Draft

Fecal Bacteria
Total Maximum Daily Load Development
For Beaver Creek
in Campbell County, Virginia

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EXECUTIVE SUMMARY

Background and Applicable Standards

Beaver Creek was initially listed in 2004 for violations of the fecal bacteria standard. Elevated levels of fecal coliform bacteria recorded at VADEQ ambient water quality monitoring stations showed that the Beaver Creek stream segments do not support the primary contact recreation use. This study area combines rural and residential land uses, with potential bacteria sources from pets, livestock, wildlife and humans.

TMDL Endpoint and Water Quality Assessment

Potential sources of fecal bacteria include both point source and nonpoint source (NPS) contributions. Nonpoint sources include: wildlife, grazing livestock, land application of manure, urban/residential runoff, failed and malfunctioning septic systems, permitted waste treatment facilities, illicit cross-connections of residential wastes to the stormwater collection system, leaking sewer lines, and uncontrolled discharges (straight pipes). There is currently one active VPDES permited point source in the watershed that is permitted for bacterial discharge. This discharge is expected to meet the 126-cfu/100 mL *E. coli* standard. 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.

Modeling Procedures

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 in the riverine segments.

For purposes of modeling the Beaver Creek study area, inputs to streamflow and in-stream fecal bacteria, the drainage area was divided into 9 subwatersheds.

Hydrologic calibration was conducted during the development of Total Maximum Daily Loads (TMDL) for the James River Study Area (VADEQ, 2007). The watershed was calibrated for hydrologic accuracy using daily flow data from USGS Gaging Station 02026000 on the James River for the period October 1995 through September 1999. The changes made to the hydrologic parameters in the James River Study Area were the same percent changes made to the same hydrologic parameters in the Beaver Creek TMDL project.

For the purpose of validating the hydrologic model of Beaver Creek, the model was simulated from 10/1/1999 to 9/30/2004. The modeled output from the Beaver Creek watershed was compared against the James River USGS Gaging Station 02026000 data.

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 nonpoint sources of uncontrolled discharges, direct deposition by wildlife, direct deposition by livestock. Contributions from all of these sources were updated to current conditions to establish existing conditions for the watershed.

The fecal bacteria calibration was conducted using monitored data collected at VADEQ monitoring stations. For HSPF, a water quality calibration period of 10/1/1994 through 9/30/1999 was used in the model; the validation period was 10/1/1999 to 9/30/2004.

Load Allocation Scenarios

The next step in the bacteria TMDL process was to reduce the various source loads to levels that would result in attainment of the water quality standard. Because Virginia's *E. coli* standard does not permit any exceedances of the standard, modeling was conducted for a target value of 0% exceedance of the geometric mean standard. 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.1. The final reductions scenarios are shown in Table ES.2.

Table ES.1 Average annual *E. coli* loads (cfu/year) modeled after allocation in Beaver Creek.

Impairment	WLA	LA	MOS	TMDL
Beaver Creek	**3.26E+11**	**2.97E+13**	*Implicit*	**3.00E+13**
VA0062031	*2.61E+10*			
Future Load	*3.00E+11*			

Table ES.2 Final load allocation scenario for the Beaver Creek impairments (percent reductions to existing bacteria loads).

Stream	Wildlife Direct	Barren, Forest, Wetlands	Livestock Direct	Cropland, Pasture	Straight Pipes	LID, MID
Beaver Creek	0	0	99	99	100	64

LID, MID - Human and Pet Land Based reduction

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standard. The first step in this process is to develop a TMDL that will result in meeting the water quality standard. This report represents the culmination of that effort for the impairments in the Beaver Creek study area. The second step is to develop a TMDL implementation plan (IP). The final step is to implement the TMDL IP and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act (CWA) and current United States Environmental Protection Agency (EPA) regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. 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. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate waterbody. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource.

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, to address the bacteria TMDL, reducing the human bacteria loading from straight pipes and failing septic systems should be a primary implementation focus because of the health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system installation/repair program. Livestock exclusion from streams has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the direct cattle deposits and by providing additional riparian buffers. Reduced trampling and soil shear on streambanks by livestock has been shown to reduce bank erosion.

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 the Environmental Protection Agency (EPA) will be able to provide comment during this process.

Public Participation

Public participation during TMDL development for the Beaver Creek area was encouraged; a summary of the meetings is presented in Table 7.1. The first public meeting was held on December 3, 2009 in Rustburg, Virginia and twelve people attended. The attendees represented state and federal agencies and MapTech. The final public meeting was held in Lynchburg, Virginia on March 23, 2010.

1. INTRODUCTION

1.1 Background

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

When streams fail to meet standards, 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.

The study area for this project is Beaver Creek located in Campbell County. The Virginia Department of Environmental Quality (VADEQ) has identified a segment of Beaver Creek as impaired with regard to fecal bacteria. For the purposes of this report, this watershed shall be referred to as the Beaver Creek study area. Figure 1.1 shows the location of the Beaver Creek study area watershed.

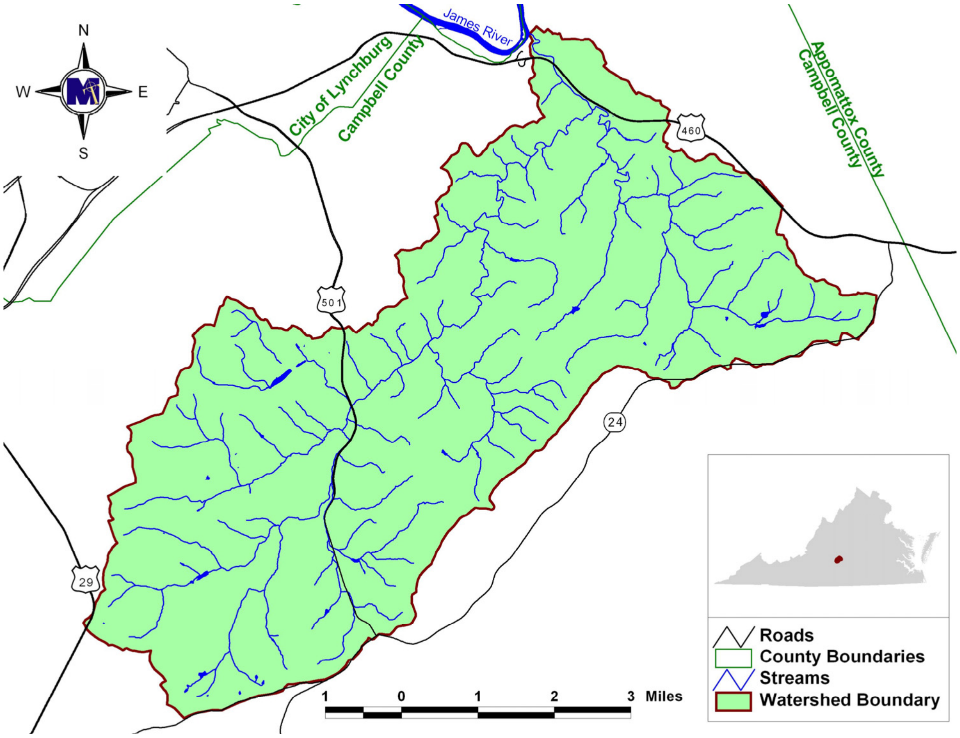

Figure 1.1 Location of the Beaver Creek study area watershed.

Beaver Creek (VAC-H05R-BCR01A00) was initially listed in 2004 for exceeding the fecal bacteria standard, in 4 out of 24 samples at listing station 2-BCR000.20. Beaver Creek is listed as impaired for 8.5 miles from an unnamed tributary at the Rt. 501 bridge, to it's mouth on the James River. Figure 1.2 shows the current impaired segment.

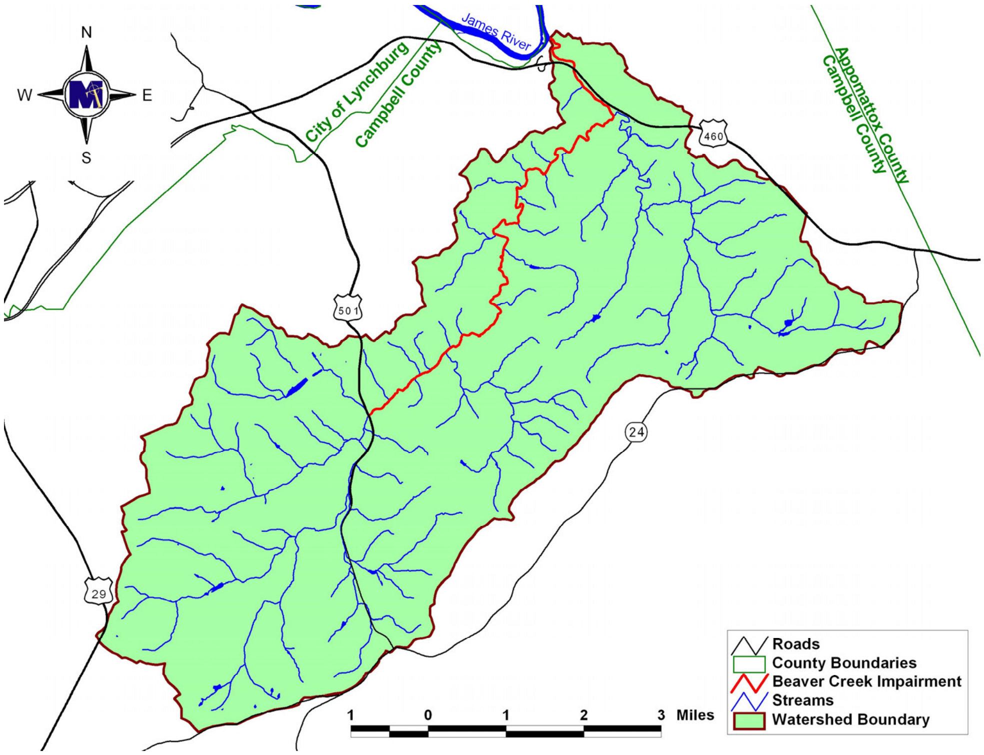

Figure 1.2 Impaired stream segment in the Beaver Creek study area.

1.2 Beaver Creek Watershed Characteristics

The Beaver Creek watershed lies entirely within the level III Piedmont ecoregion (45). The level IV subset is the Northern Inner Piedmont (45e). The Northern Inner Piedmont ecoregion is an irregular plain with low rounded ridges and shallow ravines; ranges of low hills are scattered across this ecoregion but monadnocks are much rarer than in the Inner Piedmont ecoregion. An area of rapids, cascades, waterfalls, and islands (the Fall Zone) occurs along the eastern boundary of this ecoregion and contains urban and industrial areas. Elevations range from 200 to 675 feet (61-206 m) and relief varies from 100-250 feet (30-76 m); maximum relief and elevation are less than in the Northern Inner Piedmont to the west and greater than in the Middle Atlantic Coastal Plain to the east.

The Northern Outer Piedmont is underlain mostly by deformed, deeply weathered gneissic rock that is intruded by plutons and veneered with saprolite; it is lithologically distinct from the Carolina Slate Belt and the sedimentary rock of the Southeastern Plains and Triassic Uplands. Ultisols are common and have developed from residuum; they are commonly clay-rich, acid, and relatively low in base saturation. Soils have a thermic temperature regime and contrast with the mesic soils found in higher portions of the Northern Inner Piedmont.

Channel gradients generally reflect the surrounding terrain and considerably affect fish habitat in the Piedmont. In this ecoregion (outside of the Fall Zone) channel gradients and flow velocities are usually in between those of the sluggish streams of the Middle Atlantic Coastal Plain; stream flow velocity tends to be moderately slow, both runs and riffles are short and infrequent, and substrates are chiefly composed of sand, silt, clay, and detritus. In the Fall Zone, this ecoregion has a variety of aquatic habitats including pools, swampy streams, rapids, cascades, and waterfalls; here rapids are more common and better developed than in the adjacent portions of this ecoregion and the Rolling Coastal Plain. Some cascades and waterfalls can deter or prevent upstream fish movement especially during low water.

Potential natural vegetation is mapped as Oak-Hickory-Pine Forest. Dominants include hickory (*Carya spp.*), shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), white oak (*Quercus alba*) and post oak (*Quercus stellata*). Marshes and wetlands are not as common as in the Middle Atlantic Coastal Plain.

Today, forestry and agricultural activity dominate most of the ecoregion. "Good" timber production areas are less common in the Outer Piedmont than in the Inner Piedmont. Shortleaf, loblolly, and Virginia pine woodlands are common in old fields. Pastures are common. Chestnut oak (Quercus prinus) is less common in the Northern Outer Piedmont than on the gently sloping uplands of the Northern Inner Piedmont; it is regarded as an outlier from farther west. Livestock, poultry, and dairy farms occur and corn, oats, rye, tobacco, and hay are grown.

The boundary between this ecoregion and the Rolling Coastal Plain occurs at the Fall Line. The Line roughly separates uplands with moderately slow streams from much flatter lowland with sluggish streams; it also roughly divides hard metamorphic rocks from younger, less resistant sedimentary rocks that interfinger with them. The Outer Piedmont and the Northern Inner Piedmont were separated using topographic, soil temperature, and geologic rationale. The line between them is transitional and roughly divides more rugged terrain from less rugged; it also approximates the eastern limit of monadnocks, the foresters' line for natural regeneration of loblolly pine (Pinus taeda), the Tallapoosa-Rappahannock lithofacies line, and the broad transitional, boundary between mesic and thermic soils. The boundary between this ecoregion and the Carolina Slate Belt is near the mapped limit of both the Carolina Slate Belt and the Georgeville-Herndon soil association and follows the innermost of these two lines. (http://www.eoearth.org/article/Ecoregions_of_Delaware%2C_Maryland%2C_Pennsylvania%2C_Virginia%2C_and_West_Virginia_(EPA).

As for the climatic conditions in the Beaver Creek watershed, during the period from 1930 to 2009 Lynchburg WSO Airport, Virginia (NCDC station# 445120) received an average annual total precipitation of approximately 40.82 inches, with 54% of the precipitation falling during the May through October growing season (SERCC, 2009). Average annual snowfall is 17.1 inches, with the highest snowfall occurring during February (SERCC, 2009). The highest average daily temperature of 86.7 ºF occurs in July, while the lowest average daily temperature of 27.3 ºF occurs in January (SERCC, 2009).

2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT 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, and it was updated in 2009. *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 (Bacteria; other recreational waters) and read as follows:

> *A. The following bacteria criteria (colony forming units (cfu)/100mL) shall apply to protect primary contact recreational uses in surface waters, except waters identified in subsection B of this section:*
>
> *E. coli bacteria shall not exceed a monthly geometric mean of 126 cfu/100mL in freshwater. Enterococci bacteria shall not exceed a monthly geometric mean of 35 cfu/100mL in transition and saltwater.*

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

B. The following bacteria criteria per 100mL (cfu/100mL) of water shall apply to protect secondary contact recreational uses in surface waters:

E. coli bacteria shall not exceed a monthly geometric mean of 630 cfu/100mL in freshwater. Enterococci bacteria shall not exceed a monthly geometric mean of 175 cfu/100mL in transition and saltwater.

1. *See 9VAC25-260-140 C for boundary delineations for freshwater, transition and saltwater.*
2. *Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples.*
3. *If there [are] insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 1,173 E. coli cfu/100mL.*
4. *If there [are] insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 519 cfu/100mL.*
5. *Where the existing water quality for bacteria is below the geometric mean criteria in a water body designated for secondary contact in subdivision 6 of this subsection that higher water quality will be maintained in accordance with 9VAC25-260-30 A 2.*

2.1 Selection of a TMDL Endpoint

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

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

2.2 Discussion of In-Stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal bacteria monitoring data in the watershed of the Beaver Creek study area. An examination of data from water quality stations used in the 303(d) assessment was performed and data collected during TMDL development were analyzed. Sources of data and pertinent results are discussed.

2.2.1 Inventory of Water Quality Monitoring Data

The source of available water quality information is from bacteria enumerations from a VADEQ in-stream monitoring station, 2-BCR000.20.

2.2.1.1 VADEQ Water Quality Monitoring for TMDL Assessment

Data from in-stream water samples, collected at a VADEQ monitoring station (Figure 2.1) from December 1988 through April 2008, were analyzed for fecal bacteria. Fecal bacteria samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting concentrations to 400 cfu/100 mL or less. As a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 mL or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) were not analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported values of 100 cfu/100 mL most likely represent concentrations below 100 cfu/100 mL, and reported concentrations of 8,000 or 16,000 cfu/100 mL most likely represent concentrations in excess of these values. *E. coli* samples were also collected to evaluate compliance with the state's current bacterial standard. Table 2.1 summarizes the fecal coliform and *E. coli* samples collected at the in-stream monitoring station.

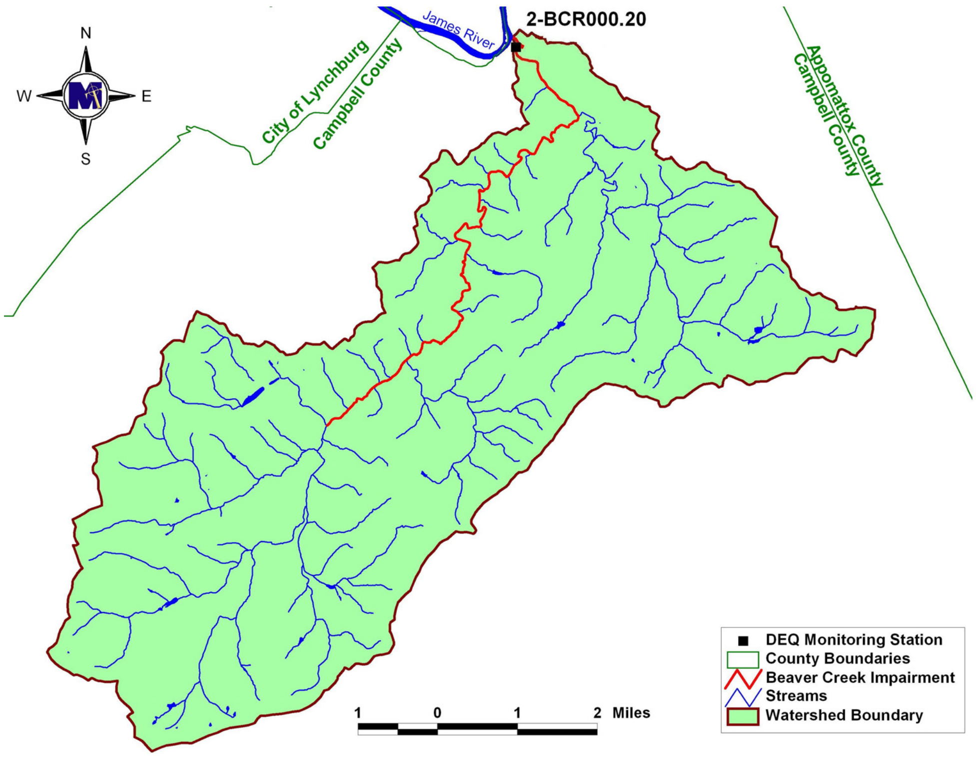

Figure 2.1 Location of VADEQ water quality monitoring station in the Beaver Creek study area.

Table 2.1 Summary of bacteria (cfu/100 mL) data collected by VADEQ from dates December 1988 – April 2008.

Stream	Station	Bacteria	Date Range	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %
Beaver Creek	2-BCR000.20	Fecal Coliform	12/88 - 6/03	61	100	8000	774	100	1773	18.0%
Beaver Creek	2-BCR000.20	E. Coli	1/07 - 4/08	20	25	1200	128	25	263	10.0%

3. SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal bacteria in the Beaver Creek 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 Chapter 4.

3.1 Watershed Characterization

The National Land Cover Database 2001 (NLCD) produced cooperatively between the U.S. Geological Survey (USGS) and U.S. Environmental Protection Agency (EPA) was utilized for this study. The collaborative effort to produce this dataset is part of a Multi-Resolution Land Characteristics (MRLC) Consortium project led by four U.S. government agencies: EPA, USGS, the Department of the Interior National Biological Service (NBS), and the National Oceanic and Atmospheric Administration (NOAA). Using 30-meter resolution Landsat 7 Thematic Mapper (TM) satellite images taken between 1999 and 2001, digital land use coverage was developed identifying up to 29 possible land use types. Classification, interpretation, and verification of the land cover dataset involved several data sources when available including: aerial photography; soils data; population and housing density data; state or regional land cover data sets; USGS land use and land cover (LUDA) data; 3-arc second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief; and National Wetlands Inventory (NWI) data. Approximate acreages and land use proportions for the Beaver Creek study area are given in Table 3.1 and shown in Figure 3.1. More details about land uses are in Section 4.2.2.

Table 3.1 Contributing land use acreage and percentage (2001) in the Beaver Creek study area.

Open Water	LMIR	Forest	Barren	Pasture/Hay	Cropland	Wetland	TOTAL
61	1,370	15,278	10	6,666	188	20	23,594
0.26%	5.81%	64.76%	0.04%	28.25%	0.80%	0.08%	100%

LMIR = Low and Medium Intensity Residential

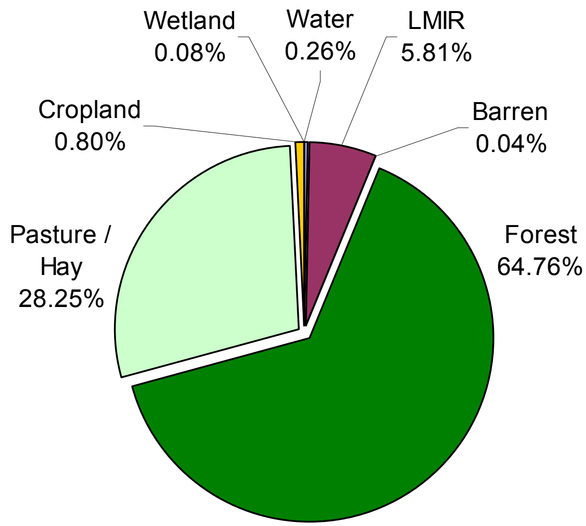

Figure 3.1 Land uses Beaver Creek watershed

3.2 Assessment of Permitted Sources

One point source, Evergreen Mobile Home Park (VA0062031), is permitted to discharge to an unnamed tributary of Tussocky Creek in the Beaver Creek study area through the Virginia Pollutant Discharge Elimination System (VPDES). This VPDES permit is permitted for fecal bacteria control (Table 3.2). Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain *E. coli* concentrations that do not exceed the 126 cfu/100mL *E. coli* standard.

There is also one Confined Animal Feeding Operation (CAFO) permit (VPG100020) in the watershed. This 500-head dairy does not have a direct discharge to a waterway but runoff from the area could contain fecal bacteria (Table 3.2).

Table 3.2 Summary of VPDES permitted facilities in the Beaver Creek study area.

VPDES Permits

Outfall Permit	Permitted for Receiving Stream(s)	Facility Name	Number(s)	Bacteria Control
VA0062031	Unnamed tributary of Tussocky Creek	Evergreen Mobile Home Park	1	Yes

CAFO Permits

Permit	Facility Name	Water Body	Type	Adjacent Stream
VPG100020	Dairy Farm	VAC-H05R	Dairy Cow(500)	Unnamed tributary of Tussocky Creek

3.3 Assessment of Nonpoint Sources

In the Beaver Creek study area, both rural residential nonpoint sources of fecal bacteria were considered. Sources include residential sewage treatment systems, direct untreated human waste, failing septic systems, land-application of livestock waste, wildlife, and pets. Sources were identified and enumerated.

3.3.1 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" 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 straight pipes.

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 coliform 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 Estimated population, housing units and residential sewage disposal methods currently in the Beaver Creek study area.

Population	Housing Units	Sanitary Sewer	Septic Systems	Other *
5,552	2,394	210	2,157	27

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

3.3.2 Biosolids

There were no biosolids applications in this watershed during the modeling time period.

3.3.3 Pets

Among pets, cats and dogs are the predominant contributors of fecal bacteria in the Beaver Creek study area and were the only pets considered in this analysis. Cat and dog populations were derived from the 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. Fecal coliform density for dogs and cats was previously measured from samples collected by MapTech. A summary of the data collected and the domestic animal populations for impairments in the Beaver Creek watershed is given in Table 3.4.

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

Source	Population Density	Total Population	Waste load	FC Density
	(an/house)	(animals)	(g/an-day)	(cfu/g)
Dog	0.534	1,360	450	480,000
Cat	0.598	1,215	19.4	9

3.3.4 Livestock

The predominant types of livestock in the Beaver Creek study area are beef cattle, dairy cattle, and horses although all types of livestock identified were considered in modeling the watershed. There is one dairy operation permitted under VADEQ's CAFO regulations. Table 3.2 gives a summary of this permitted operation in Beaver Creek study area. Table 3.5 gives a summary of livestock populations in the study area for 2009, organized by subwatershed. Animal populations were based on communication with VADEQ, Virginia Department of Conservation and Recreation (VADCR), the Natural Resources Conservation Service (NRCS) and the Robert E Lee Soil and Water Conservation District.

Table 3.5 Estimated 2009 livestock populations in the Beaver Creek study area.

Subwatershed	Beef Adult	Dairy	Calves	Sheep	Swine	Horse	Chicken
1	11	0	6	0	0	1	0
2	95	0	47	0	0	8	0
3	52	0	26	0	0	4	0
4	33	0	17	0	0	3	0
5	317	350	334	0	0	27	0
6	118	0	59	0	0	10	0
7	27	0	13	0	0	2	0
8	121	0	61	0	0	10	0
9	132	0	66	0	0	11	0
Totals	**906**	**350**	**629**	**0**	**0**	**76**	**0**

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 the American Society of Agricultural Engineers (1998). A summary of fecal coliform density values and manure production rates is presented in Table 3.6.

Table 3.6 Average fecal coliform densities and waste loads associated with livestock.

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)	Waste Storage Die-off factor
Beef stocker (850 lb)	51.0	101,000	NA
Beef calf (350 lb)	21.0	101,000	NA
Dairy milker (1,400 lb)	120.4	271,329	0.5
Dairy heifer (850 lb)	70.0	271,329	0.25
Dairy calf (350 lb)	29.0	271,329	0.5
Hog (135 lb)	11.3	400,000	0.8
Hog Lagoon	N/A	95,300[1]	NA
Horse (1,000 lb)	51.0	94,000	NA
Sheep (60 lb)	2.4	43,000	NA
Goat (140 lb)	5.7	15,000	NA
Poultry (1 lb):			
Broiler	0.17	586,000	0.5
Layer	0.26	586,000	0.5

[1]units are cfu/100ml

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 3.7 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 have drainage systems that divert wash-water and waste directly to drainage ways or streams.

Table 3.7 Average percentage of collected livestock waste applied throughout year.

Month	Applied % of Total		Land use
	Dairy	Beef	
January	2.00	4.00	Cropland
February	2.00	4.00	Cropland
March	20.00	12.00	Cropland
April	20.00	12.00	Cropland
May	5.00	12.00	Cropland
June	2.00	8.00	Pasture
July	2.00	8.00	Pasture
August	2.00	8.00	Pasture
September	21.00	12.00	Cropland
October	20.00	12.00	Cropland
November	2.00	4.00	Cropland
December	2.00	4.00	Cropland

All 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 data collected from previous projects. Beef cattle, replacement heifers, dry cows, and horses 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 Table 3.8. Table 3.9 shows the average time dairy cattle spend in pasture or confined per day, and Table 3.10 shows how the collected dairy waste applied throughout year.

Table 3.8 Average time pastured animals spend in pasture and stream access per day.

Month	Pasture (hr)	Stream Access (hr)
January	23.4	0.6
February	23.4	0.6
March	23.1	0.9
April	22.7	1.3
May	22.7	1.3
June	22.5	1.5
July	22.5	1.5
August	22.5	1.5
September	22.7	1.3
October	23.1	0.9
November	23.1	0.9
December	23.4	0.6

Table 3.9 Average time dairy cattle spend in pasture and confined per day.

Month	Pasture (hr)	Stream Access (hr)
January	7.7	16.3
February	7.7	16.3
March	8.6	15.4
April	10.1	13.9
May	10.8	13.2
June	11.3	12.7
July	11.8	12.2
August	11.8	12.2
September	11.8	12.2
October	11.8	12.2
November	10.8	13.2
December	9.4	14.6

Table 3.10 Average percentage of collected dairy waste applied throughout year.

Month	Applied % of Total	Land Use
January	1.50	Cropland
February	1.75	Cropland
March	17.00	Cropland
April	17.00	Cropland
May	17.00	Cropland
June	1.75	Pasture
July	1.75	Pasture
August	1.75	Pasture
September	5.00	Cropland
October	17.00	Cropland
November	17.00	Cropland
December	1.50	Cropland

3.3.5 Wildlife

The predominant wildlife species in the Beaver Creek watershed 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 Beaver Creek study area.

Deer (an/ac of habitat)	Turkey (an/ac of habitat)	Goose (an/ac of habitat)	Duck (an/ac of habitat)	Muskrat (an/ac of habitat)	Raccoon (an/ac of habitat)	Beaver (an/mi of stream)
0.0344	0.0091	0.0032	0.0065	0.3125	0.0703	4.8

The numbers of animals estimated to be in the Beaver Creek watershed 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 Beaver Creek study area.

Subwatershed	Deer	Turkey	Beaver	Racoon	Muskrat	Duck	Goose
1	18	4	7	38	34	1	0
2	102	26	38	209	190	4	2
3	27	7	7	56	33	1	0
4	52	12	20	106	120	3	1
5	232	57	70	475	369	8	4
6	143	36	44	294	231	5	2
7	76	19	18	157	91	2	1
8	78	19	23	160	126	3	1
9	77	19	20	159	119	2	1
Total	805	199	247	1654	1313	29	12

The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999a). 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 Type	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 performed by MapTech. The only value that was not obtained from MapTech sampling in the watershed was for beaver.

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 landuse areas
Turkey[2]	320	Primary = forested, harvested forest land, grazed woodland, orchards, wetlands, transitional land Secondary = cropland, pasture Infrequent/Seldom = remaining landuse 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)

4. 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 Beaver Creek 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. In this section, the selection of modeling tools, source assessment, selection of a representative period, calibration/validation, and model application are discussed.

4.1 Modeling Framework Selection

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

4.1.1 Modeling Free Flowing Streams

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 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. Due to the complex land uses and tributary networks of the tidal areas, HSPF is well suited for providing runoff inputs to a suitable tidal model, provided that the tidal model possesses the ability to receive temporally and spatially varying inputs from HSPF.

4.2 Model Setup

4.2.1 Subwatersheds

To adequately represent the spatial variation in the watershed, the Beaver Creek drainage area was divided into nine (9) subwatersheds (Figure 4.1) for the purpose of modeling hydrology. The rationale for choosing these subwatersheds was based on the availability of water quality data and the limitations of the HSPF model. Figure 4.1 shows all subwatersheds, which were used to achieve the unified model.

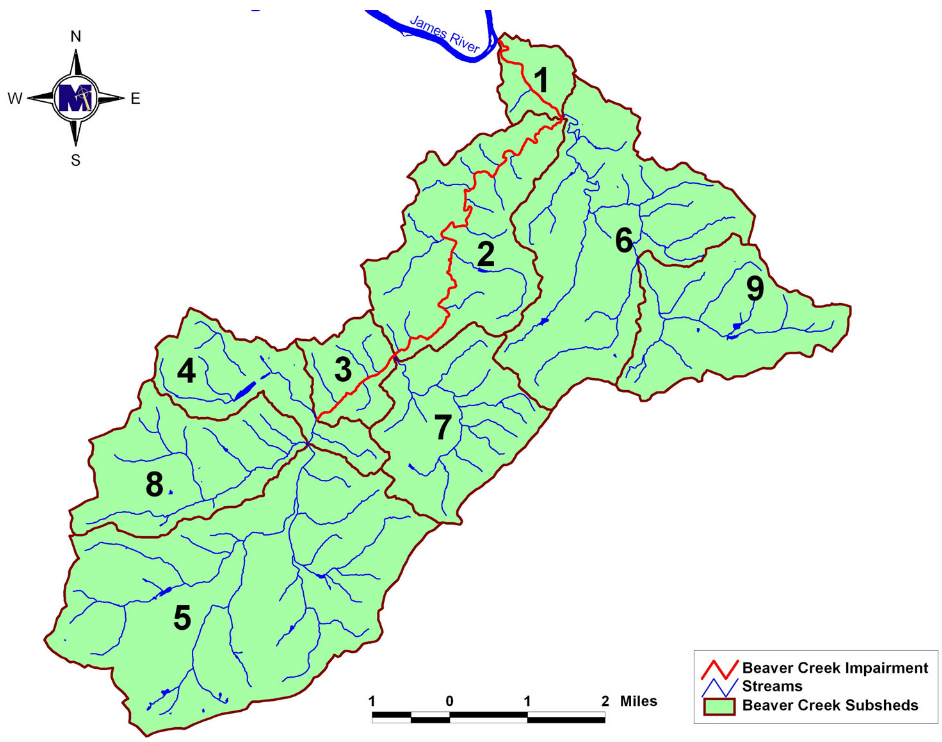

Figure 4.1 Subwatersheds delineated to model the Beaver Creek study area.

In an effort to standardize modeling efforts 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.

4.2.2 Land Uses

The MRLC land use grid identified sixteen (16) land use types in the watershed. The 16 land use types were consolidated into categories based on similarities in hydrologic and waste application/production features (Table 4.1). Within each subwatershed, up to seven 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. Table 4.1 shows the consolidated land use types in the study area. 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 seven 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 4.1 shows the land uses used in modeling the Beaver Creek study area. Table 4.2 shows the breakdown of land uses within the drainage area of each impairment. These acreages represent only what is within the boundaries of the Beaver Creek study area.

Table 4.1 Consolidation of MRLC 2001 land use categories for the Beaver Creek watershed used in HSPF modeling.

TMDL Land use Categories	Pervious/Impervious (Percentage)	MRLC Land use Classifications (Class Number)
Water	Pervious (100%)	Open Water (11)
Developed	Pervious (94%) Impervious (6%)	Developed, Open Space (21) Low Intensity Residential (22) Medium Intensity Residential (23) Commercial/Industrial/Transportation (24)
Barren	Pervious (94%) Impervious (6%)	Barren Land (31)
Forest	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43) Shrub/Scrub (52)
Pasture/Hay	Pervious (100%)	Grassland/Herbaceous (71) Pasture/Hay (81)
Cropland	Pervious (100%)	Row Crops (82)
Wetlands	Pervious (100%)	Woody Wetlands (90) Emergent Herbaceous Wetlands (95)

Table 4.2 Land uses (2001) in the Beaver Creek watershed.

Subwatershed	Open Water	Developed	Forest	Barren	Pasture	Cropland	Wetland	Total Acres
1	0	55	385	0	89	3	0	531
2	8	48	2,197	1	715	8	0	2978
3	0	39	381	0	370	5	0	796
4	19	135	1,107	0	249	11	0	1,520
5	15	467	3,894	4	2,305	81	11	6,778
6	10	229	3,034	2	891	19	0	4,184
7	2	97	1,930	0	194	2	0	2,226
8	2	174	1,207	1	872	12	4	2,272
9	6	112	1,122	2	968	46	5	2,260
Total	62	1,356	15,257	10	6653	187	20	23,545

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.

4.3 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.,* stream geometry and resistance to flow). This 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, 2006), Digital Elevation Models (DEM), nautical charts, and bathymetry data was used. The nautical charts and bathymetry data includes the elevation of stream and rivers below mean sea level (negative elevations). 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 Beaver Creek study area. The NRCS regional curve equations developed from data for streams in non-urban piedmont physiographic province in Pennsylvania and Maryland. 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 4.2). 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.

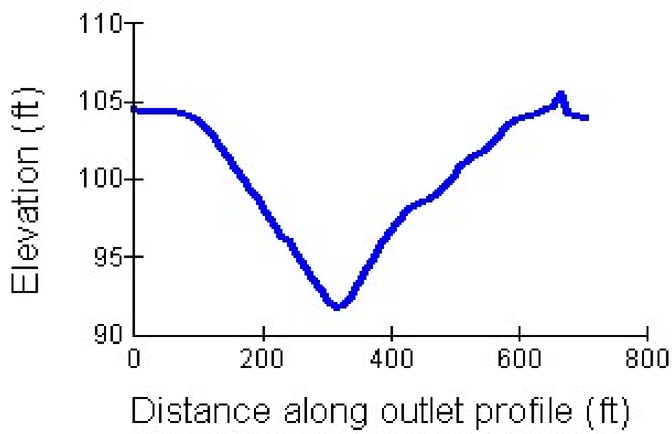

Figure 4.2 Stream profile representation in HSPF.

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 4.3. 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 4.4.

Table 4.3 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 4.4 Example of an F-table calculated for HSPF modeling.

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

4.4 Selection of a TMDL Critical Condition

EPA regulations at 40 CFR 130.7 (c)(1) require that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Beaver Creek 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 Beaver Creek 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).

Graphical analyses of fecal coliform concentrations and flow duration intervals showed that water quality standard violations occurred at nearly every flow interval at VADEQ monitoring station on the Beaver Creek (Figure 4.3). This demonstrates that this stream should have all flow regimes represented in the allocation modeling time period.

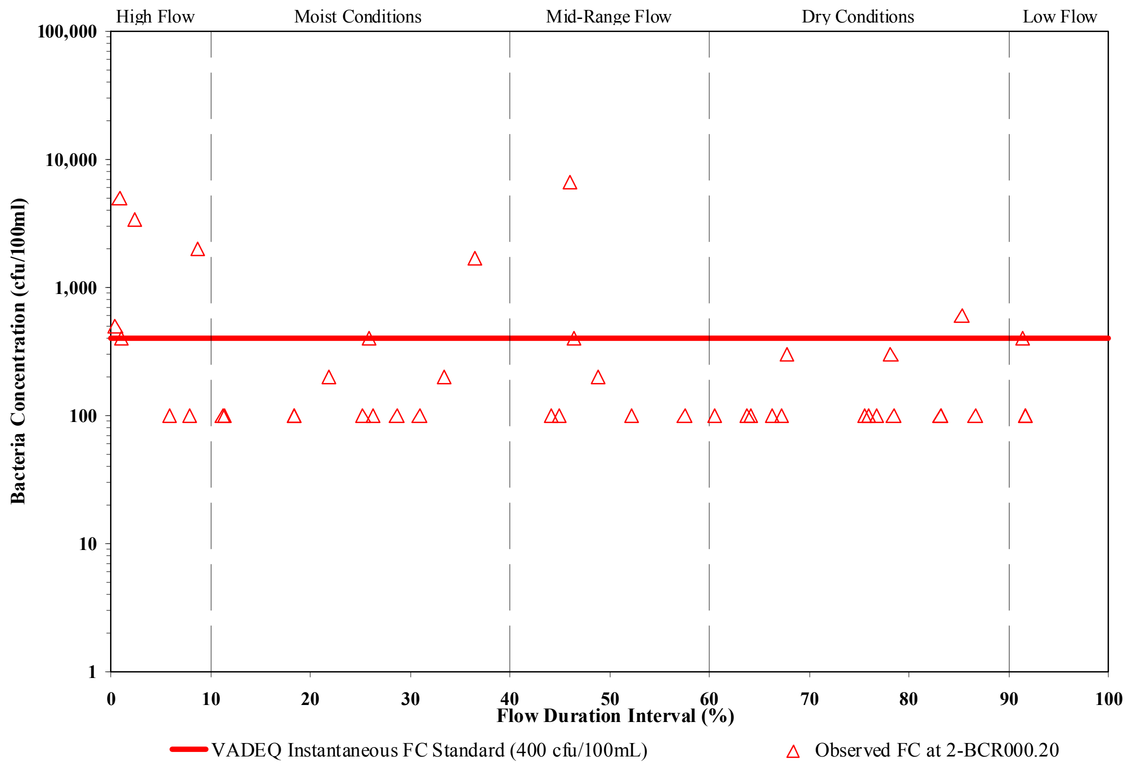

Figure 4.3 Fecal coliform concentrations at 2-BCR000.20 on Beaver Creek versus discharge at USGS Gaging Station #02026000.

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 (Section 4.5) in order to capture a wide range of hydrologic circumstances for all impaired streams in this study area. The resulting periods for calibration, validation, and allocation for each impaired stream are presented in Section 4.5.

4.5 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. Direct depositions by wildlife were modeled as being deposited from 6:00 AM to 6:00 PM. 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 numbers were used. Data representing 1998 were used for the water quality calibration period (1995-1999), and data representing 2003 were used for validation period (2000-2004). Data representing 2009 were used for the allocation runs in order to represent current conditions.

4.5.1 Permitted Sources

One point source is permitted to discharge water into surface waters in the Beaver Creek study area through the Virginia Pollutant Discharge Elimination System (VPDES) (Table 3.2). Section 3.2 discusses this permit in more detail. This VPDES permit is permitted for fecal bacteria control. For calibration and validation condition runs, recorded flow and fecal coliform concentration documented by the VADEQ were used as the input for the permit (Table 4.5). Table 4.5 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 4.5.

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 4.5 Flow rates and bacteria loads used to model VADEQ active permits in the Beaver Creek study area.

VADEQ Permit Number	Facility Name	Calibration/Validation				Allocation	
		Flow Rate (MGD)		Bacteria Concentration (cfu/100mL)		Flow Rate (MGD)	Bacteria Concentration (cfu/100mL)
		Min	Max	Min	Max	Design Flow	Fecal Coliform Geometric Mean Standard
VA0062031	Evergreen Mobile Home Park	0.010	0.135	2.2	367.3	0.024	200

4.5.2 Private Residential Sewage Treatment

The number of septic systems in the Beaver Creek 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 2009, based on current growth rates (USCB, 2000) resulting in 2,157 septic systems. (Table 4.6).

Table 4.6 Estimated failing septic for 2009 in the Beaver Creek study area.

Subwatershed	Septic systems	Falling Septic Systems
1	26	4
2	110	10
3	33	4
4	119	16
5	863	142
6	233	30
7	102	15
8	454	45
9	218	29
Total	**2,158**	**295**

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 Beaver Creek 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.

Pit privies 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 pit privies (VDH personal communication, 8/25/2009). Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. The loadings from pit privies were modeled in the same manner as failing septic systems.

4.5.3 Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The amount of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock numbers determined for 1998 were used for the calibration and 2003 populations were used for validation runs, while these numbers were projected to 2009 for the allocation runs. 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, 1995; 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 3.6). 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.

4.5.3.1 Land Application of Collected Manure

Collection of livestock manure was assumed the case on all dairy farms. The average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Section 3.3.4. For dairy cows, the only waste assumed to be collected was from currently milking cows. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. Finally, values for the percentage of loafing lot waste collected, based on data provided by SWCD representatives and local stakeholders, were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.7). Stored waste was spread on pasture and cropland. It was assumed that 100% of land-applied waste is available for transport in surface runoff.

4.5.3.2 Deposition on Land

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

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

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

4.5.3.3 Direct Deposition to Streams

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

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.

4.5.4 Biosolids

Investigation of VADEQ data indicated that no biosolids applications have occurred within the Beaver Creek area during the modeling period.

4.5.5 Wildlife

For each species of wildlife, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.3.5). An example of one of these layers is shown in Figure 4.4. 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.

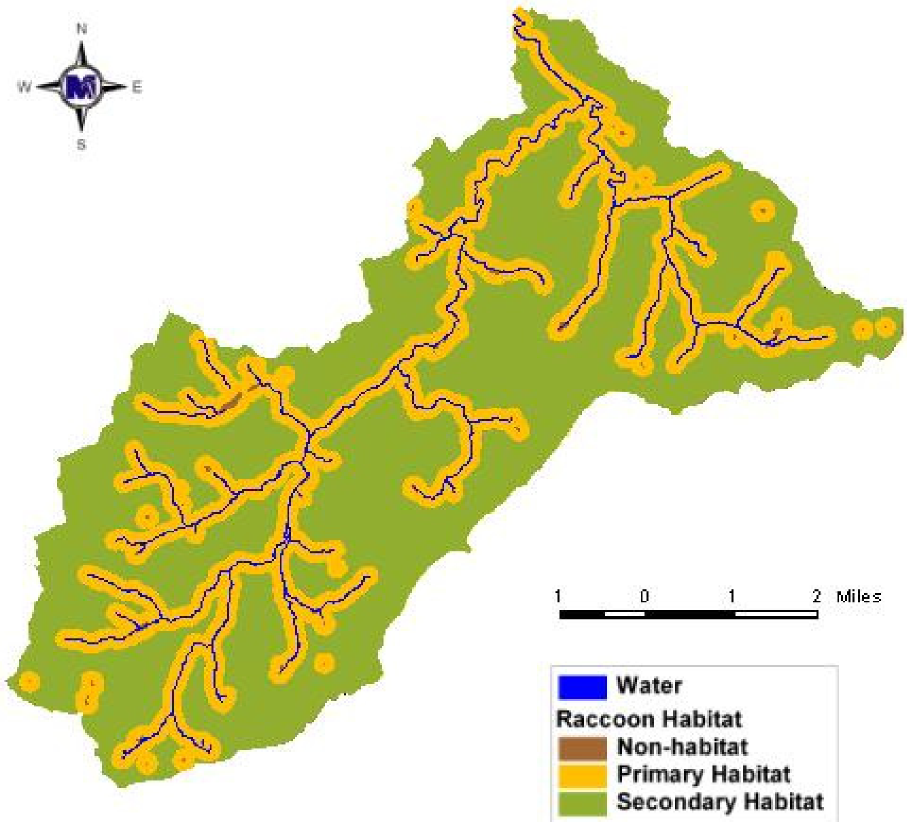

Figure 4.4 Example of raccoon habitat layer in the Beaver Creek study area, as developed by MapTech.

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 3.8). 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. No long-term (1996–2004) adjustments were made to wildlife populations, as there was no available data to support such adjustments.

4.5.6 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), wasteload, and fecal coliform density are reported in Section 3.3.3. 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 2009.

4.6 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. Sensitivity analyses were performed on the HSPF model to show how small changes in certain model parameters affect the output from the model (Appendix D).

4.6.1 HSPF - Hydrologic Calibration and Validation

Hydrologic calibration was conducted during the development of *Bacteria Total Maximum Daily Load Development for the James River Basin* (ECI, 2007). The model segment JR-7 was calibrated for hydrologic accuracy using daily flow data from USGS Gaging Station 02026000 on the James River for the period January 1995 through December 1999. The results and further details regarding hydrologic calibration can be found in the James River Basin TMDL technical document. The changes made to the hydrologic parameters in the James River Basin study, were the same percent changes made to the same hydrologic parameters in the Beaver Creek TMDL project.

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), slope of overland flow plane (SLSUR), groundwater recession flow (KVARY), active groundwater storage PET (AGWETP), and Manning's *n* for overland flow plane (NSUR). Table 4.7 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 4.7 Initial hydrologic parameters estimated for the Beaver Creek TMDL area, and resulting final values after calibration and validation.

Parameter	Units	Possible Range of Parameter Value	Initial Parameter Estimate	Final Parameter Value
LZSN	in	2.0 – 15.0	10.367 – 13.459	10.367 – 13.459
INFILT	in/hr	0.001 – 0.50	0.0696 – 0.1904	0.0696 – 0.1904
LSUR	ft	100 – 700	1.0 – 700	1.0 – 700
SLSUR	---	0.001 – 0.30	0.0402 – 0.2358	0.0402 – 0.2358
KVARY	1/in	0.0 – 5.0	0	0
AGWRC	1/day	0.85 – 0.999	0.955	0.98
DEEPFR	---	0.0 – 0.50	0.01	0.01
BASETP	---	0.0 – 0.20	0 – 0.01	0.01
AGWETP	---	0.0 – 0.20	0 – 0.01	0 – 0.71
INTFW	---	1.0 – 10.0	1.0	1.0
IRC	1/day	0.30 – 0.85	0.60	0.50
MON-INTERCEPT	in	0.01 – 0.40	0.00 – 0.40	0.00 – 0.40
MON-UZSN	in	0.05 – 2.0	0.16 – 0.67	0.16 – 0.67
MON-MANNING		0.01 – 0.5	0.06 – 0.37	0.06 – 0.37
MON-LZETP	---	0.1 – 0.9	0.01 – 0.90	0.01 – 0.90

* Represents a multiplier; + represents an addition

For the purpose of validating modeled flow from the Beaver Creek watershed was compared against the James River USGS Gaging Station 02026000 data. Figure 4.5 shows the Beaver Creek flow parallels the recorded flows within the James River demonstrating a strong correlation in flows, showing the model is properly calibrated.

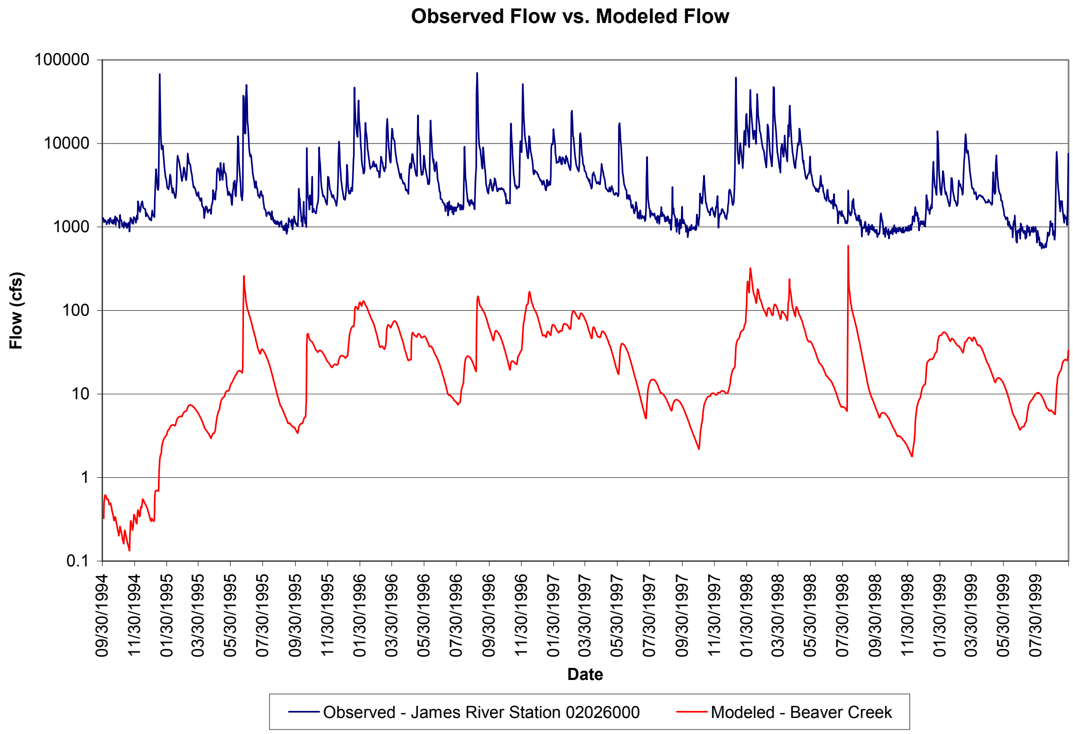

Figure 4.5 Modeled Beaver Creek flow and Observed James River Flow.

4.6.2 HSPF – *E. coli* Water Quality Calibration

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 8,000 cfu/100ml at times and at 16,000 cfu/100ml at other times. Limited amount of measured data for use in calibration and the practice of censoring both high and low concentrations impede the calibration process.

The HSPF water quality calibration was conducted using data for the time period from 10/1/1994 through 9/30/1999. Three parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), monthly maximum accumulation on land (MON-SQOLIM), and the rate of surface runoff that will remove 90% of stored fecal bacteria per hour (WSQOP). 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 *E. coli* concentrations was established (Table 4.8).

Table 4.8 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 – 3.10E+10	0.0 – 9.30E+12
WSQOP	in/hr	0.05 – 3.00	0.0 – 2.5	0.0 – 0.56
FSTDEC	1/day	0.01 – 10.00	1.0	0.6

The water land use was given a WSQOP value of zero (0) because it represents the stream channel and does not have wash-off. The minimum calibrated WSQOP value not considering the water land use was 0.20, which is within the typical range.

Figure 4.6 shows 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.

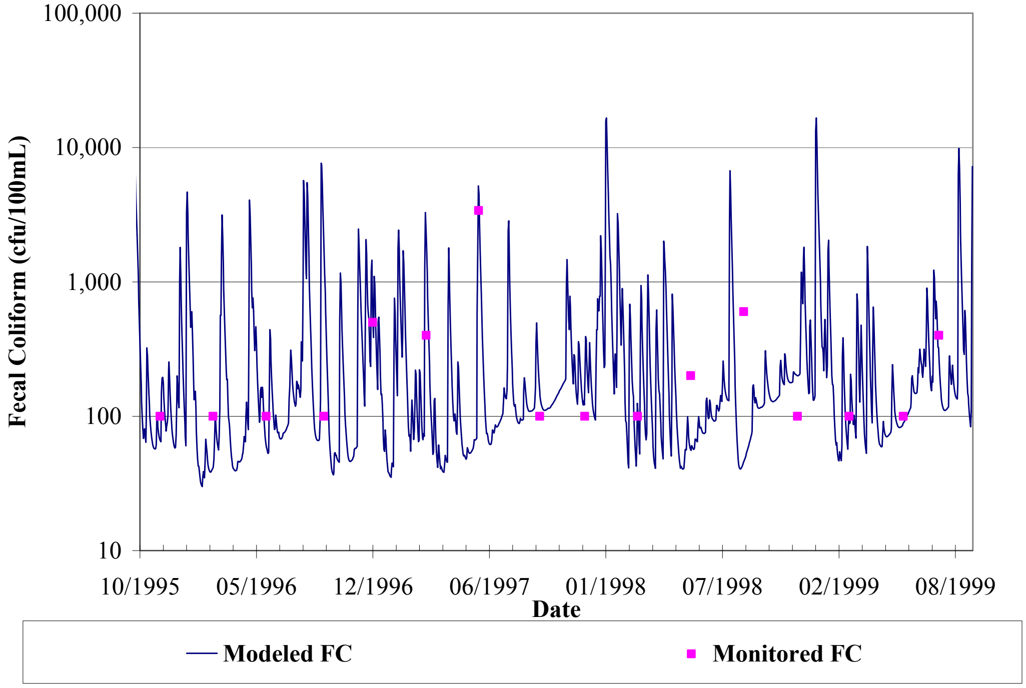

Figure 4.6 ***E. coli*** **calibration results for 10/1/1995 to 9/30/1999 for VADEQ station in subwatershed 1 in the Beaver Creek impairment.**

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. To provide a quantitative measure of the agreement between modeled and measured data while taking the inherent variability of *E. coli* concentrations into account, each observed value was compared with modeled concentrations in a 2-day window surrounding the observed data point. Standard error in each observation window was calculated as follows:

$$Standard\ Error = \frac{\sqrt{\dfrac{\sum_{i=1}^{n}(observed - modeled_i)^2}{(n-1)}}}{\sqrt{n}}$$

where

$$observed = \text{an observed value of fecal coliform}$$
$$modeled_i = \text{a modeled value in the 2-day window surrounding the observation}$$
$$n = \text{the number of modeled observations in the 2-day window}$$

This is a non-traditional use of standard error, applied here to offer a quantitative measure of model accuracy. In this context, standard error measures the variability of the sample mean of the modeled values about an instantaneous observed value. The use of limited instantaneous observed values to evaluate continuous data introduces error and, therefore, increases standard error. The mean standard error was calculated as 34.0 (Table 4.9). This can be considered quite reasonable when one takes into account the censoring of maximum values that is practiced in the collection of actual water quality samples. The standard error will be biased upwards when an observed high value censored at 8,000 or 16,000 cfu/100mL is compared to a simulated high value that may be an order of magnitude or more above the censor limit. Thus, the standard error calculated for this impairment is considered an indicator of strong model performance.

Table 4.9 Mean standard error of the *E. coli* calibrated model.

Stream	Sub	Station ID(s)	Mean Standard Error	Maximum Simulated Value	Maximum Monitored Value
				-------(cfu/100 mL)-------	
Beaver Creek	1	2-BCR000.20	34.0	7,477	1,200

Table 4.10 shows the predicted and observed values for the geometric mean and single sample (SS) instantaneous violations for Beaver Creek. The percent difference between modeled and monitored geometric means and instantaneous violations were within one standard deviation of the observed data and, therefore, the *E. coli* calibration is acceptable.

Table 4.10 Comparison of modeled and observed *Fecal Coliform* calibration results for the Beaver Creek study area watershed.

Stream	Subwatershed	Modeled *Fecal Coliform* 10/1/1995 - 9/30/1999			Monitored *Fecal Coliform* 12/04/1995 - 8/02/1999		
		n	Geometric Mean (cfu/100ml)	SS % violations [1]	*n*	Geometric Mean (cfu/100ml)	SS % violations [1]
Beaver Creek	1	1460	171.99	19.18%	16	191.47	18.75%

[1] SS = single sample instantaneous standard violations (>235 cfu/100mL)

4.6.3 HSPF – *E. coli* Water Quality Validation

E. coli water quality model validation was performed on data from 10/1/2000 to 9/30/2004. The results are shown in Table 4.11 and 4.12 and in Figure 4.7.

Table 4.11 Mean standard error of the *E. coli* validation model for impairments in the Beaver Creek study area watershed.

Stream	Sub	Station ID	Mean Standard Error	Maximum Simulated Value	Maximum Monitored Value
				-------(cfu/100 mL)-------	
Beaver Creek	1	2-BCR000.20	163.4	41,190	7,200

Table 4.12 shows the predicted and observed values for the geometric mean and single sample (SS) instantaneous violations. The maximum percent difference between modeled and monitored geometric means and instantaneous violations are within one standard deviation of the observed data, therefore, the *E. coli* validation is acceptable.

Table 4.12 Comparison of modeled and observed *Fecal Coliform* validation results for the Beaver Creek study area watershed.

Stream	Subwatershed	Modeled *Fecal Coliform* 10/1/2000 - 9/30/2004			Monitored *Fecal Coliform* 11/28/2000 – 6/26/03		
		n	Geometric Mean (cfu/100ml)	SS % violations [1]	*n*	Geometric Mean (cfu/100ml)	SS % violations [1]
Beaver Creek	1	1460	199.82	20.68%	15	213.40%	20.00%

[1] SS = single sample instantaneous standard violations (>235 cfu/100mL)

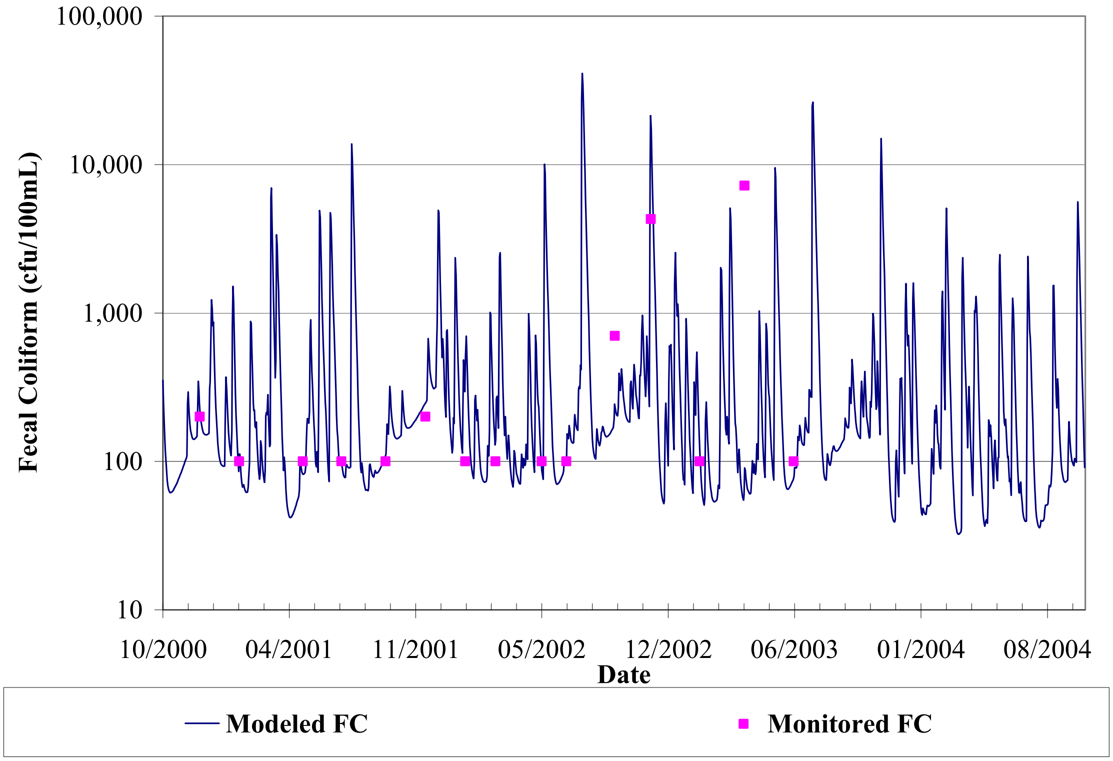

Figure 4.7 E. coli validation results for 10/1/2000 to 9/30/2004 for VADEQ station 2-BCR000.20 in subwatershed 1 of the Beaver Creek impairment.

4.7 Existing Loadings

All appropriate inputs were updated to current conditions. Figure 4.8 shows the monthly geometric mean of *E. coli* concentrations for existing conditions, in relation to the 126-cfu/100mL standard at the outlet of the Beaver Creek impairment (subwatershed 1).

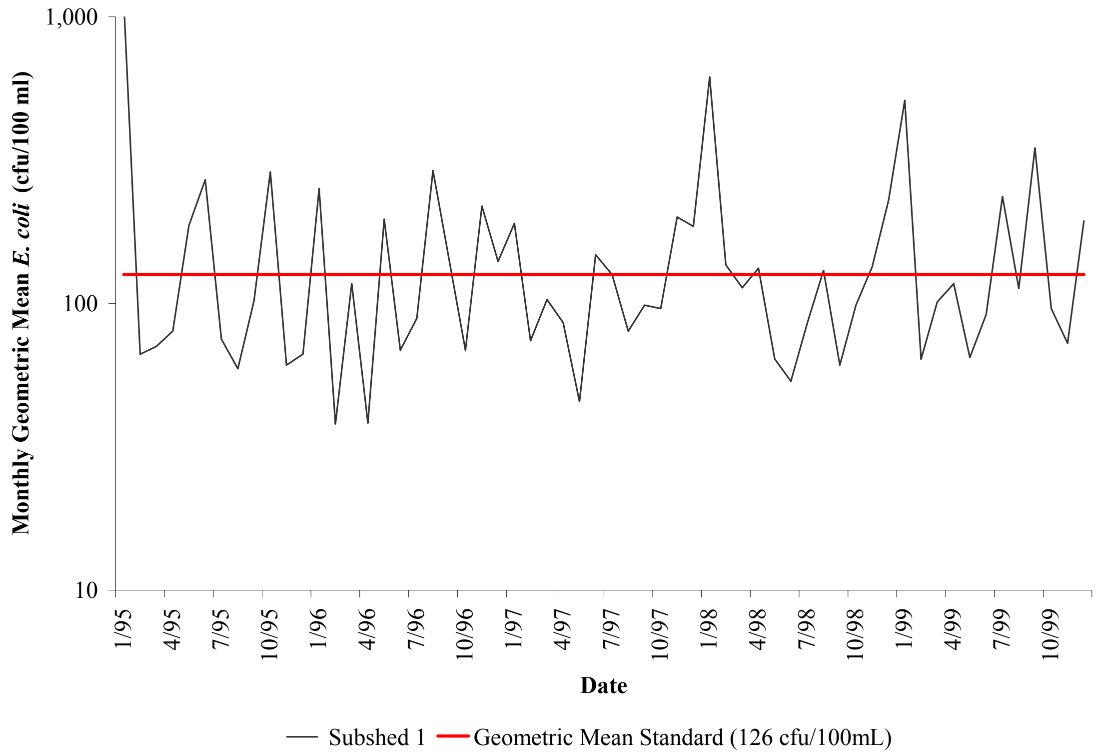

Figure 4.8 Monthly geometric mean of *E. coli* concentrations for existing conditions at the Beaver Creek impairment outlet (subwatershed 1).

5. 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 Beaver Creek and Tributaries study area were based on the *E. coli* riverine Virginia State standard. As detailed in Section 2.1, the VADEQ riverine primary contact recreational use *E. coli* standard states 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):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc}) \qquad \textit{E. coli}$$

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 standard was met. The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the calendar month geometric-mean standard of 126 cfu/100 ml.

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:

- Modeling biosolids applications at the maximum allowable rate and fecal coliform concentration in all permitted fields.
- Allocating permitted point sources at the maximum allowable fecal coliform concentration and design flow, and
- Selecting a modeling period that represented the critical hydrologic conditions in the watershed.

5.2 Waste Load Allocations (WLAs)

There is one point source currently permitted to discharge into the Beaver Creek study area streams, permitted for *E. coli* control (Table 3.2). 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 assuming a 500% growth in permit discharge for those watersheds with permitted discharge. For watersheds with no existing point sources future growth in permitted point sources was accounted for as a 1% of the current TMDL in the watershed.

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 (*e.g.,* livestock, wildlife). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads had their most significant impact during high-flow conditions, while direct deposition NPS had their most significant impact on low flow concentrations. The BST results confirmed the presence of human, livestock, pet, and wildlife contamination in all impairments. Nonpoint source load reductions were performed by land use, as opposed to reducing sources, as it is considered that the majority of NPS BMPs will be implemented by land use. Reductions on agricultural land uses (pasture and cropland) include reductions required for land applied livestock wastes.

5.4 Final Total Maximum Daily Loads (TMDLs)

Table 5.1 shows allocation scenarios used to determine the final TMDL for Beaver Creek. Because Virginia's standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational (swimming) use standard (126 cfu/100mL geometric mean). Scenario 1 describes a baseline scenario that corresponds to the existing conditions in the watershed, showing the violation percentage with no reductions. Scenario 2 showed some improvement by eliminating direct straight-pipe inputs.

Scenario 3, eliminating straight-pipe and direct livestock inputs, showed slightly more improvement. A typical management scenario, Scenario 4, improved water quality but the standard was still not met. Scenario 5 shows increased reductions to land based sources. Scenario 6 demonstrates that even with a significant reduction (99%) of agricultural land based sources, water quality is just shy of meeting the standard. Scenario 7 shows that the standard can be met, without wildlife related reductions.

Scenario 8 is the result of backing off of the reductions as far as possible, while still meeting the water quality standard. This scenario meets a geometric mean of 126 cfu/100mL with the least with the least amount of reductions. This scenario is the target goal during the implementation of best management practices (BMPs).

Table 5.1 Allocation scenarios for reducing current bacteria loads in Beaver Creek.

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, Forest, Wetlands**	**Livestock Direct**	**Cropland, Pasture**	**Straight Pipes**	**Developed**	**>126 GM**
1	0	0	0	0	0	0	58.33
2	0	0	0	0	100	0	46.67
3	0	0	100	0	100	0	43.33
4	0	0	90	50	100	50	31.67
5	0	0	100	75	100	75	15.00
6	0	0	100	99	100	50	1.67
7	0	0	100	99	100	99	0.00
8[2]	0	0	99	99	100	64	0.00

[2] Final TMDL Scenario

Figure 5.1 shows the existing and allocated monthly geometric mean *E. coli* concentrations in Beaver Creek at the impairment outlet. This graph shows existing conditions in black, with allocated conditions overlaid in blue.

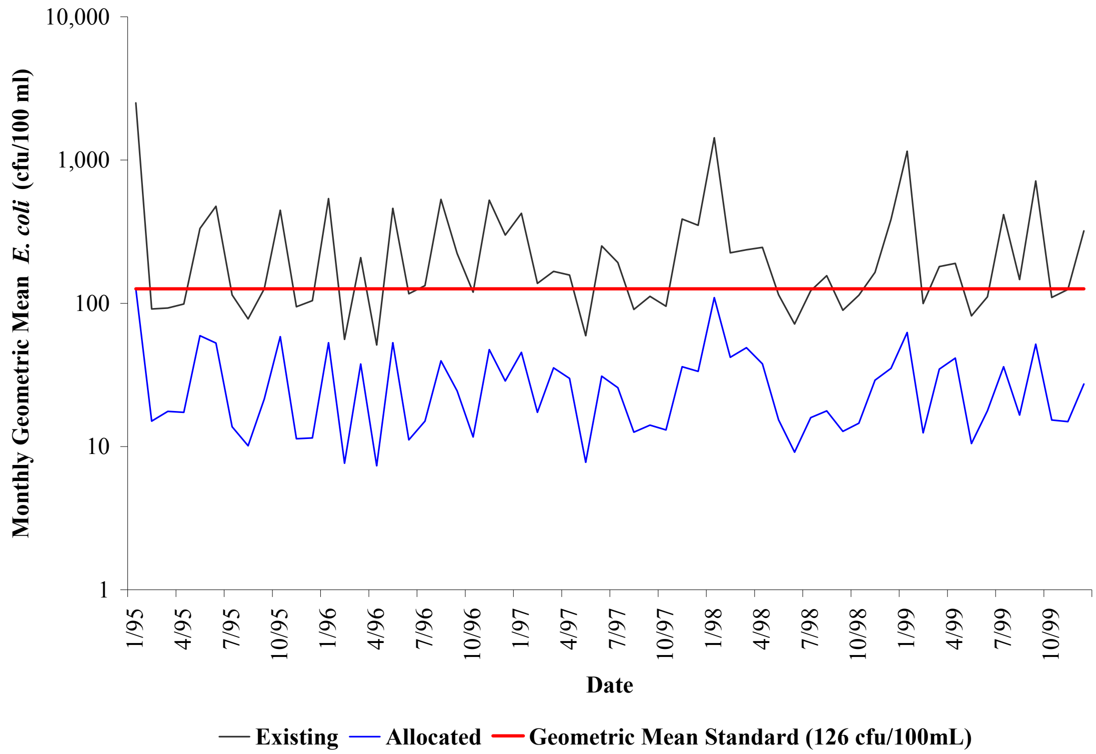

Figure 5.1 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in Beaver Creek at the impairment outlet.

Table 5.2 contains estimates of existing and allocated in-stream *E. coli* loads at the Beaver Creek 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.

Table 5.2 Estimated existing and allocated *E. coli* in-stream loads in the Beaver Creek impairment.

Source		Total Annual Loading for Existing Run[1] (cfu/yr)	Total Annual Loading for Allocation Run[1] (cfu/yr)	Percent Reduction
Land Based				
	Barren	1.49E+10	1.49E+10	0%
	Crop	2.33E+12	2.33E+10	99%
	Developed	4.09E+12	1.47E+12	64%
	Forest	2.67E+13	2.67E+13	0%
	Pasture	6.06E+13	6.06E+11	99%
	Wetland	1.68E+10	1.68E+10	0%
Direct				
	Human	9.12E+12	0.00E+00	100%
	Livestock	1.48E+12	1.48E+10	99%
	Wildlife	8.49E+11	8.49E+11	0%
	Permitted Sources	2.61E+10	2.61E+10	0%
	Future Growth	0.00E+00	3.00E+11	NA
Total Loads		**1.05E+14**	**3.00E+13**	**71.5%**

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 existing water quality standards. 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 Beaver Creek impairment.

Impairment	WLA[1]	LA	MOS	TMDL
Beaver Creek	**3.26E+11**	**2.97E+13**	*Implicit*	**3.00E+13**
VA0062031	*3.00E+11*			
Future Load	*3.00E+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.

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 Beaver Creek are shown in Table 5.4.

Table 5.4 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Beaver Creek impairment.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Beaver Creek	**8.94E+08**	**5.64E+11**	*Implicit*	**5.65+11**
VA0062031	7.15E+07			
Future Load	8.22E+08			

[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 126 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

6. TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

Once EPA has approved a TMDL, measures must be taken to reduce pollution levels from both point and nonpoint sources. 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, DEQ 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.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as 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 DEQ's 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.

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.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program. Requirements of the permit process should not be duplicated in the TMDL process, and permitted sources are not usually addressed through the development of any TMDL implementation plans.

6.3.1 Treatment Plants

No reductions to waste treatment plants were required.

6.3.2 Stormwater

DEQ and DCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. DEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while DCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. 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.

6.3.3 TMDL Modifications for New or Expanding Dischargers

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, DEQ 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 DEQ'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 nonpoint 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,

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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 cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in section 6.6, Attainability of Designated Uses.

6.5.2 Link to Ongoing Restoration Efforts

This TMDL is last remaining watershed of the previous "Development of Total Maximum Daily Loads for the James River Study Area" (VADEQ, 2007) in the Lynchburg area. This TMDL document will be a supplement to that report, and finalize the development of the Lynchburg-area James River TMDL. Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the James River and ultimately the Chesapeake Bay.

6.5.3 Implementation Funding Sources

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

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water

Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

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

6.6 Follow-Up Monitoring

Following the development of the TMDL, DEQ will make every effort to continue to monitor the impaired streams in accordance with its ambient and biological monitoring programs. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with *DEQ Guidance Memo No. 03-2004* (www.deq.virginia.gov/waterguidance/pdf/032004.pdf), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan

prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

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

In some cases, watersheds will require monitoring above and beyond what is included in DEQ's standard monitoring plan. Ancillary monitoring by citizens' 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 DEQ 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 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), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one-year period.

6.7 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. DEQ will continue to monitor biological health and 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".

7. PUBLIC PARTICIPATION

Public participation during TMDL development for the Beaver Creek area was encouraged; a summary of the meetings is presented in Table 7.1. The first public meeting was held on December 3, 2009 in Rustburg, Virginia and twelve people attended. The attendees represented state and federal agencies and MapTech. The final public meeting was held in Lynchburg, Virginia on March 23, 2010.

Table 7.1 Public participation during TMDL development for the Beaver Creek study area.

Date	Location	Attendance	Type
12/3/2009	Campbell County Agricultural Building Rustburg, Virginia	12	First Public
3/23/2010	Lynchburg Information Technology Center Lynchburg, Virginia	???	Second Public

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. This 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.*

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

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.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota. **(2)**

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

Biological Integrity. A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

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).*

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.

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 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 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 undesirable 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.*

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)

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.

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.*

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.*

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.*

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.*

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

Rapid Bioassessment Protocol II (RBP II). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP II scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach. Segment of a stream or river.

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

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

Re-mining. Extracting resources from land previously mined. This method is often used to reclaim abandoned mine areas.

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.

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).

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.*

Stressor. Any physical, chemical, or biological entity that can induce an adverse response. [2]

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.*

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.

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.*

Ton (T). A unit of measure of mass equivalent to 2,200 English lbs.

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

Total Dissolved Solids (TDS). A measure of the concentration of dissolved inorganic chemicals in water.

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.*

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.

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).*

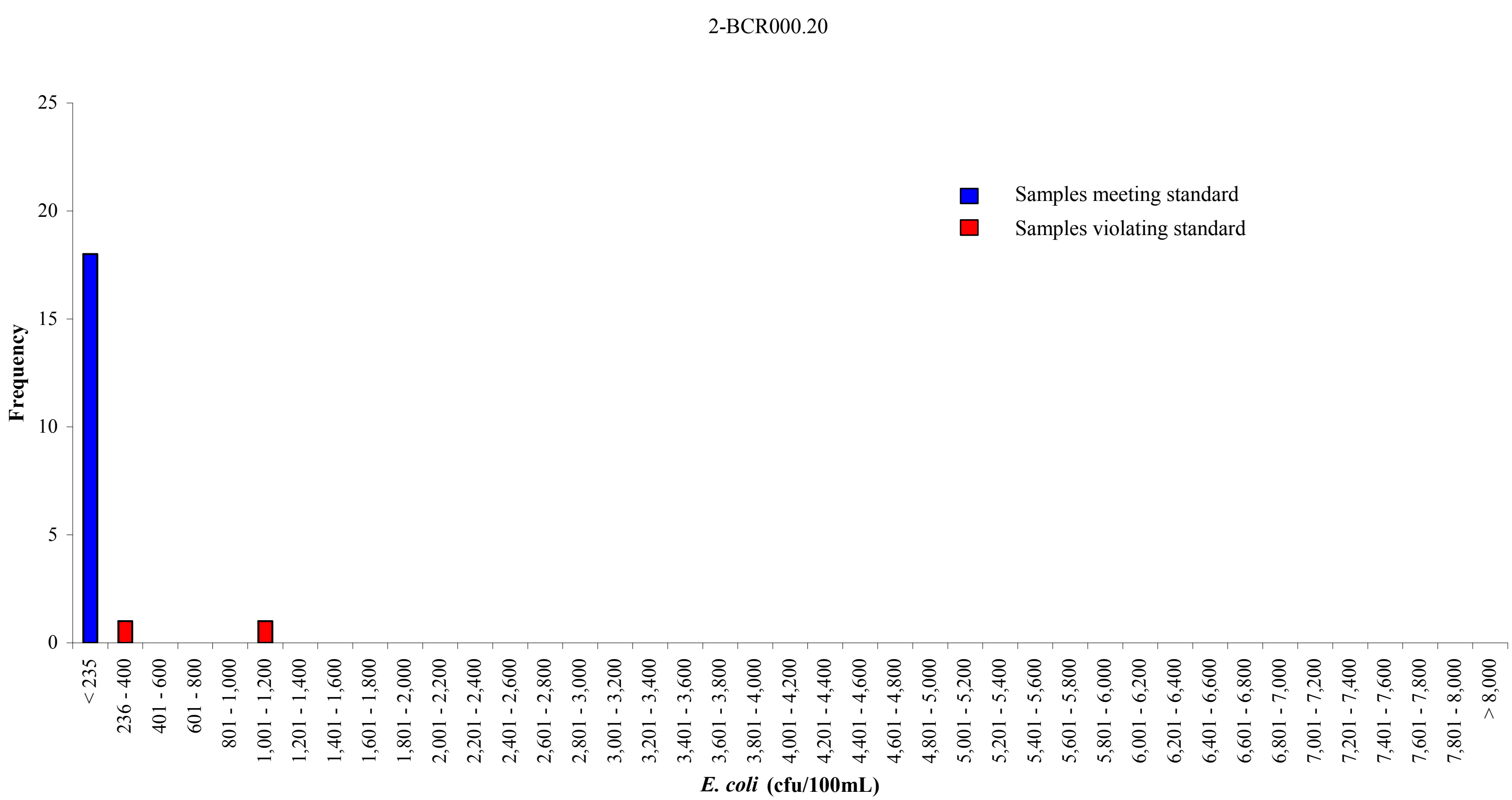
Water quality criteria*. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by the EPA or states for various pollutants of concern to protect 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.*

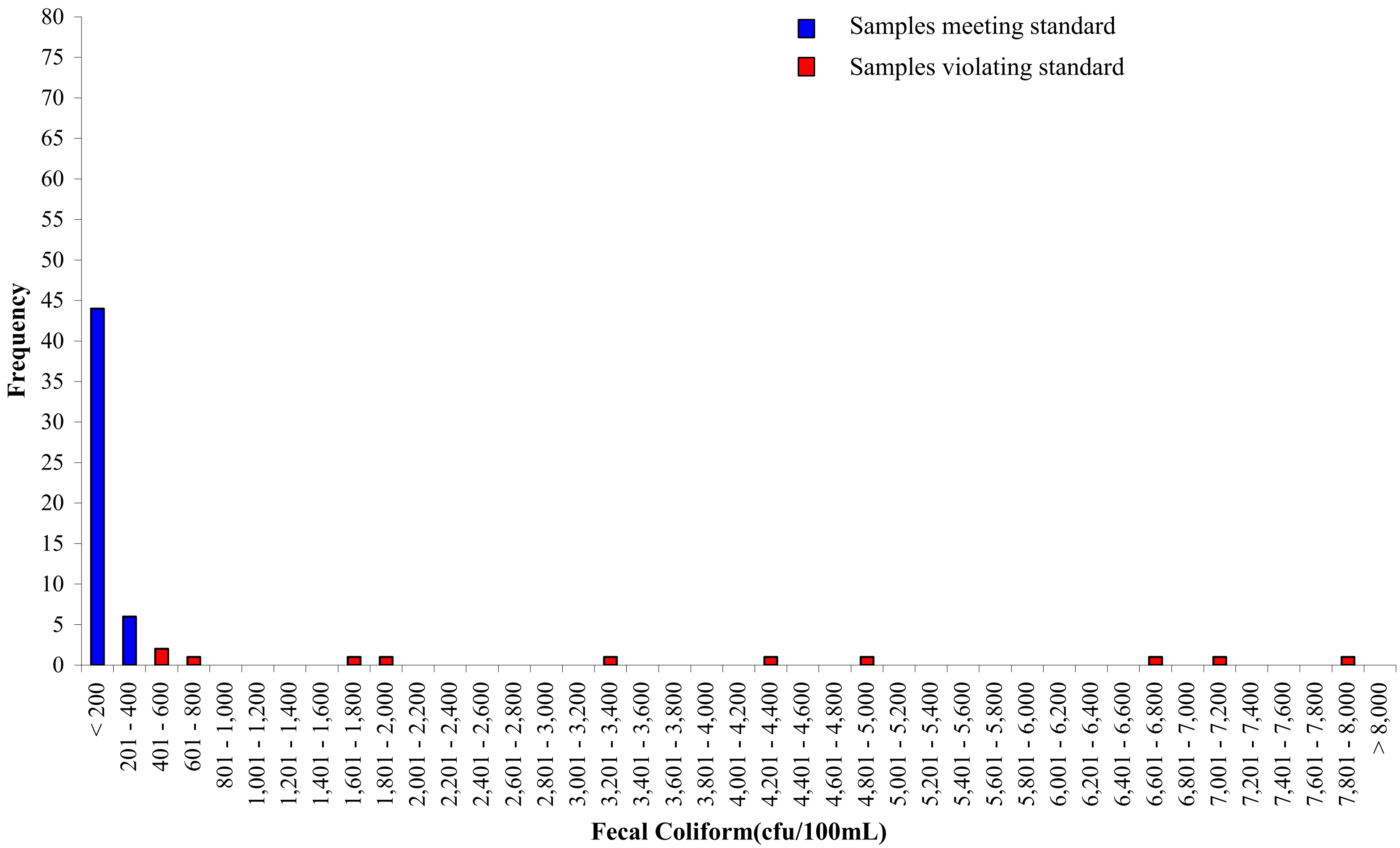
WQIA. Water Quality Improvement Act.

APPENDIX A: FREQUENCY ANALYSIS OF BACTERIA CONCENTRATIONS



Appendix A 1 Frequency analysis of *E. coli* concentrations at Station 2- BCR000.20.

2-BCR000.20



Appendix A 2 Frequency analysis of Fecal coliform concentrations at Station 2-BCR000.20.