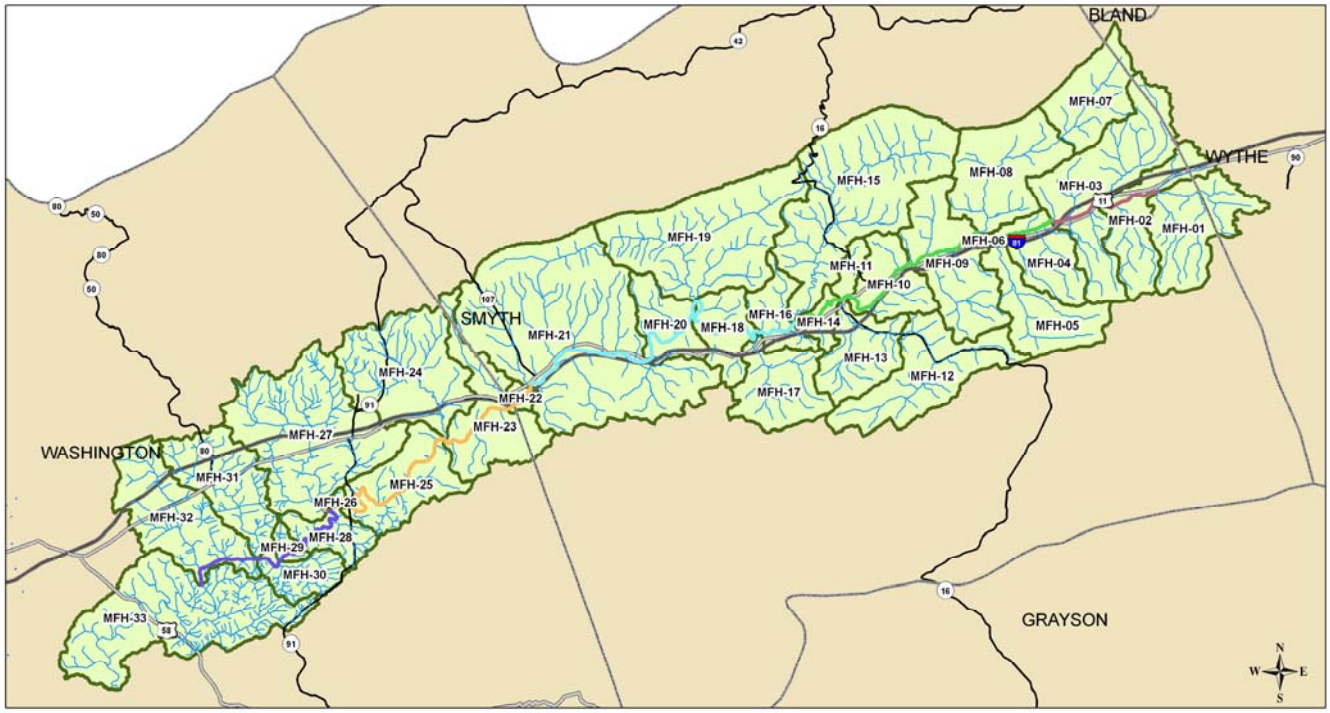
Bacteria and Benthic Total Maximum Daily Load Development for Middle Fork Holston River



Submitted by: Virginia Department of Environmental Quality

Prepared by: Engineering Concepts, Inc.

Submitted: October 2009

Table of Contents

LIST OF TABLES VII

LIST OF FIGURES XVIII

LIST OF ACRONYMS XXVI

EXECUTIVE SUMMARY XXVIII
Background xxviii
Stressor Analysis xxix
Pollutant Sources xxx
Modeling xxxi
Margin of Safety xxxii
TMDL Allocation Scenarios xxxii
TMDL Implementation and Reasonable Assurance xxxv
Public Participation xxxvii

PROJECT PERSONNEL XXXIX

ACKNOWLEDGEMENTS XL

CHAPTER 1. INTRODUCTION 1-1
1.1 Background 1-1
1.1.1 TMDL Definition and Regulatory Information 1-1
1.1.2 Impairments Listing 1-1
1.1.3 Watershed Location and Description 1-2
1.1.4 Pollutant of Concern 1-2
1.2 Designated Uses and Applicable Water Quality Standards 1-3
1.2.1 Designation of Uses (9 VAC 25-260-10) 1-3
1.2.2 Bacteria Standard (9 VAC 25-260-170) 1-3
1.2.3 General Standard (9 VAC 25-260-20) 1-4

CHAPTER 2. WATERSHED CHARACTERIZATION 2-1
2.1 Water Resources 2-1
2.2 Ecoregion 2-1
2.3 Climate 2-1
2.4 Land Use 2-1
2.5 Water Quality Data 2-2
2.5.1 Historic Data for Fecal Coliform 2-2
2.5.2 Historic Data for E. coli 2-12
2.5.3 Historic Data for Bacterial Source Tracking 2-14
2.6 Biological Monitoring Data 2-16
2.6.1 Benthic Data 2-16
2.7 VADEQ Ambient Monitoring Data 2-33

2.7.1 Physical 2-33
2.7.2 Nutrients 2-45
2.7.3 Metals 2-56
2.7.4 Organics 2-78
2.8 Sediment and Fish Tissue Sampling 2-89
2.9 TOXICITY STUDY 2-96

CHAPTER 3. BACTERIA SOURCE ASSESSMENT 3-1
3.1 Permitted Discharges 3-1
3.2 Humans 3-3
3.2.1 Failing Septic Systems 3-4
3.2.2 Straight Pipes 3-5
3.2.3 Biosolids 3-5
3.3 Pets 3-6
3.4 Domesticated Animal Sources 3-9
3.4.1 Cattle 3-9
3.4.1.1 Direct Manure Deposition in Streams 3-17
3.4.1.2 Direct Manure Deposition on Pastures 3-18
3.4.1.3 Land Application of Liquid Dairy Manure 3-18
3.4.1.4 Land Application of Solid Manure 3-20
3.4.2 Poultry 3-23
3.4.3 Horses 3-23
3.4.4 Other Livestock Sources 3-25
3.5 Wildlife 3-25
3.6 Summary: Contribution from All Sources 3-28

CHAPTER 4. BENTHIC STRESSOR ANALYSIS 4-1
4.1 Introduction 4-1
4.2 Non-Stressors 4-1
4.2.1 pH 4-1
4.2.2 Temperature 4-2
4.2.3 Dissolved Oxygen and Biochemical Oxygen Demand 4-2
4.2.4 Ammonia 4-2
4.2.5 Water Column Toxics 4-2
4.3 Possible Stressors 4-3
4.3.1 Nutrients 4-3
4.3.2 Heavy Metals 4-3
4.3.3 Organics 4-3
4.4 Most Probable Stressors 4-4
4.4.1 Sediment 4-4

CHAPTER 5. MODELING PROCESS FOR BACTERIA TMDL DEVELOPMENT 5-1
5.1 Model Description 5-1

5.2 Selection of Sub-watersheds 5-2
5.3 Land Use 5-4
5.4 Stream Channel Characteristics 5-7
5.5 Climatological Data 5-7
5.6 Accounting for Pollutant Sources 5-7
5.6.1 Overview 5-7
5.6.2 Modeling Fecal Coliform Die-off 5-8
5.6.3 Modeling Direct Nonpoint Sources 5-9
5.6.4 Modeling Land-based Nonpoint Sources 5-9
5.6.5 Modeling Existing BMPs 5-10
5.7 Model Calibration and Validation 5-10
5.7.1 Hydrology 5-10
5.7.2 Water Quality 5-23

CHAPTER 6. MODELING PROCESS FOR DEVELOPMENT OF SEDIMENT TMDL 6-1
6.1 Reference Watershed 6-1
6.2 Sediment Source Representation 6-3
6.2.1 Permitted Point Sources 6-3
6.2.2 Nonpoint Sources 6-4
6.2.3 Channel and Streambank Erosion 6-5
6.3 Model Development 6-5
6.3.1 Climate Data 6-5
6.3.2 Land use 6-6
6.3.3 Model Input Parameters 6-6
6.3.4 Model Calibration 6-8
6.4 Sediment Load Estimates 6-8
6.4.1 Upper Middle Fork Holston River 6-8
6.4.2 Lower Middle Fork Holston River 6-10
6.5 Accounting for Critical Conditions and Seasonal Variations 6-10
6.5.1 Selection of Representative Modeling Period 6-10
6.5.2 Critical Conditions 6-11
6.5.3 Seasonal Variability 6-11

CHAPTER 7. TMDL ALLOCATIONS 7-1
7.1 Bacteria TMDL 7-1
7.1.1 Background 7-1
7.1.2 Existing Conditions 7-2
7.1.2.1 Middle Fork Holston River (VAS-O03R-01) 7-2
7.1.2.2 Middle Fork Holston River (VAS-O03R-02) 7-5
7.1.2.3 Middle Fork Holston River (VAS-O04R-01) 7-9
7.1.2.4 Middle Fork Holston River (VAS-O05R-06) 7-12
7.1.2.5 Middle Fork Holston River (VAS-O05R-05) 7-15

7.1.3 Impact Analysis 7-18
7.1.3.1 Middle Fork Holston River (VAS-O03R-01) 7-18
7.1.3.2 Middle Fork Holston River (VAS-O03R-02) 7-23
7.1.3.3 Middle Fork Holston River (VAS-O04R-01) 7-28
7.1.3.4 Middle Fork Holston River (VAS-O05R-06) 7-33
7.1.3.5 Middle Fork Holston River (VAS-O05R-05) 7-38
7.1.4 TMDL Allocation Scenarios 7-43
7.1.4.1 Middle Fork Holston River (VAS-O03R-01) 7-45
7.1.4.2 Middle Fork Holston River (VAS-O03R-02) 7-49
7.1.4.3 Middle Fork Holston River (VAS-O04R-01) 7-53
7.1.4.4 Middle Fork Holston River (VAS-O05R-06) 7-57
7.1.4.5 Middle Fork Holston River (VAS-O05R-05) 7-61
7.2 Sediment TMDL 7-65
7.2.1 Point Source Wasteload Allocation 7-65
7.2.2 Nonpoint Source Load Allocation 7-65
7.2.3 Margin of Safety 7-66
7.2.4 TMDL Allocations 7-66

CHAPTER 8. TMDL IMPLEMENTATION AND REASONABLE ASSURANCE 8-1
8.1 Staged Implementation 8-1
8.2 Bacteria Stage 1 Scenarios 8-2
8.2.1 Middle Fork Holston River (VAS-O03R-01) 8-2
8.2.2 Middle Fork Holston River (VAS-O03R-02) 8-5
8.2.3 Middle Fork Holston River (VAS-O04R-01) 8-7
8.2.4 Middle Fork Holston River (VAS-O05R-06) 8-9
8.2.5 Middle Fork Holston River (VAS-O05R-05) 8-11
8.3 Link to Ongoing Restoration Efforts 8-13
8.4 Reasonable Assurance for Implementation 8-13
8.4.1 Follow-up Monitoring 8-13
8.4.2 Regulatory Framework 8-14
8.4.3 Implementation Funding Sources 8-16
8.4.4 Addressing Wildlife Contributions 8-16
8.4.5 Attainability of Designated Use 8-17

CHAPTER 9. PUBLIC PARTICIPATION 9-1

GLOSSARY G-1

REFERENCES R-1

APPENDIX A – HISTORIC WATER QUALITY DATA A-1

APPENDIX B – BACTERIA SOURCE TRACKING REPORT B-1

APPENDIX C – FECAL COLIFORM LOADING IN SUBWATERSHEDS C-1

APPENDIX D – REQUIRED REDUCTIONS IN FECAL COLIFORM LOADS BY SUBWATERSHED – ALLOCATION SCENARIO D-1

List of Tables

Table E.1. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in each impairment. xxxiii
Table E.2. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in each impairment. xxxv
Table E.3. Yearly sediment loads (T/yr) modeled after TMDL allocation in Lower Middle Fork Holston River impairment. xxxv
Table E.4. Daily sediment loads (T/d) modeled after TMDL allocation in Lower Middle Fork Holston River impairment. xxxv
Table 2.1. Impairment name, monitoring station with location, and fecal coliform and *E. coli* water quality standard exceedance rates. 2-2
Table 2.2. Number of samples collected per month from 1/1/90 to 12/31/06 in the Middle Fork Holston River impairments. 2-7
Table 2.3. Number of samples collected per month from 1/1/90 to 12/31/06 in the Middle Fork Holston River impairments. 2-8
Table 2.4. Presence/absence analysis of bacteria sources at station 6-CMFH013.21 in Middle Fork Holston River watershed. 2-15
Table 2.5. Presence/absence analysis of bacteria sources at station 6-CMFH013.21 in Middle Fork Holston River watershed. 2-15
Table 2.6. Inventory of VADEQ environmental monitoring data for Middle Fork Holston River. 2-16
Table 2.7. RBP II and VSCI metric and assessment data for station 6CMFH004.00 in Middle Fork Holston River. 2-18
Table 2.8. RBP II and VSCI metric and assessment data for station 6CMFH011.31 in Middle Fork Holston River. 2-19
Table 2.9. RBP II and VSCI metric and assessment data for station 6CMFH023.41 in Middle Fork Holston River. 2-20
Table 2.10. RBP II and VSCI metric and assessment data for station 6CMFH032.39 in Middle Fork Holston River. 2-21
Table 2.11. RBP II and VSCI metric and assessment data for station 6CMFH045.83 in Middle Fork Holston River. 2-22
Table 2.12. Taxa data for station 6CMFH004.00 in Middle Fork Holston River. 2-23
Table 2.13. Taxa data for station 6CMFH011.31 in Middle Fork Holston River. 2-24
Table 2.14. Taxa data for station 6CMFH023.41 in Middle Fork Holston River. 2-25
Table 2.15. Taxa data for station 6CMFH032.39 in Middle Fork Holston River. 2-26
Table 2.16. Taxa data for station 6CMFH045.83 in Middle Fork Holston River. 2-27
Table 2.17. Habitat scores for station 6-CMFH004.00 in Middle Fork Holston River 2-28
Table 2.18. Habitat scores for station 6-CMFH011.31 in Middle Fork Holston River 2-28
Table 2.19. Habitat scores for station 6-CMFH023.41 in Middle Fork Holston River 2-28
Table 2.20. Habitat scores for station 6-CMFH032.39 in Middle Fork Holston River 2-29
Table 2.21. Habitat scores for station 6-CMFH045.83 in Middle Fork Holston River 2-29
Table 2.22. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH005.00 in Middle Fork Holston River. 2-35
Table 2.23. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH013.21 in Middle Fork Holston River. 2-35
Table 2.24. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH023.41 in Middle Fork Holston River. 2-36
Table 2.25. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH026.00 in Middle Fork Holston River. 2-36

Table 2.26. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH027.14 in Middle Fork Holston River. 2-37
Table 2.27. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH033.40 in Middle Fork Holston River. 2-37
Table 2.28. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH040.67 in Middle Fork Holston River. 2-38
Table 2.29. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH045.72 in Middle Fork Holston River. 2-38
Table 2.30. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH005.00 in Middle Fork Holston River. 2-46
Table 2.31. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH013.21 in Middle Fork Holston River. 2-46
Table 2.32. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH023.41 in Middle Fork Holston River. 2-47
Table 2.33. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH026.00 in Middle Fork Holston River. 2-47
Table 2.34. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH027.14 in Middle Fork Holston River. 2-48
Table 2.35. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH033.40 in Middle Fork Holston River. 2-48
Table 2.36. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH040.67 in Middle Fork Holston River. 2-49
Table 2.37. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH045.72 in Middle Fork Holston River. 2-49
Table 2.38. Metals water quality data summary for station 6CMFH005.00 in Middle Fork Holston River. 2-57
Table 2.39. Metals water quality data summary for station 6CMFH013.21 in Middle Fork Holston River. 2-58
Table 2.40. Metals water quality data summary for station 6CMFH023.41 in Middle Fork Holston River. 2-59
Table 2.41. Metals water quality data summary for station 6CMFH026.00 in Middle Fork Holston River. 2-60
Table 2.42. Metals water quality data summary for station 6CMFH033.40 in Middle Fork Holston River. 2-61
Table 2.43. Metals water quality data summary for station 6CMFH045.72 in Middle Fork Holston River. 2-62
Table 2.44. Organics water quality data summary for station 6CMFH005.00 in Middle Fork Holston River. 2-79
Table 2.45. Organics water quality data summary for station 6CMFH013.21 in Middle Fork Holston River. 2-79
Table 2.46. Organics water quality data summary for station 6CMFH023.41 in Middle Fork Holston River. 2-80
Table 2.47. Organics water quality data summary for station 6CMFH026.00 in Middle Fork Holston River. 2-80
Table 2.48. Organics water quality data summary for station 6CMFH033.40 in Middle Fork Holston River. 2-81
Table 2.49. Organics water quality data summary for station 6CMFH045.72 in Middle Fork Holston River. 2-81
Table 3.1. Potential bacteria sources in the Middle Fork Holston River watershed. 3-1
Table 3.2. Active VPDES permitted point sources in the Middle Fork Holston River watershed. 3-3

Table 3.3. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O03R-01) watershed. 3-7
Table 3.4. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O03R-02) watershed. 3-7
Table 3.5. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O04R-01) watershed. 3-8
Table 3.6. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O05R-06) watershed. 3-8
Table 3.7. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O05R-05) watershed. 3-9
Table 3.8. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O03R-01) watershed. 3-10
Table 3.9. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O03R-02) watershed. 3-10
Table 3.10. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O04R-01) watershed. 3-10
Table 3.11. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O05R-06) watershed. 3-11
Table 3.12. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O05R-05) watershed. 3-11
Table 3.13. Time spent by cattle in confinement and in the stream in Middle Fork Holston River watershed. 3-12
Table 3.14. Distribution of the dairy cattle[a] population in Middle Fork Holston River (VAS-O03R-01) watershed. 3-13
Table 3.15. Distribution of the dairy cattle[a] population in Middle Fork Holston River (VAS-O04R-01) watershed. 3-13
Table 3.16. Distribution of the dairy cattle[a] population in Middle Fork Holston River (VAS-O05R-06) watershed. 3-14
Table 3.17. Distribution of the dairy cattle[a] population in Middle Fork Holston River (VAS-O05R-05) watershed. 3-14
Table 3.18. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O03R-01) watershed. 3-15
Table 3.19. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O03R-02) watershed. 3-15
Table 3.20. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O04R-01) watershed. 3-16
Table 3.21. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O05R-06) watershed. 3-16
Table 3.22. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O05R-05) watershed. 3-17
Table 3.23. Schedule of cattle waste application in Middle Fork Holston River watershed. 3-20

Table 3.24. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O03R-01) watershed. 3-21
Table 3.25. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O03R-02) watershed. 3-21
Table 3.26. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O04R-01) watershed. 3-22
Table 3.27. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O05R-06) watershed. 3-22
Table 3.28. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O05R-05) watershed. 3-22
Table 3.29. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O03R-01) watershed. 3-23
Table 3.30. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O03R-02) watershed. 3-24
Table 3.31. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O04R-01) watershed. 3-24
Table 3.32. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O05R-06) watershed. 3-24
Table 3.33. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O05R-05) watershed. 3-25
Table 3.34. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Middle Fork Holston River watershed. 3-26
Table 3.35. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O03R-01) watershed. 3-26
Table 3.36. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O03R-02) watershed. 3-27
Table 3.37. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O04R-01) watershed. 3-27
Table 3.38. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O05R-06) watershed. 3-27
Table 3.39. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O05R-05) watershed. 3-28
Table 3.40. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O03R-01) watershed. 3-29
Table 3.41. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O03R-02) watershed. 3-30

Table 3.42. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O04R-01) watershed. 3-31
Table 3.43. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O05R-06) watershed. 3-32
Table 3.44. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O05R-05) watershed. 3-33
Table 3.45. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O03R-01) watershed....3-34
Table 3.46. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O03R-02) watershed....3-35
Table 3.47. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O04R-01) watershed....3-35
Table 3.48. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O05R-06) watershed....3-36
Table 3.49. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O05R-05) watershed....3-36
Figure 5.1. Consolidation of NLCD land use categories for Middle Fork Holston River watershed....5-4
Table 5.2. Land use distribution in Middle Fork Holston River watershed. 5-5
Table 5.3. First order decay rates for different animal waste storage as affected by storage/application conditions and their sources in the Middle Fork Holston River watershed....5-8
Table 5.4. Summary statistics for the calibration period (1/1/03 to 12/31/07) at USGS station #03474000 in Middle Fork Holston River watershed. 5-11
Table 5.5. Summary statistics for the calibration period (1/1/03 to 12/31/07) at USGS station #03475000 in Middle Fork Holston River watershed. 5-11
Table 5.6. Summary statistics for the validation period (1/1/98 to 12/31/02) at USGS station #03474000 in Middle Fork Holston River watershed. 5-12
Table 5.7. Summary statistics for the validation period (1/1/98 to 12/31/02) at USGS station #03475000 in Middle Fork Holston River watershed. 5-12
Table 5.8. Flow partitioning for the calibration and validation periods in Middle Fork Holston River watershed. 5-21
Table 5.9. Calibrated hydrology HSPF parameters (PERLND) for Middle Fork Holston River watershed. 5-22
Table 5.10. Calibrated hydrology HSPF parameters (IMPLND and RCHRES) for Middle Fork Holston River watershed. 5-23
Table 5.11. Calibrated water quality HSPF parameters for Middle Fork Holston River watershed....5-25
Table 5.12. Observed and modeled geometric mean concentrations and exceedance rates of instantaneous standards for the calibration period in Middle Fork Holston River watershed. 5-40
Table 5.13. Observed and modeled geometric mean concentrations and exceedance rates of instantaneous standards for the validation period in Middle Fork Holston River watershed. 5-40
Table 6.1. VPDES permitted facilities discharging sediment in the Lower Middle Fork Holston River watershed. 6-3
Table 6.2. Industrial stormwater permitted facilities contributing sediment in the Lower Middle Fork Holston River watershed. 6-4
Table 6.3. Sediment sources and loads calculated for Upper Middle Fork Holston River watershed....6-9

Table 6.4. Sediment sources and loads calculated for Lower Middle Fork Holston River watershed. 6-10
Table 7.1. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O03R-01) impairment. 7-46
Table 7.2. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O03R-01) impairment. 7-46
Table 7.3. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O03R-01) impairment. 7-47
Table 7.4. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O03R-01) impairment. 7-47
Table 7.5. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O03R-02) impairment. 7-49
Table 7.6. Expansion matrix for bacteria WLA in the Middle Fork Holston River (VAS-O03R-02) watershed. 7-50
Table 7.7. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O03R-02) impairment. 7-50
Table 7.8. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O03R-02) impairment. 7-51
Table 7.9. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O03R-02) impairment. 7-51
Table 7.10. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O04R-01) impairment. 7-53
Table 7.11. Expansion matrix for bacteria WLA in the Middle Fork Holston River (VAS-O04R-01) watershed. 7-54
Table 7.12. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O04R-01) impairment. 7-54
Table 7.13. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O04R-01) impairment. 7-55
Table 7.14. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O04R-01) impairment. 7-55
Table 7.15. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O05R-06) impairment. 7-57
Table 7.16. Expansion matrix for bacteria WLA in the Middle Fork Holston River (VAS-O05R-06) watershed. 7-58
Table 7.17. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O05R-06) impairment. 7-58
Table 7.18. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O05R-06) impairment. 7-59
Table 7.19. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O05R-06) impairment. 7-59
Table 7.20. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O05R-05) impairment. 7-61
Table 7.21. Expansion matrix for bacteria WLA in the Middle Fork Holston River (VAS-O05R-05) watershed. 7-62
Table 7.22. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O05R-05) impairment. 7-62

Table 7.23. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O05R-05) impairment. 7-63
Table 7.24. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O05R-05) impairment. 7-63
Table 7.25. Sediment waste load allocations for permitted point sources in the Lower Middle Fork Holston River watershed. 7-65
Table 7.26. Load allocation summary with existing sediment load, sediment source reduction, and sediment allocation load for Lower Middle Fork Holston River impairment. 7-66
Table 7.27. Yearly sediment loads (T/yr) modeled after TMDL allocation in Lower Middle Fork Holston River impairment. 7-67
Table 7.28. Daily sediment loads (T/d) modeled after TMDL allocation in Lower Middle Fork Holston River impairment. 7-68
Table 8.1. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O03R-01) impairment. 8-3
Table 8.2. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O03R-02) impairment. 8-5
Table 8.3. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O04R-01) impairment. 8-7
Table 8.4. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O05R-06) impairment. 8-9
Table 8.5. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O05R-05) impairment. 8-11
Table A.1. Observed fecal coliform concentration and antecedent rainfall from 5/20/92 to 9/17/96 for VADEQ station 6-CMFH013.21 in Middle Fork Holston River watershed. A-2
Table A.2. Observed fecal coliform concentration and antecedent rainfall from 10/8/96 to 2/14/00 for VADEQ station 6-CMFH013.21 in Middle Fork Holston River watershed. A-3
Table A.3. Observed fecal coliform concentration and antecedent rainfall from 3/7/00 to 2/41/03 for VADEQ station 6-CMFH013.21 in Middle Fork Holston River watershed. A-4
Table A.4. Observed fecal coliform concentration and antecedent rainfall from 3/10/03 to 11/28/06 for VADEQ station 6-CMFH013.21 in Middle Fork Holston River watershed. A-5
Table A.5. Observed fecal coliform concentration and antecedent rainfall from 1/16/90 to 4/25/96 for VADEQ station 6-CMFH026.00 in Middle Fork Holston River watershed. A-6
Table A.6. Observed fecal coliform concentration and antecedent rainfall from 6/17/96 to 4/3/00 for VADEQ station 6-CMFH026.00 in Middle Fork Holston River watershed. A-7
Table A.7. Observed fecal coliform concentration and antecedent rainfall from 5/8/00 to 12/10/02 for VADEQ station 6-CMFH026.00 in Middle Fork Holston River watershed. A-8

Table A.8. Observed fecal coliform concentration and antecedent rainfall from 7/9/01 to 12/10/02 for VADEQ station 6-CMFH027.14 in Middle Fork Holston River watershed. A-9
Table A.9. Observed fecal coliform concentration and antecedent rainfall from 5/20/92 to 9/17/96 for VADEQ station 6-CMFH033.40 in Middle Fork Holston River watershed. A-10
Table A.10. Observed fecal coliform concentration and antecedent rainfall from 10/8/96 to 2/14/00 for VADEQ station 6-CMFH033.40 in Middle Fork Holston River watershed. A-11
Table A.11. Observed fecal coliform concentration and antecedent rainfall from 3/7/00 to 3/6/03 for VADEQ station 6-CMFH033.40 in Middle Fork Holston River watershed. A-12
Table A.12. Observed fecal coliform concentration and antecedent rainfall from 4/23/03 to 12/7/06 for VADEQ station 6-CMFH033.40 in Middle Fork Holston River watershed. A-13
Table A.13. Observed fecal coliform concentration and antecedent rainfall from 8/7/01 to 6/10/03 for VADEQ station 6-CMFH040.67 in Middle Fork Holston River watershed. A-14
Table A.14. Observed fecal coliform concentration and antecedent rainfall from 6/24/92 to 6/21/99 for VADEQ station 6-CMFH045.72 in Middle Fork Holston River watershed. A-15
Table A.15. Observed fecal coliform concentration and antecedent rainfall from 7/7/99 to 6/10/03 for VADEQ station 6-CMFH045.72 in Middle Fork Holston River watershed. A-16
Table A.16. Observed fecal coliform concentration and antecedent rainfall from 6/24/92 to 2/25/99 for VADEQ station 6-CMFH053.36 in Middle Fork Holston River watershed. A-17
Table A.17. Observed fecal coliform concentration and antecedent rainfall from 3/15/99 to 3/7/01 for VADEQ station 6-CMFH053.36 in Middle Fork Holston River watershed. A-18
Table C.1. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-01. ..... C-2
Table C.2. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-02. ..... C-2
Table C.3. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-03. ..... C-3
Table C.4. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-04. ..... C-3
Table C.5. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-05. ..... C-4
Table C.6. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-06. ..... C-4
Table C.7.Monthly nonpoint fecal coliform loadings in sub-watershed MFH-07. ..... C-5
Table C.8.Monthly nonpoint fecal coliform loadings in sub-watershed MFH-08. ..... C-5
Table C.9.Monthly nonpoint fecal coliform loadings in sub-watershed MFH-09. ..... C-6
Table C.10. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-10. ..... C-6
Table C.11. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-11. ..... C-7
Table C.12. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-12. ..... C-7
Table C.13. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-13. ..... C-8
Table C.14. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-14. ..... C-8
Table C.15. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-15. ..... C-9
Table C.16. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-16. ..... C-9
Table C.17. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-17. ..... C-10
Table C.18. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-18. ..... C-10
Table C.19. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-19. ..... C-11
Table C.20. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-20. ..... C-11
Table C.21. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-21. ..... C-12

Table C.22. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-22. ..... C-12
Table C.23. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-23. ..... C-13
Table C.24. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-24. ..... C-13
Table C.25. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-25. ..... C-14
Table C.26. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-26. ..... C-14
Table C.27. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-27. ..... C-15
Table C.28. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-28. ..... C-15
Table C.29. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-29. ..... C-16
Table C.30. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-30. ..... C-16
Table C.31. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-31. ..... C-17
Table C.32. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-32. ..... C-17
Table D.1. Required annual reductions in nonpoint sources in sub-watershed MFH-01. ..... D-2
Table D.2. Required annual reductions in direct nonpoint sources in sub-watershed MFH-01. ..... D-2
Table D.3. Required annual reductions in nonpoint sources in sub-watershed MFH-02. ..... D-3
Table D.4. Required annual reductions in direct nonpoint sources in sub-watershed MFH-02. ..... D-3
Table D.5. Required annual reductions in nonpoint sources in sub-watershed MFH-03. ..... D-4
Table D.6. Required annual reductions in direct nonpoint sources in sub-watershed MFH-03. ..... D-4
Table D.7. Required annual reductions in nonpoint sources in sub-watershed MFH-04. ..... D-5
Table D.8. Required annual reductions in direct nonpoint sources in sub-watershed MFH-04. ..... D-5
Table D.9. Required annual reductions in nonpoint sources in sub-watershed MFH-05. ..... D-6
Table D.10. Required annual reductions in direct nonpoint sources in sub-watershed MFH-05. ..... D-6
Table D.11. Required annual reductions in nonpoint sources in sub-watershed MFH-06. ..... D-7
Table D.12. Required annual reductions in direct nonpoint sources in sub-watershed MFH-06. ..... D-7
Table D.13. Required annual reductions in nonpoint sources in sub-watershed MFH-07. ..... D-8
Table D.14. Required annual reductions in direct nonpoint sources in sub-watershed MFH-07. ..... D-8
Table D.15. Required annual reductions in nonpoint sources in sub-watershed MFH-08. ..... D-9
Table D.16. Required annual reductions in direct nonpoint sources in sub-watershed MFH-08. ..... D-9
Table D.17. Required annual reductions in nonpoint sources in sub-watershed MFH-09. ..... D-10
Table D.18. Required annual reductions in direct nonpoint sources in sub-watershed MFH-09. ..... D-10
Table D.19. Required annual reductions in nonpoint sources in sub-watershed MFH-10. ..... D-11
Table D.20. Required annual reductions in direct nonpoint sources in sub-watershed MFH-10. ..... D-11
Table D.21. Required annual reductions in nonpoint sources in sub-watershed MFH-11. ..... D-12
Table D.22. Required annual reductions in direct nonpoint sources in sub-watershed MFH-11. ..... D-12
Table D.23. Required annual reductions in nonpoint sources in sub-watershed MFH-12. ..... D-13
Table D.24. Required annual reductions in direct nonpoint sources in sub-watershed MFH-12. ..... D-13
Table D.25. Required annual reductions in nonpoint sources in sub-watershed MFH-13. ..... D-14
Table D.26. Required annual reductions in direct nonpoint sources in sub-watershed MFH-13. ..... D-14
Table D.27. Required annual reductions in nonpoint sources in sub-watershed MFH-14. ..... D-15

Table D.28. Required annual reductions in direct nonpoint sources in sub-watershed MFH-14. ..... D-15
Table D.29. Required annual reductions in nonpoint sources in sub-watershed MFH-15. ..... D-16
Table D.30. Required annual reductions in direct nonpoint sources in sub-watershed MFH-15. ..... D-16
Table D.31. Required annual reductions in nonpoint sources in sub-watershed MFH-16. ..... D-17
Table D.32. Required annual reductions in direct nonpoint sources in sub-watershed MFH-16. ..... D-17
Table D.33. Required annual reductions in nonpoint sources in sub-watershed MFH-17. ..... D-18
Table D.34. Required annual reductions in direct nonpoint sources in sub-watershed MFH-17. ..... D-18
Table D.35. Required annual reductions in nonpoint sources in sub-watershed MFH-18. ..... D-19
Table D.36. Required annual reductions in direct nonpoint sources in sub-watershed MFH-18. ..... D-19
Table D.37. Required annual reductions in nonpoint sources in sub-watershed MFH-19. ..... D-20
Table D.38. Required annual reductions in direct nonpoint sources in sub-watershed MFH-19. ..... D-20
Table D.39. Required annual reductions in nonpoint sources in sub-watershed MFH-20. ..... D-21
Table D.40. Required annual reductions in direct nonpoint sources in sub-watershed MFH-20. ..... D-21
Table D.41. Required annual reductions in nonpoint sources in sub-watershed MFH-21. ..... D-22
Table D.42. Required annual reductions in direct nonpoint sources in sub-watershed MFH-21. ..... D-22
Table D.43. Required annual reductions in nonpoint sources in sub-watershed MFH-22. ..... D-23
Table D.44. Required annual reductions in direct nonpoint sources in sub-watershed MFH-22. ..... D-23
Table D.45. Required annual reductions in nonpoint sources in sub-watershed MFH-23. ..... D-24
Table D.46. Required annual reductions in direct nonpoint sources in sub-watershed MFH-23. ..... D-24
Table D.47. Required annual reductions in nonpoint sources in sub-watershed MFH-24. ..... D-25
Table D.48. Required annual reductions in direct nonpoint sources in sub-watershed MFH-24. ..... D-25
Table D.49. Required annual reductions in nonpoint sources in sub-watershed MFH-25. ..... D-26
Table D.50. Required annual reductions in direct nonpoint sources in sub-watershed MFH-25. ..... D-26
Table D.51. Required annual reductions in nonpoint sources in sub-watershed MFH-26. ..... D-27
Table D.52. Required annual reductions in direct nonpoint sources in sub-watershed MFH-26. ..... D-27
Table D.53. Required annual reductions in nonpoint sources in sub-watershed MFH-27. ..... D-28
Table D.54. Required annual reductions in direct nonpoint sources in sub-watershed MFH-27. ..... D-28
Table D.55. Required annual reductions in nonpoint sources in sub-watershed MFH-28. ..... D-29
Table D.56. Required annual reductions in direct nonpoint sources in sub-watershed MFH-28. ..... D-29
Table D.57. Required annual reductions in nonpoint sources in sub-watershed MFH-29. ..... D-30
Table D.58. Required annual reductions in direct nonpoint sources in sub-watershed MFH-29. ..... D-30
Table D.59. Required annual reductions in nonpoint sources in sub-watershed MFH-30. ..... D-31
Table D.60. Required annual reductions in direct nonpoint sources in sub-watershed MFH-30. ..... D-31
Table D.61. Required annual reductions in nonpoint sources in sub-watershed MFH-31. ..... D-32

Table D.62. Required annual reductions in direct nonpoint sources in sub-watershed MFH-31. ..... D-32
Table D.63. Required annual reductions in nonpoint sources in sub-watershed MFH-32. ..... D-33
Table D.64. Required annual reductions in direct nonpoint sources in sub-watershed MFH-32. ..... D-33

List of Figures

Figure 2.1. Fecal coliform concentrations (VADEQ station 6CMFH013.21) in the Middle Fork Holston River watershed. 2-3
Figure 2.2. Fecal coliform concentrations (VADEQ station 6-CMFH026.00) in the Middle Fork Holston River watershed. 2-4
Figure 2.3. Fecal coliform concentrations (VADEQ station 6-CMFH027.14) in the Middle Fork Holston River watershed. 2-4
Figure 2.4. Fecal coliform concentrations (VADEQ station 6-CMFH033.40) in the Middle Fork Holston River watershed. 2-5
Figure 2.5. Fecal coliform concentrations (VADEQ station 6-CMFH040.67) in the Middle Fork Holston River watershed. 2-5
Figure 2.6. Fecal coliform concentrations (VADEQ station 6-CMFH045.72) in the Middle Fork Holston River watershed. 2-6
Figure 2.7. Fecal coliform concentrations (VADEQ station 6-CMFH053.36) in the Middle Fork Holston River (VAS-O03R_MFH04A98) impairment. 2-6
Figure 2.8. Impact of seasonality on fecal coliform concentrations (VADEQ station 6-CMFH013.21) in the Middle Fork Holston River watershed from January 1990 through December 2007. 2-8
Figure 2.9. Impact of seasonality on fecal coliform concentrations (VADEQ station 6-CMFH026.00) in the Middle Fork Holston River watershed from January 1990 through December 2007. 2-9
Figure 2.10. Impact of seasonality on fecal coliform concentrations (VADEQ station 6-CMFH027.14) in the Middle Fork Holston River watershed from January 1990 through December 2007. 2-9
Figure 2.11. Impact of seasonality on fecal coliform concentrations (VADEQ station 6-CMFH033.40) in the Middle Fork Holston River watershed from January 1990 through December 2007. 2-10
Figure 2.12. Impact of seasonality on fecal coliform (VADEQ station 6-CMFH040.67) in the Middle Fork Holston River watershed from January 1990 through December 2007. 2-10
Figure 2.13. Impact of seasonality on fecal coliform (VADEQ station 6-CMFH045.72) in the Middle Fork Holston River watershed from January 1990 through December 2007. 2-11
Figure 2.14. Impact of seasonality on fecal coliform (VADEQ station 6-CMFH053.36) in the Middle Fork Holston River watershed from January 1990 through December 2007. 2-11
Figure 2.15. *E. coli* concentrations (VADEQ station 6-CMFH013.21) in the Middle Fork Holston River watershed. 2-12
Figure 2.16. *E. coli* concentrations (VADEQ station 6-CMFH033.40) in the Middle Fork Holston River watershed. 2-13
Figure 2.17. *E. coli* concentrations (VADEQ station 6-CMFH040.67) in the Middle Fork Holston River watershed. 2-13
Figure 2.18. *E. coli* concentrations (VADEQ station 6-CMFH045.72) in the Middle Fork Holston River watershed. 2-14
Figure 2.19. VSCI scores from monitoring stations 6-CMFH004.00, 6-CMFH011.31, 6-CMFH023.41, 6-CMFH032.39, and 6-CMFH045.83 in Middle Fork Holston River..... 2-17
Figure 2.20. Average, minimum, and maximum habitat scores at monitoring station 6CMFH004.00 in Middle Fork Holston River. 2-30
Figure 2.21. Average, minimum, and maximum habitat scores at monitoring station 6CMFH011.31 in Middle Fork Holston River. 2-31

Figure 2.22. Average, minimum, and maximum habitat scores at monitoring station 6CMFH032.39 in Middle Fork Holston River. 2-32
Figure 2.23. Average, minimum, and maximum habitat scores at monitoring station 6CMFH045.83 in Middle Fork Holston River. 2-33
Figure 2.24. Field pH values at water quality monitoring stations in Middle Fork Holston River. 2-39
Figure 2.25. Specific conductance values at water quality monitoring stations in Middle Fork Holston River. 2-39
Figure 2.26. Dissolved oxygen values at water quality monitoring stations in Middle Fork Holston River. 2-40
Figure 2.27. Temperature values at water quality monitoring stations in Middle Fork Holston River. 2-40
Figure 2.28. Turbidity values at water quality monitoring stations in Middle Fork Holston River. 2-41
Figure 2.29. Total solids values at water quality monitoring stations in Middle Fork Holston River. 2-41
Figure 2.30. Total suspended solids (TSS) values at water quality monitoring stations in Middle Fork Holston River. 2-42
Figure 2.31. Volatile solids values at water quality monitoring stations in Middle Fork Holston River. 2-42
Figure 2.32. Volatile suspended solids values at water quality monitoring stations in Middle Fork Holston River. 2-43
Figure 2.33. Total dissolved solids values at water quality monitoring stations in Middle Fork Holston River. 2-43
Figure 2.34. Biochemical oxygen demand (BOD_5) values at water quality monitoring stations in Middle Fork Holston River. 2-44
Figure 2.35. Chemical oxygen demand values at water quality monitoring stations in Middle Fork Holston River. 2-44
Figure 2.36. Total nitrogen values at water quality monitoring stations in Middle Fork Holston River. 2-50
Figure 2.37. Ammonia values at water quality monitoring stations in Middle Fork Holston River. 2-50
Figure 2.38. Nitrite values at water quality monitoring stations in Middle Fork Holston River. 2-51
Figure 2.39. Nitrate values at water quality monitoring stations in Middle Fork Holston River. 2-51
Figure 2.40. Total kjeldahl nitrogen values at water quality monitoring stations in Middle Fork Holston River. 2-52
Figure 2.41. Total phosphorous values at water quality monitoring stations in Middle Fork Holston River. 2-52
Figure 2.42. Ortho-phosphate values at water quality monitoring stations in Middle Fork Holston River. 2-53
Figure 2.43. Alkalinity values at water quality monitoring stations in Middle Fork Holston River. 2-53
Figure 2.44. Hardness values at water quality monitoring stations in Middle Fork Holston River. 2-54
Figure 2.45. Chloride values at water quality monitoring stations in Middle Fork Holston River. 2-54
Figure 2.46. Fluoride values at water quality monitoring stations in Middle Fork Holston River. 2-55

Figure 2.47. Sulfate values at water quality monitoring stations in Middle Fork Holston River. 2-55
Figure 2.48. Sedimentary aluminum values at water quality monitoring stations in Middle Fork Holston River. 2-63
Figure 2.49. Sedimentary antimony values at water quality monitoring stations in Middle Fork Holston River. 2-63
Figure 2.50. Total arsenic values at water quality monitoring stations in Middle Fork Holston River. 2-64
Figure 2.51. Sedimentary arsenic values at water quality monitoring stations in Middle Fork Holston River. 2-64
Figure 2.52. Total beryllium values at water quality monitoring stations in Middle Fork Holston River. 2-65
Figure 2.53. Sedimentary beryllium values at water quality monitoring stations in Middle Fork Holston River. 2-65
Figure 2.54. Total cadmium values at water quality monitoring stations in Middle Fork Holston River. 2-66
Figure 2.55. Sedimentary cadmium values at water quality monitoring stations in Middle Fork Holston River. 2-66
Figure 2.56. Total chromium values at water quality monitoring stations in Middle Fork Holston River. 2-67
Figure 2.57. Sedimentary chromium values at water quality monitoring stations in Middle Fork Holston River. 2-67
Figure 2.58. Total copper values at water quality monitoring stations in Middle Fork Holston River. 2-68
Figure 2.59. Sedimentary copper values at water quality monitoring stations in Middle Fork Holston River. 2-68
Figure 2.60. Total iron values at water quality monitoring stations in Middle Fork Holston River. 2-69
Figure 2.61. Sedimentary iron values at water quality monitoring stations in Middle Fork Holston River. 2-69
Figure 2.62. Total lead values at water quality monitoring stations in Middle Fork Holston River. 2-70
Figure 2.63. Sedimentary lead values at water quality monitoring stations in Middle Fork Holston River. 2-70
Figure 2.64. Total magnesium values at water quality monitoring stations in Middle Fork Holston River. 2-71
Figure 2.65. Total manganese values at water quality monitoring stations in Middle Fork Holston River. 2-71
Figure 2.66. Sedimentary manganese values at water quality monitoring stations in Middle Fork Holston River. 2-72
Figure 2.67. Total mercury values at water quality monitoring stations in Middle Fork Holston River. 2-72
Figure 2.68. Sedimentary mercury values at water quality monitoring stations in Middle Fork Holston River. 2-73
Figure 2.69. Total nickel values at water quality monitoring stations in Middle Fork Holston River. 2-73
Figure 2.70. Sedimentary nickel values at water quality monitoring stations in Middle Fork Holston River. 2-74
Figure 2.71. Total selenium values at water quality monitoring stations in Middle Fork Holston River. 2-74

Figure 2.72. Sedimentary selenium values at water quality monitoring stations in Middle Fork Holston River. 2-75
Figure 2.73. Sedimentary silver values at water quality monitoring stations in Middle Fork Holston River. 2-75
Figure 2.74. Total thallium values at water quality monitoring stations in Middle Fork Holston River. 2-76
Figure 2.75. Sedimentary thallium values at water quality monitoring stations in Middle Fork Holston River. 2-76
Figure 2.76. Total zinc values at water quality monitoring stations in Middle Fork Holston River. 2-77
Figure 2.77. Sedimentary zinc values at water quality monitoring stations in Middle Fork Holston River. 2-77
Figure 2.78. Sedimentary aldrin values at water quality monitoring stations in Middle Fork Holston River. 2-82
Figure 2.79. Sedimentary cdanedrytech values at water quality monitoring stations in Middle Fork Holston River. 2-82
Figure 2.80. Sedimentary DDD values at water quality monitoring stations in Middle Fork Holston River. 2-83
Figure 2.81. Sedimentary DDE values at water quality monitoring stations in Middle Fork Holston River. 2-83
Figure 2.82. Sedimentary DDT values at water quality monitoring stations in Middle Fork Holston River. 2-84
Figure 2.83. Sedimentary dicofol values at water quality monitoring stations in Middle Fork Holston River. 2-84
Figure 2.84. Sedimentary dieldrin values at water quality monitoring stations in Middle Fork Holston River. 2-85
Figure 2.85. Sedimentary endrin values at water quality monitoring stations in Middle Fork Holston River. 2-85
Figure 2.86. Sedimentary heptachlorepoxide values at water quality monitoring stations in Middle Fork Holston River. 2-86
Figure 2.87. Sedimentary heptachlor values at water quality monitoring stations in Middle Fork Holston River. 2-86
Figure 2.88. Sedimentary PCB values at water quality monitoring stations in Middle Fork Holston River. 2-87
Figure 2.89. Sedimentary PCP values at water quality monitoring stations in Middle Fork Holston River. 2-87
Figure 2.90. Sedimentary toxaphene values at water quality monitoring stations in Middle Fork Holston River. 2-88
Figure 5.1. Middle Fork Holston River impairment subwatersheds. 5-3
Figure 5.2. Middle Fork Holston River watershed land use distribution. 5-6
Figure 5.3. Observed and modeled flows for the calibration period 1/1/03 to 12/31/07 at USGS station #03474000 in Middle Fork Holston River watershed. 5-13
Figure 5.4. Observed and modeled flows for the calibration period 1/1/03 to 12/31/07 at USGS station #03475000 in Middle Fork Holston River watershed. 5-14
Figure 5.5. Observed and modeled flows for the validation period 1/1/98 to 12/31/02 at USGS station #03474000 in Middle Fork Holston River watershed. 5-15
Figure 5.6. Observed and modeled flows for the validation period 1/1/98 to 12/31/02 at USGS station #03475000 in Middle Fork Holston River watershed. 5-16
Figure 5.7. Observed and modeled flows for representative storm (11/16/03-11/30/03) during calibration period at USGS station #03474000 in Middle Fork Holston River watershed. 5-17

Figure 5.8. Observed and modeled flows for representative storms (4/1/06-4/15/06) during calibration period at USGS station #03475000 in Middle Fork Holston River watershed. 5-17
Figure 5.9. Observed and modeled flows for a representative storm (3/27/01-4/15/01) during the validation period at USGS station #01626000 in Middle Fork Holston watershed. 5-18
Figure 5.10. Observed and modeled flows for a representative storm (4/15/98-5/1/98) during the validation period at USGS station #01627500 in Middle Fork Holston watershed. 5-18
Figure 5.11. Cumulative frequency curves for the calibration period 1/1/03 to 12/31/07 at USGS station #03474000 in Middle Fork Holston River watershed. 5-19
Figure 5.12. Cumulative frequency curves for the calibration period 1/1/03 to 12/31/07 at USGS station #03475000 in Middle Fork Holston River watershed. 5-19
Figure 5.13. Cumulative frequency curves for the validation period 1/1/98 to 12/31/02 at USGS station #03474000 in Middle Fork Holston River watershed. 5-20
Figure 5.14. Cumulative frequency curves for the validation period 1/1/98 to 12/31/02 at USGS station #03475000 in Middle Fork Holston River watershed. 5-20
Figure 5.15. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-02 in Middle Fork Holston River watershed. 5-26
Figure 5.16. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-09 in Middle Fork Holston River watershed. 5-27
Figure 5.17. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-14 in Middle Fork Holston River watershed. 5-28
Figure 5.18. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-20 in Middle Fork Holston River watershed. 5-29
Figure 5.19. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-21 in Middle Fork Holston River watershed. 5-30
Figure 5.20. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-22 in Middle Fork Holston River watershed. 5-31
Figure 5.21. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-29 in Middle Fork Holston River watershed. 5-32
Figure 5.22. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-09 in Middle Fork Holston River watershed. 5-33
Figure 5.23. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-14 in Middle Fork Holston River watershed. 5-34
Figure 5.24. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-20 in Middle Fork Holston River watershed. 5-35
Figure 5.25. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-21 in Middle Fork Holston River watershed. 5-36

Figure 5.26. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-21 in Middle Fork Holston River watershed. 5-37
Figure 5.27. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-22 in Middle Fork Holston River watershed. 5-38
Figure 5.28. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-29 in Middle Fork Holston River watershed. 5-39
Figure 6.1. Location of benthic impairment, reference watershed, and VADEQ monitoring stations. 6-2
Figure 7.1. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-01 to MFH-03 in the Middle Fork Holston River (VAS-O03R-01) watershed. 7-3
Figure 7.2. Daily average *E. coli* concentrations for subwatershed MFH-03 in Middle Fork Holston River (VAS-O03R-01) watershed. 7-4
Figure 7.3. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-04 to MFH-09 in the Middle Fork Holston River (VAS-O03R-02) watershed. 7-6
Figure 7.4. Monthly E. coli geometric mean concentrations for existing conditions in subwatersheds MFH-11 to MFH-14 in the Middle Fork Holston River (VAS-O03R-02) watershed. 7-7
Figure 7.5. Daily average *E. coli* concentrations for subwatershed MFH-14 in Middle Fork Holston River (VAS-O03R-02) watershed. 7-8
Figure 7.6. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-15 to MFH-21 in the Middle Fork Holston River (VAS-O04R-01) watershed. 7-10
Figure 7.7. Daily average *E. coli* concentrations for subwatershed MFH-21 in Middle Fork Holston River (VAS-O04R-01) watershed. 7-11
Figure 7.8. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-22 to MFH-26 in the Middle Fork Holston River (VAS-O05R-06) watershed. 7-13
Figure 7.9. Daily average E. coli concentrations for subwatershed MFH-26 in Middle Fork Holston River (VAS-O05R-06) watershed. 7-14
Figure 7.10. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-27 to MFH-32 in the Middle Fork Holston River (VAS-O05R-05) watershed. 7-16
Figure 7.11. Daily average *E. coli* concentrations for subwatershed MFH-32 in Middle Fork Holston River (VAS-O05R-05) watershed. 7-17
Figure 7.12. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-03) of Middle Fork Holston River (VAS-O03R-01) watershed, as affected by direct load changes. 7-19
Figure 7.13. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-03) of Middle Fork Holston River (VAS-O03R-01) watershed, as affected by land-based load changes. 7-20
Figure 7.14. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-03) of Middle Fork Holston River (VAS-O03R-01) watershed, as affected by direct load changes. 7-21
Figure 7.15. Results of impact analysis on maximum daily average E. coli concentration per month at outlet (subwatershed MFH-03) of Middle Fork Holston River (VAS-O03R-01) watershed, as affected by land-based load changes. 7-22

Figure 7.16. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-14) of Middle Fork Holston River (VAS-O03R-02) watershed, as affected by direct load changes. 7-24
Figure 7.17. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-14) of Middle Fork Holston River (VAS-O03R-02) watershed, as affected by land-based load changes. 7-25
Figure 7.18. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-14) of Middle Fork Holston River (VAS-O03R-02) watershed, as affected by direct load changes. 7-26
Figure 7.19. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-14) of Middle Fork Holston River (VAS-O03R-02) watershed, as affected by land-based load changes. 7-27
Figure 7.20. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-21) of Middle Fork Holston River (VAS-O04R-01) watershed, as affected by direct load changes. 7-29
Figure 7.21. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-21) of Middle Fork Holston River (VAS-O04R-01) watershed, as affected by land-based load changes. 7-30
Figure 7.22. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-21) of Middle Fork Holston River (VAS-O04R-01) watershed, as affected by direct load changes. 7-31
Figure 7.23. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-21) of Middle Fork Holston River (VAS-O04R-01) watershed, as affected by land-based load changes. 7-32
Figure 7.24. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-26) of Middle Fork Holston River (VAS-O05R-06) watershed, as affected by direct load changes. 7-34
Figure 7.25. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-26) of Middle Fork Holston River (VAS-O05R-06) watershed, as affected by land-based load changes. 7-35
Figure 7.26. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-26) of Middle Fork Holston River (VAS-O05R-06) watershed, as affected by direct load changes. 7-36
Figure 7.27. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-26) of Middle Fork Holston River (VAS-O05R-06) watershed, as affected by land-based load changes. 7-37
Figure 7.28. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-32) of Middle Fork Holston River (VAS-O05R-05) watershed, as affected by direct load changes. 7-39
Figure 7.29. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-32) of Middle Fork Holston River (VAS-O05R-05) watershed, as affected by land-based load changes. 7-40
Figure 7.30. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-32) of Middle Fork Holston River (VAS-O05R-05) watershed, as affected by direct load changes. 7-41
Figure 7.31. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-32) of Middle Fork Holston River (VAS-O05R-05) watershed, as affected by land-based load changes. 7-42
Figure 7.32. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from

successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O03R-01) impairment. 7-48
Figure 7.33. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O03R-02) impairment. 7-52
Figure 7.34. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O04R-01) impairment. 7-56
Figure 7.35. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O05R-06) impairment. 7-60
Figure 7.36. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O05R-05) impairment. 7-64
Figure 8.1. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O03R-01) impairment. 8-4
Figure 8.2. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O03R-02) impairment. 8-6
Figure 8.3. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O04R-01) impairment. 8-8
Figure 8.4. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O05R-06) impairment. 8-10
Figure 8.5. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O05R-05) impairment. 8-12

List of Acronyms

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

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

Executive Summary

Background

Middle Fork Holston River (VAS-O03R, O04R and O05R) was first listed as impaired streams in 2002 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2002) indicating that the recreational use goal and the aquatic life use goal (VAS-O05R) were not being met. The stream segments were further listed in 2004 and 2006 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ 2004, 2006) based on Virginia Department of Environmental Quality (VADEQ) monitoring data

The impaired portion of MFHR (VAS-O03R-01) delineated by VADEQ, is defined upstream by its confluence with Dutton Branch in Groseclose, VA and downstream by the mainstem confluence with Snaveley Branch, parallel to Route 11. This segment is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria standard at station 6-CMFH053.36.

The impaired portion of Middle Fork Holston River (VAS-O03R-02) delineated by VADEQ, is defined upstream by its confluence with Snavely Branch and downstream by confluence with Hungry Mother Creek in Marion, VA. This segment is in Smyth County and is very close to the headwaters of Middle Fork Holston River, parallel to Route 11. This segment is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria standard at station 6-CMFH045.72.

The impaired portion of Middle Fork Holston River (VAS-O04R-01) extends from Hungry Mother Creek confluence to Sulphur Spring Creek confluence. This section is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria standard at station 6-CMFH033.40.

The impaired portion of Middle Fork Holston River (VAS-O05R-06)) is delineated by VADEQ from Sulphur Spring Creek west of Chilhowie near Route 107 downstream to Byers Creek confluence. The segment is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria standard at station 6-CMFH026.00.

The impaired portion of Middle Fork Holston River (VAS-O05R-05) from Byers Creek confluence downstream to rivermile 12.06, including Mock Mill and Neff, is listed as impaired and not meeting the Recreational Use and Aquatic Life Use goals. The segment is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria and benthic standard at station 6-CMFH013.21 and 6CMFH011.31, respectively.

The Middle Fork Holston River (VAS-O03, 4, 5R) impairment watershed is located in Smyth and Washington Counties, VA with a small portion in Wythe County, VA. The Middle Fork Holston River begins in Smyth County near the community of Groseclose flowing southwest along the Interstate 81 corridor toward Marion and Chilhowie, crossing into Washington County and continuing downstream to the backwaters of the South Holston Lake.

The Middle Fork Holston River watershed is approximately 154,667 acres, predominately forest, constituting approximately 49% of the total watershed area. The remaining land uses are divided between pasture (41%), residential (9%), and cropland (0.8%).

VADEQ personnel monitored pollutant concentrations throughout Middle Fork Holston River watershed. Of the 48 water quality samples collected from January 2000 through December 2004 (the 2006 Section 303(d) 5-year listing period) at VADEQ station 6-CMFH013.21, twelve (25%) of the samples exceeded the water quality standard. Fifteen (50%) of the samples taken at VADEQ station 6-CMFH026.00 from January 2000 through December 2004 exceeded the water quality standard. Four (26.6%) of the fifteen samples taken at VADEQ station 6-CMFH027.17 exceeded the water quality standard. Fourteen (29.7%) of the forty seven samples taken at VADEQ station 6-CMFH033.40 exceeded the water quality standard. Eight (66%) of the twelve samples taken at VADEQ station 6-CMFH040.67, eight (29.6%) of the 27 samples taken at VADEQ station 6-CMFH045.72, and four (26.6%) of the fifteen samples taken at VADEQ station 6-CMFH053.36 were all determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2006 Section 305(b) water quality assessment report and was included in the 2006 Section 303(d) List of Impaired Waters (VADEQ, 2006).

Biological monitoring data was collected at five stations (stations 6-CMFH004.00, 6-CMFH011.31, 6-CMFH023.41, 6-CMFH032.39, and 6-CMFH045.83) from 1995 to present. The Virginia Stream Condition Index (VaSCI), based on eight bio-monitoring metrics, was utilized to assess samples collected at each station. Stream health scores, in the form of SCI values, range from 0-100. A maximum score of 100 represents the best benthic community sites. The threshold criterion defines "non-impaired" sites as those with a VaSCI of 60 or above, and "impaired" sites as those with a score below 60. Impaired conditions were observed at stations 6-CMFH004.00, 6CMFH023.41, and 6CMFH045.83 on Middle Fork Holston River. The biological assessments conducted on the Middle Fork Holston River indicate that some pollutant(s) is interfering with attainment of the General Standard, as impaired invertebrate communities have been observed in the listed segment of this river. Although biological assessments are indicative of the impacts of pollution, the specific pollutant(s) and source(s) are not necessarily known based on biological assessments alone.

Stressor Analysis

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

community, potential stressors, and intermediate steps or interactions that would be consistent in establishing a cause and effect relationship with each candidate cause. Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed. Depending on the weight of evidence available, each potential stressor was placed into one of the following three categories:

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

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

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

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

Pollutant Sources

Currently, there are 21 active point source discharges with a VPDES permit to discharge bacteria within the Middle Fork Holston River watershed. However, the majority of the fecal coliform load originates from nonpoint sources. Nonpoint sources of fecal coliform are primarily agricultural (i.e., land-applied animal waste, manure deposited directly on pastures by livestock, and a significant fecal coliform load due to cattle directly depositing manure in streams) with a significant load applied to residential and forest land use categories. Non-agricultural anthropogenic nonpoint sources of fecal coliform loadings include straight pipes, leaking sanitary sewer, failing septic systems, and pet waste. Wildlife contributes to fecal coliform loadings on all land uses, according to the acceptable habitat range for each species. The amounts of fecal coliform produced in different locations (e.g., confinement, pasture, forest) were estimated on a monthly basis to account for seasonal variability in wildlife habitat and livestock production and practices. Livestock management and production factors, such as the fraction of time cattle spend in confinement or in streams, the amount of manure storage, and spreading schedules, were considered on a monthly basis.

Sediment can be delivered to the stream from point sources, nonpoint sources, and the processes of scour and deposition (primarily a function of stream flow) in the stream. Sediment loadings from permitted sources are attributable to the total suspended solids (TSS) present in discharge effluent or stormwater runoff. There are 15 VPDES permitted facilities currently active or under application within the Lower Middle Fork Holston River watershed discharging TSS. Stormwater permits are divided between 17 industrial facilities. Sediment generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural,

forestry, mining, transportation, and residential land uses. During runoff events, sediment loading occurs from both pervious and impervious surfaces around the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. Vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, and land management practices influence this process. During periods without rainfall, dirt, dust and fine sediment build up on impervious areas through dry deposition, which is then subject to wash-off during rainfall events.

Modeling

The Hydrologic Simulation Program – Fortran (HSPF) was used to simulate the fate and transport of fecal coliform bacteria in the Middle Fork Holston River watershed. To identify localized sources of fecal coliform, the watersheds were divided into subwatersheds. These subdivisions were based primarily on homogeneity of land use. The Middle Fork Holston River model was calibrated using observed flow values from USGS station #03474000 on Middle Fork Holston River near Seven Mile Ford, VA and USGS station #003475000 on Middle Fork Holston River near Mock Mill, VA for the period January 1, 2003 to December 31, 2007. The calibration period covered a wide range of hydrologic conditions, including low- and high-flow conditions, as well as seasonal variations. The calibrated HSPF model was validated on a separate period from January 1, 1998 to December 31, 2002. Calibration parameters were adjusted within the recommended ranges until the model performance was deemed acceptable. The period January 1, 1997 through December 31, 2001 was chosen for water quality calibration and January 1, 2002 through December 31, 2006 was chosen for water quality validation. Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring stations 6-CMFH053.36, 6-CMFH045.72, 6-CMFH040.67, 6-CMFH033.40, 6-CMFH027.14, 6-CMFH026.00, 6-CMFH013.21 within the Middle Fork Holston River impairment were used to calibrate the water quality component of HSPF. Inputs to the model included fecal coliform loadings on land and in the stream along with simulated flow data. A comparison of simulated and observed fecal coliform loadings in the stream indicated that the model adequately simulated the fate and transport of fecal coliform in the watershed.

A reference watershed approach was used to establish the numeric sediment TMDL endpoint for Middle Fork Holston River. The reference watershed approach pairs two watersheds – one whose streams are supportive of their designated uses and one whose streams are impaired. The reference watershed is selected on the basis of similarity of land use, topographical, ecological, and soils characteristics with those of the impaired watershed. This approach is based on the assumption that reduction of the stressor loads in the impaired watershed to the level of the loads in the reference watershed will result in elimination of the benthic impairment.

Results from biological monitoring at VADEQ station 6-CMFH032.39 have shown a healthy benthic community resulting in an un-impaired designation. The section above station 6-CMFH032.39 was labeled as the Upper Middle Fork Holston River watershed in this study. Due to similarity of land use, topographical, ecological, and soils characteristics, the Upper Middle Fork Holston River watershed was chosen as the reference watershed for sediment load

comparison. From this station to the impairment outlet was designated as the Lower Middle Fork Holston River watershed. The Generalized Watershed Loading Function (GWLF) model was used to simulate sediment load from potential sources in the impaired and reference watersheds.

Margin of Safety

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

TMDL Allocation Scenarios

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

After calibrating to the existing water quality conditions, different scenarios were evaluated to identify implementable scenarios that meet both the calendar-month geometric mean *E. coli* criterion (126 cfu/100 mL) and the single sample maximum *E. coli* criterion (235 cfu/100 mL) with zero exceedances. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality.

Required reductions in fecal coliform loading from existing conditions in the Middle Fork Holston River (VAS-O03R-01) impairment for the selected TMDL allocation include a 100% reduction in straight pipes, 97% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 97% reduction in nonpoint source loadings to residential land use, a 97% reduction in nonpoint source loadings to pasture land use, a 97% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land use.

Required reductions in fecal coliform loading from existing conditions in the Middle Fork Holston River (VAS-O03R-02) impairment for the selected TMDL allocation include a 100% reduction in straight pipes, 96% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 96% reduction in nonpoint source loadings to residential land use, a 96% reduction in nonpoint source loadings to pasture land use, a 96% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land use.

Required reductions in fecal coliform loading from existing conditions in the Middle Fork Holston River (VAS-O04R-01) impairment for the selected TMDL allocation include a 100% reduction in straight pipes, 98% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 98% reduction in nonpoint source loadings to residential land use, a 98%

reduction in nonpoint source loadings to pasture land use, a 98% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land use.

Required reductions in fecal coliform loading from existing conditions in the Middle Fork Holston River (VAS-O05R-06) impairment for the selected TMDL allocation include a 100% reduction in straight pipes, 98% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 98% reduction in nonpoint source loadings to residential land use, a 98% reduction in nonpoint source loadings to pasture land use, a 98% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land use.

Required reductions in fecal coliform loading from existing conditions in the Middle Fork Holston River (VAS-O05R-05) impairment for the selected TMDL allocation include a 100% reduction in straight pipes, 98% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 98% reduction in nonpoint source loadings to residential land use, a 98% reduction in nonpoint source loadings to pasture land use, a 98% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land use.

Sediment load allocations for nonpoint sources not covered under the general wastewater permits were based on an equal percent reduction from controllable sources. Sediment loads from forest land use are considered to be representative of the natural condition and were not subject to reductions. Overall, the sediment load in the Lower Middle Fork Holston River watershed must be reduced by 60% in order to meet the established TMDL endpoint. This translates to a 62% reduction in sediment from cropland, pasture, transitional, and residential land uses; along with sediment from channel erosion.

Using equation [E.1], summaries of the Middle Fork Holston River bacteria and sediment TMDLs for the selected allocation scenario are shown in Tables E.1 through E.12.

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

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

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

Impairment	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
MF Holston River (VAS-O03R-01)	5.29E+10	5.24E+12	Implicit	5.29E+12
MF Holston River (VAS-O03R-02)	2.61E+10	2.43E+13	Implicit	2.43E+13
MF Holston River (VAS-O04R-01)	3.56E+13	4.70E+12	Implicit	4.03E+13
MF Holston River (VAS-O05R-06)	1.04E+13	3.09E+13	Implicit	4.13E+13
MF Holston River (VAS-O05R-05)	7.62E+12	1.30E+13	Implicit	2.06E+13

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

Pollutant	WLA (cfu/d)	LA (cfu/d)	MOS	TMDL (cfu/d)
MF Holston River (VAS-O03R-01)	1.45E+08	1.30E+12	Implicit	1.30E+12
MFHolston River (VAS-O03R-02)	7.15E+07	4.52E+12	Implicit	4.52E+12
MFHolston River (VAS-O04R-01)	9.75E+10	7.99E+12	Implicit	8.09E+12
MFHolston River (VAS-O05R-06)	2.85E+10	9.36E+12	Implicit	9.39E+12
MFHolston River (VAS-O05R-05)	2.09E+10	4.04E+12	Implicit	4.06E+12

Table E.3. Yearly sediment loads (T/yr) modeled after TMDL allocation in Lower Middle Fork Holston River impairment.

WLA (T/yr)	LA (T/yr)	MOS (T/yr)	TMDL (T/yr)
100.4	1,448.8	198.0	1,747.2

Table E.4. Daily sediment loads (T/d) modeled after TMDL allocation in Lower Middle Fork Holston River impairment.

WLA (T/d)	LA (T/d)	MOS (T/d)	TMDL (T/d)
0.37	8.83	1.02	10.22

TMDL Implementation and Reasonable Assurance

The goal of the TMDL program is to establish a three-step process that will enable the attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria and benthic impairments on Middle Fork Holston River. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and monitor stream water quality to determine if water quality standards are being attained. Watershed stakeholders will have the opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

Following the development of the TMDL, the VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up

monitoring station(s) will be the same as the listing station. VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants, “water quality milestones” as established in the implementation plan, the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations. Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the watershed.

Staged implementation is a key component to restoring water quality in Middle Fork Holston River. An alternative scenario was evaluated to establish goals for the first implementation stage of the bacteria TMDL. The implementation of such a transitional scenario, or Stage 1 implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through continued data collection. The bacteria Stage 1 implementation goal was to provide an instantaneous standard exceedance rate below 10%, a geometric mean standard exceedance rate of 0%, and 0% reduction in wildlife loads. These exceedance rate criteria mirror the new proposed bacteria standard meeting a 10% exceedance rate of the single sample maximum criterion (235 cfu/100ml) and a 0% exceedance rate of the geometric mean criterion (126 cfu/100 ml).

The Stage 1 allocation for the Middle Fork Holston River (VAS-O03R-01) impairment requires a 100% reduction in straight pipes, 75% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 36% reduction in nonpoint source loadings to residential land use, a 36% reduction in nonpoint source loadings to pasture land use, a 36% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.47% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate.

The Stage 1 allocation for the Middle Fork Holston River (VAS-O03R-02) impairment requires a 100% reduction in straight pipes, 77% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 77% reduction in nonpoint source loadings to residential land use, a 77% reduction in nonpoint source loadings to pasture land use, a 77% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.96% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate.

The Stage 1 allocation for the Middle Fork Holston River (VAS-O04R-01) impairment requires a 100% reduction in straight pipes, 79% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 79% reduction in nonpoint source loadings to residential land use, a 79% reduction in nonpoint source loadings to pasture land use, a 79% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.41% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate.

The Stage 1 allocation for the Middle Fork Holston River (VAS-O05R-06) impairment requires a 100% reduction in straight pipes, 98% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 96% reduction in nonpoint source loadings to residential land use, a 96% reduction in nonpoint source loadings to pasture land use, a 96% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 5.20% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate.

The Stage 1 allocation for the Middle Fork Holston River (VAS-O05R-05) impairment requires a 100% reduction in straight pipes, 75% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 53% reduction in nonpoint source loadings to residential land use, a 53% reduction in nonpoint source loadings to pasture land use, a 53% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 6.90% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate.

After the proposed bacteria standard is adopted by the Virginia Water Control Board, the Stage I implementation scenario will become the TMDL allocation scenario, since it will meet the new revised standard.

Public Participation

During development of the Middle Fork Holston River Bacteria and Benthic TMDL, public participation was encouraged through two public meetings and two Technical Advisory Committee meetings. The first public meeting was held at the Glade Spring Community Center in Glade Spring, VA on August 7, 2008 to discuss the need for a TMDL, discuss the draft watershed source assessment, and review the approach for TMDL development. The final public meeting was held at the Glade Spring Community Center in Glade Spring, VA on July 28, 2009, to discuss the source allocations and reductions required to meet the TMDL. Copies of the draft TMDL report were available for public review and comment.

In addition to keeping the public apprised of progress in the development of the Middle Fork Holston River TMDL, a TMDL Technical Advisory Committee was also established to help advise the TMDL developers. Technical Advisory Committee meetings were held prior to public meetings. Technical Advisory Committee meetings were held for this project on June 17, 2008 and July 20, 2009 at the Mount Rogers Planning District Commission in Marion, VA. The general public was solicited to participate on the Technical Advisory Committee during the first public meeting in addition to agencies and groups already represented on the Technical Advisory Committee. The Technical Advisory Committee membership for the Middle Fork Holston River Bacteria and Benthic TMDL included representatives from the following agencies and organizations: Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation, Virginia Cooperative Extension, Virginia Department of Health, Mount Rogers Planning District Commission, Holston River Soil and Water Conservation District, Smyth County, and Washington County.

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

Project Personnel

Virginia Department of Environmental Quality (VADEQ):

- David Lazarus
- Shelley D. Williams

Virginia Department of Conservation and Recreation (VADCR):

- Martha Chapman

Mount Rogers Planning District Commission:

- Toby Boian

Engineering Concepts, Inc.:

- Hal Bailey
- Byron Petrauskas
- Sean Dadson
- Ashleigh Marshall

Acknowledgements

Karl Huber, **Virginia Department of Conservation and Recreation**

Tom Bidrowski, **Virginia Department of Game and Inland Fisheries**

Randy Farrar, **Virginia Department of Game and Inland Fisheries**

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

Washington County Government

Smyth County County Government

Engineering Concepts, Inc. of Fincastle, Virginia supported this study as a contractor to Mount Rogers Planning District Commission through funding provided by the Virginia Department of Environmental Quality

Chapter 1. Introduction

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

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

1.1.2 Impairments Listing

Middle Fork Holston River (VAS-O03R, VAS-O04R and VAS-O05R) was first listed as impaired streams in 2002 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2002) indicating that the recreational use goal and the aquatic life use goal were not being met. The stream segments were further listed in 2004 and 2006 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ 2004, 2006) based on Virginia Department of Environmental Quality (VADEQ) monitoring data.

The impaired portion of Middle Fork Holston River (VAS-O03R-01) delineated by VADEQ, is defined upstream by its confluence with Dutton Branch in Groseclose, VA and downstream by the mainstem confluence with Snaveley Branch, parallel to Route 11. This segment is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria standard at station 6-CMFH053.36.

The impaired portion of Middle Fork Holston River (VAS-O03R-02) delineated by VADEQ, is defined upstream by its confluence with Snavely Branch and downstream by confluence with Hungry Mother Creek in Marion, VA. This segment is in Smyth County and is very close to the headwaters of Middle Fork Holston River, parallel to Route 11. This segment is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria standard at station 6-CMFH045.72.

The impaired portion of Middle Fork Holston River (VAS-O04R-01) extends from Hungry Mother Creek confluence to Sulphur Spring Creek confluence. This section is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria standard at station 6-CMFH033.40.

The impaired portion of Middle Fork Holston River (VAS-O05R-06) is delineated by VADEQ from Sulphur Spring Creek west of Chilhowie near Route 107 downstream to Byers

Creek confluence. The segment is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria standard at station 6-CMFH026.00.

The impaired portion of Middle Fork Holston River (VAS-O05R-05) from Byers Creek confluence downstream to rivermile 12.06, including Mock Mill and Neff, is listed as impaired and not meeting the Recreational Use and Aquatic Life Use goals. The segment is listed as impaired on Virginia's 2006 Section 303(d) TMDL Priority List and Report (VADEQ, 2006) due to water quality exceedances of the bacteria and benthic standard at station 6-CMFH013.21 and 6CMFH011.31, respectively.

1.1.3 Watershed Location and Description

The Middle Fork Holston River impairment watershed is located in Smyth and Washington Counties, Viriginia with a small portion in Wythe County, VA (Figure 1.1). The Middle Fork Holston River begins in Smyth County near the community of Groseclose flowing southwest along the Interstate 81 corridor toward Marion and Chilhowie, crossing into Washington County and continuing downstream to the backwaters of the South Holston Lake.

The Middle Fork Holston River watershed is approximately 154,667 acres, predominately forest, constituting approximately 49% of the total watershed area. The remaining land uses are divided between pasture (41%), residential (9%), and cropland (0.8%).

For the benthic TMDL, the watershed was divided into the Upper Middle Fork Holston River and Lower Middle Fork Holston River watersheds. The section above station 6-CMFH032.39 was labeled as the Upper Middle Fork Holston River watershed. The section from station 6-CMFH032.39 to the impairment outlet was designated as the Lower Middle Fork Holston River watershed.

1.1.4 Pollutant of Concern

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

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

1.2 Designated Uses and Applicable Water Quality Standards

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

> "A. All state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)." (SWCB, 2002)

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

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

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

- **Interim Fecal Coliform Standard:** Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water.
- **Escherichia coli Standard:** *E. coli* bacteria concentrations for freshwater shall not exceed a geometric mean of 126 counts per 100 mL for two or more samples taken during any calendar month and shall not exceed an instantaneous single sample maximum of 235 cfu/100mL.

During an assessment period, conventional parameters such as bacteria require at least two exceedences of the standard, and an exceedance of greater than 10.5% of the total samples before a water is listed as impaired (VADEQ Assessment Guidance, 2006). If these conditions are met, the stream segment associated with that station is classified as impaired

and a TMDL must be developed and implemented to bring the segment into compliance with the water quality standard. The original impairment designation to Middle Fork Holston River was based on exceedances of an earlier fecal coliform standard that included a numeric single sample maximum limit of 1,000 cfu/100 mL. The bacteria TMDL for these impaired segments was developed to meet the *E. coli* standard. As recommended by VADEQ, the modeling was conducted with fecal coliform inputs, and then a translator equation developed by the VADEQ was used to convert the output of the model to *E. coli*.

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

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

> "A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.
>
> Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled." (SWCB, 2002)

The VADEQ conducts the biological monitoring program in Virginia used to evaluate compliance with the General standard. Evaluations of monitoring data to determine whether or not a stream segment has a benthic impairment focus on benthic macro-invertebrates (i.e., bottom-dwelling; visible to eyes; insects, mollusks, crustaceans, and annelid worms). Changes in water quality generally result in alterations to the quantity and diversity of the benthic organisms that live in streams and other water bodies. Besides being the major intermediate constituent of the aquatic food chain, benthic macro-invertebrates are "living recorders" of past and present water quality conditions. This is due to their relative immobility and their variable resistance to the diverse contaminants that are introduced into streams. The community structure of these organisms provides the basis for the biological analysis of water quality. Qualitative and semi-quantitative biological monitoring has been conducted by VADEQ since the early 1970's.

From 1990 to 2006, the U.S. Environmental Protection Agency's (USEPA) Rapid Bioassessment Protocol II (RBP II) was the official protocol used to assess compliance with the general standard in Virginia (Barbour et al., 1999). The RBP II was employed beginning in the fall of 1990 to utilize standardized and repeatable assessment methodology. For any single sample, the RBP II produces water quality ratings of "non-impaired," "slightly impaired," "moderately impaired," or "severely impaired." In Virginia, benthic samples are typically collected and analyzed twice a year in the spring and in the fall. The RBP II procedure evaluates the benthic macro-invertebrate community by comparing ambient monitoring "network" stations to "reference" sites. Reference bio-monitoring stations have been identified by regional biologists that are both representative of regional physiographic and ecological conditions and have a healthy, non-impaired benthic community. The RBP II evaluation also accounts for the natural

variation noted in streams in different ecoregions. One additional product of the RBP II evaluation is a habitat assessment. This is a stand alone assessment that describes bank condition and other stream and riparian corridor characteristics and serves as a measure of habitat suitability for the benthic community. Determination of the degree of support for the aquatic life designated use is based on biological monitoring data and the best professional judgment of the regional biologist, relying primarily on the most recent data collected during the current 5-year assessment period. In Virginia, any stream segment with an overall rating of "moderately impaired" or "severely impaired" is placed on the state's 303(d) list of impaired streams (DEQ, 2002).

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

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

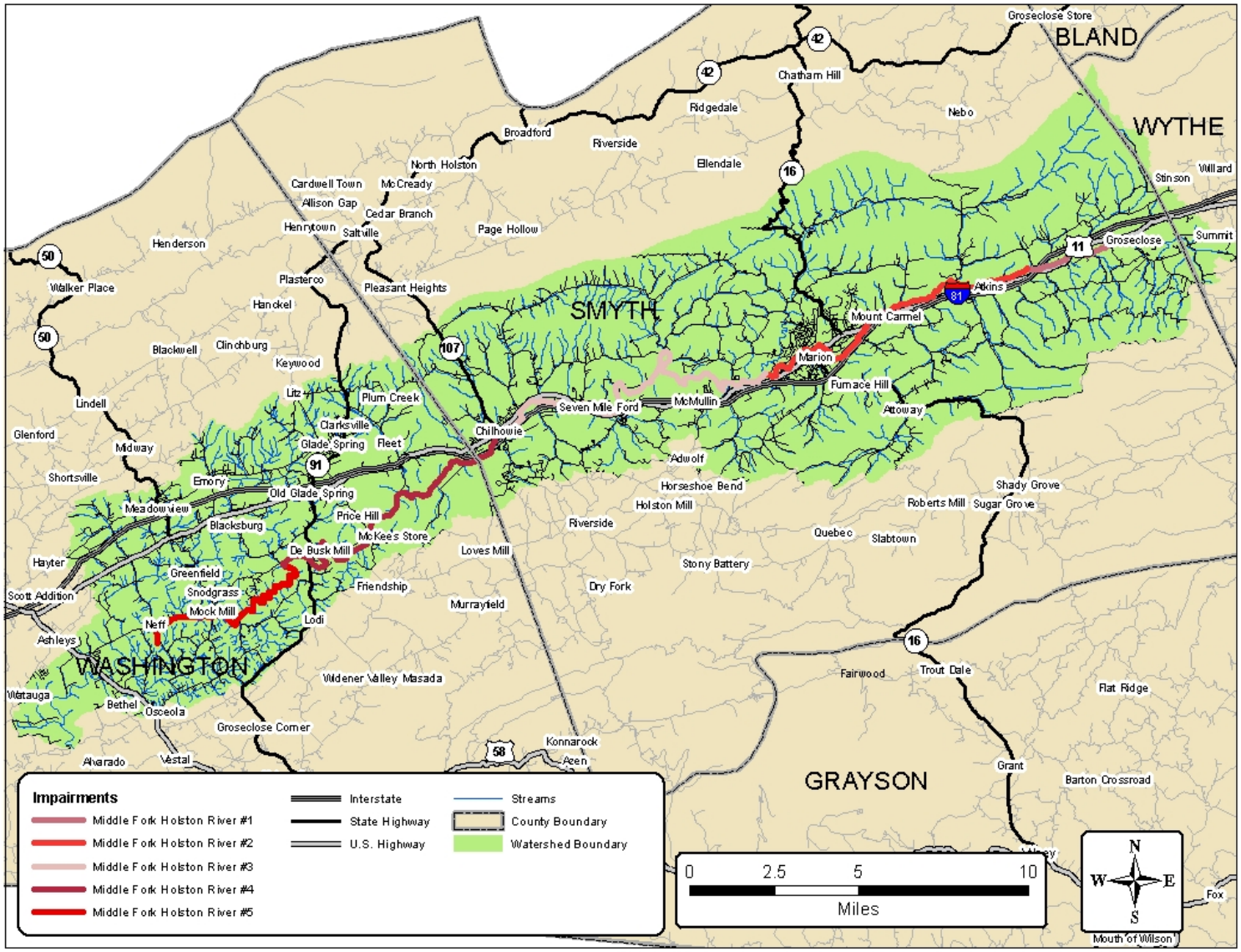


Figure 1.1 Location of Middle Fork Holston River watershed.

Chapter 2. Watershed Characterization

2.1 Water Resources

The Middle Fork Holston River watershed was subdivided into sub-watersheds for fecal coliform modeling purposes, as discussed in Section 5.2. The Middle Fork Holston River runs approximately 45 miles from the headwaters near Groseclose, VA to the backwaters of the South Holston Lake. Middle Fork Holston River is a perennial stream with a trapezoidal channel cross-section.

2.2 Ecoregion

The watershed of the Middle Fork Holston River impairments lies in the Northern Ridge and Valley Ecoregion of Virginia. The Northern Ridge and Valley Ecoregion is a northeast-southwest trending, relatively low-lying, but diverse ecoregion sandwiched between generally higher, and more rugged mountainous regions with greater forest cover. As a result of extreme folding and faulting events, the region's roughly parallel ridges and valleys have a variety of widths, heights, and geologic materials, including limestone, dolomite, shale, siltstone, sandstone, chert, mudstone, and marble. Springs and caves are relatively numerous. Present-day forests cover about 50% of the region. The ecoregion has a diversity of aquatic habitats and species of fish.

2.3 Climate

The climate of the Middle Fork Holston River watershed is characterized based on the meteorological observations from 1/ 1/1893 to 12/31/2008 assembled by the Southeast Regional Climate Center for the Wytheville Post Office, Virginia (449301) station. Average annual precipitation is 40.1 inches with 55.3% of the precipitation occurring during the crop-growing season (May-October) (SERCC, 2009). Average annual snowfall is 17.2 inches with the highest snowfall occurring during January (SERCC, 2004). Average annual daily temperature is 64.1°F. The highest average daily temperature of 83.3°F occurs in July while the lowest average daily temperature of 22.8°F occurs in January (SERCC, 2009).

2.4 Land Use

General depiction of land use draining to the impairment is outlined in Section 1.1.3. Details of landuse used in this study are described in Section 5.3 with landuse per subwatershed listed in Table 5.2. For purposes of this study, it was assumed that residential development in the Middle Fork Holston River watershed will continue at the overall average rate of 1% annually.

2.5 Water Quality Data

2.5.1 Historic Data for Fecal Coliform

Of the 48 water quality samples collected from January 2000 through December 2004 (the 2006 Section 303(d) 5-year listing period) at VADEQ station 6-CMFH013.21, twelve (25%) of the samples exceeded the water quality standard (Table 2.1). Fifteen (50%) of the samples taken at VADEQ station 6-CMFH026.00 from January 2000 through December 2004 exceeded the water quality standard. Four (26.6%) of the fifteen samples taken at VADEQ station 6-CMFH027.17 exceeded the water quality standard. Fourteen (29.7%) of the forty seven samples taken at VADEQ station 6-CMFH033.40 exceeded the water quality standard. Eight (66%) of the twelve samples taken at VADEQ station 6-CMFH040.67, eight (29.6%) of the 27 samples taken at VADEQ station 6-CMFH045.72, and four (26.6%) of the fifteen samples taken at VADEQ station 6-CMFH053.36 were all determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2006 Section 305(b) water quality assessment report and was included in the 2006 Section 303(d) List of Impaired Waters (VADEQ, 2006).

Table 2.1. Impairment name, monitoring station with location, and fecal coliform and *E. coli* water quality standard exceedance rates.

TMDL ID	Monitoring Station	Station Location	2006 Exceedance Rate	
			Fecal Coliform Standard	*E. Coli Standard*
VAS-O03R-01	6-CMFH040.67	@ Marion, Holston Hills CC Off Rt 11	66% (8 of 12)	60% (4 of 6)
VAS-O03R-02	6-CMFH045.72	RT 693 BRIDGE OFF U.S. RT 11 APPROX 30 F	29.6% (8 of 27)	33% (2 of 3)
VAS-O04R-01	6-CMFH033.40	RT 645 BRIDGE AT INTERSECTION WITH RT 64	29.7% (14 of 47)	60% (12 of 20)
VAS-O05R-06	6-CMFH027.14	Near Chilhowie Off I-81 Exit 35 us STP	26.6% (4 of 15)	No data
VAS-O05R-06	6-CMFH026.00	OFF RT. 608 WASHIGTON, SMYTH CO. LINE	50% (15 of 30)	No data
VAS-O05R-05	6-CMFH013.21	RT 803 BRIDGE APPROXIMATELY 2 MILES WEST	25% (20 of 48)	40% (8 of 40)

VADEQ personnel monitored pollutant concentrations throughout the Middle Fork Holston River. Monitoring data with corresponding 6-day antecedent precipitation used in assessment of the impairments, as well as in this study, are included in Appendix A. Time series data of fecal coliform concentration from 1990 through 2008 collected at bacteria monitoring stations 6-CMFH013.21, 6-CMFH026.00, 6-CMFH027.14, 6-CMFH033.40, 6-CMFH040.67, 6-

CMFH045.72, and 6-CMFH053.36 in the Middle Fork Holston River are shown in Figures 2.1 through 2.7.

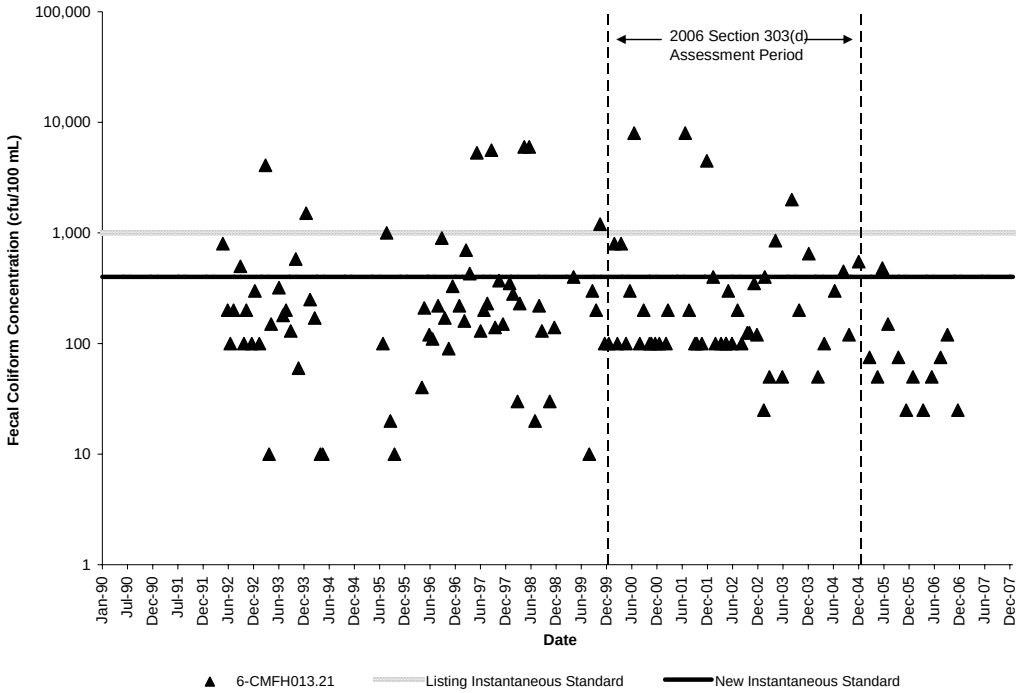


Figure 2.1. Fecal coliform concentrations (VADEQ station 6CMFH013.21) in the Middle Fork Holston River watershed.

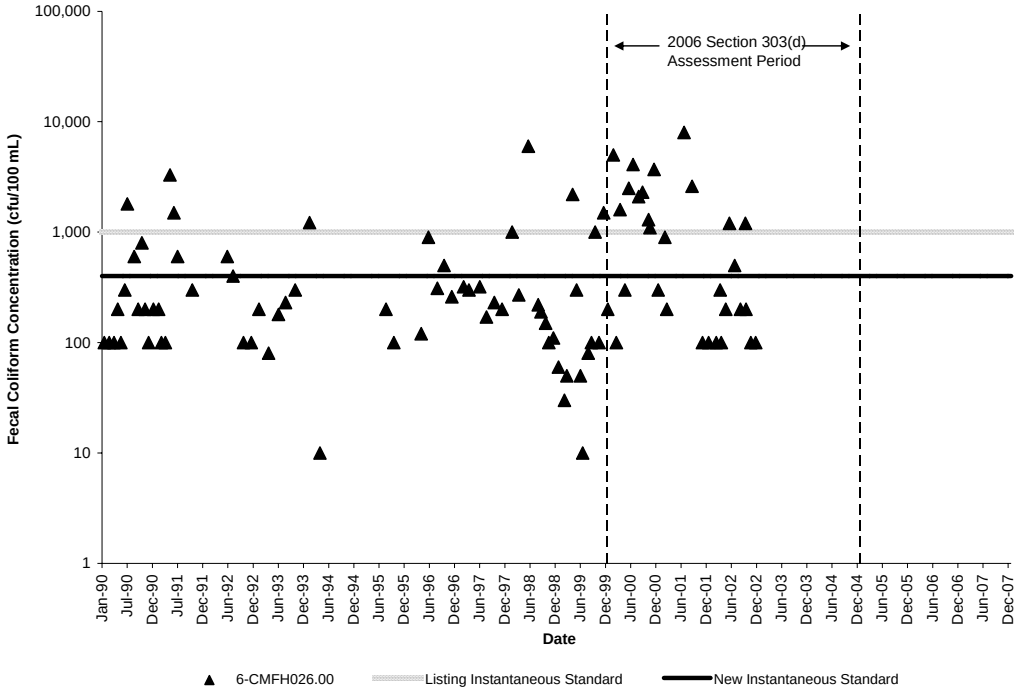


Figure 2.2. Fecal coliform concentrations (VADEQ station 6-CMFH026.00) in the Middle Fork Holston River watershed.

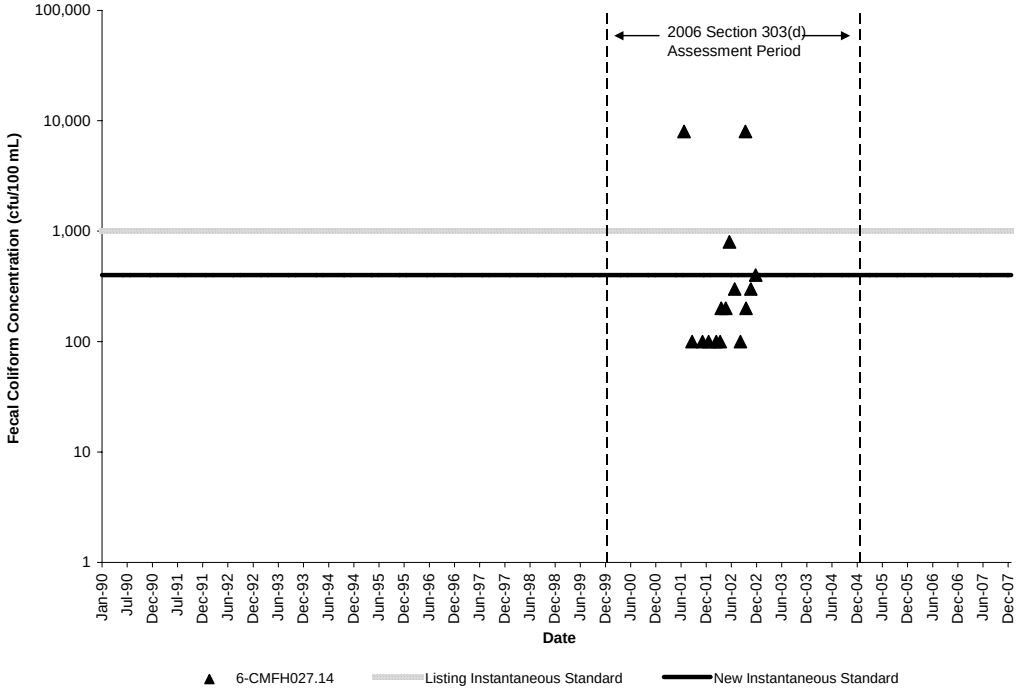


Figure 2.3. Fecal coliform concentrations (VADEQ station 6-CMFH027.14) in the Middle Fork Holston River watershed.

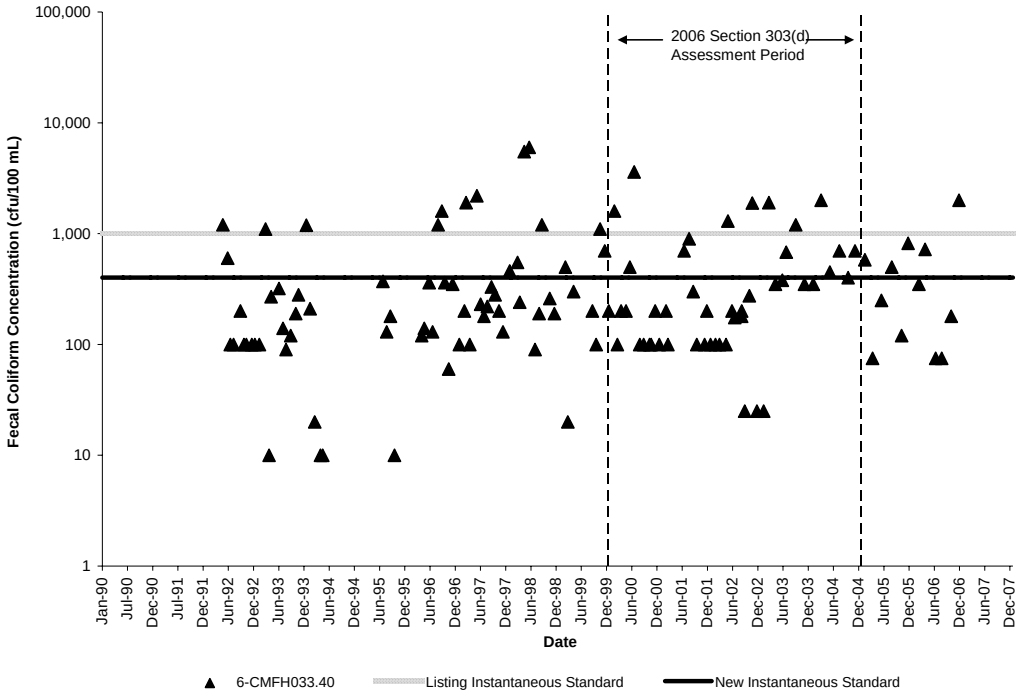


Figure 2.4. Fecal coliform concentrations (VADEQ station 6-CMFH033.40) in the Middle Fork Holston River watershed.

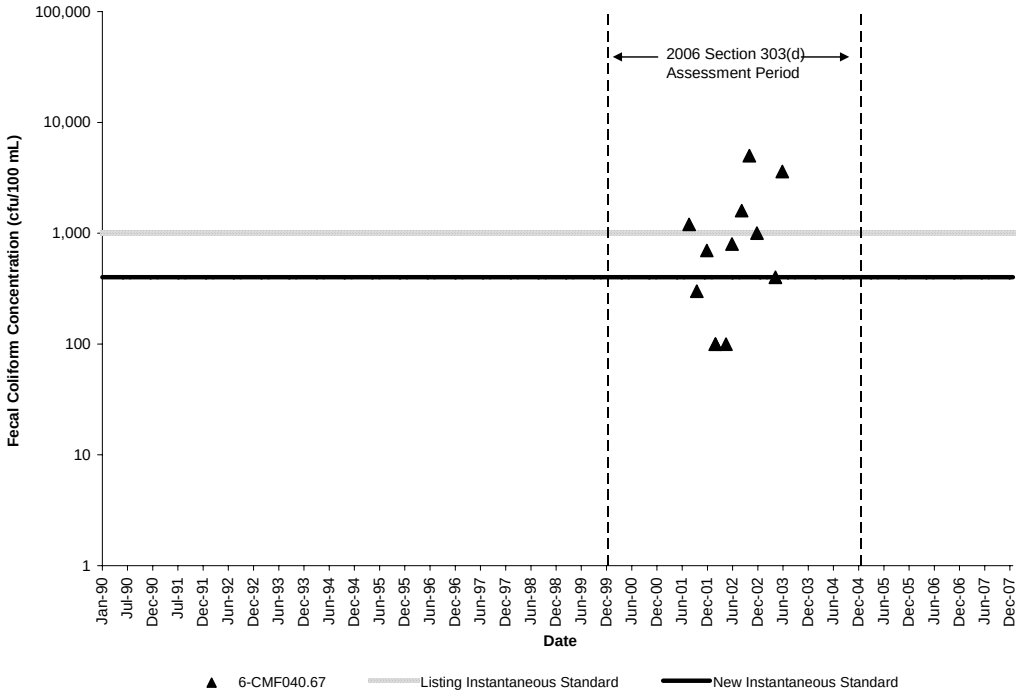


Figure 2.5. Fecal coliform concentrations (VADEQ station 6-CMFH040.67) in the Middle Fork Holston River watershed.

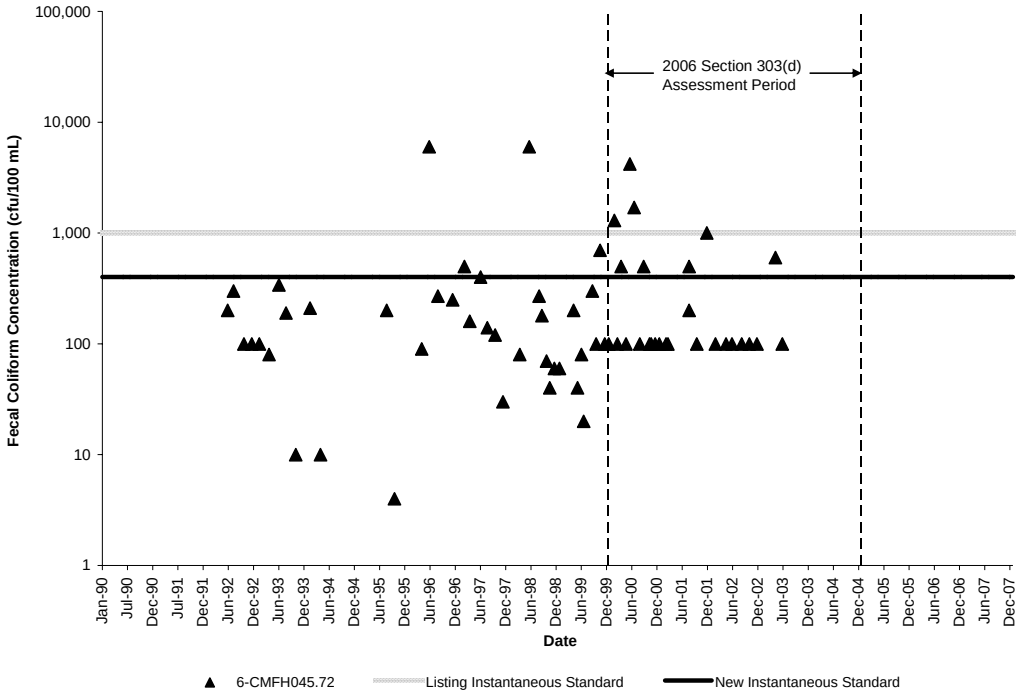


Figure 2.6. Fecal coliform concentrations (VADEQ station 6-CMFH045.72) in the Middle Fork Holston River watershed.

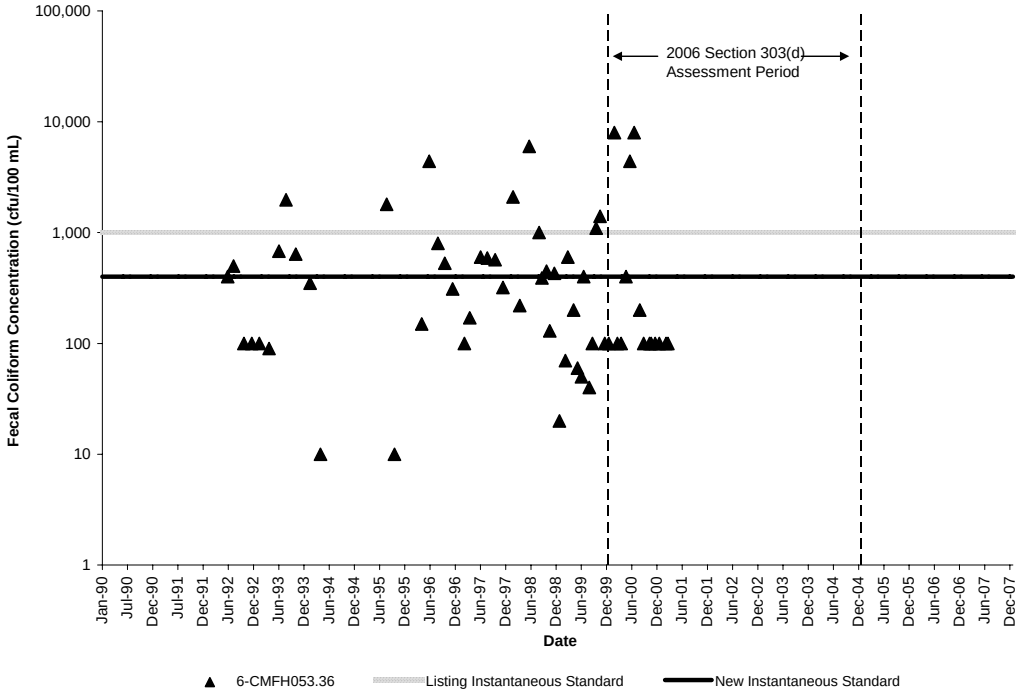


Figure 2.7. Fecal coliform concentrations (VADEQ station 6-CMFH053.36) in the Middle Fork Holston River impairment.

Seasonal variability of fecal coliform concentrations in the stream network was evaluated by plotting the mean monthly fecal coliform concentration values. Mean monthly fecal coliform concentration values were determined as the average of zero to 13 values for each month; the number of values varied according to the available number of samples for each month in the 1990 to 2007 period of record (Tables 2.2 and 2.3). A total of 511 samples were collected at seven stations in Midddle Fork Holston River. Mean monthly fecal coliform bacteria concentrations were plotted in Figures 2.8 - 2.14. Generally, the highest mean fecal coliform concentrations were recorded in the summer months. On average, the highest mean fecal coliform concentrations were observed in July followed by June and September. The maximum average was recorded in July at station 6-CMFH053.36.

Table 2.2. Number of samples collected per month from 1/1/90 to 12/31/06 in the Middle Fork Holston River impairments.

Month	Samples Collected at			
	6-CMFH013.21 (#)	**6-CMFH026.00 (#)**	**6-CMFH027.17 (#)**	**6-CMFH033.40 (#)**
January	10	6	1	11
February	10	10	1	8
March	11	6	1	11
April	12	10	1	10
May	10	5	1	11
June	11	10	1	10
July	12	6	2	12
August	12	10	1	13
September	12	6	2	12
October	11	11	1	11
November	11	6	2	11
December	10	8	1	10
TOTAL	**132**	**94**	**15**	**130**

Table 2.3. Number of samples collected per month from 1/1/90 to 12/31/06 in the Middle Fork Holston River impairments.

Month	Samples Collected at		
	6-CMFH040.67 (#)	6-CMFH045.72 (#)	6-CMFH053.36 (#)
January	0	3	3
February	2	7	7
March	0	3	3
April	2	9	7
May	0	2	2
June	2	9	7
July	0	2	2
August	2	11	8
September	0	3	3
October	2	9	8
November	0	3	3
December	2	8	6
TOTAL	**12**	**69**	**59**

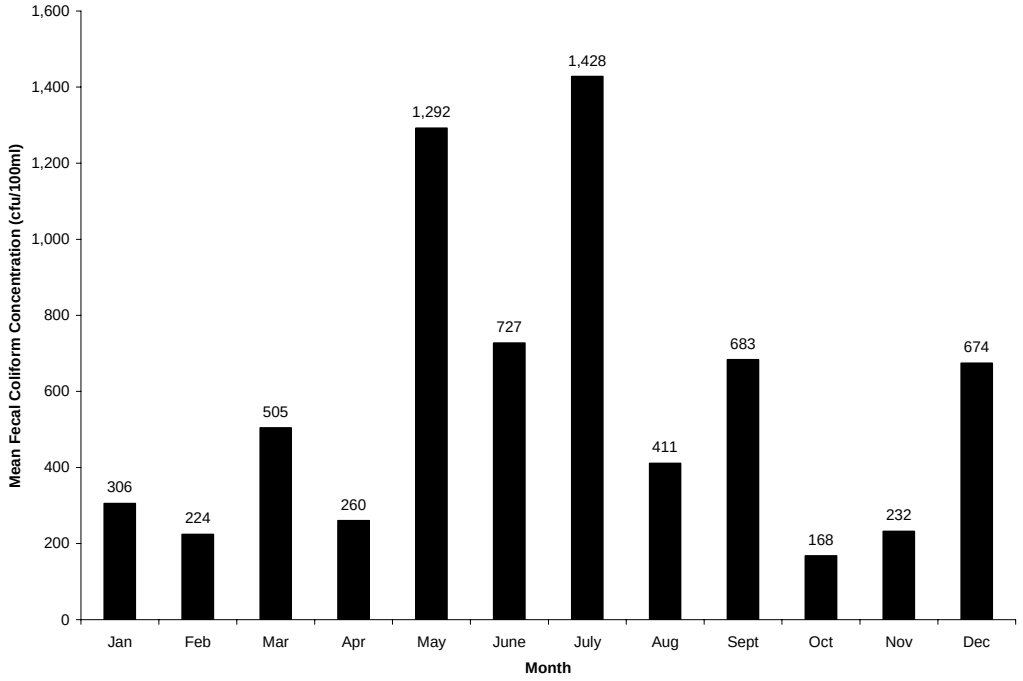


Figure 2.8. Impact of seasonality on fecal coliform concentrations (VADEQ station 6-CMFH013.21) in the Middle Fork Holston River watershed from January 1990 through December 2007.

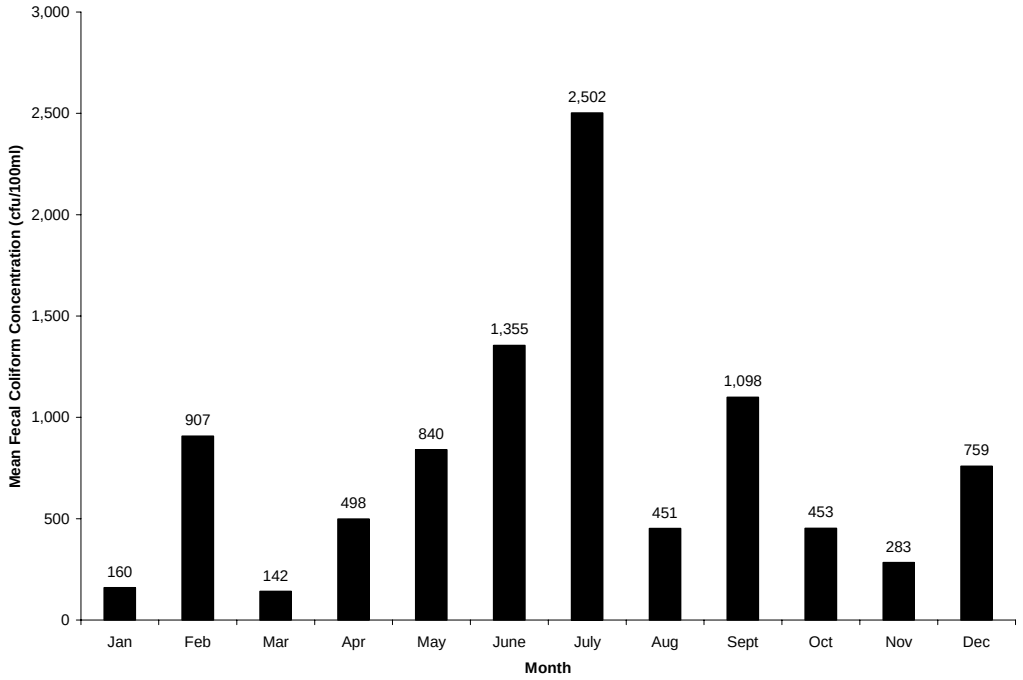


Figure 2.9. Impact of seasonality on fecal coliform concentrations (VADEQ station 6-CMFH026.00) in the Middle Fork Holston River watershed from January 1990 through December 2007.

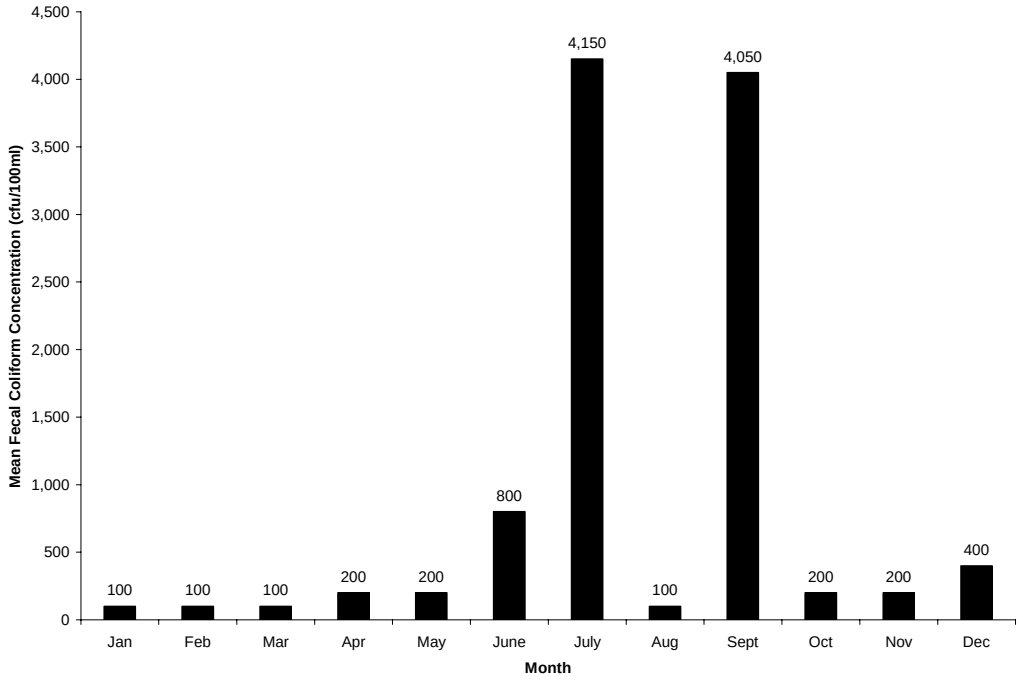


Figure 2.10. Impact of seasonality on fecal coliform concentrations (VADEQ station 6-CMFH027.14) in the Middle Fork Holston River watershed from January 1990 through December 2007.

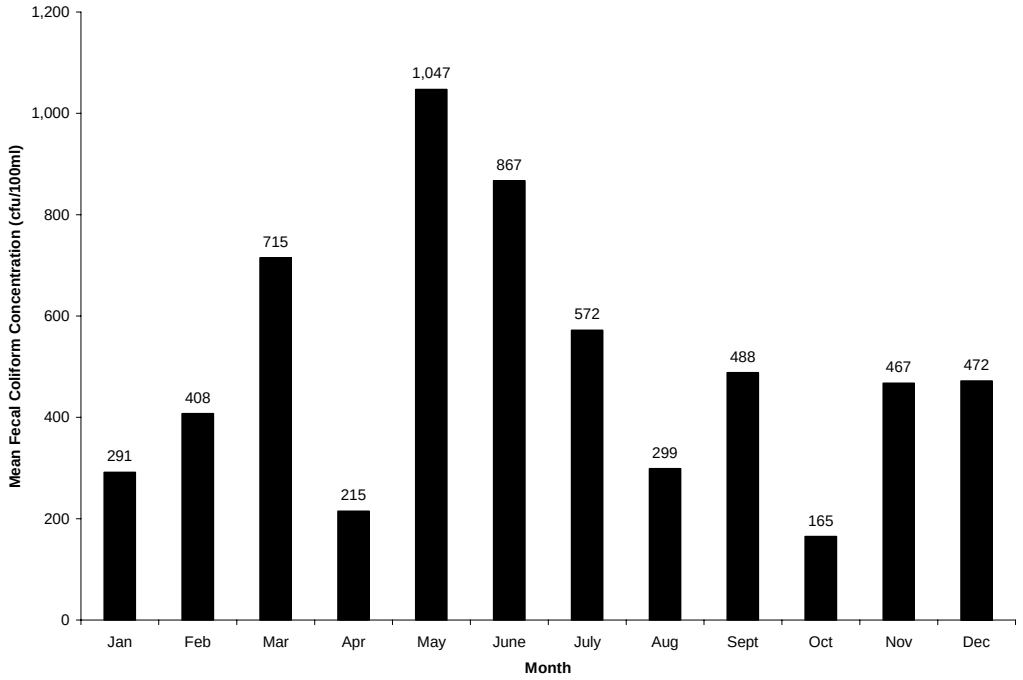


Figure 2.11. Impact of seasonality on fecal coliform concentrations (VADEQ station 6-CMFH033.40) in the Middle Fork Holston River watershed from January 1990 through December 2007.

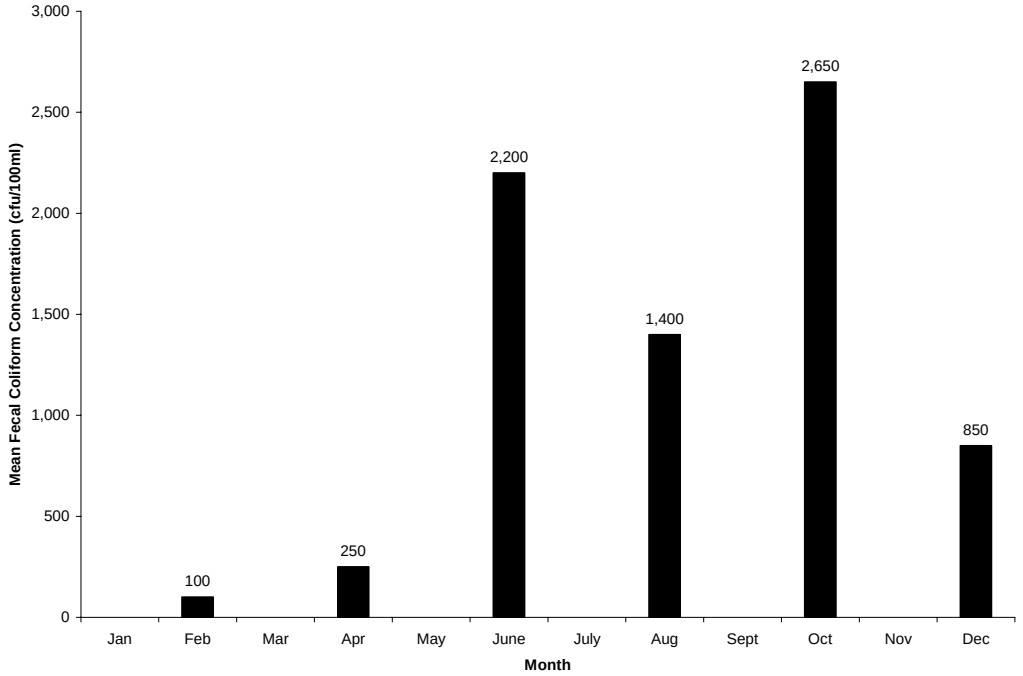


Figure 2.12. Impact of seasonality on fecal coliform (VADEQ station 6-CMFH040.67) in the Middle Fork Holston River watershed from January 1990 through December 2007.

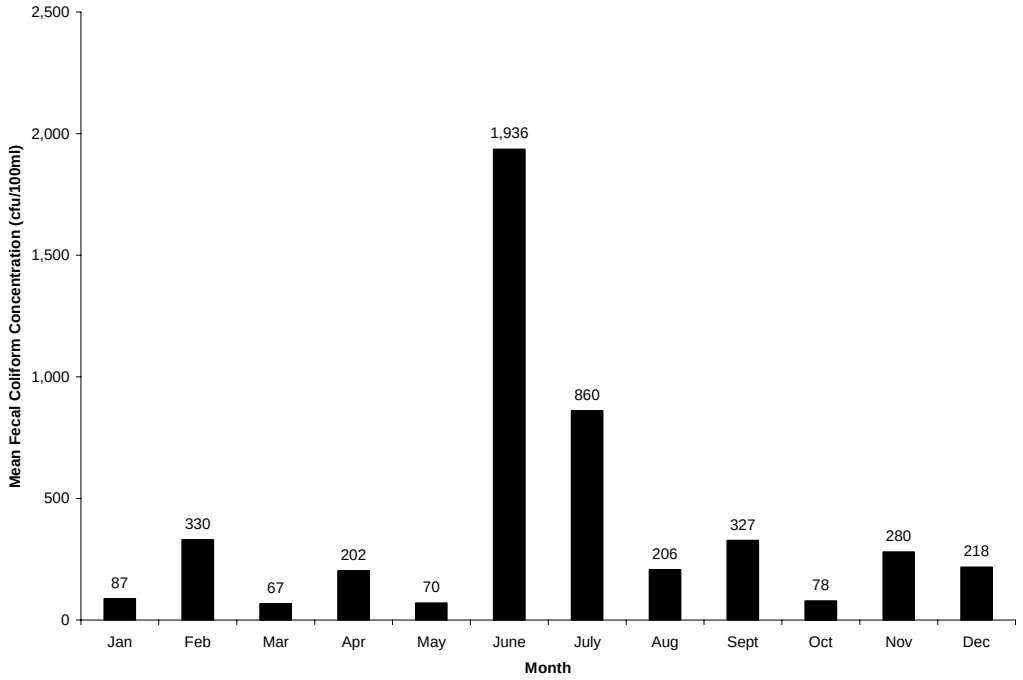


Figure 2.13. Impact of seasonality on fecal coliform (VADEQ station 6-CMFH045.72) in the Middle Fork Holston River watershed from January 1990 through December 2007.

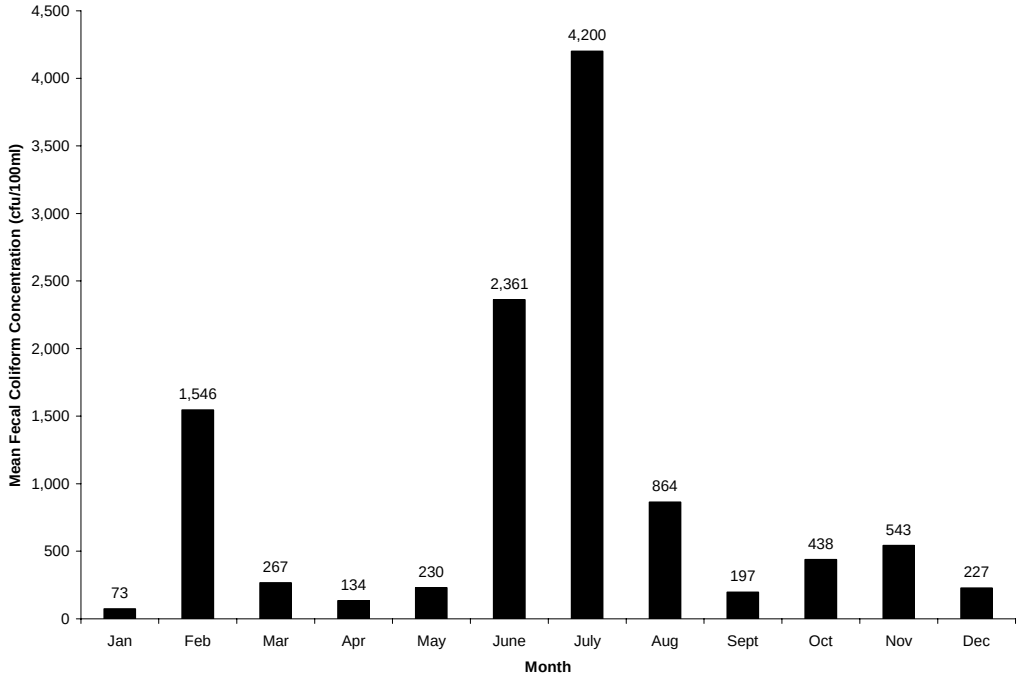


Figure 2.14. Impact of seasonality on fecal coliform (VADEQ station 6-CMFH053.36) in the Middle Fork Holston River watershed from January 1990 through December 2007.

2.5.2 Historic Data for E. coli

VADEQ staff examined water samples collected at stations 6-CMFH013.21, 6-CMFH033.40, 6-CMFH040.67, and 6-CMFH045.72 for concentration of *E. coli* (Figures 2.15 through 2.18). This analysis was conducted concurrently with other monthly testing at the stations during and after the 2006 assessment. Ten of the 50 (20%) samples analyzed from station 6-CMFH013.21 exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Of the 38 water quality samples collected at station 6-CMFH033.40, nineteen (50%) of the samples exceeded the instantaneous *E. coli* bacteria standard. At station 6-CMFH040.67, four of six (66%) samples exceeded the instantaneous *E. coli* bacteria standard. Of the 18 water quality samples collected at station 6-CMFH045.72, three (17%) of the samples exceeded the instantaneous *E. coli* bacteria standard.

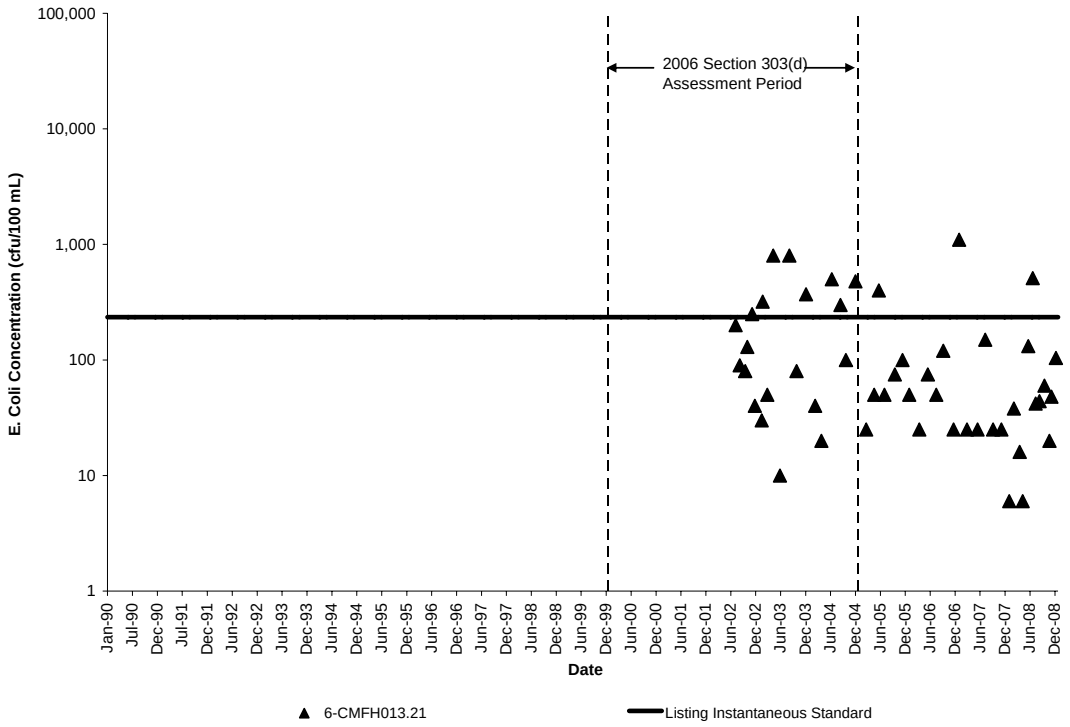


Figure 2.15. *E. coli* concentrations (VADEQ station 6-CMFH013.21) in the Middle Fork Holston River watershed.

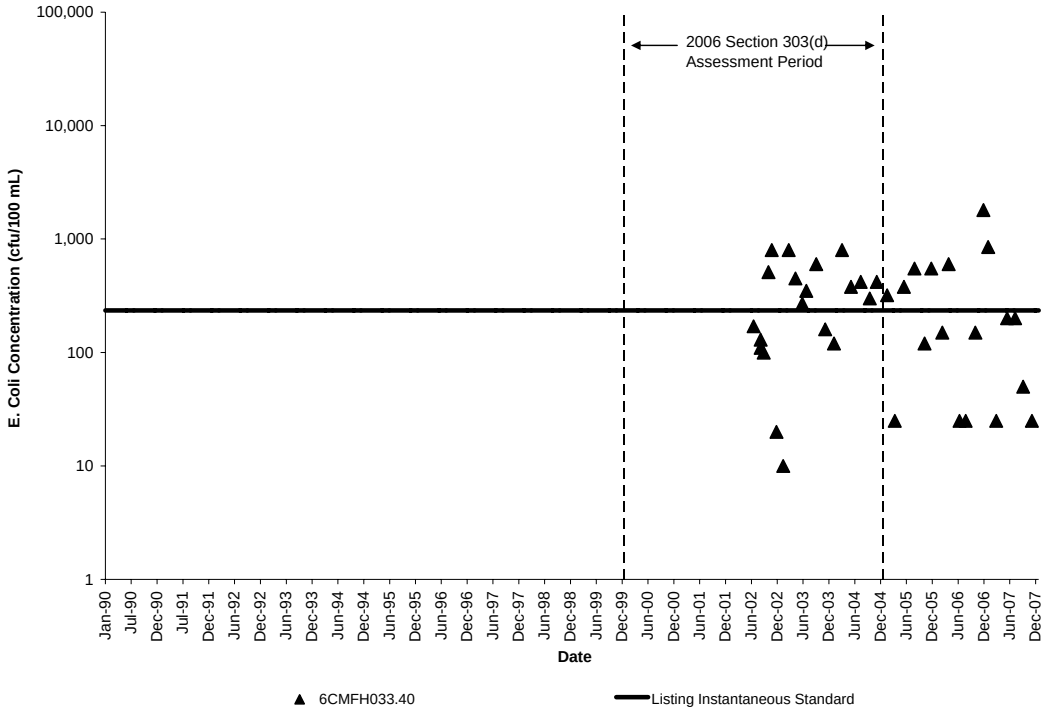


Figure 2.16. *E. coli* concentrations (VADEQ station 6-CMFH033.40) in the Middle Fork Holston River watershed.

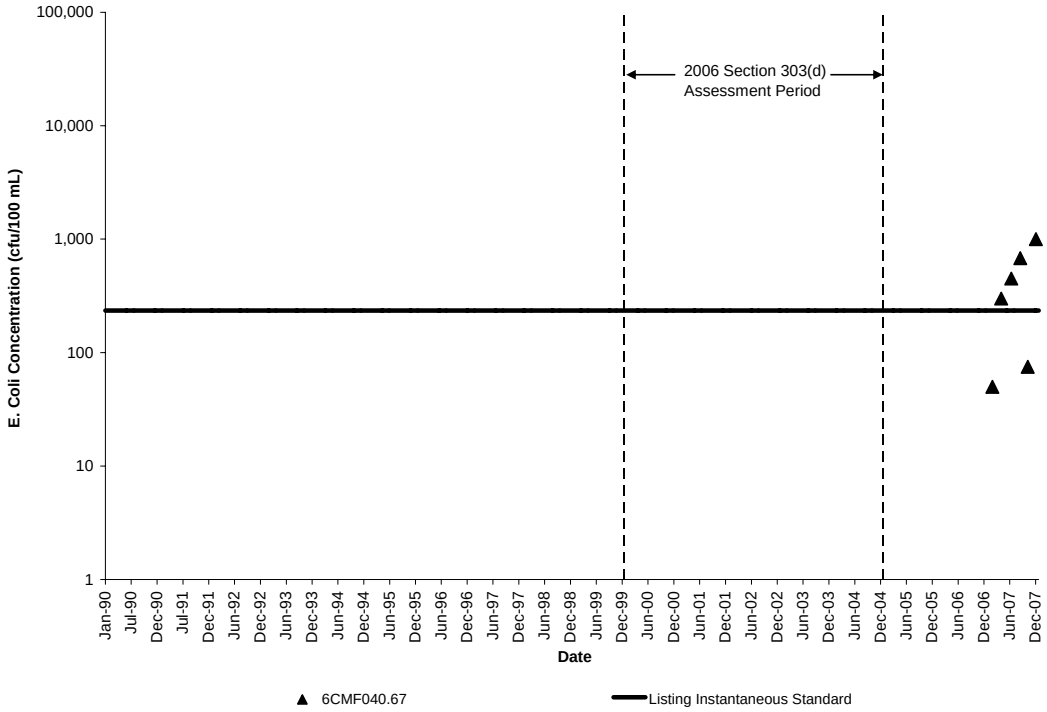


Figure 2.17. *E. coli* concentrations (VADEQ station 6-CMFH040.67) in the Middle Fork Holston River watershed.

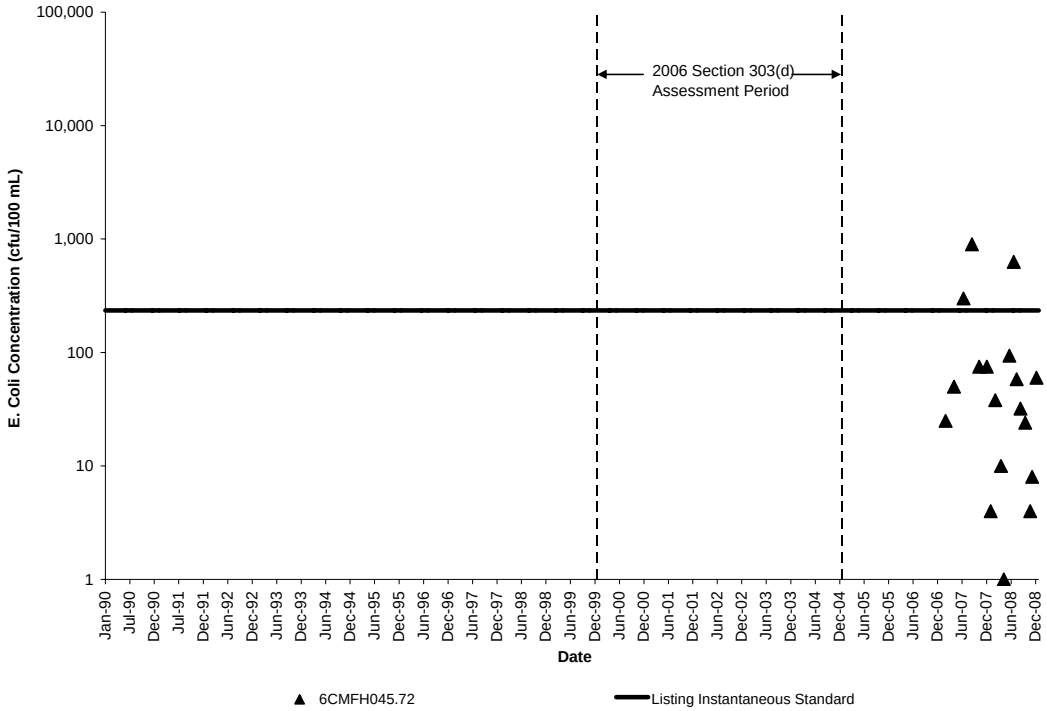


Figure 2.18. *E. coli* concentrations (VADEQ station 6-CMFH045.72) in the Middle Fork Holston River watershed.

2.5.3 Historic Data for Bacterial Source Tracking

The results from 12 monthly bacteria source tracking (BST) samples collected in 2008 at stations 6-CMFH013.21 and 6-CMFH045.72 were received at the time this report was prepared. The BST analysis was performed by MapTech, Inc. The results of the BST analysis provide a measure of the relative contribution of bacteria sources to the bacteria concentration found in the water samples. The bacteria sources were lumped into four categories: wildlife, human, livestock, and pet. Data resulting from the BST study are referenced in Appendix B. A discussion of the BST results provided by VADEQ indicates there is 90% confidence that the indicated proportions for each sample are within 15% of the sampled population (Appendix B). These data represent a brief glimpse of bacteria concentration in Middle Fork Holston River and may not be representative of long-term conditions in the stream.

The analysis in the BST report also included a test of statistical significance, providing an indication of presence or absence of contribution from a particular source. The presence/absence use of these data is most appropriate for use in this study due to statistical confidence, with presence defined as any proportional contribution greater than 15%. Tables 2.4 and 2.5 summarize the results of the presence/absence analysis of the BST data. The BST data were used to verify modeling methods and assumptions.

E. coli enumerations were also performed on the BST samples. These data are referenced in Appendix B. At station 6-CMFH013.21, 8.3% (one of 12) of the samples exceeded the *E. coli* bacteria instantaneous standard. The exceedance occurred in June of 2008. The one exceedance (8.3%) of the *E. coli* bacteria instantaneous standard occurred in June of 2005 at station 6-CMFH045.72.

Table 2.4. Presence/absence analysis of bacteria sources at station 6-CMFH013.21 in Middle Fork Holston River watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standard[2] (%)
Wildlife	42	N/D[3]
Human	42	N/D[3]
Livestock	42	N/D[3]
Pet	42	N/D[3]

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

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

3– No data available for analysis.

Table 2.5. Presence/absence analysis of bacteria sources at station 6-CMFH013.21 in Middle Fork Holston River watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standard[2] (%)
Wildlife	42	0
Human	17	0
Livestock	42	0
Pet	50	100

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

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

2.6 Biological Monitoring Data

Potential data used in the stressor identification analysis are included in Table 2.5 and presented in the following sections.

Table 2.6. Inventory of VADEQ environmental monitoring data for Middle Fork Holston River.

Data Type	Collection Period	Monitoring Stations											
		6CMFH004.00	6CMFH005.00	6CMFH011.31	6CMFH013.21	6CMFH023.41	6CMFH026.00	6CMFH027.14	6CMFH032.39	6CMFH033.40	6CMFH040.67	6CMFH045.72	6CMFH045.83
Biological (Benthic) Monitoring	1995 – 2008	X		X		X			X				X
Ambient Water Quality Monitoring													
Physical	1990 – 2008		X		X	X	X	X		X	X	X	
Nutrients	1990 – 2008		X		X	X	X	X		X	X	X	
Metals	1990 – 2008		X		X	X	X			X		X	
Organics	1990 – 2008		X		X	X	X			X		X	
Sediment and Fish Tissue Sampling	1997, 2002, 2007						X			X			
Diurnal DO Testing	N/A												
Toxicity Study	2007			X									

N/A – no data available

2.6.1 Benthic Data

Biological monitoring data was collected at five stations (stations 6CMFH004.00, 6CMFH011.31, 6CMFH023.41, 6CMFH032.39, and 6CMFH045.83) from 1995 to present, and evaluated using the modified Rapid Bioassessment Protocol II (RBP II) and Virginia Stream Condition Index (VSCI) metrics. Figure 2.19 illustrates the VSCI metrics calculated at monitoring stations throughout the Middle Fork Holston River watershed. Metrics and impairment classification are shown in Tables 2.7 through 2.11.Taxa data describing the quantities of the individual benthic macroinvertebrate organisms in each of the assessments are included in Tables 2.12 through 2.16. The RBP II assessment ratings are included for reference. Habitat data associated with each biological assessment were obtained and are summarized in Tables 2.17 through 2.21. Figures 2.20 through 2.23 illustrate the average, minimum, and maximum habitat scores throughout the watershed. Individual metric scores of 10 or below are considered poor or marginal. At station 6CMFH004.00, all values for embeddedness, sediment deposition, and riffle frequency were at or below 10 and at least 50% of the values for epifaunal substrate were below 10. At station 6CMFH011.31, all values for sediment deposition and riffle frequency were at or below 10 and the embeddedness average value was below 10. At station 6CMFH023.41, values for velocity/depth regime, sediment deposition and riffle frequency were at or below 10. At station 6CMFH032.39, averages and at least 50% of the values were above 10. At station 6CMFH045.83, at least 50% of the values for sediment deposition were below 10.

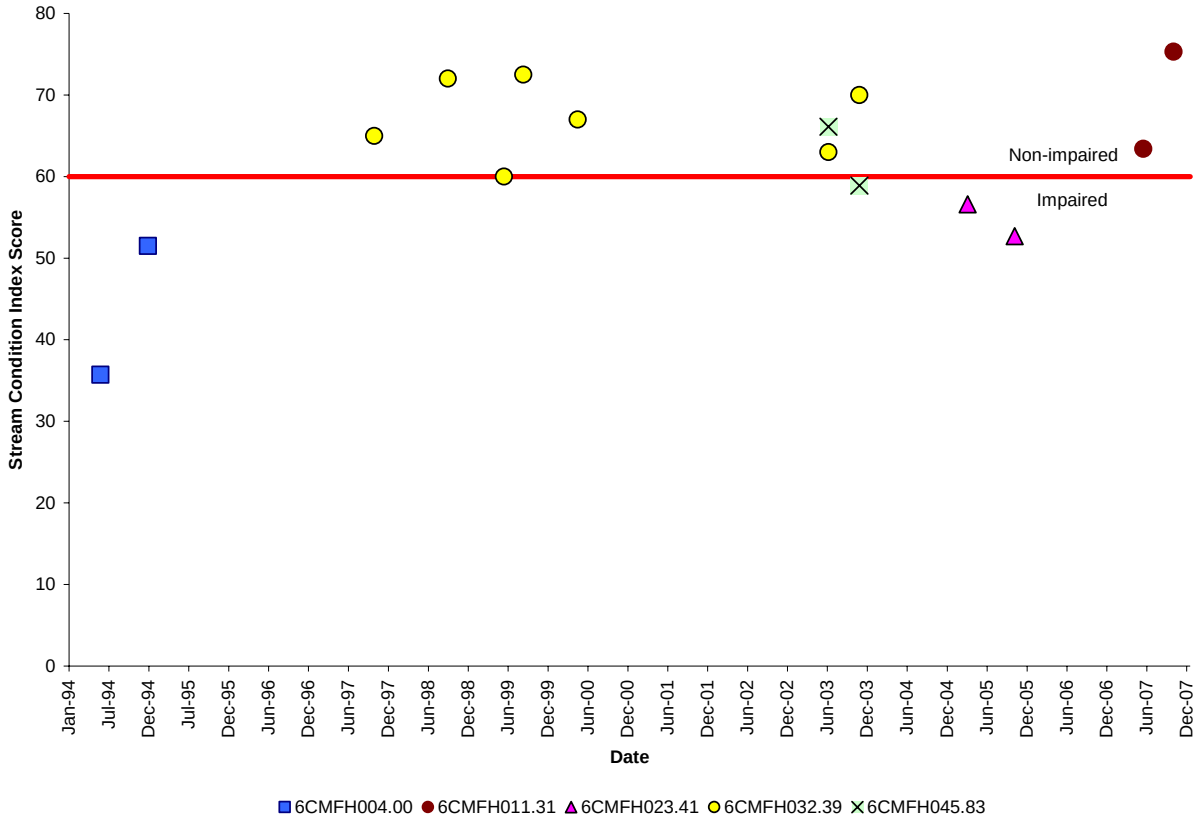


Figure 2.19. VSCI scores from monitoring stations 6-CMFH004.00, 6-CMFH011.31, 6-CMFH023.41, 6-CMFH032.39, and 6-CMFH045.83 in Middle Fork Holston River.

Table 2.7. RBP II and VSCI metric and assessment data for station 6CMFH004.00 in Middle Fork Holston River.

	24-May-94	27-Dec-94
RBP II Metric		
Taxa Richness	9	13
MFBI	5.34	5.17
SC/CF	1.40	1.25
EPT/Chi Abund	2.32	1.58
% Dominant	66.1	32.4
EPT Index	6	6
Community Loss Index	1.00	0.15
SH/Tot	0.01	0.02
Biological Condition Score	N/D	N/D
% of Reference	N/D	N/D
RBP II Assessment	MODERATE	NON-IMPAIRED
VA Stream Condition Index		
Total Taxa	N/D	N/D
EPT Taxa	N/D	N/D
% Ephemeropta	N/D	N/D
% EPT less Hydropsychidae	N/D	N/D
% Chironomidae	N/D	N/D
% Top 2 Dominant Taxa	N/D	N/D
HBI (Family Level)	N/D	N/D
% Scrapers	N/D	N/D
SCI Score	35.7	51.5
SCI Assessment	IMPAIRED	IMPAIRED

Table 2.8. RBP II and VSCI metric and assessment data for station 6CMFH011.31 in Middle Fork Holston River.

	06-Oct-97	24-Sep-98	22-Jun-99	08-May-00	31-May-07	16-Oct-07
RBP II Metric						
Taxa Richness	13	13	13	12	N/D	N/D
MFBI	4.36	4.39	4.40	4.59	N/D	N/D
SC/CF	2.72	2.35	2.09	59.00	N/D	N/D
EPT/Chi Abund	4.82	6.22	4.60	0.58	N/D	N/D
% Dominant	34.9	32.4	29.0	46.2	N/D	N/D
EPT Index	7	8	7	4	N/D	N/D
Community Loss Index	0.54	0.92	0.62	0.50	N/D	N/D
SH/Tot	0.00	0.00	0.01	0.01	N/D	N/D
Biological Condition Score	30	24	33	24	N/D	N/D
% of Reference	77.0	50.0	69.0	53.0	N/D	N/D
RBP II Assessment	MODERATE	MODERATE	MODERATE	MODERATE	N/D	N/D
VA Stream Condition Index						
Total Taxa	N/D	N/D	N/D	N/D	14	15
EPT Taxa	N/D	N/D	N/D	N/D	9.00	9.00
% Ephemeropta	N/D	N/D	N/D	N/D	31.37	54.90
% EPT less Hydropsychidae	N/D	N/D	N/D	N/D	10.78	1.96
% Chironomidae	N/D	N/D	N/D	N/D	72.5	99.0
% Top 2 Dominant Taxa	N/D	N/D	N/D	N/D	47.0588	51.9608
HBI (Family Level)	N/D	N/D	N/D	N/D	4.43	3.96
% Scrapers	N/D	N/D	N/D	N/D	25.49	54.90
SCI Score	N/D	N/D	N/D	N/D	63.4	75.3
SCI Assessment	N/D	N/D	N/D	N/D	NON-IMPAIRED	NON-IMPAIRED

Table 2.9. RBP II and VSCI metric and assessment data for station 6CMFH023.41 in Middle Fork Holston River.

	21-Mar-05	21-Oct-05
RBP II Metric		
Taxa Richness	N/D	N/D
MFBI	N/D	N/D
SC/CF	N/D	N/D
EPT/Chi Abund	N/D	N/D
% Dominant	N/D	N/D
EPT Index	N/D	N/D
Community Loss Index	N/D	N/D
SH/Tot	N/D	N/D
Biological Condition Score	N/D	N/D
% of Reference	N/D	N/D
RBP II Assessment	N/D	N/D
VA Stream Condition Index		
Total Taxa	9	9
EPT Taxa	4	5
% Ephemeropta	52.69	11.11
% EPT less Hydropsychidae		2.02
% Chironomidae	15.1	1.0
% Top 2 Dominant Taxa	69.8925	84.8485
HBI (Family Level)	4.30	3.82
% Scrapers	39.78	88.89
SCI Score	56.6	52.7
SCI Assessment	IMPAIRED	IMPAIRED

Table 2.10. RBP II and VSCI metric and assessment data for station 6CMFH032.39 in Middle Fork Holston River.

	23-Oct-97	24-Sep-98	07-Jun-99	03-Sep-99	08-May-00	26-Jun-03	14-Nov-03
RBP II Metric							
Taxa Richness	11	17	12	14	15	14	14
MFBI	3.81	3.80	4.39	3.56	4.37	4.24	3.97
SC/CF	6.18	3.87	4.86	2.79	8.63	5.09	1.31
EPT/Chi Abund	13.50	11.00	2.15	19.33	2.16	4.50	6.78
% Dominant	37.7	24.6	42.6	24.4	24.3	39.8	25.7
EPT Index	6	8	6	7	7	6	7
Community Loss Index	1.09	0.00	0.67	0.00	0.27	0.29	0.14
SH/Tot	0.00	0.01	0.00	0.00	0.01	0.02	0.00
Biological Condition Score	27	48	27	42	39	42	36
% of Reference	56.0	100.0	60.0	100.0	81.0	91.3	85.7
RBP II Assessment	MODERATE	REFERENCE	MODERATE	REFERENCE	NON-IMPAIRED	NON-IMPAIRED	NON-IMPAIRED
VA Stream Condition Index							
Total Taxa	N/D	N/D	N/D	N/D	N/D	N/D	N/D
EPT Taxa	N/D	N/D	N/D	N/D	N/D	N/D	N/D
% Ephemeropta	N/D	N/D	N/D	N/D	N/D	N/D	N/D
% EPT less Hydropsychidae	N/D	N/D	N/D	N/D	N/D	N/D	N/D
% Chironomidae	N/D	N/D	N/D	N/D	N/D	N/D	N/D
% Top 2 Dominant Taxa	N/D	N/D	N/D	N/D	N/D	N/D	N/D
HBI (Family Level)	N/D	N/D	N/D	N/D	N/D	N/D	N/D
% Scrapers	N/D	N/D	N/D	N/D	N/D	N/D	N/D
SCI Score	65.0	72.0	60.0	72.5	67.0	63.0	70.0
SCI Assessment	NON-IMPAIRED	NON-IMPAIRED	NON-IMPAIRED	NON-IMPAIRED	NON-IMPAIRED	NON-IMPAIRED	NON-IMPAIRED

Table 2.11. RBP II and VSCI metric and assessment data for station 6CMFH045.83 in Middle Fork Holston River.

	26-Jun-03	14-Nov-03
RBP II Metric		
Taxa Richness	15	11
MFBI	4.13	4.69
SC/CF	0.83	0.50
EPT/Chi Abund	3.65	12.29
% Dominant	22.4	43.5
EPT Index	7	6
Community Loss Index	0.00	0.00
SH/Tot	0.02	0.03
Biological Condition Score	46	42
% of Reference	100.0	100.0
RBP II Assessment	REFERENCE	REFERENCE
VA Stream Condition Index		
Total Taxa	15	11
EPT Taxa	7	8
% Ephemeropta	18.40	30.56
% EPT less Hydropsychidae	16.00	5.56
% Chironomidae	13.60	6.48
% Top 2 Dominant Taxa	37.60	56.48
HBI (Family Level)	4.13	4.69
% Scrapers	30.40	25.00
SCI Score	66.1	58.9
SCI Assessment	NON-IMPAIRED	IMPAIRED

Table 2.12. Taxa data for station 6CMFH004.00 in Middle Fork Holston River.

Order	Final ID	Functional Feeding Group	Tolerance Value	24-May-94	27-Dec-94
Coleoptera	Chrysomelidae	Shredder	5		1
Coleoptera	Elmidae	Scraper	4	3	8
Diptera	Chironomidae (A)	Collector	6	72	33
Diptera	Simuliidae	Filterer	6		2
Ephemeroptera	Baetidae	Collector	4	9	
Ephemeroptera	Baetiscidae	Collector	3		2
Ephemeroptera	Ephemerellidae	Collector	4	11	11
Ephemeroptera	Heptageniidae	Scraper	4		13
Ephemeroptera	Oligoneuridae	Collector	2		3
Limpets	Ancylidae	Scraper	6		1
Pelecypoda	Corbiculidae	Filterer	8	3	3
Plecoptera	Perlidae	Predator	1	3	
Plecoptera	Perlodidae	Predator	2		1
Plecoptera	Taeniopterygidae	Shredder	2		1
Trichoptera	Brachycentridae	Filterer	1	3	
Trichoptera	Hydropsychidae	Filterer	6	4	23
Trichoptera	Limnephilidae	Shredder	4	1	
			Total Organisms =	109	102
RBP II Assessment				Moderately Impaired	Non-Impaired

Table 2.13. Taxa data for station 6CMFH011.31 in Middle Fork Holston River.

Order	Final ID	Functional Feeding Group	Tolerance Value	06-Oct-97	24-Sep-98	22-Jun-99	08-May-00	31-May-07	16-Oct-07
Coleoptera	Elmidae	Scraper	4	37	34	36	43	20	25
Coleoptera	Psephenidae	Scraper	4	2	1	1	4	2	
Diptera	Chironomidae (A)	Collector	6	11	9	15	26	28	1
Diptera	Tipulidae	Shredder	3			1	1	1	
Ephemeroptera	Baetidae	Collector	4	8	13	15	4	7	4
Ephemeroptera	Caenidae	Collector	4	6	5	22		10	2
Ephemeroptera	Ephemerellidae	Collector	4		2	3	6	6	11
Ephemeroptera	Ephemeridae	Collector	4						1
Ephemeroptera	Heptageniidae	Scraper	4	9	6	6	4	4	28
Ephemeroptera	Isonychiidae	Filterer	2						10
Ephemeroptera	Leptophlebiidae	Collector	2		1				
Ephemeroptera	Oligoneuridae	Collector	2	10	10	2			
Ephemeroptera	Potamanthidae	Collector	4	3				3	
Ephemeroptera	Tricorythidae	Collector	4					2	
Gastropoda	Pleuroceridae	Scraper	4				1		2
Hemiptera	Hebridae	Predator	5	1					
Limpets	Ancylidae	Scraper	6	1	4		1		
Megaloptera	Corydalidae	Predator	5				1		1
Opisthopora	Lumbricidae	Collector	10			1			
Pelecypoda	Corbiculidae	Filterer	8	1	1		1	2	1
Pelecypoda	Sphaeriidae	Filterer	8			1			
Plecoptera	Perlidae	Predator	1				1		1
Trichoptera	Brachycentridae	Filterer	1	1	1	5		10	
Trichoptera	Glossosomatidae	Scraper	0						1
Trichoptera	Helicopsychidae	Shredder	3					1	
Trichoptera	Hydropsychidae	Filterer	6	16	18	16		6	8
Unknown	Oligochaeta (unknown)	Collector							6
			Total Organisms =	106	105	124	93	102	102
RBP II Assessment				Moderately Impaired	Moderately Impaired	Moderately Impaired	Moderately Impaired	N/D	N/D

Table 2.14. Taxa data for station 6CMFH023.41 in Middle Fork Holston River.

Order	Final ID	Functional Feeding Group	Tolerance Value	21-Mar-05	21-Oct-05
Coleoptera	Elmidae	Scraper	4	27	73
Coleoptera	Psephenidae	Scraper	4	1	1
Diptera	Chironomidae (A)	Collector	6	14	1
Diptera	Simuliidae	Filterer	6	1	
Ephemeroptera	Baetiscidae	Collector	3	2	
Ephemeroptera	Ephemerellidae	Collector	4	38	
Ephemeroptera	Heptageniidae	Scraper	4	8	3
Ephemeroptera	Isonychiidae	Filterer	2	1	3
Ephemeroptera	Leptophlebiidae	Collector	2		3
Ephemeroptera	Potamanthidae	Collector	4		2
Gastropoda	Pleuroceridae	Scraper	4	1	11
Plecoptera	Pteronarcyidae	Shredder	0		2
			Total Organisms =	93	99
RBP II Assessment				N/D	N/D

Table 2.15. Taxa data for station 6CMFH032.39 in Middle Fork Holston River.

Order	Final ID	Functional Feeding Group	Tolerance Value	23-Oct-97	24-Sep-08	07-Jun-99	03-Sep-99	08-May-00	26-Jun-03
Coleoptera	Elmidae	Scraper	4	40	16	43	12	27	37
Coleoptera	Psephenidae	Scraper	4		2	1	2	11	5
Diptera	Athericidae	Predator	2	1	1		3	1	1
Diptera	Chironomidae (A)	Collector	6	4	5	13	3	19	6
Diptera	Simuliidae	Filterer	6		7	2		4	1
Diptera	Tipulidae	Shredder	3		1			1	2
Ephemeroptera	Baetidae	Collector	4	2	9	4	4	10	3
Ephemeroptera	Caenidae	Collector	4		1				
Ephemeroptera	Ephemerellidae	Collector	4	3	3	6	8	15	12
Ephemeroptera	Heptageniidae	Scraper	4	19	8	6	10	10	3
Ephemeroptera	Isonychiidae	Filterer	2						
Ephemeroptera	Leptophlebiidae	Collector	2		2				2
Ephemeroptera	Oligoneuridae	Collector	2	20	25	2	22	2	
Gastropoda	Pleuroceridae	Scraper	4	6	29	13	7	6	11
Limpets	Ancylidae	Scraper	6						
Megaloptera	Corydalidae	Predator	5		1		3		
Pelecypoda	Corbiculidae	Filterer	8	1	1	2	2	1	3
Plecoptera	Perlidae	Predator	1				2	1	
Trichoptera	Brachycentridae	Filterer	1	3	2	3	5	1	2
Trichoptera	Hydropsychidae	Filterer	6	8	5	7	7	2	5
			Total Organisms =	107	118	102	90	111	93
RBP II Assessment				Moderately Impaired	Reference	Moderately Impaired	Reference	Non-Impaired	Non-Impaired

Table 2.16. Taxa data for station 6CMFH045.83 in Middle Fork Holston River.

Order	Final ID	Functional Feeding Group	Tolerance Value	26-Jun-03	14-Nov-03
Coleoptera	Elmidae	Scraper	4	28	14
Coleoptera	Psephenidae	Scraper	4	6	1
Decapoda - Crayfish	Cambaridae	Shredder	5	1	
Diptera	Athericidae	Predator	2	2	
Diptera	Blephariceridae	Scraper	0	1	
Diptera	Chironomidae (A)	Collector	6	17	7
Diptera	Simuliidae	Filterer	6	7	
Diptera	Tipulidae	Shredder	3	1	
Ephemeroptera	Baetidae	Collector	4	10	6
Ephemeroptera	Caenidae	Collector	4	9	
Ephemeroptera	Ephemerellidae	Collector	4		7
Ephemeroptera	Heptageniidae	Scraper	4	3	12
Ephemeroptera	Isonychiidae	Filterer	2	1	7
Ephemeroptera	Leptophlebiidae	Collector	2		1
Plecoptera	Perlidae	Predator	1	1	
Plecoptera	Taeniopterygidae	Shredder	2		3
Trichoptera	Brachycentridae	Filterer	1	1	
Trichoptera	Hydropsychidae	Filterer	6	19	47
Trichoptera	Rhyacophilidae	Predator	0		3
			Total Organisms =	107	108
RBP II Assessment				Reference	Reference

Table 2.17. Habitat scores for station 6-CMFH004.00 in Middle Fork Holston River.

Habitat Metrics	Habitat Scores[1]	
	05/24/1994	12/27/1994
Epifaunal Substrate	12	10
Embeddedness	5	9
Velocity / Depth Regimes	12	12
Sediment Deposition	10	10
Channel Flow Status	14	19
Channel Alteration	19	19
Riffle Frequency	7	9
Bank Stability	17	14
Vegetation Protection	18	19
Riparian Zone	19	13
Total Habitat Score	***133***	***134***

[1]Habitat condition categories: 0-5 = "Poor"; 6-10 = "Marginal"; 11-15 = "Sub-optimal"

Table 2.18. Habitat scores for station 6-CMFH011.31 in Middle Fork Holston River.

Habitat Metrics	Habitat Scores[1]					
	10/06/1997	09/24/1998	06/22/1999	05/08/2000	05/31/2007	10/16/2007
Epifaunal Substrate	13	14	10	9	14	16
Embeddedness	3	8	9	8	7	11
Velocity / Depth Regimes	14	15	16	12	17	12
Sediment Deposition	10	7	7	7	6	8
Channel Flow Status	17	11	8	17	13	14
Channel Alteration	19	17	18	19	17	18
Riffle Frequency	10	8	9	10	7	8
Bank Stability	17	10	15	16	16	16
Vegetation Protection	18	17	18	18	18	18
Riparian Zone	10	12	16	18	16	15
Total Habitat Score	***131***	***119***	***126***	***134***	***131***	***136***

[1]Habitat condition categories: 0-5 = "Poor"; 6-10 = "Marginal"; 11-15 = "Sub-optimal"; 16-20 = "Optimal".

Table 2.19. Habitat scores for station 6-CMFH023.41 in Middle Fork Holston River.

Habitat Metrics	Habitat Scores[1]
	3/21/2005
Epifaunal Substrate	15
Embeddedness	14
Velocity / Depth Regimes	9
Sediment Deposition	10
Channel Flow Status	15
Channel Alteration	18
Riffle Frequency	6
Bank Stability	11
Vegetation Protection	12
Riparian Zone	12
Total Habitat Score	***122***

[1]Habitat condition categories: 0-5 = "Poor"; 6-10 = "Marginal"; 11-15 = "

Table 2.20. Habitat scores for station 6-CMFH032.39 in Middle Fork Holston River.

Habitat Metrics	Habitat Scores[1]						
	10/23/1997	09/24/1998	06/07/1999	09/03/1999	05/08/2000	06/26/2003	11/14/2003
Epifaunal Substrate	15	15	15	15	14	18	15
Embeddedness	9	16	13	12	9	16	14
Velocity / Depth Regimes	17	16	17	17	17	17	18
Sediment Deposition	7	16	12	12	12	11	9
Channel Flow Status	15	16	14	11	17	18	18
Channel Alteration	15	15	15	14	15	15	15
Riffle Frequency	7	13	11	9	12	10	14
Bank Stability	12	10	14	12	15	15	13
Vegetation Protection	18	18	17	17	18	16	12
Riparian Zone	8	12	11	11	15	16	12
Total Habitat Score	***123***	***147***	***139***	***130***	***144***	***152***	***140***

[1]Habitat condition categories: 0-5 = "Poor"; 6-10 = "Marginal"; 11-15 = "Sub-optimal"; 16-20 = "Optimal".

Table 2.21. Habitat scores for station 6-CMFH045.83 in Middle Fork Holston River.

Habitat Metrics	Habitat Scores[1]	
	06/23/2003	11/14/2003
Epifaunal Substrate	18	17
Embeddedness	15	16
Velocity / Depth Regimes	18	18
Sediment Deposition	10	15
Channel Flow Status	18	18
Channel Alteration	16	17
Riffle Frequency	14	16
Bank Stability	16	15
Vegetation Protection	16	15
Riparian Zone	18	16
Total Habitat Score	***159***	***163***

[1]Habitat condition categories: 0-5 = "Poor"; 6-10 = "Marginal"; 11-15 = "Sub-optimal"

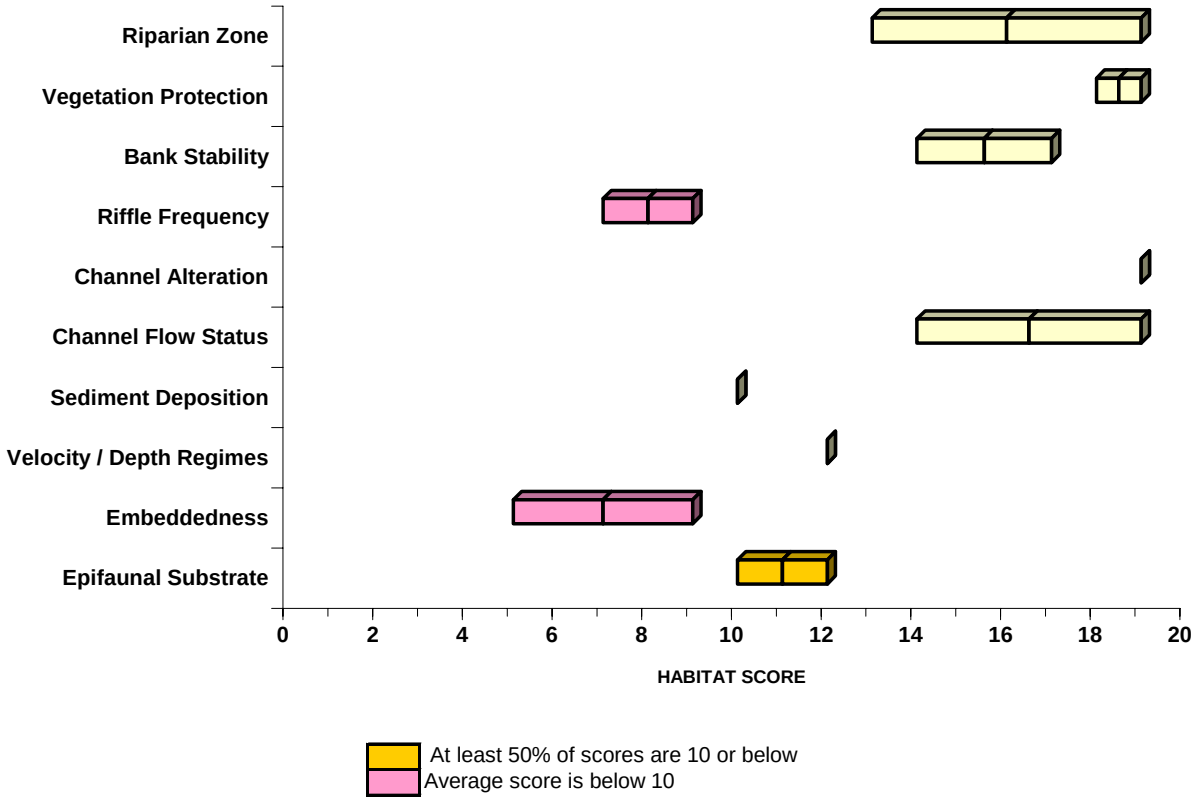


Figure 2.20. Average, minimum, and maximum habitat scores at monitoring station 6CMFH004.00 in Middle Fork Holston River.

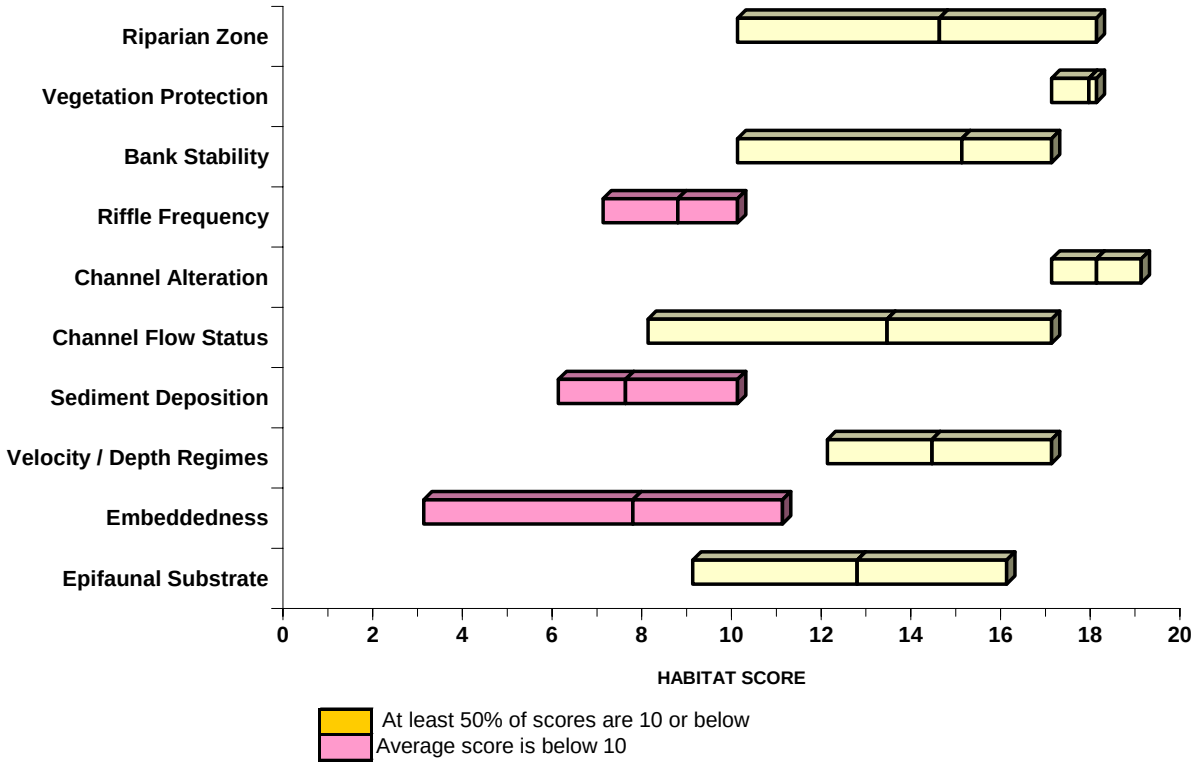


Figure 2.21. Average, minimum, and maximum habitat scores at monitoring station 6CMFH011.31 in Middle Fork Holston River.

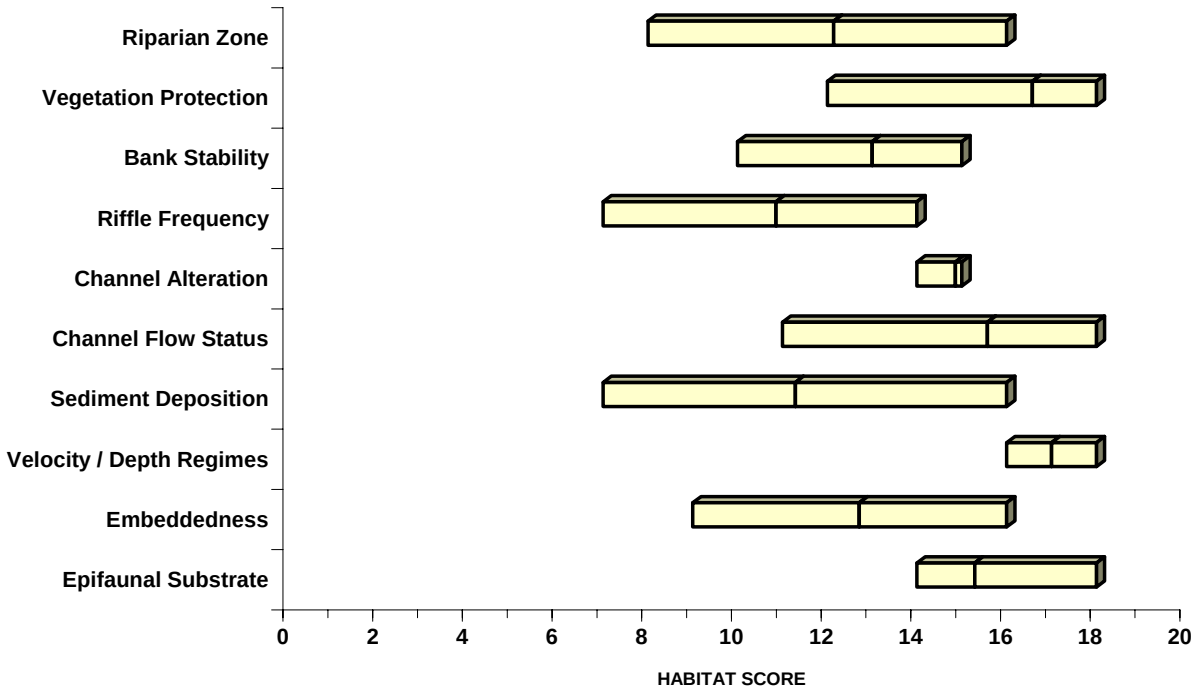


Figure 2.22. Average, minimum, and maximum habitat scores at monitoring station 6CMFH032.39 in Middle Fork Holston River.

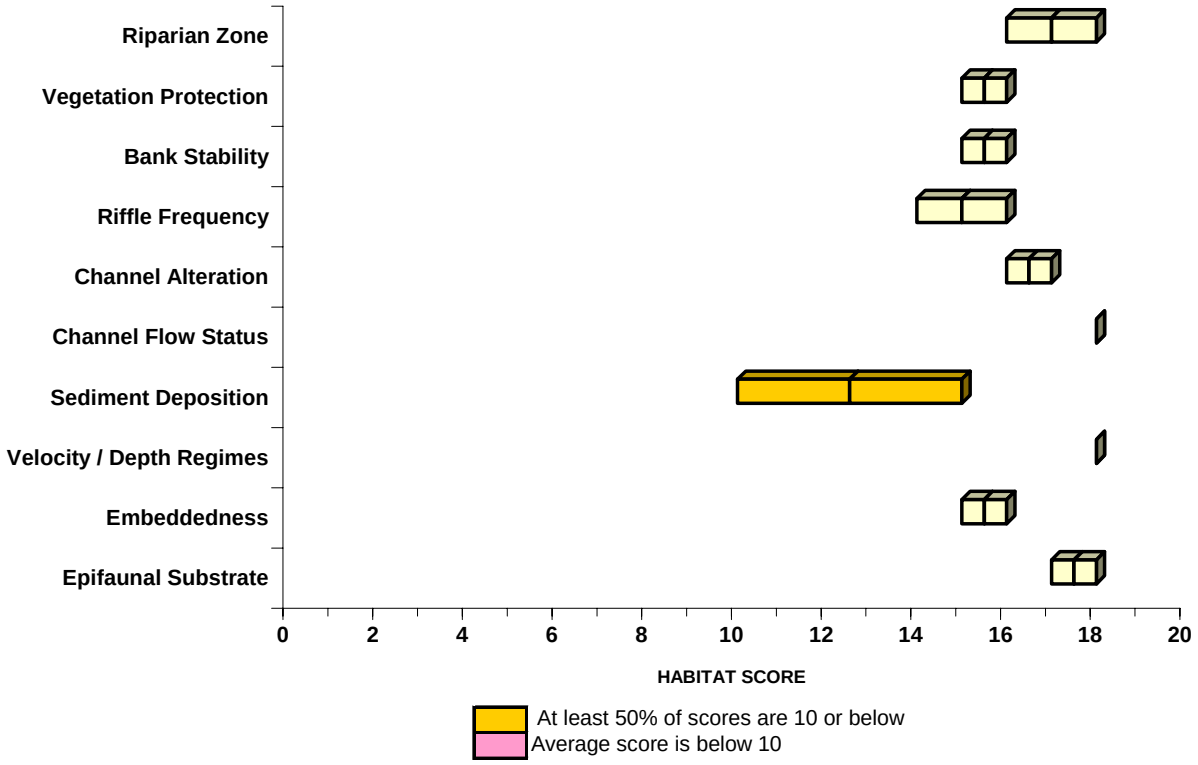


Figure 2.23. Average, minimum, and maximum habitat scores at monitoring station 6CMFH045.83 in Middle Fork Holston River.

2.7 VADEQ Ambient Monitoring Data

Ambient water quality data were collected at various points along the Middle Fork Holston River. In this analysis, we examined data collected at eight stations before, within, and upstream of the impaired reach. Stations on Middle Fork Holston River were located at river miles 5.00, 13.21, 23.41, 26.00, 27.14, 33.40, 40.67, and 45.72 (Table 2.6).

2.7.1 Physical

Tables 2.22 through 2.29 contain summary of data collected at the various water quality stations. Summary of data includes number of observations between January 1, 1990 and March 31, 2008; mean, minimum; and maximum values. The data temporal range varies from parameter to parameter, and there is not always a good overlap between biological and ambient monitoring data. Data for physical parameters collected in the watershed are depicted in Figures 2.24 through 2.35. Summary of observations includes:

- Measured pH values at all water quality monitoring (WQM) stations are within the expected range for Class IV waters and does not appear to be a stressor to the benthic community;
- Specific conductance values at all stations were above the reference filter limit of 250 umhos/cm;

- Dissolve oxygen values at all WQM stations were above the daily average concentration for Class IV waters (i.e., 5 mg/l) and does not appear to be a stressor to the benthic community;
- Temperature values at all WQM stations were below the maximum temperature criteria for Class IV waters (i.e., 31°C) and does not appear to be a stressor to the benthic community;
- Exceedances of the turbidity stressor screening value of 10 NTU were observed at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH026.00, and 6CMFH033.40;
- The total solids stressor screening value of 300 mg/l was exceeded five times at WQM station 6CMFH013.21 and one time at stations 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72; and
- TSS values at all WQM stations except 6CMFH023.41 exceeded the stressor screening value of 10 mg/l.

Table 2.22. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH005.00 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
pH - Field, std units	21	8.17	8.76	7.63
Specific Conductance, µmhos/cm	3	345.00	413.00	298.00
Turbidity - Hach Turbidimeter, FTU	N/A	N/A	N/A	N/A
Turbidity - Lab, NTU	21	13.49	60.00	1.60
Dissolved Oxygen (DO), mg/L	21	9.36	13.60	5.80
Temperature, Celsius (°C)	21	12.77	22.40	1.30
Total Solids, mg/L	21	227.00	279.00	184.00
Total Suspended Solids, mg/L	21	18.81	78.00	1.00
Total Inorganic Solids, mg/L	21	51.57	75.00	35.00
Total Inorganic Suspended Solids, mg/L	21	2.48	9.00	1.00
Total Dissolved Solids, mg/L	N/A	N/A	N/A	N/A
BOD 5, mg/L	20	1.25	3.00	1.00
COD - High Level, mg/L	21	7.89	16.00	1.00

Table 2.23. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH013.21 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
pH - Field, std units	153	8.05	8.86	6.81
Specific Conductance, µmhos/cm	154	309.91	461.00	80.00
Turbidity - Hach Turbidimeter, FTU	99	17.60	267.00	1.60
Turbidity - Lab, NTU	66	15.33	460.00	0.90
Dissolved Oxygen (DO), mg/L	153	10.73	16.92	6.38
Temperature, Celsius (°C)	154	13.85	27.60	0.00
Total Solids, mg/L	150	235.05	750.00	131.00
Total Suspended Solids, mg/L	157	25.81	662.00	3.00
Total Inorganic Solids, mg/L	129	54.57	118.00	0.00
Total Inorganic Suspended Solids, mg/L	130	5.06	70.00	1.00
Total Dissolved Solids, mg/L	111	206.59	270.00	84.00
BOD 5, mg/L	102	1.64	5.00	1.00
COD - High Level, mg/L	86	8.13	42.00	1.10

Table 2.24. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH023.41 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
pH - Field, std units	1	8.90	8.90	8.90
Specific Conductance, µmhos/cm	1	289.00	289.00	289.00
Turbidity - Hach Turbidimeter, FTU	N/A	N/A	N/A	N/A
Turbidity - Lab, NTU	1	3.50	3.50	3.50
Dissolved Oxygen (DO), mg/L	1	14.97	14.97	14.97
Temperature, Celsius (°C)	1	9.87	9.87	9.87
Total Solids, mg/L	1	188.00	188.00	188.00
Total Suspended Solids, mg/L	1	3.00	3.00	3.00
Total Inorganic Solids, mg/L	1	45.00	45.00	45.00
Total Inorganic Suspended Solids, mg/L	1	3.00	3.00	3.00
Total Dissolved Solids, mg/L	1	176.00	176.00	176.00
BOD 5, mg/L	N/A	N/A	N/A	N/A
COD - High Level, mg/L	N/A	N/A	N/A	N/A

Table 2.25. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH026.00 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
pH - Field, std units	100	7.75	8.60	6.89
Specific Conductance, µmhos/cm	83	295.99	429.00	149.00
Turbidity - Hach Turbidimeter, FTU	68	11.18	182.50	0.92
Turbidity - Lab, NTU	34	5.46	23.00	1.06
Dissolved Oxygen (DO), mg/L	101	9.61	15.47	5.83
Temperature, Celsius (°C)	102	13.24	24.80	0.51
Total Solids, mg/L	102	212.36	310.00	94.00
Total Suspended Solids, mg/L	104	12.28	292.00	1.00
Total Inorganic Solids, mg/L	101	53.19	116.00	18.00
Total Inorganic Suspended Solids, mg/L	104	3.39	34.00	1.00
Total Dissolved Solids, mg/L	66	199.47	286.00	0.00
BOD 5, mg/L	86	1.66	5.00	1.00
COD - High Level, mg/L	68	7.19	19.00	2.10

Table 2.26. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH027.14 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
pH - Field, std units	15	7.77	8.32	7.22
Specific Conductance, µmhos/cm	15	321.60	420.00	162.00
Turbidity - Hach Turbidimeter, FTU	15	9.32	56.60	1.10
Turbidity - Lab, NTU	N/A	N/A	N/A	N/A
Dissolved Oxygen (DO), mg/L	15	9.57	13.25	6.96
Temperature, Celsius (°C)	15	13.50	23.10	0.59
Total Solids, mg/L	15	213.13	257.00	146.00
Total Suspended Solids, mg/L	15	12.53	64.00	3.00
Total Inorganic Solids, mg/L	15	59.47	98.00	38.00
Total Inorganic Suspended Solids, mg/L	15	3.80	12.00	3.00
Total Dissolved Solids, mg/L	N/A	N/A	N/A	N/A
BOD 5, mg/L	N/A	N/A	N/A	N/A
COD - High Level, mg/L	N/A	N/A	N/A	N/A

Table 2.27. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH033.40 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
pH - Field, std units	155	7.81	8.97	6.72
Specific Conductance, µmhos/cm	156	245.25	383.30	70.00
Turbidity - Hach Turbidimeter, FTU	99	8.89	167.50	0.64
Turbidity - Lab, NTU	55	5.35	78.00	0.44
Dissolved Oxygen (DO), mg/L	154	10.19	16.13	6.68
Temperature, Celsius (°C)	156	12.63	24.40	0.20
Total Solids, mg/L	148	178.68	313.00	74.00
Total Suspended Solids, mg/L	155	10.48	204.00	1.00
Total Inorganic Solids, mg/L	128	45.81	87.00	5.00
Total Inorganic Suspended Solids, mg/L	127	3.66	38.00	1.00
Total Dissolved Solids, mg/L	111	164.11	245.00	46.00
BOD 5, mg/L	103	1.52	5.00	1.00
COD - High Level, mg/L	86	7.34	25.10	1.00

Table 2.28. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH040.67 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
pH - Field, std units	19	7.93	8.67	6.73
Specific Conductance, µmhos/cm	19	292.32	359.00	217.00
Turbidity - Hach Turbidimeter, FTU	11	9.10	76.00	0.80
Turbidity - Lab, NTU	8	2.66	4.30	0.84
Dissolved Oxygen (DO), mg/L	17	11.03	14.20	7.02
Temperature, Celsius (°C)	19	11.90	20.40	3.20
Total Solids, mg/L	13	176.69	224.00	131.00
Total Suspended Solids, mg/L	19	5.58	40.00	3.00
Total Inorganic Solids, mg/L	13	45.15	66.00	25.00
Total Inorganic Suspended Solids, mg/L	13	3.31	7.00	3.00
Total Dissolved Solids, mg/L	N/A	N/A	N/A	N/A
BOD 5, mg/L	N/A	N/A	N/A	N/A
COD - High Level, mg/L	N/A	N/A	N/A	N/A

Table 2.29. Physical, DO, temperature, solids, and biochemical water quality data summary for station 6CMFH045.72 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
pH - Field, std units	87	7.69	8.61	6.97
Specific Conductance, µmhos/cm	87	211.15	333.00	80.00
Turbidity - Hach Turbidimeter, FTU	65	10.78	199.00	0.21
Turbidity - Lab, NTU	21	2.12	4.80	0.60
Dissolved Oxygen (DO), mg/L	85	10.40	14.19	7.78
Temperature, Celsius (°C)	87	11.55	19.60	3.00
Total Solids, mg/L	80	164.04	436.00	97.00
Total Suspended Solids, mg/L	85	11.86	341.00	1.00
Total Inorganic Solids, mg/L	80	45.43	112.00	8.00
Total Inorganic Suspended Solids, mg/L	80	4.00	43.00	0.00
Total Dissolved Solids, mg/L	70	145.94	205.00	86.00
BOD 5, mg/L	66	1.64	5.00	1.00
COD - High Level, mg/L	49	6.60	27.00	0.00

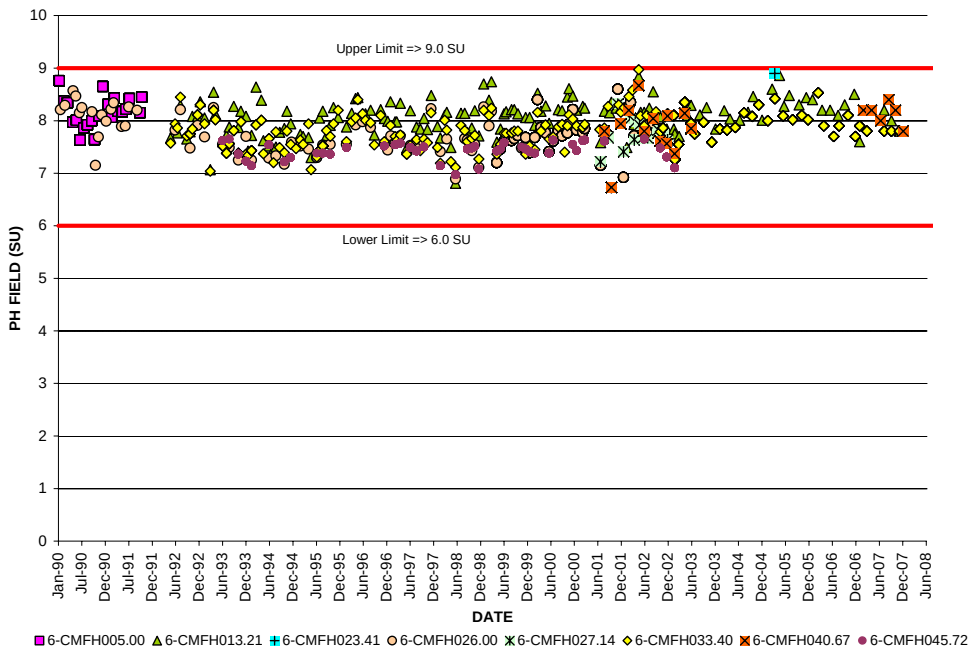


Figure 2.24. Field pH values at water quality monitoring stations in Middle Fork Holston River.

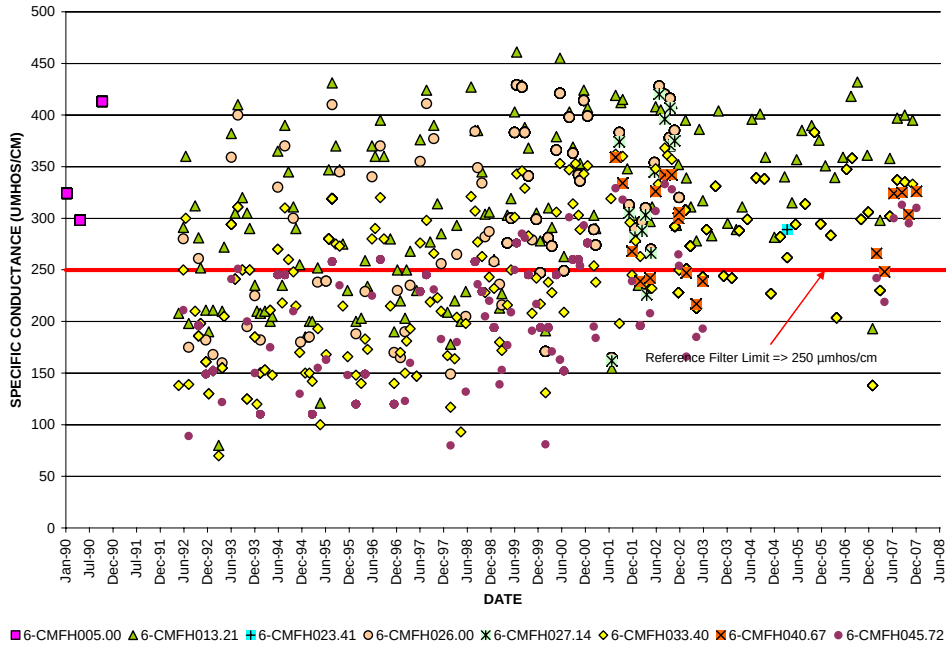


Figure 2.25. Specific conductance values at water quality monitoring stations in Middle Fork Holston River.

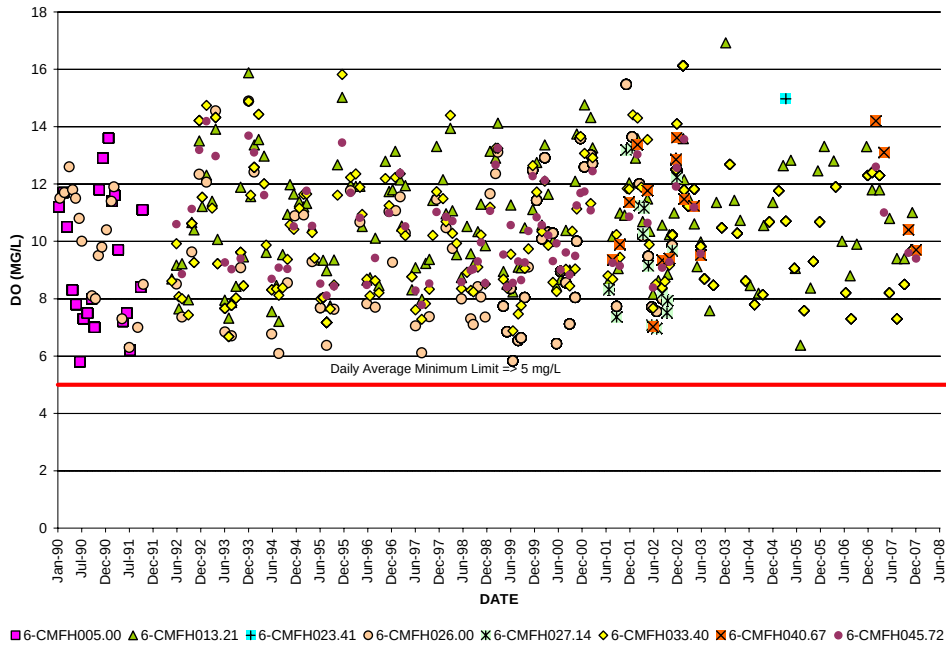


Figure 2.26. Dissolved oxygen values at water quality monitoring stations in Middle Fork Holston River.

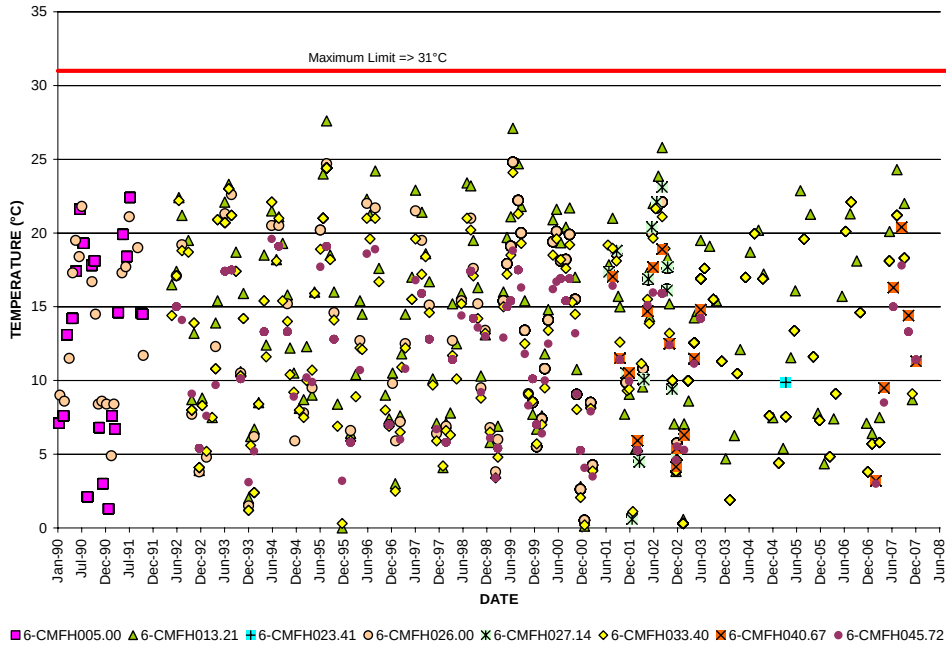


Figure 2.27. Temperature values at water quality monitoring stations in Middle Fork Holston River.

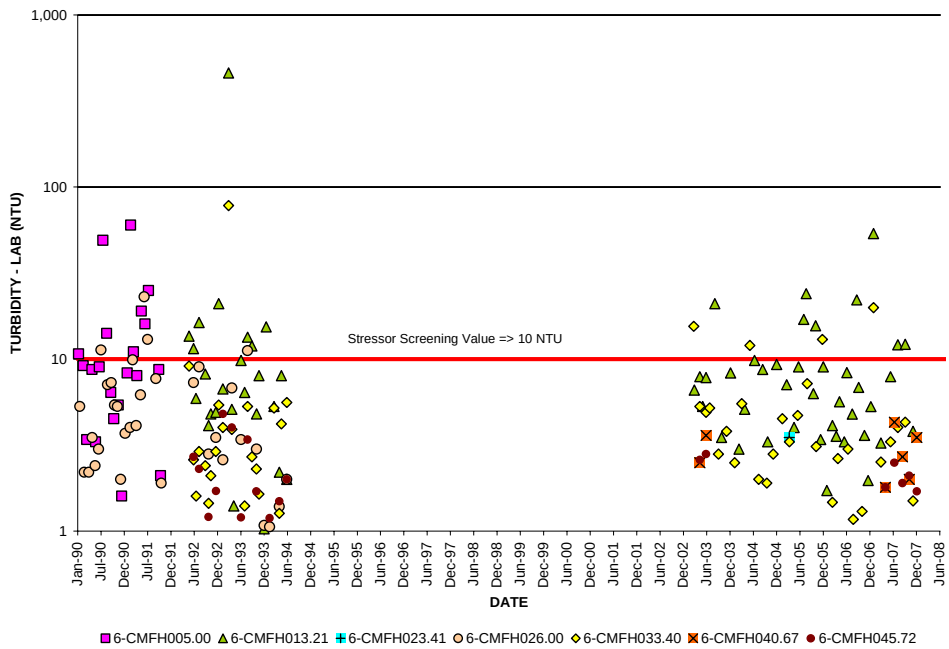


Figure 2.28. Turbidity values at water quality monitoring stations in Middle Fork Holston River.

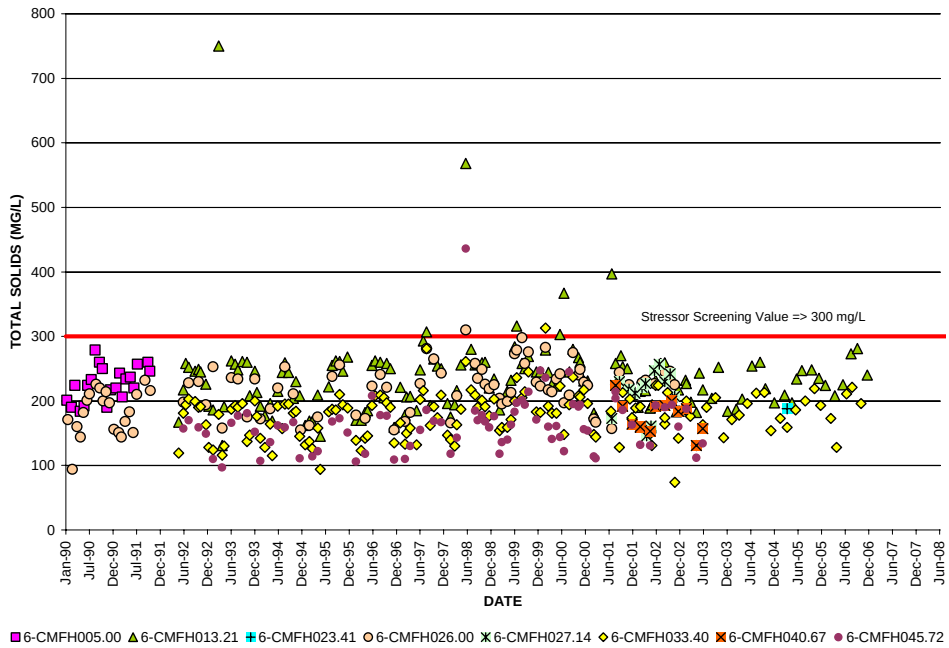


Figure 2.29. Total solids values at water quality monitoring stations in Middle Fork Holston River.

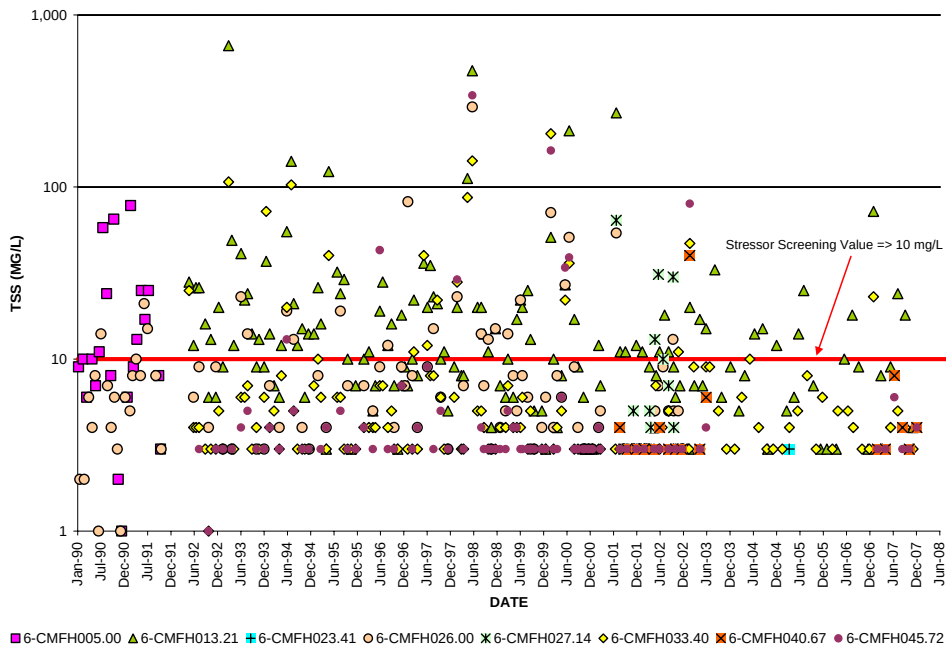


Figure 2.30. Total suspended solids (TSS) values at water quality monitoring stations in Middle Fork Holston River.

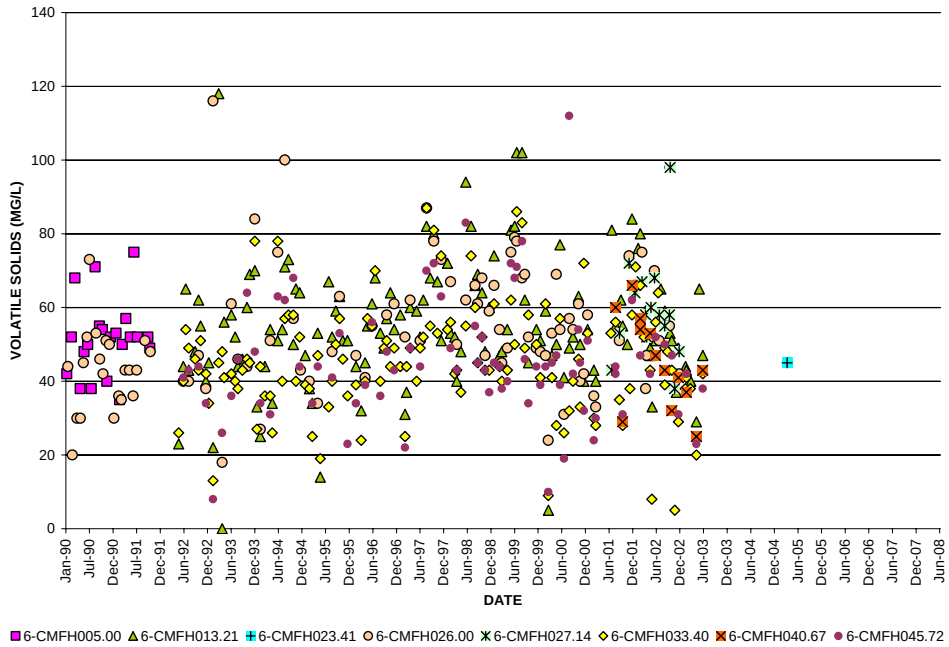


Figure 2.31. Volatile solids values at water quality monitoring stations in Middle Fork Holston River.

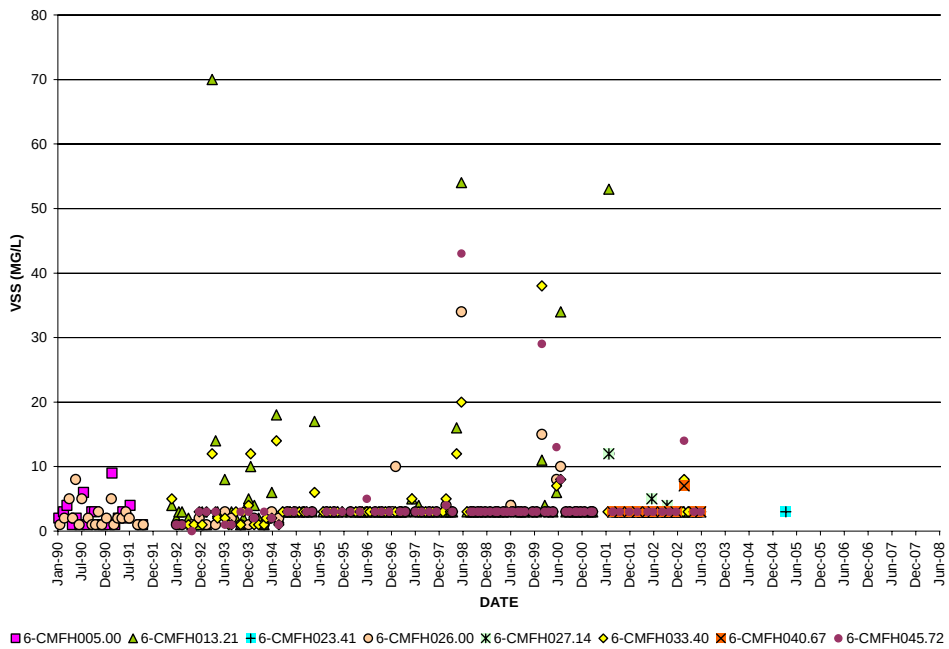


Figure 2.32. Volatile suspended solids values at water quality monitoring stations in Middle Fork Holston River.

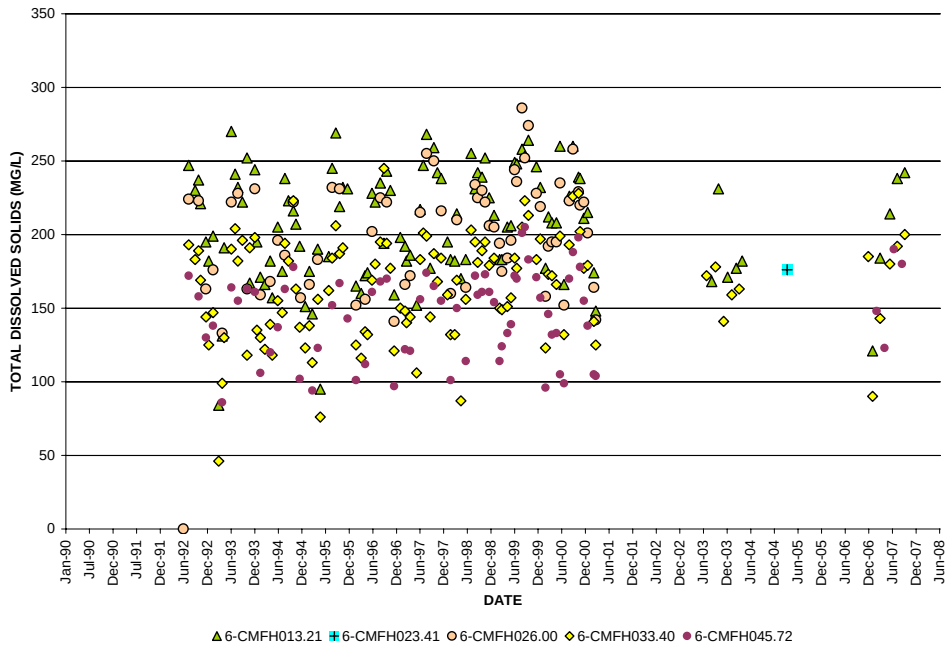


Figure 2.33. Total dissolved solids values at water quality monitoring stations in Middle Fork Holston River.

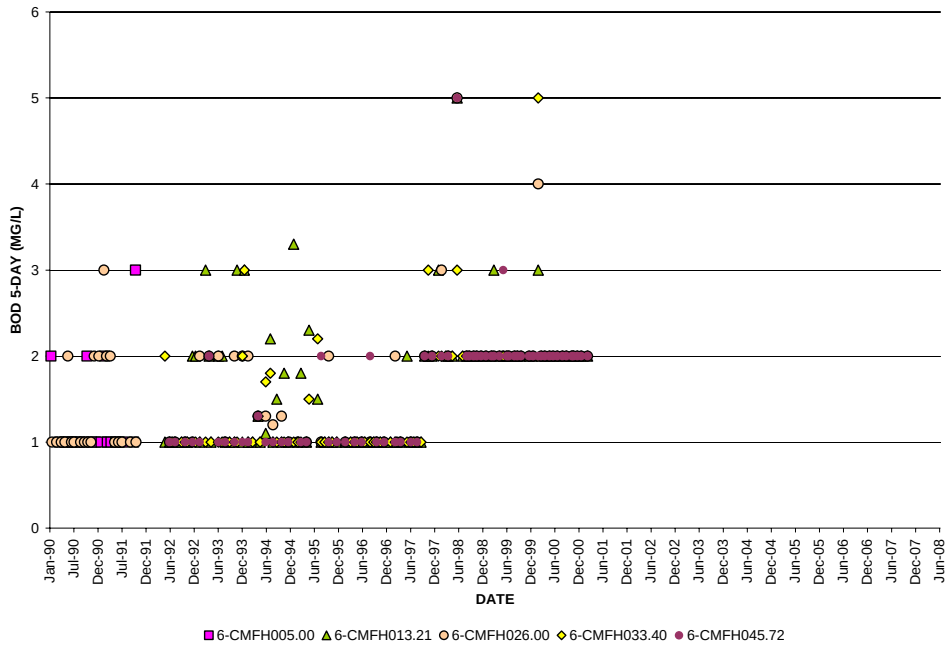


Figure 2.34. Biochemical oxygen demand (BOD_5) values at water quality monitoring stations in Middle Fork Holston River.

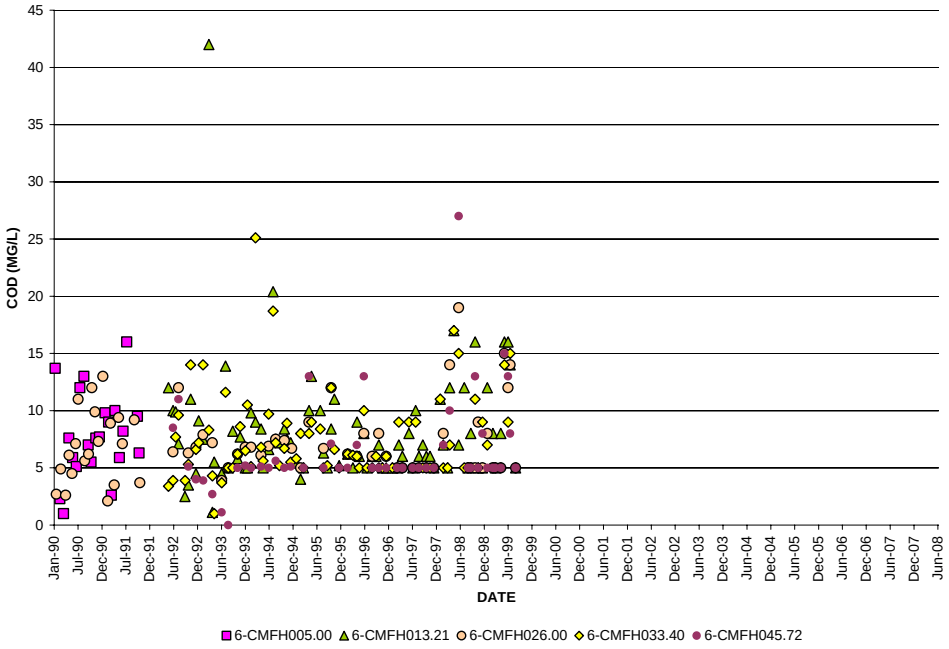


Figure 2.35. Chemical oxygen demand values at water quality monitoring stations in Middle Fork Holston River.

2.7.2 Nutrients

Tables 2.30 through 2.37 contain summary of data collected at the various water quality stations. Summary of data includes number of observations between January 1, 1990 and March 31, 2008; mean, minimum; and maximum values. The data temporal range varies from parameter to parameter, and there is not always a good overlap between biological and ambient monitoring data. Data for nutrient parameters collected in the watershed are depicted in Figures 2.36 through 2.47. Summary of observations includes:

- One total nitrogen value at WQM station 6CMFH013.21 exceeded the stressor screening value of 2 mg/l;
- Ammonia values were well below the chronic freshwater criteria and does not appear to be a stressor on the benthic community;
- Nitrate values at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH026.00, 6CMFH027.14, and 6CMFH033.40 exceeded the stressor screening value of 1.5 mg/l;
- Numerous exceedances of the total kjeldahl nitrogen stressor screening value of 0.3mg/l were observed at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH026.00, 6CMFH027.14, 6CMFH033.40, and 6CMFH045.72;
- Total phosphorous values exceeded the stressor screening value of 0.05mg/l at all WQM stations except at station 6CMFH023.41;
- Chloride values at WQM stations 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 exceeded the stressor screening value of 30 mg/l; and
- Two sulfate values at WQM station 6CMFH033.40 and one value at stations 6CMFH013.21 and 6CMFH026.00 exceeded the stressor screening value of 50 mg/l.

Table 2.30. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH005.00 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Total Nitrogen, mg/L	N/A	N/A	N/A	N/A
NH3+NH4-N - Total, mg/L	21	0.05	0.10	0.04
NO2-N - Total, mg/L	21	0.01	0.02	0.01
NO3-N - Total, mg/L	21	1.44	1.90	0.80
NO2 and NO3 N - Total, mg/L	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen, mg/L	21	0.30	0.60	0.10
Total Phosphorus, mg/L	21	0.11	0.50	0.02
Orthophosphate - Total, mg/L	21	0.04	0.11	0.01
Chlorophyll A, µg/L	N/A	N/A	N/A	N/A
Alkalinity - Total, mg/L	21	156.43	186.10	96.30
Hardness - Total CACO3, mg/L	21	167.62	208.00	66.00
Chloride - Total, mg/L	21	10.11	13.00	7.20
Fluoride - Total, mg/L	20	0.17	0.56	0.10
Sulfate - Total, mg/L	20	12.94	17.98	1.31

Table 2.31. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH013.21 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Total Nitrogen, mg/L	27	1.52	2.11	1.27
NH3+NH4-N - Total, mg/L	137	0.05	0.18	0.04
NO2-N - Total, mg/L	131	0.02	0.11	0.01
NO3-N - Total, mg/L	131	1.31	2.31	0.42
NO2 and NO3 N - Total, mg/L	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen, mg/L	131	0.35	2.10	0.10
Total Phosphorus, mg/L	157	0.08	0.52	0.01
Orthophosphate - Total, mg/L	131	0.06	0.29	0.01
Chlorophyll A, µg/L	96	1.62	22.86	0.50
Alkalinity - Total, mg/L	104	148.17	198.00	25.00
Hardness - Total CACO3, mg/L	129	168.19	230.00	42.30
Chloride - Total, mg/L	104	16.01	59.60	4.00
Fluoride - Total, mg/L	7	0.29	0.50	0.10
Sulfate - Total, mg/L	104	15.81	62.30	7.60

Table 2.32. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH023.41 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Total Nitrogen, mg/L	1	1.18	1.18	1.18
NH3+NH4-N - Total, mg/L	1	0.04	0.04	0.04
NO2-N - Total, mg/L	1	0.01	0.01	0.01
NO3-N - Total, mg/L	1	1.00	1.00	1.00
NO2 and NO3 N - Total, mg/L	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen, mg/L	1	0.10	0.10	0.10
Total Phosphorus, mg/L	1	0.02	0.02	0.02
Orthophosphate - Total, mg/L	1	0.02	0.02	0.02
Chlorophyll A, µg/L	1	4.06	4.06	4.06
Alkalinity - Total, mg/L	1	123.00	123.00	123.00
Hardness - Total CACO3, mg/L	1	145.00	145.00	145.00
Chloride - Total, mg/L	1	12.90	12.90	12.90
Fluoride - Total, mg/L	N/A	N/A	N/A	N/A
Sulfate - Total, mg/L	1	8.17	8.17	8.17

Table 2.33. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH026.00 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Total Nitrogen, mg/L	N/A	N/A	N/A	N/A
NH3+NH4-N - Total, mg/L	103	0.11	0.37	0.04
NO2-N - Total, mg/L	103	0.02	0.09	0.01
NO3-N - Total, mg/L	103	1.18	1.95	0.04
NO2 and NO3 N - Total, mg/L	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen, mg/L	102	0.42	1.70	0.10
Total Phosphorus, mg/L	102	0.11	0.50	0.01
Orthophosphate - Total, mg/L	103	0.07	0.35	0.01
Chlorophyll A, µg/L	N/A	N/A	N/A	N/A
Alkalinity - Total, mg/L	87	137.65	179.00	39.10
Hardness - Total CACO3, mg/L	102	153.84	204.00	36.60
Chloride - Total, mg/L	86	18.23	83.30	4.90
Fluoride - Total, mg/L	26	0.15	0.50	0.07
Sulfate - Total, mg/L	87	14.02	56.90	7.70

Table 2.34. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH027.14 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Total Nitrogen, mg/L	N/A	N/A	N/A	N/A
NH3+NH4-N - Total, mg/L	15	0.05	0.08	0.04
NO2-N - Total, mg/L	15	0.01	0.03	0.01
NO3-N - Total, mg/L	15	1.13	1.61	0.65
NO2 and NO3 N - Total, mg/L	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen, mg/L	15	0.25	0.70	0.10
Total Phosphorus, mg/L	15	0.07	0.11	0.01
Orthophosphate - Total, mg/L	15	0.04	0.09	0.02
Chlorophyll A, µg/L	N/A	N/A	N/A	N/A
Alkalinity - Total, mg/L	N/A	N/A	N/A	N/A
Hardness - Total CACO3, mg/L	15	144.72	188.00	46.80
Chloride - Total, mg/L	N/A	N/A	N/A	N/A
Fluoride - Total, mg/L	N/A	N/A	N/A	N/A
Sulfate - Total, mg/L	N/A	N/A	N/A	N/A

Table 2.35. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH033.40 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Total Nitrogen, mg/L	27	1.31	1.90	0.45
NH3+NH4-N - Total, mg/L	137	0.05	0.56	0.04
NO2-N - Total, mg/L	130	0.02	0.20	0.01
NO3-N - Total, mg/L	130	1.12	1.89	0.07
NO2 and NO3 N - Total, mg/L	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen, mg/L	130	0.25	1.30	0.10
Total Phosphorus, mg/L	156	0.08	0.40	0.01
Orthophosphate - Total, mg/L	130	0.06	0.55	0.01
Chlorophyll A, µg/L	21	1.94	10.65	0.50
Alkalinity - Total, mg/L	104	114.97	158.00	40.50
Hardness - Total CACO3, mg/L	128	133.04	390.00	52.00
Chloride - Total, mg/L	104	12.48	62.60	3.00
Fluoride - Total, mg/L	9	0.26	0.50	0.10
Sulfate - Total, mg/L	104	13.45	62.50	4.60

Table 2.36. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH040.67 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Total Nitrogen, mg/L	6	0.92	1.09	0.73
NH3+NH4-N - Total, mg/L	19	0.04	0.04	0.04
NO2-N - Total, mg/L	13	0.01	0.01	0.01
NO3-N - Total, mg/L	13	0.86	1.48	0.54
NO2 and NO3 N - Total, mg/L	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen, mg/L	13	0.12	0.20	0.10
Total Phosphorus, mg/L	19	0.03	0.05	0.01
Orthophosphate - Total, mg/L	13	0.02	0.03	0.02
Chlorophyll A, µg/L	12	3.04	22.43	0.55
Alkalinity - Total, mg/L	N/A	N/A	N/A	N/A
Hardness - Total CACO3, mg/L	13	117.38	166.00	75.00
Chloride - Total, mg/L	N/A	N/A	N/A	N/A
Fluoride - Total, mg/L	N/A	N/A	N/A	N/A
Sulfate - Total, mg/L	N/A	N/A	N/A	N/A

Table 2.37. Nutrients, chlorophyll A, and inorganics water quality data summary for station 6CMFH045.72 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Total Nitrogen, mg/L	6	0.87	1.01	0.66
NH3+NH4-N - Total, mg/L	87	0.04	0.12	0.04
NO2-N - Total, mg/L	81	0.01	0.05	0.01
NO3-N - Total, mg/L	81	0.78	1.52	0.04
NO2 and NO3 N - Total, mg/L	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen, mg/L	82	0.18	1.10	0.10
Total Phosphorus, mg/L	88	0.03	0.50	0.01
Orthophosphate - Total, mg/L	81	0.02	0.21	0.01
Chlorophyll A, µg/L	12	3.83	33.23	0.50
Alkalinity - Total, mg/L	67	100.36	133.00	12.40
Hardness - Total CACO3, mg/L	80	116.05	160.00	43.40
Chloride - Total, mg/L	67	10.59	33.40	1.60
Fluoride - Total, mg/L	5	0.18	0.50	0.10
Sulfate - Total, mg/L	67	11.68	45.80	3.80

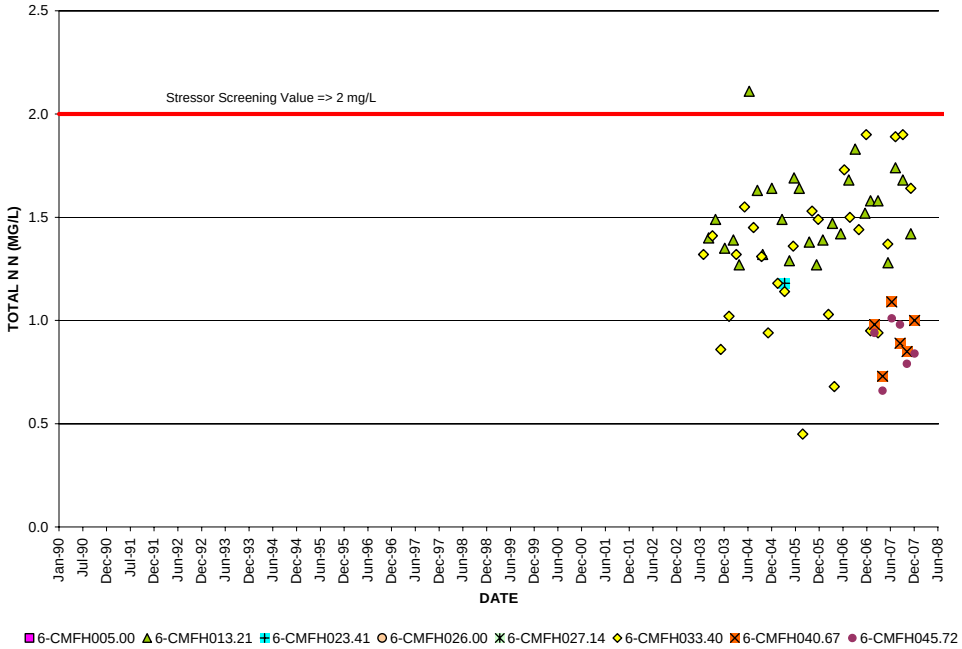


Figure 2.36. Total nitrogen values at water quality monitoring stations in Middle Fork Holston River.

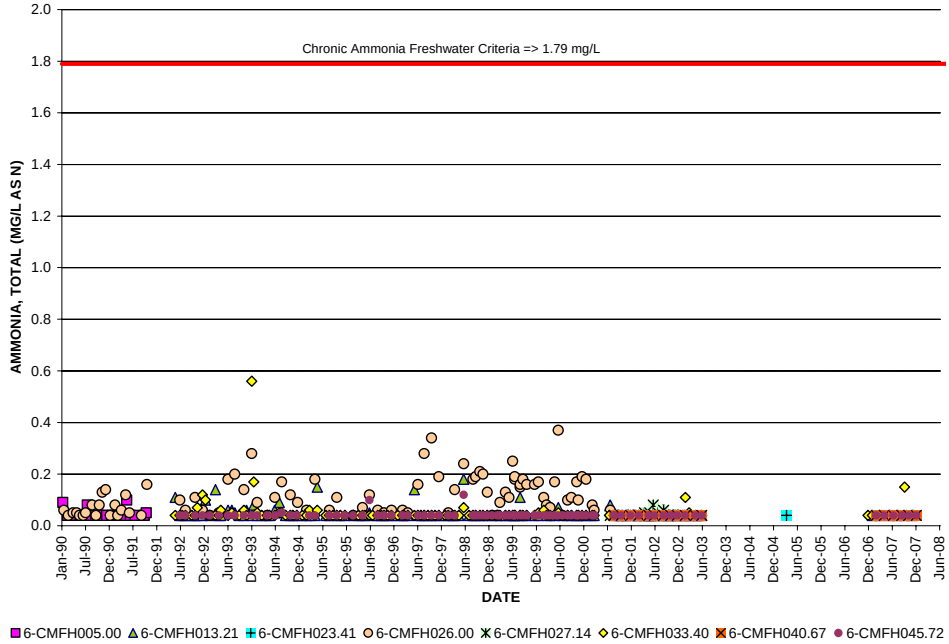


Figure 2.37. Ammonia values at water quality monitoring stations in Middle Fork Holston River.

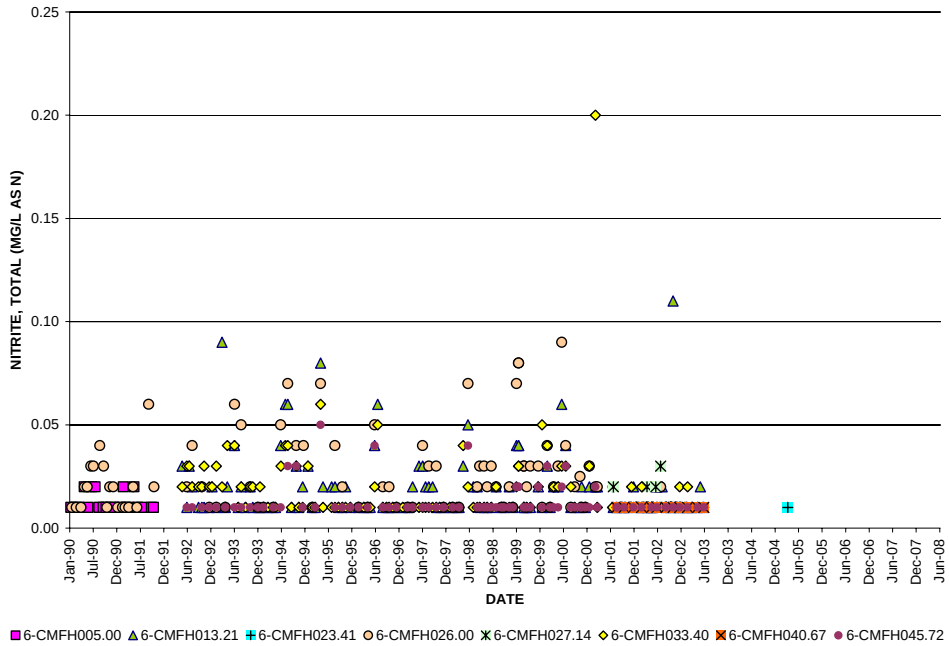


Figure 2.38. Nitrite values at water quality monitoring stations in Middle Fork Holston River.

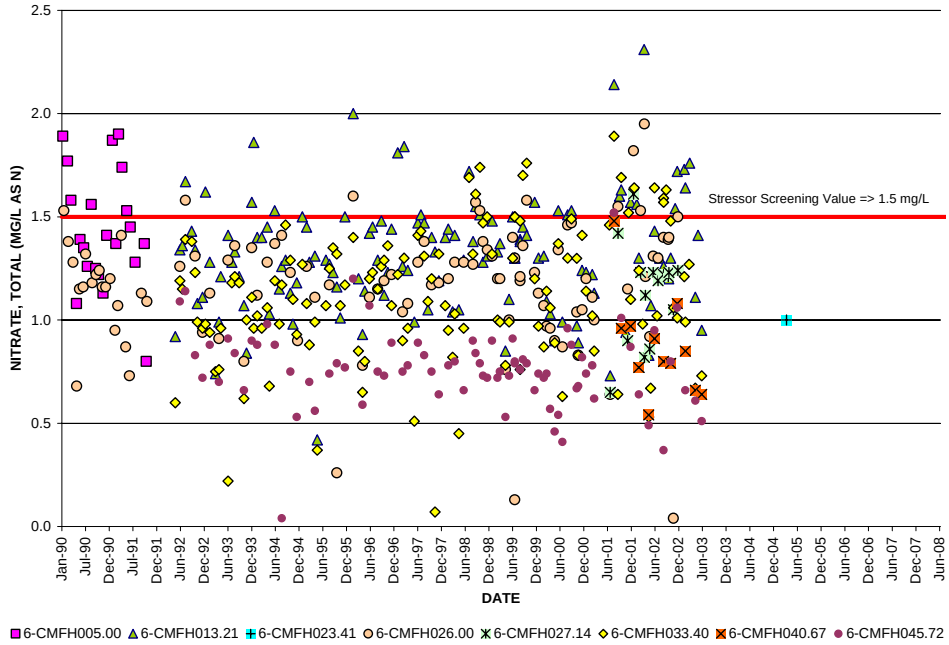


Figure 2.39. Nitrate values at water quality monitoring stations in Middle Fork Holston River.

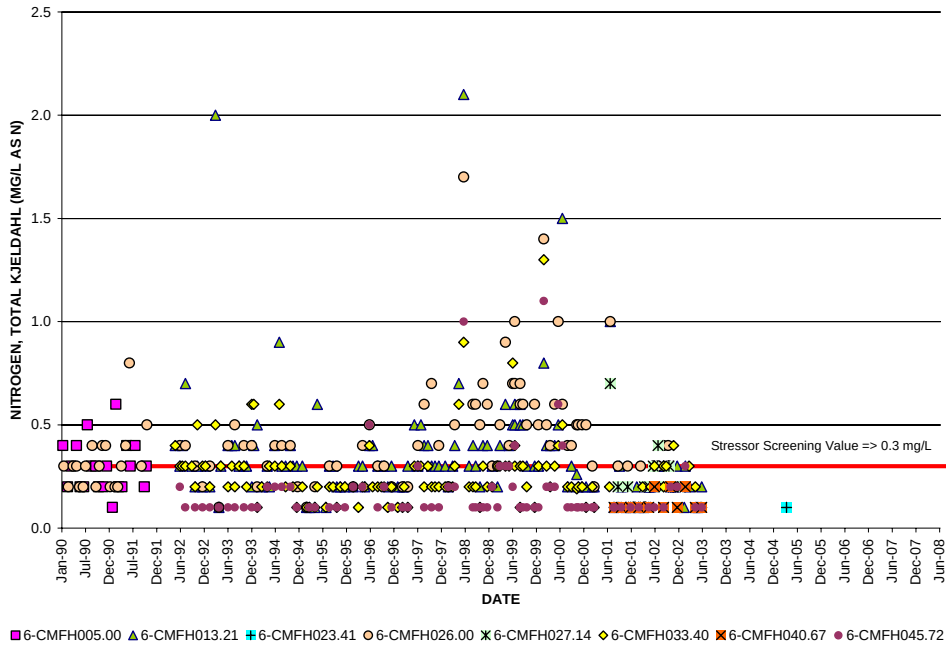


Figure 2.40. Total kjeldahl nitrogen values at water quality monitoring stations in Middle Fork Holston River.

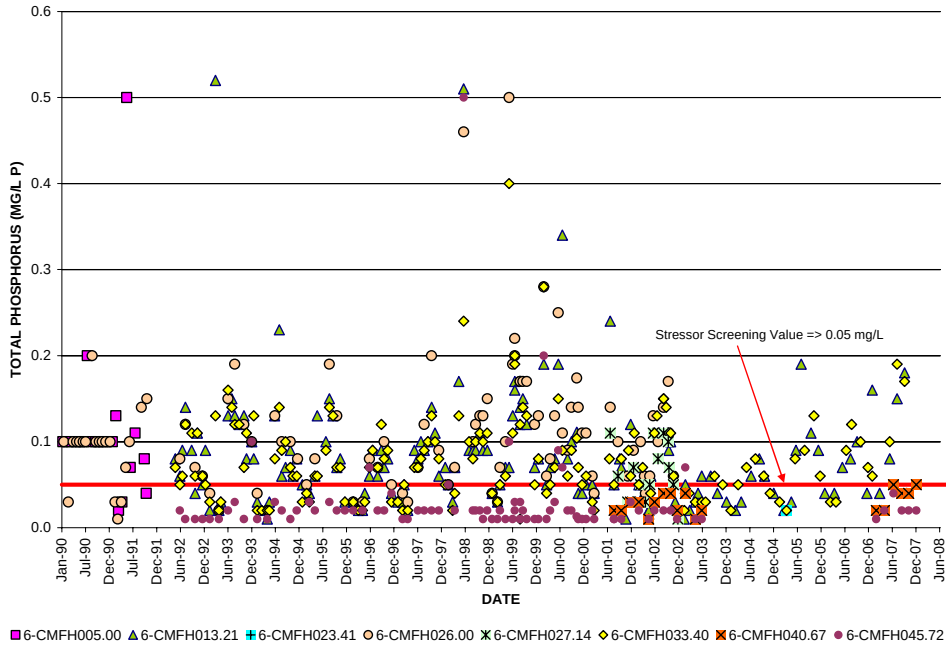


Figure 2.41. Total phosphorous values at water quality monitoring stations in Middle Fork Holston River.

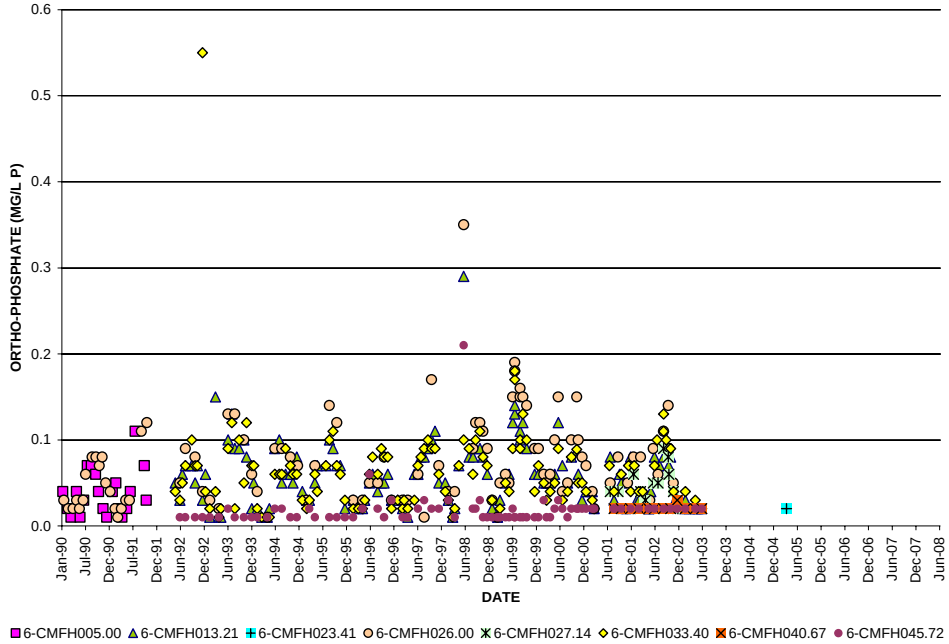


Figure 2.42. Ortho-phosphate values at water quality monitoring stations in Middle Fork Holston River.

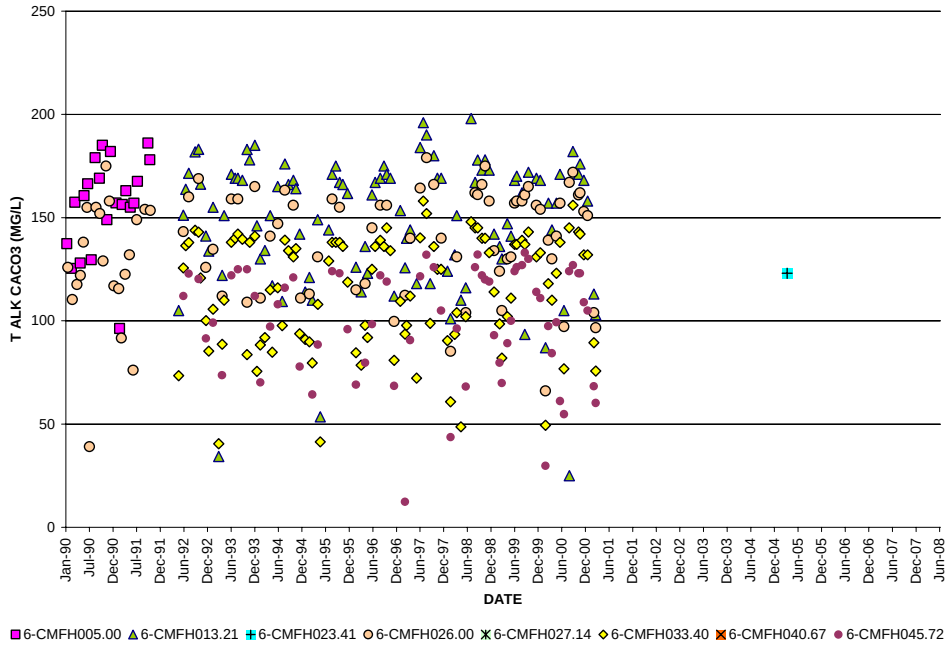


Figure 2.43. Alkalinity values at water quality monitoring stations in Middle Fork Holston River.

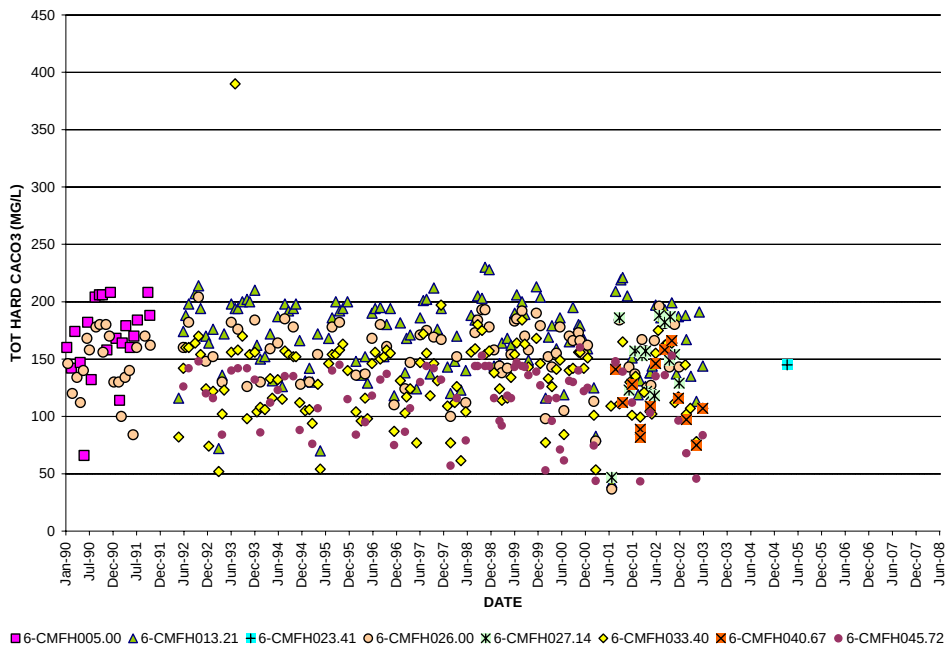


Figure 2.44. Hardness values at water quality monitoring stations in Middle Fork Holston River.

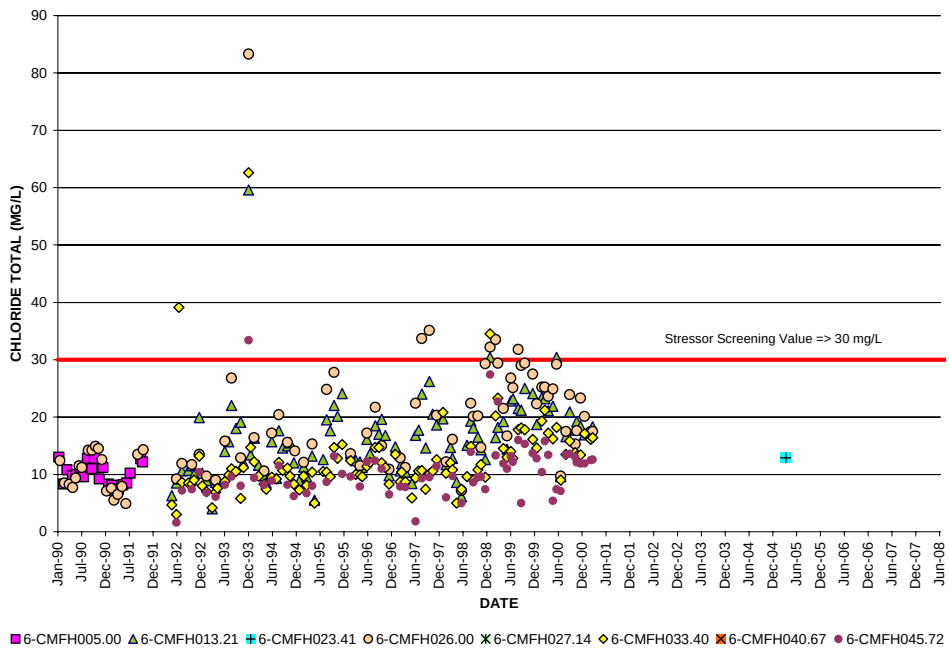


Figure 2.45. Chloride values at water quality monitoring stations in Middle Fork Holston River.

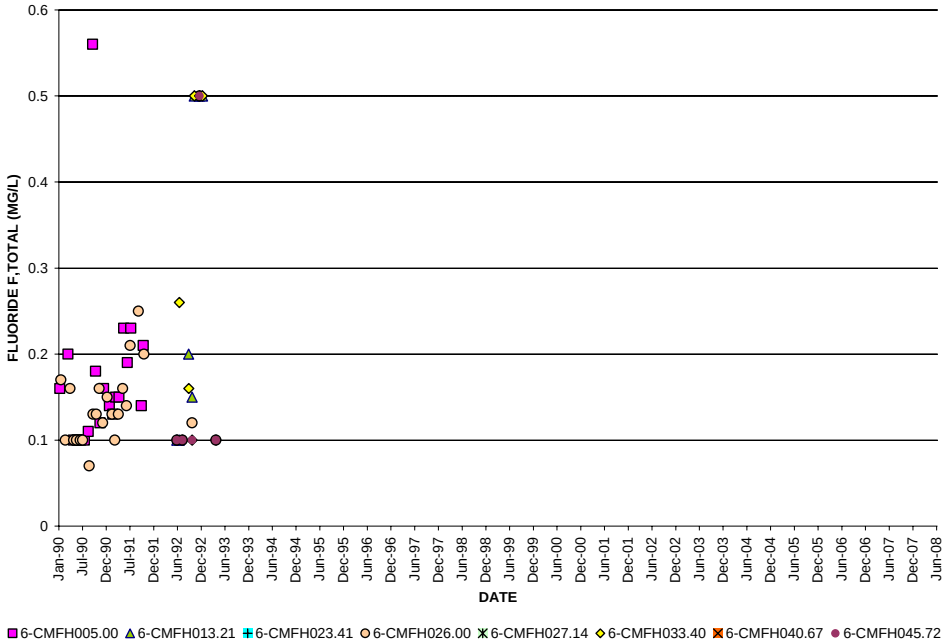


Figure 2.46. Fluoride values at water quality monitoring stations in Middle Fork Holston River.

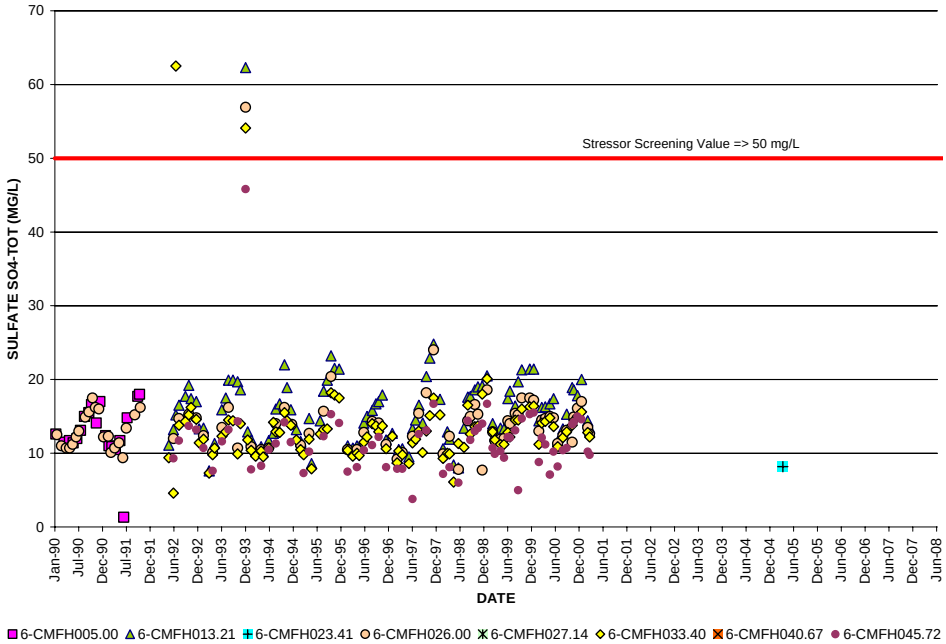


Figure 2.47. Sulfate values at water quality monitoring stations in Middle Fork Holston River.

2.7.3 Metals

Tables 2.38 through 2.43 contain summary of data collected at the various water quality stations. Summary of data includes number of observations between January 1, 1990 and March 31, 2008; mean, minimum; and maximum values. The data temporal range varies from parameter to parameter, and there is not always a good overlap between biological and ambient monitoring data. Total metal concentrations were measured at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 and sedimentary metal concentrations were measured at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH023.41, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72. Data for metal parameters collected in the watershed are depicted in Figures 2.48 through 2.77. Summary of observations includes:

- Sedimentary cadmium values at WQM stations 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 exceeded the consensus probable effect concentration of 4.98 ppm; and
- All other total metal concentrations and sedimentary metal concentrations at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH023.41, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 were below the applicable consensus probable effect concentration and do not appear to be a stressor to the benthic community.

Table 2.38. Metals water quality data summary for station 6CMFH005.00 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
METALS - TOTAL				
Arsenic µg/L	1	10.00	10.00	10.00
Beryllium, µg/l	N/A	N/A	N/A	N/A
Cadmium, µg/l	1	10.00	10.00	10.00
Chromium, µg/l	1	10.00	10.00	10.00
Copper, µg/l	1	10.00	10.00	10.00
Iron, µg/l	1	280.00	280.00	280.00
Lead, µg/l	1	10.00	10.00	10.00
Magnesium, µg/l	N/A	N/A	N/A	N/A
Manganese, µg/l	1	30.00	30.00	30.00
Mercury, µg/l	1	0.30	0.30	0.30
Nickel, µg/l	1	10.00	10.00	10.00
Selenium, µg/l	1	10.00	10.00	10.00
Thallium, µg/l	1	10.00	10.00	10.00
Zinc,µg/l	1	10.00	10.00	10.00
METALS - SEDIMENT				
Aluminum, mg/kg	N/A	N/A	N/A	N/A
Antimony, mg/kg	N/A	N/A	N/A	N/A
Arsenic mg/kg	2	6.50	9.00	4.00
Beryllium, mg/kg	2	1.50	2.00	1.00
Cadmium, mg/kg	2	1.00	1.00	1.00
Chromium, mg/kg	2	36.50	47.00	26.00
Copper, mg/kg	2	33.00	37.00	29.00
Iron, mg/kg	N/A	N/A	N/A	N/A
Lead, mg/kg	2	42	52	32
Manganese, mg/kg	N/A	N/A	N/A	N/A
Mercury, mg/kg	2	0.29	0.50	0.07
Nickel, mg/kg	2	28.50	32.00	25.00
Selenium, mg/kg	2	2.50	4.00	1.00
Silver,mg/kg	N/A	N/A	N/A	N/A
Thallium, mg/kg	2	2.00	3.00	1.00
Zinc,mg/kg	2	132.00	144.00	120.00

Table 2.39. Metals water quality data summary for station 6CMFH013.21 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
METALS - TOTAL				
Arsenic µg/L	5	10.00	10.00	10.00
Beryllium, µg/l	5	10.00	10.00	10.00
Cadmium, µg/l	5	10.00	10.00	10.00
Chromium, µg/l	5	10.00	10.00	10.00
Copper, µg/l	5	10.00	10.00	10.00
Iron, µg/l	5	188.00	306.94	78.80
Lead, µg/l	5	10.00	10.00	10.00
Magnesium, µg/l	5	15,276	18,820	12,130
Manganese, µg/l	7	20.41	39.34	8.05
Mercury, µg/l	5	0.30	0.30	0.30
Nickel, µg/l	5	10.00	10.00	10.00
Selenium, µg/l	5	20.00	20.00	20.00
Thallium, µg/l	5	20.00	20.00	20.00
Zinc,µg/l	5	10.00	10.00	10.00
METALS - SEDIMENT				
Aluminum, mg/kg	5	11,900	20,100	3,040
Antimony, mg/kg	5	11.80	34.00	5.00
Arsenic mg/kg	7	5.14	6.00	5.00
Beryllium, mg/kg	7	5.00	5.00	5.00
Cadmium, mg/kg	7	5.00	5.00	5.00
Chromium, mg/kg	5	10.00	10.00	10.00
Copper, mg/kg	7	16.26	28.00	5.00
Iron, mg/kg	5	18,680	23,800	9,000
Lead, mg/kg	7	25.41	38.00	16.28
Manganese, mg/kg	5	684.40	1140.00	190.00
Mercury, mg/kg	7	0.30	0.30	0.30
Nickel, mg/kg	7	20.74	48.00	5.71
Selenium, mg/kg	7	1.00	1.00	1.00
Silver,mg/kg	7	5.00	5.00	5.00
Thallium, mg/kg	7	5.00	5.00	5.00
Zinc,mg/kg	7	80.64	125.00	32.57

Table 2.40. Metals water quality data summary for station 6CMFH023.41 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
METALS - TOTAL				
Arsenic µg/L	N/A	N/A	N/A	N/A
Beryllium, µg/l	N/A	N/A	N/A	N/A
Cadmium, µg/l	N/A	N/A	N/A	N/A
Chromium, µg/l	N/A	N/A	N/A	N/A
Copper, µg/l	N/A	N/A	N/A	N/A
Iron, µg/l	N/A	N/A	N/A	N/A
Lead, µg/l	N/A	N/A	N/A	N/A
Magnesium, µg/l	N/A	N/A	N/A	N/A
Manganese, µg/l	N/A	N/A	N/A	N/A
Mercury, µg/l	N/A	N/A	N/A	N/A
Nickel, µg/l	N/A	N/A	N/A	N/A
Selenium, µg/l	N/A	N/A	N/A	N/A
Thallium, µg/l	N/A	N/A	N/A	N/A
Zinc,µg/l	N/A	N/A	N/A	N/A
METALS - SEDIMENT				
Aluminum, mg/kg	1	5,900	5,900	5,900
Antimony, mg/kg	1	5.00	5.00	5.00
Arsenic mg/kg	1	5.00	5.00	5.00
Beryllium, mg/kg	1	5.00	5.00	5.00
Cadmium, mg/kg	1	1.00	1.00	1.00
Chromium, mg/kg	1	15.30	15.30	15.30
Copper, mg/kg	1	10.50	10.50	10.50
Iron, mg/kg	1	14,900	14,900	14,900
Lead, mg/kg	1	17.90	17.90	17.90
Manganese, mg/kg	1	365.00	365.00	365.00
Mercury, mg/kg	1	0.10	0.10	0.10
Nickel, mg/kg	1	11.80	11.80	11.80
Selenium, mg/kg	1	1.00	1.00	1.00
Silver,mg/kg	1	1.00	1.00	1.00
Thallium, mg/kg	1	5.00	5.00	5.00
Zinc,mg/kg	1	74.30	74.30	74.30

Table 2.41. Metals water quality data summary for station 6CMFH026.00 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
METALS - TOTAL				
Arsenic µg/L	6	10.00	10.00	10.00
Beryllium, µg/l	5	10.00	10.00	10.00
Cadmium, µg/l	6	10.00	10.00	10.00
Chromium, µg/l	5	11.35	16.76	10.00
Copper, µg/l	6	10.00	10.00	10.00
Iron, µg/l	6	264.65	449.61	76.96
Lead, µg/l	6	10.00	10.00	10.00
Magnesium, µg/l	5	15,410	17,290	12,910
Manganese, µg/l	6	28.10	50.00	10.00
Mercury, µg/l	6	0.30	0.30	0.30
Nickel, µg/l	6	10.00	10.00	10.00
Selenium, µg/l	6	18.33	20.00	10.00
Thallium, µg/l	6	18.33	20.00	10.00
Zinc,µg/l	6	10.48	12.65	10.00
METALS - SEDIMENT				
Aluminum, mg/kg	6	14,437	18,700	9,390
Antimony, mg/kg	6	10.00	33.00	5.00
Arsenic mg/kg	9	6.63	10.00	5.00
Beryllium, mg/kg	9	4.11	5.00	1.00
Cadmium, mg/kg	9	4.11	5.00	1.00
Chromium, mg/kg	9	22.08	27.00	17.00
Copper, mg/kg	9	22.57	31.00	15.00
Iron, mg/kg	6	21,425	23,700	18,700
Lead, mg/kg	9	30.70	57.00	13.00
Manganese, mg/kg	6	641.00	819.00	495.00
Mercury, mg/kg	9	0.29	0.50	0.05
Nickel, mg/kg	9	20.85	25.00	16.00
Selenium, mg/kg	9	2.56	10.00	1.00
Silver,mg/kg	7	5.00	5.00	5.00
Thallium, mg/kg	9	5.11	10.00	1.00
Zinc,mg/kg	9	109.44	146.00	81.00

Table 2.42. Metals water quality data summary for station 6CMFH033.40 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
METALS - TOTAL				
Arsenic µg/L	5	10.00	10.00	10.00
Beryllium, µg/l	5	10.00	10.00	10.00
Cadmium, µg/l	5	10.00	10.00	10.00
Chromium, µg/l	5	10.00	10.00	10.00
Copper, µg/l	5	10.16	10.82	10.00
Iron, µg/l	5	152.10	397.11	63.50
Lead, µg/l	5	10.00	10.00	10.00
Magnesium, µg/l	5	13,116	18,100	9,000
Manganese, µg/l	5	18.66	41.30	10.00
Mercury, µg/l	5	0.30	0.30	0.30
Nickel, µg/l	5	10.00	10.00	10.00
Selenium, µg/l	5	20.00	20.00	20.00
Thallium, µg/l	5	20.00	20.00	20.00
Zinc,µg/l	5	51.93	145.00	10.00
METALS - SEDIMENT				
Aluminum, mg/kg	6	8,562	18,130	3,360
Antimony, mg/kg	6	7.67	21.00	5.00
Arsenic mg/kg	8	5.51	7.00	5.00
Beryllium, mg/kg	8	5.00	5.00	5.00
Cadmium, mg/kg	8	5.00	5.00	5.00
Chromium, mg/kg	8	17.61	25.00	12.00
Copper, mg/kg	8	13.75	25.00	9.00
Iron, mg/kg	6	17,833	23,100	13,500
Lead, mg/kg	8	24.92	33.00	17.00
Manganese, mg/kg	6	550.33	863.00	242.00
Mercury, mg/kg	8	0.30	0.30	0.30
Nickel, mg/kg	8	15.85	28.00	9.00
Selenium, mg/kg	8	1.00	1.00	1.00
Silver,mg/kg	8	5.00	5.00	5.00
Thallium, mg/kg	8	5.13	6.00	5.00
Zinc,mg/kg	8	95.83	160.00	47.00

Table 2.43. Metals water quality data summary for station 6CMFH045.72 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
METALS - TOTAL				
Arsenic µg/L	5	10.00	10.00	10.00
Beryllium, µg/l	5	10.00	10.00	10.00
Cadmium, µg/l	5	10.00	10.00	10.00
Chromium, µg/l	5	10.00	10.00	10.00
Copper, µg/l	5	10.00	10.00	10.00
Iron, µg/l	5	53.98	65.90	38.79
Lead, µg/l	5	10.00	10.00	10.00
Magnesium, µg/l	5	13,440	15,310	11,270
Manganese, µg/l	5	10.72	12.50	10.00
Mercury, µg/l	5	0.30	0.30	0.30
Nickel, µg/l	5	10.00	10.00	10.00
Selenium, µg/l	5	20.00	20.00	20.00
Thallium, µg/l	5	20.00	20.00	20.00
Zinc,µg/l	5	10.00	10.00	10.00
METALS - SEDIMENT				
Aluminum, mg/kg	5	9,520	18,700	3,600
Antimony, mg/kg	5	7.60	18.00	5.00
Arsenic mg/kg	7	5.29	7.00	5.00
Beryllium, mg/kg	7	5.00	5.00	5.00
Cadmium, mg/kg	7	5.00	5.00	5.00
Chromium, mg/kg	7	18.99	27.00	12.00
Copper, mg/kg	7	18.01	27.00	10.48
Iron, mg/kg	5	20,420	25,400	18,200
Lead, mg/kg	7	19.70	32.00	7.00
Manganese, mg/kg	5	450.40	901.00	160.00
Mercury, mg/kg	7	0.30	0.30	0.30
Nickel, mg/kg	7	20.17	33.00	12.00
Selenium, mg/kg	7	1.00	1.00	1.00
Silver,mg/kg	7	5.00	5.00	5.00
Thallium, mg/kg	7	5.00	5.00	5.00
Zinc,mg/kg	7	110.46	190.00	66.00

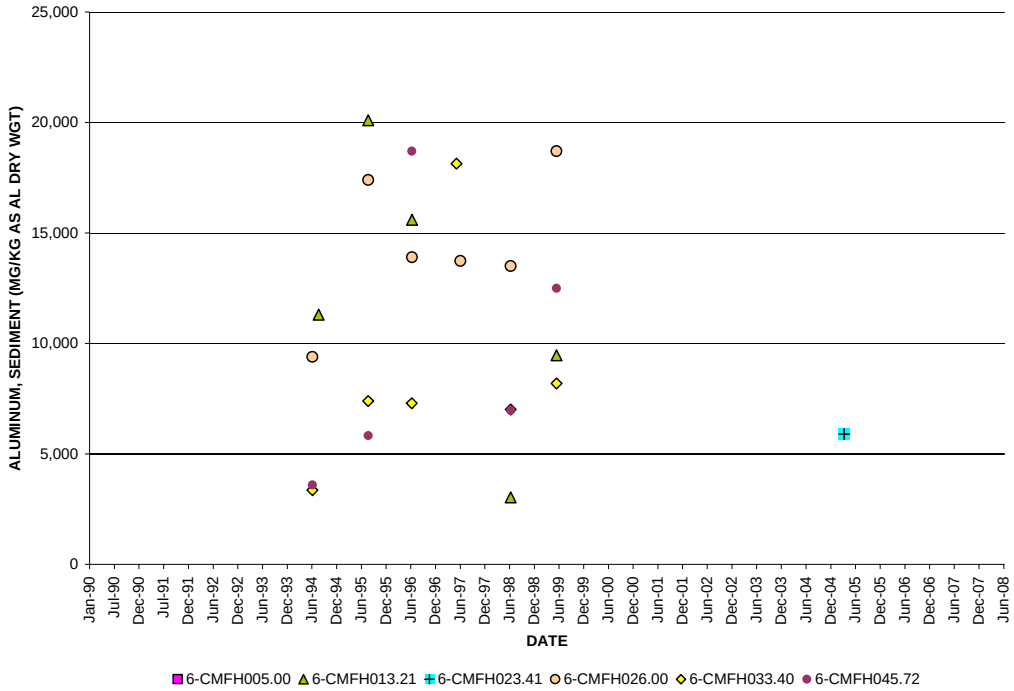


Figure 2.48. Sedimentary aluminum values at water quality monitoring stations in Middle Fork Holston River.

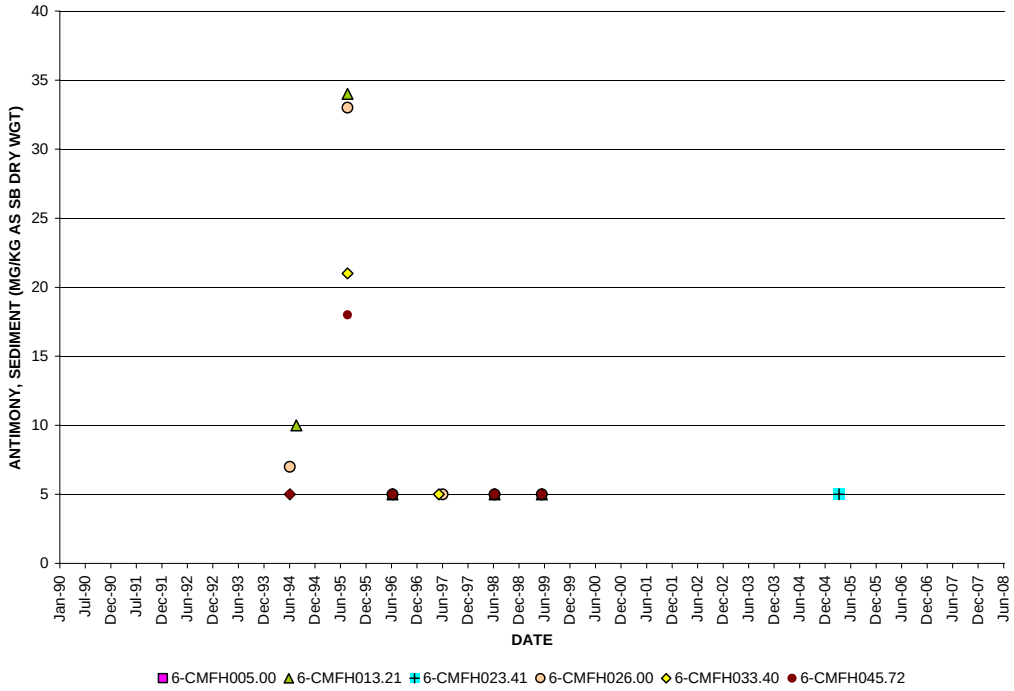


Figure 2.49. Sedimentary antimony values at water quality monitoring stations in Middle Fork Holston River.

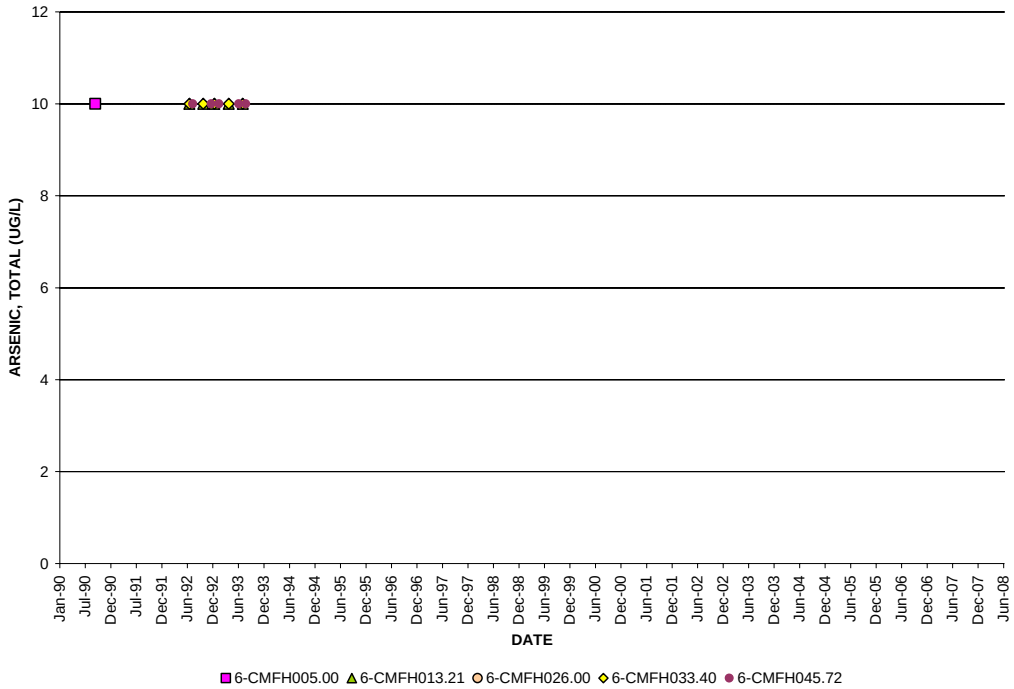


Figure 2.50. Total arsenic values at water quality monitoring stations in Middle Fork Holston River.

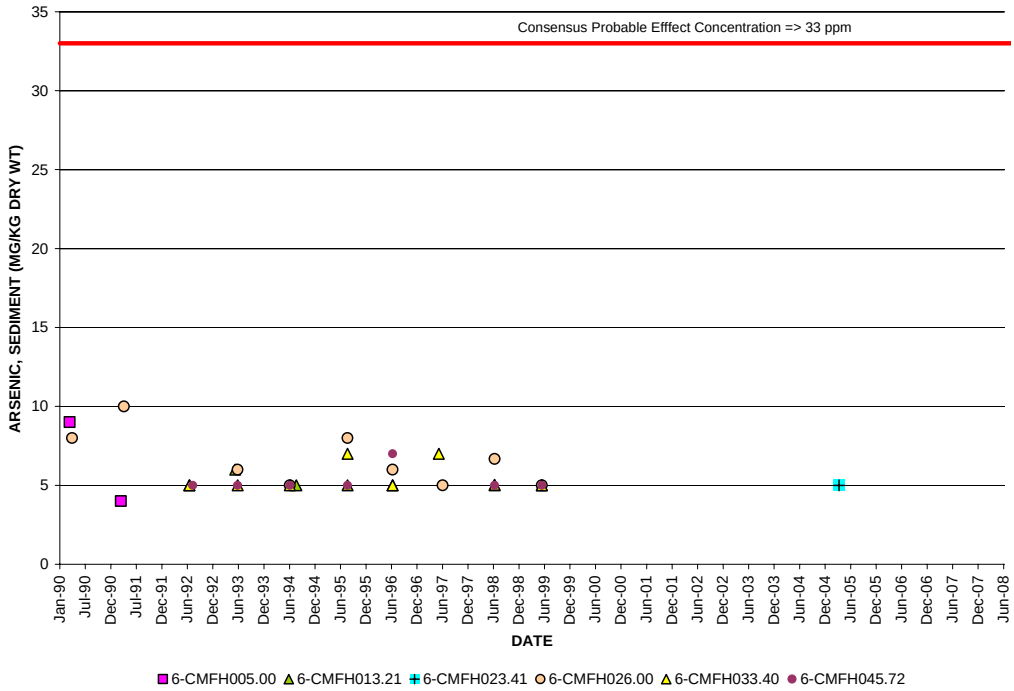


Figure 2.51. Sedimentary arsenic values at water quality monitoring stations in Middle Fork Holston River.

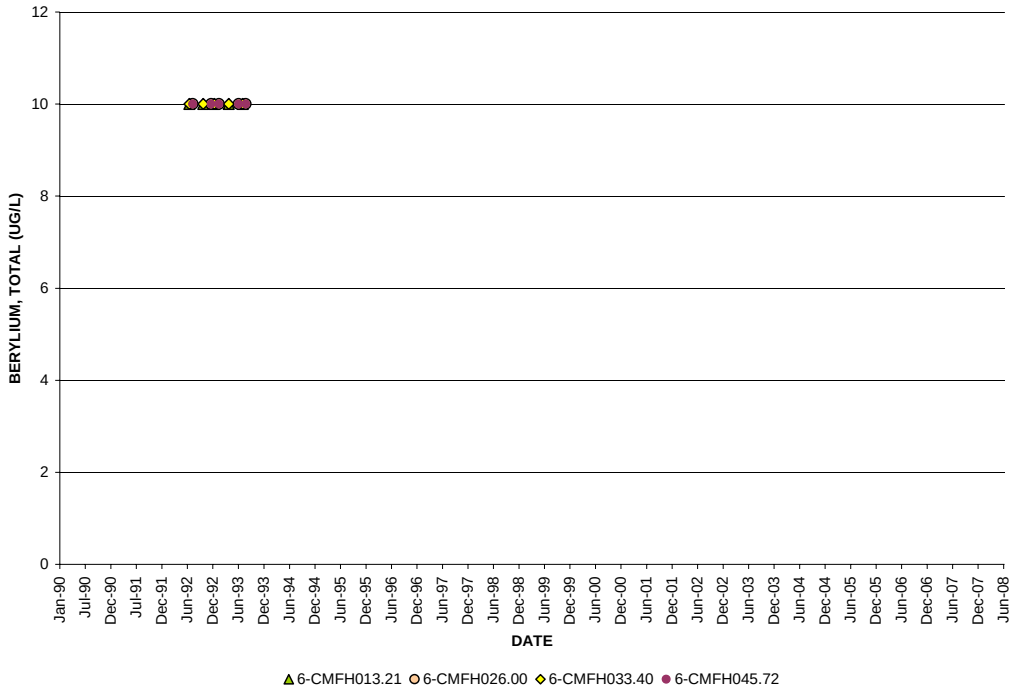


Figure 2.52. Total beryllium values at water quality monitoring stations in Middle Fork Holston River.

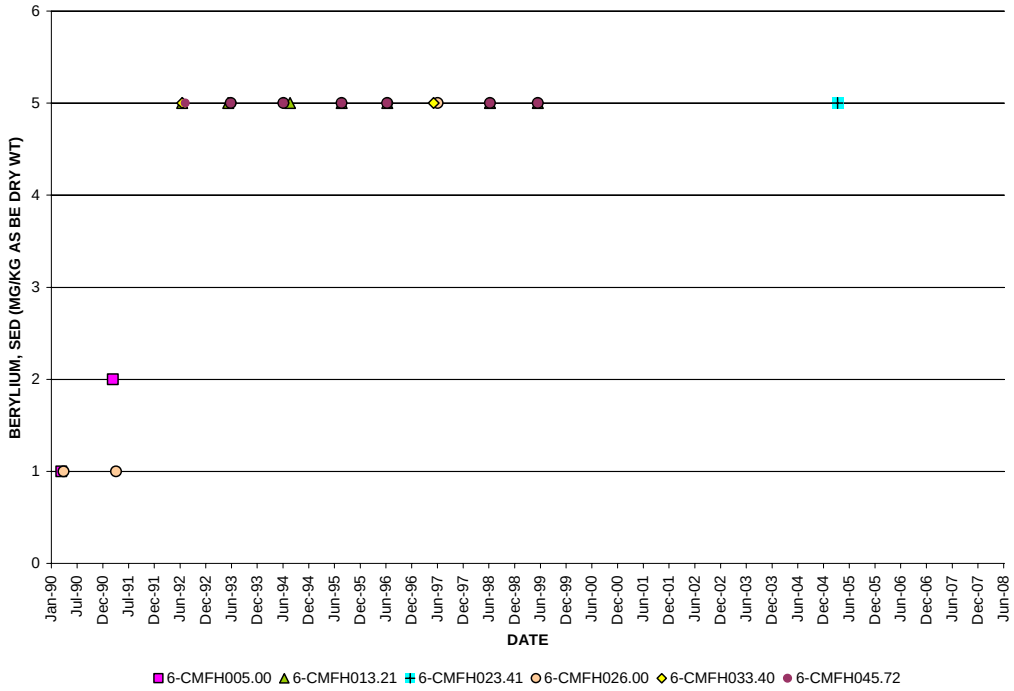


Figure 2.53. Sedimentary beryllium values at water quality monitoring stations in Middle Fork Holston River.

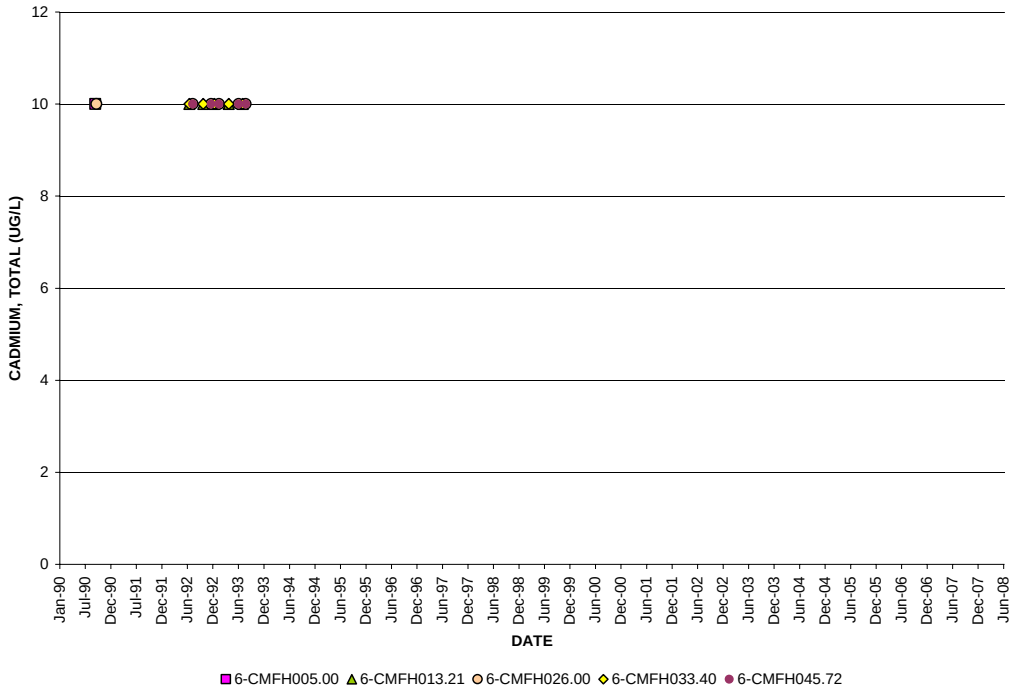


Figure 2.54. Total cadmium values at water quality monitoring stations in Middle Fork Holston River.

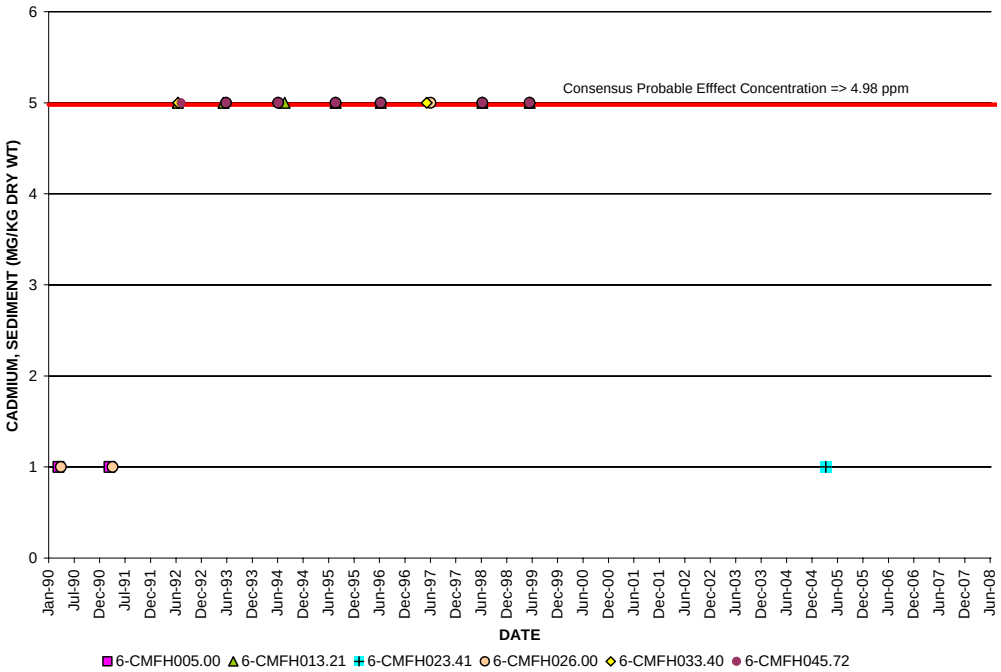


Figure 2.55. Sedimentary cadmium values at water quality monitoring stations in Middle Fork Holston River.

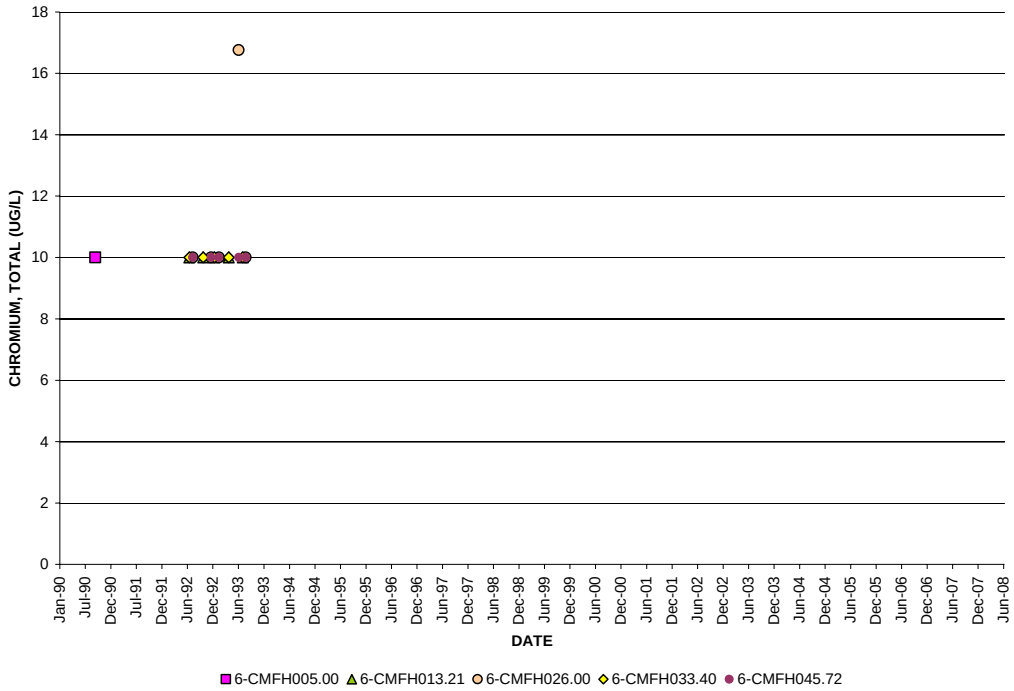


Figure 2.56. Total chromium values at water quality monitoring stations in Middle Fork Holston River.

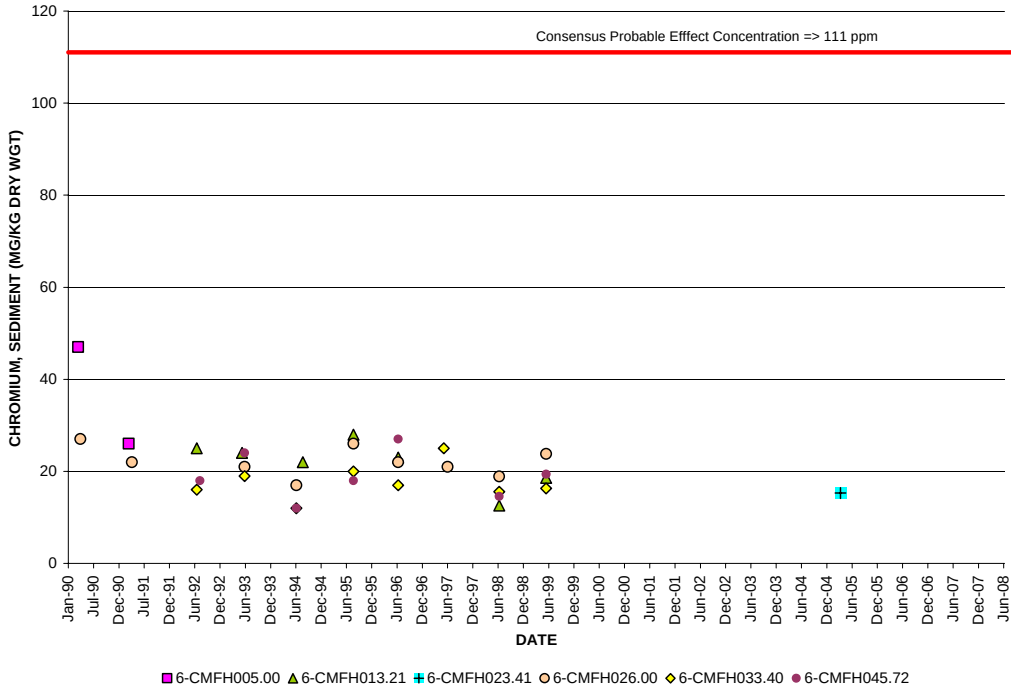


Figure 2.57. Sedimentary chromium values at water quality monitoring stations in Middle Fork Holston River.

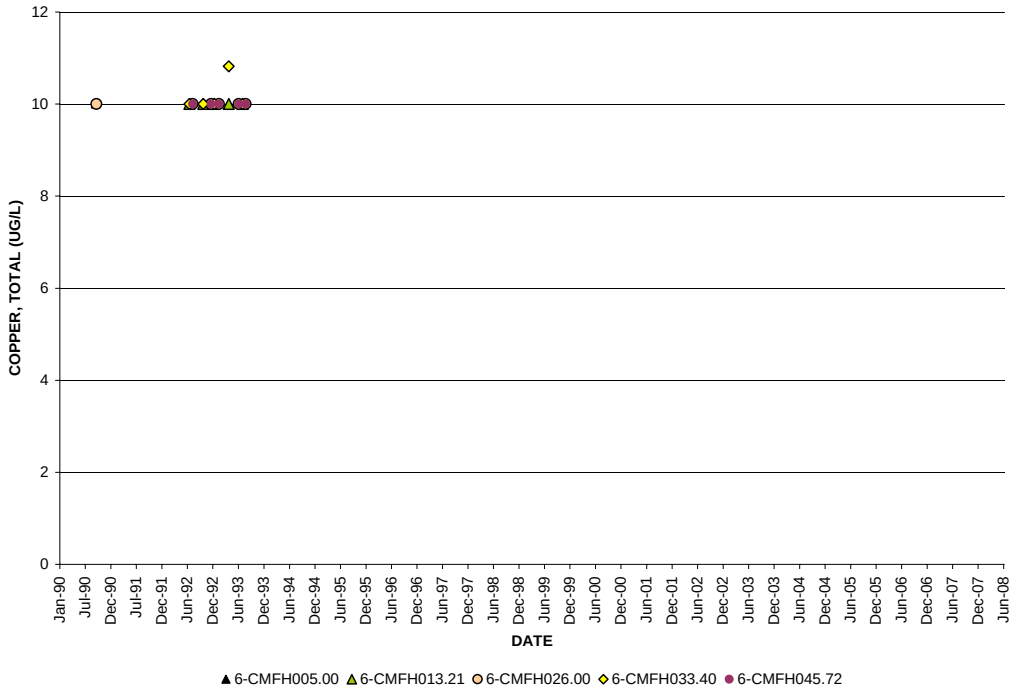


Figure 2.58. Total copper values at water quality monitoring stations in Middle Fork Holston River.

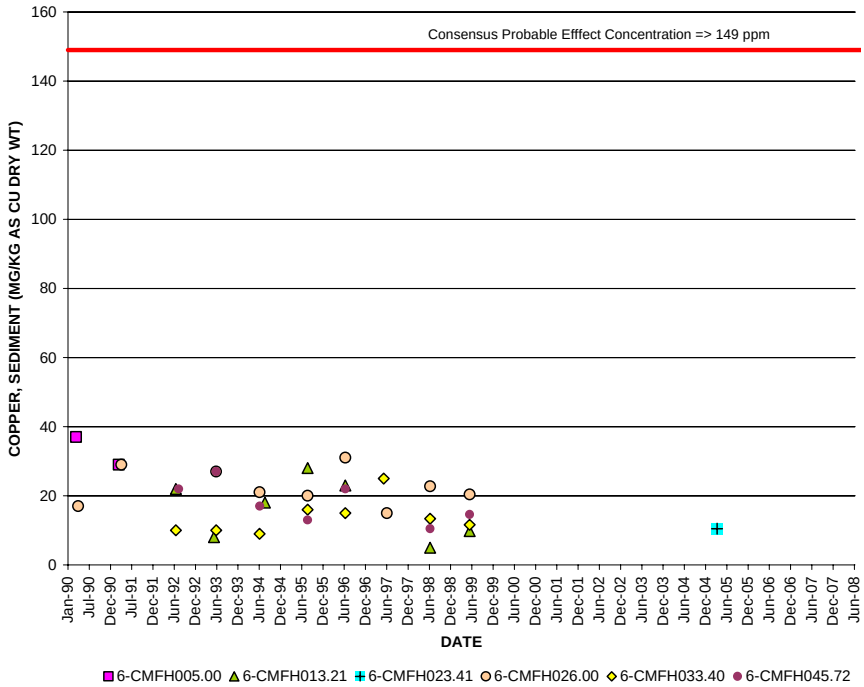


Figure 2.59. Sedimentary copper values at water quality monitoring stations in Middle Fork Holston River.

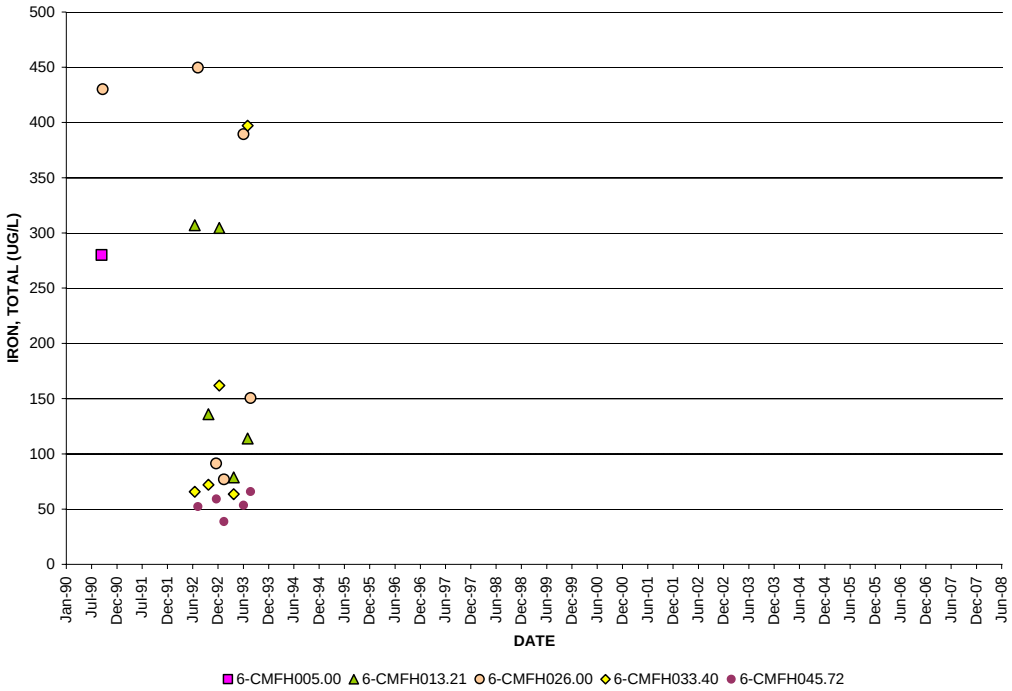


Figure 2.60. Total iron values at water quality monitoring stations in Middle Fork Holston River.

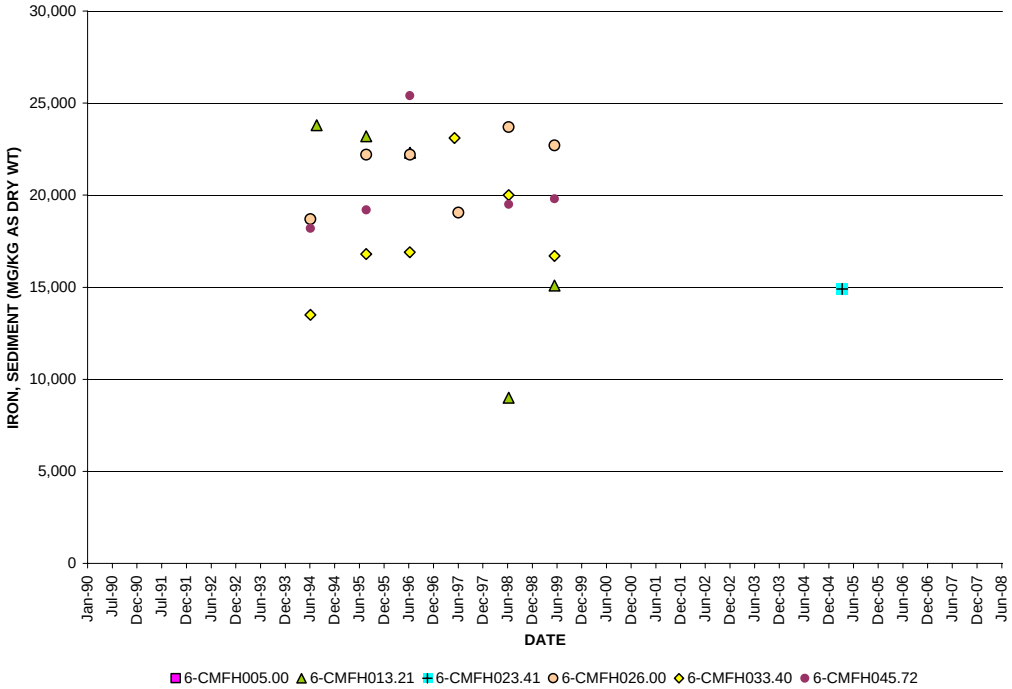


Figure 2.61. Sedimentary iron values at water quality monitoring stations in Middle Fork Holston River.

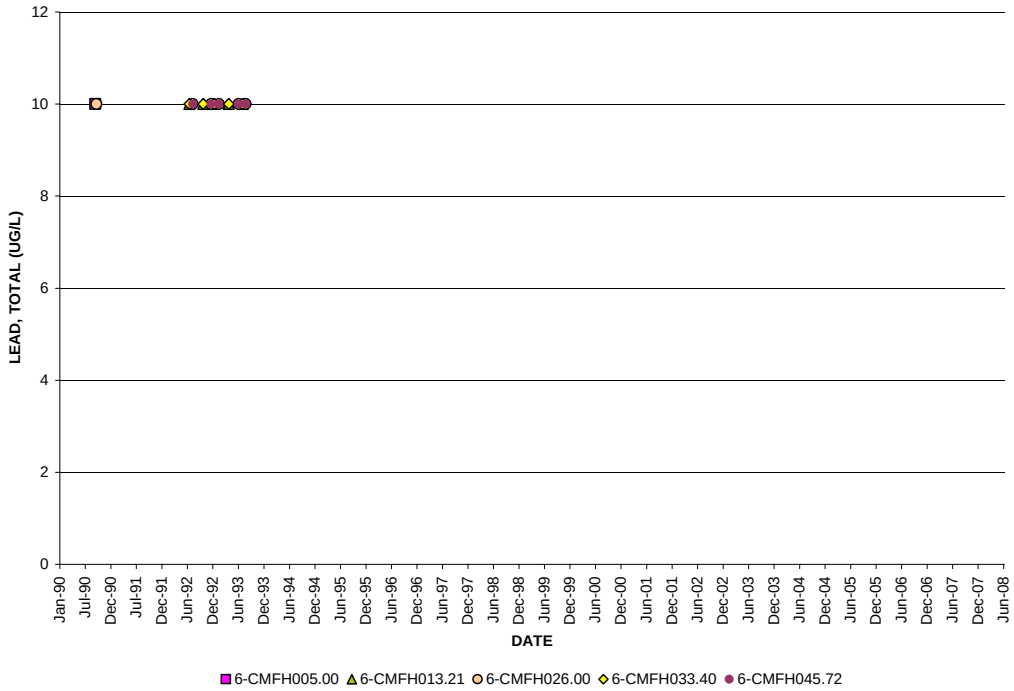


Figure 2.62. Total lead values at water quality monitoring stations in Middle Fork Holston River.

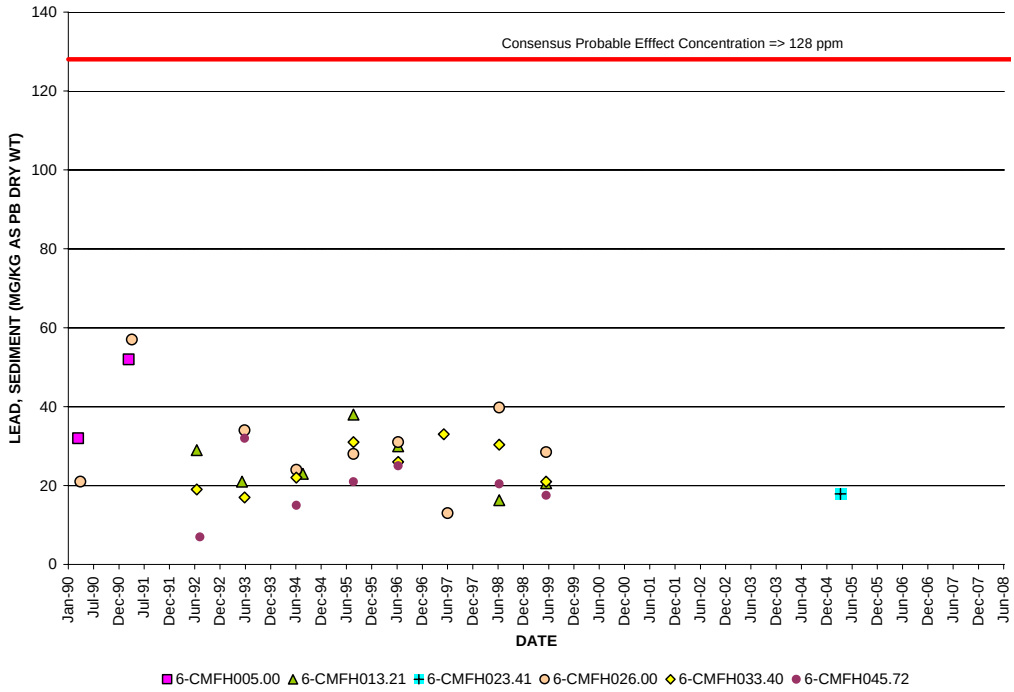


Figure 2.63. Sedimentary lead values at water quality monitoring stations in Middle Fork Holston River.

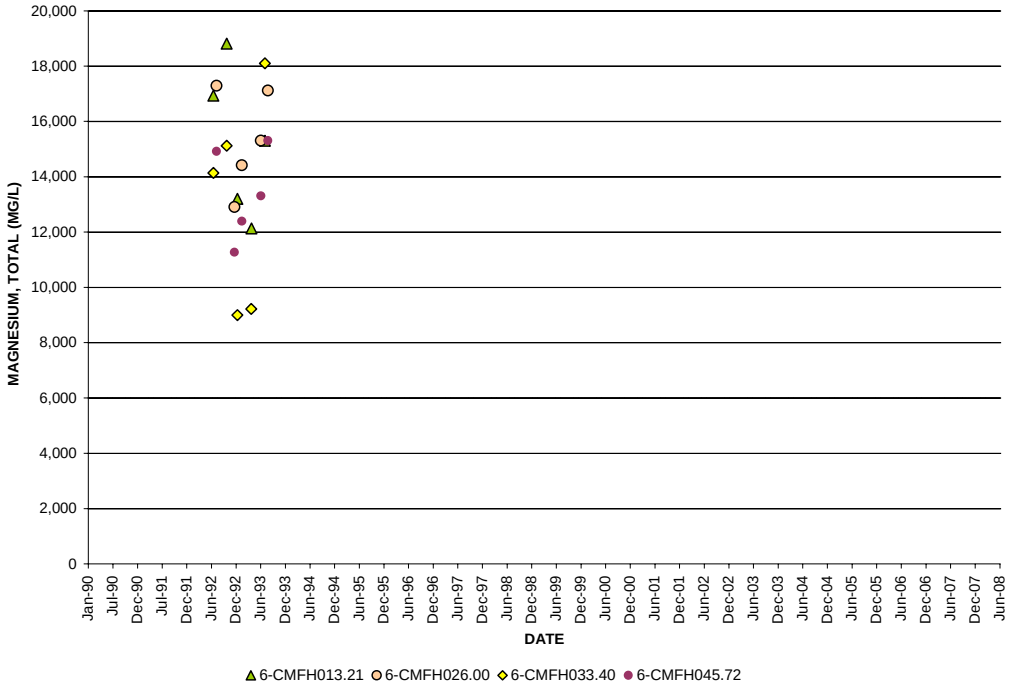


Figure 2.64. Total magnesium values at water quality monitoring stations in Middle Fork Holston River.

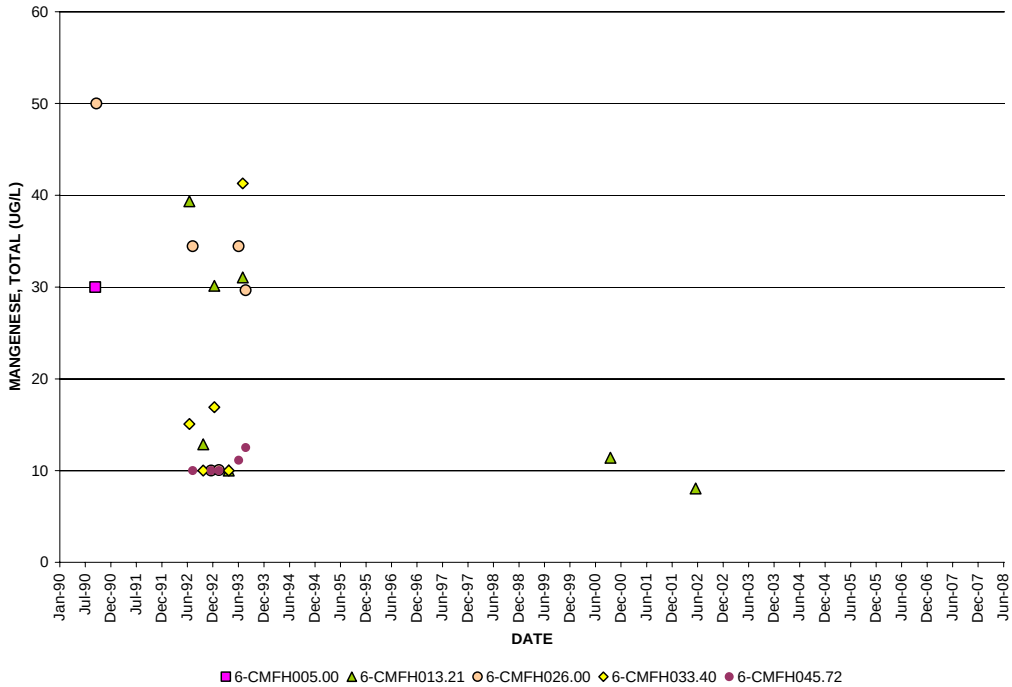


Figure 2.65. Total manganese values at water quality monitoring stations in Middle Fork Holston River.

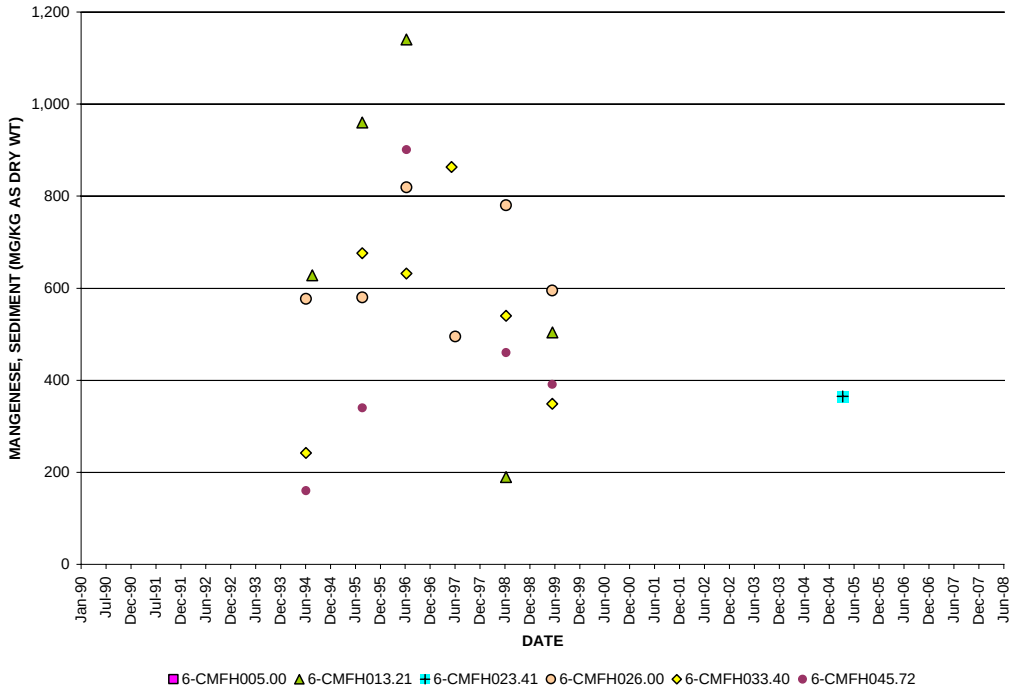


Figure 2.66. Sedimentary manganese values at water quality monitoring stations in Middle Fork Holston River.

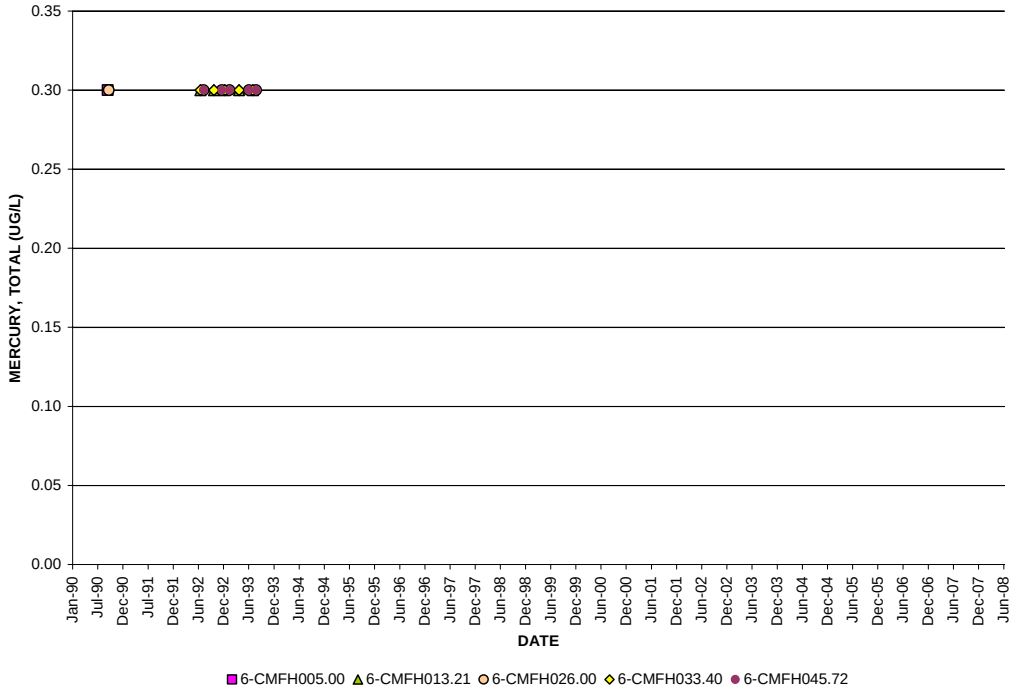


Figure 2.67. Total mercury values at water quality monitoring stations in Middle Fork Holston River.

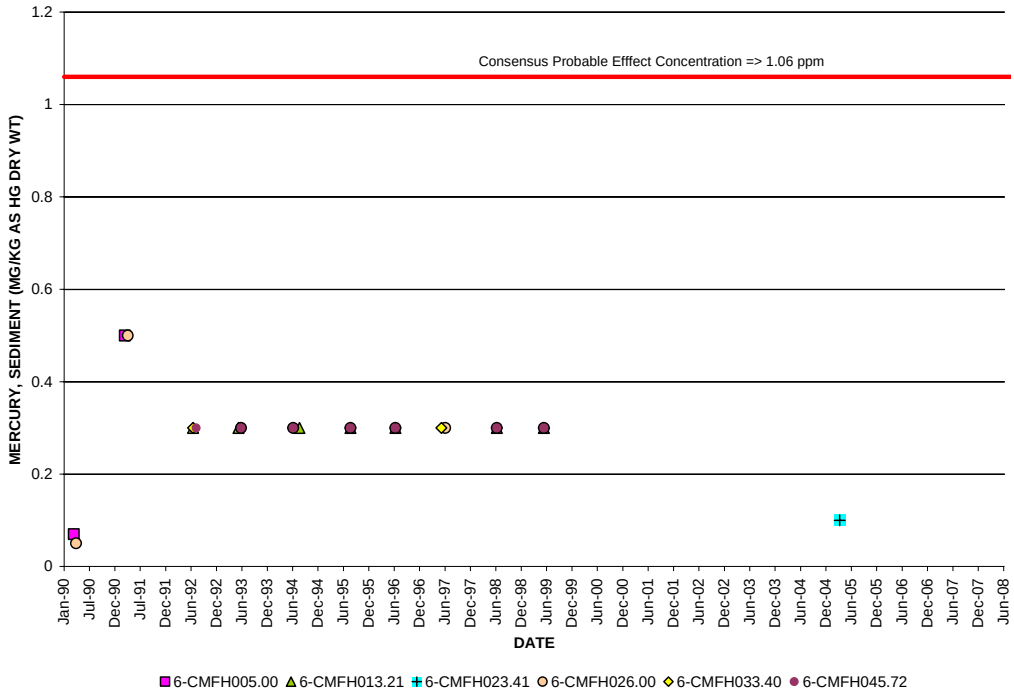


Figure 2.68. Sedimentary mercury values at water quality monitoring stations in Middle Fork Holston River.

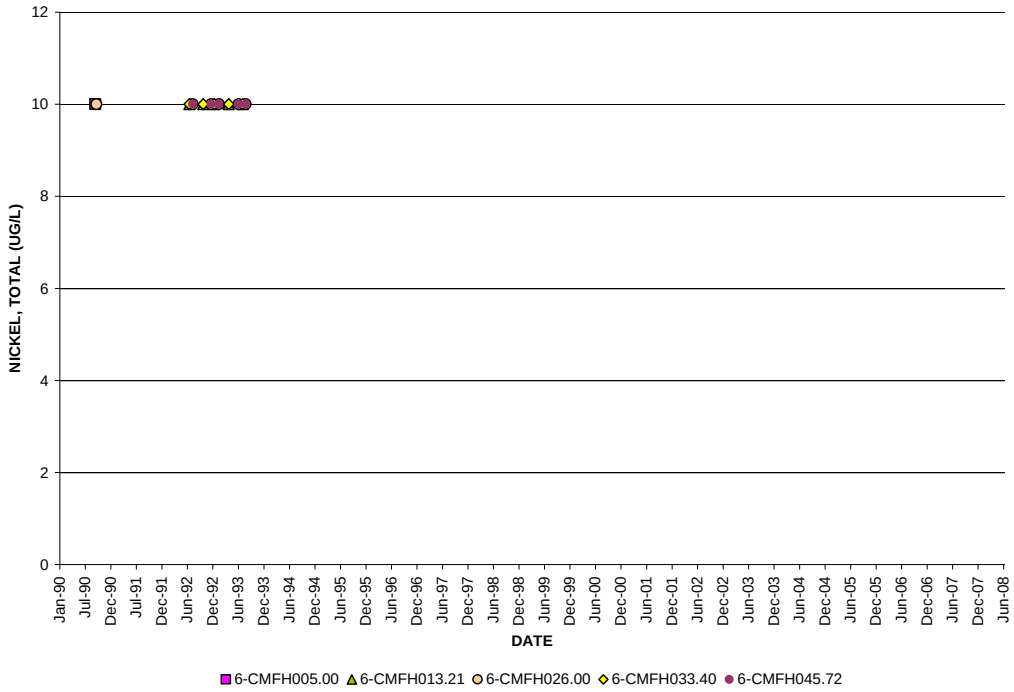


Figure 2.69. Total nickel values at water quality monitoring stations in Middle Fork Holston River.

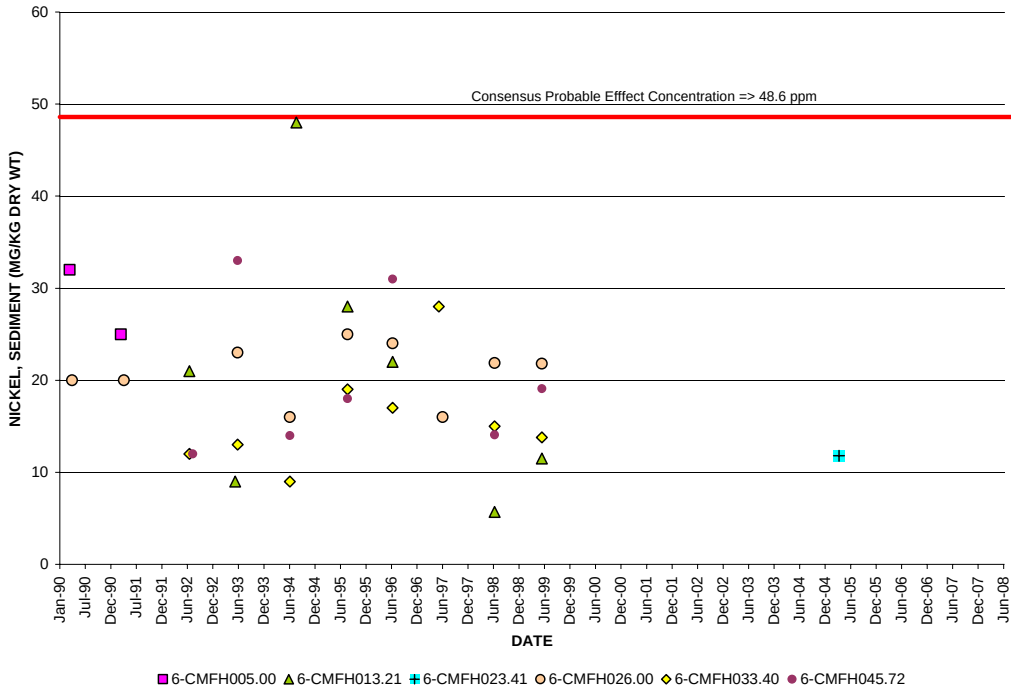


Figure 2.70. Sedimentary nickel values at water quality monitoring stations in Middle Fork Holston River.

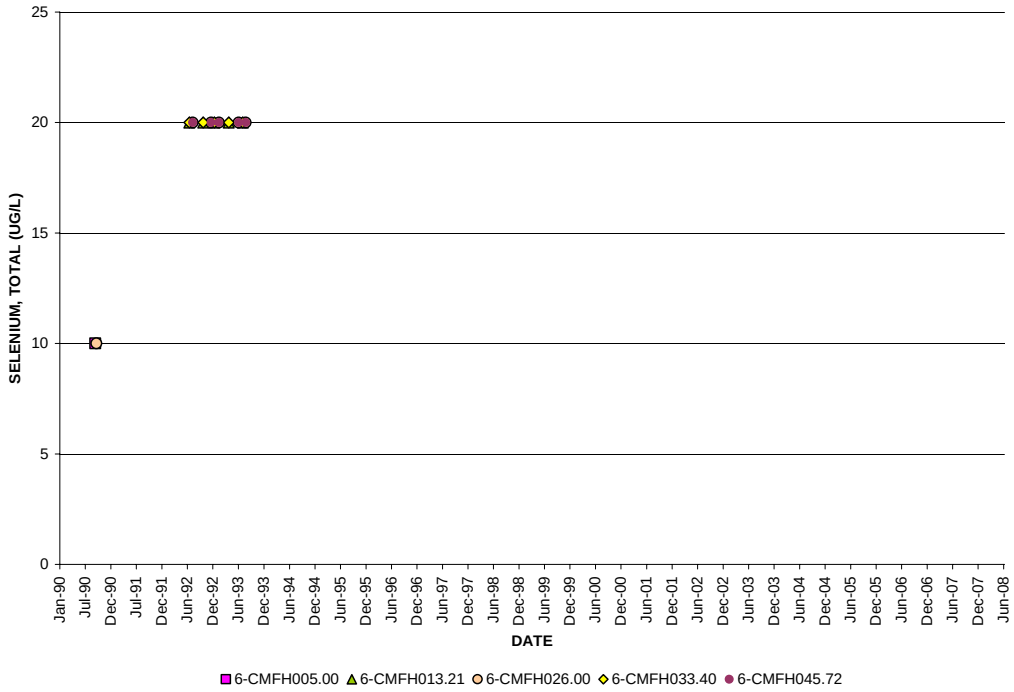


Figure 2.71. Total selenium values at water quality monitoring stations in Middle Fork Holston River.

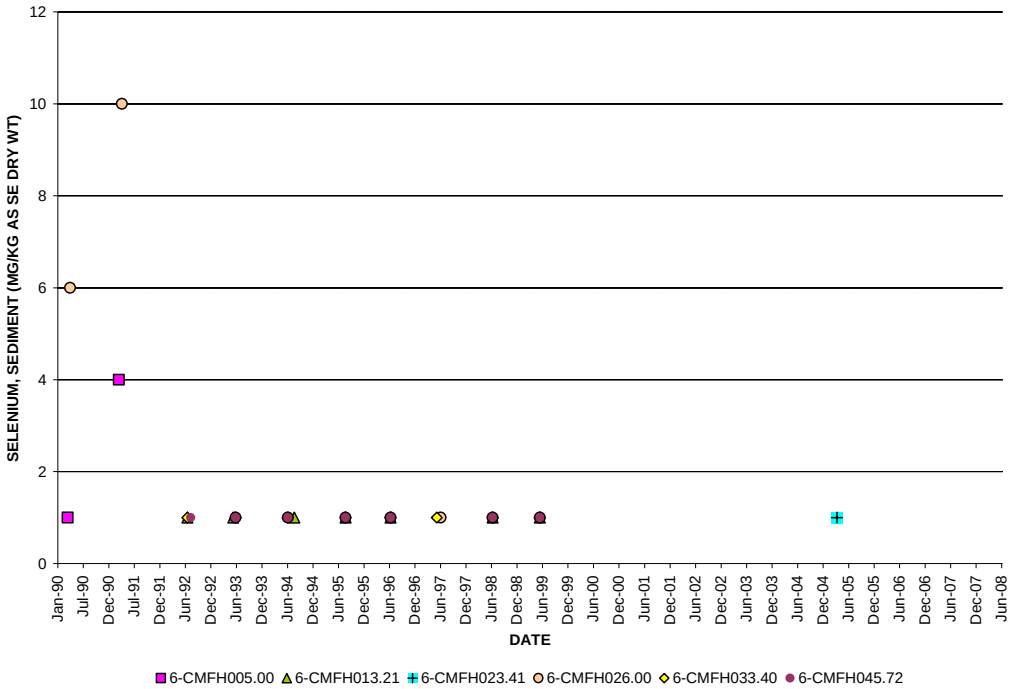


Figure 2.72. Sedimentary selenium values at water quality monitoring stations in Middle Fork Holston River.

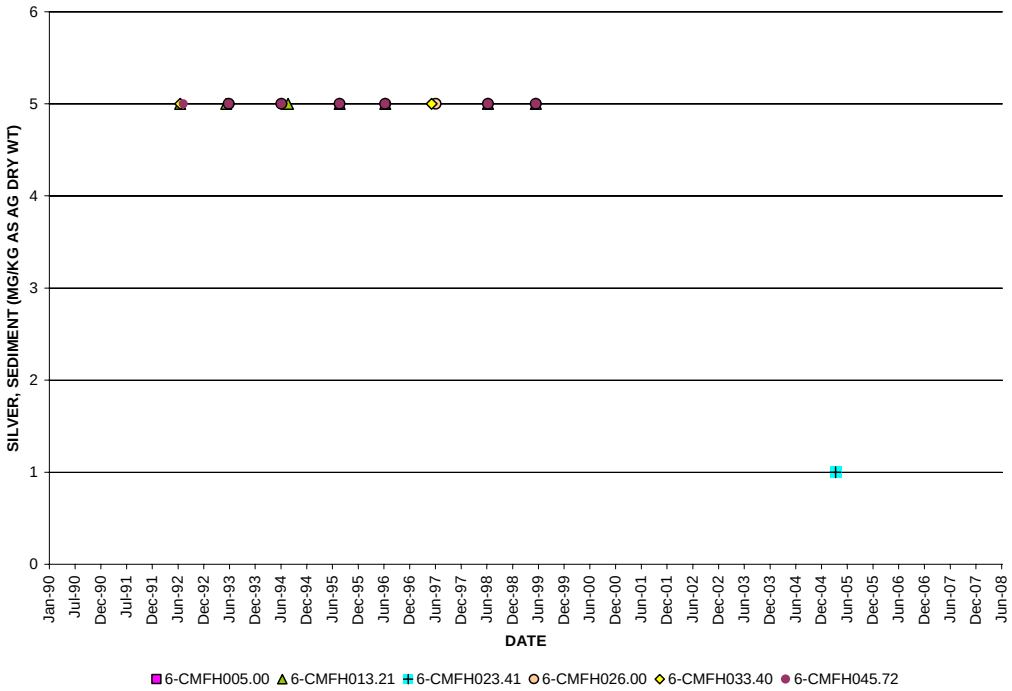


Figure 2.73. Sedimentary silver values at water quality monitoring stations in Middle Fork Holston River.

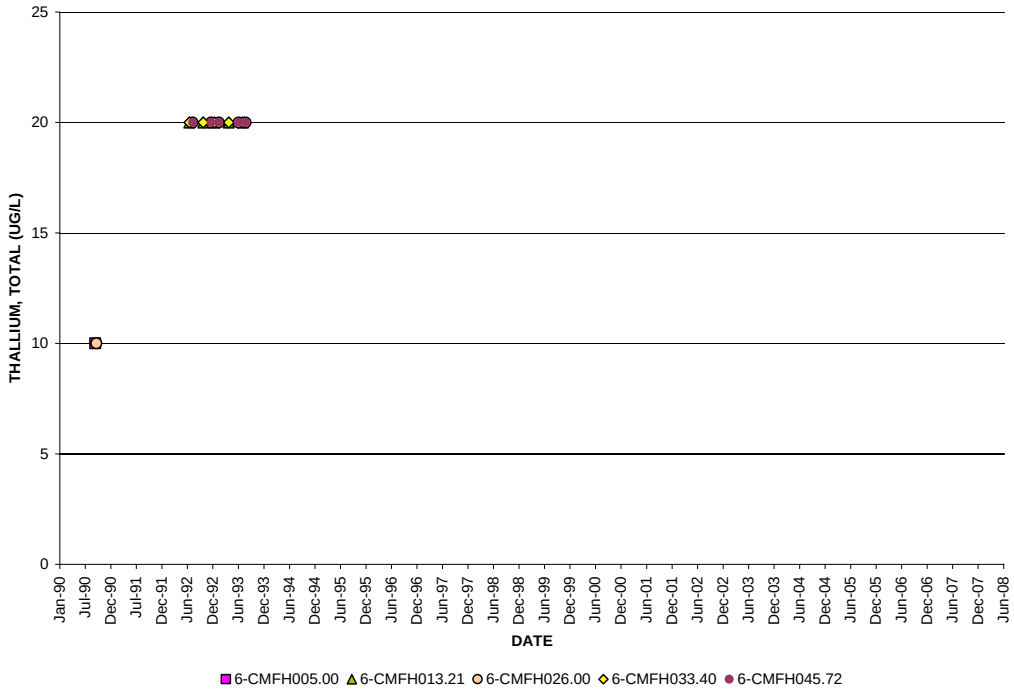


Figure 2.74. Total thallium values at water quality monitoring stations in Middle Fork Holston River.

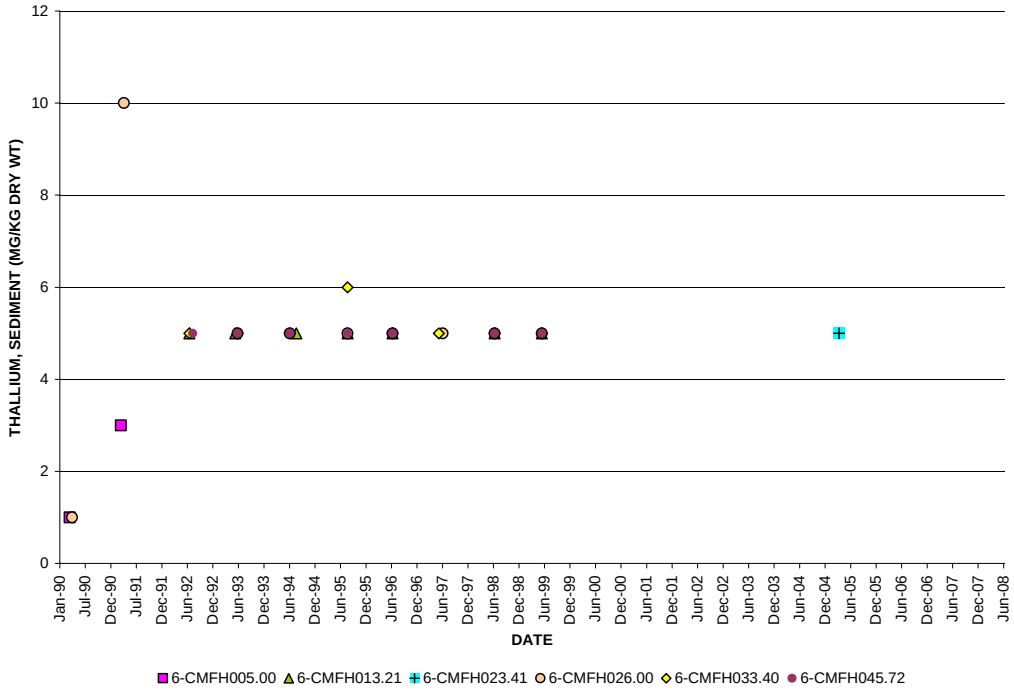


Figure 2.75. Sedimentary thallium values at water quality monitoring stations in Middle Fork Holston River.

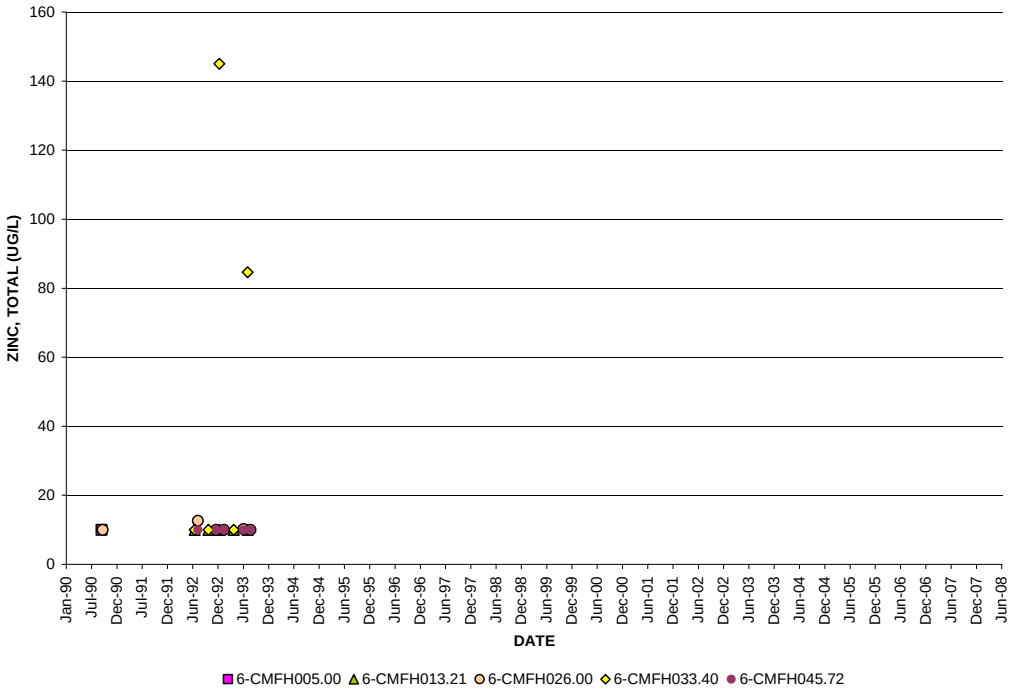


Figure 2.76. Total zinc values at water quality monitoring stations in Middle Fork Holston River.

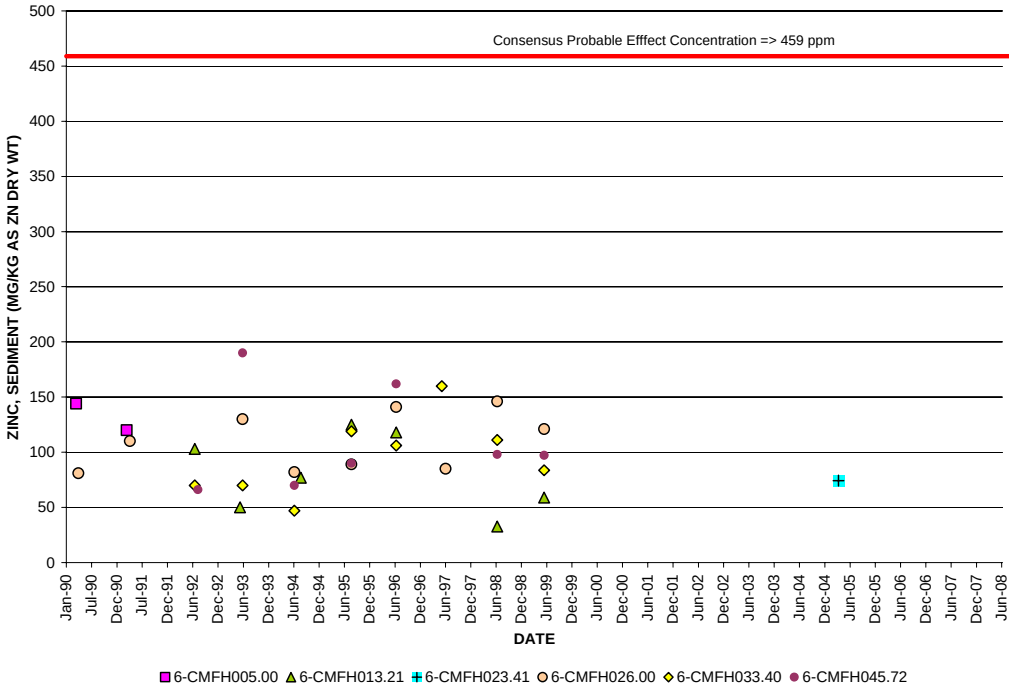


Figure 2.77. Sedimentary zinc values at water quality monitoring stations in Middle Fork Holston River.

2.7.4 Organics

Tables 2.44 through 2.49 contain summary of data collected at the various water quality stations. Summary of data includes number of observations between January 1, 1990 and March 31, 2008; mean, minimum; and maximum values. The data temporal range varies from parameter to parameter, and there is not always a good overlap between biological and ambient monitoring data. Data for organic parameters collected in the watershed are depicted in Figures 2.78 through 2.90. Summary of observations includes:

- No values were exceeded for the sample collected at WQM station 6CMFH023.41;
- Sedimentary DDD values at WQM stations 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 exceeded the consensus probable effect concentration of 28 ppb;
- Sedimentary DDE values at WQM stations 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 exceeded the consensus probable effect concentration of 31.3 ppb;
- Sedimentary DDT values at WQM stations 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 exceeded the consensus probable effect concentration of 62.9 ppb;
- Sedimentary dieldrin values at WQM stations 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 exceeded the consensus probable effect concentration of 61.8 ppb;
- Sedimentary heptachloepoxide values at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 exceeded the consensus probable effect concentration of 16 ppb; and
- All other sedimentary organic concentrations at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH023.41, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 were below an applicable consensus probable effect concentration and do not appear to be a stressor to the benthic community.

Table 2.44. Organics water quality data summary for station 6CMFH005.00 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Aldrin, µg/kg	1	100.00	100.00	100.00
Chlordane Tech Mix & Metabs, µg/kg	1	1.00	1.00	1.00
DDD, µg/kg	1	0.10	0.10	0.10
DDE, µg/kg	1	0.10	0.10	0.10
DDT, µg/kg	1	0.10	0.10	0.10
Dicofol, µg/kg	1	100.00	100.00	100.00
Dieldrin, µg/kg	1	0.10	0.10	0.10
Endrin, µg/kg	1	0.10	0.10	0.10
Heptachlor epoxide, µg/kg	1	100.00	100.00	100.00
Heptachlor, µg/kg	1	0.10	0.10	0.10
PCBs - Total, µg/kg	1	500.00	500.00	500.00
Pentachlorophenol, µg/kg	1	0.01	0.01	0.01
Toxaphene, µg/kg	1	1.00	1.00	1.00

Table 2.45. Organics water quality data summary for station 6CMFH013.21 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Aldrin, µg/kg	10	59.00	100.00	10.00
Chlordane Tech Mix & Metabs, µg/kg	10	172.00	500.00	40.00
DDD, µg/kg	10	59.00	100.00	20.00
DDE, µg/kg	10	59.50	100.00	20.00
DDT, µg/kg	10	59.50	100.00	20.00
Dicofol, µg/kg	10	135.50	220.00	85.00
Dieldrin, µg/kg	10	56.00	100.00	10.00
Endrin, µg/kg	10	88.50	160.00	40.00
Heptachlor epoxide, µg/kg	10	56.00	100.00	10.00
Heptachlor, µg/kg	10	33.02	100.00	0.10
PCBs - Total, µg/kg	10	151.50	500.00	10.00
Pentachlorophenol, µg/kg	10	98.50	150.00	50.00
Toxaphene, µg/kg	10	292.20	1,000.00	1.00

Table 2.46. Organics water quality data summary for station 6CMFH023.41 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Aldrin, µg/kg	1	2.80	2.80	2.80
Chlordane Tech Mix & Metabs, µg/kg	1	2.80	2.80	2.80
DDD, µg/kg	N/A	N/A	N/A	N/A
DDE, µg/kg	N/A	N/A	N/A	N/A
DDT, µg/kg	N/A	N/A	N/A	N/A
Dicofol, µg/kg	N/A	N/A	N/A	N/A
Dieldrin, µg/kg	1	2.80	2.80	2.80
Endrin, µg/kg	1	2.80	2.80	2.80
Heptachlor epoxide, µg/kg	1	2.80	2.80	2.80
Heptachlor, µg/kg	1	2.80	2.80	2.80
PCBs - Total, µg/kg	1	68.97	68.97	68.97
Pentachlorophenol, µg/kg	1	4.70	4.70	4.70
Toxaphene, µg/kg	1	2.80	2.80	2.80

Table 2.47. Organics water quality data summary for station 6CMFH026.00 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Aldrin, µg/kg	10	60.00	100.00	30.00
Chlordane Tech Mix & Metabs, µg/kg	10	165.10	500.00	1.00
DDD, µg/kg	10	54.01	100.00	0.10
DDE, µg/kg	10	46.02	100.00	0.10
DDT, µg/kg	10	46.52	100.00	0.10
Dicofol, µg/kg	10	157.00	280.00	90.00
Dieldrin, µg/kg	10	36.52	100.00	0.10
Endrin, µg/kg	10	68.52	105.00	0.10
Heptachlor epoxide, µg/kg	10	56.50	100.00	20.00
Heptachlor, µg/kg	10	34.52	100.00	0.10
PCBs - Total, µg/kg	10	190.00	500.00	20.00
Pentachlorophenol, µg/kg	10	96.00	140.00	0.01
Toxaphene, µg/kg	10	302.20	1,000.00	1.00

Table 2.48. Organics water quality data summary for station 6CMFH033.40 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Aldrin, µg/kg	8	36.88	100.00	10.00
Chlordane Tech Mix & Metabs, µg/kg	8	115.00	500.00	40.00
DDD, µg/kg	8	40.00	100.00	10.00
DDE, µg/kg	8	42.50	100.00	10.00
DDT, µg/kg	8	41.88	100.00	10.00
Dicofol, µg/kg	8	113.75	180.00	70.00
Dieldrin, µg/kg	8	34.38	100.00	10.00
Endrin, µg/kg	8	60.00	100.00	30.00
Heptachlor epoxide, µg/kg	8	34.38	100.00	10.00
Heptachlor, µg/kg	8	32.50	100.00	10.00
PCBs - Total, µg/kg	8	93.13	500.00	15.00
Pentachlorophenol, µg/kg	8	77.50	100.00	50.00
Toxaphene, µg/kg	8	287.50	1,000.00	100.00

Table 2.49. Organics water quality data summary for station 6CMFH045.72 in Middle Fork Holston River.

WATER QUALITY CONSTITUENT	# of SAMPLES	MEAN	MAXIMUM	MINIMUM
Aldrin, µg/kg	9	51.11	100.00	20.00
Chlordane Tech Mix & Metabs, µg/kg	9	177.22	500.00	45.00
DDD, µg/kg	9	53.89	100.00	20.00
DDE, µg/kg	9	43.90	100.00	0.10
DDT, µg/kg	9	46.68	100.00	0.10
Dicofol, µg/kg	9	152.22	240.00	70.00
Dieldrin, µg/kg	9	35.57	100.00	0.10
Endrin, µg/kg	9	66.12	100.00	0.10
Heptachlor epoxide, µg/kg	9	46.67	100.00	20.00
Heptachlor, µg/kg	9	33.34	100.00	0.10
PCBs - Total, µg/kg	9	147.22	500.00	15.00
Pentachlorophenol, µg/kg	9	101.11	190.00	50.00
Toxaphene, µg/kg	9	309.00	1,000.00	1.00

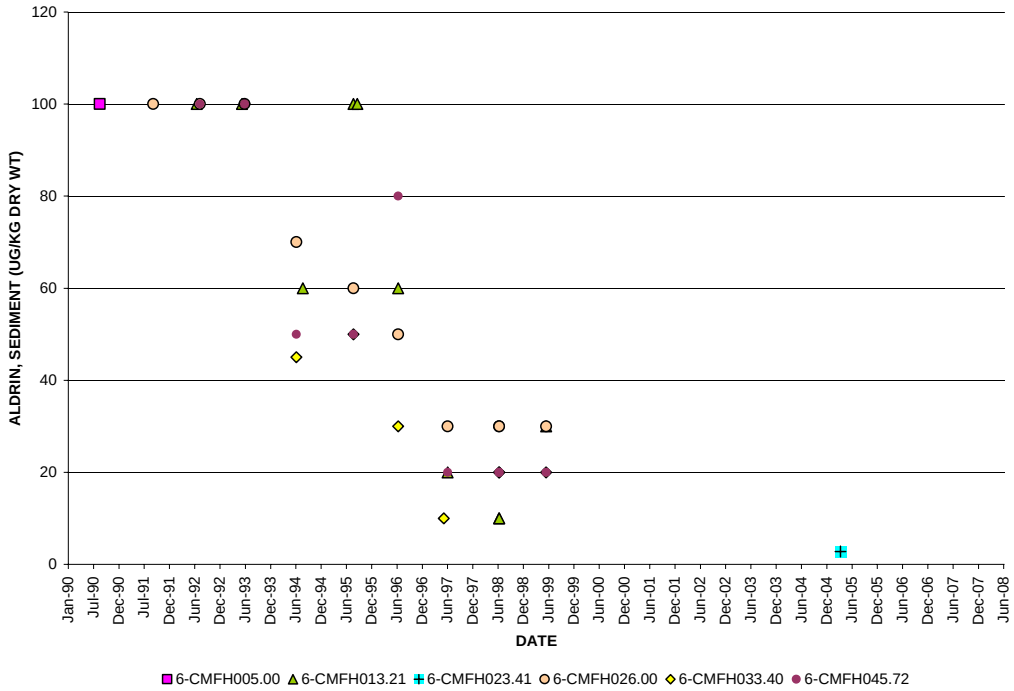


Figure 2.78. Sedimentary aldrin values at water quality monitoring stations in Middle Fork Holston River.

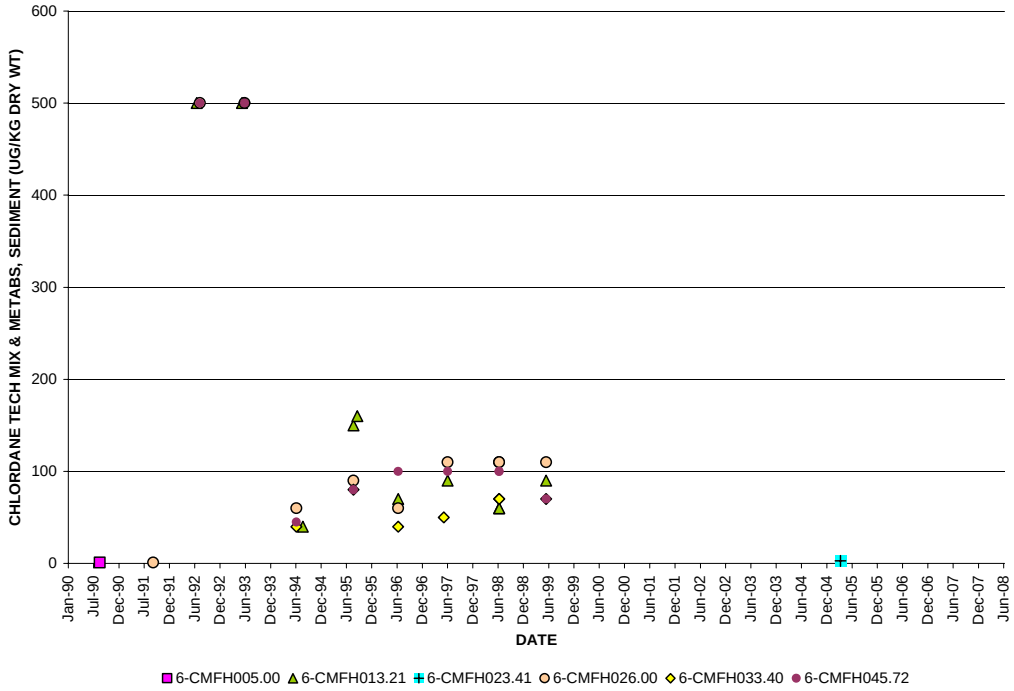


Figure 2.79. Sedimentary cdanedrytech values at water quality monitoring stations in Middle Fork Holston River.

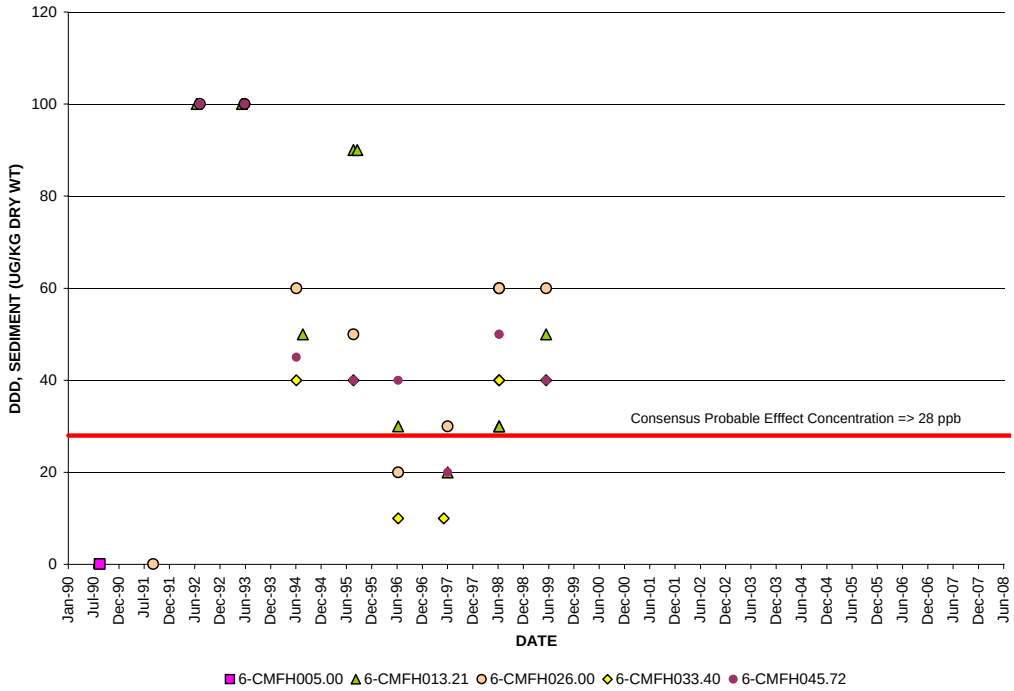


Figure 2.80. Sedimentary DDD values at water quality monitoring stations in Middle Fork Holston River.

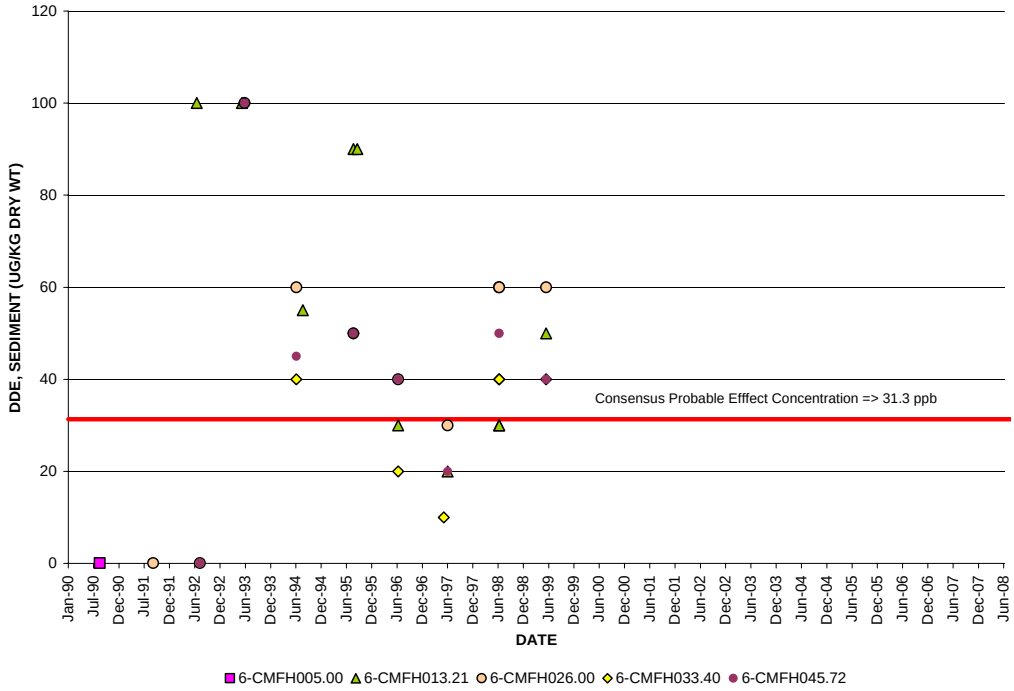


Figure 2.81. Sedimentary DDE values at water quality monitoring stations in Middle Fork Holston River.

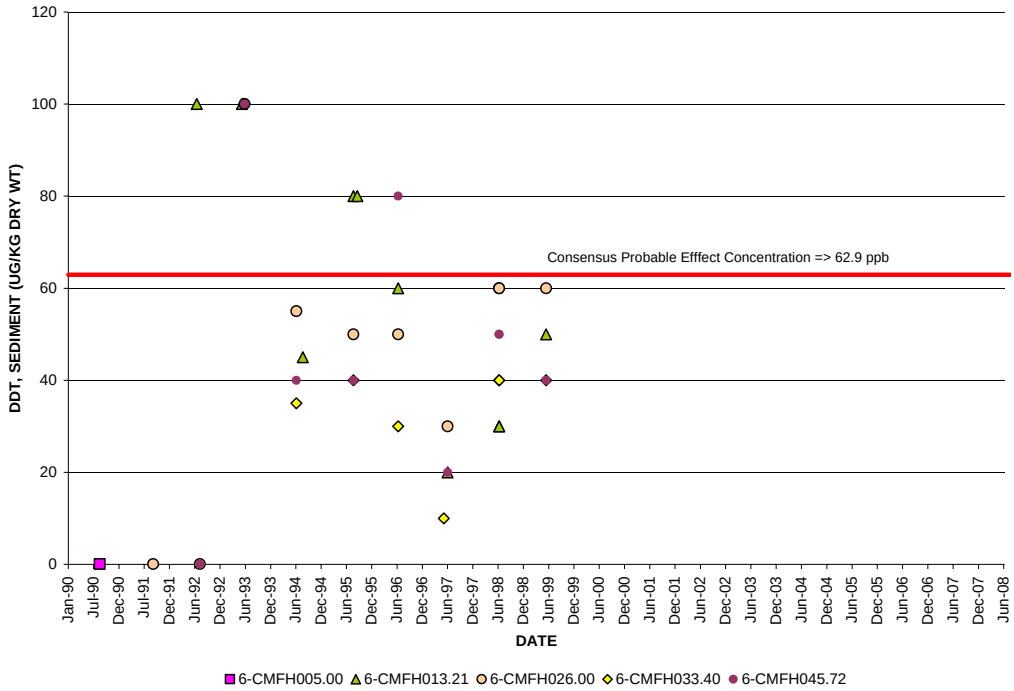


Figure 2.82. Sedimentary DDT values at water quality monitoring stations in Middle Fork Holston River.

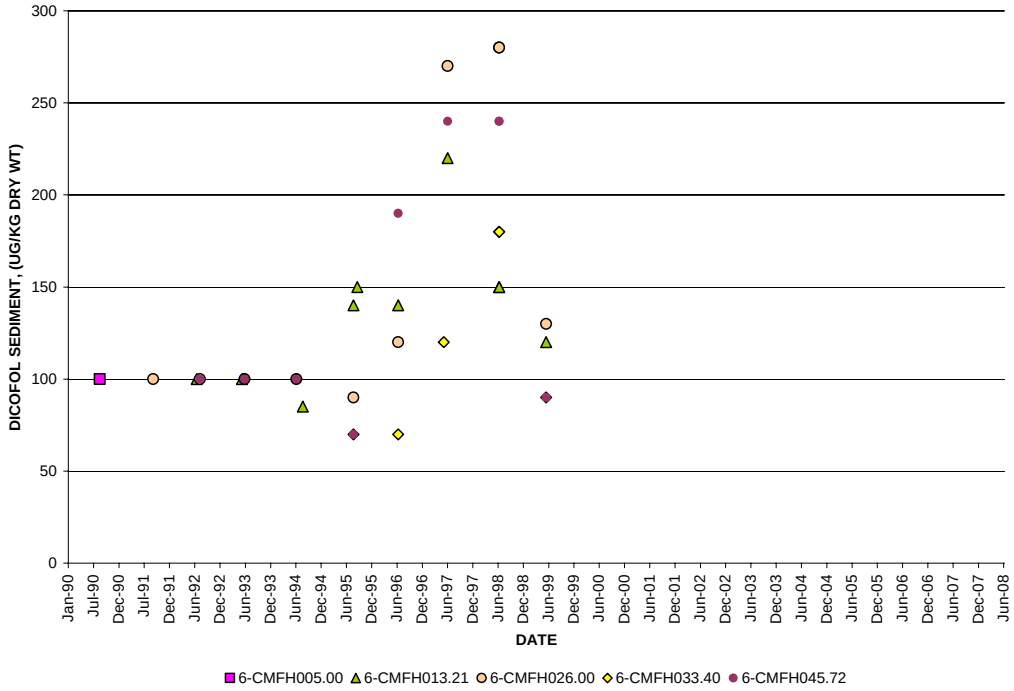


Figure 2.83. Sedimentary dicofol values at water quality monitoring stations in Middle Fork Holston River.

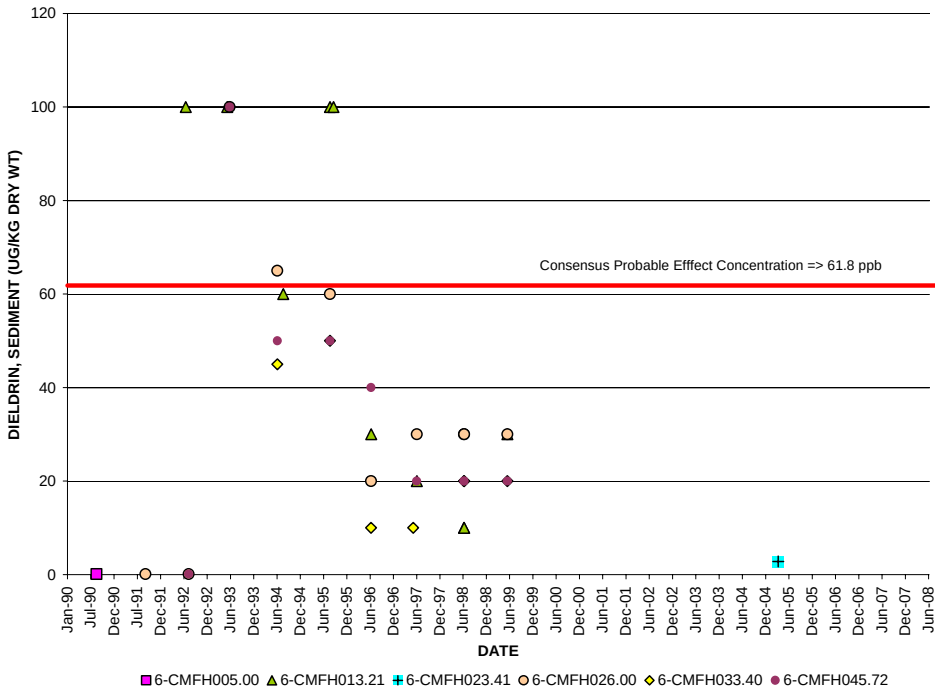


Figure 2.84. Sedimentary dieldrin values at water quality monitoring stations in Middle Fork Holston River.

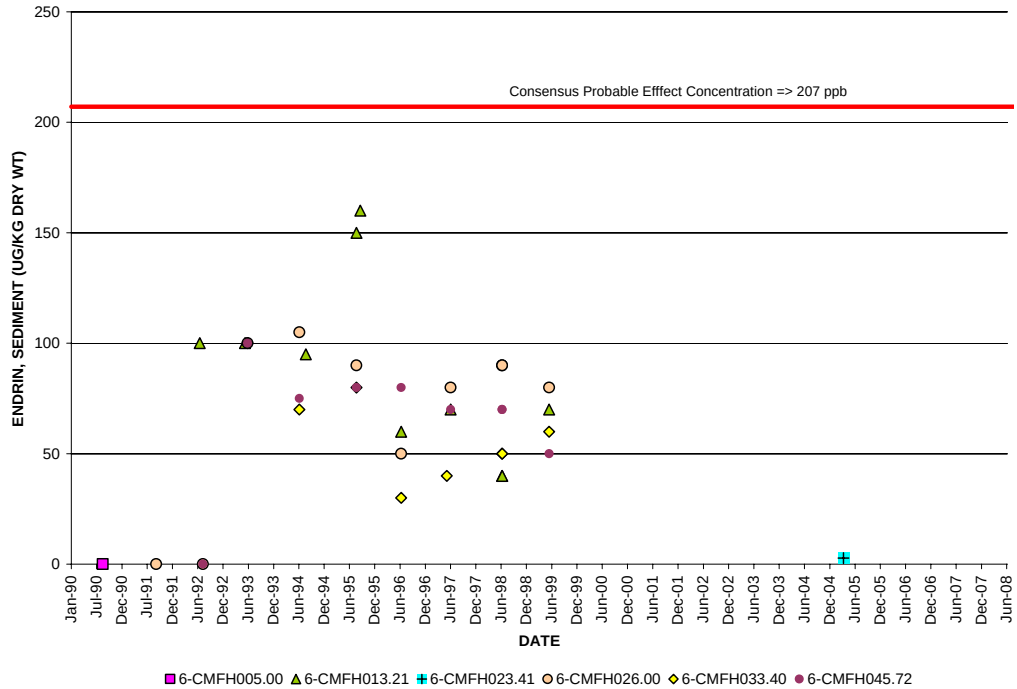


Figure 2.85. Sedimentary endrin values at water quality monitoring stations in Middle Fork Holston River.

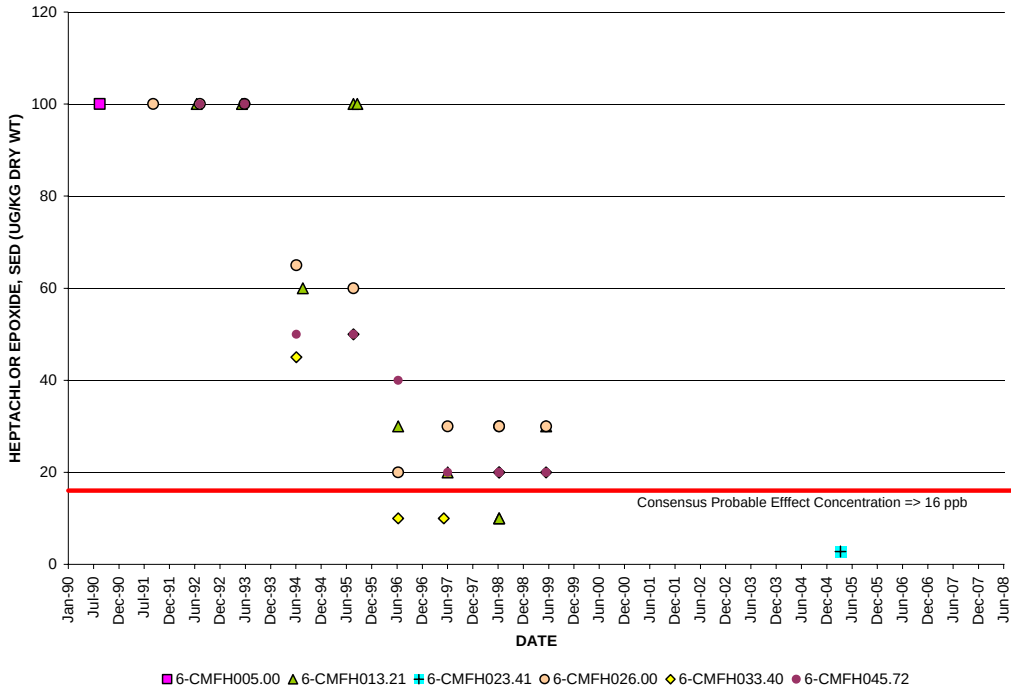


Figure 2.86. Sedimentary heptachlorepoxide values at water quality monitoring stations in Middle Fork Holston River.

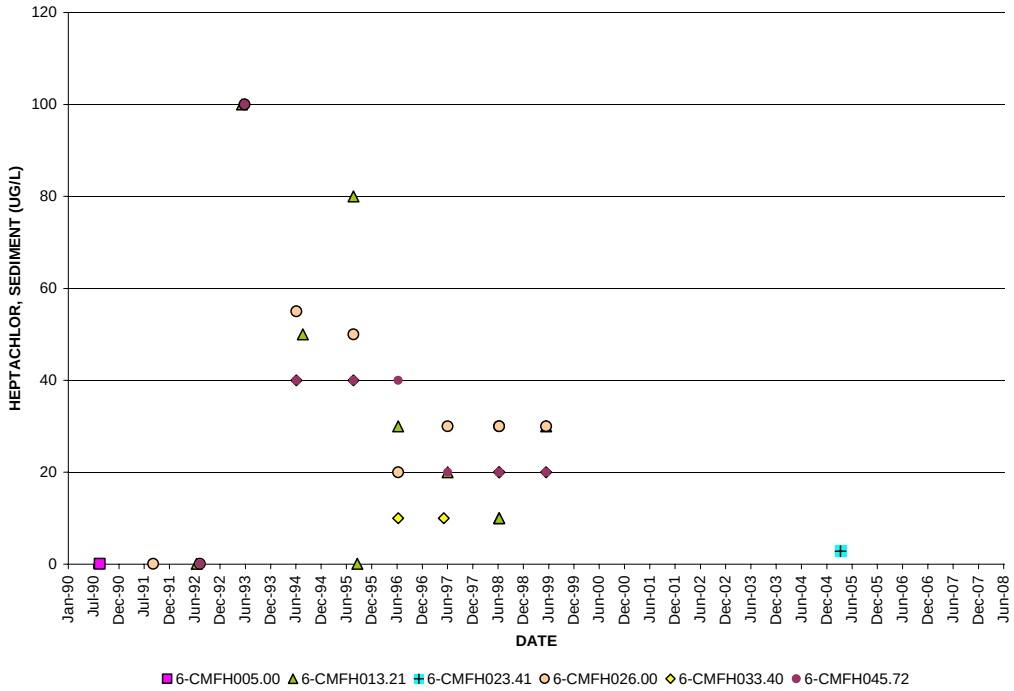


Figure 2.87. Sedimentary heptachlor values at water quality monitoring stations in Middle Fork Holston River.

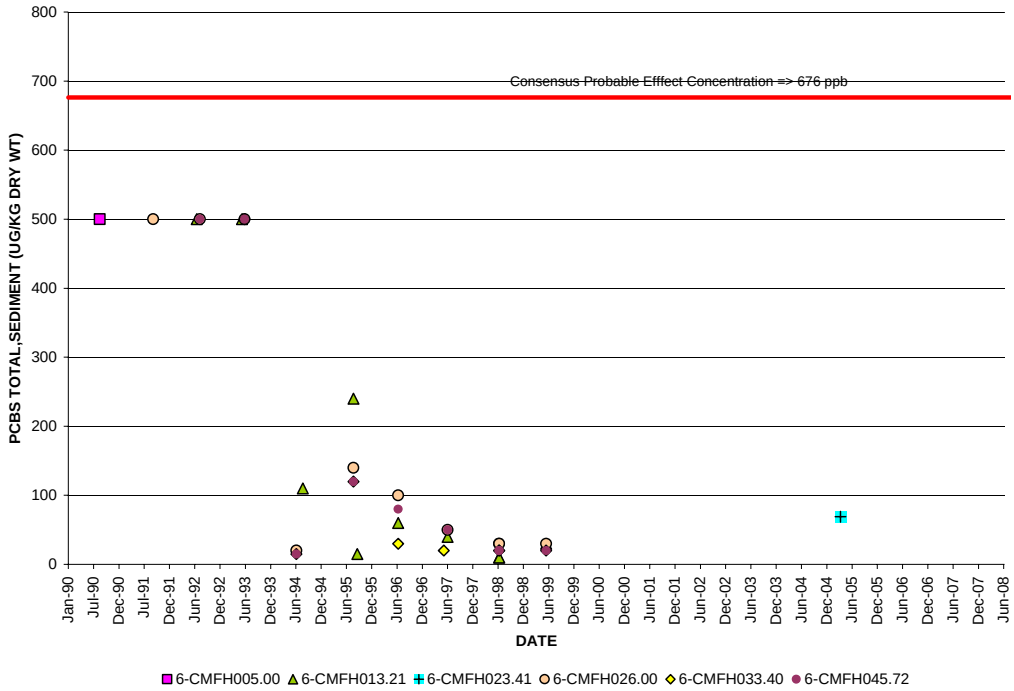


Figure 2.88. Sedimentary PCB values at water quality monitoring stations in Middle Fork Holston River.

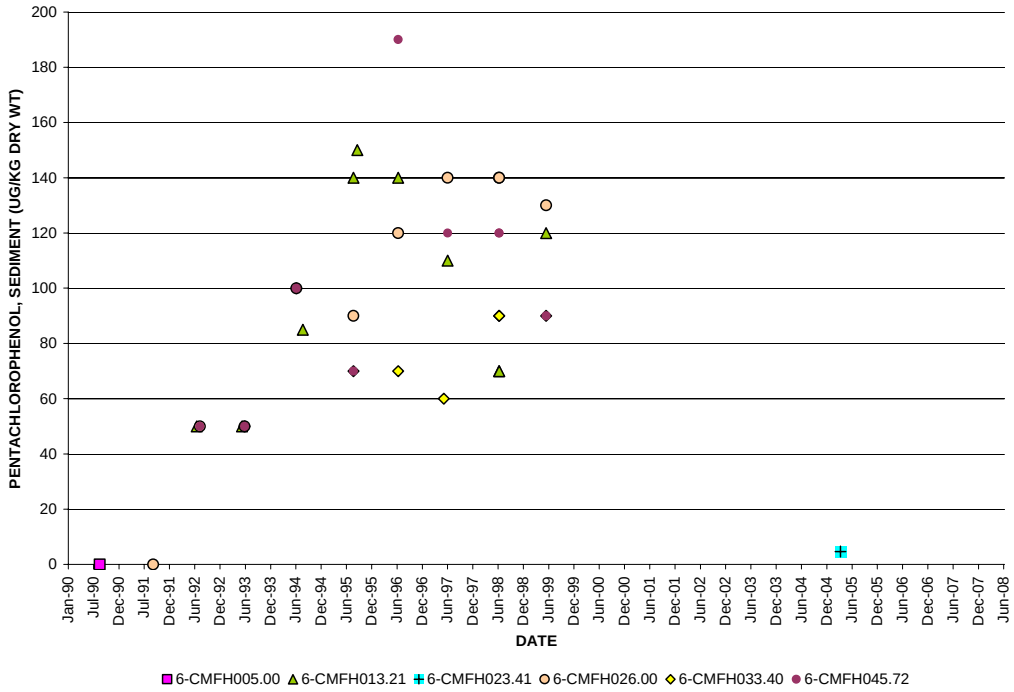


Figure 2.89. Sedimentary PCP values at water quality monitoring stations in Middle Fork Holston River.

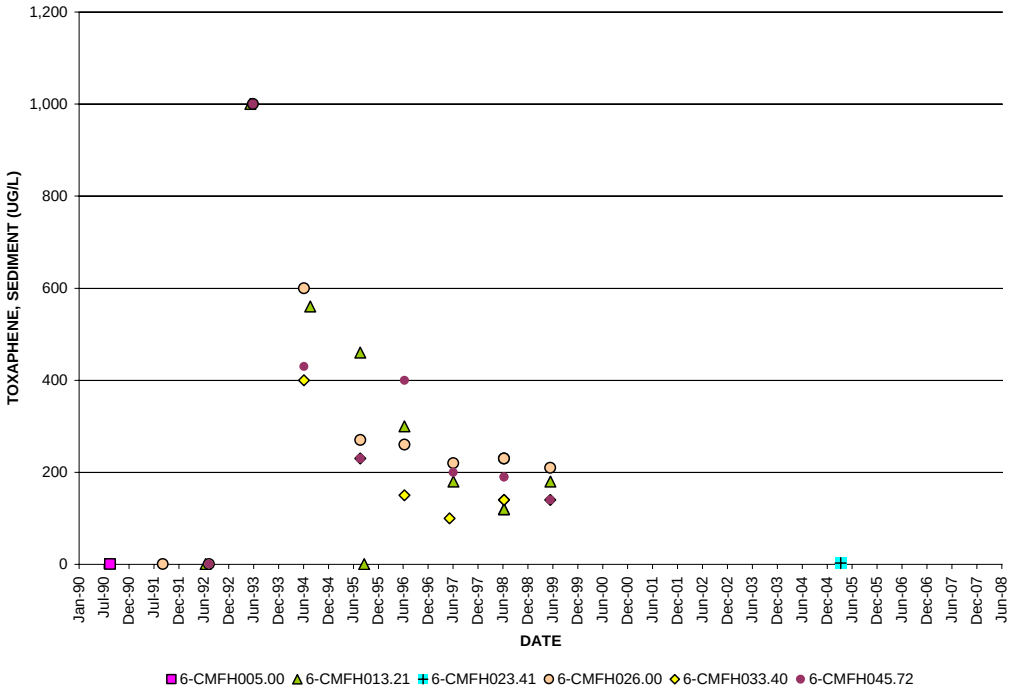


Figure 2.90. Sedimentary toxaphene values at water quality monitoring stations in Middle Fork Holston River.

2.8 Sediment and Fish Tissue Sampling

The Department of Environmental Quality - Office of Water Quality Programs' Fish Tissue and Sediment Contaminants Monitoring Program conducts routine studies of fish tissue and sediment samples in state waters. Typically, data is collected in two to three river basins per year. The data are assessed to determine the human health risks for individuals who may consume fish from state waters and to identify impaired aquatic ecosystems. At least one sediment sample is collected at each station where fish tissue are sampled and analyzed for a suit of bioaccumulative chemical contaminants. These include selected heavy metals, selected non-halogenated organic compounds (PAHs) and halogenated organic compounds (DDT, Chlordane, PCBs, etc.). Samples were collected at water quality monitoring stations 6CMFH026.00 and 6CMFH033.40 in 1997, 2002, and 2007 (Table 2.50 through 2.56 Values highlighted in red indicate exceedance of the PEC or screening value.

Table 2.50. Results of sediment analysis for heavy metals at stations 6CMFH026.00 and 6CMFH033.40 in Middle Fork Holston River.

	DEQ Station	**6-CMFH026.00**	**6-CMFH033.40**				
	Sampling Date	**06/19/97**	**06/18/97**	**06/19/02**			
	Parameter	**Observed Value**	**Observed Value**	**Observed Value**	**NOAA'S Effects Range-Median**	**NOAA'S Effects Range-Low**	**Freshwater Consensus-Based Probable Effect Concentration**
%	**TOC**	0.09	0.06	1.93	***	***	***
	Al	0.18	0.66	0.71	***	***	***
ppm (dry wgt. Basis)	**Ag**	0.1	0.1	0.1	*3.7*	*1*	*N/A*[1]
	As	5.0	6.3	5.0	*70*	*8.2*	*33*
	Cd	0.19	0.25	0.20	*9.6*	*1.2*	*4.98*
	Cr	17	12	24	*370*	*81*	*111*
	Cu	4	7	18	*270*	*34*	*149*
	Hg	0.08	0.14	0.07	*0.71*	*0.15*	*1.06*
	Ni	0.9	1.2	13.0	*51.6*	*20.9*	*48.6*
	Pb	10.0	16.0	23.8	*223*	*46.7*	*128*
	Sb	<0.5	<0.5	<0.5	***	***	***
	Se	<0.5	<0.5	<0.5	***	***	***
	Tl	<0.3	<0.3	<0.3	***	***	***
	Zn	53	79	49	*410*	*150*	*459*

[1] N/A = not available

Table 1.51. Results of sediment analysis for non-halogenated organic compounds (PAHs) at stations 6CMFH026.00 and 6CMFH033.40in Middle Fork Holston River.

	DEQ Station	6-CMFH026.00	6-CMFH033.40				
	Sampling Date	06/19/97	06/18/97	06/19/02			
	Parameter	Observed Value	Observed Value	Observed Value	NOAA'S Effects Range-Median	NOAA'S Effects Range-Low	Freshwater Consensus-Based Probable Effect Concentration
%	TOC	0.09	0.06	1.93	***	***	***
ppb	Total PAH	1,052	1,780	2,513	*44,792*	*4,022*	*22,800*
	High MW PAH	410	733	2,314	*9,600*	*1,700*	*N/A* [1]
	Low MW PAH	73	94	198	*3,160*	*552*	*N/A*
ppb (dry wgt. Basis)	NAP[5]	N/A	5	6	*2,100*	*160*	*561*
	NAP 2-Me	N/A	N/A	5	*670*	*70*	*N/A*
	NAP 1-Me	N/A	N/A	4	***	***	***
	biphenyl	N/A	N/A	1	***	***	***
	NAP d-Me	8	4	3	***	***	***
	naphthylene ace~	N/A	N/A	2	*640*	*44*	*N/A*
	naphthene ace~	N/A	N/A	6	*500*	*16*	*N/A*
	NAP t-Me	N/A	N/A	4	***	***	***
	fluorene	N/A	N/A	8	*540*	*19*	*536*
	PHH	67	70	128	*1,500*	*240*	*1,170*
	ATH	5.7	18.8	17.3	*1,100*	*85.3*	*845*
	PHH 1-Me	27	22	13	***	***	***
	FTH	129	261	286	*5,100*	*600*	*2,230*
	pyrene	103	216	232	*2,600*	*665*	*1,520*
	ATH benz(a)	49	81	217	*1,600*	*261*	*1,050*
	chrysene	85	97	152	*2,800*	*384*	*1,290*
	FTH benzo (b)	49	71	217	***	***	***
	FTH benzo (k)	26	40	157	***	***	***
	pyrene benzo (e)	36	57	159	***	***	***
	pyrene benzo (a)	38	67	238	*1,600*	*430*	*1,450*
	perylene	14	25	318	***	***	***
	pyrene IND	26	50	146	***	***	***
	ATH db (a,h)	6.0	10.7	52.0	*260*	*63.4*	*N/A*
	perylene benzo (ghi)	24	50	141	***	***	***

[1] N/A = not available

Table 1.52. Results of sediment analysis for halogenated organic compounds at stations 6CMFH026.00 and 6CMFH033.40in Middle Fork Holston River.

	DEQ Station	6-CMFH026.00	6-CMFH033.40				
	Sampling Date	06/19/97	06/18/97	06/19/02			
	Parameter	Observed Value	Observed Value	Observed Value	NOAA'S Effects Range-Median	NOAA'S Effects Range-Low	Freshwater Consensus-Based Probable Effect Concentration
%	TOC	0.09	0.06	1.93	***	***	***
ppb (dry wgt. Basis)	Total PCB	2.56	4.52	18.2	*180*	*22.7*	*676*
	Total Chlordane	0.49	0.33	1.1	*6*	*0.5*	*17.6*
	Sum DDE	0.57	4.23	1.8	*27*	*2.2*	*31.3*
	Sum DDD	0.30	0.52	1.4	*20*	*2*	*28*
	Sum DDT	1.59	1.06	8.7	*7*	*1*	*62.9*
	Total DDT	2.46	5.81	11.86	*46.1*	*1.58*	*572*
	Total BDE	0.49	0.59	3.0	***	***	***
	HCB	N/A[1]	N/A	N/A	***	***	***
	OCDD	0.20	0.15	1.42	***	***	***
	TetCAN	N/A	N/A	N/A	***	***	***
	CPD 1	N/A	N/A	N/A	***	***	***

[1] N/A = not available

Table 1.53. Results of fish tissue analysis for heavy metals at stations 6CMFH026.00 and 6CMFH033.40in Middle Fork Holston River.

		6-CMFH026.00			6-CMFH033.40						
		06/19/97			06/18/97				06/18/02		
		Rock Bass	Stoneroller	Northern Hogsucker	Rock Bass*2	Rock Bass	Golden Redhorse Sucker	Stoneroller	Rock Bass	Northern Hogsucker	DEQ Screening Value
No. Fish Analyzed		13	19	3	10	10	10	10	10	3	
Length (cm)		11.5 - 19	9.5 - 16.5	10 - 11.5	12.5 - 17.8	15.5 - 23.3	36.3 - 36.5	11.9 - 17.5	16.1 - 18.5	33.6 - 35.5	
Weight (g)		25 - 175	15 - 75	200 - 350	30 - 135.1	81.7 - 230.1	353.6 - 1010	19.6 - 63.6	74 - 132	482 - 526	
As	**ppm (wet weight basis)**	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.05	<0.05	*0.1*
Cd		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.01	<0.01	*11.00*
Cr		0.1	<0.05	<0.05	<0.05	0.2	<0.05	0.15	<0.05	<0.05	*32*
Hg		0.07	0.06	0.084	0.03	0.06	<0.01	0.15	0.09	0.04	*0.3 / 0.5*
Pb		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*N/A*
Se		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*54.0*
Tl		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*N/A*
Zn		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*N/A*
Ag		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*N/A*
Al		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*N/A*
Cu		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*N/A*
Ni		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*N/A*
Sb		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*N/A*

Table 1.54. Results of fish tissue analysis for non-halogenated organic compounds (PAHs) at station 6CMFH026.00 in Middle Fork Holston River.

		Northern Hogsucker	Rock Bass	Stoneroller	DEQ Screening Value
No. Fish Analyzed		4	13	19	
Length (cm)		10 - 11.5	11.5 - 19	9.5 - 16.5	
Weight (g)		200 - 350	25 - 175	15 - 75	
Total PCB	**ppb (wet weight basis)**	44.72	19.72	33.93	*50/54/500*
Total Chlordane		19.44	32.37	32.00	*310*
Sum DDE		12.48	4.02	10.94	*320*
Sum DDD		1.03	0.33	1.98	*450*
Sum DDT		0.78	N/A	N/A	*320*
Total DDT		14.29	4.36	12.92	*320*
Total BDE		22.53	N/A	10.14	*5,000*
HCB		N/A	N/A	N/A	*70*
Heptachlorepoxide		0.43	N/A	0.32	*10*
PCA		N/A	N/A	N/A	*N/A*
Aldrin		0.52	N/A	3.32	*6.3*
Heptachlor		0.31	0.32		*24*
Dieldrin		N/A	N/A	N/A	*6.7*
alpha BHC		N/A	N/A	N/A	*20*
gamma BHC		N/A	N/A	N/A	*3,200*
Total BHC		N/A	N/A	N/A	*20*
Endrin aldehyde		N/A	N/A	N/A	*N/A*
CPD 2		N/A	N/A	N/A	*N/A*
CPD 4		N/A	N/A	N/A	*N/A*
CPD 5		N/A	N/A	N/A	*N/A*
TriBA		N/A	N/A	N/A	*N/A*

Table 1.55. Results of fish tissue analysis for non-halogenated organic compounds (PAHs) at station 6CMFH033.40in Middle Fork Holston River.

		06/18/97				06/19/02			07/24/07			
		Golden Redhorse Sucker	Rock Bass #1	Rock Bass Group #2	Stoneroller	Rock Bass	Northern Hogsucker #1	Northern Hogsucker #2	Rock Bass	Stoneroller	Northern Hogsucker	Redhorse Sucker
No. Fish Analyzed		10	10	10	10	10	3	5	6	15	5	3
Length (cm)		36.4 - 46.5	15.5 - 23.4	12.5 - 17.8	11.9 - 17.5	16.1 - 18.5	33.6 - 35.5	22.7 - 25.0	18.8 - 21.5	14.8 - 17.2	23.3 - 30.5	33.6 - 37.4
Weight (g)		454.6 - 1010	31.7 - 240.1	40 - 135.1	19.6 - 63.6	74 - 132	482 - 526	138 - 190	122 - 215	37 - 60	146 - 380	385 - 556
Total PCB	**ppb (wet weight basis)**	257.53	10.24	6.97	37.31	4.67	5.74	7.02	4.32	4.67	3.06	1.95
Total Chlordane		126.87	3.24	6.40	45.17	4.52	4.88	4.49	N/A	N/A	N/A	N/A
Sum DDE		48.34	2.15	1.18	3.63	1.62	1.39	1.39	N/A	N/A	N/A	N/A
Sum DDD		12.98	0.35	0.23	2.39	0.28	0.54	0.36	N/A	N/A	N/A	N/A
Sum DDT		8.04	N/A	0.11	N/A	0.09	0.13	0.12	N/A	N/A	N/A	N/A
Total DDT		69.35	2.50	1.52	6.02	1.99	2.06	1.88	N/A	N/A	N/A	N/A
Total BDE		134.99	4.31	2.82	9.21	4.92	7.03	9.16	N/A	N/A	N/A	N/A
HCB		N/A	N/A	N/A	N/A	N/A	N/A	0.04	N/A	N/A	N/A	N/A
Heptachlorepoxide		5.79	0.30	0.22	0.18	N/A	N/A	0.05	N/A	N/A	N/A	N/A
PCA		N/A	N/A	N/A	N/A	N/A	N/A	0.06	N/A	N/A	N/A	N/A
Aldrin		7.59	0.44	N/A	1.63	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptachlor		N/A	N/A	0.06	2.71	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dieldrin		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
alpha BHC		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
gamma BHC		N/A	N/A	N/A	N/A	0.15	0.23	N/A	N/A	N/A	N/A	N/A
Total BHC		N/A	N/A	N/A	N/A	0.15	0.23	N/A	N/A	N/A	N/A	N/A
Endrin aldehyde		3.20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CPD 2		N/A	N/A	N/A	N/A	N/A	N/A	0.26	N/A	N/A	N/A	N/A
CPD 4		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CPD 5		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TriBA		N/A	N/A	N/A	N/A	N/A	N/A	0.05	N/A	N/A	N/A	N/A

Table 1.56. Results of fish tissue analysis for halogenated organic compounds at stations 6CMFH026.00 and 6CMFH033.40in Middle Fork Holston River.

		6-CMFH026.00			6-CMFH033.40						
		06/19/97			06/18/97				06/19/02		
		Rock Bass	Stoneroller Species	Northern Hogsucker	Rock Bass #1	Rock Bass #2	Golden Redhorse Sucker	Stoneroller Species	Rock Bass	Northern Hogsucker	DEQ Screening Value
No. Fish Analyzed		13	19	3	10	10	10	10	10	3	
Length (cm)		11.5 - 19	9.5 - 16.5	10 - 11.5	15.5 - 23.3	12.5 - 17.8	36.3 - 36.5	11.9 - 17.5	16.1 - 18.5	33.6 - 35.5	
Weight (g)		25 - 175	15 - 75	200 - 350	81.7 - 230.1	30 - 135.1	353.6 - 1010	19.6 - 63.6	74 - 132	482 - 526	
Total PAH	**ppb (wet weight basis)**	3.12	7.03	2.72	2.55	2.40	8.46	8.87	5.82	6.03	*N/A*
Sum PAH		0.05	0.07	0.09	0.13	0.06	0.02	0.15	0.03	0.03	*15*
NAP		0.11	0.11	0.14	0.15	0.13	0.21	0.24	1.20	1.38	*220,000*
NAP 2-Me		0.17	0.38	0.22	0.14	0.11	0.59	0.33	0.23	0.26	*N/A*
NAP 1-Me		0.08	0.28	0.11	0.08	0.05	0.38	0.24	0.17	0.21	*N/A*
biphenyl		0.07	0.11	0.16	0.11	0.08	0.19	0.17	0.23	0.27	*540,000*
NAP d-Me		0.05	0.26	0.07	0.04	0.03	0.64	0.33	0.02	0.04	*N/A*
naphthylene ace		0.01	0.04	0.03	0.00	0.01	0.26	0.09	0.01	0.04	*N/A*
naphthene ace		0.09	0.30	0.09	0.06	0.04	0.54	0.34	0.18	0.17	*650,000*
NAP t-Me		0.18	0.76	0.18	0.11	0.10	0.80	0.66	0.14	0.11	*N/A*
fluorene		0.21	0.70	0.21	0.12	0.13	0.93	0.76	0.18	0.21	*430,000*
PHH		1.07	2.07	0.63	0.61	0.84	2.17	2.39	0.88	0.84	*N/A*
ATH		0.07	0.11	0.05	0.06	0.06	0.24	0.27	0.50	0.55	*3,200,000*
PHH 1-Me		0.38	0.27	0.07	0.13	0.25	0.13	0.68	0.19	0.19	*N/A*
FTH		0.30	0.77	0.21	0.25	0.22	0.69	0.93	0.89	0.82	*430,000*
pyrene		0.14	0.52	0.12	0.14	0.11	0.38	0.73	0.45	0.43	*320,000*
ATH benz(a)		0.01	0.04	0.03	0.03	0.02	0.00	0.06	0.06	0.07	*15*
chrysene		0.04	0.14	0.07	0.07	0.03	0.12	0.16	0.14	0.13	*15*
FTH benzo (b)		0.03	0.07	0.05	0.08	0.03	0.01	0.09	0.12	0.12	*15*
FTH benzo (k)		0.01	0.03	0.06	0.10	0.04	0.07	0.09	0.10	0.08	15
pyrene benzo (e)		0.00	0.00	0.06	0.06	0.03	0.03	0.08	0.13	0.11	15
pyrene benzo (a)		0.04	0.04	0.04	0.07	0.04	0.01	0.08	0.00	0.00	15
perylene		0.02	0.00	0.03	0.03	0.01	0.02	0.04	0.00	0.00	N/A
pyrene IND		0.01	0.02	0.04	0.03	0.01	0.02	0.05	0.00	0.00	15
ATH db (a,h)		0.00	0.01	0.03	0.03	0.02	0.00	0.04	0.00	0.00	15
perylene benzo (ghi)		0.02	0.01	0.04	0.04	0.01	0.04	0.03	0.00	0.00	N/A

2.9 TOXICITY STUDY

A chronic toxicity study using fathead minnows (Pimephales promelas) and Ceriodaphnia dubia was conducted on a water sample collected at station 6CMFH011.31 on August 6, 2007. These tests were performed to determine if the water column toxicity was stressing the benthic community. Toxicity levels did not have a significant effect on fathead minnow or Ceriodaphnia dubia survival and/or reproduction endpoint.

Chapter 3. Bacteria Source Assessment

Potential bacteria sources in the Middle Fork Holston River watershed were assessed using multiple approaches, including information from VADEQ; Virginia Department of Conservation (VADCR); Virginia Department of Game and Inland Fisheries (VADGIF); Virginia Cooperative Extension (VCE); Virginia Department of Health (VDH); Smyth County Planning Department; Wythe County Planning Department; Natural Resources Conservation Service (NRCS); Virginia Department of Agricultural and Consumer Services (VDACS); Big Walker SWCD; Evergreen SWCD; public participation; watershed reconnaissance and monitoring; published information; and professional judgment. The gathered information was used to estimate source populations and their associated bacteria loads throughout the Middle Fork Holston River watershed, forming the basis for model development and analysis of allocation scenarios (Table 3.1). The following sections discuss available information and methods used to estimate bacteria loads for each modeling segment.

Table 3.1. Potential bacteria sources in the Middle Fork Holston River watershed.

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

3.1 Permitted Discharges

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

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

The permit manual defines an industrial facility is defined as:

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

For this reason, permitted point sources of fecal coliform include only the individual municipal or general domestic sewage permits (permits classified as industrial do not discharge bacteria). The individual municipal and general domestic sewage permits are required to maintain a fecal coliform concentration of 200 cfu/100 mL or less, and are required to meet the *E. coli* standard of 126 cfu/100 mL or less in their effluent on permit renewal. Table 3.2 shows the point sources in the Middle Fork Holston River watershed. In allocation scenarios, the entire allowable point source discharge concentration of 200 cfu/100 mL of fecal coliform was used. The ultimate waste load allocation (WLA) was calculated using the *E. coli* limit of 126 cfu/100mL, and *E. coli* loads based on the facility design flow are presented in Table 3.2.

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

Table 3.2. Active VPDES permitted point sources in the Middle Fork Holston River watershed.

Impairment	Permit No	Facility Name	Design Flow (MGD)	Fecal Coliform Load (cfu/yr)	*E. coli* Load (cfu/yr)
MFHR (VAS-O03R-02)	VAG400102	Residence	0.001	2.68E+09	1.69E+09
MFHR (VAS-O03R-02)	VAG400579	Residence	0.001	2.68E+09	1.69E+09
MFHR (VAS-O03R-02)	VAG750033	Car Wash	0.0005	1.43E+09	9.00E+08
MFHR (VAS-O04R-01)	VA0086304	Marion WWTP	3.4	9.40E+12	5.92E+12
MFHR (VAS-O04R-01)	VAG400090	Residence	0.001	2.68E+09	1.69E+09
MFHR (VAS-O04R-01)	VAG400071	Residence	0.001	2.68E+09	1.69E+09
MFHR (VAS-O04R-01)	VAG400531	Blue Ridge Knives STP	0.001	2.68E+09	1.69E+09
MFHR (VAS-O04R-01)	VAG400548	Residence	0.001	2.68E+09	1.69E+09
MFHR (VAS-O04R-01)	VAG400576	Grove Baptist Church STP	0.001	2.68E+09	1.69E+09
MFHR (VAS-O04R-01)	VAG400176	Skyview Storage STP	0.001	2.68E+09	1.69E+09
MFHR (VAS-O04R-01)	VAG400426	Smyth County Lodge #1004 Loyal Order Of Moose Inc	0.001	2.68E+09	1.69E+09
MFHR (VAS-O04R-01)	VAG400078	Budget Inn Motel STP	0.001	2.68E+09	1.69E+09
MFHR (VAS-O05R-06)	VA0026379	Chilhowie Regional WTP	0.999	2.76E+12	1.74E+12
MFHR (VAS-O05R-06)	VAG400181	Residence	0.001	2.68E+09	1.69E+09
MFHR (VAS-O05R-05)	VA0087378	Washington Cnty Service Authority -Hall Creek WWTP	0.630	1.74E+12	1.10E+12
MFHR (VAS-O05R-05)	VA0030589	Washington County Public Schools - Meadowview Elem	0.016	4.43E+10	2.79E+10
MFHR (VAS-O05R-05)	VA0076376	Washington County Industrial Park WWTP	0.080	2.21E+11	1.39E+11
MFHR (VAS-O05R-05)	VAG400654	Residence	0.001	2.68E+09	1.69E+09
MFHR (VAS-O05R-05)	VAG400618	Residence	0.001	2.68E+09	1.69E+09
MFHR (VAS-O05R-05)	VAG400324	Instar Services Group	0.001	2.68E+09	1.69E+09
MFHR (VAS-O05R-05)	VAG400585	Residence	0.001	2.68E+09	1.69E+09

3.2 Humans

There are 79 homes served by municipal sanitary sewer in the Middle Fork Holston River (VAS-O03R-01) watershed. Wastewater from 648 households within the watershed is treated on site by traditional sewage handling and disposal systems.The Middle Fork Holston River (VAS-O03R-01) watershed has an estimated population of 1,468 people (727 households at an average of 2.02 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce 1.95×10^{9} cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of 2.86×10^{12} cfu/day (1.04×10^{15} cfu/year).

There are 2,019 homes served by municipal sanitary sewer in the Middle Fork Holston River (VAS-O03R-02) watershed. Wastewater from 1,545 households within the watershed is treated on site by traditional sewage handling and disposal systems. The Middle Fork Holston River (VAS-O03R-02) watershed has an estimated population of 7,489 people (3,564 households at an average of 2.10 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce 1.95×10^{9} cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of 1.46×10^{13} cfu/day (5.331×10^{15} cfu/year).

There are 1,969 homes served by municipal sanitary sewer in the Middle Fork Holston River (VAS-O04R-01) watershed. Wastewater from 2,725 households within the watershed is treated on site by traditional sewage handling and disposal systems. The Middle Fork Holston River (VAS-O04R-01) watershed has an estimated population of 10,970 people (4,694 households at an average of 2.34 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce 1.95×10^{9} cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of 2.14×10^{13} cfu/day (7.81×10^{15} cfu/year).

There are 222 homes served by municipal sanitary sewer in the Middle Fork Holston River (VAS-O05R-06) watershed. Wastewater from 907 households within the watershed is treated on site by traditional sewage handling and disposal systems. The Middle Fork Holston River (VAS-O05R-06) watershed has an estimated population of 2,427 people (1,129 households at an average of 2.15 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce 1.95×10^{9} cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of 4.73×10^{12} cfu/day (1.73×10^{15} cfu/year).

There are 337 homes served by municipal sanitary sewer in the Middle Fork Holston River (VAS-O05R-05) watershed. Wastewater from 1,951 households within the watershed is treated on site by traditional sewage handling and disposal systems. The Middle Fork Holston River (VAS-O05R-05) watershed has an estimated population of 5,762 people (2,288 households at an average of 2.52 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce 1.95×10^{9} cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of 1.12×10^{13} cfu/day (4.10×10^{15} cfu/year).

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

3.2.1 Failing Septic Systems

Septic systems are designed to filter septic tank effluent through the soil allowing removal of bacteria and nutrients from the wastewater. Septic system failure is manifested by the rise of effluent to the soil surface. It was assumed treatment of effluent ceased once effluent containing fecal coliform reached the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters.

Total septic systems were classified into one of three age categories (pre-1967, 1967-1987, and post-1987) based on 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB, 1990, 2000, and 2004). In accordance with estimates from Dr. Raymond B. Reneau, Jr. from Virginia Tech, a 15% failure rate for systems designed and installed prior to 1967, a 8% failure rate for systems designed and installed between 1967 and 1987, and a 3% failure rate on all systems designed and installed after 1987 was used in the development of the Middle Fork Holston River TMDL. The rates reported by Dr. Raymond B. Reneau, Jr. were a culmination of studies he performed throughout the state with numerous variables (e.g., soils) considered. These rates have been accepted by the Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation, and United States Environmental Protection Agency in TMDLs throughout Virginia. Estimates of these failure rates were also supported by the Holmans Creek Watershed Study which found that over 30% of all septic systems checked in the watershed were either failing or not functioning at all (SAIC, 2001).

An average number of people per household and number of houses and people in each subwatershed in 2008 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). The applicable failure rate was multiplied by each total and summed to get the total failed septic systems per subwatershed. Daily total fecal coliform load to the land from a failing septic system in a particular sub-watershed was determined by multiplying the average household occupancy rate for that subwatershed by the per capita fecal coliform production rate of 1.95×10^9 cfu/day (Geldreich et al., 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a subwatershed with an occupancy rate of 2.02 persons/household was 3.94×10^9 cfu/day. Transport of some portion of the fecal coliform to a stream by runoff may occur during storm events. The number of failing septic systems in the watershed is given in Tables 3.3 through 3.7.

3.2.2 Straight Pipes

Houses that deliver a waste load directly to the stream, or straight pipes, were estimated by identifying those houses located within 150 feet of streams in the pre-1969 and 1970-1988 age categories. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1969, 1970 – 1988, post 1988), 10% of old houses (pre-1969) within 150 ft of streams and 2% of mid-age houses (1970 – 1988) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 18, 30, 23, 11, and 18 houses that potentially could be classified as straight pipes in the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), and Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) impairment watersheds (Table 3.3 through 3.7).

3.2.3 Biosolids

According to the VADEQ records, none of the facilities permitted for biosolids land application are currently disposing biosolids via land application in the Middle Fork Holston River watershed.

3.3 Pets

According to the American Veterinary Medical Association (AVMA), there are on average 0.53 dogs per household and 0.60 cats per household in the Unites States (AVMA, 1997). Based on these densities and number of households in each watershed, 385 dogs and 436 cats were projected to reside in the Middle Fork Holston River (VAS-O03R-01) watershed. All pets were combined for modeling purposes into a standard 'unit pet' category. This 'unit pet' was assumed equivalent to one dog or several cats, and a rate of one 'unit pet' per household was used to calculate a total pet population of 727. The maximum typical fecal coliform production for both dogs and cats is 5.0×10^9 cfu/day-animal (Keeling, 2003), and the typical ranges overlap significantly. The pet population was estimated to produce 4.5×10^8 cfu/day-animal based on these published values. The total bacteria production attributed to pets in Middle Fork Holston River (VAS-O03R-01) watershed is 3.27×10^{11} cfu/day (1.19×10^{14} cfu/yr).

In Middle Fork Holston River (VAS-O03R-02) watershed, 1,889 dogs and 2,138 cats were projected to reside in the watershed based on AVMA estimated densities. Combining all pets into a standard 'unit pet' category yielded a total pet population of 3,564.The total bacteria production attributed to pets in the Middle Fork Holston River (VAS-O03R-02) watershed is 1.60×10^{12} cfu/day (5.85×10^{14} cfu/yr).

An estimated 2,488 dogs and 2,816 cats were projected to reside in the Middle Fork Holston River (VAS-O04R-01) watershed based on AVMA estimated densities. Combining all pets into a standard 'unit pet' category yielded a total pet population of 4,694. The total bacteria production attributed to pets in the Middle Fork Holston River (VAS-O04R-01) watershed is 2.11×10^{12} cfu/day (7.71×10^{14} cfu/yr).

In Middle Fork Holston River (VAS-O05R-06) watershed, 598 dogs and 677 cats were projected to reside in the watershed based on AVMA estimated densities. Combining all pets into a standard 'unit pet' category yielded a total pet population of 1,129. The total bacteria production attributed to pets in the Middle Fork Holston River (VAS-O05R-06) watershed is 5.08×10^{11} cfu/day (1.85×10^{14} cfu/yr).

An estimated 1,213 dogs and 1,373 cats were projected to reside in the Middle Fork Holston River (VAS-O05R-05) watershed based on AVMA estimated densities. Combining all pets into a standard 'unit pet' category yielded a total pet population of 2,288. The total bacteria production attributed to pets in the Middle Fork Holston River (VAS-O05R-05) watershed is 1.03×10^{12} cfu/day (3.76×10^{14} cfu/yr).

Pet population distribution among subwatersheds is listed in Tables 3.3 through 3.7. Pet waste is generated in the residential land use type. Bacteria loading to streams from pet waste can result from surface runoff transporting bacteria from residential areas.

Table 3.3. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O03R-01) watershed.

Sub-shed	Human Population	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
		Pre-1967	1967-1987	Post-1987			
MFH-01	716	184	44	39	31	6	334
MFH-02	356	143	26	11	23	4	186
MFH-03	396	147	37	17	24	8	207
Total	**1,468**	**474**	**107**	**67**	**78**	**18**	**727**

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

Table 3.4. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O03R-02) watershed.

Sub-shed	Human Population	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
		Pre-1967	1967-1987	Post-1987			
MFH-04	471	177	41	23	29	6	256
MFH-05	321	90	14	4	14	3	136
MFH-06	40	14	4	3	3	0	22
MFH-07	93	25	14	8	5	0	47
MFH-08	291	94	35	20	17	4	157
MFH-09	948	209	33	10	33	8	404
MFH-10	1,022	161	18	3	25	2	425
MFH-11	763	57	4	1	9	0	407
MFH-12	755	194	30	16	31	4	331
MFH-13	1,305	135	11	2	21	3	675
MFH-14	1,480	84	9	2	13	0	704
Total	**7,489**	**1,240**	**213**	**92**	**200**	**30**	**3,564**

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

Table 3.5. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O04R-01) watershed.

Sub-shed	Human Population	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
		Pre-1967	1967-1987	Post-1987			
MFH-15	1,356	240	37	23	39	5	655
MFH-16	991	102	11	105	19	2	388
MFH-17	603	171	30	19	28	2	270
MFH-18	1,519	195	20	106	34	2	586
MFH-19	1,358	341	49	77	56	6	618
MFH-20	792	175	17	8	27	2	323
MFH-21	4,351	711	173	115	123	4	1,854
Total	**10,970**	**1,935**	**337**	**453**	**326**	**23**	**4,694**

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

Table 3.6. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O05R-06) watershed.

Sub-shed	Human Population	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
		Pre-1967	1967-1987	Post-1987			
MFH-22	166	18	3	1	3	0	74
MFH-23	754	180	34	18	30	2	340
MFH-24	952	339	45	19	54	7	451
MFH-25	524	182	34	20	30	2	249
MFH-26	31	11	2	1	2	0	15
Total	**2,427**	**730**	**118**	**59**	**119**	**11**	**1,129**

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

Table 3.7. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Middle Fork Holston River (VAS-O05R-05) watershed.

Sub-shed	Human Population	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
		Pre-1967	1967-1987	Post-1987			
MFH-27	2,661	573	133	136	100	2	992
MFH-28	177	46	9	12	7	4	73
MFH-29	42	12	3	3	2	0	18
MFH-30	146	43	8	10	7	4	64
MFH-31	1,270	272	66	76	47	5	496
MFH-32	1,466	346	94	109	62	3	645
Total	**5,762**	**1,292**	**313**	**346**	**225**	**18**	**2,288**

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

3.4 Domesticated Animal Sources

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

3.4.1 Cattle

Based on information obtained from VADCR and SWCD, there are one, zero, two, two, and two dairy farms presently operating in the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), and Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) watersheds, respectively. Based on information provided, it was determined that there were 1,097 milk cows, 549 dry cows, and 549 heifers distributed between the farms. The dairy cattle population was distributed among the sub-watersheds based on the location of the dairy farm (Tables 3.8 through 3.12). Beef cattle in the Middle Fork Holston River watershed (13,340 pairs) included cow/calf and feeder operations (Tables 3.8 through 3.12).

Table 3.8. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O03R-01) watershed.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
MFH-01	330	1	606
MFH-02	0	0	368
MFH-03	0	0	581
Total	**330**	**1**	**1,555**

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

Table 3.9. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O03R-02) watershed.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
MFH-04	0	0	277
MFH-05	0	0	124
MFH-06	0	0	7
MFH-07	0	0	0
MFH-08	0	0	260
MFH-09	0	0	704
MFH-10	0	0	304
MFH-11	0	0	62
MFH-12	0	0	142
MFH-13	0	0	106
MFH-14	0	0	44
Total	**0**	**0**	**2,030**

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

Table 3.10. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O04R-01) watershed.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
MFH-15	0	0	449
MFH-16	300	1	308
MFH-17	200	1	425
MFH-18	0	0	402
MFH-19	0	0	579
MFH-20	0	0	366
MFH-21	0	0	2,632
Total	**500**	**2**	**5,161**

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

Table 3.11. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O05R-06) watershed.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
MFH-22	0	0	31
MFH-23	0	0	640
MFH-24	0	0	703
MFH-25	944	2	510
MFH-26	0	0	10
Total	**944**	**2**	**1,894**

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

Table 3.12. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Middle Fork Holston River (VAS-O05R-05) watershed.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
MFH-27	420	2	1,014
MFH-28	0	0	218
MFH-29	0	0	53
MFH-30	0	0	206
MFH-31	0	0	556
MFH-32	0	0	653
Total	**420**	**2**	**2,700**

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

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

- Cows are confined according to the schedule given in Table 3.13.
- When cattle are not confined, they spend their time on pasture and in loafing lots, where applicable.
- Pasture 1 (improved pasture/hay land) stocks twice as many cows per unit area as pasture 2 (unimproved pasture/grazed woodlands), which stocks twice as many cows per unit area as pasture 3 (overgrazed pasture).
- Cows on pastures that are contiguous to streams have stream access.
- Cows with stream access spend varying amounts of time in the stream during different seasons (Table 3.13). Cows spend more time in the stream during the three summer months to protect their hooves from hornflies, among other things.

- Thirty percent of cows in and around streams directly deposit fecal coliform into the stream. The remaining 70% of the manure is deposited on pastures.

Table 3.13. Time spent by cattle in confinement and in the stream in Middle Fork Holston River watershed.

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

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

The time cattle spend each month in various land uses or a given stream reach was estimated based on typical agricultural practice, and adjusted to reflect feedback from TAC members and agricultural producers. Using these data describing where cattle spend their time, the cattle and their resulting bacteria loads were distributed among the land uses for modeling purposes. The resulting numbers of cattle in each land use type as well as in the stream for all subwatersheds are given in Tables 3.14 through 3.17 for dairy cattle and in Tables 3.18 through 3.22 for beef cattle. Tables 3.18 through 3.22 reflect animal unit (i.e., 1,000 lb) per beef cow-calf pair variation throughout year.

Table 3.14. Distribution of the dairy cattle[a] population in Middle Fork Holston River (VAS-O03R-01) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream[b]
January	190.15	107.24	26.86	6.71	0.04
February	190.15	107.24	26.86	6.71	0.04
March	66.00	201.73	50.52	12.63	0.12
April	49.50	214.25	53.66	13.41	0.18
May	49.50	214.19	53.64	13.41	0.26
June	49.50	213.92	53.57	13.39	0.62
July	49.50	213.92	53.57	13.39	0.62
August	49.50	213.92	53.57	13.39	0.62
September	49.50	214.19	53.64	13.41	0.26
October	49.50	214.25	53.66	13.41	0.18
November	66.00	201.73	50.52	12.63	0.12
December	190.15	107.24	26.86	6.71	0.04

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

Table 3.15. Distribution of the dairy cattle[a] population in Middle Fork Holston River (VAS-O04R-01) watershed.

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

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

Table 3.16. Distribution of the dairy cattle[a] population in Middle Fork Holston River (VAS-O05R-06) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream[b]
January	542.80	305.45	76.50	19.12	0.13
February	542.80	305.45	76.50	19.12	0.13
March	188.80	574.88	143.97	35.99	0.35
April	141.60	610.72	152.95	38.24	0.50
May	141.60	610.52	152.90	38.22	0.75
June	141.60	609.76	152.71	38.18	1.76
July	141.60	609.76	152.71	38.18	1.76
August	141.60	609.76	152.71	38.18	1.76
September	141.60	610.52	152.90	38.22	0.75
October	141.60	610.72	152.95	38.24	0.50
November	188.80	574.88	143.97	35.99	0.35
December	542.80	305.45	76.50	19.12	0.13

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

Table 3.17. Distribution of the dairy cattle[a] population in Middle Fork Holston River (VAS-O05R-05) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream[b]
January	241.50	135.90	34.03	8.51	0.06
February	241.50	135.90	34.03	8.51	0.06
March	84.00	255.77	64.06	16.01	0.16
April	63.00	271.72	68.05	17.01	0.22
May	63.00	271.63	68.03	17.01	0.33
June	63.00	271.29	67.94	16.99	0.78
July	63.00	271.29	67.94	16.99	0.78
August	63.00	271.29	67.94	16.99	0.78
September	63.00	271.63	68.03	17.01	0.33
October	63.00	271.72	68.05	17.01	0.22
November	84.00	255.77	64.06	16.01	0.16
December	241.50	135.90	34.03	8.51	0.06

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

Table 3.18. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O03R-01) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*
January	715.30	816.89	204.58	51.15	0.34
February	839.70	958.96	240.16	60.04	0.39
March	0.00	1645.36	412.06	103.02	1.01
April	0.00	1692.44	423.85	105.96	1.39
May	0.00	1739.24	435.57	108.89	2.14
June	0.00	1784.33	446.86	111.72	5.14
July	0.00	1831.60	458.70	114.68	5.27
August	0.00	1878.87	470.54	117.63	5.41
September	0.00	1928.55	482.98	120.75	2.38
October	0.00	1183.53	296.40	74.10	0.97
November	0.00	1242.90	311.27	77.82	0.77
December	684.20	781.37	195.69	48.92	0.32

*Number of beef cattle defecating in stream.

Table 3.19. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O03R-02) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*
January	933.80	1,066.42	267.07	66.77	0.44
February	1,096.20	1,251.89	313.52	78.38	0.51
March	0.00	2,147.96	537.93	134.48	1.32
April	0.00	2,209.43	553.32	138.33	1.81
May	0.00	2,270.52	568.62	142.16	2.80
June	0.00	2,329.39	583.37	145.84	6.71
July	0.00	2,391.09	598.82	149.70	6.88
August	0.00	2,452.80	614.27	153.57	7.06
September	0.00	2,517.65	630.52	157.63	3.10
October	0.00	1,545.06	386.94	96.74	1.27
November	0.00	1,622.56	406.35	101.59	1.00
December	893.20	1,020.06	255.46	63.87	0.42

*Number of beef cattle defecating in stream.

Table 3.20. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O04R-01) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*
January	2,374.06	2,711.23	679.00	169.75	1.11
February	2,786.94	3,182.75	797.08	199.27	1.31
March	0.00	5,460.91	1,367.62	341.90	3.36
April	0.00	5,617.18	1,406.75	351.69	4.61
May	0.00	5,772.49	1,445.65	361.41	7.11
June	0.00	5,922.15	1,483.13	370.78	17.05
July	0.00	6,079.03	1,522.42	380.60	17.50
August	0.00	6,235.91	1,561.71	390.43	17.95
September	0.00	6,400.79	1,603.00	400.75	7.89
October	0.00	3,928.09	983.74	245.94	3.23
November	0.00	4,125.14	1,033.09	258.27	2.54
December	2,270.84	2,593.35	649.47	162.37	1.06

*Number of beef cattle defecating in stream.

Table 3.21. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O05R-06) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*
January	871.24	994.98	249.18	62.29	0.41
February	1,022.76	1,168.02	292.52	73.13	0.48
March	0.00	2,004.06	501.89	125.47	1.23
April	0.00	2,061.41	516.25	129.06	1.69
May	0.00	2,118.41	530.53	132.63	2.61
June	0.00	2,173.33	544.28	136.07	6.26
July	0.00	2,230.90	558.70	139.68	6.42
August	0.00	2,288.47	573.12	143.28	6.59
September	0.00	2,348.98	588.27	147.07	2.89
October	0.00	1,441.54	361.02	90.25	1.18
November	0.00	1,513.86	379.13	94.78	0.93
December	833.36	951.72	238.35	59.59	0.39

*Number of beef cattle defecating in stream.

Table 3.22. Distribution of the beef cattle population (pairs) in the Middle Fork Holston River (VAS-O05R-05) watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*
January	1,242.00	1,418.39	355.22	88.80	0.58
February	1,458.00	1,665.07	417.00	104.25	0.68
March	0.00	2,856.90	715.48	178.87	1.76
April	0.00	2,938.65	735.95	183.99	2.41
May	0.00	3,019.91	756.30	189.07	3.72
June	0.00	3,098.20	775.91	193.98	8.92
July	0.00	3,180.27	796.46	199.11	9.15
August	0.00	3,262.34	817.01	204.25	9.39
September	0.00	3,348.60	838.62	209.65	4.13
October	0.00	2,055.00	514.65	128.66	1.69
November	0.00	2,158.09	540.47	135.12	1.33
December	1,188.00	1,356.72	339.78	84.94	0.56

*Number of beef cattle defecating in stream.

3.4.1.1 Direct Manure Deposition in Streams

Direct manure loading to streams is due to both dairy and beef cattle defecating in the stream. However, only cattle on pastures contiguous to streams which have not been fenced off have stream access. Manure loading increases during the warmer months when cattle spend more time in water, compared to the cooler months.

Average annual manure loading directly deposited by cattle in the stream for the Middle Fork Holston River (VAS-O03R-01) watershed is 55,653lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 7.59×10^{10} cfu/day (2.77×10^{13} cfu/year).

For Middle Fork Holston River (VAS-O03R-02), the average annual manure loading directly deposited by cattle in the stream is 61,140 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 9.21×10^{11} cfu/day (3.36×10^{13} cfu/year).

For Middle Fork Holston River (VAS-O04R-01), the average annual manure loading directly deposited by cattle in the stream is 168,762 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 2.42×10^{11} cfu/day (8.85×10^{13} cfu/year).

For Middle Fork Holston River (VAS-O05R-06), the average annual manure loading directly deposited by cattle in the stream is 82,196 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 1.02×10^{11} cfu/day (3.71×10^{13} cfu/year).

For Middle Fork Holston River (VAS-O05R-05), the average annual manure loading directly deposited by cattle in the stream is 92,510 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 1.30×10^{11} cfu/day (4.73×10^{13} cfu/year).

Part of the fecal coliform deposited in the stream stays in the dissolved form while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that dissolved fecal coliform bacteria are the primary form transported with the flow. Sediment-bound

bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. For this TMDL, the dissolved form of bacteria was modeled and re-suspension of sediment-bound bacteria was accounted for through calibration (see Chapter 5). Die-off of fecal coliform in the stream results from sunlight, predation, turbidity, and other environmental factors.

3.4.1.2 Direct Manure Deposition on Pastures

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

In the Middle Fork Holston River (VAS-O03R-01) watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 11,449; 5,736, and 2,845, lb/ac-year, respectively. The loadings vary because the stocking rate varies with pasture type, with improved pasture able to stock the most cattle. Fecal coliform loadings from cattle in Middle Fork Holston River (VAS-O03R-01), averaged over the year, are 6.02×10^{12}, 3.07×10^{12}, and 1.42×10^{12} cfu/ac-year for pastures 1, 2, and 3, respectively.

In the Middle Fork Holston River (VAS-O03R-02) watershed, manure loadings for pastures 1, 2, and 3 were 10,371; 5,196; and 2,577 lb/ac-year and fecal coliform loadings were 6.00×10^{12}, 3.05×10^{12}, and 1.42×10^{12} cfu/ac-year for pastures 1, 2, and 3, respectively.

In Middle Fork Holston River (VAS-O04R-01) watershed, manure loadings for pastures 1, 2, and 3 were 11,286; 5,655; and 2,803 lb/ac-year and fecal coliform loadings were 6.24×10^{12}, 3.18×10^{12}, and 1.47×10^{12} cfu/ac-year for pastures 1, 2, and 3, respectively.

In Middle Fork Holston River (VAS-O05R-06) watershed, manure loadings for pastures 1, 2, and 3 were 9,527; 4,780; and 2,358 lb/ac-year and fecal coliform loadings were 4.72×10^{12}, 2.44×10^{12}, and 1.06×10^{12} cfu/ac-year for pastures 1, 2, and 3, respectively.

In Middle Fork Holston River (VAS-O05R-05) watershed, manure loadings for pastures 1, 2, and 3 were 7,228; 3,637; and 1,773 lb/ac-year and fecal coliform loadings were 4.31×10^{12}, 2.27×10^{12}, and 9.08×10^{11} cfu/ac-year for pastures 1, 2, and 3, respectively.

Fecal coliform bacteria deposited on the pasture surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

3.4.1.3 Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 pounds and produces 17 gallons of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule and the number of milk cows,

annual liquid dairy manure production is 438,386 gallons in Middle Fork Holston River (VAS-O03R-01) watershed; 664,222 in Middle Fork Holston River (VAS-O04R4-01) watershed; 1,254,051 in Middle Fork Holston River (VAS-O05R-06) watershed; and 557,946 in Middle Fork Holston River (VAS-O05R-05) watershed. Based on per capita fecal coliform production of milk cows, the fecal coliform concentration in fresh liquid dairy manure is 3.88×10^7 cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) in application to land. Liquid dairy manure application rates are 6,600 and 3,900 gal/ac-year to cropland and pasture land use categories (BSE, 2003), respectively, with cropland receiving priority in application. Based on availability of land and liquid dairy manure, as well as the assumptions regarding application rates and priority of application, it was estimated that liquid dairy manure was applied to 27.7 acres of cropland and 65.5 acres of pasture in the Middle Fork Holston River (VAS-O03R-01) watershed. For the Middle Fork Holston River (VAS-O03R-02) watershed, it was estimated that liquid dairy manure was applied to 0.0 acres of cropland and 0.0 acres of pasture. For the Middle Fork Holston River (VAS-O04R-01) watershed, it was estimated that liquid dairy manure was applied to 24.3 acres of cropland and 129.2 acres of pasture 1. For the Middle Fork Holston River (VAS-O05R-06) watershed, it was estimated that liquid dairy manure was applied to 112.9 acres of cropland and 130.5 acres of pasture 1. For the Middle Fork Holston River (VAS-O05R-05) watershed, it was estimated that liquid dairy manure was applied to 84.5 acres of cropland and 0.0 acres of pasture.

The typical crop rotation in the watershed is a seven-year rotation with three years of corn-rye and four years of rotational hay (BSE, 2003). It was assumed that 50% of the corn acreage was under no-till cultivation. Liquid manure is applied to cropland during February through May (prior to planting) and in October-November (after the crops are harvested). For spring application to cropland, liquid manure is applied on the soil surface to rotational hay and no-till corn and is incorporated into the soil for corn in conventional tillage. In fall, liquid manure is incorporated into the soil for cropland under rye and surface-applied to cropland under rotational hay. It was assumed that only 10% of the subsurface-applied fecal coliform was available for removal in surface runoff based on local knowledge. The application schedule of liquid manure (BSE, 2003) is given in Table 3.23. Dry cows and heifers were assumed to produce only solid manure.

Table 3.23. Schedule of cattle waste application in Middle Fork Holston River watershed.

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

* As percent of annual production.

3.4.1.4 Land Application of Solid Manure

Solid manure produced by dry cows, heifers, and beef cattle during confinement is collected for land application. It was assumed that milk cows produce only liquid manure while in confinement. The number of cattle, their typical weights, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Tables 3.24 through 3.28.

Solid manure is last on the priority list for application to land (it falls behind liquid manure and poultry litter). The amount of solid manure produced in each sub-watershed was estimated based on the populations of dry cows, heifers, and beef cattle in the sub-watershed and their confinement schedules. Solid manure from dry cows, heifers, and beef cattle exhibits different fecal coliform concentrations (cfu/lb) (Tables 3.24 through 3.28). Hence, a weighted average fecal coliform concentration in solid manure was calculated based on the relative manure contribution from dry cows, heifers, and beef cattle (Tables 3.24 through 3.28). Solid manure is applied at the rate of 12 tons/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid manure, solid manure is only applied to cropland during February through May and the months of October and November.

Solid manure can be applied to pasture during the whole year except during December and January. The method of application of solid manure to cropland or pasture is assumed to be identical to the method of application of liquid dairy manure. The application schedule for solid manure is given in Table 3.23. Based on availability of land and solid manure, as well as the assumptions regarding application rate, it was estimated that solid manure was applied to 40.9 acres of cropland and 146.3 acres of pasture 1 in the Middle Fork Holston River (VAS-O03R-01) watershed. For the Middle Fork Holston River (VAS-O03R-02) watershed, it was estimated that solid manure was applied to 37.7 acres of cropland and 181.3 acres of pasture 1. For the Middle Fork Holston River (VAS-O04R-01) watershed, it was estimated that solid manure was applied

to 176.3 acres of cropland and 409.8 acres of pasture 1. For the Middle Fork Holston River (VAS-O05R-06) watershed, it was estimated that solid manure was applied to 148.2 acres of cropland and 111.4 acres of pasture 1. For the Middle Fork Holston River (VAS-O05R-05) watershed, it was estimated that solid manure was applied to 287.7 acres of cropland and 28.1 acres of pasture 1.

Table 3.24. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O03R-01) watershed.

Type of Cattle	Population	Typical Weight (lb) [a]	Solid Manure Produced (lb/animal-day) [a]	Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb) [a]	Weighted Average Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb)
Dry Cow	83	1,400	115	2.17	**5.09**
Heifer	83	640	40.7	2.17	
Beef (pairs)	1,555	1,000	60	5.5	

[a]Source: BSE (2003)

Table 3.25. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O03R-02) watershed.

Type of Cattle	Population	Typical Weight (lb) [a]	Solid Manure Produced (lb/animal-day) [a]	Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb) [a]	Weighted Average Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb)
Dry Cow	0	1,400	115	2.17	**5.50**
Heifer	0	640	40.7	2.17	
Beef (pairs)	2,030	1,000	60	5.5	

[a]Source: BSE (2003)

Table 3.26. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O04R-01) watershed.

Type of Cattle	Population	Typical Weight (lb) [a]	Solid Manure Produced (lb/animal-day) [a]	Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb) [a]	Weighted Average Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb)
Dry Cow	125	1,400	115	2.17	**5.30**
Heifer	125	640	40.7	2.17	
Beef (pairs)	5,161	1,000	60	5.5	

[a]Source: BSE (2003)

Table 3.27. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O05R-06) watershed.

Type of Cattle	Population	Typical Weight (lb) [a]	Solid Manure Produced (lb/animal-day) [a]	Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb) [a]	Weighted Average Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb)
Dry Cow	361	1,400	115	2.17	**4.40**
Heifer	361	640	40.7	2.17	
Beef (pairs)	1,894	1,000	60	5.5	

[a]Source: BSE (2003)

Table 3.28. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Middle Fork Holston River (VAS-O05R-05) watershed.

Type of Cattle	Population	Typical Weight (lb) [a]	Solid Manure Produced (lb/animal-day) [a]	Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb) [a]	Weighted Average Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb)
Dry Cow	105	1,400	115	2.17	**5.19**
Heifer	105	640	40.7	2.17	
Beef (pairs)	2,700	1,000	60	5.5	

[a]Source: BSE (2003)

3.4.2 Poultry

Based on confined animal feeding operations information obtained from VADCR and feedback from the TAC, no poultry facilities are presently operating in the Middle Fork Holston River watershed. In addition, no imported poultry litter to the watershed was identified.

3.4.3 Horses

The estimated number of horses in the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) watersheds is included in Tables 3.29 through 3.33, respectively. The horse population in the watershed has risen in the last several years. Horse populations were estimated using data from the 2001 Virginia Equine Report produced by VASS (VASS, 2002).The number of horses within the watershed was estimated by distributing the equine population evenly throughout all pasture in each county and determining the number of horses in the watershed based on pasture area in the watershed. The same method was used to determine the equine population in each subwatershed. The estimates were adjusted based on feedback from the TAC. The typical horse produces 4.2×10^{8} cfu/day (VADCR, 2003). Therefore, the daily fecal coliform production by horses is 4.27×10^{10} cfu/day (1.56×10^{13} cfu/year) in the Middle Fork Holston River (VAS-O03R-01) watershed, 5.01×10^{10} cfu/day (1.83×10^{13} cfu/year) in the Middle Fork Holston River (VAS-O03R-02) watershed, 1.28×10^{11} cfu/day (4.69×10^{13} cfu/year) in the Middle Fork Holston River (VAS-O04R-01) watershed, 1.41×10^{11} cfu/day (5.14×10^{13} cfu/year) in the Middle Fork Holston River (VAS-O05R-06) watershed, and 2.16×10^{11} cfu/day (7.89×10^{13} cfu/year) in the Middle Fork Holston River (VAS-O05R-05) watershed.

Table 3.29. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O03R-01) watershed.

Subwatershed	Horses	Ewes	Goats
MFH-01	44	40	35
MFH-02	24	0	24
MFH-03	34	21	43
Total	**102**	**61**	**102**

Table 3.30. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O03R-02) watershed.

Subwatershed	Horses	Ewes	Goats
MFH-04	16	0	20
MFH-05	7	0	9
MFH-06	0	0	1
MFH-07	0	0	0
MFH-08	15	0	19
MFH-09	42	26	52
MFH-10	18	0	22
MFH-11	4	0	5
MFH-12	8	0	10
MFH-13	6	0	8
MFH-14	3	0	3
Total	**119**	**26**	**149**

Table 3.31. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O04R-01) watershed.

Subwatershed	Horses	Ewes	Goats
MFH-15	27	0	33
MFH-16	18	0	23
MFH-17	25	0	31
MFH-18	24	0	30
MFH-19	34	21	43
MFH-20	22	0	27
MFH-21	156	96	195
Total	**306**	**117**	**382**

Table 3.32. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O05R-06) watershed.

Subwatershed	Horses	Ewes	Goats
MFH-22	2	0	2
MFH-23	100	47	77
MFH-24	134	60	96
MFH-25	97	44	70
MFH-26	2	0	1
Total	**335**	**151**	**246**

Table 3.33. Horse and sheep population by subwatershed in the Middle Fork Holston River (VAS-O05R-05) watershed.

Subwatershed	Horses	Ewes	Goats
MFH-27	193	400	139
MFH-28	42	0	30
MFH-29	10	0	7
MFH-30	39	0	28
MFH-31	106	48	76
MFH-32	124	56	89
Total	**514**	**504**	**369**

3.4.4 Other Livestock Sources

Based on county sheep population data obtained from VASS and input from SWCDs, the sheep population was distributed to individual subwatersheds (Tables 3.29 through 3.33). Based on information provided, it was determined that there were 859 ewes and 1,248 goats throughout the Middle Fork Holston River watershed. Other minor livestock-related sources of bacteria (e.g., llama) were present during watershed visits; however, a significant population was not identified within the Middle Fork Holston River watershed. The potential bacteria load from these sources was accounted for during water quality calibration.

3.5 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Tables 3.40 through 3.44. The total wildlife fecal coliform production each year in the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) watersheds is 1.23×10^{14} cfu/yr,2.51×10^{14} cfu/yr, 3.71×10^{14} cfu/yr, 1.21×10^{14} cfu/yr, and 1.97×10^{14} cfu/yr, respectively.

Wildlife fecal coliform contributions can be from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF, USF&WS, and watershed residents was used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.34).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.34). Fecal matter produced by deer that is not directly deposited in streams is distributed among pastures and forest. Raccoons deposit their waste in streams and forests. Muskrats deposit their waste in streams and pastures.

Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among sub-watersheds based on habitat descriptions included in Table 3.34, and further details of the wildlife habitat were used to distribute the populations

among the sub-watersheds. For example, the deer population was evenly distributed across the watershed, whereas the 66 feet buffer around streams and impoundments determined the muskrat population. Therefore, a sub-watershed with more stream length and impoundments would have more muskrats than a sub-watershed with shorter stream length and fewer impoundments. Distribution of wildlife among sub-watersheds is given in Tables 3.35 through 3.39.

Table 3.34. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Middle Fork Holston River watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.022	0.10
Raccoon	Primary: 600 feet buffer around streams and impoundments Secondary: 601 feet -7,920 feet buffer from streams and impoundments	0.070	0.10
Muskrat	Primary: 66 feet buffer around streams and impoundments in forest and cropland Secondary: 67-300 feet buffer from same	0.037[a]	0.25
Beaver	300 feet buffer around streams and impoundments in forest and pasture	0.015	0.50
Geese	300 feet buffer around main streams	0.003[b]	0.25
Wood Duck	300 feet buffer around main streams	0.004[b]	0.25
Wild Turkey	Entire watershed except urban areas	0.007[c]	0.00

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

Table 3.35. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O03R-01) watershed.

Subwatershed	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Wood Duck (#)	Wild Turkey (#)
MFH-01	116	175	531	18	15	18	19
MFH-02	81	136	278	13	12	14	15
MFH-03	172	273	501	27	24	29	38
Total	**369**	**584**	**1,310**	**58**	**51**	**61**	**72**

Table 3.36. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O03R-02) watershed.

Subwatershed	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Wood Duck (#)	Wild Turkey (#)
MFH-04	63	113	245	11	10	11	12
MFH-05	86	101	74	10	12	15	22
MFH-06	1	4	8	0	0	0	0
MFH-07	90	94	0	10	12	14	28
MFH-08	128	133	266	13	18	21	31
MFH-09	120	166	488	15	18	22	18
MFH-10	49	78	165	6	9	11	7
MFH-11	11	16	26	1	2	3	2
MFH-12	134	173	188	17	19	23	36
MFH-13	69	139	125	12	11	13	18
MFH-14	10	30	29	2	3	3	2
Total	**761**	**1,047**	**1,614**	**97**	**114**	**136**	**176**

Table 3.37. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O04R-01) watershed.

Subwatershed	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Wood Duck (#)	Wild Turkey (#)
MFH-15	253	398	398	40	37	44	64
MFH-16	41	69	237	7	6	7	4
MFH-17	84	121	302	12	12	15	14
MFH-18	50	78	234	8	8	9	5
MFH-19	220	339	641	35	31	37	50
MFH-20	52	90	223	8	8	10	6
MFH-21	382	632	1,748	58	58	69	48
Total	**1,082**	**1,727**	**3,783**	**168**	**160**	**191**	**191**

Table 3.38. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O05R-06) watershed.

Subwatershed	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Wood Duck (#)	Wild Turkey (#)
MFH-22	5	12	20	1	1	2	1
MFH-23	89	121	439	13	16	18	8
MFH-24	112	274	909	27	23	27	13
MFH-25	77	147	690	19	14	16	7
MFH-26	4	12	11	1	1	1	1
Total	**287**	**566**	**2,069**	**61**	**55**	**64**	**30**

Table 3.39. Distribution of wildlife among sub-watersheds in Middle Fork Holston River (VAS-O05R-05) watershed.

Subwatershed	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Wood Duck (#)	Wild Turkey (#)
MFH-27	166	391	1,615	46	33	39	20
MFH-28	33	89	438	12	6	7	3
MFH-29	9	22	112	4	2	2	1
MFH-30	33	88	527	16	6	7	4
MFH-31	72	198	1,077	24	15	17	4
MFH-32	98	242	1,052	28	19	23	10
Total	**411**	**1,030**	**4,821**	**130**	**81**	**95**	**42**

3.6 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the Middle Fork Holston River watershed along with average fecal coliform production rates are shown in Table 3.40 through 3.44. The total fecal coliform production by all sources in the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) watersheds is 3.01×10^{16} cfu/yr, 3.65×10^{16} cfu/yr, 9.56×10^{16} cfu/yr, 4.30×10^{16} cfu/yr, and 5.72×10^{16} cfu/yr, respectively.

Table 3.40. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O03R-01) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($x10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($x10^7$ cfu/ day)[b]
Dairy Cattle			
Milk and Dry Cows	248	25,000	620,425
Heifers	83	8,800	94,922
Beef Cattle (pairs)	1,555	33,000	6,937,893
Horses	102	420	4,287
Humans	1,468	1,950	89,631
Pets (Dog & Cats)	727	450	32,737
Deer	369	350	12,924
Raccoon	584	50	2,922
Muskrat	1,310	25	3,277
Beaver	58	0.2	1
Wild Turkey	72	93	670
Geese	51	800	10,960
Wood Duck	61	2,400	3,054

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

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

Table 3.41. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O03R-02) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($x10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($x10^7$ cfu/ day)[b]
Dairy Cattle			
Milk and Dry Cows	0	25,000	0
Heifers	0	8,800	0
Beef Cattle (pairs)	2,030	33,000	9,057,186
Horses	119	420	5,001
Humans	7,489	1,950	239,468
Pets (Dog & Cats)	3,564	450	160,490
Deer	761	350	26,653
Raccoon	1,047	50	5,239
Muskrat	1,614	25	4,038
Beaver	97	0.2	2
Wild Turkey	176	93	1,638
Geese	114	800	24,435
Wood Duck	136	2,400	6,828

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

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

Table 3.42. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O04R-01) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($x10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($x10^7$ cfu/ day)[b]
Dairy Cattle			
Milk and Dry Cows	*375*	25,000	938,142
Heifers	*125*	8,800	142,955
Beef Cattle (pairs)	5,161	33,000	23,026,668
Horses	306	420	12,861
Humans	10,970	1,950	403,324
Pets (Dog & Cats)	4,694	450	211,375
Deer	1,082	350	37,896
Raccoon	1,727	50	8,641
Muskrat	3,783	25	9,464
Beaver	168	0.2	3
Wild Turkey	191	93	1,778
Geese	160	800	34,317
Wood Duck	191	2,400	9,603

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

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

Table 3.43. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O05R-06) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($x10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($x10^7$ cfu/ day)[b]
Dairy Cattle			
Milk and Dry Cows	*708*	25,000	1,771,212
Heifers	*236*	8,800	269,899
Beef Cattle (pairs)	1,894	33,000	8,450,399
Horses	335	420	14,080
Humans	2,427	1,950	139,163
Pets (Dog & Cats)	1,129	450	50,840
Deer	287	350	10,052
Raccoon	566	50	2,832
Muskrat	2,069	25	5,176
Beaver	61	0.2	1
Wild Turkey	30	93	279
Geese	55	800	11,559
Wood Duck	64	2,400	3,334

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

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

Table 3.44. Potential fecal coliform sources and daily fecal coliform production by source in Middle Fork Holston River (VAS-O05R-05) watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($x10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($x10^7$ cfu/ day)[b]
Dairy Cattle			
Milk and Dry Cows	*315*	25,000	788,039
Heifers	*105*	8,800	120,082
Beef Cattle (pairs)	2,700	33,000	12,046,503
Horses	514	420	21,603
Humans	5,762	1,950	302,805
Pets (Dog & Cats)	2,288	450	103,031
Deer	411	350	14,395
Raccoon	1,030	50	5,154
Muskrat	4,821	25	12,061
Beaver	130	0.2	3
Wild Turkey	42	93	391
Geese	81	800	17,069
Wood Duck	95	2,400	4,851

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

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

Based on the inventory of fecal coliform sources, a summary of the contributions made by the nonpoint sources to annual fecal coliform loading directly to the stream and to various land use categories is given in Tables 3.45 through 3.49. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Tables 3.45 through 3.49.

From Table 3.45, it is clear in the Middle Fork Holston River (VAS-O03R-01) watershed that nonpoint source loadings to the land surface are more than 412 times as large as direct loadings to the streams, with pastures receiving about 97.8% of the total fecal coliform load.

From Table 3.46, it is clear in the Middle Fork Holston River (VAS-O03R-02) watershed that nonpoint source loadings to the land surface are more than 292 times as large as direct loadings to the streams, with pastures receiving about 94.9% of the total fecal coliform load.

From Table 3.47, it is clear in the Middle Fork Holston River (VAS-O04R-01) watershed that nonpoint source loadings to the land surface are more than 485 times as large as direct loadings to the streams, with pastures receiving about 96.9% of the total fecal coliform load.

From Table 3.48, it is clear in the Middle Fork Holston River (VAS-O05R-06) watershed that nonpoint source loadings to the land surface are more than 518 times as large as direct loadings to the streams, with pastures receiving about 97.5% of the total fecal coliform load.

From Table 3.49, it is clear in the Middle Fork Holston River (VAS-O05R-05) watershed that nonpoint source loadings to the land surface are more than 466 times as large as direct loadings to the streams, with pastures receiving about 96.5% of the total fecal coliform load.

It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily from pastures. However, other factors such as precipitation (amount and pattern), manure application activities (time and method), type of waste (solid versus liquid manure), proximity to streams and environmental factors also impact the amount of fecal coliform from upland areas that reaches the stream. The HSPF model considers these factors when estimating fecal coliform loads to the receiving waters, as described in Chapter 5.

Table 3.45. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O03R-01) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	2,612	0.10
Cattle in Stream	2,774	0.10
Wildlife in Stream	1,208	0.04
Loading to Land Surfaces		
Cropland	3,499	0.13
Pasture 1	2,032,357	74.58
Pasture 2	515,284	18.91
Pasture 3	119,038	4.37
Forest	6,394	0.23
Residential*	42,052	1.54
Total	2,725,218	100.00

*Includes loads received from failed septic systems and pets.

Table 3.46. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O03R-02) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	4,675	0.14
Cattle in Stream	3,363	0.10
Wildlife in Stream	3,516	0.10
Loading to Land Surfaces		
Cropland	2,575	0.08
Pasture 1	2,446,063	72.30
Pasture 2	619,471	18.31
Pasture 3	144,159	4.26
Forest	18,292	0.54
Residential*	141,309	4.18
Total	**3,383,423**	**100.00**

*Includes loads received from failed septic systems and pets.

Table 3.47. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O04R-01) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	3,842	0.04
Cattle in Stream	8,850	0.10
Wildlife in Stream	5,332	0.06
Loading to Land Surfaces		
Cropland	12,668	0.14
Pasture 1	6,464,874	73.80
Pasture 2	1,640,421	18.73
Pasture 3	379,828	4.34
Forest	23,566	0.27
Residential*	220,523	2.52
Total	**8,759,905**	**100.00**

*Includes loads received from failed septic systems and pets.

Table 3.48. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O05R-06) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	1,712	0.04
Cattle in Stream	3,705	0.10
Wildlife in Stream	1,973	0.05
Loading to Land Surfaces		
Cropland	13,068	0.34
Pasture 1	2,849,064	74.24
Pasture 2	734,387	19.14
Pasture 3	159,852	4.17
Forest	6,064	0.16
Residential*	67,640	1.76
Total	**3,837,465**	**100.00**

*Includes loads received from failed septic systems and pets.

Table 3.49. Annual fecal coliform loadings to the stream and the various land use categories in the Middle Fork Holston River (VAS-O05R-05) watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	3,206	0.06
Cattle in Stream	4,725	0.09
Wildlife in Stream	3,343	0.06
Loading to Land Surfaces		
Cropland	21,084	0.40
Pasture 1	3,859,627	73.30
Pasture 2	1,016,287	19.30
Pasture 3	203,333	3.86
Forest	9,168	0.17
Residential*	144,924	2.75
Total	**5,265,698**	**100.00**

*Includes loads received from failed septic systems and pets.

Chapter 4. Benthic Stressor Analysis

4.1 Introduction

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

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

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

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

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

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

4.2 Non-Stressors

4.2.1 pH

Benthic macro-invertebrates require a specific pH range of 6.0 to 9.0 to thrive. Changes in pH may adversely affect the survival of benthic macro-invertebrates. Treated wastewater, mining discharge, and urban runoff can potentially alter in-stream levels of pH.

Measured pH values at all water quality monitoring (WQM) stations are within the expected range for Class IV waters. Therefore, pH does not appear to be adversely impacting benthic communities in Middle Fork Holston River and is classified as a non-stressor.

4.2.2 Temperature

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

4.2.3 Dissolved Oxygen and Biochemical Oxygen Demand

Adequate dissolved oxygen (DO) levels are necessary for invertebrates and other aquatic organisms to survive in the benthic sediments of rivers or streams. Decreases in in-stream oxygen levels can result in oxygen depletion or anoxic sediments, which adversely impact the river's benthic community. Dissolve oxygen values at all WQM stations were above the daily average concentration for Class IV waters (i.e., 5 mg/l); therefore, dissolved oxygen is not considered to be impacting the benthic community and was classified as a non-stressor. Elevated biochemical oxygen demand (BOD) levels can contribute to low DO levels, adversely affecting the benthic community. Since observed BOD values were not elevated, aside from two values of 5 mg/l and one 4 mg/l sample, BOD was classified as a non-stressor.

4.2.4 Ammonia

High values of ammonia are toxic to many fish species and may impact the benthic community as well. All values recorded at VADEQ ambient monitoring stations were at or below 0.58 mg/L, well below the chronic ammonia freshwater criteria of 1.79 mg/L. No fish kills have been reported in this watershed and nothing in the ambient monitored data indicates ammonia as a stressor, therefore ammonia was classified as a non-stressor.

4.2.5 Water Column Toxics

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

A chronic toxicity study using fathead minnows (Pimephales promelas) and Ceriodaphnia dubia was conducted on a water sample collected at station 6CMFH011.31 on August 6, 2007. These tests were performed to determine if the water column toxicity was stressing the benthic community. Toxicity levels did not have a significant effect on fathead minnow or Ceriodaphnia dubia survival and/or reproduction endpoint; therefore, toxics were classified as a non-stressor.

4.3 Possible Stressors

4.3.1 Nutrients

Excessive nutrient inputs can lead to excessive algal growth, eutrophication, and low DO concentrations that may adversely affect the survival of benthic macro-invertebrates. In particular, DO levels may become low during overnight hours due to respiration. Exceedances of the stressor screening values for total nitrogen nitrate, and TKN were observed at various water quality monitoring stations throughout the Middle Fork Holston River watershed. Ammonia values were not elevated with all values well below the chronic freshwater criteria. The stressor screening value for total phosphorous was exceeded at all WQM stations except 6-CMFH023.41. No diurnal dissolved oxygen sampling was performed in the Middle Fork Holston River watershed and all field observations were above the daily average concentrations for ClassIV waters. While the benthic community in Middle Fork Holston River has occasional high populations of Chironomidae or Hydropsychidae – organisms associated with excessive nutrients, it has also contained high numbers of low pollution tolerant organisms. Improvements (e.g., correcting overflows) to several permitted point sources have occurred over the last five years that will help reduce nutrient loadings. Given these improvements and since nutrients would be reduced through implementation of control measures to address bacteria and sediment loads in the Middle Fork Holston River watershed, the Technical Advisory Committee decided to classify nutrients as a possible stressor.

4.3.2 Heavy Metals

Sedimentary cadmium values at WQM stations 6CMFH013.21, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 exceeded the consensus probable effect concentration. All other total metal concentrations and sedimentary metal concentrations at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH023.41, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 were below the applicable consensus probable effect concentration and do not appear to be a stressor to the benthic community; therefore, heavy metals was classified as a possible stressor.

4.3.3 Organics

Exceedances of sedimentary DDD, DDE, DDT, dieldrin, and heptachloepoxide consensus probable effect concentrations were observed at water quality monitoring stations in the watershed. All other sedimentary organic concentrations at WQM stations 6CMFH005.00, 6CMFH013.21, 6CMFH023.41, 6CMFH026.00, 6CMFH033.40, and 6CMFH045.72 were below an applicable consensus probable effect concentration and do not appear to be a stressor to the benthic community; therefore, organics was classified as a possible stressor.

4.4 Most Probable Stressors

4.4.1 Sediment

Sedimentation has been identified as a most probable stressor in the Middle Fork Holston River benthic impaired segment, based on the composition of the benthic community, benthic habitat data, and excessive TSS values from the stations along the impaired segment. At station 6-CMFH004.00, all values for embeddedness, sediment deposition, and riffle frequency were at or below 10 and at least 50% of the values for epifaunal substrate were below 10. At station 6-CMFH011.31, all values for sediment deposition and riffle frequency were at or below 10 and the embeddedness average value was below 10. At station 6-CMFH023.41, values for velocity/depth regime, sediment deposition, and riffle frequency were at or below 10. Samples of the benthic community in Lower Middle Fork Holston River have shown high populations of Chironomids and Hydropsychids, which thrive in sediment rich water. TSS values at all WQM stations except 6CMFH023.41 exceeded the stressor screening value of 10 mg/l. Exceedances of the turbidity stressor screening value of 10 NTU were observed at stations 6-CMFH005.00, 6-CMFH013.21, 6-CMFH026.00, and 6-CMFH033.40. The total solids stressor screening value of 300 mg/l was exceeded five times at station 6-CMFH013.21 and one time at stations 6-CMFH026.00, 6-CMFH033.40, and 6-CMFH045.72.

Chapter 5. Modeling Process for Bacteria TMDL Development

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

5.1 Model Description

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

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

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

5.2 Selection of Sub-watersheds

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

The Middle Fork Holston River watershed is approximately 154,667 acres and the model framework selected is suitable for this size. To account for the spatial distribution of fecal coliform sources, the watershed was divided into 33 subwatersheds as shown in Figure 5.1. Middle Fork Holston River (VAS-O03R-01) impairment begins at subwatershed MFH-02, at the confluence of Dulton Branch (MFH-01) in the community of Groseclose, and continues downstream until the confluence with Snaveley Branch (MFH-03). Middle Fork Holston River (VAS-O03R-02) impairment begins in subwatershed MFH-04 where Middle Fork Holston River (VAS-O03R-01) impairment ends at the confluence with Snaveley Branch and flows downstream receiving waters from subwatersheds, MFH-05, MFH-06, MFH-07, MFH-08, MFH-09, MFH-10, MFH-11, MFH-12, MFH-13, MFH-14 and ending at the confluence with Hungry Mother Creek in MFH-15. Middle Fork Holston River (VAS-O04R-01) impairment begins in subwatershed MFH-16 at the confluence with Hungry Mother Creek, and flows through MFH-17, MFH-18, MFH-19, MFH20 and ends at the confluence with Sulphur Spring Creek in MFH-21. Middle Fork Holston River (VAS-O05R-06) impairment begins in MFH-22 at the confluence with Sulphur Spring Creek and continues downstream through MFH-23, MFH-25 and MFH-26 receiving waters from MFH-24 and ending at the confluence with Byers Creek in MFH-27. Middle Fork Holston River (VAS-O05R-05) impairment begins in MFH-28 at the confluence with Byers Creek and flows downstream MFH-29, MFH-30 and MFH-32 receiving waters from MFH-31 along the way, and ends downstream at rivermile 12.06 at the beginning of MFH-33.

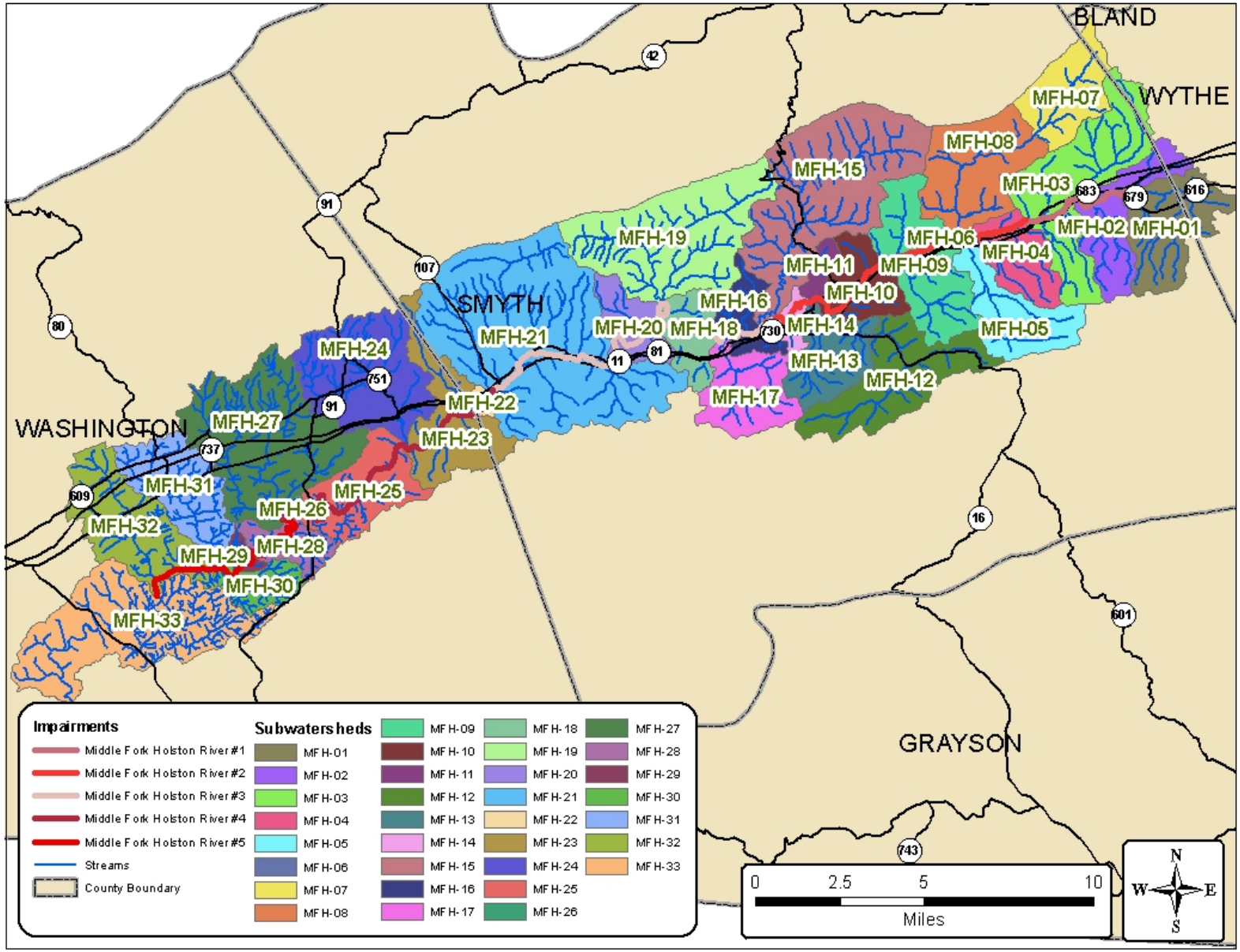


Figure 5.1. Middle Fork Holston River impairment subwatersheds.

5.3 Land Use

The National Land Cover Data (NLCD) produced by U.S. Geological Survey (USGS) in cooperation with the USEPA was used for this study. NLCD was developed from 30-meter Landsat 7 thematic mapper (TM) data between 1990 and 1994 and updated with data between 1999 and 2003 acquired by the Multi-resolution Land Characterization (MRLC) Consortium, a partnership between USGS, USEPA, U.S. Forest Service, National Oceanic and Atmospheric Administration (NOAA), Bureau of Land Management (BLM), NRCS, National Park Service (NPS), National Aeronautics and Space Administration (NASA), and United States Fish and Wildlife Service (USFWS). NLCD is classified into 21 land use types. The NLCD land use types within the watershed were consolidated into eight categories based on similarities in hydrologic and waste application/production features (Table 5.1). The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Some hydrology and water quality model parameters used in the PERLND and IMPLND modules are a function of land use.

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

Figure 5.1. Consolidation of NLCD land use categories for Middle Fork Holston River watershed.

TMDL Land Use Categories	Pervious / Impervious* (%)	NLCD Land Use Classification (Class No.)
Cropland	Pervious (100)	Cultivated Crops (82)
Pasture 1	Pervious (100)	Pasture/Hay (81)
Pasture 2	Pervious (100)	Pasture/Hay (81)
Pasture 3	Pervious (100)	Pasture/Hay (81)
Residential	Pervious (72), Impervious (28)	Developed, Open Space (21) Developed, Low Intensity (22) Developed, Medium Intensity (23) Developed, High Intensity (24)
Water	Impervious (100)	Open Water (11)
Wetland	Pervious (100)	Woody Wetlands (91) Emergent Herbaceous Wetlands (92)
Forest	Pervious (100)	Barren Land, Rock, Sand, Clay (31) Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)

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

Table 5.2. Land use distribution in Middle Fork Holston River watershed.

Total Landuse							
Subwatershed	**Cropland**	**Forest**	**Pasture**	**Transitional**	**Water**	**Wetland**	**Residential**
MFH-1	27.7	2,017.9	2,455.5	4.4	1.2	4.8	250.8
MFH-2	17.3	1,926.8	1,393.2	1.1	0.0	4.9	420.9
MFH-3	23.6	5,125.0	2,033.2	5.7	0.0	0.0	444.2
MFH-4	4.0	1,717.6	968.2	11.8	0.0	0.0	322.9
MFH-5	2.4	3,252.8	431.9	5.5	0.0	0.8	165.0
MFH-6	0.3	19.4	25.5	0.8	0.0	2.0	38.3
MFH-7	0.0	3,723.5	0.6	0.0	0.0	7.1	1.2
MFH-8	5.9	4,575.8	907.8	10.5	0.0	7.2	150.7
MFH-9	20.4	2,663.4	2,460.0	12.1	0.0	0.3	553.7
MFH-10	4.7	1,048.5	1,062.0	5.0	0.0	0.0	748.1
MFH-11	0.0	259.0	215.4	0.5	0.0	0.0	278.3
MFH-12	0.0	5,219.1	495.9	12.7	0.0	0.0	257.4
MFH-13	0.0	2,601.1	368.9	8.7	0.0	0.0	479.0
MFH-14	0.0	253.0	154.3	1.2	0.0	0.0	511.1
MFH-15	11.1	9,243.6	1,569.5	29.7	72.9	2.3	616.1
MFH-16	11.6	643.9	1,077.1	5.9	0.0	0.0	220.9
MFH-17	12.7	2,092.4	1,485.6	1.9	0.0	0.0	243.7
MFH-18	12.7	724.6	1,404.1	2.4	0.0	0.9	276.5
MFH-19	20.2	7,343.2	2,023.1	41.3	0.0	2.2	315.4
MFH-20	26.4	917.1	1,279.6	4.2	0.0	3.0	319.6
MFH-21	105.9	6,926.7	9,203.6	142.4	2.1	7.4	1,742.4
MFH-22	13.4	88.4	112.9	0.0	0.0	1.5	222.4
MFH-23	104.3	1,126.2	3,333.7	3.7	0.0	13.6	283.6
MFH-24	91.2	1,868.5	4,077.6	8.1	0.0	0.0	1,070.7
MFH-25	112.9	1,052.4	2,960.1	13.8	1.5	6.1	113.9
MFH-26	0.0	127.5	55.4	11.7	0.0	4.9	15.2
MFH-27	193.4	2,844.9	5,882.9	36.6	0.0	8.2	1,340.5
MFH-28	29.1	489.0	1,265.3	3.5	1.4	21.0	81.6
MFH-29	2.7	163.3	309.5	8.9	0.0	6.2	8.9
MFH-30	34.7	569.7	1,195.1	6.1	0.0	2.6	67.8
MFH-31	76.2	596.7	3,227.1	6.8	0.0	2.3	671.4
MFH-32	72.4	1,445.0	3,786.9	7.9	6.0	11.4	677.4
MFH-33	136.0	4,690.0	4,767.1	37.2	26.3	20.0	535.2
Total	**1,173**	**77,356**	**61,989**	**452**	**111**	**141**	**13,445**
Total %	**0.8%**	**49.0%**	**41.0%**	**0.3%**	**0.1%**	**0.1%**	**9.0%**

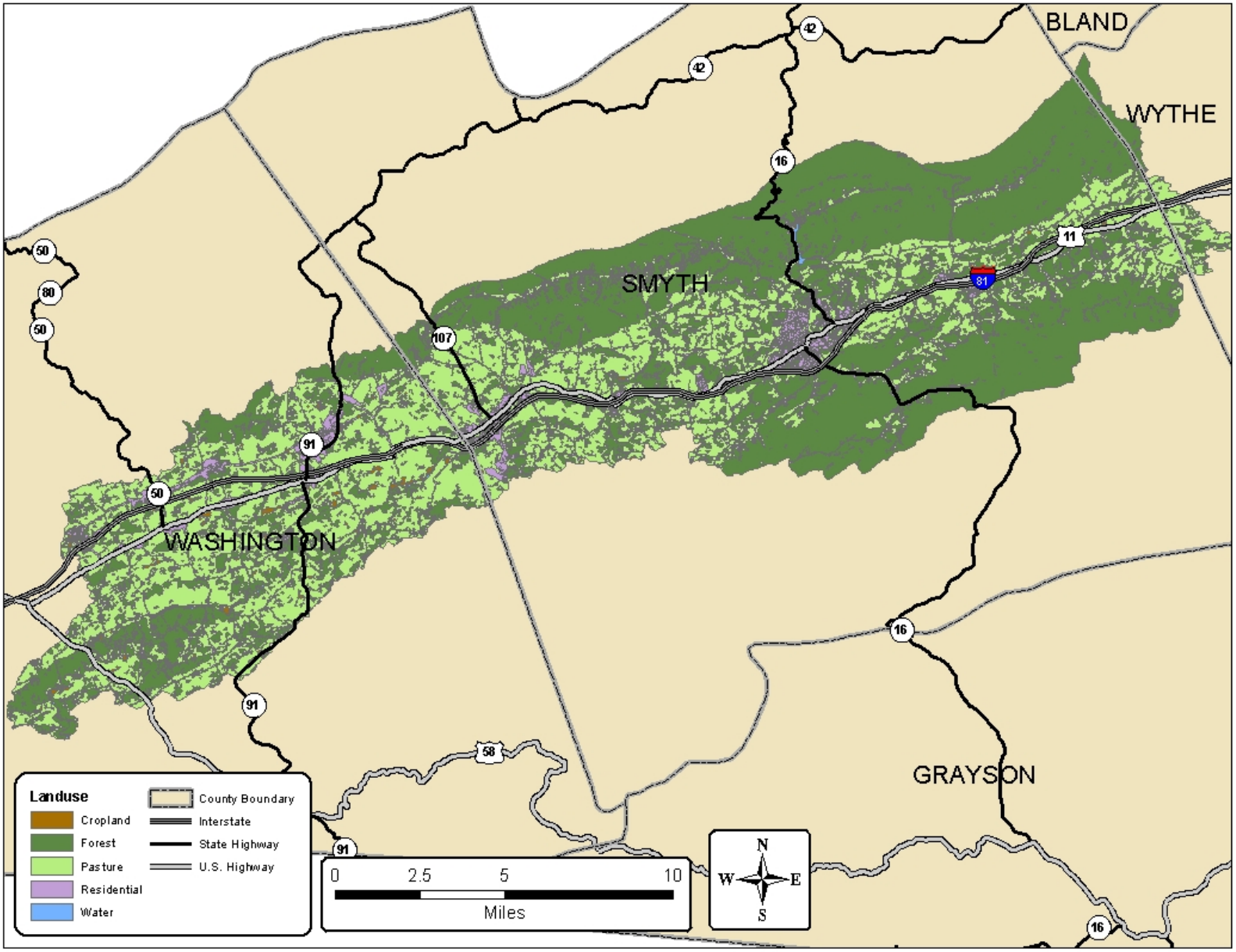


Figure 5.2. Middle Fork Holston River watershed land use distribution.

5.4 Stream Channel Characteristics

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

5.5 Climatological Data

The climate data needed for model simulations conducted as a part of this study were obtained from the National Climatic Data Center (NCDC) (NCDC, 2008), part of the National Weather Service (NWS). Simulations performed for Middle Fork Holston River watershed used hourly weather data from the Troutdale 3 SSE (448547) and Abingdon 3 S (440021) weather stations. Daily precipitation data from stations Troutdale 3 SSE (448547), Abingdon 3 S (440021), and Saltville 1 N (447506) were transformed to address discrepancies (i.e., missing data) between observed runoff and hourly precipitation records.

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

5.6 Accounting for Pollutant Sources

5.6.1 Overview

There are zero, three, nine, two, and seven permitted point discharges of bacteria located in the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) watersheds, respectively. This source was modeled using the permitted concentration and design discharge. Currently, MS4 permitted facilities do not exist in the Middle Fork Holston River watershed.

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

Nonpoint source loading was applied as fecal coliform counts to the pervious fraction of each land use category in a sub-watershed on a daily basis. Both direct nonpoint and nonpoint source loadings were varied by month to account for seasonal differences such as cattle and wildlife access to streams. Nonpoint source loading was applied as fecal coliform counts to the

impervious fraction of each land use category in a subwatershed at a constant rate during the year. These constant application rates are a function of land use and are discussed in detail in Section 5.6.4. Fecal coliform die-off was simulated during periods when manure is stored, while on the land between runoff generating precipitation events, and while in streams.

5.6.2 Modeling Fecal Coliform Die-off

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

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

where: C_t = concentration or load at time t;

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

K = decay rate (day-1); and

t = time in days.

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

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

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

*Cited in Crane and Moore (1986).

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

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

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

year was estimated. Monthly fecal coliform application to land was estimated by multiplying the amount of fecal coliform available for application to land per year by the fraction of manure applied to land during that month. The decay rate for fecal coliform on the land surface was represented in HSPF by specifying a maximum surface buildup (i.e., MON-SQOLIM) based on the daily loading rate (i.e., MON-ACCUM). An in-stream decay rate for each reach segment (i.e., FSTDEC) was specified in HSPF.

5.6.3 Modeling Direct Nonpoint Sources

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

5.6.4 Modeling Land-based Nonpoint Sources

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

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

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

- Residential: Fecal coliform loading on the pervious fraction of this land use category is described in Chapter 3. Residential land use loading came from failing septic systems and waste from pets. In the model simulations, fecal coliform loads

produced by failing septic systems and pets in a sub-watershed were combined and assumed to be uniformly applied. Loading to the impervious fraction of this land use category was assumed constant throughout the year varying per subwatershed.

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

5.6.5 Modeling Existing BMPs

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

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

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

5.7 Model Calibration and Validation

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

5.7.1 Hydrology

The Middle Fork Holston River model was calibrated using observed flow values from USGS station #03474000 on Middle Fork Holston River near Seven Mile Ford, VA and USGS station #003475000 on Middle Fork Holston River near Mock Mill, VA for the period January 1, 2003 to December 31, 2007. The model was validated for the period January 1, 1998 to

December 31, 2002. The daily average flow data were used in the hydrologic calibration and validation. Output from the HSPF model for both calibration and validation was daily average flow in cubic feet per second (cfs). Calibration parameters were adjusted within the recommended ranges until the model performance was deemed acceptable.

The HSPEXP decision support system developed by USGS and tools developed by Engineering Concepts, Inc. were used to calibrate and validate the hydrologic portion of HSPF. Calibration and validation criteria as well as model performance are presented in Tables 5.4 through 5.7. All criteria were within the recommended ranges. As shown in Figures 5.3 through 5.6, the simulated flow for both the calibration and validation matched the observed flow well. The agreement with observed flows is further illustrated in Figures 5.7 through 5.10 for a representative storm. The agreement of the simulated and observed time series can be further seen through the comparison of their cumulative frequency curves (Figures 5.11 through 5.14).

Table 5.4. Summary statistics for the calibration period (1/1/03 to 12/31/07) at USGS station #03474000 in Middle Fork Holston River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	10	86.21	84.20	-2.32
Total of Highest 10% Flow Volume (in)	15	31.01	34.31	10.63
Total of Lowest 50% Flow Volume (in)	10	16.41	16.90	2.93
Total Winter Flow Volume (in)	20	30.31	30.44	0.41
Total Summer Flow Volume (in)	20	12.38	13.52	9.20
Total Storm Volume (in)	20	70.76	74.27	4.96
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.77			

Table 5.5. Summary statistics for the calibration period (1/1/03 to 12/31/07) at USGS station #03475000 in Middle Fork Holston River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	10	85.60	85.45	-0.18
Total of Highest 10% Flow Volume (in)	15	28.50	30.81	8.09
Total of Lowest 50% Flow Volume (in)	10	18.11	18.43	1.81
Total Winter Flow Volume (in)	20	29.76	30.27	1.70
Total Summer Flow Volume (in)	20	13.71	14.32	4.44
Total Storm Volume (in)	20	68.65	74.06	7.88
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.82			

Table 5.6. Summary statistics for the validation period (1/1/98 to 12/31/02) at USGS station #03474000 in Middle Fork Holston River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	20	70.81	69.65	-1.64
Total of Highest 10% Flow Volume (in)	25	28.63	29.04	1.46
Total of Lowest 50% Flow Volume (in)	20	12.13	12.81	5.61
Total Winter Flow Volume (in)	30	25.07	24.30	-3.09
Total Summer Flow Volume (in)	30	12.64	11.62	-8.08
Total Storm Volume (in)	30	54.84	58.69	7.01
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.72			

Table 5.7. Summary statistics for the validation period (1/1/98 to 12/31/02) at USGS station #03475000 in Middle Fork Holston River watershed.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	20	68.89	70.60	2.49
Total of Highest 10% Flow Volume (in)	25	26.08	26.62	2.05
Total of Lowest 50% Flow Volume (in)	20	13.54	14.04	3.69
Total Winter Flow Volume (in)	30	23.53	23.64	0.47
Total Summer Flow Volume (in)	30	12.78	12.35	-3.40
Total Storm Volume (in)	30	49.49	58.41	18.04
Groundwater Recession Coefficient	1	0.97	0.98	1.0
Coefficient of Determination, r^2	0.78			

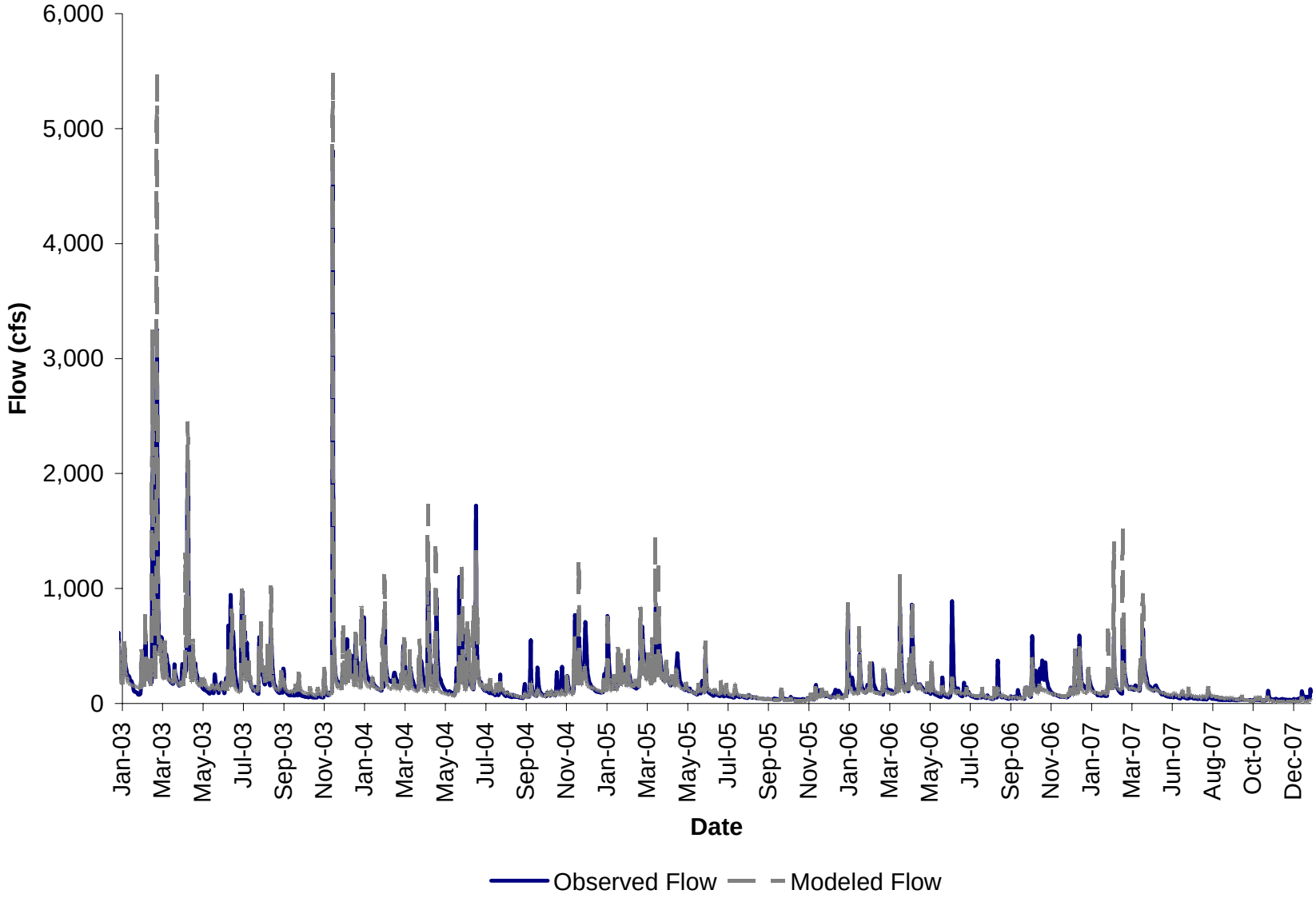


Figure 5.3. Observed and modeled flows for the calibration period 1/1/03 to 12/31/07 at USGS station #03474000 in Middle Fork Holston River watershed.

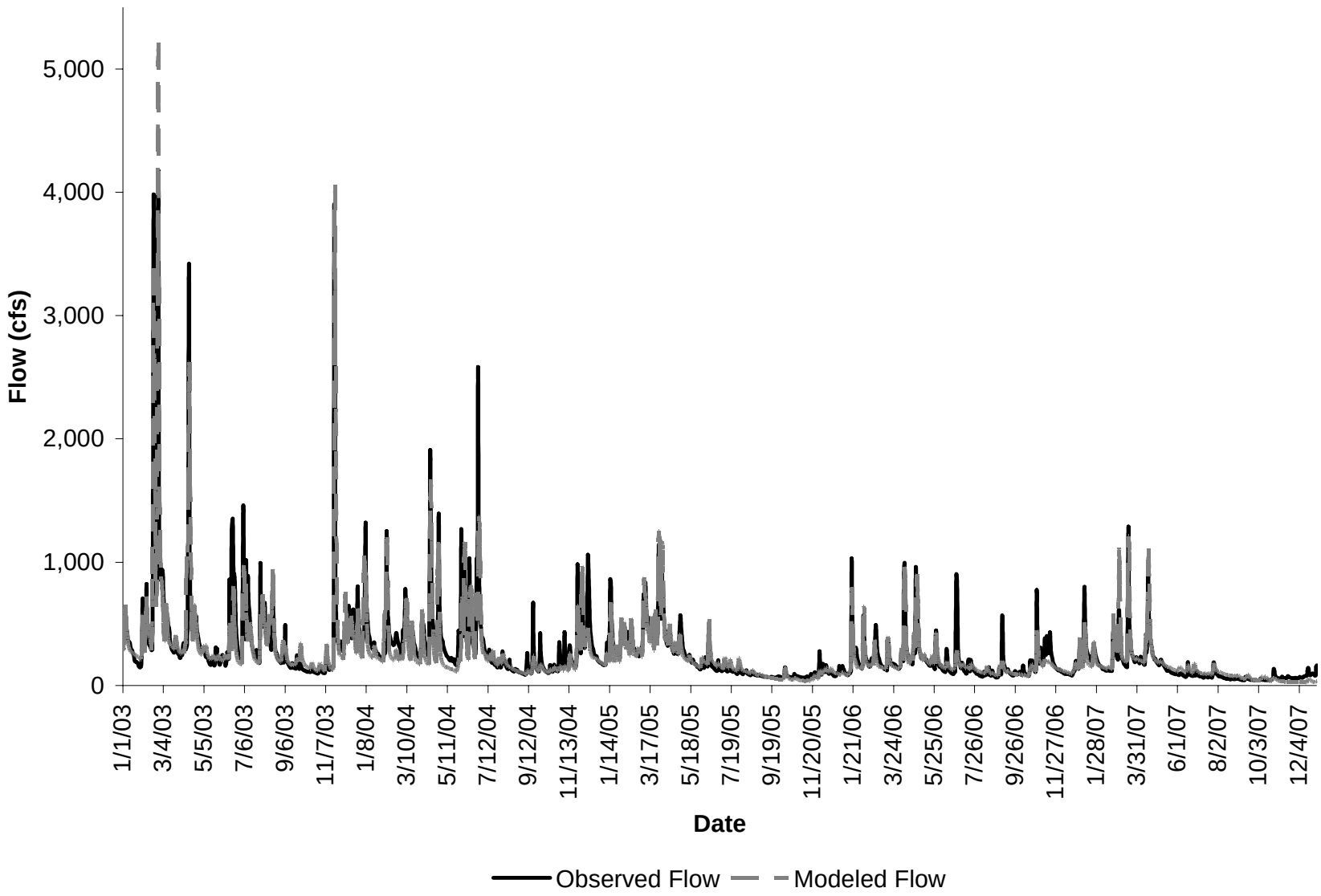


Figure 5.4. Observed and modeled flows for the calibration period 1/1/03 to 12/31/07 at USGS station #03475000 in Middle Fork Holston River watershed.

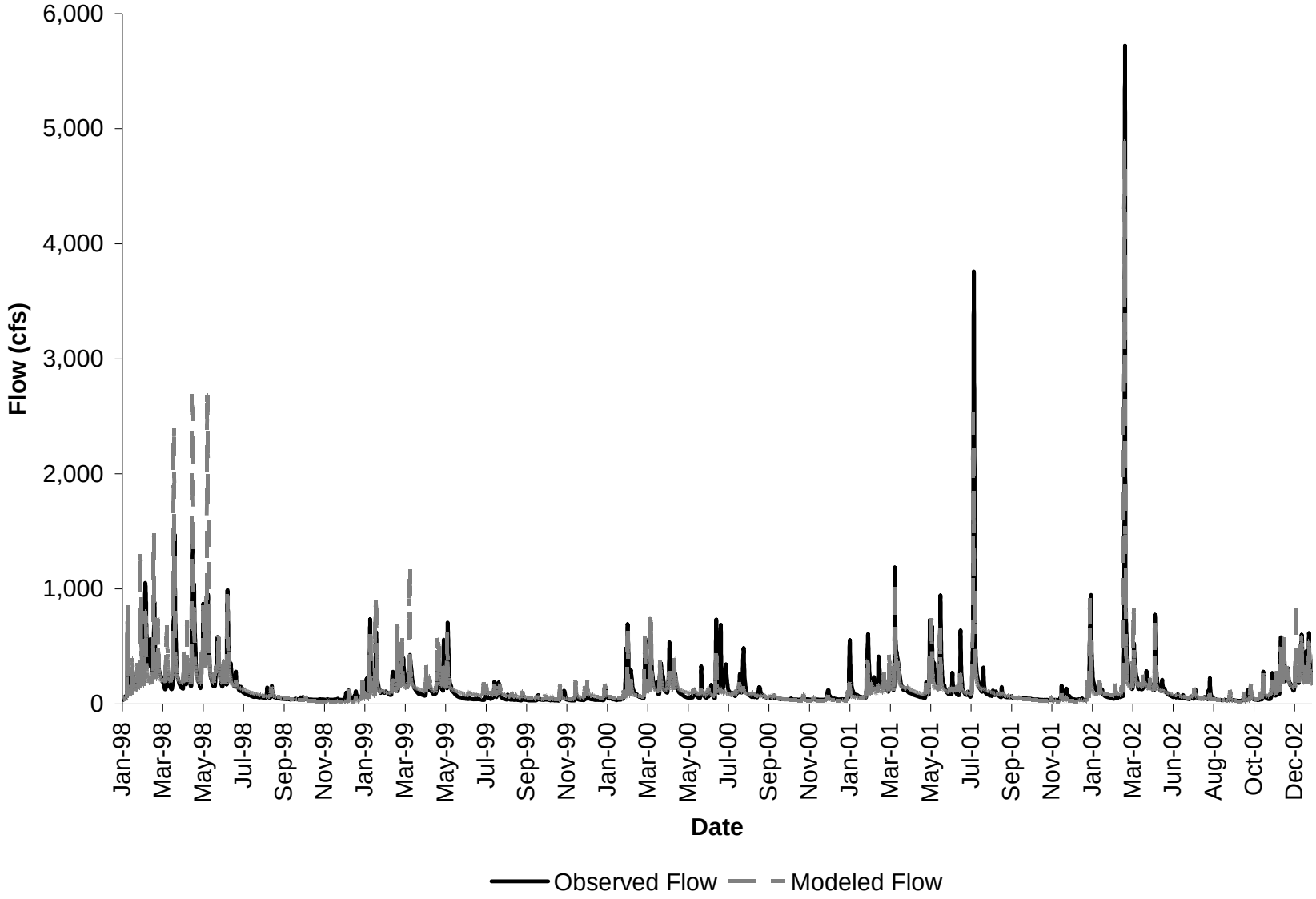


Figure 5.5. Observed and modeled flows for the validation period 1/1/98 to 12/31/02 at USGS station #03474000 in Middle Fork Holston River watershed.

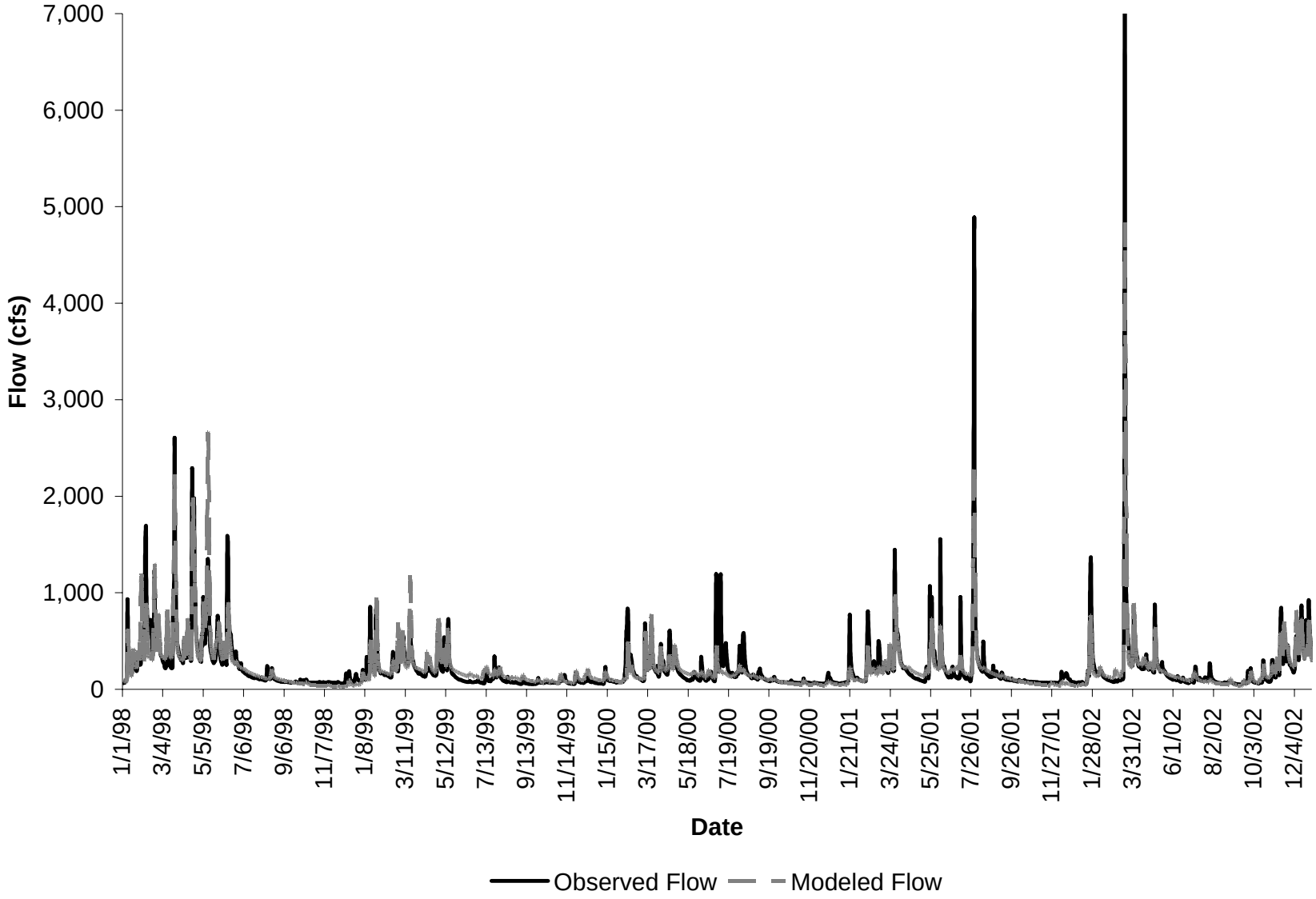


Figure 5.6. Observed and modeled flows for the validation period 1/1/98 to 12/31/02 at USGS station #03475000 in Middle Fork Holston River watershed.

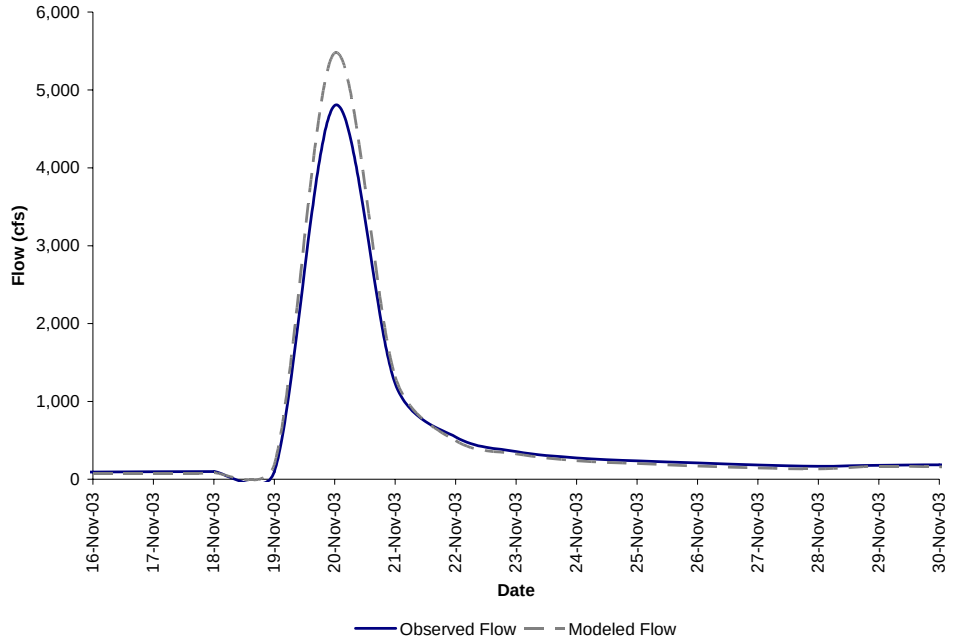


Figure 5.7. Observed and modeled flows for representative storm (11/16/03-11/30/03) during calibration period at USGS station #03474000 in Middle Fork Holston River watershed.

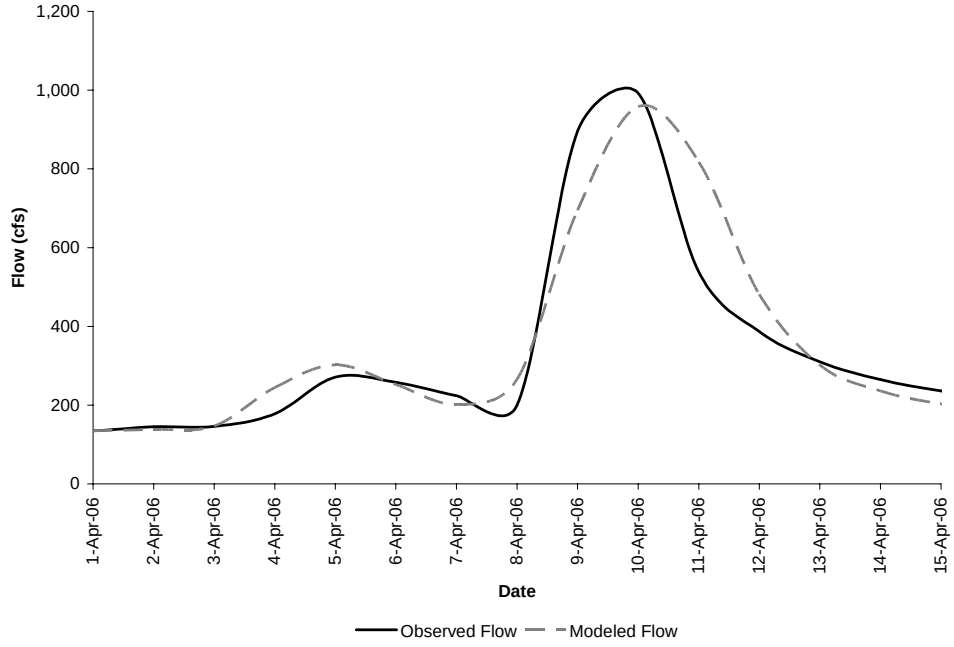


Figure 5.8. Observed and modeled flows for representative storms (4/1/06-4/15/06) during calibration period at USGS station #03475000 in Middle Fork Holston River watershed.

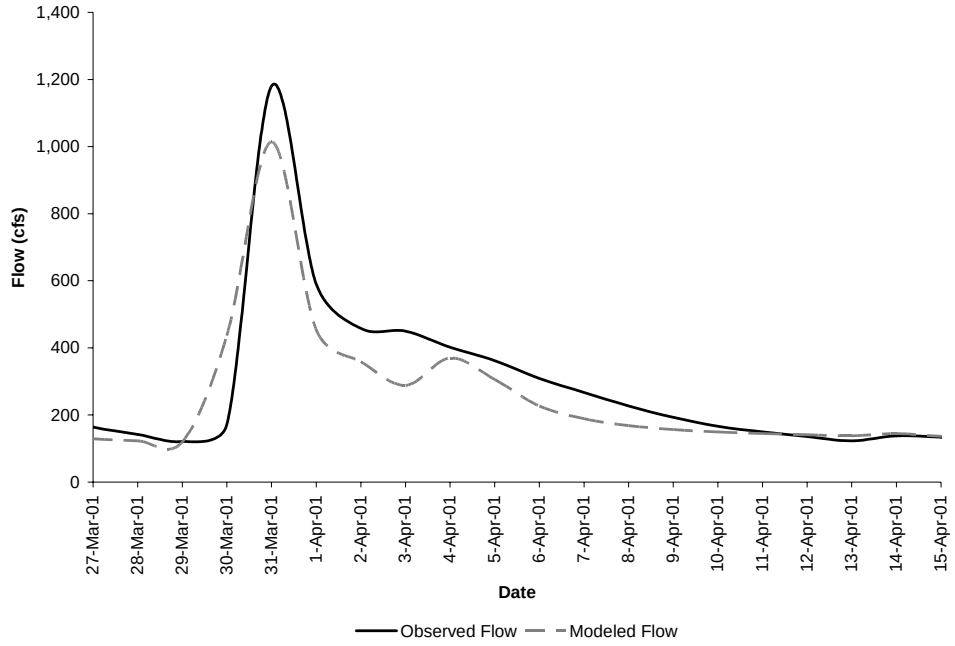


Figure 5.9. Observed and modeled flows for a representative storm (3/27/01-4/15/01) during the validation period at USGS station #03474000 in Middle Fork Holston River watershed.

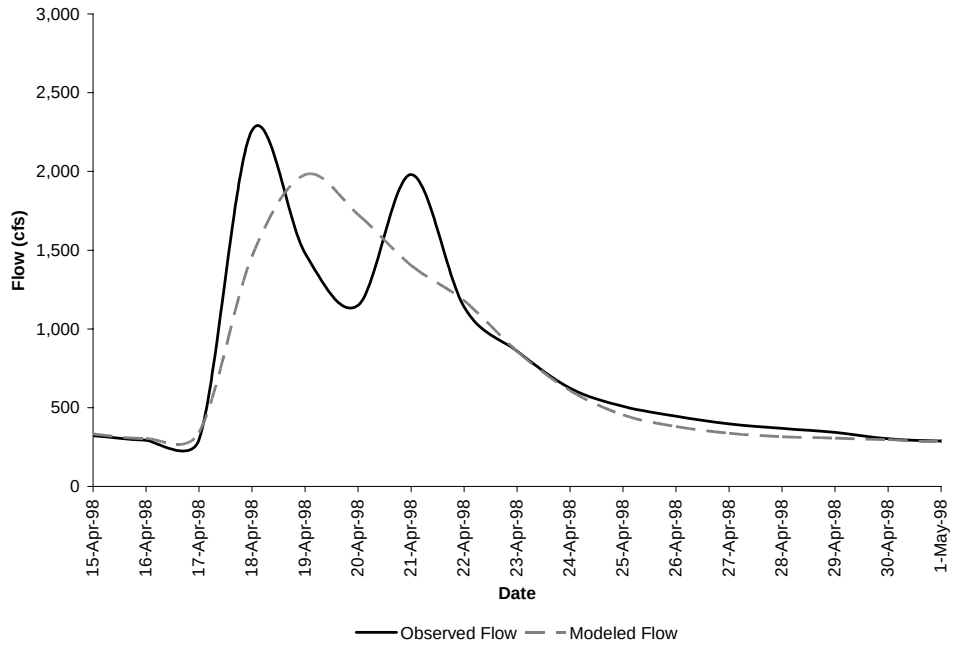


Figure 5.10. Observed and modeled flows for a representative storm (4/15/98-5/1/98) during the validation period at USGS station #03475000 in Middle Fork Holston River watershed.

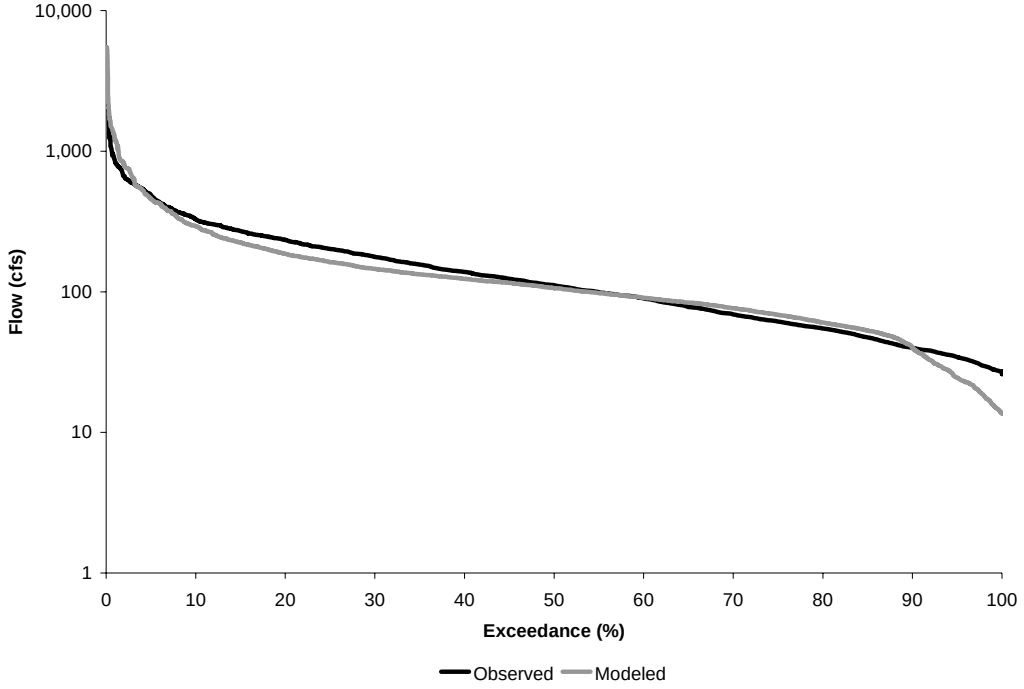


Figure 5.11. Cumulative frequency curves for the calibration period 1/1/03 to 12/31/07 at USGS station #03474000 in Middle Fork Holston River watershed.

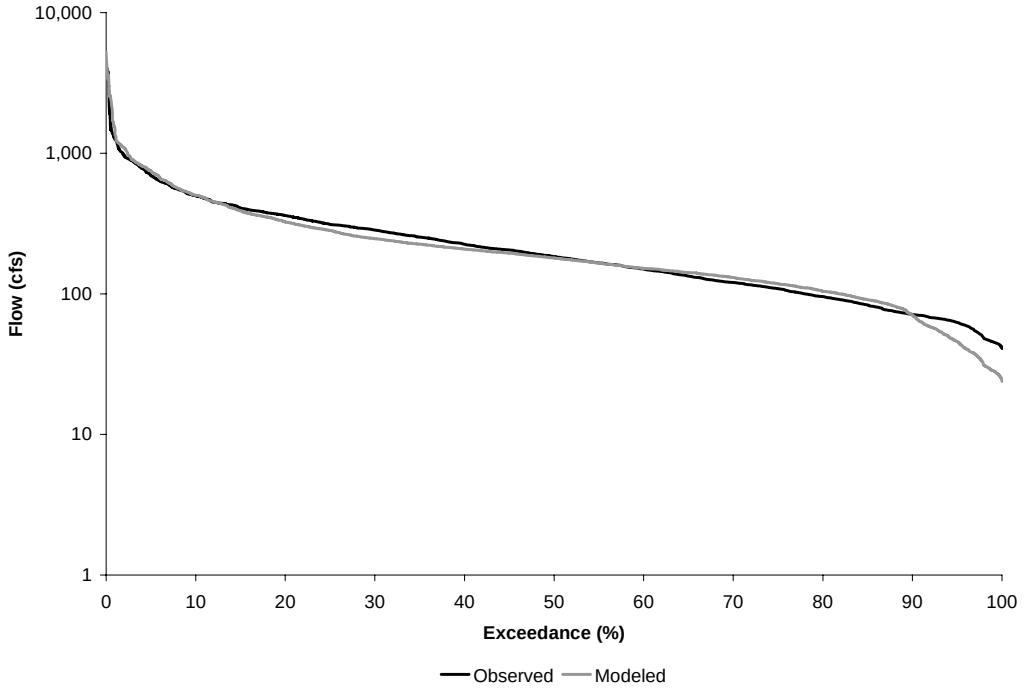


Figure 5.12. Cumulative frequency curves for the calibration period 1/1/03 to 12/31/07 at USGS station #03475000 in Middle Fork Holston River watershed.

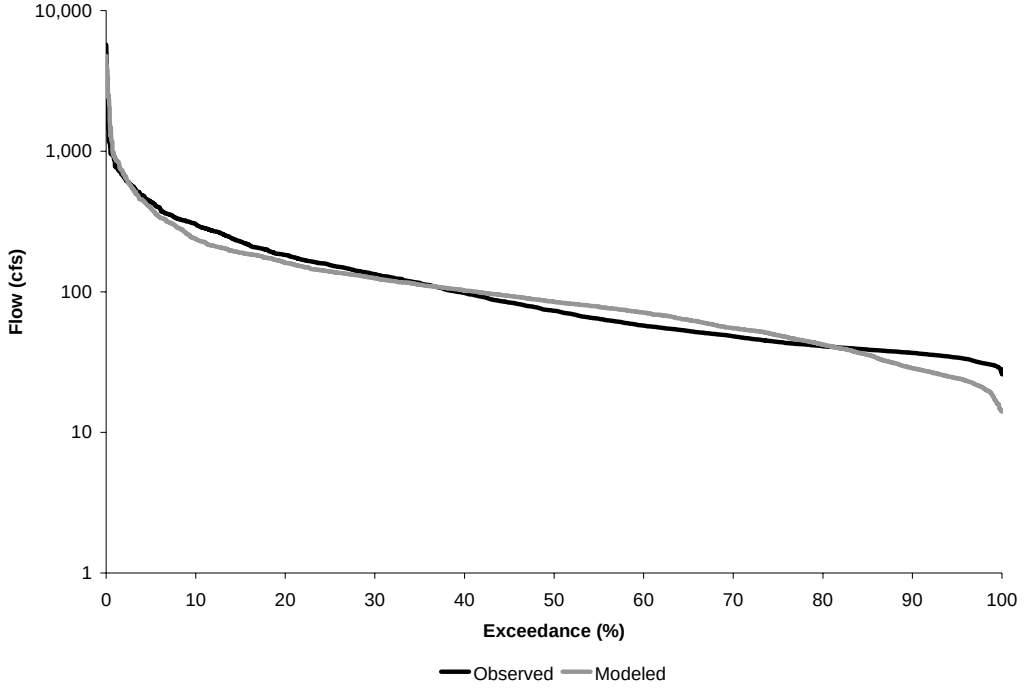


Figure 5.13. Cumulative frequency curves for the validation period 1/1/98 to 12/31/02 at USGS station #03474000 in Middle Fork Holston River watershed.

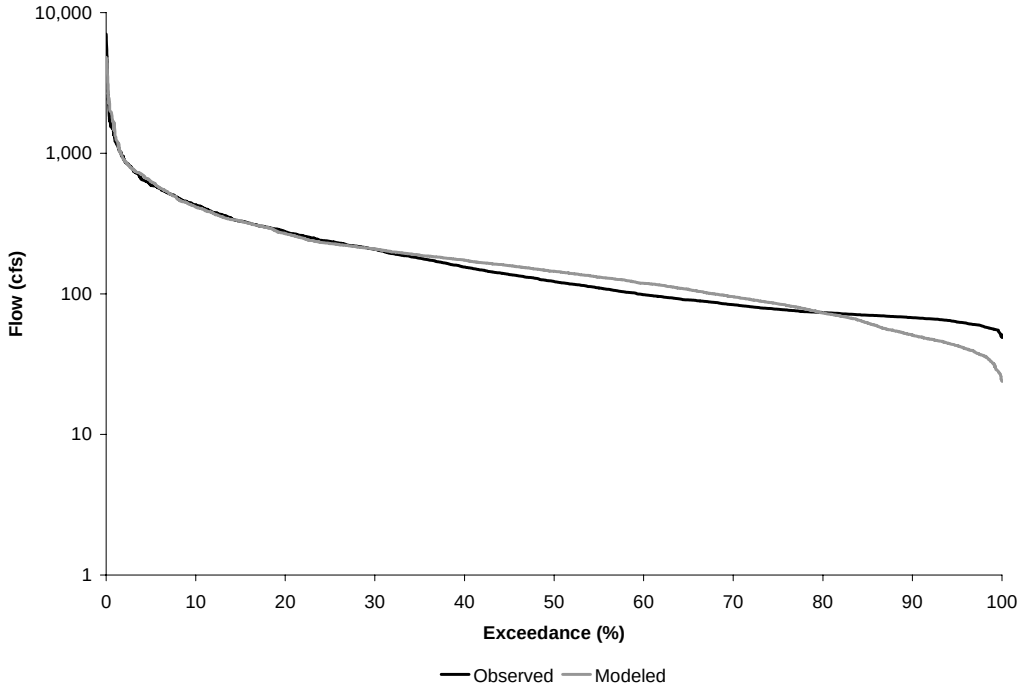


Figure 5.14. Cumulative frequency curves for the validation period 1/1/98 to 12/31/02 at USGS station #03475000 in Middle Fork Holston River watershed.

Flow partitioning for Middle Fork Holston River hydrologic model calibration and validation is shown in Table 5.8.

Table 5.8. Flow partitioning for the calibration and validation periods in Middle Fork Holston River watershed.

Average Annual Flow	Calibration	Validation
Total Runoff (in)	50.0	42.2
Surface Runoff (in)	11.6 (23.8%)	9.0 (22.4%)
Interflow (in)	9.6 (19.6%)	6.7 (16.6%)
Baseflow (in)	28.8 (59.0%)	26.5 (66.0%)

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

Table 5.9. Calibrated hydrology HSPF parameters (PERLND) for Middle Fork Holston River watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
PERLND									
PWAT-PARM2									
FOREST	Fraction forest cover	none	0.0	0.5	0.0	0.95	0.5	0.5	Forest cover
LZSN	Lower zone nominal soil moisture storage	in	3.0	8.0	2.0	15.0	3.0	3.5	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.10	0.003-0.320	Soil and cover condition
LSUR	Length of overland flow	ft	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.007-0.099	0.007-0.099	Determined by GIS
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	0	Calibrate
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.975	0.981	Calibrate
PWAT-PARM3									
PETMAX	Temp below which evapotranspiration (ET) is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soil properties
DEEPFR	Fraction of groundwater inflow to deep recharge	none	0.0	0.2	0.0	0.5	0.0	0.0	Geology
BASETP	Fraction of remain ET from active baseflow	none	0.0	0.05	0.0	0.2	0.1	0.0	Riparian vegetation
AGWETP	Fraction of remain ET from active groundwater	none	0.0	0.05	0.0	0.2	0.0	0.0 – 0.7	Marsh/wetlands ET
PWAT-PARM4									
CEPSC	Interception storage capacity	in	0.03	0.2	0.01	0.4	0.1-0.3	0.01 – 0.224	Vegetation
UZSN	Upper zone nominal soil moisture storage	in	0.10	1	0.05	2	1.50	1.5 – 2.0	Soil properties
NSUR	Manning's n (roughness)	none	0.15	0.35	0.1	0.5	0.20 - 0.35	0.20 – 0.35	Land use, surface conditions
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	2.0	1.0	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.8	0.3 – 0.519	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	0.3-0.9	0.3 - 0.890	Vegetation

* USEPA, 2000.

Table 5.10. Calibrated hydrology HSPF parameters (IMPLND and RCHRES) for Middle Fork Holston River watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
IMPLND									
IWAT-PARM2									
LSUR	Length of overland flow	ft	200	500	100	700	100	100	Topography
SLSUR	Slope of overland flow	none	0.01	0.15	0.001	0.3	0.20	0.010-0.077	Topography
NSUR	Manning's n (roughness)	none	0.15	0.35	0.1	0.5	0.1	0.1	Land use, surface condition
RETSC	Retention/interception storage capacity	in	0.03	0.2	0.01	0.4	0.065	0.065	Land use, surface condition
IWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
RCHRES									
HYDR-PARM2									
KS	Weighting factor for hydraulic routing	none	0.3	0.7	0.0	0.9	0.5	0.5	Stream channel, topography

* USEPA, 2000.

5.7.2 Water Quality

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

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

A number of factors, not inclusive to description below, complicate the water quality calibration. The difficulty in measuring bacteria concentrations is attributed to variability in

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

The period January 1, 1997 through December 31, 2001 was chosen for water quality calibration and January 1, 2002 through December 31, 2006 was chosen for water quality validation. Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring stations 6-CMFH053.36, 6-CMFH045.72, 6-CMFH040.67, 6-CMFH033.40, 6-CMFH027.14, 6-CMFH026.00, 6-CMFH013.21 within the Middle Fork Holston River impairment were used to calibrate the water quality component of HSPF. The final water quality calibration parameters are shown in Table 5.11. Observations from VADEQ stations station 6-CMFH053.36, 6-CMFH045.72, 6-CMFH040.67, 6-CMFH033.40, 6-CMFH027.14, 6-CMFH026.00, 6-CMFH013.21; were graphically compared to corresponding modeled concentrations at subwatersheds MFH-02, MFH-09, MFH-14, MFH-20, MFH-21, MFH-22, MFH-29; respectively (Figures 5.15 through 5.27). It should be noted that each observed bacteria concentration datum represents a “snapshot” resulting from the examination of one grab sample, while the modeled data represent a continuous time series of bacteria concentration. Uncertainty exists in the stream condition the grab sample represents. For example, was the sample taken as the bacteria concentration was increasing or decreasing in the stream? The short-period fluctuations in the modeled bacteria concentration represent the variability within daily concentrations associated with the wildlife, livestock, and straight pipe direct deposition distribution across each day. Careful inspection of graphical comparisons between continuous simulation results and limited observed points yielded acceptable results given the modeling constraints listed above. Seasonal variations are exhibited by the modeled concentrations, and most observed concentrations are simulated accurately for the calibration period.

To provide a quantitative measure of the agreement between observed and modeled data, the geometric mean and exceedance rate of the 400 cfu/100mL fecal coliform instantaneous standard were calculated. Tables 5.12 and 5.13 show the observed and modeled comparisons of the geometric mean and exceedance rates for the calibration and validation periods, respectively. The difference between observed and modeled geometric mean concentrations ranged from -0.6% to -4.0% during the calibration period (Table 5.12). The highest difference (-4.0%) was recorded during at subwatershed MFH-09. During the validation period, differences between observed and modeled geometric mean concentrations ranged from -1.2% to -10.5% (Table 5.13) at subwatersheds MFH-29 and MFH-22, respectively. It should be noted that a limited number of observed values were available for comparison when determining exceedance rates in Tables 5.12 and 5.13. Modeled exceedance rates matched all observed exceedance rates except during the validation period in subwatershed MFH-21. Two additional samples were predicted to exceeding the water quality standard. At one of these samples, the observed concentration was 400 cfu/100 ml and was classified as not exceeding the water quality standard. The modeled versus observed geometric mean concentrations and

exceedance rates comparison yielded acceptable results for the calibration and validation periods.

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

Table 5.11. Calibrated water quality HSPF parameters for Middle Fork Holston River watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
PERLND									
QUAL-INPUT									
SQO	Initial storage of constituent	#/ac	0	1E20	0	1E30	1E08	1E08	Land use
ACQOP	Rate of accumulation of constituent	#/day	0	1E20	0	1E30	00E00-34E08	00E00-34E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	00E00-09E10	00E00-09E10	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	2.0	2.0	Land use
IOQC	Constituent concentration in interflow	#/ft^3	0	1E6	0	1E10	1E03	1E03	Land use
AOQC	Constituent concentration in active groundwater	#/ft^3	0	1E6	0	1E10	0E00	0E00	Land use
IMPLND									
QUAL-INPUT									
SQO	Initial storage of constituent	#/ac	0	1E20	0	1E30	1E09	1E09	Land use
ACQOP	Rate of accumulation of constituent	#/day	0	1E20	0	1E30	21E06-01E08	21E06-01E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	02E08-10E08	02E08-10E08	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.1	0.1	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	1.5	0.5-7.5	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

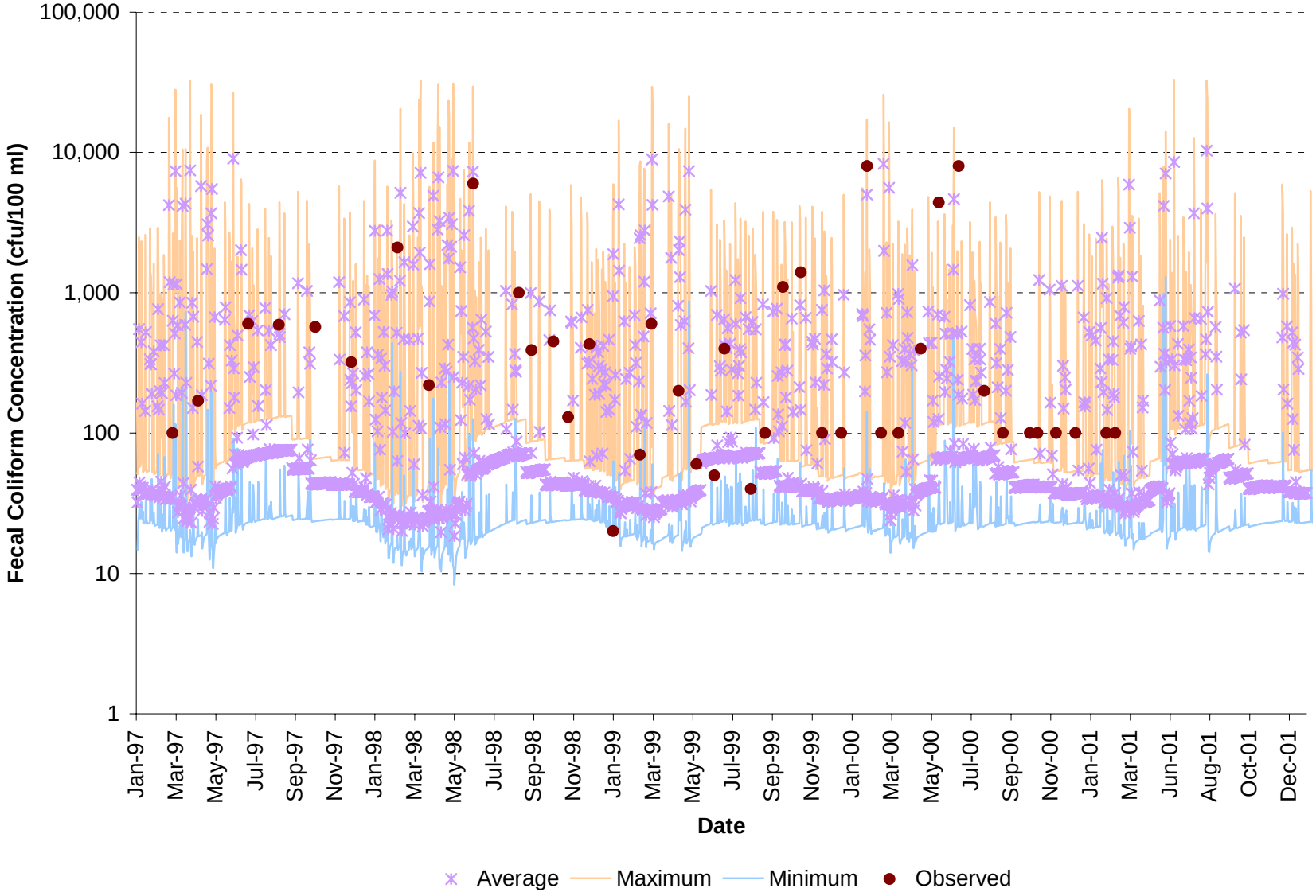


Figure 5.15. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-02 in Middle Fork Holston River watershed.

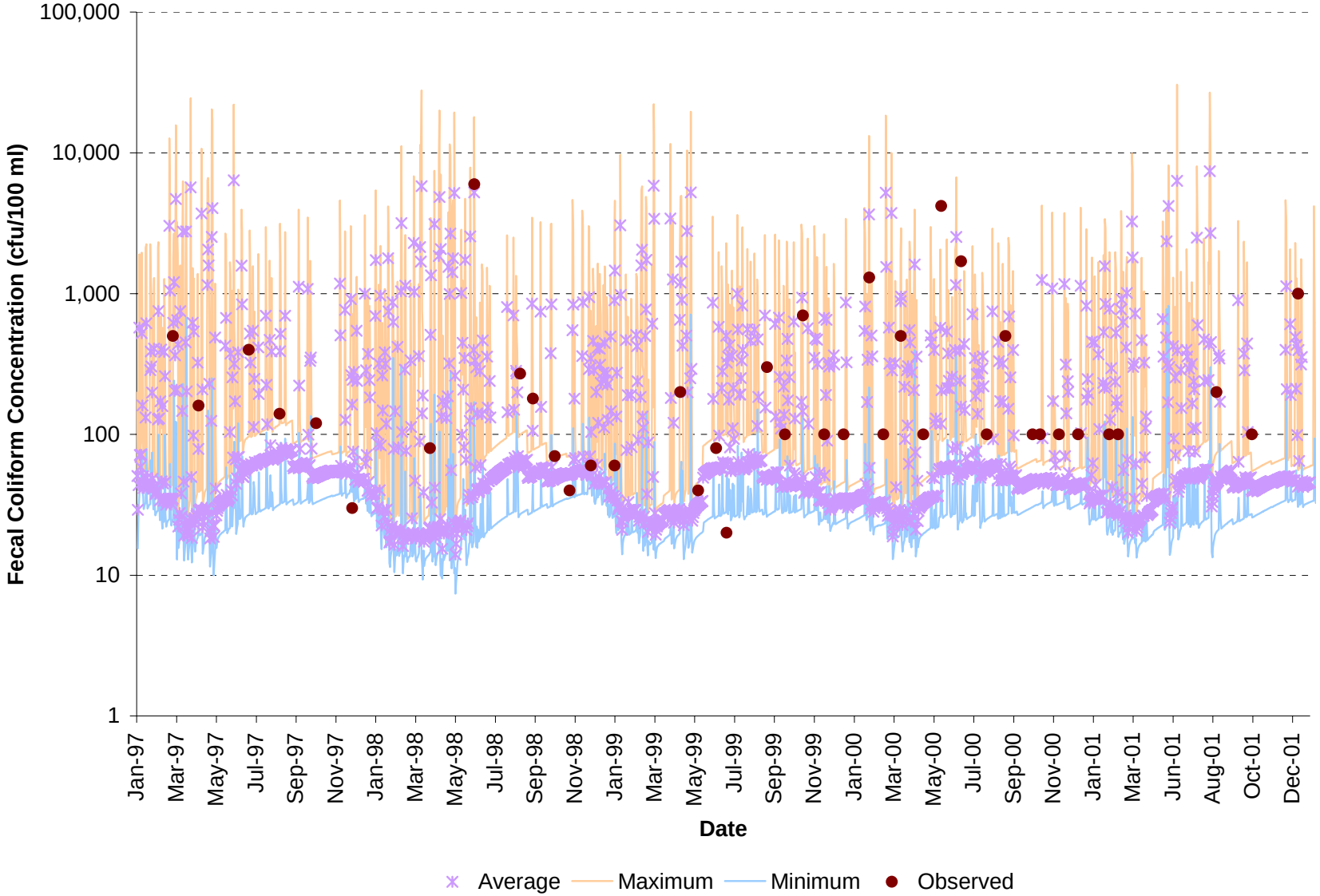


Figure 5.16. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-09 in Middle Fork Holston River watershed.

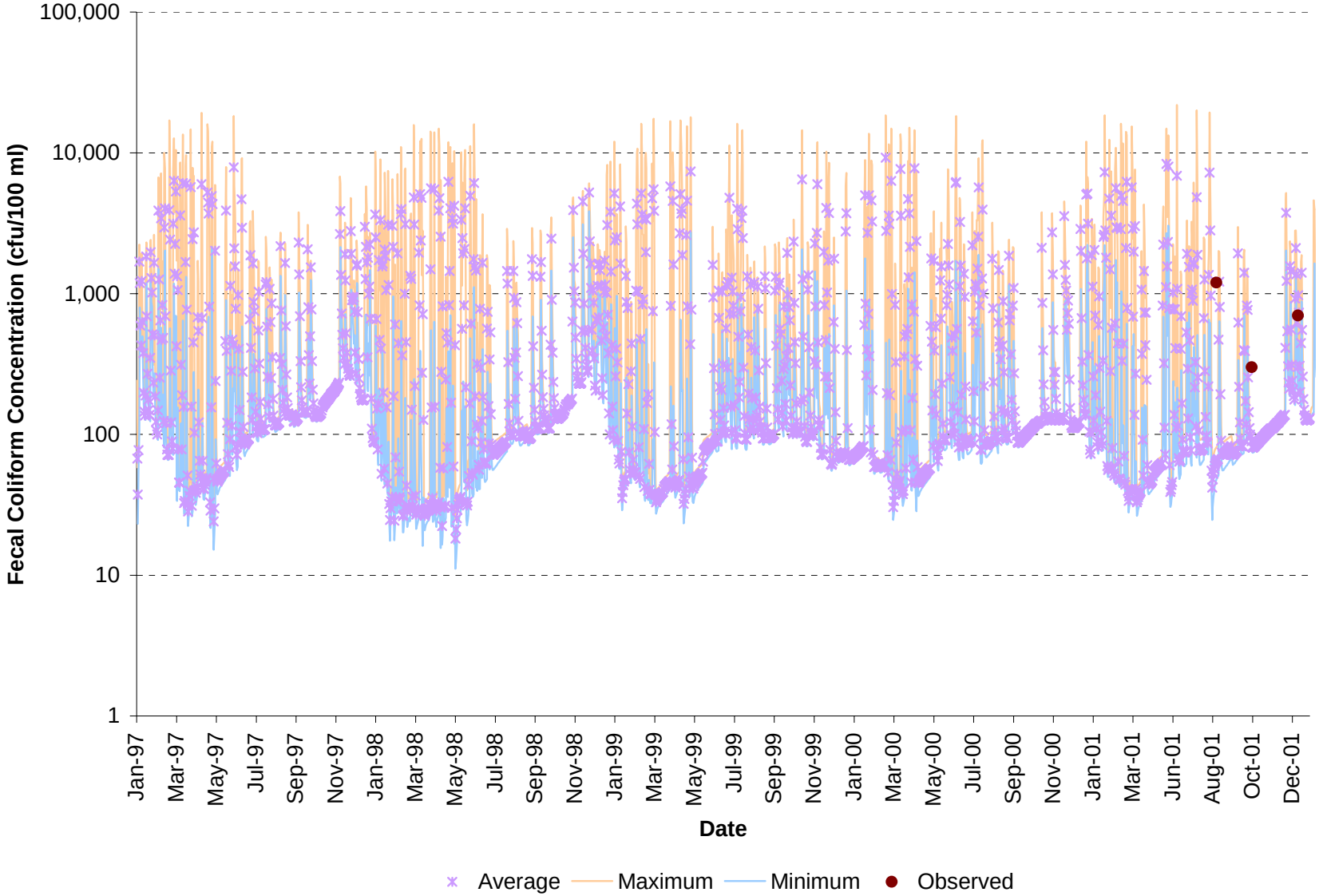


Figure 5.17. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-14 in Middle Fork Holston River watershed.

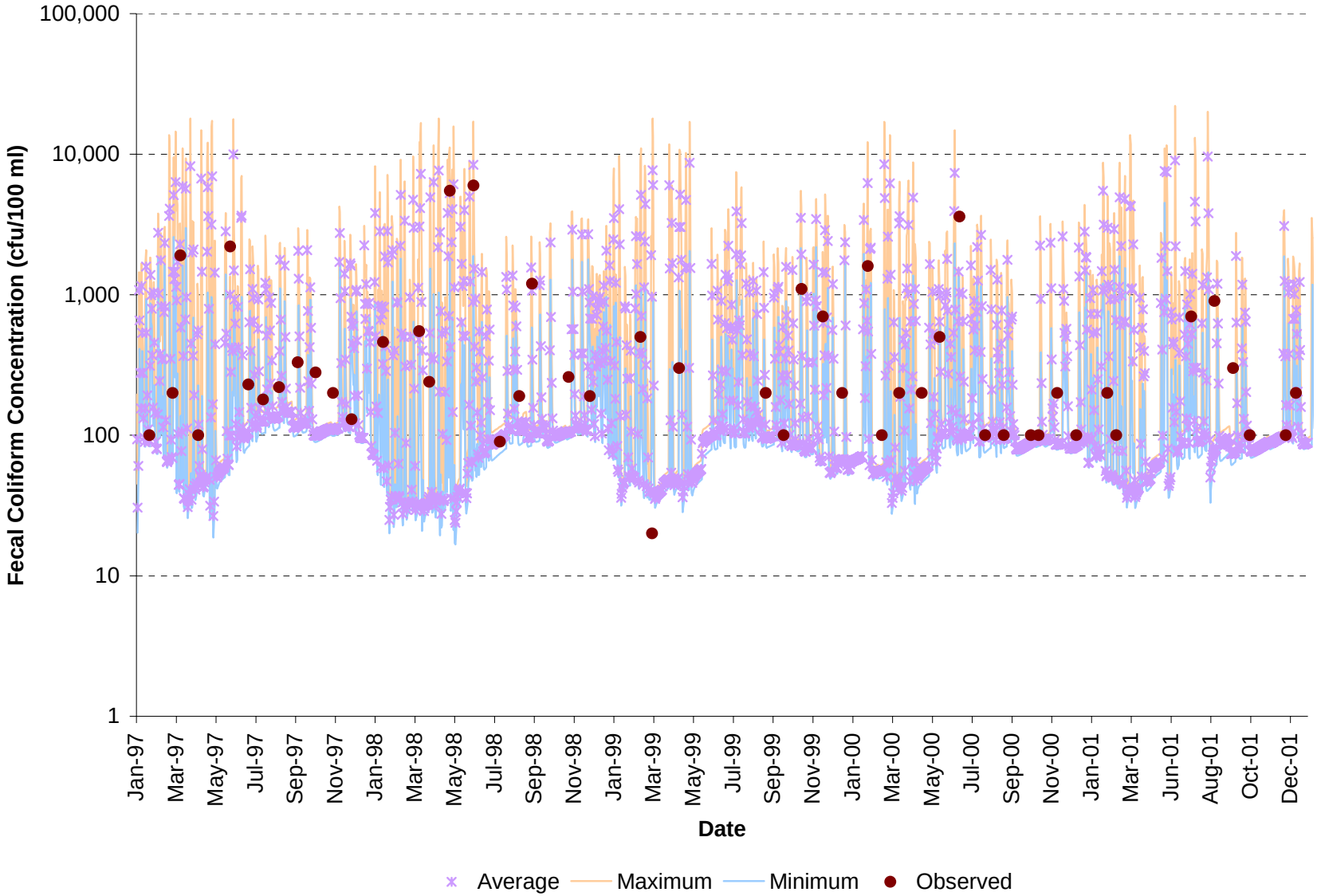


Figure 5.18. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-20 in Middle Fork Holston River watershed.

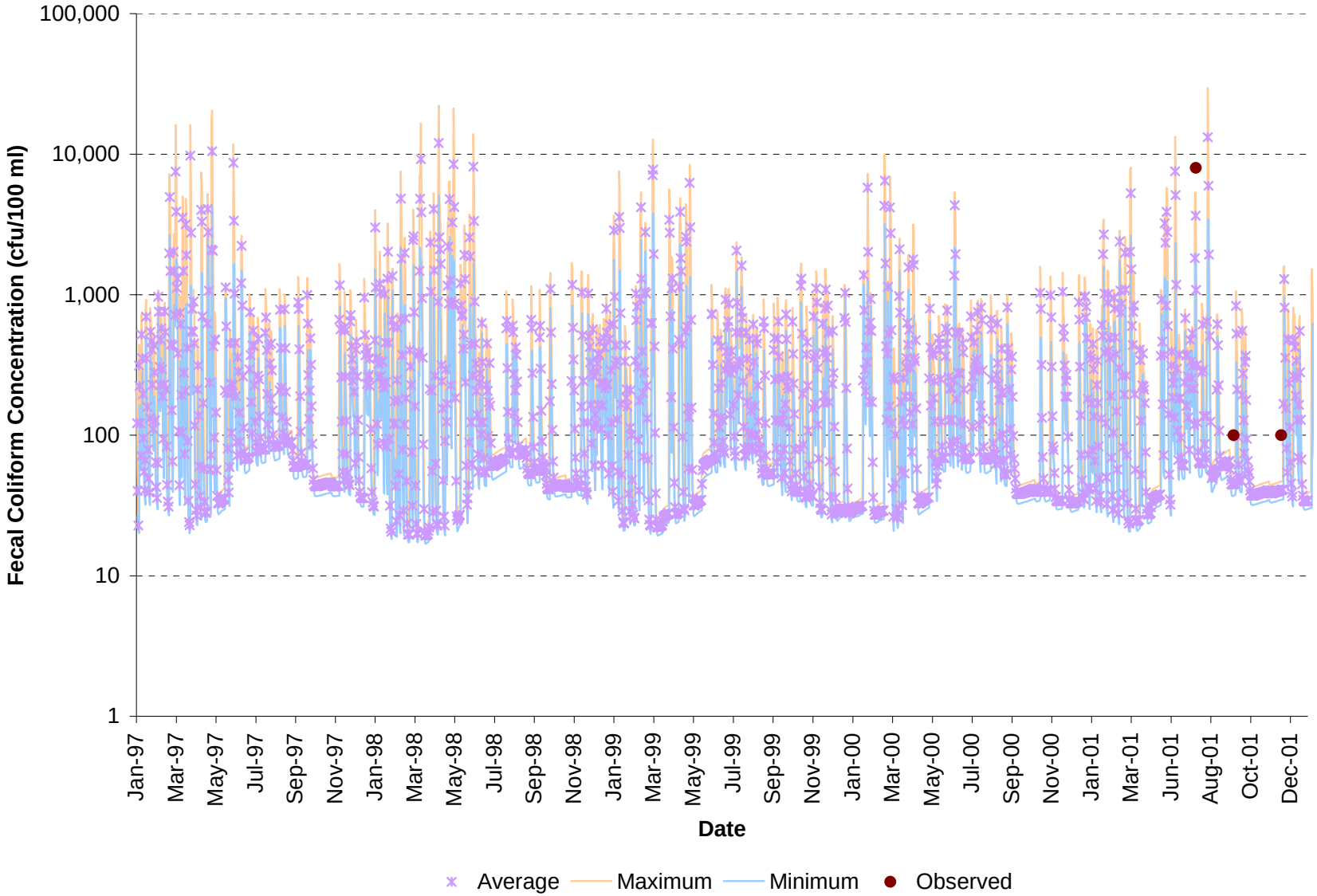


Figure 5.19. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-21 in Middle Fork Holston River watershed.

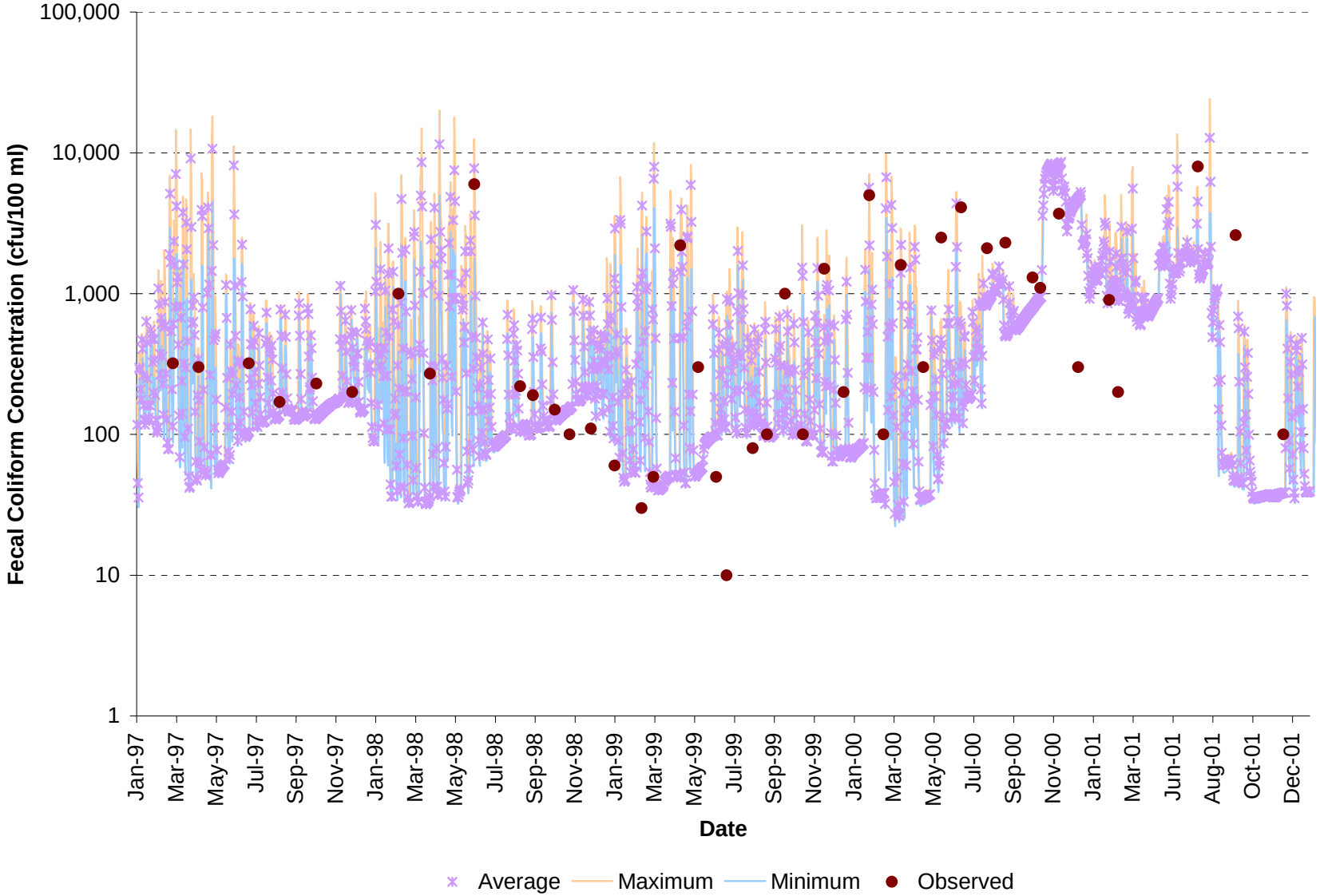


Figure 5.20. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-22 in Middle Fork Holston River watershed.

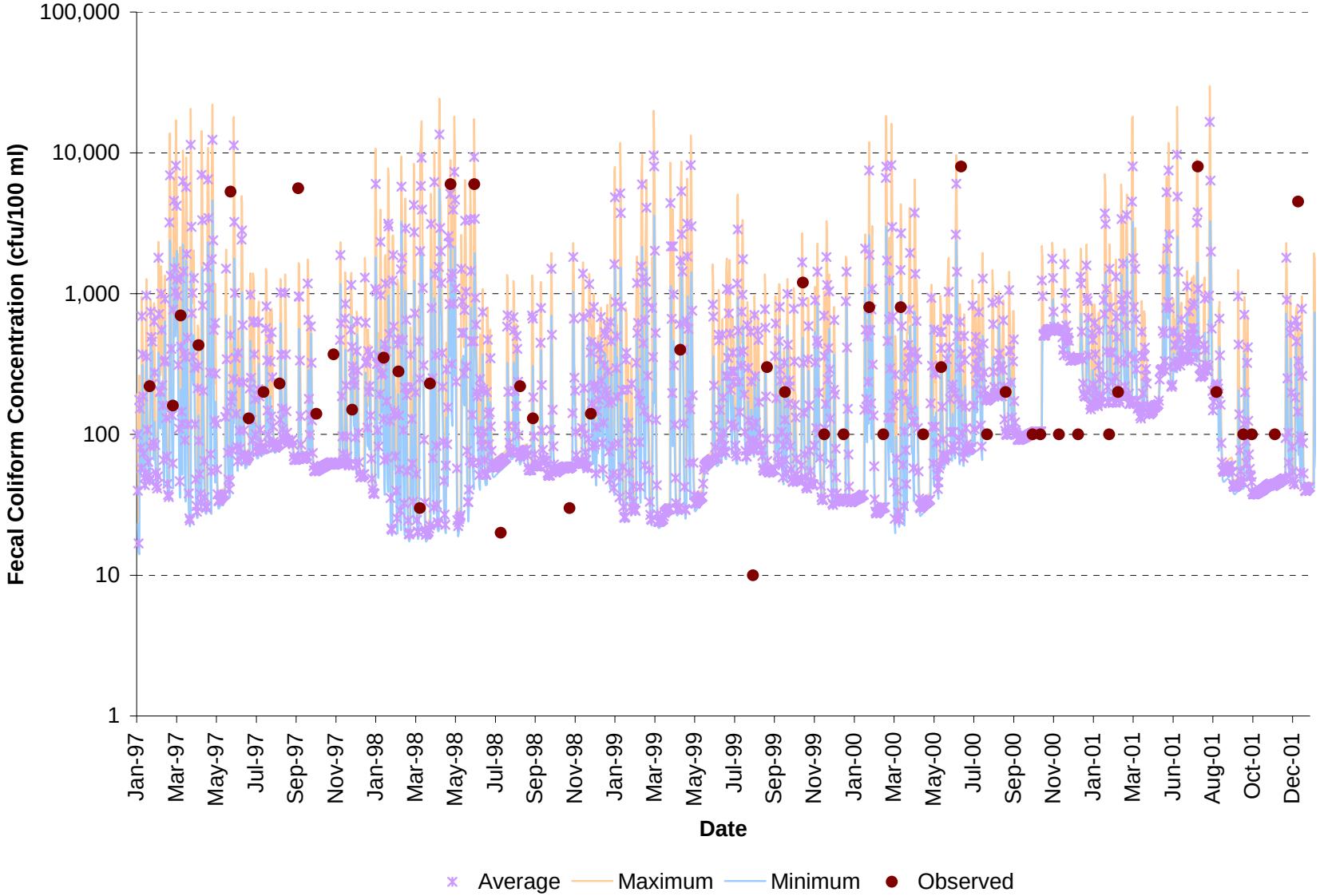


Figure 5.21. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-29 in Middle Fork Holston River watershed.

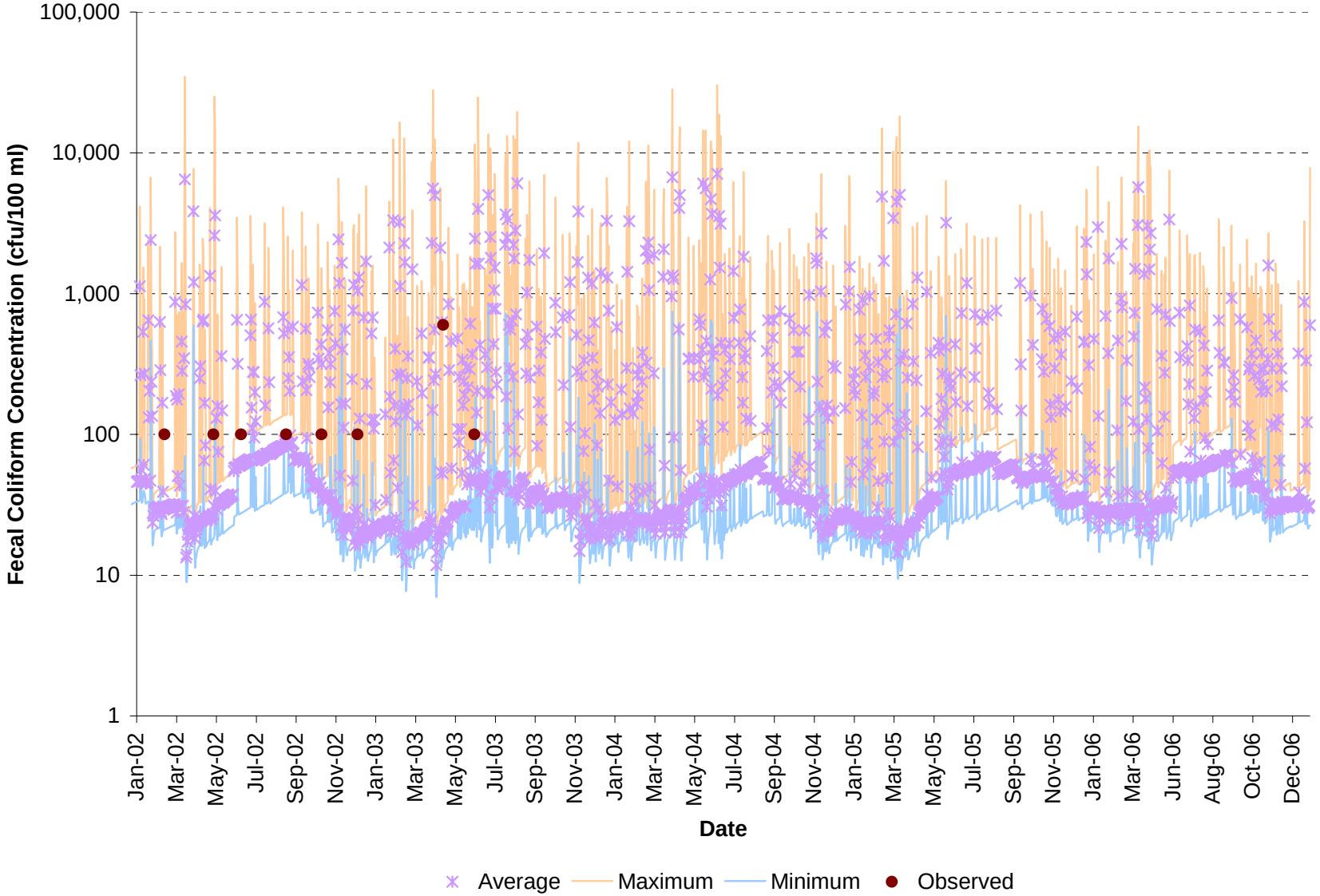


Figure 5.22. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-09 in Middle Fork Holston River watershed.

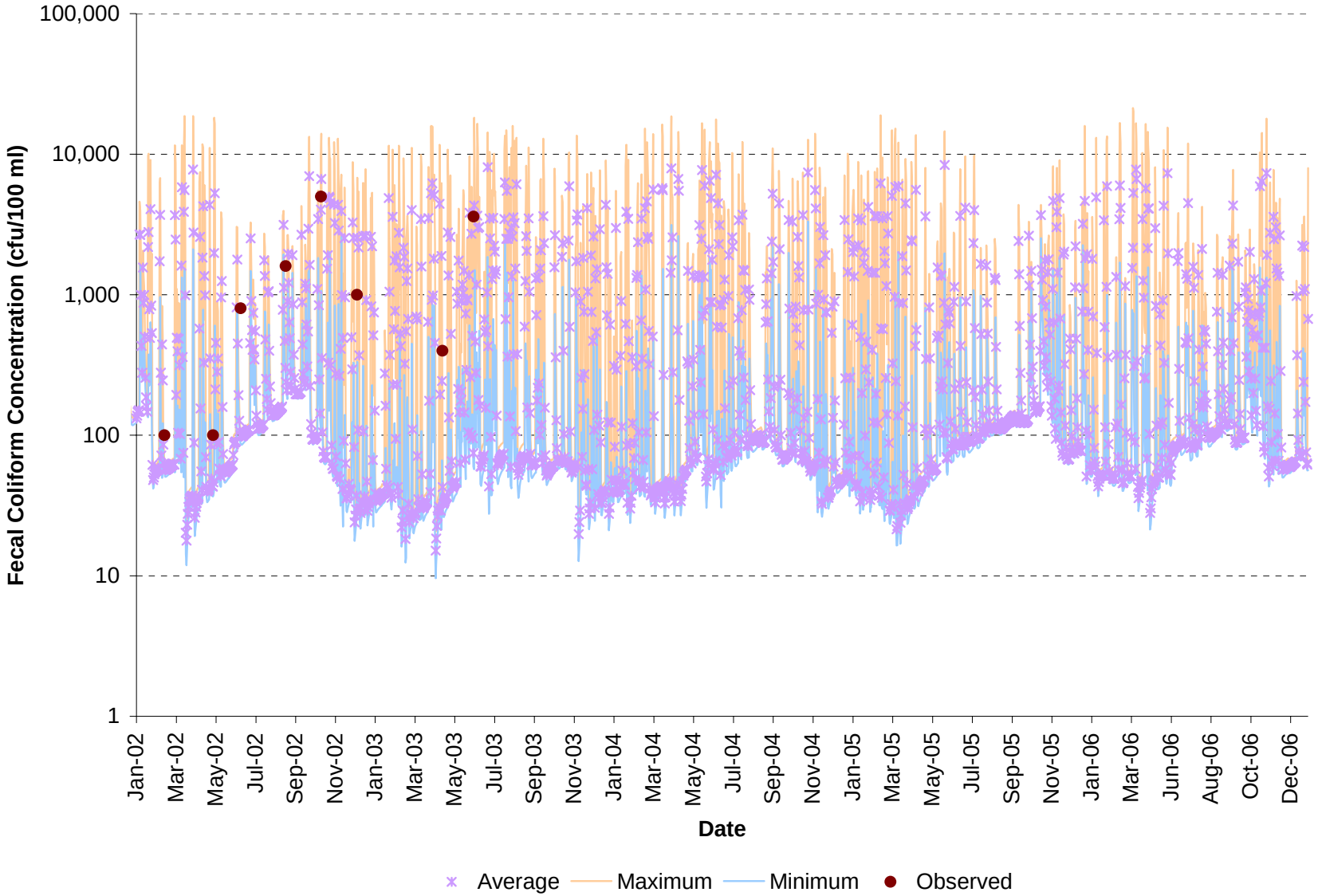


Figure 5.23. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-14 in Middle Fork Holston River watershed.

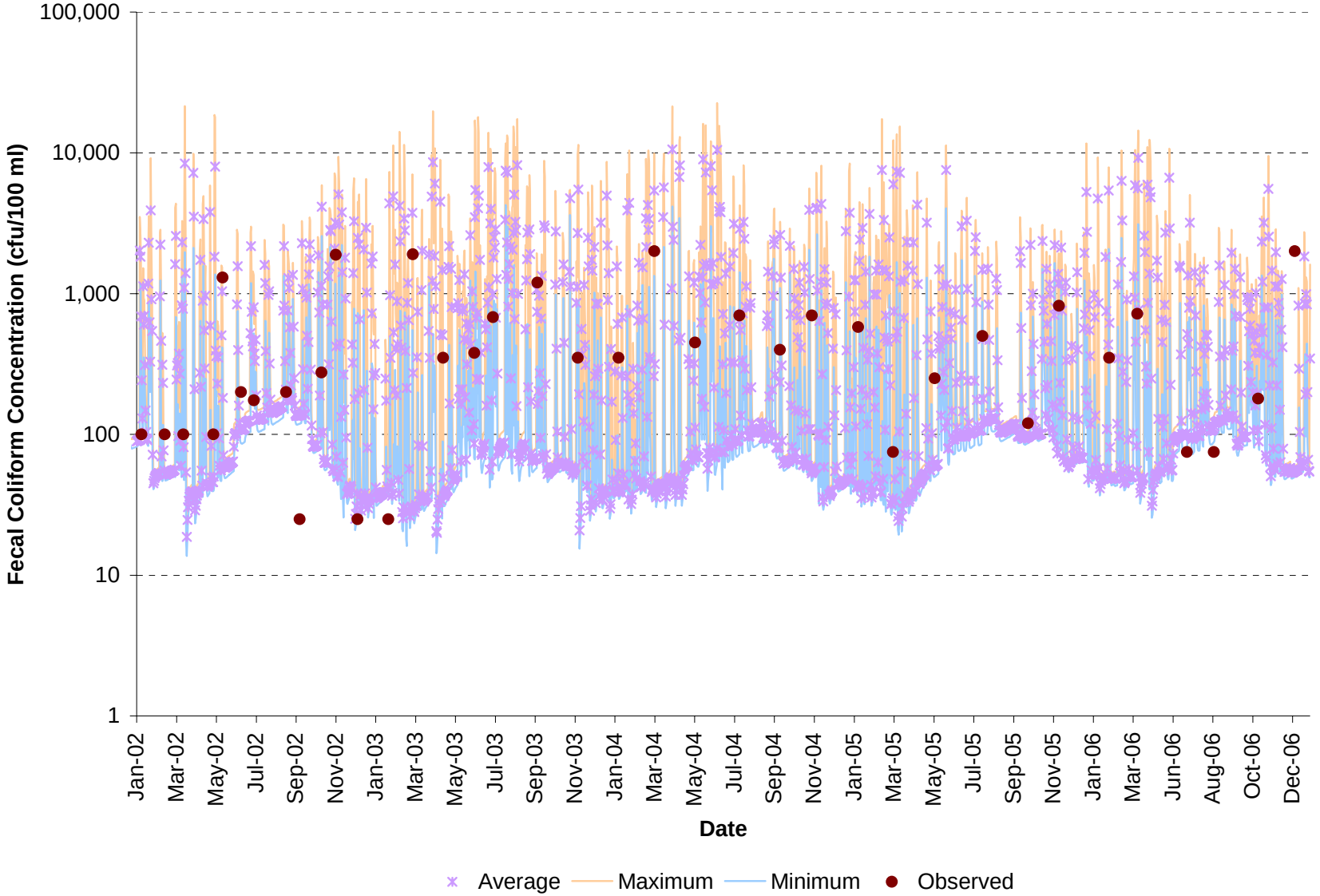


Figure 5.24. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-20 in Middle Fork Holston River watershed.

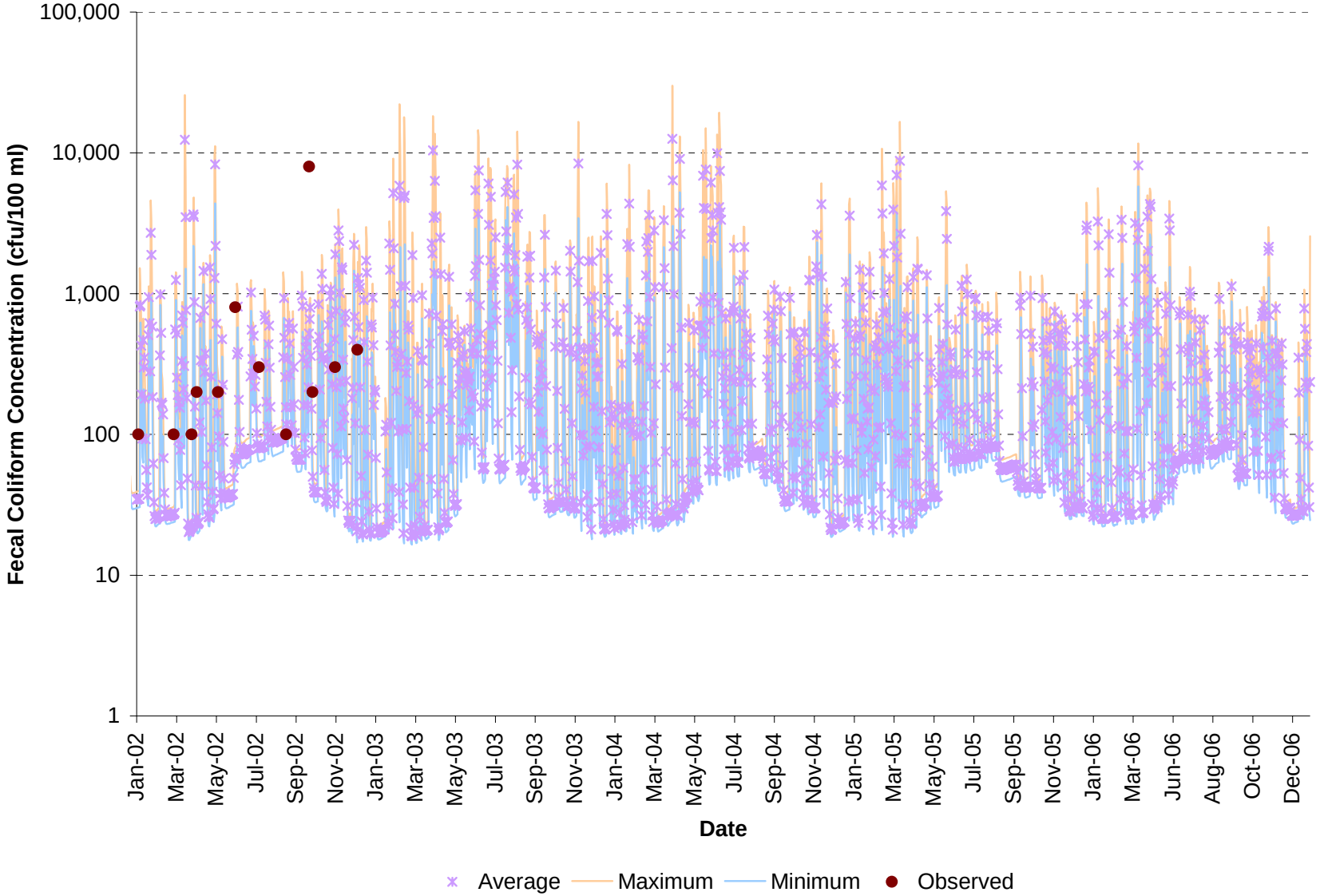


Figure 5.25. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-21 in Middle Fork Holston River watershed.

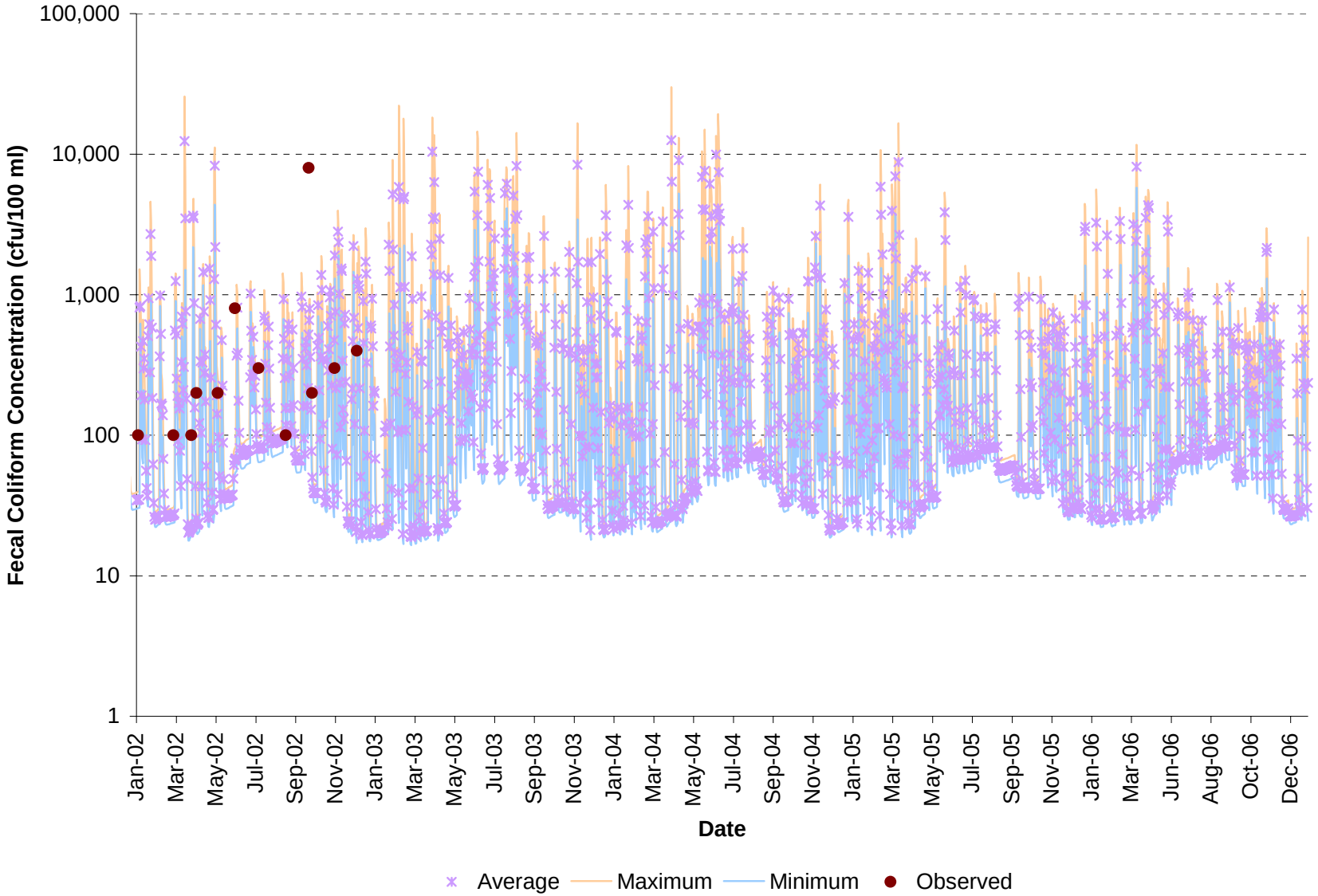


Figure 5.26. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-21 in Middle Fork Holston River watershed.

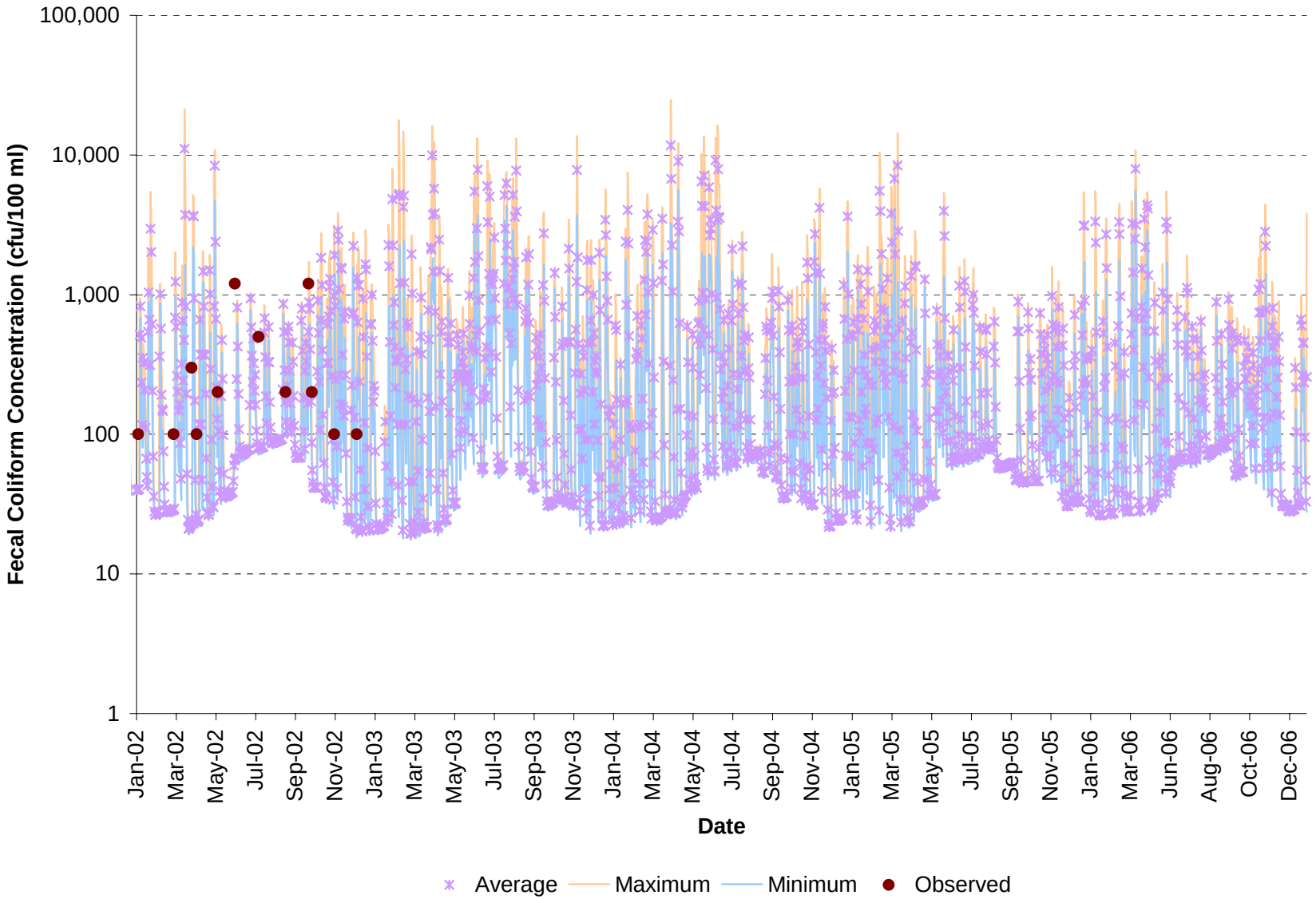


Figure 5.27. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-22 in Middle Fork Holston River watershed.

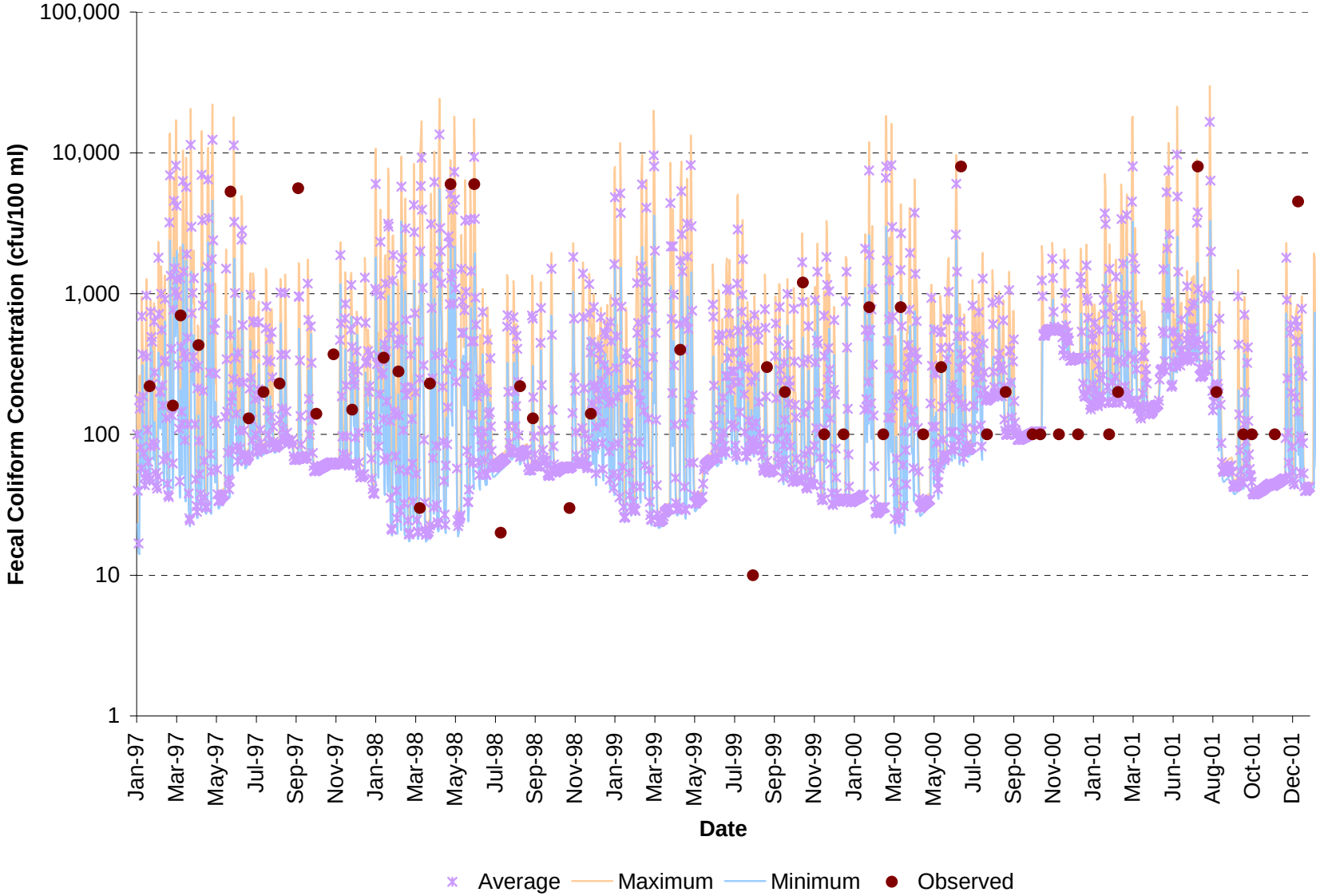


Figure 5.28. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed MFH-29 in Middle Fork Holston River watershed.

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

Parameter	Sub MFH-02	Sub MFH-09	Sub MFH-20	Sub MFH-22	Sub MFH-29
Geometric Mean of Observed Values (cfu/100mL)	274	179	285	393	263
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	271	172	280	390	275
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	34.1	24.4	30.0	38.6	24.0
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	34.1	24.4	30.0	38.6	24.0

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

Parameter	Sub MFH-09	Sub MFH-14	Sub MFH-20	Sub MFH-21	Sub MFH-22	Sub MFH-29
Geometric Mean of Observed Values (cfu/100mL)	125	594	284	275	225	130
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	117	635	275	264	204	128
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	12.5	55.6	36.8	16.7	25.0	15.4
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	12.5	55.6	36.8	25.0	25.0	15.4

Chapter 6. Modeling Process for Development of Sediment TMDL

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

6.1 Reference Watershed

Virginia has no numeric in-stream criteria for sediment. As a result, a “reference watershed” approach was used to set allowable loads for sediment in the impaired watershed. The reference watershed approach pairs two watersheds – one whose streams are supportive of their designated uses and one whose streams are impaired. This reference watershed may be, but does not have to be, the watershed corresponding to the reference monitoring site used for determining comparative biological metric scores. The reference watershed is selected on the basis of similarity of land use, topographical, ecological, and soils characteristics with those of the impaired watershed. This approach is based on the assumption that reduction of the stressor loads in the impaired watershed to the level of the loads in the reference watershed will result in elimination of the benthic impairment. The reference watershed approach involves assessment of the impaired reach and its watershed, identification of potential causes of impairment through a benthic stressor analysis, selection of an appropriate reference watershed, model parameterization and pollutant simulation within the TMDL watershed, definition of the TMDL endpoint, and development of alternative TMDL reduction (allocation) scenarios. Where a simulated load is used as the TMDL endpoint, pollutant loads are also simulated from the reference watershed. TMDL endpoints may be developed using either modeled loads or a statistical measure of monitored pollutant concentrations from the reference watershed.

Results from biological monitoring at VADEQ station 6-CMFH032.39 have shown a healthy benthic community resulting in an un-impaired designation. The section above station 6-CMFH032.39 was labeled as the Upper Middle Fork Holston River watershed in this study (Figure 6.1). Due to similarity of land use, topographical, ecological, and soils characteristics, the Upper Middle Fork Holston River watershed was chosen as the reference watershed for sediment load comparison. From this station to the impairment outlet was designated as the Lower Middle Fork Holston River watershed.

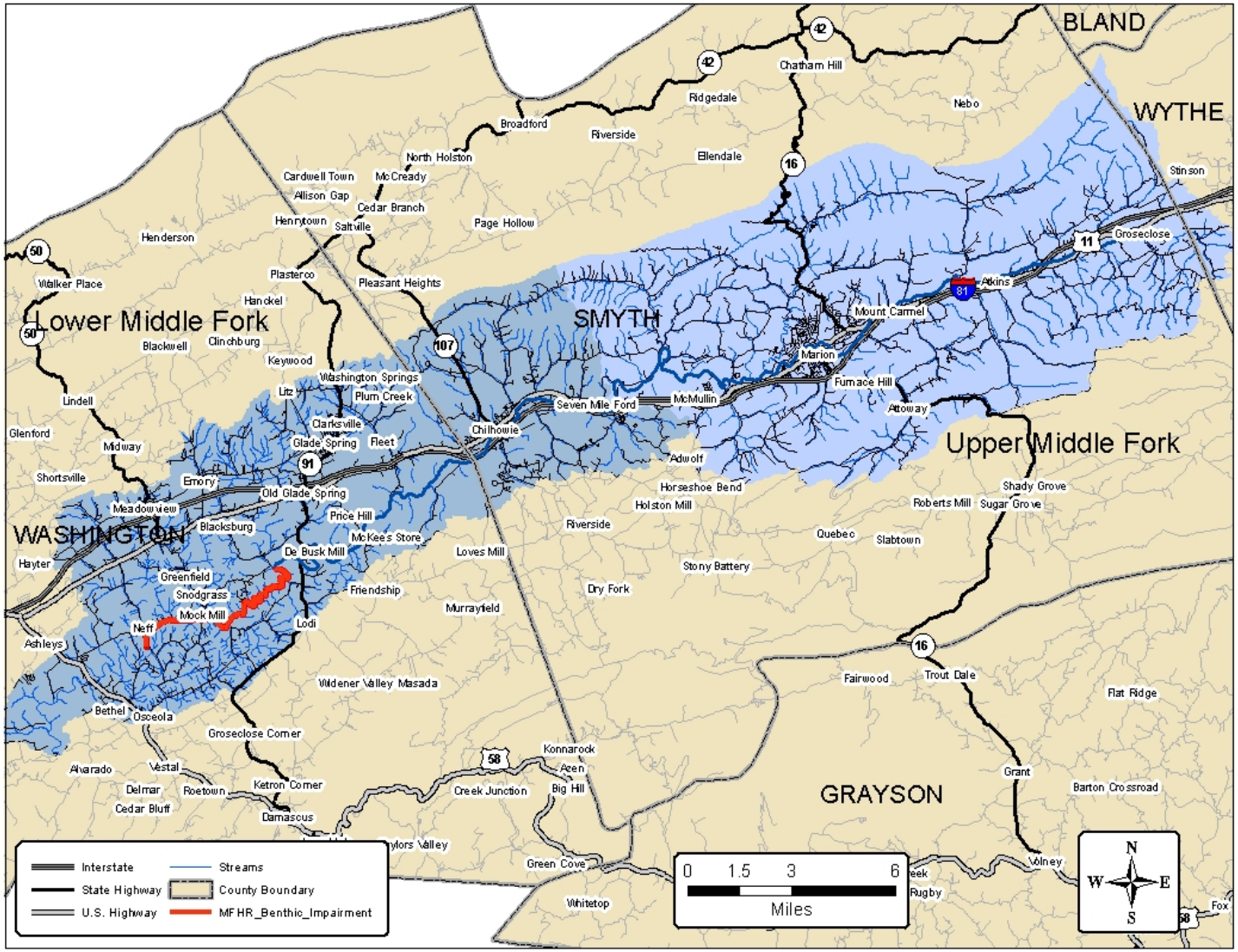


Figure 6.1. Location of benthic impairment, reference watershed, and VADEQ monitoring stations.

6.2 Sediment Source Representation

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

6.2.1 Permitted Point Sources

Sediment loadings from permitted sources are attributable to the total suspended solids (TSS) present in discharge effluent or stormwater runoff. There are 15 VPDES permitted facilities currently active or under application within the Lower Middle Fork Holston River watershed discharging TSS (Table 6.1). Stormwater permits are divided between 17 industrial facilities (Table 6.2).

Table 6.1. VPDES permitted facilities discharging sediment in the Lower Middle Fork Holston River watershed.

Facility Name	Permit Number	VPDES Permit Category	Permit Type	TSS Design Flow (MGD)	TSS Avg. (mg/L)
Dillows Shop and Wash	VA0071366	Individual	Industrial	0.004	30
Chilhowie Regional Wastewater Treatment Plant	VA0026379	Individual	Municipal	0.999	30
Washington Cnty Service Authority -Hall Creek WWTP	VA0087378	Individual	Municipal	0.630	30
Washington County Public Schools - Meadowview Elem	VA0030589	Individual	Municipal	0.016	30
Washington County Industrial Park WWTP	VA0076376	Individual	Municipal	0.080	30
Budget Inn Motel STP	VAG400078	General	SFDS	0.001	30
Skyview Storage STP	VAG400176	General	SFDS	0.001	30
Smyth County Lodge #1004 Loyal Order Of Moose Inc	VAG400426	General	SFDS	0.001	30
Smith James D Residence SFH STP	VAG400181	General	SFDS	0.001	30
Boone Robert F Residence STP	VAG400618	General	SFDS	0.001	30
Heath Russell Dennis Residence STP	VAG400654	General	SFDS	0.001	30
Mountain Materials Inc - Glade Stone Plant	VAG840153	General	SFDS	0.001	30
Mountain Materials Inc - Glade Stone Plant	VAG840153	General	SFDS	0.001	30
Instar Services Group	VAG400324	General	SFDS	0.001	30
Baugher Larry Residence SFH STP	VAG400585	General	SFDS	0.001	30

Table 6.2. Industrial stormwater permitted facilities contributing sediment in the Lower Middle Fork Holston River watershed.

Facility	Permit Number	Yearly Runoff (cm/acre)	Total Suspended Solids (mg/L)
Marion Mold and Tool Incorporated	VAR050042	82.42	100
Utility Trailer Manufactoring Co - Atkins	VAR050045	82.42	100
Kennametal - Chilhowie	VAR050072	82.42	100
Wellborn Cabinet Inc - 1	VAR050074	82.42	100
Wellborn Cabinet Inc - 2 - Bear Creek Facility	VAR050075	82.42	100
Coffman Stairs LLC - Marion North Facility	VAR050077	82.42	100
Coffman Stairs LLC - Marion Main Plant	VAR050078	82.42	100
TRW Automotive	VAR050087	82.42	100
General Shale Products - Plant 6 and 28	VAR050089	82.42	100
Masco Builder Cabinet Group (MBCG)	VAR050091	82.42	100
Masco Builder Cabinet Group(MBCG)	VAR050093	82.42	100
SuperFlo Inc	VAR050121	82.42	100
Superior Carriers Inc	VAR050122	82.42	100
Berry Iron and Metal	VAR050132	82.42	100
Utility Trailer Manufacturing Company - Glade	VAR050748	82.42	100
General Dynamics Armament and Tech Prod- Marion Op	VAR051525	82.42	100
EPOCH Composite Products Inc	VAR051579	82.42	100

6.2.2 Nonpoint Sources

Sediment generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, mining, transportation, and residential land uses. During runoff events, sediment loading occurs from both pervious and impervious surfaces around the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. This process is influenced by vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, and land management practices. During periods without rainfall, dirt, dust and fine sediment build up on impervious areas through dry deposition, which is then subject to wash-off during rainfall events. Sediment generated from impervious areas can be reduced through the use of management practices that reduce the surface load subject to wash-off. The land use types in the Middle Fork Holston River watershed were characterized from NLCD 2001. The Lower Middle Fork Holston River watershed is predominately pasture, constituting approximately 59% of the total watershed area. The remaining land uses are divided between forest (29%), residential (11%), and cropland (1%). Land use distribution for Middle Fork Holston River watersheds was previously shown in Chapter 5.

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

construction sites) typically have sparse vegetative cover, exposing the soil, and resulting in high sediment loads.

6.2.3 Channel and Streambank Erosion

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

6.3 Model Development

The model selected for development of the sediment TMDLs was the Virginia Tech modified version (Yagow and Hession, 2007) of Generalized Watershed Loading Functions (GWLF) model, originally developed at Cornell University (Haith and Shoemaker, 1987; Haith, et al., 1992) for use in un-gaged watersheds. GWLF is a continuous simulation spatially-lumped parameter model that operates on a daily time step. The model estimates runoff, sediment, and dissolved and attached nitrogen and phosphorus loads delivered to streams from complex watersheds with a combination of point and nonpoint sources of pollution. The model considers flow inputs from both surface runoff and groundwater.

The hydrology in the model is simulated with a daily water balance procedure that takes into consideration types of storages within the system. Runoff is generated based on the Soil Conservation Service's Curve Number method as presented in Technical Release 55 (SCS, 1986). Erosion is calculated from a modification of the Universal Soil Loss Equation (USLE) (Schwab et al., 1983; Wischmeier and Smith, 1978). Sediment estimates uses a delivery ratio as a function of watershed area coupled with erosion estimates. The sediment transported depends on the transport capacity of runoff.

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

6.3.1 Climate Data

The climate in Middle Fork Holston River watershed was characterized by meteorological observations from the National Weather Service Cooperative Troutdale 3 SSE (448547), Abingdon 3 S (440021), and Saltville 1 N (447506) weather stations located in

Washington and Smyth Counties, Virginia. The period of record used for modeling was from January 1987 through December 2003.

6.3.2 Land use

Landuse for the Middle Fork Holston River watersheds was derived from the NLCD 2001 landuse – land cover digital data, as discussed in Section 2.5. The NLCD land use types within the watershed were consolidated into 12 categories based on similarities in hydrologic and pollutant production features (Table 2.1). The pasture/hay category was subdivided into three categories based on percentages assessed during the 2002 Statewide NPS Pollution Assessment study (Yagow et al., 2002). Cropland was divided into high-tillage cropland and low-tillage cropland based on input from the Technical Advisory Committee and field observations. Land use distribution in the Middle Fork Holston River watershed is presented in Chapter 5.

6.3.3 Model Input Parameters

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

Hydrology Parameters

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

- *Unsaturated Soil Moisture Capacity (SMC)*: The amount of moisture in the root zone, evaluated as a function of the area-weighted soil type attribute - available water capacity.
- *Recession coefficient (day-1)*: The recession coefficient is a measure of the rate at which stream flow recedes following the cessation of a storm, and is approximated by averaging the ratios of stream flow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph. This parameter was evaluated using the following relationship from Lee et al. (2000): RecCoeff = 0.045+1.13/(0.306+Area in square kilometers).
- *Seepage coefficient (day-1)*: The seepage coefficient represents the amount of flow lost as seepage to deep storage (initially set to zero).

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

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

Month-Related Parameter Descriptions

- *Month*: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model and its assumption that all annual detached sediment is flushed from the system at the end of each Apr-Mar cycle.
- *ET_CV*: Composite evapotranspiration cover coefficient, calculated as an area-weighted average from land uses within each watershed.
- *Hours per Day*: Mean number of daylight hours.
- *Erosion Coefficient*: This is a regional coefficient used in Richardson's equation for calculating daily rainfall erosivity. Each region is assigned separate coefficients for the months October-March, and for April- September.

Land Use-Related Parameter Descriptions

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

Sediment Parameters

Watershed-Related Parameter Descriptions

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

Land Use-Related Parameter Descriptions

- *USLE K-factor*: The soil erodibility factor was calculated as an area-weighted average of all component soil types.
- *USLE LS-factor*: This factor is calculated from slope and slope length measurements by land use. Slope is evaluated by GIS analysis, and slope length is calculated as an inverse function of slope.
- *USLE C-factor*: The vegetative cover factor for each land use was evaluated following GWLF manual guidance, Wischmeier and Smith (1978), and Hession et al. (1997); and then adjusted after consultation with local NRCS personnel.
- *Daily sediment buildup rate on impervious surfaces*: The daily amount of dry deposition deposited from the air on impervious surfaces on days without rainfall, assigned using GWLF manual guidance.

Streambank Erosion Parameter Descriptions (Evans et al., 2003)

- *% Developed land*: percentage of the watershed with urban-related land uses – defined as all land in MDR, HDR, and COM land uses, as well as the impervious portions of LDR.
- *Animal density*: calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by the watershed area in acres.
- *Curve Number*: area-weighted average value for the watershed.
- *K Factor*: area-weighted USLE soil erodibility factor for the watershed.

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

Nutrient Parameters

Watershed-Related Parameter Descriptions

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

Land Use-Related Parameter Descriptions

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

6.3.4 Model Calibration

GWLF was originally developed as a planning tool for estimating nutrient and sediment loadings on non-gaged watersheds, not requiring calibration. To ensure the general validity of the model, simulations were performed from 1987 to 2003 to account for both seasonal and annual variations in hydrology as well as sediment loadings. The simulated flow from GWLF was calibrated based on USGS station #03474000 on Middle Fork Holston River near Seven Mile Ford, VA and USGS station #003475000 on Middle Fork Holston River near Mock Mill, VA. The groundwater seepage coefficient and unsaturated zone available water capacity were adjusted to obtain a best fit with observed data. All other GWLF hydrologic parameters were calibrated using GWLF user manual guidance and professional judgment.

6.4 Sediment Load Estimates

6.4.1 Upper Middle Fork Holston River

Both the reference and TMDL watersheds were modeled to develop the sediment TMDLs. The size of the selected reference watershed, Upper Middle Fork Holston River, was adjusted to match the area of the Lower Middle Fork Holston River watershed. Land use distributions and other watershed characteristics were preserved throughout the adjustment.

The sediment load TMDL target endpoint (t/yr) was established as the sediment load from the area-adjusted reference watersheds, “Upper Middle Fork Holston River as Lower Middle Fork Holston River” (Table 6.3). The GWLF model was used to estimate sediment loading contributions from each land use and estimate channel erosion. Point source sediment loads were based on design flow or calculated runoff and the permitted concentration of total suspended solids for each facility.

Table 6.3. Sediment sources and loads calculated for Upper Middle Fork Holston River watershed.

Sediment Sources	Upper MFHR as Lower MFHR (t/yr)
Hi till cropland	14.9
Low-till cropland	76.6
Pasture 1	302.2
Pasture 2	423.2
Pasture 3	408.9
Transitional	42.8
Forest	57.8
Open urban grass	80.9
Low density residential	22.5
Medium density residential	13.4
High density residential	14.8
Channel erosion	278.2
Point sources	243.6
TOTAL	*1,979.9*

6.4.2 Lower Middle Fork Holston River

Point source sediment loads were based on design flow or calculated runoff and the permitted concentration of total suspended solids for each facility. The GWLF model was used to estimate sediment loading contributions from each land use and estimate channel erosion. Point source and nonpoint source loads for Lower Middle Fork Holston River are presented below in Table 6.3**.**

Table 6.4. Sediment sources and loads calculated for Lower Middle Fork Holston River watershed.

Sediment Sources	Existing Load (t/yr)	Portion of Total Load (%)
Hi till cropland	90.2	2.1
Low-till cropland	462.8	10.6
Pasture 1	758.7	17.3
Pasture 2	1,062.4	24.3
Pasture 3	1,026.5	23.5
Transitional	46.4	1.1
Forest	37.3	0.9
Open urban grass	144.7	3.3
Low density residential	21.8	0.5
Medium density residential	12.3	0.3
High density residential	8.7	0.2
Channel erosion	601.2	13.7
Point sources	100.4	2.3
TOTAL	4,373.4	100.0

6.5 Accounting for Critical Conditions and Seasonal Variations

6.5.1 Selection of Representative Modeling Period

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

was used to calculate average annual sediment loads in the Middle Fork Holston River watershed.

6.5.2 Critical Conditions

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

6.5.3 Seasonal Variability

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

Chapter 7. TMDL Allocations

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

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

where:

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

7.1 Bacteria TMDL

7.1.1 Background

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

Bacteria loadings were updated to reflect 2008 conditions for the existing conditions and allocation runs. The simulation period selected for the load allocation study was January 2000 to December 2004. This period incorporates average rainfall, low rainfall, and high rainfall years allowing the representation of both low and high flow conditions.

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

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

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

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

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

7.1.2 Existing Conditions

Bacteria loadings for 2008 conditions were inserted into the model and simulated for the period January 2000 to December 2004. Model output was translated to average daily *E. coli* concentrations and the monthly geometric mean was calculated. Average daily *E. coli* concentrations at the impairment outlets were compared to the single sample maximum standard of 235 cfu/100 mL. Subwatershed outlets were used for comparison of modeled concentrations to water quality standards for the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) impairments. Appendix C contains tables with monthly land-based and direct bacteria loadings for existing conditions.

7.1.2.1 Middle Fork Holston River (VAS-O03R-01)

Figure 7.1 shows the monthly geometric mean for each subwatershed in relation to the monthly geometric mean (126 cfu/100mL) standard. Average daily *E. coli* concentrations at the impairment outlet were compared to the single sample maximum standard of 235 cfu/100 mL (Figure 7.2). Subwatershed 3 was used for comparison of modeled concentrations to water quality standards for the Middle Fork Holston River (VAS-O03R-01) impairment.

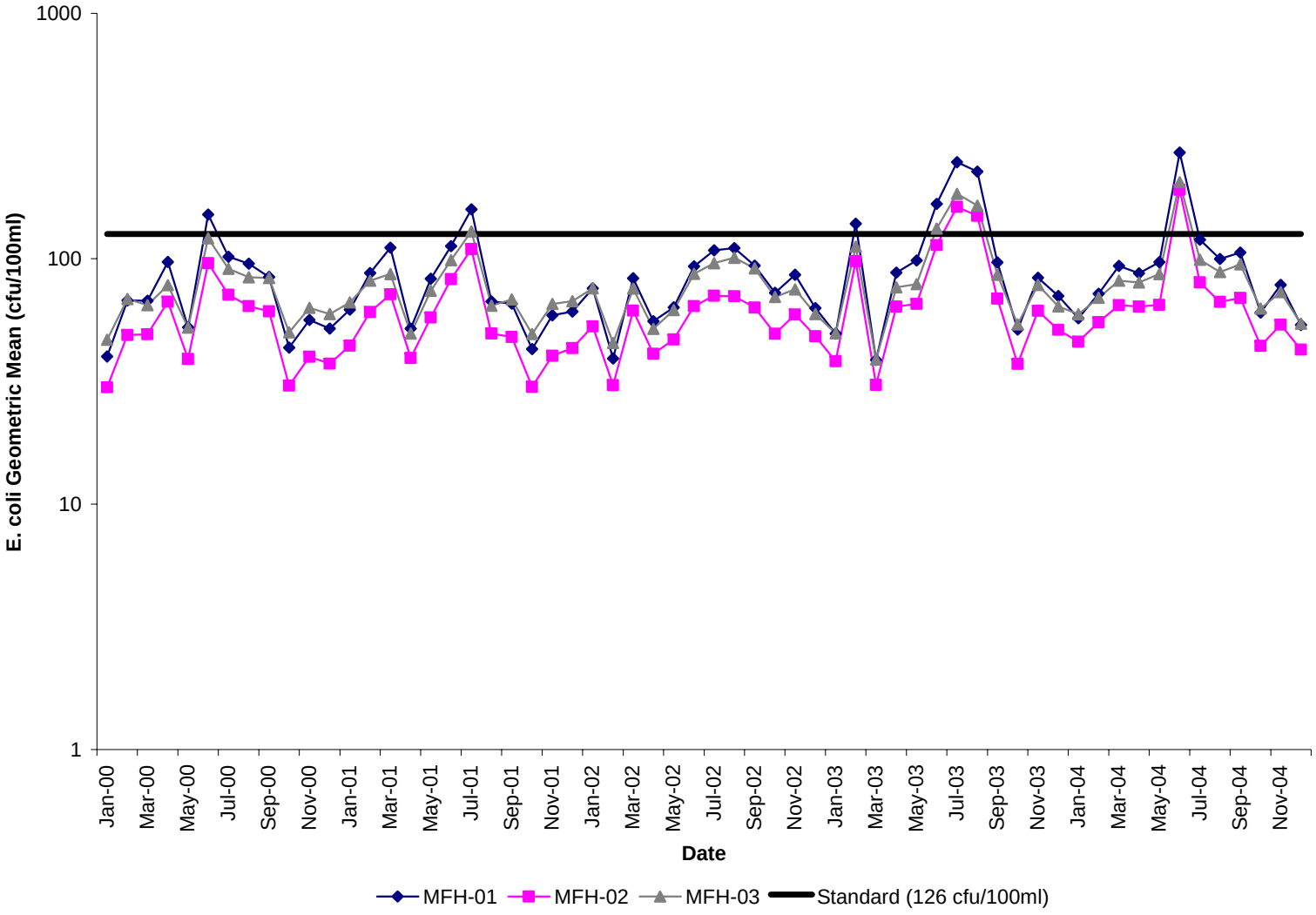


Figure 7.1. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-01 to MFH-03 in the Middle Fork Holston River (VAS-O03R-01) watershed.

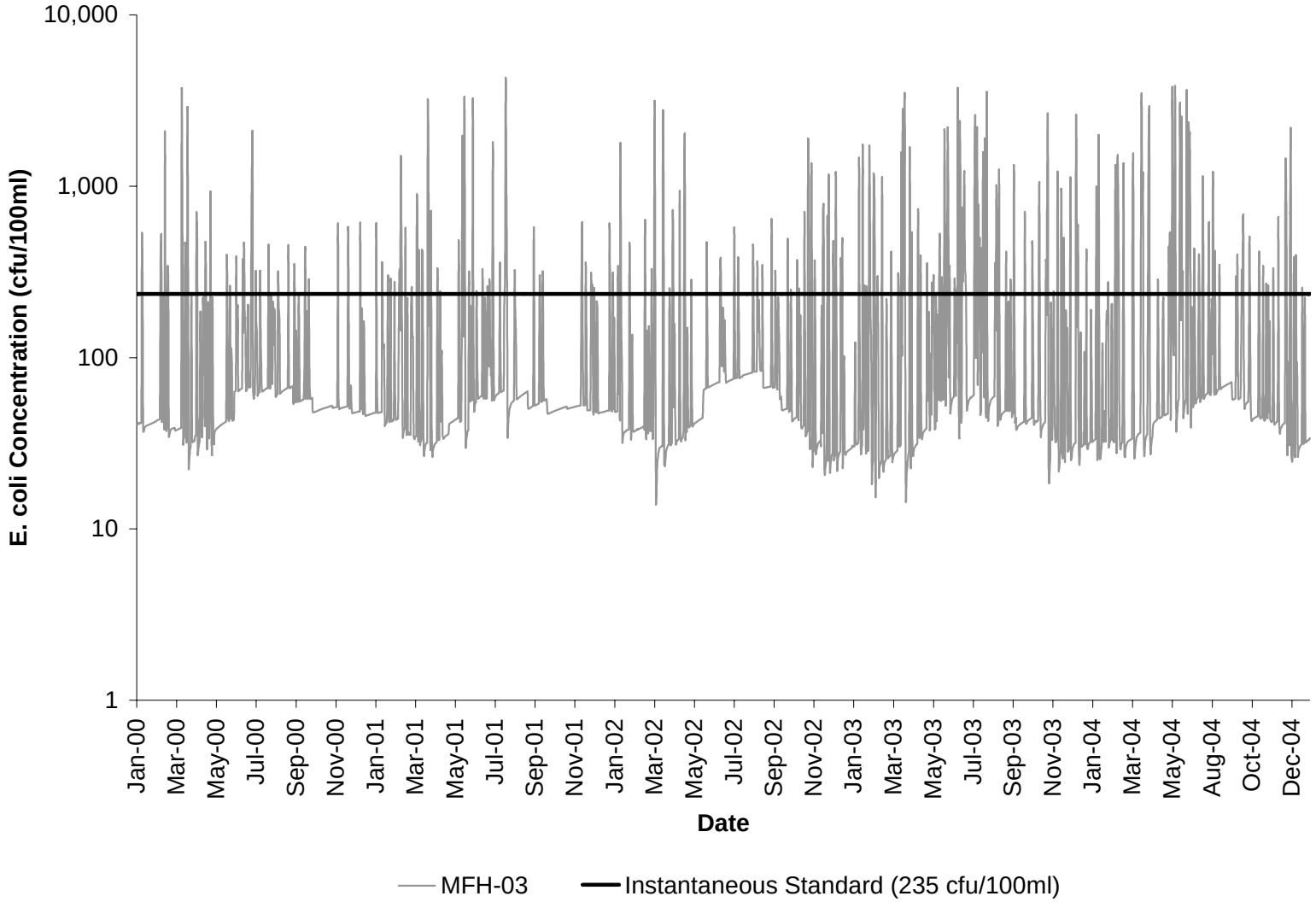


Figure 7.2. Daily average *E. coli* concentrations for subwatershed MFH-03 in Middle Fork Holston River (VAS-O03R-01) watershed.

7.1.2.2 Middle Fork Holston River (VAS-O03R-02)

Figures 7.3 and 7.4 show the monthly geometric mean for each subwatershed in relation to the monthly geometric mean (126 cfu/100mL) standard. Average daily *E. coli* concentrations at the impairment outlet were compared to the single sample maximum standard of 235 cfu/100 mL (Figure 7.5). Subwatershed 14 was used for comparison of modeled concentrations to water quality standards for the Middle Fork Holston River (VAS-O03R-02) impairment.

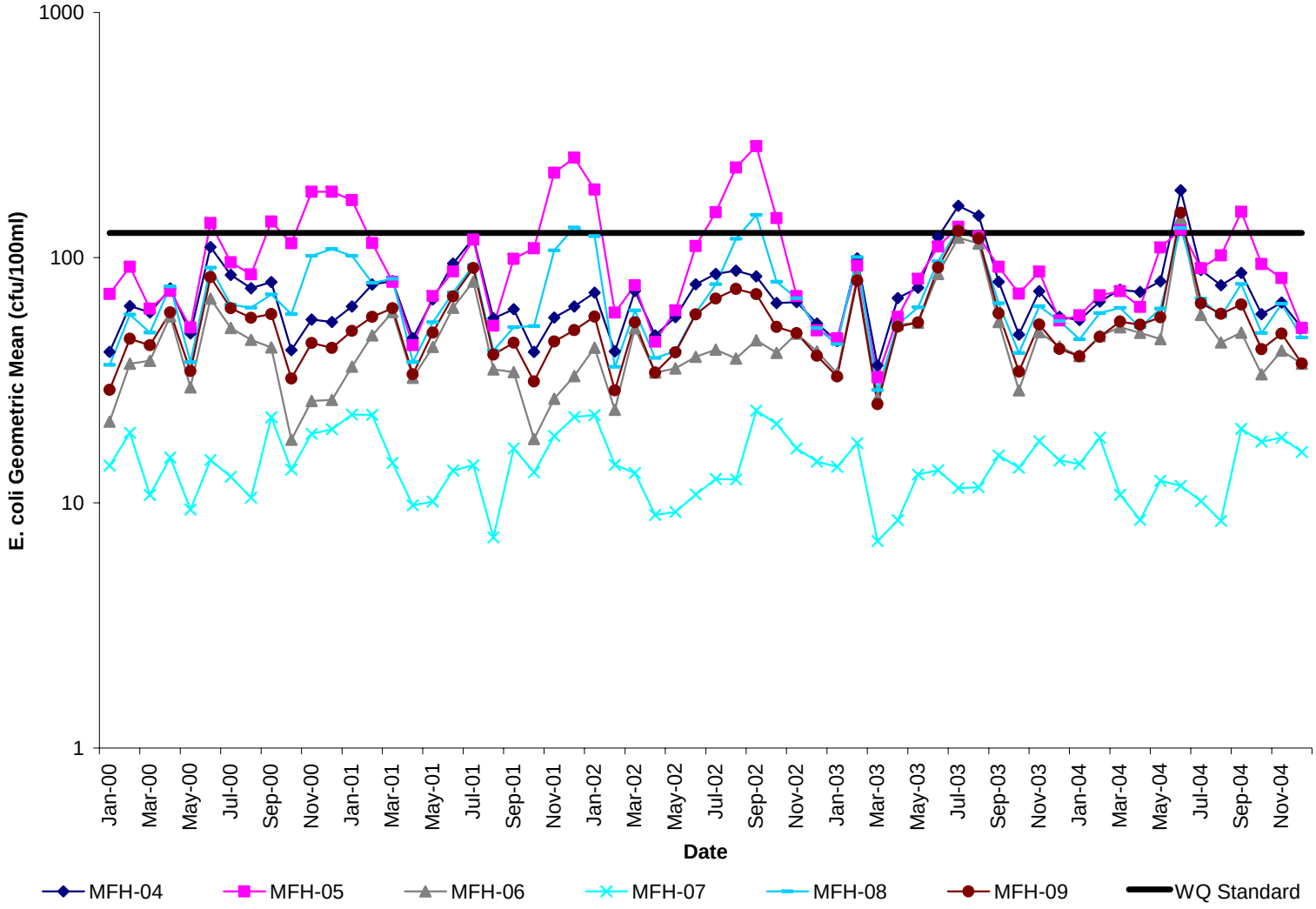


Figure 7.3. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-04 to MFH-09 in the Middle Fork Holston River (VAS-O03R-02) watershed.

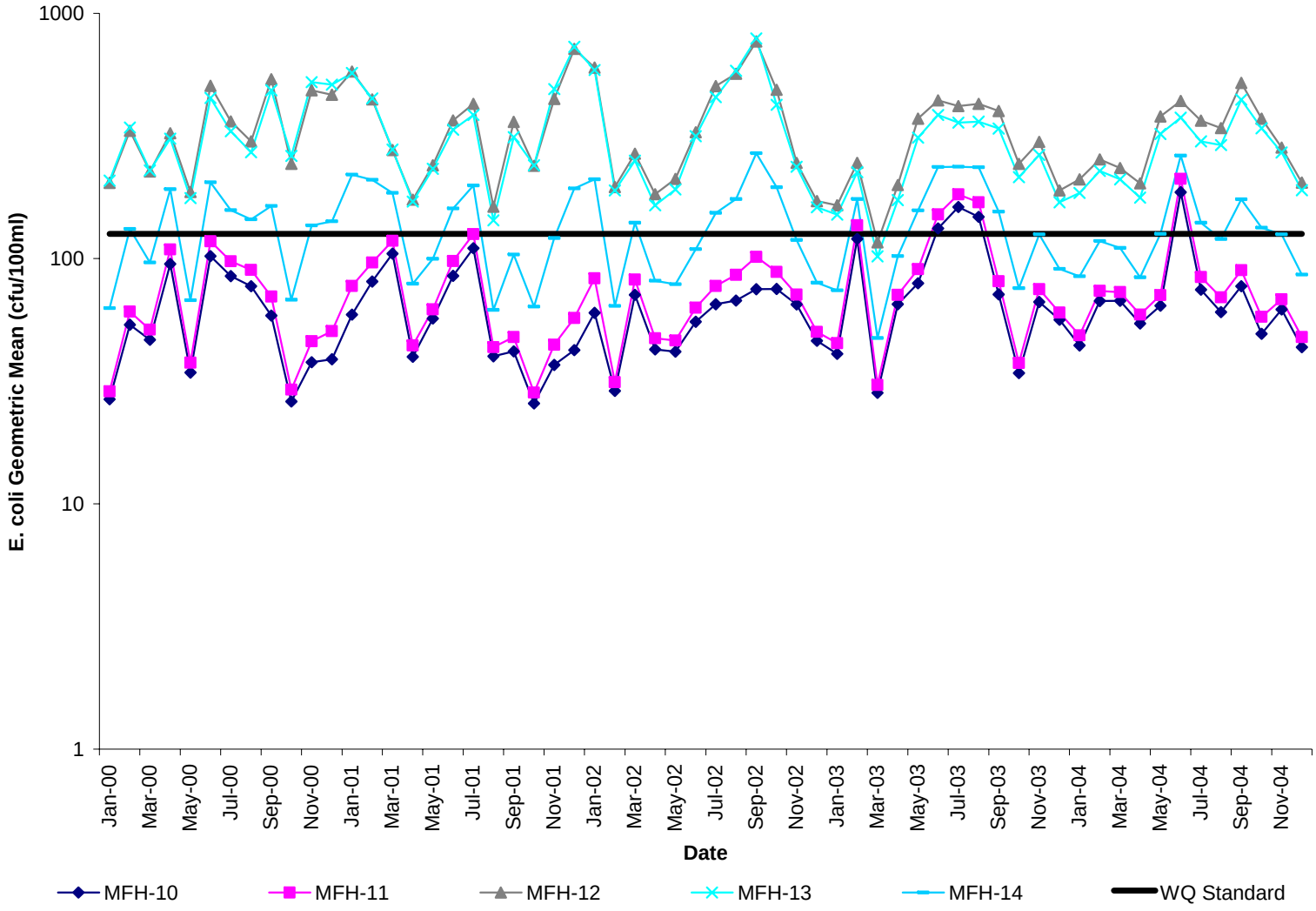


Figure 7.4. Monthly E. coli geometric mean concentrations for existing conditions in subwatersheds MFH-11 to MFH-14 in the Middle Fork Holston River (VAS-O03R-02) watershed.

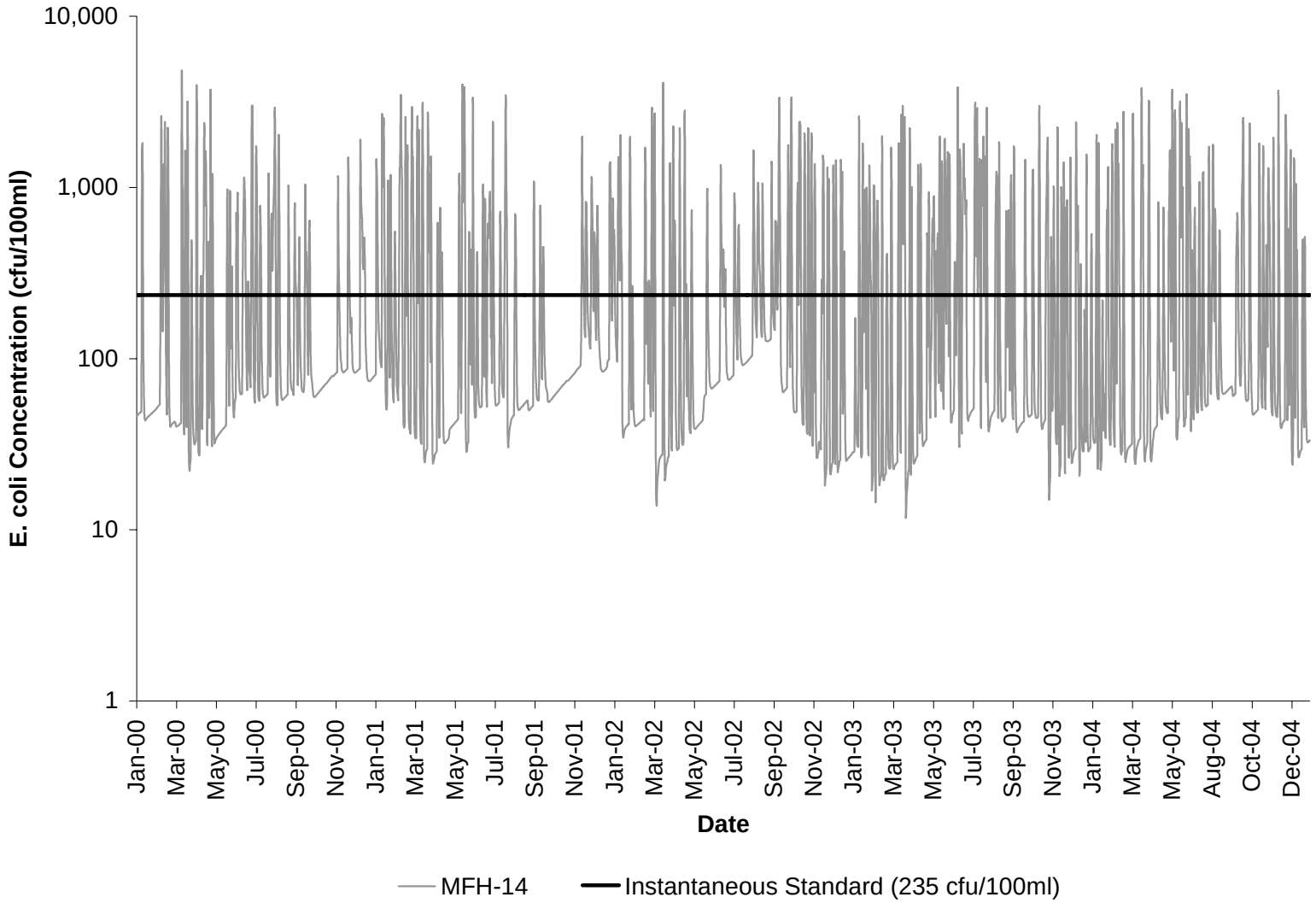


Figure 7.5. Daily average *E. coli* concentrations for subwatershed MFH-14 in Middle Fork Holston River (VAS-O03R-02) watershed.

7.1.2.3 Middle Fork Holston River (VAS-O04R-01)

Figure 7.6 shows the monthly geometric mean for each subwatershed in relation to the monthly geometric mean (126 cfu/100mL) standard. Average daily *E. coli* concentrations at the impairment outlet were compared to the single sample maximum standard of 235 cfu/100 mL (Figure 7.7). Subwatershed 21 was used for comparison of modeled concentrations to water quality standards for the Middle Fork Holston River (VAS-O04R-01) impairment.

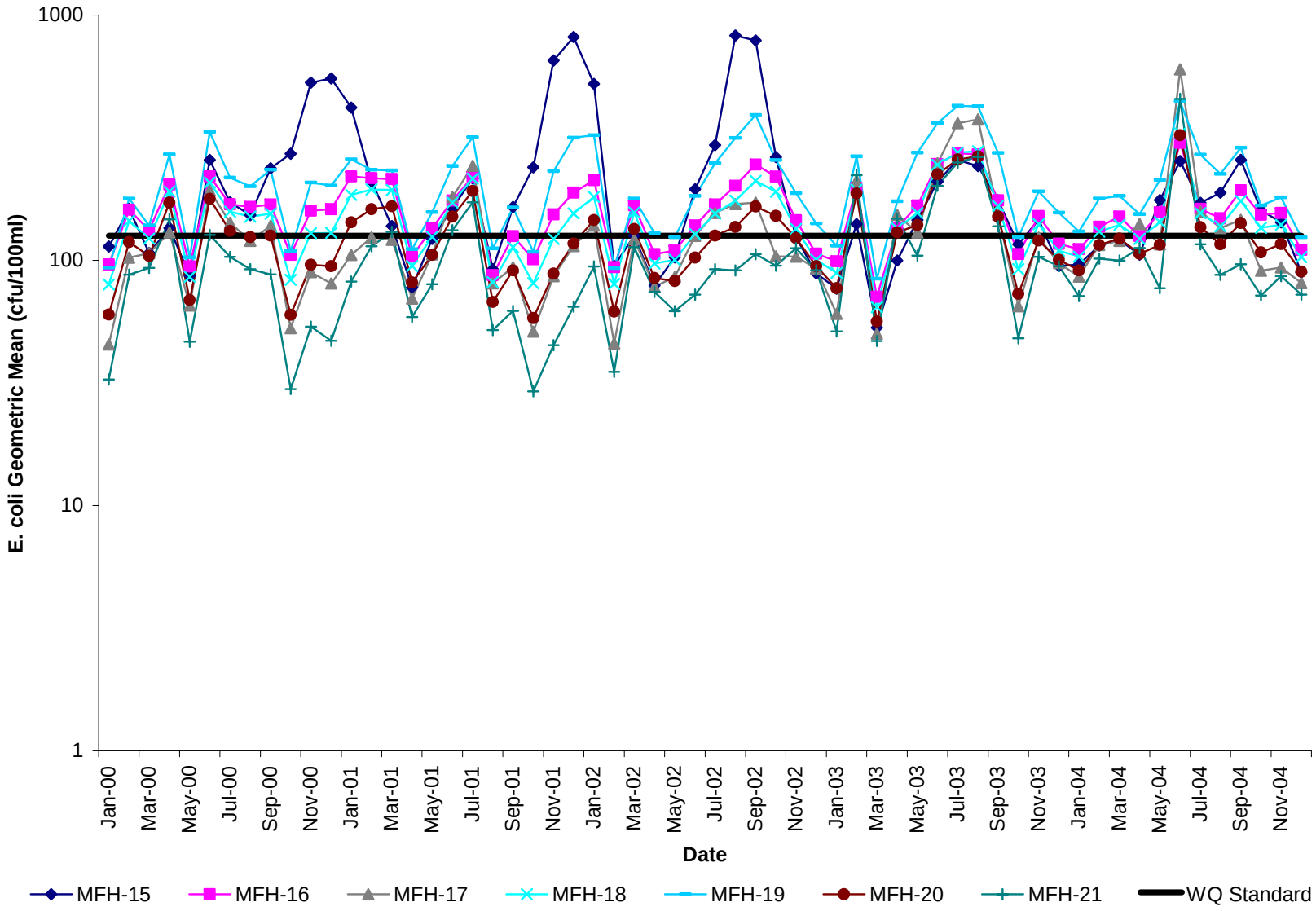


Figure 7.6. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-15 to MFH-21 in the Middle Fork Holston River (VAS-O04R-01) watershed.

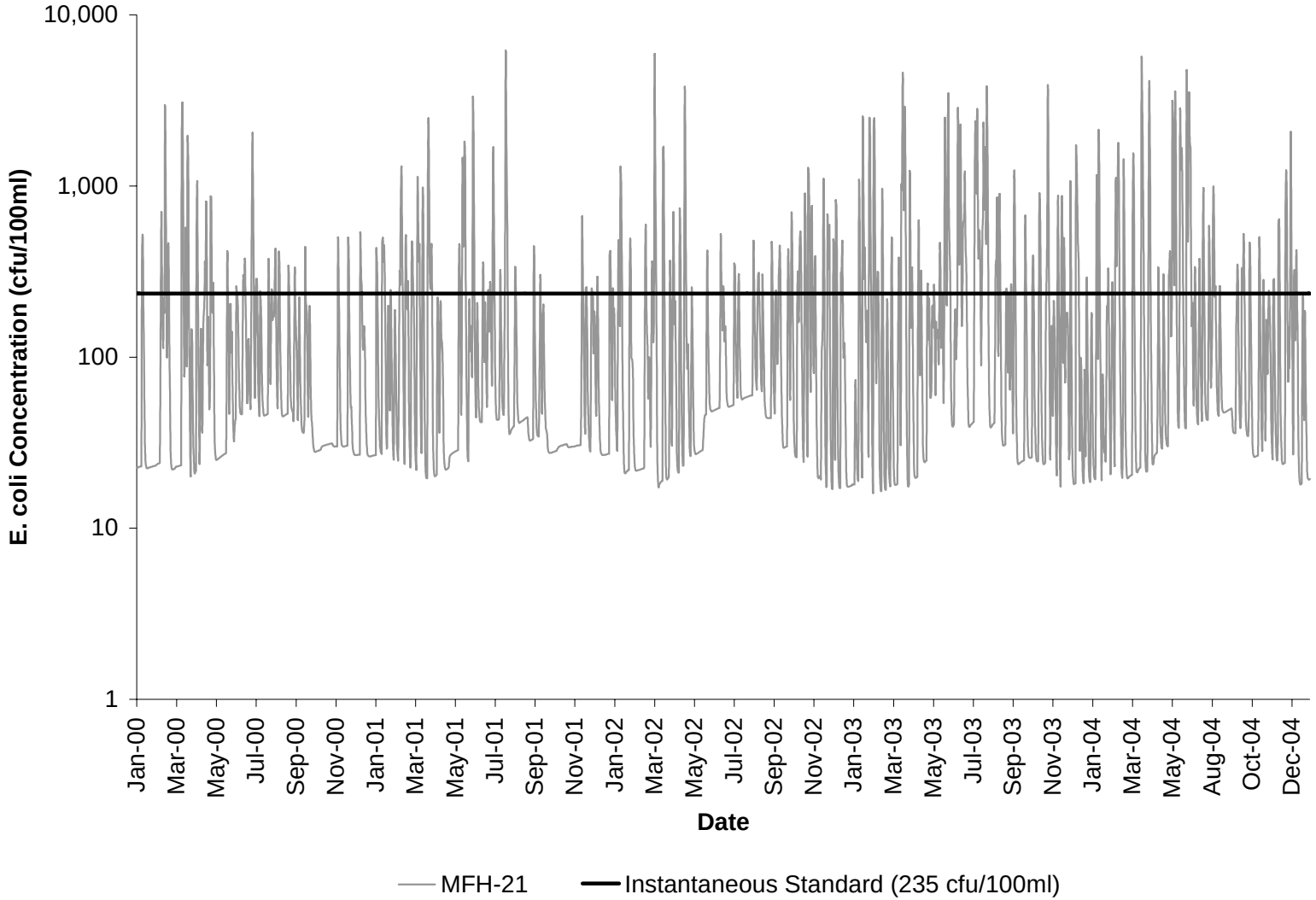


Figure 7.7. Daily average *E. coli* concentrations for subwatershed MFH-21 in Middle Fork Holston River (VAS-O04R-01) watershed.

7.1.2.4 Middle Fork Holston River (VAS-O05R-06)

Figure 7.8 shows the monthly geometric mean for each subwatershed in relation to the monthly geometric mean (126 cfu/100mL) standard. Average daily *E. coli* concentrations at the impairment outlet were compared to the single sample maximum standard of 235 cfu/100 mL (Figure 7.9). Subwatershed 26 was used for comparison of modeled concentrations to water quality standards for the Middle Fork Holston River (VAS-O05R-06) impairment.

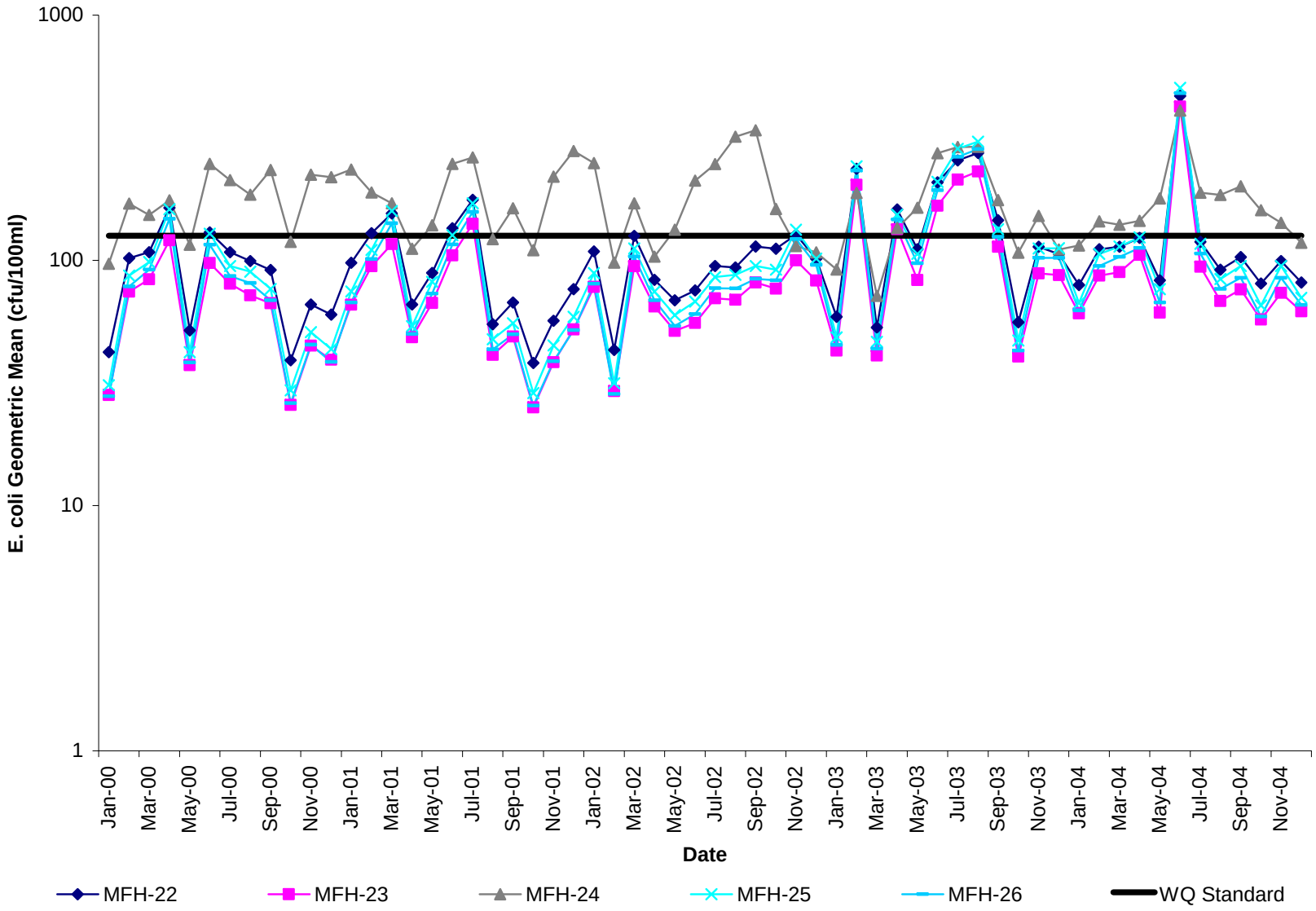


Figure 7.8. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-22 to MFH-26 in the Middle Fork Holston River (VAS-O05R-06) watershed.

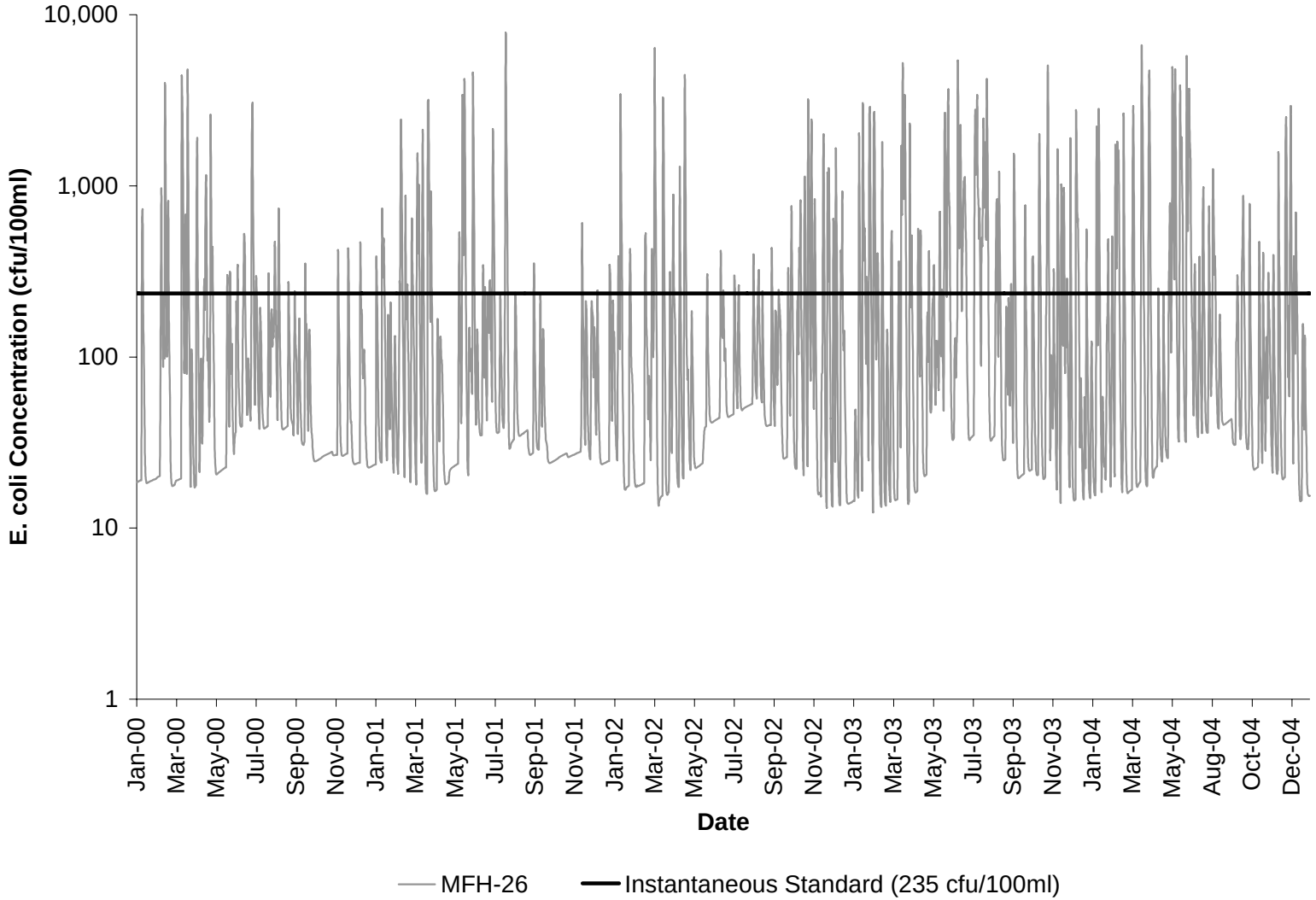


Figure 7.9. Daily average E. coli concentrations for subwatershed MFH-26 in Middle Fork Holston River (VAS-O05R-06) watershed.

7.1.2.5 Middle Fork Holston River (VAS-O05R-05)

Figure 7.10 shows the monthly geometric mean for each subwatershed in relation to the monthly geometric mean (126 cfu/100mL) standard. Average daily *E. coli* concentrations at the impairment outlet were compared to the single sample maximum standard of 235 cfu/100 mL (Figure 7.11). Subwatershed 3 was used for comparison of modeled concentrations to water quality standards for the Middle Fork Holston River (VAS-O05R-05) impairment.

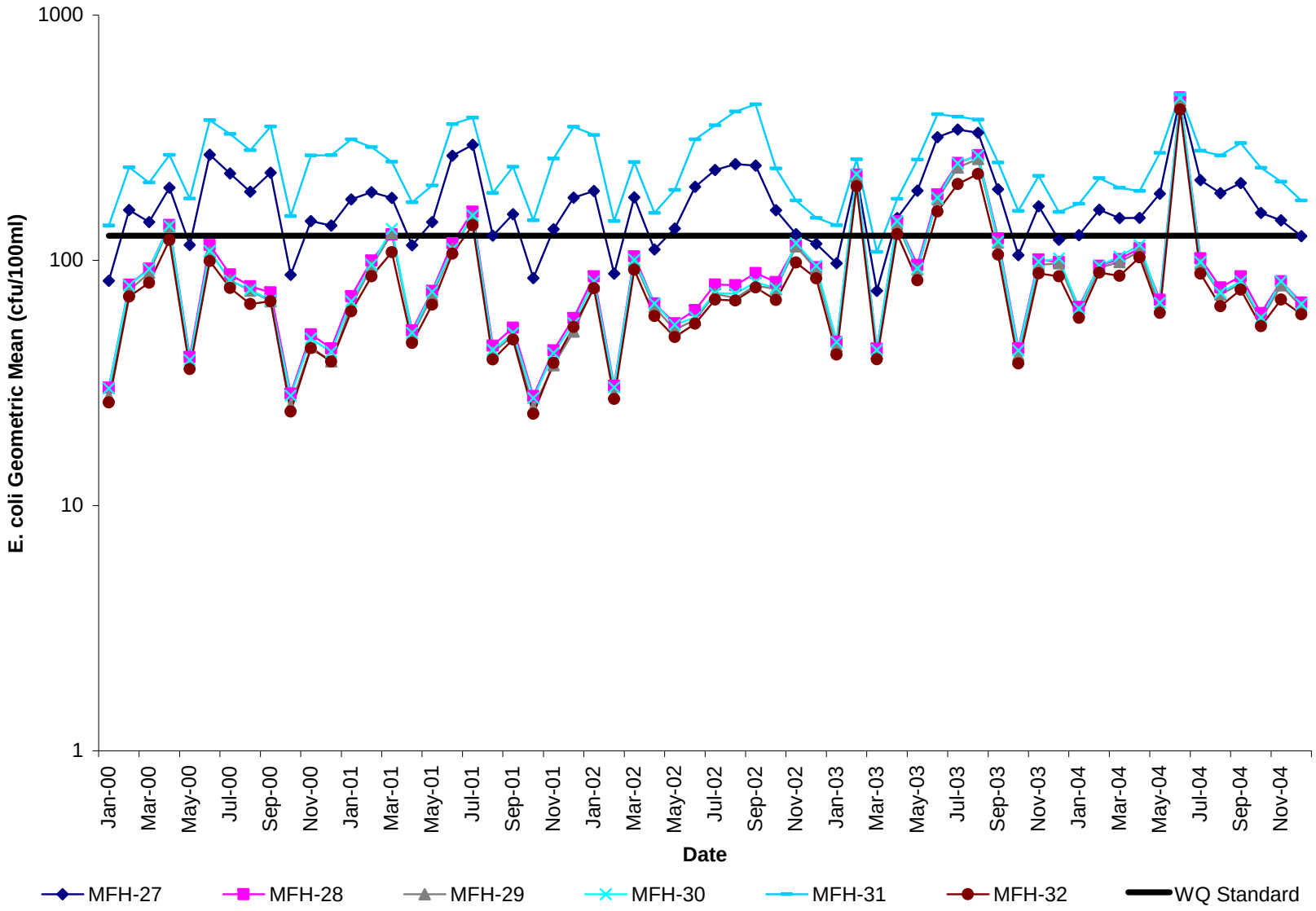


Figure 7.10. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds MFH-27 to MFH-32 in the Middle Fork Holston River (VAS-O05R-05) watershed.

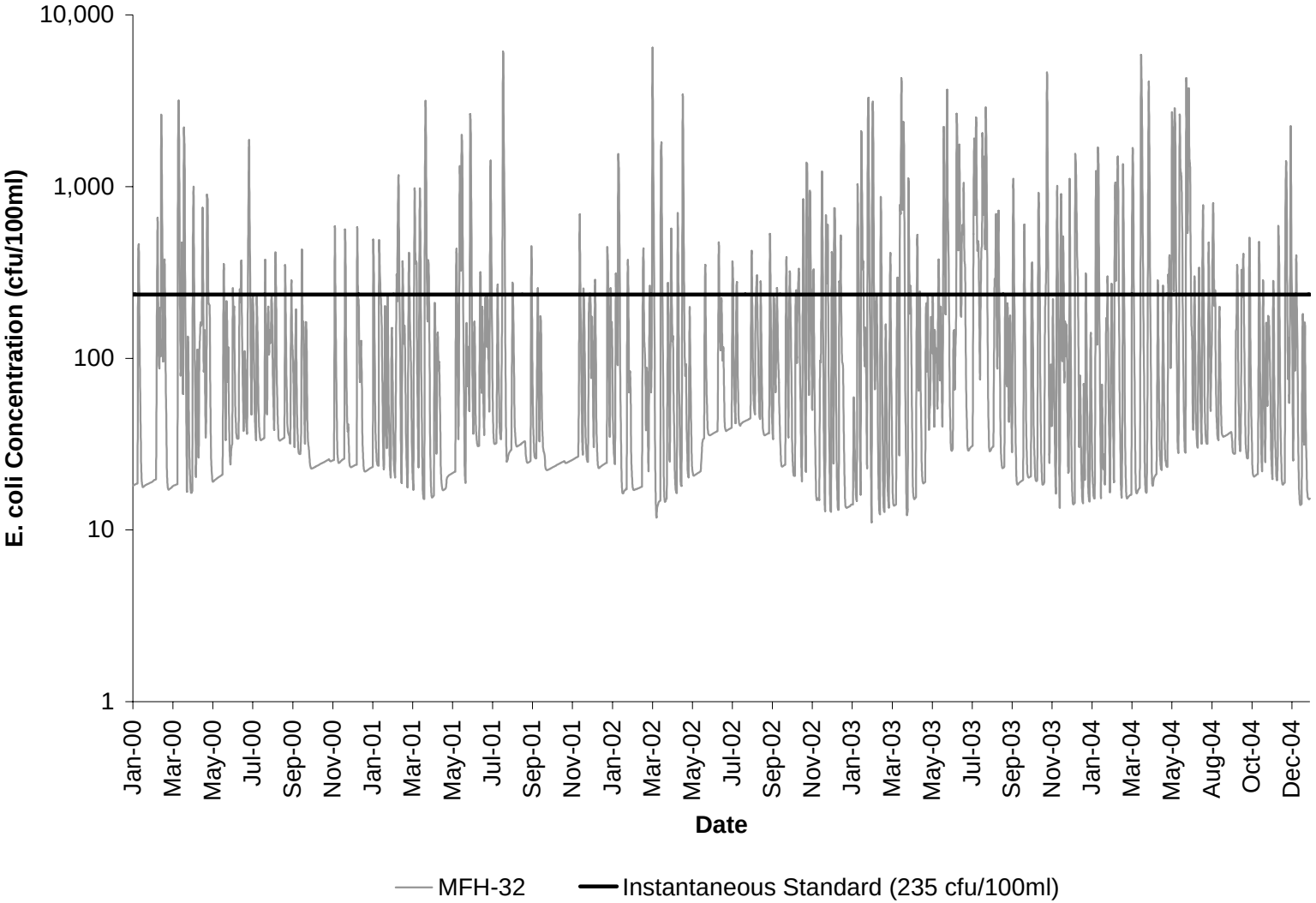


Figure 7.11. Daily average *E. coli* concentrations for subwatershed MFH-32 in Middle Fork Holston River (VAS-O05R-05) watershed.

7.1.3 Impact Analysis

Analyses were conducted to assess the impact of unknown variability in source allocations on changes in direct and land-based loads. Model output from existing conditions was set as the comparative base to adjustments in direct and land-based loads of +100%, +10%, -10%, and -100% of the base value. Model simulations were made for the period January 2000 to December 2004, corresponding with the period used in the allocation scenarios. Percent difference in monthly geometric mean *E. coli* concentration and maximum daily average *E. coli* concentration per month for each direct and land-based load change to base value was calculated and plotted. Analysis results were used to assess the affects of future growth on the rate of water quality standards exceedance.

7.1.3.1 Middle Fork Holston River (VAS-O03R-01)

Percent difference in monthly geometric mean *E. coli* concentration for each direct and land-based load change to base value was calculated and plotted in Figures 7.12 and 7.13, respectively. Figures 7.14 and 7.15, respectively, show the percent difference in the maximum daily average *E. coli* concentration per month for each direct load and land load change to base value. It is apparent by comparing Figure 7.12 with Figure 7.13 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 7.14 to Figure 7.15 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected by increasing directly deposited loads during lower flow periods.

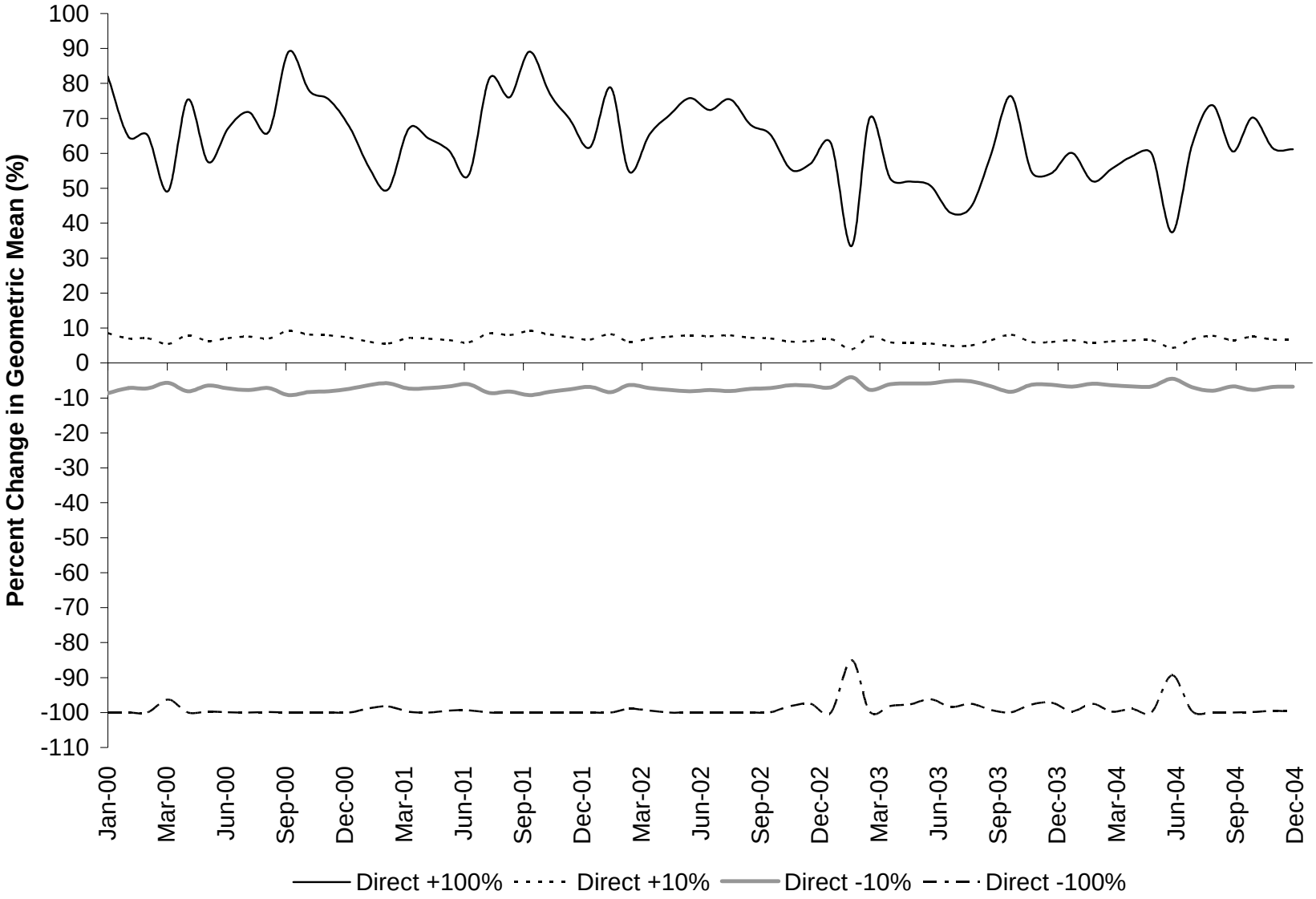


Figure 7.12. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-03) of Middle Fork Holston River (VAS-O03R-01) watershed, as affected by direct load changes.

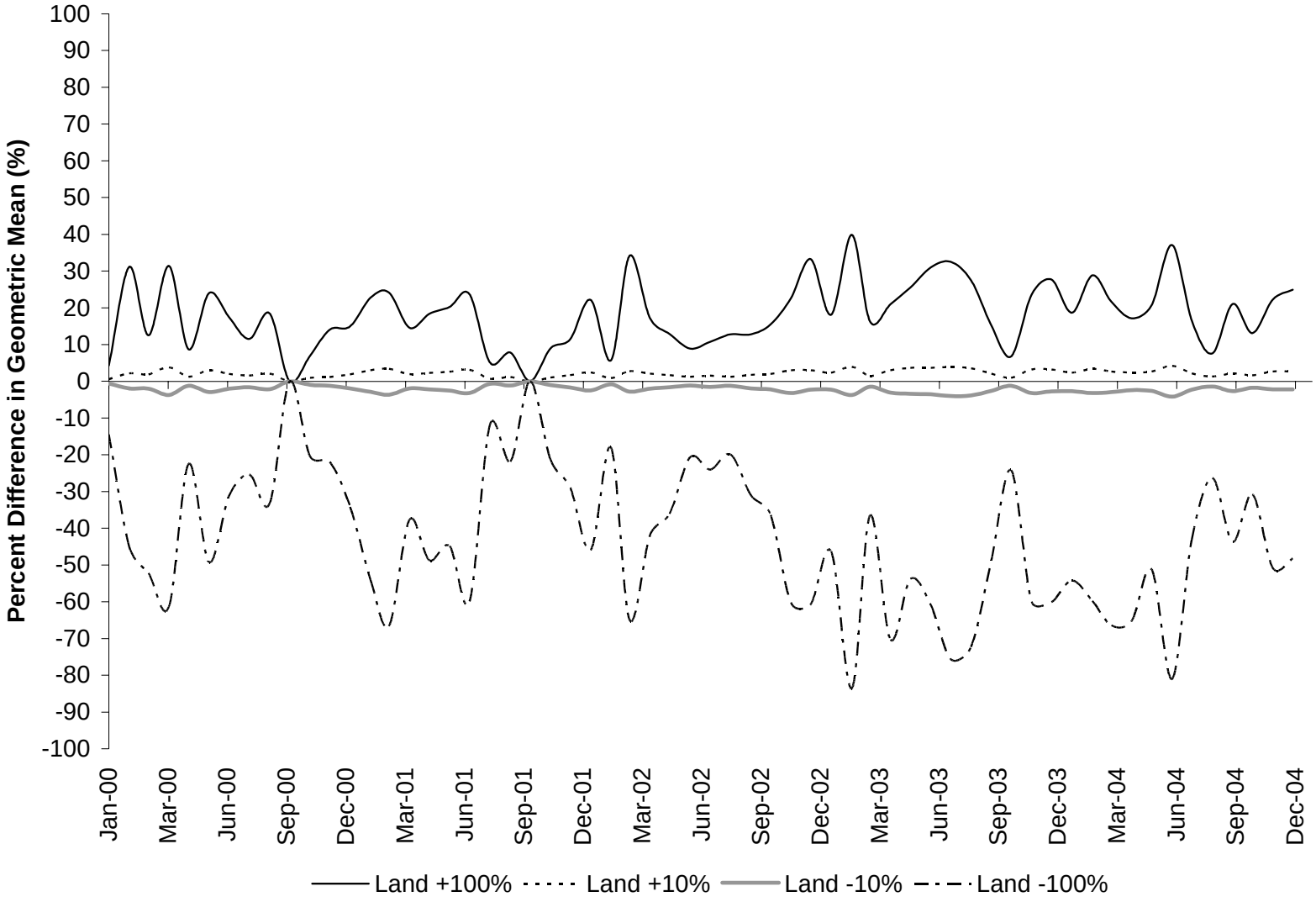


Figure 7.13. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-03) of Middle Fork Holston River (VAS-O03R-01) watershed, as affected by land-based load changes.

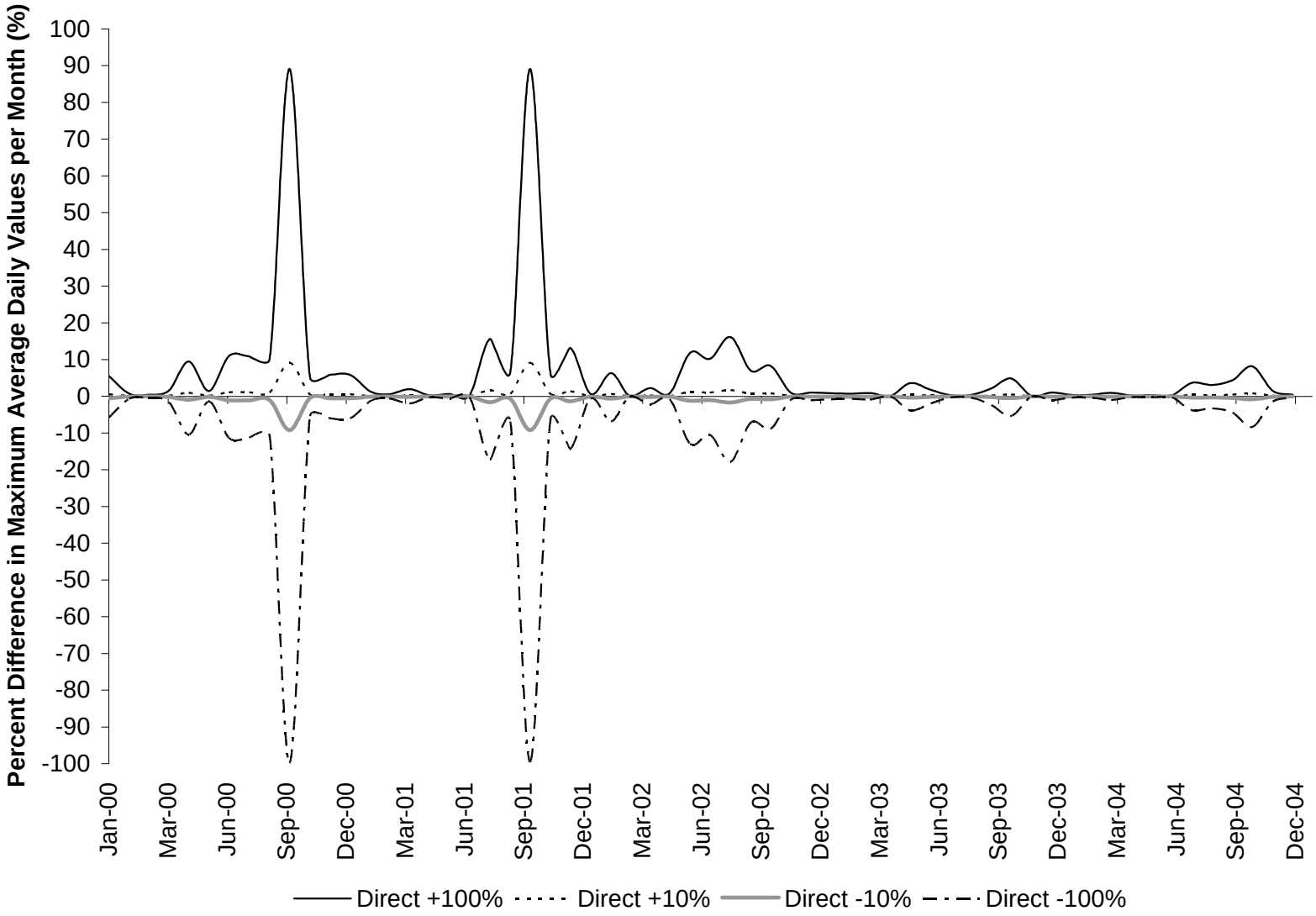


Figure 7.14. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-03) of Middle Fork Holston River (VAS-O03R-01) watershed, as affected by direct load changes.

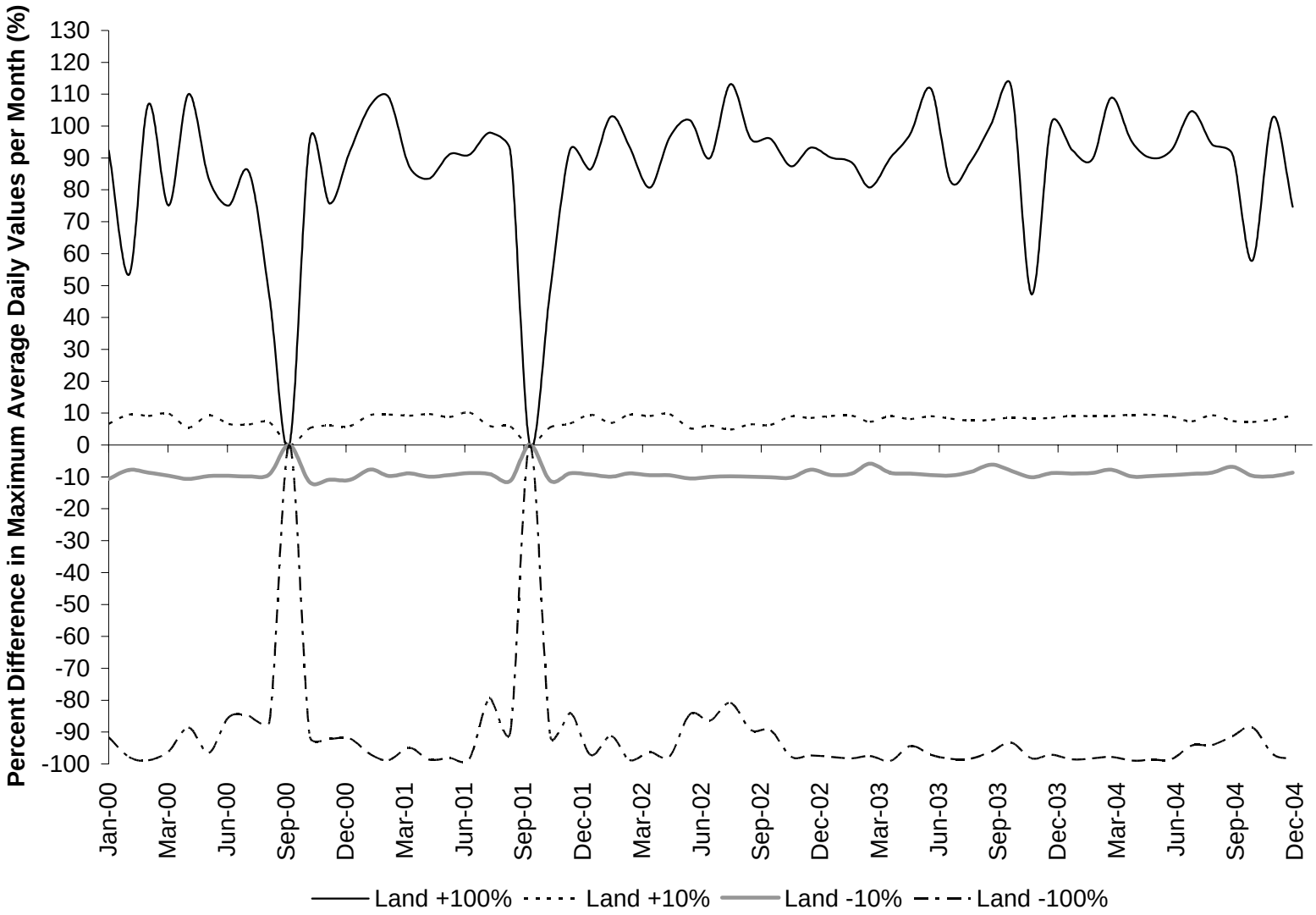


Figure 7.15. Results of impact analysis on maximum daily average E. coli concentration per month at outlet (subwatershed MFH-03) of Middle Fork Holston River (VAS-O03R-01) watershed, as affected by land-based load changes.

7.1.3.2 Middle Fork Holston River (VAS-O03R-02)

Percent difference in monthly geometric mean *E. coli* concentration for each direct and land-based load change to base value was calculated and plotted in Figures 7.16 and 7.17, respectively. Figures 7.18 and 7.19, respectively, show the percent difference in the maximum daily average *E. coli* concentration per month for each direct load and land load change to base value. It is apparent by comparing Figure 7.16 with Figure 7.17 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 7.18 to Figure 7.19 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected by increasing directly deposited loads during lower flow periods.

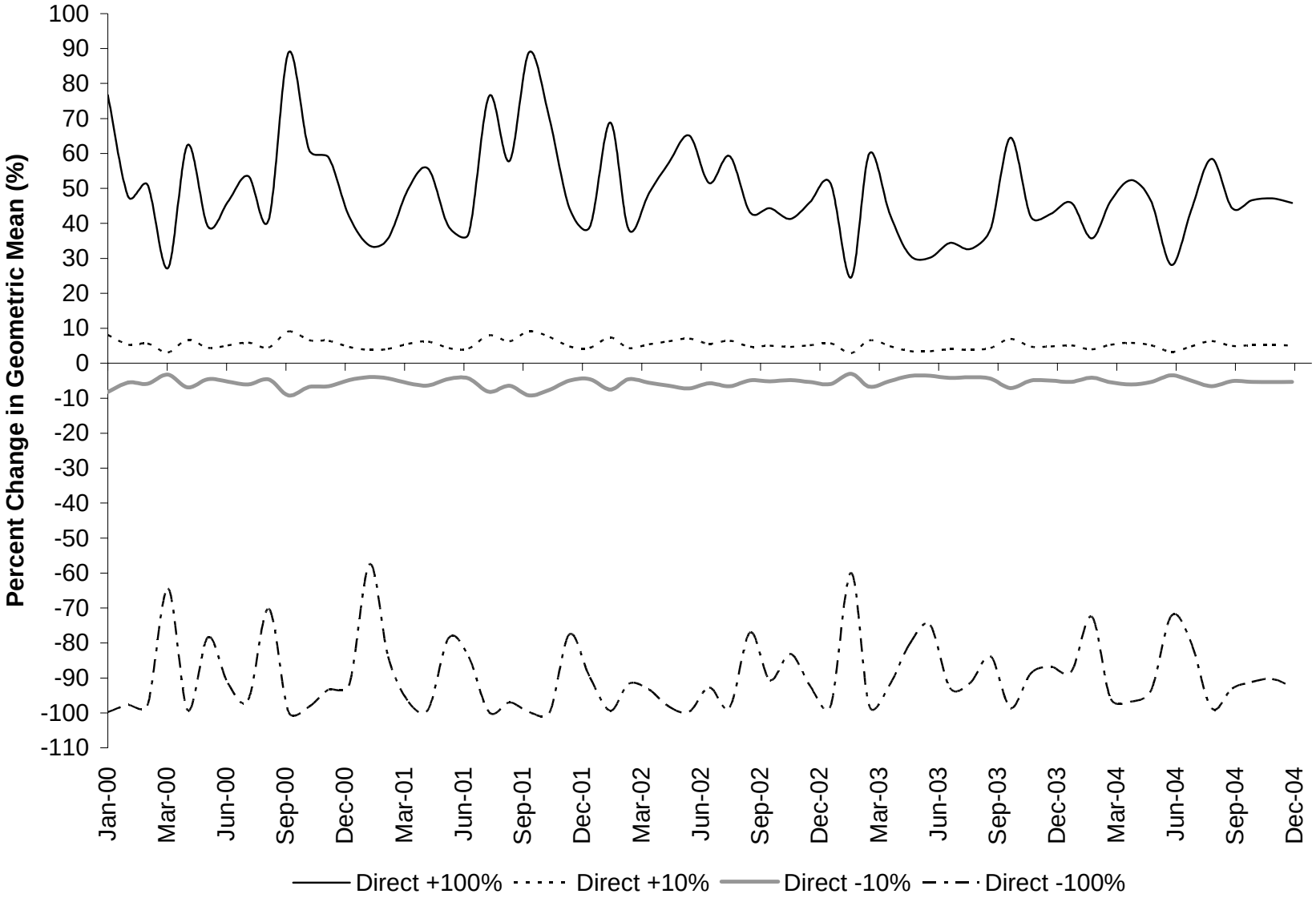


Figure 7.16. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-14) of Middle Fork Holston River (VAS-O03R-02) watershed, as affected by direct load changes.

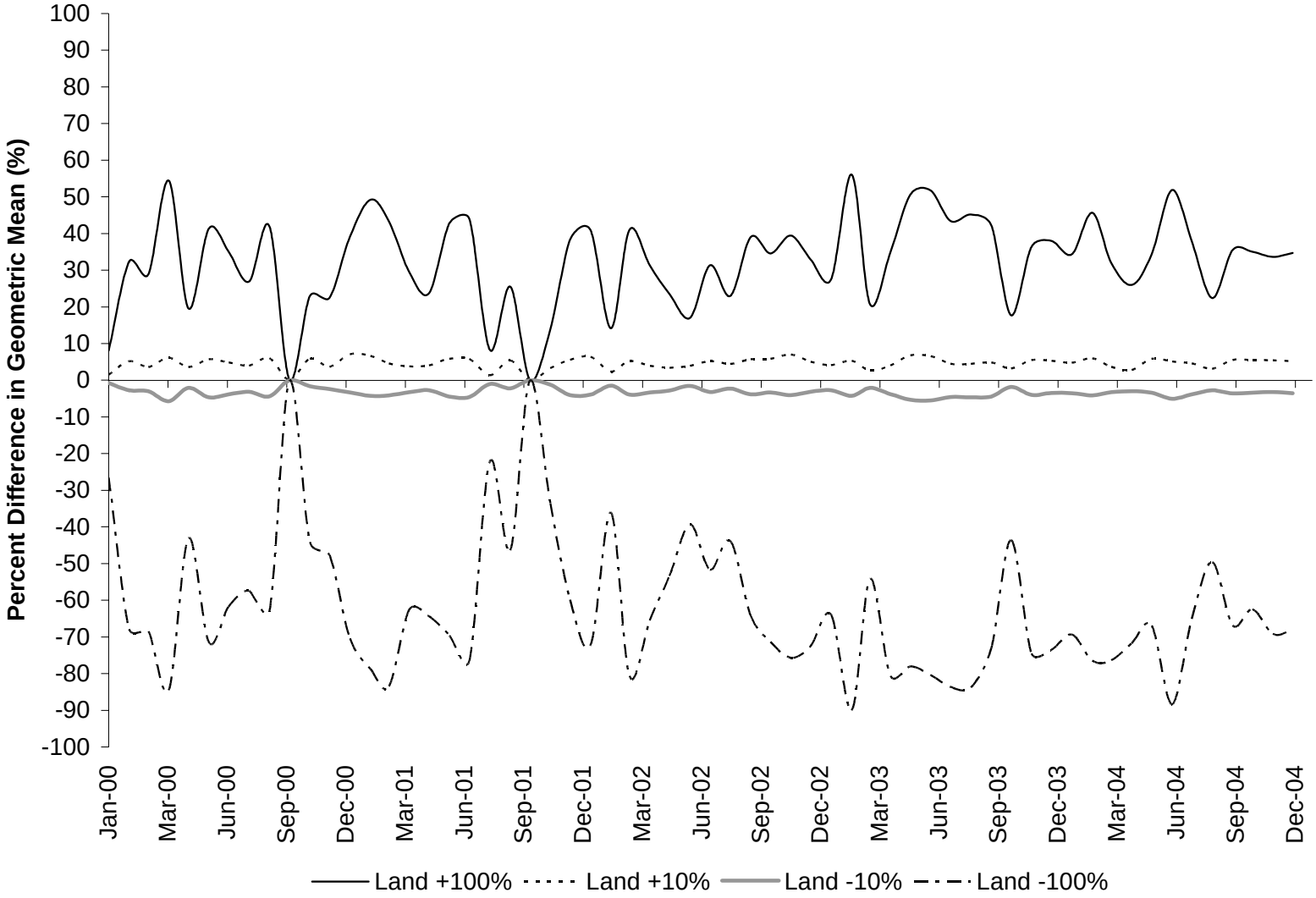


Figure 7.17. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-14) of Middle Fork Holston River (VAS-O03R-02) watershed, as affected by land-based load changes.

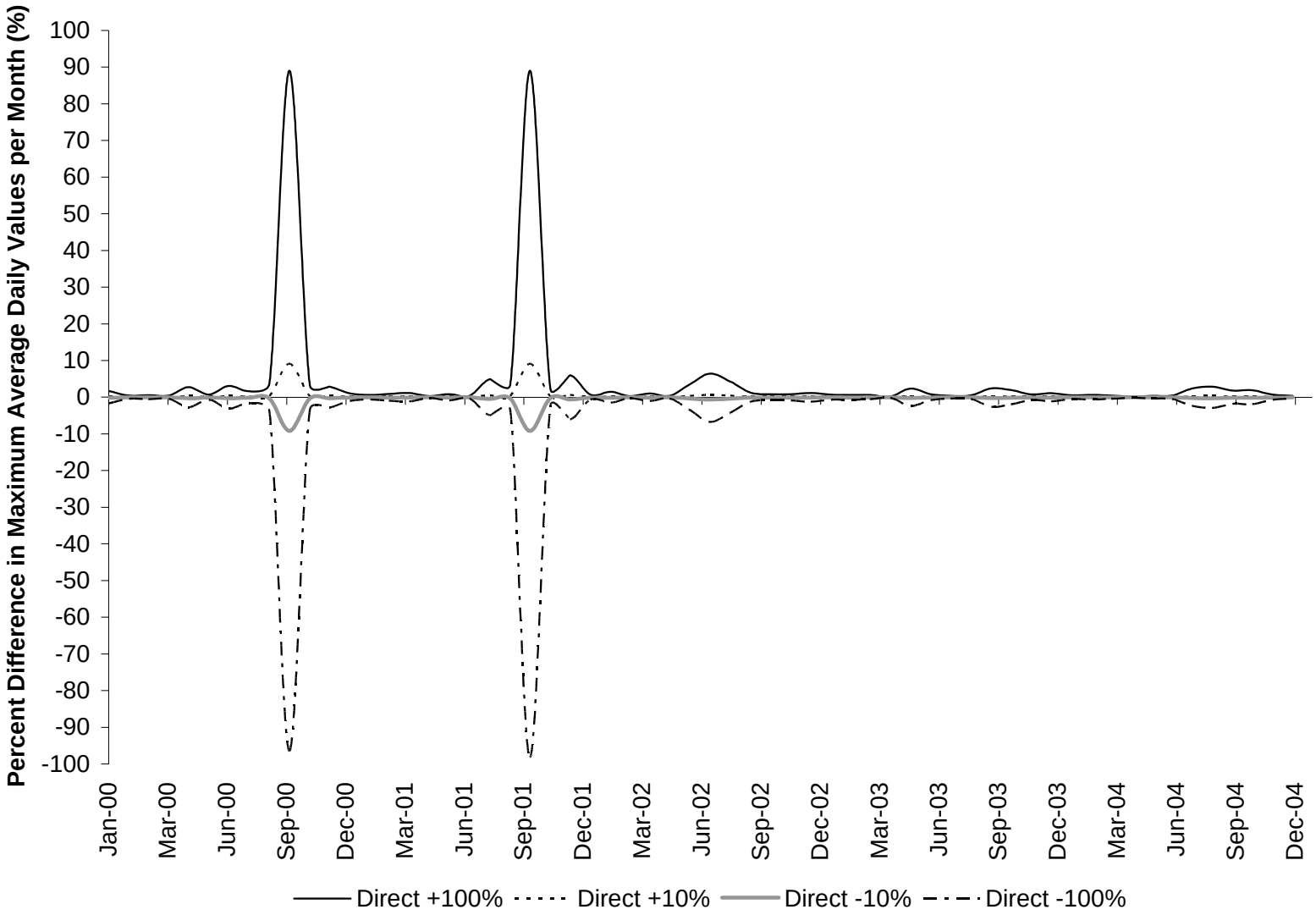


Figure 7.18. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-14) of Middle Fork Holston River (VAS-O03R-02) watershed, as affected by direct load changes.

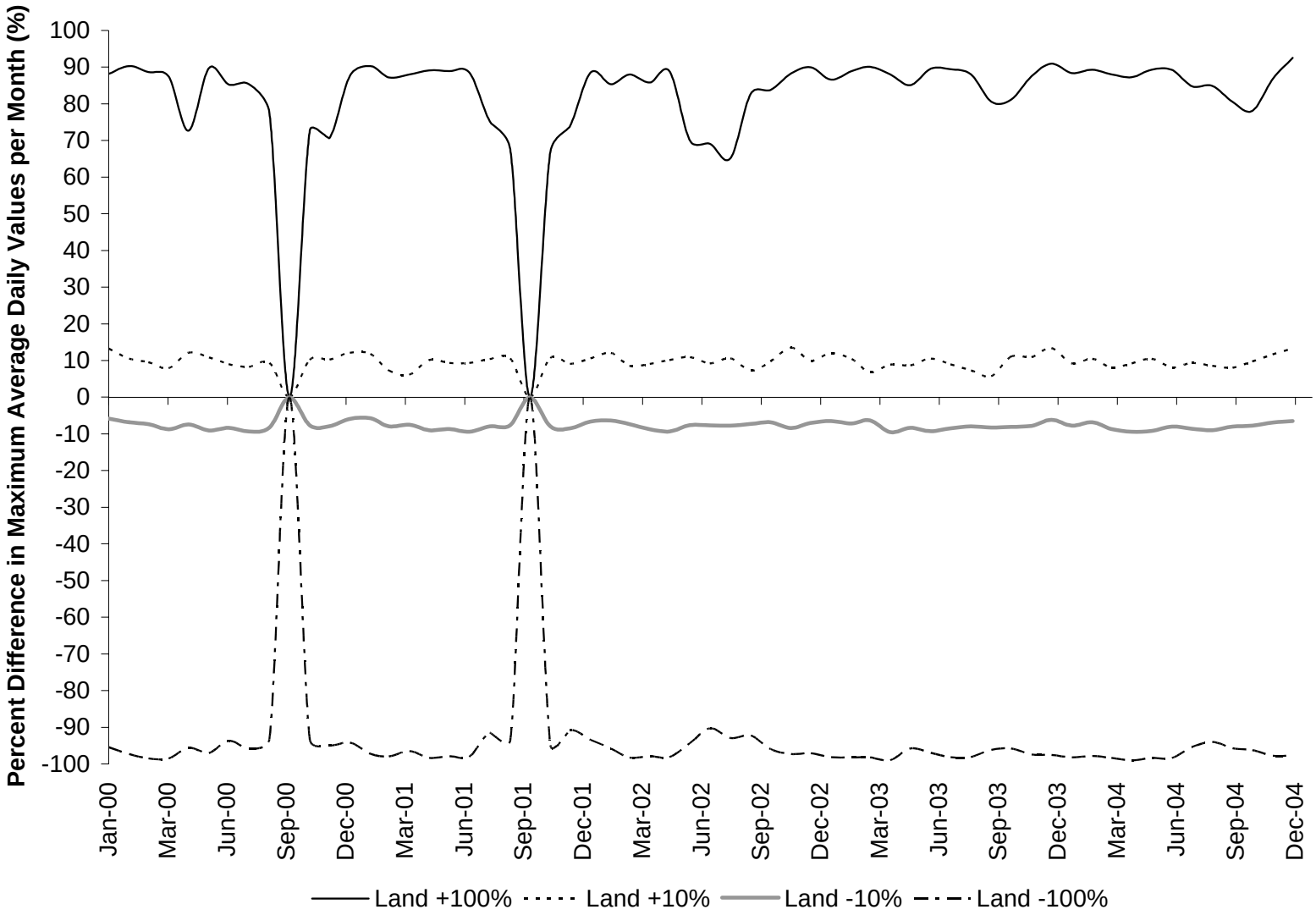


Figure 7.19. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-14) of Middle Fork Holston River (VAS-O03R-02) watershed, as affected by land-based load changes.

7.1.3.3 Middle Fork Holston River (VAS-O04R-01)

Percent difference in monthly geometric mean *E. coli* concentration for each direct and land-based load change to base value was calculated and plotted in Figures 7.20 and 7.21, respectively. Figures 7.22 and 7.23, respectively, show the percent difference in the maximum daily average *E. coli* concentration per month for each direct load and land load change to base value. It is apparent by comparing Figure 7.20 with Figure 7.21 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 7.22 to Figure 7.23 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected by increasing directly deposited loads during lower flow periods.

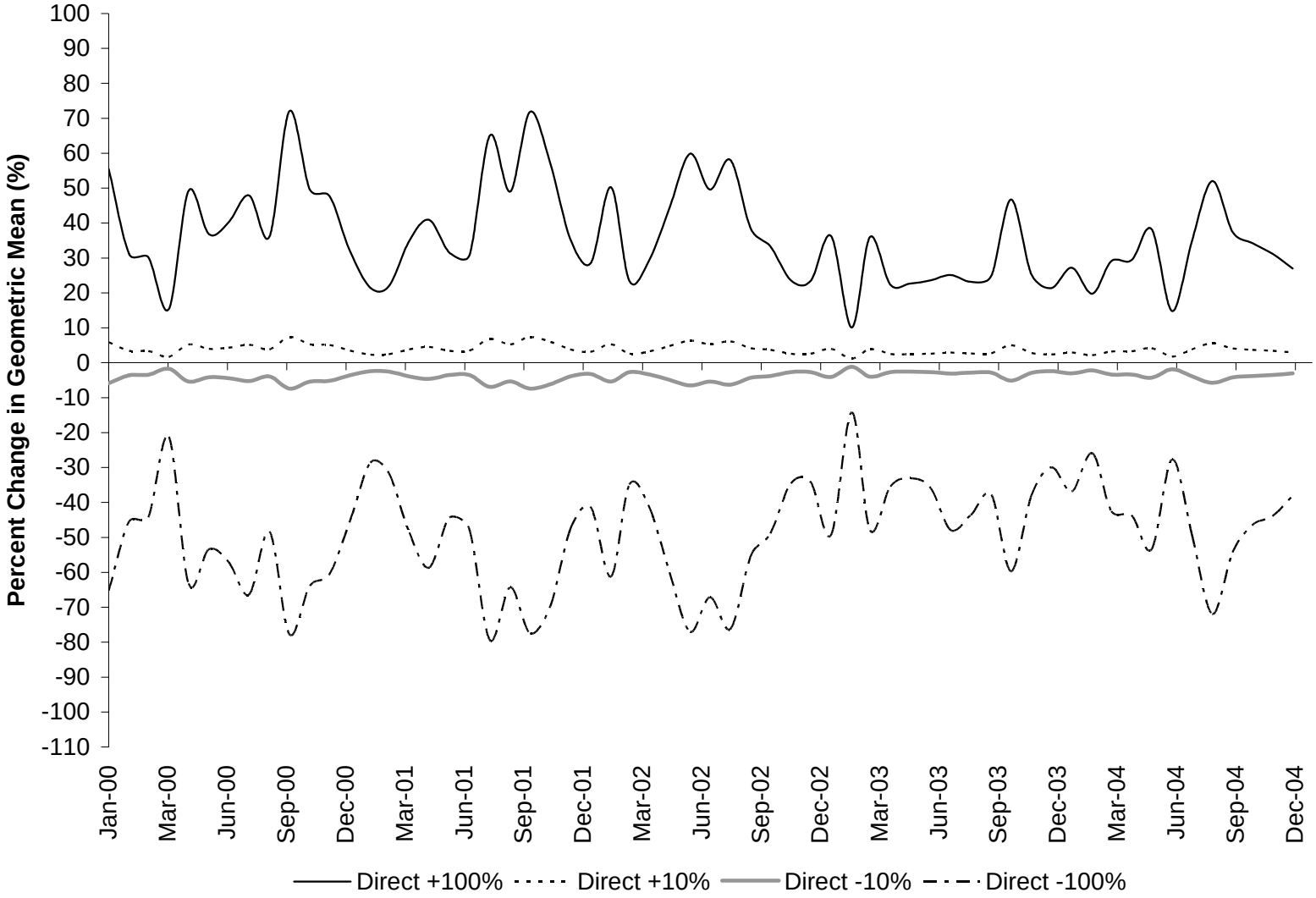


Figure 7.20. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-21) of Middle Fork Holston River (VAS-O04R-01) watershed, as affected by direct load changes.

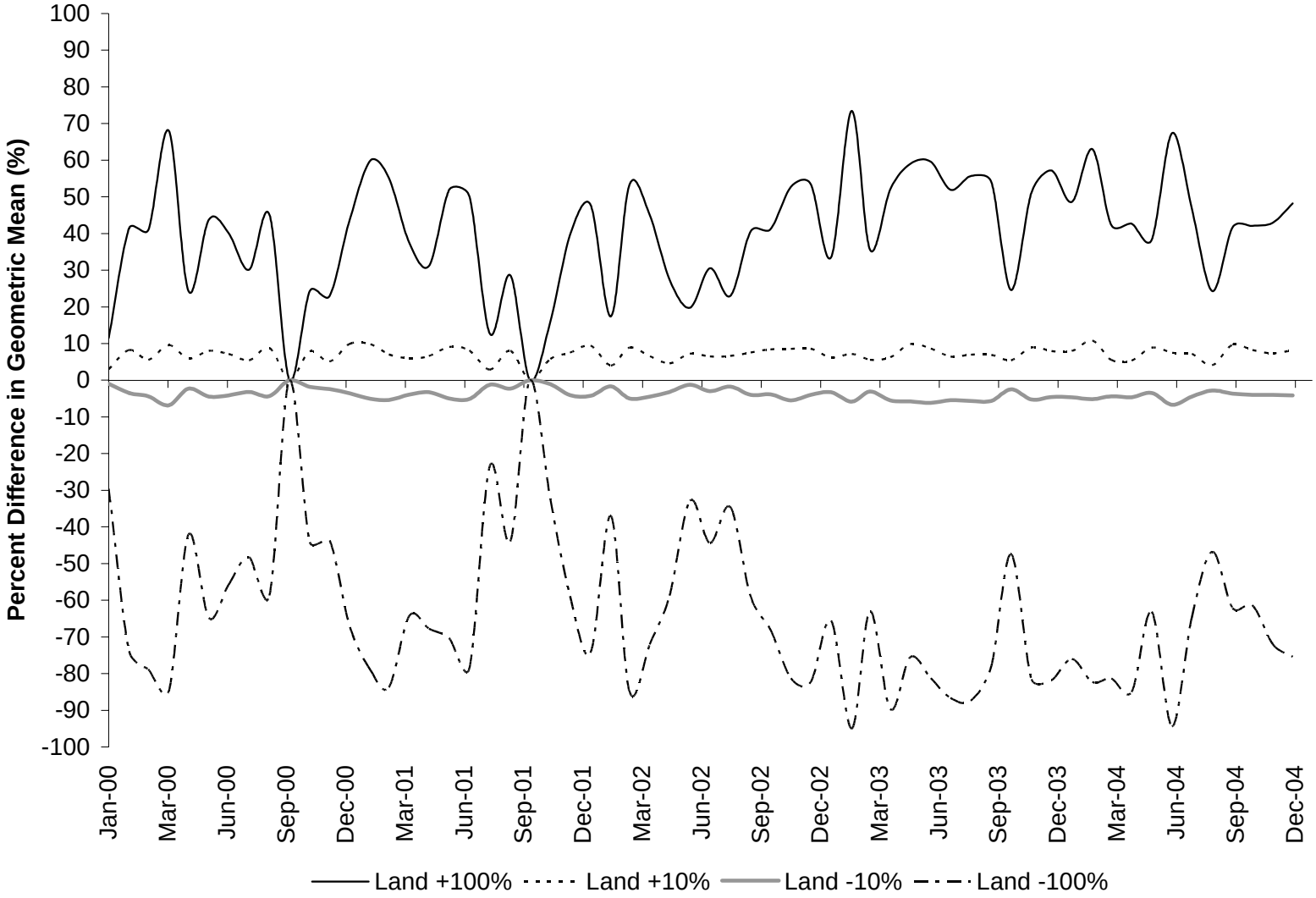


Figure 7.21. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-21) of Middle Fork Holston River (VAS-O04R-01) watershed, as affected by land-based load changes.

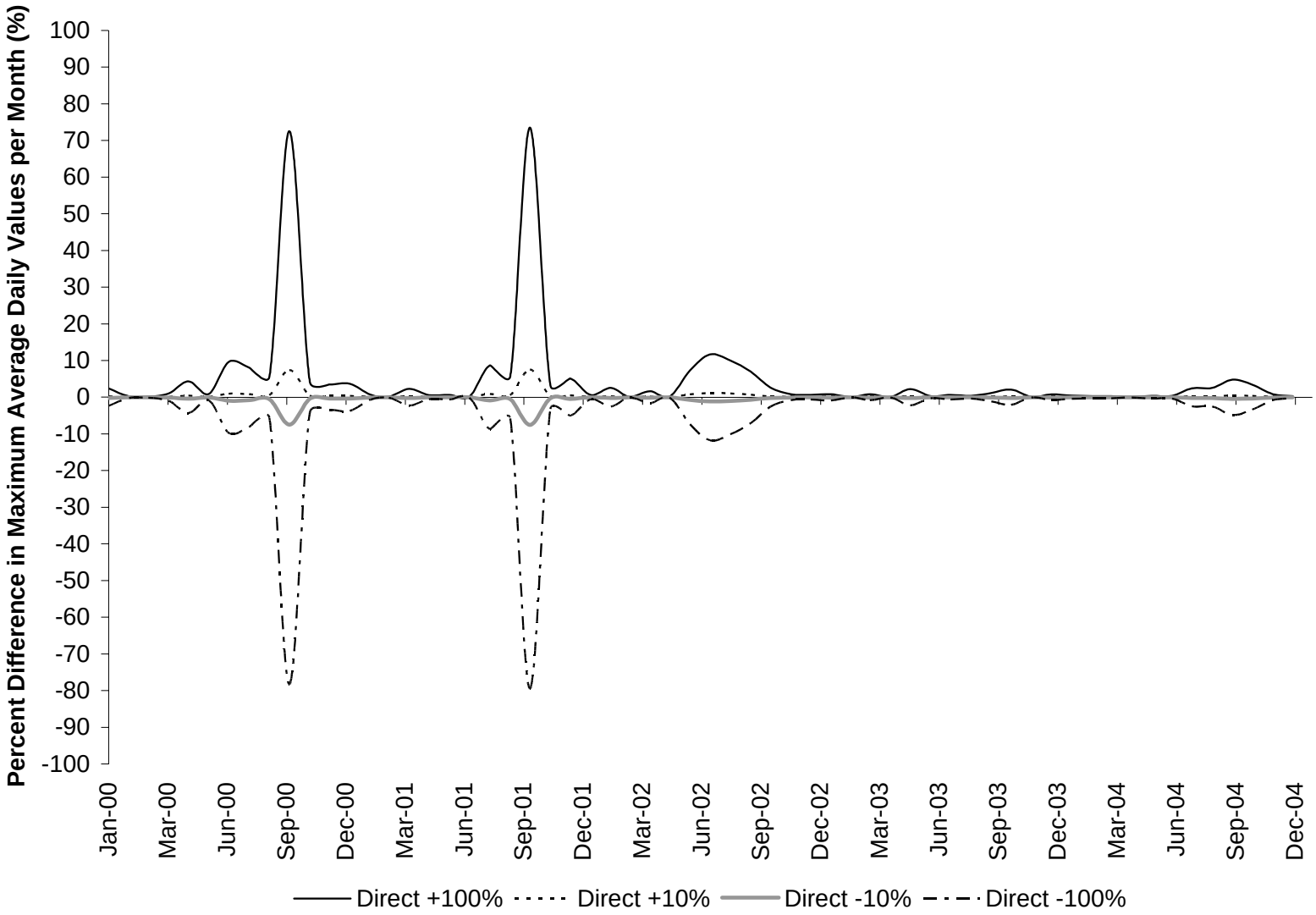


Figure 7.22. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-21) of Middle Fork Holston River (VAS-O04R-01) watershed, as affected by direct load changes.

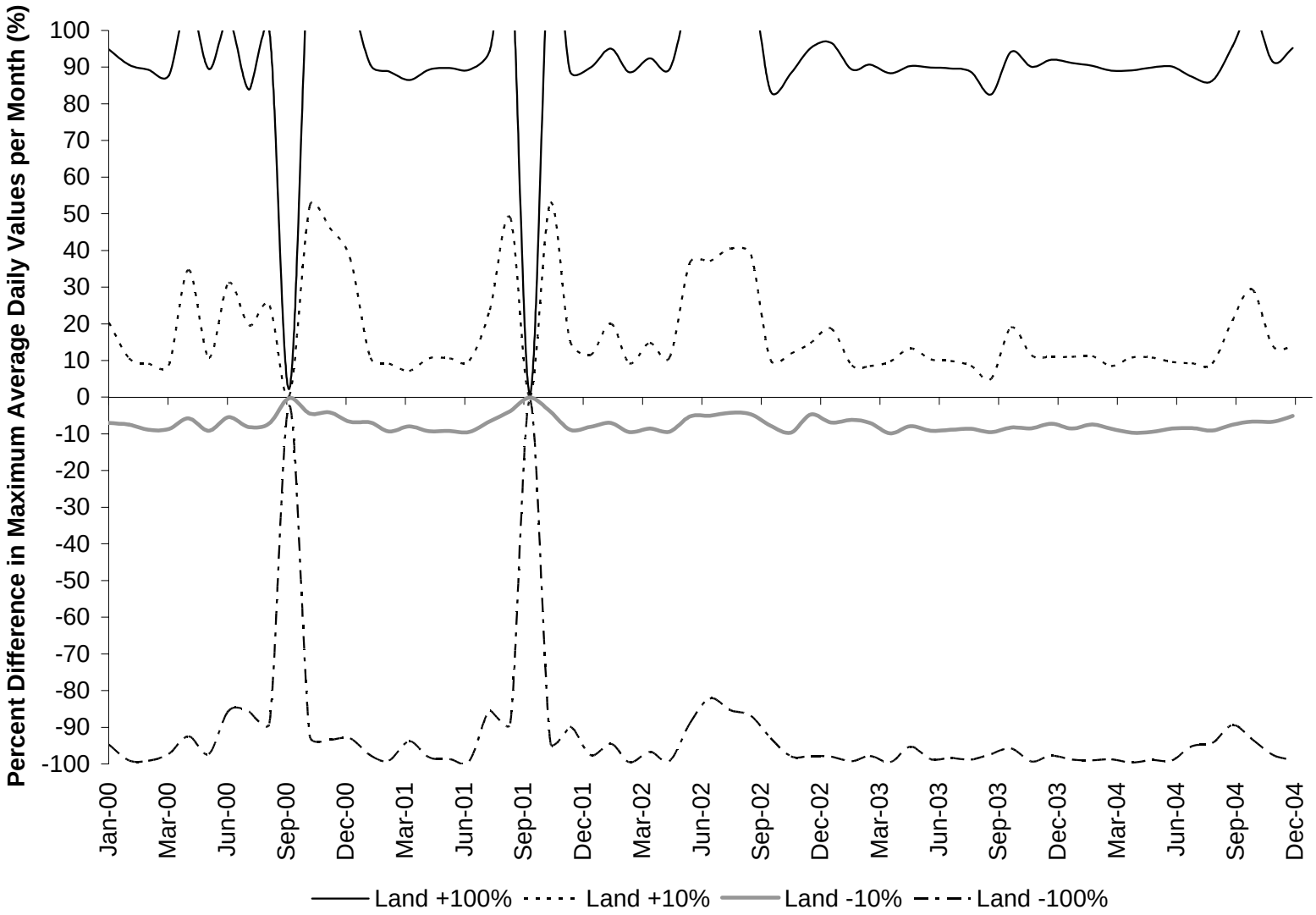


Figure 7.23. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-21) of Middle Fork Holston River (VAS-O04R-01) watershed, as affected by land-based load changes.

7.1.3.4 Middle Fork Holston River (VAS-O05R-06)

Percent difference in monthly geometric mean *E. coli* concentration for each direct and land-based load change to base value was calculated and plotted in Figures 7.24 and 7.25, respectively. Figures 7.26 and 7.27, respectively, show the percent difference in the maximum daily average *E. coli* concentration per month for each direct load and land load change to base value. It is apparent by comparing Figure 7.24 with Figure 7.25 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 7.26 to Figure 7.27 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected by increasing directly deposited loads during lower flow periods.

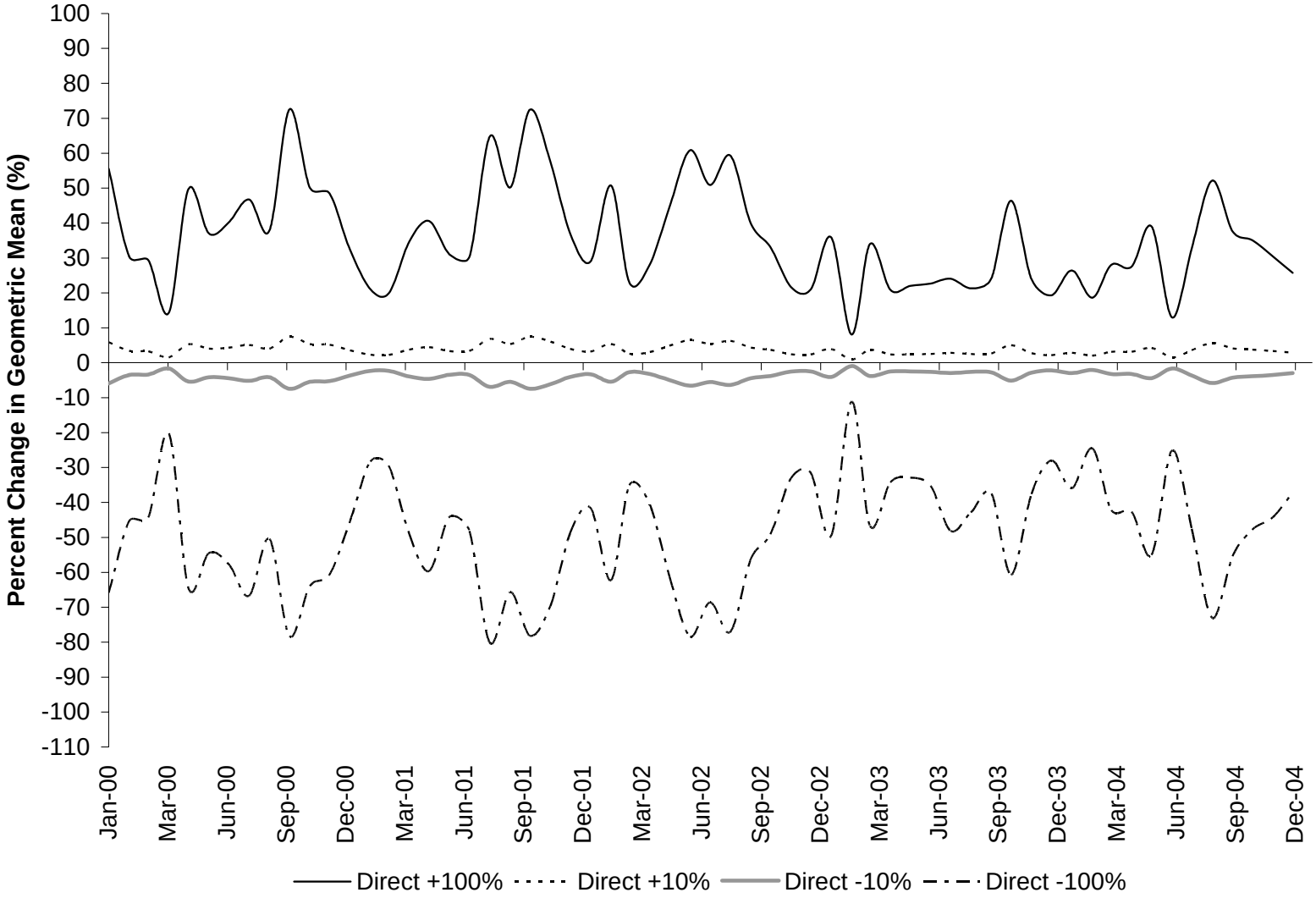


Figure 7.24. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-26) of Middle Fork Holston River (VAS-O05R-06) watershed, as affected by direct load changes.

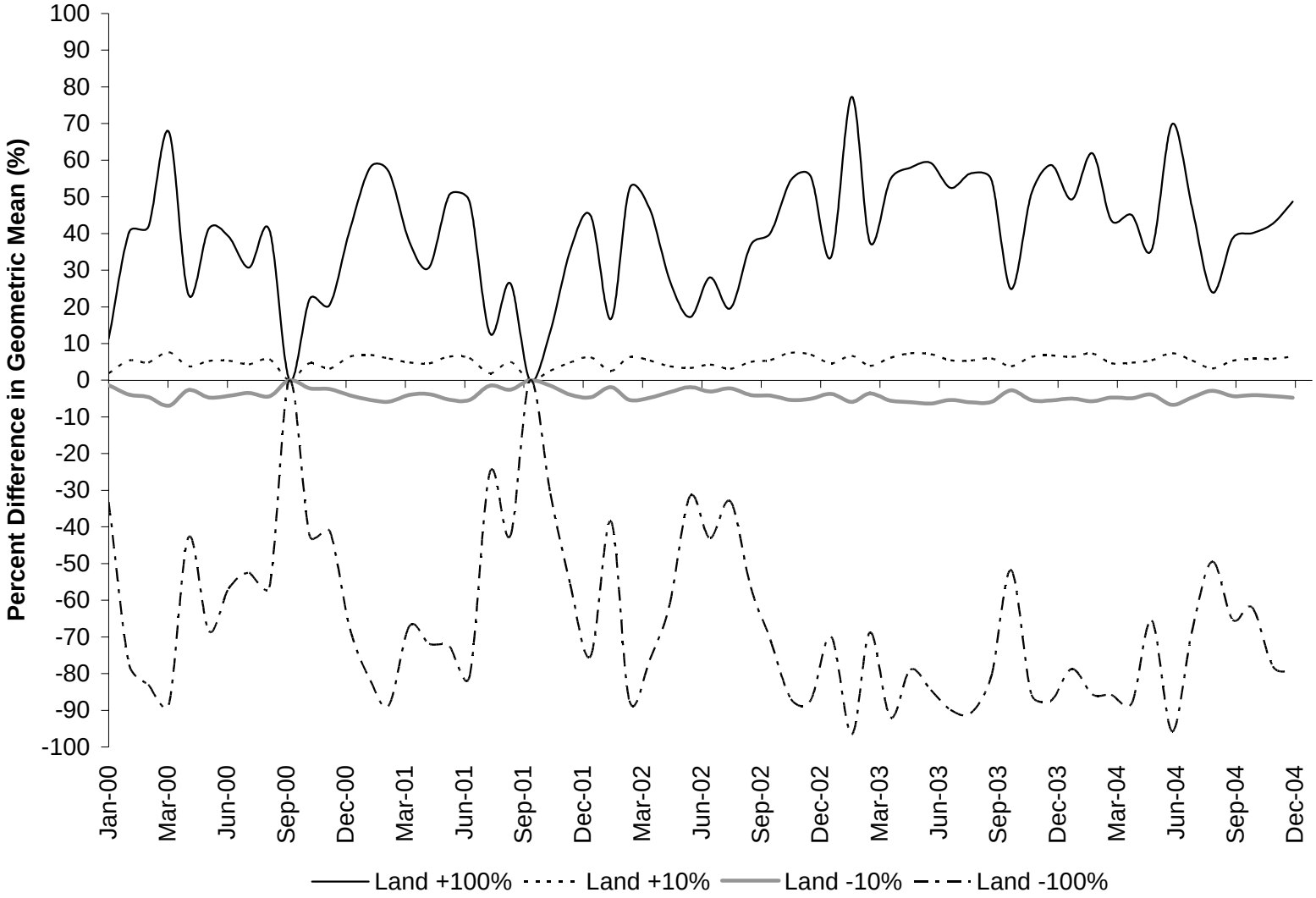


Figure 7.25. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-26) of Middle Fork Holston River (VAS-O05R-06) watershed, as affected by land-based load changes.

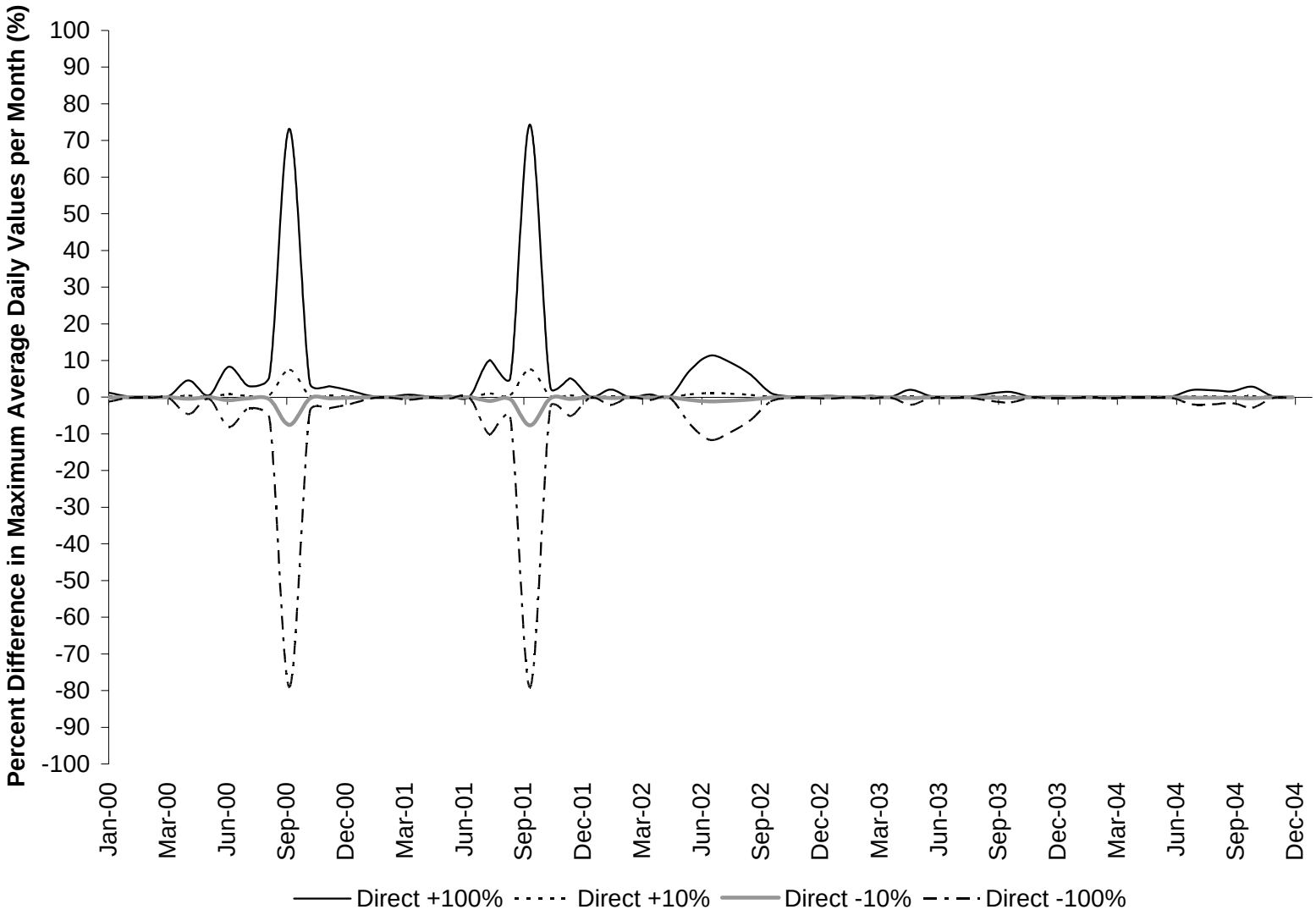


Figure 7.26. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-26) of Middle Fork Holston River (VAS-O05R-06) watershed, as affected by direct load changes.

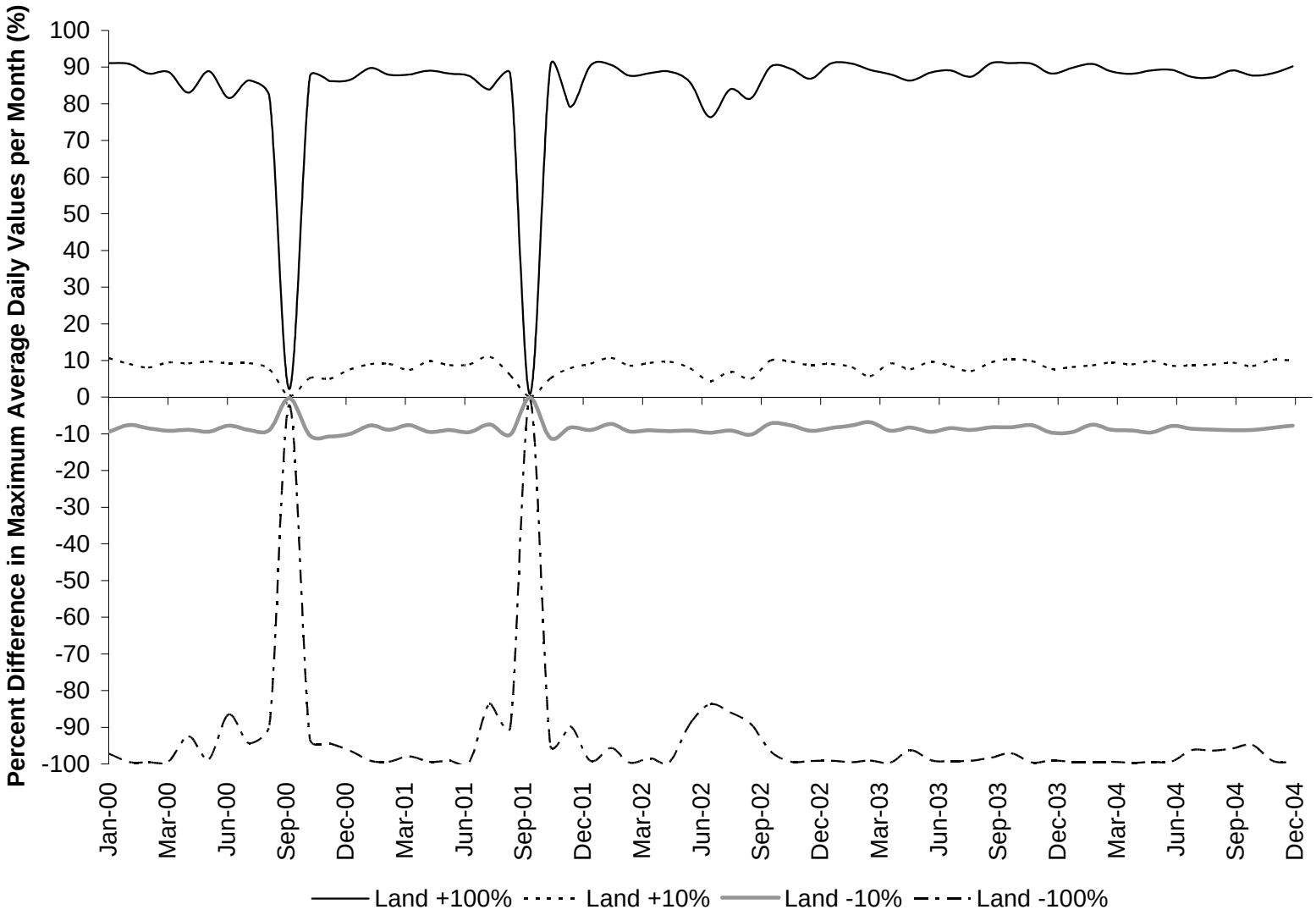


Figure 7.27. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-26) of Middle Fork Holston River (VAS-O05R-06) watershed, as affected by land-based load changes.

7.1.3.5 Middle Fork Holston River (VAS-O05R-05)

Percent difference in monthly geometric mean *E. coli* concentration for each direct and land-based load change to base value was calculated and plotted in Figures 7.28 and 7.29, respectively. Figures 7.30 and 7.31, respectively, show the percent difference in the maximum daily average *E. coli* concentration per month for each direct load and land load change to base value. It is apparent by comparing Figure 7.28 with Figure 7.29 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 7.30 to Figure 7.31 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected by increasing directly deposited loads during lower flow periods.

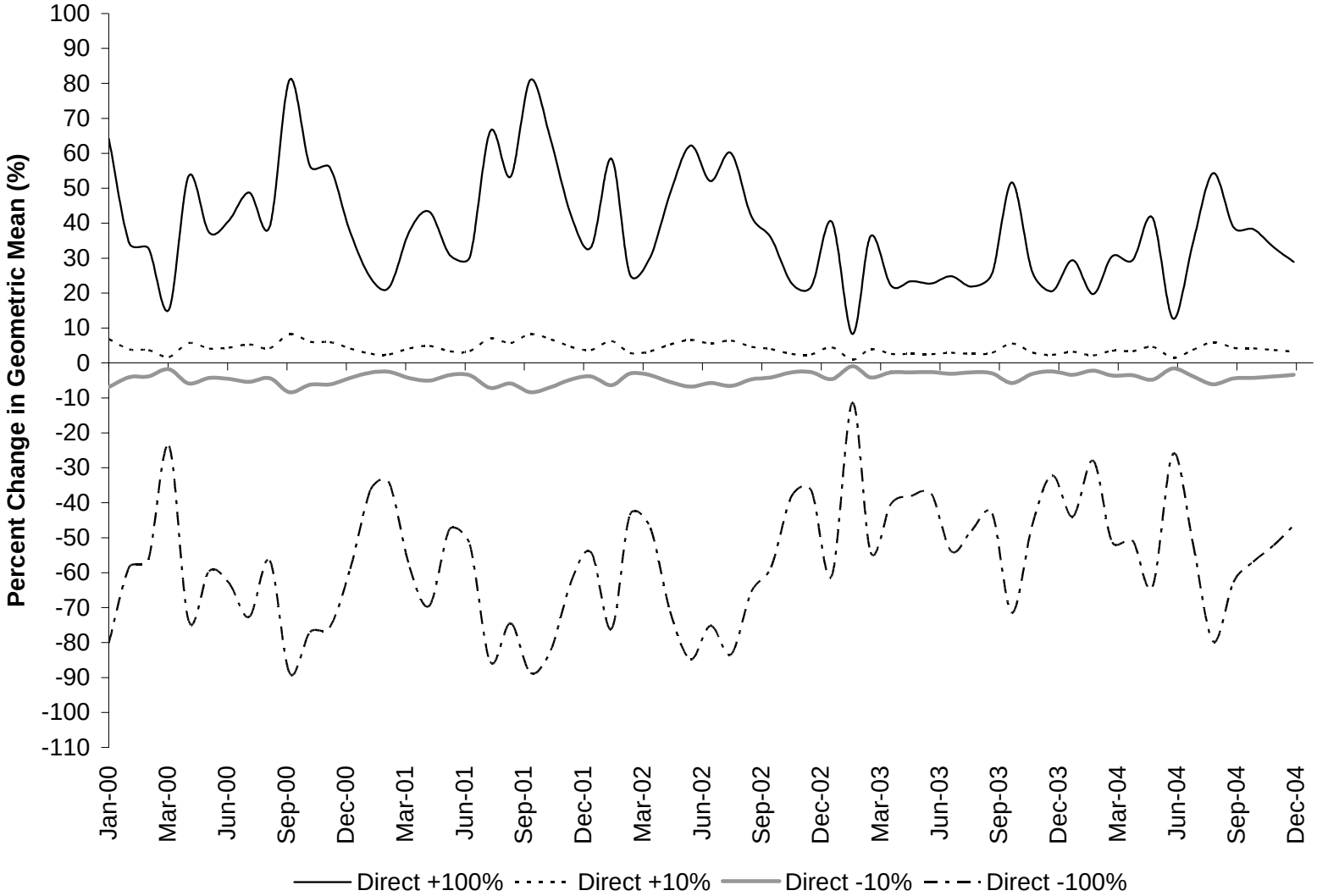


Figure 7.28. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-32) of Middle Fork Holston River (VAS-O05R-05) watershed, as affected by direct load changes.

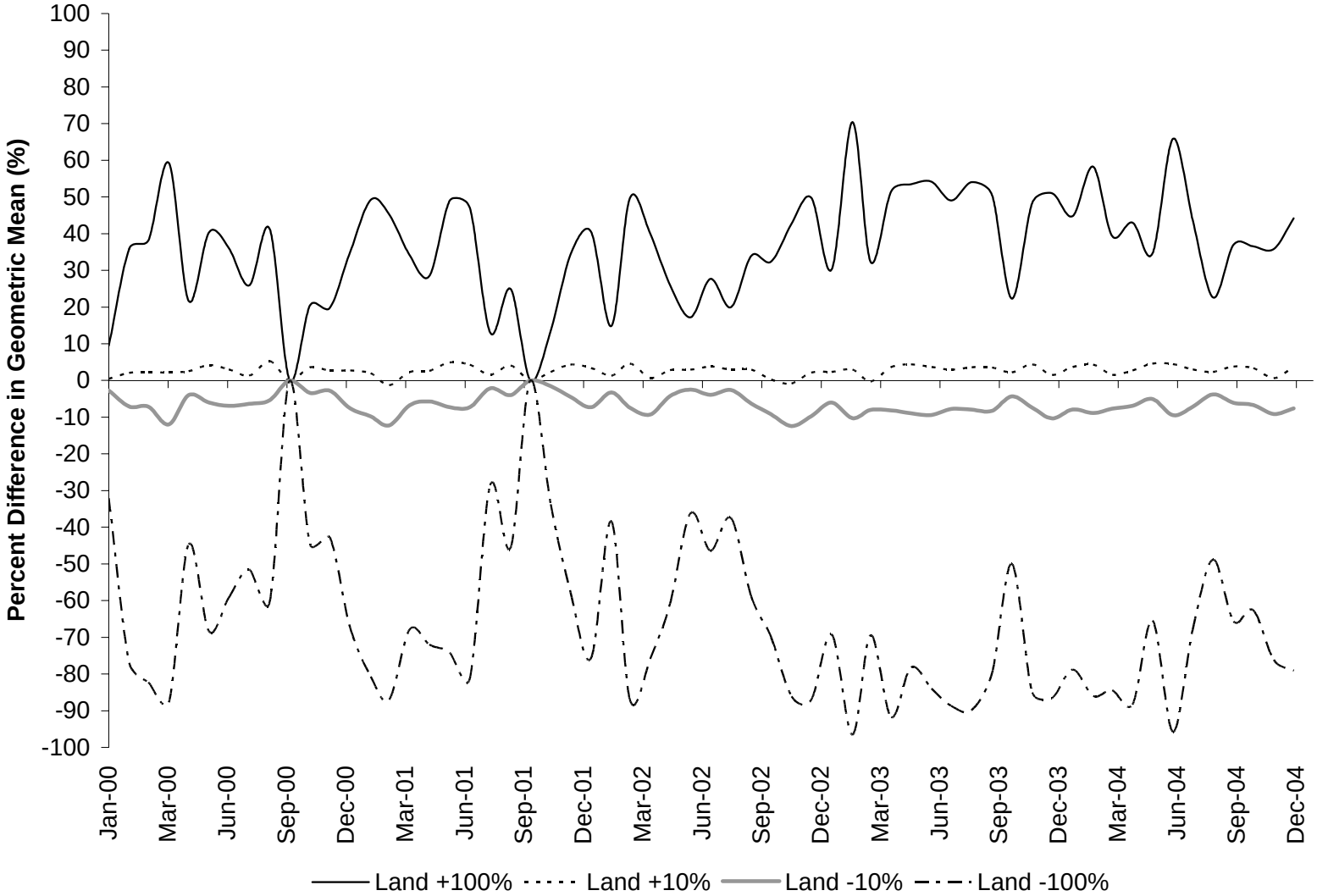


Figure 7.29. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed MFH-32) of Middle Fork Holston River (VAS-O05R-05) watershed, as affected by land-based load changes.

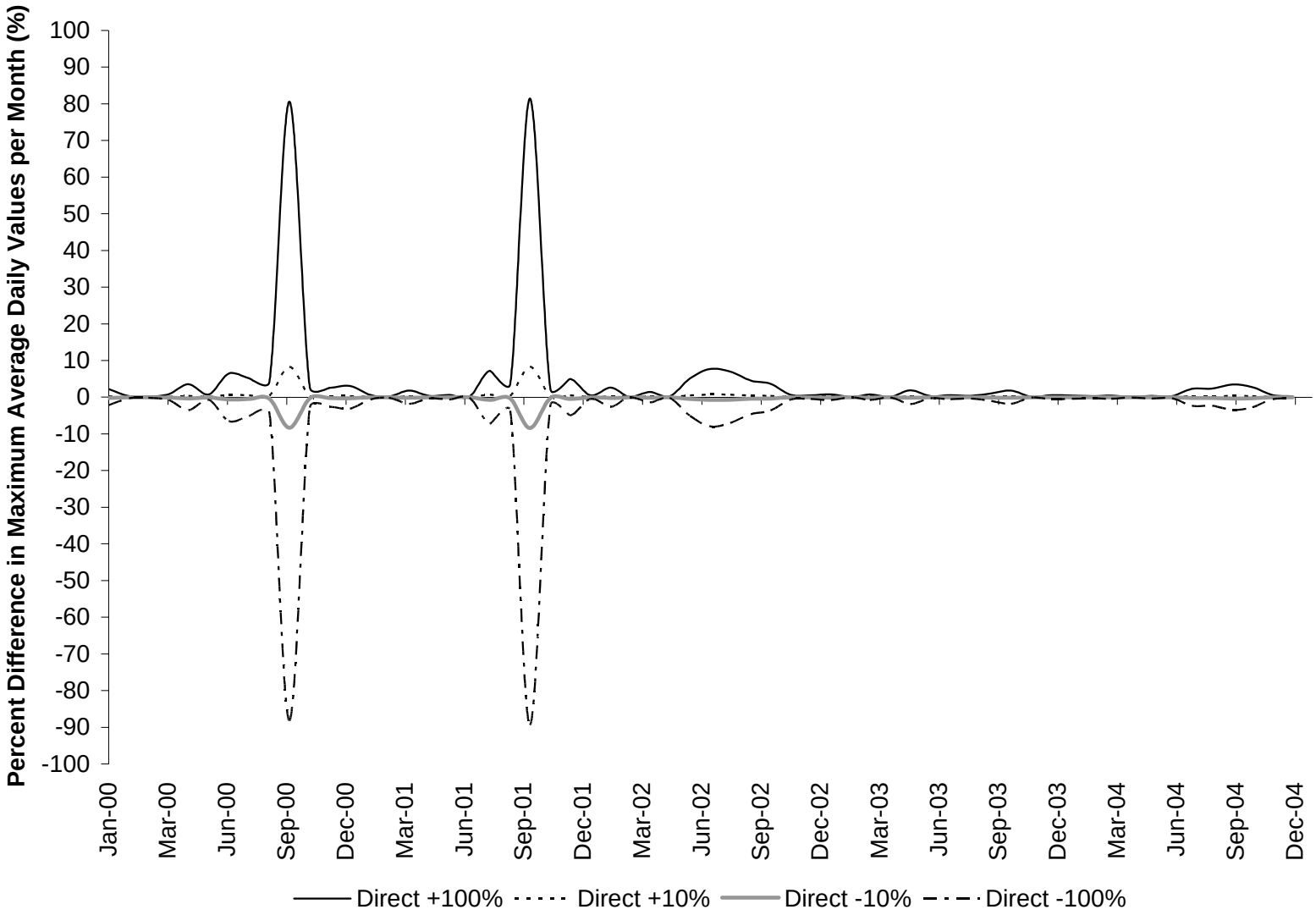


Figure 7.30. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-32) of Middle Fork Holston River (VAS-O05R-05) watershed, as affected by direct load changes.

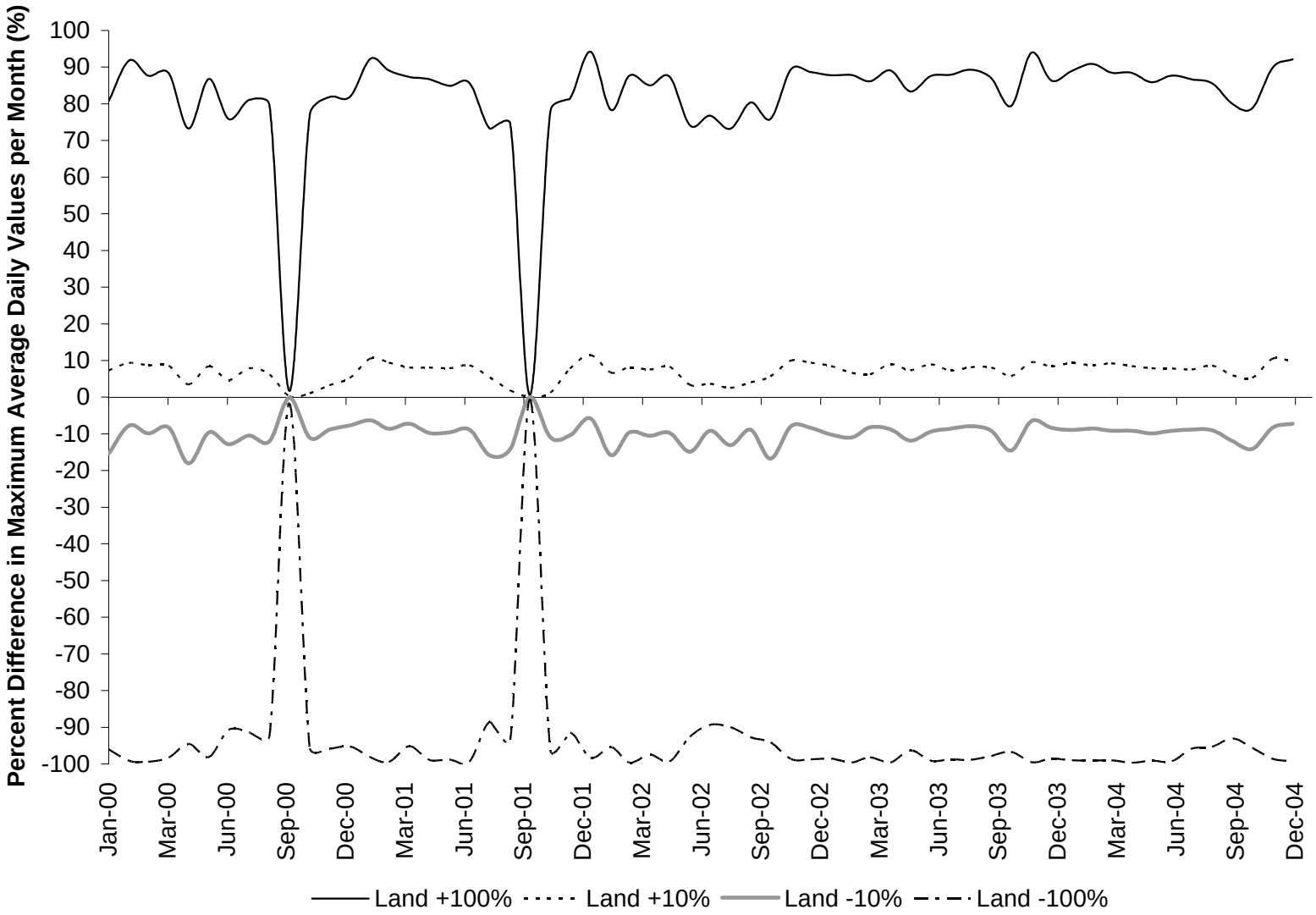


Figure 7.31. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed MFH-32) of Middle Fork Holston River (VAS-O05R-05) watershed, as affected by land-based load changes.

7.1.4 TMDL Allocation Scenarios

Direct and land-based loads representing existing conditions were reduced in a variety of allocation scenarios (addressing anthropogenic sources first) until the *E. coli* TMDL goals of a calendar-month geometric mean of 126 cfu/100mL and the single sample maximum limit of 235 cfu/100mL were met. The representative modeling period selected for allocation scenarios was January 2000 through December 2004. This period incorporates average rainfall, low rainfall, and high rainfall years allowing the representation of both low and high flow conditions. The general approach to allocation scenario development was to develop a scenario that allowed the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) impairments to meet bacteria water quality standards. As each impairment met bacteria standards, the loads that allowed it to do so were adopted for those segments for subsequent runs. Due to similarities in the five impairments, the final allocation scenarios for the five segments were similar.

Zero, three, nine, two, and seven active point discharges in the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) watersheds currently have VPDES permits, respectively. The permitted point source discharges are described in Table 3.2. The ultimate waste load allocation (WLA) for Middle Fork Holston River (VAS-O03R-01) impairment was calculated at <1% of the TMDL. During allocation development, permitted point sources were modeled with effluent fecal coliform concentrations of 200 cfu/100 mL and flows equal to their design flows as listed in Table 3.2. The ultimate waste load allocation (WLA) was calculated using the *E. coli* limit of 126 cfu/100mL and facility design flows. No municipalities with MS4 permits were identified within the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) watersheds.

Scenarios to address the load allocations to nonpoint sources were divided between direct and land-based loadings affected by both high and low stream flow conditions. Bacterial source tracking results from samples taken during 2008 confirmed the presence of human, pet, livestock, and wildlife contamination. As a result, scenarios were formulated to address reductions from all sources and delivery mechanisms (See Section 8.5.4 for discussion of wildlife bacteria). In general, direct loads modeled as consistent loadings independent of the flow regime heavily influenced low flow concentrations, whereas land-applied loads reached the stream through runoff producing events during high flow conditions. Representative allocation reduction scenarios developed for the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) impairments and their results are summarized in Sections 7.1.4.1 through 7.1.4.5.

The general approach used to determine the TMDL allocation was very similar among the five impairments. The first scenario represents existing conditions. Scenario number 1 reduces straight pipes and livestock directly deposited loads by 100%, keeping the remaining

source reductions at 0%. Scenarios numbered 2 through 4 represent a stepwise reduction of the following anthropogenic sources: residential land-based, cropland land-based, and pasture land-based. In these scenarios, wildlife loads (directly deposited and forest land-based) were not reduced and straight pipes and livestock directly deposited loads were reduced 100%. Load from straight pipes was reduced by 100% in all reduction scenarios since they are illegal. The results of Scenarios 1 through 4 were then used to formulate additional scenarios that led to the TMDL allocation. These additional scenarios were designed to first determine non-anthropogenic source reductions required to meet bacteria water quality standards, if any. Subsequent scenarios were used to determine required reductions in anthropogenic sources (Sections 7.1.4.1 through 7.1.4.5). (Further discussion of wildlife reduction allocations can be found in Section 8.5.4.)

Future applications for permitted point source discharges in the Middle Fork Holston River (VAS-O03R-01) watershed was accounted for by developing the WLA at <1% of the TMDL. This WLA did not result in exceedance of the water quality standard. Growth expansion WLA matrix calculated for Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) impairments did not result in exceedance of the water quality standards. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but it will be allocated to both new and existing permits as determined by the VADEQ Virginia Pollutant Discharge Elimination System program. All current permit limits remain in effect and can only be altered through the VADEQ permitting process. From information provided by the Technical Advisory Committee, it is our understanding that no major zoning changes are planned by counties in the watersheds that would result in accelerated development of the watershed. For purposes of this study, it was assumed that residential development in the study watersheds will continue at the current rates. New housing development is expected to produce no direct deposition, and a minimal land-based load increase based on the 3% failure rate associated with new septic systems and the number of pets added by this development. Data from the VASS indicated that beef cattle populations in Smyth County peaked in 2006 and decreased by about 50% from that in 2008. Beef cattle populations in Washington and Wythe Counties have increased on average 5% each year from 1999 to 2007. There is no evidence that any new dairy or poultry operations are planned. Wildlife populations are expected to remain relatively constant over the next five years. Based on these observations and the TMDL allocations, it is anticipated that the increase in directly deposited and land-based loads in the study watersheds will be negligible over the next five years. The effects of changes in loads on the in-stream bacteria concentration is examined in the impact analysis in Section 7.1.3. These changes are adequately accounted for in the implicit MOS. This implies that the final TMDL allocation is valid for the next five years, accounting for the anticipated growth during that time period.

The selected *E. coli* TMDL allocation for the Middle Fork Holston River (VAS-O03R-01), Middle Fork Holston River (VAS-O03R-02), Middle Fork Holston River (VAS-O04R-01), Middle Fork Holston River (VAS-O05R-06), and Middle Fork Holston River (VAS-O05R-05) impairments that meets both the calendar-month geometric mean and single sample maximum water quality goals addresses the following issues:

- The TMDL was developed to meet the calendar-month geometric mean and single sample water quality standards.
- Because *E. coli* loading data were not available to quantify point or nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations on which the bacteria TMDLs were based.
- The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
- An implicit MOS was incorporated by utilizing professional judgment and conservative estimates of model parameters.
- Both high- and low-flow stream conditions were considered while developing the TMDL.
- Both the flow regime and bacteria loading to Middle Fork Holston River are seasonal. The TMDL accounts for these seasonal effects.
- The exceedance rates listed in the allocation scenario table indicate the highest exceedance rate observed at a subwatershed outlet within the impaired segments (i.e., subwatershed MFH-03, MFH-14, MFH-21, MFH-26, and MFH-32). Some scenarios resulted in bacteria water quality standard exceedances in subwatersheds upstream of the outlet but not within the impaired reach subwatersheds.
- The TMDL was developed to account for future growth in the Middle Fork Holston River watershed.

7.1.4.1 Middle Fork Holston River (VAS-O03R-01)

Formulations of Scenarios 1 through 4 are discussed in Section 7.1.4. The results of those scenarios, and additional scenarios, are displayed in Table 7.1. Scenarios 5 through 7 are further reductions to the anthropogenic sources. Scenario 5 tested the land use load reductions at 96%. Table 7.1 shows that exceedances are present when the anthropogenic sources are tested at a 96% reduction rate. Scenario 6 met the 0% exceedance criteria of both standards, but an attempt to reduce the livestock direct deposition was performed to match the land-based anthropogenic source reductions. Scenario 7 tested the land use and livestock directly deposited loads at a 97% reduction rate. Scenario 7 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. It was determined that no reductions were required in wildlife loads (directly deposited and forest land-based) to meet the bacteria water quality standards in the impairment.

Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 7.32 for the final TMDL allocation (Scenario 7), along with the geometric mean and instantaneous standards. Table 7.2 presents the existing and allocated direct and land-applied fecal coliform and *E. coli* loads that result in in-stream *E. coli* concentrations to meet the applicable *E. coli* water quality standards after application of the VADEQ translator for fecal

coliform to *E. coli* concentration. Table 7.3 presents the final allocated in-stream *E. coli* loads for the Middle Fork Holston River (VAS-O03R-01) impairment. Table 7.4 presents the TMDL for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Table 7.1. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O03R-01) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of *E. coli* Standard	
	Straight Pipes	Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Single Sample
0	0	0	0	0	0	0	0	8.33	15.05
1	100	0	100	0	0	0	0	0	14.07
2	100	50	100	50	50	0	0	0	7.88
3	100	75	100	75	75	0	0	0	4.82
4	100	90	100	90	90	0	0	0	1.92
5	100	96	100	96	96	0	0	0	0.05
6	100	97	100	97	97	0	0	0	0
7	100	97	97	97	97	0	0	0	0

Table 7.2. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O03R-01) impairment.

Source	Fecal Coliform		*E. coli*[1]		Scenario Reduction (%)
	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	
Direct					
Straight Pipes	2.61E+13	0.00E+00	2.12E+12	0.00E+00	100
Livestock	2.77E+13	8.31E+11	2.23E+12	8.90E+10	97
Wildlife	1.73E+13	1.73E+13	1.45E+12	1.45E+12	0
Total	*7.11E+13*	*1.81E+13*	*5.80E+12*	*1.54E+12*	74
Land-based					
Residential	4.21E+14	1.26E+13	2.72E+13	1.08E+12	97
Cropland	3.52E+13	1.06E+12	2.78E+12	1.11E+11	97
Pasture	2.67E+16	8.01E+14	1.23E+15	4.92E+13	97
Forest	7.75E+13	7.75E+13	5.75E+12	5.75E+12	0
Total	*2.72E+16*	*8.92E+14*	*1.27E+15*	*5.62E+13*	97

[1] Loads derived from fecal coliform loads using equation 7.2

Table 7.3. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O03R-01) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	5.29E+10	5.24E+12	Implicit	5.29E+12

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

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

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

Table 7.4. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O03R-01) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	1.45E+08	1.30E+12	Implicit	1.30E+12

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

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

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

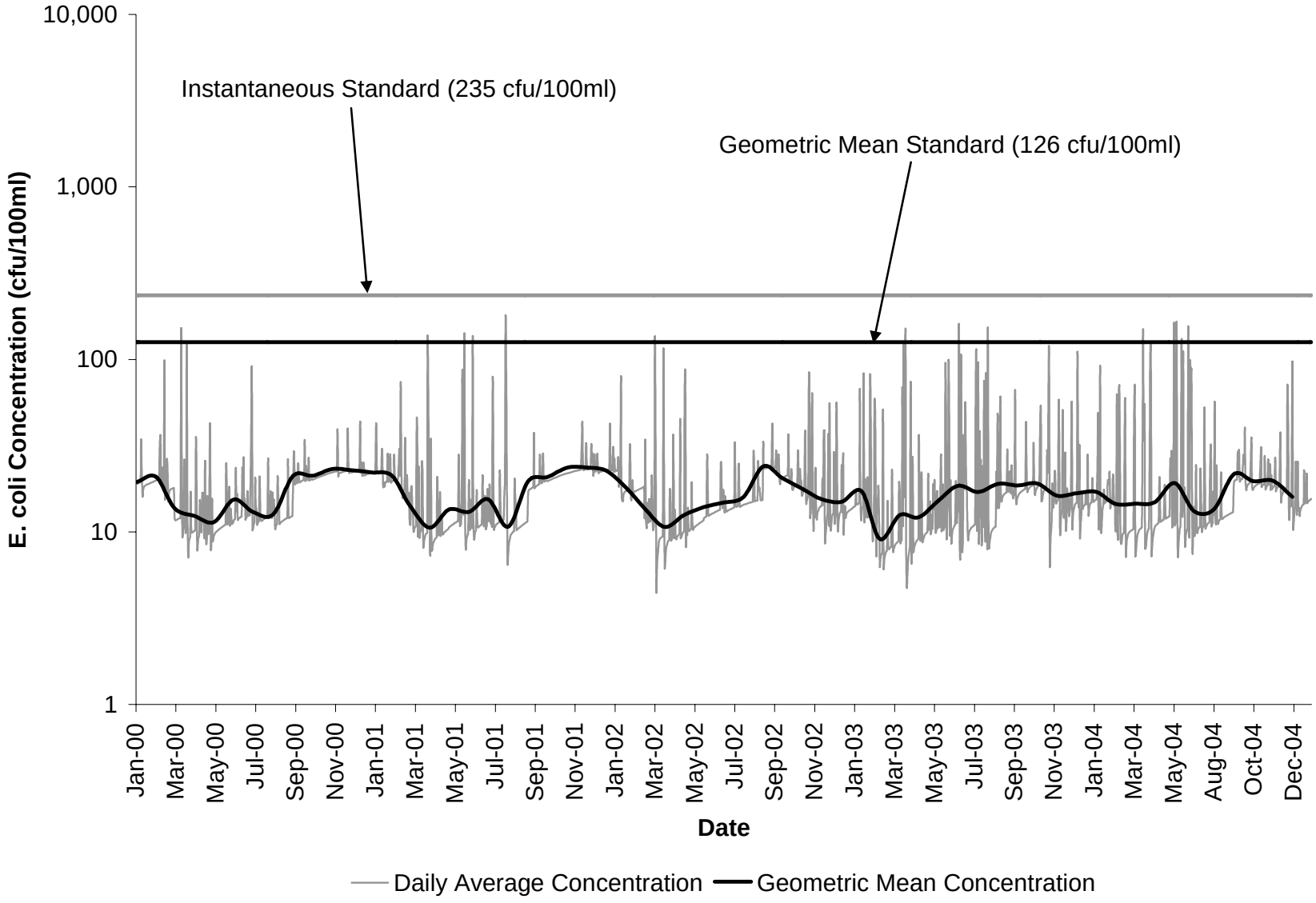


Figure 7.32. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O03R-01) impairment.

7.1.4.2 Middle Fork Holston River (VAS-O03R-02)

Formulations of Scenarios 1 through 4 are discussed in Section 7.1.4. The results of those scenarios, and additional scenarios, are displayed in Table 7.5. Scenarios 5 through 7 are further reductions to the anthropogenic sources. Scenario 5 tested the land use load reductions at 95%. Table 7.5 shows that exceedances are present when the anthropogenic sources are tested at a 95% reduction rate. Scenario 6 met the 0% exceedance criteria of both standards, but an attempt to reduce the livestock direct deposition was performed to match the land-based anthropogenic source reductions. Scenario 7 tested the land use and livestock directly deposited loads at a 96% reduction rate. Scenario 7 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. It was determined that no reductions were required in wildlife loads (directly deposited and forest land-based) to meet the bacteria water quality standards in the impairment.

Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 7.33 for the final TMDL allocation (Scenario 7), along with the geometric mean and instantaneous standards. Expansion matrix for the permitted source WLA is contained in Table 7.6. Table 7.7 presents the existing and allocated direct and land-applied fecal coliform and *E. coli* loads that result in in-stream *E. coli* concentrations to meet the applicable *E. coli* water quality standards after application of the VADEQ translator for fecal coliform to *E. coli* concentration. Table 7.8 presents the final allocated in-stream *E. coli* loads for the Middle Fork Holston River (VAS-O03R-02) impairment. Table 7.9 presents the TMDL for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Table 7.5. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O03R-02) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of *E. coli* Standard	
	Straight Pipes	Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Single Sample
0	0	0	0	0	0	0	0	51.67	29.67
1	100	0	100	0	0	0	0	16.67	28.41
2	100	50	100	50	50	0	0	1.67	19.81
3	100	75	100	75	75	0	0	0	10.18
4	100	90	100	90	90	0	0	0	1.86
5	100	95	100	95	95	0	0	0	0.05
6	100	96	100	96	96	0	0	0	0
7	100	96	96	96	96	0	0	0	0

Table 7.6. Expansion matrix for bacteria WLA in the Middle Fork Holston River (VAS-O03R-02) watershed.

Permit No	Facility Name	Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/yr)
VAG400102	Residence	0.0010	126	1.74E+09
VAG400579	Residence	0.0010	126	1.74E+09
VAG750033	Car Wash	0.0005	126	8.70E+08
Point Source Future Growth Allocation (5x)		0.0125	126	2.18E+10
			Total	2.61E+10

Table 7.7. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O03R-02) impairment.

Source	Fecal Coliform		*E. coli*[1]		Scenario Reduction
	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	(%)
Direct					
Straight Pipes	4.68E+13	0.00E+00	3.62E+12	0.00E+00	100
Livestock	3.36E+13	1.34E+12	2.67E+12	1.38E+11	96
Wildlife	3.52E+13	3.52E+13	2.78E+12	2.78E+12	0
Total	*1.16E+14*	*3.65E+13*	*9.07E+12*	*2.92E+12*	68
Land-based					
Residential	1.41E+15	5.64E+13	8.27E+13	4.29E+12	96
Cropland	2.58E+13	1.03E+12	2.09E+12	1.08E+11	96
Pasture	3.21E+16	1.28E+15	1.46E+15	7.57E+13	96
Forest	1.83E+14	1.83E+14	1.27E+13	1.27E+13	0
Total	*3.37E+16*	*1.52E+15*	*1.56E+15*	*9.28E+13*	95

[1] Loads derived from fecal coliform loads using equation 7.2

Table 7.8. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O03R-02) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	2.61E+10	2.43E+13	Implicit	2.43E+13

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

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

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

Table 7.9. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O03R-02) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	7.15E+07	4.52E+12	Implicit	4.52E+12

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

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

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

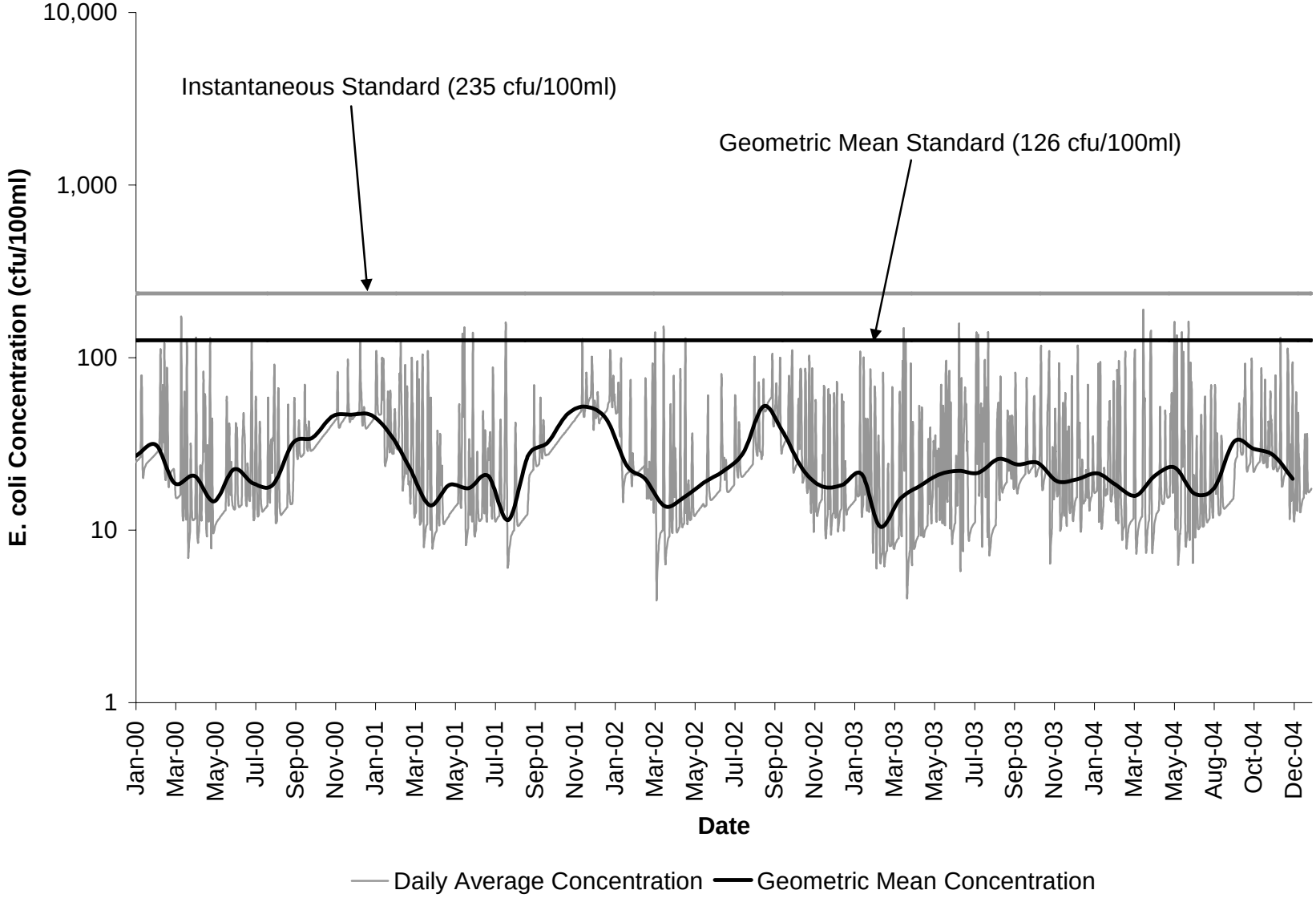


Figure 7.33. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O03R-02) impairment.

7.1.4.3 Middle Fork Holston River (VAS-O04R-01)

Formulations of Scenarios 1 through 4 are discussed in Section 7.1.4. The results of those scenarios, and additional scenarios, are displayed in Table 7.10. Scenarios 5 through 7 are further reductions to the anthropogenic sources. Scenario 5 tested the land use load reductions at 97%. Table 7.10 shows that exceedances are present when the anthropogenic sources are tested at a 97% reduction rate. Scenario 6 met the 0% exceedance criteria of both standards, but an attempt to reduce the livestock direct deposition was performed to match the land-based anthropogenic source reductions. Scenario 7 tested the land use and livestock directly deposited loads at a 98% reduction rate. Scenario 7 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. It was determined that no reductions were required in wildlife loads (directly deposited and forest land-based) to meet the bacteria water quality standards in the impairment.

Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 7.34 for the final TMDL allocation (Scenario 7), along with the geometric mean and instantaneous standards. Expansion matrix for the permitted source WLA is contained in Table 7.11. Table 7.12 presents the existing and allocated direct and land-applied fecal coliform and *E. coli* loads that result in in-stream *E. coli* concentrations to meet the applicable *E. coli* water quality standards after application of the VADEQ translator for fecal coliform to *E. coli* concentration. Table 7.13 presents the final allocated in-stream *E. coli* loads for the Middle Fork Holston River (VAS-O04R-01) impairment. Table 7.14 presents the TMDL for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Table 7.10. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O04R-01) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of *E. coli* Standard	
	Straight Pipes	Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Single Sample
0	0	0	0	0	0	0	0	70	23.15
1	100	0	100	0	0	0	0	46.67	22.06
2	100	50	100	50	50	0	0	16.67	10.45
3	100	75	100	75	75	0	0	1.67	5.53
4	100	90	100	90	90	0	0	0	2.3
5	100	97	100	97	97	0	0	0	0.05
6	100	98	100	98	98	0	0	0	0
7	100	98	98	98	98	0	0	0	0

Table 7.11. Expansion matrix for bacteria WLA in the Middle Fork Holston River (VAS-O04R-01) watershed.

Permit No	Facility Name	Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/yr)
VA0086304	Marion WWTP	3.400	126	5.92E+12
8 Domestic Sewage General Permits		0.008	126	1.39E+10
Point Source Future Growth Allocation (5x)		17.040	126	2.97E+13
			Total	3.56E+13

Table 7.12. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O04R-01) impairment.

Source	Fecal Coliform		*E. coli*[1]		Scenario Reduction
	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	(%)
Direct					
Straight Pipes	3.84E+13	0.00E+00	3.02E+12	0.00E+00	100
Livestock	8.85E+13	1.77E+12	6.50E+12	1.78E+11	98
Wildlife	5.33E+13	5.33E+13	4.08E+12	4.08E+12	0
Total	*1.80E+14*	*5.51E+13*	*1.36E+13*	*4.26E+12*	69
Land-based					
Residential	2.21E+15	4.42E+13	1.25E+14	3.43E+12	98
Cropland	1.27E+14	2.54E+12	9.06E+12	2.49E+11	98
Pasture	8.49E+16	1.70E+15	3.58E+15	9.83E+13	98
Forest	2.36E+14	2.36E+14	1.60E+13	1.60E+13	0
Total	*8.75E+16*	*1.98E+15*	*3.73E+15*	*1.18E+14*	98

[1] Loads derived from fecal coliform loads using equation 7.2

Table 7.13. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O04R-01) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	3.56E+13	4.70E+12	Implicit	4.03E+13

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

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

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

Table 7.14. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O04R-01) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	9.75E+10	7.99E+12	Implicit	8.09E+12

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

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

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

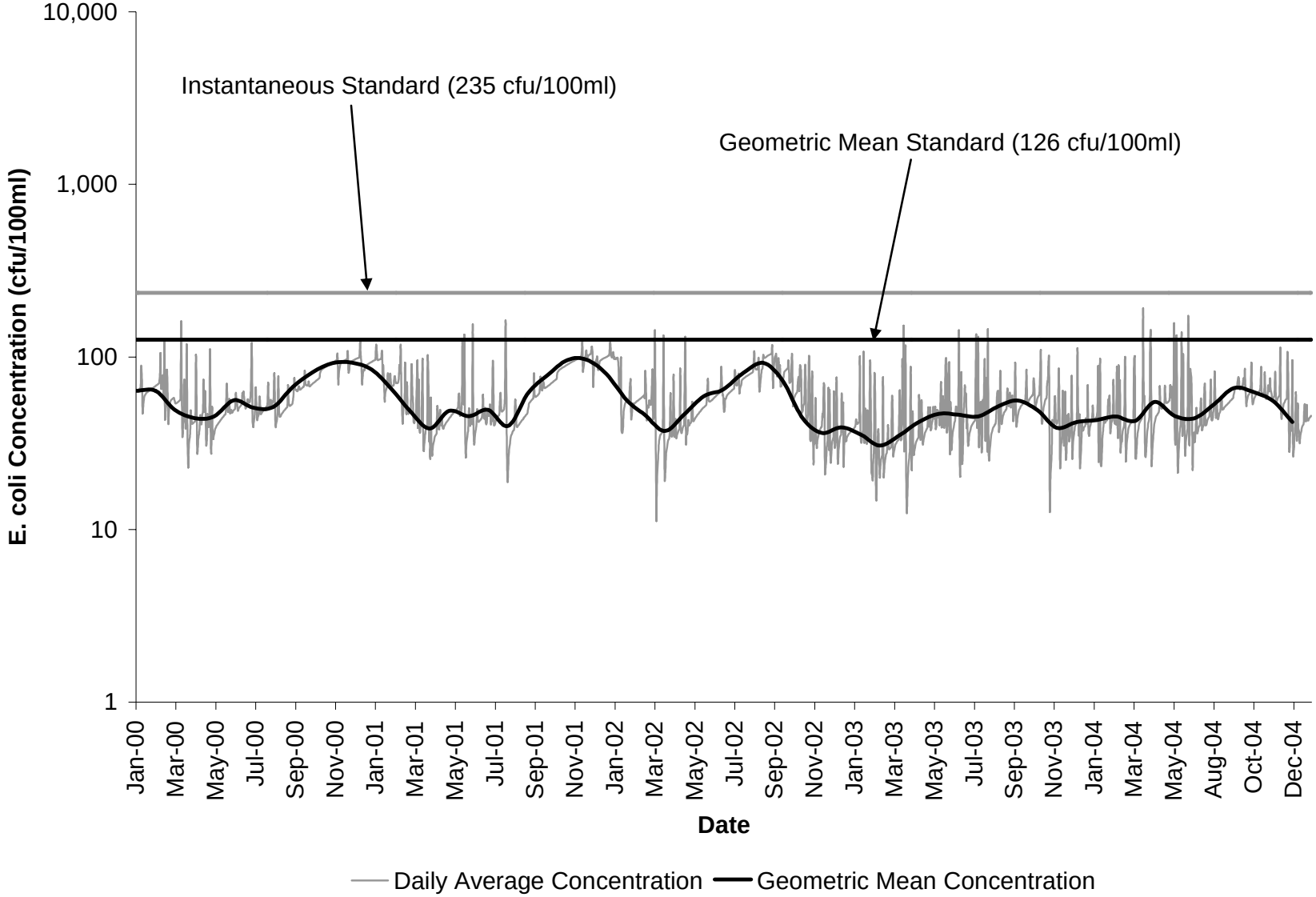


Figure 7.34. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O04R-01) impairment.

7.1.4.4 Middle Fork Holston River (VAS-O05R-06)

Formulations of Scenarios 1 through 4 are discussed in Section 7.1.4. The results of those scenarios, and additional scenarios, are displayed in Table 7.15. Scenarios 5 through 7 are further reductions to the anthropogenic sources. Scenario 5 tested the land use load reductions at 97%. Table 7.15 shows that exceedances are present when the anthropogenic sources are tested at a 97% reduction rate. Scenario 6 met the 0% exceedance criteria of both standards, but an attempt to reduce the livestock direct deposition was performed to match the land-based anthropogenic source reductions. Scenario 7 tested the land use and livestock directly deposited loads at a 98% reduction rate. Scenario 7 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. It was determined that no reductions were required in wildlife loads (directly deposited and forest land-based) to meet the bacteria water quality standards in the impairment.

Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 7.35 for the final TMDL allocation (Scenario 7), along with the geometric mean and instantaneous standards. Expansion matrix for the permitted source WLA is contained in Table 7.16. Table 7.17 presents the existing and allocated direct and land-applied fecal coliform and *E. coli* loads that result in in-stream *E. coli* concentrations to meet the applicable *E. coli* water quality standards after application of the VADEQ translator for fecal coliform to *E. coli* concentration. Table 7.18 presents the final allocated in-stream *E. coli* loads for the Middle Fork Holston River (VAS-O05R-06) impairment. Table 7.19 presents the TMDL for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Table 7.15. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O05R-06) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of *E. coli* Standard	
	Straight Pipes	Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Single Sample
0	0	0	0	0	0	0	0	21.67	21.18
1	100	0	100	0	0	0	0	11.67	20.25
2	100	50	100	50	50	0	0	6.67	12.97
3	100	75	100	75	75	0	0	1.67	7.61
4	100	90	100	90	90	0	0	0	3.67
5	100	97	100	97	97	0	0	0	0.05
6	100	98	100	98	98	0	0	0	0
7	100	98	98	98	98	0	0	0	0

Table 7.16. Expansion matrix for bacteria WLA in the Middle Fork Holston River (VAS-O05R-06) watershed.

Permit No	Facility Name	Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/yr)
VA0026379	Chilhowie Regional Wastewater Treatment Pla	0.999	126	1.74E+12
1 Domestic Sewage General Permit		0.0010	126	1.74E+09
Point Source Future Growth Allocation (5x)		5.00	126	8.70E+12
			Total	1.04E+13

Table 7.17. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O05R-06) impairment.

Source	Fecal Coliform		*E. coli*[1]		Scenario Reduction
	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	(%)
Direct					
Straight Pipes	1.71E+13	0.00E+00	1.43E+12	0.00E+00	100
Livestock	3.71E+13	7.42E+11	2.92E+12	8.02E+10	98
Wildlife	1.97E+13	1.97E+13	1.63E+12	1.63E+12	0
Total	*7.39E+13*	*2.04E+13*	*5.99E+12*	*1.71E+12*	72
Land-based					
Residential	6.76E+14	1.35E+13	4.21E+13	1.15E+12	98
Cropland	1.31E+14	2.62E+12	9.32E+12	2.56E+11	98
Pasture	3.74E+16	7.48E+14	1.68E+15	4.62E+13	98
Forest	6.06E+13	6.06E+13	4.59E+12	4.59E+12	0
Total	*3.83E+16*	*8.25E+14*	*1.74E+15*	*5.22E+13*	98

[1] Loads derived from fecal coliform loads using equation 7.2

Table 7.18. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O05R-06) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	1.04E+13	3.09E+13	Implicit	4.13E+13

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

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

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

Table 7.19. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O05R-06) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	2.85E+10	9.36E+12	Implicit	9.39E+12

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

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

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

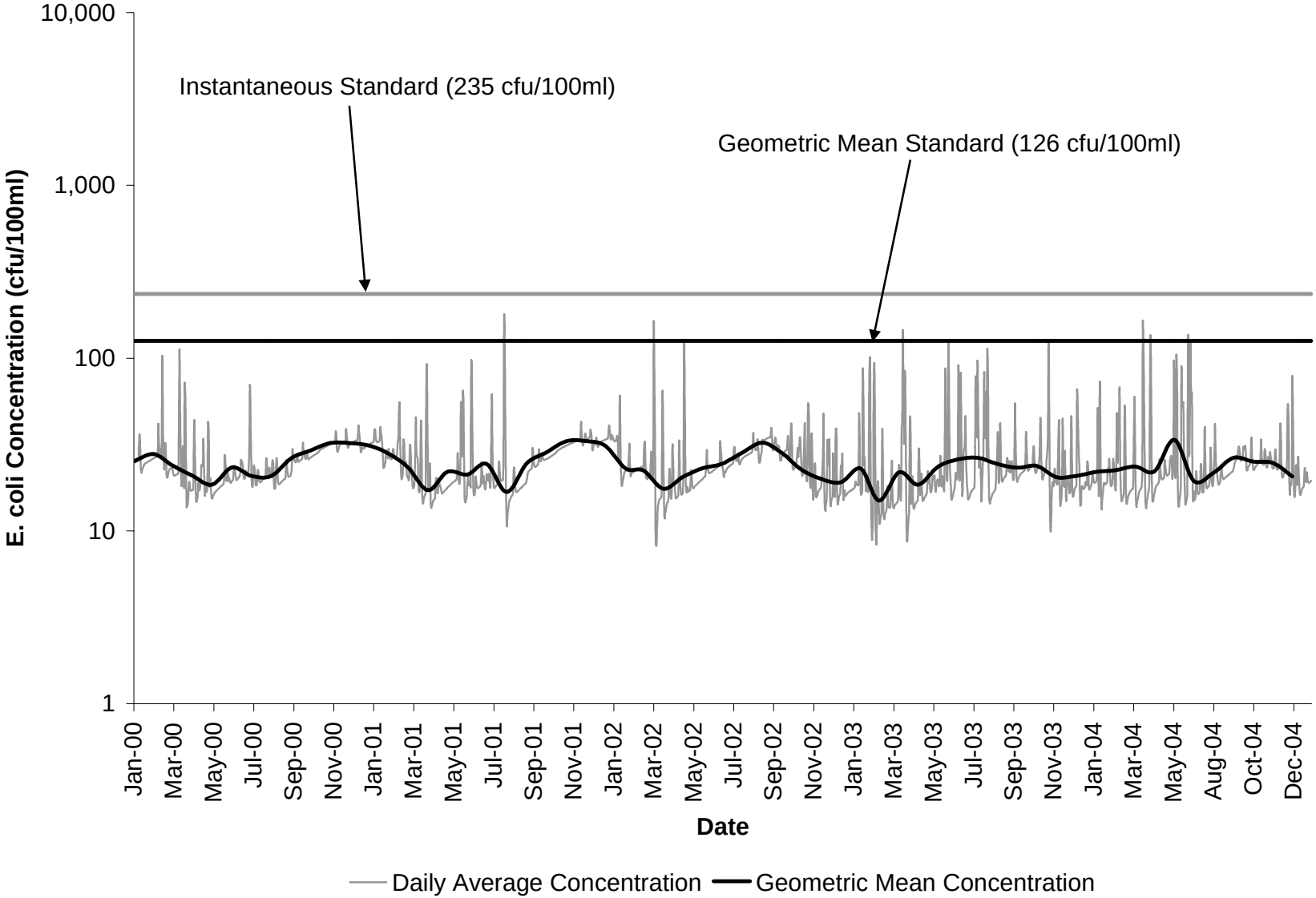


Figure 7.35. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O05R-06) impairment.

7.1.4.5 Middle Fork Holston River (VAS-O05R-05)

Formulations of Scenarios 1 through 4 are discussed in Section 7.1.4. The results of those scenarios, and additional scenarios, are displayed in Table 7.20. Scenarios 5 through 7 are further reductions to the anthropogenic sources. Scenario 5 tested the land use load reductions at 97%. Table 7.20 shows that exceedances are present when the anthropogenic sources are tested at a 97% reduction rate. Scenario 6 met the 0% exceedance criteria of both standards, but an attempt to reduce the livestock direct deposition was performed to match the land-based anthropogenic source reductions. Scenario 7 tested the land use and livestock directly deposited loads at a 98% reduction rate. Scenario 7 met the 0% exceedance criteria of both standards and was selected as the final TMDL allocation. It was determined that no reductions were required in wildlife loads (directly deposited and forest land-based) to meet the bacteria water quality standards in the impairment.

Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 7.36 for the final TMDL allocation (Scenario 7), along with the geometric mean and instantaneous standards. Expansion matrix for the permitted source WLA is contained in Table 7.21. Table 7.22 presents the existing and allocated direct and land-applied fecal coliform and *E. coli* loads that result in in-stream *E. coli* concentrations to meet the applicable *E. coli* water quality standards after application of the VADEQ translator for fecal coliform to *E. coli* concentration. Table 7.23 presents the final allocated in-stream *E. coli* loads for the Middle Fork Holston River (VAS-O05R-05) impairment. Table 7.24 presents the TMDL for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Table 7.20. Bacteria TMDL allocation scenarios for Middle Fork Holston River (VAS-O05R-05) impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of *E. coli* Standard	
	Straight Pipes	Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Single Sample
0	0	0	0	0	0	0	0	15	21.02
1	100	0	100	0	0	0	0	8.33	18.12
2	100	50	100	50	50	0	0	3.33	10.29
3	100	75	100	75	75	0	0	1.67	5.75
4	100	90	100	90	90	0	0	0	1.97
5	100	97	100	97	97	0	0	0	0.11
6	100	98	100	98	98	0	0	0	0
7	100	98	98	98	98	0	0	0	0

Table 7.21. Expansion matrix for bacteria WLA in the Middle Fork Holston River (VAS-O05R-05) watershed.

Permit No	Facility Name	Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/yr)
VA0087378	Washington Cnty Service Authority -Hall Creek	0.630	126	1.10E+12
VA0030589	Washington County Public Schools - Meadow	0.016	126	2.79E+10
VA0076376	Washington County Industrial Park WWTP	0.080	126	1.39E+11
4 Domestic Sewage General Permit		0.004	126	6.96E+09
Point Source Future Growth Allocation (5x)		3.650	126	6.35E+12
			Total	7.62E+12

Table 7.22. Annual nonpoint source fecal coliform and *E. coli* loads for existing conditions and final allocation along with corresponding reductions in Middle Fork Holston River (VAS-O05R-05) impairment.

Source	Fecal Coliform		*E. coli*[1]		Scenario Reduction
	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	(%)
Direct					
Straight Pipes	3.21E+13	0.00E+00	2.56E+12	0.00E+00	100
Livestock	4.73E+13	9.46E+11	3.65E+12	1.00E+11	98
Wildlife	3.34E+13	3.34E+13	2.65E+12	2.65E+12	0
Total	*1.13E+14*	*3.43E+13*	*8.87E+12*	*2.75E+12*	70
Land-based					
Residential	1.45E+15	2.90E+13	8.49E+13	2.33E+12	98
Cropland	2.11E+14	4.22E+12	1.44E+13	3.96E+11	98
Pasture	5.08E+16	1.02E+15	2.23E+15	6.14E+13	98
Forest	9.17E+13	9.17E+13	6.71E+12	6.71E+12	0
Total	*5.26E+16*	*1.14E+15*	*2.34E+15*	*7.09E+13*	98

[1] Loads derived from fecal coliform loads using equation 7.2

Table 7.23. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Middle Fork Holston River (VAS-O05R-05) impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	7.62E+12	1.30E+13	Implicit	2.06E+13

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

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

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

Table 7.24. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Middle Fork Holston River (VAS-O05R-05) impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	2.09E+10	4.04E+12	Implicit	4.06E+12

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

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

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

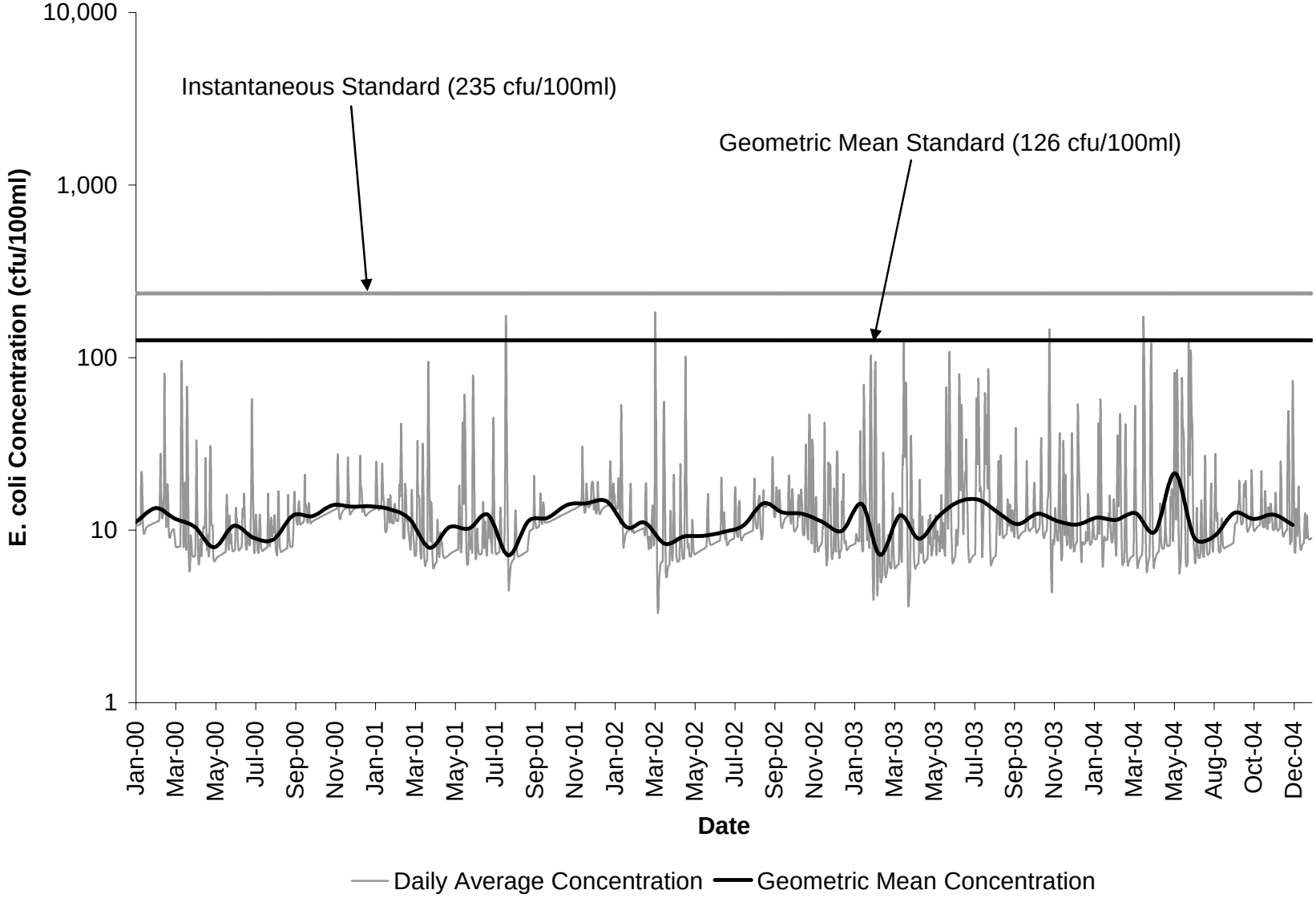


Figure 7.36. Geometric mean water quality standard, single sample water quality standard, and average daily and geometric mean *E. coli* concentrations from successful TMDL allocation (Allocation Scenario 7) in Middle Fork Holston River (VAS-O05R-05) impairment.

7.2 Sediment TMDL

7.2.1 Point Source Wasteload Allocation

The wasteload allocated to point sources in the watershed was based on the design flow or calculated runoff and the permitted concentration of total suspended solids for each facility (Table 7.25).

Table 7.25. Sediment waste load allocations for permitted point sources in the Lower Middle Fork Holston River watershed.

Facility Name	Permit Number	Design Flow (MGD)	TSS (mg/L)	Yearly Load (T/yr)	Daily Load (T/day)
Dillows Shop and Wash	VA0071366	0.0036	30	0.1	0.000
Chilhowie Regional Wastewater Treatment Plant	VA0026379	0.999	30	41.4	0.153
Washington County Service Authority	VA0087378	0.630	30	26.1	0.096
Washington County Public Schools- Meadowview Elem	VA0030589	0.016	30	0.7	0.003
Washington County Industrial Park WWTP	VA0076376	0.080	30	3.3	0.012
10 Single Family Domestic Sewage Facilities		0.010	30	0.4	0.001
17 Industrial Stormwater Facilities		N/A	100	28.35	0.105
			Total Load	**100.4**	**0.37**

7.2.2 Nonpoint Source Load Allocation

Load allocations for nonpoint sources not covered under the general wastewater permits were based on an equal percent reduction from controllable sources. Sediment loads from forest land use are considered to be representative of the natural condition and were not subject to reductions. The existing and allocated sediment loads for each nonpoint source in the Lower Middle Fork Holston River impaired watershed are presented in Table 7.26. In addition, the necessary percent reduction is shown for each source.

Table 7.26. Load allocation summary with existing sediment load, sediment source reduction, and sediment allocation load for Lower Middle Fork Holston River impairment.

Sediment Sources	Existing Load	Sediment Source Reduction	Allocation Load	Allocation Load
	(t/yr)	(%)	(t/yr)	(t/d)
Hi till cropland	90.2	62	34.3	.185
Low-till cropland	462.8	62	175.9	.949
Pasture 1	758.7	62	288.3	1.555
Pasture 2	1,062.4	62	403.7	2.178
Pasture 3	1,026.5	62	390.1	2.104
Transitional	46.4	62	17.6	.095
Forest	37.3	0	37.3	.148
Open urban grass	144.7	62	55.0	.297
Low density residential	21.8	62	8.3	.045
Medium density residential	12.3	62	4.7	.025
High density residential	8.7	62	3.3	.018
Channel erosion	601.2	62	228.4	1.232
Point sources	100.4	0	100.4	.370
TOTAL	4,373.4		1,747.2	9.2
		Reference Load (t/yr) =	1,979.9	
		10% Margin of Safety (t/yr) =	198.0	
		Allocation Goal (t/yr) =	1,781.9	
		Total Load after Allocation (t/yr) =	1,747.2	

7.2.3 Margin of Safety

An explicit margin of safety of 10% was used for the Lower Middle Fork Holston River impairment to account for uncertainties in the methodologies used to determine sediment loadings (Tables 7.27 and 7.28).

7.2.4 TMDL Allocations

The sediment TMDL in Lower Middle Fork Holston River is designed to restore aquatic life uses by reducing sedimentation and improving benthic habitat. While sediment loadings are very dynamic, the accumulation of sediment in the stream is reflective of conditions over extended time periods, ranging from seasonal to annual. Consequently, the most relevant

expression of sediment loadings in the Middle Fork Holston River TMDL is the annual average loading. Table 7.27 shows the total load, wasteload allocations, and margin of safety for Lower Middle Fork Holston River expressed as an average annual load. No sediment reductions to the point sources in Lower Middle Fork Holston River are required. The recommended allocations for each nonpoint source are provided in Table 7.26. Overall, the sediment load in the Lower Middle Fork Holston River watershed must be reduced by 60% in order to meet the established TMDL endpoint.

Table 7.27. Yearly sediment loads (T/yr) modeled after TMDL allocation in Lower Middle Fork Holston River impairment.

WLA (T/yr)	LA (T/yr)	MOS (T/yr)	TMDL (T/yr)
100.4	1,448.8	198.0	1,747.2

In order to comply with current USEPA guidance (USEPA, 2007), the Middle Fork Holston River sediment TMDL was also expressed as a daily load by evaluating the variability and distribution of simulated loads (Table 7.28). The following formula from USEPA's *Technical Support Document for Water Quality-Based Toxics Control* (USEPA, 1991) and USEPA's draft *Options for Expressing Daily Loads in TMDLs* (USEPA, 2007) was used to calculate the daily expression of the TMDL:

$$MDL = LTA * \exp(Z_p \sigma_y - 0.5\sigma_y^{\ 2}) \qquad [7.2]$$

where,

MDL = maximum daily load,

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

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

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

CV = coefficient of variation (estimated at 0.6).

The total maximum daily load was determined from Equation 7.2 using a 95th percentile, a CV of 0.6, and a long term average of 4.79 T/d. It should be noted that the maximum daily load expression represents extreme conditions (with a 5% frequency of occurrence), and routine loadings of this level would not meet average annual loadings that are necessary to restore aquatic life health.

Table 7.28. Daily sediment loads (T/d) modeled after TMDL allocation in Lower Middle Fork Holston River impairment.

WLA (T/d)	LA (T/d)	MOS (T/d)	TMDL (T/d)
0.37	8.83	1.02	10.22

Chapter 8. TMDL Implementation and Reasonable Assurance

The goal of the TMDL program is to establish a three-step process that will enable the attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria and benthic impairment on Middle Fork Holston River. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by USEPA and then the State Water Control Board (SWCB), measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation. VADCR and VADEQ will work closely with watershed stakeholders, interested state agencies, and support groups to develop an acceptable implementation plan that will result in meeting the water quality target.

8.1 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

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

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning. Among the sediment sources identified in the impairment, promising management practices include streambank

stabilization, riparian buffers, establishing vegetative cover on barren areas, street sweeping, and improved erosion and sediment control.

The iterative implementation of BMPs in the watershed has several benefits:

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

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

8.2 Bacteria Stage 1 Scenarios

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

HSPF was run with a one-hour time step for the period January 2000 to December 2004, as with the TMDL allocation scenarios. The implicit MOS used in allocation scenarios was utilized in determining the Stage 1 implementation scenarios. Several scenarios were run until the Stage 1 goal was met. Stage 1 allocation results are presented in Sections 8.2.1 through 8.2.5.

8.2.1 Middle Fork Holston River (VAS-O03R-01)

The Stage 1 allocation for the Middle Fork Holston River (VAS-O03R-01) impairment requires a 100% reduction in straight pipes, 75% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 36% reduction in nonpoint source loadings to residential

land use, a 36% reduction in nonpoint source loadings to pasture land use, a 36% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.47% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate. Fecal coliform loadings for existing conditions and the Stage 1 allocation scenario for nonpoint sources by land use and direct nonpoint sources are presented in Table 8.1 for the Middle Fork Holston River (VAS-O03R-01) impairment. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the fecal coliform loads from the Stage 1 scenario are presented graphically in Figure 8.1.

Table 8.1. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O03R-01) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	2.61E+13	0.00E+00	100
Livestock	2.77E+13	6.93E+12	75
Wildlife	1.73E+13	1.73E+13	0
Total	*7.11E+13*	*2.42E+13*	66
Land-based			
Residential	4.21E+14	2.69E+14	36
Cropland	3.52E+13	2.25E+13	36
Pasture	2.67E+16	1.71E+16	36
Forest	7.75E+13	7.75E+13	0
Total	*2.72E+16*	*1.75E+16*	36

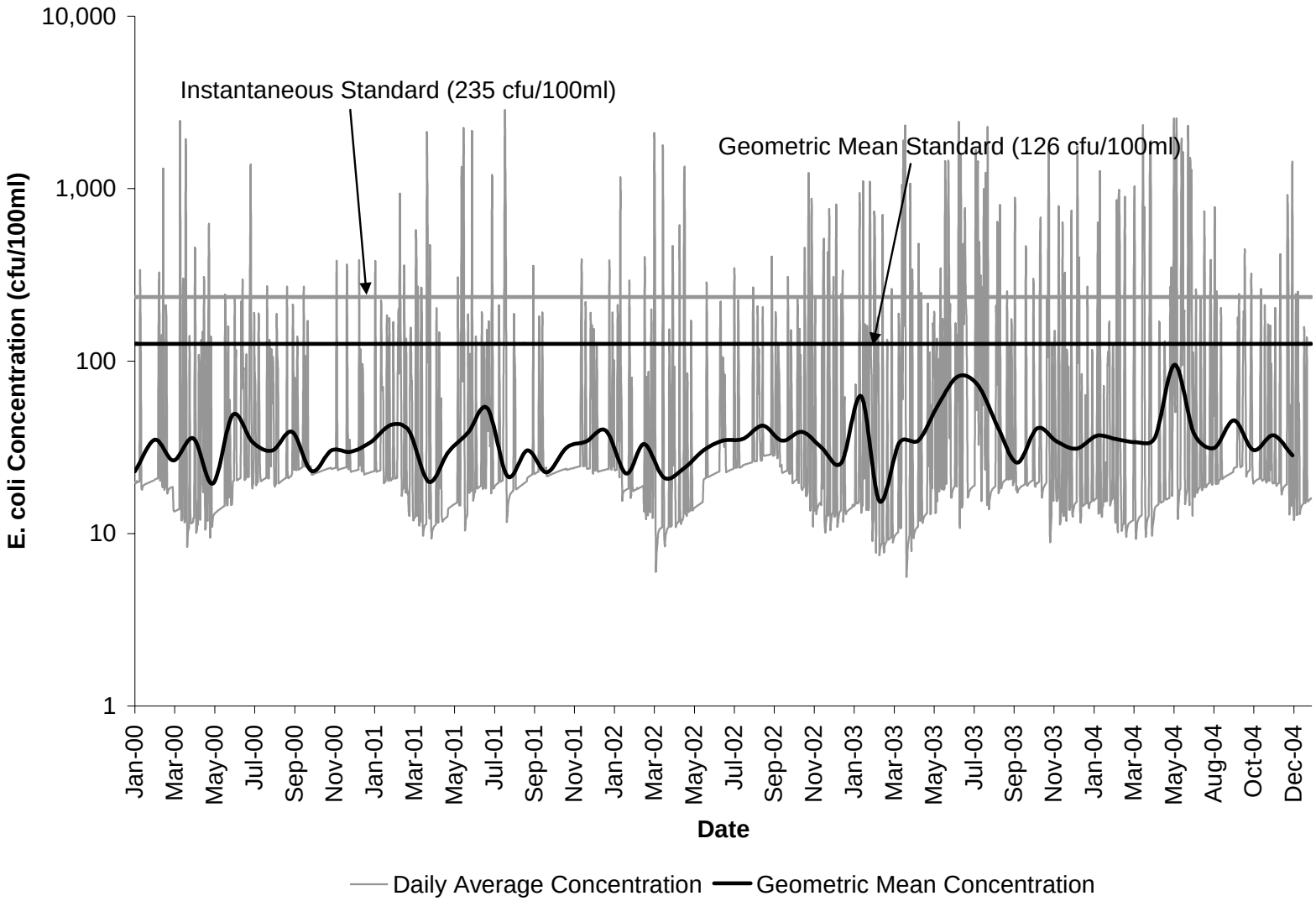


Figure 8.1. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O03R-01) impairment.

8.2.2 Middle Fork Holston River (VAS-O03R-02)

The Stage 1 allocation for the Middle Fork Holston River (VAS-O03R-02) impairment requires a 100% reduction in straight pipes, 77% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 77% reduction in nonpoint source loadings to residential land use, a 77% reduction in nonpoint source loadings to pasture land use, a 77% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.96% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate. Fecal coliform loadings for existing conditions and the Stage 1 allocation scenario for nonpoint sources by land use and direct nonpoint sources are presented in Table 8.2 for the Middle Fork Holston River (VAS-O03R-02) impairment. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the fecal coliform loads from the Stage 1 scenario are presented graphically in Figure 8.2.

Table 8.2. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O03R-02) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	4.68E+13	0.00E+00	100
Livestock	3.36E+13	7.73E+12	77
Wildlife	3.52E+13	3.52E+13	0
Total	*1.16E+14*	*4.29E+13*	63
Land-based			
Residential	1.41E+15	3.24E+14	77
Cropland	2.58E+13	5.93E+12	77
Pasture	3.21E+16	7.38E+15	77
Forest	1.83E+14	1.83E+14	0
Total	*3.37E+16*	*7.90E+15*	77

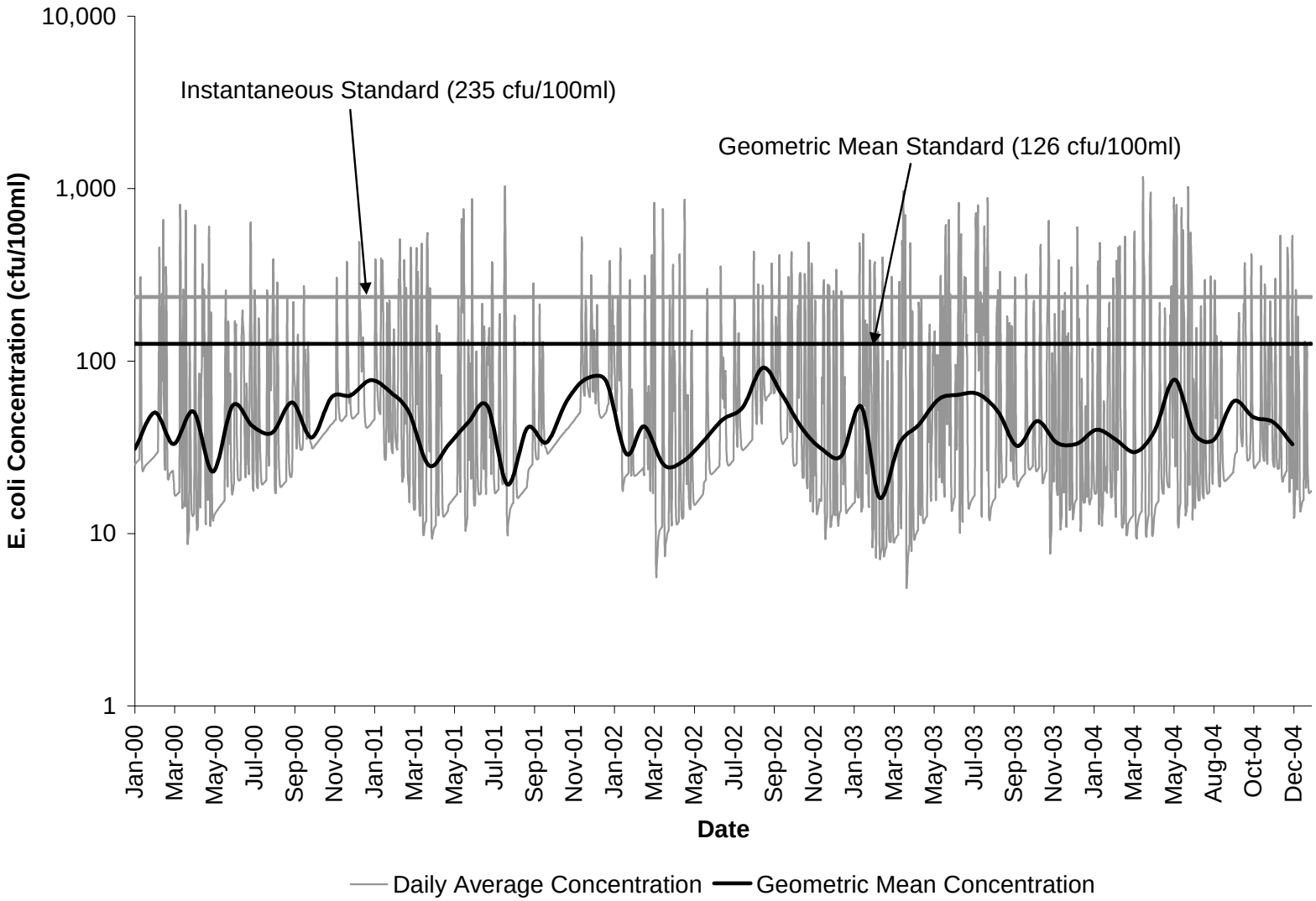


Figure 8.2. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O03R-02) impairment.

8.2.3 Middle Fork Holston River (VAS-O04R-01)

The Stage 1 allocation for the Middle Fork Holston River (VAS-O04R-01) impairment requires a 100% reduction in straight pipes, 79% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 79% reduction in nonpoint source loadings to residential land use, a 79% reduction in nonpoint source loadings to pasture land use, a 79% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.41% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate. Fecal coliform loadings for existing conditions and the Stage 1 allocation scenario for nonpoint sources by land use and direct nonpoint sources are presented in Table 8.3 for the Middle Fork Holston River (VAS-O04R-01) impairment. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the fecal coliform loads from the Stage 1 scenario are presented graphically in Figure 8.3.

Table 8.3. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O04R-01) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	3.84E+13	0.00E+00	100
Livestock	8.85E+13	1.86E+13	79
Wildlife	5.33E+13	5.33E+13	0
Total	*1.80E+14*	*7.19E+13*	60
Land-based			
Residential	2.21E+15	4.64E+14	79
Cropland	1.27E+14	2.67E+13	79
Pasture	8.49E+16	1.78E+16	79
Forest	2.36E+14	2.36E+14	0
Total	*8.75E+16*	*1.86E+16*	79

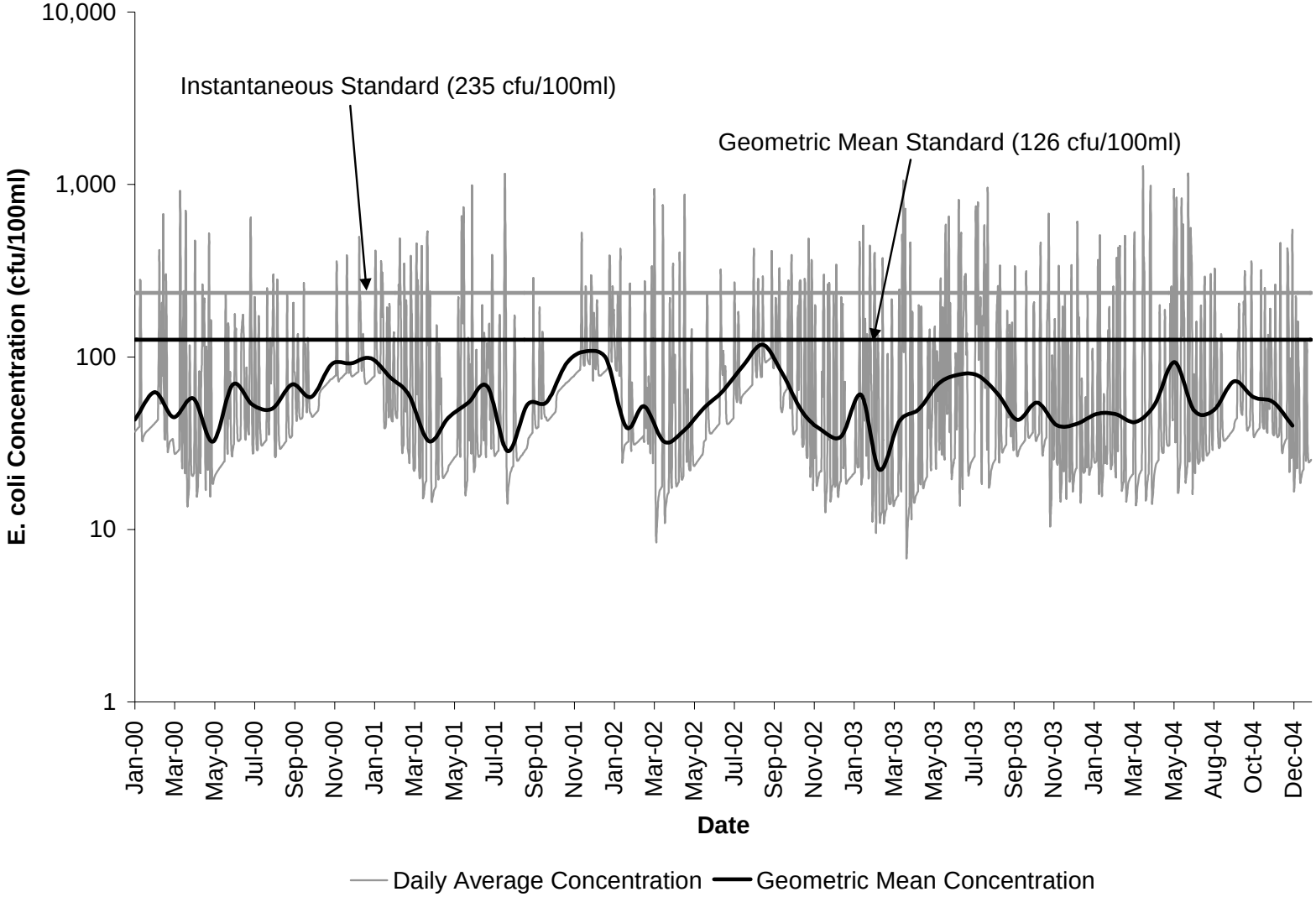


Figure 8.3. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O04R-01) impairment.

8.2.4 Middle Fork Holston River (VAS-O05R-06)

The Stage 1 allocation for the Middle Fork Holston River (VAS-O05R-06) impairment requires a 100% reduction in straight pipes, 98% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 96% reduction in nonpoint source loadings to residential land use, a 96% reduction in nonpoint source loadings to pasture land use, a 96% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 5.20% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate. Fecal coliform loadings for existing conditions and the Stage 1 allocation scenario for nonpoint sources by land use and direct nonpoint sources are presented in Table 8.4 for the Middle Fork Holston River (VAS-O05R-06) impairment. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the fecal coliform loads from the Stage 1 scenario are presented graphically in Figure 8.4.

Table 8.4. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O05R-06) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	1.71E+13	0.00E+00	100
Livestock	3.71E+13	7.42E+11	98
Wildlife	1.97E+13	1.97E+13	0
Total	*7.39E+13*	*2.04E+13*	72
Land-based			
Residential	6.76E+14	2.70E+13	96
Cropland	1.31E+14	5.24E+12	96
Pasture	3.74E+16	1.50E+15	96
Forest	6.06E+13	6.06E+13	0
Total	*3.83E+16*	*1.59E+15*	96

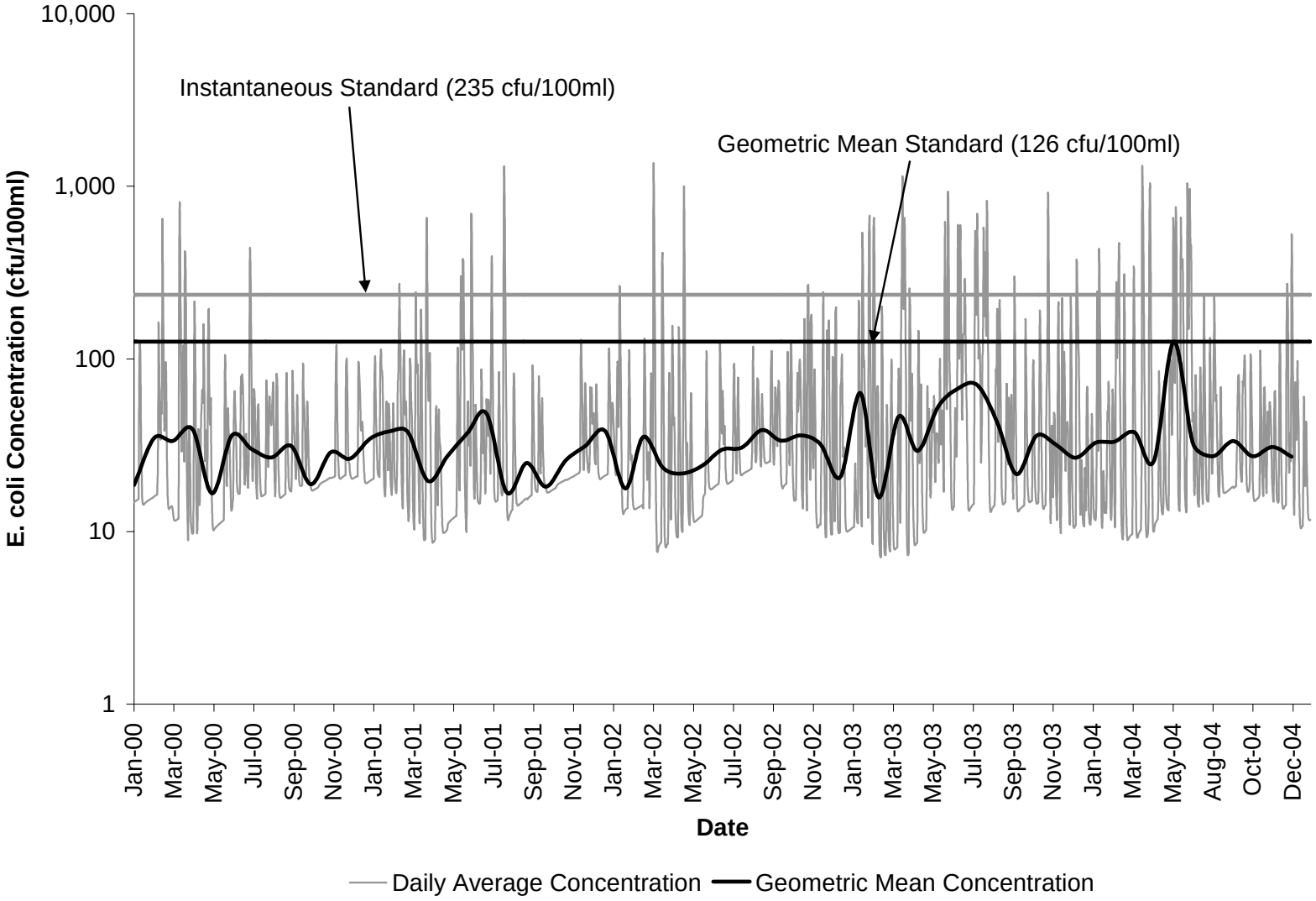


Figure 8.4. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O05R-06) impairment.

8.2.5 Middle Fork Holston River (VAS-O05R-05)

The Stage 1 allocation for the Middle Fork Holston River (VAS-O05R-05) impairment requires a 100% reduction in straight pipes, 75% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 53% reduction in nonpoint source loadings to residential land use, a 53% reduction in nonpoint source loadings to pasture land use, a 53% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 6.90% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate. Fecal coliform loadings for existing conditions and the Stage 1 allocation scenario for nonpoint sources by land use and direct nonpoint sources are presented in Table 8.5 for the Middle Fork Holston River (VAS-O05R-05) impairment. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the fecal coliform loads from the Stage 1 scenario are presented graphically in Figure 8.5.

Table 8.5. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Middle Fork Holston River (VAS-O05R-05) impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	3.21E+13	0.00E+00	100
Livestock	4.73E+13	1.18E+13	75
Wildlife	3.34E+13	3.34E+13	0
Total	*1.13E+14*	*4.52E+13*	60
Land-based			
Residential	1.45E+15	6.82E+14	53
Cropland	2.11E+14	9.92E+13	53
Pasture	5.08E+16	2.39E+16	53
Forest	9.17E+13	9.17E+13	0
Total	*5.26E+16*	*2.47E+16*	53

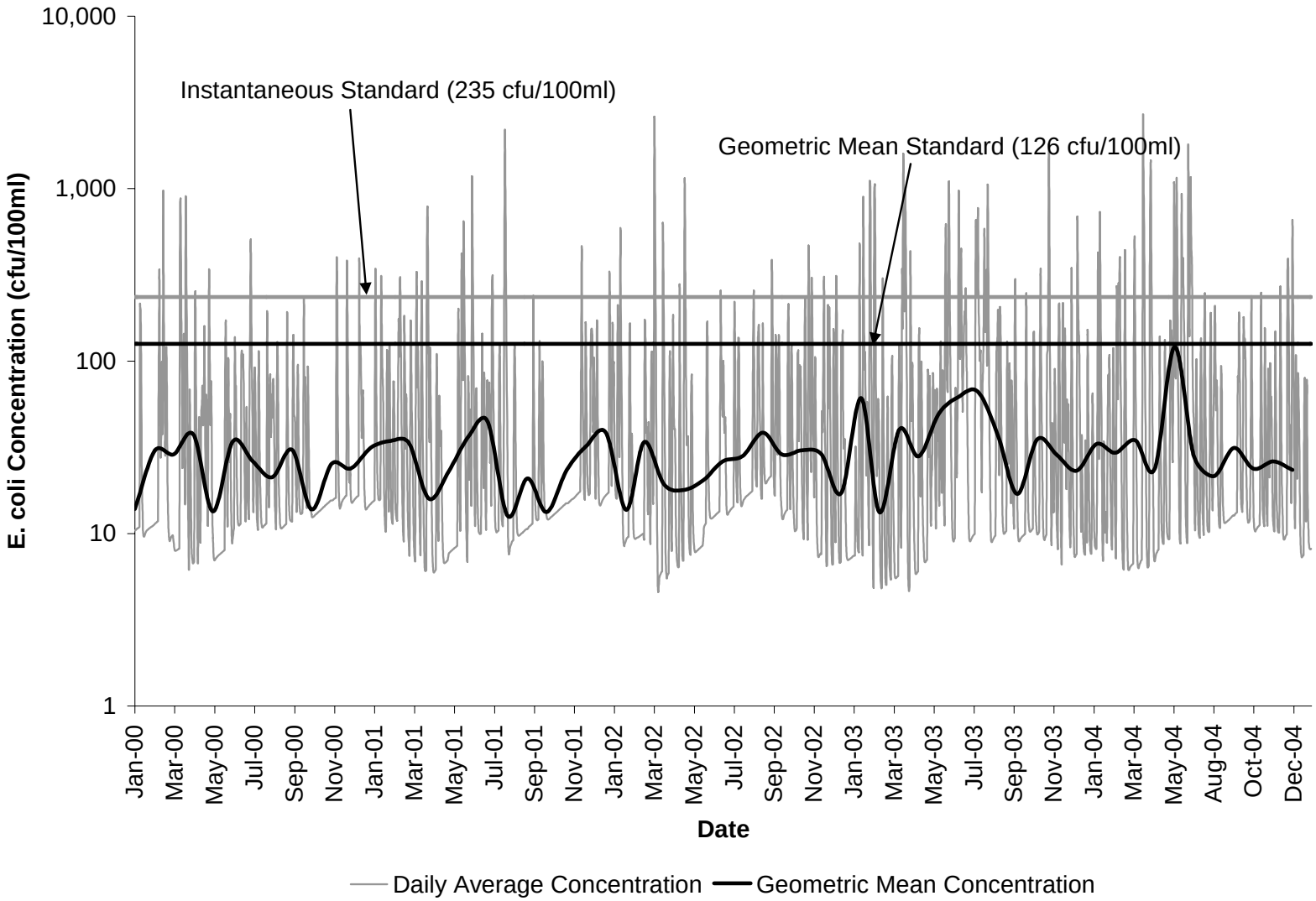


Figure 8.5. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Middle Fork Holston River (VAS-O05R-05) impairment.

8.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the watershed. Several BMPs known to be effective in controlling bacteria have also been identified for implementation to control sediment and nutrients in the southern rivers region.

8.4 Reasonable Assurance for Implementation

8.4.1 Follow-up Monitoring

Following the development of the TMDL, the VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004 (http://www.deq.virginia.gov/waterguidance/pdf/032004.pdf), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

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

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

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plan. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be

made to ensure that ancillary monitoring follows established quality assurance/quality control (QA/QC) guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

In order to demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year

8.4.2 Regulatory Framework

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

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

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and IP development, especially those implemented through the water quality based effluent limitations. However, those requirements that are considered BMPs may be enhanced by inclusion in the TMDL IP, and their connection to the targeted impairment. New permitted point source discharges will be allowed under the waste load

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

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed. An exception are the municipal separate storm sewer systems (MS4s) that are both covered by NPDES permits and expected to be included in TMDL implementation plans. It is the intent of the Commonwealth that the TMDL will be implemented using existing regulations and programs. VADEQ and VADCR coordinate separate State programs that regulate the management of pollutants carried by storm water runoff. VADEQ regulates storm water discharges associated with "industrial activities", while VADCR regulates storm water discharges from construction sites and MS4s. USEPA approved VADCR's VPDES stormwater program on December 30, 2004. VADCR's regulations became effective on January 29, 2005. VADEQ is no longer the regulatory agency responsible for administration and enforcement of the MS4 and construction stormwater permitting programs. More information is available on VADCR's web site through the following link: http://www.dcr.virginia.gov/sw/vsmp. Additional information on Virginia's Stormwater Management program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/soil_&_water/stormwat.shtml. As there are no MS4s permitted in the watershed at the time of this TMDL, they are not included in this study.

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

In response to a Memorandum of Understanding (MOU) between USEPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to USEPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

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

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit

limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on VADEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

8.4.3 Implementation Funding Sources

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

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

8.4.4 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. Virginia and USEPA are not proposing the elimination of natural wildlife to allow for the attainment of water quality standards. However, managing overpopulations of wildlife remains an option available to local stakeholders. Should during the implementation plan development phase of a TMDL process, and in consultation with a local government or land owner, the Department of Game and Inland Fisheries (VDGIF) determine that a population of resident geese, deer or other wildlife is a at "nuisance" levels, measures to reduce such populations may be deemed acceptable if undertaken under the supervision, or issued permit, of the VDGIF or the U.S. Fish and Wildlife Service as appropriate. Additional information on VDGIF's wildlife programs can be found at http://www.dgif.virginia.gov/hunting/va_game_wildlife/.

Based on the above, USEPA and Virginia have developed a process to address the wildlife issue. First step in this process is the development of a Stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the Stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the Stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described above. VADEQ will re-assess water quality in the stream during and subsequent to the implementation of the Stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct.

If water quality standards are not being met, a use attainability analysis (UAA) may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

8.4.5 Attainability of Designated Use

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

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

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

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

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

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

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

Chapter 9. Public Participation

The development of the Middle Fork Holston River TMDL would not have been possible without public participation. The stakeholder insight provided is gratefully acknowledged.

The first public meeting was held at the Glade Spring Community Center in Glade Spring, VA on August 7, 2008 to discuss the need for a TMDL, discuss the draft watershed source assessment, and review the approach for TMDL development. Twenty-four people attended the meeting. Copies of the presentation materials, watershed history results, source assessment per subwatershed, and various TMDL information handouts were available for public distribution. Public notice of the meetings was printed in the Virginia Register and advertised on the VADEQ and Mount Rogers Planning District Commission websites. Notification regarding the meetings was sent to area appointed and elected officials and Technical Advisory Committee (TAC) members. Members of the TAC were encouraged to distribute fliers advertising the meetings as appropriate. The general public was notified of the meetings through advertisements in the community calendar section of local newspapers, through post card mailings randomly distributed throughout the watershed, and through advertisements on the local cable television channels. There was a 30-day public comment period for the public meeting (August 7, 2008 to September 7, 2008) and no written comment was received.

The second and final public meeting was held at the Glade Spring Community Center in Glade Spring, VA on July 28, 2009 to discuss the source allocations and reductions required to meet the TMDL. Copies of the draft TMDL report were available for public review and comment. Public notice of the meetings was printed in the Virginia Register and advertised on the VADEQ and Mount Rogers Planning District Commission websites. Notification regarding the meeting was sent to area appointed and elected officials, TAC members, and prior public meeting attendees. Members of the TAC were encouraged to distribute fliers advertising the meetings as appropriate. The general public was notified of the meeting through advertisements in the community calendar section of local newspapers and through advertisements on the local cable television channels. In addition, postcard mailings were randomly distributed throughout the watershed. There was a 30-day public comment period for the meeting that extended from July 28, 2009 to August 28, 2009. Eleven people attended and no written comment was received.

In addition to keeping the public apprised of progress in the development of the Middle Fork Holston River TMDL, a TMDL TAC was also established to help advise the TMDL developers. TAC meetings were held prior to public meetings. TAC meetings were held for this project on June 17, 2008 and July 20, 2009 at the Mount Rogers Planning District Commission in Marion, VA. Public notice was provided for these meetings in the Virginia Register. The TAC meetings were also advertised on the VADEQ and Mount Rogers Planning District Commission websites. Notification regarding the meeting was sent to area appointed and elected officials and TAC members. The TAC membership for the Middle Fork Holston River TMDL included representatives from the following agencies and organizations:

- Virginia Department of Environmental Quality

- Virginia Department of Conservation and Recreation
- Virginia Department of Health
- Virginia Cooperative Extension
- Mount Rogers Planning District Commission
- Evergreen Soil and Water Conservation District
- Holston River Soil and Water Conservation District
- Town of Abingdon
- Smyth County
- Washington County

Twelve and 14 people attended the June and July meetings, respectively. TAC meetings were used as a forum to review data and assumptions used in the modeling, and to provide local government agencies an opportunity to raise concerns about the implications of the TMDL for their jurisdictions. The generous assistance of the staff of these agencies is gratefully acknowledged.

Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Margin of Safety (MOS)
A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

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

Nonpoint Source
Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

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

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

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

Reach
Segment of a stream or river.

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

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

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

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

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

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

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

Wasteload Allocation (WLA)
The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

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

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

References

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

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

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates, and fish. Second Edition. EPA 841-B-99-002. U. S. Environmental Protection Agency. Washington, DC. (http://www.epa.gov/OWOW/monitoring/techmon.html).

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

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

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

DEQ, 1998. Virginia Water Quality Assessment 1998 305(b) Report to the EPA Administrator and Congress for the Period July 1, 1992 to June 30, 1997. Virginia Department of Environmental Quality and Virginia Department of Conservation and Recreation. Richmond, Virginia. Available at: http://www.DEQ.virginia.gov/wqa/305b1998.html.

DEQ. 2002. 2002 303(d) Report on Impaired Waters. Richmond, VA: DEQ. (http://www.deq.state.va.us/water/303d.html)

DEQ. 2004. 2004 Impaired Waters Fact Sheets. 2004 303(d) Report on Impaired Waters. Appendix A. Richmond, Virginia. Available at: http://www.deq.virginia.gov/wqa/pdf/2004ir/irapay04.pdf . Accessed November 2006.

DEQ, 2005. Memorandum from Jutta Schneider, entitled “Error in Channel Erosion Calculation using GWLF”. December 16, 2005. Virginia Department of Environmental Quality. Richmond, Virginia.

DEQ. 2006. Using probabilistic monitoring data to validate the non-coastal Virginia Stream Condition Index. VDEQ Technical Bulletin WQA/2006-001. Richmond, Va.: Virginia Department of Environmental Quality; Water Quality Monitoring, Biological Monitoring and Water Quality Assessment Programs.

DEQ. 2007. Water quality guidance manual for Y2008 305(b)/303(d) integrated water quality report. Richmond, Va.: Virginia Department of Environmental Quality.

Evans, B. M., S. A. Sheeder, K. J. Corradini, and W. S. Brown. 2001. AVGWLF version 3.2. Users Guide. Environmental Resources Research Institute, Pennsylvania State

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

University and Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation.

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

Hession, W. C., M. McBride, and L. Misiura. 1997. Revised Virginia nonpoint source pollution assessment methodology. A report submitted to the Virginia Department of Conservation and Recreation, Richmond, Virginia. The Academy of Natural Sciences of Philadelphia, Patrick Center for Environmental Research. Philadelphia, Pennsylvania

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

Lee, K. Y., T. R. Fisher, T. E. Jordan, D. L. Correll, and D. E. Weller. 2000. Modeling the hydrochemistry of the Choptank River Basin using GWLF and Arc/Info: 1.Model calibration and validation. Biogeochemistry 49: 143-173.

MacDonald, D. D., C. G. Ingersoll, and T. A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31

Metcalf and Eddy. 1991. Wastewater Engineering. Treatment, Disposal, and Reuse. 3rd edition, McGraw-Hill Book Co., Singapore.

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

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

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

SERCC (Southeast Regional Climate Center). 2008. South Carolina Department of Natural Resources, 1000 Assembly Street, Suite 230, Columbia, SC 29201. (http://www.sercc.com/climateinfo/historical/historical_va.html)

SWCB (State Water Control Board). 2006. 9 VAC 26-280 Virginia Water Quality Standards. Available at: http://www.deq.virginia.gov/wqs/documents/WQS06_EDIT_001.pdf.

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

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

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

USDA-NRCS. 2008. Augusta County, Virginia. Tabular and spatial data. Soil Data Mart. U.S. Department of Agriculture, Natural Resources Conservation Service. Available at: http://soildatamart.usda.nrcs.gov/

USDA-NRCS. 2005. Regional Hydraulic Geometry Curves. Available at wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/index.html .

USEPA 1991. Technical Support Document for Water Quality Based Toxins Control. EPA/505/2-90-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

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

USEPA. 1998a. Water Quality Planning and Management Regulations (40 CFR Part 130) (Section 303(d) Report). Washington, D.C.: Office of Water, USEPA.

USEPA. 1998b. National Water Quality Inventory: Report to Congress (40 CFR Part 130) (Section 305(b) Report). Washington, D.C.: Office of Water, USEPA.

USEPA. 2000. Stressor identification guidance document. EPA-822-B-00-025. Washington, D.C.: U. S. Environmental Protection Agency, Office of Water and Office of Research and Development.

USEPA. 2002. Mid-Atlantic Ecoregions. (http://www.epa.gov/ceisweb1/ceishome/atlas/maiaatlas/mid_atlantic_ecoregions.html)

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

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

USEPA. 2006a. Memorandum from Benjamin H. Grumbles, Subject: Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. vs. EPA et al., No. 05-5015 (April 25, 2006) and Implications for NPDES Permits, November 15, 2006.

USGS (U.S. Geological Survey). 2008. Daily Streamflow for the Nation. (http://waterdata.usgs.gov/nwis/discharge).

VADEQ (Virginia Department of Environmental Quality). 2003. 2002 Section 303(d) List of Impaired Waters. (http://www.deq.state.va.us/water/303d.html)

VADEQ (Virginia Department of Environmental Quality). 2004. 2004 Section 303(d) List of Impaired Waters. (http://www.deq.state.va.us/water/303d.html)

VADEQ (Virginia Department of Environmental Quality). 2006. 2006 Section 303(d) List of Impaired Waters. (http://www.deq.state.va.us/water/303d.html)

VADEQ 2000. Guidance Memo No. 00-2011; dance on Preparing VPDES Permit Limits. Virginia Department of Environmental Quality, Richmond, Va.

VASS (Virginia Agricultural Statistics Service). 2002. 2001 Virginia Equine Report. Virginia Agricultural Statistics Service. Richmond, Virginia.

VDH (Virginia Department of Health). 1997. Biosolids Use Regulations. 12 VAC 5-585. Virginia Department of Health, Richmond, Virginia.

VWCB (Virginia Water Control Board). 1985. Ground Water Map of Virginia, ed. P.J. Smith and R.P. Ellison. Richmond, VA.: Virginia Water Control Board (VWCB) Ground Water Program.

Wischmeier, W. H. and D. D. Smith. 1978. Predicting rainfall erosion losses – A guide to conservation planning. Agriculture Handbook 537, U.S. Department of Agriculture, Science and Education Administration. Beltsville, Maryland.

Woods, A.J., J.M. Omernik, D.D. Brown. 1999. Level III and IV Ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. Corvallis, Or.: USEPA. (ftp://ftp.epa.gov/wed/ecoregions/reg3/FinalFullRgnIIIText3).

Yagow, G. and W.C. Hession. 2007. Statewide NPS Pollutant Load Assessment in Virginia at the Sixth Order NWBD Level: Final Project Report. VT-BSE Document No. 2007-0003. Submitted to the Virginia Department of Conservation and Recreation, Richmond. May 31, 2007. 50pp.

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

Appendix A – Historic Water Quality Data

Table A.1. Observed fecal coliform concentration and antecedent rainfall from 5/20/92 to 9/17/96 for VADEQ station 6-CMFH013.21 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH013.21	05/20/1992	800	2.86
6-CMFH013.21	06/24/1992	200	0.33
6-CMFH013.21	07/13/1992	100	0.53
6-CMFH013.21	08/05/1992	200	0.56
6-CMFH013.21	09/23/1992	500	0.14
6-CMFH013.21	10/19/1992	100	0.14
6-CMFH013.21	11/05/1992	200	1.13
6-CMFH013.21	12/15/1992	100	0.51
6-CMFH013.21	01/06/1993	300	0.41
6-CMFH013.21	02/08/1993	100	0.00
6-CMFH013.21	03/24/1993	4,100	1.65
6-CMFH013.21	04/19/1993	10	0.17
6-CMFH013.21	05/04/1993	150	0.00
6-CMFH013.21	06/29/1993	320	0.05
6-CMFH013.21	07/28/1993	180	0.96
6-CMFH013.21	08/19/1993	200	0.28
6-CMFH013.21	09/22/1993	130	0.97
6-CMFH013.21	10/28/1993	580	0.00
6-CMFH013.21	11/17/1993	60	0.18
6-CMFH013.21	01/12/1994	1,510	1.69
6-CMFH013.21	02/08/1994	250	0.37
6-CMFH013.21	03/14/1994	170	1.09
6-CMFH013.21	04/25/1994	10	0.00
6-CMFH013.21	05/11/1994	10	0.72
6-CMFH013.21	07/20/1995	100	0.35
6-CMFH013.21	08/15/1995	1,000	0.30
6-CMFH013.21	09/12/1995	20	0.03
6-CMFH013.21	10/11/1995	10	0.33
6-CMFH013.21	04/25/1996	40	0.36
6-CMFH013.21	05/13/1996	210	1.42
6-CMFH013.21	06/17/1996	120	0.45
6-CMFH013.21	07/11/1996	110	0.60
6-CMFH013.21	08/20/1996	220	0.08
6-CMFH013.21	09/17/1996	900	0.97

Table A.2. Observed fecal coliform concentration and antecedent rainfall from 10/8/96 to 2/14/00 for VADEQ station 6-CMFH013.21 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH013.21	10/08/1996	170	0.96
6-CMFH013.21	11/05/1996	90	0.21
6-CMFH013.21	12/04/1996	330	2.51
6-CMFH013.21	01/21/1997	220	0.62
6-CMFH013.21	02/26/1997	160	0.72
6-CMFH013.21	03/10/1997	700	1.34
6-CMFH013.21	04/07/1997	430	0.05
6-CMFH013.21	05/27/1997	5,300	0.74
6-CMFH013.21	06/24/1997	130	0.11
6-CMFH013.21	07/17/1997	200	0.00
6-CMFH013.21	08/11/1997	230	0.00
6-CMFH013.21	09/09/1997	5,600	0.00
6-CMFH013.21	10/07/1997	140	0.00
6-CMFH013.21	11/03/1997	370	0.65
6-CMFH013.21	12/02/1997	150	0.33
6-CMFH013.21	01/20/1998	350	0.89
6-CMFH013.21	02/12/1998	280	0.00
6-CMFH013.21	03/17/1998	30	0.43
6-CMFH013.21	04/02/1998	230	0.46
6-CMFH013.21	05/04/1998	6,000	1.02
6-CMFH013.21	06/10/1998	6,000	3.05
6-CMFH013.21	07/21/1998	20	0.36
6-CMFH013.21	08/20/1998	220	1.42
6-CMFH013.21	09/09/1998	130	0.32
6-CMFH013.21	11/05/1998	30	0.24
6-CMFH013.21	12/08/1998	140	0.48
6-CMFH013.21	04/26/1999	400	0.03
6-CMFH013.21	08/17/1999	10	0.42
6-CMFH013.21	09/08/1999	300	0.92
6-CMFH013.21	10/06/1999	200	0.12
6-CMFH013.21	11/03/1999	1,200	0.89
6-CMFH013.21	12/06/1999	100	0.24
6-CMFH013.21	01/05/2000	100	0.08
6-CMFH013.21	02/14/2000	800	1.34

Table A.3. Observed fecal coliform concentration and antecedent rainfall from 3/7/00 to 2/41/03 for VADEQ station 6-CMFH013.21 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH013.21	03/07/2000	100	0.00
6-CMFH013.21	04/03/2000	800	0.73
6-CMFH013.21	05/08/2000	100	0.00
6-CMFH013.21	06/05/2000	300	0.00
6-CMFH013.21	07/06/2000	8,000	3.64
6-CMFH013.21	08/15/2000	100	0.40
6-CMFH013.21	09/13/2000	200	0.03
6-CMFH013.21	10/25/2000	100	0.05
6-CMFH013.21	11/06/2000	100	0.00
6-CMFH013.21	12/05/2000	100	0.08
6-CMFH013.21	01/04/2001	100	0.14
6-CMFH013.21	02/21/2001	100	0.86
6-CMFH013.21	03/07/2001	200	1.05
6-CMFH013.21	07/09/2001	8,000	2.67
6-CMFH013.21	08/07/2001	200	0.19
6-CMFH013.21	09/18/2001	100	0.00
6-CMFH013.21	10/01/2001	100	0.00
6-CMFH013.21	11/06/2001	100	0.02
6-CMFH013.21	12/12/2001	4,500	1.45
6-CMFH013.21	01/28/2002	400	2.87
6-CMFH013.21	02/13/2002	100	0.05
6-CMFH013.21	03/25/2002	100	0.15
6-CMFH013.21	04/30/2002	100	0.68
6-CMFH013.21	04/30/2002	100	0.68
6-CMFH013.21	05/16/2002	300	0.65
6-CMFH013.21	06/12/2002	100	0.60
6-CMFH013.21	07/22/2002	200	1.09
6-CMFH013.21	08/21/2002	100	0.64
6-CMFH013.21	09/30/2002	125	1.66
6-CMFH013.21	10/15/2002	125	0.81
6-CMFH013.21	11/19/2002	350	0.82
6-CMFH013.21	12/10/2002	120	1.79
6-CMFH013.21	01/28/2003	25	0.12
6-CMFH013.21	02/04/2003	400	1.45

Table A.4. Observed fecal coliform concentration and antecedent rainfall from 3/10/03 to 11/28/06 for VADEQ station 6-CMFH013.21 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH013.21	03/10/2003	50	0.35
6-CMFH013.21	04/22/2003	850	2.38
6-CMFH013.21	06/10/2003	50	0.79
6-CMFH013.21	08/18/2003	2,000	3.74
6-CMFH013.21	10/09/2003	200	0.01
6-CMFH013.21	12/18/2003	650	0.76
6-CMFH013.21	02/23/2004	50	0.00
6-CMFH013.21	04/08/2004	100	0.11
6-CMFH013.21	06/23/2004	300	0.72
6-CMFH013.21	08/25/2004	450	0.61
6-CMFH013.21	10/04/2004	120	0.46
6-CMFH013.21	12/13/2004	550	2.07
6-CMFH013.21	03/01/2005	75	0.84
6-CMFH013.21	04/28/2005	50	0.81
6-CMFH013.21	06/02/2005	480	0.47
6-CMFH013.21	07/12/2005	150	1.34
6-CMFH013.21	09/26/2005	75	0.00
6-CMFH013.21	11/21/2005	25	0.61
6-CMFH013.21	01/09/2006	50	0.02
6-CMFH013.21	03/23/2006	25	0.40
6-CMFH013.21	05/25/2006	50	0.85
6-CMFH013.21	07/26/2006	75	1.80
6-CMFH013.21	09/14/2006	120	0.73
6-CMFH013.21	11/28/2006	25	0.00

Table A.5. Observed fecal coliform concentration and antecedent rainfall from 1/16/90 to 4/25/96 for VADEQ station 6-CMFH026.00 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH026.00	01/16/1990	100	0.00
6-CMFH026.00	02/20/1990	100	2.29
6-CMFH026.00	03/28/1990	100	1.20
6-CMFH026.00	04/24/1990	200	0.63
6-CMFH026.00	05/16/1990	100	0.09
6-CMFH026.00	06/13/1990	300	0.72
6-CMFH026.00	07/02/1990	1,800	0.33
6-CMFH026.00	08/21/1990	600	0.00
6-CMFH026.00	09/19/1990	200	0.34
6-CMFH026.00	10/15/1990	800	3.01
6-CMFH026.00	11/07/1990	200	0.00
6-CMFH026.00	12/03/1990	100	0.50
6-CMFH026.00	01/07/1991	200	0.04
6-CMFH026.00	02/13/1991	200	0.00
6-CMFH026.00	03/05/1991	100	1.84
6-CMFH026.00	04/03/1991	100	2.02
6-CMFH026.00	05/06/1991	3,300	0.71
6-CMFH026.00	06/04/1991	1,500	1.73
6-CMFH026.00	07/01/1991	600	0.23
6-CMFH026.00	10/15/1991	300	0.06
6-CMFH026.00	06/24/1992	600	0.33
6-CMFH026.00	08/05/1992	400	0.56
6-CMFH026.00	10/19/1992	100	0.14
6-CMFH026.00	12/15/1992	100	0.51
6-CMFH026.00	02/08/1993	200	0.00
6-CMFH026.00	04/19/1993	80	0.17
6-CMFH026.00	06/29/1993	180	0.05
6-CMFH026.00	08/19/1993	230	0.28
6-CMFH026.00	10/28/1993	300	0.00
6-CMFH026.00	02/08/1994	1,220	0.37
6-CMFH026.00	04/25/1994	10	0.00
6-CMFH026.00	08/15/1995	200	0.30
6-CMFH026.00	10/11/1995	100	0.33
6-CMFH026.00	04/25/1996	120	0.36

Table A.6. Observed fecal coliform concentration and antecedent rainfall from 6/17/96 to 4/3/00 for VADEQ station 6-CMFH026.00 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH026.00	06/17/1996	900	0.45
6-CMFH026.00	08/20/1996	310	0.08
6-CMFH026.00	10/08/1996	500	0.96
6-CMFH026.00	12/04/1996	260	2.51
6-CMFH026.00	02/26/1997	320	0.72
6-CMFH026.00	04/07/1997	300	0.05
6-CMFH026.00	06/24/1997	320	0.11
6-CMFH026.00	08/11/1997	170	0.00
6-CMFH026.00	10/07/1997	230	0.00
6-CMFH026.00	12/02/1997	200	0.33
6-CMFH026.00	02/12/1998	1,000	0.00
6-CMFH026.00	04/02/1998	270	0.46
6-CMFH026.00	06/10/1998	6,000	3.05
6-CMFH026.00	08/20/1998	220	1.42
6-CMFH026.00	09/09/1998	190	0.32
6-CMFH026.00	10/13/1998	150	0.96
6-CMFH026.00	11/05/1998	100	0.24
6-CMFH026.00	12/08/1998	110	0.48
6-CMFH026.00	01/14/1999	60	0.44
6-CMFH026.00	02/25/1999	30	0.44
6-CMFH026.00	03/15/1999	50	1.00
6-CMFH026.00	04/26/1999	2,200	0.03
6-CMFH026.00	05/24/1999	300	0.41
6-CMFH026.00	06/21/1999	50	0.24
6-CMFH026.00	07/07/1999	10	0.05
6-CMFH026.00	08/17/1999	80	0.42
6-CMFH026.00	09/08/1999	100	0.92
6-CMFH026.00	10/06/1999	1,000	0.12
6-CMFH026.00	11/03/1999	100	0.89
6-CMFH026.00	12/06/1999	1,500	0.24
6-CMFH026.00	01/05/2000	200	0.08
6-CMFH026.00	02/14/2000	5,000	1.34
6-CMFH026.00	03/07/2000	100	0.00
6-CMFH026.00	04/03/2000	1,600	0.73

Table A.7. Observed fecal coliform concentration and antecedent rainfall from 5/8/00 to 12/10/02 for VADEQ station 6-CMFH026.00 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH026.00	05/08/2000	300	0.00
6-CMFH026.00	06/05/2000	2,500	0.00
6-CMFH026.00	07/06/2000	4,100	3.64
6-CMFH026.00	08/15/2000	2,100	0.40
6-CMFH026.00	09/13/2000	2,300	0.03
6-CMFH026.00	10/25/2000	1,300	0.05
6-CMFH026.00	11/06/2000	1,100	0.00
6-CMFH026.00	12/05/2000	3,700	0.08
6-CMFH026.00	01/04/2001	300	0.14
6-CMFH026.00	02/21/2001	900	0.86
6-CMFH026.00	03/07/2001	200	1.05
6-CMFH026.00	07/09/2001	8,000	2.67
6-CMFH026.00	09/06/2001	2,600	1.30
6-CMFH026.00	11/19/2001	100	0.00
6-CMFH026.00	01/03/2002	100	0.00
6-CMFH026.00	02/27/2002	100	0.02
6-CMFH026.00	03/27/2002	300	0.22
6-CMFH026.00	04/04/2002	100	1.39
6-CMFH026.00	05/07/2002	200	1.13
6-CMFH026.00	06/03/2002	1,200	0.27
6-CMFH026.00	07/10/2002	500	0.03
6-CMFH026.00	08/21/2002	200	0.64
6-CMFH026.00	09/26/2002	1,200	1.97
6-CMFH026.00	10/01/2002	200	1.66
6-CMFH026.00	11/05/2002	100	0.47
6-CMFH026.00	12/10/2002	100	1.79

Table A.8. Observed fecal coliform concentration and antecedent rainfall from 7/9/01 to 12/10/02 for VADEQ station 6-CMFH027.14 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH027.14	07/09/2001	8,000	2.67
6-CMFH027.14	09/06/2001	100	1.30
6-CMFH027.14	11/19/2001	100	0.00
6-CMFH027.14	01/03/2002	100	0.00
6-CMFH027.14	02/27/2002	100	0.02
6-CMFH027.14	03/27/2002	100	0.22
6-CMFH027.14	04/04/2002	200	1.39
6-CMFH027.14	05/07/2002	200	1.13
6-CMFH027.14	06/03/2002	800	0.27
6-CMFH027.14	07/10/2002	300	0.03
6-CMFH027.14	08/21/2002	100	0.64
6-CMFH027.14	09/26/2002	8,000	1.97
6-CMFH027.14	10/01/2002	200	1.66
6-CMFH027.14	11/05/2002	300	0.47
6-CMFH027.14	12/10/2002	400	1.79

Table A.9. Observed fecal coliform concentration and antecedent rainfall from 5/20/92 to 9/17/96 for VADEQ station 6-CMFH033.40 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH033.40	05/20/1992	1,200	2.86
6-CMFH033.40	06/24/1992	600	0.33
6-CMFH033.40	07/13/1992	100	0.53
6-CMFH033.40	08/05/1992	100	0.56
6-CMFH033.40	09/23/1992	200	0.14
6-CMFH033.40	10/19/1992	100	0.14
6-CMFH033.40	11/05/1992	100	1.13
6-CMFH033.40	12/15/1992	100	0.51
6-CMFH033.40	01/06/1993	100	0.41
6-CMFH033.40	02/08/1993	100	0.00
6-CMFH033.40	03/24/1993	1,100	1.65
6-CMFH033.40	04/19/1993	10	0.17
6-CMFH033.40	05/04/1993	270	0.00
6-CMFH033.40	06/29/1993	320	0.05
6-CMFH033.40	07/28/1993	140	0.96
6-CMFH033.40	08/19/1993	90	0.28
6-CMFH033.40	09/22/1993	120	0.97
6-CMFH033.40	10/28/1993	190	0.00
6-CMFH033.40	11/17/1993	280	0.18
6-CMFH033.40	01/12/1994	1,190	1.69
6-CMFH033.40	02/08/1994	210	0.37
6-CMFH033.40	03/14/1994	20	1.09
6-CMFH033.40	04/25/1994	10	0.00
6-CMFH033.40	05/11/1994	10	0.72
6-CMFH033.40	07/20/1995	370	0.35
6-CMFH033.40	08/15/1995	130	0.30
6-CMFH033.40	09/12/1995	180	0.03
6-CMFH033.40	10/11/1995	10	0.33
6-CMFH033.40	04/25/1996	120	0.36
6-CMFH033.40	05/13/1996	140	1.42
6-CMFH033.40	06/17/1996	360	0.45
6-CMFH033.40	07/11/1996	130	0.60
6-CMFH033.40	08/20/1996	1,200	0.08
6-CMFH033.40	09/17/1996	1,600	0.97

Table A.10. Observed fecal coliform concentration and antecedent rainfall from 10/8/96 to 2/14/00 for VADEQ station 6-CMFH033.40 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH033.40	10/08/1996	360	0.96
6-CMFH033.40	11/05/1996	60	0.21
6-CMFH033.40	12/04/1996	350	2.51
6-CMFH033.40	01/21/1997	100	0.62
6-CMFH033.40	02/26/1997	200	0.72
6-CMFH033.40	03/10/1997	1,900	1.34
6-CMFH033.40	04/07/1997	100	0.05
6-CMFH033.40	05/27/1997	2,200	0.74
6-CMFH033.40	06/24/1997	230	0.11
6-CMFH033.40	07/17/1997	180	0.00
6-CMFH033.40	08/11/1997	220	0.00
6-CMFH033.40	09/09/1997	330	0.00
6-CMFH033.40	10/07/1997	280	0.00
6-CMFH033.40	11/03/1997	200	0.65
6-CMFH033.40	12/02/1997	130	0.33
6-CMFH033.40	01/20/1998	460	0.89
6-CMFH033.40	03/17/1998	550	0.43
6-CMFH033.40	04/02/1998	240	0.46
6-CMFH033.40	05/04/1998	5,500	1.02
6-CMFH033.40	06/10/1998	6,000	3.05
6-CMFH033.40	07/21/1998	90	0.36
6-CMFH033.40	08/20/1998	190	1.42
6-CMFH033.40	09/09/1998	1,200	0.32
6-CMFH033.40	11/05/1998	260	0.24
6-CMFH033.40	12/08/1998	190	0.48
6-CMFH033.40	02/25/1999	500	0.44
6-CMFH033.40	03/15/1999	20	1.00
6-CMFH033.40	04/26/1999	300	0.03
6-CMFH033.40	09/08/1999	200	0.92
6-CMFH033.40	10/06/1999	100	0.12
6-CMFH033.40	11/03/1999	1,100	0.89
6-CMFH033.40	12/06/1999	700	0.24
6-CMFH033.40	01/05/2000	200	0.08
6-CMFH033.40	02/14/2000	1,600	1.34

Table A.11. Observed fecal coliform concentration and antecedent rainfall from 3/7/00 to 3/6/03 for VADEQ station 6-CMFH033.40 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH033.40	03/07/2000	100	0.00
6-CMFH033.40	04/03/2000	200	0.73
6-CMFH033.40	05/08/2000	200	0.00
6-CMFH033.40	06/05/2000	500	0.00
6-CMFH033.40	07/06/2000	3,600	3.64
6-CMFH033.40	08/15/2000	100	0.40
6-CMFH033.40	09/13/2000	100	0.03
6-CMFH033.40	10/25/2000	100	0.05
6-CMFH033.40	11/06/2000	100	0.00
6-CMFH033.40	12/05/2000	200	0.08
6-CMFH033.40	01/04/2001	100	0.14
6-CMFH033.40	02/21/2001	200	0.86
6-CMFH033.40	03/07/2001	100	1.05
6-CMFH033.40	07/02/2001	700	1.08
6-CMFH033.40	08/07/2001	900	0.19
6-CMFH033.40	09/05/2001	300	1.30
6-CMFH033.40	10/01/2001	100	0.00
6-CMFH033.40	11/26/2001	100	0.29
6-CMFH033.40	12/12/2001	200	1.45
6-CMFH033.40	01/08/2002	100	0.15
6-CMFH033.40	02/13/2002	100	0.05
6-CMFH033.40	03/14/2002	100	0.57
6-CMFH033.40	04/30/2002	100	0.68
6-CMFH033.40	05/14/2002	1,300	1.01
6-CMFH033.40	06/12/2002	200	0.60
6-CMFH033.40	07/02/2002	175	1.48
6-CMFH033.40	08/21/2002	200	0.64
6-CMFH033.40	08/21/2002	180	0.64
6-CMFH033.40	09/11/2002	25	0.00
6-CMFH033.40	10/15/2002	275	0.81
6-CMFH033.40	11/06/2002	1,890	1.15
6-CMFH033.40	12/10/2002	25	1.79
6-CMFH033.40	01/27/2003	25	0.12
6-CMFH033.40	03/06/2003	1,900	0.35

Table A.12. Observed fecal coliform concentration and antecedent rainfall from 4/23/03 to 12/7/06 for VADEQ station 6-CMFH033.40 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH033.40	04/22/2003	350	2.38
6-CMFH033.40	06/10/2003	380	0.79
6-CMFH033.40	07/09/2003	680	1.89
6-CMFH033.40	09/16/2003	1,200	0.44
6-CMFH033.40	11/18/2003	350	0.81
6-CMFH033.40	01/20/2004	350	0.56
6-CMFH033.40	03/16/2004	2,000	0.30
6-CMFH033.40	05/18/2004	450	0.21
6-CMFH033.40	07/26/2004	700	0.37
6-CMFH033.40	09/27/2004	400	0.00
6-CMFH033.40	11/16/2004	700	0.85
6-CMFH033.40	01/27/2005	580	0.39
6-CMFH033.40	03/22/2005	75	0.20
6-CMFH033.40	05/26/2005	250	0.31
6-CMFH033.40	08/08/2005	500	0.62
6-CMFH033.40	10/18/2005	120	0.00
6-CMFH033.40	12/05/2005	820	1.25
6-CMFH033.40	02/21/2006	350	0.47
6-CMFH033.40	04/06/2006	720	0.91
6-CMFH033.40	06/22/2006	75	0.03
6-CMFH033.40	08/03/2006	75	0.75
6-CMFH033.40	10/11/2006	180	1.18
6-CMFH033.40	12/07/2006	2,000	0.36

Table A.13. Observed fecal coliform concentration and antecedent rainfall from 8/7/01 to 6/10/03 for VADEQ station 6-CMFH040.67 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH040.67	08/07/2001	1,200	0.19
6-CMFH040.67	10/01/2001	300	0.00
6-CMFH040.67	12/12/2001	700	1.45
6-CMFH040.67	02/13/2002	100	0.05
6-CMFH040.67	02/13/2002	100	0.05
6-CMFH040.67	04/30/2002	100	0.68
6-CMFH040.67	06/12/2002	800	0.60
6-CMFH040.67	08/21/2002	1,600	0.64
6-CMFH040.67	10/15/2002	5,000	0.81
6-CMFH040.67	12/10/2002	1,000	1.79
6-CMFH040.67	04/22/2003	400	2.38
6-CMFH040.67	06/10/2003	3,600	0.79

Table A.14. Observed fecal coliform concentration and antecedent rainfall from 6/24/92 to 6/21/99 for VADEQ station 6-CMFH045.72 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH045.72	06/24/1992	200	0.33
6-CMFH045.72	08/05/1992	300	0.56
6-CMFH045.72	10/19/1992	100	0.14
6-CMFH045.72	12/15/1992	100	0.51
6-CMFH045.72	02/08/1993	100	0.00
6-CMFH045.72	04/19/1993	80	0.17
6-CMFH045.72	06/29/1993	340	0.05
6-CMFH045.72	08/19/1993	190	0.28
6-CMFH045.72	10/28/1993	10	0.00
6-CMFH045.72	02/08/1994	210	0.37
6-CMFH045.72	04/25/1994	10	0.00
6-CMFH045.72	08/15/1995	200	0.30
6-CMFH045.72	10/11/1995	4	0.33
6-CMFH045.72	04/25/1996	90	0.36
6-CMFH045.72	06/17/1996	6,000	0.45
6-CMFH045.72	08/20/1996	270	0.08
6-CMFH045.72	12/04/1996	250	2.51
6-CMFH045.72	02/26/1997	500	0.72
6-CMFH045.72	04/07/1997	160	0.05
6-CMFH045.72	06/24/1997	400	0.11
6-CMFH045.72	08/11/1997	140	0.00
6-CMFH045.72	10/07/1997	120	0.00
6-CMFH045.72	12/02/1997	30	0.33
6-CMFH045.72	04/02/1998	80	0.46
6-CMFH045.72	06/10/1998	6,000	3.05
6-CMFH045.72	08/20/1998	270	1.42
6-CMFH045.72	09/09/1998	180	0.32
6-CMFH045.72	10/13/1998	70	0.96
6-CMFH045.72	11/05/1998	40	0.24
6-CMFH045.72	12/08/1998	60	0.48
6-CMFH045.72	01/14/1999	60	0.44
6-CMFH045.72	04/26/1999	200	0.03
6-CMFH045.72	05/24/1999	40	0.41
6-CMFH045.72	06/21/1999	80	0.24

Table A.15. Observed fecal coliform concentration and antecedent rainfall from 7/7/99 to 6/10/03 for VADEQ station 6-CMFH045.72 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH045.72	07/07/1999	20	0.05
6-CMFH045.72	09/08/1999	300	0.92
6-CMFH045.72	10/06/1999	100	0.12
6-CMFH045.72	11/03/1999	700	0.89
6-CMFH045.72	12/06/1999	100	0.24
6-CMFH045.72	01/05/2000	100	0.08
6-CMFH045.72	02/14/2000	1,300	1.34
6-CMFH045.72	03/07/2000	100	0.00
6-CMFH045.72	04/03/2000	500	0.73
6-CMFH045.72	05/08/2000	100	0.00
6-CMFH045.72	06/05/2000	4,200	0.00
6-CMFH045.72	07/06/2000	1,700	3.64
6-CMFH045.72	08/15/2000	100	0.40
6-CMFH045.72	09/13/2000	500	0.03
6-CMFH045.72	10/25/2000	100	0.05
6-CMFH045.72	11/06/2000	100	0.00
6-CMFH045.72	12/05/2000	100	0.08
6-CMFH045.72	01/04/2001	100	0.14
6-CMFH045.72	02/21/2001	100	0.86
6-CMFH045.72	03/07/2001	100	1.05
6-CMFH045.72	08/07/2001	200	0.19
6-CMFH045.72	08/07/2001	500	0.19
6-CMFH045.72	10/01/2001	100	0.00
6-CMFH045.72	12/12/2001	1,000	1.45
6-CMFH045.72	02/13/2002	100	0.05
6-CMFH045.72	04/30/2002	100	0.68
6-CMFH045.72	06/12/2002	100	0.60
6-CMFH045.72	08/21/2002	100	0.64
6-CMFH045.72	10/15/2002	100	0.81
6-CMFH045.72	12/10/2002	100	1.79
6-CMFH045.72	04/22/2003	600	2.38
6-CMFH045.72	06/10/2003	100	0.79

Table A.16. Observed fecal coliform concentration and antecedent rainfall from 6/24/92 to 2/25/99 for VADEQ station 6-CMFH053.36 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH053.36	06/24/1992	400	0.33
6-CMFH053.36	08/05/1992	500	0.56
6-CMFH053.36	10/19/1992	100	0.14
6-CMFH053.36	12/15/1992	100	0.51
6-CMFH053.36	02/08/1993	100	0.00
6-CMFH053.36	04/19/1993	90	0.17
6-CMFH053.36	06/29/1993	680	0.05
6-CMFH053.36	08/19/1993	1,980	0.28
6-CMFH053.36	10/28/1993	640	0.00
6-CMFH053.36	02/08/1994	350	0.37
6-CMFH053.36	04/25/1994	10	0.00
6-CMFH053.36	08/15/1995	1,800	0.30
6-CMFH053.36	10/11/1995	10	0.33
6-CMFH053.36	04/25/1996	150	0.36
6-CMFH053.36	06/17/1996	4,400	0.45
6-CMFH053.36	08/20/1996	800	0.08
6-CMFH053.36	10/08/1996	530	0.96
6-CMFH053.36	12/04/1996	310	2.51
6-CMFH053.36	02/26/1997	100	0.72
6-CMFH053.36	04/07/1997	170	0.05
6-CMFH053.36	06/24/1997	600	0.11
6-CMFH053.36	08/11/1997	590	0.00
6-CMFH053.36	10/07/1997	570	0.00
6-CMFH053.36	12/02/1997	320	0.33
6-CMFH053.36	02/12/1998	2,100	0.00
6-CMFH053.36	04/02/1998	220	0.46
6-CMFH053.36	06/10/1998	6,000	3.05
6-CMFH053.36	08/20/1998	1,000	1.42
6-CMFH053.36	09/09/1998	390	0.32
6-CMFH053.36	10/13/1998	450	0.96
6-CMFH053.36	11/05/1998	130	0.24
6-CMFH053.36	12/08/1998	430	0.48
6-CMFH053.36	01/14/1999	20	0.44
6-CMFH053.36	02/25/1999	70	0.44

Table A.17. Observed fecal coliform concentration and antecedent rainfall from 3/15/99 to 3/7/01 for VADEQ station 6-CMFH053.36 in Middle Fork Holston River watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
6-CMFH053.36	03/15/1999	600	1.00
6-CMFH053.36	04/26/1999	200	0.03
6-CMFH053.36	05/24/1999	60	0.41
6-CMFH053.36	06/21/1999	50	0.24
6-CMFH053.36	07/07/1999	400	0.05
6-CMFH053.36	08/17/1999	40	0.42
6-CMFH053.36	09/08/1999	100	0.92
6-CMFH053.36	10/06/1999	1,100	0.12
6-CMFH053.36	11/03/1999	1,400	0.89
6-CMFH053.36	12/06/1999	100	0.24
6-CMFH053.36	01/05/2000	100	0.08
6-CMFH053.36	02/14/2000	8,000	1.34
6-CMFH053.36	03/07/2000	100	0.00
6-CMFH053.36	04/03/2000	100	0.73
6-CMFH053.36	05/08/2000	400	0.00
6-CMFH053.36	06/05/2000	4,400	0.00
6-CMFH053.36	07/06/2000	8,000	3.64
6-CMFH053.36	08/15/2000	200	0.40
6-CMFH053.36	09/13/2000	100	0.03
6-CMFH053.36	10/25/2000	100	0.05
6-CMFH053.36	11/06/2000	100	0.00
6-CMFH053.36	12/05/2000	100	0.08
6-CMFH053.36	01/04/2001	100	0.14
6-CMFH053.36	02/21/2001	100	0.86
6-CMFH053.36	03/07/2001	100	1.05

Appendix B – Bacteria Source Tracking Report

The bacterial source tracking (BST) data were generated in a separate study for VADEQ performed by MapTech, Inc. and New River Highlands RC&D. The reader should refer to data and analyses for station 6-CMFH013.21 and 6-CMFH045.72.

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

Incorporated by Reference

Please refer to full document posted at:

http://www.deq.virginia.gov/tmdl/pdf/bstreports/directoryListing/032009bst.pdf

or contact VADEQ-SWRO

Appendix C – Fecal Coliform Loading in Subwatersheds

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

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	43,916	11,376	2,474	211	1,541
Feb.	55	45,577	11,659	2,578	192	1,404
Mar.	269	85,182	21,215	4,934	148	1,541
Apr.	215	84,859	21,221	4,947	143	1,491
May.	55	88,310	22,394	5,229	148	1,541
Jun.	1	87,262	22,103	5,168	141	1,491
Jul.	1	91,910	23,312	5,458	146	1,541
Aug.	1	93,859	23,784	5,576	146	1,541
Sep.	1	93,238	23,501	5,517	204	1,491
Oct.	42	66,490	16,847	3,842	211	1,541
Nov.	83	65,784	16,642	3,803	204	1,491
Dec.	1	42,500	11,021	2,385	211	1,541
Total	724	888,885	225,076	51,911	2,106	18,152

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

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

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	21,401	5,490	1,246	172	982
Feb.	84	22,737	5,788	1,332	157	895
Mar.	419	41,960	10,513	2,502	122	982
Apr.	335	41,625	10,450	2,490	118	950
May.	84	43,831	11,082	2,644	122	982
Jun.	1	43,477	10,989	2,625	118	950
Jul.	1	46,067	11,642	2,784	122	982
Aug.	1	47,211	11,929	2,856	122	982
Sep.	1	46,956	11,835	2,836	167	950
Oct.	128	30,478	7,713	1,802	172	982
Nov.	128	30,892	7,812	1,831	167	950
Dec.	1	20,541	5,274	1,192	172	982
Total	1,183	437,176	110,517	26,139	1,730	11,568

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

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

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	35,276	9,166	1,967	384	1,047
Feb.	115	37,271	9,592	2,102	350	954
Mar.	570	67,820	17,096	3,950	284	1,047
Apr.	456	67,227	16,981	3,931	275	1,013
May.	115	70,706	17,995	4,174	284	1,047
Jun.	1	70,099	17,832	4,144	269	1,013
Jul.	1	74,237	18,879	4,395	278	1,047
Aug.	1	76,043	19,332	4,508	278	1,047
Sep.	1	75,609	19,168	4,478	372	1,013
Oct.	174	49,641	12,676	2,844	384	1,047
Nov.	174	50,247	12,817	2,890	372	1,013
Dec.	1	33,919	8,826	1,882	384	1,047
Total	1,610	708,096	180,361	41,266	3,913	12,332

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

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

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	16,241	4,177	938	141	1,236
Feb.	20	17,275	4,397	1,002	129	1,126
Mar.	98	31,918	7,958	1,883	104	1,236
Apr.	78	31,621	7,909	1,874	101	1,196
May.	20	33,165	8,387	1,990	104	1,236
Jun.	0	32,894	8,315	1,976	95	1,196
Jul.	0	34,848	8,808	2,095	98	1,236
Aug.	0	35,709	9,024	2,149	98	1,236
Sep.	0	35,553	8,952	2,135	137	1,196
Oct.	30	23,154	5,850	1,356	141	1,236
Nov.	30	23,462	5,924	1,378	137	1,196
Dec.	0	15,593	4,015	897	141	1,236
Total	276	331,433	83,717	19,674	1,426	14,557

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

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

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	7,268	1,869	419	207	748
Feb.	12	7,728	1,968	448	189	682
Mar.	58	14,272	3,562	843	157	748
Apr.	47	14,142	3,540	839	152	724
May.	12	14,841	3,753	891	157	748
Jun.	0	14,720	3,721	884	146	724
Jul.	0	15,595	3,942	938	151	748
Aug.	0	15,980	4,039	962	151	748
Sep.	0	15,908	4,007	955	200	724
Oct.	18	10,357	2,618	607	207	748
Nov.	18	10,495	2,651	617	200	724
Dec.	0	6,978	1,796	401	207	748
Total	164	148,285	37,465	8,804	2,126	8,814

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

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

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	433	113	24	1	108
Feb.	1	456	118	25	1	98
Mar.	7	825	209	48	1	108
Apr.	5	817	207	47	1	104
May.	1	859	220	50	1	108
Jun.	0	852	217	50	1	104
Jul.	0	902	230	53	1	108
Aug.	0	924	236	54	1	108
Sep.	0	918	234	54	1	104
Oct.	2	606	155	34	1	108
Nov.	2	613	157	35	1	104
Dec.	0	416	109	23	1	108
Total	19	8,620	2,205	497	12	1,272

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

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

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	0	0	218	226
Feb.	0	0	0	199	206
Mar.	0	0	0	168	226
Apr.	0	0	0	163	219
May.	0	0	0	168	226
Jun.	0	0	0	163	219
Jul.	0	0	0	168	226
Aug.	0	0	0	168	226
Sep.	0	0	0	211	219
Oct.	0	0	0	218	226
Nov.	0	0	0	211	219
Dec.	0	0	0	218	226
Total	0	0	0	2,273	2,662

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

Table C.8.Monthly nonpoint fecal coliform loadings in sub-watershed MFH-08.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	15,242	3,920	880	291	724
Feb.	29	16,204	4,127	941	265	659
Mar.	143	29,909	7,469	1,768	219	724
Apr.	115	29,641	7,424	1,759	212	700
May.	29	31,118	7,871	1,868	219	724
Jun.	0	30,864	7,804	1,855	206	700
Jul.	0	32,698	8,267	1,967	213	724
Aug.	0	33,506	8,470	2,018	213	724
Sep.	0	33,350	8,402	2,004	282	700
Oct.	44	21,712	5,491	1,273	291	724
Nov.	44	22,001	5,560	1,294	282	700
Dec.	0	14,634	3,768	842	291	724
Total	405	310,878	78,574	18,470	2,984	8,527

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

Table C.9.Monthly nonpoint fecal coliform loadings in sub-watershed MFH-09.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	42,766	11,112	2,382	249	1,826
Feb.	99	45,218	11,628	2,546	227	1,664
Mar.	492	82,384	20,722	4,784	171	1,826
Apr.	394	81,627	20,582	4,762	165	1,767
May.	99	85,734	21,811	5,057	171	1,826
Jun.	1	84,997	21,613	5,020	165	1,767
Jul.	1	90,011	22,882	5,324	171	1,826
Aug.	1	92,200	23,430	5,461	171	1,826
Sep.	1	91,711	23,232	5,425	241	1,767
Oct.	150	60,246	15,365	3,445	249	1,826
Nov.	150	60,979	15,536	3,501	241	1,767
Dec.	1	41,121	10,700	2,279	249	1,826
Total	1,389	858,994	218,614	49,986	2,468	21,512

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

Table C.10. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-10.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	17,804	4,577	1,028	116	1,609
Feb.	23	18,940	4,819	1,099	106	1,466
Mar.	114	35,003	8,726	2,066	81	1,609
Apr.	91	34,680	8,673	2,056	78	1,557
May.	23	36,377	9,197	2,183	81	1,609
Jun.	0	36,080	9,119	2,167	71	1,557
Jul.	0	38,224	9,659	2,299	73	1,609
Aug.	0	39,169	9,896	2,358	73	1,609
Sep.	0	38,997	9,818	2,342	112	1,557
Oct.	35	25,389	6,413	1,487	116	1,609
Nov.	35	25,727	6,494	1,511	112	1,557
Dec.	0	17,094	4,399	984	116	1,609
Total	322	363,485	91,791	21,580	1,136	18,957

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

Table C.11. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-11.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	3,676	948	210	29	846
Feb.	3,908	996	224	27	771
Mar.	7,205	1,795	421	22	846
Apr.	7,133	1,783	419	21	819
May.	7,468	1,890	445	22	846
Jun.	7,406	1,874	442	16	819
Jul.	7,845	1,985	469	16	846
Aug.	8,038	2,033	481	16	846
Sep.	8,005	2,017	478	29	819
Oct.	5,231	1,323	303	29	846
Nov.	5,299	1,339	308	29	819
Dec.	3,531	912	201	29	846
Total	74,746	18,895	4,401	286	9,968

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

Table C.12. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-12.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	8,297	2,132	481	329	1,621
Feb.	8,839	2,246	514	299	1,477
Mar.	16,380	4,071	966	251	1,621
Apr.	16,220	4,046	961	242	1,569
May.	16,982	4,290	1,021	251	1,621
Jun.	16,844	4,254	1,013	235	1,569
Jul.	17,845	4,506	1,075	243	1,621
Aug.	18,287	4,617	1,102	243	1,621
Sep.	18,217	4,580	1,095	318	1,569
Oct.	11,860	2,990	696	329	1,621
Nov.	12,018	3,028	707	318	1,569
Dec.	7,965	2,049	460	329	1,621
Total	169,754	42,810	10,092	3,386	19,098

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

Table C.13. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-13.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	6,244	1,608	359	182	1,600
Feb.	6,644	1,692	384	166	1,458
Mar.	12,278	3,055	721	139	1,600
Apr.	12,157	3,036	717	135	1,548
May.	12,727	3,219	762	139	1,600
Jun.	12,623	3,192	756	127	1,548
Jul.	13,371	3,381	802	132	1,600
Aug.	13,701	3,463	823	132	1,600
Sep.	13,647	3,435	817	176	1,548
Oct.	8,903	2,249	519	182	1,600
Nov.	9,020	2,277	528	176	1,548
Dec.	5,996	1,546	344	182	1,600
Total	127,313	32,154	7,532	1,866	18,849

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

Table C.14. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-14.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	2,567	659	149	34	1,451
Feb.	2,735	694	159	31	1,322
Mar.	5,072	1,260	299	26	1,451
Apr.	5,022	1,252	298	25	1,404
May.	5,258	1,328	316	26	1,451
Jun.	5,216	1,317	314	18	1,404
Jul.	5,526	1,395	333	19	1,451
Aug.	5,663	1,429	341	19	1,451
Sep.	5,641	1,418	339	32	1,404
Oct.	3,671	925	215	34	1,451
Nov.	3,720	937	219	32	1,404
Dec.	2,464	633	142	34	1,451
Total	52,556	13,246	3,124	329	17,094

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

Table C.15. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-15.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	26,350	6,779	1,520	618	2,223
Feb.	54	28,004	7,135	1,625	563	2,026
Mar.	268	51,659	12,907	3,052	461	2,223
Apr.	215	51,198	12,828	3,038	446	2,151
May.	54	53,762	13,602	3,226	461	2,223
Jun.	0	53,322	13,486	3,202	446	2,151
Jul.	0	56,490	14,285	3,397	461	2,223
Aug.	0	57,887	14,635	3,484	461	2,223
Sep.	0	57,612	14,518	3,461	598	2,151
Oct.	82	37,515	9,491	2,198	618	2,223
Nov.	82	38,013	9,610	2,233	598	2,151
Dec.	0	25,300	6,516	1,454	618	2,223
Total	758	537,113	135,792	31,891	6,349	26,190

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

Table C.16. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-16.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	24,187	6,183	1,423	77	1,253
Feb.	23	24,929	6,292	1,461	70	1,142
Mar.	112	47,971	11,809	2,829	54	1,253
Apr.	90	47,980	11,873	2,849	53	1,212
May.	23	49,695	12,505	3,004	54	1,253
Jun.	0	49,051	12,319	2,961	47	1,212
Jul.	0	51,469	12,970	3,120	49	1,253
Aug.	0	52,508	13,210	3,180	49	1,253
Sep.	0	52,159	13,031	3,139	74	1,212
Oct.	17	38,621	9,686	2,299	77	1,253
Nov.	34	37,781	9,451	2,244	74	1,212
Dec.	0	23,468	6,003	1,378	77	1,253
Total	303	499,820	125,332	29,887	754	14,760

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

Table C.17. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-17.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	28,967	7,422	1,692	178	1,414
Feb.	25	30,292	7,670	1,768	162	1,288
Mar.	123	57,286	14,171	3,379	128	1,414
Apr.	98	57,052	14,175	3,386	123	1,368
May.	25	59,400	14,975	3,580	128	1,414
Jun.	0	58,749	14,795	3,540	118	1,368
Jul.	0	61,925	15,619	3,741	122	1,414
Aug.	0	63,293	15,950	3,824	122	1,414
Sep.	0	62,935	15,775	3,785	172	1,368
Oct.	19	44,093	11,084	2,607	178	1,414
Nov.	38	43,770	10,986	2,588	172	1,368
Dec.	0	27,974	7,173	1,630	178	1,414
Total	331	595,736	149,795	35,521	1,780	16,655

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

Table C.18. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-18.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	23,616	6,077	1,360	95	2,166
Feb.	62	25,082	6,395	1,453	86	1,974
Mar.	307	46,214	11,564	2,732	65	2,166
Apr.	246	45,813	11,492	2,719	63	2,096
May.	62	48,147	12,185	2,887	65	2,166
Jun.	0	47,752	12,081	2,866	57	2,096
Jul.	0	50,589	12,797	3,040	59	2,166
Aug.	0	51,839	13,110	3,118	59	2,166
Sep.	0	51,581	13,006	3,097	92	2,096
Oct.	94	33,587	8,505	1,967	95	2,166
Nov.	94	34,032	8,611	1,998	92	2,096
Dec.	0	22,676	5,841	1,301	95	2,166
Total	866	480,930	121,665	28,538	922	25,524

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

Table C.19. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-19.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	35,172	9,141	1,961	507	2,854
Feb.	98	37,174	9,565	2,096	462	2,600
Mar.	488	67,679	17,044	3,937	379	2,854
Apr.	391	67,072	16,929	3,919	367	2,762
May.	98	70,496	17,940	4,161	379	2,854
Jun.	1	69,890	17,777	4,131	360	2,762
Jul.	1	74,014	18,821	4,381	372	2,854
Aug.	1	75,814	19,272	4,494	372	2,854
Sep.	1	75,396	19,109	4,464	491	2,762
Oct.	149	49,518	12,639	2,836	507	2,854
Nov.	149	50,121	12,779	2,881	491	2,762
Dec.	1	33,820	8,802	1,876	507	2,854
Total	1,379	706,165	179,817	41,136	5,195	33,621

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

Table C.20. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-20.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	21,481	5,526	1,238	107	1,544
Feb.	128	22,751	5,816	1,323	97	1,407
Mar.	639	41,723	10,522	2,487	72	1,544
Apr.	511	41,425	10,457	2,475	69	1,494
May.	128	43,748	11,088	2,629	72	1,544
Jun.	1	43,390	10,993	2,610	69	1,494
Jul.	1	45,972	11,645	2,768	72	1,544
Aug.	1	47,110	11,930	2,839	72	1,544
Sep.	1	46,809	11,835	2,820	104	1,494
Oct.	195	30,427	7,737	1,791	107	1,544
Nov.	195	30,832	7,833	1,820	104	1,494
Dec.	1	20,626	5,312	1,184	107	1,544
Total	1,802	436,295	110,691	25,983	1,051	18,195

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

Table C.21. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-21.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	4	159,888	41,546	8,905	762	7,263
Feb.	515	168,921	43,475	9,518	694	6,619
Mar.	2,561	307,336	77,472	17,886	518	7,263
Apr.	2,050	304,642	76,949	17,803	502	7,029
May.	515	320,396	81,543	18,904	518	7,263
Jun.	4	317,642	80,805	18,767	496	7,029
Jul.	4	336,388	85,548	19,905	513	7,263
Aug.	4	344,572	87,598	20,418	513	7,263
Sep.	4	342,607	86,857	20,280	737	7,029
Oct.	782	224,971	57,445	12,879	762	7,263
Nov.	782	227,714	58,084	13,087	737	7,029
Dec.	4	153,738	40,006	8,520	762	7,263
Total	7,229	3,208,816	817,329	186,872	7,515	85,578

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

Table C.22. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-22.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	1,810	465	105	17	214
Feb.	17	1,914	490	112	16	195
Mar.	81	3,500	888	211	11	214
Apr.	65	3,480	883	210	11	207
May.	17	3,691	936	223	11	214
Jun.	0	3,661	928	221	11	207
Jul.	0	3,880	983	234	11	214
Aug.	0	3,976	1,007	240	11	214
Sep.	0	3,946	999	239	16	207
Oct.	25	2,558	652	152	17	214
Nov.	25	2,593	661	154	16	207
Dec.	0	1,738	447	100	17	214
Total	232	36,747	9,339	2,201	167	2,519

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

Table C.23. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-23.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	3	42,221	11,193	2,167	171	1,562
Feb.	336	43,926	11,565	2,316	156	1,423
Mar.	1,670	77,103	19,929	4,351	106	1,562
Apr.	1,337	76,534	19,766	4,331	103	1,511
May.	336	81,056	20,918	4,599	106	1,562
Jun.	3	80,278	20,704	4,565	103	1,511
Jul.	3	84,944	21,892	4,842	106	1,562
Aug.	3	86,935	22,391	4,967	106	1,562
Sep.	3	86,154	22,175	4,933	166	1,511
Oct.	510	57,658	15,059	3,134	171	1,562
Nov.	510	58,217	15,179	3,184	166	1,511
Dec.	3	40,725	10,818	2,074	171	1,562
Total	4,718	815,753	211,589	45,463	1,631	18,400

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

Table C.24. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-24.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	3	47,625	12,704	2,385	270	2,500
Feb.	369	49,388	13,076	2,548	246	2,278
Mar.	1,834	85,941	22,299	4,784	177	2,500
Apr.	1,468	85,276	22,108	4,761	171	2,419
May.	369	90,283	23,387	5,056	177	2,500
Jun.	3	89,389	23,138	5,019	164	2,419
Jul.	3	94,555	24,457	5,323	170	2,500
Aug.	3	96,741	25,004	5,460	170	2,500
Sep.	3	95,843	24,754	5,423	261	2,419
Oct.	560	64,582	16,950	3,446	270	2,500
Nov.	560	65,156	17,069	3,502	261	2,419
Dec.	3	45,983	12,292	2,282	270	2,500
Total	5,179	910,762	237,238	49,988	2,608	29,454

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

Table C.25. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-25.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	4	53,728	14,022	2,928	157	1,394
Feb.	221	53,787	13,866	2,941	143	1,270
Mar.	1,093	101,790	25,456	5,787	100	1,394
Apr.	875	102,321	25,691	5,864	97	1,349
May.	222	105,780	26,938	6,157	100	1,394
Jun.	4	103,928	26,423	6,047	97	1,349
Jul.	4	108,700	27,701	6,348	100	1,394
Aug.	4	110,415	28,098	6,447	100	1,394
Sep.	4	109,141	27,608	6,343	152	1,349
Oct.	170	87,500	22,271	4,991	157	1,394
Nov.	335	84,072	21,362	4,782	152	1,349
Dec.	4	52,536	13,724	2,854	157	1,394
Total	2,939	1,073,699	273,163	61,490	1,513	16,423

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

Table C.26. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-26.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	597	154	34	12	72
Feb.	634	161	36	11	65
Mar.	1,166	290	68	12	72
Apr.	1,154	288	68	12	69
May.	1,209	306	72	12	72
Jun.	1,198	303	71	12	69
Jul.	1,269	321	76	12	72
Aug.	1,300	329	78	12	72
Sep.	1,295	326	77	12	69
Oct.	848	214	49	12	72
Nov.	859	217	50	12	69
Dec.	574	148	32	12	72
Total	12,104	3,058	711	145	843

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

Table C.27. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-27.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	7	94,726	26,307	3,975	392	5,687
Feb.	640	95,061	26,136	4,163	357	5,183
Mar.	3,173	158,443	42,138	7,933	256	5,687
Apr.	2,540	157,483	41,839	7,942	248	5,504
May.	640	165,532	44,014	8,402	256	5,687
Jun.	7	163,085	43,318	8,312	241	5,504
Jul.	7	171,671	45,552	8,786	249	5,687
Aug.	7	174,824	46,342	8,984	249	5,687
Sep.	7	172,518	45,655	8,896	380	5,504
Oct.	846	128,568	34,732	6,081	392	5,687
Nov.	970	127,064	34,272	6,050	380	5,504
Dec.	7	92,357	25,714	3,827	392	5,687
Total	8,852	1,701,333	456,020	83,353	3,793	67,010

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

Table C.28. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-28.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	13,751	3,600	741	73	388
Feb.	115	14,388	3,746	791	66	354
Mar.	569	25,633	6,576	1,485	50	388
Apr.	455	25,460	6,528	1,478	49	376
May.	115	26,979	6,913	1,569	50	388
Jun.	1	26,735	6,847	1,558	43	376
Jul.	1	28,304	7,245	1,652	45	388
Aug.	1	28,982	7,415	1,694	45	388
Sep.	1	28,737	7,348	1,683	70	376
Oct.	174	19,010	4,917	1,070	73	388
Nov.	174	19,220	4,965	1,087	70	376
Dec.	1	13,242	3,473	709	73	388
Total	1,609	270,441	69,573	15,516	706	4,573

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

Table C.29. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-29.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	3,315	866	180	21	113
Feb.	13	3,486	902	192	19	103
Mar.	66	6,270	1,589	361	14	113
Apr.	53	6,216	1,578	359	13	109
May.	13	6,544	1,671	382	14	113
Jun.	0	6,486	1,656	379	13	109
Jul.	0	6,866	1,752	402	14	113
Aug.	0	7,031	1,793	412	14	113
Sep.	0	6,986	1,777	409	21	109
Oct.	20	4,620	1,186	260	21	113
Nov.	20	4,672	1,198	264	21	109
Dec.	0	3,191	835	172	21	113
Total	187	65,683	16,805	3,773	208	1,330

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

Table C.30. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-30.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	2	12,965	3,393	701	74	346
Feb.	109	13,569	3,532	749	68	315
Mar.	538	24,193	6,205	1,404	52	346
Apr.	431	24,030	6,160	1,397	50	335
May.	109	25,465	6,524	1,483	52	346
Jun.	2	25,235	6,461	1,473	45	335
Jul.	2	26,717	6,837	1,562	46	346
Aug.	2	27,357	6,998	1,602	46	346
Sep.	2	27,126	6,935	1,591	72	335
Oct.	165	17,934	4,638	1,012	74	346
Nov.	165	18,134	4,683	1,028	72	335
Dec.	2	12,484	3,273	671	74	346
Total	1,526	255,209	65,638	14,672	724	4,076

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

Table C.31. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-31.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	3	37,704	10,061	1,889	162	2,628
Feb.	292	39,094	10,355	2,018	148	2,395
Mar.	1,451	68,007	17,651	3,786	105	2,628
Apr.	1,162	67,480	17,499	3,768	101	2,544
May.	293	71,441	18,511	4,001	105	2,628
Jun.	3	70,733	18,313	3,972	94	2,544
Jul.	3	74,820	19,357	4,213	97	2,628
Aug.	3	76,549	19,790	4,321	97	2,628
Sep.	3	75,838	19,592	4,292	157	2,544
Oct.	444	51,114	13,420	2,728	162	2,628
Nov.	444	51,567	13,513	2,772	157	2,544
Dec.	3	36,404	9,736	1,807	162	2,628
Total	4,103	720,752	187,797	39,567	1,549	30,967

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

Table C.32. Monthly nonpoint fecal coliform loadings in sub-watershed MFH-32.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	3	44,257	11,808	2,217	227	3,138
Feb.	343	45,893	12,153	2,368	207	2,859
Mar.	1,704	79,848	20,721	4,445	149	3,138
Apr.	1,363	79,229	20,543	4,424	144	3,036
May.	343	83,881	21,731	4,698	149	3,138
Jun.	3	83,049	21,500	4,663	137	3,036
Jul.	3	87,848	22,725	4,946	141	3,138
Aug.	3	89,879	23,233	5,073	141	3,138
Sep.	3	89,045	23,001	5,039	220	3,036
Oct.	520	60,008	15,752	3,203	227	3,138
Nov.	520	60,540	15,862	3,254	220	3,036
Dec.	3	42,731	11,426	2,121	227	3,138
Total	4,808	846,208	220,455	46,452	2,188	36,967

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

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

Table D.1. Required annual reductions in nonpoint sources in sub-watershed MFH-01.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	72,433	0.1%	2,173	97%
Pasture	116,587,124	98%	3,497,610	97%
Forest	210,576	0.2%	210,576	0%
Residential	1,815,219	2%	54,457	97%
Total	118,685,352	100%	3,764,816	97%

Table D.2. Required annual reductions in direct nonpoint sources in sub-watershed MFH-01.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	120,289	45%	3,609	97%
Wildlife in Streams	54,580	20%	54,580	0%
Straight Pipes	93,796	35%	0	100%
Total	268,665	100%	58,189	78%

Table D.3. Required annual reductions in nonpoint sources in sub-watershed MFH-02.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	117,546	0.2%	3,526	97%
Pasture	57,322,918	98%	1,719,686	97%
Forest	104,889	0.2%	104,889	0%
Residential	1,156,820	2%	34,705	97%
Total	58,702,173	100%	1,862,806	97%

Table D.4. Required annual reductions in direct nonpoint sources in sub-watershed MFH-02.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	118,297	0.2%	3,549	97%
Wildlife in Streams	57,383,255	98%	1,721,496	97%
Straight Pipes	172,989	0.3%	172,989	0%
Total	1,156,820	2%	34,705	97%

Table D.5. Required annual reductions in nonpoint sources in sub-watershed MFH-03.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	60,959	39%	1,829	97%
Pasture	39,432	25%	39,432	0%
Forest	55,810	36%	0	100%
Residential	156,202	100%	41,261	74%
Total	60,959	39%	1,829	97%

Table D.6. Required annual reductions in direct nonpoint sources in sub-watershed MFH-03.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	160,980	0.2%	4,829	97%
Wildlife in Streams	92,972,264	98%	2,789,165	97%
Straight Pipes	391,324	0.4%	391,324	0%
Total	1,233,194	1%	36,996	97%

Table D.7. Required annual reductions in nonpoint sources in sub-watershed MFH-04.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	96,243	34%	2,887	97%
Pasture	79,422	28%	79,422	0%
Forest	111,620	39%	0	100%
Residential	287,285	100%	82,309	71%
Total	96,243	34%	2,887	97%

Table D.8. Required annual reductions in direct nonpoint sources in sub-watershed MFH-04.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	45,885	29%	1,835	96%
Wildlife in Streams	32,006	20%	32,006	0%
Straight Pipes	80,647	51%	0	100%
Total	158,539	100%	33,842	79%

Table D.9. Required annual reductions in nonpoint sources in sub-watershed MFH-05.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	16,429	0.1%	657	96%
Pasture	19,455,363	95%	778,215	96%
Forest	212,602	1%	212,602	0%
Residential	881,421	4%	35,257	96%
Total	20,565,815	100%	1,026,731	95%

Table D.10. Required annual reductions in direct nonpoint sources in sub-watershed MFH-05.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	20,541	19%	822	96%
Wildlife in Streams	35,862	33%	35,862	0%
Straight Pipes	51,939	48%	0	100%
Total	108,341	100%	36,684	66%

Table D.11. Required annual reductions in nonpoint sources in sub-watershed MFH-06.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	1,938	0.2%	78	96%
Pasture	1,132,256	90%	45,290	96%
Forest	1,201	0.1%	1,201	0%
Residential	127,180	10%	5,087	96%
Total	1,262,575	100%	51,656	96%

Table D.12. Required annual reductions in direct nonpoint sources in sub-watershed MFH-06.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	1,160	81%	46	96%
Wildlife in Streams	268	19%	268	0%
Total	1,428	100%	315	78%

Table D.13. Required annual reductions in nonpoint sources in sub-watershed MFH-07.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	20	0%	1	96%
Forest	227,286	46%	227,286	0%
Residential	266,231	54%	10,649	96%
Total	493,537	100%	237,936	52%

Table D.14. Required annual reductions in direct nonpoint sources in sub-watershed MFH-07.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Wildlife in Streams	32,477	100%	32,477	0%
Total	32,477	100%	32,477	0%

Table D.15. Required annual reductions in nonpoint sources in sub-watershed MFH-08.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	40,481	0.1%	1,619	96%
Pasture	40,792,206	97%	1,631,689	96%
Forest	298,385	0.7%	298,385	0%
Residential	852,676	2%	34,107	96%
Total	41,983,747	100%	1,965,800	95%

Table D.16. Required annual reductions in direct nonpoint sources in sub-watershed MFH-08.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	43,069	28%	1,723	96%
Wildlife in Streams	54,514	36%	54,514	0%
Straight Pipes	54,057	36%	0	100%
Total	151,640	100%	56,237	63%

Table D.17. Required annual reductions in nonpoint sources in sub-watershed MFH-09.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	138,896	0.1%	5,556	96%
Pasture	112,759,411	98%	4,510,379	96%
Forest	246,780	0.2%	246,780	0%
Residential	2,151,176	2%	86,047	96%
Total	115,296,263	100%	4,848,762	96%

Table D.18. Required annual reductions in direct nonpoint sources in sub-watershed MFH-09.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	116,618	37%	4,665	96%
Wildlife in Streams	61,678	20%	61,678	0%
Straight Pipes	136,750	43%	0	100%
Total	315,046	100%	66,343	79%

Table D.19. Required annual reductions in nonpoint sources in sub-watershed MFH-10.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	32,176	0.1%	1,287	96%
Pasture	47,685,567	96%	1,907,424	96%
Forest	113,589	0.2%	113,589	0%
Residential	1,895,684	4%	75,827	96%
Total	49,727,016	100%	2,098,127	96%

Table D.20. Required annual reductions in direct nonpoint sources in sub-watershed MFH-10.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	50,358	44%	2,014	96%
Wildlife in Streams	28,796	25%	28,796	0%
Straight Pipes	35,210	31%	0	100%
Total	114,364	100%	30,811	73%

Table D.21. Required annual reductions in nonpoint sources in sub-watershed MFH-11.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	9,804,076	91%	392,163	96%
Forest	28,633	0.3%	28,633	0%
Residential	996,804	9%	39,872	96%
Total	10,829,513	100%	460,668	96%

Table D.22. Required annual reductions in direct nonpoint sources in sub-watershed MFH-11.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	10,270	59%	411	96%
Wildlife in Streams	7,045	41%	7,045	0%
Total	17,315	100%	7,456	57%

Table D.23. Required annual reductions in nonpoint sources in sub-watershed MFH-12.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	22,265,573	91%	890,623	96%
Forest	338,648	1%	338,648	0%
Residential	1,909,783	8%	76,391	96%
Total	24,514,004	100%	1,305,662	95%

Table D.24. Required annual reductions in direct nonpoint sources in sub-watershed MFH-12.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	23,522	16%	941	96%
Wildlife in Streams	57,385	39%	57,385	0%
Straight Pipes	66,622	45%	0	100%
Total	147,529	100%	58,326	60%

Table D.25. Required annual reductions in nonpoint sources in sub-watershed MFH-13.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	16,699,856	89%	667,995	96%
Forest	186,606	1.0%	186,606	0%
Residential	1,884,873	10%	75,395	96%
Total	18,771,334	100%	929,995	95%

Table D.26. Required annual reductions in direct nonpoint sources in sub-watershed MFH-13.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	17,559	19%	702	96%
Wildlife in Streams	33,665	36%	33,665	0%
Straight Pipes	42,296	45%	0	100%
Total	93,520	100%	34,367	63%

Table D.27. Required annual reductions in nonpoint sources in sub-watershed MFH-14.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	6,892,595	80%	275,704	96%
Forest	32,886	0.4%	32,886	0%
Residential	1,709,370	20%	68,375	96%
Total	8,634,851	100%	376,965	96%

Table D.28. Required annual reductions in direct nonpoint sources in sub-watershed MFH-14.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	7,289	48%	292	96%
Wildlife in Streams	7,903	52%	7,903	0%
Total	15,192	100%	8,195	46%

Table D.29. Required annual reductions in nonpoint sources in sub-watershed MFH-15.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	75,813	0.1%	1,516	98%
Pasture	70,479,508	95%	1,409,589	98%
Forest	634,877	0.9%	634,877	0%
Residential	2,618,952	4%	52,379	98%
Total	73,809,150	100%	2,098,361	97%

Table D.30. Required annual reductions in direct nonpoint sources in sub-watershed MFH-15.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	74,377	28%	1,488	98%
Wildlife in Streams	112,363	43%	112,363	0%
Straight Pipes	75,607	29%	0	100%
Total	262,347	100%	113,850	57%

Table D.31. Required annual reductions in nonpoint sources in sub-watershed MFH-16.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	30,259	0%	605	98%
Pasture	65,503,963	98%	1,310,078	98%
Forest	75,393	0.1%	75,393	0%
Residential	1,475,975	2%	29,519	98%
Total	67,085,591	100%	1,415,596	98%

Table D.32. Required annual reductions in direct nonpoint sources in sub-watershed MFH-16.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	69,059	54%	1,381	98%
Wildlife in Streams	21,966	17%	21,966	0%
Straight Pipes	37,256	29%	0	100%
Total	128,281	100%	23,347	82%

Table D.33. Required annual reductions in nonpoint sources in sub-watershed MFH-17.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	33,050	0%	661	98%
Pasture	78,105,202	98%	1,562,103	98%
Forest	178,037	0.2%	178,037	0%
Residential	1,665,540	2%	33,311	98%
Total	79,981,829	100%	1,774,111	98%

Table D.34. Required annual reductions in direct nonpoint sources in sub-watershed MFH-17.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	82,427	53%	1,649	98%
Wildlife in Streams	41,380	26%	41,380	0%
Straight Pipes	32,580	21%	0	100%
Total	156,388	100%	43,029	72%

Table D.35. Required annual reductions in nonpoint sources in sub-watershed MFH-18.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	86,622	0.1%	1,732	98%
Pasture	63,113,249	96%	1,262,264	98%
Forest	92,186	0.1%	92,186	0%
Residential	2,552,440	4%	51,049	98%
Total	65,844,497	100%	1,407,231	98%

Table D.36. Required annual reductions in direct nonpoint sources in sub-watershed MFH-18.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	66,591	51%	1,332	98%
Wildlife in Streams	26,553	20%	26,553	0%
Straight Pipes	37,840	29%	0	100%
Total	130,984	100%	27,885	79%

Table D.37. Required annual reductions in nonpoint sources in sub-watershed MFH-19.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	137,910	0.1%	2,758	98%
Pasture	92,711,805	96%	1,854,234	98%
Forest	519,516	0.5%	519,516	0%
Residential	3,362,126	3%	67,242	98%
Total	96,731,356	100%	2,443,751	97%

Table D.38. Required annual reductions in direct nonpoint sources in sub-watershed MFH-19.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	95,912	33%	1,918	98%
Wildlife in Streams	101,422	35%	101,422	0%
Straight Pipes	96,426	33%	0	100%
Total	293,759	100%	103,340	65%

Table D.39. Required annual reductions in nonpoint sources in sub-watershed MFH-20.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	180,194	0.3%	3,604	98%
Pasture	57,296,964	96%	1,145,938	98%
Forest	105,079	0.2%	105,079	0%
Residential	1,819,493	3%	36,390	98%
Total	59,401,730	100%	1,291,011	98%

Table D.40. Required annual reductions in direct nonpoint sources in sub-watershed MFH-20.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	60,628	49%	1,213	98%
Wildlife in Streams	28,189	23%	28,189	0%
Straight Pipes	35,795	29%	0	100%
Total	124,612	100%	29,402	76%

Table D.41. Required annual reductions in nonpoint sources in sub-watershed MFH-21.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	722,918	0.2%	14,458	98%
Pasture	421,301,706	98%	8,426,026	98%
Forest	751,503	0.2%	751,503	0%
Residential	8,557,808	2%	171,156	98%
Total	431,333,934	100%	9,363,143	98%

Table D.42. Required annual reductions in direct nonpoint sources in sub-watershed MFH-21.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	435,992	62%	8,720	98%
Wildlife in Streams	201,336	29%	201,336	0%
Straight Pipes	68,667	10%	0	100%
Total	705,995	100%	210,055	70%

Table D.43. Required annual reductions in nonpoint sources in sub-watershed MFH-22.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	23,240	0.5%	465	98%
Pasture	4,828,714	94%	96,574	98%
Forest	16,745	0.3%	16,745	0%
Residential	251,949	5%	5,039	98%
Total	5,120,648	100%	118,823	98%

Table D.44. Required annual reductions in direct nonpoint sources in sub-watershed MFH-22.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	5,135	52%	103	98%
Wildlife in Streams	4,753	48%	4,753	0%
Total	9,888	100%	4,856	51%

Table D.45. Required annual reductions in nonpoint sources in sub-watershed MFH-23.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	471,770	0.4%	9,435	98%
Pasture	107,280,419	98%	2,145,606	98%
Forest	163,115	0.1%	163,115	0%
Residential	1,839,983	2%	36,800	98%
Total	109,755,288	100%	2,354,956	98%

Table D.46. Required annual reductions in direct nonpoint sources in sub-watershed MFH-23.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	106,016	56%	2,120	98%
Wildlife in Streams	51,656	27%	51,656	0%
Straight Pipes	32,434	17%	0	100%
Total	190,106	100%	53,776	72%

Table D.47. Required annual reductions in nonpoint sources in sub-watershed MFH-24.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	517,880	0.4%	10,358	98%
Pasture	119,798,846	97%	2,395,975	98%
Forest	260,776	0.2%	260,776	0%
Residential	2,945,413	2%	58,908	98%
Total	123,522,915	100%	2,726,017	98%

Table D.48. Required annual reductions in direct nonpoint sources in sub-watershed MFH-24.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	116,452	38%	2,329	98%
Wildlife in Streams	84,076	27%	84,076	0%
Straight Pipes	107,895	35%	0	100%
Total	308,424	100%	86,406	72%

Table D.49. Required annual reductions in nonpoint sources in sub-watershed MFH-25.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	293,931	0.2%	5,879	98%
Pasture	140,835,128	99%	2,816,700	98%
Forest	151,278	0.1%	151,278	0%
Residential	1,642,347	1%	32,847	98%
Total	142,922,683	100%	3,006,703	98%

Table D.50. Required annual reductions in direct nonpoint sources in sub-watershed MFH-25.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	141,243	63%	2,825	98%
Wildlife in Streams	53,334	24%	53,334	0%
Straight Pipes	30,827	14%	0	100%
Total	225,404	100%	56,159	75%

Table D.51. Required annual reductions in nonpoint sources in sub-watershed MFH-26.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	1,587,241	94%	31,745	98%
Forest	14,502	0.9%	14,502	0%
Residential	84,263	5%	1,685	98%
Total	1,686,007	100%	47,932	97%

Table D.52. Required annual reductions in direct nonpoint sources in sub-watershed MFH-26.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	1,657	32%	33	98%
Wildlife in Streams	3,447	68%	3,447	0%
Total	5,104	100%	3,480	32%

Table D.53. Required annual reductions in nonpoint sources in sub-watershed MFH-27.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	885,152	0.4%	17,703	98%
Pasture	224,070,544	97%	4,481,407	98%
Forest	379,347	0.2%	379,347	0%
Residential	6,701,023	3%	134,020	98%
Total	232,036,066	100%	5,012,477	98%

Table D.54. Required annual reductions in direct nonpoint sources in sub-watershed MFH-27.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	193,224	54%	3,864	98%
Wildlife in Streams	128,190	36%	128,190	0%
Straight Pipes	39,155	11%	0	100%
Total	360,568	100%	132,054	63%

Table D.55. Required annual reductions in nonpoint sources in sub-watershed MFH-28.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	160,861	0.4%	3,217	98%
Pasture	35,553,007	98%	711,059	98%
Forest	70,627	0.2%	70,627	0%
Residential	457,256	1%	9,145	98%
Total	36,241,751	100%	794,049	98%

Table D.56. Required annual reductions in direct nonpoint sources in sub-watershed MFH-28.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	36,112	27%	722	98%
Wildlife in Streams	26,816	20%	26,816	0%
Straight Pipes	71,005	53%	0	100%
Total	133,932	100%	27,538	79%

Table D.57. Required annual reductions in nonpoint sources in sub-watershed MFH-29.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	18,748	0.2%	375	98%
Pasture	8,626,078	98%	172,521	98%
Forest	20,761	0.2%	20,761	0%
Residential	133,024	2%	2,660	98%
Total	8,798,611	100%	196,318	98%

Table D.58. Required annual reductions in direct nonpoint sources in sub-watershed MFH-29.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	8,779	54%	176	98%
Wildlife in Streams	7,450	46%	7,450	0%
Total	16,230	100%	7,626	53%

Table D.59. Required annual reductions in nonpoint sources in sub-watershed MFH-30.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	152,561	0.4%	3,051	98%
Pasture	33,551,958	98%	671,039	98%
Forest	72,385	0.2%	72,385	0%
Residential	407,619	1%	8,152	98%
Total	34,184,522	100%	754,627	98%

Table D.60. Required annual reductions in direct nonpoint sources in sub-watershed MFH-30.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	34,124	26%	682	98%
Wildlife in Streams	28,834	22%	28,834	0%
Straight Pipes	67,206	52%	0	100%
Total	130,164	100%	29,517	77%

Table D.61. Required annual reductions in nonpoint sources in sub-watershed MFH-31.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	410,276	0.4%	8,206	98%
Pasture	94,811,675	96%	1,896,232	98%
Forest	154,906	0.2%	154,906	0%
Residential	3,096,736	3%	61,935	98%
Total	98,473,593	100%	2,121,278	98%

Table D.62. Required annual reductions in direct nonpoint sources in sub-watershed MFH-31.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	92,102	37%	1,842	98%
Wildlife in Streams	65,214	26%	65,214	0%
Straight Pipes	93,504	37%	0	100%
Total	250,819	100%	67,056	73%

Table D.63. Required annual reductions in nonpoint sources in sub-watershed MFH-32.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	480,823	0.4%	9,616	98%
Pasture	111,311,446	96%	2,226,227	98%
Forest	218,765	0.2%	218,765	0%
Residential	3,696,732	3%	73,935	98%
Total	115,707,765	100%	2,528,543	98%

Table D.64. Required annual reductions in direct nonpoint sources in sub-watershed MFH-32.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	108,170	46%	2,163	98%
Wildlife in Streams	77,824	33%	77,824	0%
Straight Pipes	49,747	21%	0	100%
Total	235,741	100%	79,987	66%