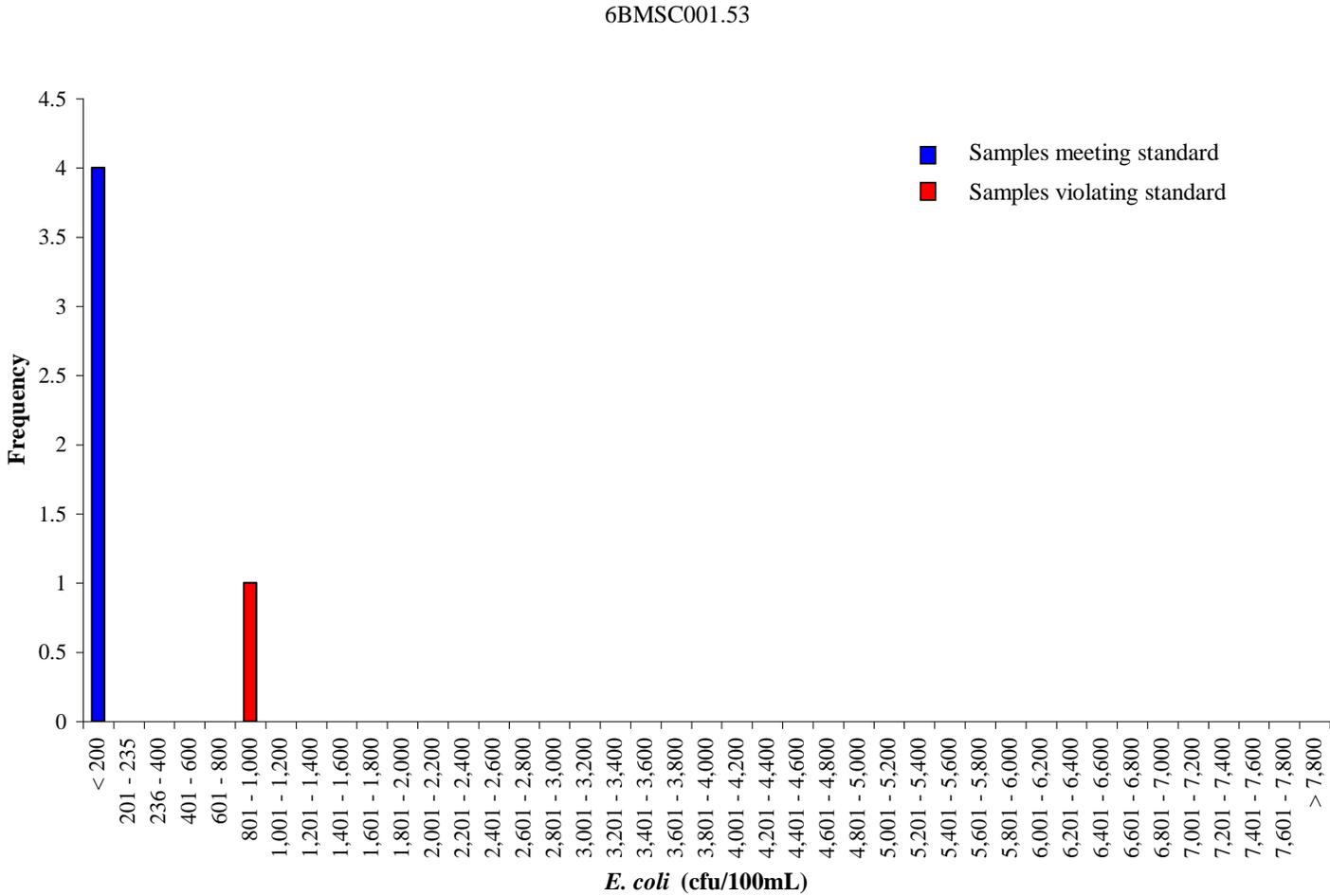
**Figure A. 7** Frequency analysis of *E. coli* concentrations at station 6BLTR025.45 in the Little River for the period from January 2007 to November 2008.



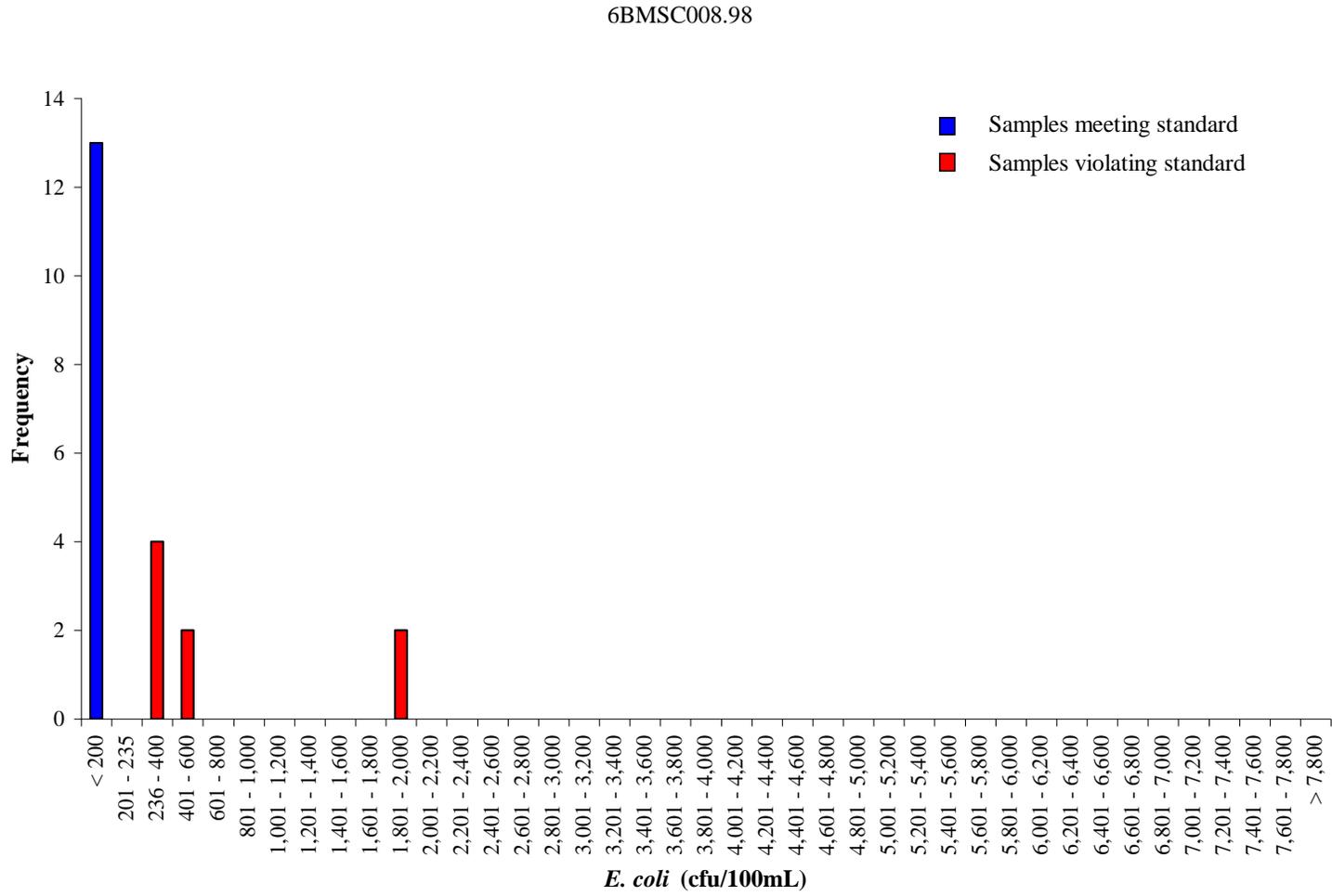
**Figure A. 8** Frequency analysis of *E. coli* concentrations at station 6BLWS000.06 in the Lewis Creek for the period from February 2007 to January 2011.



**Figure A. 9** Frequency analysis of *E. coli* concentrations at station 6BLWS004.84 in the Lewis Creek for the period from February 2007 to January 2011.



**Figure A. 10** Frequency analysis of *E. coli* concentrations at station 6BMSC001.53 in Maiden Spring Creek for the period from January 2007 to April 2010.



**Figure A. 11** Frequency analysis of *E. coli* concentrations at station 6BMSC008.98 in Maiden Spring Creek for the period from January 2007 to January 2011.

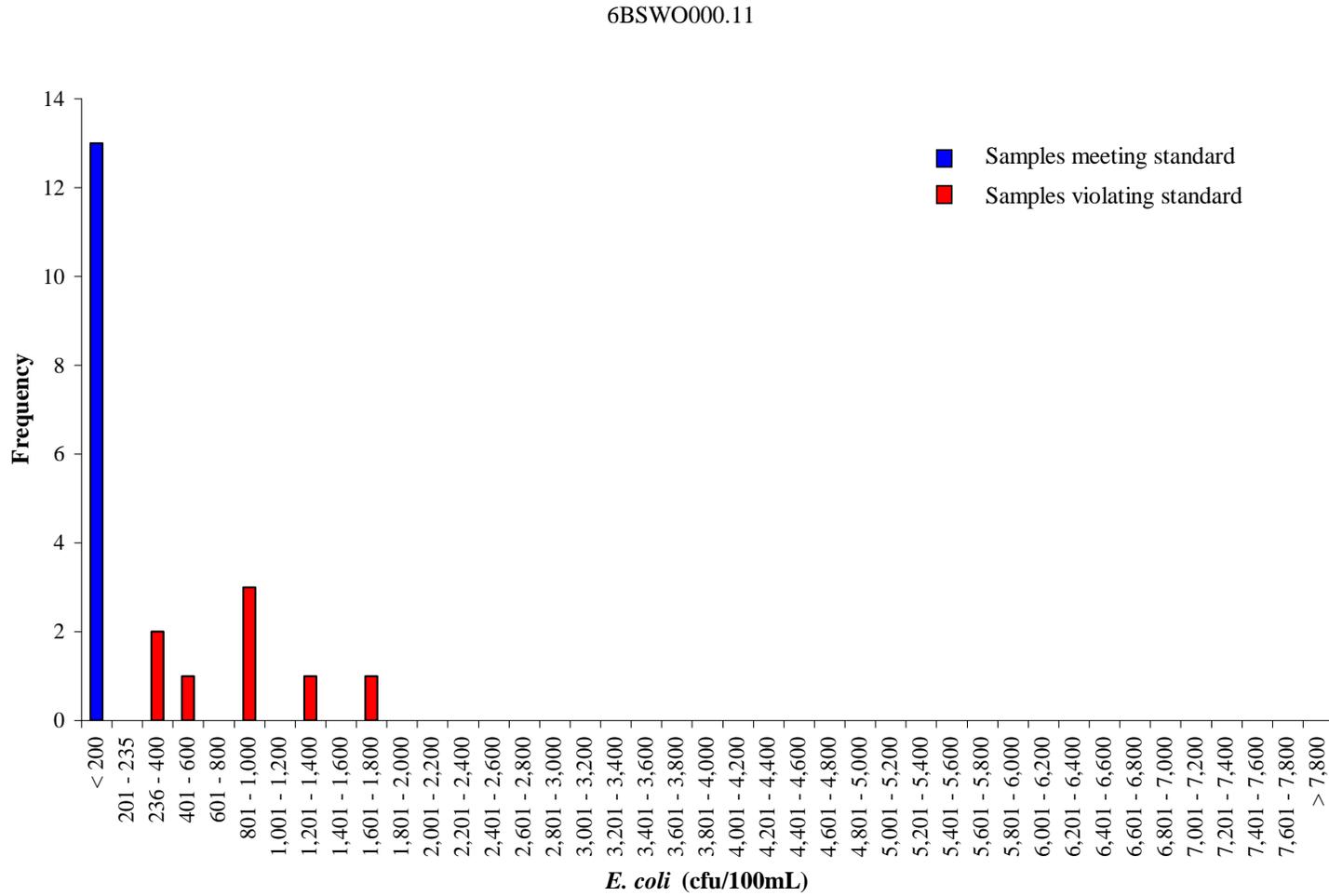


Figure A. 12 Frequency analysis of *E. coli* concentrations at station 6BSWO000.11 in the Swords Creek for the period from April 2009 to January 2011.

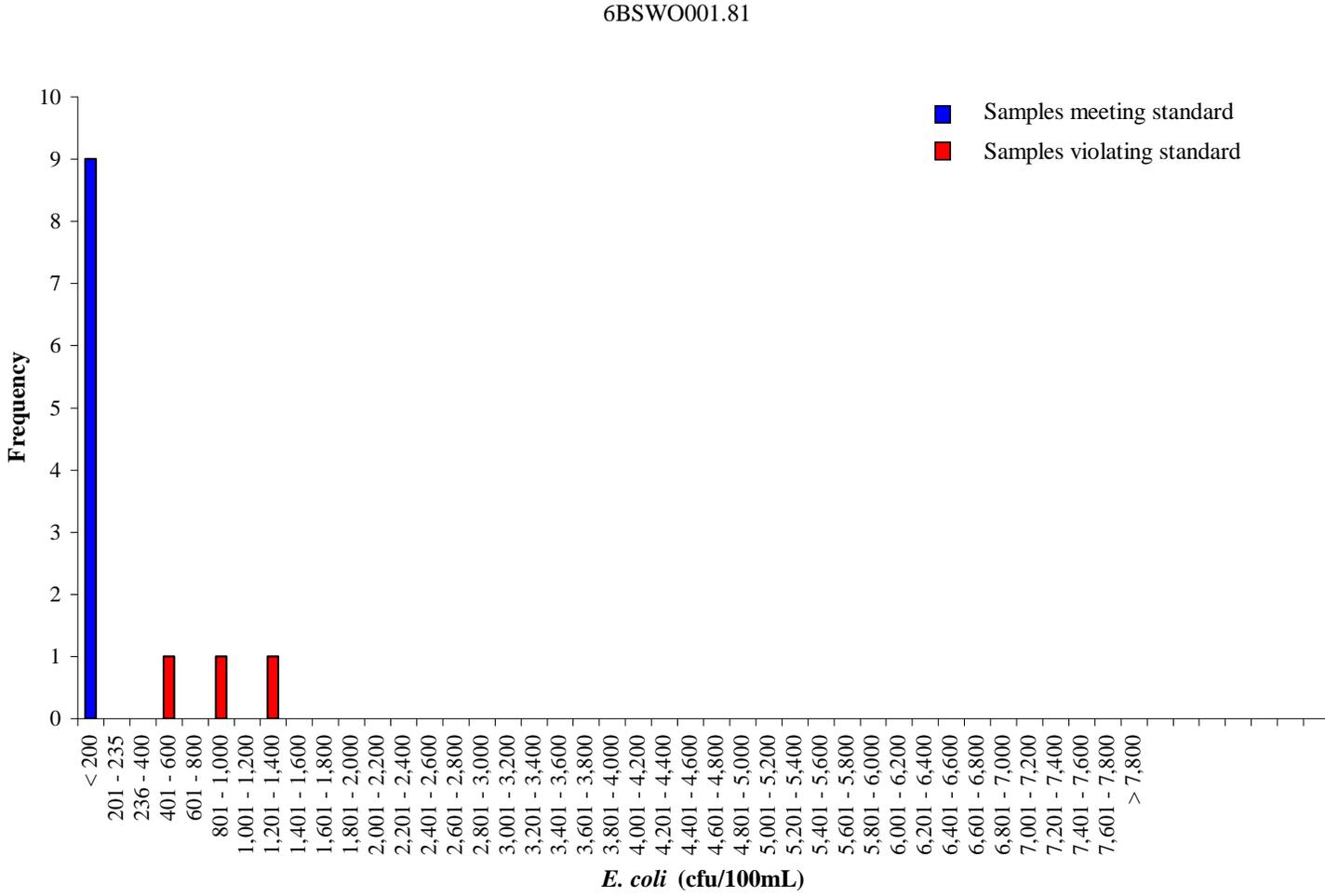


Figure A. 13 Frequency analysis of *E. coli* concentrations at station 6BSWO001.81 in the Swords Creek for the period from February 2007 to December 2008.

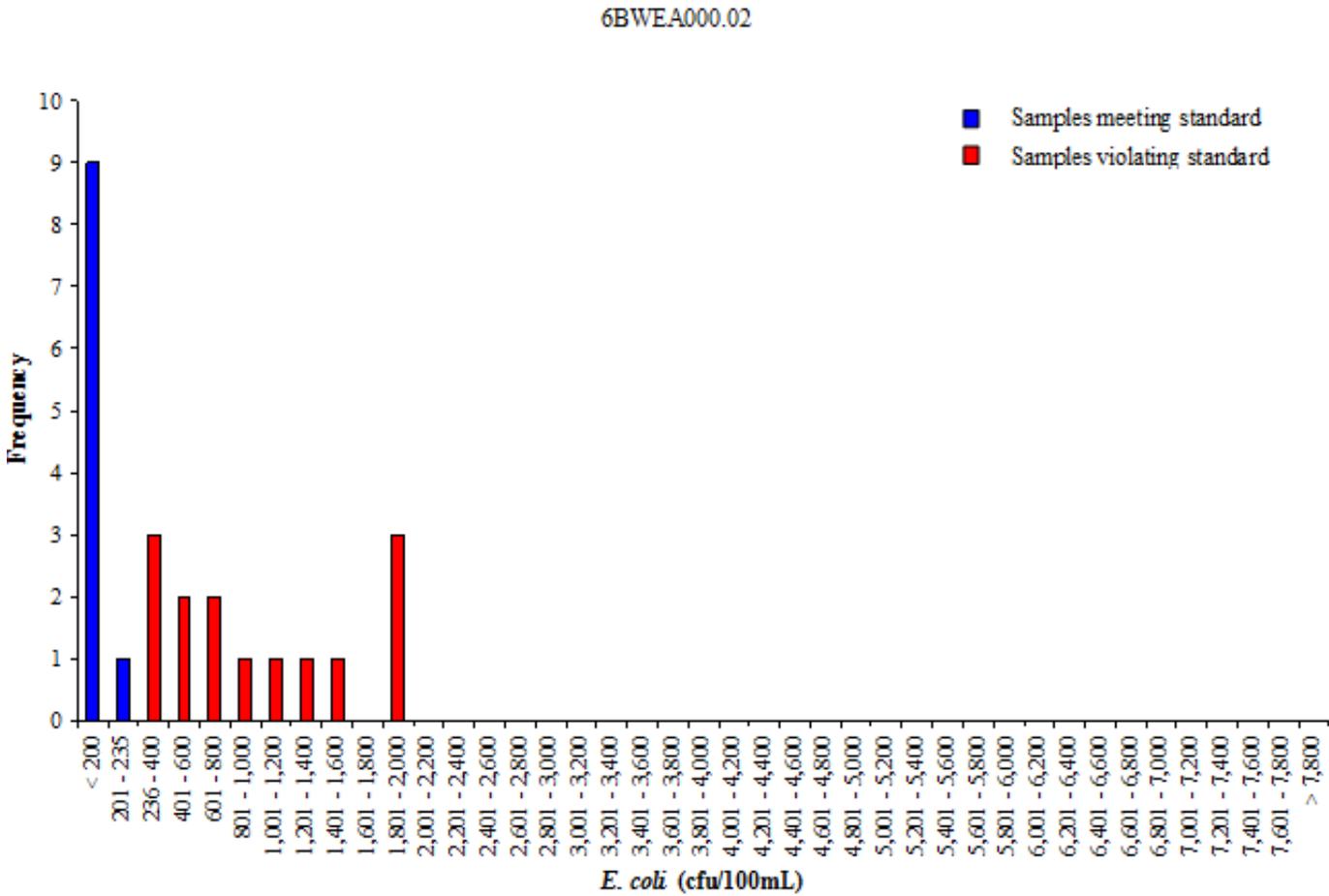


Figure A. 14 Frequency analysis of *E. coli* concentrations at station 6BWEA000.02 in the Weaver Creek for the period from August 2003 to December 2010.

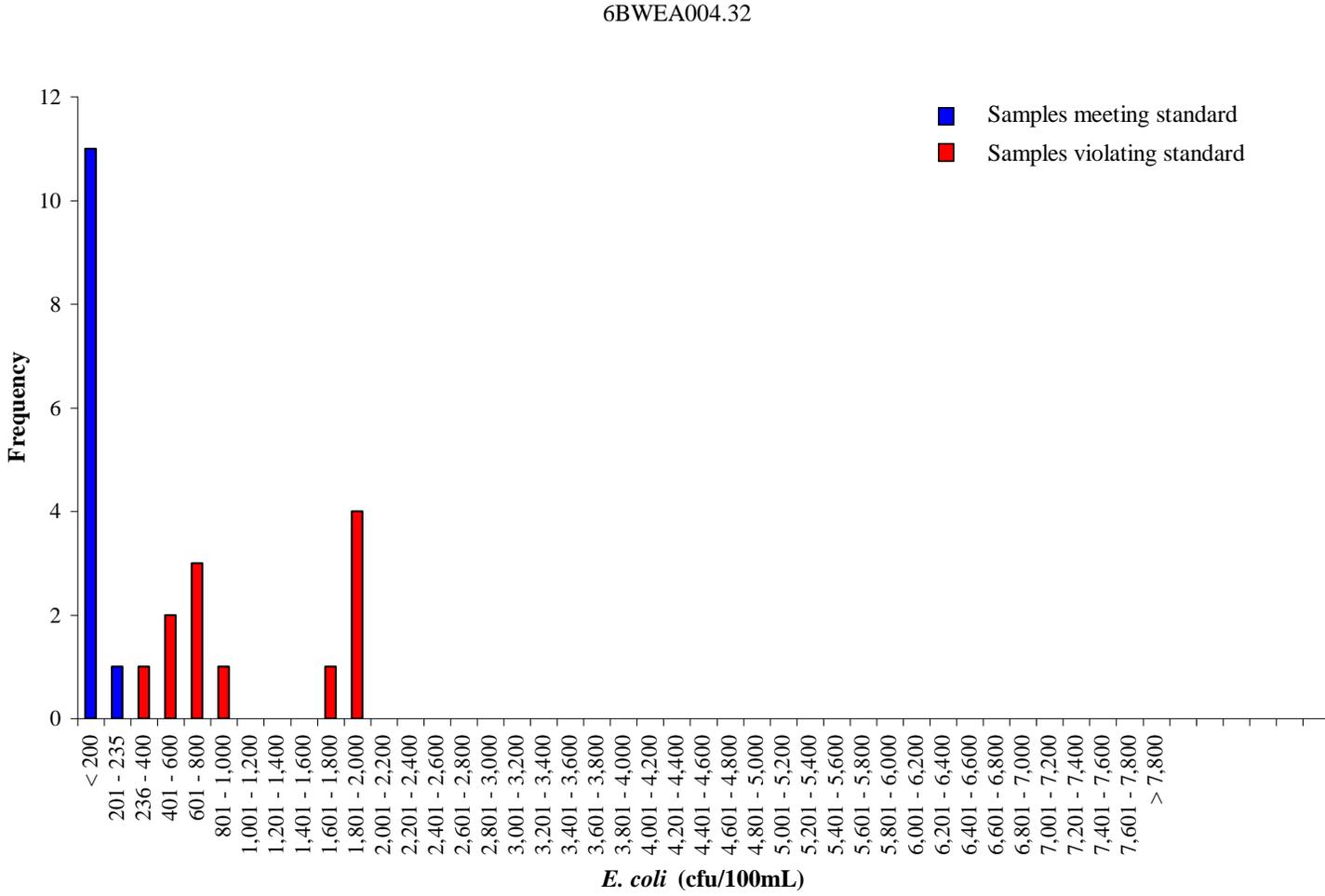


Figure A. 15 Frequency analysis of E. coli concentrations at station 6BWEA004.32 in the Weaver Creek for the period from August 2003 to December 2010.

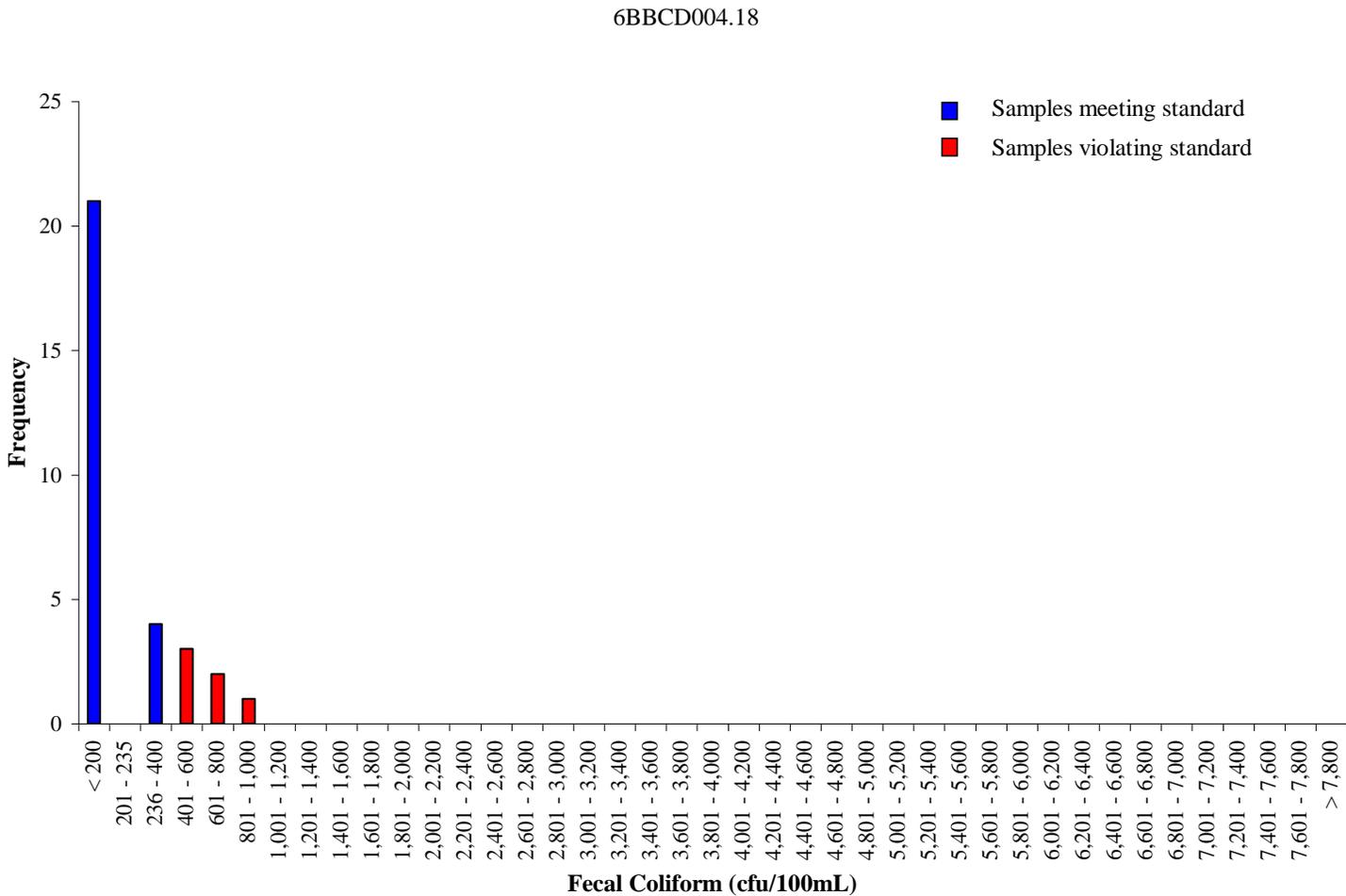
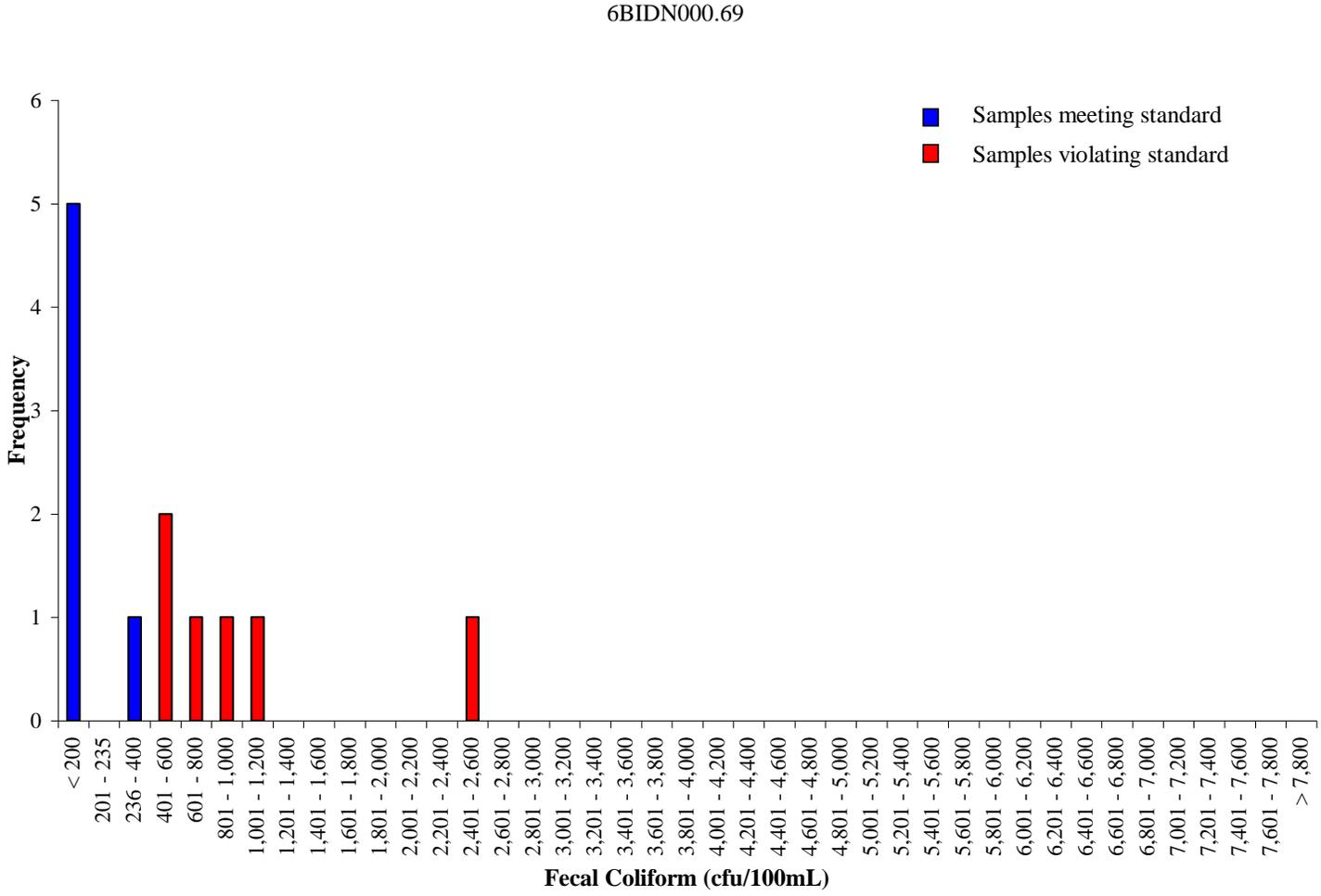


Figure A. 16 Frequency analysis of Fecal Coliform concentrations at station 6BBCD004.18 in Big Cedar Creek for the period from May 1994 to March 2001.



**Figure A. 17** Frequency analysis of Fecal Coliform concentrations at station 6BIDN000.69 in Indian Creek for the period from August 2001 to June 2003.

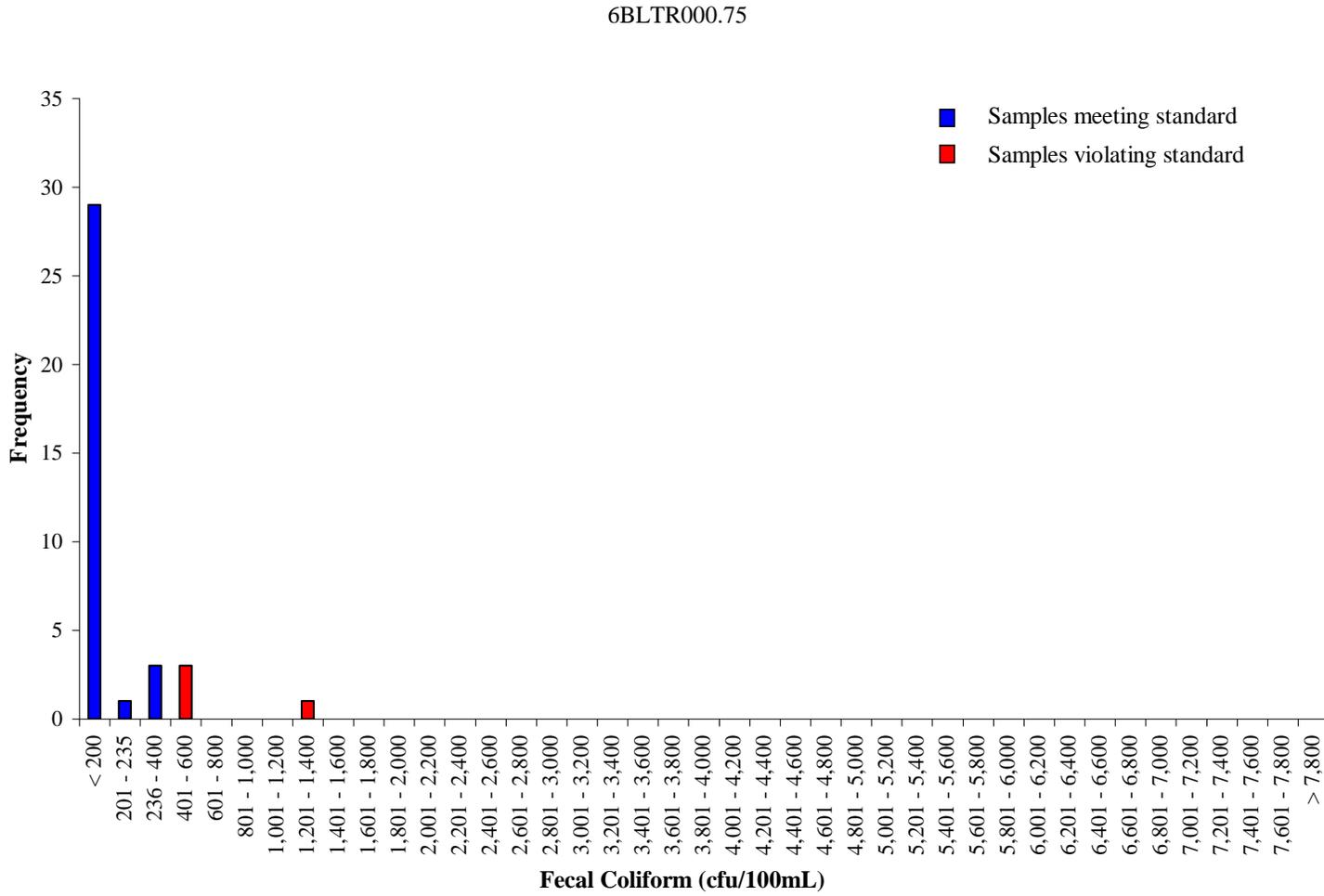


Figure A. 18 Frequency analysis of Fecal Coliform concentrations at station 6BLTR000.75 in the Little River for the period from September 1995 to June 2003.

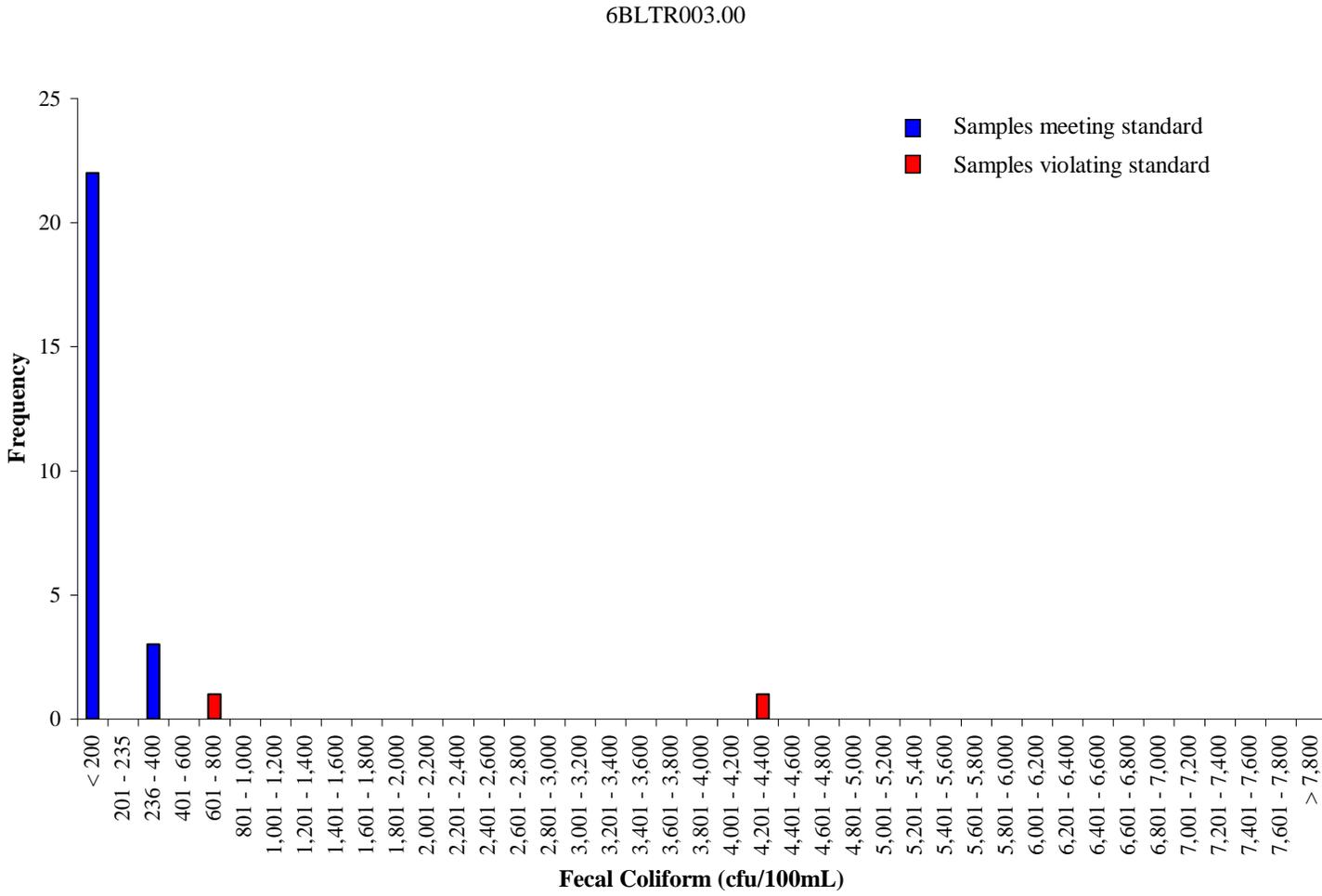


Figure A. 19 Frequency analysis of Fecal Coliform concentrations at station 6BLTR003.00 in the Little River for the period from January 1990 to March 1994.

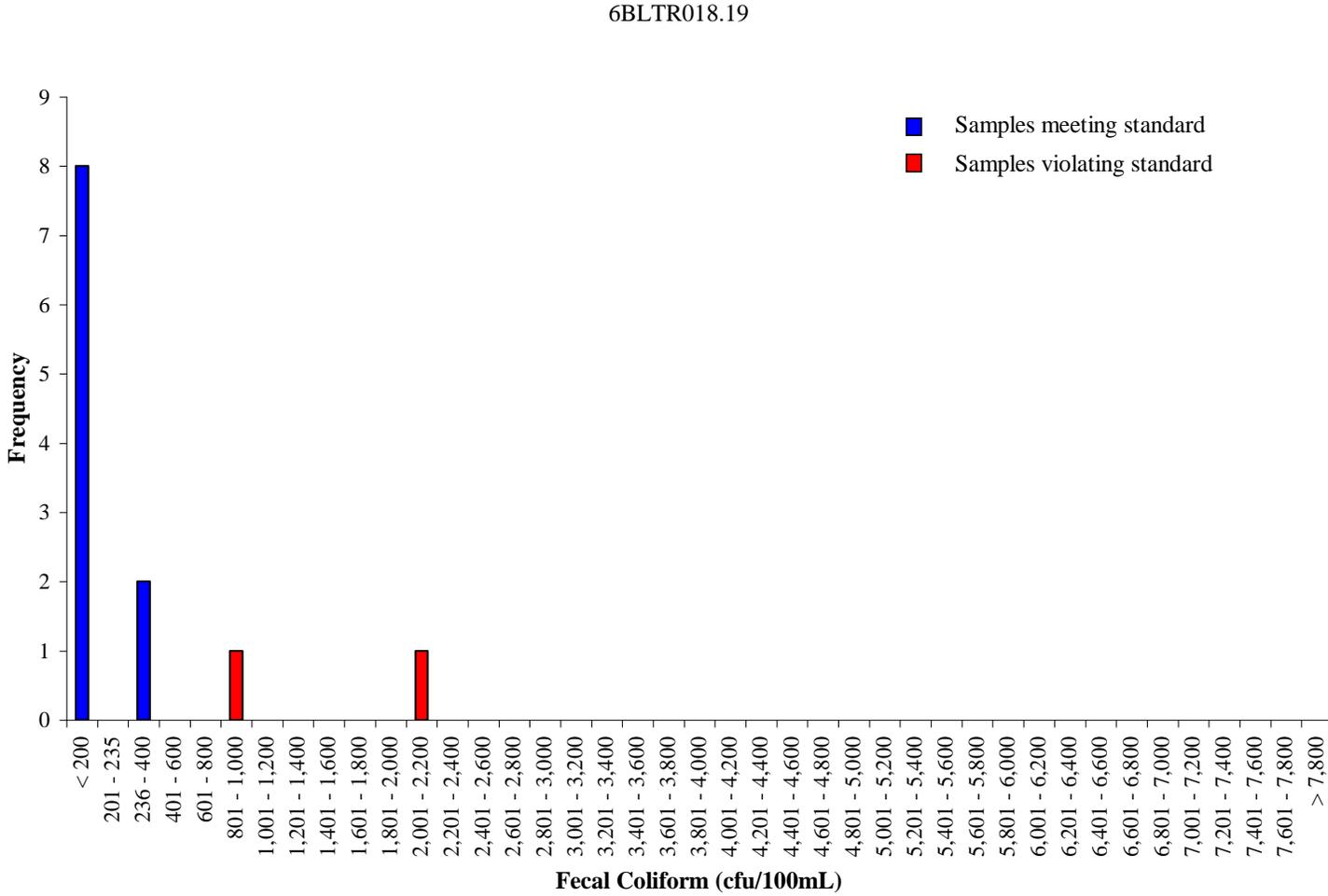


Figure A. 20 Frequency analysis of Fecal Coliform concentrations at station 6BLTR018.19 in the Little River for the period from August 2001 to June 2003.

6BLWS000.06

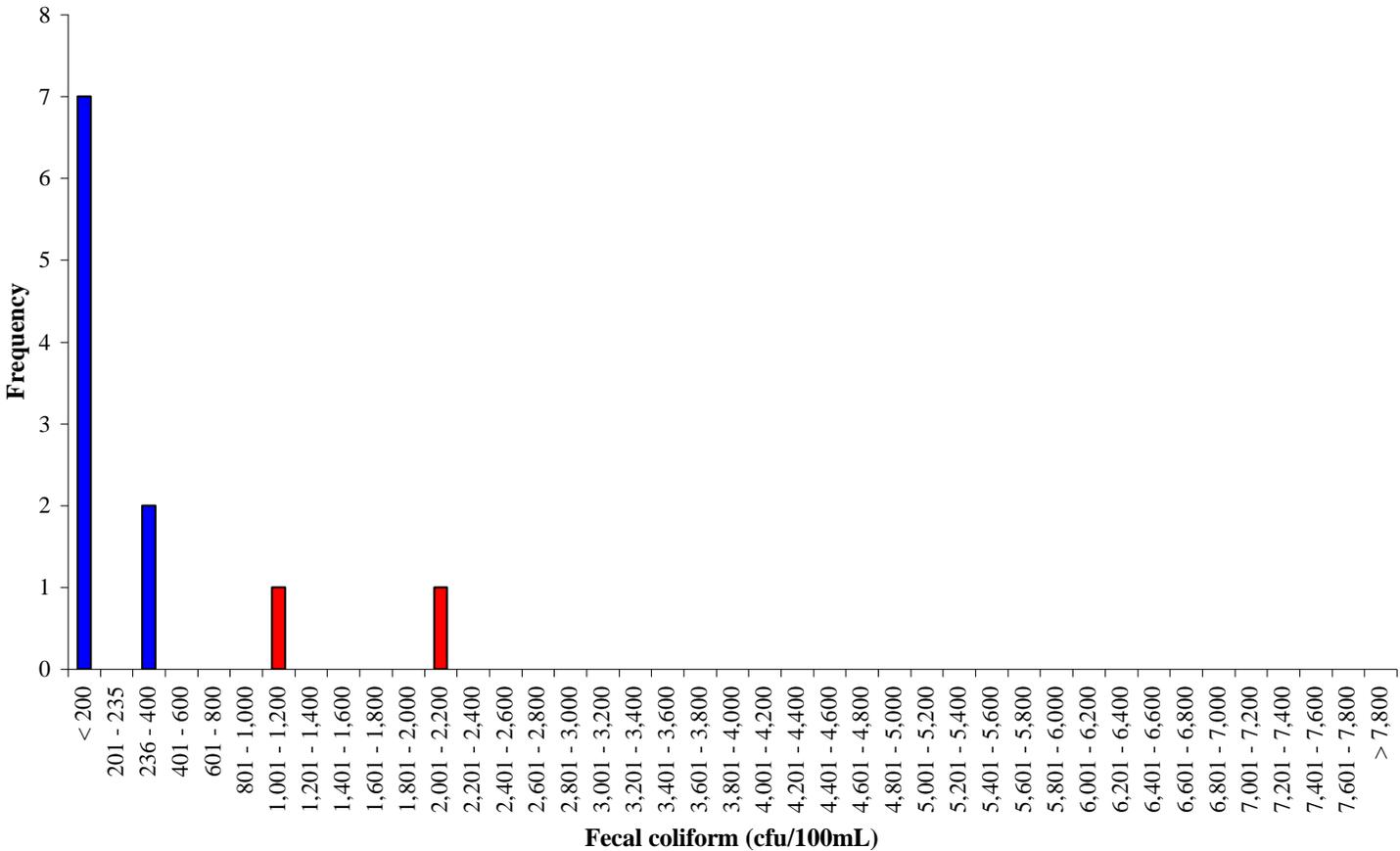
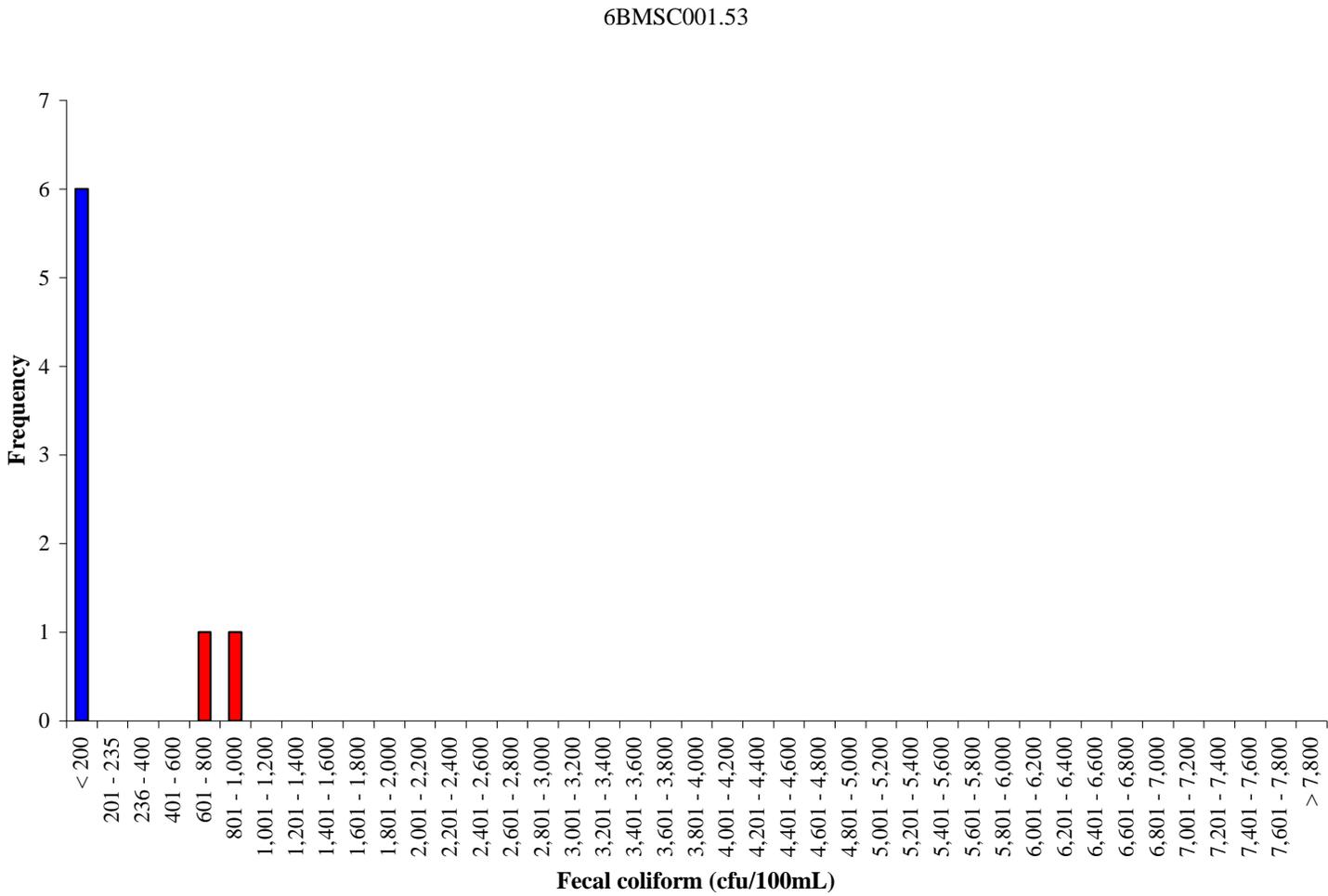


Figure A. 21 Frequency analysis of Fecal Coliform concentrations at station 6BWS000.06 in Lewis Creek for the period from August 2001 to June 2003.



**Figure A. 22** Frequency analysis of Fecal Coliform concentrations at station 6BMSC001.53 in Maiden Spring Creek for the period from August 2001 to June 2003.

6BMSC008.98

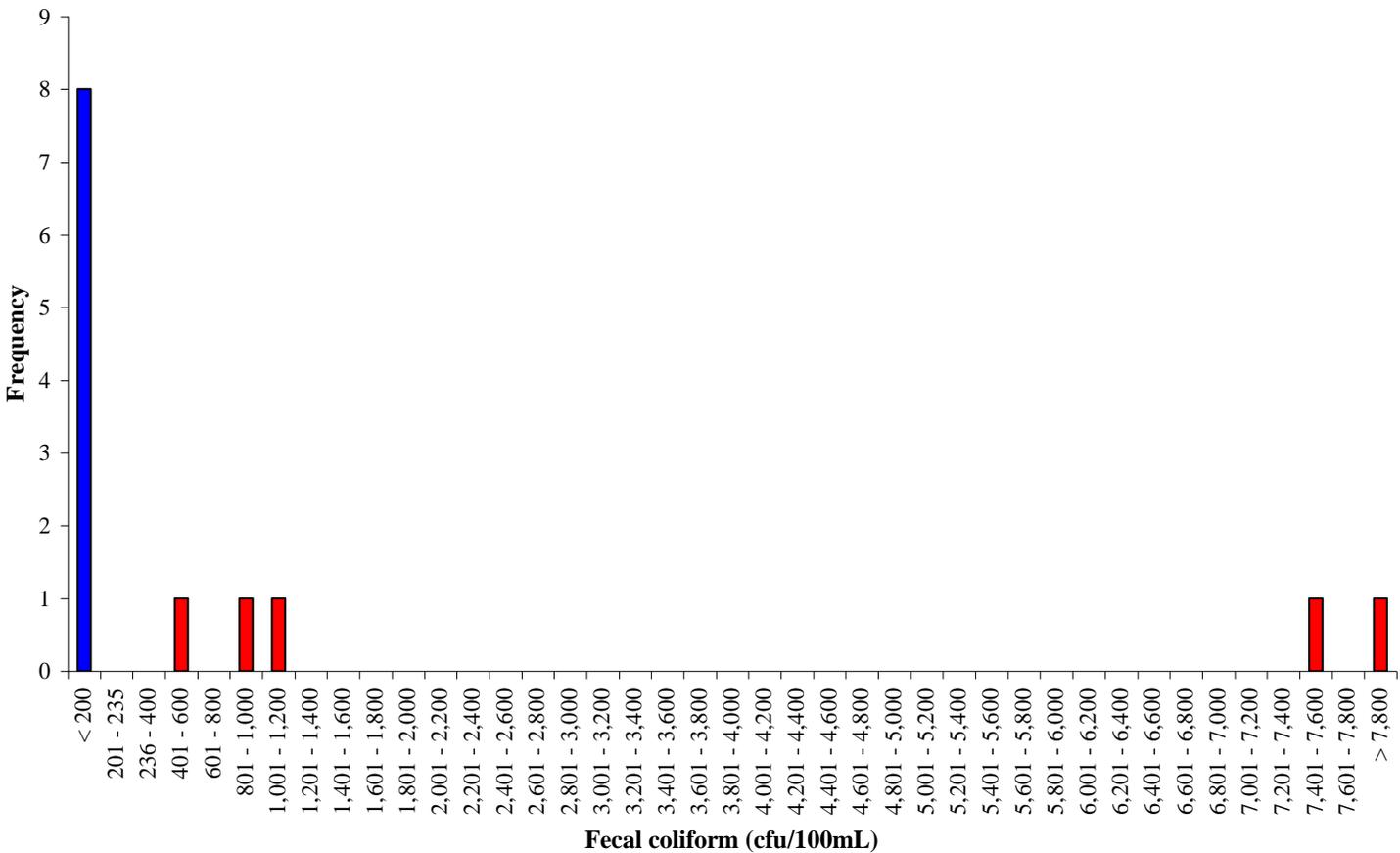


Figure A. 23 Frequency analysis of Fecal Coliform concentrations at station 6BMSC008.98 in Maiden Spring Creek for the period from August 2001 to March 2007.

## **APPENDIX B CURRENT CONDITIONS OF FECAL COLIFORM LOADS**

**Table B.1 Current conditions for land applied fecal coliform load for the Middle Clinch River by land use.**

Land-use	January	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual Total Loads (cfu/yr)
Crop	9.53E+13	1.11E+14	1.05E+15	1.05E+15	1.05E+15	2.48E+12	2.56E+12	2.56E+12	3.12E+14	1.05E+15	1.05E+15	9.53E+13	5.89E+15
Barren	4.41E+12	3.98E+12	4.41E+12	4.27E+12	4.41E+12	4.27E+12	4.41E+12	4.41E+12	4.27E+12	4.41E+12	4.27E+12	4.41E+12	5.19E+13
Reclaimed	1.44E+13	1.30E+13	1.44E+13	1.40E+13	1.44E+13	1.40E+13	1.44E+13	1.44E+13	1.40E+13	1.44E+13	1.40E+13	1.44E+13	1.70E+14
Gas Well	5.07E+11	4.58E+11	5.07E+11	4.91E+11	5.07E+11	4.91E+11	5.07E+11	5.07E+11	4.91E+11	5.07E+11	4.91E+11	5.07E+11	5.97E+12
Forest	4.49E+14	4.06E+14	4.49E+14	4.35E+14	4.49E+14	4.35E+14	4.49E+14	4.49E+14	4.35E+14	4.49E+14	4.35E+14	4.49E+14	5.29E+15
Commercial	5.23E+12	4.72E+12	5.23E+12	5.06E+12	5.23E+12	5.06E+12	5.23E+12	5.23E+12	5.06E+12	5.23E+12	5.06E+12	5.23E+12	6.16E+13
LAX	1.20E+14	1.08E+14	1.69E+14	2.26E+14	2.33E+14	2.74E+14	2.83E+14	2.83E+14	2.26E+14	1.69E+14	1.64E+14	1.20E+14	2.37E+15
Pasture	4.92E+15	4.44E+15	4.86E+15	4.64E+15	4.79E+15	4.69E+15	4.85E+15	4.85E+15	4.64E+15	4.86E+15	4.71E+15	4.92E+15	5.72E+16
Developed	1.08E+14	9.77E+13	1.08E+14	1.04E+14	1.08E+14	1.04E+14	1.07E+14	1.07E+14	1.04E+14	1.07E+14	1.04E+14	1.08E+14	1.27E+15
<b>Total</b>	<b>5.72E+15</b>	<b>5.18E+15</b>	<b>6.66E+15</b>	<b>6.48E+15</b>	<b>6.65E+15</b>	<b>5.53E+15</b>	<b>5.72E+15</b>	<b>5.72E+15</b>	<b>5.74E+15</b>	<b>6.66E+15</b>	<b>6.49E+15</b>	<b>5.72E+15</b>	<b>7.23E+16</b>

**Table B.2 Monthly, directly deposited, fecal coliform loads in the Middle Clinch River modeling group.**

Source Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
Human	3.93E+12	3.55E+12	3.93E+12	3.80E+12	3.93E+12	3.80E+12	3.93E+12	3.93E+12	3.80E+12	3.93E+12	3.80E+12	3.93E+12	4.63E+13
Livestock	1.30E+13	1.18E+13	1.74E+13	2.52E+13	2.60E+13	2.94E+13	3.04E+13	3.04E+13	2.52E+13	1.74E+13	1.68E+13	1.30E+13	2.56E+14
Wildlife	7.42E+12	6.70E+12	7.42E+12	7.17E+12	7.42E+12	7.17E+12	7.42E+12	7.42E+12	7.17E+12	7.42E+12	7.17E+12	7.42E+12	8.74E+13

**Table B.3 Existing annual fecal coliform loads from land-based sources for the Middle Clinch River modeling group by land use.**

<b>Source</b>	<b>Commercial</b>	<b>Pasture</b>	<b>Developed</b>	<b>LAX</b>	<b>Crop</b>	<b>Barren</b>	<b>Reclaimed</b>	<b>Water</b>	<b>Gas Well</b>	<b>Forest</b>
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.79E+11	0.00E+00	0.00E+00
Beef	0.00E+00	3.82E+16	0.00E+00	1.81E+15	0.00E+00	0.00E+00	0.00E+00	2.01E+14	0.00E+00	0.00E+00
Beef Calves	0.00E+00	7.86E+15	0.00E+00	3.73E+14	0.00E+00	0.00E+00	0.00E+00	4.14E+13	0.00E+00	0.00E+00
Cat	0.00E+00	0.00E+00	4.86E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dairy	0.00E+00	3.25E+14	0.00E+00	0.00E+00	5.86E+15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dairy Calves	0.00E+00	7.39E+14	0.00E+00	3.51E+13	0.00E+00	0.00E+00	0.00E+00	3.89E+12	0.00E+00	0.00E+00
Dairy Dry	0.00E+00	1.78E+15	0.00E+00	8.46E+13	0.00E+00	0.00E+00	0.00E+00	9.40E+12	0.00E+00	0.00E+00
Deer	2.09E+12	3.26E+14	3.05E+13	2.87E+12	3.85E+12	1.11E+12	1.83E+13	0.00E+00	7.87E+11	5.98E+14
Dog	0.00E+00	0.00E+00	5.44E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	8.04E+08	2.10E+10	9.03E+09	1.93E+09	1.66E+08	5.84E+08	1.67E+09	0.00E+00	2.94E+07	4.02E+10
Goose	4.28E+10	1.12E+12	4.81E+11	1.03E+11	8.83E+09	3.11E+10	8.90E+10	0.00E+00	1.57E+09	2.14E+12
Horse	0.00E+00	5.33E+15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Muskrat	1.39E+13	3.62E+14	1.55E+14	3.32E+13	2.85E+12	1.01E+13	2.88E+13	0.00E+00	5.07E+11	6.93E+14
Failing Septics	0.00E+00	0.00E+00	2.84E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Straight Pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.63E+13	0.00E+00	0.00E+00
Raccoon	4.56E+13	2.17E+15	5.09E+14	3.46E+13	2.35E+13	4.07E+13	1.23E+14	0.00E+00	4.68E+12	4.00E+15
Sheep	0.00E+00	1.17E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Turkey	3.02E+08	4.87E+10	5.33E+09	4.74E+08	5.29E+08	2.65E+08	3.61E+09	0.00E+00	2.98E+08	2.75E+11
<b>Totals</b>	<b>6.16E+13</b>	<b>5.72E+16</b>	<b>1.27E+15</b>	<b>2.37E+15</b>	<b>5.89E+15</b>	<b>5.19E+13</b>	<b>1.70E+14</b>	<b>3.03E+14</b>	<b>5.98E+12</b>	<b>5.29E+15</b>

**Table B.4 Existing annual loads from direct-deposition sources for the Middle Clinch River modeling group.**

<b>Source</b>	<b>Annual Total Loads (cfu/yr)</b>
Beaver	6.79E+11
Beef	2.01E+14
Beef Calves	4.14E+13
Dairy	0.00E+00
Dairy Calves	3.89E+12
Dairy Dry	9.40E+12
Deer	2.49E+12
Duck	3.19E+09
Goose	1.12E+11
Horse	0.00E+00
Muskrat	6.64E+13
Straight Pipes	4.63E+13
Raccoon	1.77E+13
Sheep	0.00E+00
Swine	0.00E+00
Turkey	8.46E+08
<b>Total</b>	<b>3.89E+14</b>

**Table B.5 Current conditions of land applied fecal coliform load for the Dumps Creek modeling group, by land-use.**

Land-use	January	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual Total Loads (cfu/yr)
Gas Well	1.02E+11	9.24E+10	1.02E+11	9.90E+10	1.02E+11	9.90E+10	1.02E+11	1.02E+11	9.90E+10	1.02E+11	9.90E+10	1.02E+11	1.20E+12
Forest	4.53E+13	4.09E+13	4.53E+13	4.38E+13	4.53E+13	4.38E+13	4.53E+13	4.53E+13	4.38E+13	4.53E+13	4.38E+13	4.53E+13	5.33E+14
Pasture	8.64E+13	7.80E+13	8.54E+13	8.13E+13	8.40E+13	8.17E+13	8.44E+13	8.44E+13	8.13E+13	8.54E+13	8.26E+13	8.64E+13	1.00E+15
Commercial	7.24E+11	6.54E+11	7.24E+11	7.01E+11	7.24E+11	7.01E+11	7.24E+11	7.24E+11	7.01E+11	7.24E+11	7.01E+11	7.24E+11	8.53E+12
LAX	2.10E+12	1.90E+12	3.03E+12	4.06E+12	4.20E+12	4.96E+12	5.12E+12	5.12E+12	4.06E+12	3.03E+12	2.93E+12	2.10E+12	4.26E+13
Developed	4.48E+12	4.05E+12	4.48E+12	4.33E+12	4.47E+12	4.33E+12	4.47E+12	4.47E+12	4.32E+12	4.47E+12	4.32E+12	4.48E+12	5.27E+13
Crop	1.17E+12	1.36E+12	1.32E+13	1.32E+13	1.32E+13	3.50E+09	3.62E+09	3.62E+09	3.88E+12	1.32E+13	1.32E+13	1.17E+12	7.35E+13
Barren	2.30E+12	2.07E+12	2.30E+12	2.22E+12	2.30E+12	2.22E+12	2.30E+12	2.30E+12	2.22E+12	2.30E+12	2.22E+12	2.30E+12	2.70E+13
Reclaimed	4.98E+12	4.50E+12	4.98E+12	4.82E+12	4.98E+12	4.82E+12	4.98E+12	4.98E+12	4.82E+12	4.98E+12	4.82E+12	4.98E+12	5.87E+13
<b>Total</b>	<b>1.48E+14</b>	<b>1.34E+14</b>	<b>1.60E+14</b>	<b>1.55E+14</b>	<b>1.59E+14</b>	<b>1.43E+14</b>	<b>1.47E+14</b>	<b>1.47E+14</b>	<b>1.45E+14</b>	<b>1.60E+14</b>	<b>1.55E+14</b>	<b>1.48E+14</b>	<b>1.80E+15</b>

**Table B.6 Monthly, directly deposited fecal coliform loads in the Dumps Creek modeling group.**

<b>Source Type</b>	<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>June</b>	<b>July</b>	<b>Aug</b>	<b>Sept</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>	<b>Annual Total Loads (cfu/yr)</b>
<b>Human</b>	9.14E+10	8.26E+10	9.14E+10	8.85E+10	9.14E+10	8.85E+10	9.14E+10	9.14E+10	8.85E+10	9.14E+10	8.85E+10	9.14E+10	1.08E+12
<b>Livestock</b>	2.40E+11	2.17E+11	3.20E+11	4.65E+11	4.81E+11	5.43E+11	5.61E+11	5.61E+11	4.65E+11	3.20E+11	3.10E+11	2.40E+11	4.72E+12
<b>Wildlife</b>	5.64E+11	5.09E+11	5.64E+11	5.46E+11	5.64E+11	5.46E+11	5.64E+11	5.64E+11	5.46E+11	5.64E+11	5.46E+11	5.64E+11	6.64E+12

**Table B.7 Existing annual loads from land-based sources for the Dumps Creek modeling group by land-use.**

Source	Commercial	Pasture	Developed	LAX	Crop	Barren	Reclaimed	Water	Gas Well	Forest
Beaver	0.00E+00	5.78E+10	0.00E+00	0.00E+00						
Beef	0.00E+00	7.18E+14	0.00E+00	3.41E+13	0.00E+00	0.00E+00	0.00E+00	3.79E+12	0.00E+00	0.00E+00
Beef Calves	0.00E+00	1.48E+14	0.00E+00	7.02E+12	0.00E+00	0.00E+00	0.00E+00	7.80E+11	0.00E+00	0.00E+00
Cat	0.00E+00	0.00E+00	5.86E+06	0.00E+00						
Dairy	0.00E+00	4.07E+12	0.00E+00	0.00E+00	7.34E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dairy Calves	0.00E+00	8.66E+12	0.00E+00	4.11E+11	0.00E+00	0.00E+00	0.00E+00	4.57E+10	0.00E+00	0.00E+00
Dairy Dry	0.00E+00	2.09E+13	0.00E+00	9.92E+11	0.00E+00	0.00E+00	0.00E+00	1.10E+11	0.00E+00	0.00E+00
Deer	4.41E+11	7.42E+11	1.83E+12	3.47E+09	1.11E+10	4.11E+11	7.60E+12	0.00E+00	1.56E+11	6.06E+13
Dog	0.00E+00	0.00E+00	6.62E+12	0.00E+00						
Duck	9.10E+07	3.77E+07	6.72E+08	2.82E+06	0.00E+00	3.43E+08	4.57E+08	0.00E+00	6.47E+06	3.92E+09
Goose	4.85E+09	2.01E+09	3.58E+10	1.50E+08	0.00E+00	1.83E+10	2.43E+10	0.00E+00	3.45E+08	2.09E+11
Horse	0.00E+00	9.37E+13	0.00E+00							
Muskrat	1.57E+12	6.49E+11	1.16E+13	4.86E+10	0.00E+00	5.91E+12	7.87E+12	0.00E+00	1.11E+11	6.75E+13
Failing Septics	0.00E+00	0.00E+00	4.48E+11	0.00E+00						
Straight Pipes	0.00E+00	1.08E+12	0.00E+00	0.00E+00						
Raccoon	6.51E+12	4.43E+12	3.22E+13	4.62E+10	3.15E+10	2.07E+13	4.32E+13	0.00E+00	9.37E+11	4.05E+14
Sheep	0.00E+00	1.78E+12	0.00E+00							
Swine	0.00E+00									
Turkey	1.06E+08	1.33E+08	4.92E+08	9.23E+05	1.49E+06	9.23E+07	1.45E+09	0.00E+00	5.32E+07	2.79E+10
<b>Totals</b>	<b>8.53E+12</b>	<b>1.00E+15</b>	<b>5.27E+13</b>	<b>4.26E+13</b>	<b>7.34E+13</b>	<b>2.70E+13</b>	<b>5.87E+13</b>	<b>5.86E+12</b>	<b>1.20E+12</b>	<b>5.33E+14</b>

**Table B.8 Existing annual loads from direct-deposition sources for the Dumps Creek modeling group.**

<b>Source</b>	<b>Annual Total Loads (cfu/yr)</b>
Beaver	5.78E+10
Beef	3.79E+12
Beef Calves	7.80E+11
Dairy	0.00E+00
Dairy Calves	4.57E+10
Dairy Dry	1.10E+11
Deer	1.81E+11
Duck	2.44E+08
Goose	8.54E+09
Horse	0.00E+00
Muskrat	5.07E+12
Straight Pipes	1.08E+12
Raccoon	1.32E+12
Sheep	0.00E+00
Swine	0.00E+00
Turkey	7.61E+07
<b>Total</b>	<b>1.24E+13</b>

**Table B.9 Current conditions of land applied fecal coliform load for the Big Cedar/Burgess modeling group, by land-use.**

<b>Land-use</b>	<b>January</b>	<b>February</b>	<b>March</b>	<b>April</b>	<b>May</b>	<b>June</b>	<b>July</b>	<b>August</b>	<b>September</b>	<b>October</b>	<b>November</b>	<b>December</b>	<b>Annual Total Loads (cfu/yr)</b>
Barren	4.44E+11	4.01E+11	4.44E+11	4.30E+11	4.44E+11	4.30E+11	4.44E+11	4.44E+11	4.30E+11	4.44E+11	4.30E+11	4.44E+11	5.23E+12
Forest	9.42E+13	8.51E+13	9.42E+13	9.12E+13	9.42E+13	9.12E+13	9.42E+13	9.42E+13	9.12E+13	9.42E+13	9.12E+13	9.42E+13	1.11E+15
Pasture	5.30E+14	4.78E+14	5.24E+14	5.01E+14	5.17E+14	5.03E+14	5.19E+14	5.19E+14	5.01E+14	5.24E+14	5.07E+14	5.30E+14	6.15E+15
Commercial	1.10E+12	9.95E+11	1.10E+12	1.07E+12	1.10E+12	1.07E+12	1.10E+12	1.10E+12	1.07E+12	1.10E+12	1.07E+12	1.10E+12	1.30E+13
Developed	3.09E+13	2.79E+13	3.08E+13	2.98E+13	3.08E+13	2.97E+13	3.07E+13	3.07E+13	2.97E+13	3.06E+13	2.97E+13	3.08E+13	3.62E+14
LAX	1.29E+13	1.16E+13	1.77E+13	2.31E+13	2.38E+13	2.77E+13	2.87E+13	2.87E+13	2.31E+13	1.77E+13	1.71E+13	1.29E+13	2.45E+14
Crop	7.05E+12	7.94E+12	6.87E+13	6.87E+13	6.87E+13	1.05E+12	1.08E+12	1.08E+12	2.09E+13	6.87E+13	6.87E+13	7.05E+12	3.90E+14
<b>Total</b>	<b>6.77E+14</b>	<b>6.12E+14</b>	<b>7.37E+14</b>	<b>7.15E+14</b>	<b>7.36E+14</b>	<b>6.54E+14</b>	<b>6.75E+14</b>	<b>6.75E+14</b>	<b>6.67E+14</b>	<b>7.37E+14</b>	<b>7.15E+14</b>	<b>6.76E+14</b>	<b>8.28E+15</b>

**Table B.10 Monthly, directly deposited fecal coliform loads in the Big Cedar/Burgess modeling group.**

<b>Source Type</b>	<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>June</b>	<b>July</b>	<b>Aug</b>	<b>Sept</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>	<b>Annual Total Loads (cfu/yr)</b>
<b>Human</b>	3.65E+11	3.31E+11	3.65E+11	3.54E+11	3.65E+11	3.54E+11	3.65E+11	3.65E+11	3.54E+11	3.65E+11	3.54E+11	3.65E+11	4.31E+12
<b>Livestock</b>	1.26E+12	1.14E+12	1.68E+12	2.44E+12	2.52E+12	2.84E+12	2.94E+12	2.94E+12	2.44E+12	1.68E+12	1.62E+12	1.26E+12	2.47E+13
<b>Wildlife</b>	1.95E+12	1.76E+12	1.95E+12	1.89E+12	1.95E+12	1.89E+12	1.95E+12	1.95E+12	1.89E+12	1.95E+12	1.89E+12	1.95E+12	2.30E+13

**Table B.11 Existing annual loads from land-based sources for the Big Cedar/Burgess modeling group by land-use.**

Source	Commercial	Pasture	Developed	LAX	Crop	Barren	Reclaimed	Water	Gas Well	Forest
Beaver	0.00E+00	2.90E+10	0.00E+00	0.00E+00						
Beef	0.00E+00	3.76E+15	0.00E+00	1.78E+14	0.00E+00	0.00E+00	0.00E+00	1.98E+13	0.00E+00	0.00E+00
Beef Calves	0.00E+00	7.73E+14	0.00E+00	3.67E+13	0.00E+00	0.00E+00	0.00E+00	4.08E+12	0.00E+00	0.00E+00
Cat	0.00E+00	0.00E+00	1.55E+08	0.00E+00						
Dairy	0.00E+00	2.09E+13	0.00E+00	0.00E+00	3.77E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dairy Calves	0.00E+00	4.83E+13	0.00E+00	2.29E+12	0.00E+00	0.00E+00	0.00E+00	2.54E+11	0.00E+00	0.00E+00
Dairy Dry	0.00E+00	1.16E+14	0.00E+00	5.53E+12	0.00E+00	0.00E+00	0.00E+00	6.14E+11	0.00E+00	0.00E+00
Deer	3.33E+11	9.58E+13	6.87E+12	8.66E+11	1.20E+12	1.81E+11	0.00E+00	0.00E+00	0.00E+00	1.05E+14
Dog	0.00E+00	0.00E+00	1.74E+14	0.00E+00						
Duck	1.53E+08	7.86E+09	2.32E+09	6.24E+08	1.08E+08	6.09E+07	0.00E+00	0.00E+00	0.00E+00	1.05E+10
Goose	8.16E+09	4.18E+11	1.24E+11	3.32E+10	5.74E+09	3.24E+09	0.00E+00	0.00E+00	0.00E+00	5.58E+11
Horse	0.00E+00	4.91E+14	0.00E+00							
Muskrat	2.64E+12	1.35E+14	4.00E+13	1.07E+13	1.86E+12	1.05E+12	0.00E+00	0.00E+00	0.00E+00	1.81E+14
Failing Septics	0.00E+00	0.00E+00	7.61E+12	0.00E+00						
Straight Pipes	0.00E+00	4.30E+12	0.00E+00	0.00E+00						
Raccoon	9.99E+12	7.07E+14	1.34E+14	1.05E+13	9.68E+12	4.00E+12	0.00E+00	0.00E+00	0.00E+00	8.23E+14
Sheep	0.00E+00	9.25E+12	0.00E+00							
Swine	0.00E+00									
Turkey	8.66E+06	1.39E+10	7.29E+08	1.36E+08	1.63E+08	4.61E+07	0.00E+00	0.00E+00	0.00E+00	4.75E+10
<b>Totals</b>	<b>1.30E+13</b>	<b>6.16E+15</b>	<b>3.63E+14</b>	<b>2.45E+14</b>	<b>3.90E+14</b>	<b>5.23E+12</b>	<b>0.00E+00</b>	<b>2.91E+13</b>	<b>0.00E+00</b>	<b>1.11E+15</b>

**Table B.12 Existing annual loads from direct-deposition sources for the Big Cedar/Burgess modeling group.**

<b>Source</b>	<b>Annual Total Loads (cfu/yr)</b>
Beaver	2.90E+10
Beef	1.98E+13
Beef Calves	4.08E+12
Dairy	0.00E+00
Dairy Calves	2.54E+11
Dairy Dry	6.14E+11
Deer	5.30E+11
Duck	8.70E+08
Goose	3.05E+10
Horse	0.00E+00
Muskrat	1.81E+13
Straight Pipes	4.30E+12
Raccoon	4.29E+12
Sheep	0.00E+00
Swine	0.00E+00
Turkey	1.57E+08
<b>Total</b>	<b>5.20E+13</b>

**Table B.13 Current conditions of land applied fecal coliform load for the Elk Garden/Loop modeling group, by land-use.**

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Barren	1.14E+11	1.03E+11	1.14E+11	1.10E+11	1.14E+11	1.10E+11	1.14E+11	1.14E+11	1.10E+11	1.14E+11	1.10E+11	1.14E+11	1.34E+12
Forest	4.67E+13	4.22E+13	4.67E+13	4.52E+13	4.67E+13	4.52E+13	4.67E+13	4.67E+13	4.52E+13	4.67E+13	4.52E+13	4.67E+13	5.50E+14
Pasture	2.07E+14	1.87E+14	2.05E+14	1.95E+14	2.02E+14	1.96E+14	2.03E+14	2.03E+14	1.95E+14	2.05E+14	1.98E+14	2.07E+14	2.40E+15
Commercial	4.55E+10	4.11E+10	4.55E+10	4.41E+10	4.55E+10	4.41E+10	4.55E+10	4.55E+10	4.41E+10	4.55E+10	4.41E+10	4.55E+10	5.36E+11
Developed	7.26E+12	6.55E+12	7.23E+12	6.98E+12	7.20E+12	6.96E+12	7.17E+12	7.17E+12	6.94E+12	7.15E+12	6.94E+12	7.22E+12	8.48E+13
LAX	5.28E+12	4.77E+12	7.16E+12	9.24E+12	9.55E+12	1.10E+13	1.14E+13	1.14E+13	9.24E+12	7.16E+12	6.93E+12	5.28E+12	9.85E+13
Crop	2.96E+12	3.28E+12	2.70E+13	2.70E+13	2.70E+13	6.11E+11	6.31E+11	6.31E+11	8.36E+12	2.70E+13	2.70E+13	2.96E+12	1.54E+14
<b>Total</b>	<b>2.69E+14</b>	<b>2.44E+14</b>	<b>2.93E+14</b>	<b>2.84E+14</b>	<b>2.93E+14</b>	<b>2.60E+14</b>	<b>2.69E+14</b>	<b>2.69E+14</b>	<b>2.65E+14</b>	<b>2.93E+14</b>	<b>2.84E+14</b>	<b>2.69E+14</b>	<b>3.29E+15</b>

**Table B.14 Monthly, directly deposited fecal coliform loads in the Elk Garden/Loop modeling group.**

Source Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
Human	9.14E+10	8.26E+10	9.14E+10	8.85E+10	9.14E+10	8.85E+10	9.14E+10	9.14E+10	8.85E+10	9.14E+10	8.85E+10	9.14E+10	1.08E+12
Livestock	4.89E+11	4.41E+11	6.51E+11	9.46E+11	9.77E+11	1.10E+12	1.14E+12	1.14E+12	9.46E+11	6.51E+11	6.30E+11	4.89E+11	9.60E+12
Wildlife	8.33E+11	7.52E+11	8.33E+11	8.06E+11	8.33E+11	8.06E+11	8.33E+11	8.33E+11	8.06E+11	8.33E+11	8.06E+11	8.33E+11	9.81E+12

**Table B.15 Existing annual loads from land-based sources for the Elk Garden/Loop modeling group by land-use.**

<b>Source</b>	<b>Commercial</b>	<b>Pasture</b>	<b>Developed</b>	<b>LAX</b>	<b>Crop</b>	<b>Barren</b>	<b>Reclaimed</b>	<b>Water</b>	<b>Gas Well</b>	<b>Forest</b>
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E+10	0.00E+00	0.00E+00
Beef	0.00E+00	1.46E+15	0.00E+00	6.92E+13	0.00E+00	0.00E+00	0.00E+00	7.69E+12	0.00E+00	0.00E+00
Beef Calves	0.00E+00	3.00E+14	0.00E+00	1.42E+13	0.00E+00	0.00E+00	0.00E+00	1.58E+12	0.00E+00	0.00E+00
Cat	0.00E+00	0.00E+00	3.22E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dairy	0.00E+00	8.14E+12	0.00E+00	0.00E+00	1.47E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dairy Calves	0.00E+00	1.86E+13	0.00E+00	8.81E+11	0.00E+00	0.00E+00	0.00E+00	9.79E+10	0.00E+00	0.00E+00
Dairy Dry	0.00E+00	4.48E+13	0.00E+00	2.13E+12	0.00E+00	0.00E+00	0.00E+00	2.36E+11	0.00E+00	0.00E+00
Deer	1.55E+10	3.72E+13	1.88E+12	4.84E+11	6.37E+11	5.08E+10	0.00E+00	0.00E+00	0.00E+00	5.46E+13
Dog	0.00E+00	0.00E+00	3.60E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	7.46E+06	3.30E+09	5.65E+08	3.40E+08	6.67E+07	5.64E+06	0.00E+00	0.00E+00	0.00E+00	4.86E+09
Goose	3.97E+08	1.76E+11	3.01E+10	1.81E+10	3.55E+09	3.01E+08	0.00E+00	0.00E+00	0.00E+00	2.59E+11
Horse	0.00E+00	1.90E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Muskrat	1.28E+11	5.69E+13	9.73E+12	5.86E+12	1.15E+12	9.72E+10	0.00E+00	0.00E+00	0.00E+00	8.37E+13
Failing Septics	0.00E+00	0.00E+00	2.69E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Straight Pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E+12	0.00E+00	0.00E+00
Raccoon	3.92E+11	2.85E+14	3.45E+13	5.68E+12	5.65E+12	1.19E+12	0.00E+00	0.00E+00	0.00E+00	4.11E+14
Sheep	0.00E+00	3.59E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Turkey	6.58E+05	5.51E+09	2.32E+08	8.00E+07	8.73E+07	8.42E+06	0.00E+00	0.00E+00	0.00E+00	2.50E+10
<b>Totals</b>	<b>5.36E+11</b>	<b>2.40E+15</b>	<b>8.48E+13</b>	<b>9.85E+13</b>	<b>1.54E+14</b>	<b>1.34E+12</b>	<b>0.00E+00</b>	<b>1.07E+13</b>	<b>0.00E+00</b>	<b>5.50E+14</b>

**Table B.16 Existing annual loads from direct-deposition sources for the Elk Garden/Loop modeling group.**

<b>Source</b>	<b>Annual Total Loads (cfu/yr)</b>
Beaver	2.17E+10
Beef	7.69E+12
Beef Calves	1.58E+12
Dairy	0.00E+00
Dairy Calves	9.79E+10
Dairy Dry	2.36E+11
Deer	2.38E+11
Duck	3.68E+08
Goose	1.29E+10
Horse	0.00E+00
Muskrat	7.66E+12
Straight Pipes	1.08E+12
Raccoon	1.87E+12
Sheep	0.00E+00
Swine	0.00E+00
Turkey	7.76E+07
<b>Total</b>	<b>2.05E+13</b>

**Table B.17 Current conditions of land applied fecal coliform load for the Lewis Creek modeling group, by land-use.**

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Gas Well	1.62E+11	1.46E+11	1.62E+11	1.57E+11	1.62E+11	1.57E+11	1.62E+11	1.62E+11	1.57E+11	1.62E+11	1.57E+11	1.62E+11	1.90E+12
Forest	2.69E+13	2.43E+13	2.69E+13	2.60E+13	2.69E+13	2.60E+13	2.69E+13	2.69E+13	2.60E+13	2.69E+13	2.60E+13	2.69E+13	3.16E+14
Pasture	9.76E+14	8.81E+14	9.64E+14	9.19E+14	9.49E+14	9.23E+14	9.53E+14	9.53E+14	9.19E+14	9.64E+14	9.33E+14	9.76E+14	1.13E+16
Commercial	8.61E+11	7.78E+11	8.61E+11	8.33E+11	8.61E+11	8.33E+11	8.61E+11	8.61E+11	8.33E+11	8.61E+11	8.33E+11	8.61E+11	1.01E+13
LAX	2.38E+13	2.15E+13	3.42E+13	4.60E+13	4.75E+13	5.60E+13	5.79E+13	5.79E+13	4.60E+13	3.42E+13	3.31E+13	2.38E+13	4.82E+14
Developed	9.72E+12	8.77E+12	9.68E+12	9.36E+12	9.66E+12	9.34E+12	9.63E+12	9.63E+12	9.32E+12	9.62E+12	9.32E+12	9.67E+12	1.14E+14
Crop	1.30E+13	1.52E+13	1.47E+14	1.47E+14	1.47E+14	6.47E+10	6.69E+10	6.69E+10	4.32E+13	1.47E+14	1.47E+14	1.30E+13	8.18E+14
Barren	4.55E+10	4.11E+10	4.55E+10	4.40E+10	4.55E+10	4.40E+10	4.55E+10	4.55E+10	4.40E+10	4.55E+10	4.40E+10	4.55E+10	5.36E+11
Reclaimed	2.65E+12	2.39E+12	2.65E+12	2.56E+12	2.65E+12	2.56E+12	2.65E+12	2.65E+12	2.56E+12	2.65E+12	2.56E+12	2.65E+12	3.12E+13
<b>Total</b>	<b>1.05E+15</b>	<b>9.54E+14</b>	<b>1.19E+15</b>	<b>1.15E+15</b>	<b>1.18E+15</b>	<b>1.02E+15</b>	<b>1.05E+15</b>	<b>1.05E+15</b>	<b>1.05E+15</b>	<b>1.19E+15</b>	<b>1.15E+15</b>	<b>1.05E+15</b>	<b>1.31E+16</b>

**Table B.18 Monthly, directly deposited fecal coliform loads in the Lewis Creek modeling group.**

Source Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
<b>Human</b>	3.66E+11	3.30E+11	3.66E+11	3.54E+11	3.66E+11	3.54E+11	3.66E+11	3.66E+11	3.54E+11	3.66E+11	3.54E+11	3.66E+11	4.30E+12
<b>Livestock</b>	2.71E+12	2.45E+12	3.62E+12	5.25E+12	5.42E+12	6.12E+12	6.33E+12	6.33E+12	5.25E+12	3.62E+12	3.50E+12	2.71E+12	5.33E+13
<b>Wildlife</b>	3.93E+11	3.55E+11	3.93E+11	3.81E+11	3.93E+11	3.81E+11	3.93E+11	3.93E+11	3.81E+11	3.93E+11	3.81E+11	3.93E+11	4.63E+12

**Table B.19 Existing annual loads from land-based sources for the Lewis Creek modeling group by land-use.**

Source	Commercial	Pasture	Developed	LAX	Crop	Barren	Reclaimed	Water	Gas Well	Forest
Beaver	0.00E+00	3.32E+10	0.00E+00	0.00E+00						
Beef	0.00E+00	8.09E+15	0.00E+00	3.84E+14	0.00E+00	0.00E+00	0.00E+00	4.27E+13	0.00E+00	0.00E+00
Beef Calves	0.00E+00	1.67E+15	0.00E+00	7.91E+13	0.00E+00	0.00E+00	0.00E+00	8.79E+12	0.00E+00	0.00E+00
Cat	0.00E+00	0.00E+00	4.82E+07	0.00E+00						
Dairy	0.00E+00	4.53E+13	0.00E+00	0.00E+00	8.17E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dairy Calves	0.00E+00	1.03E+14	0.00E+00	4.87E+12	0.00E+00	0.00E+00	0.00E+00	5.42E+11	0.00E+00	0.00E+00
Dairy Dry	0.00E+00	2.48E+14	0.00E+00	1.18E+13	0.00E+00	0.00E+00	0.00E+00	1.31E+12	0.00E+00	0.00E+00
Deer	2.53E+11	8.24E+12	2.21E+12	8.82E+10	1.25E+11	1.38E+10	2.82E+12	0.00E+00	2.22E+11	3.61E+13
Dog	0.00E+00	0.00E+00	5.39E+13	0.00E+00						
Duck	1.63E+08	6.29E+08	8.26E+08	6.12E+07	2.47E+06	8.65E+06	3.20E+08	0.00E+00	1.07E+07	2.14E+09
Goose	8.70E+09	3.35E+10	4.40E+10	3.26E+09	1.32E+08	4.61E+08	1.71E+10	0.00E+00	5.72E+08	1.14E+11
Horse	0.00E+00	1.06E+15	0.00E+00							
Muskrat	2.81E+12	1.08E+13	1.42E+13	1.05E+12	4.26E+10	1.49E+11	5.52E+12	0.00E+00	1.85E+11	3.69E+13
Failing Septics	0.00E+00	0.00E+00	2.42E+12	0.00E+00						
Straight Pipes	0.00E+00	4.30E+12	0.00E+00	0.00E+00						
Raccoon	7.06E+12	5.80E+13	4.09E+13	1.08E+12	6.19E+11	3.73E+11	2.28E+13	0.00E+00	1.50E+12	2.43E+14
Sheep	0.00E+00	1.99E+13	0.00E+00							
Swine	0.00E+00									
Turkey	2.28E+07	1.30E+09	4.48E+08	1.54E+07	2.02E+07	2.69E+06	5.52E+08	0.00E+00	8.90E+07	1.72E+10
<b>Totals</b>	<b>1.01E+13</b>	<b>1.13E+16</b>	<b>1.14E+14</b>	<b>4.82E+14</b>	<b>8.18E+14</b>	<b>5.36E+11</b>	<b>3.12E+13</b>	<b>5.77E+13</b>	<b>1.91E+12</b>	<b>3.16E+14</b>

**Table B.20 Existing annual loads from direct-deposition sources for the Lewis Creek modeling group.**

<b>Source</b>	<b>Annual Total Loads (cfu/yr)</b>
Beaver	3.32E+10
Beef	4.27E+13
Beef Calves	8.79E+12
Dairy	0.00E+00
Dairy Calves	5.42E+11
Dairy Dry	1.31E+12
Deer	1.26E+11
Duck	1.69E+08
Goose	5.92E+09
Horse	0.00E+00
Muskrat	3.52E+12
Straight Pipes	4.30E+12
Raccoon	9.48E+11
Sheep	0.00E+00
Swine	0.00E+00
Turkey	4.94E+07
<b>Total</b>	<b>6.23E+13</b>

**Table B.21 Current conditions of land applied fecal coliform load for the Swords/Hess Creek modeling group, by land-use.**

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Gas Well	2.01E+11	1.82E+11	2.01E+11	1.95E+11	2.01E+11	1.95E+11	2.01E+11	2.01E+11	1.95E+11	2.01E+11	1.95E+11	2.01E+11	2.37E+12
Forest	5.83E+13	5.27E+13	5.83E+13	5.64E+13	5.83E+13	5.64E+13	5.83E+13	5.83E+13	5.64E+13	5.83E+13	5.64E+13	5.83E+13	6.86E+14
Pasture	1.44E+15	1.30E+15	1.42E+15	1.35E+15	1.40E+15	1.36E+15	1.40E+15	1.40E+15	1.35E+15	1.42E+15	1.38E+15	1.44E+15	1.67E+16
Commercial	1.14E+12	1.03E+12	1.14E+12	1.10E+12	1.14E+12	1.10E+12	1.14E+12	1.14E+12	1.10E+12	1.14E+12	1.10E+12	1.14E+12	1.34E+13
Developed	1.78E+13	1.61E+13	1.78E+13	1.72E+13	1.77E+13	1.71E+13	1.77E+13	1.77E+13	1.71E+13	1.76E+13	1.71E+13	1.77E+13	2.09E+14
LAX	3.52E+13	3.18E+13	5.05E+13	6.78E+13	7.00E+13	8.26E+13	8.53E+13	8.53E+13	6.78E+13	5.05E+13	4.89E+13	3.52E+13	7.11E+14
Crop	1.91E+13	2.23E+13	2.15E+14	2.15E+14	2.15E+14	1.11E+11	1.15E+11	1.15E+11	6.34E+13	2.15E+14	2.15E+14	1.91E+13	1.20E+15
Barren	6.68E+11	6.03E+11	6.68E+11	6.47E+11	6.68E+11	6.47E+11	6.68E+11	6.68E+11	6.47E+11	6.68E+11	6.47E+11	6.68E+11	7.87E+12
Reclaimed	6.10E+12	5.51E+12	6.10E+12	5.90E+12	6.10E+12	5.90E+12	6.10E+12	6.10E+12	5.90E+12	6.10E+12	5.90E+12	6.10E+12	7.18E+13
<b>Total</b>	<b>1.58E+15</b>	<b>1.43E+15</b>	<b>1.77E+15</b>	<b>1.71E+15</b>	<b>1.77E+15</b>	<b>1.52E+15</b>	<b>1.57E+15</b>	<b>1.57E+15</b>	<b>1.56E+15</b>	<b>1.77E+15</b>	<b>1.73E+15</b>	<b>1.58E+15</b>	<b>1.96E+16</b>

**Table B.22 Monthly, directly deposited fecal coliform loads in the Swords/Hess Creek modeling group.**

Source Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
<b>Human</b>	1.19E+12	1.07E+12	1.19E+12	1.15E+12	1.19E+12	1.15E+12	1.19E+12	1.19E+12	1.15E+12	1.19E+12	1.15E+12	1.19E+12	1.40E+13
<b>Livestock</b>	3.99E+12	3.60E+12	5.32E+12	7.73E+12	7.98E+12	9.02E+12	9.31E+12	9.31E+12	7.73E+12	5.32E+12	5.15E+12	3.99E+12	7.85E+13
<b>Wildlife</b>	8.40E+11	7.59E+11	8.40E+11	8.13E+11	8.40E+11	8.13E+11	8.40E+11	8.40E+11	8.13E+11	8.40E+11	8.13E+11	8.40E+11	9.89E+12

**Table B.23 Existing annual loads from land-based sources for the Swords/Hess Creek modeling group by land-use.**

Source	Commercial	Pasture	Developed	LAX	Crop	Barren	Reclaimed	Water	Gas Well	Forest
Beaver	0.00E+00	1.17E+11	0.00E+00	0.00E+00						
Beef	0.00E+00	1.19E+16	0.00E+00	5.65E+14	0.00E+00	0.00E+00	0.00E+00	6.28E+13	0.00E+00	0.00E+00
Beef Calves	0.00E+00	2.45E+15	0.00E+00	1.16E+14	0.00E+00	0.00E+00	0.00E+00	1.29E+13	0.00E+00	0.00E+00
Cat	0.00E+00	0.00E+00	7.77E+07	0.00E+00						
Dairy	0.00E+00	6.64E+13	0.00E+00	0.00E+00	1.20E+15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dairy Calves	0.00E+00	1.52E+14	0.00E+00	7.22E+12	0.00E+00	0.00E+00	0.00E+00	8.02E+11	0.00E+00	0.00E+00
Dairy Dry	0.00E+00	3.67E+14	0.00E+00	1.74E+13	0.00E+00	0.00E+00	0.00E+00	1.94E+12	0.00E+00	0.00E+00
Deer	4.46E+11	1.21E+13	4.85E+12	1.70E+11	1.94E+11	1.40E+11	6.64E+12	0.00E+00	3.38E+11	7.70E+13
Dog	0.00E+00	0.00E+00	8.70E+13	0.00E+00						
Duck	1.92E+08	1.05E+09	1.56E+09	1.27E+08	5.06E+06	6.49E+07	8.37E+08	0.00E+00	9.07E+06	4.71E+09
Goose	1.02E+10	5.57E+10	8.32E+10	6.76E+09	2.69E+08	3.46E+09	4.46E+10	0.00E+00	4.83E+08	2.51E+11
Horse	0.00E+00	1.56E+15	0.00E+00							
Muskrat	3.31E+12	1.80E+13	2.69E+13	2.19E+12	8.71E+10	1.12E+12	1.44E+13	0.00E+00	1.56E+11	8.11E+13
Failing Septics	0.00E+00	0.00E+00	4.30E+12	0.00E+00						
Straight Pipes	0.00E+00	1.40E+13	0.00E+00	0.00E+00						
Raccoon	9.64E+12	9.70E+13	8.54E+13	2.25E+12	1.07E+12	6.61E+12	5.07E+13	0.00E+00	1.88E+12	5.28E+14
Sheep	0.00E+00	2.94E+13	0.00E+00							
Swine	0.00E+00									
Turkey	9.12E+07	2.06E+09	1.16E+09	3.08E+07	3.14E+07	3.08E+07	1.35E+09	0.00E+00	1.29E+08	3.64E+10
<b>Totals</b>	<b>1.34E+13</b>	<b>1.67E+16</b>	<b>2.09E+14</b>	<b>7.10E+14</b>	<b>1.20E+15</b>	<b>7.87E+12</b>	<b>7.18E+13</b>	<b>9.26E+13</b>	<b>2.37E+12</b>	<b>6.86E+14</b>

**Table B.24 Existing annual loads from direct-deposition sources for the Swords/Hess Creek modeling group.**

<b>Source</b>	<b>Annual Total Loads (cfu/yr)</b>
Beaver	1.17E+11
Beef	6.28E+13
Beef Calves	1.29E+13
Dairy	0.00E+00
Dairy Calves	8.02E+11
Dairy Dry	1.94E+12
Deer	2.57E+11
Duck	3.61E+08
Goose	1.26E+10
Horse	0.00E+00
Muskrat	7.51E+12
Straight Pipes	1.40E+13
Raccoon	1.99E+12
Sheep	0.00E+00
Swine	0.00E+00
Turkey	1.04E+08
<b>Total</b>	<b>1.02E+14</b>

Page intentionally blank

**APPENDIX C      BACTERIA      MODELING      PROCEDURE:  
LINKING THE SOURCES TO THE ENDPOINT**

## **Modeling Procedure: Linking the Sources to the Endpoint**

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of the TMDL for the Middle Clinch River watershed study area, the relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality.

### **Modeling Framework Selection**

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate streamflow, overland runoff and to perform TMDL allocations.

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

The HSPF model is a continuous simulation model that can account for nonpoint source (NPS) pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

### **Model Setup**

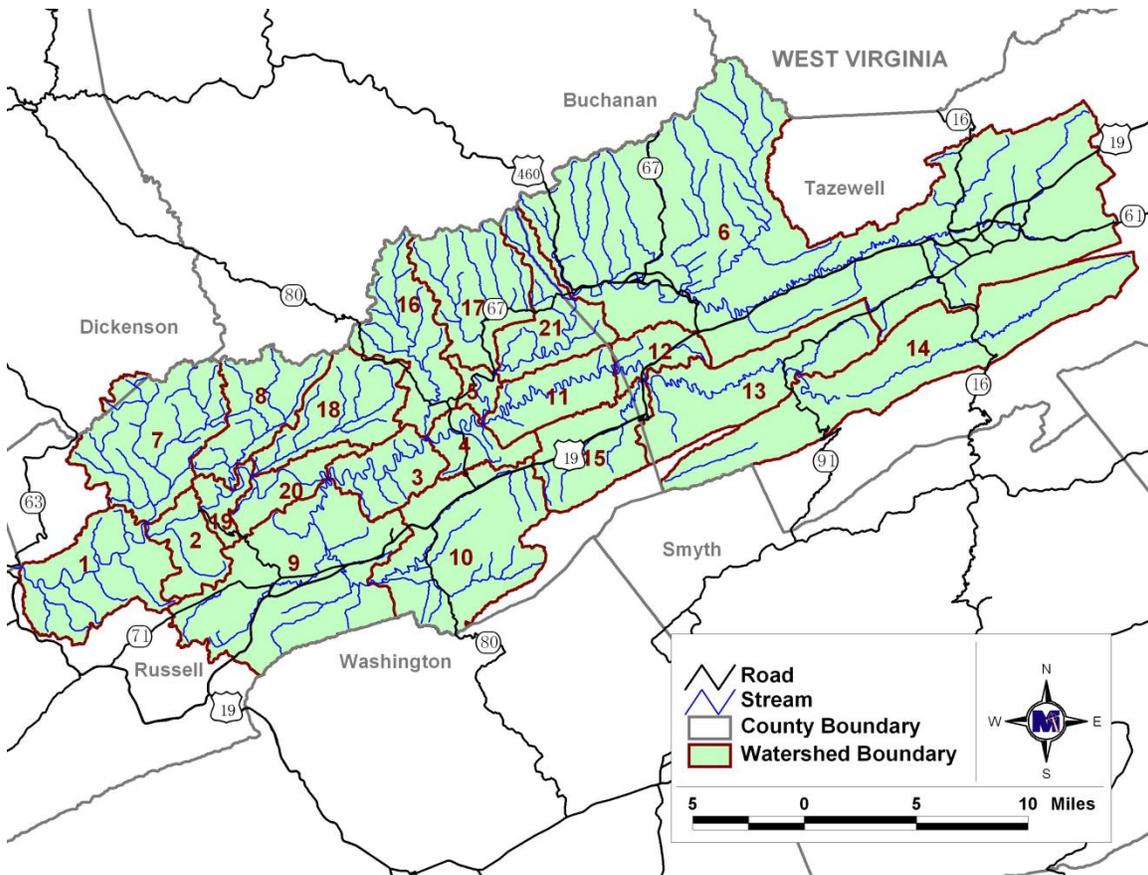
Daily precipitation data was available within the watershed at the Richlands NCDC Coop station #447174. Missing values were filled using daily precipitation from the Lebanon NCDC Coop station #444777, and then from the Abingdon NCDC Coop station #440021 as needed. The final filled daily precipitation was disaggregated using the hourly station data from Bristol Tri City Airport NCDC Coop station #401094.

### ***Subwatersheds***

To adequately represent the spatial variation in the watershed, the Middle Clinch River watershed drainage area was divided into twenty-one (21) subwatersheds (Figure C.1).

The rationale for choosing these subwatersheds was based on the availability of water quality data, the stream network configuration, and the limitations of the HSPF model. All of the subwatersheds upstream of subwatershed 2 were used in hydrologic calibration since they were upstream of the flow gage with observed data. The flow gage was the USGS Clinch River gage (#03524000) in Cleveland, VA (at the outlet of subwatershed 19). All subwatersheds were used in the bacteria calibration.

Figure C. 1 shows all subwatersheds, which were used to achieve the unified model. Table C. 1 notes the subwatersheds contained within each impairment, the impaired stream segments, and the outlet subwatershed for each impairment.



**Figure C. 1 All subwatersheds delineated for modeling in the Middle Clinch River watershed study area.**

**Table C.1** Impairments and subwatersheds within the Middle Clinch River watershed study area.

Impairment	Impaired Subwatershed (s)	Outlet	Contributing Subwatersheds
Indian Creek VAS-P05R_IDN01A04	15	15	15
Clinch River VAS-P07R_CLN01A00	2, 19, 20	2	All (except 1 and 7)
Big Cedar Creek VAS-P06R_BCD01A98	9	9	9, 10
Big Cedar Creek VAS-P06R_BCD02A02	9	Big Cedar Creek Segment BCD01A98	9, 10
Big Cedar Creek VAS-P06R_BCD02A00	9	Big Cedar Creek Segment BCD02A02	9, 10
Big Cedar Creek VAS-P06R_BCD03A00	9	Big Cedar Creek Segment BCD02A00	9, 10
Loop Creek VAS-P06R_LOO01A06	10	10	10
Burgess Creek VAS-P06R_BUG01A06	9	Big Cedar Creek Segment BCD03A00	9
Elk Garden Creek VAS-P06R_EKG01A06	10	10	10
Weaver Creek VAS-P07R_WEA01A06	8	8	8
Thompson Creek VAS-P07R_TMP01A06	18	18	18
Lewis Creek VAS-P04R_LWS01A98	16	16	16
Lewis Creek VAS-P04R_LWS01A10	16	16	16
Hess Creek VAS-P04R_HES01A10	17	Swords Creek	17
Swords Creek VAS-P04R_HES01A10	17	17	17
Little River VAS-P05R_LTR02A00	13	13	13, 14
Little River VAS-P05R_LTR02A02	12	12	12, 13, 14, 15
Dumps Creek VAS-P08R_DUM01A94	7	7	7
Maiden Spring Creek VAS-P05R_MSC01A02	14	14	14
Maiden Spring Creek VAS-P05R_MSC01C04	14	Maiden Spring Creek segment MSC01A02	14

In an effort to standardize modeling procedures across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watersheds allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watersheds.

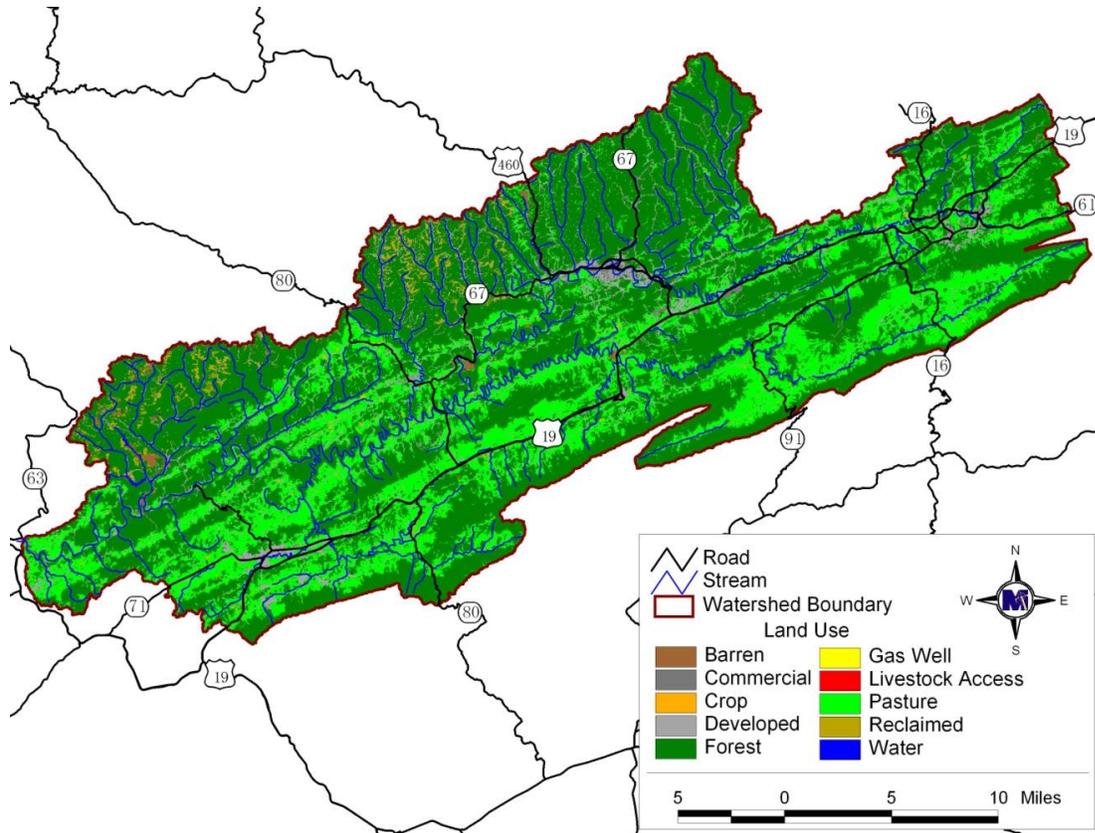
### *Land Uses*

Ten (10) land uses were identified in the watershed. These land uses were obtained by merging different sources including the MRLC land use grid, active mining layers provided by the Virginia Department of Mines, Minerals, and Energy (DMME), topographic maps, and aerial photography of the region. The 10 land use types are given in Table C. 2. Within each subwatershed, up to the ten land use types were represented. Each land use in each subwatershed has hydrologic parameters (e.g., average slope length) and pollutant behavior parameters (e.g., E. coli accumulation rate) associated with it. These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). Impervious areas in the watershed are represented in four IMPLND types, while there are ten PERLND types, each with parameters describing a particular land use. Some IMPLND and PERLND parameters (e.g., slope length) vary with the particular subwatershed in which they are located. Others vary with the season (e.g., upper zone storage) to account for plant growth, die-off, and removal.

Figure C. 2 shows the land uses used in modeling the Middle Clinch River Watershed study area. Table C. 3 shows the breakdown of land uses within each NTU. These acreages represent only what is within the boundaries of the Middle Clinch River Watershed study area.

**Table C. 2 Consolidated land use categories for the Middle Clinch River watershed drainage area used in HSPF modeling.**

TMDL Land use Categories	Pervious / Impervious (%)
Barren	Pervious (94%) Impervious (6%)
Cropland	Pervious (100%)
Commercial	Pervious (40%) Impervious (60%)
Forest	Pervious (100%)
Gas Wells	Pervious (94%) Impervious (6%)
Livestock Access	Pervious (100%)
Pasture	Pervious (100%)
Residential	Pervious (90%) Impervious (10%)
Reclaimed Mine Land	Pervious (100%)
Water	Pervious (100%)



**Figure C. 2 Land uses in the Middle Clinch River watershed study area.**

**Table C. 3 Spatial distribution of land use types in acres in the Middle Clinch River watershed study area.**

<b>NTU</b>	<b>Barren</b>	<b>Commercial</b>	<b>Crop</b>	<b>Forest</b>	<b>Gas Wells</b>	<b>LAX*</b>	<b>Pasture</b>	<b>Re-claimed Mine</b>	<b>Developed</b>	<b>Water</b>	<b>Total</b>
<b>250</b>	329	420	606	82,839	20	488	55,034	331	7,222	1,602	<b>148,891</b>
<b>251</b>	669	247	3	15,915	43	1	196	2,012	937	284	<b>20,309</b>
<b>252</b>	74	306	152	13,173	0	108	15,465	0	3,086	160	<b>32,524</b>
<b>253</b>	38	13	167	14,061	0	129	9,736	0	943	103	<b>25,190</b>
<b>298</b>	10	184	33	9,426	61	26	2,209	757	1,217	70	<b>13,994</b>
<b>421</b>	234	258	50	20,195	93	51	3,248	1,799	2,516	270	<b>28,714</b>
<b>Total</b>	<b>1,354</b>	<b>1,428</b>	<b>1,011</b>	<b>155,609</b>	<b>217</b>	<b>803</b>	<b>85,888</b>	<b>4,899</b>	<b>15,921</b>	<b>2,489</b>	<b>269,622</b>

\*LAX is livestock access to a stream.

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

### Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.*, stream geometry and resistance to flow). These data are entered into HSPF via the Hydraulic Function Tables (F-tables). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and discharge (ft<sup>3</sup>/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume in the reach, and is reported in acre-feet. The discharge is simply the stream outflow, in cubic feet per second.

In order to develop the entries for the F-tables, a combination of the NRCS Regional Hydraulic Geometry Curves (NRCS, 2011), Digital Elevation Models (DEM), nautical charts, and bathymetry data was used. The NRCS has developed empirical formulas for estimating stream top width, cross-sectional area, average depth, and flow rate, at bank-full depth as functions of the drainage area for regions of the United States. Appropriate equations were selected based on the geographic location of the Middle Clinch River watershed. Using these NRCS equations, an entry was developed in the F-table that represented a bank-full situation for the streams at each subwatershed outlet. A profile perpendicular to the channel was generated showing the stream profile height with

distance for each subwatershed outlet (Figure C. 3). Consecutive entries to the F-table are generated by estimating the volume of water and surface area in the reach at incremental depths taken from the profile. An example of an F-table used in HSPF is shown in Table C. 4.

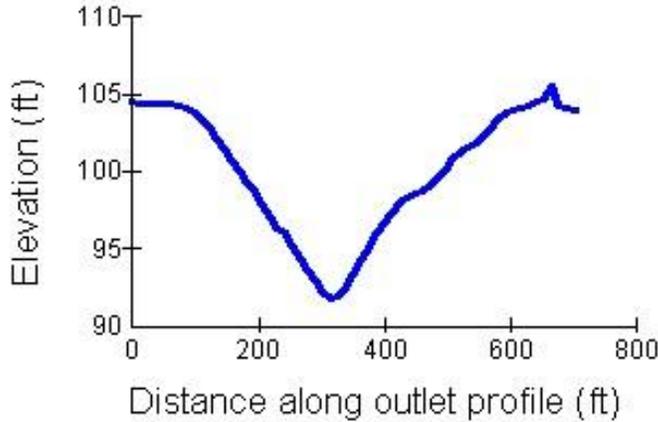


Figure C. 3 Stream profile representation in HSPF.

Table C. 4 Example of an F-table calculated for an HSPF model.

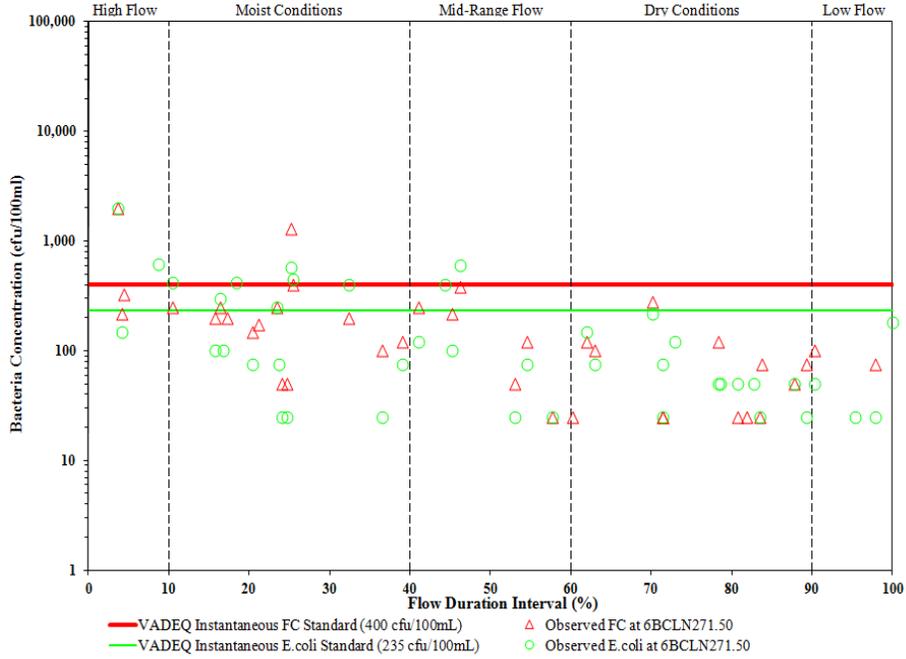
Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft <sup>3</sup> /s)
0	0	0	0
3.28	0.71	1.41	17.07
6.56	1.89	5.15	45.23
9.84	2.54	12.18	85.02
13.12	4.77	24.80	152.82
16.40	56.55	77.51	637.72
19.68	1,047.22	1,635.10	18,846.85
22.96	2,875.31	7,405.99	69,827.77
26.24	3,495.32	18,464.40	133,806.76
29.52	4,426.89	31,720.10	160,393.97

**Bacteria TMDL Critical Condition**

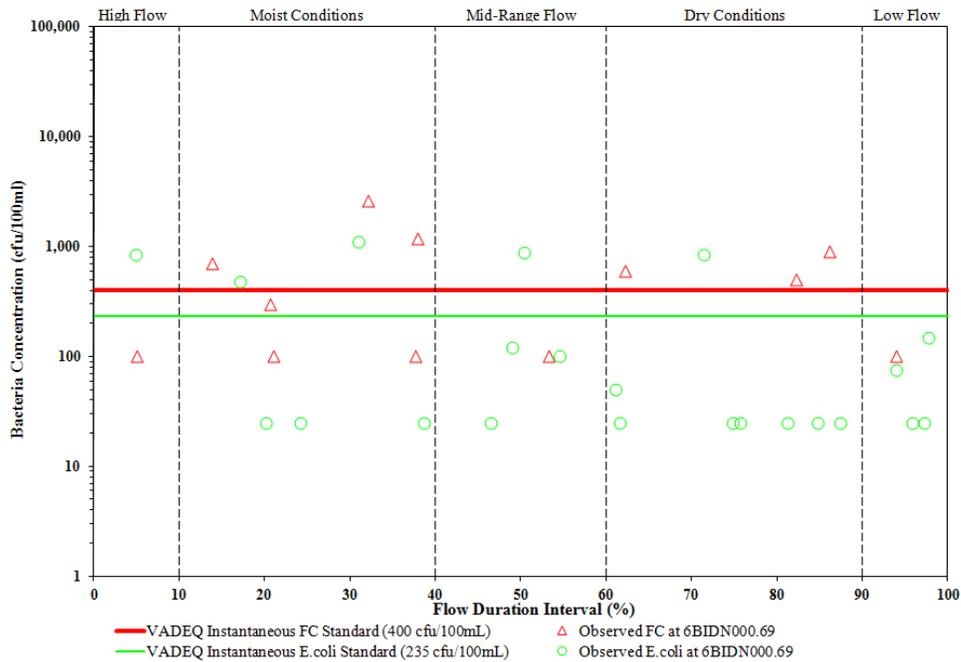
EPA regulations at 40 CFR 130.7 (c)(1) require that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Middle Clinch River watershed study area is protected during times when it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

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

A description of the data used in these analyses is shown in Table 2.1 in Chapter 2. Graphical analyses of fecal bacteria concentrations and flow duration intervals showed that water quality standard violations occurred at nearly every flow interval at 22 VADEQ monitoring stations in the Middle Clinch River watershed study area (Figures C.4 - Figure C.25). Generally, more violations occurred during periods of high flow. This demonstrates that this stream should have all flow regimes represented in the allocation modeling time period.



**Figure C. 4 Fecal and *E. coli* bacteria concentrations at 6BCLN271.50 on the Middle Clinch River versus discharge at USGS Gaging Station # 03524000.**



**Figure C. 5 Fecal and *E. coli* bacteria concentrations at 6BIDN000.69 on Indian Creek versus discharge at USGS Gaging Station # 03524000.**

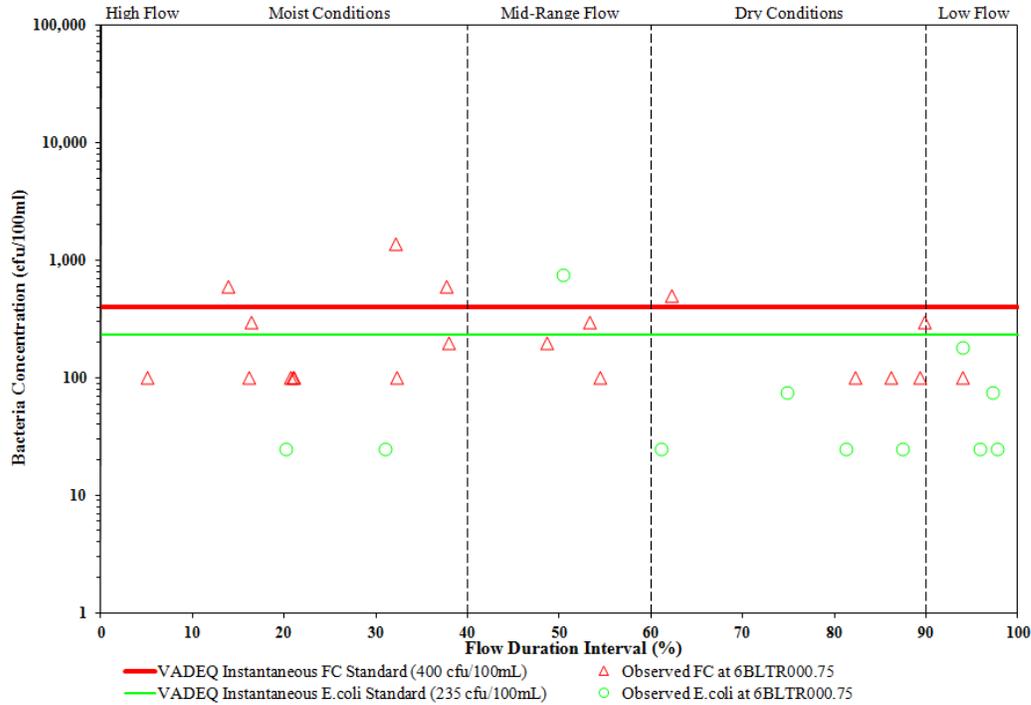


Figure C. 6 Fecal and *E. coli* bacteria concentrations at 6BLTR000.75 on Little River versus discharge at USGS Gaging Station # 03524000.

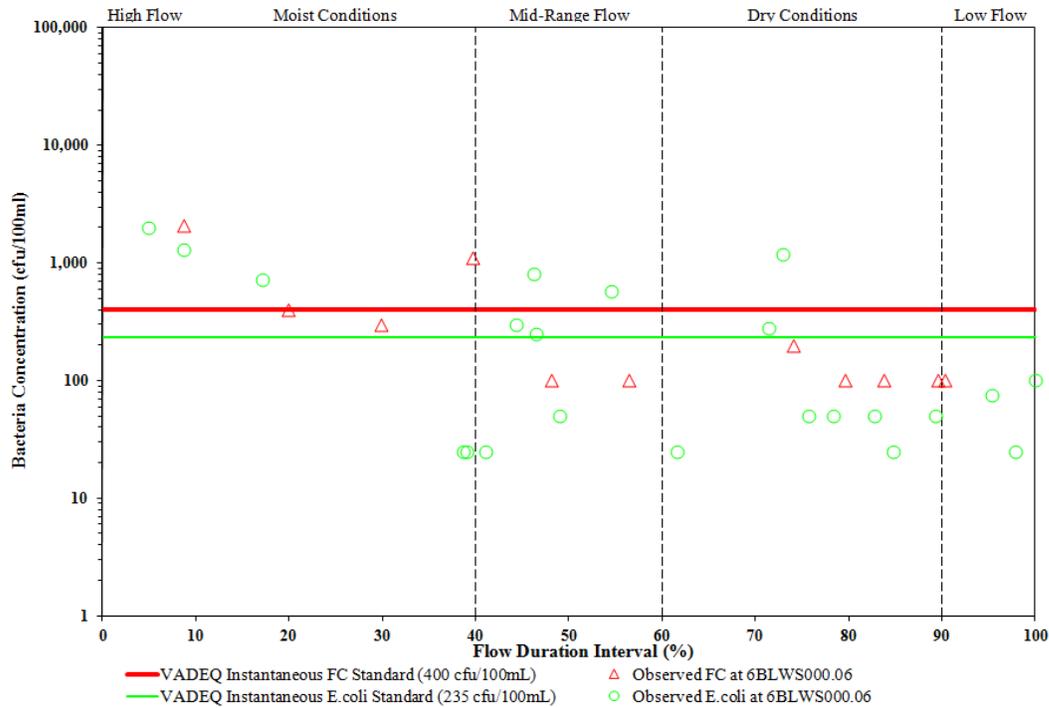
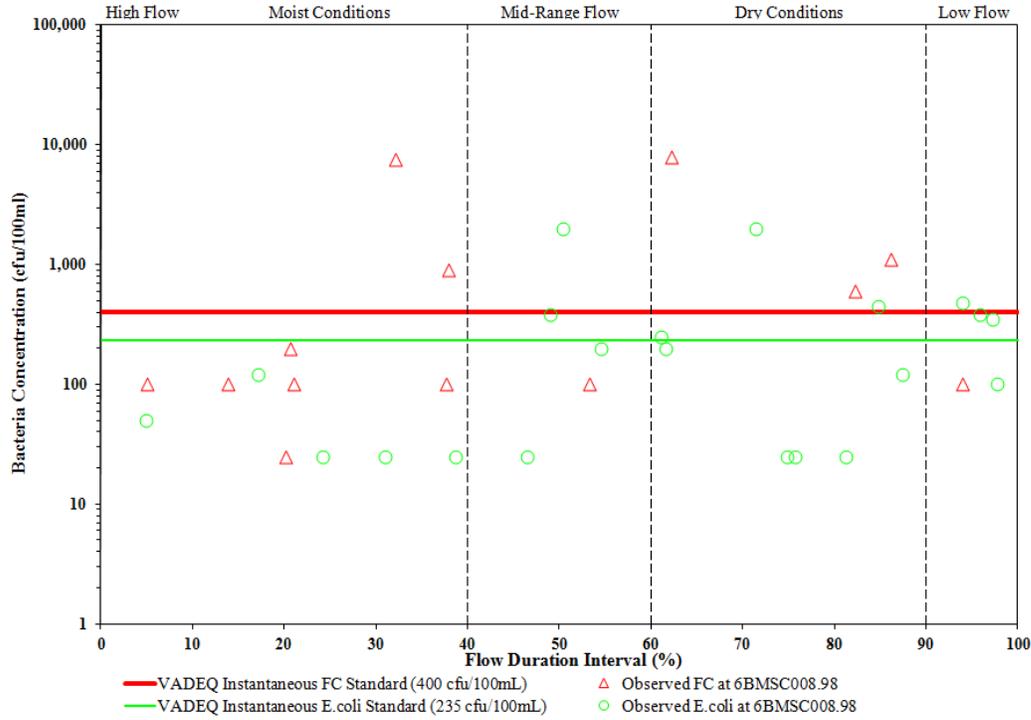
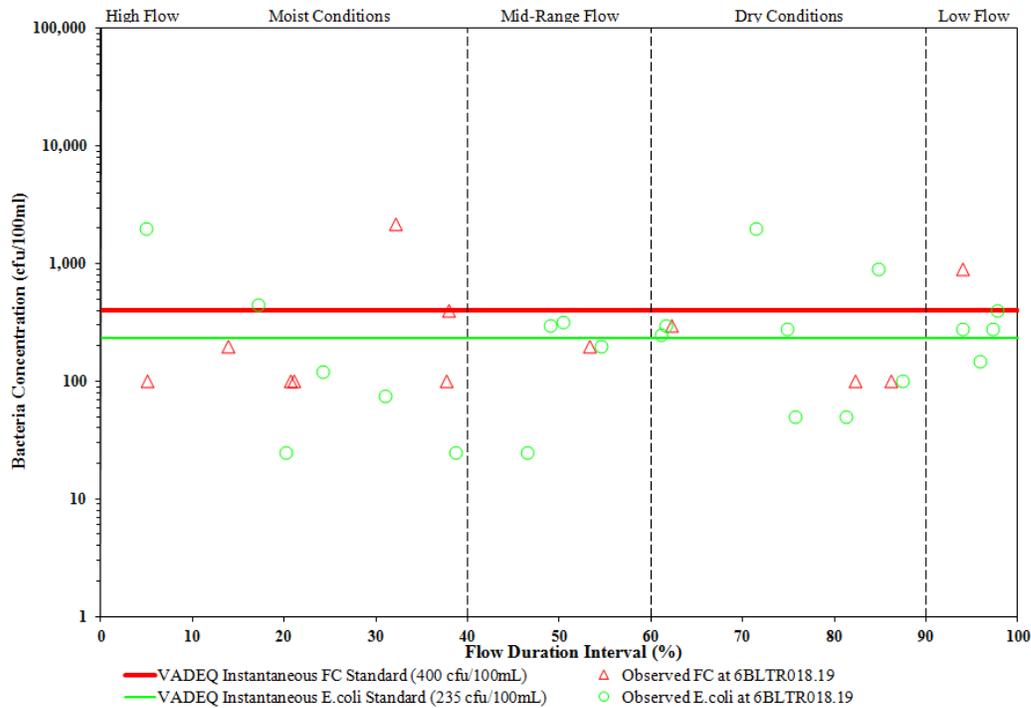


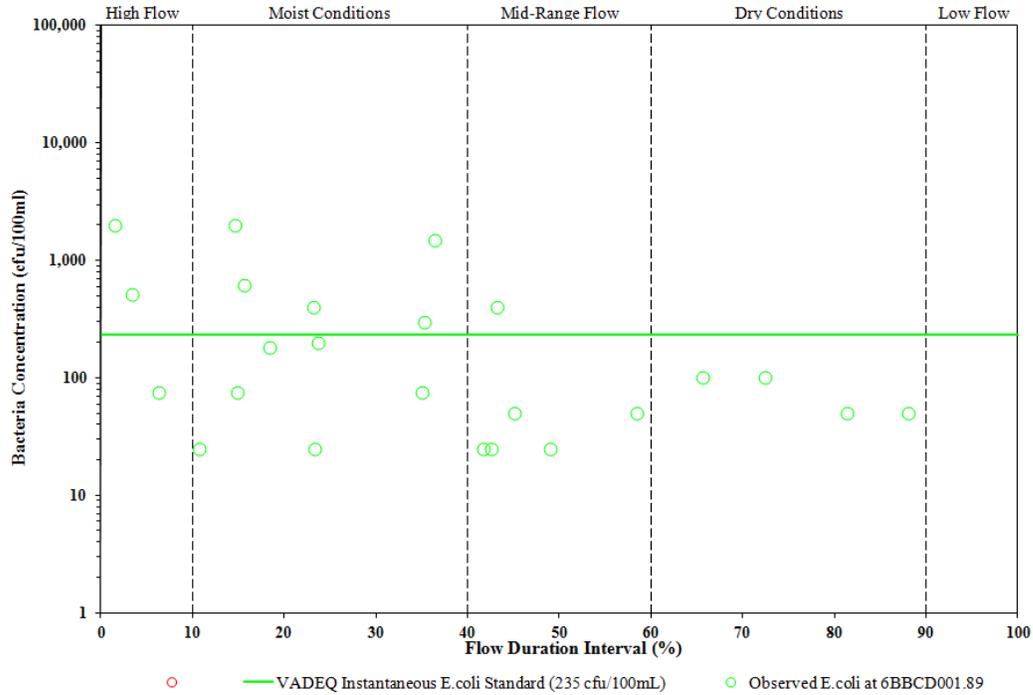
Figure C. 7 Fecal and *E. coli* bacteria concentrations at 6BLWS000.06 on Lewis Creek versus discharge at USGS Gaging Station # 03524000.



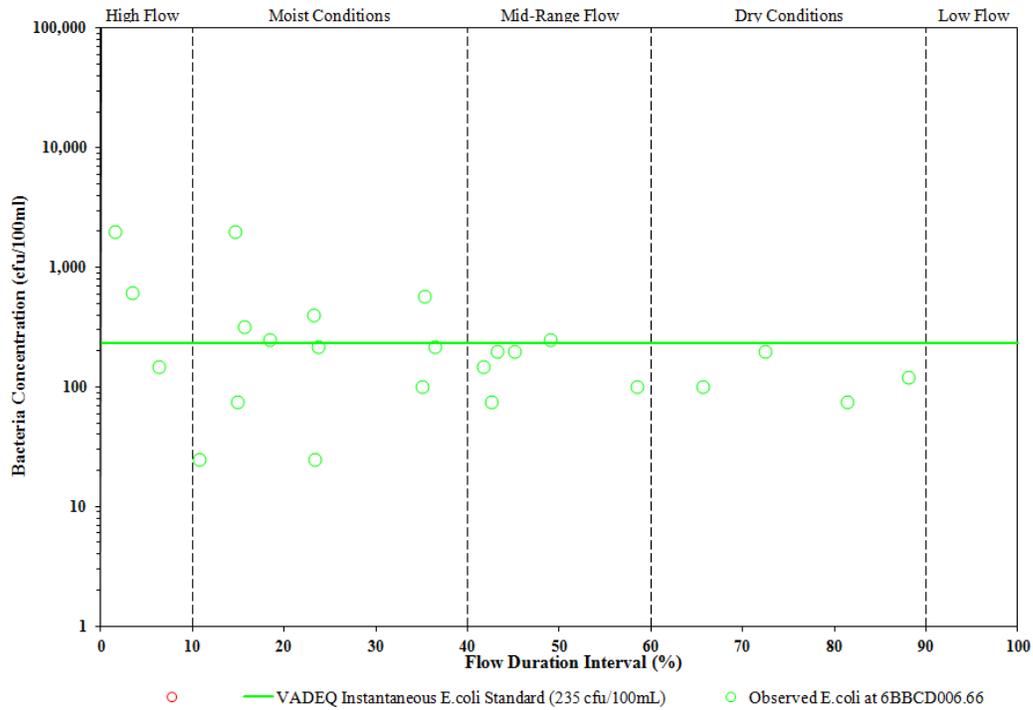
**Figure C. 8 Fecal and *E. coli* bacteria concentrations at 6BMSC008.98 on Maiden Springs Creek versus discharge at USGS Gaging Station # 03524000.**



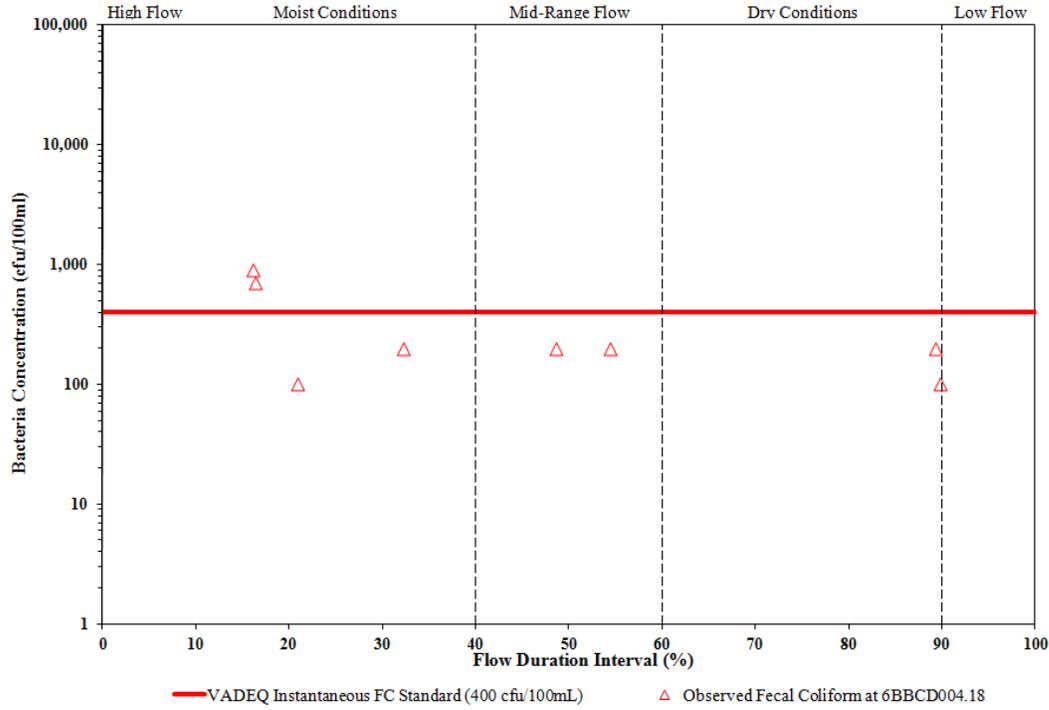
**Figure C. 9 Fecal and *E. coli* bacteria concentrations at 6BLTR018.19 on Little River versus discharge at USGS Gaging Station # 03524000.**



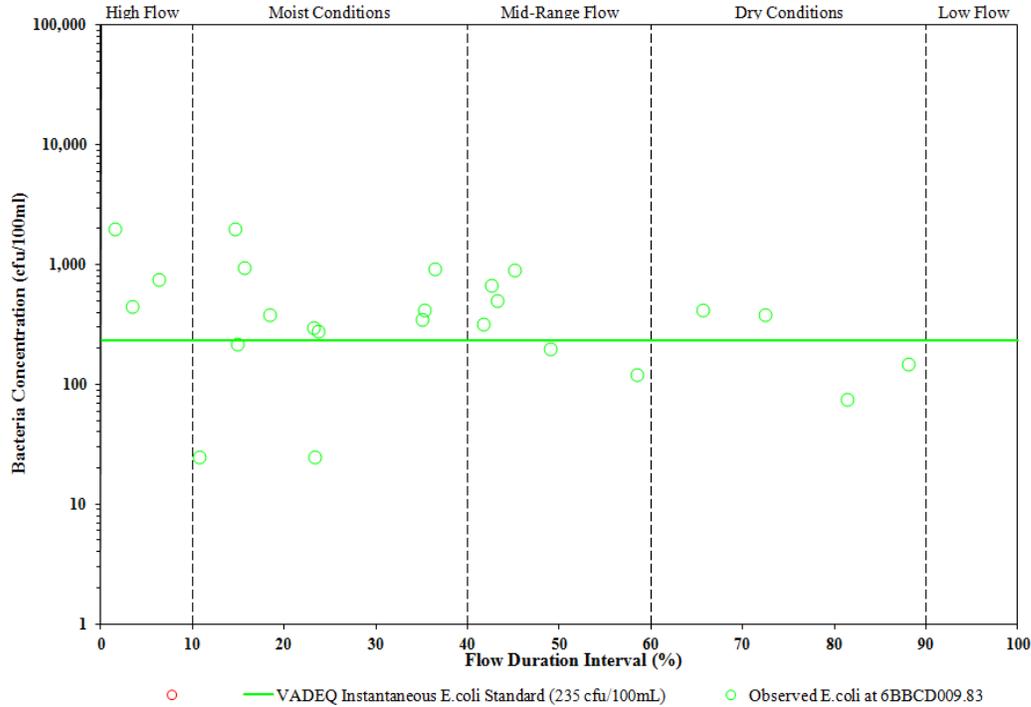
**Figure C. 10** *E. coli* bacteria concentrations at 6BBCD001.89 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.



**Figure C. 11** *E. coli* bacteria concentrations at 6BBCD006.66 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.



**Figure C. 12 Fecal bacteria concentrations at 6BBCD004.18 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.**



**Figure C. 13 E. coli bacteria concentrations at 6BBCD009.83 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.**

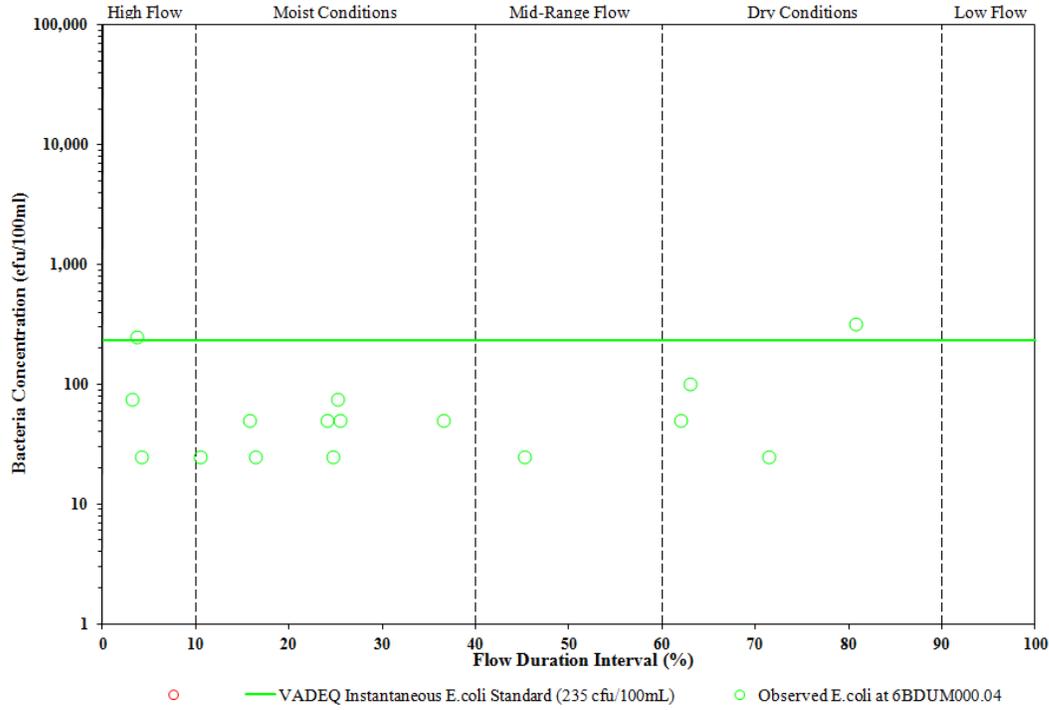


Figure C. 14 *E. coli* bacteria concentrations at 6BDUM000.04 on the Dumps Creek versus discharge at USGS Gaging Station # 03524000.

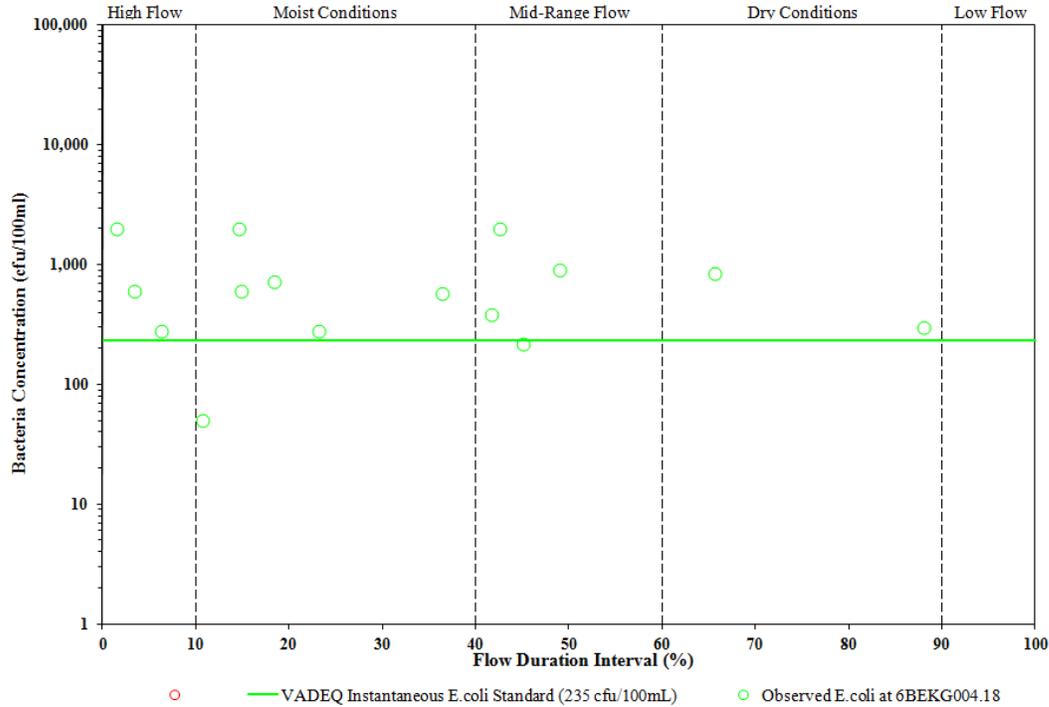


Figure C. 15 *E. coli* bacteria concentrations at 6BEKG004.18 on Big Cedar Creek versus discharge at USGS Gaging Station # 03524000.

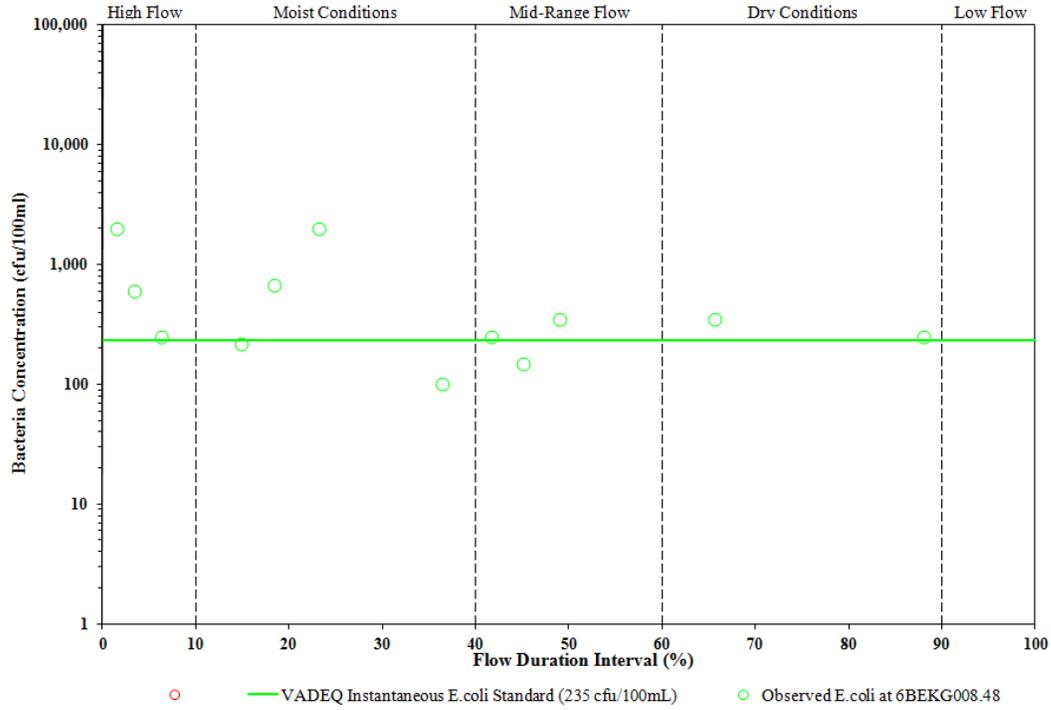


Figure C. 16 *E. coli* bacteria concentrations at 6BEKG008.48 on Elk Garden Creek versus discharge at USGS Gaging Station # 03524000.

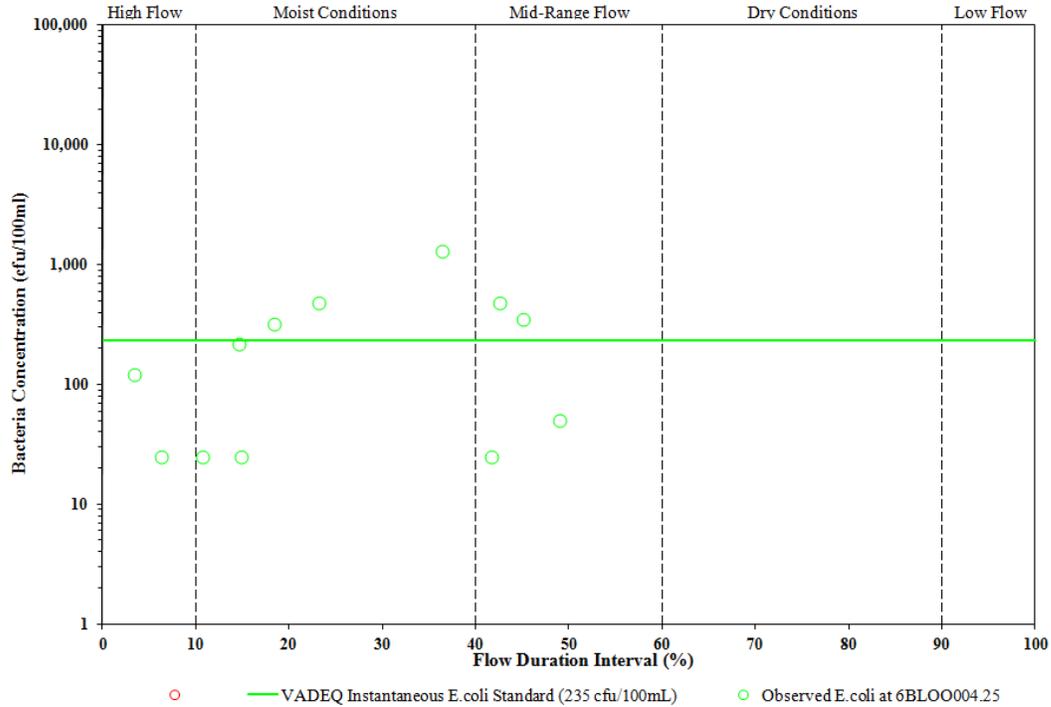


Figure C. 17 *E. coli* bacteria concentrations at 6BLOO004.25 on Loop Creek versus discharge at USGS Gaging Station # 03524000.

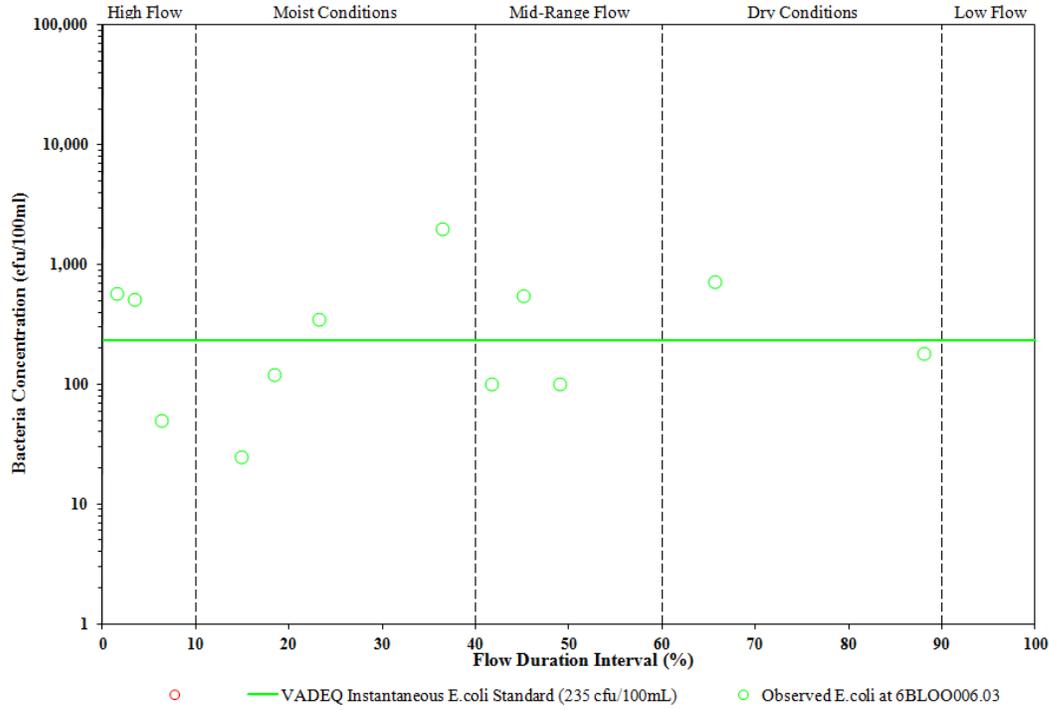


Figure C. 18 *E. coli* bacteria concentrations at 6BLOO006.03 on Loop Creek watershed versus discharge at USGS Gaging Station # 03524000.

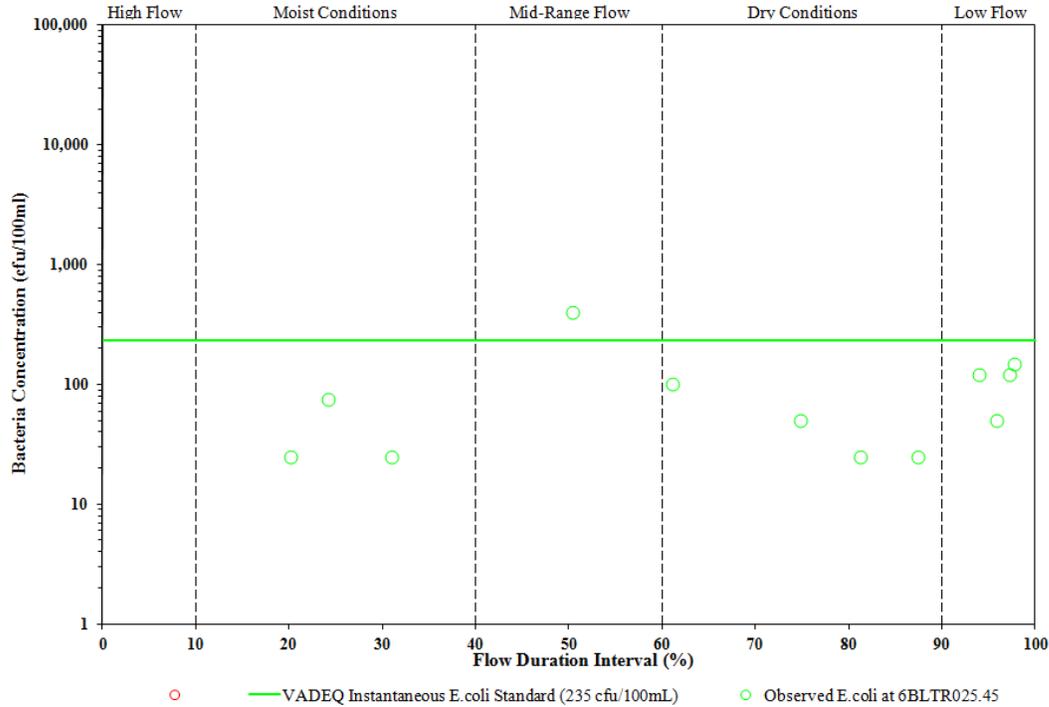


Figure C. 19 *E. coli* bacteria concentrations at 6BLTR025.45 on Little River versus discharge at USGS Gaging Station # 03524000.

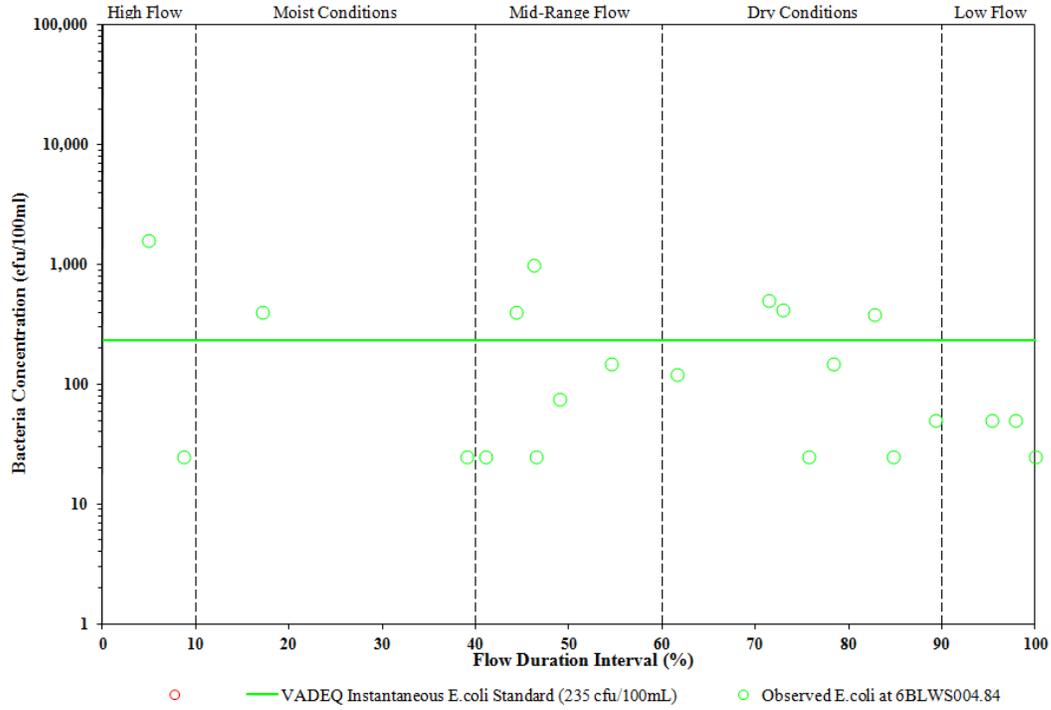


Figure C. 20 *E. coli* bacteria concentrations at 6BLWS004.84 on the Lewis Creek versus discharge at USGS Gaging Station # 03524000.

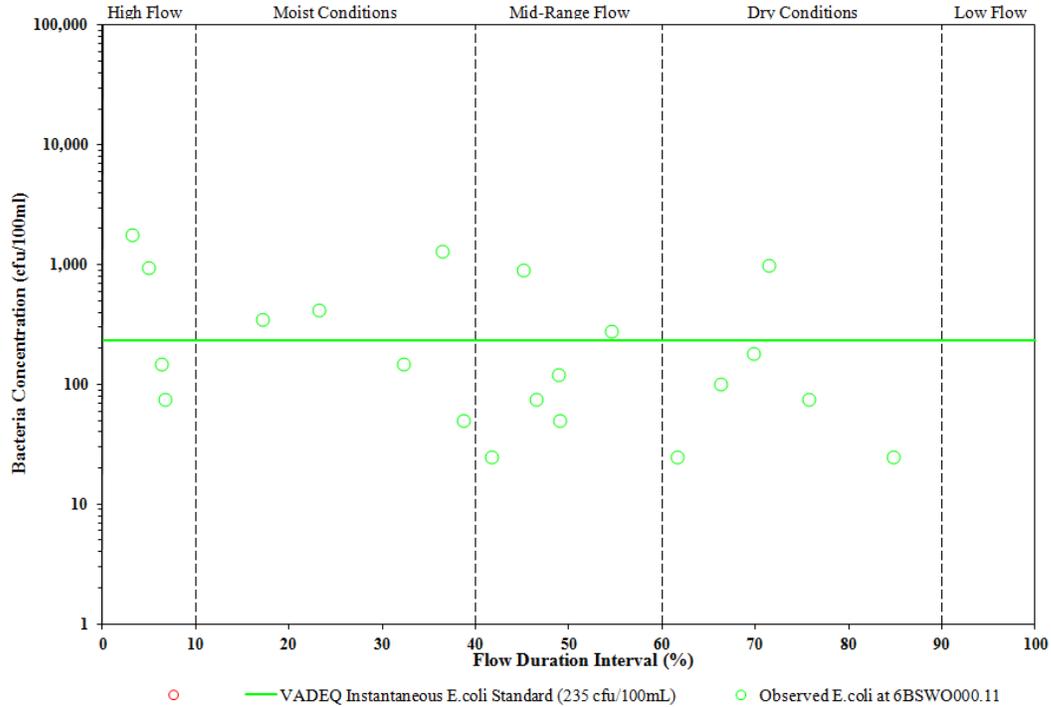


Figure C. 21 *E. coli* bacteria concentrations at 6BSWO000.11 on Swords Creek versus discharge at USGS Gaging Station # 03524000.

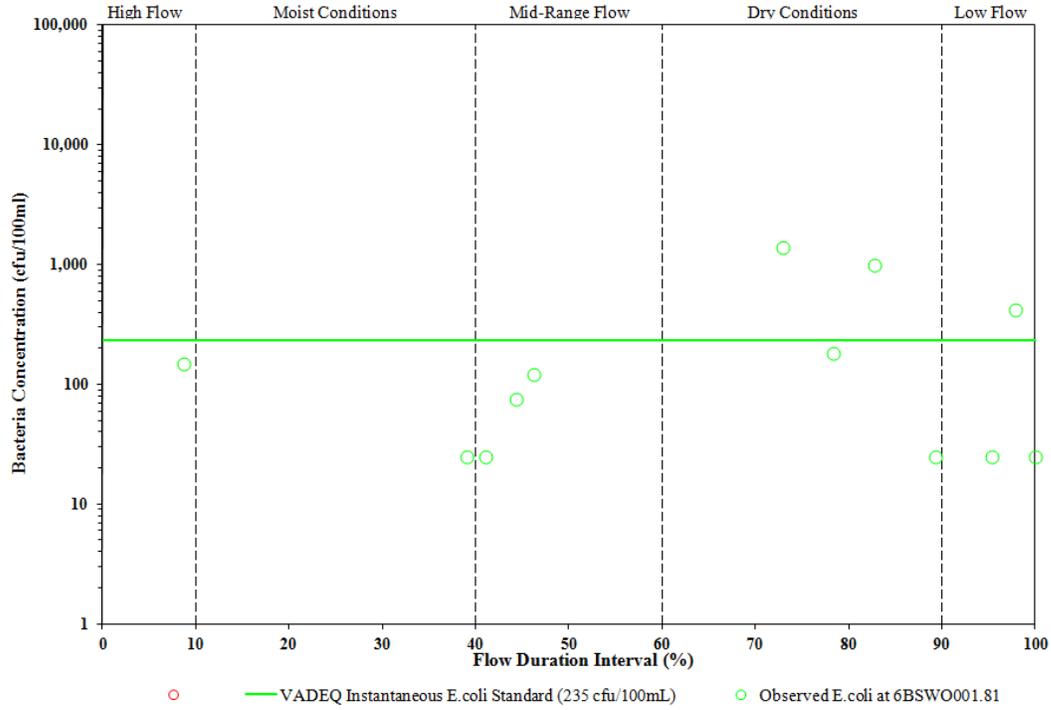


Figure C. 22 *E. coli* bacteria concentrations at 6BSWO001.81 on Swords Creek versus discharge at USGS Gaging Station # 03524000.

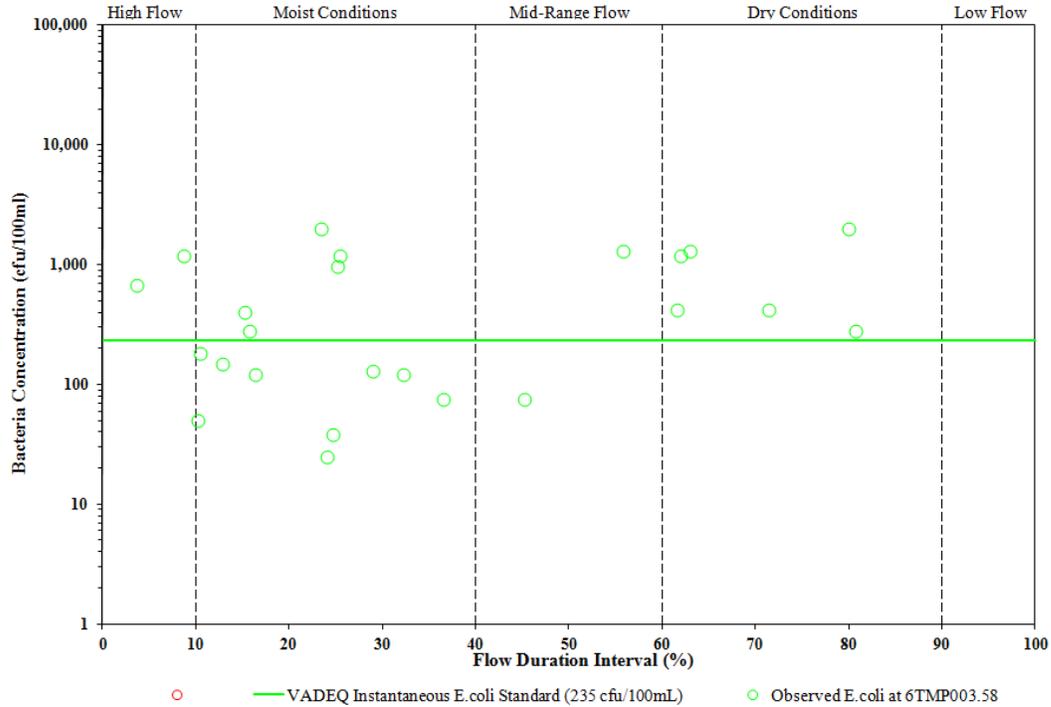


Figure C. 23 *E. coli* bacteria concentrations at 6BTMP003.58 on Thompson Creek versus discharge at USGS Gaging Station # 03524000.

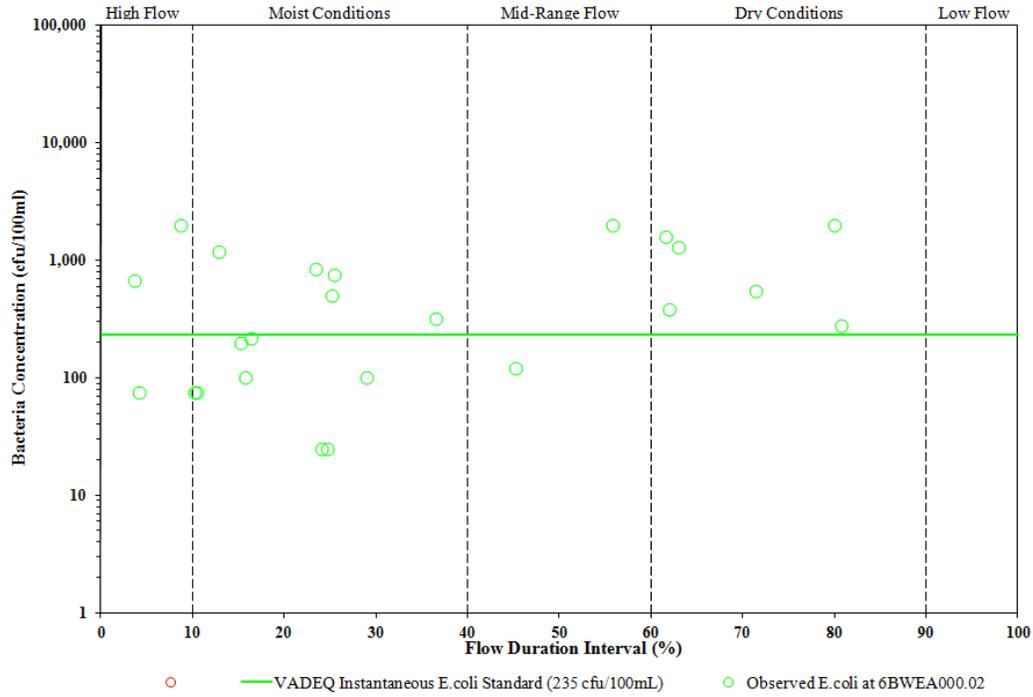


Figure C. 24 *E. coli* bacteria concentrations at 6BWEA000.02 on the Weaver Creek versus discharge at USGS Gaging Station # 03524000.

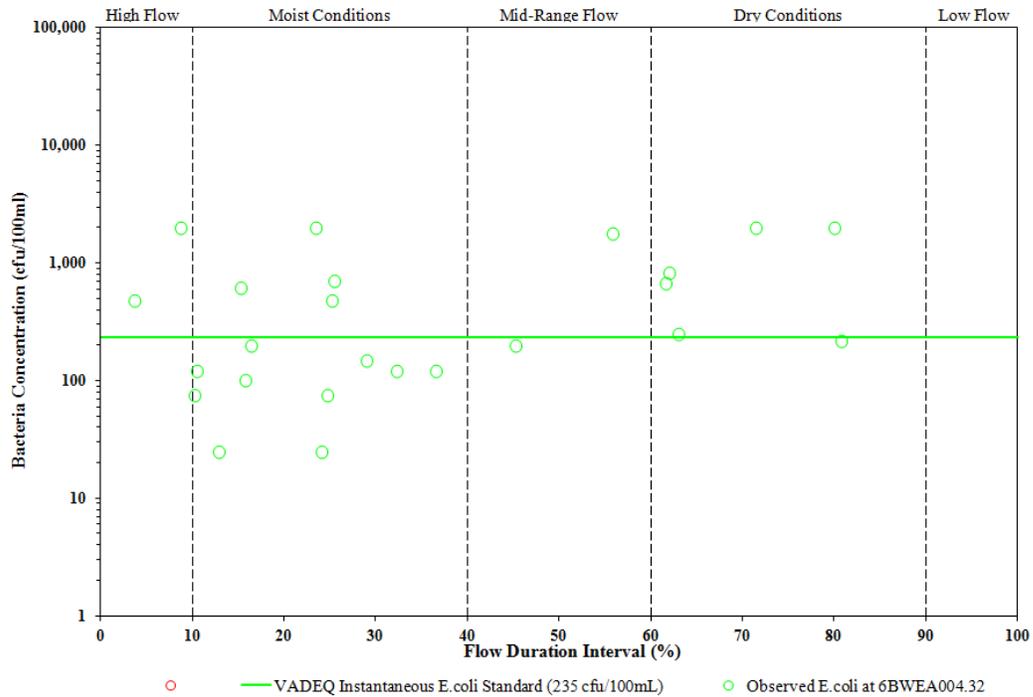


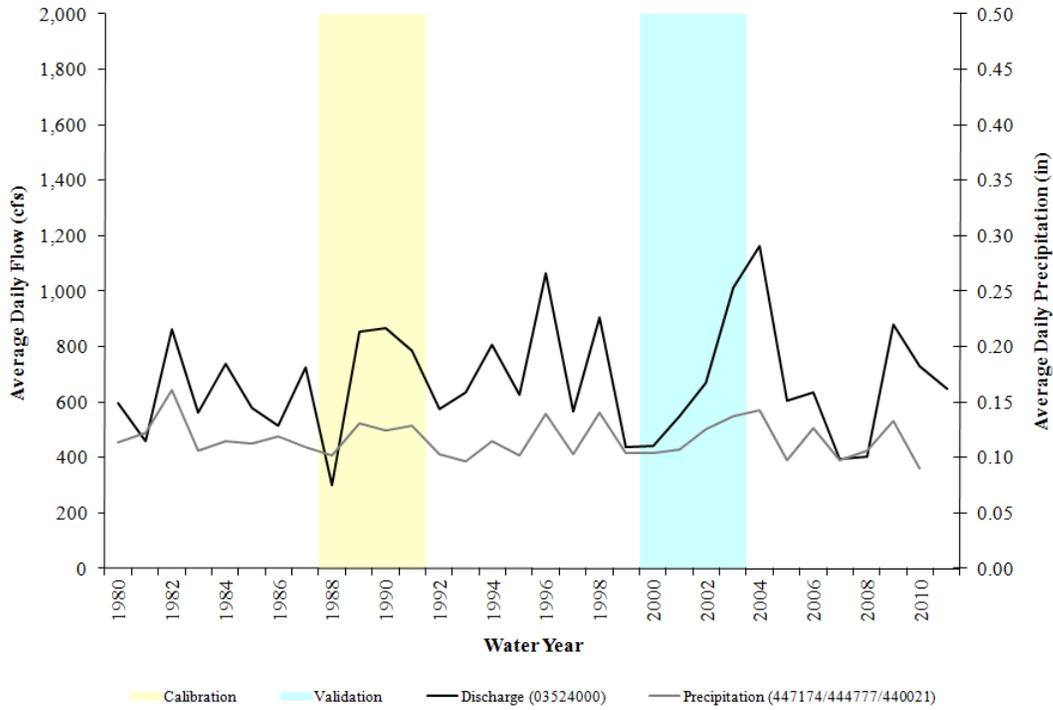
Figure C. 25 *E. coli* bacteria concentrations at 6BWEA004.32 on Weaver Creek versus discharge at USGS Gaging Station # 03524000.

Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons in order to capture a wide range of hydrologic circumstances for all impaired streams in this study area.

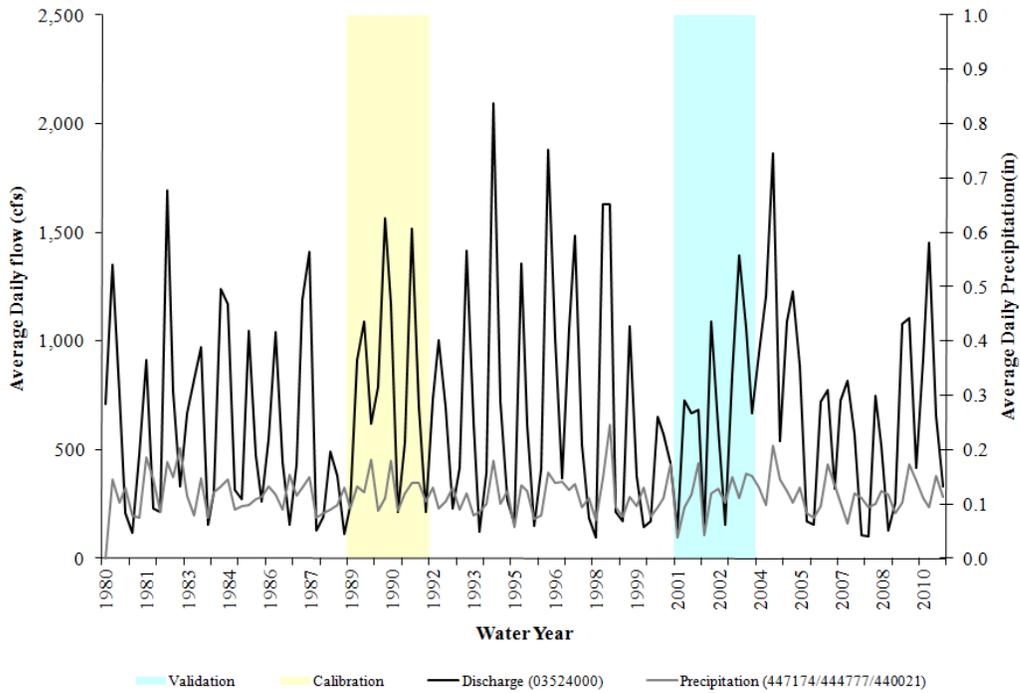
### ***Selection of Representative Modeling Periods***

Selection of the modeling period was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station 03524000 in the Clinch River at Cleveland was available from October 1920 to the present. The Hydrologic calibration period was October 1988 to September 1991 and hydrologic validation period was October 2000 to September 2003. The fecal concentration data were evaluated to determine the relationship between concentration and the level of flow in the stream. High concentrations of fecal coliform were recorded in all flow regimes, but most critically in high flows, thus it was concluded that the critical hydrological condition included a wide range of wet and dry seasons. Multiple periods were used for water quality calibration and validation depending on the availability of monitored data.

The hydrology calibration/validation/water quality calibration and validation time period, has both the high and low daily average streamflow at USGS Gaging Station #03524000 located at Cleveland and precipitation, which represent the high and low flow critical regimes (Figures C.26 and C.27). The figures are shown here to demonstrate the historical annual and seasonal stream flow and precipitation and how the selected time period encompasses a representative range of values. Table C. 5 shows the statistical comparison between calibration/validation time periods and historic time period.



**Figure C. 26 Modeling time periods, annual historical flow (USGS Station 03524000), and precipitation (Station 447174/444777/440021) data.**



**Figure C. 27 Modeling time periods, seasonal historical flow (USGS Station 03524000), and precipitation (Station 447174/444777/440021) data.**

Table C. 5 Comparison of modeled period to historical records for the Clinch River.

	Discharge (03524000)				Precipitation (447174/444777/440021)			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
	<b>Historical Record (1921 - 2011)</b>				<b>Historical Record (1970 - 2010)</b>			
<b>Mean</b>	480	1,288	777	293	0.102	0.120	0.138	0.128
<b>Variance</b>	102,320	204,811	97,896	30,051	0.001	0.001	0.001	0.001
	<b>Calibration and Validation Time Periods (10/88-9/91; 10/00-9/03)</b>				<b>Calibration and Validation Time Periods (10/88-9/91; 10/00-9/03)</b>			
<b>Mean</b>	438	1,261	866	291	0.093	0.125	0.141	0.126
<b>Variance</b>	135,939	145,032	199,019	30,314	0.000	0.0004	0.003	0.001
	<b>p-values</b>				<b>p-values</b>			
<b>Mean</b>	0.385	0.430	0.302	0.487	0.185	0.285	0.436	0.451
<b>Variance</b>	0.253	0.356	0.069	0.425	0.269	0.090	0.041	0.279

## Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.*, animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.*, population). Depending on the timeframe of the simulation being run, different estimates were used. Data were obtained for the appropriate timeframe for water quality calibration and validation. Data representing 2011 were used for the allocation runs in order to represent current conditions.

### *Permitted Sources*

Sixty eight (68) point sources are permitted to discharge water into surface waters in the Middle Clinch River Watershed study area through the Virginia Pollutant Discharge Elimination System (VPDES) (Tables 3.1 and 3.2). Section 3.2 discusses these permits in more detail. Sixty two (62) of the VPDES permits are domestic or single family home permits that discharge less than 1,000 gallons per day. For calibration and validation condition runs, recorded flow and fecal bacteria concentration or Total Residual Chlorine (TRC) levels documented by the VADEQ were used as the input for each permit. The TRC data was related to fecal bacteria concentrations using a regression analysis. Table C.6 shows the minimum and maximum discharge rate in million gallons per day (MGD) and the minimum and maximum fecal coliform bacteria concentration in colony forming units per 100 milliliters (cfu/100mL). These values are the sums of all the data for each outfall.

The design flow capacity was used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu per 100 mL to ensure that compliance with state

water quality standards could be met even if permitted loads were at maximum levels. The design flow rates and fecal coliform bacteria concentrations are shown in Table C. 6.

Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

**Table C. 6 Flow rates and bacteria loads used to model VADEQ active permits in the Middle Clinch River watershed study area.**

VADEQ Permit Number	Facility Name	Calibration/Validation				Allocation	
		Flow Rate (MGD)		Bacteria Concentration (cfu/100mL)		Flow Rate (MGD)	Bacteria Concentration (cfu/100mL)
		Min	Max	Min	Max	Design Flow	Fecal Coliform Geometric Mean Standard
VA0020672	DOC - Appalachian Detention Center 29	0.006	0.012	3.39	4.89	0.021	200
VA0020745	Lebanon WWTP	0.257	0.864	3.79	8.18	0.999	200
VA0026387	Honaker STP	0.069	1.460	0.00	125.18	0.400	200
VA0064271	Claypool Hill STP	0.086	0.376	2.79	4.28	0.350	200
VA0001015	American Electric Power – Clinch River Plant 008	0.000	0.008	1.1	162.0	0.036	200
VA0021016	Cleveland STP	0.001	0.225	0.0	1325.0	0.040	200
VAG*****	Each of the 62 Domestic Waste Treatment Permits	0.001	0.001	200	200	0.001	200

The number of septic systems in the Middle Clinch River watershed study area was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the subwatersheds. During allocation runs, the number of households was projected to 2011, based on current growth rates (USCB, 2000) resulting in 9,472 septic systems and 44 straight pipes (Table C. 7).

**Table C. 7 Estimated failing septic systems and straight pipes for 2011 in the Middle Clinch River watershed study area.**

NTU	Septic Systems	Failing Septic Systems	Straight Pipes
250	4,531	151	22
251	139	5	1
252	1,640	55	3
253	890	30	1
298	810	27	4
421	1,462	49	12
Total	9,472	316	44

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. Total septic systems were calculated using U.S. Census Bureau block demographics. The initial estimates of the number of failing septic systems was based on the assumption that each septic system fails, on average, once during an expected lifetime of 30 years. Those initial estimates were reduced based on feedback that failing septic system estimates seemed too high. Feedback from a Virginia Department of Health representative on how to reduce the failing septic system numbers in the related Upper Clinch River Watershed TMDL, which is part of this watershed, were employed to adjust the failing septic numbers.

The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors to account for more frequent failures during wet months.

Straight pipes were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category “other means” were assumed to be disposing sewage via straight pipes. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. The loadings from straight pipes were modeled in the same manner as direct discharges to the stream.

### ***Livestock***

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The amount of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Different livestock populations were estimated for each water quality modeling period (calibration/validation/allocation). The numbers are based on data provided by Virginia Agricultural Statistics (VASS), with values updated and discussed by VADCR, NRCS and SWCDs as well as taking into account growth rates in these counties as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1997; VASS, 2002). For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.7). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

### ***Land Application of Collected Manure***

The average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Section 3.2.5. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. Finally, values for the percentage of loafing lot waste collected, based on data provided by SWCD representatives and local stakeholders, were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.8). Stored waste was spread on pasture and cropland. It was assumed that 100% of land-applied waste is available for transport in surface runoff.

### ***Deposition on Land***

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

$$\text{Proportion} = [(24 \text{ hr}) - (\text{time in confinement}) - (\text{time in stream access areas})]/(24 \text{ hr})$$

All other livestock (horse, sheep, goats) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land was area-weighted.

### ***Direct Deposition to Streams***

The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in “stream access” areas was calculated based on the “Modeling Cattle Stream Access” study. The proportion was calculated as follows:

$$\text{Proportion} = (\text{time in stream access areas})/(24 \text{ hr})$$

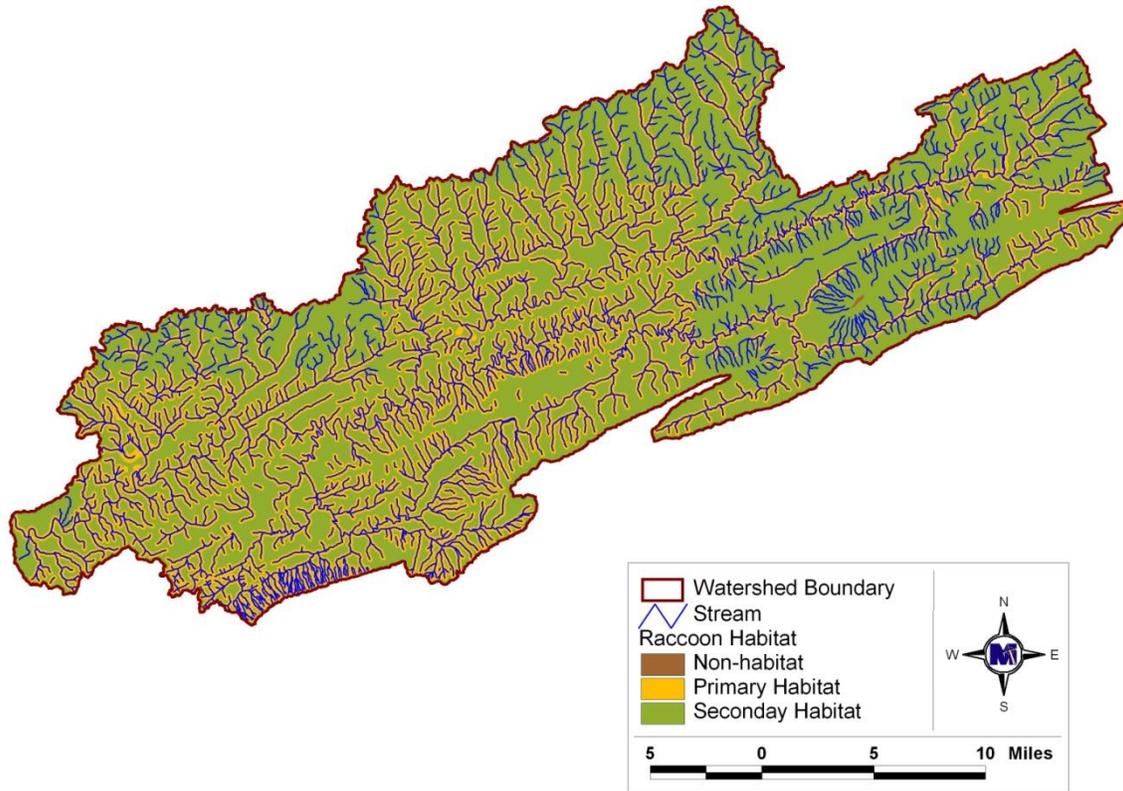
For the waste produced on the “stream access” land use, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream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

### ***Biosolids***

Investigation of VADEQ data indicated that biosolids applications have not occurred within the Middle Clinch River watershed study area during the modeling periods.

**Wildlife**

For each species of wildlife, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.6). An example of one of these layers is shown in Figure C. 28. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the wasteload, fecal coliform densities, and number of animals for each species.



**Figure C. 28 Example of raccoon habitat layer in the Middle Clinch River watershed study area, as developed by MapTech.**

For each species, a portion of the total wasteload was considered land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.13). It was estimated that, for all animals other than beaver, 5% of fecal matter produced while

in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams.

### ***Pets***

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), wasteload, and fecal coliform density are reported in Section 3.2.4. Waste from pets was distributed on residential land uses. The number of households per subwatershed was taken from the 2000 Census (USCB, 1990 and USCB, 2000). The number of animals per subwatershed was determined by multiplying the number of households by the pet population density. The amount of fecal coliform deposited daily by pets in each subwatershed was calculated by multiplying the wasteload, fecal coliform density, and number of animals for both cats and dogs. The wasteload was assumed not to vary seasonally. The populations of cats and dogs were projected from 2000 data to 2011.

### ***Sensitivity Analysis***

Sensitivity analyses are performed to determine a model's response to changes in certain parameters. This process involves changing a single parameter a certain percentage from a baseline value while holding all other parameters constant. This process is repeated for several parameters in order to gain a complete picture of the model's behavior. The information gained during sensitivity analysis can aid in model calibration, and it can also help to determine the potential effects of uncertainty in parameter estimation. Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.*, seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads).

### ***Hydrology Sensitivity Analysis***

The HSPF parameters adjusted for the hydrologic sensitivity analysis are presented in Table C. 8, with base values for the model runs given. The parameters were adjusted to -

50%, -10%, 10%, and 50% of the base value, and the model was run for water years 1997-2000. Where an increase of 50% exceeded the maximum value for the parameters, the maximum value was used and the parameters increased over the base value were reported. The hydrologic quantities of greatest interest in a fecal coliform model are those that govern peak flows and low flows. Peak flows, being a function of runoff, are important because they are directly related to the transport of fecal coliforms from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration such as INFILT (Infiltration), LZSN (Lower Zone Storage), and by UZSN (Upper Zone Storage), which governs surface transport, LZETP (Lower Zone Evapotranspiration), which affects soil moisture and AGWRC (Groundwater Recession Rate). Low flows are important in a water quality model because they control the level of dilution during dry periods. Parameters with the greatest influence on low flows (as evidenced by their influence in the *Low Flows* and *Summer Flow Volume* statistics) were AGWRC (Groundwater Recession Rate), BASETTP (Base Flow Evapotranspiration), LZETP, INFILT, UZSN, CEPSC (Interception Storage Capacity), and LZSN. The responses of these and other hydrologic outputs are reported in Table C. 9.

**Table C. 8 HSPF base parameter values used to determine hydrologic model response.**

Parameter	Description	Units	Base Value
LZSN	Lower Zone Nominal Storage	in	7.46 – 19.28
INFILT	Soil Infiltration Capacity	in/hr	0.08 – 0.20
BASETTP	Base Flow Evapotranspiration	---	0 – 0.01
INTFW	Interflow Inflow	---	1
DEEPFR	Groundwater Inflow to Deep Recharge	---	0.01 – 0.02
AGWRC	Groundwater Recession rate	---	0
KVARY	Groundwater Recession Flow	1/in	1.5
MON-INTERCEP	Monthly Interception Storage Capacity	in	0.01 – 0.2
MON-UZSN	Monthly Upper Zone Nominal Storage	in	0.50 – 1.93
MON-LZETP	Monthly Lower Zone Evapotranspiration	in	0.01 – 0.8

**Table C. 9 HSPF Sensitivity analysis results for hydrologic model parameters for the Middle Clinch River and Tributaries Watershed.**

Model Parameter	Parameter Change (%)	Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume
AGWRC <sup>1</sup>	0.85	0.35	18.33	-42.26	-0.11	0.73	-0.53	4.17	5.80
AGWRC <sup>1</sup>	0.92	0.20	8.17	-20.40	0.20	-0.80	0.03	2.58	4.71
AGWRC <sup>1</sup>	0.96	-0.05	-1.53	3.92	-0.17	0.52	-0.12	-0.41	-0.83
AGWRC <sup>1</sup>	0.999	-21.31	-37.68	35.63	-39.05	1.19	-22.88	5.71	-20.83
BASETP	-50	0.03	-0.32	1.37	-0.20	0.48	0.09	-0.18	-0.35
BASETP	-10	-0.32	-0.06	-0.85	-1.03	-3.63	0.95	4.13	0.03
BASETP	10	-0.33	0.06	-1.39	-0.95	-3.83	0.92	4.19	0.13
BASETP	50	-0.03	0.30	-1.32	0.17	-0.48	-0.09	0.24	0.28
DEEPFR	-50	0.40	0.37	0.37	0.40	0.39	0.38	0.48	0.41
DEEPFR	-10	0.08	0.07	0.07	0.08	0.08	0.08	0.10	0.08
DEEPFR	10	-0.08	-0.07	-0.07	-0.08	-0.08	-0.08	-0.10	-0.08
DEEPFR	50	-0.40	-0.37	-0.37	-0.40	-0.39	-0.38	-0.48	-0.41
INFILT	-50	-0.24	8.93	-11.25	2.91	-0.79	-2.53	-3.05	0.15
INFILT	-10	-0.09	1.07	-1.64	0.45	-0.46	-0.32	-0.60	-0.08
INFILT	10	0.10	-0.90	1.48	-0.43	0.52	0.26	0.66	0.08
INFILT	50	0.55	-3.31	5.91	-1.79	3.13	0.93	2.97	0.77
INTFW	10	0.03	-0.08	0.00	0.01	-0.13	0.12	0.08	0.03
INTFW	50	0.10	-0.25	-0.02	0.03	-0.42	0.41	0.31	0.12
INTFW	100	0.17	-0.20	-0.07	0.06	-0.58	0.60	0.50	0.20
INTFW	200	0.29	0.03	-0.21	0.16	-0.70	0.86	0.74	0.33
LZSN	-50	9.32	12.13	5.44	19.06	5.99	-0.54	12.81	10.44
LZSN	-10	1.95	2.35	1.59	3.77	1.25	0.19	2.48	2.04
LZSN	10	-1.98	-2.32	-1.61	-3.74	-1.28	-0.32	-2.35	-2.03
LZSN	50	-9.96	-11.64	-8.85	-17.98	-6.61	-2.63	-11.41	-10.05
CEPSC	-50	1.59	-0.68	8.28	0.05	7.40	0.57	-0.23	1.23
CEPSC	-10	0.26	-0.13	1.41	0.02	1.27	0.18	-0.46	0.22
CEPSC	10	-0.25	0.11	-1.32	-0.02	-1.14	-0.21	0.44	-0.20
CEPSC	50	-1.18	0.63	-6.41	0.01	-5.36	-0.70	0.62	-0.67
LZETP	-50	14.52	17.00	16.95	13.79	4.55	13.31	39.33	14.39
LZETP	-10	1.80	1.98	2.58	1.88	0.53	1.56	4.65	1.64
LZETP	10	-1.47	-1.62	-2.01	-1.61	-0.45	-1.28	-3.49	-1.30
LZETP	50	-9.07	-10.63	-11.21	-9.84	-2.79	-9.25	-17.23	-7.93

**Table C. 9 HSPF Sensitivity analysis results for hydrologic model parameters for the Middle Clinch River and Tributaries Watershed (cont.)**

<b>Model Parameter</b>	<b>Parameter Change (%)</b>	<b>Total Flow</b>	<b>High Flows</b>	<b>Low Flows</b>	<b>Winter Flow Volume</b>	<b>Spring Flow Volume</b>	<b>Summer Flow Volume</b>	<b>Fall Flow Volume</b>	<b>Total Storm Volume</b>
MANNING	-50	0.23	0.63	-0.29	0.29	1.22	-0.26	-0.25	0.24
MANNING	-10	0.04	0.14	-0.03	0.06	0.19	-0.05	-0.05	0.04
MANNING	10	-0.03	-0.13	0.02	-0.06	-0.16	0.04	0.03	-0.04
MANNING	50	-0.14	-0.49	0.06	-0.25	-0.45	0.04	0.23	-0.15
UZSN	-50	3.81	9.63	-3.06	5.09	6.74	2.52	-1.91	4.33
UZSN	-10	0.62	1.61	-0.62	0.92	0.76	0.53	-0.46	0.67
UZSN	10	-0.59	-1.53	0.64	-0.88	-0.70	-0.55	0.52	-0.63
UZSN	50	-2.60	-6.76	2.89	-4.14	-2.33	-2.60	2.45	-2.84

<sup>1</sup>Actual parameter value used

### *Water Quality Parameter Sensitivity Analysis*

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 2007 through 2010, and model parameters established for 2011 conditions. The three HSPF parameters impacting the model's water quality response (Table C. 10) were increased and decreased by amounts that were consistent with the range of values for the parameter. The First Order Decay (FSTDEC) was the parameter with the greatest influence on monthly geometric mean concentration (Table C. 11). The reason behind the more pronounced impact of change in decay rate on concentration of bacteria in the stream is that changes in decay rate impact bacteria from nonpoint as well as point sources and direct-nonpoint sources. On the other hand, changes in maximum fecal coliform accumulation on the land (MON-SQOLIM) and wash-off rate for fecal coliform on land surface (WSQOP) only impact the nonpoint portion of the bacteria. Graphical depictions of the results of this sensitivity analysis can be seen in Figures C.29 through C.31.

**Table C. 10 Base parameter values used to determine water quality model response.**

<b>Parameter</b>	<b>Description</b>	<b>Units</b>	<b>Base Value</b>
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	0 – 8.9E+12
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	0.8 – 2.5
FSTDEC	In-stream First Order Decay Rate	1/day	1

**Table C. 11 Percent change in average monthly *E.coli* mean for the years 2007-2010**

Model Parameter	Parameter Change (%)	Percent Change in Average Monthly <i>E. coli</i> Geometric Mean for 2007-2010											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	31.56	28.15	30.01	30.13	29.43	30.46	30.55	30.14	30.00	29.42	29.35	30.61
FSTDEC	-10	5.42	4.89	5.19	5.19	5.09	5.25	5.27	5.20	5.18	5.08	5.07	5.28
FSTDEC	10	-5.04	-4.57	-4.84	-4.83	-4.76	-4.90	-4.91	-4.85	-4.83	-4.73	-4.73	-4.92
FSTDEC	50	-22.05	-20.14	-21.26	-21.17	-20.90	-21.46	-21.52	-21.27	-21.18	-20.77	-20.80	-21.61
SQOLIM	10	3.35	2.74	2.81	2.26	3.09	3.79	2.82	2.80	1.89	1.45	2.49	4.06
SQOLIM	25	9.27	8.08	7.96	6.37	8.87	10.76	8.00	7.94	5.47	4.16	7.15	11.46
SQOLIM	50	19.27	16.46	16.32	13.01	18.15	21.86	15.82	15.86	10.86	8.32	14.29	23.51
SQOLIM	100	36.25	30.57	29.95	24.02	33.80	40.51	28.79	29.01	19.92	15.30	25.86	43.71
WSQOP	-50	33.44	27.15	27.15	19.94	28.21	28.71	20.02	22.40	11.62	11.61	20.34	37.21
WSQOP	-10	4.46	3.69	3.78	2.81	3.87	4.06	2.87	3.20	1.85	1.70	2.93	5.04
WSQOP	10	-3.86	-3.23	-3.31	-2.48	-3.37	-3.58	-2.53	-2.84	-1.69	-1.51	-2.59	-4.35
WSQOP	50	-15.25	-12.96	-13.34	-10.19	-13.56	-14.55	-10.42	-11.68	-7.25	-6.25	-10.66	-17.35

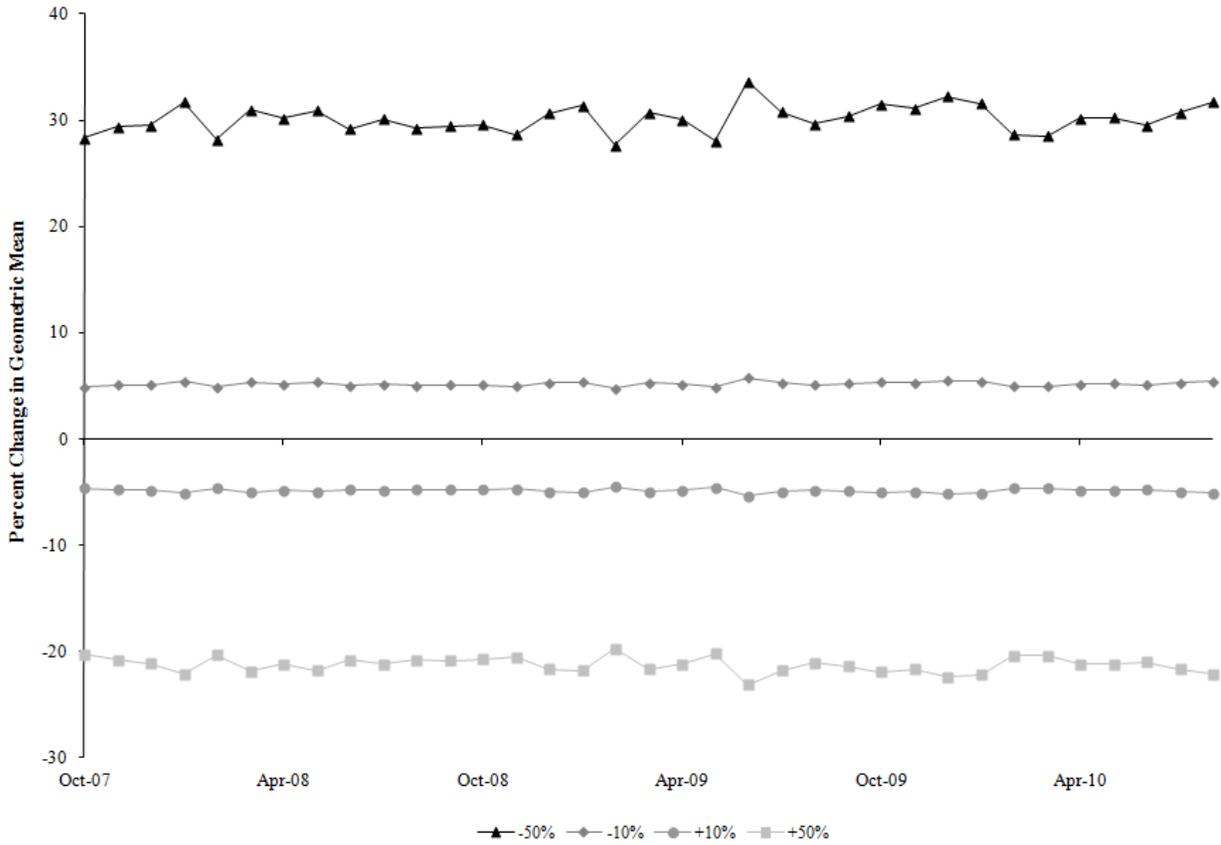


Figure C. 29 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the in-stream first-order decay rate (FSTDEC).

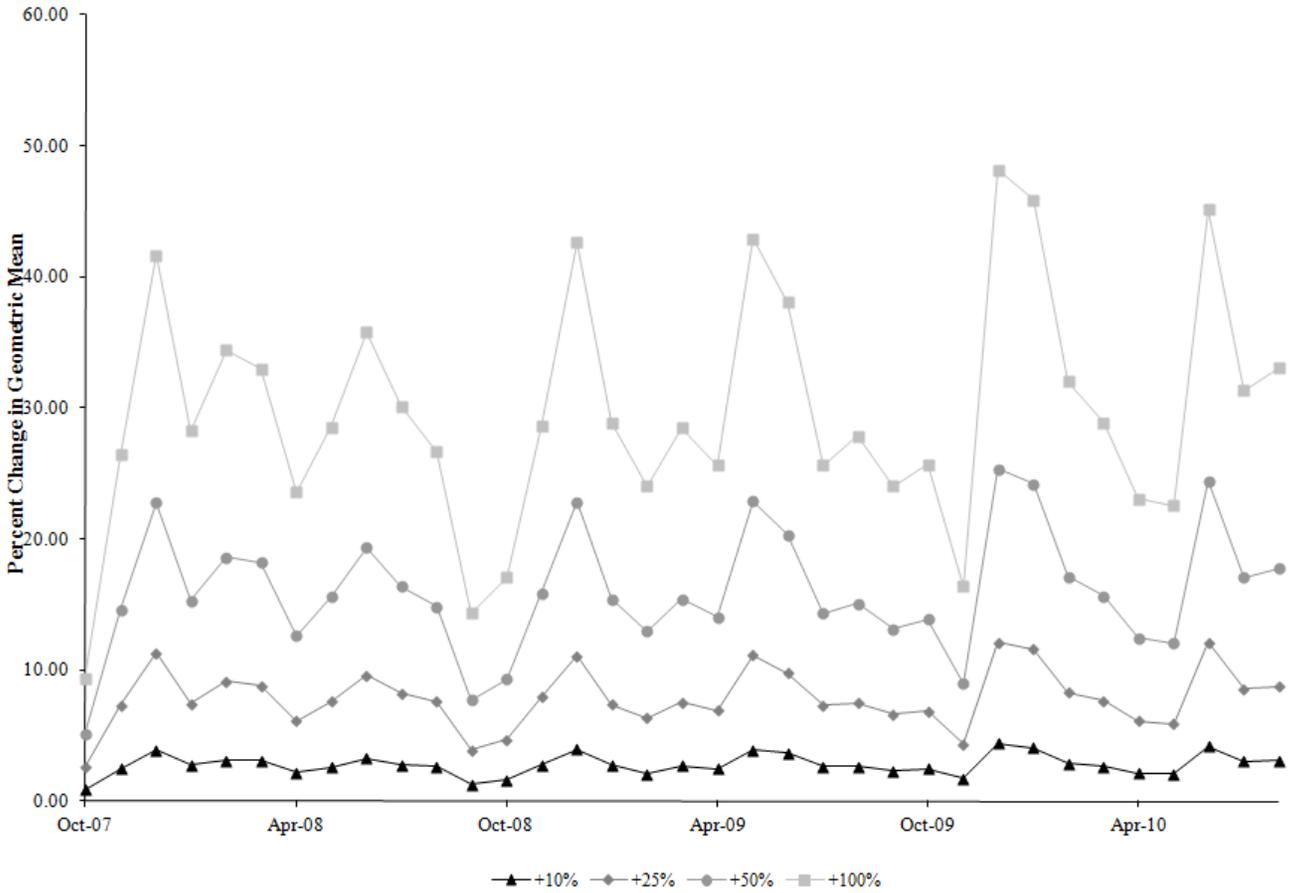


Figure C. 30 Results of sensitivity analysis on monthly mean concentrations as affected by changes in maximum fecal accumulation on land (MON-SQOLIM).

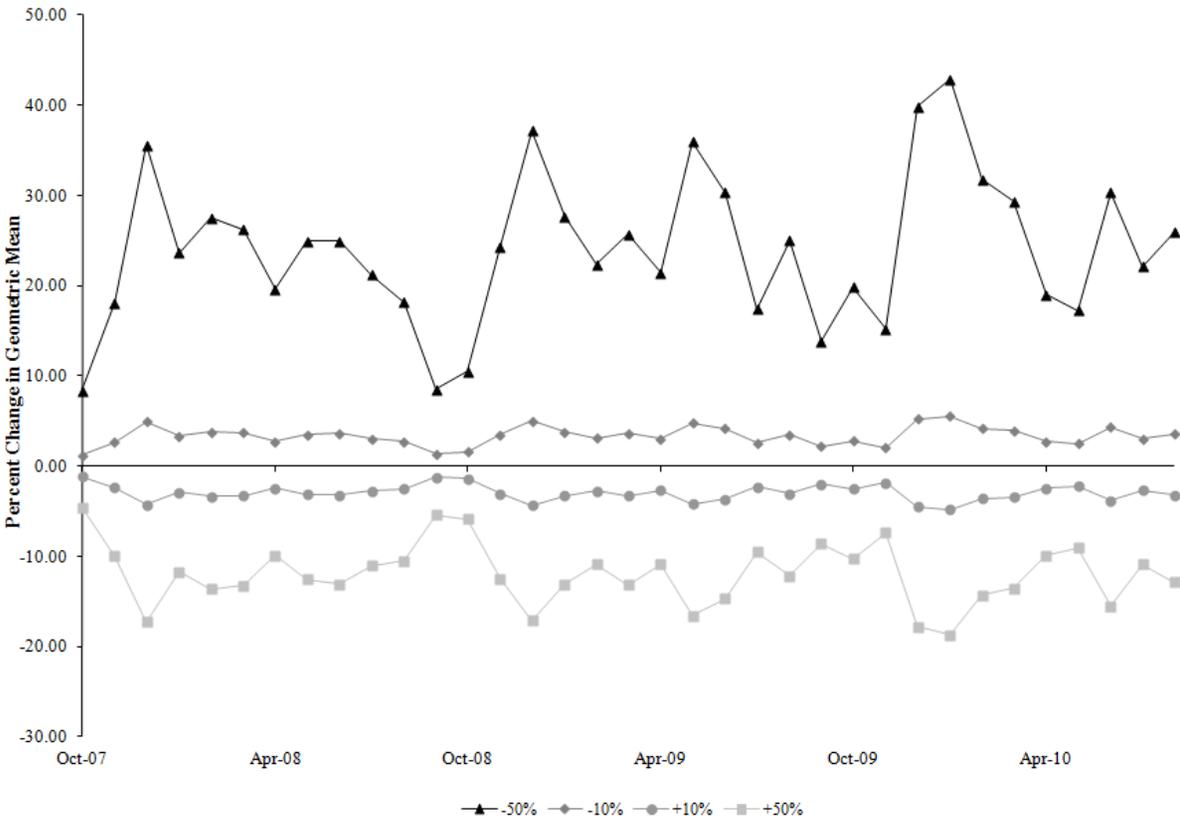
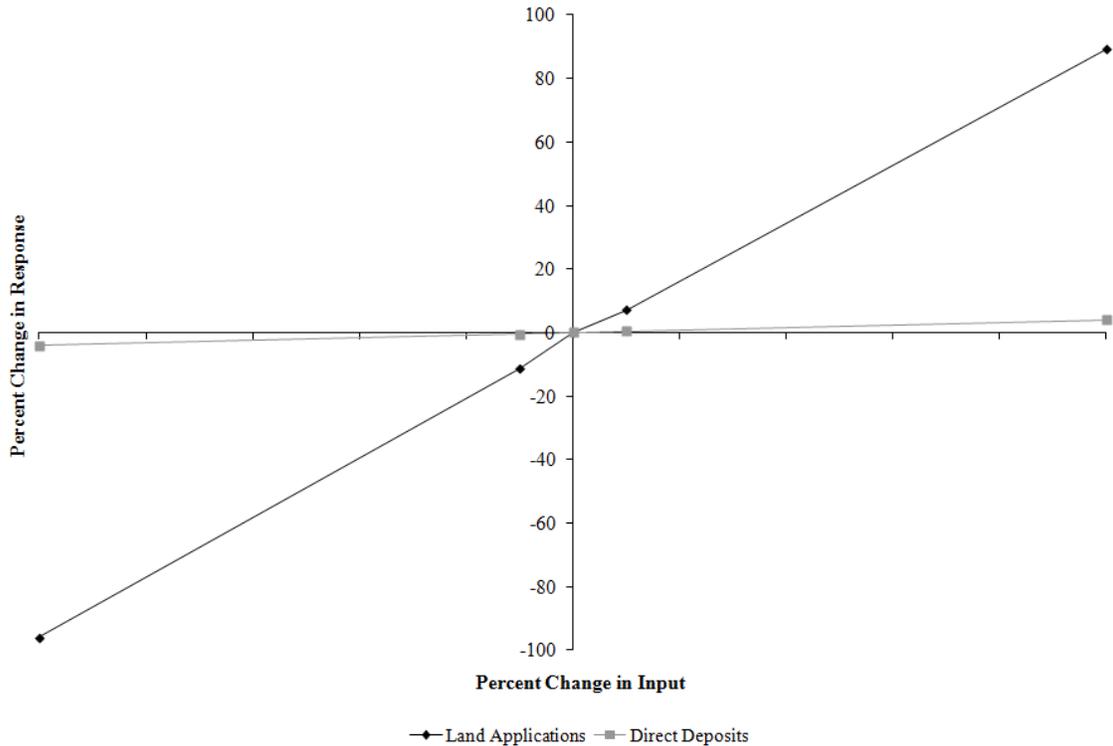
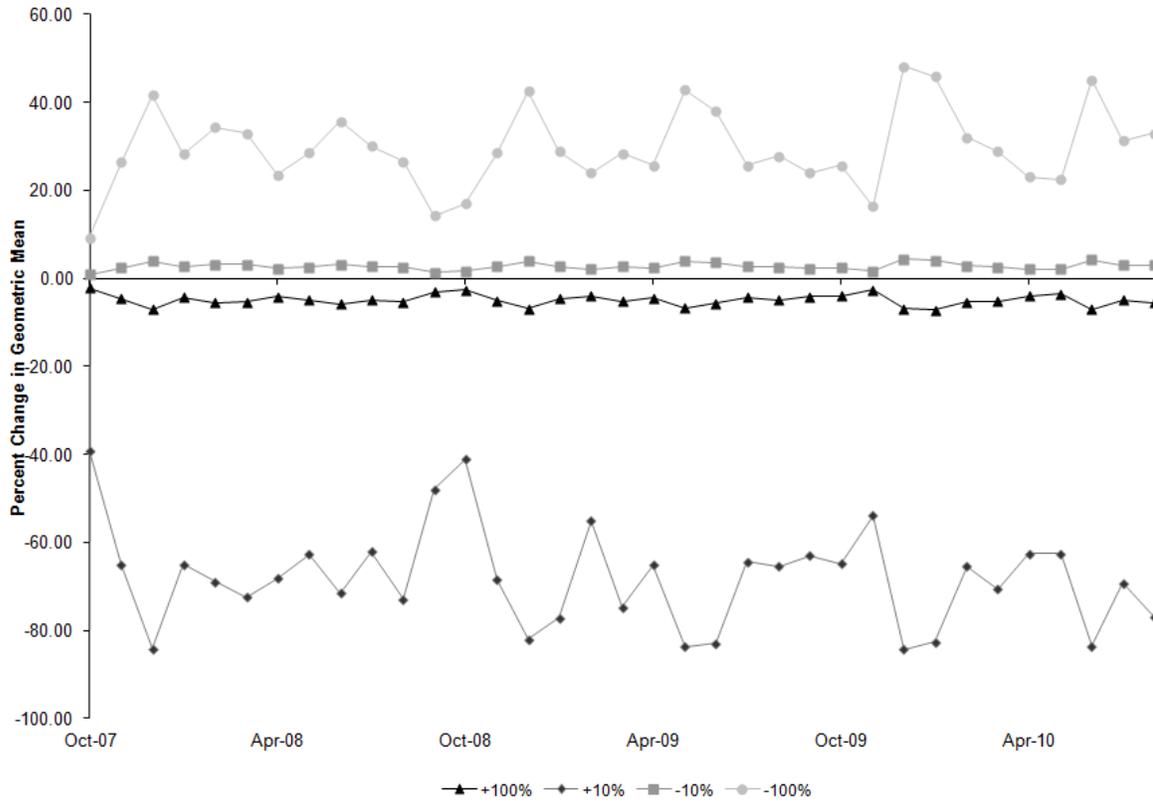


Figure C. 31 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the wash-off rate from land surfaces (WSQOP).

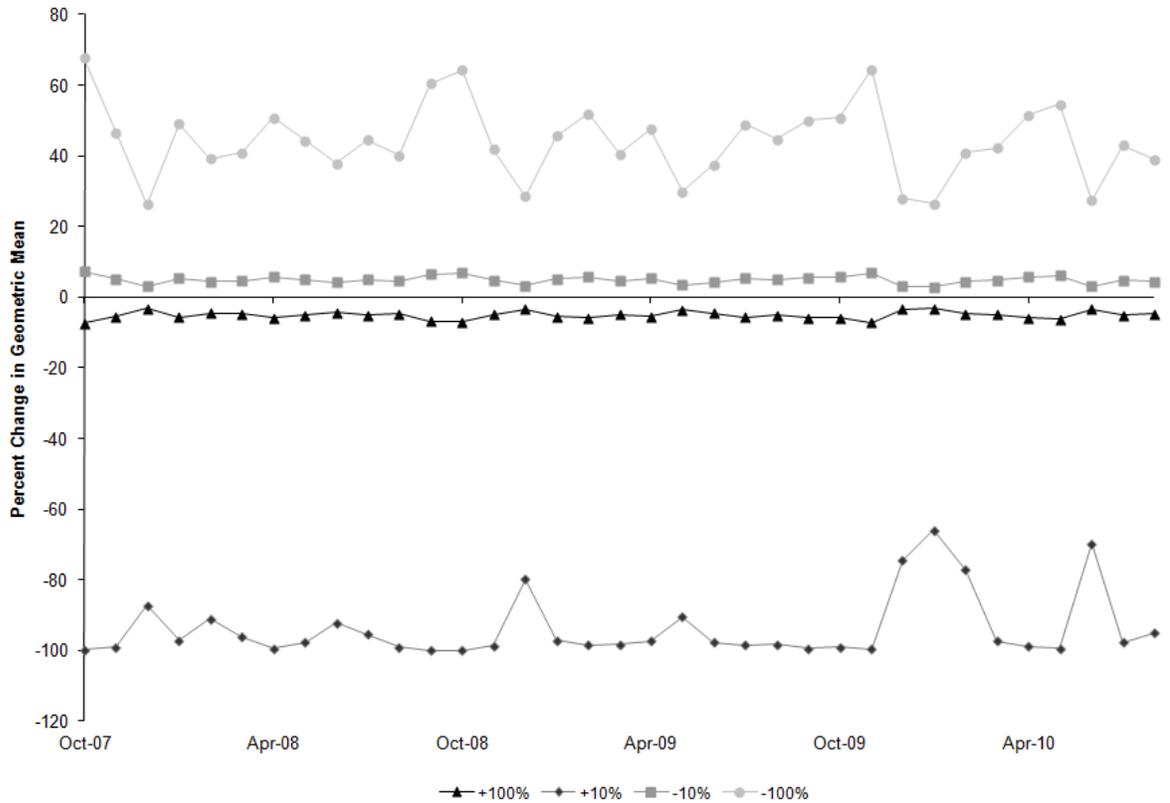
In addition to analyzing the sensitivity of the model response to changes in water quality transport and die-off parameters, the response of the model to changes in land-based and direct loads was also analyzed. It is evident in Figure C. 32 that the model predicts a linear relationship between increased fecal coliform concentrations in both land and direct applications, and total load reaching the stream. The magnitude of this relationship differs between land applied and direct loadings; a 100% increase in the land applied loads results in an increase of about 96% in stream loads, while a 100% increase in direct loads results in approximately a 4% increase in stream loads. Both direct loads and land applied loads have a significant impact on the geometric mean concentrations (Figures B.33 and B.34).



**Figure C. 32 Results of total loading sensitivity analysis for outlet of the Middle Clinch River and Tributaries Watershed study area.**



**Figure C. 33 Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle Clinch River and Tributaries Watershed study area, as affected by changes in land-based loadings.**



**Figure C. 34 Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle Clinch River and Tributaries Watershed study area, as affected by changes in loadings from direct nonpoint sources.**

### Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model’s hydrologic parameters were set based on available soils, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

HSPF parameters that were adjusted during the hydrologic calibration represented: the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the length of overland flow (LSUR), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the

amount of interception storage (CEPSC), the infiltration capacity (INFILT), the amount of soil water contributing to interflow (INTFW), deep groundwater inflow fraction (DEEPER), baseflow PET (BASETP), groundwater recession flow (KVARY), and active groundwater storage PET (AGWETP). Table C. 12 contains the possible range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions.

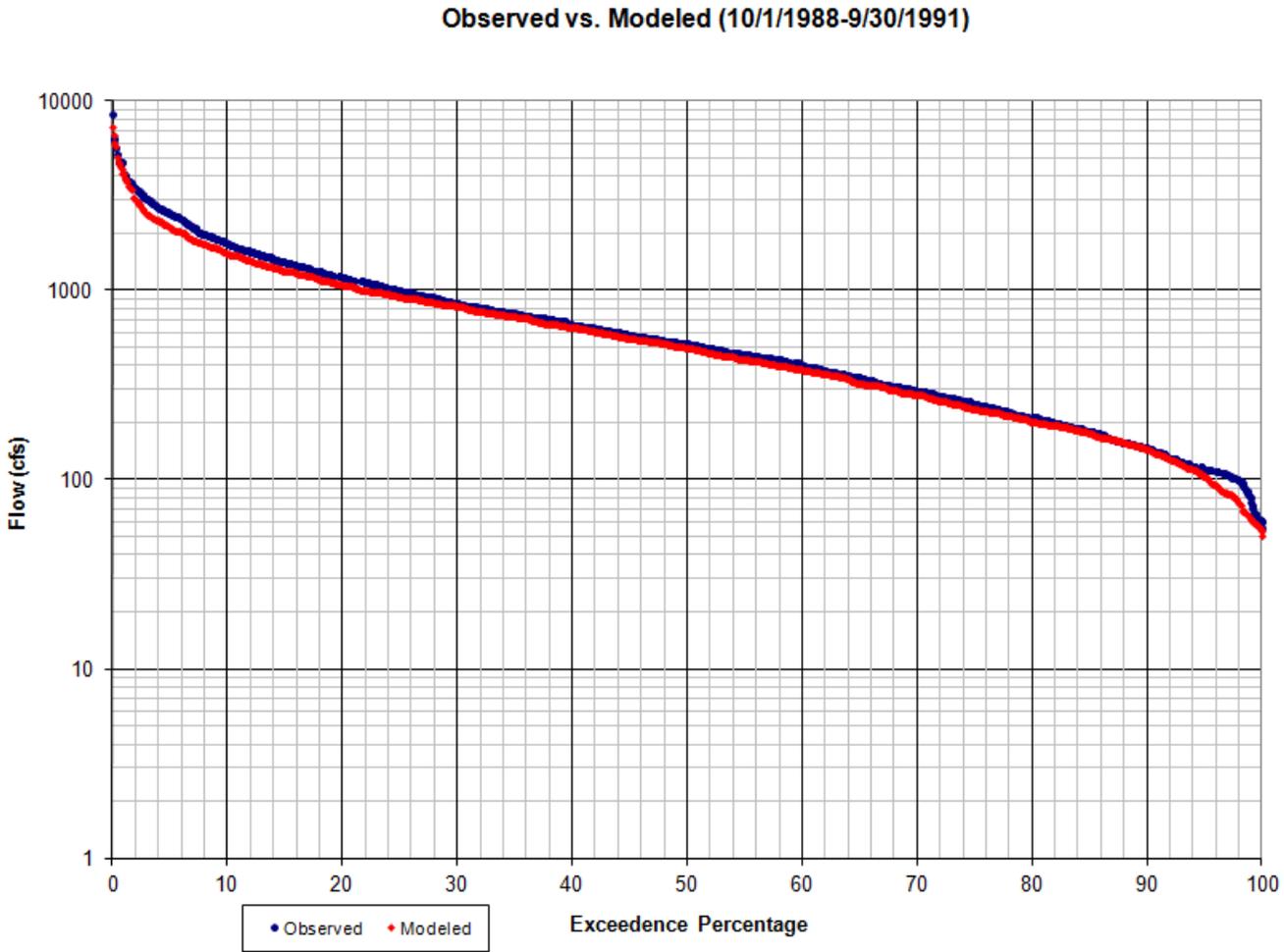
**Table C. 12 Initial hydrologic parameters estimated for the Middle Clinch River watershed TMDL study area, and resulting final values after calibration.**

Parameter	Units	Possible Range of Parameter Value	Initial Parameter Estimate	Final Calibrated Parameter Value
LZSN	in	2.0 – 15.0	7.0	5.0
INFILT	in/hr	0.001 – 0.50	0.08 – 0.202	0.048 – 0.121
KVARY	1/in	0.0 – 5.0	1.5	4.5
AGWRC	1/day	0.85 – 0.999	0.955	0.98
DEEPFR	---	0.0 – 0.50	0.01 – 0.02	0.01 – 0.02
BASETP	---	0.0 – 0.20	0 – 0.01	0.05
AGWETP	---	0.0 – 0.20	0 – 0.01	0 – 0.01
INTFW	---	1.0 – 10.0	1.0	3
IRC	1/day	0.30 – 0.85	0.6	0.3
MON-INTERCEPT	in	0.01 – 0.40	0 – 0.2	0 – 0.40
MON-UZSN	in	0.05 – 2.0	0.5 – 1.93	0.25 – 1.93
MON-LZETP	---	0.1 – 0.9	0 – 0.8	0 – 0.9

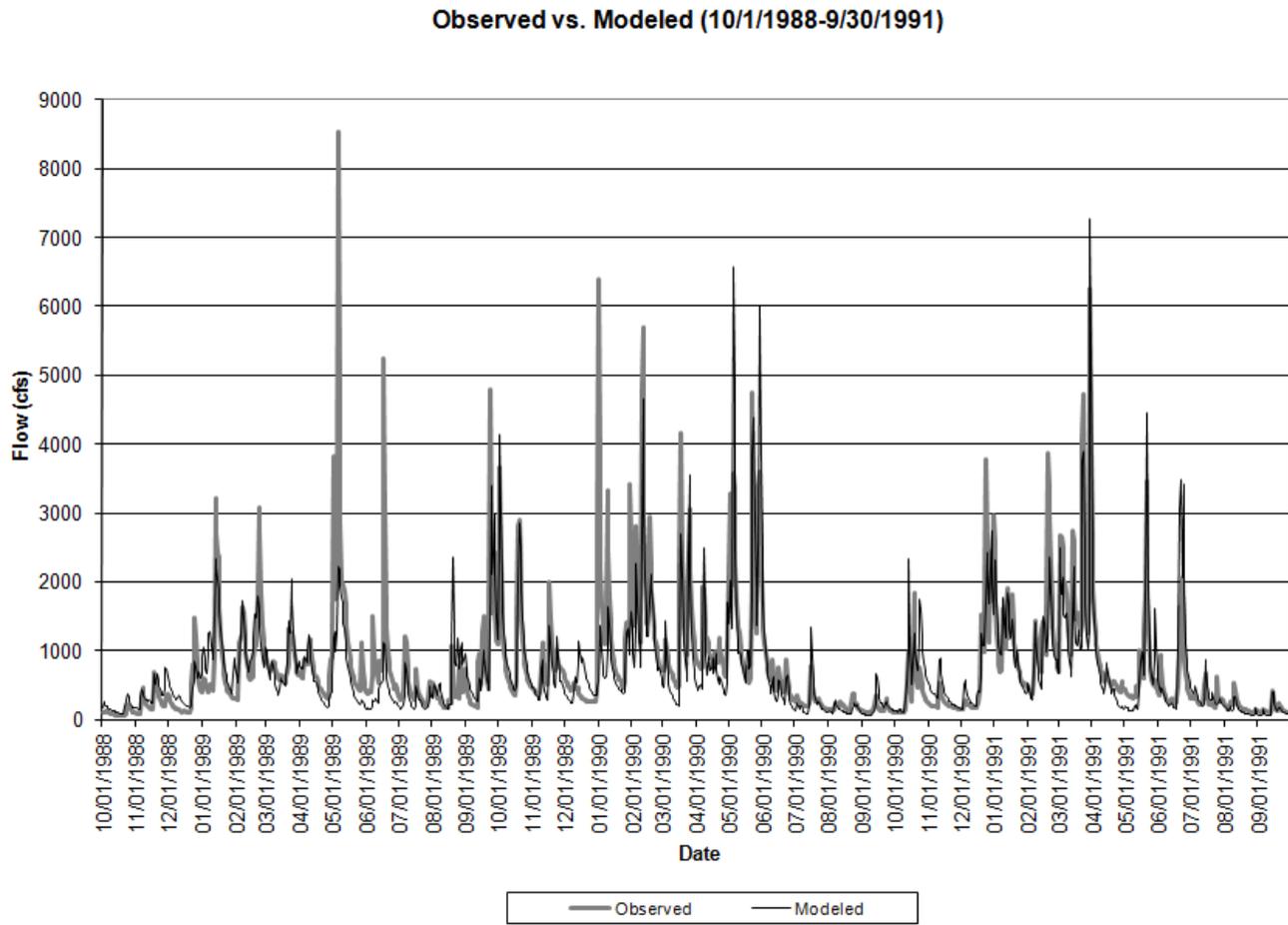
Table C. 13 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating the model was well calibrated. Figures C.35 and C.36 graphically show these comparisons.

**Table C. 13 Hydrology calibration model performance from 10/1/1988 through 9/30/1991 at USGS Gaging Station # 03524000 on the Clinch River (subwatershed 19).**

<b>Criterion</b>	<b>Observed</b>	<b>Modeled</b>	<b>Error</b>
Total In-stream Flow:	53.84	49.52	-8.04%
Upper 10% Flow Values:	19.34	17.17	-11.25%
Lower 50% Flow Values:	9.15	8.66	-5.39%
Winter Flow Volume	22.27	19.01	-14.65%
Spring Flow Volume	16.68	14.48	-13.20%
Summer Flow Volume	5.97	5.87	-1.79%
Fall Flow Volume	8.92	10.16	13.95%
Total Storm Volume	47.03	44.09	-6.26%
Winter Storm Volume	20.59	17.67	-14.18%
Spring Storm Volume	14.97	13.12	-12.39%
Summer Storm Volume	4.25	4.52	6.34%
Fall Storm Volume	7.22	8.79	21.60%



**Figure C. 35 Clinch River modeled flow duration versus USGS Gaging Station #03524000 data from 10/1/1988 to 9/30/1991 (subwatershed 19).**



**Figure C. 36 Clinch River modeled results versus USGS Gaging Station # 03524000 data from 10/1/1988 to 9/30/1991 (subwatershed 19).**

The modeled output was validated for the period of 10/1/2000 to 9/30/2003. Simulated flow at subwatershed 19 was compared with daily flow at the Clinch River USGS Gaging Station #03524000. Table C. 14 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating the model was well calibrated and has been validated during a different time period. Figures C.37 and C.38 graphically show these comparisons.

**Table C. 14 Hydrology validation model performance from 10/1/2000 through 9/30/2003 at USGS Gaging Station #03524000 on the Clinch River (subwatershed 19).**

<b>Criterion</b>	<b>Observed</b>	<b>Modeled</b>	<b>Error</b>
Total In-stream Flow:	45.86	42.41	-7.51%
Upper 10% Flow Values:	21.01	18.49	-11.97%
Lower 50% Flow Values:	5.80	5.86	1.10%
Winter Flow Volume	17.87	14.50	-18.88%
Spring Flow Volume	13.09	10.25	-21.72%
Summer Flow Volume	8.58	9.62	12.13%
Fall Flow Volume	6.32	8.05	27.42%
Total Storm Volume	40.50	38.99	-3.72%
Winter Storm Volume	16.54	13.65	-17.49%
Spring Storm Volume	11.75	9.39	-20.06%
Summer Storm Volume	7.24	8.76	20.96%
Fall Storm Volume	4.96	7.19	44.92%

Observed vs. Modeled (10/1/2000-9/30/2003)

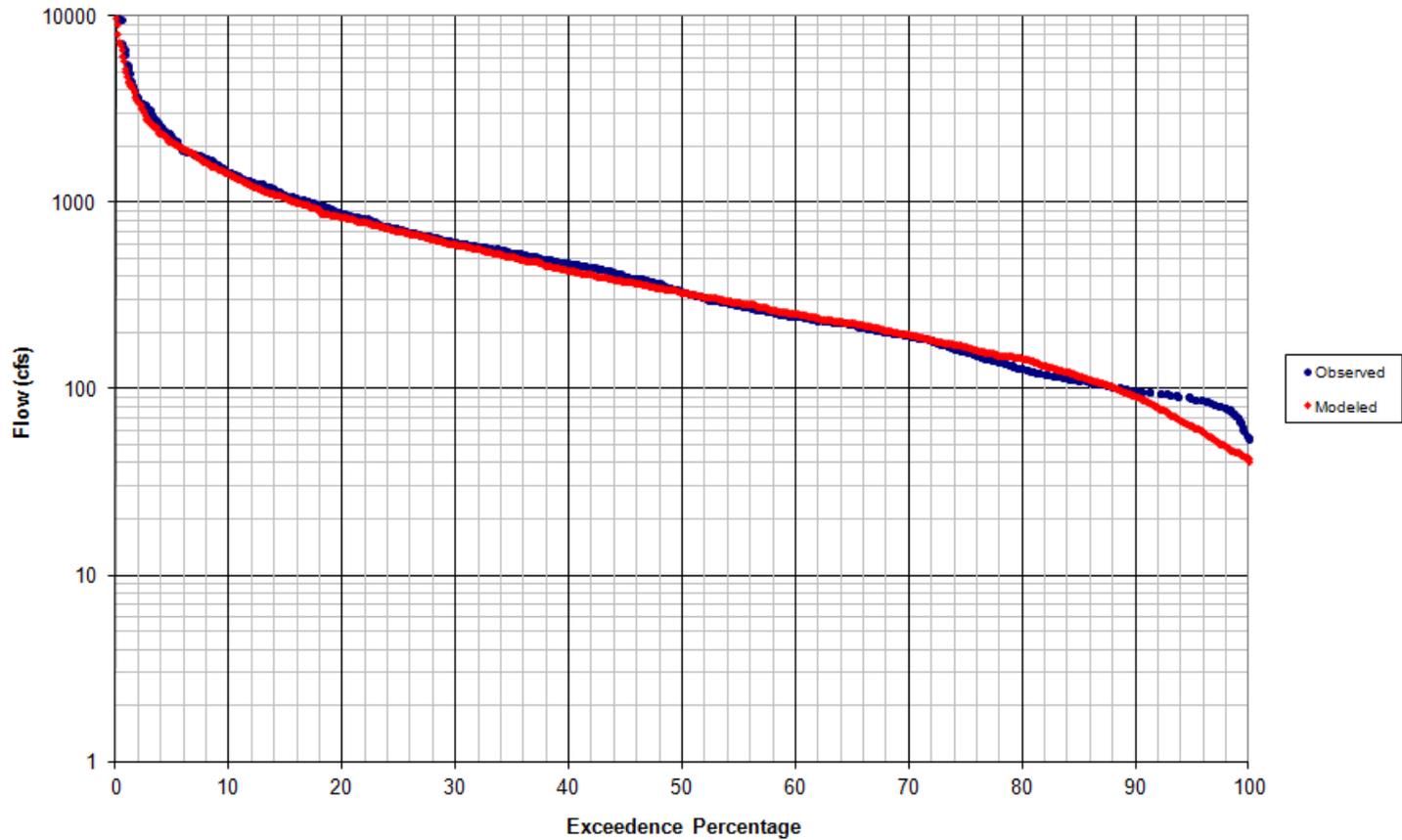
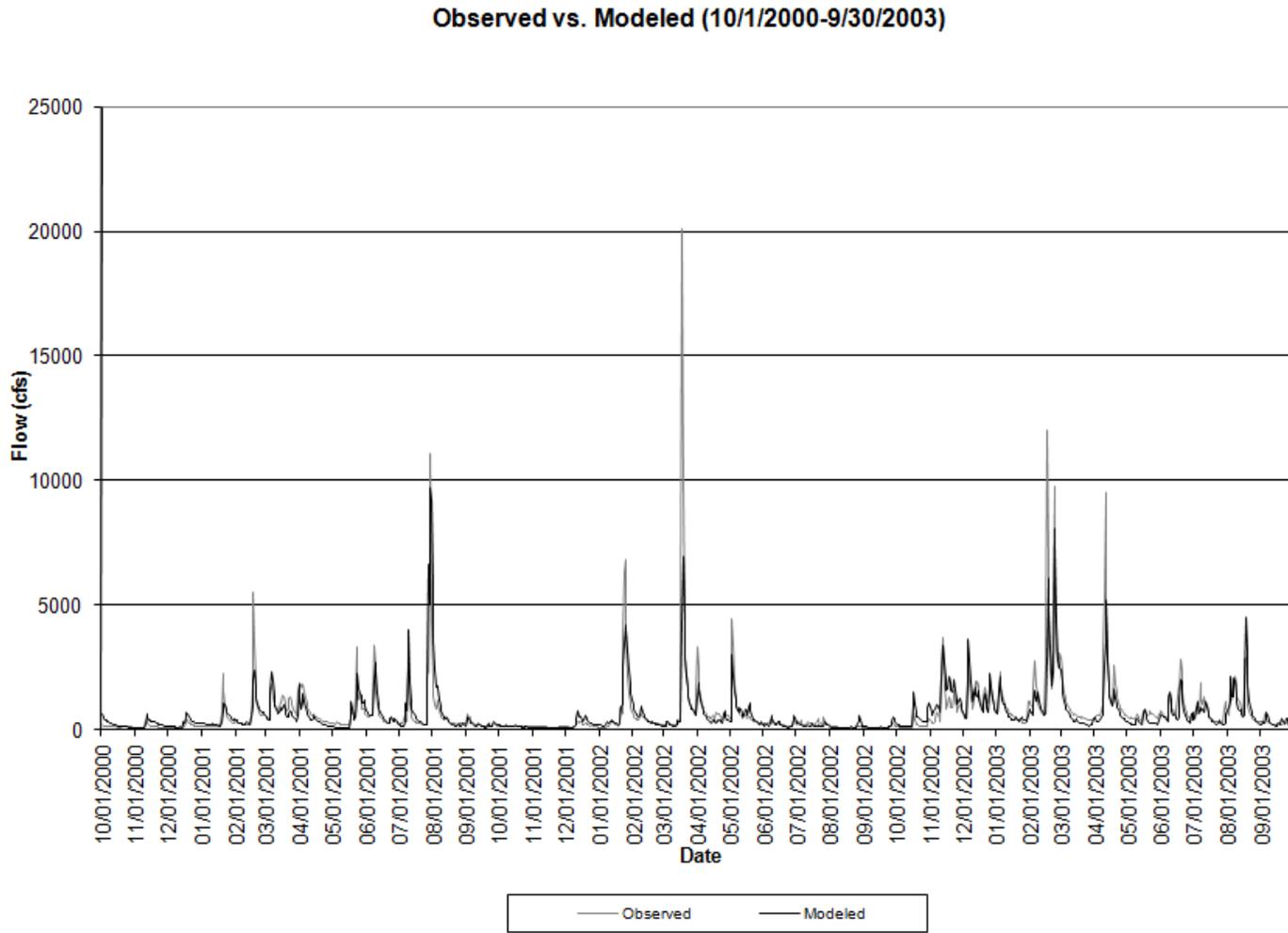


Figure C. 37 Clinch River modeled flow duration versus USGS Gaging Station #03524000 data from 10/1/2000 through 9/30/2003 at (subwatershed 19).



**Figure C. 38 Clinch River validation modeled results versus USGS Gaging Station #03524000 data from 10/1/2000 through 9/30/2003 at (subwatershed 19).**

Water quality calibration is complicated by a number of factors; first, water quality (*E. coli*) concentrations are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters. Second, the concentration of *E. coli* is particularly variable. Variability in location and timing of fecal deposition, variability in the density of bacteria in feces (among species and for an individual animal), environmental impacts on re-growth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling *E. coli* concentrations. Additionally, the VADEQ data were censored at specific high and low values (e.g. 8,000 cfu/100mL or 16,000 cfu/100mL as highs or 100 cfu/100mL as low value). Limited amount of measured data for use in calibration and the practice of censoring both high and low concentrations impede the calibration process.

Four parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), monthly maximum accumulation on land (MON-SQOLIM), the rate of surface runoff that will remove 90% of stored fecal bacteria per hour (WSQOP), and the temperature correction coefficient for first-order decay of quality (THFST). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled bacteria concentrations was established. Depending on the type of available bacteria data, either fecal coliform or *E. coli* monitored data were used. Table C. 15 shows the model parameters utilized in calibration with their typical ranges, initial estimates, and final calibrated values. Table C. 16 shows the time period, the subwatershed which the station is located, and bacteria type used for each monitoring station used in the calibration.

**Table C. 15 Model parameters utilized for water quality calibration.**

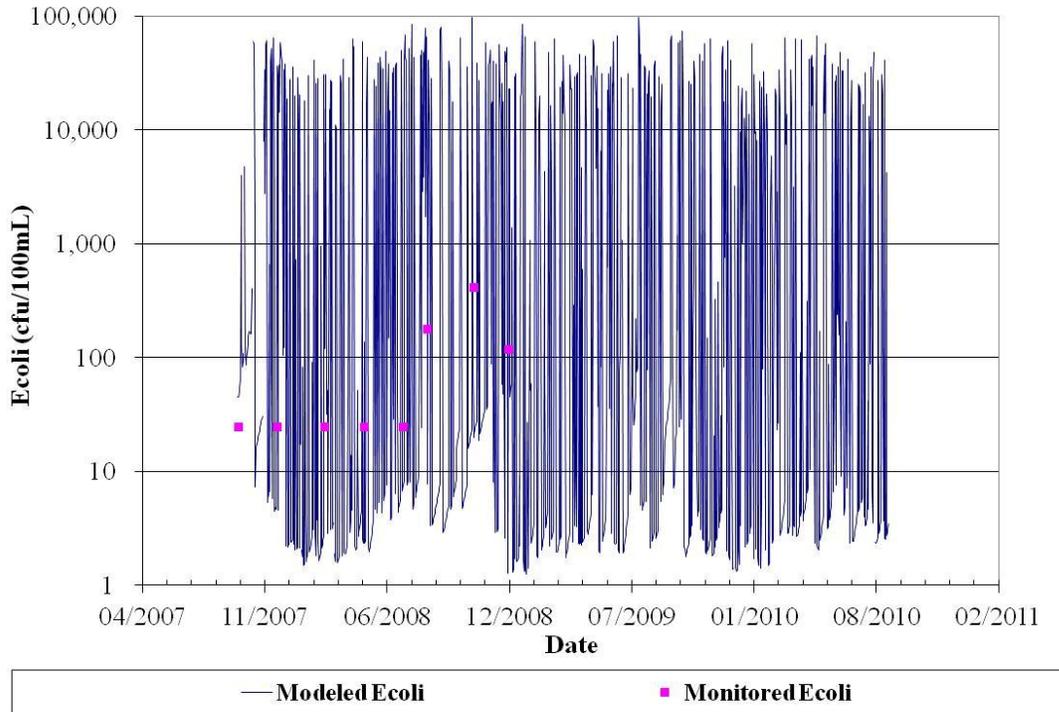
Parameter	Units	Typical Range	Initial Parameter Estimate	Calibrated Parameter Value
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0.0 – 5.8E+12	0.0 – 5.8E+12
WSQOP	in/hr	0.05 – 3.00	0.0 – 2.80	0 – 3
FSTDEC	1/day	0.01 – 10.00	1.0	1-10
THFST	none	1.0 – 2.0	1.07	1.07

**Table C. 16 Bacteria calibration periods, subwatersheds and streams containing stations, and type of bacteria used in the Clinch River watershed study area.**

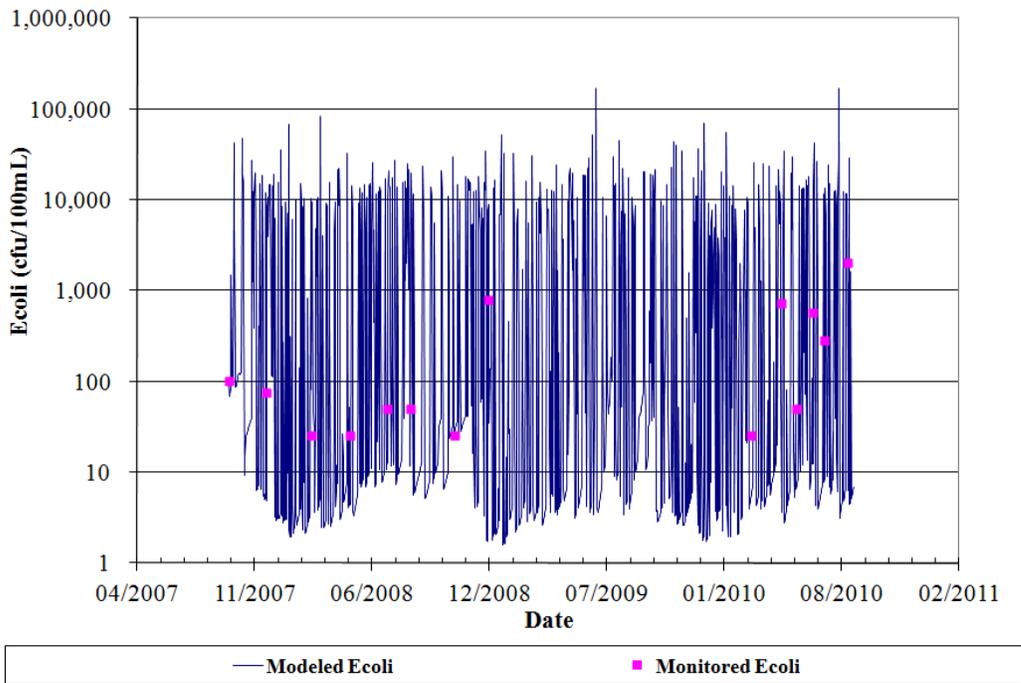
Station	Stream	Calibration Period	Subwatershed	Type of Bacteria Used
6BSWO001.81	Swords	10/1/2007 – 8/31/2010	17	<i>E. coli</i>
6BLWS000.06	Lewis Creek	10/1/2007 – 8/31/2010	16	<i>E. coli</i>
6BDUM000.04	Dumps Creek	10/1/2007 – 8/31/2010	7	<i>E. coli</i>
6BEKG004.18	Elk Garden Creek	10/1/2007 – 8/31/2010	10	<i>E. coli</i>
6BBCD001.89	Big Cedar Creek	10/1/2007 – 8/31/2010	9	<i>E. coli</i>
6BCLN271.50	Clinch River	10/1/2007 – 8/31/2010	19	<i>E. coli</i>

Figures C.39 through C.44 show the results of water quality calibration. Monitored values are an instantaneous snapshot of the bacteria level, whereas the modeled values are daily averages based on hourly modeling. The monitored values may have been sampled at the highest concentration of the day and thus correctly appear above the modeled daily average. Although the range of modeled daily average values may not reach every instantaneous monitored value, the modeled data follows the trend of monitored data, and typically includes the monitored extremes.

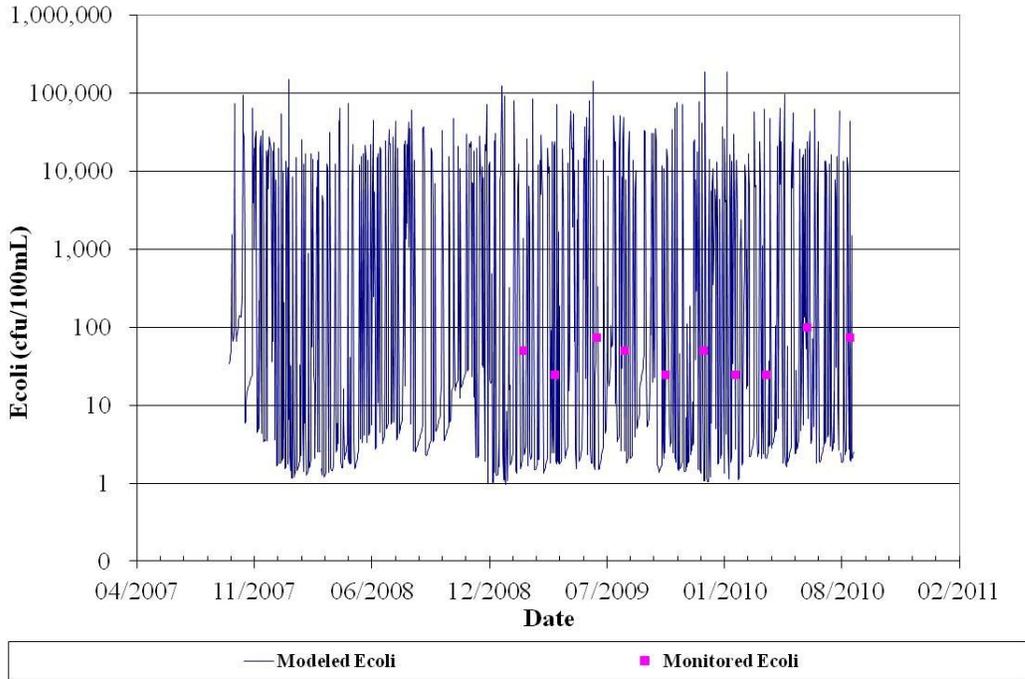
Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. Table C. 17 shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the Clinch River stream segments.



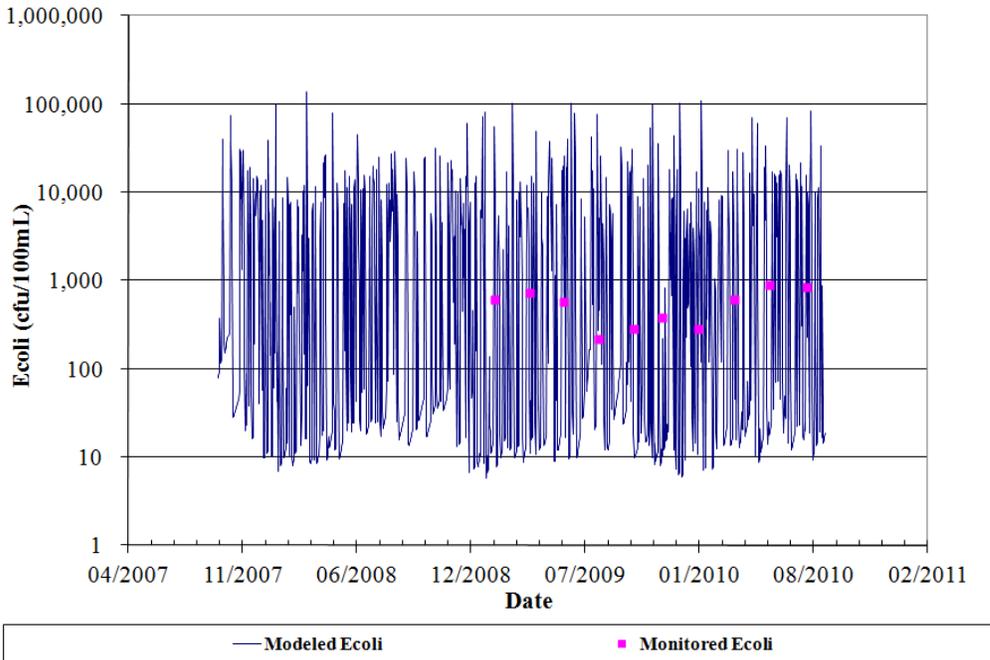
**Figure C. 39 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BSWO001.81 in subwatershed 16 on Swords Creek.**



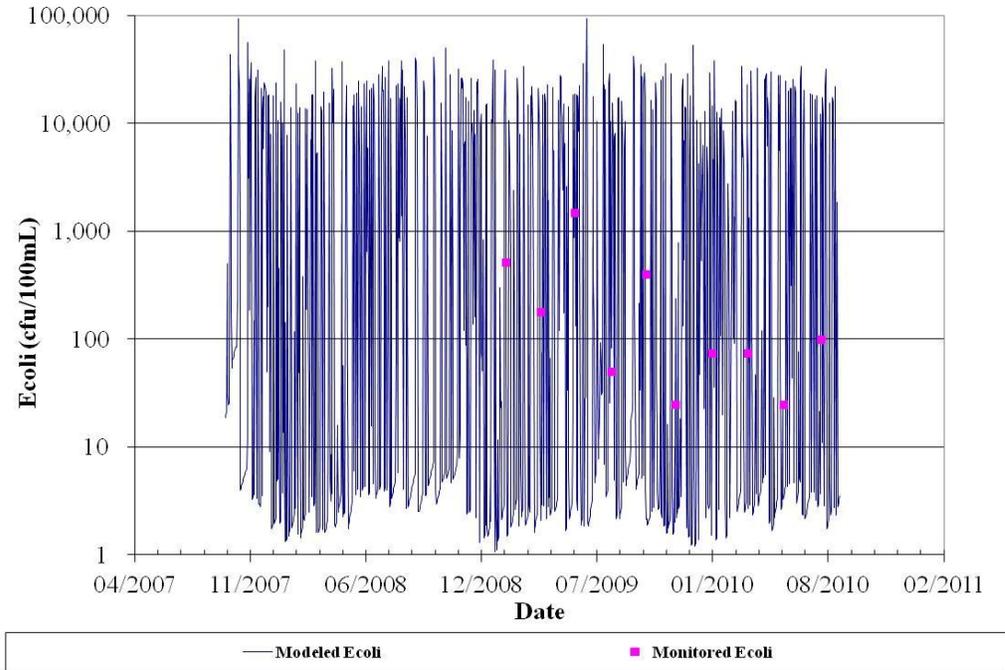
**Figure C. 40 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BLWS000.06 in subwatershed 16 on Lewis Creek.**



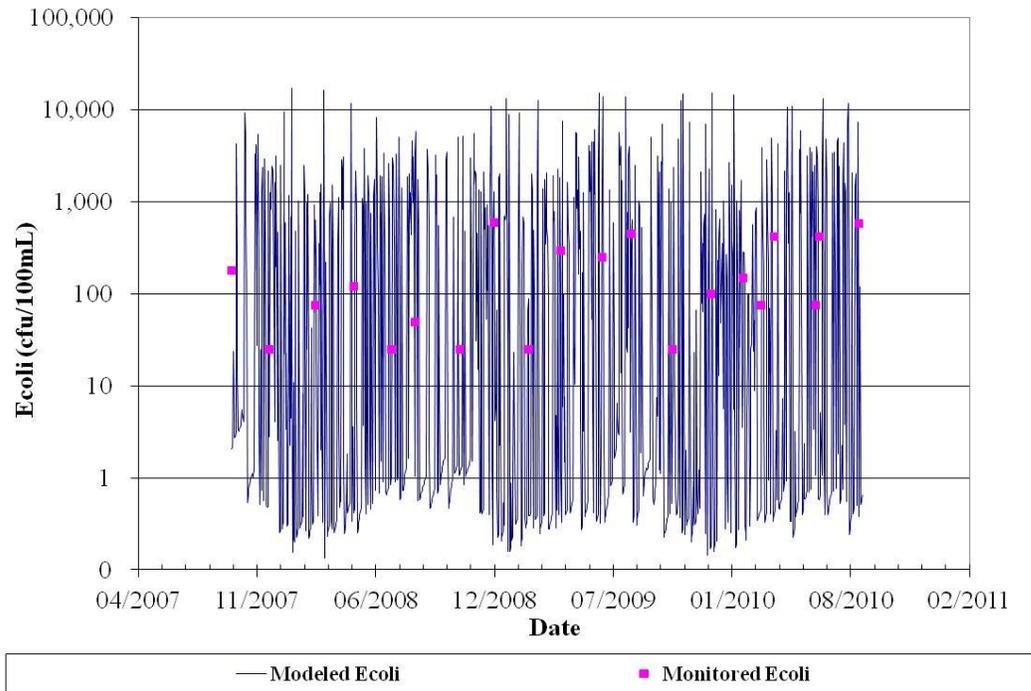
**Figure C. 41 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BDUM000.04 in subwatershed 7 on Dumps Creek.**



**Figure C. 42 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BEKG004.18 in subwatershed 10 on Elk Garden Creek.**



**Figure C. 43 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BBCD001.89 in subwatershed 9 on Big Cedar Creek.**



**Figure C. 44 E. coli calibration for 10/1/2007 – 8/31/2010 for VADEQ station 6BCLN271.50 in subwatershed 19 on Clinch River.**

**Table C. 17 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the calibration period.**

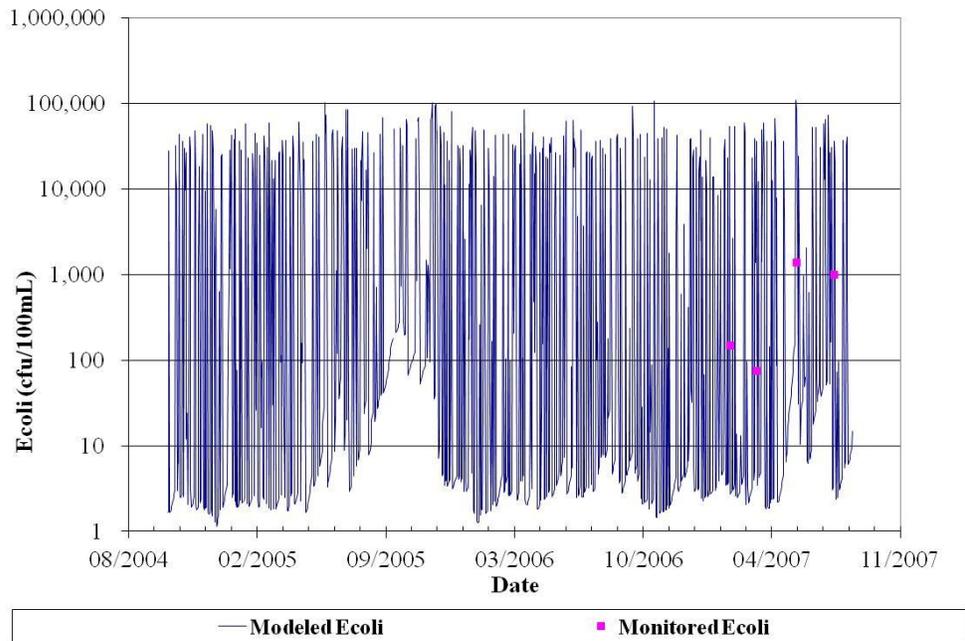
Station	Subwatershed	Maximum Value (cfu/100mL)		Geometric Mean (cfu/100mL)		SS % violations <sup>1</sup>	
		Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
6BSWO001.81	17	420	98,637	55.39	108.07	13%	37%
6BLWS000.06	16	2,000	82,570	108.55	100.69	33%	36%
6BDUM000.04	7	100	187,644	44.04	74.06	0%	34%
6BEKG004.18	10	900	68,828	487.22	254.99	90%	44%
6BBCD001.89	9	1,500	94,508	125.73	81.84	30%	37%
6BCLN271.50	19	600	17,309	114.03	110.64	35%	31%

<sup>1</sup> SS = single sample instantaneous standard violations (>235 cfu/100mL for E. coli)

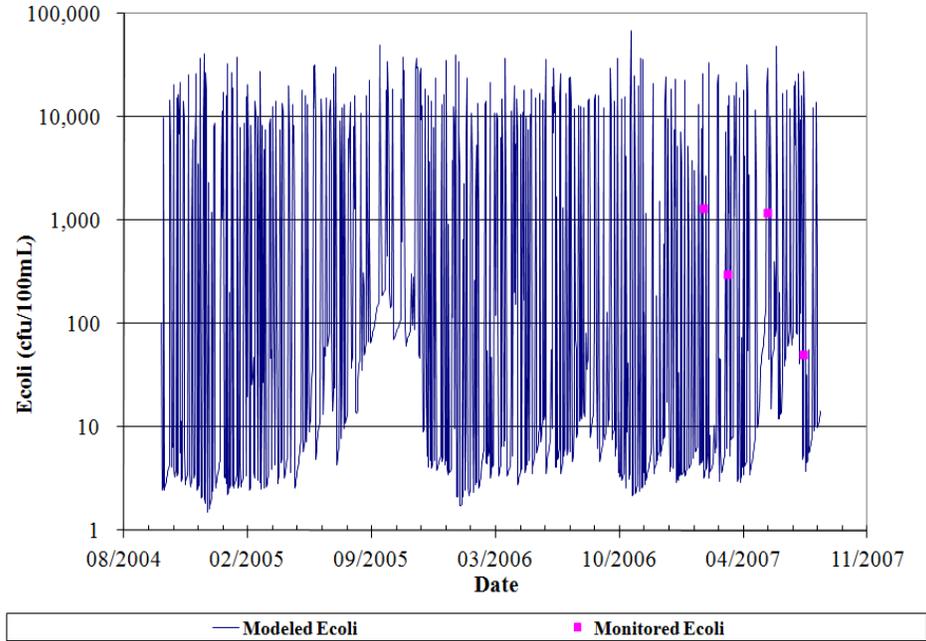
Bacteria water quality model validation was performed on stations shown in Table C. 18. Figures C.45 through C.50 shows the results of water quality validation. Table C. 19 shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the Clinch River stream segment.

**Table C. 18 Bacteria validation periods, subwatersheds and streams containing stations, and type of bacteria used in the Clinch River watershed study area.**

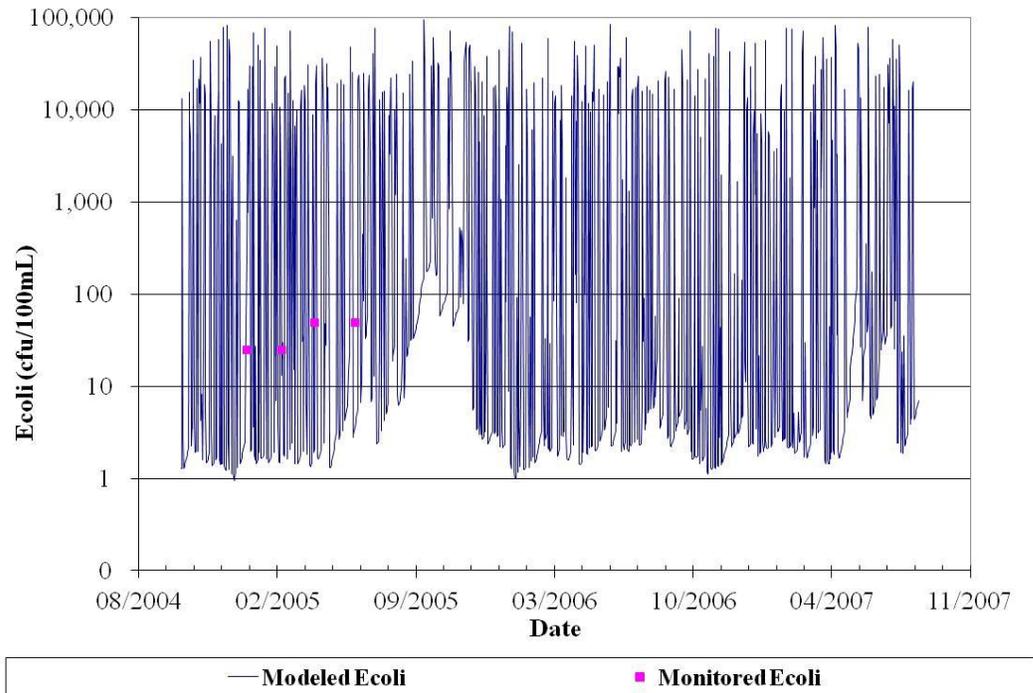
Station	Stream	Validation Period	Subwatershed	Type of Bacteria Used
6BSWO001.81	Swords	10/1/2004 – 9/30/2007	17	E. Coli
6BLWS000.06	Lewis Creek	10/1/2004 – 9/30/2007	16	E. Coli
6BDUM000.04	Dumps Creek	10/1/2004 – 9/30/2007	7	E. Coli
6BEKG004.18	Elk Garden Creek	10/1/2004 – 9/30/2007	10	E. Coli
6BBCD001.89	Big Cedar Creek	10/1/2004 – 9/30/2007	9	E. Coli
6BCLN271.50	Clinch River	10/1/2004 – 9/30/2007	19	E. Coli



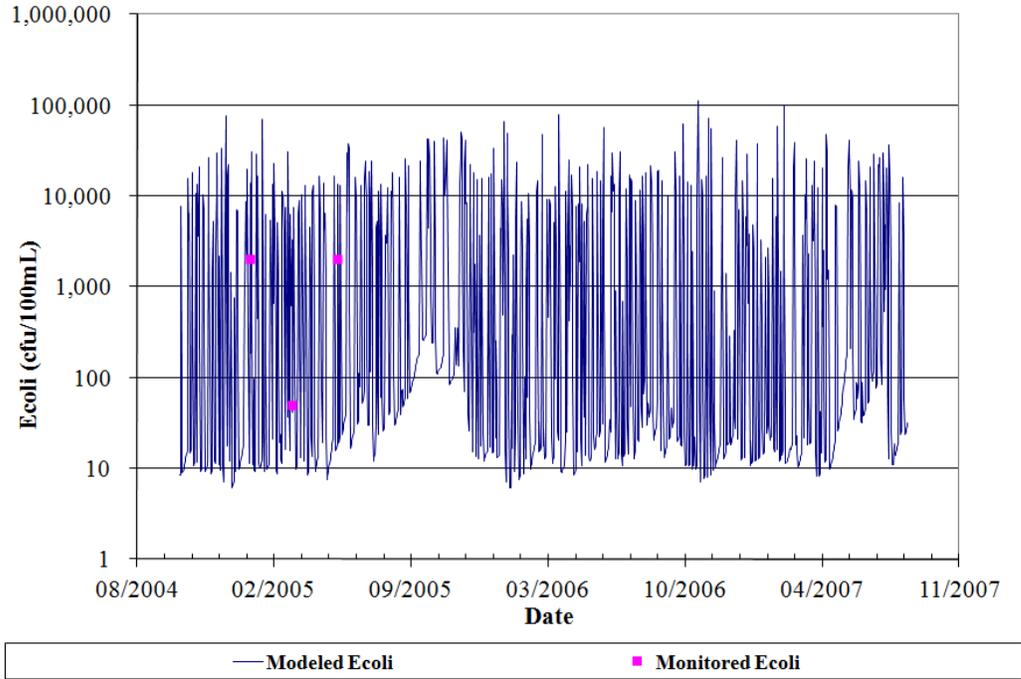
**Figure C. 45 E. coli validation for 10/1/2007 – 8/31/2010 for VADEQ station 6BSWO001.81 in subwatershed 16 on Swords Creek.**



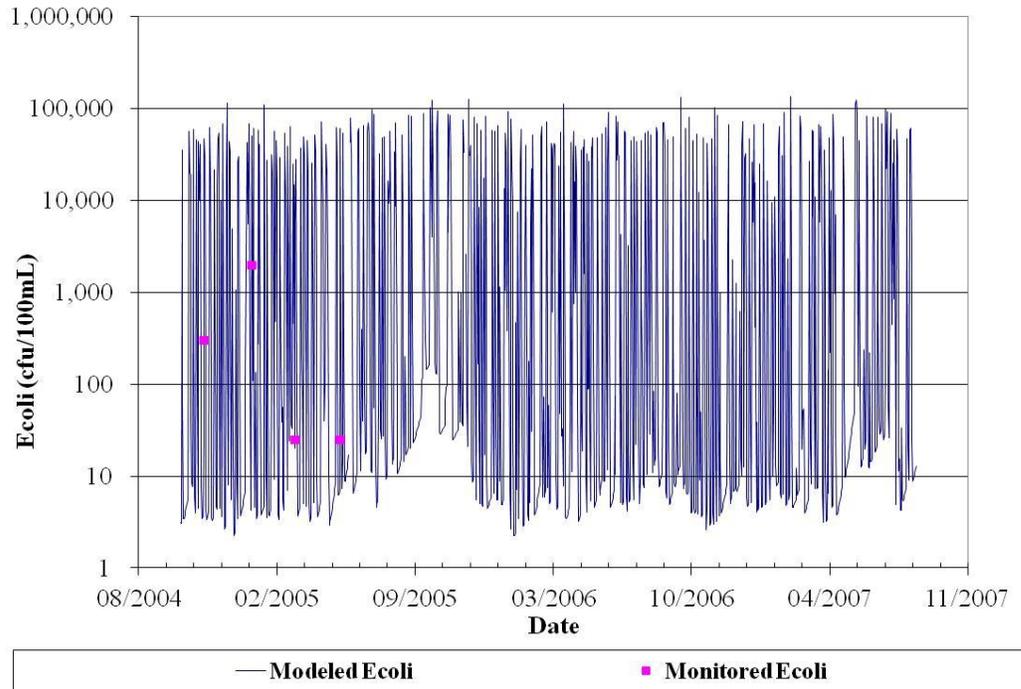
**Figure C. 46 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BLWS000.06 in subwatershed 16 on Lewis Creek.**



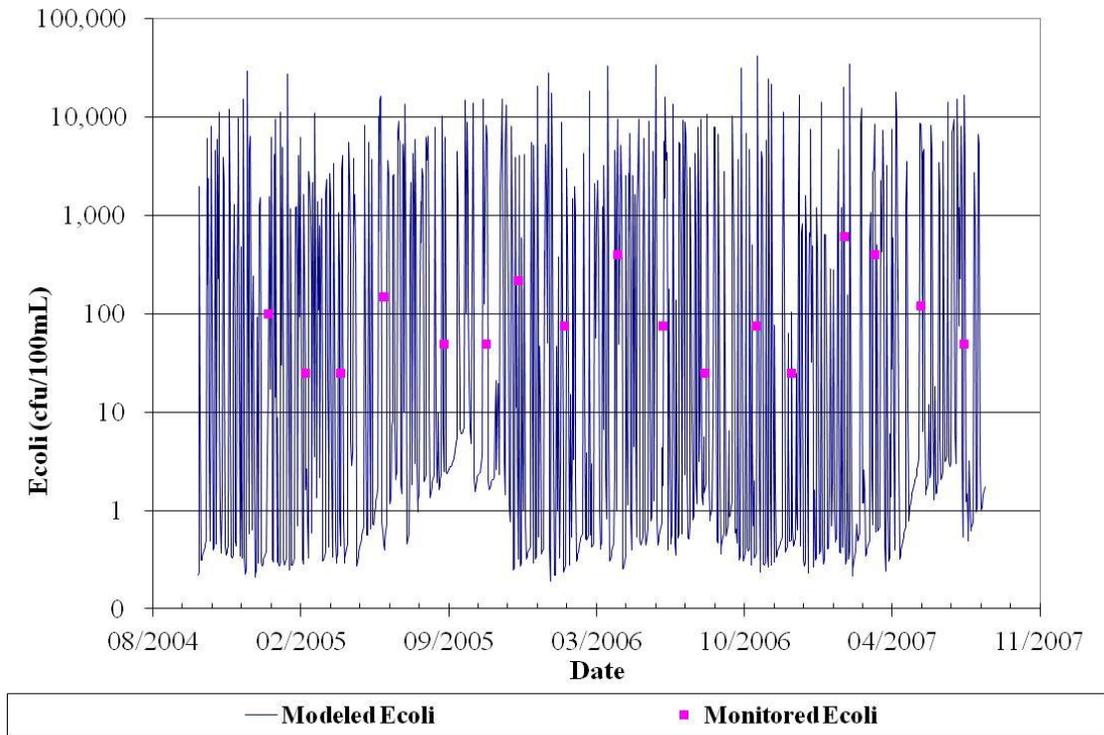
**Figure C. 47 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BDUM000.04 in subwatershed 7 on Dumps Creek.**



**Figure C. 48 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BEKG004.18 in subwatershed 10 on Elk Garden Creek.**



**Figure C. 49 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BBCD001.89 in subwatershed 9 on Big Cedar Creek.**



**Figure C. 50 E. coli validation for 10/1/2004 – 9/30/2007 for VADEQ station 6BCLN271.50 in subwatershed 19 on Clinch River.**

**Table C. 19 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the validation period.**

Station	Subwatershed	Maximum Value (cfu/100mL)		Geometric Mean (cfu/100mL)		SS % violations <sup>1</sup>	
		Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
6BSWO001.81	17	1,400	109,688	354.26	87.79	50%	34%
6BLWS000.06	16	1,300	67,896	391.11	83.39	75%	33%
6BDUM000.04	7	50	96,377	35.36	60.27	0%	32%
6BEKG004.18	10	2,000	112,780	584.80	212.19	67%	41%
6BBCD001.89	9	2,000	134,483	139.16	173.38	50%	38%
6BCLN271.50	19	620	41,831	86.25	94.47	18%	18%

<sup>1</sup> SS = single sample instantaneous standard violations (>235 cfu/100mL for E. coli)