E. coli Total Maximum Daily Loads in the Upper Clinch River Watershed of Tazewell County, Virginia

(A Nested TMDL Approach)

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ACKNOWLEDGEMENTS

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Virginia Department of Conservation and Recreation (VADCR)

Tazewell Soil and Water Conservation District (SWCD)

Virginia Department of Health

Watershed citizens

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EXECUTIVE SUMMARY

Background and Applicable Standards

There are four different impaired streams in this study area, Clinch River, Middle Creek, Plum Creek and Coal Creek. There are seven separate impaired segments. Three segments are located on Coal, Plum and Middle Creeks with the remainder on the Clinch River.

All seven segments have bacterial impairments. Table ES.1 shows the details of these impairments.

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

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

Stream Name Impairment ID	**Impairment(s) Contracted**	**Initial Listing Year**	**2008 River Miles**	**2008 Listing Violation%**	**Impairment Location Description**
					Fecal Bacteria Impairments in the Clinch River Watershed Near Richlands
Middle Creek VAS-P03R_MID01A98	*E. coli*	2006	2.65	30 EC	River mile 2.53 downstream to Clinch River
Clinch River VAS-P03R_CLN02A00	*E. coli*	2004	5.39	24 EC	Dry Branch confluence downstream to the Raven-Doran raw intake just upstream from Town Hill Creek
Clinch River VAS_P03R_CLN01A98	*E. coli*	2002	3.10	18 EC	Raven-Doran raw water intake downstream to the Mill Creek confluence.
Coal Creek VAS-P03R_COL01A04	*E. coli*	2008	3.07	NA	Left Fork Coal Creek downstream to Clinch River
					Fecal Bacteria Impairments in the Clinch River Watershed Near Tazewell
Clinch River VAS-P01R_CLN01A98	Fecal coliform	2004	5.5	33 FC	Lincolnshire Branch confluence downstream to Plum Creek confluence.
Clinch River VAS-P02R_CLN01A98	Fecal coliform	2006	6.01	27 FC	Plum Creek confluence downstream to community of Pounding Mill
Plum Creek VAS-P01R_PLU01A04	Fecal coliform	2004	5.06	33 FC	From the headwaters downstream to the Clinch River confluence.

FC Based on the interim instantaneous fecal coliform standard of 400 cfu/100mL.
EC Based on the instantaneous *E. coli* standard of 235 cfu/100mL.

TMDL Endpoint and Water Quality Assessment

Fecal bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard. For this TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126-cfu/100 mL. A translator developed by VADEQ was used to convert fecal coliform values to E. coli values.

Source Assessment

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

Modeling Procedures

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

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

Hydrology

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and fecal coliform loads. For purposes of modeling the Upper Clinch River watershed, inputs to streamflow and in-stream fecal bacteria, the drainage area was divided into nine (9) subwatersheds.

Fecal Coliform

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

Load Allocation Scenarios

The next step in the TMDL processes was to reduce the various source loads to levels that would result in attainment of the water quality standards or endpoints. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. The final TMDL information is shown in Table ES.2.

The final bacterial TMDLs for the Upper Clinch River watershed include 100% reductions in straight pipes and sewer overflows.

Table ES.2 Average annual in-stream cumulative pollutant loads modeled after allocation in the Upper Clinch River impairments.

Pollutant	Units	Impairment	WLA[1]	LA	MOS	TMDL	Existing Load	Percent Reduction[2]
E. coli	cfu/yr	**Clinch River near Tazewell**	2.09E+13	6.80E+14	*Implicit*	7.01E+14	1.23E+16	94.30%
E. coli	cfu/yr	**Clinch River near Richlands**	6.29E+13	3.26E+15	*Implicit*	3.32E+15	1.46E+16	77.26%

[1] WLA by permit can be found in the corresponding allocation chapters.
[2] Percent reduction does not include the Margin of Safety (MOS).

Implementation

The goal of the TMDL program is to establish a path that will lead to attainment of water quality standards. The first step in this process is to develop TMDLs that will result in meeting water quality standards. This report represents the first phase of that effort for the impairments in the Upper Clinch River watershed. The next step will be development of a TMDL implementation plan (IP), required by Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA). The final step is to implement the TMDL IPs and to monitor stream water quality to determine if water quality standards are being attained.

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

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

Public Participation

During development of the TMDL for the impairments in the Upper Clinch River study area, public involvement was encouraged through a technical advisory committee meeting (07/08/2010), a first public meeting (07/08/2010), and a final public meeting (12/21/2010). An introduction of the agencies involved, an overview of the TMDL process, details of the pollutant sources, and the specific approach to developing the

Upper Clinch River watershed TMDLs were presented at the first of the public meeting. Public understanding of and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting. Written comments were addressed in the final document.

1. INTRODUCTION

1.1 Regulations Background

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

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

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

1.2 *Upper Clinch River and Tributaries Watershed Characteristics*

The Upper Clinch River watershed (USGS Hydrologic Unit Code 06010205) is located in Tazewell County, Virginia. This watershed is a part of the Tennessee/Big Sandy River basin, which drains via the Mississippi River to the Gulf of Mexico. The location of the watershed is shown in Figure 1.1. The drainage area flowing into the most downstream impairment in this project is approximately 115,000 acres.

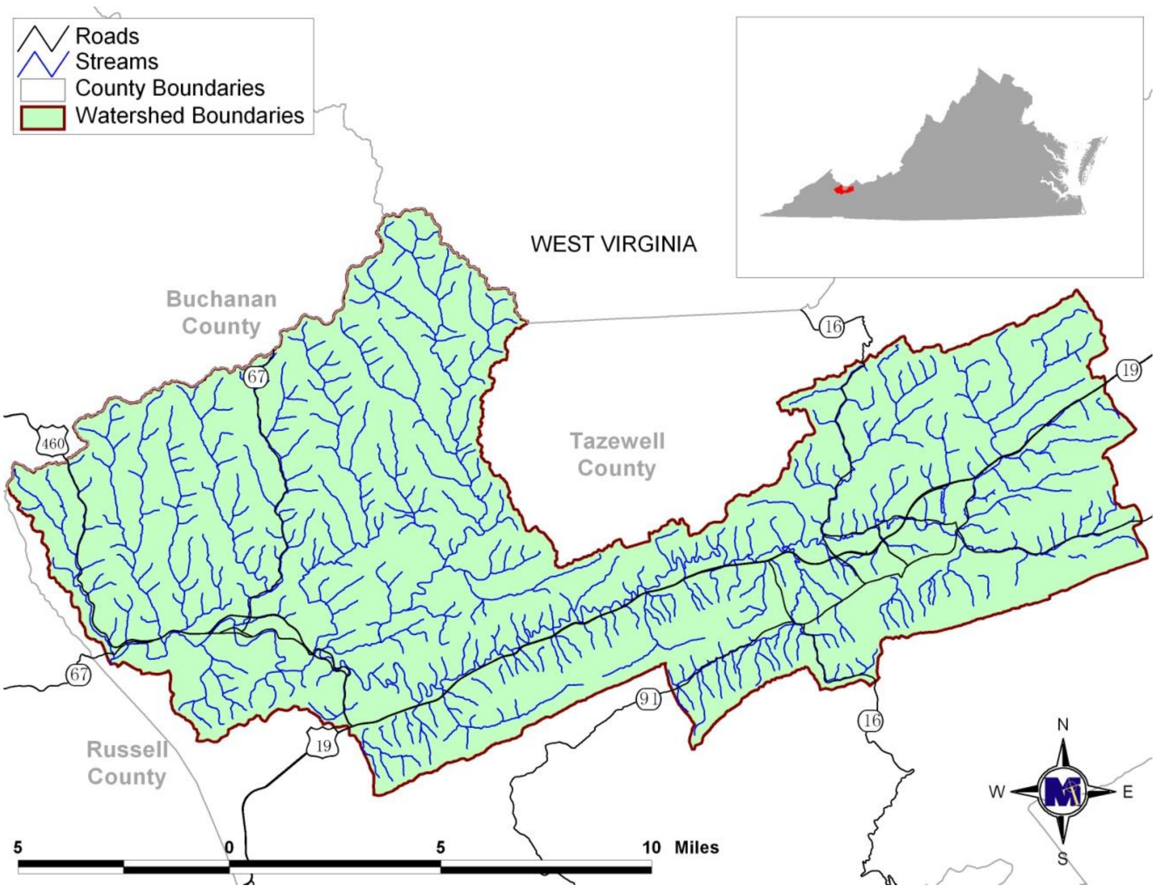

Figure 1.1 Location of the Upper Clinch River watershed.

The Upper Clinch River and Tributaries watershed is located within the level III Central Appalachian (Level IV subset - Cumberland Mountains) and the level III Ridge and Valley ecoregions with three level IV subsets: Southern Shale Valleys, Southern Sandstone Ridges and Southern Limestone/Dolomite Valleys and Low Rolling Hills.

As for the climatic conditions in the headwaters of the Upper Clinch River watershed, during the period from 1896 to 2009 Burkes Gap, Virginia (NCDC station# 441209) received an average annual precipitation of approximately 45 inches, with 52% of the precipitation occurring during the May through October growing season (SERCC, 2009). Average annual snowfall is 41.8 inches, with the highest snowfall occurring during January (SERCC, 2009). The highest average daily temperature of 78.5 ºF occurs in July, while the lowest average daily temperature of 21.7 ºF occurs in January (SERCC, 2009).

Land use in the study area was characterized using the National Land Cover Database 2001 (NLCD). The drainage area is predominantly forest with woodlands covering approximately 68% of the area. Pasture and hay land covers account for roughly 19% of the drainage area. Developed, mining, and water land uses account for the remainder of the study area. A detailed breakdown of land use is shown in Table 1.1.

Table 1.1 Spatial distribution of land use types in acres in the Upper Clinch River Watershed study area.

Land Use Type	Acres	Percentage
Open Water	832	0.73%
AML	1,401	1.22%
Gas Wells	266	0.23%
Residential	8,647	7.55%
Forest	78,081	68.19%
Commercial	3,007	2.63%
Barren*	160	0.14%
Pasture/Hay	21,517	18.79%
Cropland	244	0.21%
LAX**	350	0.31%
Total Acres	114,505	100%

* AML – Abandoned Mine Land

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

*** LAX - Livestock pasture access near flowing streams.

Note: Does not include land use from the Indian Creek watershed, which has an approved TMDL.

1.3 Upper Clinch River and Tributaries Impairments

There are four different impaired streams in this study area, Clinch River, Middle Creek, Plum Creek and Coal Creek. There are seven separate impaired segments. In the sections below each impaired stream segment is described. Also, see Figure 1.2 for a map of the impaired segments in the Upper Clinch River and Tributaries, and see Table 1.2 for a chart of the impairments within the Upper Clinch River and Tributaries watershed included in this study.

The USEPA approved a bacterial TMDL on April 17, 2008 for Indian Creek, which is located in the study area. In addition, Clinch River segment (VAS-P01R_CLN01A98) had a benthic macroinvertebrate TMDL approved by the USEPA on April 26, 2004 (https://www.deq.virginia.gov/TMDLDataSearch/ReportSearch.jspx).

1.3.1 Clinch River (VAS-P01R_CLN01A98)

This portion of the Clinch River in Tazewell County, VA flows southwest from the Lincolnshire Branch confluence downstream to the Plum Creek confluence (5.5 stream miles). Monitoring at VADEQ ambient monitoring station 6BCLN346.60 showed a 33% bacteria standard violation rate in the 2004 assessment.

1.3.2 Plum Creek (VAS-P01R_PLU01A04)

Plum Creek in Tazewell County flows north before its confluence with the Clinch River. Plum Creek from its headwaters to its confluence with the Clinch River was listed as impaired for not supporting the recreation/swimming use on the 2008 303(d) list. This segment was first listed in 2004. Ambient monitoring at 6BPLU000.40 showed a 33% bacteria standard violation rate in the 2004 assessment.

1.3.3 Clinch River (VAS-P02R_CLN01A98)

This portion of the Clinch River in Tazewell County, VA flows southwest from Plum Creek near Pisgah downstream to Deskins Creek near Maxwell (6.01 stream miles). Monitoring at VADEQ ambient monitoring station 6BCLN339.53 showed a 27% bacteria standard violation rate in the 2004 assessment.

1.3.4 Clinch River (VAS-P03R_CLN02A00)

This impaired segment was added to the 2004 impaired waters list for not supporting the recreation/swimming use. This impaired segment extends from the confluence with Dry Branch downstream to the Raven-Doran raw water intake just upstream of Town Hill Creek (5.39 stream miles). Monitoring station 6BCLN321.13 had a bacteria standard violation rate of 24% in the 2008 assessment.

1.3.5 Middle Creek (VAS-P03R_MID01A98)

Middle Creek in Tazewell County, VA flows south into the Clinch River near Cedar Bluff. Middle Creek, from river mile 2.53 downstream to the confluence with the Clinch River, was initially listed in 2006 as impaired for not supporting the recreation/swimming use. Monitoring at station 6BMID000.20 showed a 30% bacteria standard violation rate in the 2008 assessment.

1.3.6 Coal Creek (VAS-P03R_COL01A04)

Coal Creek in Tazewell County flows south through Red Ash before its confluence with the Clinch River.

A 3.07-mile segment of Coal Creek was listed as impaired on the 2010 303(d) list. This segment, from the Left Fork of Coal Creek downstream to the outlet at the Clinch River, does not support the recreation/swimming use. VADEQ monitoring station 6BCOL000.12 showed an 83% bacteria standard violation rate in the 2010 assessment.

1.3.7 Clinch River (VAS-P03R_CLN01A98)

This impaired segment was added to the 2002 impaired waters list for not supporting the recreation/swimming use. This impaired segment extends from the Raven-Doran raw water intake downstream to the Mill Creek confluence (3.10 stream miles). Monitoring station 6BCLN315.11 had a bacteria standard violation rate of 18% in the 2008 assessment.

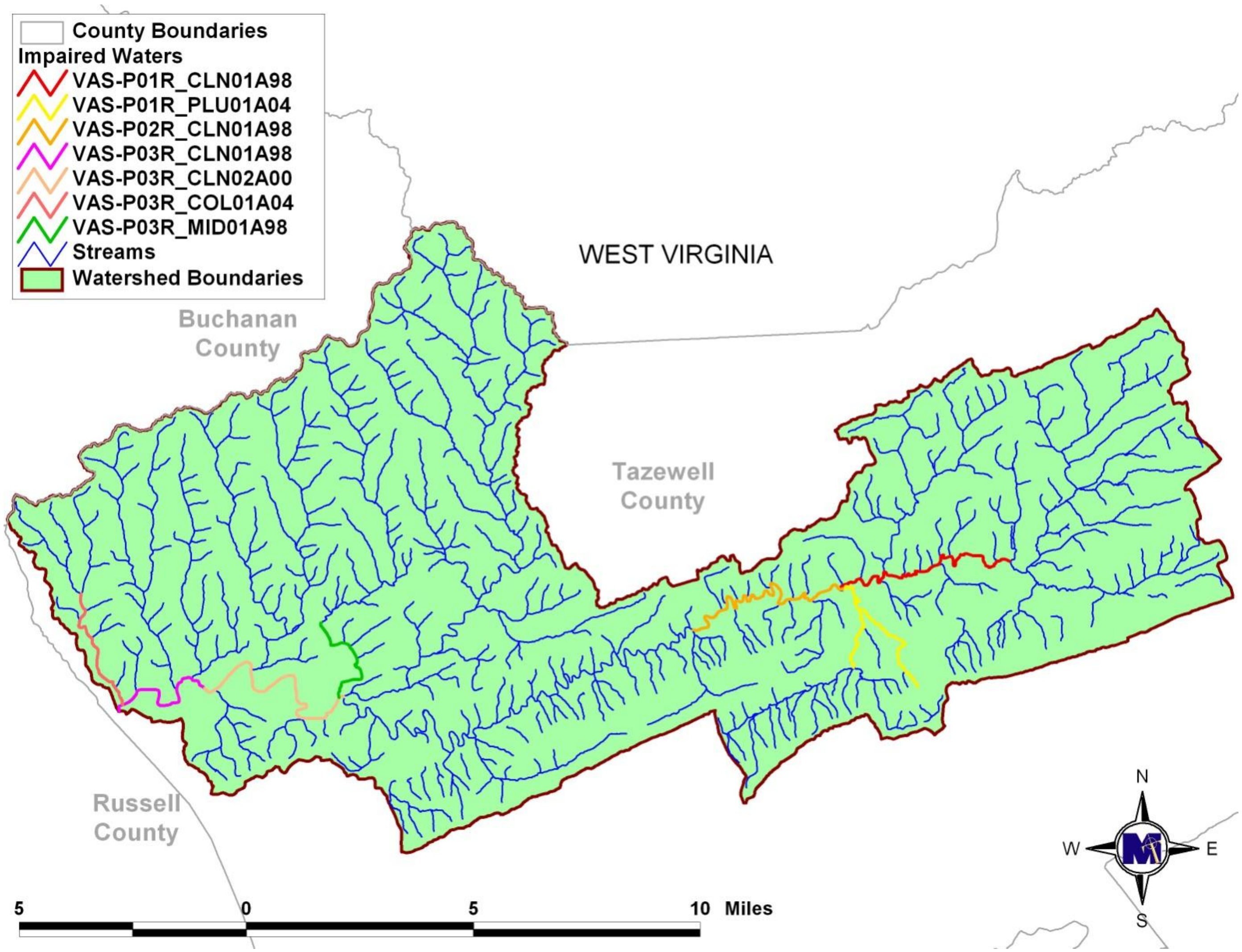

Figure 1.2 The impaired segments in the Upper Clinch River and Tributaries watershed.

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

Stream Name Impairment ID	**Impairment(s) Contracted**	**Initial Listing Year**	**2008 River Miles**	**2008 Listing Violation%**	**Impairment Location Description**
Middle Creek VAS-P03R_MID01A98	*E. coli*	2006	2.65	30 EC	River mile 2.53 downstream to Clinch River.
Coal Creek VAS-P03R_COL01A04	*E. coli*	2008/2010	3.07	NA	Left Fork Coal Creek downstream to Clinch River.
Clinch River VAS-P03R_CLN02A00	*E. coli*	2004	5.39	24 EC	Dry Branch confluence downstream to the Raven-Doran raw intake just upstream from Town Hill Creek.
Clinch River VAS_P03R_CLN01A98	*E. coli*	2002	3.10	18 EC	Raven-Doran raw water intake downstream to the Mill Creek confluence.
Clinch River VAS-P01R_CLN01A98	Fecal coliform	2004	5.5	33 FC	Lincolnshire Branch confluence downstream to Plum Creek confluence.
Clinch River VAS-P02R_CLN01A98	Fecal coliform	2006	6.01	27 FC	Plum Creek confluence downstream to the Deskins Creek confluence.
Plum Creek VAS-P01R_PLU01A04	Fecal coliform	2004	5.06	33 FC	From the headwaters downstream to the Clinch River confluence.

EC - Based on the interim instantaneous *E. coli* standard of 235 cfu/100Ml.
FC - Based on the interim instantaneous fecal coliform standard of 400 cfu/100mL

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2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Applicable Water Quality Standards

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

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

> *A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*
>
> ♦
>
> *D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

Virginia adopted its current *E. coli* and *enterococci* standard in January 2003. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals; there is a strong correlation between these and the incidence of gastrointestinal illness. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

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

> *A. In surface waters, except shellfish waters and certain waters identified in subsection B of this section, the following criteria shall apply to protect primary contact recreational uses:*

1. 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. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.

2. E. coli and enterococci bacteria per 100 ml of water shall not exceed the following:

	Geometric Mean[1]	*Single Sample Maximum*[2]
Freshwater[3]		
E. coli	*126*	*235*
Saltwater and Transition Zone[3]		
enterococci	*35*	*104*

[1] For two or more samples taken during any calendar month.
[2] No single sample maximum for *enterococci* and *E. coli* shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater and 0.7 shall be as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.
[3] See 9 VAC 25-260-140 C for freshwater and transition zone delineation.

2.2 Selection of a TMDL Endpoint

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

Since modeling provided simulated output of *E. coli* concentrations at 1-hour intervals, assessment of TMDLs was made using both the geometric mean standard and the instantaneous standard. Therefore, the in-stream *E. coli* targets for the TMDLs in this study were a monthly geometric mean not exceeding 126 cfu/100 ml and a single sample not exceeding 235 cfu/100 ml.

2.3 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal bacteria monitoring data in the Upper Clinch River and Tributaries watershed. An examination of data from water quality stations used in the 303(d) assessment was performed. Sources of data and pertinent results are discussed.

2.3.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- Bacteria enumerations from nineteen VADEQ in-stream monitoring stations with date from January 1990 to December 2009,
- Bacterial source tracking at one VADEQ in-stream monitoring station.

2.3.1.1 VADEQ Water Quality Monitoring for TMDL Assessment

Data from in-stream water samples, collected at VADEQ monitoring stations from January 1990 to December 2009 (Figure 2.1), were analyzed for fecal coliform (Table 2.1) and *E.coli* (Table 2.2). Samples were taken for the express purpose of determining compliance with the state instantaneous bacteria standards. Until recent years, and as a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 mL or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) were not analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported values of 100 cfu/100 mL most likely represent concentrations below 100 cfu/100 mL, and reported concentrations of 8,000 or 16,000 cfu/100 mL most likely represent concentrations in excess of these values. Information in the tables is arranged in alphabetical order by stream name then from downstream to upstream station location. Appendix A contains bacteria water quality standard frequency violation graphs for each monitoring station with sufficient data.

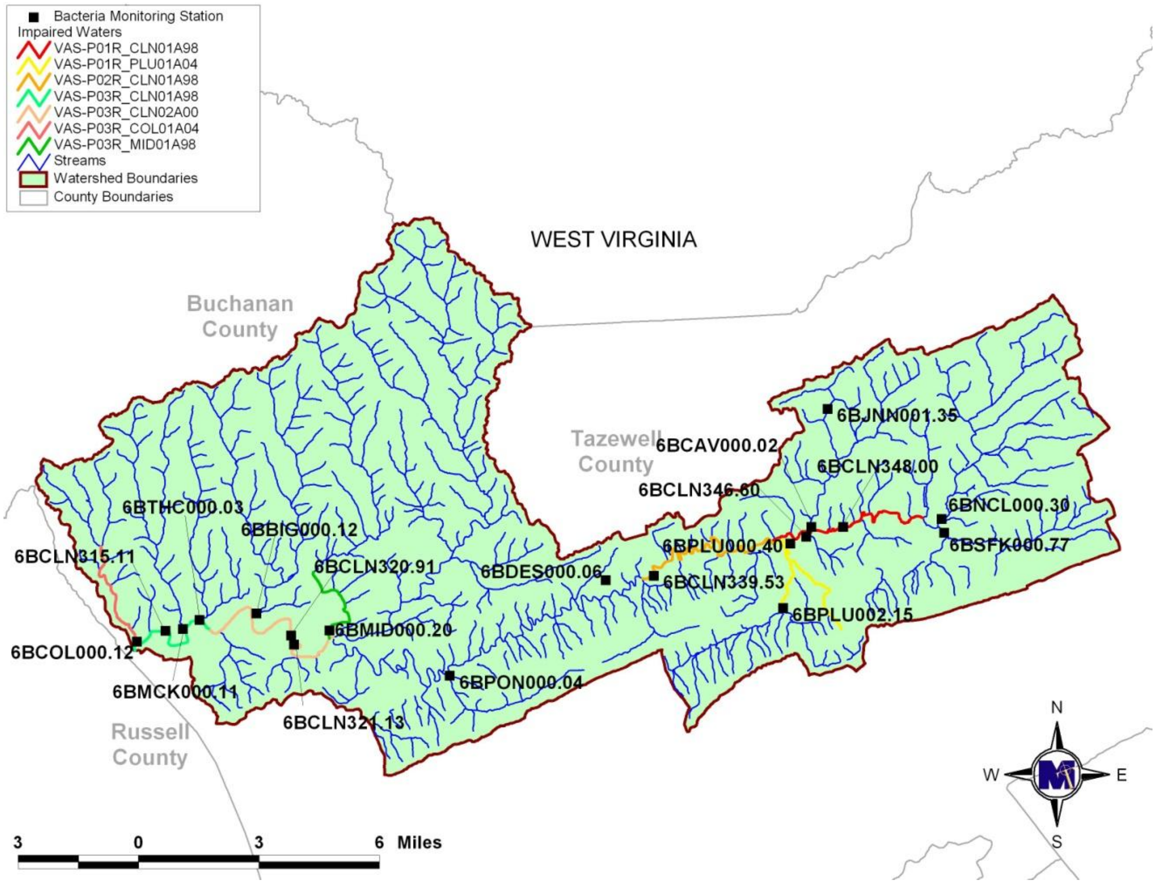

Figure 2.1 Location of VADEQ water quality monitoring stations in the Upper Clinch River and Tributaries watershed.

Table 2.1 Summary of fecal coliform (cfu/100mL) data collected by VADEQ from January 1990 – December 2009.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Clinch River	6BCLN315.11	1/90 - 6/03	80	0	4,400	397	200	624	22.5%
Clinch River	6BCLN320.91	4/04	1	50	50	50	NA	NA	0.0%
Clinch River	6BCLN321.13	7/05 - 12/09	62	25	2,100	321	100	544	16.1%
Clinch River	6BCLN339.53	5/92 - 3/01	56	0	6,000	439	100	1,078	12.5%
Clinch River	6BCLN346.60	8/01 - 6/03	12	100	2,800	633	300	814	33.3%
Clinch River	6BCLN348.00	8/01 - 6/03	12	100	900	292	150	297	25.0%
Johnson Branch	6BJNN001.35	5/02 - 3/03	2	180	450	315	NA	191	50.0%
North Fork Clinch River	6BNCL000.30	8/01 - 6/03	12	100	1,300	233	100	345	8.3%
Plum Creek	6BPLU000.40	8/01 - 6/03	12	100	7,200	1,038	125	2,023	33.3%

NA – Not applicable

[1] Based on the interim instantaneous fecal coliform standard of 400 cfu/100mL.

Table 2.2 Summary of *E. coli* (cfu/100mL) data collected by VADEQ from May 2002 – December 2009.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Big Creek	6BBIG000.12	1/07 - 12/09	21	25	920	300	135	324	38.1%
Cavitts Creek	6BCAV000.02	2/07 - 12/08	12	25	2,000	280	135	549	25.0%
Clinch River	6BCLN315.11	1/07 - 12/09	21	25	1,600	297	120	442	33.3%
Clinch River	6BCLN320.91	4/04	1	10	10	10	NA	NA	0.0%
Clinch River	6BCLN321.13	7/02 - 12/09	56	10	2,000	222	78	419	17.9%
Coal Creek	6BCOL000.12	7/07 – 12/09	18	120	2,000	701	475	513	94.4%
Mudlick Creek	6BMCK000.11	1/07 - 12/09	21	25	480	115	25	135	19.0%
Middle Creek	6BMID000.20	11/04 - 12/09	36	25	2,000	441	110	642	38.9%
Town Hill Creek	6BTHC000.03	1/07 - 12/08	12	25	1,800	461	290	507	50.0%
Clinch River	6BCLN346.60	2/07 - 12/08	12	50	2,000	534	315	603	58.3%
Clinch River	6BCLN348.00	2/07 - 12/08	12	25	1,800	467	160	640	41.7%
Deskin Creek	6BDES000.06	2/07 - 1/09	12	25	1,700	356	185	510	41.7%
Johnson Branch	6BJNN001.35	5/02 - 3/03	2	180	360	270	270	127	50.0%
North Fork Clinch River	6BNCL000.30	2/07 - 12/08	12	25	900	204	88	316	16.7%
Plum Creek	6BPLU000.40	2/07 - 12/08	12	25	700	135	50	195	16.7%
Plum Creek	6BPLU002.15	2/07 - 12/08	12	25	1,200	510	440	328	83.3%
Pounding Mill Creek	6BPON000.04	2/07 - 1/09	4	25	350	75	25	122	14.3%
South Fork Clinch River	6BSFK000.77	2/07 - 12/08	12	25	800	272	220	258	41.7%

[1] Based on the current instantaneous *E. coli* standard of 235 cfu/100mL.

3. BACTERIA SOURCE ASSESSMENT

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

3.1 Assessment of Permitted Sources

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

Table 3.2 shows the 51 single family home permits within the Upper Clinch River and Tributaries study area. These permits allow treated residential wastewater to be discharged to surface waters. All of these housing units discharge water and bacteria to the streams.

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

Table 3.1 Summary of VPDES permitted point sources permitted for fecal bacteria control in the Upper Clinch River and Tributaries study area.

Permit	Receiving Stream(s)	Facility Name	Permitted for *E. coli* Control
VA0021199	Clinch River	Richlands Regional WWTF	Y
VA0026298	Clinch River	Tazewell WWTP	Y
VA0065676	Mundy Branch, UT	Glenrae II Mobile Home Park STP	Y
VA0053465	Clinch River	Greater Tazewell Area Regional WTP	N

UT – Unnamed tributary

Table 3.2 Single family home permits in the Upper Clinch River and Tributaries study area.

Permit	Receiving Stream	Facility Type
VAG400046	Clinch River	Domestic
VAG400085	Big Creek	Domestic
VAG400092	Mundy Branch	Domestic
VAG400098	Clinch River, UT	Domestic
VAG400148	Pounding Mill Branch	Domestic
VAG400205	Mundy Branch	Domestic
VAG400306	Clinch River	Domestic
VAG400315	Mundy Branch	Domestic
VAG400327	Clinch River, UT	Domestic
VAG400345	Clinch River, UT	Domestic
VAG400360	Johnson Branch, UT	Domestic
VAG400367	Cavitts Creek	Domestic
VAG400384	Middle Creek	Domestic
VAG400385	Clinch River	Domestic
VAG400401	Big Creek	Domestic
VAG400422	Plum Creek, UT	Domestic
VAG400443	Big Creek	Domestic
VAG400453	Johnson Branch	Domestic
VAG400488	Clinch River, UT	Domestic
VAG400498	Big Creek	Domestic
VAG400509	Clinch River, UT	Domestic
VAG400510	Clinch River, UT	Domestic
VAG400525	Johnson Branch	Domestic
VAG400553	Plum Creek, UT	Domestic
VAG400561	Deskin Creek	Domestic
VAG400568	Big Creek	Domestic
VAG400569	Big Creek, UT	Domestic
VAG400575	Pounding Mill Branch,	Domestic
VAG400591	Cavitts Creek	Domestic
VAG400594	Cavitts Creek	Domestic
VAG400606	Plum Creek, UT	Domestic
VAG400630	Johnson Branch	Domestic
VAG400636	Cavitts Creek	Domestic
VAG400644	Pounding Mill Branch	Domestic
VAG400653	Clinch River, UT	Domestic
VAG400660	Cavitts Creek	Domestic
VAG400662	Clinch River	Domestic
VAG400546	Pounding Mill Branch	Domestic

UT – Unnamed tributary

Table 3.2 Single family home permits in the Upper Clinch River and Tributaries study area (cont.).

Permit	Receiving Stream	Facility Type
VAG400665	North Fork Clinch Rive	Domestic
VAG400669	Lowe Branch	Domestic
VAG400672	Middle Creek	Domestic
VAG400690	Clinch River, UT	Domestic
VAG400695	Coal Creek, UT	Domestic
VAG400702	Big Creek	Domestic
VAG400745	Middle Creek	Domestic
VAG400784	Coal Creek	Domestic
VAG400786	Cavitts Creek	Domestic
VAG400897	Clinch River	Domestic
VAG400900	Clinch River, UT	Domestic
VAG400791	Clinch River, UT	Domestic
VAG400806	Clinch River, UT	Domestic

UT – Unnamed tributary

3.2 Assessment of Nonpoint Sources

In the Upper Clinch River and Tributaries study area, both residential and agricultural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage disposal systems, land application of waste (livestock), livestock, wildlife, and pets. Sources were identified and enumerated. MapTech previously collected samples of fecal coliform sources (*i.e.*, wildlife, livestock, pets, and human waste) and enumerated the density of fecal coliform bacteria. This analysis was used to support the modeling process for the current project and to expand the database of known fecal coliform sources for purposes of bacterial source tracking (Section 2.3.1.3). Where appropriate, spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

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

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant.

When the flow of wastewater exceeds the design capacity or the capacity is reduced by a blockage, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows. Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system.

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

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

MapTech previously sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml (MapTech, 2001). An average fecal coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

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

Population	Housing Units	Sanitary Sewer	Septic Systems	Other *
20,464	10,467	6,212	3,873	384

*Houses with sewage disposal systems other than sanitary sewer and septic systems.

3.2.2 Biosolids

Biosolids have not been applied in the Upper Clinch River and Tributaries study area.

3.2.3 Pets

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

Table 3.4 Domestic animal population density, waste load, and fecal coliform (FC) density.

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

* animals per house
** grams per animal per day

Table 3.5 Estimated domestic animal populations in areas contributing to impaired segments in the Upper Clinch River and Tributaries study area.

Animal	Number
Dogs	5,153
Cats	5,768

3.2.4 Livestock

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

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

Animal	Number
Beef	3,297
Beef Calf	4,670
Dairy Cow	0
Goat	1,892
Horse	945
Sheep	1,263

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

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

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

[1] pounds per day per animal

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

Table 3.8 Average percentage of collected livestock waste applied throughout year.

Month	Applied % of Total		Land use
	Dairy	Beef	
January	2	4	Cropland
February	2	4	Cropland
March	20	12	Cropland
April	20	12	Cropland
May	5	12	Cropland
June	2	8	Pasture
July	2	8	Pasture
August	2	8	Pasture
September	21	12	Cropland
October	20	12	Cropland
November	2	4	Cropland
December	2	4	Cropland

Some livestock were expected to deposit a portion of waste on land areas. The percentage of time spent on pasture for dairy and beef cattle was estimated based on projects in other areas of southwest Virginia. Horses, sheep, and goats were assumed to be in pasture 100% of the time.

It was assumed that beef cattle were expected to make a significant contribution through direct deposition with access to flowing water. For areas where direct deposition by cattle is assumed, the average amount of time spent by dairy and beef cattle in stream access areas for each month is given in Tables 3.9 and Table 3.10.

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

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot (hr)
January	23.3	0.7	0
February	23.3	0.7	0
March	22.6	1.4	0
April	21.8	2.2	0
May	21.8	2.2	0
June	21.1	2.9	0
July	21.1	2.9	0
August	21.1	2.9	0
September	21.8	2.2	0
October	22.6	1.4	0
November	22.6	1.4	0
December	23.3	0.7	0

Table 3.10 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day.

Month	Pasture (hr)	Stream Access (hr)
January	23.3	0.7
February	23.3	0.7
March	23.0	1.0
April	22.6	1.4
May	22.6	1.4
June	22.3	1.7
July	22.3	1.7
August	22.3	1.7
September	22.6	1.4
October	23.0	1.0
November	23.0	1.0
December	23.3	0.7

3.2.5 Wildlife

The predominant wildlife species in the Upper Clinch River and Tributaries study area were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), United States Fish and Wildlife Service (FWS), citizens from the watershed, and source sampling. Population densities were calculated from data provided by VDGIF and FWS, and are listed in Table 3.11 (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; Raftovich, 2004; Rose and Cranford, 1987).

Table 3.11 Wildlife population densities for the Upper Clinch River and Tributaries study area.

Animal	Value (an/ac of habitat)*
Deer	0.0279
Turkey	0.0087
Goose	0.0189
Duck	0.0333
Muskrat	0.6115
Raccoon	0.0226
Beaver**	0.25

* animal per acre
** Beaver (an/mi of stream)

The numbers of animals estimated to be in the Upper Clinch River and Tributaries study area are reported in Table 3.12. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996, and Yagow, 1999b).

Table 3.12 Estimated wildlife populations in the Upper Clinch River and Tributaries study area.

Animal	Number
Deer	3,017
Duck	83
Goose	122
Raccoon	6,481
Turkey	730
Muskrat	3,962

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

Table 3.13 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	380,000	5
Turkey	1,332	5
Goose	250,000	50
Duck	3,500	75

Table 3.14 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife scat previously performed by MapTech. The only value that was not obtained from MapTech sampling was for beaver.

The bacterial loads from the sources described in this chapter used in the modeling can be found in Appendix B Tables B.1 through B.8.

Table 3.14 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	**Primary** = region within 600 ft of perennial streams **Secondary** = region between 601 and 7,920 ft from perennial streams **Infrequent/Seldom** = rest of watershed area including waterbodies (lakes, ponds)
Muskrat	100	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area
Beaver[1]	200	**Primary** = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) **Infrequent/Seldom** = rest of the watershed area
Deer	772	**Primary** = forested, harvested forest land, orchards, grazed woodland, urban grassland, cropland, pasture, wetlands, transitional land **Secondary** = low density residential, medium density residential **Infrequent/Seldom** = remaining land use areas
Turkey[2]	320	**Primary** = forested, harvested forest land, grazed woodland, orchards, wetlands, transitional land **Secondar**y = cropland, pasture **Infrequent/Seldom** = remaining land use areas
Goose[3]	225	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area
Mallard (Duck)	150	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area

[1] Beaver waste load was calculated as twice that of muskrat, based on field observations.
[2] Waste load for domestic turkey (ASAE, 1998).
[3] Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2003)

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

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

Flow was calibrated by comparing model output to observed flow within the Upper Clinch River and making the proper adjustments to obtain the best match between simulated and observed flow. Once the flow component was built, the bacteria concentration was calibrated by comparing model simulations of bacteria to observed bacteria values collected by VADEQ at two locations. Finally the bacteria concentration was validated using a different time period from the calibration period.

Bacteria loadings from various sources are simulated including point sources, runoff from the watershed, interflow and groundwater. A complete description of the modeling approach is presented in Appendix C.

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5. BACTERIAL ALLOCATION

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

TMDL = WLAs + LAs + MOS

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

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

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

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

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

Pollutant concentrations were modeled over the entire duration of a representative modeling period and pollutant loads were adjusted until the standards were met. The Indian Creek watershed (subwatershed 7) was set to its allocated load for the modeling runs because it has a previously approved bacteria TMDL. The development of the allocation scenarios was an iterative process that required numerous runs with each followed by an assessment of source reduction against the applicable water quality standards.

5.1 Margin of Safety (MOS)

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

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

5.2 Waste Load Allocations (WLAs)

There are 70 point sources currently permitted to discharge into the Upper Clinch River watershed study area. The allocation for the sources permitted for *E. coli* control is equivalent to their current permit levels (design discharge and 126 cfu/100 ml). Future growth in each watershed was accounted for by setting aside 1% of the TMDL for growth in permitted discharges or creation of new ones. There are currently no Municipal Separate Storm Sewer System (MS4) permits in the Clinch River and Tributaries study area.

5.3 Load Allocations (LAs)

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

5.4 Final Total Maximum Daily Loads (TMDLs)

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

Reduction scenarios exploring the role of anthropogenic sources in standards violations were explored first to determine the feasibility of meeting standards without wildlife reductions. In each table, a scenario reflects the impact of eliminating direct human sources from straight pipes and sewer overflows. Further scenarios in each table explore a range of management scenarios, leading to the final allocation scenario that contains the predicted reductions needed to meet 0% exceedance of all applicable water quality standards. The graphs in the following sections depict the existing and allocated 30-day geometric mean in-stream bacteria concentrations.

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

The tables and graphs in the following sections all depict values at the corresponding impairment outlet or the most limiting subwatershed. The impairment outlet is the mouth of subwatersheds four (4) and one (1). The other impairments are considered nested within the Clinch River subwatershed one (1).

5.4.1 Clinch River near Tazewell (VAS-P01R_CLN01A98, VAS-P02R_CLN01A98 and VAS-P01R_PLU01A04)

Table 5.1 shows allocation scenarios used to determine the final TMDL for the headwaters of the Upper Clinch River and Plum Creek impairments (VAS-P01R_CLN01A98, VAS-P02R_CLN01A98 and VAS-P01R_PLU01A04). Because Virginia’s water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 69.44% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement (violation rate 55.56%. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide additional water quality benefits. Scenario number 5 showed that elimination of all anthropogenic sources provided considerable water quality improvement but there were still exceedances persisted. Scenario 7 requires a 36% reduction to direct wildlife sources and a 39% reduction to indirect wildlife sources in addition to reductions in all anthropogenic categories. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 7 will be the target goal during the implementation of best management practices (BMPs).

An appropriate Stage I scenario would be a 50% reduction in straight pipe bacteria loads.

Table 5.1 Allocation scenarios for reducing current bacteria loads in the Upper Clinch River (subwatersheds 4, 5 and 6).

Percent Reductions to Existing Bacteria Loads							
		Wildlife Land Based		Agricultural Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	**Wildlife Direct**	**Barren[1], Commercial, Forest, AML[2]**	**Livestock Direct**	**Cropland, Pasture, LAX[3]**	**Straight Pipes**	**Residential**	**% >126 GM**
1	0	0	0	0	0	0	69.44
2	0	0	0	0	100	0	55.56
3	0	0	100	0	100	0	41.67
5	0	0	100	100	100	100	2.78
6	35	35	100	99	100	99	2.78
7[4]	36	39	100	99	100	99	0.00

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]AML – Abandoned Mine Land
[3]LAX - livestock pasture access near flowing streams.
[4]Final TMDL Scenario

Figure 5.1 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Clinch River impairment outlet (subwatershed 5). Subwatershed 5 is shown because it was the most limiting subwatershed out of the three in this portion of the river. The graph shows existing conditions in black, with allocated conditions overlaid in blue.

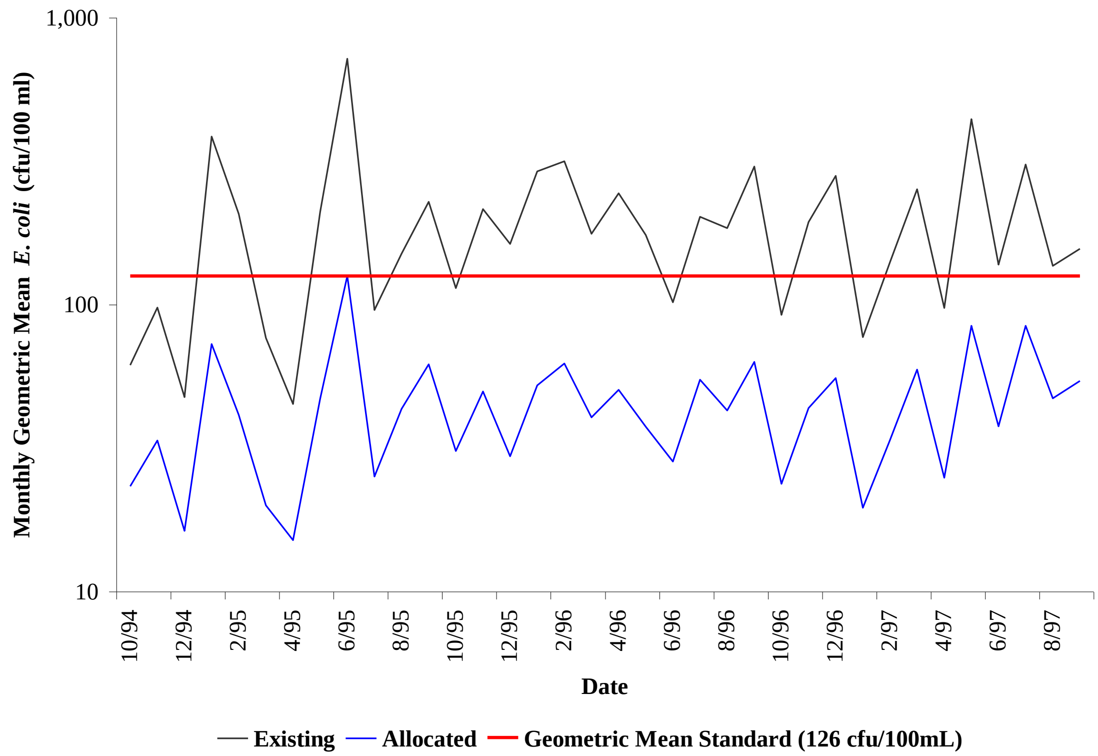

Figure 5.1 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 5, Clinch River impairment.

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

Tables B.1 through B.4 in Appendix B include the land-based fecal coliform load distributions and offer more details for specific implementation development and source assessment evaluation.

Table 5.2 Estimated existing and allocated *E. coli* in-stream loads in the headwaters of the Upper Clinch River near Tazewell impairment.

Source		Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based				
	AML*	9.84E+10	6.00E+10	39%
	Barren**	1.03E+11	6.29E+10	39%
	Commercial	1.90E+13	1.16E+13	39%
	Crop	1.85E+10	1.85E+08	99%
	Forest	1.43E+14	8.72E+13	39%
	LAX***	7.71E+11	7.71E+09	99%
	Pasture	3.38E+14	3.38E+12	99%
	Residential	1.09E+14	1.09E+12	99%
Direct				
	Wildlife	9.01E+14	5.77E+14	36%
	Livestock	5.39E+15	0.00E+00	100%
	Human	5.40E+15	0.00E+00	100%
	Permitted Sources	3.54E+12	3.54E+12	0%
Future Growth	Future Growth	0.00E+00	1.74E+13	NA
Total Loads		**1.23E+16**	**7.01E+14**	**94.3%**

* AML – Abandoned Mine Land
** Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
***LAX - livestock pasture access near flowing streams.

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

Table 5.3 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the headwaters of the Upper Clinch River near Tazewell impairment.

Impairment	WLA[1] (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
Upper Clinch River	2.09E+13	6.80E+14	*Implicit*	7.01E+14
VA0026298	*3.48E+12*			
VA0065676	*1.74E+10*			
VAG400046	*1.74E+09*			
VAG400098	*1.74E+09*			
VAG400092	*1.74E+09*			
VAG400205	*1.74E+09*			
VAG400315	*1.74E+09*			
VAG400360	*1.74E+09*			
VAG400367	*1.74E+09*			
VAG400453	*1.74E+09*			
VAG400509	*1.74E+09*			
VAG400510	*1.74E+09*			
VAG400525	*1.74E+09*			
VAG400591	*1.74E+09*			
VAG400594	*1.74E+09*			
VAG400630	*1.74E+09*			
VAG400636	*1.74E+09*			
VAG400660	*1.74E+09*			
VAG400665	*1.74E+09*			
VAG400786	*1.74E+09*			
VAG400422	*1.74E+09*			
VAG400553	*1.74E+09*			
VAG400606	*1.74E+09*			
Future Load	*1.74E+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.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for the headwaters of the Upper Clinch River are shown in Table 5.4. The daily TMDL was calculated using the 99th

percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.4 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the headwaters of the Upper Clinch River near Tazewell impairment.

Impairment	WLA[1] (cfu/day)	LA (cfu/day)	MOS	TMDL[2] (cfu/day)
Upper Clinch River	5.74E+10	2.96E+12	*Implicit*	3.02E+12
VA0026298	*9.55E+09*			
VA0065676	*4.77E+07*			
VAG400046	*4.77E+06*			
VAG400098	*4.77E+06*			
VAG400092	*4.77E+06*			
VAG400205	*4.77E+06*			
VAG400315	*4.77E+06*			
VAG400360	*4.77E+06*			
VAG400367	*4.77E+06*			
VAG400453	*4.77E+06*			
VAG400509	*4.77E+06*			
VAG400510	*4.77E+06*			
VAG400525	*4.77E+06*			
VAG400591	*4.77E+06*			
VAG400594	*4.77E+06*			
VAG400630	*4.77E+06*			
VAG400636	*4.77E+06*			
VAG400660	*4.77E+06*			
VAG400665	*4.77E+06*			
VAG400786	*4.77E+06*			
VAG400422	*4.77E+06*			
VAG400553	*4.77E+06*			
VAG400606	*4.77E+06*			
Future Load	*4.77E+10*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.2 Clinch River near Richlands (VAS-P03R_CLN01A98, VAS-P03R_CLN02A00 and VAS-P03R_MID01A98)

Table 5.5 shows allocation scenarios used to determine the final TMDL for the Upper Clinch River and Middle Creek impairments (VAS-P03R_CLN01A98, VAS-P03R_CLN02A00 and VAS-P03R_MID01A098). The Upper Clinch River impairment receives outflow from Indian Creek, which has an approved bacteria TMDL. Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean). The existing condition, Scenario 1, shows 22.22% violations of the geometric mean standard. Scenario 2 (eliminating straight pipe inputs) showed some improvement (violation rate 13.89%. Scenario 3 showed that eliminating straight pipes and direct inputs from livestock would provide a little additional water quality benefit. Scenario number 4 showed that elimination of all anthropogenic sources provided considerable water quality improvement and no water quality standard exceedances. Scenarios 5,6 and 7 were simulated with an allocated outflow from Indian Creek (previously approved TMDL). Scenario 7 was the best scenario for bacteria reductions in the watershed and no wildlife reductions were required. This scenario meets the geometric mean standard of 126 cfu/100mL. Scenario 7 will be the target goal during the implementation of best management practices (BMPs).

An appropriate Stage I scenario would be a 50% reduction in straight pipe bacteria loads.

Table 5.5 Allocation scenarios for reducing current bacteria loads in the Upper Clinch River (subwatersheds 1,2,3,4,5,6,7,8 and 9).

Percent Reductions to Existing Bacteria Loads							
		Wildlife Land Based			Agricultural Land Based	Human Direct	Human and Pet Land Based
Scenario	**Wildlife Direct**	**Barren[1], Commercial, Forest, AML[2], Gas Wells**	**Livestock Direct**	**Cropland, Pasture, LAX[3]**	**Straight Pipes**	**Residential**	**% >126 GM**
Upper Clinch River Impairment and Indian Creek (sub 7) existing:							
1	0	0	0	0	0	0	22.22
2	0	0	0	0	100	0	13.89
3	0	0	100	0	100	0	11.11
4	0	0	100	100	100	100	0.00
Upper Clinch River Impairment and Indian Creek (sub 7) allocated:							
5	0	0	100	99	100	99	0.00
6	0	0	100	85	100	85	2.78
7[4]	0	0	100	59	100	86	0.00

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]AML – Abandoned Mine Land
[3]LAX - Livestock pasture access near flowing streams.
[4]Final TMDL Scenario

Figure 5.2 shows the existing and allocated monthly geometric mean *E. coli* concentrations, from the Clinch River impairment outlet (subwatershed 1). The graph shows existing conditions in black, with allocated conditions overlaid in blue.

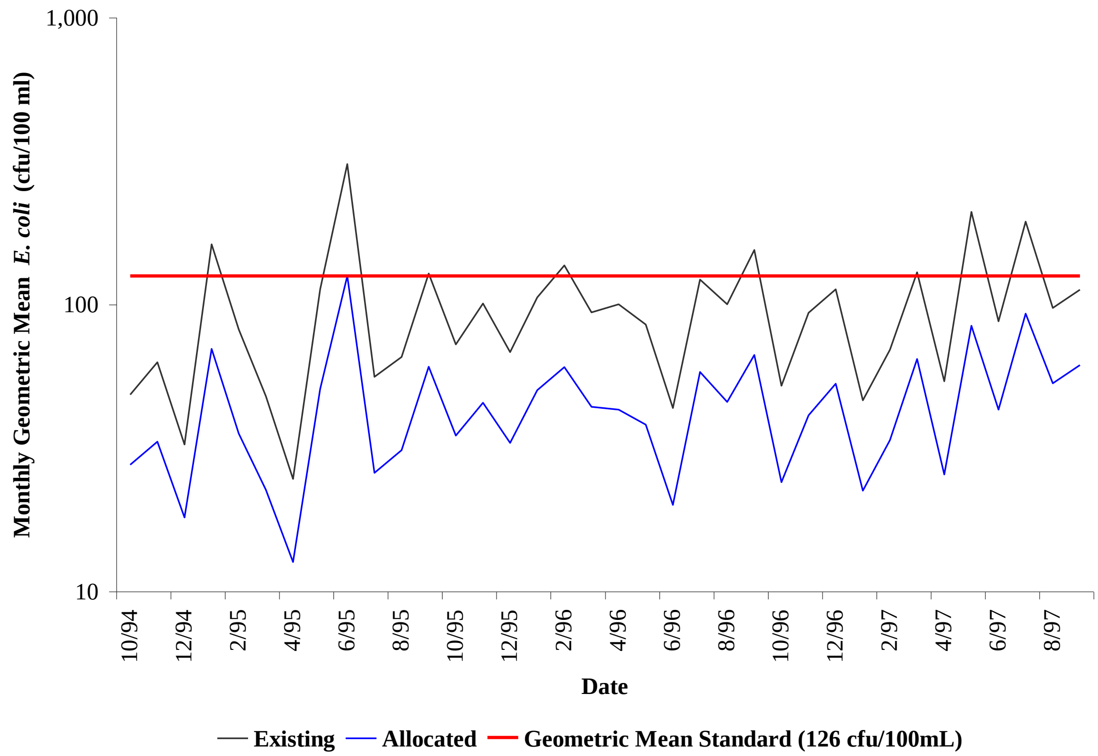

Figure 5.2 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 1, Upper Clinch River near Richlands impairment.

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

Tables B.5 through B.8 in Appendix B include the land-based fecal coliform load distributions and offer more details for specific implementation development and source assessment evaluation.

Table 5.6 Estimated existing and allocated *E. coli* in-stream loads in the Upper Clinch River near Richlands impairment.

Source		Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based				
	AML[1]	3.43E+13	3.43E+13	0%
	Barren[2]	3.94E+11	3.94E+11	0%
	Commercial	5.19E+13	5.19E+13	0%
	Crop	3.91E+10	1.60E+10	59%
	Forest	1.17E+15	1.17E+15	0%
	GasWell	7.92E+11	7.92E+11	0%
	LAX[3]	2.33E+12	9.55E+11	59%
	Pasture	3.10E+14	1.27E+14	59%
	Residential	4.50E+14	6.30E+13	86%
Direct				
	Wildlife	1.81E+15	1.81E+15	0%
	Livestock	5.39E+15	0.00E+00	100%
	Human	5.40E+15	0.00E+00	100%
	Permitted Sources	1.06E+13	1.06E+13	0%
Future Growth	Future Growth	0.00E+00	5.23E+13	NA
Total Loads		**1.46E+16**	**3.32E+15**	**77.26%**

[1] AML – Abandoned Mine Land
[2] Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[3] LAX – Livestock pasture accesss near flowing streams.

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

Table 5.7 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Upper Clinch River near Richlands impairment.

Impairment	WLA[1] (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
Clinch River near Richlands	**6.29E+13**	**3.26E+15**	***Implicit***	**3.32E+15**
VA0026298	*3.48E+12*			
VA0065676	*1.74E+10*			
VA0021199	*6.97E+12*			
VAG400098	*1.74E+09*			
VAG400092	*1.74E+09*			
VAG400205	*1.74E+09*			
VAG400315	*1.74E+09*			
VAG400360	*1.74E+09*			
VAG400367	*1.74E+09*			
VAG400453	*1.74E+09*			
VAG400509	*1.74E+09*			
VAG400510	*1.74E+09*			
VAG400525	*1.74E+09*			
VAG400591	*1.74E+09*			
VAG400594	*1.74E+09*			
VAG400630	*1.74E+09*			
VAG400636	*1.74E+09*			
VAG400660	*1.74E+09*			
VAG400665	*1.74E+09*			
VAG400786	*1.74E+09*			
VAG400422	*1.74E+09*			
VAG400553	*1.74E+09*			
VAG400606	*1.74E+09*			
VAG400085	*1.74E+09*			
VAG400345	*1.74E+09*			
VAG400401	*1.74E+09*			
VAG400443	*1.74E+09*			
VAG400488	*1.74E+09*			
VAG400498	*1.74E+09*			
VAG400568	*1.74E+09*			
VAG400569	*1.74E+09*			
VAG400653	*1.74E+09*			
VAG400702	*1.74E+09*			
VAG400791	*1.74E+09*			
VAG400806	*1.74E+09*			
VAG400900	*1.74E+09*			
VAG400148	*1.74E+09*			
VAG400306	*1.74E+09*			
VAG400327	*1.74E+09*			

[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.

Table 5.7 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Upper Clinch River near Richlands impairment (Cont.)

Impairment	WLA[1] (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
Clinch River near Richlands	**6.29E+13**	**3.26E+15**	*Implicit*	**3.32E+15**
VAG400561	*1.74E+09*			
VAG400546	*1.74E+09*			
VAG400385	*1.74E+09*			
VAG400046	*1.74E+09*			
VAG400575	*1.74E+09*			
VAG400644	*1.74E+09*			
VAG400662	*1.74E+09*			
VAG400669	*1.74E+09*			
VAG400690	*1.74E+09*			
VAG400897	*1.74E+09*			
VAG400035	*1.74E+09*			
VAG400314	*1.74E+09*			
VAG400317	*1.74E+09*			
VAG400331	*1.74E+09*			
VAG400352	*1.74E+09*			
VAG400461	*1.74E+09*			
VAG400483	*1.74E+09*			
VAG400501	*1.74E+09*			
VAG400540	*1.74E+09*			
VAG400597	*1.74E+09*			
VAG400609	*1.74E+09*			
VAG400655	*1.74E+09*			
VAG400691	*1.74E+09*			
VAG400767	*1.74E+09*			
VAG400794	*1.74E+09*			
VAG400867	*1.74E+09*			
VAG400384	*1.74E+09*			
VAG400672	*1.74E+09*			
VAG400745	*1.74E+09*			
VAG400695	*1.74E+09*			
VAG400784	*1.74E+09*			
Future Load	*5.23E+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.

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

Table 5.8 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Upper Clinch River near Richlands impairment.

Impairment	WLA[1] (cfu/day)	LA (cfu/day)	MOS	TMDL (cfu/day)
Clinch River Near Richlands	**1.72E+11**	**7.20E+12**	***Implicit***	**7.37E+12**
VA0026298	*9.55E+09*			
VA0065676	*4.77E+07*			
VA0021199	*1.91E+10*			
VAG400046	*4.77E+06*			
VAG400098	*4.77E+06*			
VAG400092	*4.77E+06*			
VAG400205	*4.77E+06*			
VAG400315	*4.77E+06*			
VAG400360	*4.77E+06*			
VAG400367	*4.77E+06*			
VAG400453	*4.77E+06*			
VAG400509	*4.77E+06*			
VAG400510	*4.77E+06*			
VAG400525	*4.77E+06*			
VAG400591	*4.77E+06*			
VAG400594	*4.77E+06*			
VAG400630	*4.77E+06*			
VAG400636	*4.77E+06*			
VAG400660	*4.77E+06*			
VAG400665	*4.77E+06*			
VAG400786	*4.77E+06*			
VAG400422	*4.77E+06*			
VAG400553	*4.77E+06*			
VAG400606	*4.77E+06*			
VAG400085	*4.77E+06*			
VAG400345	*4.77E+06*			
VAG400401	*4.77E+06*			
VAG400443	*4.77E+06*			
VAG400488	*4.77E+06*			
VAG400498	*4.77E+06*			
VAG400568	*4.77E+06*			
VAG400569	*4.77E+06*			
VAG400653	*4.77E+06*			
VAG400702	*4.77E+06*			
VAG400791	*4.77E+06*			
VAG400806	*4.77E+06*			
VAG400900	*4.77E+06*			
VAG400148	*4.77E+06*			
VAG400306	*4.77E+06*			
VAG400327	*4.77E+06*			

[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.

Table 5.8 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Upper Clinch River near Richlands impairment (Cont.).

Impairment	WLA (cfu/day)	LA (cfu/day)	MOS	TMDL (cfu/day)
Clinch River Near Richlands	**1.72E+11**	**7.20E+12**	*Implicit*	**7.37E+12**
VAG400546	*4.77E+06*			
VAG400561	*4.77E+06*			
VAG400385	*4.77E+06*			
VAG400575	*4.77E+06*			
VAG400644	*4.77E+06*			
VAG400690	*4.77E+06*			
VAG400897	*4.77E+06*			
VAG400035	*4.77E+06*			
VAG400314	*4.77E+06*			
VAG400317	*4.77E+06*			
VAG400331	*4.77E+06*			
VAG400352	*4.77E+06*			
VAG400461	*4.77E+06*			
VAG400483	*4.77E+06*			
VAG400501	*4.77E+06*			
VAG400540	*4.77E+06*			
VAG400597	*4.77E+06*			
VAG400609	*4.77E+06*			
VAG400655	*4.77E+06*			
VAG400691	*4.77E+06*			
VAG400767	*4.77E+06*			
VAG400794	*4.77E+06*			
VAG400867	*4.77E+06*			
VAG400384	*4.77E+06*			
VAG400672	*4.77E+06*			
VAG400745	*4.77E+06*			
VAG400695	*4.77E+06*			
VAG400784	*4.77E+06*			
VAG400662	*4.77E+06*			
VAG400669	*4.77E+06*			
Future Load	*1.43E+11*			

[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.

6. IMPLEMENTATION

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

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

6.1 Continuing Planning Process and Water Quality Management Planning

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

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on the VADEQ web site under www.deq.state.va.us/export/sites/default/tmdl/pdf/ppp.pdf.

6.2 Staged Implementation

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following implementation through follow-up stream monitoring;

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3. It provides a mechanism for developing public support through periodic updates on implementation levels and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

6.3 Implementation of Waste Load Allocations

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

6.3.1 Stormwater

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

6.3.2 TMDL Modifications for New or Expanding Discharges

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

6.4 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

6.4.1 Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19:7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments". EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

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

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

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

6.4.2 Staged Implementation Scenarios

6.4.2.1 Bacteria

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

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

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

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

6.4.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality downstream in the Upper Clinch River watershed.

6.4.4 Implementation Funding Sources

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

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

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding source for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at www.deq.virginia.gov/bay/wqif.html and at www.dcr.virginia.gov/soil_&_water/wqia.shtml.

6.5 Follow-Up Monitoring

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired streams in accordance with its ambient monitoring programs. 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* (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. The details of the follow-up ambient monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office.

The objective of the Statewide Fish Tissue and Sediment Monitoring Program is to systematically assess and evaluate, using a multi-tier screening, waterbodies in Virginia in order to identify toxic contaminant(s) accumulation with the potential to adversely affect human users of the resource. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30 of each year.

VADEQ staff, in cooperation with the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plans. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or to monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on VADEQ's citizen monitoring in Virginia and QA/QC guidelines is available at www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years.

6.6 Attainability of Designated Uses

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

In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and

§306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

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

1. Naturally occurring pollutant concentration prevents the attainment of the use;

2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

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

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

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

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

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

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

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7. PUBLIC PARTICIPATION

Public participation during TMDL development for the Upper Clinch River watershed was encouraged; a summary of the meetings is presented in Table 12.1. The first Technical Advisory Committee (TAC) and public meetings took place on July 8, 2010 at the Cedar Bluff Municipal Building in Tazewell County, Virginia. Five people attended the meeting. The second public meeting was held on December 21, 2010 and three people attended. The meetings were publicized by placing notices in the Virginia Register, signs in the watershed, and emailing notices to local stakeholders and representatives.

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

Date	Location	Attendance[1]	Type
7/08/2010	Municipal Building Cedar Bluff, VA	5	1st public
12/21/2010	Municipal Building Cedar Bluff, VA	3	2nd public

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

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

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GLOSSARY

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

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

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

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

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

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity. *The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

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

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

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

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

Biochemical Oxygen Demand (BOD). Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

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

Cause. 1. That which produces an effect (a general definition).

2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition). [2]

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

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

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

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

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

Conductivity. An indirect measure of the presence of dissolved substances within water.

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

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

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

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

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

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

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

Decomposition*. Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration.***

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

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

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

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

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

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

Dispersion*. The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Dissolved Oxygen (DO). The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

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

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

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

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

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

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

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

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

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

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

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

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undersirable for recreation, and may not support normal fish populations.

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

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

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

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

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

General Standard. A narrative standard that ensures the general health of state waters. 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 (9VAC25-260-20). (4)

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

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

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

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

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

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

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

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

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

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

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

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause.

Indirect effects. Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor.

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

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

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

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

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

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

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

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

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

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

Mass loading. *The quantity of a pollutant transported to a waterbody.*

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

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

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

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

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

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

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

Narrative criteria*. Nonquantitative guidelines that describe the desired water quality goals.*

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

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

Nitrogen. An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

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

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

Numerical model*.* Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

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

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

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

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

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

Phosphorus. An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

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

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

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

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

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

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

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

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

Reach. Segment of a stream or river.

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

Reserve capacity*. Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

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

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

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

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

Roughness coefficient*. A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

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

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles. (Gilbert, 1987)

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquate systems as a result of erosion.

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

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

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

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

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

Spatial segmentation. *A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

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

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

Standard. In reference to water quality (e.g. 200 cfu/100 mL geometric mean limit).

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

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

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

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

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

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

Stream Reach. A straight portion of a stream.

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

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

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

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

Technology-based standards. *Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

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

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

Total Suspended Solids. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

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

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

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

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

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

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

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

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

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

DMLR. Virginia Department of mine Land Reclamation.

DMME. Virginia Department of Mines, Minerals, and Energy.

VDH. Virginia Department of Health.

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

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

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

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

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

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

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

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

WQIA. Water Quality Improvement Act.

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APPENDIX A FREQUENCY ANALYSIS OF BACTERIA DATA

Figures A.1 through A.17 show the frequency of bacteria water quality standard violations for the VADEQ monitoring stations described in chapter 2.

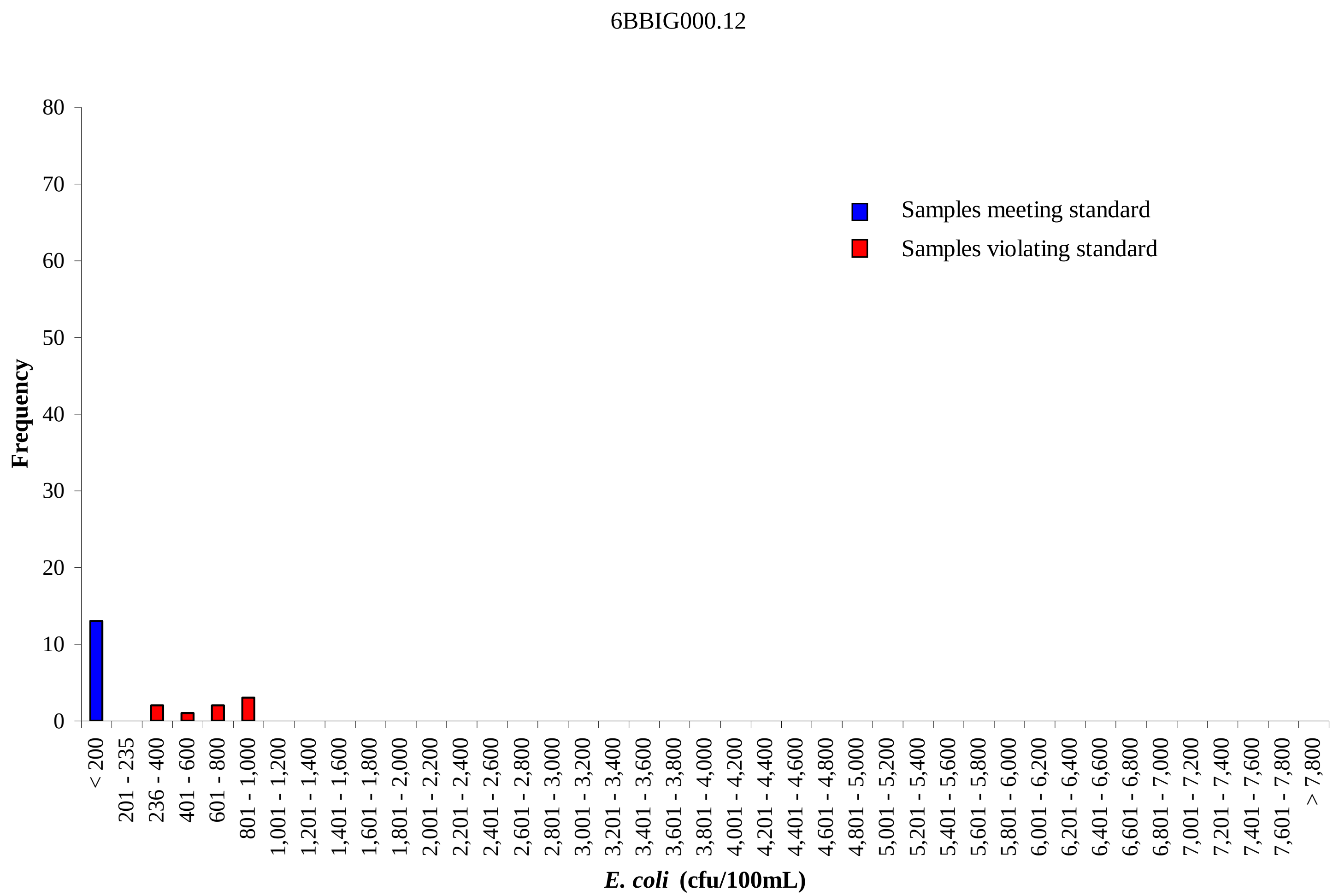

Figure A. 1 Frequency analysis of *E. coli* concentrations at station 6BBIG000.12 in Big Creek for the period from January 2007 to December 2009.

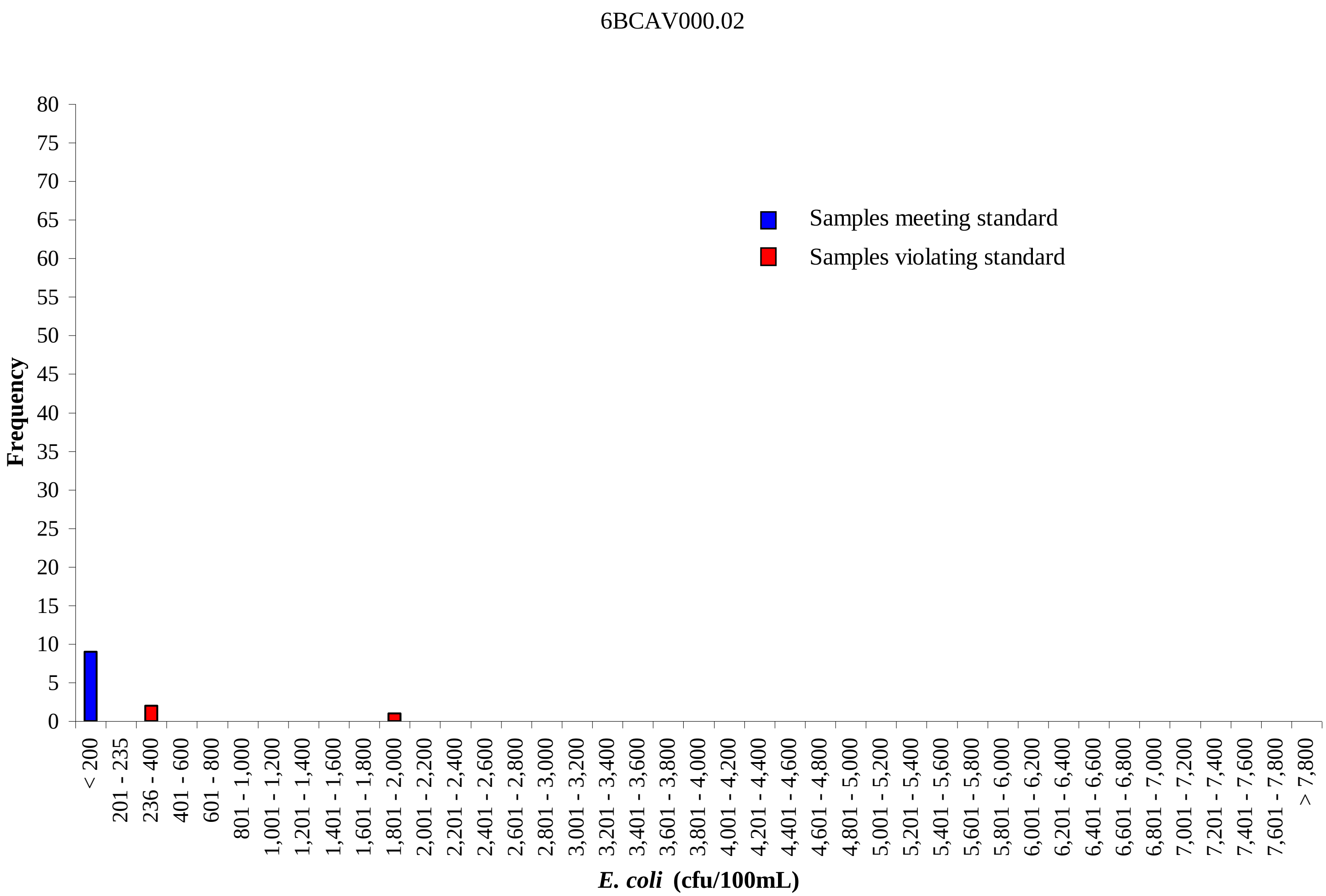

Figure A. 2 Frequency analysis of *E. coli* concentrations at station 6BCAV000.02 in Cavitts Creek for the period from January 2007 to December 2008.

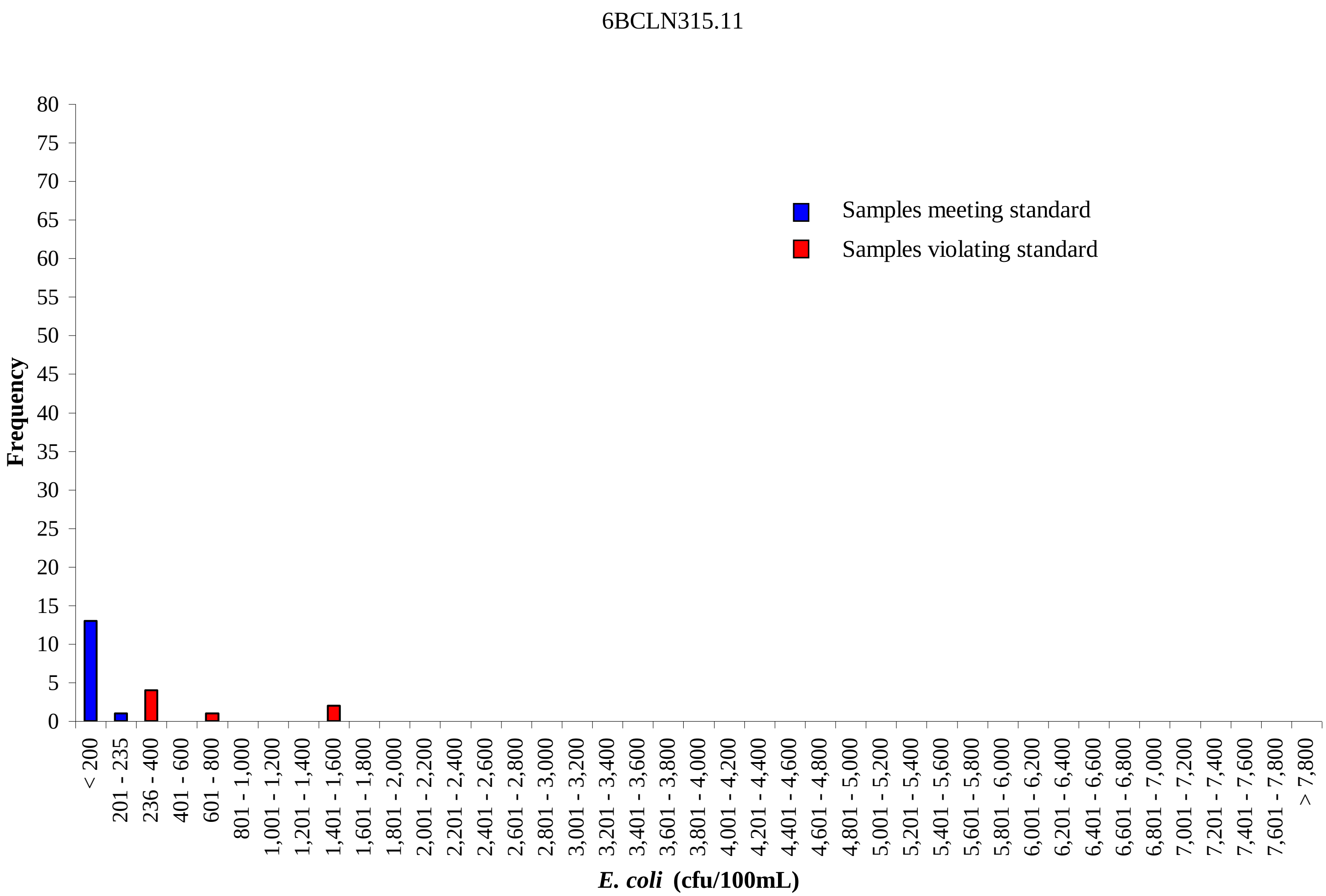

Figure A. 3 Frequency analysis of *E. coli* concentrations at station 6BCLN315.11 in the Clinch River for the period from January 2007 to December 2009.

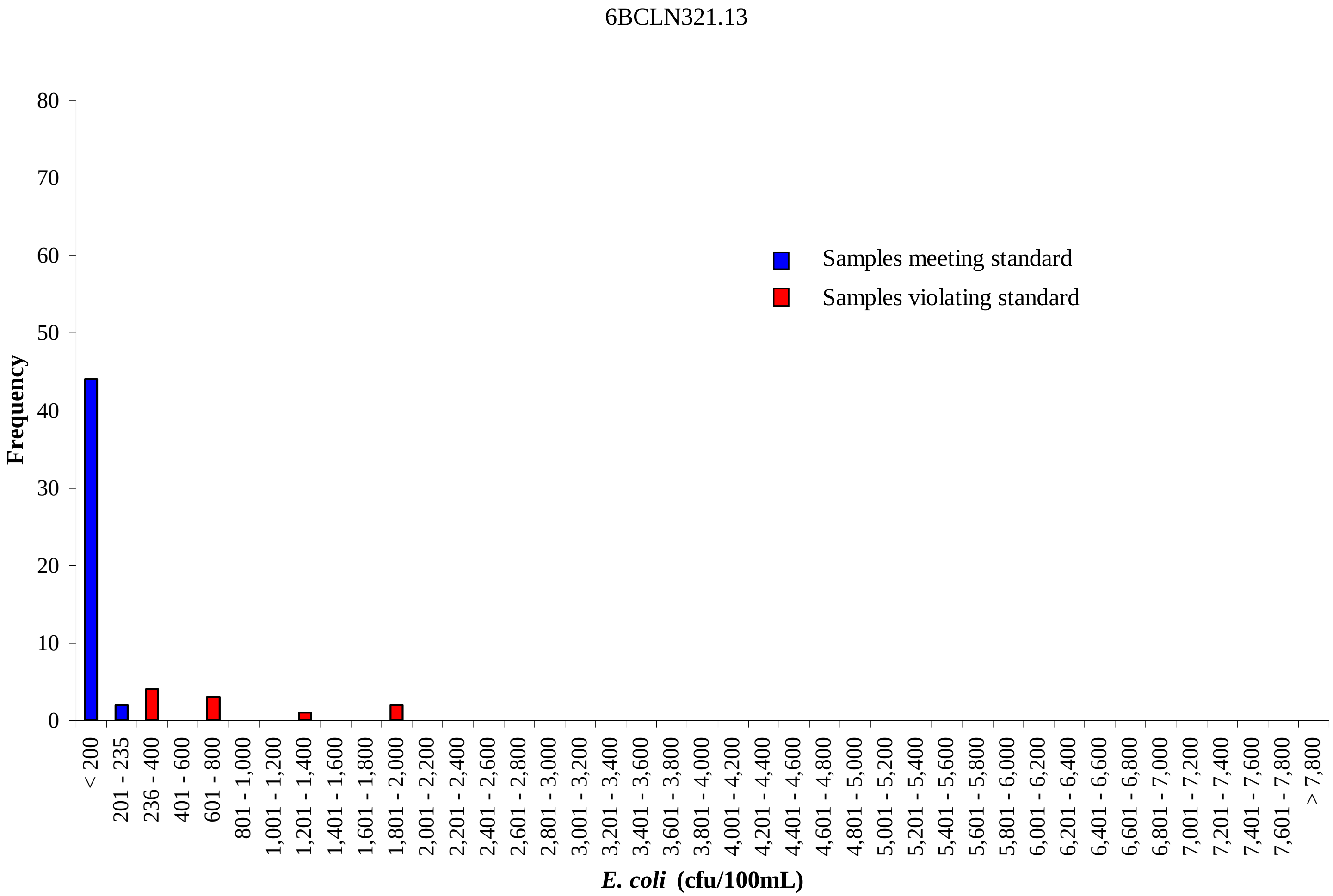

Figure A. 4 Frequency analysis of *E. coli* concentrations at station 6BCLN321.13 in the Clinch River for the period from July 2002 to December 2009.

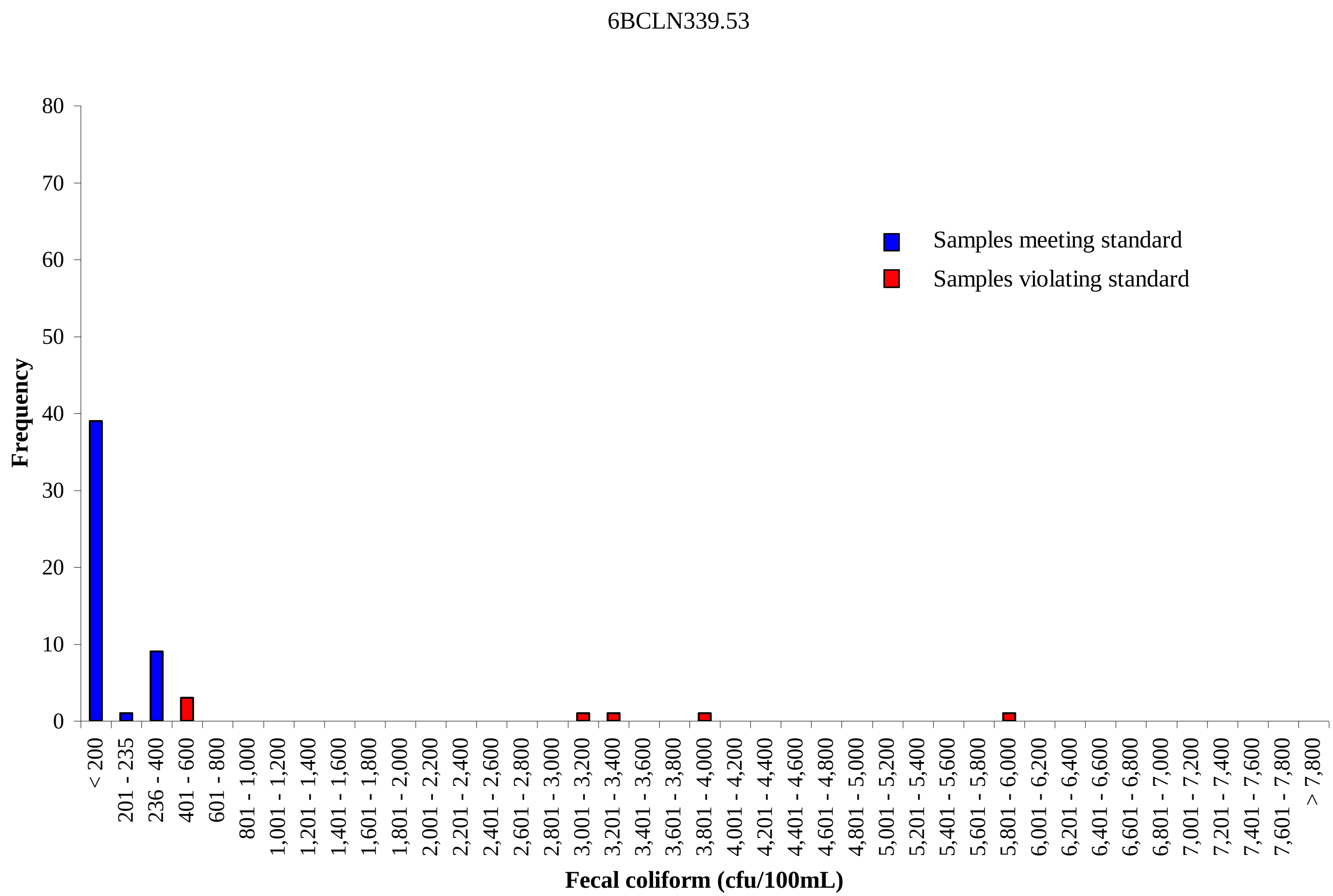

Figure A. 5 Frequency analysis of fecal coliform concentrations at station 6BCLN339.53 in the Clinch River for the period from May 1992 to March 2001.

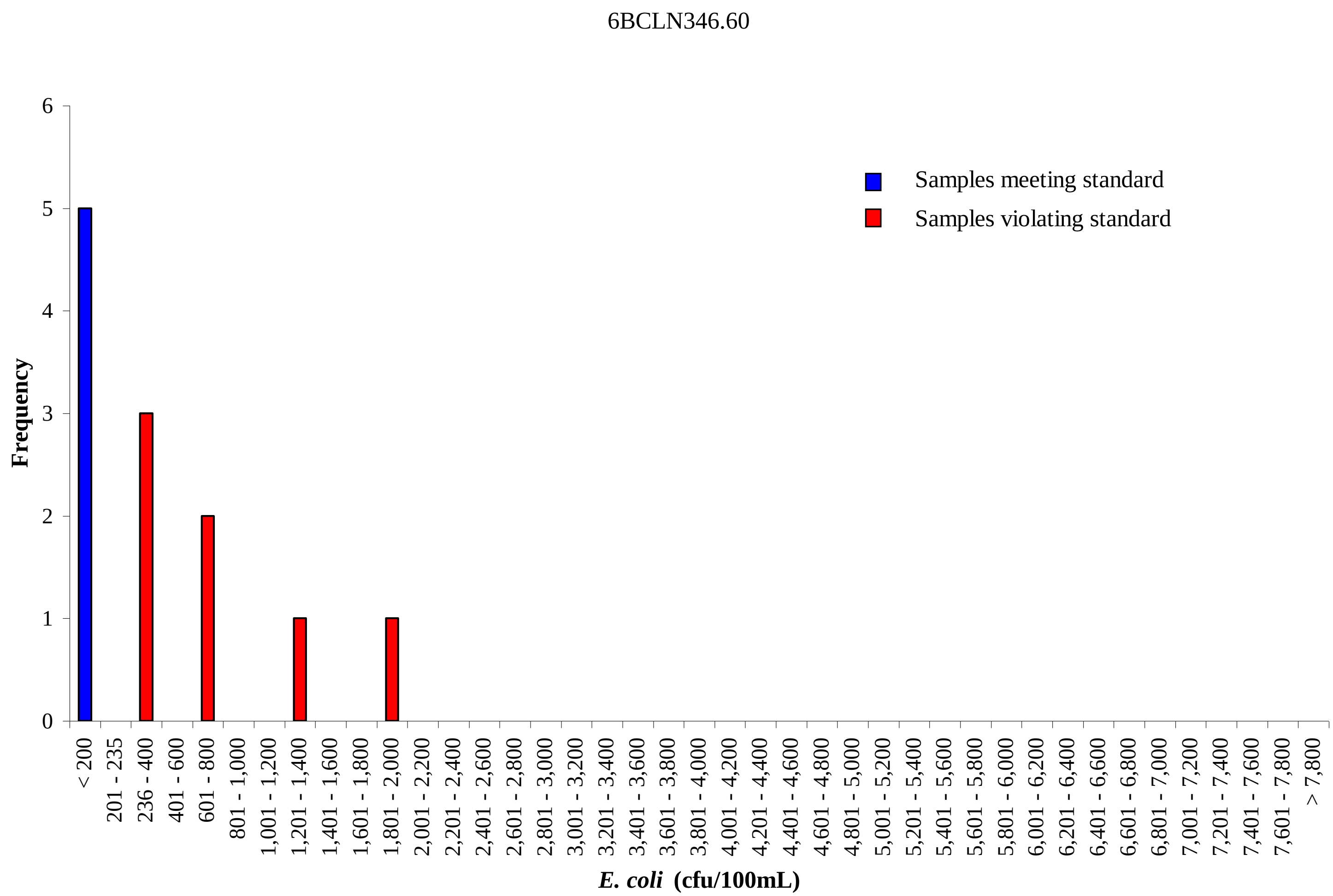

Figure A. 6 Frequency analysis of *E. coli* concentrations at station 6BCLN346.60 in the Clinch River for the period from January 2007 to December 2008.

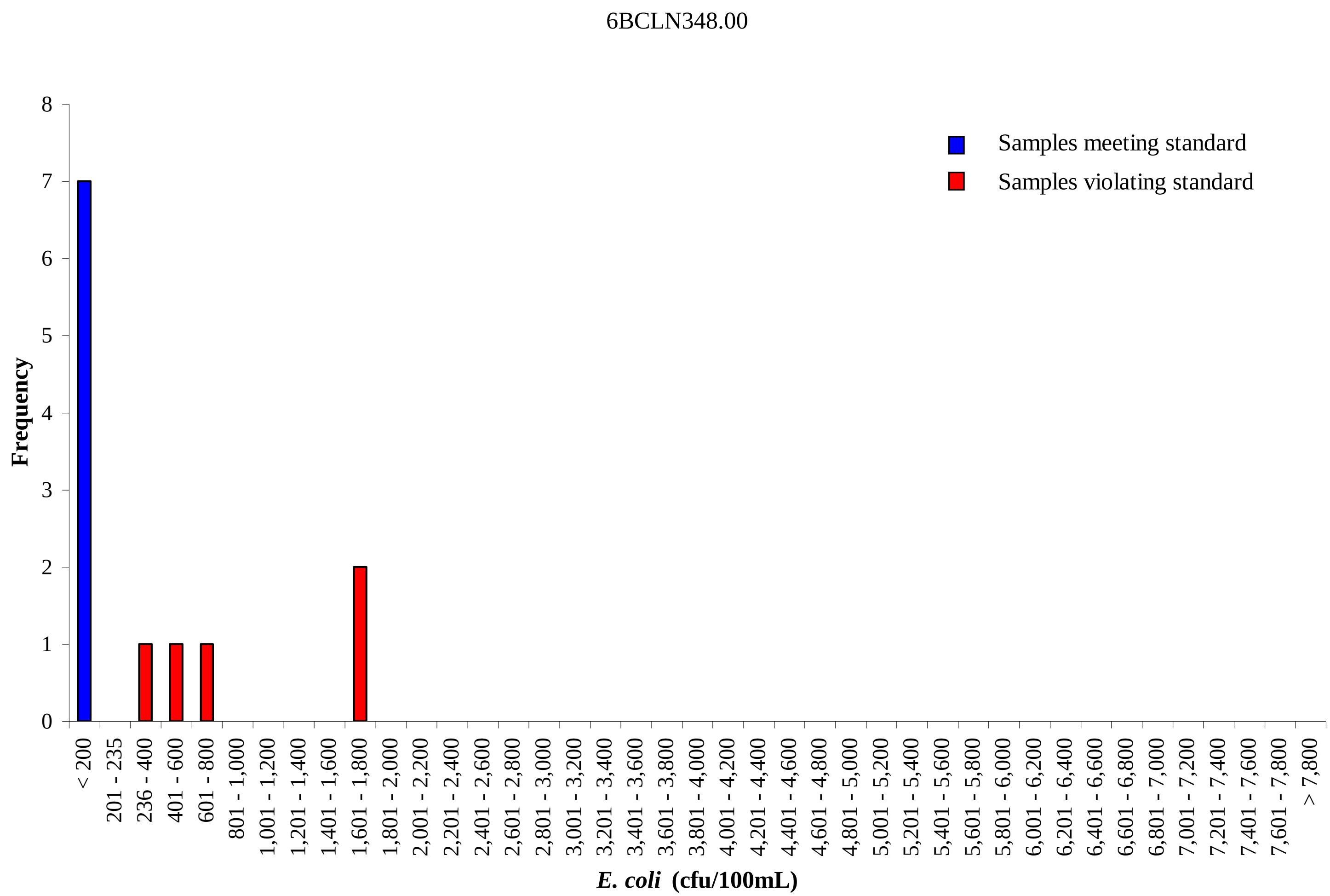

Figure A. 7 Frequency analysis of *E. coli* concentrations at station 6BCLN348.00 in the Clinch River for the period from January 2007 to December 2008.

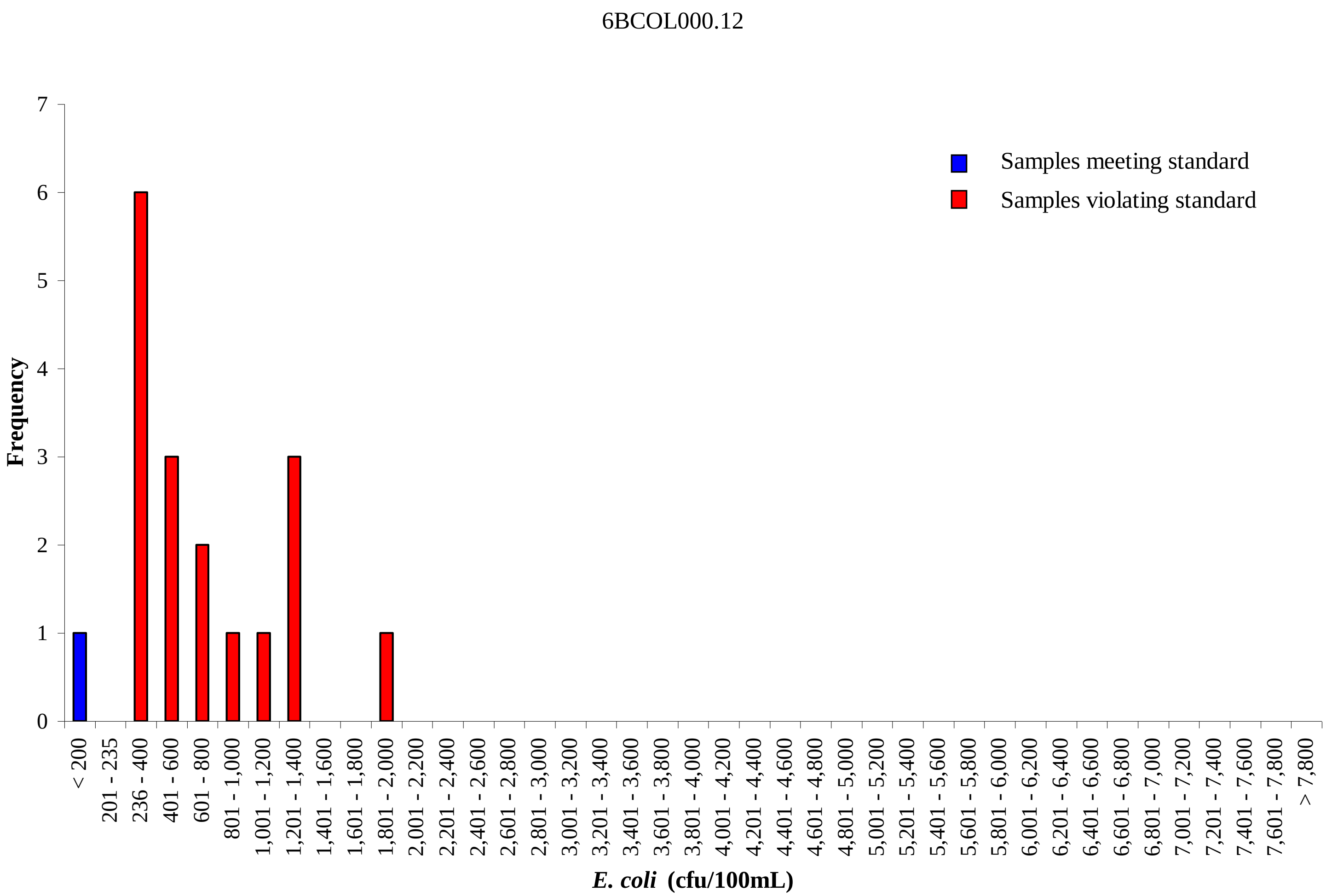

Figure A. 8 Frequency analysis of *E. coli* concentrations at station 6BCOL00.12 in the Coal Creek for the period from July 2007 to December 2009.

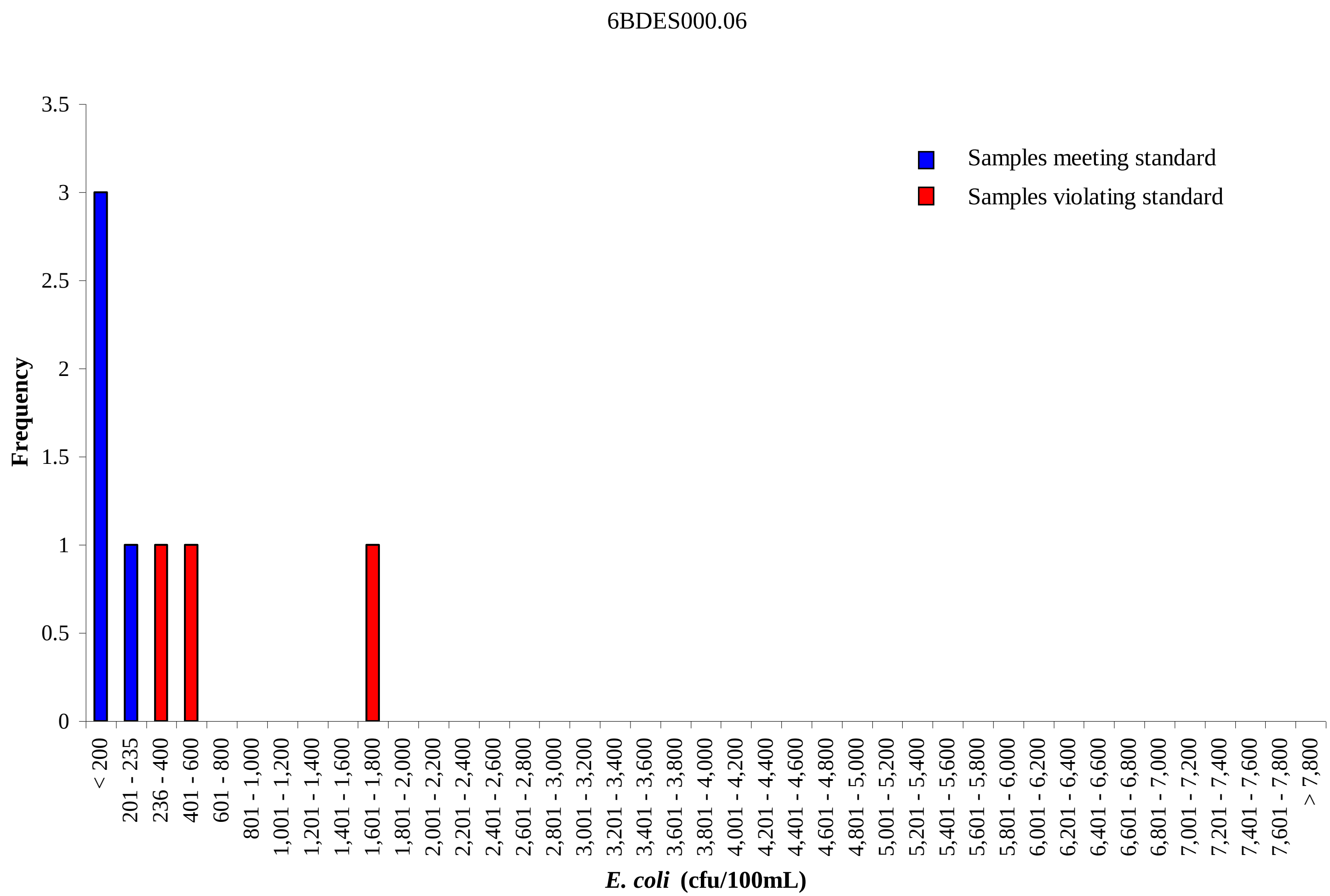

Figure A. 9 Frequency analysis of *E. coli* concentrations at station 6BDES000.06 in Deskin Creek for the period from February 2007 to February 2008.

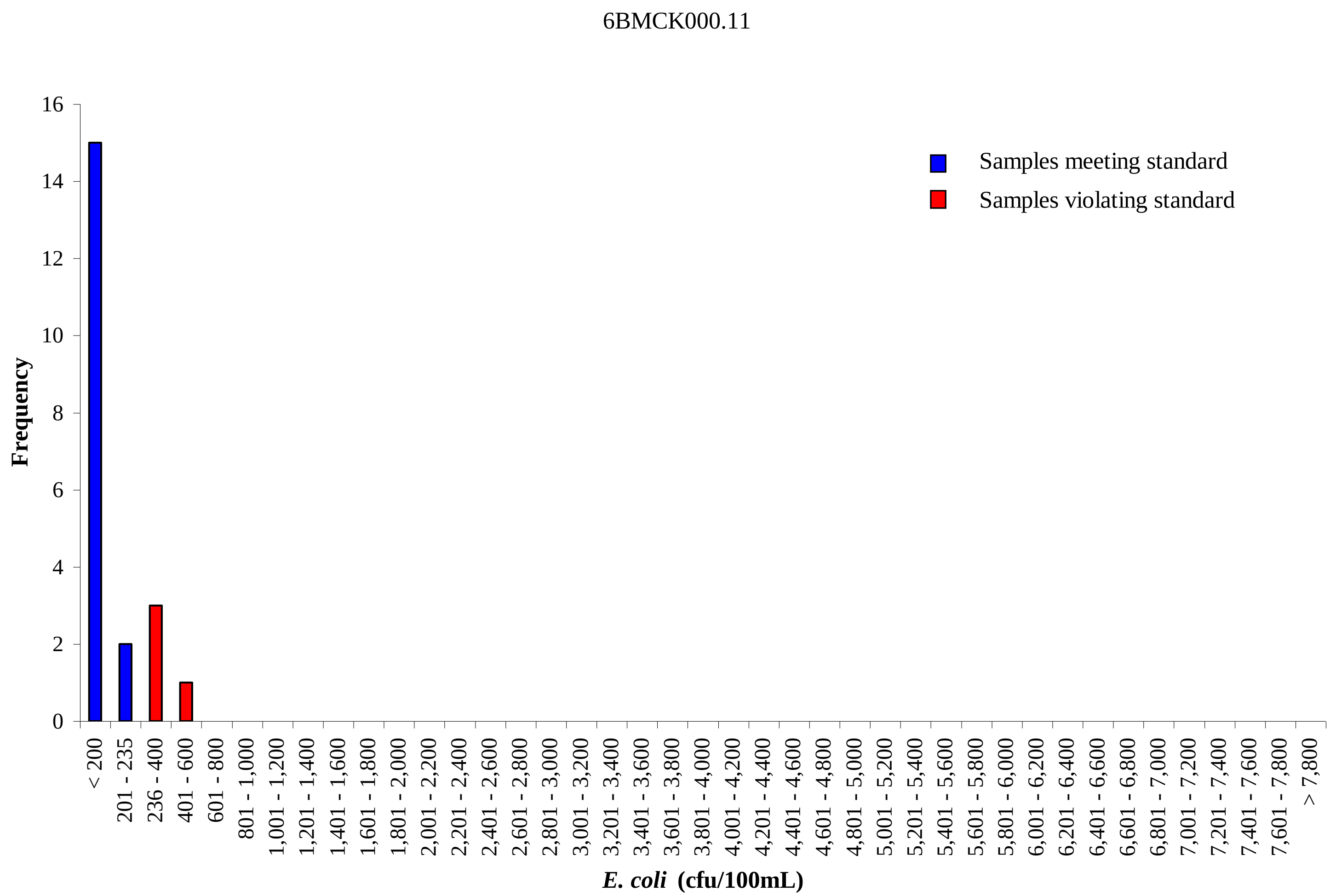

Figure A. 10 Frequency analysis of *E. coli* concentrations at station 6BMCK000.11 in Mudlick Creek for the period from January 2007 to December 2009.

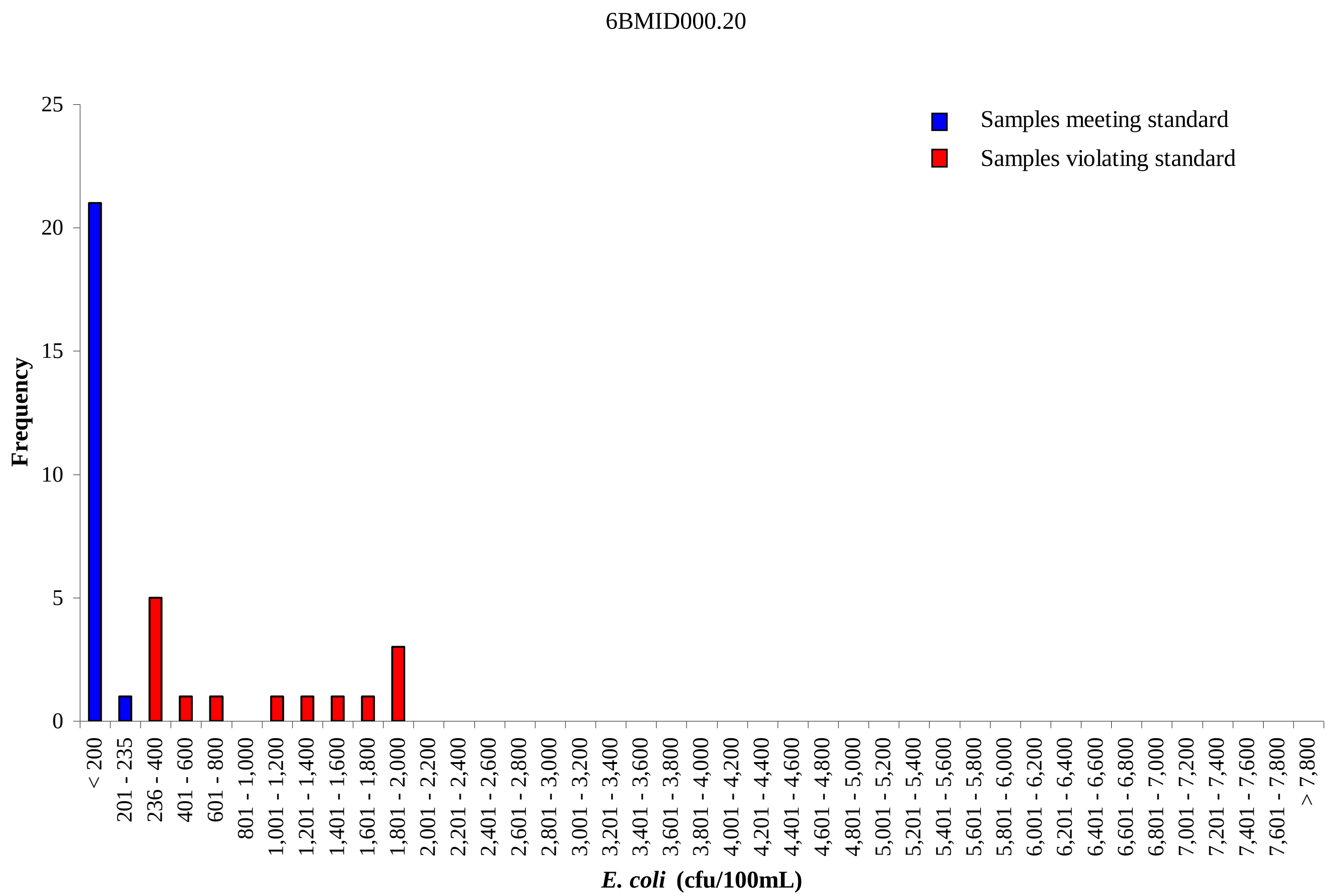

Figure A. 11 Frequency analysis of *E. coli* concentrations at station 6BMID000.20 in Middle Creek for the period from November 2004 to December 2009.

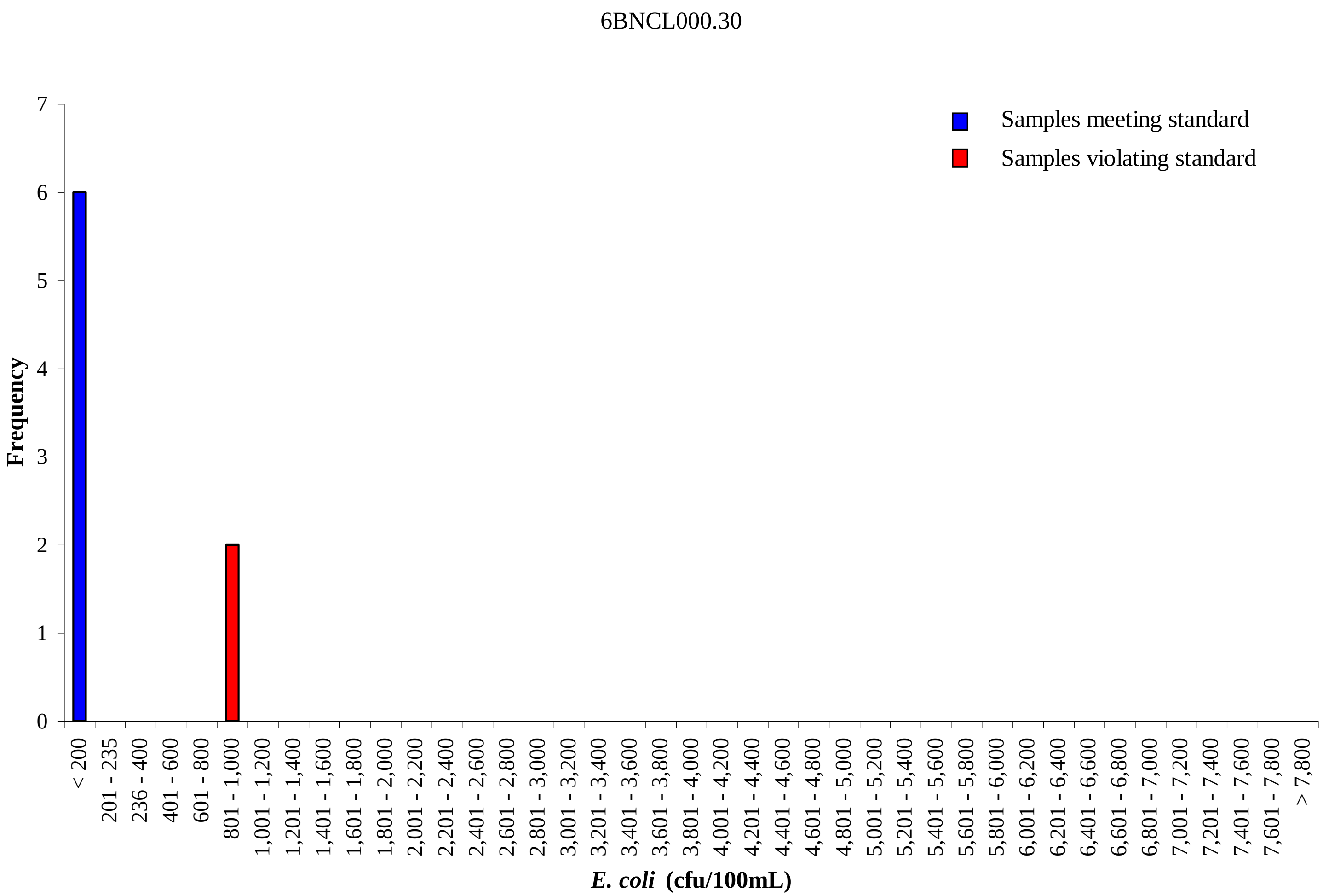

Figure A. 12 Frequency analysis of *E. coli* concentrations at station 6BNCL000.30 in the North Fork Clinch River for the period from February 2007 to April 2008.

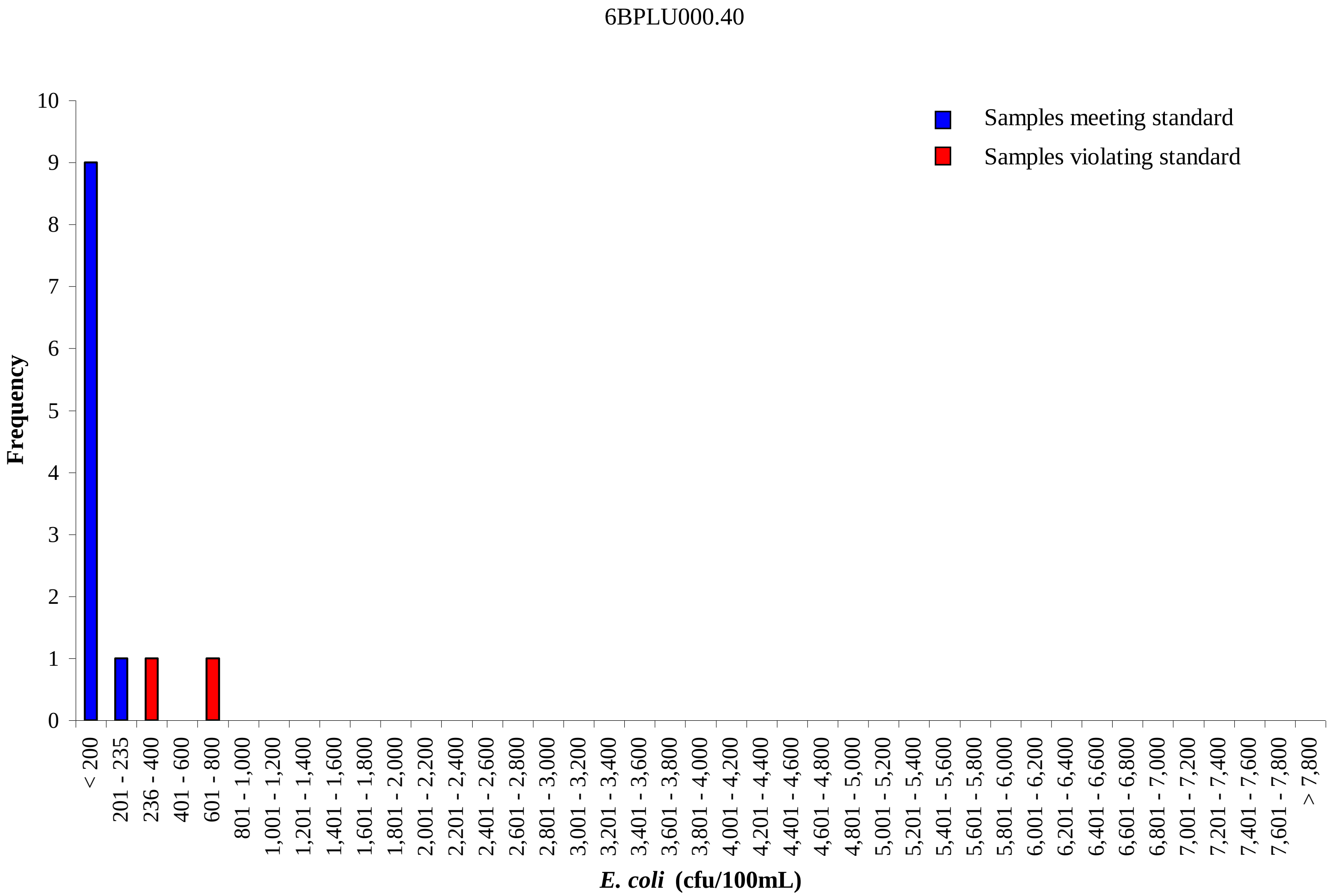

Figure A. 13 Frequency analysis of *E. coli* concentrations at station 6BPLU000.40 in the Plum Creek for the period from February 2007 to April 2008.

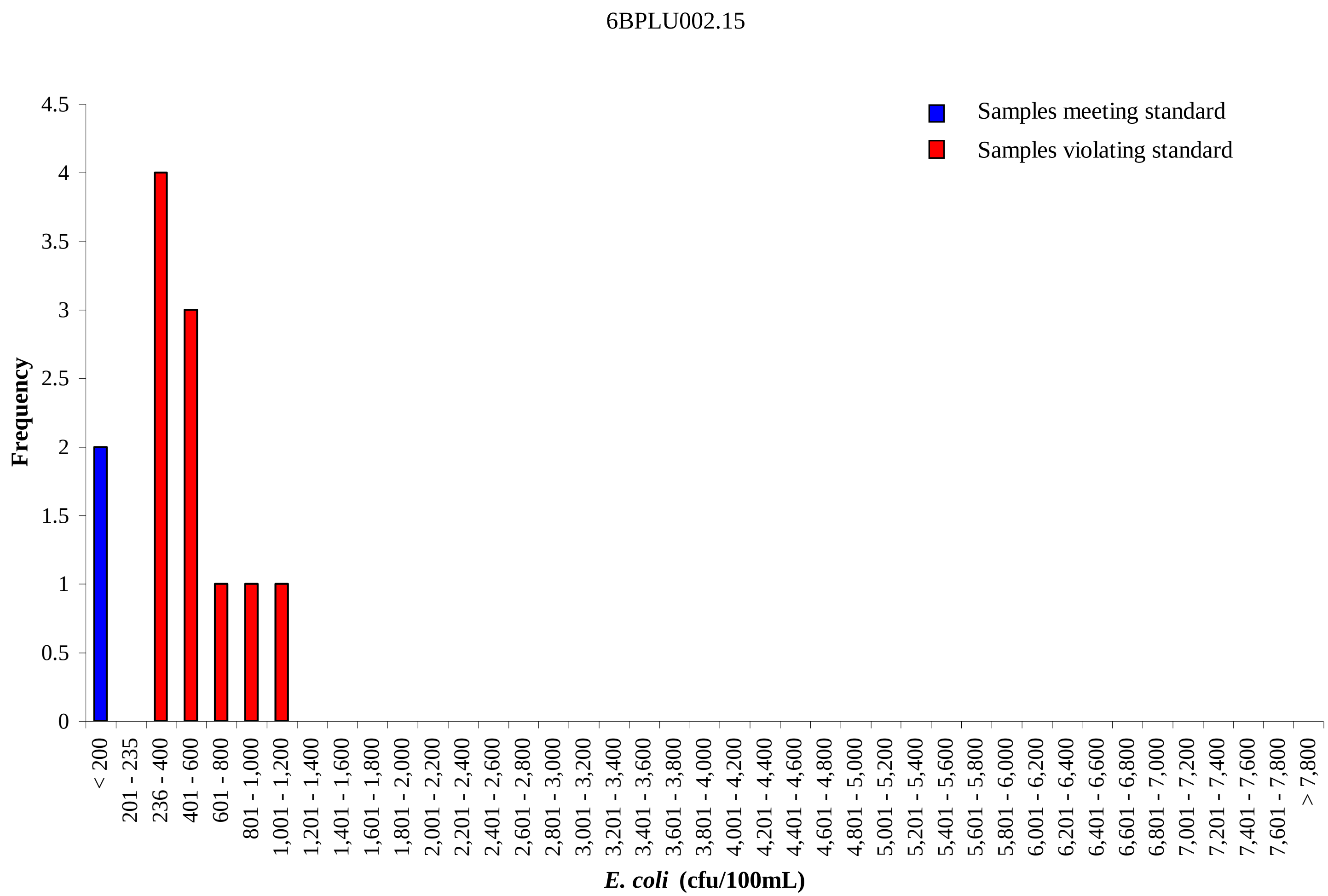

Figure A. 14 Frequency analysis of *E. coli* concentrations at station 6BPLU002.15 in the Plum Creek for the period from February 2007 to April 2008.

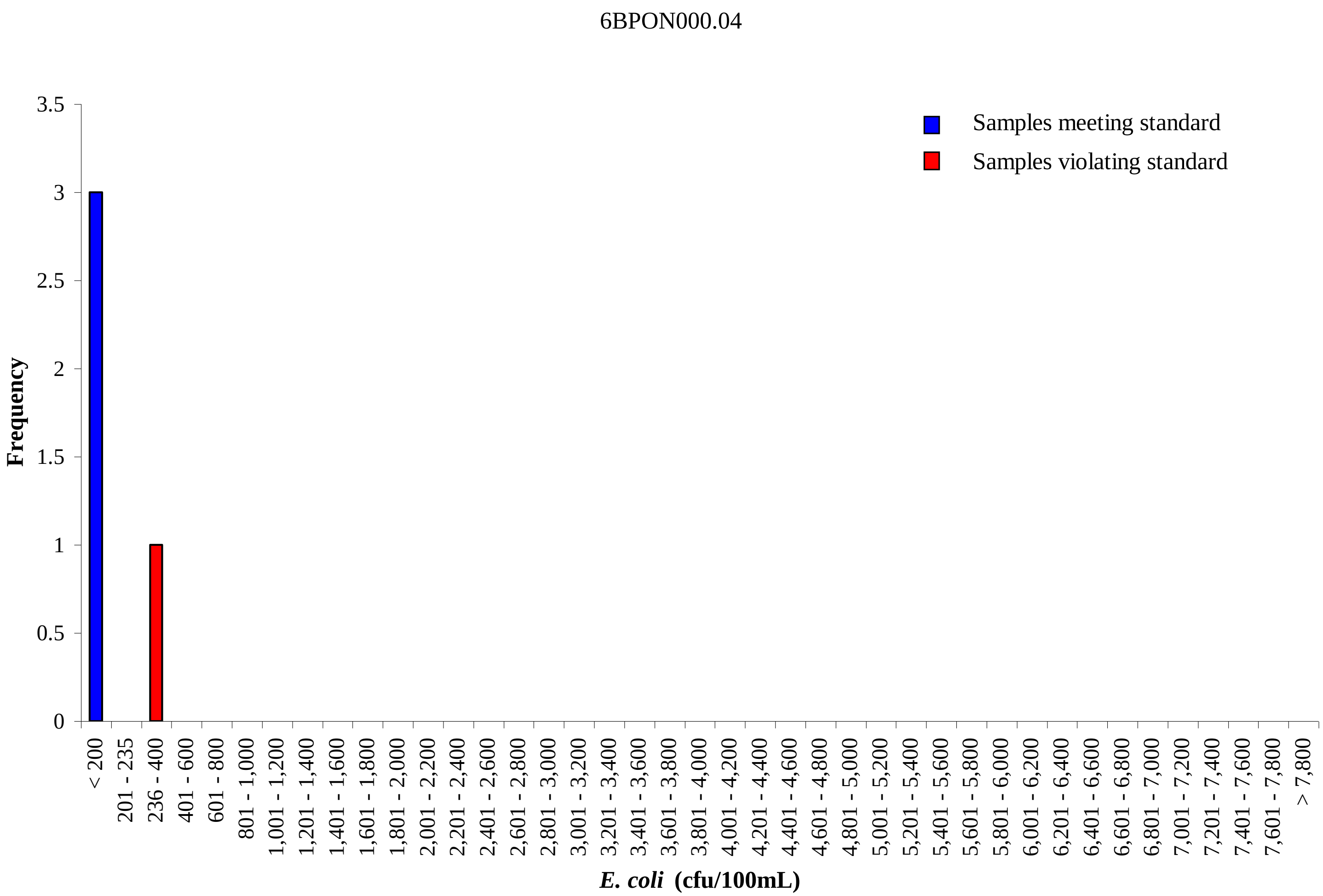

Figure A. 15 Frequency analysis of *E. coli* concentrations at station 6BPON000.04 in the Pounding Mill Branch for the period from February 2007 to February 2008.

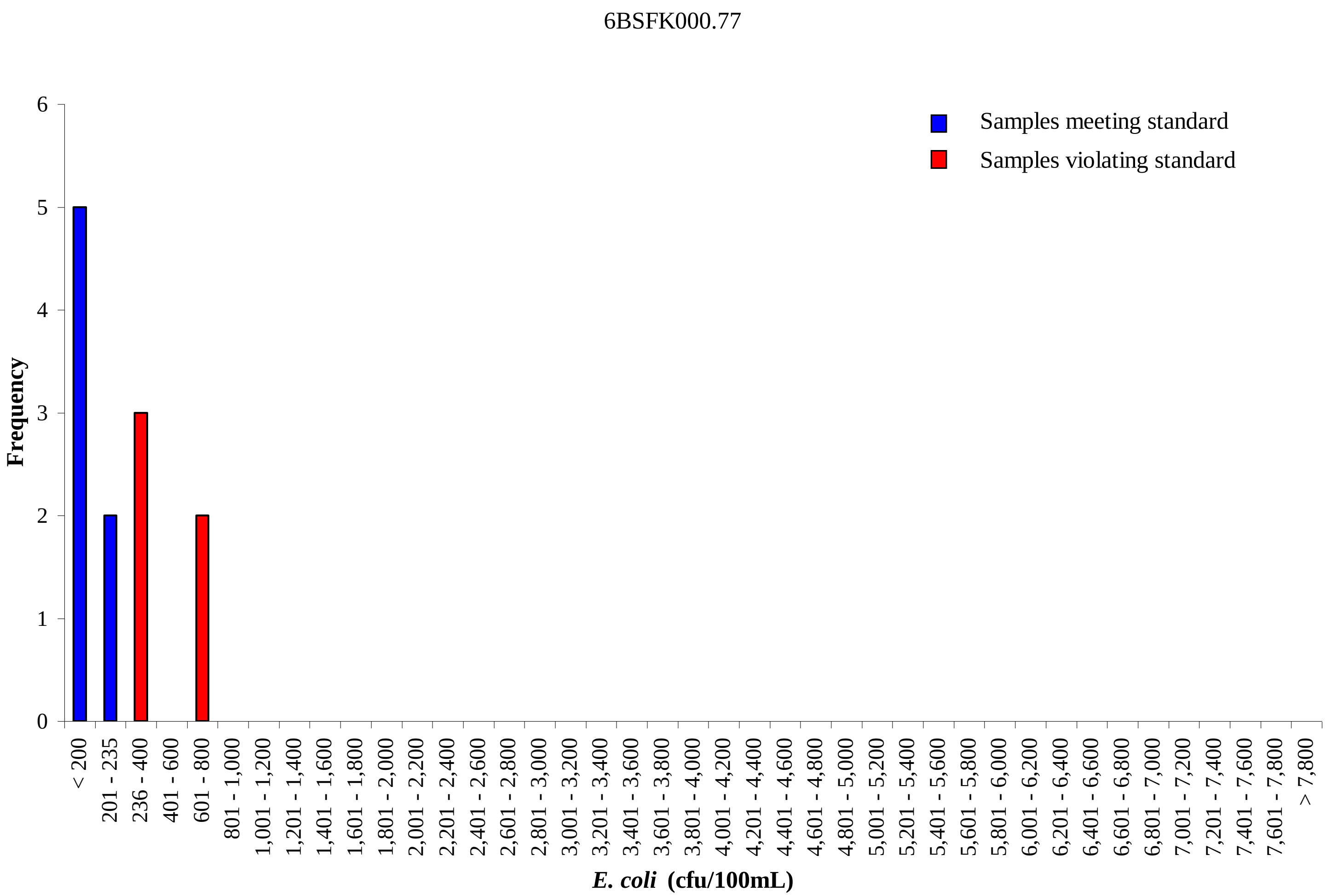

Figure A. 16 Frequency analysis of *E. coli* concentrations at station 6BSFK000.77 in the South Fork Clinch River for the period from February 2007 to December 2008.

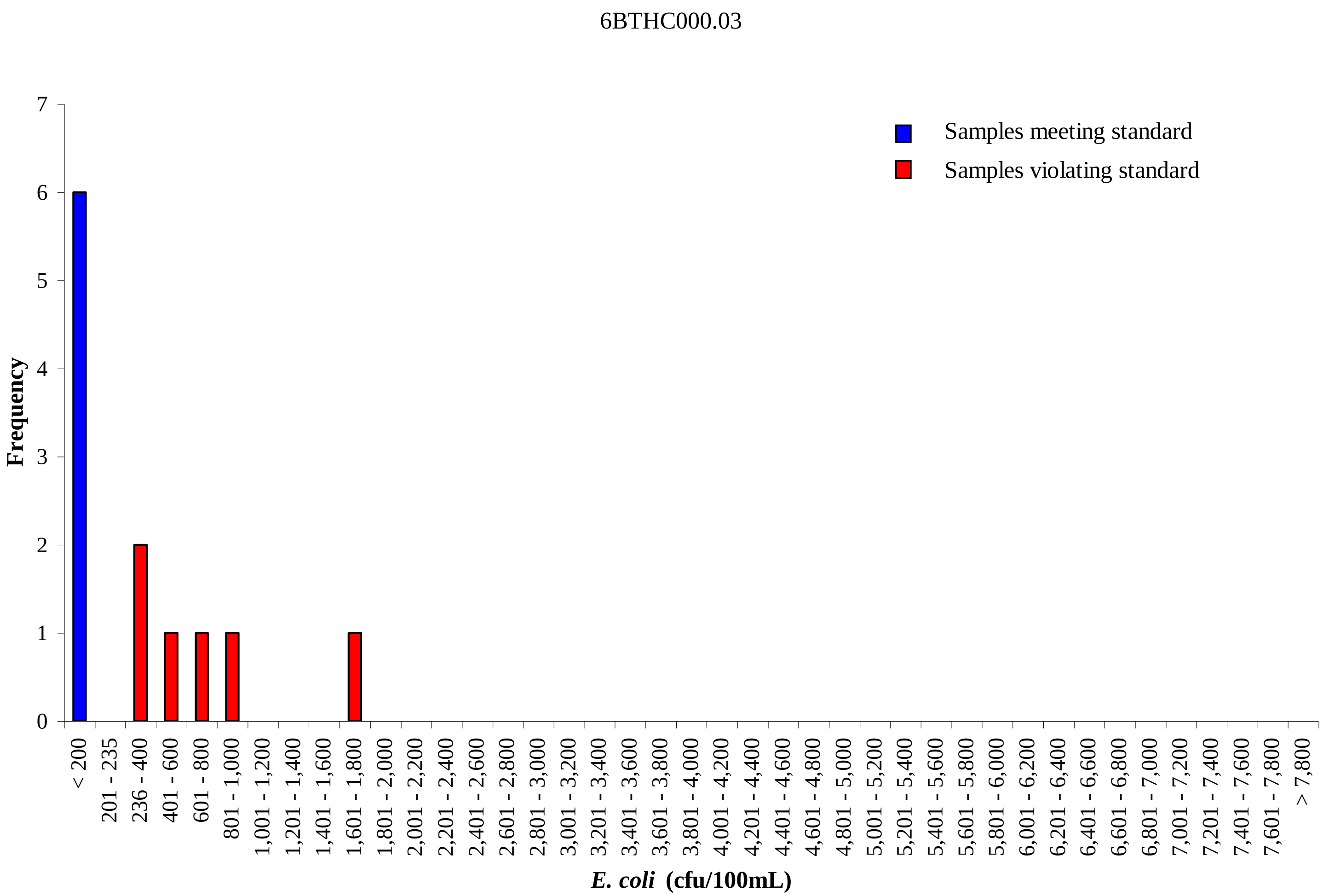

Figure A. 17 Frequency analysis of *E. coli* concentrations at station 6BTHC000.03 in the Town Hill Creek for the period from January 2007 to December 2008.

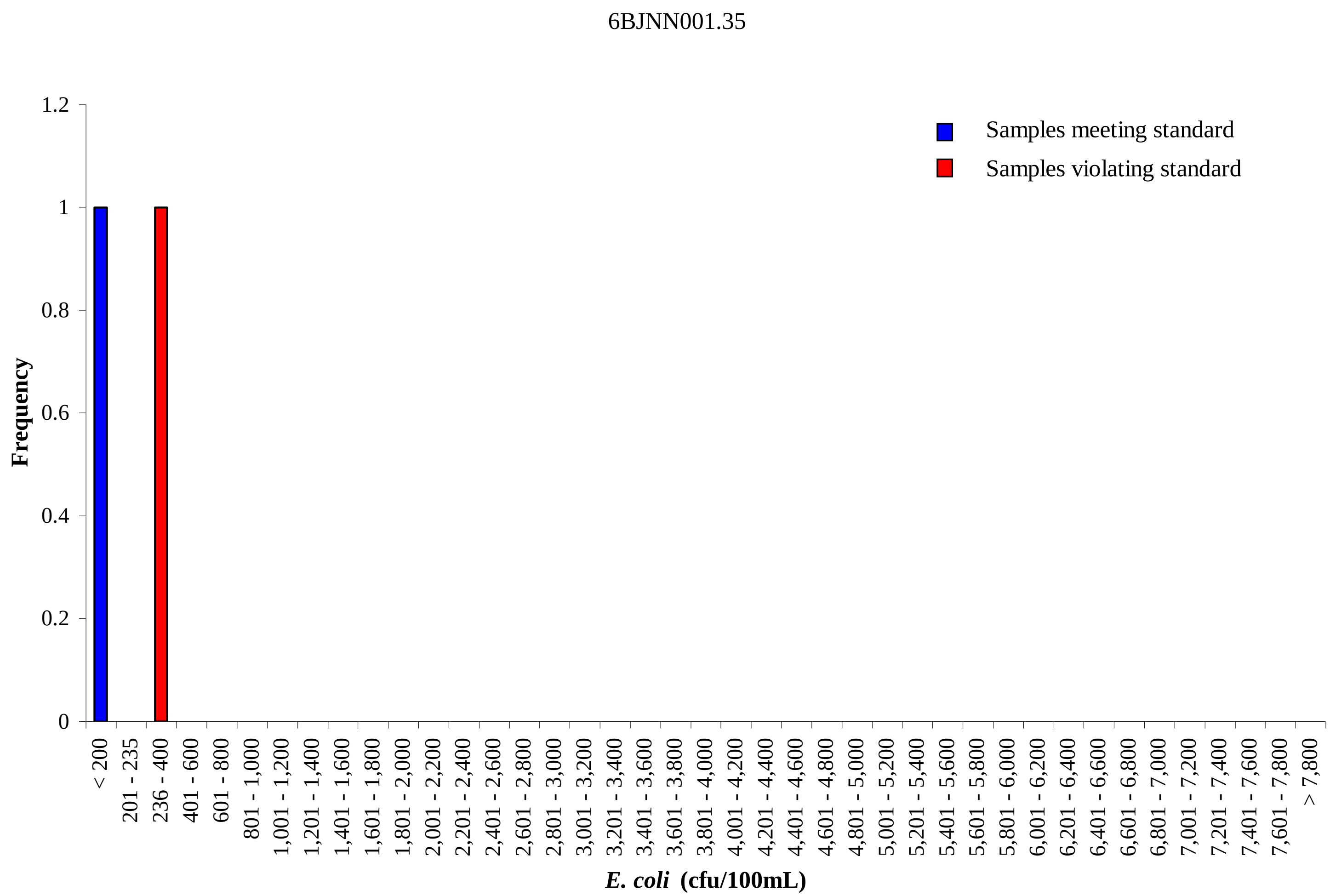

Figure A. 18 Frequency analysis of *E. coli* concentrations at station 6BJNN001.35 in the Johnson Branch for the period from January 2007 to December 2008.

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APPENDIX B LAND-BASED FECAL COLIFORM LOADS FOR EXISTING CONDITIONS

The tables in this appendix show the breakdown of the annual fecal coliform per animal per land use for contributing subwatersheds to each impairment. In addition direct deposition fecal coliform data by source are also shown.

Upper Clinch River – Near Tazewell

Table B.1 Current conditions of land applied fecal coliform load for the Upper Clinch River (Headwaters) by land use (subwatersheds 4,5,6).

Land use	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
AML	1.46E+11	1.32E+11	1.46E+11	1.41E+11	1.46E+11	1.41E+11	1.46E+11	1.46E+11	1.41E+11	1.46E+11	1.41E+11	1.46E+11	1.72E+12
Barren	1.90E+11	1.72E+11	1.90E+11	1.84E+11	1.90E+11	1.84E+11	1.90E+11	1.90E+11	1.84E+11	1.90E+11	1.84E+11	1.90E+11	2.24E+12
Commercial	4.36E+12	3.94E+12	4.36E+12	4.22E+12	4.36E+12	4.22E+12	4.36E+12	4.36E+12	4.22E+12	4.36E+12	4.22E+12	4.36E+12	5.14E+13
Crop	3.84E+11	3.47E+11	3.84E+11	3.72E+11	3.84E+11	3.72E+11	3.84E+11	3.84E+11	3.72E+11	3.84E+11	3.72E+11	3.84E+11	4.52E+12
Forest	5.18E+13	4.68E+13	5.18E+13	5.01E+13	5.18E+13	5.01E+13	5.18E+13	5.18E+13	5.01E+13	5.18E+13	5.01E+13	5.18E+13	6.10E+14
LAX	5.66E+12	5.12E+12	7.48E+12	9.48E+12	9.80E+12	1.12E+13	1.16E+13	1.16E+13	9.48E+12	7.48E+12	7.24E+12	5.66E+12	1.02E+14
Pasture	3.23E+14	2.92E+14	3.21E+14	3.08E+14	3.18E+14	3.06E+14	3.16E+14	3.16E+14	3.08E+14	3.21E+14	3.11E+14	3.23E+14	3.76E+15
Residential	3.12E+13	2.79E+13	3.01E+13	2.87E+13	2.93E+13	2.80E+13	2.82E+13	2.82E+13	2.73E+13	2.78E+13	2.73E+13	2.97E+13	3.44E+14
Total	**4.17E+14**	**3.76E+14**	**4.15E+14**	**4.01E+14**	**4.14E+14**	**4.00E+14**	**4.13E+14**	**4.13E+14**	**4.00E+14**	**4.13E+14**	**4.01E+14**	**4.15E+14**	**4.88E+15**

Table B.2 Monthly, directly deposited fecal coliform loads in the Upper Clinch River (Headwaters) by land use (subwatersheds 4,5,6)

Source Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
Human	2.51E+13	2.26E+13	2.51E+13	2.43E+13	2.51E+13	2.43E+13	2.51E+13	2.51E+13	2.43E+13	2.51E+13	2.43E+13	2.51E+13	2.96E+14
Livestock	4.75E+11	4.29E+11	6.33E+11	9.18E+11	9.49E+11	1.07E+12	1.11E+12	1.11E+12	9.18E+11	6.33E+11	6.13E+11	4.75E+11	9.33E+12
Wildlife	5.54E+11	4.99E+11	5.54E+11	5.36E+11	5.54E+11	5.36E+11	5.54E+11	5.54E+11	5.36E+11	5.54E+11	5.36E+11	5.54E+11	6.52E+12

Table B.3 Existing annual fecal coliform loads from land-based sources for the Upper Clinch River (Headwaters) by land use (subwatersheds 4,5,6).

Source	Active Mine	AML	Barren	Comm.	Crop	Forest	Gas Wells	LAX	Pasture	Reclaimed Mine	Residential	Water
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.11E+10
BeefCalves	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+15	0.00E+00	0.00E+00	0.00E+00
BeefStockers	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.39E+13	1.77E+15	0.00E+00	0.00E+00	9.32E+12
Cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	144000000	0.00E+00
DairyCalves	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DairyDry	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DairyMilkers	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.49E+11	9.79E+13	0.00E+00	6.68E+11	4.87E+13	0.00E+00	2.63E+12	0.00E+00
Dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E+14	0.00E+00
Duck	0.00E+00	2.75E+07	2.10E+07	4.54E+08	1.18E+07	1.74E+09	0.00E+00	4.62E+08	1.42E+09	0.00E+00	8.95E+08	0.00E+00
Goats	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.14E+13	0.00E+00	0.00E+00	0.00E+00
Goose	0.00E+00	1.46E+09	1.12E+09	2.42E+10	6.29E+08	9.26E+10	0.00E+00	2.46E+10	7.56E+10	0.00E+00	4.76E+10	0.00E+00
Hogs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Horses	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.97E+14	0.00E+00	0.00E+00	0.00E+00
Muskrat	0.00E+00	4.73E+11	3.62E+11	7.82E+12	2.03E+11	3.00E+13	0.00E+00	7.97E+12	2.44E+13	0.00E+00	1.54E+13	0.00E+00
Failed Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.33E+13	0.00E+00
Straight Pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.95E+14
Raccoon	0.00E+00	1.24E+12	1.87E+12	4.35E+13	3.67E+12	4.82E+14	0.00E+00	9.31E+12	3.05E+14	0.00E+00	8.35E+13	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.43E+13	0.00E+00	0.00E+00	0.00E+00
Turkey	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.01E+07	4.23E+10	0.00E+00	7.21E+07	5.26E+09	0.00E+00	0.00E+00	0.00E+00
Total	**0.00E+00**	**1.71E+12**	**2.23E+12**	**5.13E+13**	**4.52E+12**	**6.10E+14**	**0.00E+00**	**1.02E+14**	**3.77E+15**	**0.00E+00**	**3.44E+14**	**3.04E+14**

Table B.4 Existing annual fecal coliform loads from direct-deposition sources for the Upper Clinch River (Headwaters) by land use (subwatersheds 4,5,6).

Source	Annual Total Loads (cfu/yr)
Beaver	2.11E+10
BeefCalves	0.00E+00
BeefStockers	9.32E+12
DairyCalves	0.00E+00
DairyDry	0.00E+00
DairyMilkers	0.00E+00
Deer	7.53E+10
Duck	1.96E+08
Goats	0.00E+00
Goose	6.87E+09
Hogs	0.00E+00
Horses	0.00E+00
Muskrat	4.08E+12
Straight Pipes	2.95E+14
Raccoon	2.33E+12
Sheep	0.00E+00
Turkey	2.39E+07
Total	**9.13E+14**

Upper Clinch River – Near Richlands

Table B.5 Current conditions of land applied fecal coliform load for the Upper Clinch River (Richlands) by land use (all subwatersheds)

Land use	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
AML	3.17E+12	2.86E+12	3.17E+12	3.06E+12	3.17E+12	3.06E+12	3.17E+12	3.17E+12	3.06E+12	3.17E+12	3.06E+12	3.17E+12	3.73E+13
Barren	5.08E+11	4.59E+11	5.08E+11	4.92E+11	5.08E+11	4.92E+11	5.08E+11	5.08E+11	4.92E+11	5.08E+11	4.92E+11	5.08E+11	5.98E+12
Commercial	1.10E+13	9.91E+12	1.10E+13	1.06E+13	1.10E+13	1.06E+13	1.10E+13	1.10E+13	1.06E+13	1.10E+13	1.06E+13	1.10E+13	1.29E+14
Crop	5.76E+11	5.20E+11	5.76E+11	5.57E+11	5.76E+11	5.57E+11	5.76E+11	5.76E+11	5.57E+11	5.76E+11	5.57E+11	5.76E+11	6.78E+12
Forest	1.84E+14	1.66E+14	1.84E+14	1.78E+14	1.84E+14	1.78E+14	1.84E+14	1.84E+14	1.78E+14	1.84E+14	1.78E+14	1.84E+14	2.16E+15
GasWells	5.68E+11	5.13E+11	5.68E+11	5.49E+11	5.68E+11	5.49E+11	5.68E+11	5.68E+11	5.49E+11	5.68E+11	5.49E+11	5.68E+11	6.68E+12
LAX	1.03E+13	9.29E+12	1.34E+13	1.69E+13	1.74E+13	1.99E+13	2.06E+13	2.06E+13	1.69E+13	1.34E+13	1.30E+13	1.03E+13	1.82E+14
Pasture	5.51E+14	4.97E+14	5.47E+14	5.25E+14	5.43E+14	5.22E+14	5.39E+14	5.39E+14	5.25E+14	5.47E+14	5.30E+14	5.51E+14	6.42E+15
Residential	8.59E+13	7.69E+13	8.35E+13	8.00E+13	8.18E+13	7.84E+13	7.93E+13	7.93E+13	7.68E+13	7.85E+13	7.68E+13	8.26E+13	9.60E+14
Total	**8.47E+14**	**7.63E+14**	**8.44E+14**	**8.15E+14**	**8.42E+14**	**8.14E+14**	**8.39E+14**	**8.39E+14**	**8.12E+14**	**8.39E+14**	**8.13E+14**	**8.44E+14**	**9.91E+15**

Table B.6 Monthly, directly deposited fecal coliform loads in the Upper Clinch River (Richlands) by land use (all subwatersheds).

Source Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
Human	7.45E+13	6.72E+13	7.45E+13	7.21E+13	7.45E+13	7.21E+13	7.45E+13	7.45E+13	7.21E+13	7.45E+13	7.21E+13	7.45E+13	8.77E+14
Livestock	8.21E+11	7.41E+11	1.09E+12	1.59E+12	1.64E+12	1.85E+12	1.91E+12	1.91E+12	1.59E+12	1.09E+12	1.06E+12	8.21E+11	1.61E+13
Wildlife	1.74E+12	1.57E+12	1.74E+12	1.69E+12	1.74E+12	1.69E+12	1.74E+12	1.74E+12	1.69E+12	1.74E+12	1.69E+12	1.74E+12	2.05E+13

Table B.7 Existing annual fecal coliform loads from land-based sources for the Upper Clinch River (Richlands) by land use (all subwatersheds).

Source	Active Mine	AML	Barren	Comm.	Crop	Forest	Gas Wells	LAX	Pasture	Reclaimed Mine	Residential	Water
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.21E+10
BeefCalves	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E+15	0.00E+00	0.00E+00	0.00E+00
BeefStockers	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45E+14	3.06E+15	0.00E+00	0.00E+00	1.61E+13
Cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	398000000	0.00E+00
DairyCalves	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DairyDry	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DairyMilkers	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E+11	3.05E+14	0.00E+00	1.37E+12	8.43E+13	0.00E+00	8.47E+12	0.00E+00
Dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.40E+14	0.00E+00
Duck	0.00E+00	1.57E+08	5.73E+07	1.18E+09	1.82E+07	8.15E+09	2.86E+07	9.49E+08	2.84E+09	0.00E+00	3.16E+09	0.00E+00
Goats	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E+13	0.00E+00	0.00E+00	0.00E+00
Goose	0.00E+00	8.39E+09	3.05E+09	6.26E+10	9.69E+08	4.34E+11	1.52E+09	5.05E+10	1.51E+11	0.00E+00	1.68E+11	0.00E+00
Hogs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Horses	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.51E+14	0.00E+00	0.00E+00	0.00E+00
Muskrat	0.00E+00	2.71E+12	9.87E+11	2.02E+13	3.13E+11	1.40E+14	4.92E+11	1.63E+13	4.90E+13	0.00E+00	5.43E+13	0.00E+00
Failing Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.82E+14	0.00E+00
Straight Pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.76E+14
Raccoon	0.00E+00	3.46E+13	4.99E+12	1.09E+14	5.51E+12	1.72E+15	6.19E+12	1.91E+13	5.40E+14	0.00E+00	2.75E+14	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.47E+13	0.00E+00	0.00E+00	0.00E+00
Turkey	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E+08	1.32E+11	0.00E+00	1.48E+08	9.10E+09	0.00E+00	0.00E+00	0.00E+00
Total	**0.00E+00**	**3.73E+13**	**5.98E+12**	**1.29E+14**	**6.78E+12**	**2.17E+15**	**6.68E+12**	**1.82E+14**	**6.42E+15**	**0.00E+00**	**9.60E+14**	**8.92E+14**

Table B.8 Existing annual fecal coliform loads from direct-deposition sources for the Upper Clinch River (Richlands) by land use (all subwatersheds).

Source	Annual Total Loads (cfu/yr)
Beaver	7.21E+10
BeefCalves	0.00E+00
BeefStockers	1.61E+13
DairyCalves	0.00E+00
DairyDry	0.00E+00
DairyMilkers	0.00E+00
Deer	2E+11
Duck	6.44E+08
Goats	0.00E+00
Goose	2.26E+10
Hogs	0.00E+00
Horses	0.00E+00
Muskrat	1.34E+13
Straight Pipes	8.76E+14
Raccoon	6.80E+12
Sheep	0.00E+00
Turkey	7.05E+07
Total	9.13E+14

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APPENDIX C BACTERIA MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Modeling Procedure: Linking the Sources to the Endpoint

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of TMDLs in the Upper Clinch River Watershed study area, the relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality.

Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate streamflow, overland runoff and to perform TMDL allocations.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLND) and pervious land areas (PERLND). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, representing the various land uses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES in that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

The HSPF model is a continuous simulation model that can account for nonpoint source (NPS) pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

Model Setup

Daily precipitation data was available within the watershed at the Richlands NCDC Coop station #447174. Missing values were filled using daily precipitation from the Lebanon NCDC Coop station #444777. The final filled daily precipitation was disaggregated using the hourly station data.

To adequately represent the spatial variation in the watershed, the Upper Clinch River Watershed drainage area was divided into nine (9) subwatersheds (Figure C.1). The rationale for choosing these subwatersheds was based on the availability of water quality data, the stream network configuration, and the limitations of the HSPF model. Seven of these subwatersheds were used in hydrologic calibration since they were upstream of the flow gage with observed data (outlet of subwatershed 2). The entire set of 9 subwatersheds was used in the bacteria calibration. Subwatershed 7 (Indian Creek) had a bacteria TMDL approved in April of 2008 and output from the existing model was used as input to the Clinch model.

Figure C.1 shows all subwatersheds, which were used to achieve the unified model. Table C.1 notes the subwatersheds contained within each impairment, the impaired stream segments, and the outlet subwatershed for each impairment.

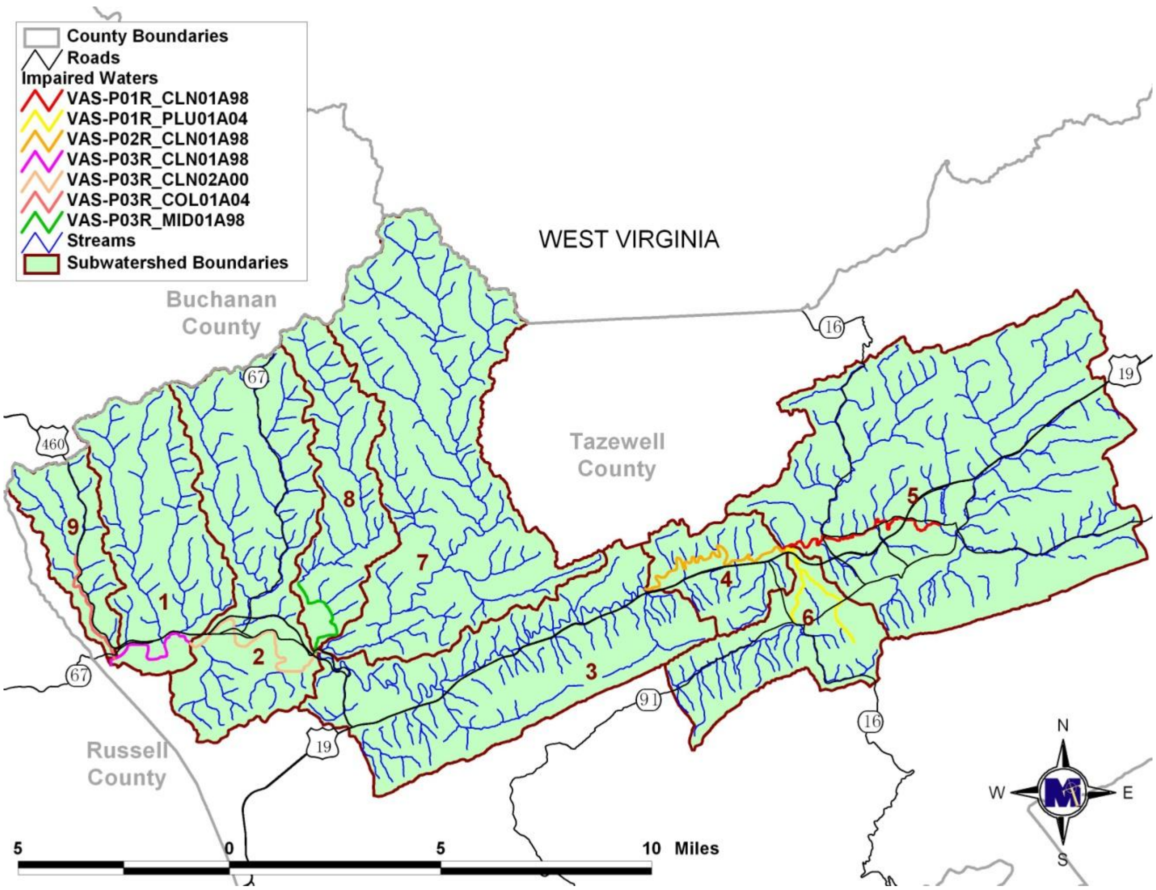

Figure C.1 All subwatersheds delineated for modeling in the Upper Clinch River Watershed study area.

Table C.2 Impairments and subwatersheds within the Upper Clinch River Watershed study area.

Impairment	Impaired Subwatershed(s)	Outlet	Contributing Subwatersheds
Clinch River VAS-P03R_CLN02A00	2	2	2,3,4,5,6,7,8
Clinch River VAS-P03R_CLN01A98	1	1	1,2,3,4,5,6,7,8,9
Coal Creek VAS-P03R_COL01A04	9	9	9
Middle Creek VAS-P03R_MID01A98	8	8	8
Clinch River VAS-P02R_CLN01A98	4	4	4,5,6
Clinch River VAS-P01R_CLN01A98	5	5	5
Plum Creek VAS-P01R_PLU01A04	6	6	6

In an effort to standardize modeling procedures across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watersheds allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watersheds.

Ten land uses were identified in the watershed. These land uses were obtained by merging different sources including the MRLC land use grid, active mining layers provided by the Virginia Department of Mines, Minerals, and Energy (DMME), topographic maps (for delineating abandoned mine lands), and aerial photography of the region. The 10 land use types are given in Table C.2. Within each subwatershed, up to the ten land use types were represented. Each land use in each subwatershed has hydrologic parameters (*e.g.,* average slope length) and pollutant behavior parameters (*e.g., E. coli* accumulation rate) associated with it. These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments

(IMPLNDs). Impervious areas in the watershed are represented in four IMPLND types, while there are ten PERLND types, each with parameters describing a particular land use. Some IMPLND and PERLND parameters (*e.g.,* slope length) vary with the particular subwatershed in which they are located. Others vary with the season (*e.g.,* upper zone storage) to account for plant growth, die-off, and removal.

Figure C.2 shows the land uses used in modeling the Upper Clinch River Watershed study area. Table C.3 shows the breakdown of land uses within the drainage area of each impairment. These acreages represent only what is within the boundaries of the Upper Clinch River Watershed study area.

Table C.3 Consolidated land use categories for the Upper Clinch River Watershed drainage area used in HSPF modeling.

TMDL Land use Categories	Pervious / Impervious (%)
Abandoned Mine Land	Pervious (80%) Impervious (20%)
Active Mining	Pervious (75%) Impervious (25%)
Barren	Pervious (94%) Impervious (6%)
Cropland	Pervious (100%)
Commercial	Pervious (40%) Impervious (60%)
Forest	Pervious (100%)
Gas Wells	Pervious (94%) Impervious (6%)
Livestock Access	Pervious (100%)
Pasture	Pervious (100%)
Residential	Pervious (90%) Impervious (10%)
Reclaimed Mine Land	Pervious (100%)
Water	Pervious (100%)

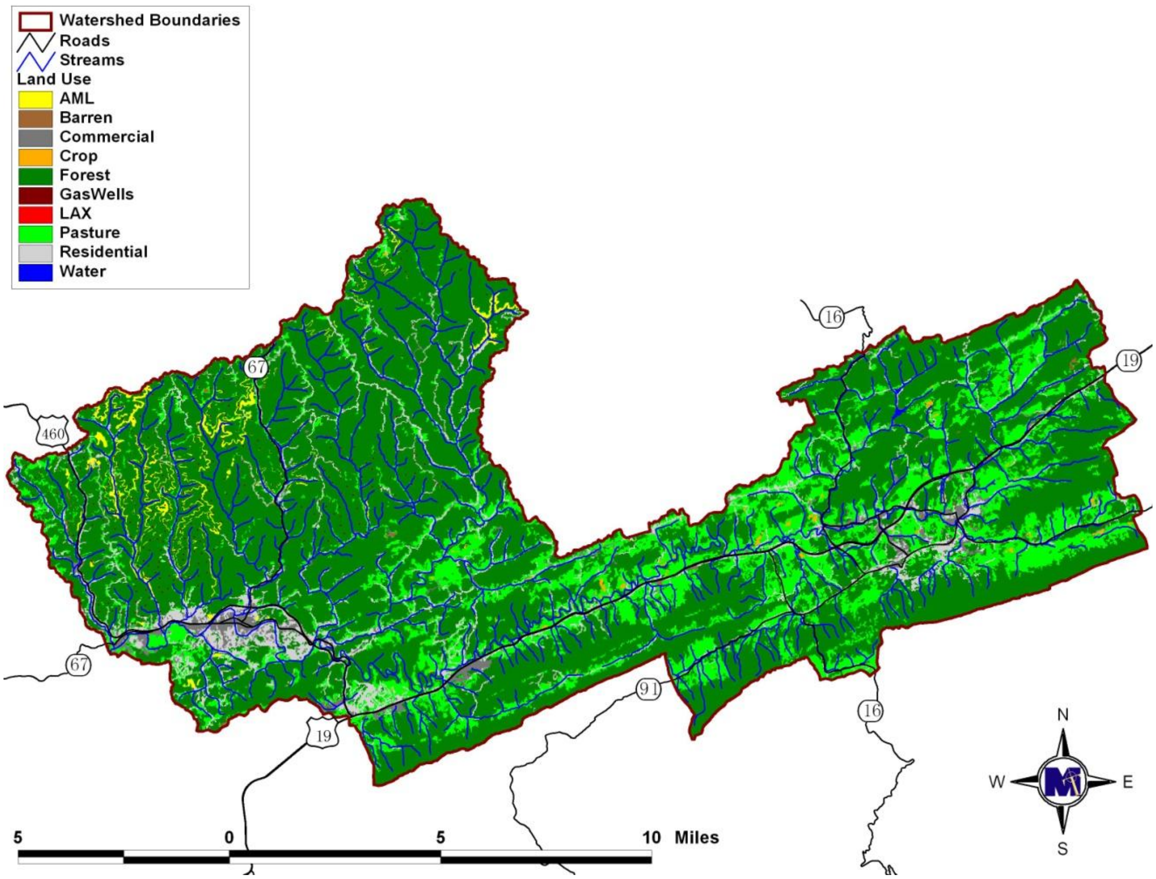

Figure C.2 Land uses in the Upper Clinch River Watershed study area watershed.

Table C.4 Spatial distribution of land use types in acres in the Upper Clinch River Watershed study area.

Sub-Water-shed	Active Mine	AML	Barren	Comm	Crop	Forest	Gas Wells	LAX	Pasture	Re-claimed Mine	Res	Water	Total
1	3.31	707.23	2.37	276.67	0.12	7,293.68	112.73	17.74	688.52	18.08	726.21	86.17	9,932.83
2	0.00	381.88	27.52	611.25	1.68	10,242.62	44.58	37.76	910.08	37.81	1,806.56	126.29	14,228.03
3	0.00	0.00	17.38	556.55	54.03	9,536.94	0.00	46.91	3,861.31	0.00	1,137.76	188.50	15,399.38
4	0.00	0.00	3.30	86.57	34.47	2,125.17	0.00	22.04	1,681.82	0.00	256.08	62.15	4,271.60
5	0.00	22.78	61.27	1,102.89	121.01	19,075.17	0.00	112.20	8,468.31	0.00	2,107.07	185.03	31,255.73
6	0.00	0.00	2.48	24.62	10.33	3,809.14	0.00	36.40	2,291.31	0.00	320.67	27.99	6,522.94
7	9.29	217.66	11.23	153.18	21.41	16,860.97	45.72	46.05	2,724.05	0.00	1,460.06	93.58	21,643.20
8	0.00	24.72	15.96	62.52	0.94	6,318.42	33.49	16.67	371.60	2.51	305.84	37.13	7,189.80
9	246.63	46.45	18.93	132.58	0.00	2,499.10	29.64	14.56	519.91	1.85	526.79	25.20	4,061.64
Total	**259.23**	**1,400.72**	**160.44**	**3,006.83**	**243.99**	**77,761.21**	**266.16**	**350.33**	**21,516.91**	**60.25**	**8,647.04**	**832.04**	**114,505.14**

Comm is commercial
LAX is livestock access to a stream.
Res is residential

Die-off of fecal bacteria can be handled implicitly or explicitly. For land-applied fecal matter (mechanically applied and deposited directly), die-off was addressed implicitly through monitoring and modeling. Samples of collected waste prior to land application (*i.e.,* dairy waste from loafing areas) were collected and analyzed by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal bacteria entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.,* stream geometry and resistance to flow). These data are entered into HSPF via the Hydraulic Function Tables (F-tables). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and discharge (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume in the reach, and is reported in acre-feet. The discharge is simply the stream outflow, in cubic feet per second.

In order to develop the entries for the F-tables, a combination of the NRCS Regional Hydraulic Geometry Curves (NRCS, 2008), Digital Elevation Models (DEM), nautical charts, and bathymetry data was used. The NRCS has developed empirical formulas for estimating stream top width, cross-sectional area, average depth, and flow rate, at bank-full depth as functions of the drainage area for regions of the United States. Appropriate equations were selected based on the geographic location of the Upper Clinch River Watershed. Using these NRCS equations, an entry was developed in the F-table that represented a bank-full situation for the streams at each subwatershed outlet. A profile perpendicular to the channel was generated showing the stream profile height with distance for each subwatershed outlet (Figure C.3). Consecutive entries to the F-table are generated by estimating the volume of water and surface area in the reach at incremental depths taken from the profile.

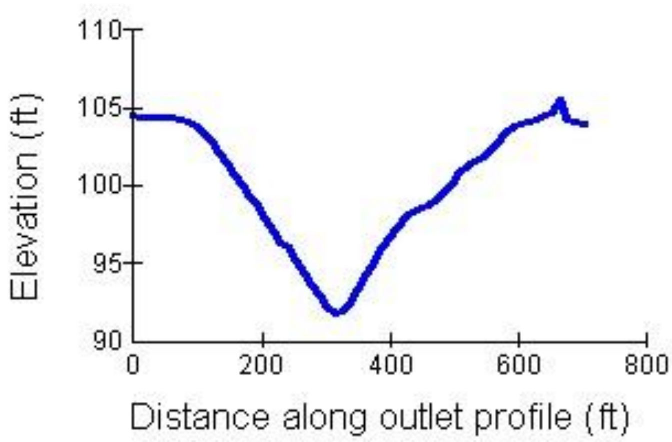

Figure C.3 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with values for resistance to flow (Manning's *n*) assigned based on recommendations by Brater and King (1976) and shown in Table C.4. The conveyance was calculated for each of the two floodplains and the main channel; these figures were then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from DEMs and a stream-flow network based on National Hydrography Dataset (NHD) data. The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth. An example of an F-table used in HSPF is shown in Table C.5.

Table C.5 Summary of Manning's roughness coefficients for channel cells*.

Section	Upstream Area (ha)	Manning's *n*
Intermittent stream	18 - 360	0.06
Perennial stream	360 and greater	0.05

*Brater and King (1976)

Table C.6 Example of an F-table calculated for the HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0	0	0	0
3.28	0.71	1.41	17.07
6.56	1.89	5.15	45.23
9.84	2.54	12.18	85.02
13.12	4.77	24.80	152.82
16.40	56.55	77.51	637.72
19.68	1,047.22	1,635.10	18,846.85
22.96	2,875.31	7,405.99	69,827.77
26.24	3,495.32	18,464.40	133,806.76
29.52	4,426.89	31,720.10	160,393.97

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

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken in order to meet water quality standards. Fecal bacteria sources within the Upper Clinch River Watershed study area are attributed to both point and non-point sources. Critical conditions for waters impacted by land-based non-point sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include non-point sources that are not precipitation driven (*e.g.*, fecal deposition to stream).

A description of the data used in these analyses is shown in Table 2.1 in Chapter 2. Graphical analyses of fecal bacteria concentrations and flow duration intervals showed that water quality standard violations occurred at nearly every flow interval at four (4) VADEQ monitoring stations in the Upper Clinch River Watershed study area (Figures C.4 - Figure C.7). This demonstrates that this stream should have all flow regimes represented in the allocation modeling time period.

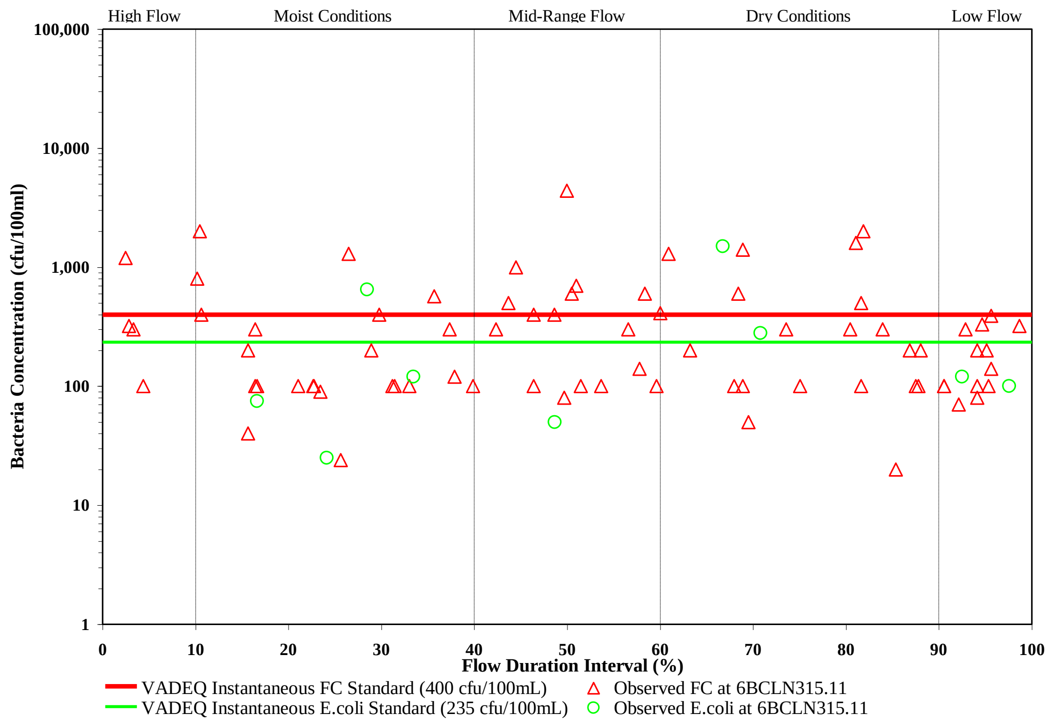

Figure C.4 Fecal and *E. coli* bacteria concentrations at 6BCLN315.11 on the Clinch River versus discharge at USGS Gaging Station # 03524000.

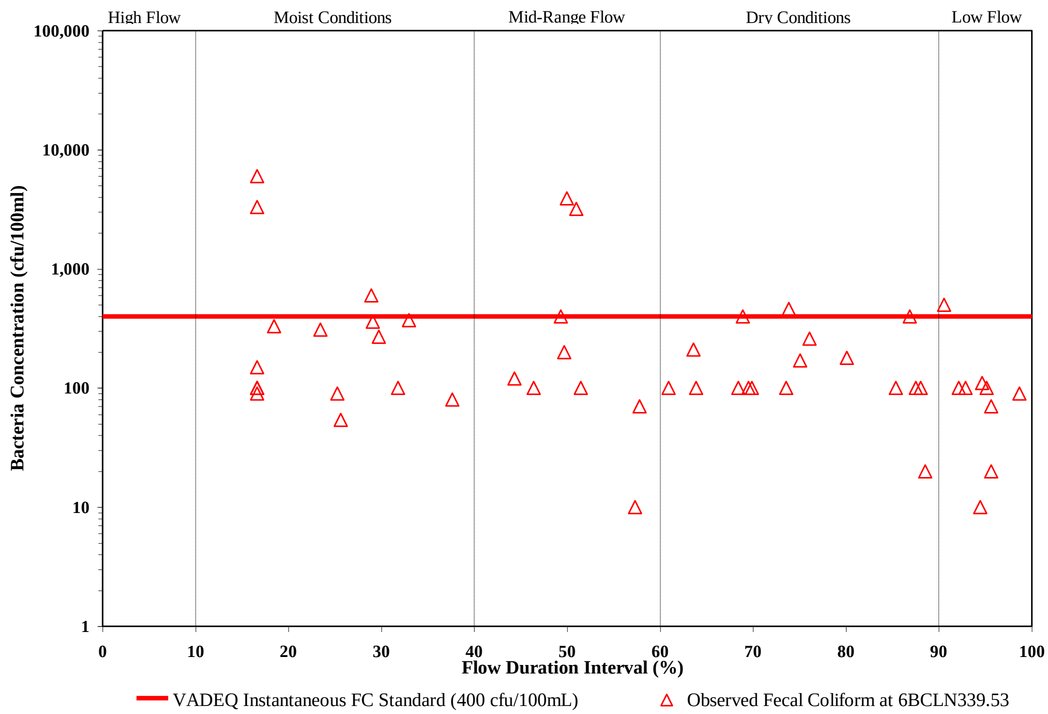

Figure C.5 Fecal bacteria concentrations at 6BCLN339.53 on the Clinch River versus discharge at USGS Gaging Station #03524000.

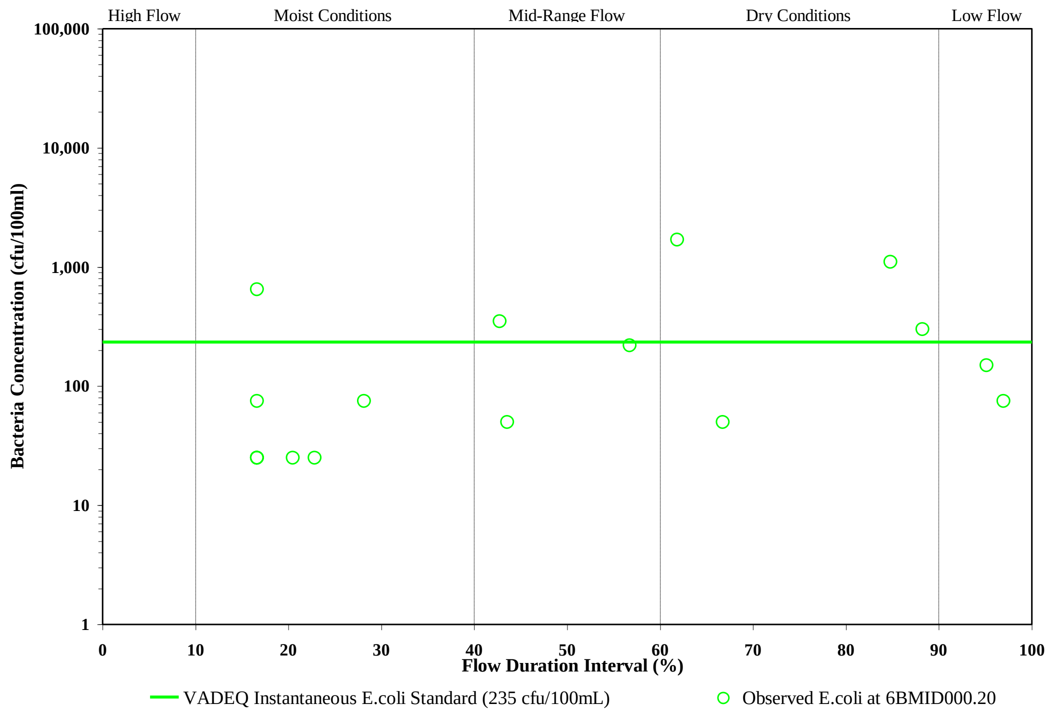

Figure C.6 ***E. coli*** **bacteria concentrations at 6BMID000.20 on Middle Creek versus discharge at USGS Gaging Station #03524000.**

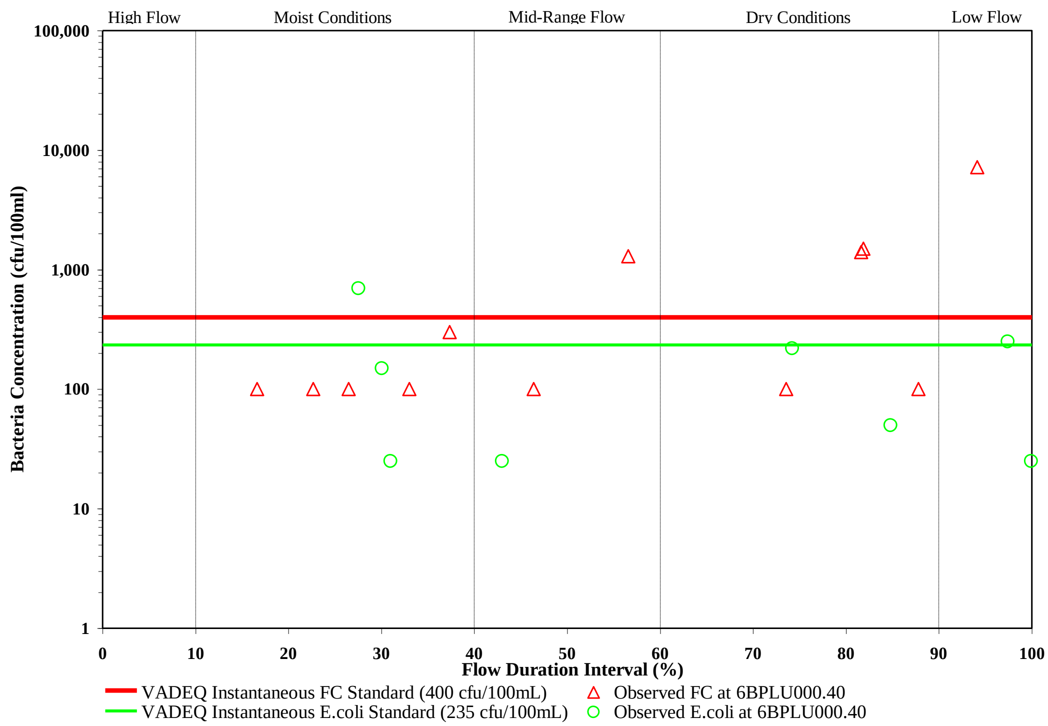

Figure C.7 **Fecal and** ***E. coli*** **bacteria concentrations at 6BPLU000.40 on the Plum Creek versus discharge at USGS Gaging Station # 03524000.**

Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons in order to capture a wide range of hydrologic circumstances for all impaired streams in this study area.

Selection of the modeling period was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station 03521500 in the Clinch River at Richlands was available from 1945 through 1989. To account for the missing recent data a regression was performed using the data from the USGS Gaging Station 03524000 located downstream at Cleveland. The regression analysis produced an R^2 value of 94.23%. The Hydrologic calibration period was October 1994 to September 1997 and hydrologic validation period was October 1988 to September 1991. The fecal concentration data were evaluated to determine the relationship between concentration and the level of flow in the stream. High concentrations of fecal coliform were recorded in all flow regimes, thus it was concluded that the critical hydrological condition included a wide range of wet and dry seasons. Multiple periods were used for water quality calibration and validation depending on the availability of monitored data.

The critical flow regime study showed that all flow regimes, but most critically high flows, should be represented in the modeling time periods of the impaired streams in this study. The hydrology calibration/validation/water quality calibration and validation time period, has both the high and low daily average streamflow at USGS Gaging Station #03524000 located at Cleveland and precipitation, which represent the high and low flow critical regimes (Figures C.8 and C.9). The figures are shown here to demonstrate the historical annual and seasonal stream flow and precipitation and how the selected time period encompasses a representative range of values. Table C.6 shows the statistical comparison between calibration/validation time periods and historic time period.

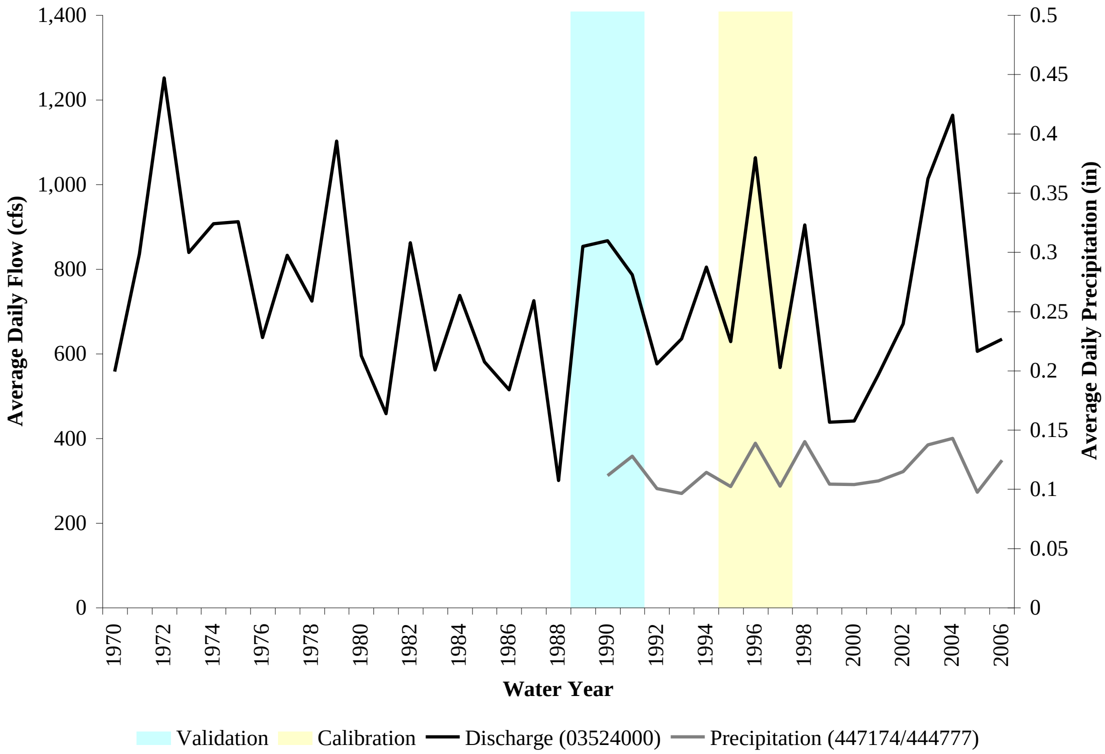

Figure C.8 Modeling time periods, annual historical flow (USGS Station 03524000), and precipitation (Station 447174/444777) data.

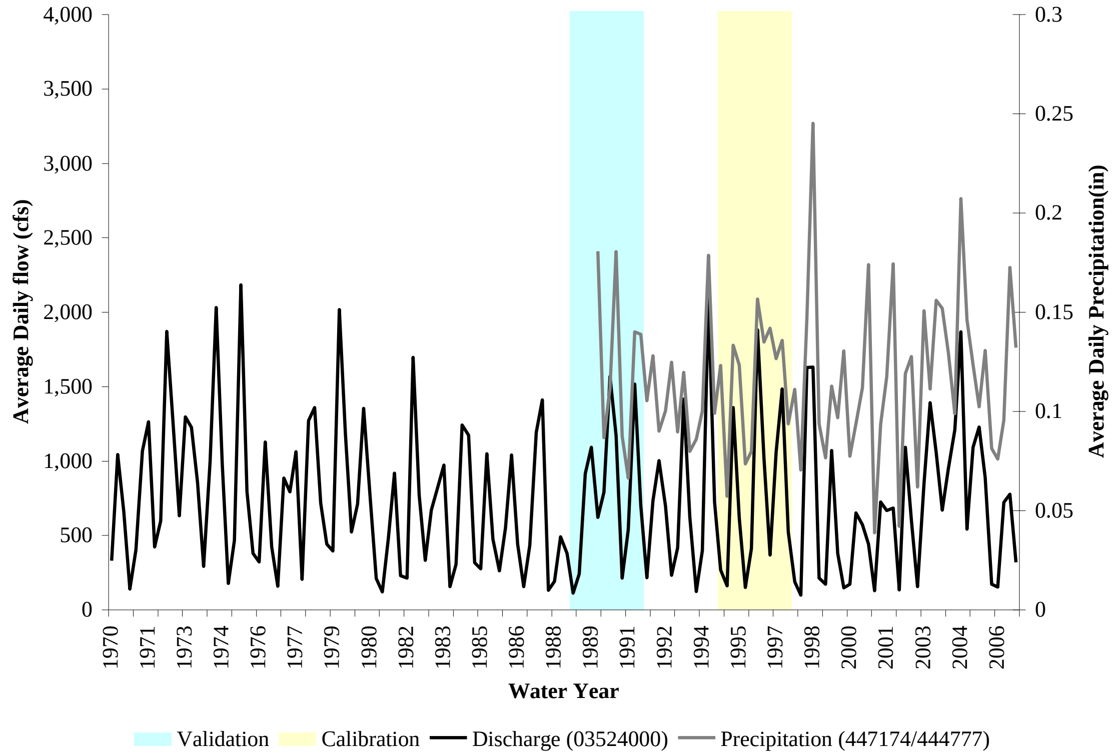

Figure C.9 Modeling time periods, seasonal historical flow (USGS Station 03524000), and precipitation (Station 447174/444777) data.

Table C.7 Comparison of modeled period to historical records for the Clinch River.

	Discharge (03524000)				**Precipitation (447174/444777)**			
	Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**
	Historical Record (1970 - 2010)				**Historical Record (1970 - 2010)**			
Mean	506	1,246	850	287	0.090	0.116	0.135	0.120
Variance	118,786	198,331	117,987	28,381	0.001	0.001	0.002	0.001
	Calibration and Validation Time Periods (10/94-9/97; 10/88-9/91)				**Calibration and Validation Time Periods (10/94-9/97; 10/88-9/91)**			
Mean	533	1,453	852	292	0.083	0.135	0.134	0.117
Variance	116,161	99,681	74,660	31,620	0.001	0.0003	0.001	0.002
	p-values				**p-values**			
Mean	0.429	0.083	0.494	0.478	0318	0.027	0.490	0.416
Variance	0.556	0.228	0.324	0.369	0.437	0.158	0.306	0.307

Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.,* animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.,* population). Depending on the timeframe of the simulation being run, different estimates were used. Data were obtained for the appropriate timeframe for water quality calibration and validation. Data representing 2010 were used for the allocation runs in order to represent current conditions.

Fifty five (55) point sources are permitted to discharge water into surface waters in the Upper Clinch River Watershed study area through the Virginia Pollutant Discharge Elimination System (VPDES) (Tables 3.1 and 3.2). Section 3.2 discusses these permits in more detail. Fifty four (54) of these VPDES permits are permitted for fecal bacteria control. Fifty one (51) of the VPDES permits are domestic or single family home permits that discharge less than 1,000 gallons per day. For calibration and validation condition runs, recorded flow and fecal bacteria concentration or Total Residual Chlorine (TRC) levels documented by the VADEQ were used as the input for each permit. The TRC data was related to fecal bacteria concentrations using a regression analysis. Table C.7 shows the minimum and maximum discharge rate in million gallons per day (MGD) and the minimum and maximum fecal coliform bacteria concentration in colony forming units per 100 milliliters (cfu/100mL). These values are the sums of all the data for each outfall.

The design flow capacity was used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu per 100 ml to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels. The design flow rates and fecal coliform bacteria concentrations are shown in Table C.7.

Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

Table C.8 Flow rates and bacteria loads used to model VADEQ active permits in the Upper Clinch River Watershed study area.

		Calibration/Validation				Allocation	
		Flow Rate (MGD)		Bacteria Concentration (cfu/100mL)		Flow Rate (MGD)	Bacteria Concentration (cfu/100mL)
VADEQ Permit Number	Facility Name	Min	Max	Min	Max	Design Flow	Fecal Coliform Geometric Mean Standard
VA0021199	Richlands Regional WWTF	1.122	4.413	1.0	27.0	4.00	200
VA0026298	Tazewell WWTP	0.479	2.5	0.0	111.0	2.0	200
VA0065676	Glenrae II Mobile Home Park STP	0.003	0.007	0.0	0.0	0.01	200
VAG*****	Each of 51 domestic Waste Treatment Plants	0.001	0.001	200	200	0.001	200

The number of septic systems in the Upper Clinch River Watershed study area was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the subwatersheds. During allocation runs, the number of households was projected to 2010, based on current growth rates (USCB, 2000) resulting in 3,873 septic systems and 384 straight pipes (Table C.8).

Table C.9 Estimated failing septic systems and straight pipes for 2010 in the Upper Clinch River Watershed study area.

Subwatershed	Septic Systems	Failing Septic Systems	Straight Pipes
1	206	42	61
2	551	130	82
3	1,038	147	35
4	229	49	11
5	1,517	362	112
6	67	27	6
8	91	37	22
9	174	70	55
Total	**3,873**	**864**	**384**

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of the TMDLs for the Upper Clinch River Watershed study area. Total septic systems in each category were calculated using U.S. Census Bureau block demographics. The applicable failure rate was multiplied by each total and summed to get the total failing septic systems per subwatershed. The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors to account for more frequent failures during wet months.

Straight pipes were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category “other means” were assumed to be disposing sewage via straight pipes. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. The loadings from straight pipes were modeled in the same manner as direct discharges to the stream.

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The amount of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Different livestock populations were estimated for each water quality modeling period (calibration/validation/allocation). The numbers are based on data provided by Virginia Agricultural Statistics (VASS), with values updated and discussed by VADCR, NRCS and SWCDs as well as taking into account growth rates in these counties as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1997; VASS, 2002). For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.7). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the study entitled "Modeling Cattle Stream Access" conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR. The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horse, sheep, goats) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land was area-weighted.

The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in "stream access" areas was calculated based on the "Modeling Cattle Stream Access" study. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 30% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

Investigation of VADEQ data indicated that biosolids applications have not occurred within the Upper Clinch River Watershed study area during the modeling periods.

For each species of wildlife, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.5). An example of one of these layers is shown in Figure C.10. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the wasteload, fecal coliform densities, and number of animals for each species.

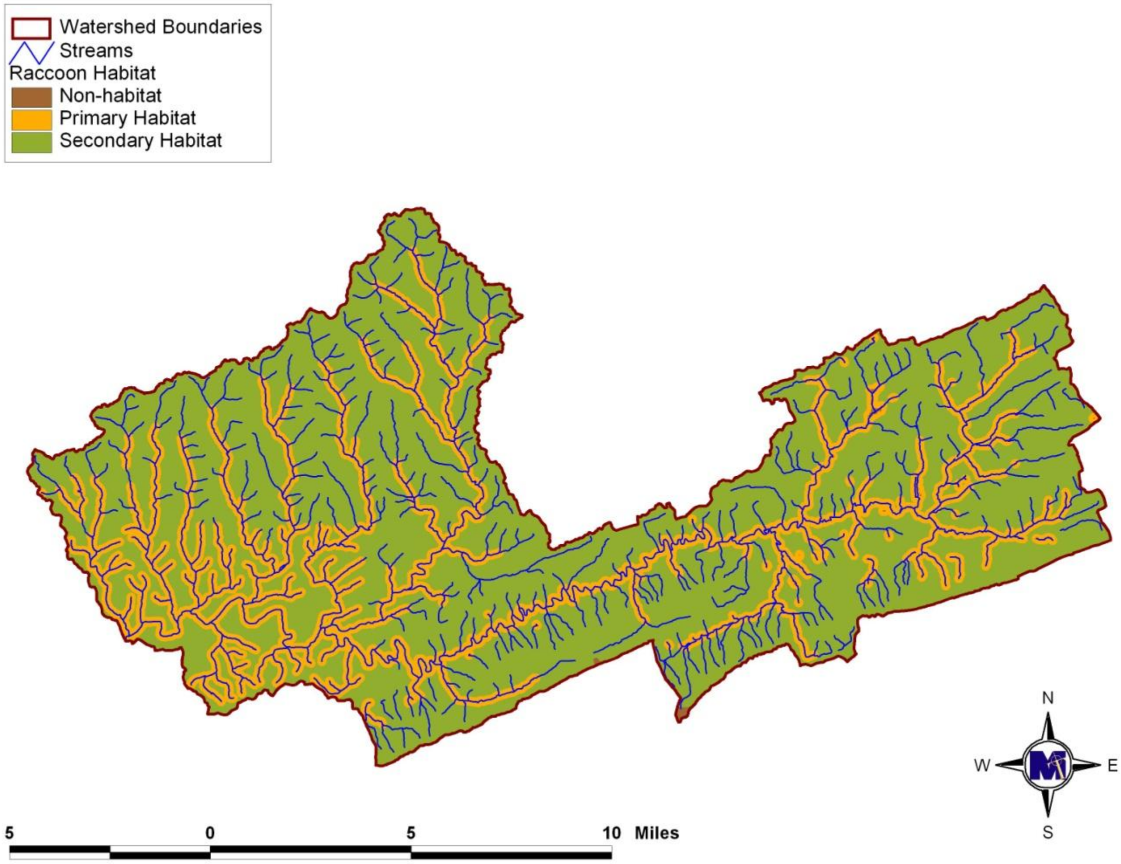

Figure C.10 Example of raccoon habitat layer in the Upper Clinch River Watershed study area, as developed by MapTech.

For each species, a portion of the total wasteload was considered land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.13). It was estimated that, for all animals other than beaver, 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams.

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), wasteload, and fecal coliform density are reported in Section 3.2.3. Waste from pets was distributed on residential land uses. The number of households per subwatershed was taken from the 2000 Census (USCB, 1990 and USCB, 2000). The number of animals per subwatershed was determined by multiplying the number of households by the pet population density. The amount of fecal coliform deposited daily by pets in each subwatershed was calculated by multiplying the wasteload, fecal coliform density, and number of animals for both cats and dogs. The wasteload was assumed not to vary seasonally. The populations of cats and dogs were projected from 2000 data to 2010.

Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

The model was calibrated for hydrologic accuracy using daily flow data for the period October 1994 through September 1997. The daily stream flow used was a regression output between the Clinch River at Cleveland (USGS Gaging Station #03524000, October 1920 to the present) and the Clinch River at Richlands (USGS Gaging Station #03521500, October 1945 to September 1989). The R^2 value for the regression between the two flow gages was 94.23%. The modeled output from subwatershed 2 was compared against the regressed flow data for the Richlands USGS Gaging Station.

HSPF parameters that were adjusted during the hydrologic calibration represented: the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the length of overland flow (LSUR), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), the amount of soil water contributing to interflow (INTFW), deep groundwater inflow fraction (DEEPER), baseflow PET (BASETP), groundwater recession flow (KVARY), and active groundwater storage PET (AGWETP). Table C.9 contains the possible range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions.

Table C.10 Initial hydrologic parameters estimated for the Clinch River TMDL study area, and resulting final values after calibration.

Parameter	Units	Possible Range of Parameter Value	Initial Parameter Estimate	Final Calibrated Parameter Value
LZSN	in	2.0 – 15.0	18.95 - 20	15
INFILT	in/hr	0.001 – 0.50	0.1 – 0.2021	0.07 – 0.1415
KVARY	1/in	0.0 – 5.0	1.5	1.25
AGWRC	1/day	0.85 – 0.999	0.955	0.996
DEEPFR	---	0.0 – 0.50	0.01 – 0.0	0.41
BASETP	---	0.0 – 0.20	0 – 0.01	0.05
AGWETP	---	0.0 – 0.20	0 – 0.01	0 – 0.01
INTFW	---	1.0 – 10.0	1.0	5
IRC	1/day	0.30 – 0.85	0.6	0.6
MON-INTERCEPT	in	0.01 – 0.40	0 – 0.2	0 – 0.4
MON-UZSN	in	0.05 – 2.0	1.89 – 2	0.39 – 2
MON-LZETP	---	0.1 – 0.9	0 – 0.8	0 – 0.9

Table C.10 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating the model was well calibrated. Figures C.11 and C.12 graphically show these comparisons.

Table C.11 Hydrology calibration model performance from 10/1/1994 through 9/30/1997 at USGS Gaging Station #03521500 on the Clinch River (subwatershed 2).

Criterion	Observed	Modeled	Error
Total In-stream Flow:	517.13	470.98	-8.92%
Upper 10% Flow Values:	235.49	242.41	2.94%
Lower 50% Flow Values:	55.54	55.42	-0.21%
Winter Flow Volume	273.01	224.18	-17.89%
Spring Flow Volume	131.42	115.16	-12.38%
Summer Flow Volume	39.98	46.88	17.25%
Fall Flow Volume	72.72	84.77	16.56%
Total Storm Volume	473.25	433.55	-8.39%
Winter Storm Volume	262.13	214.89	-18.02%
Spring Storm Volume	120.45	105.79	-12.17%
Summer Storm Volume	29.03	37.58	29.43%
Fall Storm Volume	61.64	75.30	22.15%

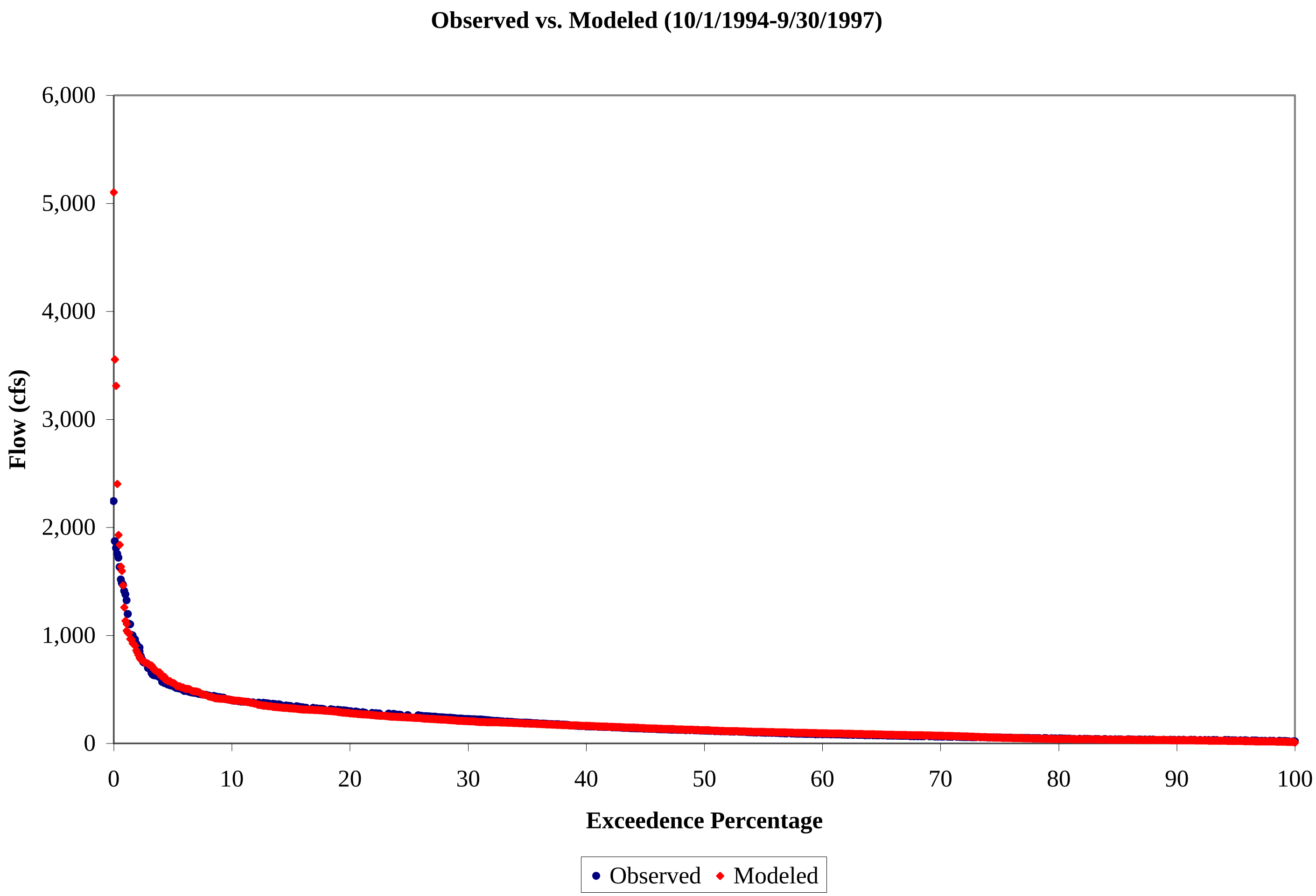

Figure C.11 Clinch River modeled flow duration versus USGS Gaging Station #03521500 data from 10/1/1994 to 9/30/1997 (subwatershed 2).

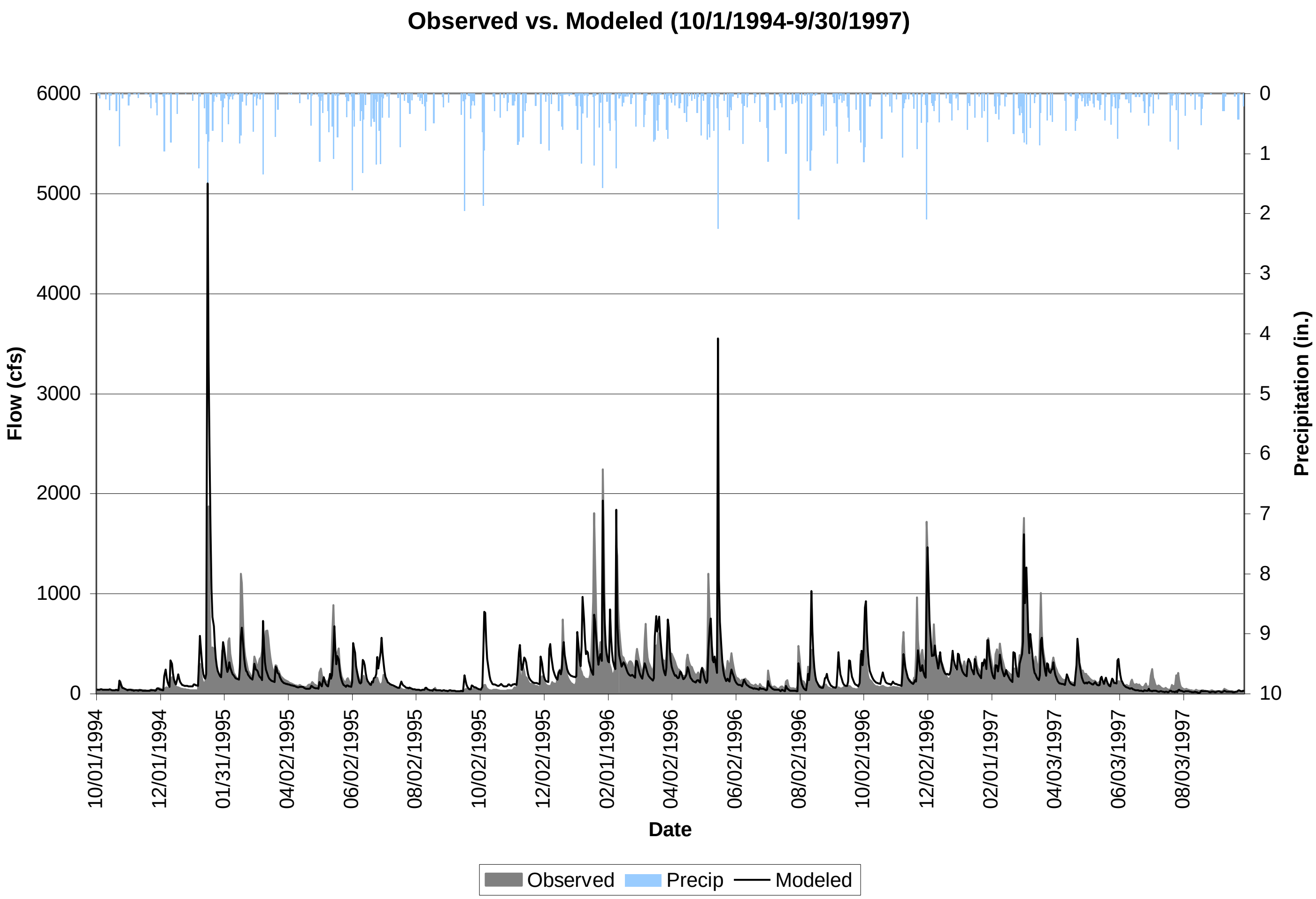

Figure C.12 Clinch River modeled results versus USGS Gaging Station #03521500 data from 10/1/1994 to 9/30/1997 (subwatershed 2).

The modeled output was validated for the period of 10/1988 to 9/30/1991. Simulated flow at subwatershed 2 was compared with daily flow at the Clinch River USGS Gaging Station #03521500. Table C.11 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating the model was well calibrated and has been validated during a different time period. Figures C.13 and C.14 graphically show these comparisons.

Table C.12 Hydrology validation model performance from 10/1/1988 through 9/30/1991 at USGS Gaging Station #03521500 on the Clinch River (subwatershed 2).

Criterion	Observed	Modeled	Error
Total In-stream Flow:	52.94	49.30	-6.87%
Upper 10% Flow Values:	18.78	18.73	-0.29%
Lower 50% Flow Values:	9.23	8.88	-3.79%
Winter Flow Volume	21.31	18.25	-14.39%
Spring Flow Volume	16.83	12.38	-26.44%
Summer Flow Volume	5.99	7.52	25.66%
Fall Flow Volume	8.80	11.15	26.63%
Total Storm Volume	45.49	42.48	-6.62%
Winter Storm Volume	19.47	16.56	-14.95%
Spring Storm Volume	14.96	10.67	-28.67%
Summer Storm Volume	4.10	5.82	41.96%
Fall Storm Volume	6.96	9.43	35.52%

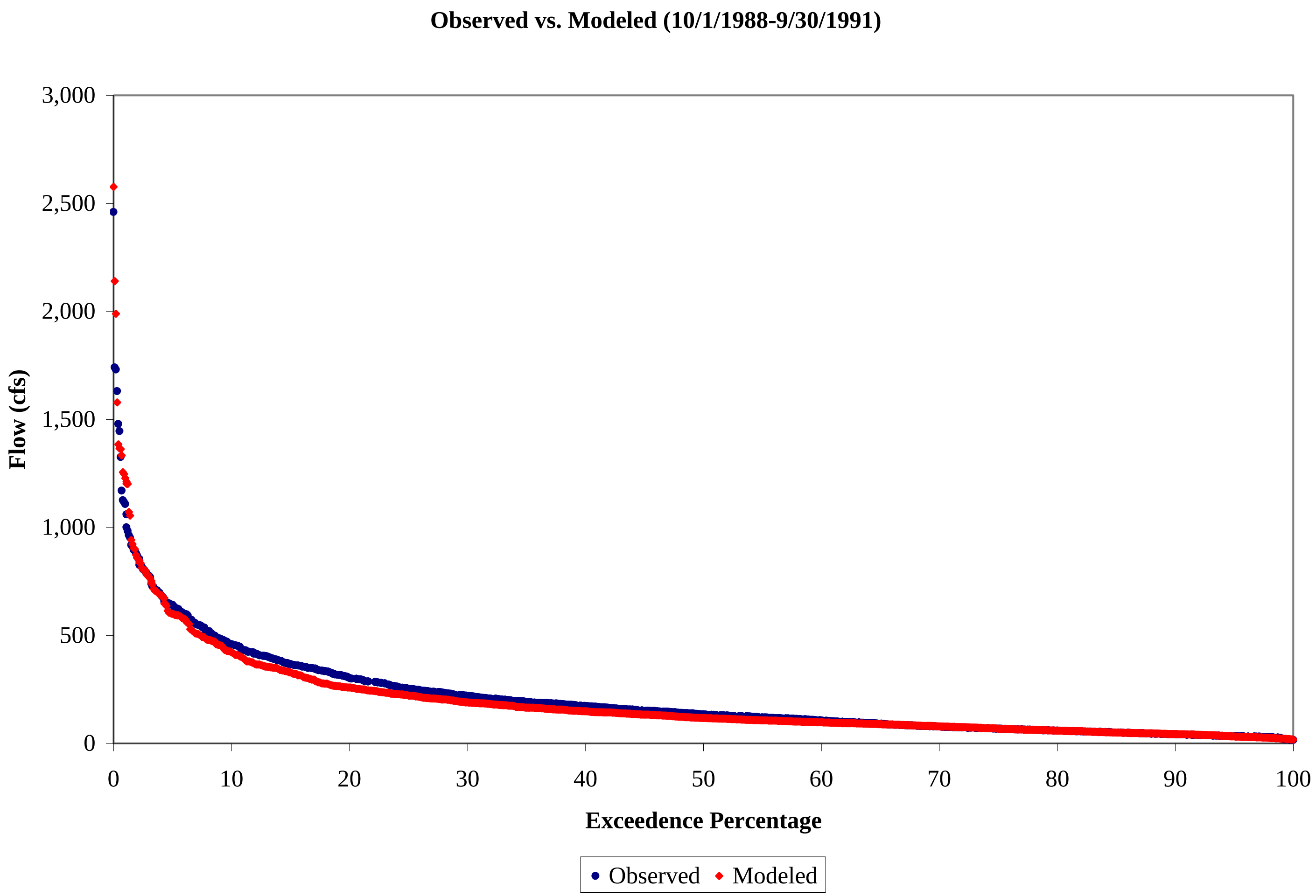

Figure C.13 Clinch River modeled flow duration versus USGS Gaging Station #03521500 data for validation (subwatershed 2).

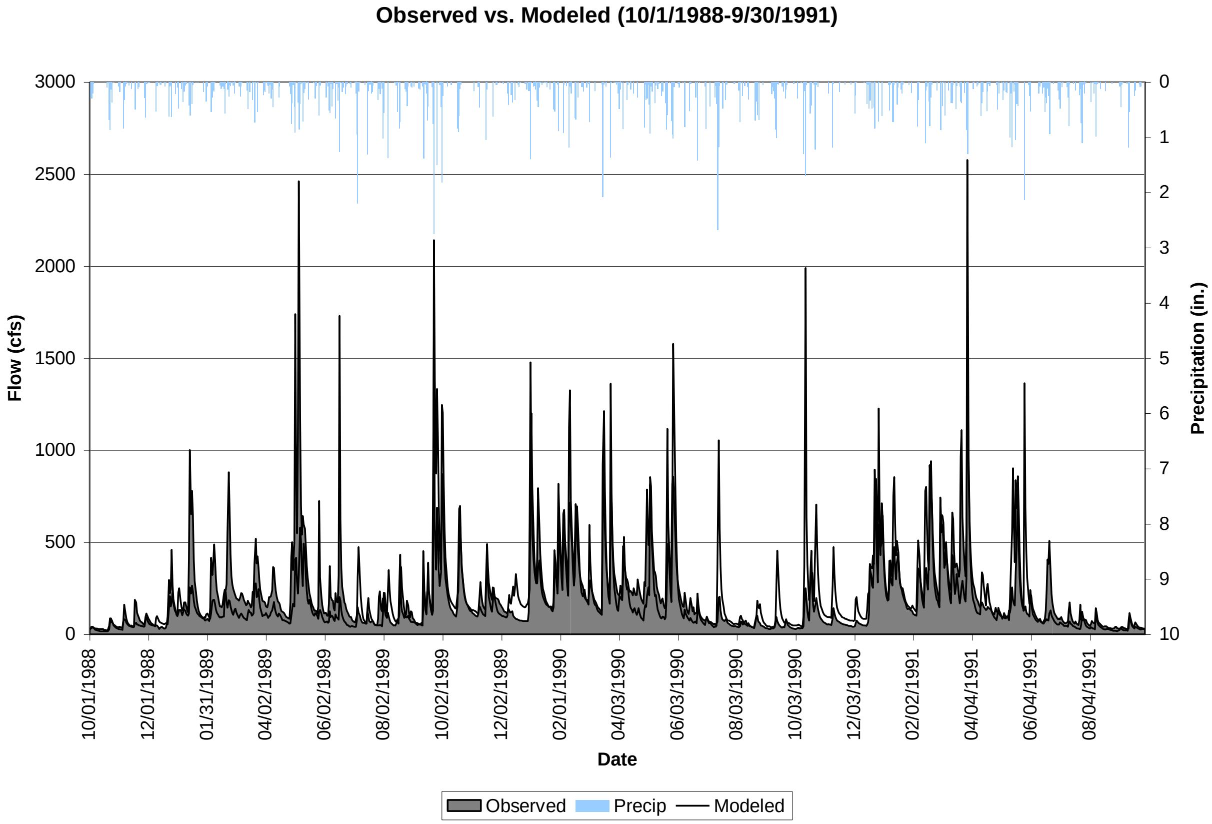

Figure C.14 Clinch River validation modeled results versus USGS Gaging Station #03521500 data from (subwatershed 2).

Water quality calibration is complicated by a number of factors; first, water quality (*E. coli*) concentrations are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters. Second, the concentration of *E. coli* is particularly variable. Variability in location and timing of fecal deposition, variability in the density of bacteria in feces (among species and for an individual animal), environmental impacts on re-growth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling *E. coli* concentrations. Additionally, the VADEQ data were censored at specific high and low values (e.g. 8,000 cfu/100ml or 16,000 cfu/100ml as highs or 100 cfu/100ml as low value). Limited amount of measured data for use in calibration and the practice of censoring both high and low concentrations impede the calibration process.

Four parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), monthly maximum accumulation on land (MON-SQOLIM), the rate of surface runoff that will remove 90% of stored fecal bacteria per hour (WSQOP), and the temperature correction coefficient for first-order decay of quality (THFST). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled bacteria concentrations was established. Depending on the type of available bacteria data, either fecal coliform or *E. coli* monitored data were used. Table C.12 shows the model parameters utilized in calibration with their typical ranges, initial estimates, and final calibrated values. Table C.13 shows the time period, the subwatershed which the station is located, and bacteria type used for each monitoring station used in the calibration.

Table C.13 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range	Initial Parameter Estimate	Calibrated Parameter Value
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0.0 – 5.8E+12	0.0 – 5.8E+12
WSQOP	in/hr	0.05 – 3.00	0.0 – 2.80	0 – 3
FSTDEC	1/day	0.01 – 10.00	1.0	10
THFST	none	1.0 – 2.0	1.07	1.0

Table C.14 Bacteria calibration periods, subwatersheds containing stations, and type of bacteria used in the Upper Clinch River Watershed study area.

Stream	Calibration Period	Subwatershed	Type of Bacteria Used
6BCLN315.11	10/1/1998 – 9/30/2001	1	Fecal Coliform
6BCLN339.53	10/1/1998 – 9/30/2001	4	Fecal Coliform

Figures C.15 and C.16 show the results of water quality calibration. Monitored values are an instantaneous snapshot of the bacteria level, whereas the modeled values are daily averages based on hourly modeling. The monitored values may have been sampled at the highest concentration of the day and thus correctly appear above the modeled daily average. Although the range of modeled daily average values may not reach every instantaneous monitored value, the modeled data follows the trend of monitored data, and typically includes the monitored extremes.

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. Table C.14 shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the Upper Clinch River stream segments.

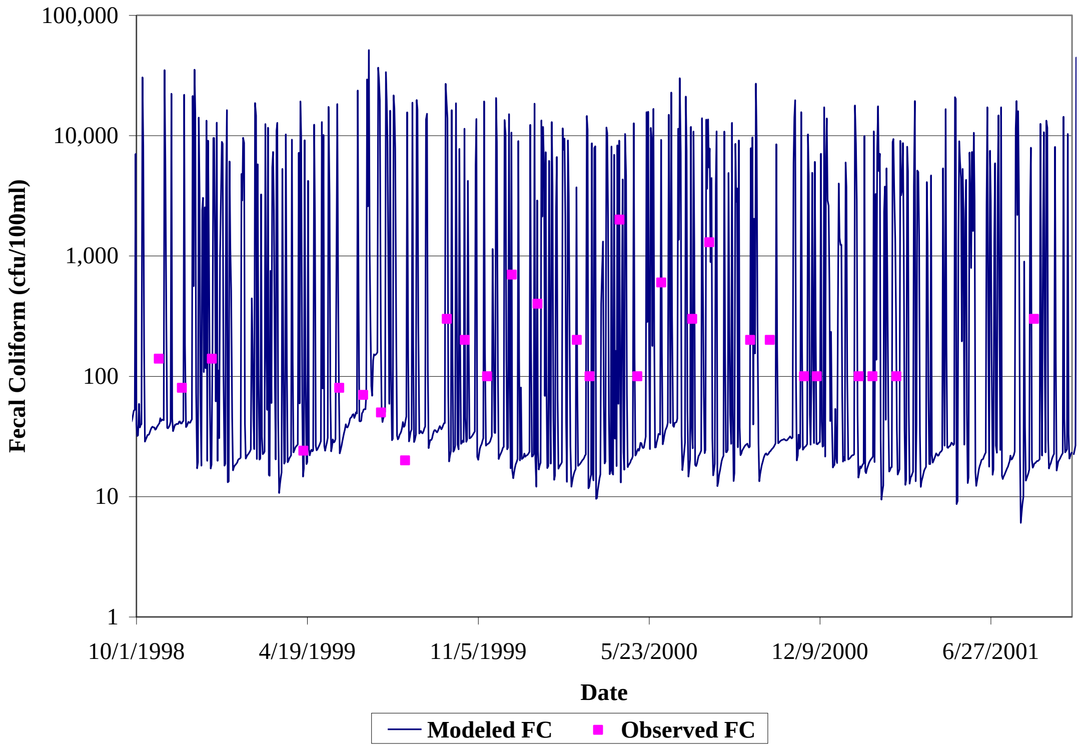

Figure C.15 Fecal coliform calibration for 10/1/1998 to 9/30/2001 for VADEQ station 6BCLN315.11 in subwatershed 1 on the Clinch River.

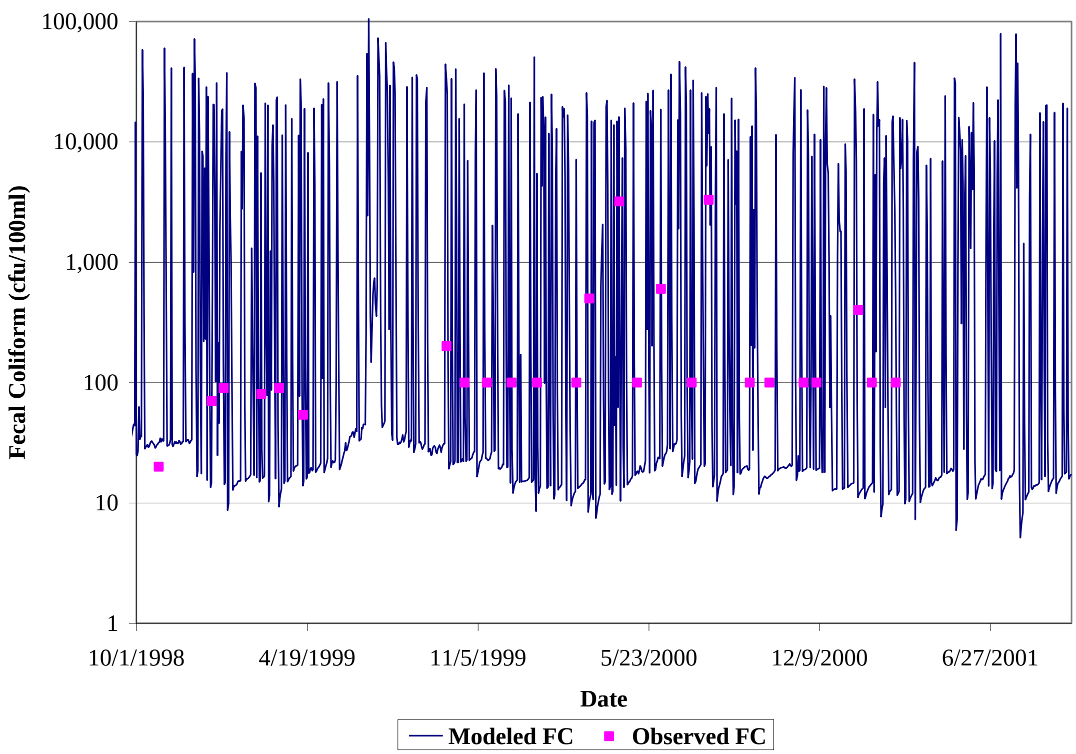

Figure C.16 Fecal coliform calibration for 10/1/1998 to 9/30/2001 for VADEQ station 6BCLN339.53 in subwatershed 4 on the Clinch River.

Table C.15 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the calibration period.

Station	Subwatershed	Maximum Value (cfu/100ml)		Geometric Mean (cfu/100ml)		SS % violations [1]	
		Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
6BCLN315.11	1	2,000	51,466.46	158.48	122.54	16.13	26.19
6BCLN339.53	4	3,300	105,114.80	146.65	131.03	17.24	27.46

[1] SS = single sample instantaneous standard violations (>400 cfu/100mL for fecal coliform)

Bacteria water quality model validation was performed on stations shown in Table C.15. Figures C.17 and C.18 show the results of water quality validation. Table C.16 shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the Upper Clinch River stream segments.

Table C.16 Bacteria validation periods, subwatersheds containing stations, and type of bacteria used in the Upper Clinch River Watershed study area.

Stream	Calibration Period	Subwatershed	Type of Bacteria Used
6BCLN315.11	10/1/1995 – 9/30/1998	1	Fecal coliform
6BCLN339.53	10/1/1995 – 9/30/1998	4	Fecal coliform

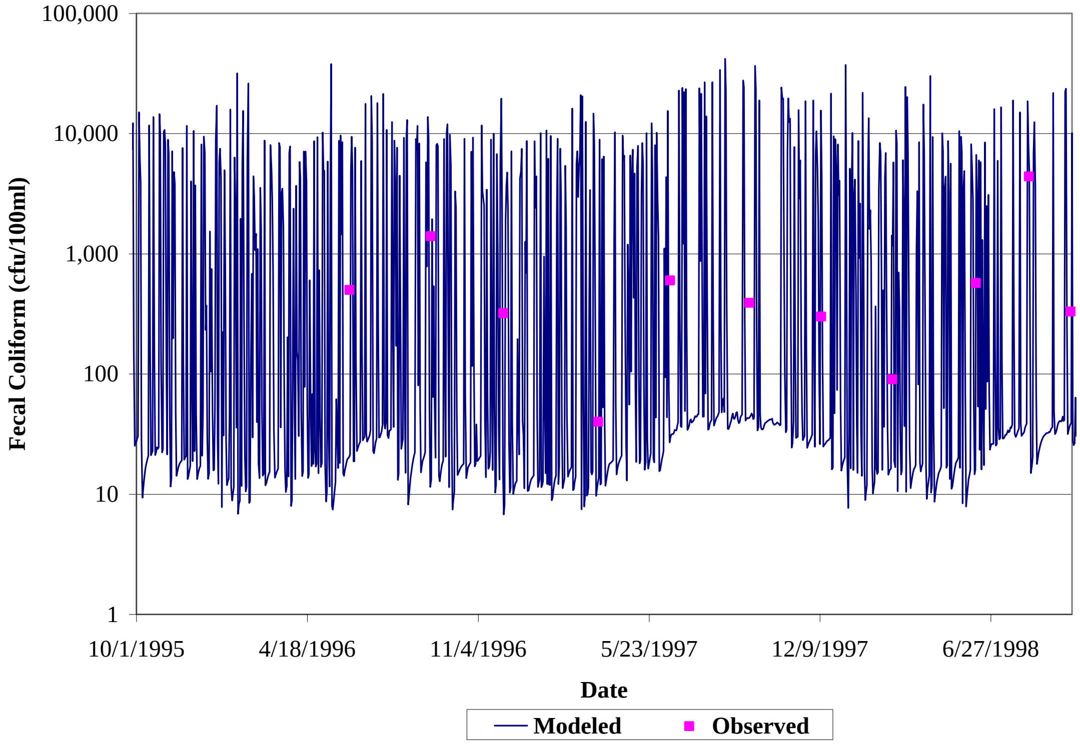

Figure C.17 *E. coli* validation for 10/1/1995 to 9/30/1998 for VADEQ station 6BCLN315.11 in subwatershed 1 on the Clinch River.

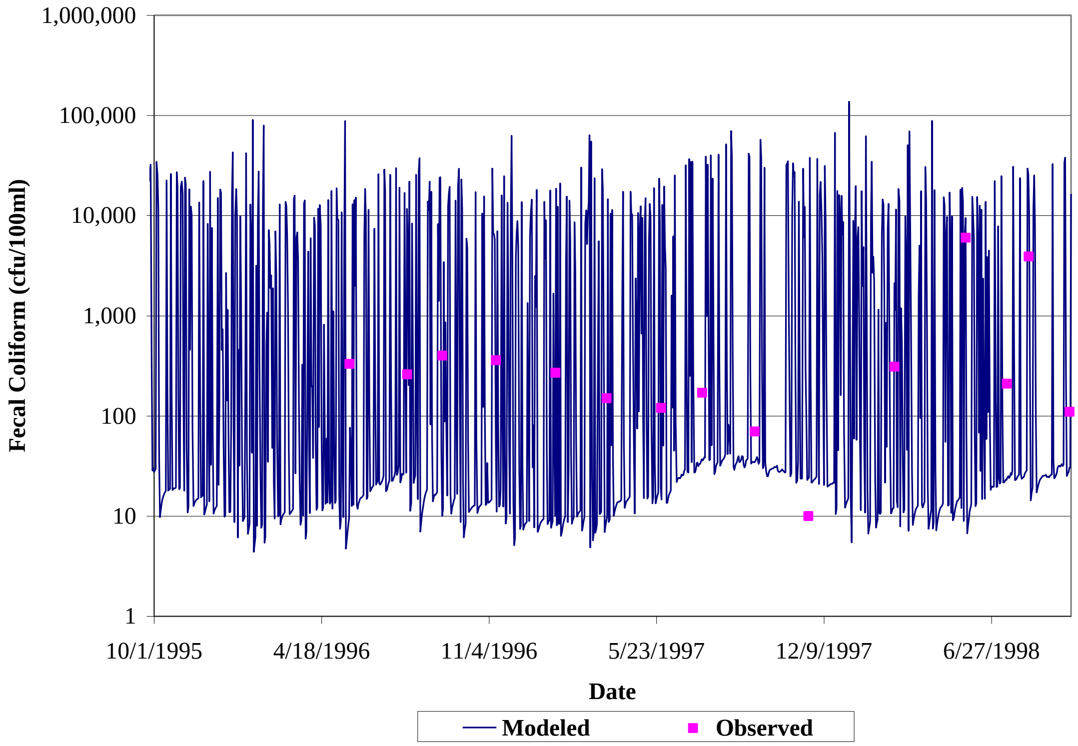

Figure C.18 Fecal coliform validation for 10/1/1995 to 9/30/1998 for VADEQ station 6BCLN339.53 in subwatershed 4 on the Clinch River.

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

Station	Subwatershed	Maximum Value (cfu/100ml)		SS % violations [1]		Geometric Mean (cfu/100ml)	
		Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
6BCLN315.11	1	4,400	41,879.22	45.45	30.66	404.05	137.67
6BCLN339.53	4	6,000	137,363.90	20.00	31.57	254.22	153.47

[1] SS = single sample instantaneous standard violations (>400 cfu/100mL for fecal coliform)