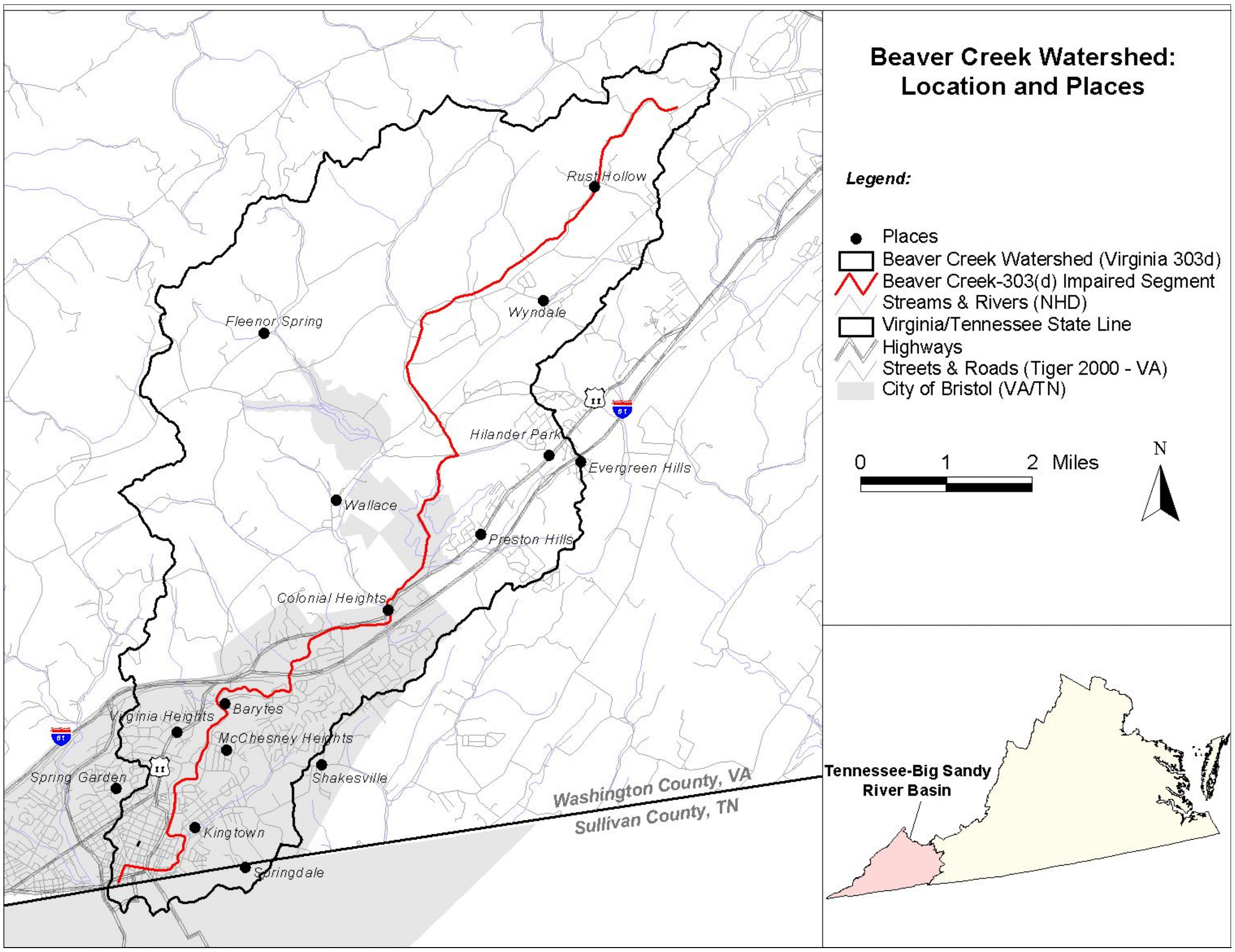
Total Maximum Daily Load (TMDL) Development for the Beaver Creek Watershed

Aquatic Life Use (Benthic) and E. coli (Bacteria) Impairments



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Impairment Listing

The Beaver Creek watershed (Virginia WBID: VAS-O07) is located in the Tennessee-Big Sandy River Basin (HUC: 06010102). The headwaters begin in Washington County, Virginia in a mostly rural area and flows in a southwesterly direction through the City of Bristol (Virginia and Tennessee) until it confluences with the South Fork Holston River in Tennessee. The Virginia portion of the Beaver Creek watershed (delineated at the state boundary) is approximately 22,654 acres, which represents 32.3% of the entire Beaver Creek watershed (70,074 acres in Virginia and Tennessee).

Beaver Creek was listed as impaired on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the State's water quality standards for fecal coliform bacteria and violations of the General Standard (Benthics) (VADEQ 1998 and 2002a). The impaired segment is approximately 13.46 miles in length and extends from the Route 611 Bridge, near the headwaters of Beaver Creek, to the Virginia/Tennessee state line.

Bacteria Impairment

Background

Elevated levels of fecal coliform bacteria and *E. coli* bacteria were recorded at several water quality monitoring stations along Beaver Creek. In order to improve water quality conditions that have resulted in the bacteria impairment, a Total Maximum Daily Load (TMDL) was developed for the impaired stream, taking into account all sources of bacteria in the watershed, plus an implicit margin of safety (MOS).

Upon implementation, the bacteria TMDL will ensure that water quality conditions relating to bacteria impairment will meet the recently adopted *E. coli* criteria in Virginia's Water Quality Standards (9 VAC 25-260-170).

Sources of Bacteria

Point and nonpoint sources of bacteria in the Beaver Creek watershed were considered in TMDL development. Intense agricultural areas in the upper portion of the watershed and urban areas downstream (City of Bristol) are listed as contributing to water quality impacts, according to the 2002 303(d) Fact Sheet for Beaver Creek Nonpoint sources of bacteria include failing septic systems and straight pipes, livestock (including manure application loads), wildlife, and domestic pets. Point sources, such as municipal sewage treatment plants, can contribute bacteria loads to surface waters through effluent discharges. There are currently two point sources of bacteria in the watershed that are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) that is managed by VADEQ (Table 1). The MS4 permit load was calculated based on the load contributed by urban (built-up) lands in the watershed and the percentage of urban land located within the Bristol city limits. The bacteria load contributed by this private residence was calculated based on the permitted flow (1000 gallons/day) and the applicable *E. coli* limit (126 cfu/100ml, geometric mean concentration). Note that failing septic discharges were included in the built up (urban land) load and the Bristol MS4 permit load.

Table 1. VPDES bacteria point source facilities in the Beaver Creek watershed

VPDES Permit No.	Facility Name	Discharge Type
VAG400012	Private Residence	Treated Domestic Sewage
VAR040048	City of Bristol, MS4	Stormwater

Modeling

E. coli TMDLs were developed using the Loading Simulation Program C++ (LSPC) model. LSPC is a watershed modeling system that includes streamlined Hydrologic Simulation Program Fortran (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream transport model.

Weather conditions are the driving force for watershed hydrology processes. For the Beaver Creek watershed simulation model, the required parameters included hourly precipitation and hourly potential evapotranspiration. There were no NCDC monitoring stations located in the Smith Creek watershed. NCDC weather data collected at the Abingdon 3 S weather station (4400021) were used to setup the LSPC model. Available daily precipitation data were disaggregated to hourly measurements based on the hourly distribution of nearby weather stations.

Streamflow data are needed to calibrate watershed hydrologic parameters in the LSPC model. Hourly streamflow data from the USGS gage located on Beaver Creek at Bristol, VA (03478400) were used to calibrate hydrology. Flow data were available from 1980 through 2002. The calibration periods covered a range of hydrologic conditions, including low and high flow conditions, as well as seasonal variation. The calibrated LSPC model adequately simulated the hydrology of the impaired watershed.

Following hydrology calibration, water quality was calibrated by comparing modeled versus observed in-stream fecal coliform bacteria concentrations. The water quality calibration consisted of executing the watershed model, comparing water quality time series output to available water quality observation data, and adjusting water quality parameters within a reasonable range.

Existing Conditions

The model was run for the representative hydrologic period January 1, 1990 through December 31, 2002. The modeling run represents the existing bacteria concentrations and loadings at the watershed outlet. The model predicts fecal coliform bacteria concentrations, which were converted to *E. coli* concentrations using the VADEQ fecal coliform bacteria/*E. coli* translator (VADEQ 2003). These data were compared to the 235 cfu/100mL instantaneous and 126 cfu/100mL geometric mean water quality criteria for *E. coli* to assess the magnitude of in-stream concentrations. Existing *E. coli* loadings by land use category for Beaver Creek subwatersheds are presented in Table 3. These values represent the contribution of *E. coli* from all sources in the watershed.

Margin of Safety

While developing the Beaver Creek model, an implicit margin of safety (MOS) was used. Conservative assumptions, the use of a detailed watershed model (LSPC), and other considerations were used in developing the bacteria TMDL, such that an explicit MOS was not necessary.

Allocation Scenarios

Load or wasteload allocations were assigned to each source category in the watershed. Various allocation scenarios were examined for reducing *E. coli* loads to levels that would result in the attainment of water quality standards (Table 2). Scenario 10 presents the source reductions required to achieve the *E. Coli* instantaneous and calendar month geometric mean criteria. Scenario 5 presents the reductions required to meet the Stage 1 implementation goal of <10% violation of the instantaneous criteria. Reductions in load contributions from in-stream sources had the greatest impact on *E. coli* concentrations. Significant reductions from land-based loadings were also required to meet water quality standards. Although the *E. coli* bacteria loads that are produced by wildlife are less than the loads produced by livestock in the watershed, reductions in wildlife direct deposition to the stream were also required due to the magnitude of *E. coli* bacteria levels in Beaver Creek. Direct deposition during low flow conditions and loads transported by runoff during high flow conditions are controlled in these allocation scenarios.

Table 2. TMDL allocation scenarios and percent violations

Scenario Number	Direct (Instream) Sources			Indirect (NPS) Sources				Percent Violations	
	Straight Pipes	Livestock	Wildlife	Cropland	Pasture	Built up	Forest	Inst. Exceeds 235 #/100ml	Geom. Exceeds 126 #/100ml
1	0	0	0	0	0	0	0	85%	100%
2	100	50	0	50	50	75	0	66%	99%
3	100	75	0	75	75	90	0	37%	80%
4	100	90	0	90	90	95	0	12%	41%
5	100	95	0	92	92	93	0	10%	33%
6	100	90	0	90	90	95	0	12%	41%
7	100	95	0	95	95	98	0	5%	24%
8	100	99	0	99	99	99	0	3%	22%
9	100	99	50	99	99	99	50	0%	2%
10	100	99	60	99	99	99	0	0%	0%

The TMDL consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and an implicit margin of safety (MOS).

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources (e.g., failing septic discharges, cattle direct deposition). Implicit MOS factors were incorporated into the TMDL development process through the use of conservative model assumptions and source load estimates. TMDL allocations for Beaver Creek (under Scenario 10) are presented in Tables 3 through 5.

Table 3. Existing and allocation loads for LAs under Allocation Scenario 10

Sources		Total Annual Loading for Existing Conditions (cfu/yr)	Total Annual Loading for Allocation Conditions (cfu/yr)	Percent Reduction
Direct	Straight Pipes	1.07E+09	0.00E+00	100%
	Livestock	9.66E+13	9.66E+11	99%
	Wildlife	1.87E+13	7.47E+12	60%
Indirect	Cropland*	1.24E+13	1.24E+11	99%
	Pasture**	1.88E+14	1.88E+12	99%
	Built up***	4.59E+13	4.59E+11	99%
	Forest****	4.97E+11	4.97E+11	0%
Total		3.62E+14	1.14E+13	97%

* Includes Stipmining and Barren
** Includes Hayland
*** Includes Non MS4 Urban Pervious and Urban Impervious
**** Includes Wetland

Table 4. Existing and allocation loads for WLAs under Allocation Scenario 10

Sources	Total Annual Loading for Existing Conditions (cfu/yr)	Total Annual Loading for Allocation Conditions (cfu/yr)	Percent Reduction
Private Resdence - VAG4400012	1.74E+09	1.74E+09	0%
City of Bristol MS4 - VAR040048	1.23E+14	1.23E+12	99%
Total	1.23E+14	1.23E+12	99%

Table 5. *E. coli* TMDL for Beaver Creek

WLA	LA	MOS	TMDL
1.23E+12	1.14E+13	Implicit	1.26E+13

Benthic Impairment

Background

Benthic stressor analyses indicate that the primary cause of the benthic community impairment in Beaver Creek is excessive sedimentation. In order to improve water quality conditions that have resulted in benthic community impairments, a Total Maximum Daily Load (TMDL) was developed for Beaver Creek, taking into account sources of sediment in the watershed, plus an explicit margin of safety (MOS). Upon implementation, the sediment TMDL will ensure that water quality conditions relating to benthic impairment will meet the allowable loadings estimated by use of a reference watershed (a non-impaired watershed with similar characteristics).

Sources of Sediment

Sediment sources can be divided into point and nonpoint sources. The major nonpoint sources of sediment are agricultural land and urban land. Agricultural lands can contribute excessive sediment loads through erosion and build-up/washoff processes. Agricultural lands are particularly susceptible to erosion due to less vegetative coverage.

Point source facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ. All VPDES permitted facilities in the Beaver Creek watershed are covered by general permits or stormwater permits due to the type of point source discharge associated with each. There are currently no VPDES individual permits in the Beaver Creek watershed. A list of the facilities permitted to discharge sediment is provided in Table 6.

Table 6. VPDES sediment point source facilities in the Beaver Creek watershed

Stream	Facility Name	VPDES Permit No.	Discharge Type	Design Flow (MGD)	Permitted Concentration (mg/L)	TSS Load (lbs/year)
Beaver Creek	Private Residence	VAG400012	General	0.0010	30	91
Beaver Creek	Bristol Ready Mix	VAG110004	General	0.0010	30	91
Beaver Creek	Twin City Iron & Metal Co.*	VAR050037	Stormwater	N/A	100**	1,783
Beaver Creek	Visador Co.-Bristol Plant*	VAR510074	Stormwater	N/A	100**	2,158
Beaver Creek	General Shale Bristol Concrete*	VAR510084	Stormwater	N/A	100**	1,077
Clear Creek	Carolina Steel*	VAR050084	Stormwater	N/A	100**	8,725
Beaver Creek UT	V & S Galvanizing Inc.*	VAR510133	Stormwater	N/A	100**	375
Beaver Creek UT	Federal Pacific Transformer Co. Electro Mechanical Corp*	VAR510075	Stormwater	N/A	100**	751
Beaver Creek	City of Bristol, VA***	VAR040048	Stormwater	N/A	N/A	1,709,262

*Permitted load was calculated as the average annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 100 mg/L. Flow was based on the average annual runoff from urban lands.
**No limit was specified in the permit; threshold value was used.

***The City of Bristol MS4 permit sediment load was calculated based on the load contributed by urban lands in the watershed and the percentage of urban land located within the Bristol city limits.
MGD = million gallons per day

Modeling

TMDLs were developed using BasinSim 1.0 and the GWLF model. GWLF is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment, based on daily water balance totals that are summed to give monthly values.

Virginia does not currently have numeric criteria for sediment; therefore, a reference watershed approach was used to determine the sediment load that corresponds with acceptable water quality and habitat conditions necessary to support aquatic life. This approach is based on selecting a non-impaired watershed that shares similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. Sediment reductions required for the Beaver Creek watershed were based on the reference sediment load that was calculated through modeling of the Walker Creek reference watershed.

Daily streamflow data were needed to calibrate watershed hydrologic parameters in the GWLF model. The USGS streamflow gage (03478400), located on Beaver Creek at Bristol, VA, was used to calibrate hydrology for the impaired watershed (Beaver Creek). USGS gage station 03173000, located on Walker Creek at Bane, VA, was used to calibrate hydrology for the reference watershed. The calibration periods are April 1, 1990 - September 30, 2002 for the impaired watershed and April 1, 1980 through May 31, 1999 for the reference watershed. The calibration periods covered a range of hydrologic conditions, including low- and high-flow conditions as well as seasonal variations. The calibrated GWLF model adequately simulated the hydrology of the impaired watershed.

Existing Conditions

Impaired and reference watershed models were calibrated for hydrology using different modeling periods and weather input files. To establish baseline (reference watershed) loadings for sediment, the GWLF model results for Walker Creek were used. For TMDL calculation both the calibrated reference and impaired watersheds were modeled for a 9-year period from 4/1/1990 to 3/31/1999. This was done to standardize the modeling period. In addition, the total area for the reference watershed was reduced to be equal to the impaired watershed. This was necessary because watershed size influences sediment delivery to the stream and other model variables.

The 8-year means for sediment were determined for each land use/source category in the reference and the impaired watershed. This modeling period was used, after calibration, to represent a broad range of recent weather and hydrologic conditions.

Margin of Safety

While developing allocation scenarios for the TMDL, an explicit margin of safety (MOS) of ten percent was used. Ten percent of the reference sediment load was calculated and added to the sum of the load allocation (LA) and wasteload allocation (WLA) to produce the TMDL. It is assumed that a MOS of 10% will account for any uncertainty in the data and the computational methodology used for the analysis, as well as provide an additional level of protection for designated uses.

Allocation Scenarios

Load or wasteload allocations were assigned to each source category in the watersheds. Several allocation scenarios were developed for the Beaver Creek watershed to examine the outcome of various load reduction combinations. The recommended scenario for Beaver Creek (Table 7) is based on maintaining the existing percent load contribution from each source category, in general. Two additional scenarios are presented for comparison purposes (Table 8). Load reductions from agricultural sources are minimized in the first alternative and reductions from urban lands are minimized in the second alternative. The recommended scenario balances the reductions from agricultural and urban sources by maintaining existing watershed loading characteristics. In each scenario, loadings from certain source categories were allocated according to their existing loads. For instance, sediment loads from forest lands represent the natural condition that would be expected to exist; therefore, the loading from forest lands was not reduced. Also, sediment loads were reduced for the MS4 permit, but no reductions were made to other point sources because these facilities are currently meeting their pollutant discharge limits and other permit requirements. Current permit requirements are expected to result in attainment of the WLAs as required by the TMDL. Note that the sediment WLA values presented in the following tables represent the sum of all point source WLAs.

Table 7. Recommended sediment allocations for Beaver Creek

Source Category	Existing Sediment Load (lbs/yr)	Sediment % Reduction	Sediment Load Allocation (lbs/yr)
Forest	95,932	0.0%	95,932
Water	0	0.0%	0
Pasture/Hay	6,672,577	54.9%	3,009,332
Cropland	2,477,641	55.4%	1,105,028
Barren/ Transitional/ Quarries	453,705	55.5%	201,899
Urban (pervious & impervious)	588,320	55.5%	261,802
Groundwater	0	0.0%	0
Point Sources (not incl. MS4)	14,868 *Private Residence = 91* *Bristol Ready Mix = 91* *Twin City Iron & Metal Co. = 1,783* *Visador Co. = 2,158* *General Shale Bristol Concrete = 1,077* *Carolina Steel = 8,725* *V&S Galvanizing = 375* *Federal Pacific Transformer Co. = 751*	0.0%	14,868 *Private Residence = 91* *Bristol Ready Mix = 91* *Twin City Iron & Metal Co. = 1,783* *Visador Co. = 2,158* *General Shale Bristol Concrete = 1,077* *Carolina Steel = 8,725* *V&S Galvanizing = 375* *Federal Pacific Transformer Co. = 751*
MS4 Permit (point source)	1,709,261	55.0%	769,168
TMDL Load (minus MOS)	N/A	54.6%	5,458,029

Table 8. Alternative sediment allocations for Beaver Creek

Source Category	Minimize Agricultural Reductions	Minimize Urban Reductions
Forest	0.0%	0.0%
Water	0.0%	0.0%
Pasture/Hay	42.0%	68.3%
Cropland	42.0%	68.2%
Barren/Transitional/Quarries	98.0%	68.2%
Urban (pervious & impervious)	98.0%	0.0%
Groundwater	0.0%	0.0%
Point Sources (WLA)	0.0%	0.0%
MS4 Permit	99.0%	0.0%

The TMDLs established for Beaver Creek consist of a point source waste load allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The sediment TMDL for Beaver Creek was based on the total load calculated for the Walker Creek watershed (area adjusted to the impaired watershed size). Loads for urban areas have been lumped together (pervious and impervious). The sediment loadings from the impervious urban areas were estimated by multiplying literature values of the unit area loading rates (840 kg/ha/yr) times the impervious urban area in the watershed.

Note that the MS4 permit load was calculated based on the load contributed by urban (built-up) lands in the watershed and the percentage of urban land located within the Bristol city limits. The urban load expressed in these tables represents the sediment load contributed by urban lands outside the Bristol city limits - MS4 permitted area.

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

A TMDL was calculated by adding reference watershed loads for sediment together with point source loads to give the TMDL value (Table 9).

Table 9. Sediment TMDL for Beaver Creek

TMDL (lbs/yr)	LA (lbs/yr)	WLA (lbs/yr) (including MS4)	MOS (lbs/yr)	Overall % Reduction
6,064,643	4,673,993	784,036 *City of Bristol MS4 = 769,168* *Private Residence = 91* *Bristol Ready Mix = 91* *Twin City Iron & Metal Co. = 1,783* *Visador Co. = 2,158* *General Shale Bristol Concrete = 1,077* *Carolina Steel = 8,725* *V&S Galvanizing = 375* *Federal Pacific Transformer Co. = 751*	606,615	54.6%

SECTION 1

INTRODUCTION

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are violating water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (USEPA 1991).

1.1.2 Impairment Listing

Beaver Creek was listed as impaired on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the State's water quality standards for fecal coliform bacteria and violations of the General Standard (Benthics) (VADEQ 1998 and 2002a). The impaired segment is approximately 13.46 miles in length and extends from the Route 611 Bridge, near the headwaters of Beaver Creek, to the Virginia/Tennessee state line.

1.1.3 Watershed Location

The Beaver Creek watershed (Virginia WBID: VAS-O07) is located in the Tennessee-Big Sandy River Basin (HUC: 06010102). The headwaters begin in Washington County, Virginia in a mostly rural area and flow in a southwesterly direction through the City of Bristol (Virginia and Tennessee) until it confluences with the South Fork Holston River in Tennessee (Figure 1.1). Major tributaries include Clear Creek, Goose Creek, and Little Creek. The Virginia portion of the Beaver Creek watershed (delineated at the state boundary) is approximately 22,541 acres, which represents 32.3% of the entire Beaver Creek watershed (70,074 acres in Virginia and Tennessee). The watershed delineation was provided by the Tennessee Department of Environment and Conservation, Division of Water Pollution Control.

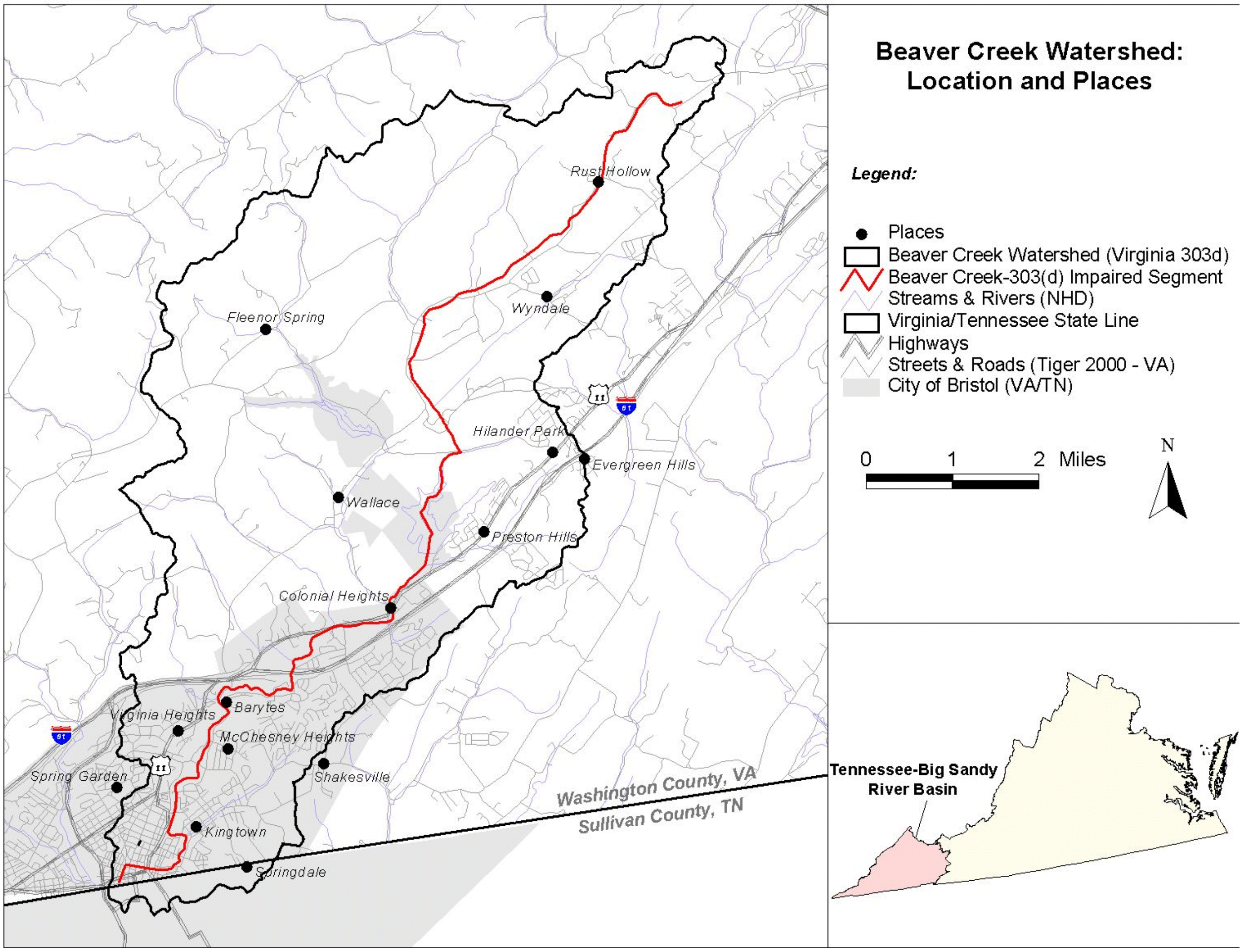

Figure 1.1 Beaver Creek watershed location (Virginia portion)

1.2 Designated Uses and Applicable Water Quality Standards

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

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

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.*

Beaver Creek partially supports the aquatic life designated use and does not support the recreational (swimming) designated use due to violations of the General Criteria (Benthic) and Bacteria Criteria.

1.2.2 Water Quality Standards

Bacteria (9 VAC 25-260-170)

Beaver Creek was listed as impaired on Virginia's 1998 and 2002 303(d) list for non-compliance with the following fecal coliform bacteria criteria:

A. General Requirements: In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 ml at any time.

Virginia's Water Quality Standards were amended to include new criteria for fecal coliform bacteria, *E. coli*, and *enterococci*. Standards were adopted for *E. coli* and *enterococci* because of the higher correlation between *E. coli* and *enterococci* concentrations and gastrointestinal illness. These new criteria became effective on January 15, 2003. Fecal coliform bacteria and *E. coli* criteria apply to Beaver Creek, which is a freshwater stream. Bacteria concentrations are expressed as the number of colony forming units per 100ml of water (cfu/100ml).

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

1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.

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

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

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

General Criteria (9 VAC 25-260-20)

A. *All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.*

   Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled.

1.3 Water Quality Assessment and TMDL Endpoint Selection

1.3.1 Bacteria Assessment

Beaver Creek was listed as impaired for fecal coliform bacteria on Virginia's 303(d) list based on monitoring conducted by VADEQ. Elevated levels of fecal coliform bacteria were recorded at several water quality monitoring stations along Beaver Creek. VADEQ began monitoring for *E. coli* in 2000 in anticipation of the change in indicator species. Elevated levels of *E. coli* have also been recorded on Beaver Creek. As a result, Beaver Creek does not currently support the recreational (swimming) beneficial use.

TMDL development requires the identification of a numeric endpoint that will allow for the attainment of designated uses and water quality criteria. The new fecal coliform bacteria criteria specified in 9 VAC 25-260-170 shall not apply after a minimum of 12 samples for *E. coli* have been collected or after June 30, 2008, whichever comes first. As a result, the applicable TMDL endpoint is compliance with the recently adopted *E. coli* criteria. Virginia's Water Quality Standards specify a maximum *E. coli* bacteria concentration of 235 cfu/100ml, at any time, and a geometric mean criteria of 126 cfu/100 ml for two or more samples over the calendar month period (9 VAC 25-260-170).

1.3.2 Biomonitoring and Assessment

Direct investigations of biological communities using rapid bioassessment protocols, or other biosurvey techniques, are best used for detecting aquatic life impairments and assessing their relative severity (Plafkin et al. 1989). Biological communities reflect overall ecological integrity; therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act. Biological communities integrate the effects of different pollutant stressors and thus provide a holistic measure of their aggregate impact. Communities also integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions.

Many state water quality agencies use benthic macroinvertebrate community data to assess the biological condition of a waterbody. Virginia uses EPA's Rapid Bioassessment Protocol (RBP II) to determine the status of a stream's benthic macroinvertebrate community. This procedure relies on comparisons of the benthic macroinvertebrate community between a monitoring station and its designated reference site. Measurements of the benthic community, called metrics, are used to identify differences between monitored and reference stations. Metrics used in the RBP II protocol include taxa richness, percent contribution of dominant family, and other measurements that provide information on the abundance of pollution tolerant versus pollution intolerant organisms. Biomonitoring stations are typically sampled in the spring and fall of each year. The biological condition scoring criteria and the bioassessment matrix are discussed in the technical document, *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish* (Plafkin et al. 1989). The RBPII bioassessment scoring matrix is presented in Table 1.1.

Table 1.1 Bioassessment scoring matrix (Plafkin et al. 1989)

% Compare to Reference Score (a)	Biological Condition Category	Attributes
>83%	Non-Impaired	Optimum community structure (composition and dominance).
54 - 79%	Slightly Impaired	Lower species richness due to loss of some intolerant forms.
21 - 50%	Moderately Impaired	Fewer species due to loss of most intolerant forms.
<17%	Severely Impaired	Few species present. Dominant by one or two taxa. Only tolerant organisms present.
(a) Percentage values obtained that are intermediate to the above ranges require subjective judgement as to the correct placement.		

Virginia 305(b)/303(d) guidance states that support of the aquatic life beneficial use is determined by the assessment of conventional pollutants (dissolved oxygen, pH, and temperature); toxic pollutants in the water column, fish tissue and sediments; and biological evaluation of benthic community data (VADEQ 2002b). Benthic community assessments are, therefore, used to determine compliance with the General Criteria section of Virginia's Water Quality Standards (9 VAC 25-260-

20). In general, the stream reach that a biomonitoring station represents is classified as impaired if the RBP ranking is classified as either moderately or severely impaired. As a result, Beaver Creek was listed as impaired due to violations of the general standard (aquatic life). Sediment TMDLs were developed for Beaver Creek, based on an analysis of potential benthic macroinvertebrate community stressors and the use of a reference watershed approach.

SECTION 2

WATERSHED CHARACTERIZATION AND MONITORING SUMMARY

2.1 Watershed Characterization

2.1.1 General Information

The Beaver Creek watershed (Virginia WBID: VAS-O07) is located in the Tennessee-Big Sandy River Basin (HUC: 06010102). The headwaters begin in Washington County, Virginia in a mostly rural area and Beaver Creek flows in a southwesterly direction through the City of Bristol (Virginia and Tennessee) until it confluences with the South Fork Holston River in Tennessee. The Virginia portion of the Beaver Creek watershed (delineated at the state boundary) is approximately 22,541 acres, which represents 32 percent of the entire Beaver Creek watershed (70,074 acres in Virginia and Tennessee). This portion of the watershed includes the impaired segment and is characterized in the following sections.

2.1.2 Geology

Beaver Creek is located in the Valley and Ridge physiographic province. The Valley and Ridge physiographic province is a belt of folded and faulted clastic and carbonate sedimentary rocks situated west of the Blue Ridge crystalline rocks and east of the Appalachian Plateaus. This area makes up part of the Great Valley subprovince, which extends from New York southwest to Alabama. This area is characterized by broad valleys with low to moderate slopes underlain by carbonate rocks. Limestone and dolomite (which are carbonate rocks) occur beneath the surface forming the most productive aquifers in Virginia's consolidated rock formations. The gently rolling lowland of the valley floor lies at an elevation of approximately 1000 feet above sea level. Sinkholes, caves, and caverns are common in the valley due to its karst (carbonate rock) geology.

2.1.3 Soils

Soils data were obtained from the State Soil Geographic (STATSGO) database which includes general soils data and map unit delineations for the United States. GIS coverages provide accurate locations for the soil map units (MUIDs) at a scale of 1:250,000 (NRCS 1994). A map unit is composed of several soil series having similar properties.

STATSGO map unit - VA003 encompasses the Beaver Creek watershed and is composed of the following soil series, in order of dominance: Frederick, Carbo, Timberville, Poynor, Chilhowie, Laidig, and Sindion. The Frederick series accounts for 66% of the map unit. The Frederick series consists of very deep, well-drained soils formed in residuum derived mainly from dolomitic limestone with interbeds of sandstone, siltstone, and shale. They are located on nearly level to very steep uplands. Permeability is moderate and slopes range from 0 to 60 percent. These soils are classified as Hydrologic Group B soils based on these properties (NRCS 1994).

2.1.4 Climate

The area's climate is typical of other valley regions in Southwest Virginia. Weather data for the Beaver Creek watershed can be characterized using the Abingdon 3 S meteorological station (National Climatic Data Center - NCDC), which is located within 5 miles of the watershed to the northeast (period of record: 1969-2003). The growing season lasts from April 27 through October 20 in a typical year (SERCC 2003). Average annual precipitation is 47 inches with July having the highest average precipitation (4.86 inches). Average annual snowfall is 16.3 inches, most of which occurs in January and February. The average annual maximum and minimum daily temperature is 66.8ºF and 41.7ºF, respectively. The highest monthly temperatures are recorded in July (85.3ºF - avg. maximum) and the lowest temperatures are recorded in January (23.4ºF - avg. minimum).

2.1.5 Land Use

General land use/land cover data for the Beaver Creek watershed were extracted from the Multi-Resolution Land Characterization (MRLC) database (USEPA 1992), as shown in Figure 2.2. This database was derived from satellite imagery taken during the early 1990s and is the most current detailed land use data available. Land uses in the watershed include various urban, agricultural, and forest categories (Table 2.1 and Figure 2.1). Nearly 50% of the watershed is forested, while approximately 32% of the watershed is used for agricultural purposes. Urban lands account for almost 17% of the watershed. Individual land use types were consolidated into six broader categories that had similar erosion/pollutant transport attributes for modeling.

Table 2.1 MRLC and consolidated land uses in the Beaver Creek watershed (Source: USEPA, 1992)

MRLC Land Use	Area (acres)	Percent	Consolidated Land Use	Area (acres)	Percent
Woody Wetlands	56.8	0.25%	Forest	11,107.1	49.27%
Emergent Herbaceous Wetlands	13.1	0.06%			
Deciduous Forest	8,647.2	38.36%			
Evergreen Forest	1,570.8	6.97%			
Mixed Forest	819.2	3.63%			
Open Water	43.0	0.19%	Water	43.0	0.19%
Pasture/Hay	6,906.1	30.64%	Pasture/Hay	6,906.1	30.64%
Row Crops	562.9	2.50%	Cropland	562.9	2.50%
Quarries/Strip Mines/Gravel Pits	16.3	0.07%	Barren/ Transitional/ Quarries	133.7	0.59%
Transitional	117.4	0.52%			
Other Grasses (Urban/recreational)	20.3	0.09%	Urban (pervious & impervious)	3,788.6	16.81%
High Intensity Residential	245.6	1.09%			
High Intensity Commercial/ Industrial/ Transportation	514.7	2.28%			
Low Intensity Residential	2,096.7	9.30%			
High Intensity Residential - impervious	163.6	0.73%			
High Intensity Commercial/ Industrial/ Transportation - impervious	514.7	2.28%			
Low Intensity Residential - impervious	233.0	1.03%			
Total	22,541	100%	Total	22,541	100%

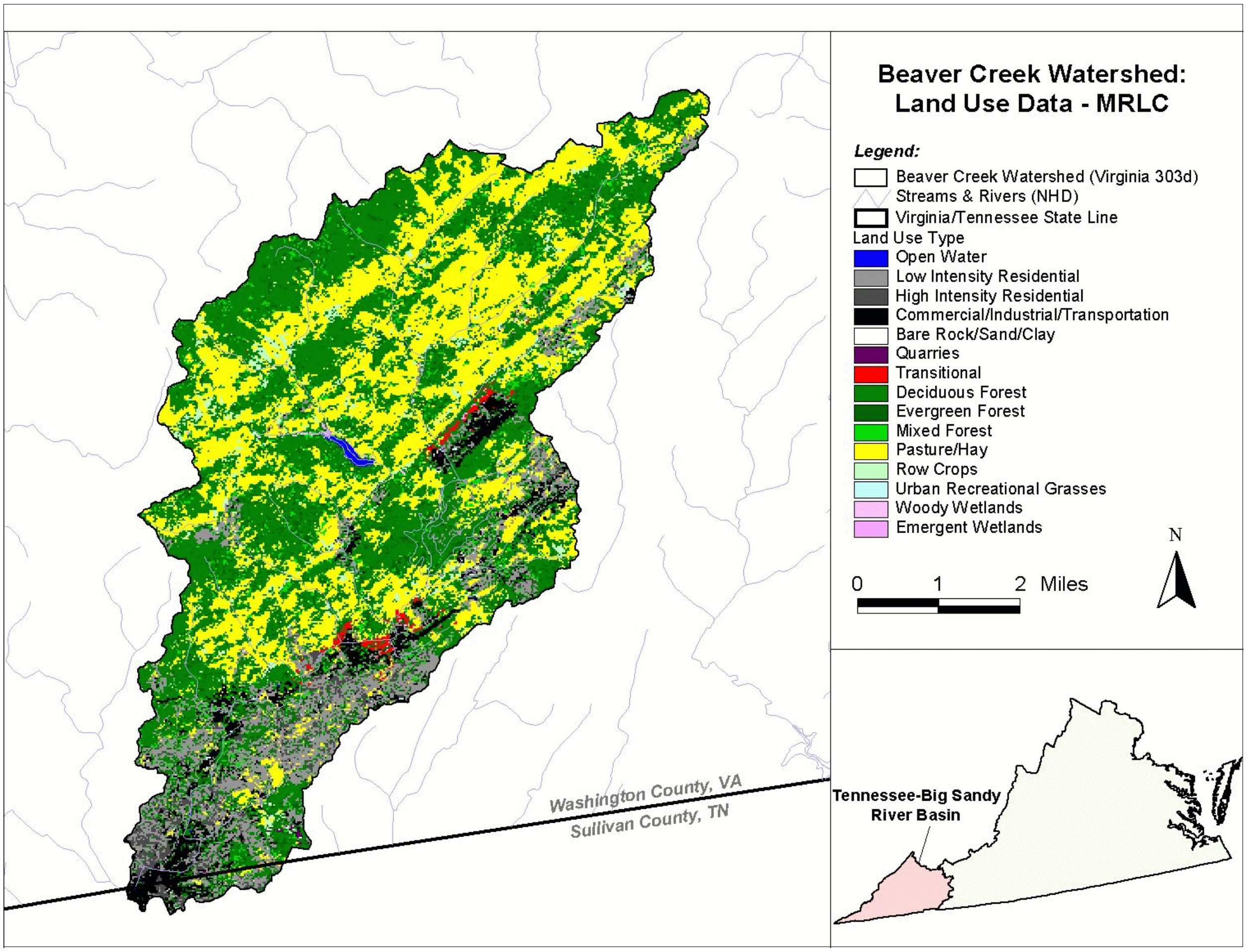

Figure 2.1 MRLC land uses in the Beaver Creek watershed (Source: US EPA, 1992)

2.1.6 Ecoregion

Beaver Creek is located in the Valley and Ridge ecoregion - Level III classification 67 (Woods et al. 1999). This ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia. It is characterized by alternating forested ridges and agricultural valleys that are elongated, folded and faulted. The region's roughly parallel ridges and valleys have a variety of widths, heights, and geologic materials, including limestone, dolomite, shale, siltstone, and sandstone. The valleys generally fall into two types, those underlain by limestone and those underlain by shale. The nutrient rich limestone valleys contain productive agricultural land and tend to have few streams. By contrast, the shale valleys are generally less productive, more irregular, and have greater densities of streams. Most of the streams in the limestone valleys are colder and flow all year, whereas those in the shale valleys tend to lack flow in dry periods. Limestone areas commonly have numerous springs and caves. Present-day forests cover about 50% of the region. A diversity of aquatic habitats and species of fish exist in this ecoregion due to the variation in its components.

At a finer scale, the Beaver Creek watershed is located in the Southern Limestone/Dolomite Valleys - Level IV classification 67f (Woods et al. 1999) (Figure 2.3). The Southern Limestone/Dolomite Valleys subecoregion is a lowland characterized by broad, undulating, fertile valleys that are extensively farmed. Sinkholes, underground streams, and other karst features have developed on the underlying limestone/dolomite, and as a result, the drainage density is low. Where streams occur they tend to have gentle gradients, plentiful year round flow, and distinctive fish assemblages. Ordovician and Cambrian limestone and dolomite commonly underlie the region. Interbedded with the carbonates are other rocks, including shale. Crestal elevations vary from 1,640 to 3,200 feet. Local relief typically ranges from 150 to 500 feet

2.2 Stream Characterization

Beaver Creek flows predominantly through pasture/hay and forest lands before continuing through the City of Bristol in the lower reach. Several mainstem and tributary sections were placed in underground culverts years ago to allow for construction of city buildings and other structures. Other sections have been channelized and urban encroachment into riparian areas has occurred. Streams show evidence of de-stabilization including bank erosion, down-cutting (erosive deepening of the stream channel), and excessive sedimentation. This de-stabilization is likely caused by hydromodification of the stream channel due to increased runoff from impervious areas and stormwater outfalls during storm events. Stream banks have been armored with rip-rap or retaining walls in some sections to prevent bank erosion and slumping. Downstream areas of Beaver Creek have also been negatively impacted by erosion from agricultural lands and riparian disturbances.

2.3 Water Quality and Biomonitoring Summary

2.3.1 Monitoring Stations

There are twelve VADEQ water quality and biomonitoring stations located in the Beaver Creek watershed. Three other stations (6CBEV021.44, 6CBEV021.45, and 6CCLE002.89) were only monitored in the 1970s (limited data) and are not included in this report. VADEQ maintains two biomonitoring stations on Beaver Creek: 6CBEV023.99 (located downstream of Bristol Industrial Park at Rt. 625) and 6CBEV024.60 (located upstream of the Bristol Industrial Park). Biomonitoring data collected at these stations were used to assess Beaver Creek as impaired for aquatic life. As part of the benthic TMDL study, George Mason University (GMU) personnel also conducted water quality and biomonitoring at six stations in the watershed in 2003. Several of these stations are co-located with VADEQ monitoring stations. Benthic samples collected at GMU stations BeaverCrWQ4, BeaverCrWQ5, and BeaverCrWQ6 are currently being processed. In addition, a thesis study was conducted by Emory and Henry College (EHC) to assess water quality conditions and provide a general characterization of Beaver Creek. Ten stations were monitored in 2001 and 2002 as part of the EHC study. VADEQ, GMU, and EHC monitoring stations located in the Beaver

Creek watershed are presented in Table 2.2 and shown in Figure 2.2. The water quality data periods shown in Table 2.2 include field parameters collected during biomonitoring site visits. Note that VADEQ station 6CBEV021.07 referenced in the 2002 303(d) Fact Sheet is now listed as station 6CBEV020.86 due to river mile re-classification using the National Hydrography Dataset (NHD).

Table 2.2 Monitoring stations on Beaver Creek

Station	Organization	Station Type	Location	Data Period
6CBEV015.27	VADEQ	WQ	State Street and 8th in Bristol	1980-2003
6CBEV015.62	VADEQ	WQ	Lee St. Bridge #8020, beside Bri. Fire Dept.	2001-2003
6CBEV016.59	VADEQ	WQ	Vermont & Fairview Avenues, Bridge #8001	2001-2003
6CBEV017.15	VADEQ	WQ	Elm Street Bridge #8027 & Mumpower Drive	2001-2003
6CBEV017.96	VADEQ	WQ	McChesney Dr. Bridge # 0025, Elecro Plant	2001-2003
6CBEV019.21	VADEQ	WQ	Beaver Creek Drive at YMCA Pool	2001-2003
6CBEV020.82	VADEQ	WQ	Approx. 100 yds downstream of 6CBEV020.86 at Rt. 11	2001-2003
6CBEV020.86	VADEQ	WQ	at Bristol off Rt. 11 at Sonic Burger Bridge (old station 6CBEV021.07)	1980-2002
6CBEV020.90	VADEQ	WQ	Upstream of confluence of Goose and Beaver Creeks	2001-2002
6CBEV022.29	VADEQ	WQ	Sugar Hollow Park foot bridge between D & F	2001-2003
6CBEV023.99	VADEQ	Bio	Downstream of Bristol Industrial Park at Rt. 625	1992-2002
6CBEV024.60	VADEQ	Bio	Above Bristol Industrial Park	1992-1993
BeavCrWQ1	GMU	WQ, Bio	Beaver Cr@625 (VADEQ 6CBEV023.99)	4/2003 (WQ) & 6/2003
BeavCrWQ2	GMU	WQ, Bio	Beaver Cr above Indus Site nr. Railroad Crossing (VADEQ 6CBEV024.60)	4/2003 (WQ) & 6/2003
BeavCrWQ3	GMU	WQ, Bio	Beaver Cr @Alexis Dr off Lee Hwy (Pal's Sudden Service) (VADEQ 6CBEV020.86 & USGS gauge)	4/2003 (WQ) & 6/2003
BeavCrWQ4	GMU	WQ, Bio	Beaver Cr@Beaver View Dr (Swim Club) (VADEQ 6CBEV019.21)	4/2003 (WQ) & 6/2003
BeavCrWQ5	GMU	WQ, Bio	Beaver Cr@Elm St.(along Mumpower Dr) (VADEQ 6CBEV017.15)	4/2003 (WQ) & 6/2003
BeavCrWQ6	GMU	WQ, Bio	Beaver Cr@State Line (8th St.)	4/2003 (WQ) & 6/2003
Site 1	EHC	WQ	Sugar Hollow Park	3/2001 - 4/2002
Site 2	EHC	WQ	Clear Creek at Dunn Brothers	3/2001 - 4/2002
Site 3	EHC	WQ	Mumpower Park	3/2001 - 4/2002
Site 4	EHC	WQ	Vermont Avenue	3/2001 - 4/2002
Site 5	EHC	WQ	Cumberland Square Park	3/2001 - 4/2002
Site 6	EHC	WQ	Corner of 8th and Shelby	3/2001 - 4/2002
Site 7	EHC	WQ	Down from Viking Hall (6th Street Extension):	3/2001 - 4/2002
Site 8	EHC	WQ	Landmark Lane	3/2001 - 4/2002
Site 9	EHC	WQ	Rooster Front Park	3/2001 - 4/2002
Site 10	EHC	WQ	Volunteer Baptist Church	3/2001 - 4/2002

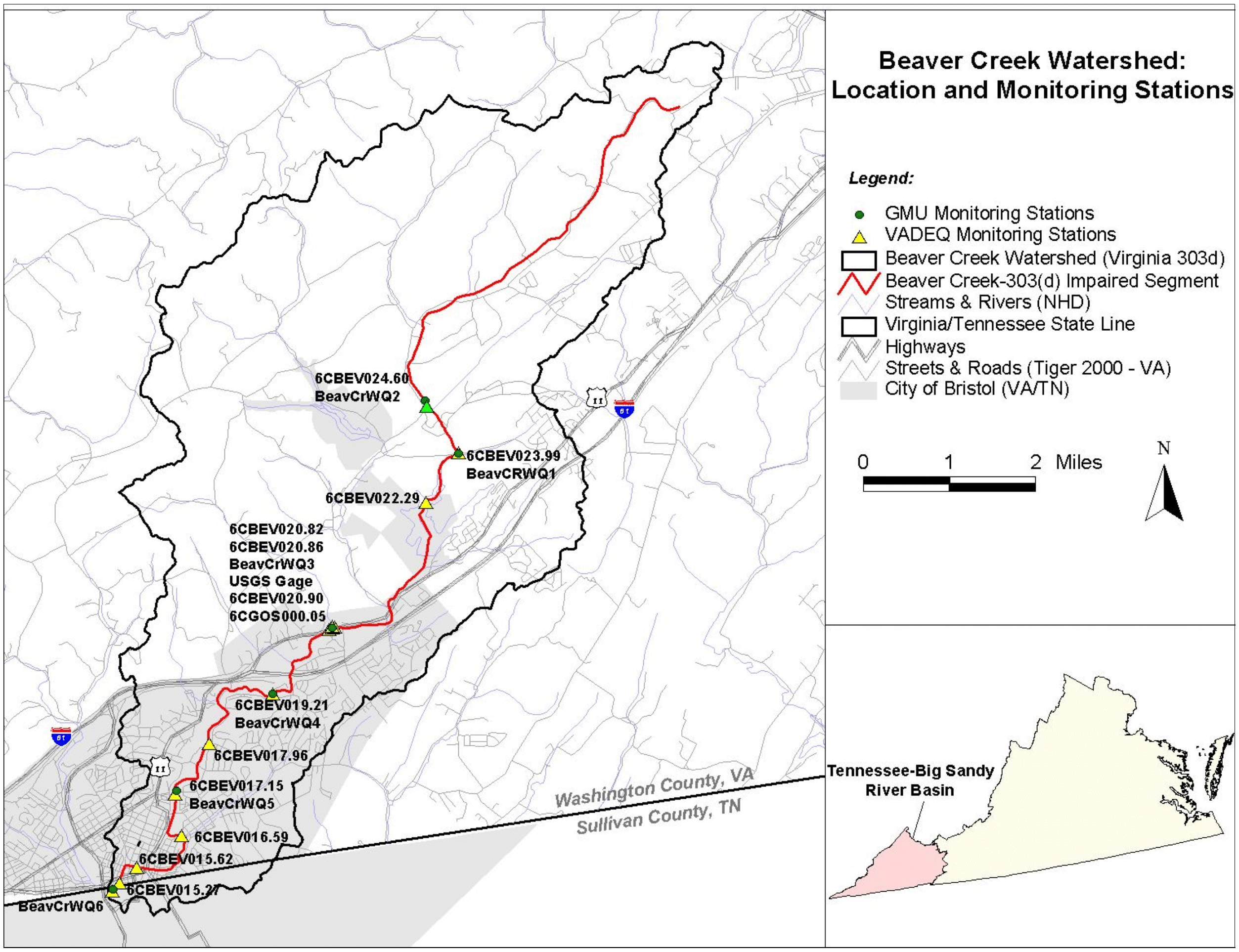

Figure 2.2 Monitoring stations on Beaver Creek

2.3.2 Fecal Coliform Bacteria and *E. coli* Data

Data collected by VADEQ from January 3, 1980 through June 11, 2003 were compared to the new instantaneous criteria for fecal coliform bacteria and *E. coli*. Bacteria Source Tracking (BST) data were also collected by VADEQ at station 6CBEV015.27 from September 5, 2002 through August 5, 2003. These data were also included in the following analysis. The results of the BST study are presented in Section 2.3.3.

The bacteria data collected at each VADEQ monitoring station are summarized in Table 2.3.

Table 2.3 Bacteria monitoring summary

Station	Date	Sample Type[1]	Count	Min-Max	Instantaneous Criteria FC: 400 cfu EC: 235 cfu (% Violations)
6CBEV015.27	1/3/80 -8/5/03	FC	162	0-24,200	94
	3/7/00 -8/5/03	EC	18	250-14,000	100
6CBEV015.62	8/28/01 - 6/11/03	FC	12	200-6,000	92
		EC	**no data**		
6CBEV016.59	8/28/01 - 6/11/03	FC	12	100-3,300	42
		EC	**no data**		
6CBEV017.15	8/28/01 - 6/11/03	FC	12	100-1,700	58
		EC	**no data**		
6CBEV017.96	8/28/01 - 6/11/03	FC	12	100-900	33
		EC	**no data**		
6CBEV019.21	8/28/01 - 6/11/03	FC	12	100-1,500	50
		EC	**no data**		
6CBEV020.82	10/2/01 - 6/11/03	FC	20	50-2,000	30
	7/22/02 - 6/11/03	EC	11	20-800	36
6CBEV020.86	1/3/80 - 1/28/02	FC	154	0-8,000	61
		EC	**no data**		
6CBEV020.90	10/2/01 - 1/28/02	FC	4	200-400	0
		EC	no data		
6CBEV022.29	8/28/01 - 6/11/03	FC	12	100-6,000	50
		EC	**no data**		

[1] Sample type: FC = Fecal Coliform Bacteria, EC = *E. coli*

The upper limit of laboratory analysis was typically 6,000 or 8,000 cfu/100 ml, depending on collection date. Therefore, many of these samples likely represent concentrations much higher than these limits. The percent violation analysis and the number of extremely high concentrations provide insight into the magnitude of the bacteria contamination problems in this stream. Violations occurred in all flow regimes.

2.3.3 Bacteria Source Tracking (BST)

VADEQ collected BST data at station 6CBEV015.27 for a period of one year from September 5, 2002 through August 5, 2003 (12 monthly samples) to help identify the predominant sources of bacteria in the watershed (Table 2.4). Fecal coliform bacteria and *E. coli* concentrations were measured and the Antibiotic Resistance Analysis (ARA) methodology was used to determine the likely sources of bacteria in each sample. This methodology provides information on the presence or absence of human, pet, livestock, and wildlife sources in the watershed. No information was provided for upstream areas of the watershed.

Table 2.4 BST results for VADEQ station 6CBEV015.27

Date	Fecal concentration (cfu/100ml)	*E. coli* concentration (cfu/100ml)	Wildlife (%)	Human (%)	Livestock (%)	Pets (%)
9/5/02	1600	14000	**33**	**46**	8	13
10/23/02	850	830	**33**	4	4	**59**
11/21/02	600	480	8	**29**	**42**	**21**
12/16/02	2000	410	4	**17**	**58**	**21**
1/27/03	2500	800	**29**	8	13	**50**
2/18/03	2900	830	**50**	4	**38**	8
3/4/03	780	250	**29**	**17**	**33**	**21**
4/21/03	2500	1600	**62**	4	13	**21**
5/21/03	10000	5200	**49**	**21**	13	**17**
6/9/03	17000	4000	**50**	**25**	**17**	8
7/21/03	8500	1500	**42**	**21**	**33**	4
8/5/03	15000	1900	**14**	**19**	**38**	**29**

* bold values were statistically significant

2.3.4 Biomonitoring Data

VADEQ currently uses the EPA Rapid Bioassessment Protocol (RBP II method) to determine the impairment status of monitored streams based on comparisons to reference streams. Stations 6CBEV023.99 and 6CBEV024.60 were sampled on 11/20/92 and 10/29/93. These data indicated a moderate impairment of the benthic macroinvertebrate community on each occasion, which resulted in the impairment listing. Station 6CBEV023.99 was also sampled on 4/30/02 and was assessed as slightly impaired.

2.3.5 Virginia Stream Condition Index (VaSCI)

Available biomonitoring data were summarized to help characterize the benthic community in Beaver Creek. The Virginia Stream Condition Index (VaSCI) was used to assess the biological community in each stream. The benthic multimetric scores provided by this index allow for a more detailed and reliable assessment of the benthic macroinvertebrate community in Virginia's non-coastal, wadeable streams (USEPA 2003). VADEQ and GMU biomonitoring data were used to calculate the VaSCI score for each station (Table 2.5). The upstream VADEQ biomonitoring station, 6CBEV024.60, had the highest VaSCI scores for the period of record. These scores are lower than comparable scores at several reference stations in the region.

Table 2.5 VaSCI standardized scores for Beaver Creek

Station ID	Organization	Stream	Sample Date	VaSCI Index Score
6CBEV023.99	DEQ	Beaver Creek	11/20/92	47
			10/25/93	43
			04/30/02	54
Beaver1	GMU		06/25/03	40
			Average	46
6CBEV024.60	DEQ	Beaver Creek	11/20/92	59
			10/25/93	51
Beaver2	GMU		06/25/03	38
			Average	49
Beaver3	GMU	Beaver Creek	06/25/03	55
			Average	55

SECTION 3

SOURCE ASSESSMENT - BACTERIA

Point and nonpoint sources of bacteria in the Beaver Creek watershed were considered in TMDL development. The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources including, agricultural and land use information, water quality monitoring and point source data, local housing and other spatial coverages, past TMDL studies, literature sources, and other information. Procedures and assumptions used in estimating bacteria loads are described in the following sections.

3.1 Assessment of Nonpoint Sources

Intense agricultural areas in the upper portion of the watershed and urban areas downstream (City of Bristol) are listed as contributing to water quality impacts, according to the 2002 303(d) fact sheet for Beaver Creek. Nonpoint sources of bacteria can include failing septic systems and leaking sewer lines, straight pipes, livestock (including manure application loads), wildlife, and domestic pets. The representation of the following sources in the model is discussed in Section 4.

3.1.1 Septic Systems and Straight Pipes

Residential septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. Fecal coliform bacteria naturally die-off as the effluent percolates through the soil to the groundwater. These systems effectively remove fecal coliform bacteria when properly installed and maintained.

A septic system failure occurs when there is a discharge of waste to the soil surface where it is available for washoff into surface waters. Failing septic systems can deliver high bacteria loads to surface waters, depending on the proximity of the discharge to a stream and the timing of rainfall events. Septic system failures typically occur in older systems that are not adequately maintained with periodic sewage pump-outs.

An estimated 4,050 people live in houses with a septic system or other means of sewage disposal (e.g., straight pipe) in the Beaver Creek watershed, as determined using the following methods. U.S. Census block-group data for 2000 and 1990 were used to estimate the population served by sewer systems, septic systems, and other means (Census 1990 and 2000). The 2000 Census questionnaire did not include information regarding the type of sewage disposal means, as did the 1990 Census. The ratio of the 1990 population served by each type of system was used to determine the current population served by septic systems and other means.

The number of failing septic systems was estimated using a failure rate of 20% based on discussions with Virginia Department of Health personnel and review of failure rates used in other TMDL watersheds with a significant urban population. A fecal coliform bacteria concentration of 10^5 cfu/100mL and a septic system waste flow of 70 gallons/person/day was used to estimate the contribution from failing septic systems to surface waters (Metcalf and Eddy, Inc. 1991). In some cases, human waste is directly deposited into surface waters from houses without septic systems. These “straight pipes” and other illicit discharges are illegal under Virginia regulations. Houses with straight pipes are typically older structures that are located in close proximity to a stream. The population served by straight pipes was assumed to be 1% of the total septic/other disposal means population in the watershed. Houses considered to have a normal functioning septic system were assumed to have a negligible contribution of fecal coliform bacteria to surface waters.

3.1.2 Livestock

Animal population estimates for the Beaver Creek watershed were based on the 1997 and 2002 Virginia Agricultural Census data for Washington County (VASS 1997 and 2002) and information provided by the Holston River Soil and Water Conservation District (HRSWCD) and local Natural Resources Conservation Service (NRCS) personnel (Wayne Turley, HRSWCD, pers. comm. 2004) (Table 3.1). A weighted average was used to estimate the population of horses, hogs/pigs, sheep/lambs, and turkeys in the watershed using county agricultural census data and the percentage of pasture/hayland in the watershed. Population estimates for beef cattle and calves, dairy cattle and replacement heifers, and chickens were based on data provided by HRSWCD and NRCS personnel. Other livestock animals had very small populations as compared to the major livestock species listed in the table; therefore, the fecal loads from these animals were assumed to be negligible.

Table 3.1 Livestock population estimates

Livestock Species	Beaver Creek Population
Beef Cattle + Calves (5-weight average)	1,676 + 2,243
Dairy Cattle + Replacement Heifers	245 + 245
Horses	298
Hogs/Pigs	15
Sheep/Lambs	112
Chickens (pullets, layers, and broilers)	800,000
Turkeys	negligible

Bacteria produced by livestock can be deposited on the land, directly deposited in the stream (as is common when grazing animals have stream access), manually applied to cropland and other agricultural lands as fertilizer, or contributed to surface waters through illicit discharges from animal confinement areas. Bacteria deposited on the land, either directly or through manure application, are available for washoff into surface waters during rainfall events. There are no known illicit discharges of animal waste in the watershed.

Grazing animals, such as beef and dairy cattle, typically spend portions of the day confined to loafing lots, grazing on pasture lands, and watering in nearby streams. The percentage of time spent in each area effects the relative contribution of bacteria loads to the stream. The amount of time beef and dairy cattle spend in or near streams primarily depends on time of year and the availability of stream access and off-stream watering facilities. Estimates of the amount of time cattle spend in these different areas were based on HRSWCD/NRCS data, a recent study funded by the Virginia Department of Conservation and Recreation entitled *Modeling Cattle Stream Access* (VADCR 2002) and watershed modeling results. Beef cattle data are presented in Table 3.2. Beef cattle typically spend more time grazing in open areas than dairy cattle, which are confined for milking several hours a day. There are two dairy farms in the Beaver Creek watershed, which are located in different subwatersheds. The grazing/confinement data for these two farms are presented in Tables 3.3 and 3.4, by subwatershed. Beaver Creek subwatersheds are shown in Section 4 (Figure 4.5). Horse and sheep estimates were based on the data used to develop fecal coliform bacteria TMDLs for Cedar Creek, Hall/Byers Creek, and Hutton Creek in Washington County, Virginia (VADEQ 2000a).

Table 3.2 Beef Cattle - time spent grazing, in confinement, and in streams

Month	Grazing (hours/day)	Loafing Lot - Confinement (hours/day)	Stream Access (hours/day)
January	23.75	0	0.25
February	23.75	0	0.25
March	23.5	0	0.5
April	23.25	0	0.75
May	23.25	0	0.75
June	23	0	1
July	23	0	1
August	23	0	1
September	23.25	0	0.75
October	23.5	0	0.5
November	23.5	0	0.5
December	23.75	0	0.25

Table 3.3 Dairy Cattle (Subwatershed 12) - time spent grazing, in confinement, and in streams

Month	Grazing (hours/day)	Loafing Lot - Confinement (hours/day)	Stream Access (hours/day)
January	2.80	21.12	0.08
February	2.80	21.12	0.08
March	4.19	19.68	0.13
April	6.52	17.28	0.20
May	7.69	16.08	0.23
June	8.15	15.6	0.25
July	8.85	14.88	0.27
August	8.85	14.88	0.27
September	8.85	14.88	0.27
October	8.39	15.36	0.25
November	7.22	16.56	0.22
December	5.36	18.48	0.16

Table 3.4 Dairy Cattle (Subwatershed 15) - time spent grazing, in confinement, and in streams

Month	Grazing (hours/day)	Loafing Lot - Confinement (hours/day)	Stream Access (hours/day)
January	20.98	2.8	0.55
February	20.98	2.8	0.22
March	19.39	4.19	0.42
April	16.92	6.52	0.56
May	15.79	7.69	0.52
June	15.17	8.15	0.68
July	14.50	8.85	0.65
August	14.50	8.85	0.65
September	14.67	8.85	0.48
October	15.28	8.39	0.33
November	16.43	7.22	0.35
December	18.45	5.36	0.19

Collected manure from livestock animals was applied to cropland and pasture in the Beaver Creek watershed based on manure application information presented in the Cedar Creek, Hall/Byers Creek, and Hutton Creek TMDLs (VADEQ 2000a). The majority of the manure collected was applied to cropland (75%) in spring and fall months. A small percentage of the manure collected was applied to pastureland areas in the winter and summer months. Cattle and poultry manure represent the primary sources of land-applied livestock waste. Turkeys and chickens are confined to poultry houses and hogs are confined to feed lots in the watershed; therefore, the litter produced is manually applied to cropland and pasture. HRSWCD and NRCS personnel indicated that approximately 25% of the chicken litter produced is applied to agricultural land in the Beaver Creek watershed (75% is exported or applied to land outside the watershed).

The application of collected manure for these species follows the schedule listed in Table 3.5. The manure is used to fertilize corn and other primary crops in the spring and winter wheat in the fall. Tillage allows for the incorporation of fecal coliform bacteria that is applied to the soil surface. Based on field observations of cropland in the watershed and past TMDL studies, it was assumed that 25% of the manure that was applied was incorporated into the soil, resulting in 75% of the fecal coliform bacteria load being available for washoff.

Table 3.5 Livestock - Fraction of the annual manure application that is applied each month

Month	Livestock Manure Fraction Applied
January	0.0375
February	0.0375
March	0.075
April	0.15
May	0.075
June	0.0375
July	0.075
August	0.0375
September	0.0375
October	0.075
November	0.075
December	0.0375

Fecal coliform bacteria production rates used for livestock species in the Beaver Creek watershed are listed in Table 3.6. A variety of sources, including past TMDL studies and literature sources, were consulted to determine the appropriate daily fecal coliform bacteria production value for each species.

Table 3.6 Livestock fecal coliform bacteria production rates

Livestock Species	Daily Production (cfu/animal/day)	Primary Sources
Beef cattle	4.46×10^{10}	ASAE 1998, USGS 2002
Dairy cattle	3.90×10^{10}	ASAE 1998, USGS 2002
Chickens	6.75×10^{7}	ASAE 1998, USGS 2002
Turkeys	9.30×10^{7}	ASAE 1998, USGS 2002
Hogs/Pigs	1.08×10^{10}	ASAE 1998, USGS 2002
Sheep	1.96×10^{10}	ASAE 1998, USGS 2002

3.1.3 Wildlife

Wildlife species in the watershed were identified through consultation with the Virginia Department of Game and Inland Fisheries (VDGIF) and local residents familiar with wildlife populations in the area. The predominant species include ducks, geese, deer, beaver, raccoon, and muskrat. A colony of federally endangered gray bats (*Myotis grisescens*) also exists in the watershed and is the only maternal colony in Virginia (Kevin Hamed, Virginia Highlands Community College, pers. comm. 2004). The colony includes approximately 3,000 to 4,500 bats, which live under Piedmont Avenue in the City of Bristol (near the mouth of Beaver Creek).

The population of each wildlife species (except gray bats) was estimated using the population density per square mile of habitat area and the total area of suitable habitat in the watershed (Table 3.7). Habitat areas were determined using GIS and the watershed land use coverage (MRLC). The density and habitat assumptions used to estimate the population of each wildlife species were updated based on information provided by state and local VDGIF personnel. Population estimates and the defined habitat of each species in the Beaver Creek watershed are listed in Table 3.8.

Table 3.7 Wildlife population density by land use (# animals per square mile of habitat)

Land Use	Ducks		Geese		Deer	Beaver	Raccoon	Muskrat
	Summer	Winter	Summer	Winter				
Cropland	30	40	50	70	0	5	2.5	320
Pasture/Hay	30	40	50	70	16	5	2.5	160
Forest	10	20	0	0	16	10	5	160
Built-Up (Urban)	30	40	50	70	0	5	2.5	320

Table 3.8 Wildlife habitat descriptions, population estimates, and percent of time spent in streams

Wildlife Species	Habitat Description	# of Animals	% in Streams
Ducks	100 meter buffer around perennial streams for all land uses	126 in summer 187 in winter	2.5%
Geese	100 meter buffer around perennial streams for Pasture/Hay, Cropland, and Built-Up	160 in summer 224 in winter	2.5
Deer	25 deer/mi^2 for Pasture and Forest	153 year-round	1
Beaver	20 meter buffer around perennial streams for all land uses	1 year-round	50
Raccoon	0.5 mile buffer around perennial streams for all land uses	119 year-round	1
Muskrat	20 meter buffer around perennial streams for all land uses	238 year-round	2.5

As with grazing livestock, wildlife deposit on the land and directly to surface waters. The percentage of fecal coliform bacteria that was directly deposited to surface waters was estimated based on the habitat of each species. The remaining fecal coliform bacteria load was applied to the upland land uses, according to the total area of each land use within established habitat areas. The daily fecal coliform bacteria production value for each wildlife species was used to calculate bacteria loads (Table 3.9).

Table 3.9 Fecal coliform bacteria production rates for wildlife species

Wildlife Species	Daily Production (cfu/animal/day)	Primary Sources
Ducks	7.35×10^9	ASAE 1998, USGS 2002
Geese	7.99×10^8	USGS 2002
Deer	3.47×10^8	VADEQ 2001
Beaver	2.0×10^5	VADEQ 2000b
Raccoon	5.0×10^9	VADEQ 2001
Muskrat (daily production rate also used for bats, no other information exists)	2.5×10^7	VADEQ 2001

3.1.4 Domestic Pets

Domestic pets were also considered in source assessment and watershed modeling. The bacteria contribution from domestic pets was represented by the waste deposited by dogs. The contribution from other pets was considered negligible. Housing estimates were used to determine the number of dogs in the watershed (Census 2000). Based on the assumption of one dog for every two households, the number of dogs in the Beaver Creek watershed was estimated to be approximately 3,255. The fecal coliform concentration in dog waste is 1.85×10^9 cfu/100mL (Mara and Oragui 1981).

3.2 Assessment of Point Sources

Point sources, such as municipal sewage treatment plants, can contribute fecal coliform bacteria loads to surface waters through effluent discharges. These facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ. There are currently two point sources of bacteria in the Beaver Creek watershed (Table 3.10). A Municipal Separate Storm Sewer System (MS4) permit was issued to the City of Bristol to help control impacts caused by stormwater runoff from urban areas. The bacteria load contributed by the MS4 permit during runoff events was calculated based on the modeling results for urban lands located within the City of Bristol and the Beaver Creek watershed. A domestic sewage general permit was also issued to one private residence located in the watershed. The bacteria load contributed by this private residence was calculated based on the permitted flow (1000 gallons/day) and the applicable *E. coli* limit (126 cfu/100ml, geometric mean concentration).

Table 3.10 VPDES point source facilities

VPDES Permit No.	Facility Name	Discharge Type
VAG400012	Private Residence	Treated Domestic Sewage
VAR040048	City of Bristol, MS4	Stormwater

SECTION 4

WATERSHED MODELING - BACTERIA

Establishing the relationship between the in-stream water quality targets and source loadings is a critical component of TMDL development. It allows for evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. The objective of this section is to present the approach taken to develop the linkage between sources and in-stream response for the development of bacteria TMDLs for Beaver Creek.

4.1 Modeling Framework Selection

Selection of the appropriate approach or modeling technique required consideration of the following:

- Expression of water quality criteria
- Dominant processes
- Source integration
- Scale of analysis
- Efficient TMDL scenario evaluation

The applicable criteria for bacteria are presented in Section 1. Numeric criteria require evaluation of magnitude, frequency, and duration. Thresholds of a numeric measure are often evaluated for frequency of exceedance. Acute standards typically require evaluation over short time periods and violations may occur under variable flow conditions. Chronic criteria require the evaluation of the response over a monthly averaging period. The *E. coli* criteria are presented as both a geometric mean using a minimum of two consecutive samples over a calendar month and an instantaneous maximum standard. The approach or modeling technique must permit representation of in-stream concentrations under a variety of flow conditions in order to evaluate critical periods for comparison to chronic and acute criteria.

The appropriate approach must also consider the dominant processes regarding pollutant loadings and in-stream fate. For the Beaver Creek watershed, primary sources contributing to the bacteria impairment include an array of nonpoint or diffuse sources as well as discrete direct inputs to the stream either by permitted point source discharges or animal direct deposition to the stream. Loading processes for nonpoint sources or land-based activities are typically rainfall-driven and thus relate to surface runoff and subsurface discharge to a stream.

Key in-stream factors that must be considered include routing of flow, dilution, transport, and fate (decay or transformation) of bacteria. In the Beaver Creek watershed, the primary physical process affecting the transport of bacteria is the die-off rate.

Scale of analysis and waterbody type must also be considered in the selection of the overall approach. The approach should have the capability to evaluate watersheds at multiple scales, and be able to adequately represent the spatial distribution of sources and the delivery processes whereby bacteria are delivered throughout the stream network.

Based on the considerations described above, analysis of the monitoring data, review of the literature, characterization of the bacteria sources, the need to represent source controls to individual sources, and previous modeling experience, the Loading Simulation Program C++ (LSPC) was selected to represent the source-response linkage in the Beaver Creek watershed. LSPC, the primary watershed modeling system for the EPA TMDL Toolbox, is currently maintained by the EPA Office of Research and Development in Athens, GA (http://www.epa.gov/athens/wwqtsc).

4.1.1 Loading Simulation Program C++ (LSPC) Overview

LSPC is a watershed modeling system that includes the Hydrologic Simulation Program Fortran (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream transport model. A key data management feature of this system is that it uses a Microsoft Access database to manage model data and weather text files for driving the simulation. The system also contains a module to assist in TMDL calculation and source allocations. For each model run, it automatically generates comprehensive text-file output by subwatershed for all land-layers, reaches, and simulated modules, which can be expressed on hourly or daily intervals. Output from LSPC has been linked to other model applications such as EFDC, WASP, and CE-QUAL-W2. LSPC has no inherent limitations in terms of modeling size or model operations. The Microsoft Visual C++ programming architecture allows for seamless integration with modern-day, widely available software such as Microsoft Access and Excel.

LSPC was designed to facilitate data management for large-scale or complex watershed modeling applications. The model has been successfully used to model watershed systems composed of over 1,000 subwatersheds at a National Hydrography Dataset (NHD) stream-segment scale. The system is also tailored for source representation and TMDL calculation. The LSPC GIS interface, which is compatible with ArcView shapefiles, acts as the control center for launching watershed model scenarios. This stand-alone interface easily communicates with both shapefiles and an underlying Microsoft Access database, but does not directly rely on either of these main programs. Therefore, once a watershed application is created, it is easily transferable to users who may not have ArcView or MS Access installed on their computers.

Selected HSPF modules were re-coded in C++ and included in the LSPC model. LSPC's algorithms are identical to those in HSPF. Table 4.1 presents the modules from HSPF that are incorporated in LSPC. The user may refer to the Hydrologic Simulation Program FORTRAN User's Manual for a more detailed discussion of simulated processes and model parameters (Bicknell et al. 1996).

Table 4.1 HSPF modules available and supported in the LSPC watershed model

Simulation Type	HSPF Module	HSPF Module Description
Land Based Processes	PWATER	Water budget for pervious land
	IWATER	Water budget for impervious land
	SNOW	Incorporates snow fall and melt into water budget
	SEDMNT	Production and removal of sediment
	PWTGAS	Est. water temperature, dissolved gas concentrations
	IQUAL	Simple relationships with solids and water yield
	PQUAL	Simple relationships with sediment and water yield
In-stream Processes	HYDR ADCALC	Hydraulic behavior, pollutant transport
	CONS	Conservative constituents
	HTRCH	Heat exchange, water temperature
	SEDTRN	Behavior of inorganic sediment
	GQUAL	Generalized quality constituent

Meteorological Data Processing

Weather conditions are the driving force for watershed hydrology processes. For the simulation options selected for the Beaver Creek watershed model, the required parameters include hourly precipitation and hourly potential evapotranspiration. Precipitation is measured, while potential evapotranspiration is empirically computed using temperature and latitude data. Table 4.2 summarizes the weather data that were used to develop the Beaver Creek watershed model. These data were obtained from the listed National Climatic Data Center (NCDC) meteorological stations.

Table 4.2 NCDC meteorological datasets compiled for Beaver Creek watershed model

Station ID	Timestep	Data Type	Station Name	Start Date	End Date	Elevation (ft)	Percent Complete
TN1094	Hourly	Precipitation	BRISTOL AP	5/1/1948	12/31/2002	1,500	100%
VA8547	Hourly	Precipitation	TROUT DALE 3 SSE	1/1/1984	12/25/2002	2,820	77%
VA9215	Hourly	Precipitation	WISE 3 E	9/1/1948	12/26/2002	2,549	87%
440021	Daily	Precipitation	ABINGDON 3 S	1/1/1969	12/31/2002	1,920	95%
440021	Daily	Min Temperature	ABINGDON 3 S	1/1/1969	12/31/2002	1,920	96%
440021	Daily	Max Temperature	ABINGDON 3 S	1/1/1969	12/31/2002	1,920	96%

There are no NCDC meteorological stations located within the Beaver Creek watershed. The nearest hourly station is the Bristol Airport (TN1094). The other two hourly stations, Wise 3 E (VA9215) and Trout Dale 3 SSE (VA8547), are located approximately 30-40 miles away. The nearest daily monitoring station is Abingdon 3 S (440021), which is located approximately 5 miles northeast of the watershed. These NCDC meteorological stations and the Beaver Creek watershed are shown in Figure 4.1.

Daily minimum and maximum temperature between 1980 and 2002 were used to compute the potential evapotranspiration time-series data. This process is described in greater detail in Section 4.1.2.

Of the four precipitation stations, Abingdon 3 S is the closest station to the watershed; however, the data collected at this station are daily. The normal-ratio method (Dunn and Leopold 1978) was used to disaggregate the daily rainfall data to hourly values based on hourly rainfall distributions at the three nearby stations. First, a composite hourly distribution was determined as a weighted average hourly time-series of the three nearby surrounding gages. Second, the daily values were distributed to the resulting hourly time-series, keeping the original rainfall volume intact. Also using the same methodology, missing or deleted intervals in the data were simultaneously patched using the normal-weighted hourly distributions at the three nearby stations. This entire process is described in greater detail in Section 4.1.3.

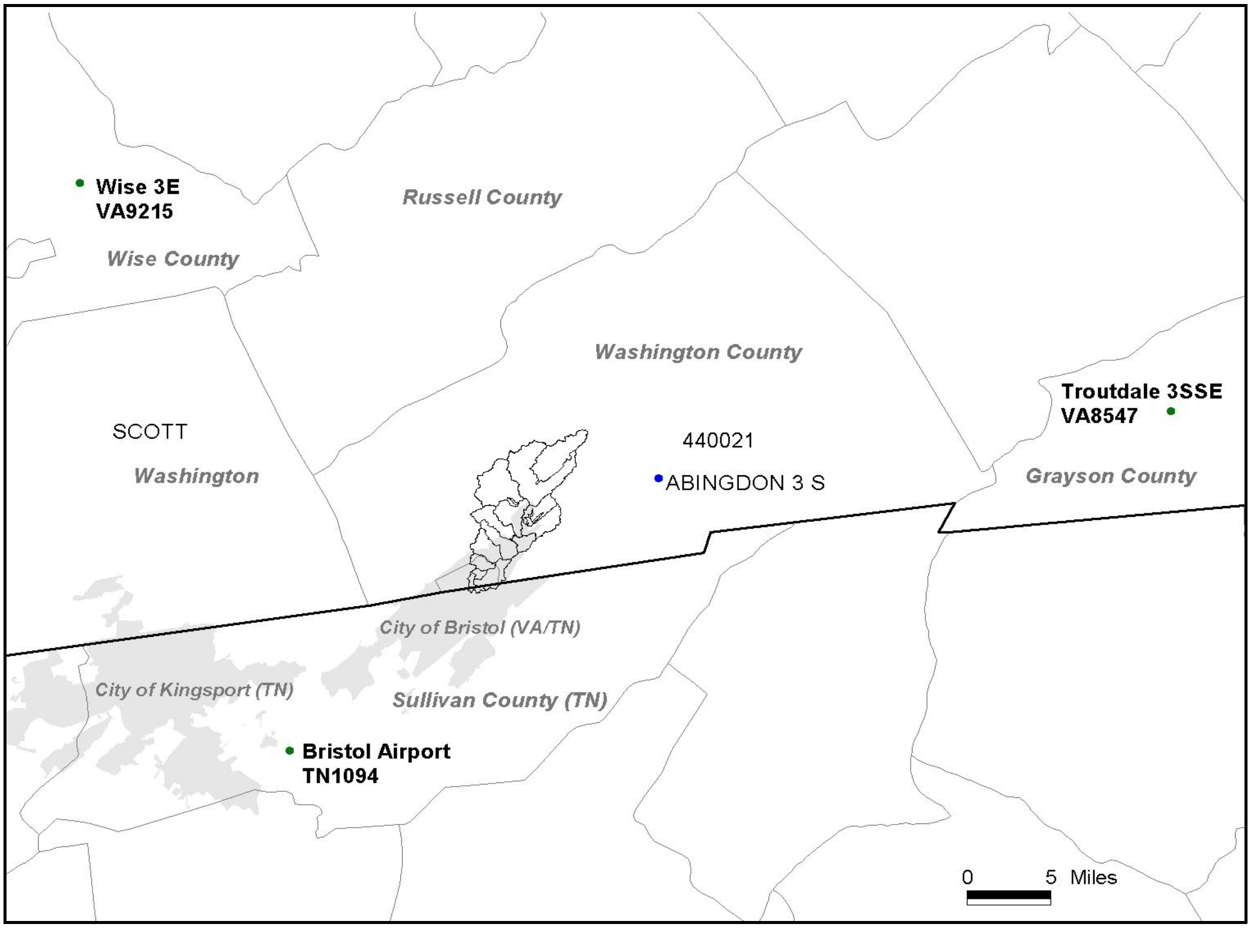

Figure 4.1 Location of meteorological stations used for the Beaver Creek watershed model

4.1.2 Computing Potential Evapotranspiration

Daily minimum and maximum temperature data between 1980 and 2002 for the Abingdon 3 S station were used to compute the potential evapotranspiration time-series. The Hamon method (1961) was used to compute evapotranspiration. The Hamon formula states that:

$$PET = CTS \times DYL \times DYL \times VDSAT \qquad \text{Eqn 5.1}$$

where:

PET	daily potential evapotranspiration (in)
CTS	monthly variable coefficient (a value of 0.0055 is suggested)
DYL	possible hours of sunshine, in units of 12 hours, computed as a function of latitude and time of year
VDSAT	saturated water vapor density (absolute humidity) at the daily mean air temperature (g/cm3)

The formula to compute saturated water vapor density (*VDSAT*) states that:

$$VDSAT = \frac{216.7 \times VPSAT}{TAVC + 273.3} \qquad \text{Eqn 5.2}$$

where

VPSAT	saturated vapor pressure at the air temperature
TAVC	mean daily temperature computed from daily min and max (Deg C)

The formula for saturation vapor pressure (*VPSAT*) states that:

$$VPSAT = 6.108 \times \exp\left(\frac{17.26939 \times TAVC}{TAVC + 273.3}\right) \qquad \text{Eqn 5.3}$$

Finally, the daily *PET* values were disaggregated to hourly time-series values using a standard sine wave equation, over the daylight hours (*DYL*), which reaches its peak at noon of each day. The minimum and maximum temperature values monitored at the NCDC Abingdon 3 S station were used to compute potential evapotranspiration.

4.1.3 Patching and Disaggregating Rainfall Data

Unless the percent coverage is 100%, meaning that the weather station is always in operation and is accurately recording data throughout the specified time period, precipitation stations may contain various intervals of accumulated, missing, or deleted data. Missing or deleted intervals are periods over which either the rainfall station malfunctioned or the data records were somehow lost. Accumulated intervals represent cumulative precipitation over several hours, but the exact hourly distribution of the data is unknown.

To disaggregate the daily rainfall totals to hourly values, each day that rainfall is recorded is treated as an accumulated interval over the 24-hour period. The normal-ratio method (Dunn & Leopold 1978) was used to repair accumulated, missing, and deleted data intervals based on hourly rainfall patterns at nearby stations where unimpaired data is measured. The normal-ratio method estimates a missing rainfall value using a weighted average from surrounding stations with similar rainfall patterns according to the relationship:

$$P_A = \frac{1}{n}\left(\sum_{i=1}^{n} \frac{N_A}{N_i} P_i\right) \qquad \text{Eqn 5.4}$$

where P_A is the impaired precipitation value at station A, n is the number of surrounding stations with unimpaired data at the same specific point in time, N_A is the long term average precipitation at station

A, N_i is the long term average precipitation at nearby station *i*, and P_i is the observed precipitation at nearby station *i*. For each impaired data record at station *A*, *n* consists of only the surrounding stations with unimpaired data; therefore, for each record, *n* varies from 1 to the maximum number of surrounding stations (three in this case). When no precipitation is available at the surrounding stations, zero precipitation is assumed at station *A*. The US Weather Bureau has a long established practice of using the long-term average rainfall as the precipitation normal. Since the normal ratio considers the long-term average rainfall as the weighting factor, this method is adaptable to regions where there is a large orthographic variation in precipitation; therefore, elevation differences will not bias the predictive capability of the method.

Figure 4.2 shows 20-water-year annual rainfall totals at the Abingdon 3 S station by water year. Figure 4.3 shows monthly data quality assessments for three selected model calibration years.

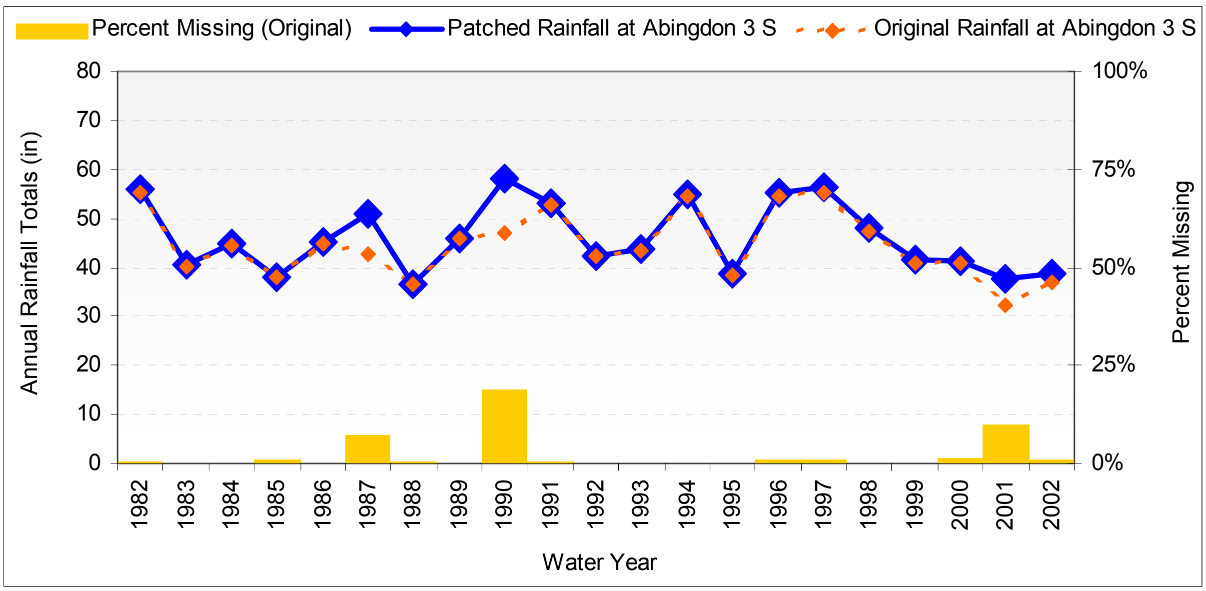

Figure 4.2 Total annual precipitation totals and data quality at Abingdon 3 S gage before and after patching

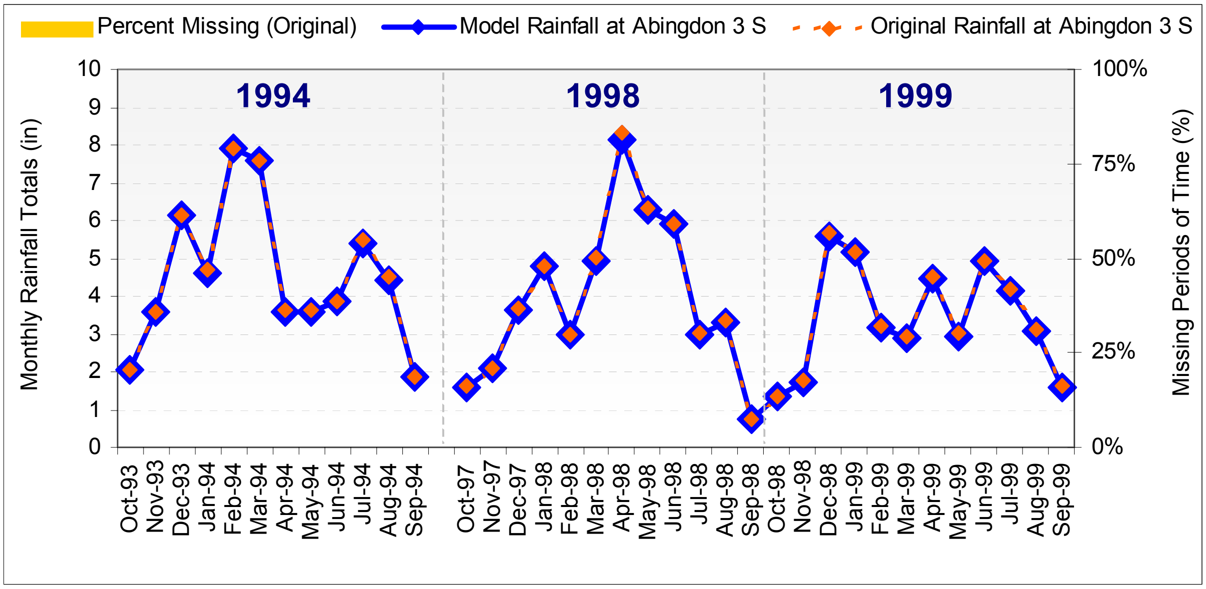

Figure 4.3 Total monthly precipitation and data quality assessments at Abingdon 3 S for three selected model calibration years, before and after patching

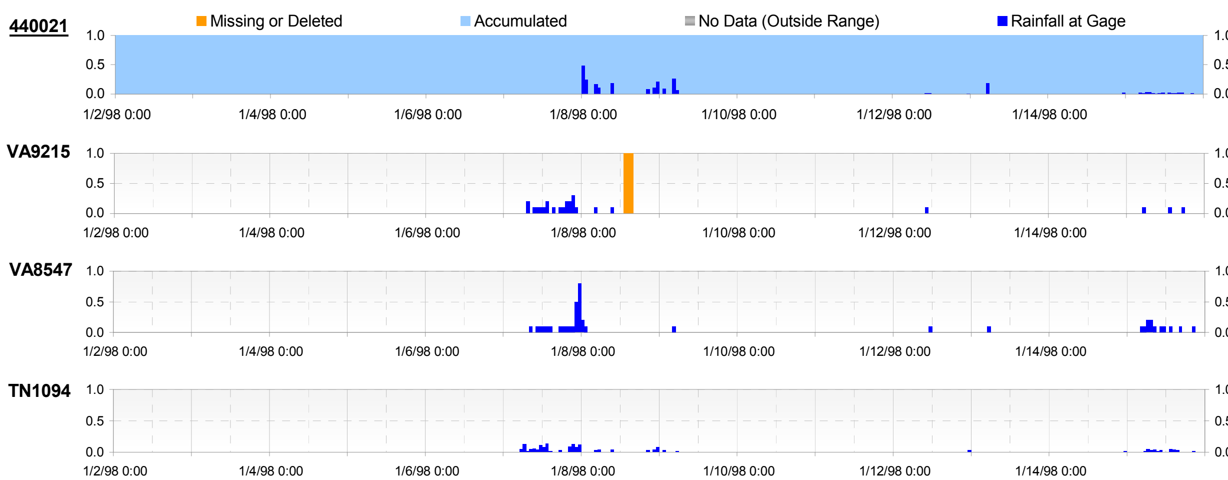

Figure 4.4 Example daily-to-hourly disaggregation at the Abingdon 3 S gage for a two week period using available data at three nearby rainfall gages

4.2 Model Setup

LSPC was configured to simulate the Beaver Creek watershed as a series of hydrologically connected subwatersheds. Configuration of the model involved subdividing the Beaver Creek watershed into modeling units, allowing for the continuous simulation of flow and water quality for these units using meteorological, land use, point source loading, and stream data. The watershed was subdivided into eighteen subwatersheds to adequately represent the spatial variation in bacteria sources, watershed characteristics, hydrology, and the location of water quality monitoring and streamflow gaging stations. Subwatershed delineation was based primarily on the location of streams and a topographic analysis of the watershed. Beaver Creek subwatersheds are shown in Figure 4.5. The spatial division of the watershed allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watershed.

A continuous simulation period was used in the hydrologic simulation analysis, based on the availability of weather and flow data. An important factor driving model simulations is precipitation data. The pattern and intensity of rainfall affects the build-up and wash-off of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream.

Modeled land uses that contribute bacteria loads to the stream include pasture, cropland, urban land (including loads from failing septic systems), and forest. Other sources, such as straight pipes and livestock in streams, were modeled as direct sources in the model. Development of initial loading rates for land uses and direct sources are described in Section 4.3.

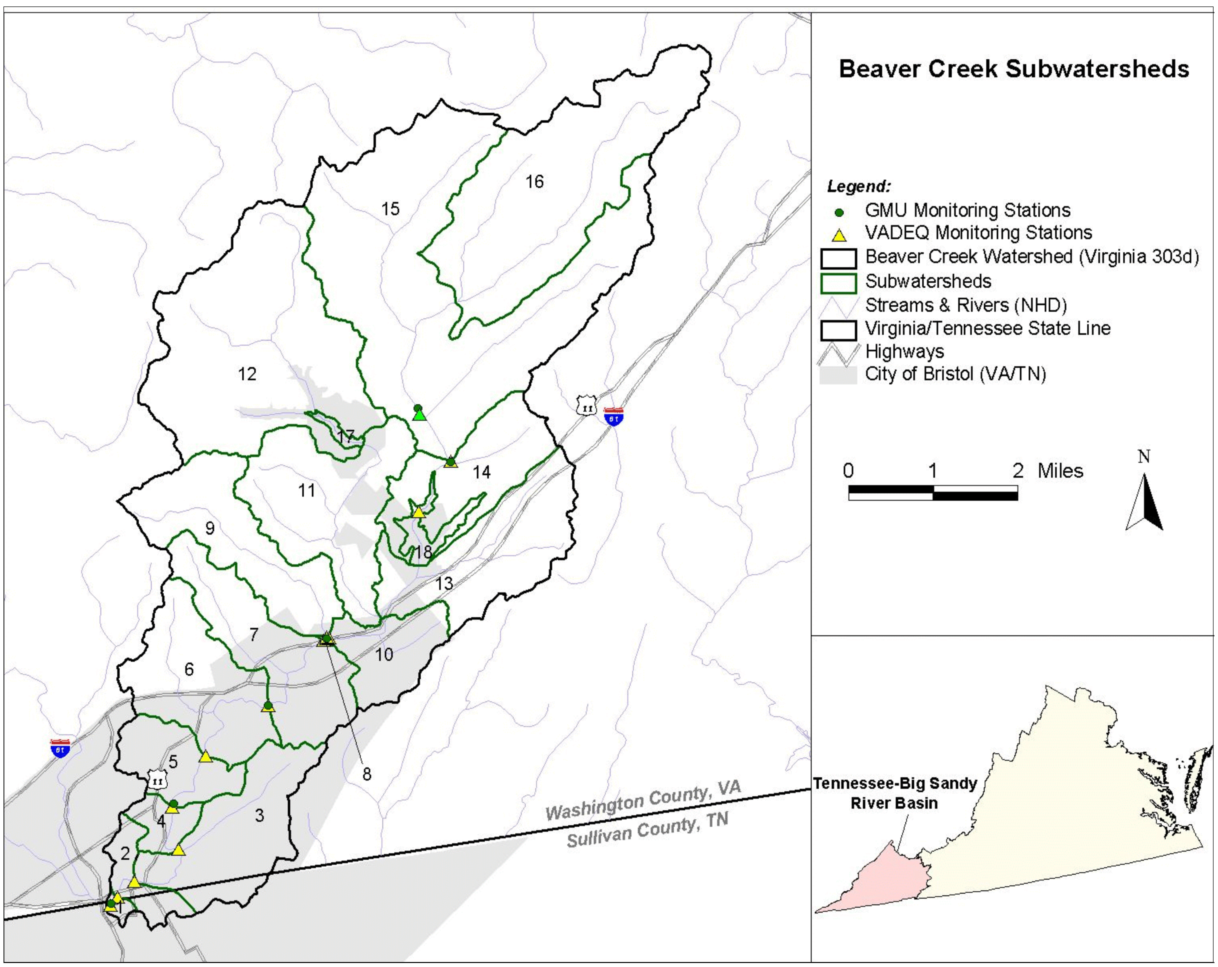

Figure 4.5 Beaver Creek subwatershed delineation

4.3 Source Representation

Both point and nonpoint sources were represented in the model for Beaver Creek. In general, point sources were added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources were 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.

4.3.1 Failing Septic Systems

Septic systems provide the potential to deliver bacteria loads to surface waters (primarily through runoff events) due to system failures caused by improper maintenance and/or malfunctions. The number of septic systems in each subwatershed was determined using U.S. Census Year 2000 and 1990 block group data for Washington County and the City of Bristol, as described in Section 3.1.1 (Table 4.3). The number of failing septic systems was estimated using a failure rate of 20% based on discussions with Virginia Department of Health personnel and review of failure rates used in other TMDL watersheds with a significant urban population. In some cases, human waste is directly deposited into surface waters from houses without septic systems. The population served by straight pipes was assumed to be 1% of the total septic/other disposal means population in the watershed. Houses considered to have a normal functioning septic system were assumed to have a negligible contribution of fecal bacteria to surface waters.

Table 4.3 Total and failing septic population estimates (by subwatershed)

Subwatershed	Septic Population	Population served by failing septic systems
1	0	0
2	14	3
3	59	12
4	16	3
5	27	5
6	208	42
7	192	38
8	0	0

Subwatershed	Septic Population	Population served by failing septic systems
9	363	73
10	22	4
11	392	78
12	366	73
13	307	61
14	290	58
15	975	195
16	819	164
17	Included in the total for Subwatershed #12	
18	Included in the total for Subwatershed #14	

4.3.2 Livestock

Bacteria produced by livestock can be deposited on the land, directly deposited in the stream (as is common when grazing animals have stream access), manually applied to cropland and other agricultural lands as fertilizer, or contributed to surface waters through illicit discharges from animal confinement areas. Bacteria deposited on the land, either directly or through manure application, are available for washoff into surface waters during rainfall events. There are no known illicit discharges of animal waste in the watershed.

Animal population estimates for the Beaver Creek watershed were based on the 1997 and 2002 Virginia Agricultural Census data for Washington County and information provided by the Holston River Soil and Water Conservation District (HRSWCD) and local Natural Resource Conservation Service (NRCS) personnel. Bacteria loads directed through each pathway were calculated by multiplying the bacteria density with the amount of waste expected through that pathway.

The livestock population for each subwatershed is presented in Table 4.4. The beef cattle, hogs, sheep, and horse estimates were based on the amount of pasture land in each subwatershed. There are two dairy operations in the Beaver Creek watershed (Subwatersheds 12 and 15) and one large poultry facility in Subwatershed 16.

Table 4.4 Livestock population by subwatershed

Subwatershed	Beef Cattle (& Calves)	Dairy Cattle (& Replacement Heifers)	Hogs	Sheep	Chickens	Horses
1	0 (0)	0 (0)	0	0	0	0
2	0 (1)	0 (0)	0	0	0	0
3	23 (38)	0 (0)	0	2	0	4
4	1 (2)	0 (0)	0	0	0	0
5	7 (12)	0 (0)	0	0	0	1
6	46 (75)	0 (0)	0	3	0	8
7	80 (131)	0 (0)	1	5	0	14
8	0 (0)	0 (0)	0	0	0	0
9	118 (192)	0 (0)	1	8	0	21
10	12 (19)	0 (0)	0	1	0	2
11	129 (211)	0 (0)	1	9	0	23
12	292 (246)	115 (115)	3	19	0	52
13	99 (161)	0 (0)	1	7	0	18
14	69 (112)	0 (0)	1	5	0	12
15	467 (501)	130 (130)	4	31	0	83
16	332 (542)	0 (0)	3	22	800,000	59
17	Included in the total for Subwatershed #12					
18	Included in the total for Subwatershed #14					

Liquid manure from confined animals is applied to cropland and pasture/hayland in the Beaver Creek watershed. Application rates vary monthly, with application primarily occurring during the spring and fall, according to the schedule presented in Section 3.1.2. Application of manure results in the accumulation of bacteria on the land surface. Therefore, bacteria accumulation rates are directly influenced by and based on the application rates of manure. To determine bacteria accumulation factors for the model, it was necessary to determine the amount present in manure. The fraction of manure application available for runoff was calculated by subtracting the amount typically incorporated into the soil matrix through tillage and natural processes (assumed 25% soil incorporation).

Beef and dairy cattle in streams were represented in the model as direct inputs (e.g. point sources) of bacteria. Using the fecal coliform bacteria production rates for beef and dairy cattle, the daily contribution from cattle in streams was calculated and then totaled by subwatershed depending on the population estimates of beef and dairy cattle watering in streams in each subwatershed (refer to Section 3.1.2). Bacteria contributions from cattle in streams were represented in the model using the total load delivered to the stream (#/day) and the flow rate at which it is delivered (cfs). The flow rate was determined using the amount of waste produced by beef and dairy cattle each day (lbs/day) and an assumed density of the manure produced (lbs/gal). Cattle in the stream were assumed to discharge at a constant rate.

Grazing animals also contribute bacteria to the land surface, which is available for washoff to surface waters during storm events. Beef and dairy cattle were the most abundant grazing animals in the watershed, as shown in Table 4.4 Sheep and horses represent the only other significant grazing livestock species in the Beaver Creek watershed. Cattle, sheep, and horses were distributed throughout pasture areas in each subwatershed. Bacteria accumulation rates (#/acre/day) for each of these livestock species were calculated using subwatershed population estimates and the bacteria production rate established for each species.

4.3.3 Wildlife

The population of each wildlife species was estimated using the population density per square mile of habitat and the total area of suitable habitat in each subwatershed (Table 4.5). As with grazing livestock, wildlife deposit manure on the land and directly to surface waters. The habitat and percentage of time each species typically spends in streams was used to determine the proportion of bacteria that was deposited on land versus directly to surface waters. Loads applied to the land (in each subwatershed) were distributed according to the total area of each land use type within the established habitat area of each species.

The colony of gray bats that live in the watershed are located in Subwatershed #2 in downtown Bristol (culvert under Piedmont Avenue). The average population was assumed to be 3,750 bats that contribute bacteria to Beaver Creek throughout the year.

Table 4.5 Wildlife population by subwatershed (gray bat population discussed above)

Subwatershed	Ducks		Geese		Deer	Beaver	Raccoon	Muskrat
	Summer	Winter	Summer	Winter				
1	<1	<1	<1	<1	<1	<1	<1	<1
2	2	2	2	3	<1	<1	1	3
3	8	11	11	16	6	<1	5	17
4	2	3	3	4	1	<1	1	5
5	2	3	3	4	3	<1	3	5
6	7	11	9	12	11	<1	8	17

Subwatershed	Ducks		Geese		Deer	Beaver	Raccoon	Muskrat
	Summer	Winter	Summer	Winter				
7	8	12	10	15	7	<1	7	15
8	<1	<1	<1	<1	<1	<1	<1	<1
9	8	12	11	16	11	<1	8	13
10	4	6	5	7	3	<1	3	11
11	12	19	14	20	14	<1	11	23
12	14	22	16	22	27	<1	17	29
13	11	16	14	20	9	<1	8	20
14	7	12	7	10	8	<1	7	17
15	24	36	32	45	32	<1	25	42
16	15	23	21	29	20	<1	16	23
17	Included in the total for Subwatershed #12							
18	Included in the total for Subwatershed #14							

4.3.4 Domestic Pets

Housing estimates were used to determine the number of pets in each Beaver Creek subwatershed (Census 2000). An assumption of one dog per two households was used to calculate the pet population. Bacteria loading was applied to urban (built-up) lands and as direct deposition to the stream in each subwatershed.

4.4 Stream Characteristics

The channel geometry for the stream reaches in Beaver Creek subwatersheds were based on the visual observation of stream channel configurations throughout the watershed and through an analysis of typical stream channel geometry values for these stream types. The stream segment length and slope values for each subwatershed were determined using GIS analysis of digitized streams and digital elevation models (DEMs).

4.5 Selection of a Representative Modeling Period

The selection of a representative modeling period was based on the availability of stream flow and water quality data collected in the Beaver Creek watershed that cover varying wet and dry time periods. Hourly flow discharge data were available from the USGS gage located in the watershed (USGS 03478400) from 1980 through 2002. Monthly water quality data were also collected by VADEQ on Beaver Creek during this period; therefore, this time period was selected for modeling purposes. This time period represented varying climatic and hydrologic conditions, including dry (1999), average (1998), and wet (1994) periods that typically occur in the area. This was an important consideration because during dry weather and low flow periods, constant direct discharges primarily affect instream concentrations; however, during wet weather and high flow periods, surface runoff delivers nonpoint source bacteria loads to the stream, affecting instream concentrations more so than direct discharges.

4.6 Model Calibration Process

Hydrology and water quality calibration were performed in sequence, since water quality modeling is dependent on an accurate hydrology simulation.

Hydrology was the first model component calibrated. The hydrology calibration involved a comparison of model results to stream flow observations at the USGS gage on Beaver Creek (03478400 - Beaver Creek at Bristol, VA). Figure 2.2 shows the location of the USGS stream flow gage. The Beaver Creek watershed includes two dams upstream of the flow monitoring station. Clear Creek Reservoir, built in 1965 by TVA, has a dam 51 feet high with top capacity of 2,825 acre feet. Under normal conditions, this reservoir maintains an average volume of 299 acre feet. Clear Creek Reservoir was modeled as a simple reservoir and conceptually dimensioned to maintain near average pool volume. Beaver Creek Dam is a non-pooling earthen dam whose primary objective is flood control. Beaver Creek Dam was not explicitly modeled in the watershed model, since the dam never restricted stream flow during the model simulation period.

The model was calibrated using daily stream flow observations from the Beaver Creek USGS gage for three selected years during the 1990s. Model calibration years were selected using the following criteria:

1. Completeness of the weather data available for the selected period.
2. Representation of low-flow, average-flow, and high-flow water years.
3. Consistency of selected period with key model inputs (i.e. land use coverage)
4. Quality of initial modeled versus observed data correlation

Based on a review of these four selection criteria, water years 1994, 1998, and 1999 were chosen as model calibration years. These three water years all had 100% data coverage at the Abingdon 3 S rainfall station, and also represented high-flow (1994), average-flow (1998), and low-flow (1999) water years, when compared with other water years within the 20 year simulation period. Also, since the MRLC land use coverage used in the model was developed during the mid 1990s, the selected calibration periods are consistent with this key model input. The model was validated for long-term and seasonal representation of hydrologic trends using two composite 10-year periods (1993-2002) and (1983-1992). Figure 4.6 shows the selected calibration and validation years.

Model calibration was performed using the error statistics criteria specified in HSPEXP, temporal comparisons, and comparisons of seasonal, high flows, and low flows. Calibration involved the adjustment of infiltration, subsurface storage, evapotranspiration, surface runoff, and interception storage parameters. After adjusting the appropriate parameters within acceptable ranges, good correlations were found between model results and observed data. The model was validated for 20 years using composite results for two independent ten-year periods in an effort to ensure systematic hydrologic consistency.

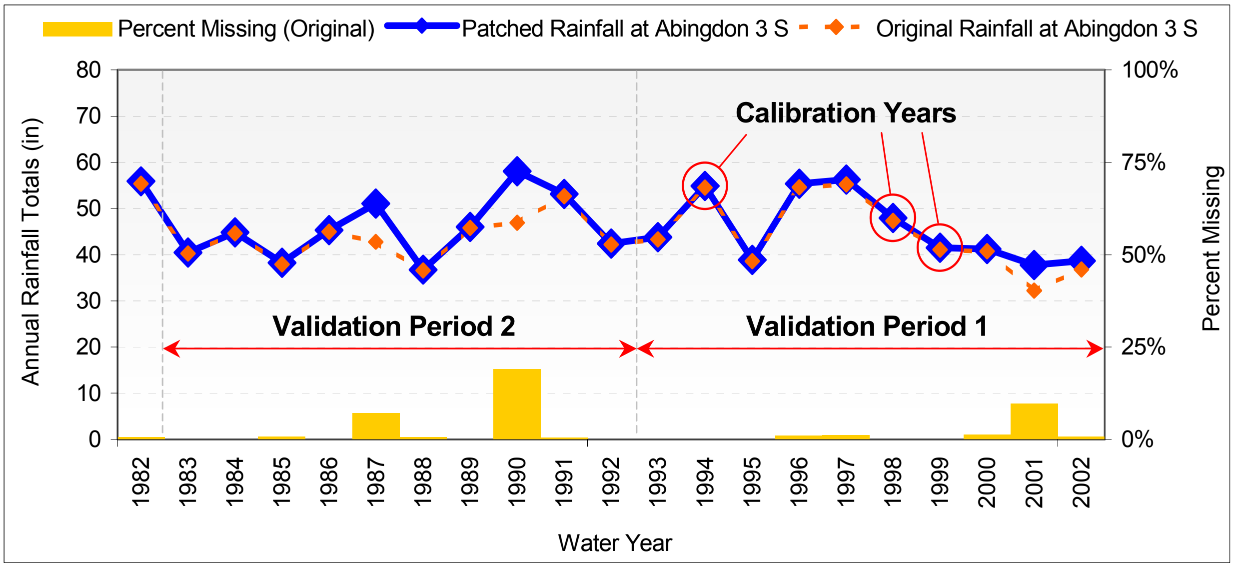

Figure 4.6 Selected calibration and validation periods

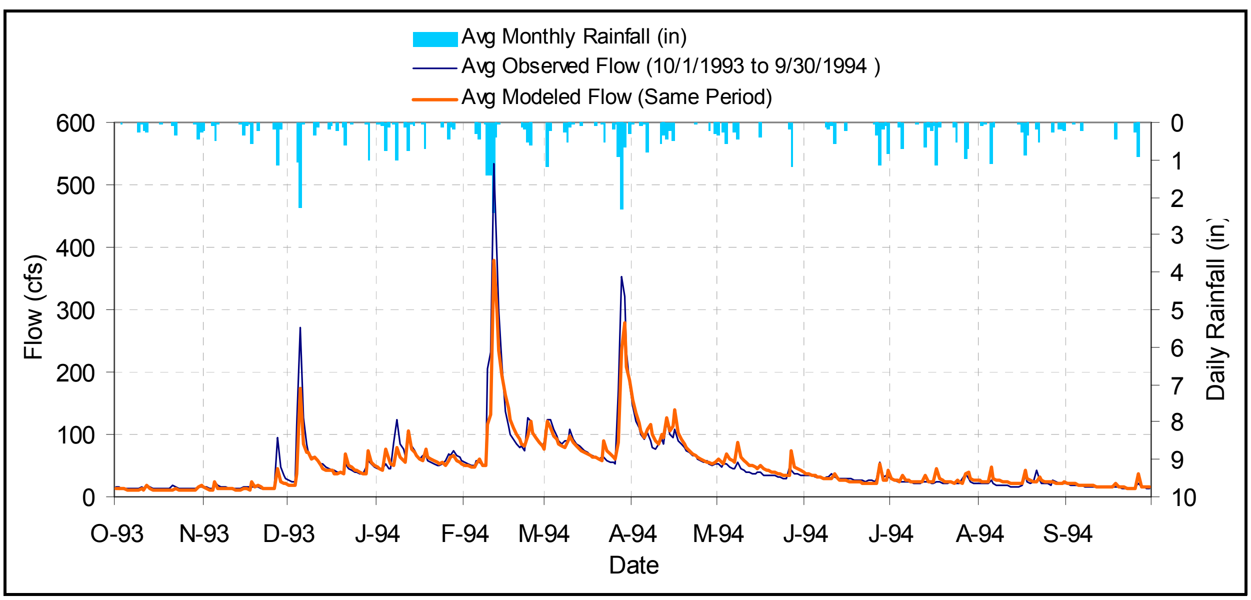

Figure 4.7 Daily flow calibration comparison for water year 1994 at USGS 03478400

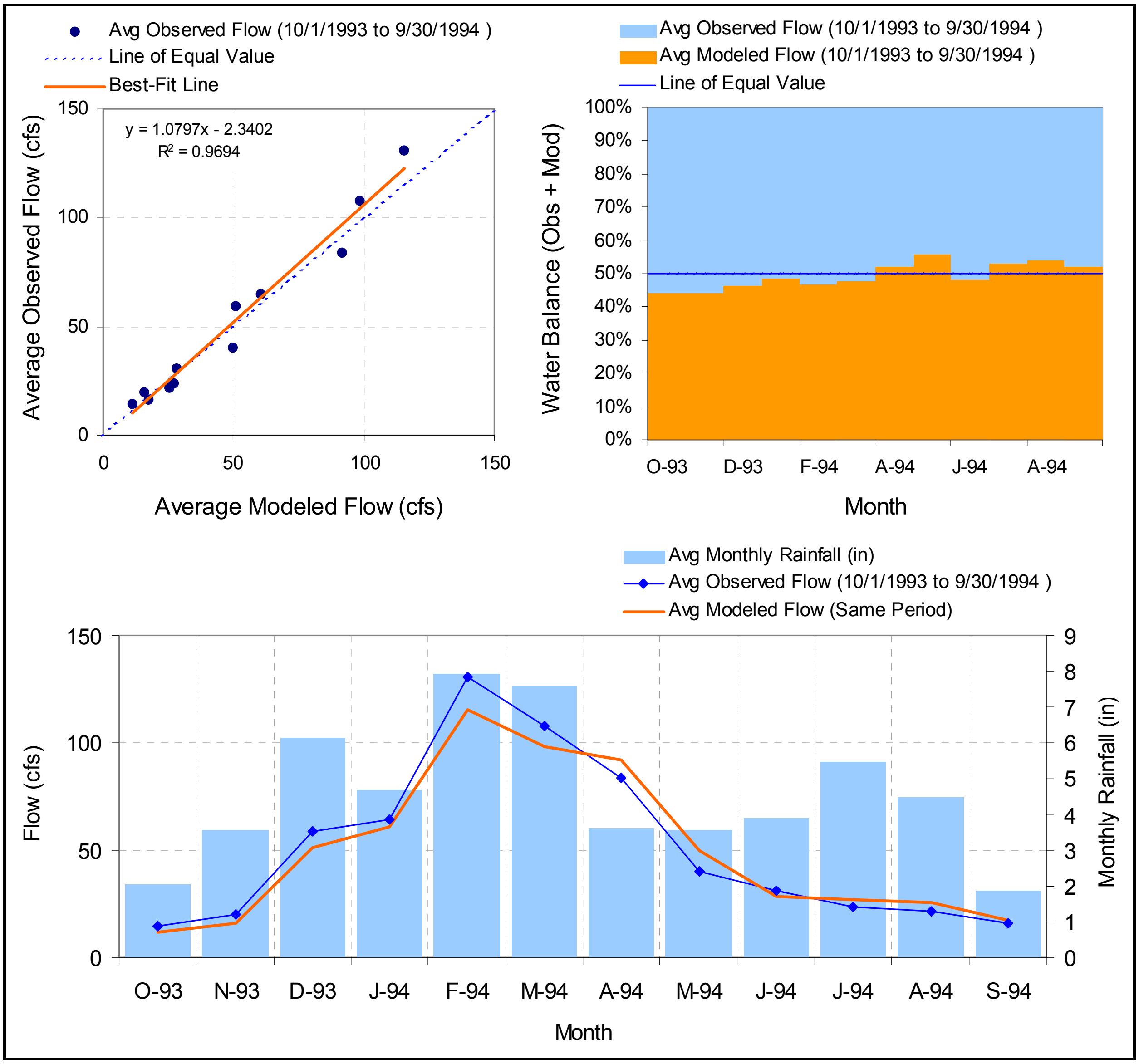

Figure 4.8 Monthly flow calibration comparison for water year 1994 at USGS 03478400.

Table 4.6 Error statistics for calibration water year 1994

LSPC Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM SUBBASIN 8 1-Year Analysis Period: 10/1/1993 - 9/30/1994 Flow volumes are (inches/year) for upstream drainage area		**USGS 03478400 BEAVER CREEK AT BRISTOL, VA** Bristol City, Virginia Hydrologic Unit Code 06010102 Latitude 36°37'54", Longitude 82°08'02" NAD27 Drainage area 27.70 square miles	
Total Simulated In-stream Flow:	**24.06**	Total Observed In-stream Flow:	**24.80**
Total of simulated highest 10% flows:	**7.32**	Total of Observed highest 10% flows:	**8.36**
Total of Simulated lowest 50% flows:	**5.00**	Total of Observed Lowest 50% flows:	**4.98**
Simulated Summer Flow Volume (months 7-9):	**2.89**	Observed Summer Flow Volume (7-9):	**2.53**
Simulated Fall Flow Volume (months 10-12):	**3.25**	Observed Fall Flow Volume (10-12):	**3.87**
Simulated Winter Flow Volume (months 1-3):	**10.98**	Observed Winter Flow Volume (1-3):	**12.11**
Simulated Spring Flow Volume (months 4-6):	**6.94**	Observed Spring Flow Volume (4-6):	**6.29**
Total Simulated Storm Volume:	**5.13**	Total Observed Storm Volume:	**6.03**
Simulated Summer Storm Volume (7-9):	**0.38**	Observed Summer Storm Volume (7-9):	**0.26**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	-3.10	10	
Error in 50% lowest flows:	0.41	10	
Error in 10% highest flows:	-14.14	15	
Seasonal volume error - Summer:	12.32	30	
Seasonal volume error - Fall:	-19.02	30	
Seasonal volume error - Winter:	-10.28	30	
Seasonal volume error - Spring:	9.33	30	
Error in storm volumes:	-17.52	20	
Error in summer storm volumes:	29.95	50	

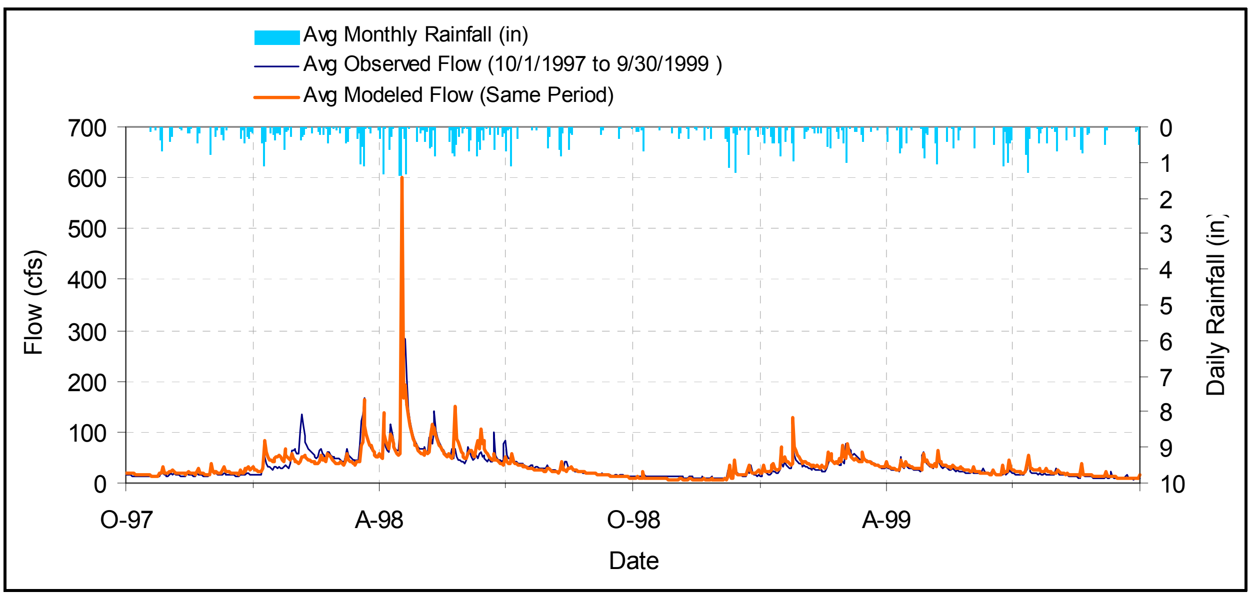

Figure 4.9 Daily flow calibration comparison for water years 1998 and 1999 at USGS 03478400

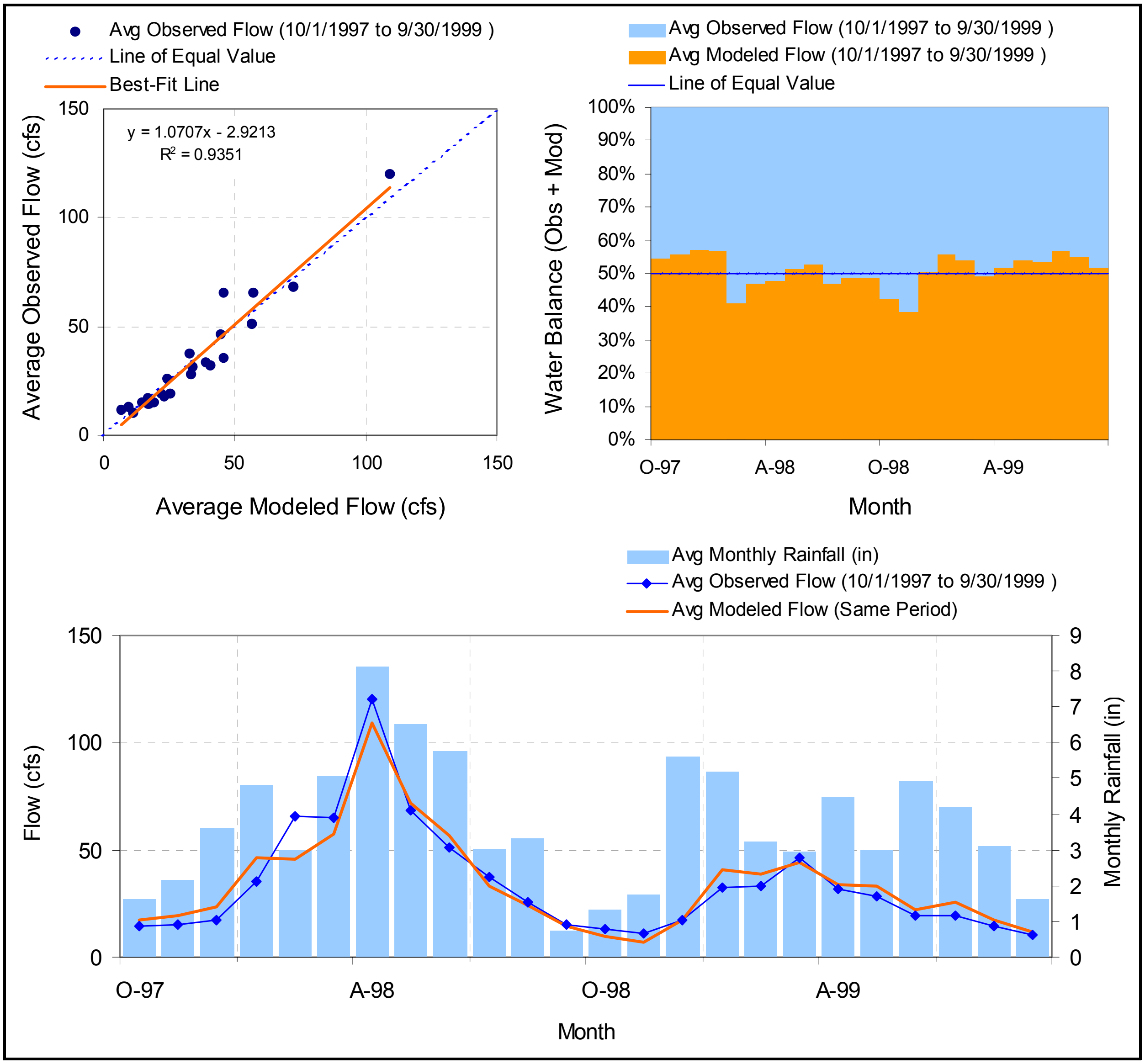

Figure 4.10 Monthly flow calibration comparison for water years 1998 and 1999 at USGS 03478400.

Table 4.7 Error statistics for calibration water years 1998 and 1999 at USGS 03478400

LSPC Simulated Flow		Observed Flow Gage		
REACH OUTFLOW FROM SUBBASIN 8 2-Year Analysis Period: 10/1/1997 - 9/30/1999 Flow volumes are (inches/year) for upstream drainage area		**USGS 03478400 BEAVER CREEK AT BRISTOL, VA** Bristol City, Virginia Hydrologic Unit Code 06010102 Latitude 36°37'54", Longitude 82°08'02" NAD27 Drainage area 27.70 square miles		
Total Simulated In-stream Flow:	**16.73**	Total Observed In-stream Flow:		**16.45**
Total of simulated highest 10% flows:	**4.70**	Total of Observed highest 10% flows:		**5.02**
Total of Simulated lowest 50% flows:	**4.10**	Total of Observed Lowest 50% flows:		**3.73**
Simulated Summer Flow Volume (months 7-9):	**2.61**	Observed Summer Flow Volume (7-9):		**2.54**
Simulated Fall Flow Volume (months 10-12):	**1.93**	Observed Fall Flow Volume (10-12):		**1.83**
Simulated Winter Flow Volume (months 1-3):	**5.52**	Observed Winter Flow Volume (1-3):		**5.58**
Simulated Spring Flow Volume (months 4-6):	**6.67**	Observed Spring Flow Volume (4-6):		**6.50**
Total Simulated Storm Volume:	**3.25**	Total Observed Storm Volume:		**3.27**
Simulated Summer Storm Volume (7-9):	**0.30**	Observed Summer Storm Volume (7-9):		**0.31**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	1.68	10		
Error in 50% lowest flows:	8.81	10		
Error in 10% highest flows:	-6.75	15		
Seasonal volume error - Summer:	2.65	30		
Seasonal volume error - Fall:	5.25	30		
Seasonal volume error - Winter:	-1.17	30		
Seasonal volume error - Spring:	2.62	30		
Error in storm volumes:	-0.62	20		
Error in summer storm volumes:	-5.19	50		

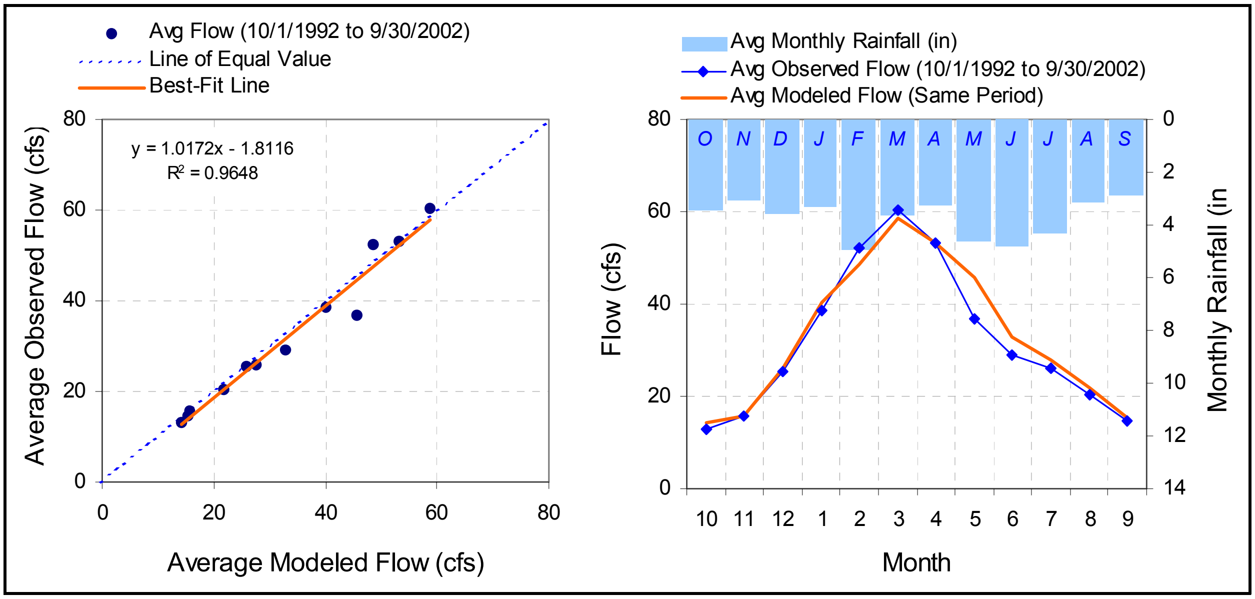

Figure 4.11 10-year annualized composite validation at USGS 03478400 (water years 1993-2002)

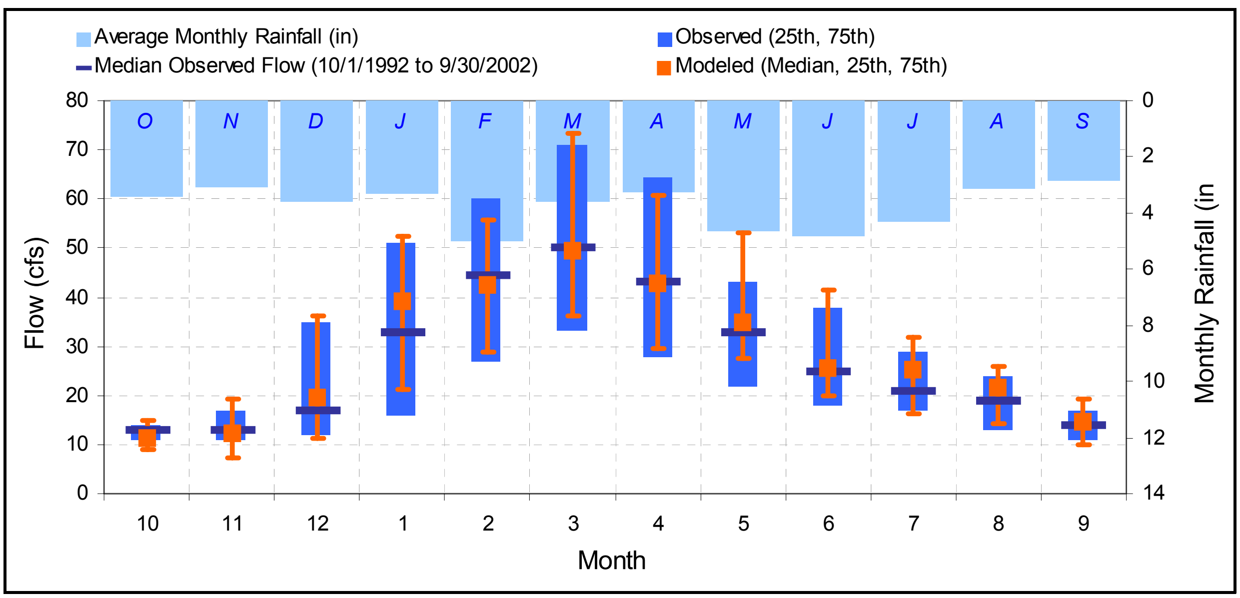

Figure 4.12 10-year annualized composite validation at USGS 03478400 for seasonal trend analysis (water years 1993-2002)

Table 4.8 Table of summary statistics for 10-year annualized validation at USGS 03478400 for water years 1993-2002

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	12.92	13.00	11.00	14.00	14.38	11.35	8.98	14.85
Nov	15.65	13.00	11.00	17.00	15.60	12.16	7.18	19.27
Dec	25.53	17.00	12.00	34.75	26.03	19.47	11.19	36.07
Jan	38.67	33.00	16.00	51.00	40.26	39.16	21.37	52.55
Feb	52.29	44.50	27.00	60.00	48.73	42.44	28.85	55.77
Mar	60.39	50.00	33.25	71.00	58.67	49.40	36.11	73.24
Apr	53.07	43.00	27.75	64.25	53.11	42.88	29.51	60.62
May	36.79	33.00	22.00	43.00	45.69	35.02	27.66	53.18
Jun	28.91	25.00	18.00	38.00	32.86	25.50	19.78	41.65
Jul	25.96	21.00	17.00	29.00	27.69	25.07	16.20	31.76
Aug	20.47	19.00	13.00	24.00	21.82	21.63	14.40	25.98
Sep	14.61	14.00	11.00	17.00	15.28	14.49	9.99	19.34

Table 4.9 Error statistics for validation period 1 (water years 1993 to 2002)

LSPC Simulated Flow		Observed Flow Gage		
REACH OUTFLOW FROM SUBBASIN 8 10-Year Analysis Period: 10/1/1992 - 9/30/2002 Flow volumes are (inches/year) for upstream drainage area		**USGS 03478400 BEAVER CREEK AT BRISTOL, VA** Bristol City, Virginia Hydrologic Unit Code 06010102 Latitude 36°37'54", Longitude 82°08'02" NAD27 Drainage area 27.70 square miles		
Total Simulated In-stream Flow:	**16.32**	Total Observed In-stream Flow:		**15.69**
Total of simulated highest 10% flows:	**4.79**	Total of Observed highest 10% flows:		**4.85**
Total of Simulated lowest 50% flows:	**3.69**	Total of Observed Lowest 50% flows:		**3.53**
Simulated Summer Flow Volume (months 7-9):	**2.68**	Observed Summer Flow Volume (7-9):		**2.52**
Simulated Fall Flow Volume (months 10-12):	**2.31**	Observed Fall Flow Volume (10-12):		**2.23**
Simulated Winter Flow Volume (months 1-3):	**5.96**	Observed Winter Flow Volume (1-3):		**6.10**
Simulated Spring Flow Volume (months 4-6):	**5.37**	Observed Spring Flow Volume (4-6):		**4.83**
Total Simulated Storm Volume:	**3.30**	Total Observed Storm Volume:		**3.12**
Simulated Summer Storm Volume (7-9):	**0.43**	Observed Summer Storm Volume (7-9):		**0.42**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	3.83	10		
Error in 50% lowest flows:	4.23	10		
Error in 10% highest flows:	-1.25	15		
Seasonal volume error - Summer:	5.79	30		
Seasonal volume error - Fall:	3.44	30		
Seasonal volume error - Winter:	-2.36	30		
Seasonal volume error - Spring:	9.90	30		
Error in storm volumes:	5.44	20		
Error in summer storm volumes:	3.58	50		

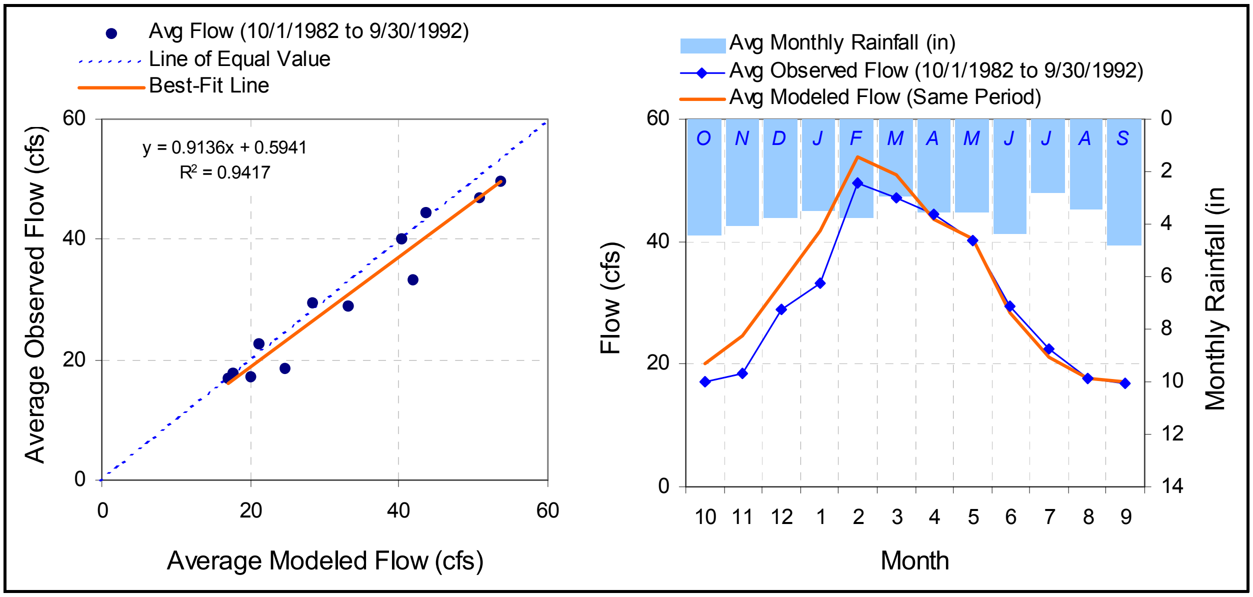

Figure 4.13 10-year annualized composite validation at USGS 03478400 (water years 1983-1992)

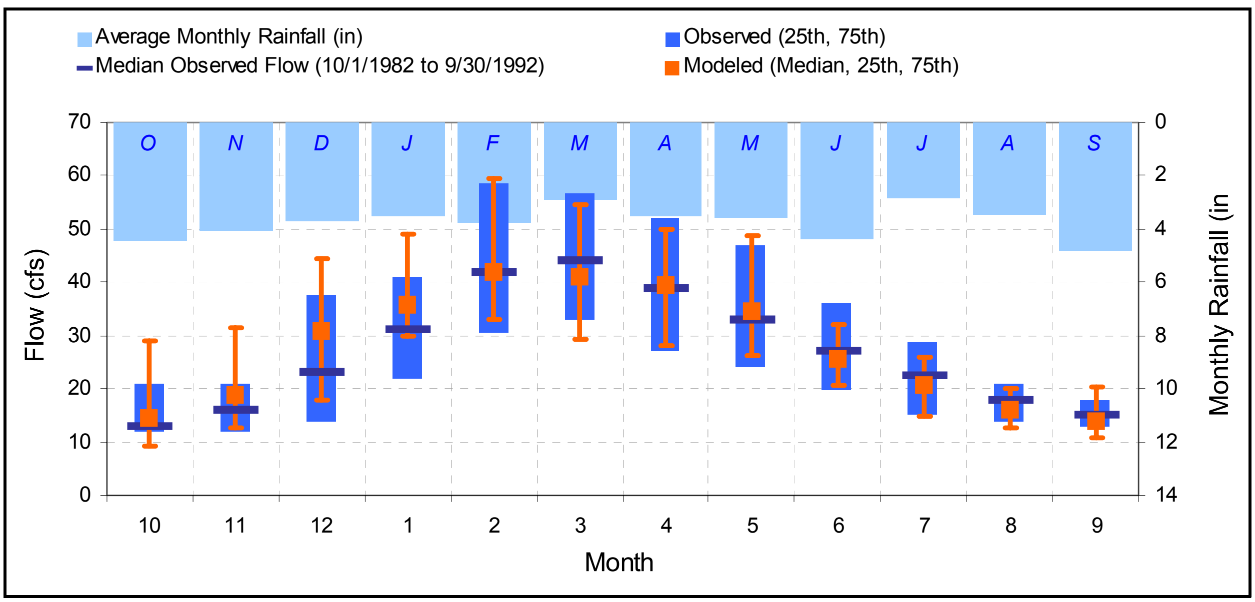

Figure 4.14 10-year annualized composite validation at USGS 03478400 for seasonal trend analysis (water years 1983-1992)

Table 4.10 Table of summary statistics for 10-year annualized validation at USGS 03478400 for water years 1983-1992

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	17.27	13.00	12.00	21.00	20.10	14.49	9.40	29.00
Nov	18.61	16.00	12.00	21.00	24.61	18.82	12.71	31.50
Dec	28.99	23.00	14.00	37.75	33.26	30.95	17.80	44.50
Jan	33.22	31.00	22.00	41.00	41.84	35.92	30.03	48.93
Feb	49.66	42.00	30.50	58.50	53.75	42.07	33.09	59.40
Mar	47.03	44.00	33.00	56.75	50.82	41.07	29.24	54.44
Apr	44.43	39.00	27.00	52.00	43.73	39.38	28.19	49.95
May	40.21	33.00	24.00	46.75	40.43	34.40	26.18	48.57
Jun	29.53	27.00	19.75	36.00	28.46	25.58	20.51	32.14
Jul	22.59	22.50	15.00	28.75	21.20	20.77	14.80	25.93
Aug	17.67	18.00	14.00	21.00	17.68	16.05	12.74	20.18
Sep	16.87	15.00	13.00	18.00	17.01	13.84	10.85	20.45

Table 4.11 Error statistics for validation period 2 (water years 1983 to 1992)

LSPC Simulated Flow		Observed Flow Gage		
REACH OUTFLOW FROM SUBBASIN 8 10-Year Analysis Period: 10/1/1982 - 9/30/1992 Flow volumes are (inches/year) for upstream drainage area		**USGS 03478400 BEAVER CREEK AT BRISTOL, VA** Bristol City, Virginia Hydrologic Unit Code 06010102 Latitude 36°37'54", Longitude 82°08'02" NAD27 Drainage area 27.70 square miles		
Total Simulated In-stream Flow:	**16.00**	Total Observed In-stream Flow:		**14.91**
Total of simulated highest 10% flows:	**4.26**	Total of Observed highest 10% flows:		**3.89**
Total of Simulated lowest 50% flows:	**4.18**	Total of Observed Lowest 50% flows:		**3.98**
Simulated Summer Flow Volume (months 7-9):	**2.30**	Observed Summer Flow Volume (7-9):		**2.36**
Simulated Fall Flow Volume (months 10-12):	**3.21**	Observed Fall Flow Volume (10-12):		**2.67**
Simulated Winter Flow Volume (months 1-3):	**5.90**	Observed Winter Flow Volume (1-3):		**5.23**
Simulated Spring Flow Volume (months 4-6):	**4.59**	Observed Spring Flow Volume (4-6):		**4.65**
Total Simulated Storm Volume:	**3.07**	Total Observed Storm Volume:		**2.47**
Simulated Summer Storm Volume (7-9):	**0.37**	Observed Summer Storm Volume (7-9):		**0.28**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	6.84	10		
Error in 50% lowest flows:	4.85	10		
Error in 10% highest flows:	8.53	15		
Seasonal volume error - Summer:	-2.24	30		
Seasonal volume error - Fall:	16.73	30		
Seasonal volume error - Winter:	11.39	30		
Seasonal volume error - Spring:	-1.35	30		
Error in storm volumes:	19.54	20		
Error in summer storm volumes:	24.77	50		

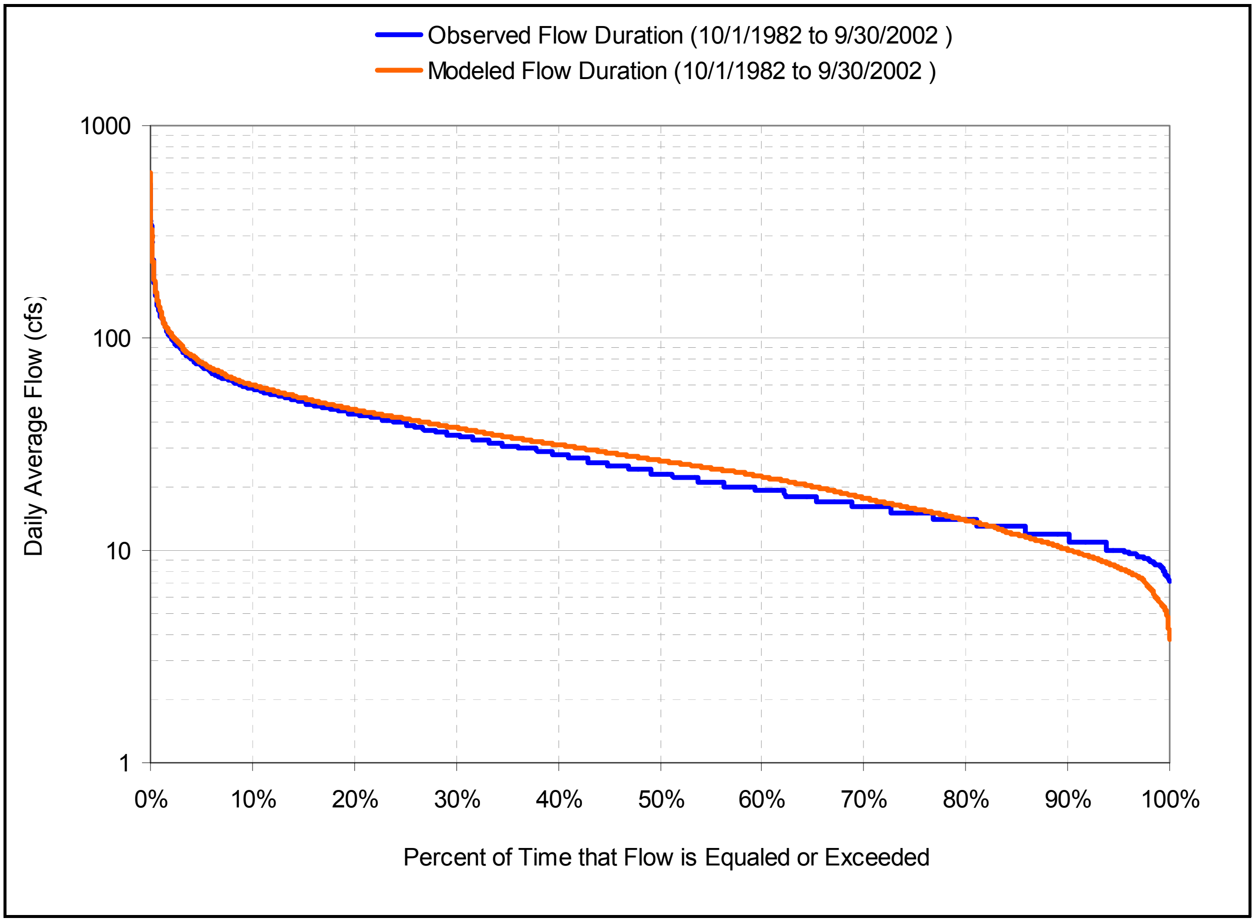

Figure 4.15 Modeled versus observed flow duration-exceedance curves for entire simulation time period at USGS 03478400 (water years 1983-2002)

It is important to note that although the semi-log plot allows for comparative visualization of flows that span several orders of magnitude, this type of graph tends to diminish the differences in high flows, while exaggerating the differences in low flows. The validity of any hydrology calibration must be evaluated using multiple comparisons like those shown previously.

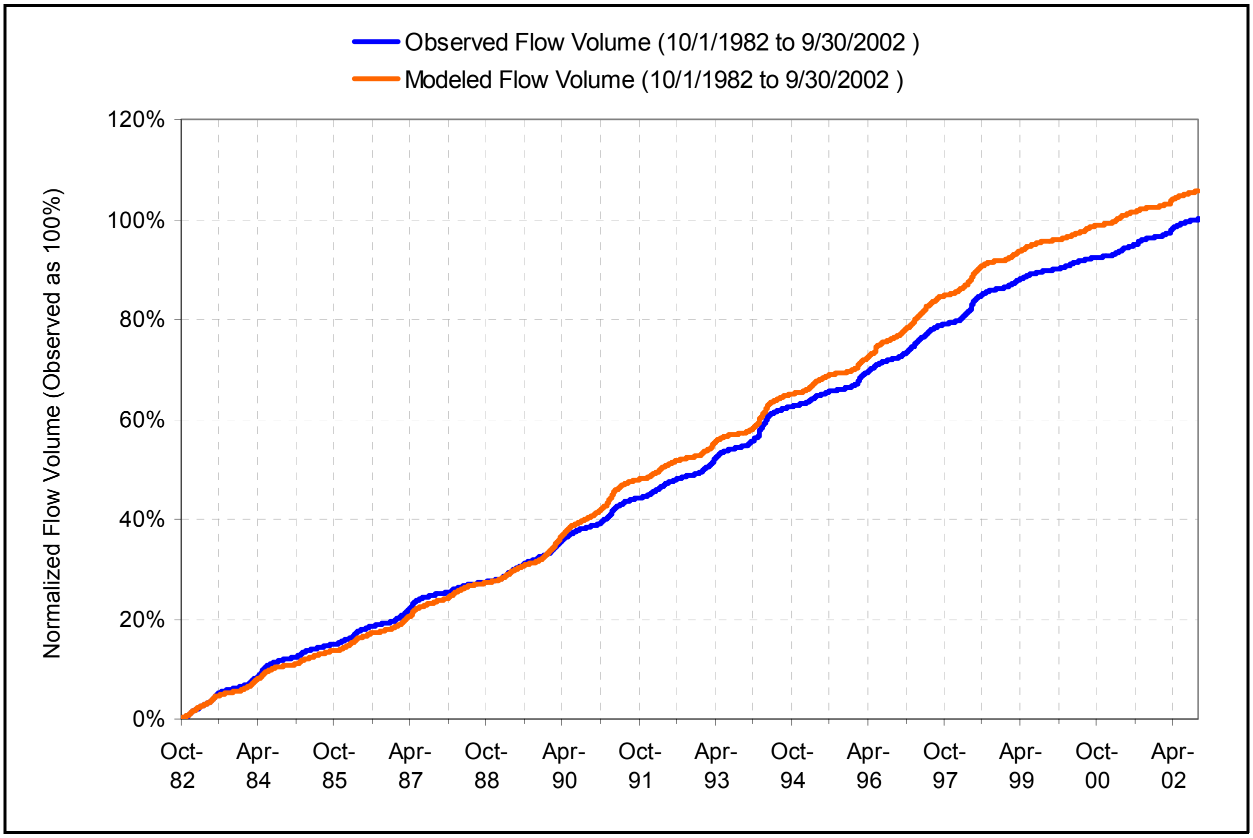

Figure 4.16 Modeled versus observed cumulative flow curves for entire simulation time period at USGS 03478400 (water years 1983-2002)

The cumulative flow shows about a 5.32% error in total flow volume over the 20-year period. Since the model uses fixed land use areas for the entire simulation period, it cannot adequately reflect the hydrologic impact of land use change over a long period of time. Looking at the two independent validation periods, the model predicted only 3.83% increase in flow from the observed between 1993 and 2002, but predicted a 6.84% increase in flow from observed data between 1983 and 1992 using 1990s land use data. It is not unreasonable to speculate that at least some of the model error is associated with gradual land use change over the 20 year simulation period; changes which are not reflected by the model.

A table of final hydrology calibration parameters is shown in Table 4.12.

Table 4.12 Final LSPC model hydrology calibration parameters by land use

Parameter	Barren	Cropland	Forest	Pasture	Strip Mining	Wetlands	Urban Pervious	Urban Impervious
LZSN	3	3	3	3	3	3	3	n/a
INFILT	0.2	0.2	0.3	0.2	0.2	0.3	0.2	n/a
KVARY	0.05	0.05	0.05	0.05	0.05	0.05	0.05	n/a
AGWRC	0.98	0.983	0.987	0.983	0.98	0.988	0.98	n/a
PETMAX	40	40	40	40	40	40	40	n/a
PETMIN	35	35	35	35	35	35	35	n/a
INFEXP	2	2	2	2	2	2	2	n/a
INFILD	2	2	2	2	2	2	2	n/a
DEEPFR	0.1	0.1	0.1	0.1	0.1	0.1	0.1	n/a
BASETP	0.03	0.03	0.03	0.03	0.03	0.03	0.03	n/a
AGWETP	0	0	0	0	0	0	0	n/a
UZSN	0.9	0.9	0.9	0.9	0.9	0.9	0.9	n/a
NSUR	0.1	0.3	0.45	0.3	0.1	0.45	0.15	0.15
INTFW	1	1	1	1	1	1	1	n/a
IRC	0.4	0.6	0.75	0.6	0.5	0.75	0.5	n/a
CEPSC-JAN	0.08	0.1	0.13	0.08	0.02	0.13	0.08	0.08
CEPSC-FEB	0.08	0.1	0.13	0.08	0.02	0.13	0.08	0.08
CEPSC-MAR	0.09	0.12	0.15	0.09	0.02	0.15	0.09	0.09
CEPSC-APR	0.11	0.15	0.19	0.11	0.02	0.19	0.11	0.11
CEPSC-MAY	0.17	0.23	0.29	0.17	0.02	0.29	0.17	0.17
CEPSC-JUN	0.21	0.27	0.34	0.21	0.07	0.34	0.21	0.21
CEPSC-JUL	0.22	0.3	0.37	0.22	0.07	0.37	0.22	0.22
CEPSC-AUG	0.23	0.31	0.38	0.23	0.07	0.38	0.23	0.23
CEPSC-SEP	0.22	0.3	0.37	0.22	0.07	0.37	0.22	0.22
CEPSC-OCT	0.21	0.28	0.35	0.21	0.02	0.35	0.21	0.21
CEPSC-NOV	0.18	0.25	0.31	0.18	0.02	0.31	0.18	0.18
CEPSC-DEC	0.11	0.15	0.19	0.11	0.02	0.19	0.11	0.11
LZETP-JAN	0.2	0.2	0.2	0.2	0.2	0.2	0.2	n/a
LZETP-FEB	0.25	0.2	0.2	0.2	0.25	0.25	0.2	n/a
LZETP-MAR	0.3	0.25	0.25	0.25	0.3	0.3	0.25	n/a
LZETP-APR	0.35	0.3	0.3	0.3	0.35	0.35	0.3	n/a
LZETP-MAY	0.48	0.5	0.5	0.5	0.48	0.72	0.6	n/a
LZETP-JUN	0.66	0.55	0.55	0.55	0.66	0.9	0.66	n/a
LZETP-JUL	0.84	0.6	0.6	0.6	0.84	0.9	0.72	n/a
LZETP-AUG	0.84	0.6	0.6	0.6	0.84	0.9	0.72	n/a
LZETP-SEP	0.72	0.5	0.5	0.5	0.72	0.72	0.6	n/a
LZETP-OCT	0.3	0.4	0.4	0.4	0.3	0.3	0.4	n/a
LZETP-NOV	0.25	0.25	0.25	0.25	0.25	0.25	0.25	n/a
LZETP-DEC	0.2	0.2	0.2	0.2	0.2	0.2	0.2	n/a

Fecal coliform accumulation and surface loading parameters for land uses were calculated based on contributions from various sources, as discussed in Section 3. After incorporating these model parameters and inputs, as well as contributions from livestock and wildlife point sources, septic systems, and background concentrations in the streams, modeled in-stream fecal coliform bacteria concentrations were compared to observed data. The modeled concentrations closely correspond to the observed fecal coliform bacteria values, as shown in Figures 4.17 and 4.18. The relative pattern of observed concentration levels is maintained in the modeled concentrations. It should be noted that the difference between the highest fecal coliform observed values and the modeled peak concentrations is due to laboratory detection limits which cap the maximum reported concentration at either 6,000 cfu/100mL or 8,000 cfu/100mL, depending on when the samples were collected and which laboratory protocol was used. Because of these maximum laboratory detection limits, the actual value may be significantly higher than the reported detection limit.

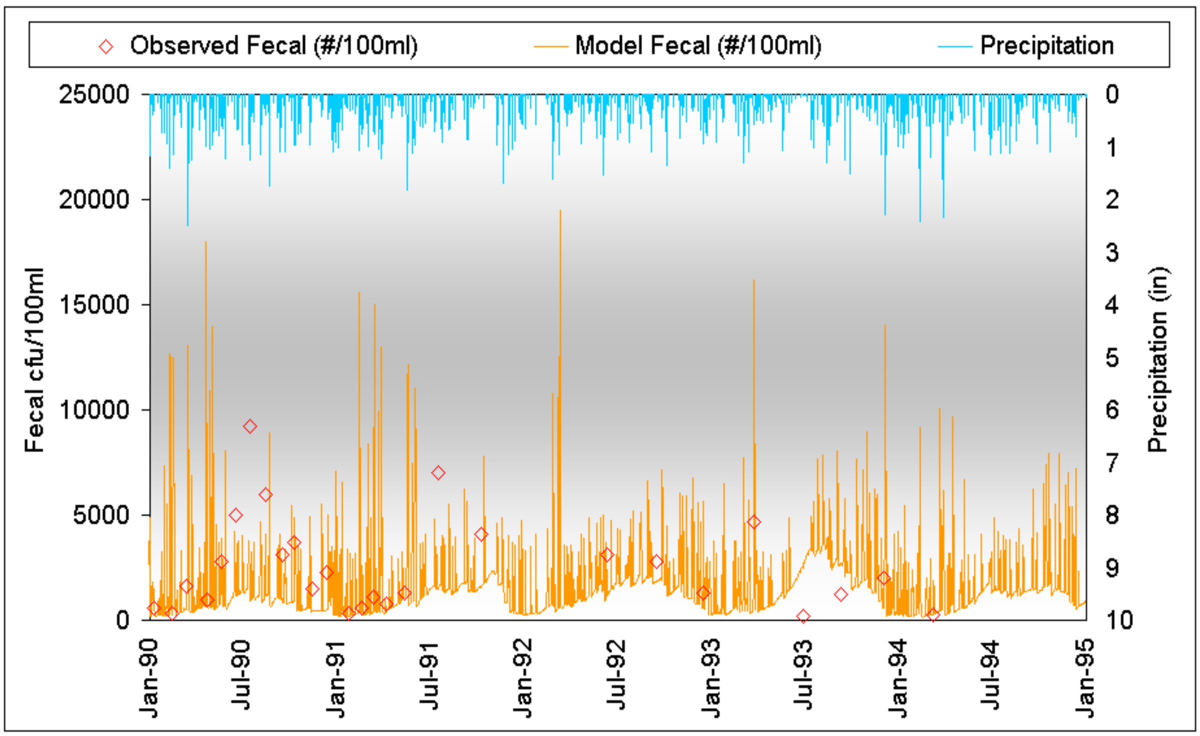

Figure 4.17 Water quality calibration at Station 6CBEV015.27 from 1/1/1990 - 1/1/1995

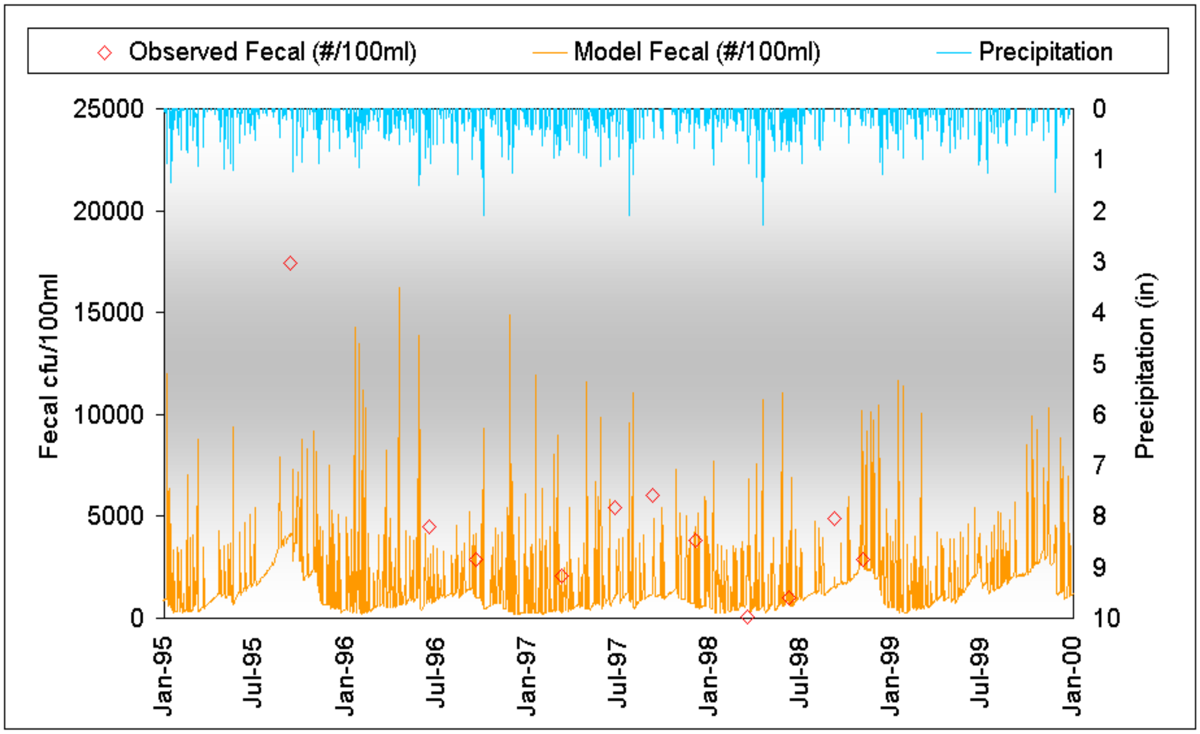

Figure 4.18 Water quality validation at Station 6CBEV015.27 from 1/1/1995 to 1/1/2000

4.7 Existing Loadings

The model was run for the representative hydrologic period January 1, 1990 through December 31, 2002. The modeling run represents the existing bacteria concentrations and loadings at the watershed outlet. The model predicts fecal coliform bacteria concentrations, which were converted to *E. coli* concentrations using the VADEQ fecal coliform bacteria/*E. coli* translator (VADEQ 2003). Figure 4.19 shows the existing instantaneous and geometric mean concentrations of *E. coli*. These data were compared to the 235 cfu/100mL instantaneous and 126 cfu/100mL geometric mean water quality criteria for *E. coli* to assess the magnitude of in-stream concentrations. Existing *E. coli* loadings by land use category for Beaver Creek subwatersheds are presented in Section 8. These values represent the contribution of *E. coli* loads from all sources in the watershed.

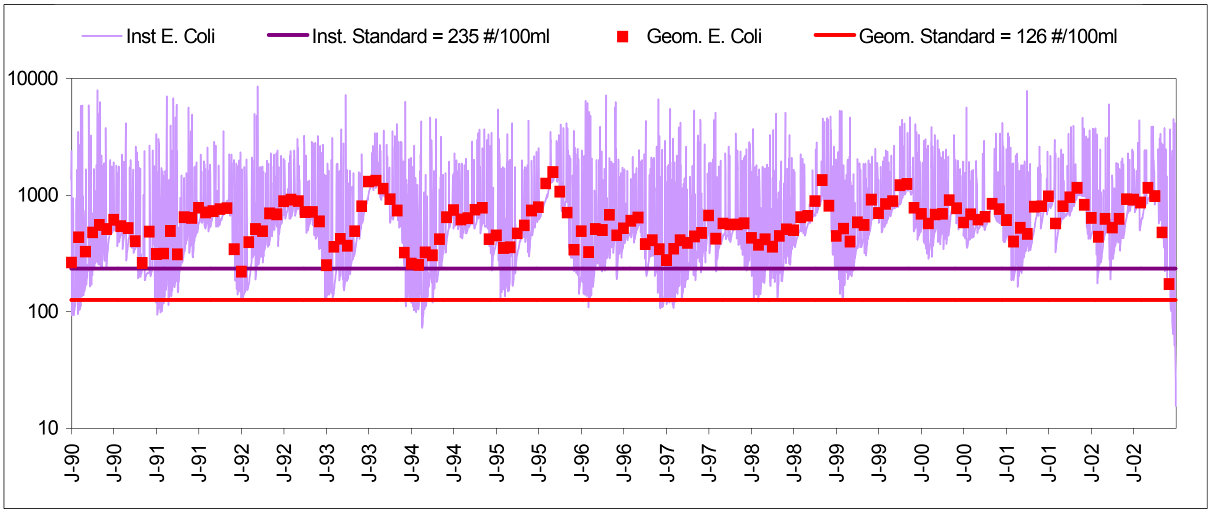

Figure 4.19 Existing instantaneous and geometric mean *E. coli* concentrations

SECTION 5

BENTHIC STRESSOR IDENTIFICATION

5.1 Stressor Identification Process

Biological assessments are useful in detecting impairment, but they do not necessarily identify the cause(s) of impairment. EPA developed the *Stressor Identification: Technical Guidance Document* to assist water resource managers in identifying stressors or combinations of stressors that cause biological impairment (Cormier et al. 2000). Elements of the stressor identification process were used to evaluate and identify the primary stressors of the benthic community in Beaver Creek. Watershed and water quality data from these streams, reference watershed data, and field observations were used to help identify candidate causes.

5.2 Candidate Causes

Based on information provided by VADEQ and watershed data collected at the beginning of the TMDL study, it was hypothesized that excessive sedimentation was responsible for the listed benthic impairments. Field visits to Beaver Creek were conducted by Tetra Tech, GMU, and VADEQ personnel on April 9 and June 25, 2003 to gather information on stream and watershed characteristics for stressor identification and modeling studies. Field observations confirmed the likelihood that sedimentation was primarily responsible for negative impacts to the benthic macroinvertebrate community in this stream. Potential stressors and their relationships to benthic community condition are discussed below.

5.2.1 Low Dissolved Oxygen

Organic enrichment can cause low dissolved oxygen (DO) levels which stress benthic organisms. In general, high nitrogen and phosphorus levels can lead to increased production of algae and macrophytes, which can result in the depletion of oxygen in the water column through metabolic respiration. In addition, at higher water temperatures the concentration of dissolved oxygen is lower because the solubility of oxygen (and other gases) decreases with increasing temperature. Higher water temperatures can be caused by the loss of shading, higher evaporation rates, reduced stream flow, and other factors.

Aquatic organisms, including benthic macroinvertebrates, are dependent upon an adequate concentration of dissolved oxygen. Less tolerant organisms generally cannot survive or are outcompeted by more tolerant organisms under low dissolved oxygen conditions. This process reduces diversity and alters community composition from a natural state. Aquatic insects and other benthic organisms serve as food items for fishes, therefore, alterations in the benthic community can impact fish feeding ecology (Hayward and Margraf 1987; Leach et al. 1977).

5.2.2 Sedimentation

Excessive sedimentation from anthropogenic sources is a common problem that can impact the stream biota in a number of ways. Deposited sediments reduce habitat complexity by filling pools, critical riffle areas, and the interstitial spaces used by aquatic invertebrates. Substrate size is a particularly important factor that influences the abundance and distribution of aquatic insects. Sediment particles at high concentrations can directly affect aquatic invertebrates by clogging gill surfaces and lowering respiration capacity. Suspended sediment also increases turbidity in the water column which can affect the feeding efficiency of visual predators and filter feeders. In addition, pollutants, such as phosphorus, adsorb to sediment particles and are transported to streams through erosion processes.

5.2.3 Habitat Alteration

The relative lack of riparian vegetation along sections of these streams was considered to be a potential factor affecting the benthic community. Minimal riparian vegetation was observed in specific areas during the TMDL field visit. In this watershed, riparian areas are often used to grow crops and as pasture for livestock. Additionally, the stream is channelized at several points throughout the watershed as it flows through urban areas. In these areas, riparian vegetation is lacking. Riparian areas perform many functions that are critical to the ecology of the streams that they border, such as:

- Flood detention
- Nutrient cycling
- Plant roots stabilize banks and prevent erosion
- Wildlife habitat
- Canopy vegetation provides shading (decreases water temperature and increases baseflow through lower evaporation rates)

5.2.4 Toxic Pollutants

Toxic pollutants in the water column and sediment can result in acute and chronic effects on aquatic organisms. Increased mortality rates, reduced growth and fecundity, respiratory problems, tumors, deformities, and other consequences have been documented in toxicity studies of aquatic organisms. Degraded water quality conditions and other environmental stressors can lead to higher rates of incidence of these problems.

5.3 Monitoring Data Summary

5.3.1 Water Quality Criteria

Beaver Creek is classified as a Mountainous Zone Water (Class IV) in Virginia's Water Quality Standards (9 VAC 25-260-50). Numeric criteria for dissolved oxygen (DO), pH, and maximum temperature for Class IV waters are shown in Table 5.1.

Table 5.1 Virginia numeric criteria for Class IV waters

Dissolved Oxygen (mg/L)		pH (standard units)	Maximum Temperature (ºC)
Minimum	Daily Average		
4	5	6.0 - 9.0	31

Data collected on Beaver Creek include VADEQ Ambient Water Quality Monitoring (AWQM) data, VADEQ biomonitoring data, GMU water quality and biomonitoring data, and EHC water quality data (see Section 2.3). VADEQ AWQM data are typically collected on a monthly basis and biomonitoring data are typically collected in the spring and fall of each year. GMU personnel collected monitoring data on Beaver Creek on April 9 and June 25, 2003. EHC collected water quality data from March 2001 through April 2002.

5.3.2 Water Quality Summary Plots

Selected parameters were plotted to examine spatial trends and to compare impaired and reference stream conditions. Water quality monitoring data collected by VADEQ and GMU are shown in a time-series format for the period of record 1985 to present (Figures 5.1 through 5.15). Time-series plots show all the individual observations over the period of record for each station. Water quality data collected during biomonitoring field visits were not included in these plots. Station locations and other summary data are presented in Section 2.3.

*Note that GMU water quality data were added to the VADEQ data set for each station because of the approximate co-location of VADEQ and GMU monitoring stations on both streams. Stations are identified using VADEQ station codes in each plot. Time-series plots show the individual observations for all VADEQ and GMU data.

Dissolved Oxygen

DO concentrations measured at VADEQ and GMU monitoring stations were above established criteria (5.0 mg/L) (Figure 5.1). The lowest measurements were recorded at VADEQ stations 6CBEV015.27 and 6CBEV020.86.

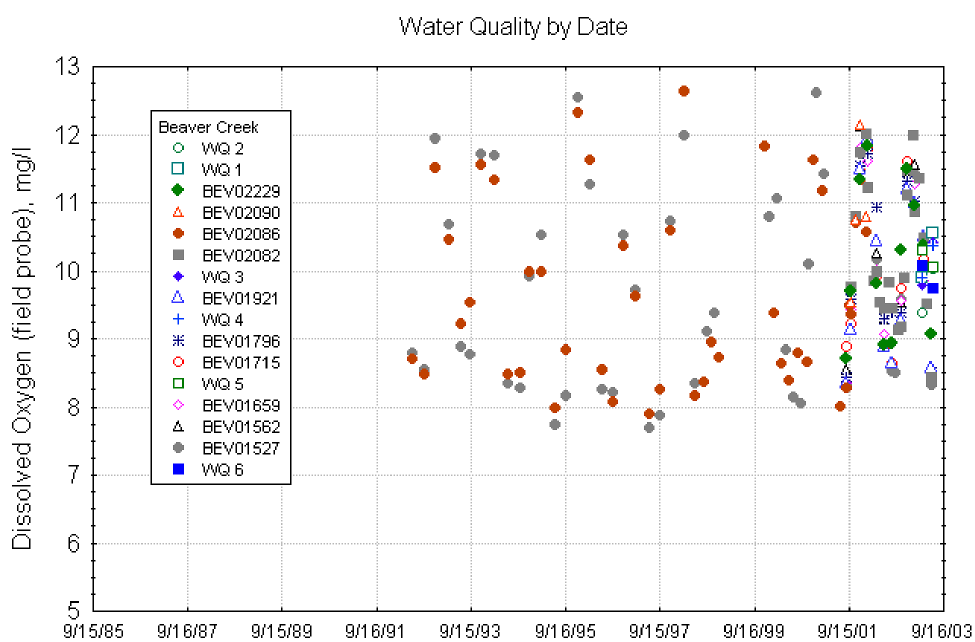

Figure 5.1 Time-series DO values for Beaver Creek stations

Water Temperature

Surface water temperature data for all monitoring stations are shown in Figure 5.2. All observations were below the Class IV maximum criteria (31 degrees Celsius). The highest water temperatures were recorded at station 6CBEV015.27.

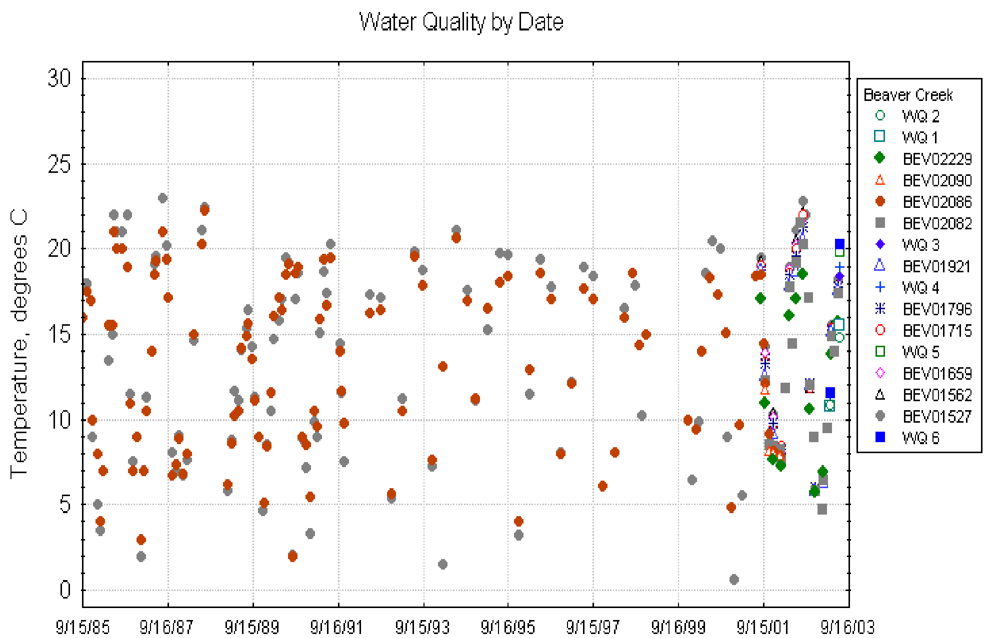

Figure 5.2 Time-series temperature values for Beaver Creek stations

pH

pH data for Beaver Creek are shown in Figure 5.3. All pH values were within the acceptable Class IV range (6.0 – 9.0 standard units). VADEQ station 6CBEV020.86 displayed the greatest fluctuation in pH conditions.

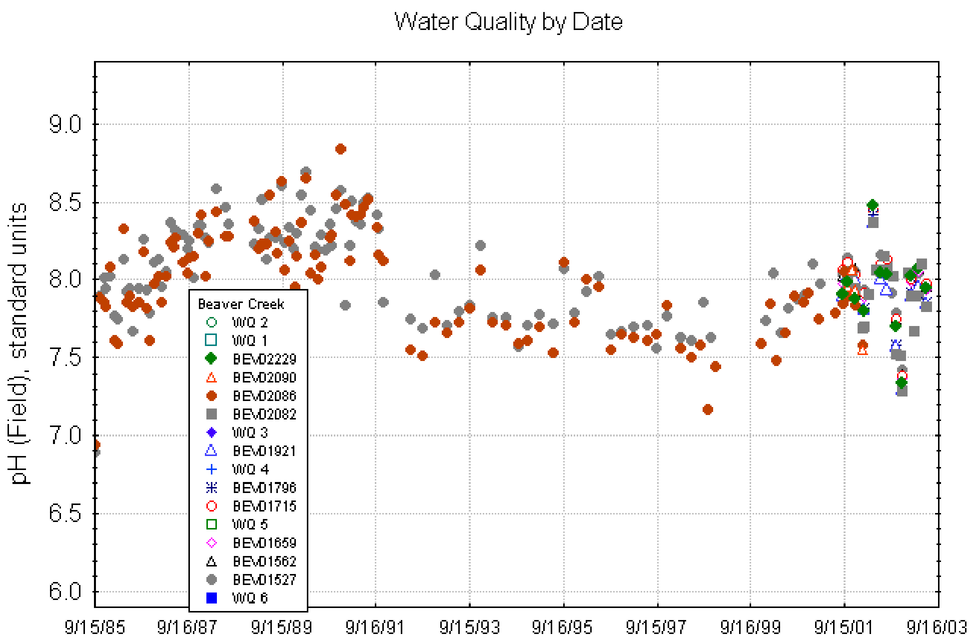

Figure 5.3 Time-series pH values for Beaver Creek stations

Conductivity (Specific Conductance)

Conductivity data are presented in Figure 5.4. Conductivity is used as a general indicator of possible water quality problems. High conductivity values were recorded at all Beaver Creek stations. These high values are indicative of anthropogenic (human caused) inputs to the stream and Station 6CBEV015.27 had the highest conductivity measurements.

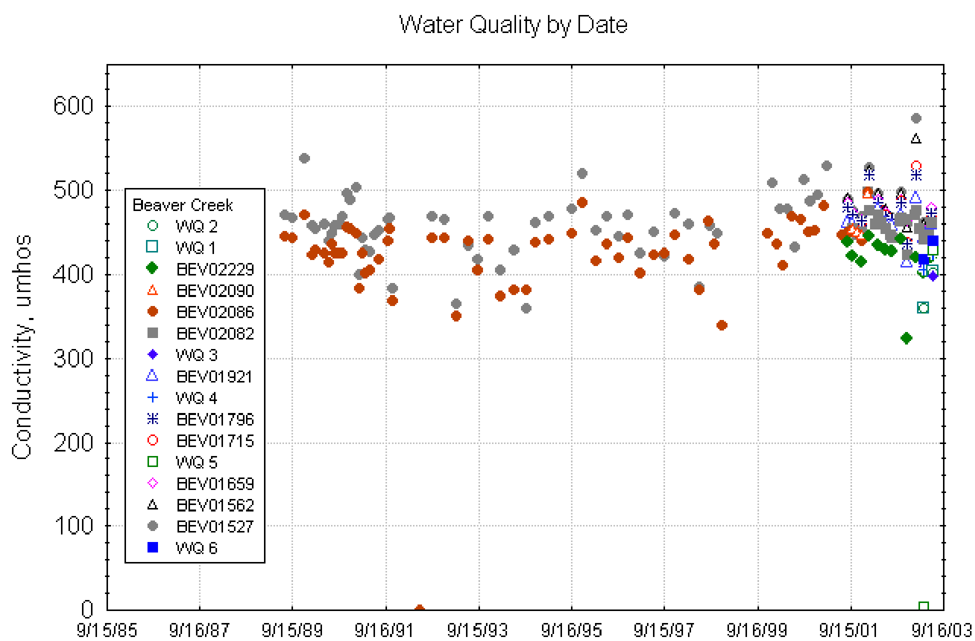

Figure 5.4 Time-series conductivity values for Beaver Creek stations

BOD5

Biochemical oxygen demand (BOD) is the measure of the amount of oxygen consumed by microorganisms during decomposition of organic matter. BOD5 is the biochemical oxygen demand measured over five days. This parameter is a good indicator of the amount of organic matter contributed to a waterbody. BOD5 data for Beaver Creek are presented in Figure 5.5. High BOD5 measurements were recorded on several occasions at Beaver Creek stations (> 3 mg/L).

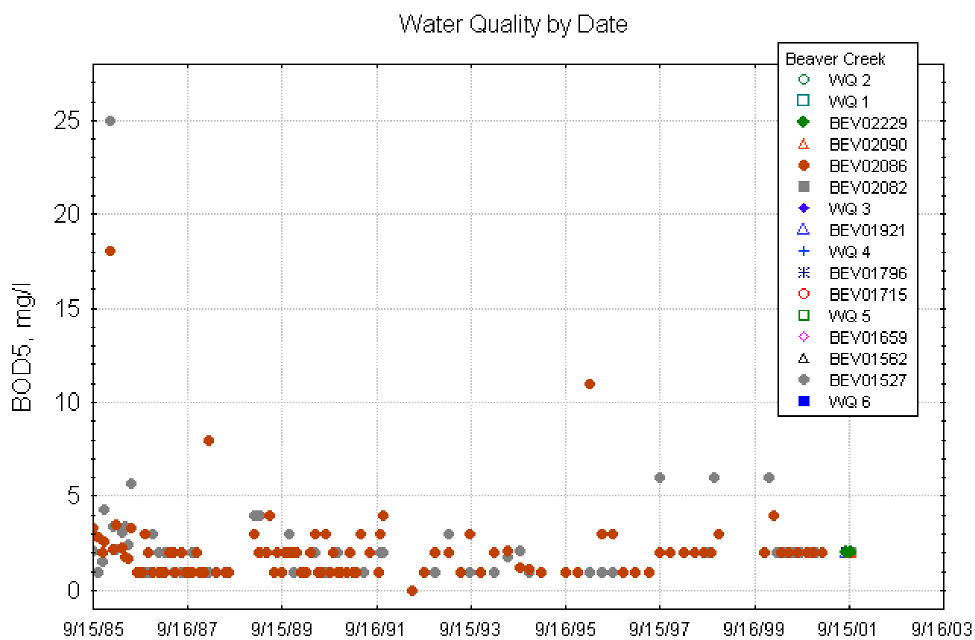

Figure 5.5 Time-series BOD5 values for Beaver Creek stations

Phosphorus

Phosphorus is generally present in waters and wastewaters in different species of soluble (dissolved) and insoluble (particulate or suspended) phosphates, including inorganic (ortho- and condensed) phosphates and organic phosphates. Major sources of phosphorus include detergents, fertilizers, domestic sewage, and agricultural runoff. Total phosphorus and orthophosphate data are presented in Figures 5.6 and 5.7. Station 6CBEV020.86 exhibited the highest phosphorus concentrations. Several observations were noted above the VADEQ assessment guidance threshold of 0.2 mg/L.

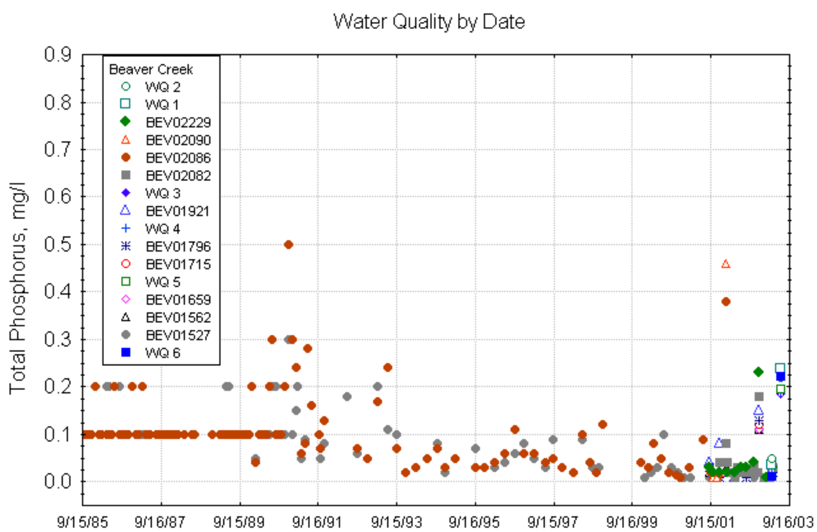

Figure 5.6 Time-series total phosphorus values for Beaver Creek stations

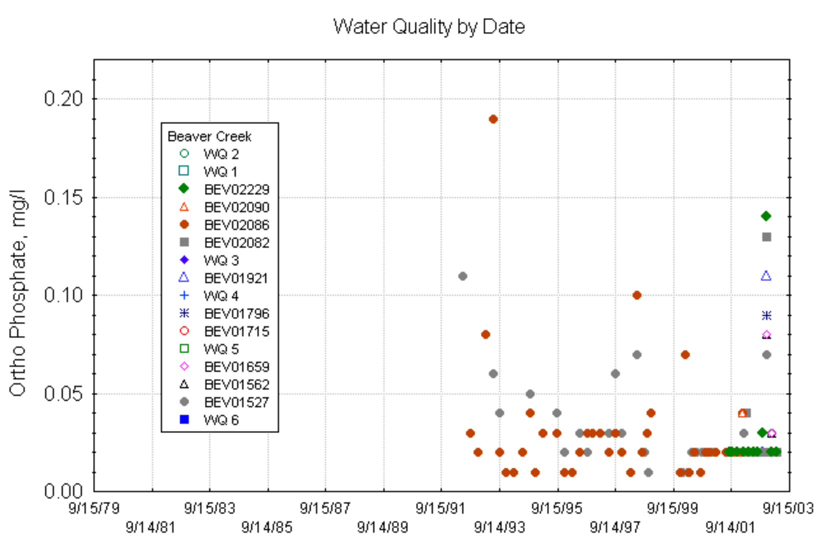

Figure 5.7 Times-series orthophosphate values for Beaver Creek stations

Nitrogen

Major sources of nitrogen to the watershed include municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes, runoff from fertilized agricultural field and lawns, and discharges from car exhausts. Nitrogen species data are shown in Figures 5.8 through 5.10. Total Kjeldahl Nitrogen (TKN) data are presented in Figure 5.11. The highest single nitrate measurement was recorded for stationWQ2. Several other Beaver Creek stations had nitrate and nitrite concentrations above background conditions.

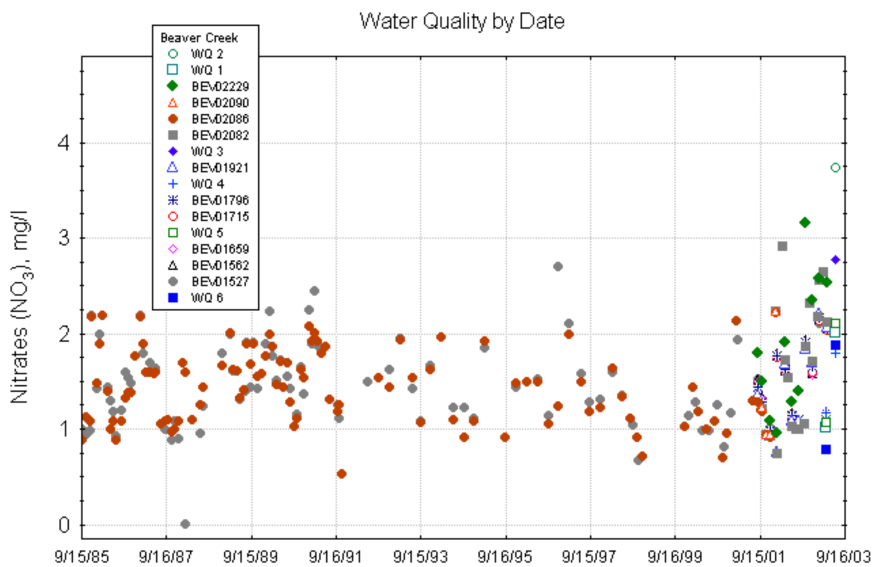

Figure 5.8 Time-series nitrate values for Beaver Creek stations

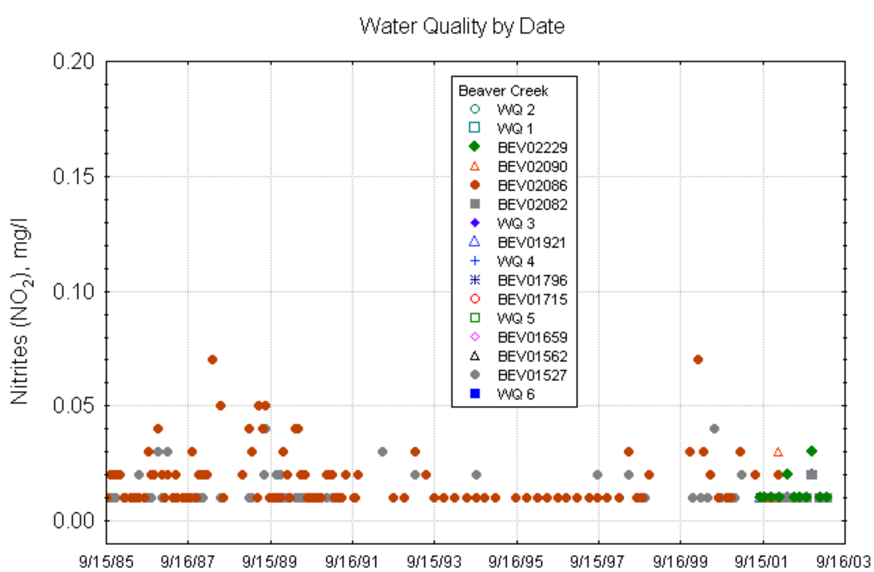

Figure 5.9 Time-series nitrite values for Beaver Creek stations

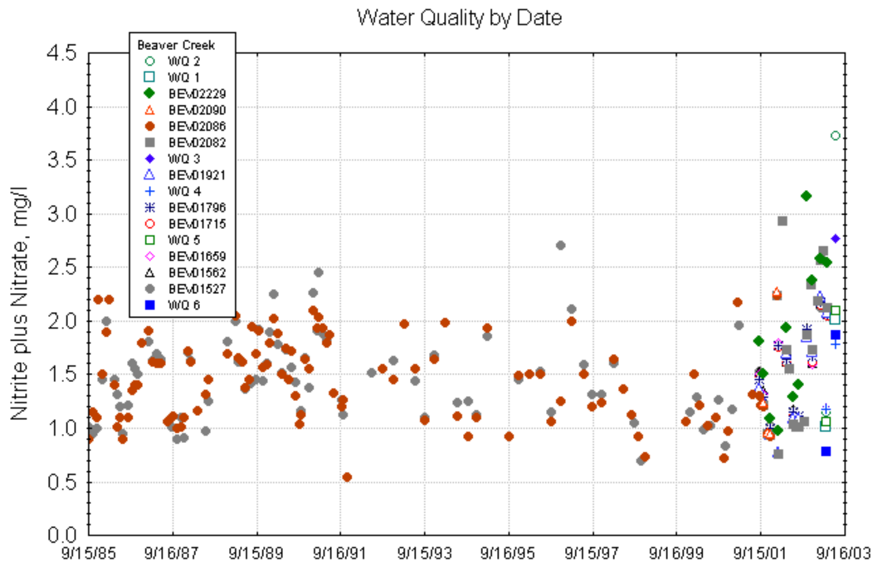

Figure 5.10 Time-series nitrite+nitrate values for Beaver Creek stations

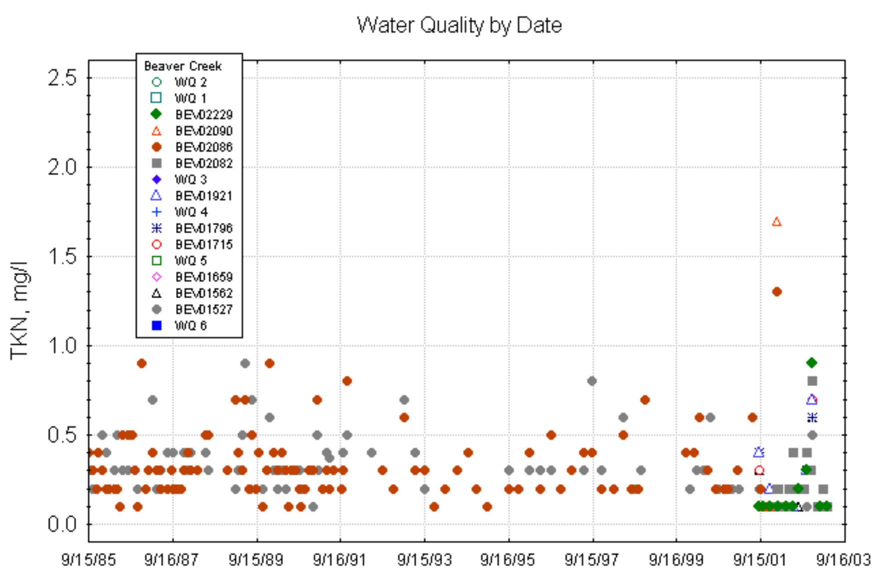

Figure 5.11 Time-series TKN values for Beaver Creek stations

Ammonia

Ammonia is a critical component of the nitrogen cycle. At high concentrations, ammonia is toxic to aquatic life, depending on instream pH and temperature levels. In general, higher temperature and pH levels increase the toxicity of ammonia. Virginia Water Quality Standards (9 VAC 25-260-140) list acute and chronic criteria for ammonia. Figure 5.12 shows total ammonia ($NH3+NH4$) values for Beaver Creek stations. High ammonia measurements were recorded for several stations on Beaver Creek. Station 6CBEV015.27 had the highest single observation during the period of record. Ammonia is also discussed in Section 5.5 (Toxic Pollutants).

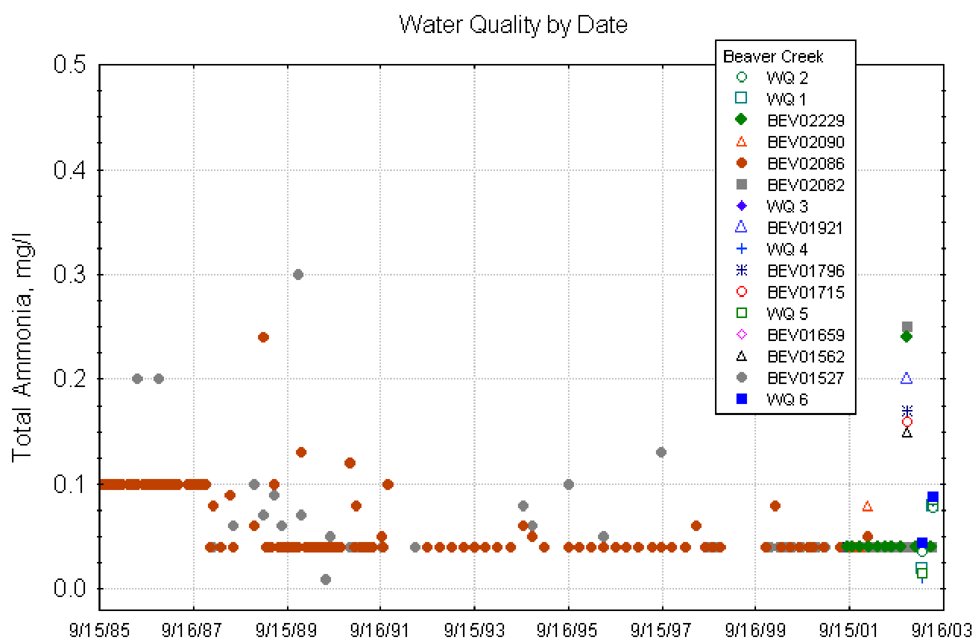

Figure 5.12 Time-series ammonia values for Beaver Creek stations

Nitrogen to Phosphorus ratios (N:P)

Based on available water quality data, nitrogen to phosphorus ratios were calculated for each water quality station to determine the limiting nutrient in the Beaver Creek watershed (Figure 5.13). An N:P ratio greater than 10 typically indicates a phosphorus limited system; while a ratio of less than 10 indicates a nitrogen limited system. The majority of the calculated N:P ratios were above 10, which indicates phosphorus is the limiting nutrient for algal production in the stream.

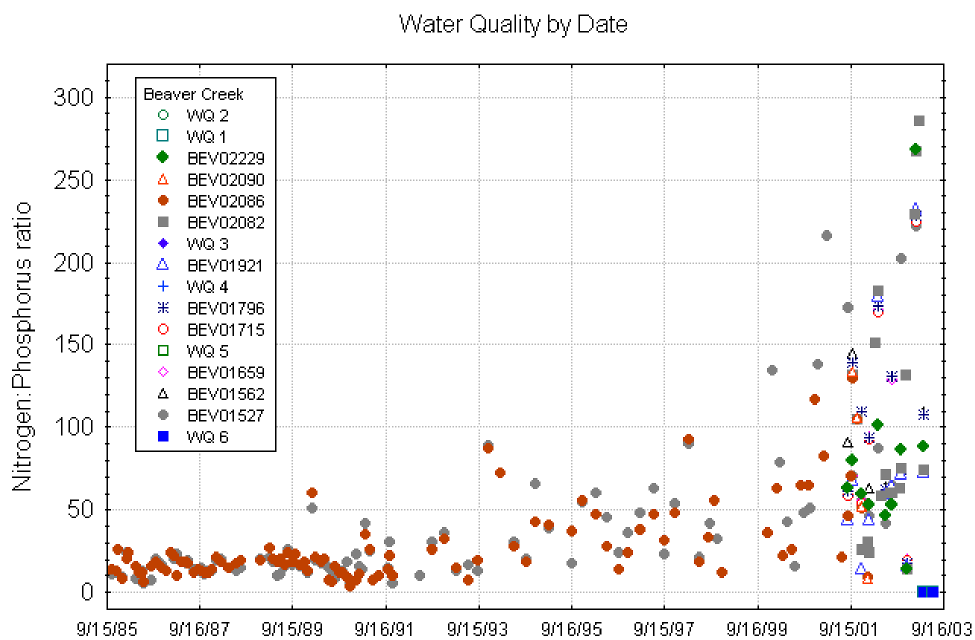

Figure 5.13 Time-series N:P ration for Beaver Creek stations

<u>Total Suspended Solids and Turbidity</u>

Total suspended solids (TSS) and turbidity data were used to help examine possible sedimentation impacts on the benthic macroinvertebrate community (Figures 5.14 through 5.15). These sedimentation measurements show a similar pattern with high observations recorded at several stations on Beaver Creek. VADEQ does not have established criteria for these parameters.

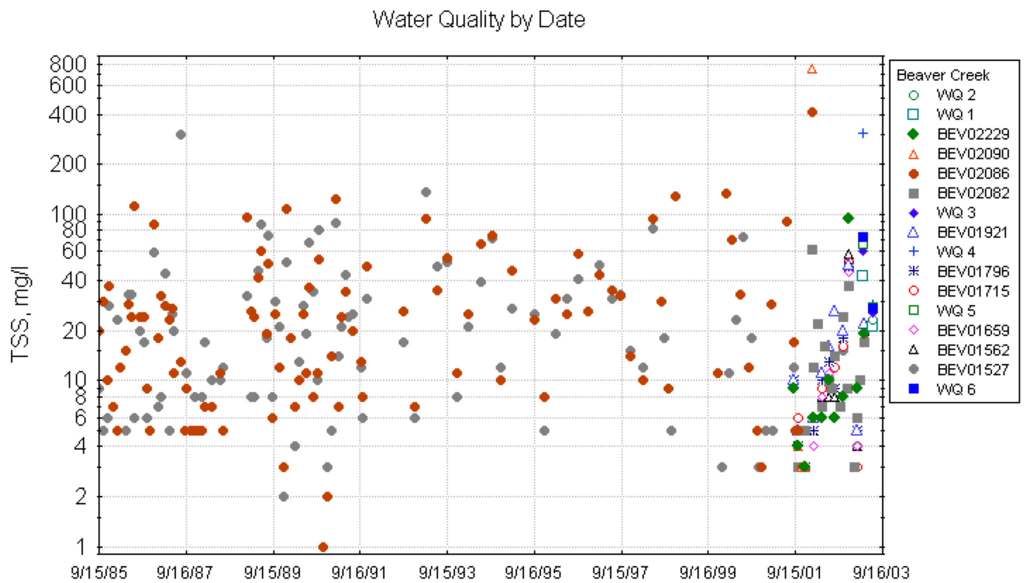

Figure 5.14 Time-series TSS values for Beaver Creek stations

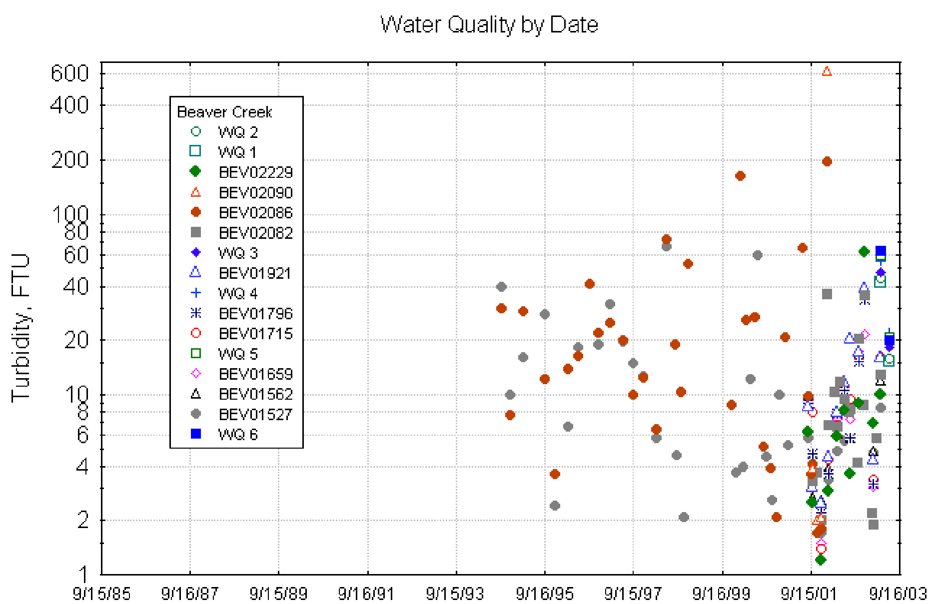

Figure 5.15 Time-series turbidity data for Beaver Creek stations

5.3.3 DO Analysis

Primary producers (algae and macrophytes) produce oxygen during the day through photosynthesis and use oxygen at night through respiration. This diel photosynthesis/respiration cycle results in higher DO concentrations during the day and lower concentrations at night. VADEQ and GMU data collected at Beaver Creek stations were compared to the daily average (5.0 mg/L) and minimum (4 mg/L) DO criteria listed in Virginia's Water Quality Standards to help determine if DO conditions are considered to be a primary cause of the benthic impairment. DO data collected indicated acceptable DO conditions in Beaver Creek (Figure 5.1). There were no ambient observations below the 5.0 mg/L daily average criteria. The lowest DO measurements recorded (at VADEQ stations 6CBEV015.27 and 6CBEV020.86) were above 7.5 mg/L

To further investigate the potential for low DO conditions, VADEQ conducted dissolved oxygen monitoring at two stations on Beaver Creek in the early morning hours on September 6, 2002 (Table 5.2). DO conditions are typically lowest during summer months in the early morning hours due to higher temperatures and lower flow. These data did not show observations below the 5.0 mg/L daily average criteria for both Beaver Creek stations.

Table 5.2 VADEQ early morning DO study (Summer 2002)

Station	Date/Time	Temperature (Celsius)	PH (std. units)	Conductivity (umhos)	DO (mg/L)
6CBEV023.99	9/6/02 5:35am	15.8	7.59	714	8.45
6CBEV023.99	9/6/02 6:15am	15.6	7.63	419	8.33
6CBEV015.27	9/6/02 5:55am	18.8	7.87	474	7.67

5.3.4 GMU Taxa Data

Taxa data collected by GMU personnel in June of 2003 are shown in Table 5.3. This table includes data for three sites on Beaver Creek. Samples from other sites in the watershed are currently being processed. The high number of hydropsychids, chironomids, and oligochaetes indicate excessive sedimentation and corresponding habitat problems. These data do not show strong evidence of metals toxicity. VADEQ compared toxic pollutant and biomonitoring data from station 6CBEV020.86 (GMU station Beaver3). Mayflies and caddisflies are represented primarily by facultative families, but there is also representation from a metals-sensitive family (i.e., *Glossosomatidae*) plus sensitive Coleopterans (*Elmidae* and *Psephnidae*). Note that the stations listed in Table 5.3 are located upstream of several industrial point sources in the watershed and VADEQ station 6CBEV015.27, which reported the highest concentrations of toxic pollutants.

Table 5.3 GMU macroinvertebrate assessment

Site ID		**Beaver1**	**Beaver2**	**Beaver3**
Corresponding DEQ station		6CBEV023.99	6CBEV024.60	6CBEV020.86
Date		6/25/2003	6/25/2003	6/25/2003
Organisms Identified		**Count**		
Order	**Family**			
Trichoptera (Caddisflies)	Hydropsychidae	26	9	16
	Glossosomatidae	1		18
	Polycentropodidae	2		
Ephemeroptera (Mayflies)	Ephemerellidae	21	27	12
Diptera (True flies)	Chironomidae (midges)	83	64	10
	Simuliidae (Black flies)		27	26
	Tipuliidae (crane flies)	2		7
	Empididae (Aquatic Dance flies)			1
	Stratiomyidae (soldier flies)			1
Coleoptera (Water Beetles)	Elmidae	27	24	31
	Psephenidae			1
Coleoptera (Water Beetles)	Dytiscidae		2	
Odonata (Dragonflies & Damselflies)	Gomphidae (Clubtails)			1
Hemiptera (Waterbugs)				
Crustacea	Isopoda/ Asellidae (sowbugs)	1	1	2
	Decapoda/ Astacidae (Crayfish)	7	1	
P. Annelida	C. Oligochaeta (Earthworms)	37	64	64
	C. Hirudinea (Leeches)		5	
P. Mollusca	C. Gastropoda (Snails)	1		5
	C. Bivalvia (Clams & Mussels)			6
Total		208	224	201

5.3.5 Rapid Bioassessment Protocol - Habitat Data

Rapid Bioassessment Protocol (RBP) habitat data for Beaver Creek VADEQ and GMU biomonitoring stations are shown in Tables 5.4 and 5.5. These data were used to examine possible sedimentation and other habitat impacts to the benthic community, along with the TSS and turbidity data discussed above. All habitat scores were evaluated and rated by observation (0-20, with higher scores being better). The following parameters are included in the habitat assessment for Beaver Creek:

- Channel alteration – measure of large-scale changes in the shape of the stream channel
- Bank condition/stability – whether the stream banks are eroded (or have the potential for erosion)
- Bank vegetative protection – the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone
- Instream cover (for fish)
- Embeddedness – extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of the stream bottom
- Channel flow status – degree to which the channel is filled with water
- Grazing or other bank disruptive pressure
- Frequency of riffles
- Riparian vegetation zone width – width of natural vegetation from the edge of the stream bank out through the riparian zone
- Sediment deposition – amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition
- Epifaunal substrate – relative quantity and variety of natural structures in the stream for spawning and nursery functions of aquatic macrofauna
- Velocity/depth regimes

Table 5.4 VADEQ RBP habitat scores for Beaver Creek

StationID	CollDate	Total Habitat Score	Habitat Parameter Name / DEQ Category Number											
			Instream Cover	Epifaunal Substrate	Embed-dedness	Velocity Depth Regimes	Channel Alteration	Sediment Deposition	Riffle Frequency	Channel Flow Status	Bank Condition	Bank Vegetative Protection	Grazing/ other disruptive pressure	Riparian Vegetative Zone
BEV23.99	11/20/1992	109	13	7	8	17	13	8	8	8	5	8	5	9
BEV23.99	10/25/1993	95	6	3	11	17	5	6	8	9	7	9	6	8
BEV24.60	11/4/1991	108	13	9	7	16	12	8	8	8	6	6	6	9
BEV24.60	5/12/1992	107	13	7	7	16	8	9	8	12	6	7	5	9
BEV24.60	11/20/1992	119	15	12	7	16	10	8	8	12	8	9	5	9
BEV24.60	10/25/1993	120	16	11	7	17	13	8	8	9	8	9	5	9

Table 5.5 GMU RBP habitat scores for Beaver Creek

StationID	CollDate	Total Habitat Score	Epifaunal substrate/ Available cover	Embed-dedness	Velocity/ Depth Regime	Channel Alteration	Sediment Deposition	Frequency of Riffles	Channel Flow Status	Bank Stability	Vegetative Protection	Riparian Vegetative Zone Width
Beaver2	6/25/2003	91.5	6	5	12	15	8	10	16	8	8	3.5
Beaver3	6/25/2003	70	7	8	6	9	4	6	18	5	6	1

Total suspended solids (TSS) data, habitat data collected during biomonitoring site visits, and field observations made during TMDL site visits were used to examine the likelihood of sedimentation impacts on the benthic community in Beaver Creek.

Habitat parameters which provide information on possible sedimentation problems (epifaunal substrate, embeddedness, and sediment deposition) received some of the lowest scores, especially in the more recent assessment done by GMU personnel in 2003.

5.4 Toxic Pollutants - Surface Water

Virginia Water Quality Standards list acute and chronic criteria for surface waters (9 VAC 25-260-140). These numeric criteria were developed for metals, pesticides, and other toxic chemicals which can cause acute and chronic adverse effects on aquatic life and human health. Available water quality data were compared to these criteria to determine possible effects on aquatic life. Ammonia data collected on Beaver Creek (see Section 5.4.2, Figure 5.13) were compared to the calculated acute and chronic criteria. No violations of the ammonia criteria were noted. All other available water quality data were compared to these criteria to determine possible effects on aquatic life. No violations were noted based on the data available (only water column metals data were available).

5.5 Toxic Pollutants - Sediment

Virginia's Water Quality Standards and updated 305(b) assessment guidance for sediment parameters were consulted to determine if the available data indicate high levels for metals, pesticides, or other constituents that can cause acute or chronic toxic effects on aquatic life. Sediment data were assessed using EPA Probable Effects Concentration (PEC) thresholds and the NOAA Effects Range-Median (ER-M) and Effects Range-Low (ER-L) screening values. Concentrations above these values may indicate possible toxic effects, depending on magnitude and duration of exposure. Sediment parameter data are presented in Table 5.6. Recorded detection limits and off-scale low values (known to be less than the value shown) are referenced in the table (STORET remark codes U and K, respectively).

VADEQ uses the Probable Effects Concentration (PEC) criteria to help determine possible toxic effects to aquatic life (VADEQ 2002b). PEC criteria were exceeded for copper and lead at Station 6CBEV015.27. The copper exceedances were recorded on June 17, 1981 and March 12, 1991. The lead exceedances were recorded on 11 occasions from June 17, 1981 through June 3, 1994. Recent data do not show exceedances of these criteria; therefore, metals toxicity does not appear to be a current problem.

Table 5.6 Sediment parameter exceedances

* Bolded threshold levels were exceeded on at least one occasion

Parameter	Date	Value	PEC	ER-M	ER-L
DEQ station 6CBEV015.27					
PCB Total (ppb)	6/24/1997	80	676	180	**22.7**
- 12 total samples: 6/6/84 – 7/7/98					
- 10 samples below detection limit, all prior to 1997	7/7/1998	70			
Arsenic (ppm)	5/22/1980	10.3	33	70	**8.2**
- 16 total samples: 5/22/80 – 9/9/02	6/17/1981	10.4			
- 8 samples < ER-L or below detection limit, since 3/23/88	6/14/1983	11.1			
	6/6/1984	9.5			
	4/11/1985	9.7			
	3/6/1986	10.3			
	3/13/1989	9			
	3/12/1990	10			
Cadmium (ppm)	6/17/1981	4.6	4.98	9.6	**1.2**
- 16 total samples: 5/22/80 – 9/9/02					
- 15 samples < ER-L or below detection limit					
Copper (ppm)	6/17/1981	360	**149**	**270**	**34**
- 15 total samples: 5/22/80 – 9/9/02	6/14/1983	35.2			
- 5 samples < ER-L	3/6/1986	45.3			
- Recent samples:	3/23/1988	68			
7/7/98 12.89 ppm	3/12/1990	94			
9/9/02 28.8 ppm	3/12/1991	150			
	9/22/1992	76			
	6/4/1993	59			
	6/3/1994	69			
	7/8/1996	57			
Mercury (ppm)	6/6/1984	0.24	1.06	0.71	**0.15**
- 15 total samples: 5/22/80 – 9/9/02					
- 13 samples < ER-L or below detection limit	3/6/1986	0.26			
Nickel (ppm)	6/17/1981	28.3	48.6	**51.6**	**20.9**
- 15 total samples: 5/22/80 – 9/9/02	6/14/1983	22.2			
- 12 samples < ER-L	6/6/1984	61			
Lead (ppm)	5/22/1980	38.5	**128**	**223**	**46.7**
- 15 total samples: 5/22/80 – 9/9/02	6/17/1981	210			
- Lower concentrations observed in recent samples	6/14/1983	204			
	6/6/1984	342			
	4/11/1985	136			
	3/6/1986	123			
	3/23/1988	221			
	3/12/1990	298			
	3/12/1991	410			
	9/22/1992	1462			
	6/4/1993	190			
	6/3/1994	740			
	7/8/1996	94			
	7/7/1998	66.81			
	9/9/2002	60.6			
DEQ Station 6CBEV020.86					
Arsenic (ppm)	5/22/1980	14.9	33	70	**8.2**
- 15 total samples: 5/22/80 – 7/7/98	6/17/1981	15.5			
- 5 samples < ER-L or below detection limit	6/14/1983	35.7			
- Recent sample:	6/6/1984	13			
7/7/98 6.34 ppm	4/11/1985	20			
	3/6/1986	16.5			
	3/13/1989	9			
	3/12/1991	10			
	6/3/1994	10			
	7/8/1996	10			
Cadmium (ppm)	6/17/1981	3.2	4.98	9.6	**1.2**
- 15 total samples: 5/22/80 – 7/7/98					
- 14 samples < ER-L and below detection limit					

5.6 Emory and Henry College Pollutant Study

A general stream characterization and water quality study of Beaver Creek was conducted by Emory and Henry College in 2001 and 2002. Ten sites along Beaver Creek were monitored in this thesis study. Station locations and other summary data are presented in Section 2.3. Water quality indicators measured included temperature, conductivity, total dissolved solids, pH, dissolved oxygen, nitrate, phosphate, and fecal and total coliform levels. Measurements were taken in September, October, and November of 2001 and in March and April of 2002. Antibiotic resistance and optical brightener tests were also performed in March and April of 2002 to better understand bacteria sources and the use of detergents in the watershed.

The study concluded that the general health of Beaver Creek was satisfactory. Temperature, conductivity, total dissolved solids, pH, and dissolved oxygen levels were adequate. However, high fecal coliform bacteria and nutrient levels were observed in Beaver Creek at several locations. The study indicated that agricultural areas in the watershed were likely responsible for the high bacteria and nutrient concentrations measured in Beaver Creek, although additional data collection and verification was needed.

5.7 Summary

Based on the above analysis, excessive sedimentation is considered to be primarily responsible for the benthic impairment in Beaver Creek. Past sediment metals and total PCB concentrations indicated possible toxic effects; however, recent data do not show violations of EPA's Probable Effects Concentration (PEC) criteria. Biomonitoring data did not show conclusive evidence of metals toxicity problems, although these stations are located upstream of areas with higher concentrations. EPA toxicity tests were not conducted for this stream. Follow-up monitoring is needed to assess possible metals contamination problems. DO concentrations are adequate to support aquatic life, therefore, nutrient (phosphorus) reductions do not appear to be required. Sediment reductions, as required by the TMDL, will likely result in the reduction in nutrients and other parameters that may be causing water quality and biological problems in Beaver Creek.

SECTION 6

SOURCE ASSESSMENT - SEDIMENT

Point and nonpoint sources of sediment were assessed in TMDL development. The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources in impaired and reference watersheds including: MRLC land use/land cover data, water quality monitoring and point source data provided by VADEQ, STATSGO soils data (NRCS), site visit observations, literature sources, and other information. Procedures and assumptions used in estimating sediment sources in impaired and reference watersheds are described in the following sections. Whenever possible, data development and source characterization was accomplished using locally-derived information.

6.1 Assessment of Nonpoint Sources

Erosion of the land results in the transport of sediment to receiving waters through various processes. Factors that influence erosion include characteristics of the soil, vegetative cover, topography, and climate. Nonpoint sources, such as agricultural land uses and construction areas, are large contributors of sediment because the percentage of vegetative cover is typically lower. Urban areas can also contribute quantities of sediment to surface waters through the build-up and eventual washoff of soil particles, dust, debris, and other accumulated materials. Pervious urban areas, such as lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses. In addition, streambank erosion and scouring processes can result in the transport of additional sediment loads.

6.1.1 Agricultural Land

Agricultural land was identified as a primary source of sediment to Beaver Creek. Agricultural runoff can contribute increased pollutant loads when farm management practices allow soils rich in nutrients from fertilizers or animal waste to be washed into the stream, increasing in-stream sediment and phosphorus levels. The erosion potential of cropland and over-grazed pasture land is particularly high due to the lack of year-round vegetative cover. The use of cover crops and other management practices have been shown to reduce the transport of pollutant loads from agricultural lands.

The MRLC land use coverage for the Beaver Creek watershed is shown in Section 2.1.5.

6.1.2 Forest Land

Agricultural and urban development in these watersheds has replaced some mature forest areas, especially along the stream and at lower elevations. The sediment yield from undisturbed forest lands, especially during the growing season, is low due to the amount of dense vegetative cover which stabilizes soils and reduces rainfall impact.

6.1.3 Urban Areas

Urban land uses represented in the MRLC land use coverage include commercial, industrial, transportation, and residential areas. Urban land uses consist of pervious and impervious areas. Stormwater runoff from impervious areas, such as paved roads and parking lots, contribute pollutants that accumulate on these surfaces directly to receiving waters without being filtered by soil or vegetation. Sediment deposits in impervious areas originate from vehicle exhaust, industrial and commercial activities, outdoor storage piles, and other sources. In addition, stormwater runoff can cause streambank erosion and bottom scouring through high flow volumes, resulting in increased sedimentation and other habitat impacts.

The primary urban sources of sediment are construction sites and other pervious lands. Construction sites have high erosion rates due to the removal of vegetation and top soil. Typical erosion rates for construction sites are 35 to 45 tons per acre per year as compared to 1 to 10 tons per acre per year for cropland. Residential lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses.

Urban land use areas were separated into pervious and impervious fractions based on the estimated percent impervious surface of each urban land use category. Field observations and literature values were used to determine the effective percent imperviousness of urban land uses (Table 6.1).

Table 6.1 Percent imperviousness of urban land uses

Urban land uses	Percent impervious
High Intensity Residential	40%
Low Intensity Residential	20%

6.2 Assessment of Point Sources

Point sources can contribute sediment loads to surface waters through effluent discharges. These facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ. VPDES individual permits are issued to facilities that must comply with permit conditions that include specific discharge limits and requirements. There are currently no VPDES individual permits in the Beaver Creek watershed**.**

General permits are granted for smaller facilities, such as domestic sewage discharges, that must comply with a standard set of permit conditions, depending on facility type. Currently, there are nine permitted facilities in the Beaver Creek watershed, one of which is a Municipal Separate Storm Sewer System (MS4) permit that was issued to the City of Bristol to help control impacts caused by stormwater runoff from urban areas. The sediment load contributed by the MS4 permit during runoff events was calculated based on the modeling results for urban lands located within the City of Bristol and the Beaver Creek watershed. A list of all permitted facilities and corresponding sediment loads (Total Suspended Solids - TSS) are provided in Table 6.2.

Table 6.2 VPDES permitted facilities in the Beaver Creek watershed

Stream	Facility Name	VPDES Permit No.	Discharge Type	Design Flow (MGD)	Permitted Concentration (mg/L)	TSS Load (lbs/year)
Beaver Creek	Private Residence	VAG400012	General	0.0010	30	91
Beaver Creek	Bristol Ready Mix	VAG110004	General	0.0010	30	91
Beaver Creek	Twin City Iron & Metal Co.*	VAR050037	Stormwater	N/A	100**	1,783
Beaver Creek	Visador Co.-Bristol Plant*	VAR510074	Stormwater	N/A	100**	2,158
Beaver Creek	General Shale Bristol Concrete*	VAR510084	Stormwater	N/A	100**	1,077
Clear Creek	Carolina Steel*	VAR050084	Stormwater	N/A	100**	8,725
Beaver Creek UT	V & S Galvanizing Inc.*	VAR510133	Stormwater	N/A	100**	375
Beaver Creek UT	Federal Pacific Transformer Co. Electro Mechanical Corp*	VAR510075	Stormwater	N/A	100**	751
Beaver Creek	City of Bristol, VA***	VAR040048	Stormwater	N/A	N/A	1,709,262

*Permitted load was calculated as the average annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 100 mg/L. Flow was based on the average annual runoff from urban lands.
**No limit was specified in the permit; threshold value was used.
***The City of Bristol MS4 permit sediment load was calculated based on the load contributed by urban lands in the watershed and the percentage of urban land located within the Bristol city limits.
MGD = million gallons per day

SECTION 7

WATERSHED MODELING - SEDIMENT

7.1 Reference Watershed Approach

7.1.1 Background

Biological communities respond to any number of environmental stressors, including physical impacts and changes in water and sediment chemistry. According to Virginia's 2002 303(d) list, the probable causes of benthic impairment in Beaver Creek were attributed to nonpoint source pollution associated with intense agriculture in the upper portion of the watershed and urban development in the lower portion of the watershed.

TMDL development requires the identification of impairment causes and the establishment of numeric endpoints that will allow for the attainment of designated uses and water quality criteria. Numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. Virginia does not currently have numeric criteria for nutrients (i.e., total phosphorus and total nitrogen), sediment, and other parameters that may be contributing to the impaired condition of the benthic community in this stream. A reference watershed approach was, therefore, used to determine the primary benthic community stressors and to establish numeric endpoints for these stressors. This approach is based on selecting non-impaired watersheds that share similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. The Virginia Stream Condition Index (VaSCI) was used to define differences in the benthic communities in impaired and reference streams (USEPA 2003). Loading rates for pollutants of concern are determined for impaired and reference watersheds through modeling studies. Both point and nonpoint sources are considered in the analysis of pollutant sources and in watershed modeling. Numeric endpoints are based on reference watershed loadings for pollutants of concern and load reductions necessary to meet these endpoints are determined. TMDL load allocation scenarios are then developed based on an analysis of the degree to which contributing sources can be reasonably reduced

7.1.2 Reference Watershed Selection

The reference watershed selection process is based on a comparison of key watershed, stream and biological characteristics. The goal of the process is to select one or several similar, unimpaired reference watersheds that can be used to identify benthic community stressors and develop TMDL endpoints. Reference watershed selection was based on the results of VADEQ biomonitoring studies and comparisons of key watershed characteristics. Data used in the reference watershed selection process for Beaver Creek are shown in Table 7.1.

Table 7.1 Reference watershed selection data

Biomonitoring Data	Ecoregion Coverages
Topography	Land use Distribution
Soils	Watershed Size
Water Quality Data	Point Source Inventory

Tetra Tech, VADEQ, and USEPA recently developed the Virginia Stream Condition Index (VaSCI), which provides a more detailed and reliable assessment of the benthic macroinvertebrate community in Virginia's non-coastal, wadeable streams (USEPA 2003). This new multi-metric index, was used to compare relative differences in the benthic community between impaired and reference streams. This index allows for the evaluation of biological condition as a factor in the reference watershed selection process and can be used to measure improvements in the benthic macroinvertebrate community in the future. VADEQ biomonitoring data were used to calculate the VaSCI scores shown in Table 7.2. The Walker Creek scores are shown for comparison.

Table 7.2 Bioassessment index comparison

Station ID	Organization	Stream	Number of Samples	VaSCI Score
6CBEV023.99	DEQ	Beaver Creek	3	48
Beaver1	GMU		1	40
6CBEV024.60	DEQ		2	55
Beaver2	GMU		1	38
Beaver3	GMU		1	55
Average				47
WLK050.85	DEQ	Walker Creek	2	75

7.1.3 Selected Reference Watershed

The Walker Creek watershed, delineated at the VADEQ biomonitoring station, was selected as the reference for this TMDL study (Figure 7.1). This determination was based on the degree of similarity between this stream and its associated watershed to the impaired stream and the results of the VaSCI scores. Figures 7.2, 7.3, and 7.4 show comparisons of the MRLC land use, soils, and ecoregion distributions within the Beaver Creek watershed and the Walker Creek watershed.

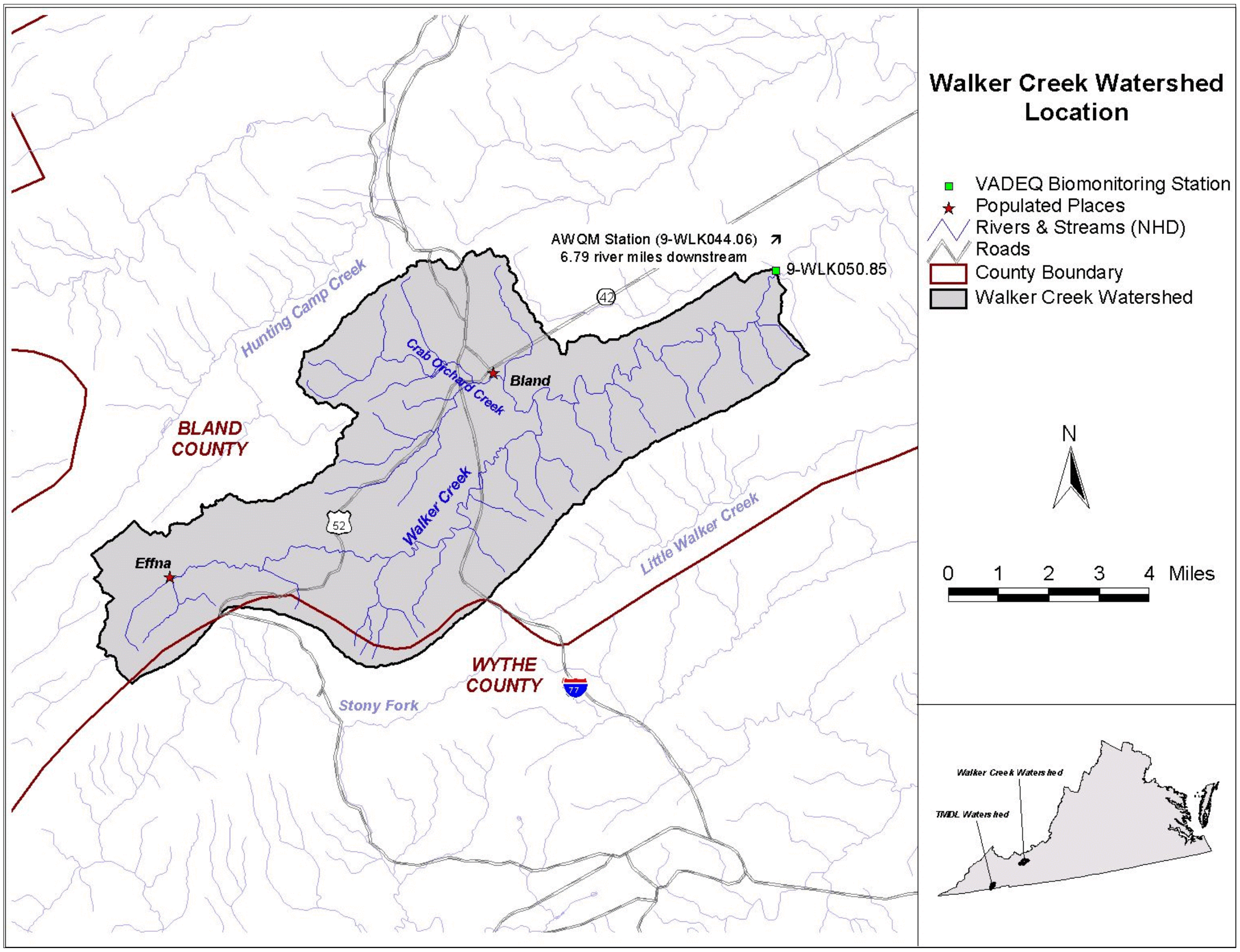

Figure 7.1 Reference watershed location and monitoring stations

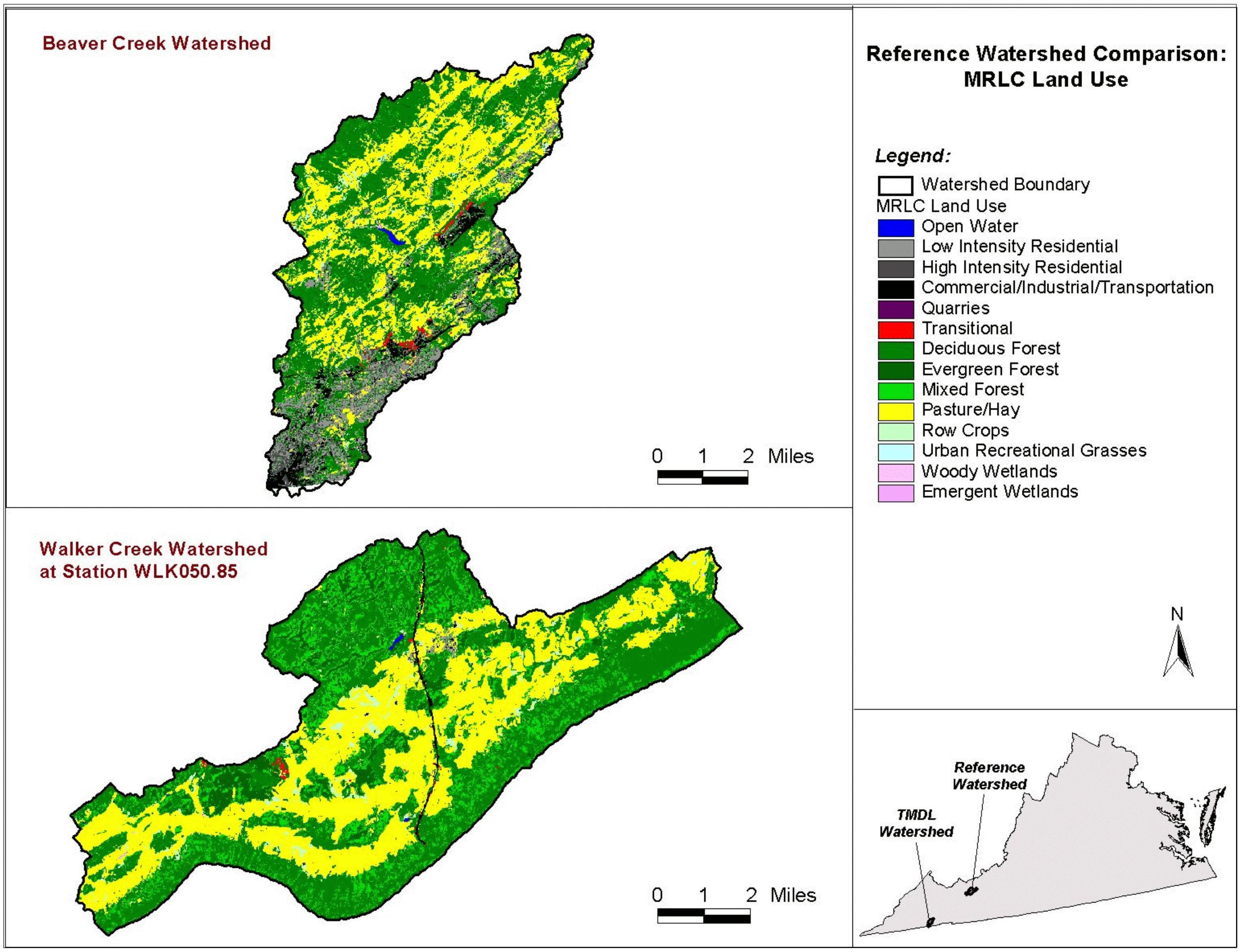

Figure 7.2 MRLC land use in the impaired and reference watersheds

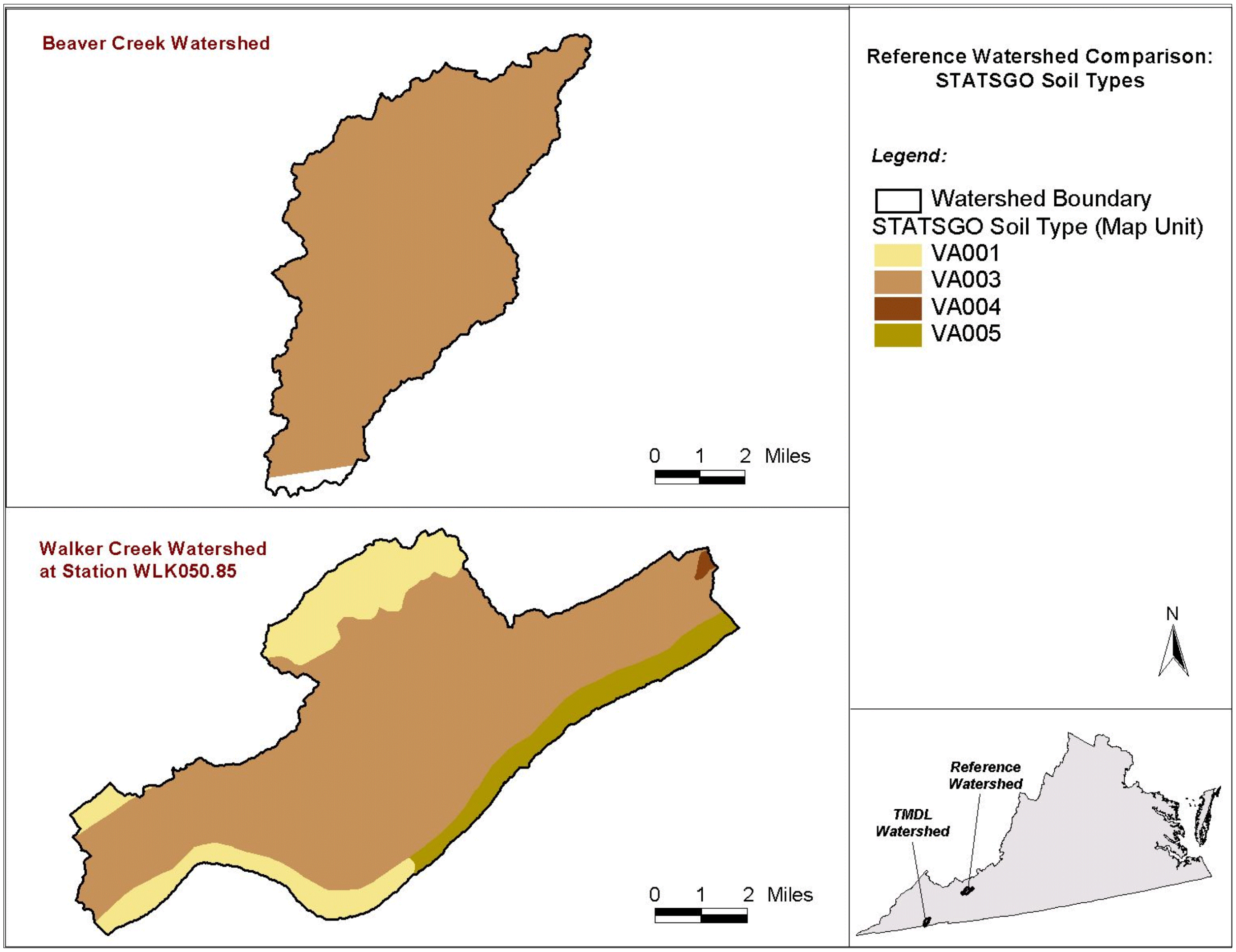

Figure 7.3 STATSGO soil types in the impaired and reference watersheds

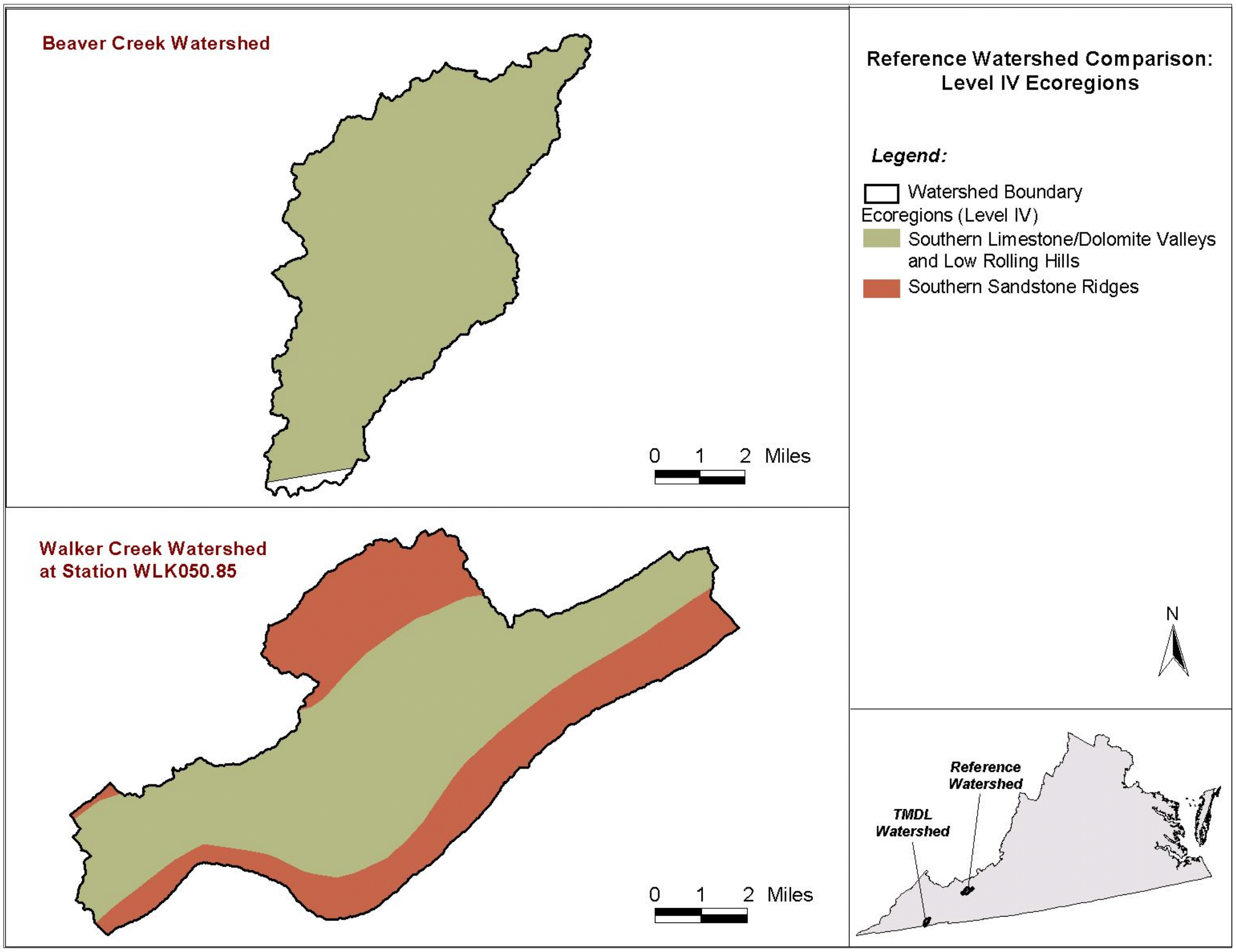

Figure 7.4 Level IV ecoregions in the impaired and reference watersheds

7.2 Watershed Model

TMDLs were developed using BasinSim 1.0 and the GWLF model (Dai et al. 2000). The GWLF model, which was originally developed by Cornell University (Haith and Shoemaker 1987, Haith et al. 1992), provides the ability to simulate runoff, sediment, and nutrient loadings from watersheds given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. GWLF is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values.

GWLF is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous with respect to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as for a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss/erosion (K), the length/slope factor (LS), the vegetation cover factor (C), and the conservation practices factor (P). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. Point source discharges also can contribute to loads to the stream. Evapotranspiration is determined using daily weather data and a cover factor dependent on land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be found in the original GWLF paper (Haith and Shoemaker 1987) and GWLF User's Manual (Haith et al. 1992).

For execution, the model requires three separate input files containing transport, nutrient, and weather-related data. The transport file (TRANSPRT.DAT) defines the necessary parameters for each source area to be considered (e.g., area size, curve number) as well as global parameters (e.g., initial storage, sediment delivery ratio) that apply to all source areas. The nutrient file (NUTRIENT.DAT) specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations). The nutrient file is necessary for the model to run but is not used in any of the calculations. The weather file (WEATHER .DAT) contains daily average temperature and total precipitation values for each year simulated.

7.3 Model Setup

Watershed data needed to run the GWLF model in BasinSim 1.0 were generated using GIS spatial coverages, water quality monitoring and streamflow data, local weather data, literature values, and other information. The watershed boundary for Beaver Creek was provided by the Tennessee Department of Conservation and Recreation, Water Pollution Control Division. The Beaver Creek watershed and reference watershed were delineated based on hydrologic and topographic data (USGS 7.5 minute digital topographic maps), and the location of VADEQ monitoring stations. The outlet of the Beaver Creek watershed is the Virginia/Tennessee state line. The reference watershed outlet is located at the VADEQ biomonitoring station on Walker Creek. To equate target and reference watershed areas for TMDL development, the total area for the reference watershed was reduced to be equal to the area of the Beaver Creek watershed, after hydrology calibration. To accomplish this, land use areas (in the reference watershed) were proportionally reduced based on the percent land use distribution.

Local rainfall and temperature data were used to simulate flow conditions in modeled watersheds. Daily precipitation and temperature data were obtained from local National Climatic Data Center (NCDC) weather stations. Weather data collected at the NCDC stations in Bristol and Wytheville (precipitation and temperature data) were used to construct the weather files used in each watershed simulation. The weather stations and data periods that correspond with the modeled watersheds are shown in Table 7.3. The periods of record selected for model calibration runs (April 1, 1991 through September 30, 2002 for the Beaver Creek model and April 1, 1981 through May 31, 1999 for the reference model) were based on the availability of recent weather data and corresponding streamflow records.

Table 7.3 Weather stations used in GWLF models

Watershed	Weather Station	Data Type	Data Period
Beaver Creek	Bristol Airport (TN1094)	Daily Temperature, Daily Precipitation	4/1/1990 - 3/31/2003
Walker Creek	Wytheville 1S (VA9031)	Daily Precipitation	4/1/1980 - 5/31/1999
	Bristol Airport (TN1094)	Daily Temperature	4/1/1980 - 5/31/1999

Daily streamflow data are needed to calibrate watershed hydrologic parameters in the GWLF model. The USGS gage station located on Beaver Creek at Bristol, VA was used to calibrate the impaired watershed and the USGS gage located on Walker Creek at Bane, VA was used to calibrate the reference watershed. Table 7.4 lists the USGS gaging stations along with the period of record used for these watersheds.

Table 7.4 USGS gaging stations used in modeling studies

Modeled Watershed	USGS station number	USGS gage location	Data Period
Beaver Creek	03478400	Beaver Creek at Bristol, VA	4/1/1991 - 9/30/2002
Walker Creek	03173000	Walker Creek at Bane, VA	4/1/1981 - 5/31/1999

7.4 Explanation of Important Model Parameters

In the GWLF model, the nonpoint source load calculation is affected by terrain conditions, such as the amount of agricultural land, land slope, soil erodibility, farming practices used in the area, and by background concentrations of nutrients (nitrogen and phosphorus) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. Some of the more important parameters are summarized as follows:

Areal extent of different land use/cover categories: The MRLC land use coverage was used to calculate the area of each land use category in impaired and reference watersheds, respectively (USEPA, 1992).

Curve number: This parameter determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type and is calculated directly using digital land use and soils coverages. Soils data for both the impaired and reference watersheds were obtained from the State Soil Geographic (STATSGO) database for Virginia, developed by NRCS.

K factor: This factor relates to inherent soil erodibility, and it affects the amount of soil erosion taking place on a given unit of land. The K factor and other Universal Soils Loss Equation (USLE) parameters were downloaded from the NRCS Natural Resources Inventory (NRI) database (1992). Average values for specific crops/land uses in the watershed county were used (Washington County). The predominant crop grown in these watersheds is corn; therefore, cropland values were based on data collected in corn crops.

LS factor: This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

C factor: This factor is related to the amount of vegetative cover in an area. In agricultural areas, this factor is largely controlled by the crops grown and the cultivation practices used. Values range from 0 to 1.0, with larger values indicating a higher potential for erosion.

P factor: This factor is directly related to the conservation practices used in agricultural areas. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion.

Sediment delivery ratio: This parameter specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size.

Unsaturated available water-holding capacity: This parameter relates to the amount of water that can be stored in the soil and affects runoff and infiltration.

Other less important factors that can affect sediment loads in a watershed also are included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF User's Manual (Haith et al. 1992). Pages 15 through 41 of the manual provide specific details that describe equations and typical parameter values used in the model.

7.5 Hydrology Calibration

Using the input files created in BasinSim 1.0, GWLF predicted overall water balances in the impaired and reference watersheds. As discussed in Section 7.3, the modeling period is determined based on the availability of weather and flow data that were collected during the same time period. The Beaver Creek watershed was calibrated for a period of 11.5 years from 4/1991 to 9/2002 using the stream flow data from USGS gage 03478400 on Beaver Creek at Bristol, VA. The Walker Creek watershed (reference watershed) was calibrated for a period of 18 years from 4/1981 to 6/1999 using the stream flow data from USGS gage 03173000 on Walker Creek at Bane, VA. USGS gage locations do not coincide with the outlet (pour point) of each modeled watershed; therefore, stream flow measurements were normalized by area to facilitate calibration. Calibration statistics are presented in Table 7.5. These results indicate a good correlation between simulated and observed results for these watersheds. A total flow volume error percentage of approximately 11% was achieved in calibration of the Beaver Creek watershed model and less than 4% for the reference watershed. In general, the seasonal trends and peaks are captured reasonably well for the 11 and 18 year periods in the impaired and reference watersheds, respectively. Hydrology calibration results and the modeled time period for each watershed are presented in Figures 7.5 and 7.6. Differences between observed and modeled flows are likely due to inherent errors in flow estimation procedures based on normalization for watershed size and the proximity of the selected weather stations to each modeled watershed and the corresponding USGS gage.

Table 7.5 GWLF flow calibration statistics

Modeled Watershed	Simulation Period	R2 (Correlation) Value	Total Volume % Error
Beaver Creek	4/1/1991 - 9/30/2002	0.4338	11.0%
Walker Creek	4/1/1981 - 5/31/1999	0.4383	3.4%

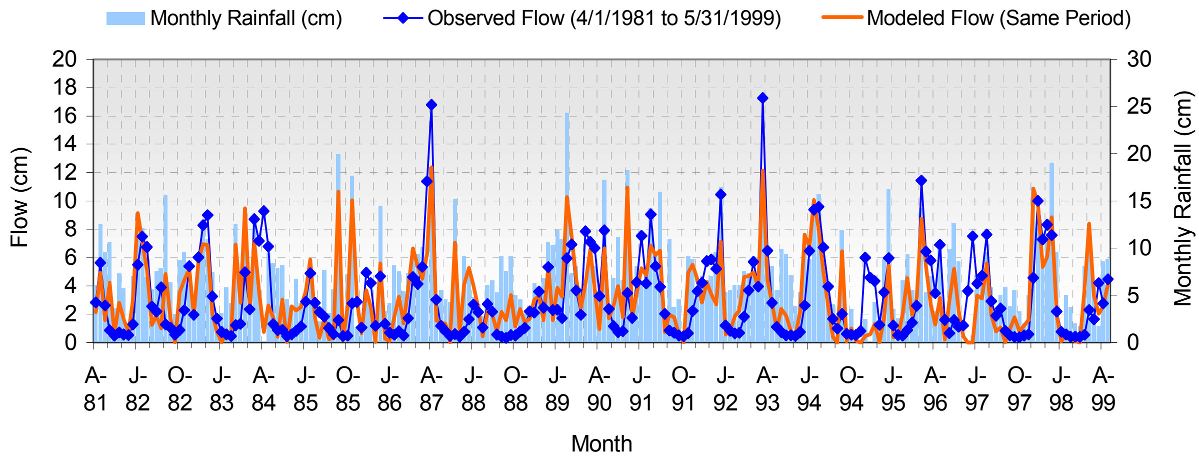

Figure 7.5 Walker Creek hydrology calibration using USGS gage 03173000

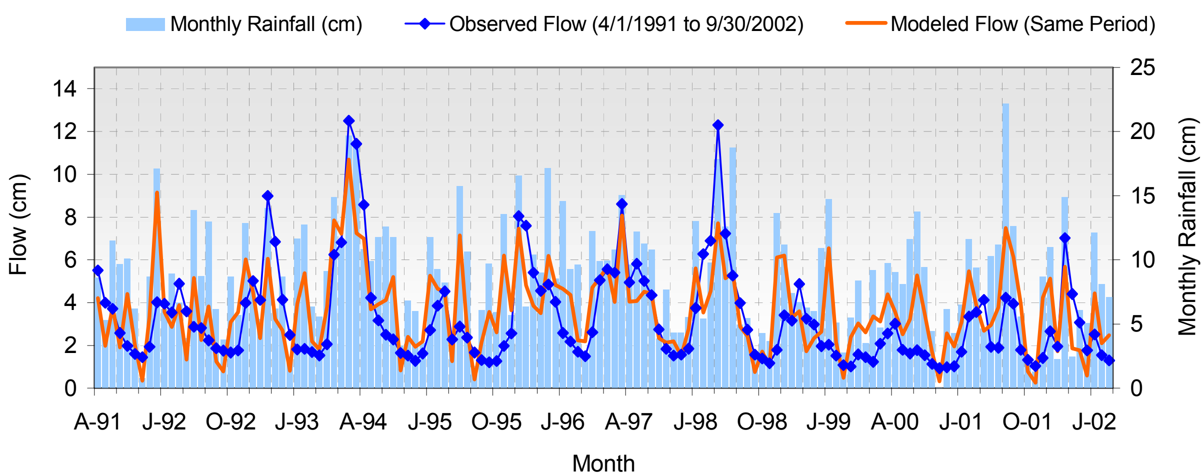

Figure 7.6 Beaver Creek hydrology calibration using USGS gage 03478400

SECTION 8

TMDL METHODOLOGY - BACTERIA

8.1 TMDL Calculation

The *E. coli* bacteria TMDL established for Beaver Creek consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The TMDL is the total amount of a pollutant that can be assimilated by the receiving waterbody while still achieving water quality standards. For *E. coli*, TMDLs are expressed in terms of bacteria counts (or resulting concentration).

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources (e.g., sewage treatment plants or municipal separate storm sewer system (MS4) permits). The LA portion represents the loading assigned to nonpoint sources (e.g., failing septic discharges, cattle direct deposition). The MOS accounts for any uncertainty in the data and the modeling process. Implicit MOS factors were incorporated into the TMDL development process through the use of conservative model assumptions and source load estimates.

8.2 Wasteload Allocations

There are currently two permitted bacteria point sources in the Beaver Creek watershed: the City of Bristol MS4 permit and a private residence (Table 8.1). The MS4 permit load was calculated based on the load contributed by urban (built-up) lands in the watershed and the percentage of urban land located within the Bristol city limits. The bacteria load contributed by the private residence was calculated based on the permitted flow (1,000 gallons/day) and the applicable *E. coli* limit (126 cfu/100ml, geometric mean concentration).

Table 8.1 VPDES point sources and existing loads

VPDES Permit No.	Facility	Design Flow (gallons/day)	Permit Limit (*E.coli* cfu/100 ml)	Existing Annual Load (*E. coli* cfu/year)
VAG400012	Private Residence	1,000	126	1.74E+09
VAR040048	City of Bristol	NA	NA	1.23E+14

8.3 Load Allocations

Load allocations to nonpoint sources are divided into land-based loads from land uses in the watershed and direct discharges from straight pipes, cattle, and wildlife. Failing septic discharges were included in the built up (urban land) load. Also, the built up load expressed in the following tables represents the bacteria load contributed by urban lands outside the Bristol city limits - MS4 permitted area.

Using the model developed to represent existing conditions, various allocation scenarios were examined for reducing *E. coli* loads to levels that would result in the attainment of water quality standards. This examination focused on understanding the water quality response and sensitivity of Beaver Creek to variations in source loading characteristics.

Allocation scenarios are presented with percent violations between 1/1/1990 and 12/31/2002 in Table 8.2. Scenario 1 is represents the existing condition in Beaver Creek. Scenario 10 presents the source reductions required to achieve the *E. Coli* instantaneous and calendar month geometric mean criteria. **Scenario 5 presents the reductions required to meet the Stage 1 implementation goal of <10% violation of the instantaneous criteria. The** calendar month geometric mean concentrations for existing and final allocation scenarios are shown in Figure 8.1. The instantaneous concentrations for existing and final allocation scenarios are shown in Figure 8.2. Reductions in load contributions from in-stream sources had the greatest impact on *E. coli* concentrations. Significant reductions from land-based loadings were also required to meet water quality standards. Although the *E. coli* bacteria loads that are produced by wildlife are less than the loads produced by livestock in the watershed, reductions in wildlife direct deposition to the stream were also required due to the magnitude of *E. coli* bacteria levels in Beaver Creek. Direct deposition during low flow conditions and loads transported by runoff during high flow conditions are controlled in these allocation scenarios.

To account for possible future growth in the bacteria load contributed by the private residence point source discharge (VAG400012), the model was run with this load multiplied by a factor of 5. This change did not result in an increase in the percent violation rates shown under Scenario 10 (0% violation of the instantaneous and geometric mean criteria). The existing load contributed by this facility is reported in the following tables.

Table 8.2 TMDL allocation scenarios and percent violations

Scenario Number	Direct (Instream) Sources			Indirect (NPS) Sources				Percent Violations	
	Straight Pipes	Livestock	Wildlife	Cropland	Pasture	Built up	Forest	Inst. Exceeds 235 #/100ml	Geom. Exceeds 126 #/100ml
1	0	0	0	0	0	0	0	85%	100%
2	100	50	0	50	50	75	0	66%	99%
3	100	75	0	75	75	90	0	37%	80%
4	100	90	0	90	90	95	0	12%	41%
5	100	95	0	92	92	93	0	10%	33%
6	100	90	0	90	90	95	0	12%	41%
7	100	95	0	95	95	98	0	5%	24%
8	100	99	0	99	99	99	0	3%	22%
9	100	99	50	99	99	99	50	0%	2%
10	100	99	60	99	99	99	0	0%	0%

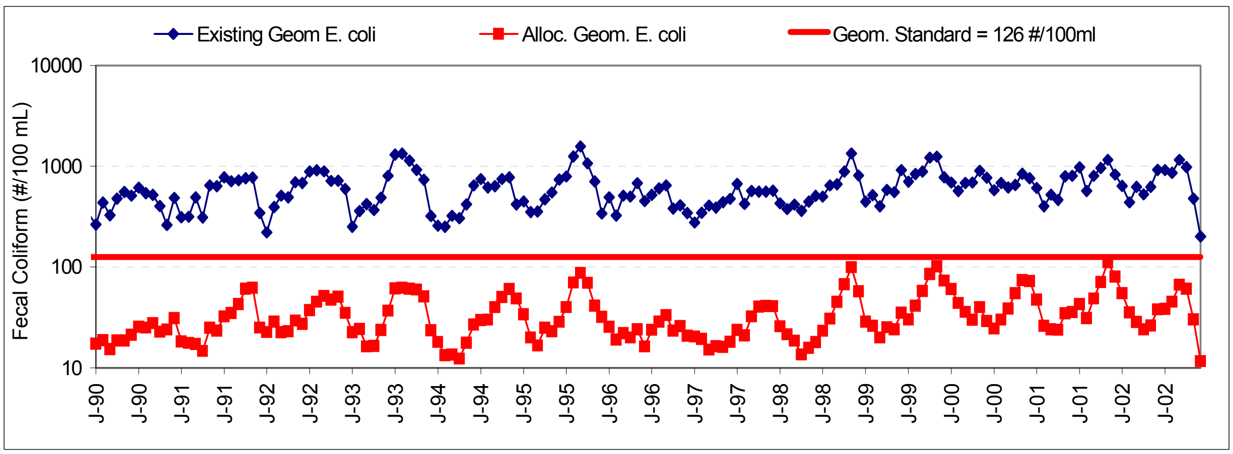

Figure 8.1 Calendar month geometric mean concentrations for existing and final allocation scenarios

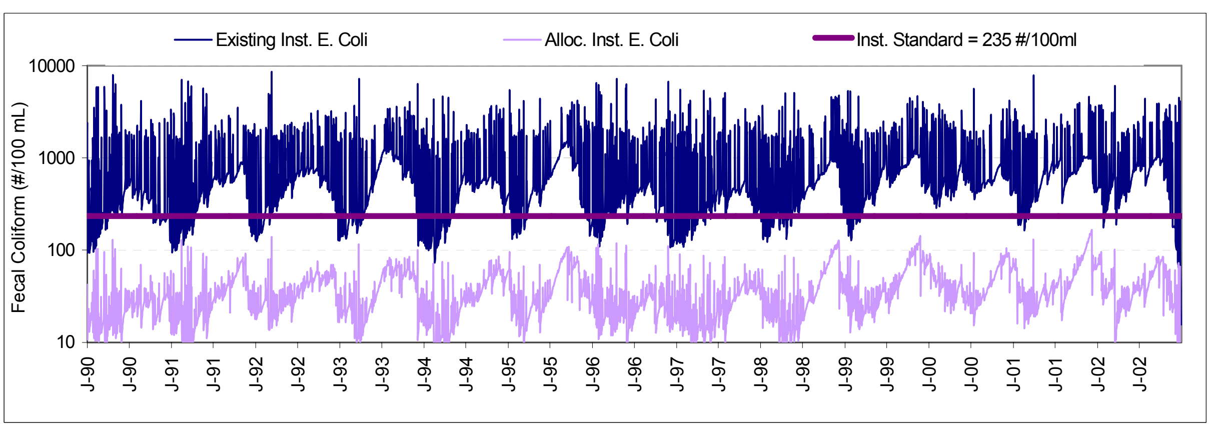

Figure 8.2 Instantaneous concentrations for existing and final allocation scenarios

The Load Allocations (LAs) and Wasteload Allocations (WLAs) under Scenario 10 are presented in Tables 8.3 and 8.4, respectively. The load allocation in this scenario includes a 99% reduction in cropland, pasture, and built up (urban) land-based sources in the watershed. No reductions are required in forest land-based sources. This load allocation scenario also includes a 100% reduction in *E. coli* direct deposition from straight pipes, a 99% reduction in *E. coli* direct deposition from livestock, and a 60% reduction in *E. coli* direct deposition from wildlife. Other allocation scenarios failed to meet the instantaneous and geometric mean criteria. The TMDL for Beaver Creek is presented in Table 8.5.

Table 8.3 Existing and allocation loads for LAs under Allocation Scenario 10

Sources		Total Annual Loading for Existing Conditions (cfu/yr)	Total Annual Loading for Allocation Conditions (cfu/yr)	Percent Reduction
Direct	Straight Pipes	1.07E+09	0.00E+00	100%
	Livestock	9.66E+13	9.66E+11	99%
	Wildlife	1.87E+13	7.47E+12	60%
Indirect	Cropland*	1.24E+13	1.24E+11	99%
	Pasture**	1.88E+14	1.88E+12	99%
	Built up***	4.59E+13	4.59E+11	99%
	Forest****	4.97E+11	4.97E+11	0%
Total		3.62E+14	1.14E+13	97%

* Includes Stipmining and Barren
** Includes Hayland
*** Includes Non MS4 Urban Pervious and Urban Impervious
**** Includes Wetland

Table 8.4 Existing and allocation loads for WLAs under Allocation Scenario 10

Sources	Total Annual Loading for Existing Conditions (cfu/yr)	Total Annual Loading for Allocation Conditions (cfu/yr)	Percent Reduction
Private Resdence - VAG4400012	1.74E+09	1.74E+09	0%
City of Bristol MS4 - VAR040048	1.23E+14	1.23E+12	99%
Total	1.23E+14	1.23E+12	99%

Table 8.5 *E. coli* TMDL for Beaver Creek

WLA	LA	MOS	TMDL
1.23E+12	1.14E+13	Implicit	1.26E+13

8.4 Consideration of Critical Conditions

The LSPC model is a continuous-simulation model; therefore, all flow conditions are taken into account for loading calculations. The modeling period represents typical high and low flow periods in the watershed; therefore, loads contributed through direct deposition (e.g., cattle in streams) and through runoff under critical conditions were accounted for in the model.

8.5 Consideration of Seasonal Variations

Seasonal variation was explicitly included in the modeling approach for this TMDL. Bacteria accumulation rates for each land use were determined on a monthly basis. The monthly accumulation rates accounted for the temporal variation in activities within the watershed, including seasonal application of agricultural waste, grazing schedules of livestock, and seasonal variation in number of cows in the stream. Also, the use of continuous simulation modeling resulted in consideration of the seasonal aspects of rainfall patterns. In addition, seasonal variation was accounted for in the allocation scenario.

SECTION 9

TMDL METHODOLOGY - SEDIMENT

9.1 TMDL Calculation

Impaired and reference watershed models were calibrated for hydrology using different modeling periods and weather input files. To establish baseline (reference watershed) loadings for sediment the GWLF model results for the Walker Creek watershed were used. For TMDL calculation, both the calibrated impaired and reference watersheds were run for an 9 year period from 4/1/1990 to 3/31/1999. This was done to standardize the modeling period. Based on the availability of weather and flow data it is assumed that this period sufficiently captures hydrologic and weather conditions. In addition, the total area for the reference watershed was reduced to be equal to the impaired watershed, as discussed in Section 7.3. This was necessary because watershed size influences sediment delivery to the stream and other model variables.

The 8 year annual average for pollutants of concern were determined for each land use/source category in the reference and impaired watersheds. The first year of the model run was excluded from the pollutant load summaries because the GWLF model takes a few months in the first year to stabilize. Model output is only presented for the years following the initialization year, although the model was run for a 9 year time period. The existing average annual sediment loads for Beaver Creek are presented in Table 9.1.

Table 9.1 Existing sediment loading in Beaver Creek

Source Category	Sediment Load (lbs/yr)	Sediment % of Total
Forest	95,932	0.8%
Water	0	0.0%
Pasture/Hay	6,672,577	55.5%
Cropland	2,477,641	20.6%
Barren/Transitional/Quarries	453,705	3.8%
Urban (pervious & impervious)	588,320	4.9%
Groundwater	0	0.0%
Point Sources (not incl. MS4)	14,868	0.1%
MS4 Permit (point source)	1,709,262	14.2%
Total Existing Load	12,012,304	100.0%

The TMDLs established for Beaver Creek consist of a point source waste load allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The sediment TMDL for Beaver Creek was based on the total load calculated for the Walker Creek watershed (area adjusted to the impaired watershed size). Loads for urban areas have been lumped together (pervious and impervious). The sediment loadings from the impervious urban areas were estimated by multiplying literature values of the unit area loading rates (840 kg/ha/yr) times the impervious urban area in the watershed.

Note that the MS4 permit load was calculated based on the load contributed by urban (built-up) lands in the watershed and the percentage of urban land located within the Bristol city limits. The urban load expressed in these tables represents the sediment load contributed by urban lands outside the Bristol city limits - MS4 permitted area.

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of 10% was used in TMDL calculations to provide an additional level of protection for designated uses.

The TMDL for Beaver Creek was calculated by adding reference watershed loads for sediment together with point source loads to give the TMDL value (Table 9.2).

Table 9.2 Sediment TMDL for Beaver Creek

TMDL (lbs/yr)	LA (lbs/yr)	WLA (lbs/yr) (including MS4)	MOS (lbs/yr)	Overall % Reduction
6,064,643	4,673,993	784,036 *City of Bristol MS4 = 769,168* *Private Residence = 91* *Bristol Ready Mix = 91* *Twin City Iron & Metal Co. = 1,783* *Visador Co. = 2,158* *General Shale Bristol Concrete = 1,077* *Carolina Steel = 8,725* *V&S Galvanizing = 375* *Federal Pacific Transformer Co. = 751*	606,615	54.6%

9.2 Wasteload Allocations

A waste load allocation was assigned to each point source in the watershed. The point sources were represented by their current permit conditions. Although reductions were made to the MS4 permitted load from the City of Bristol, all other current permit requirements are expected to result in attainment of WLAs, as required by the TMDL, without any reductions. Note that the sediment WLA value presented in the previous table represents the sum of all point source WLAs in the watershed.

9.3 Load Allocations

Load or waste load allocations were assigned to each source category in the watershed. Various allocation scenarios were developed for the Beaver Creek watershed to examine the outcome of various load reduction combinations. The recommended scenario for Beaver Creek (Table 9.3) is based on maintaining the existing percent load contribution from each source category, in general. Two additional scenarios are presented for comparison purposes (Table 9.4). Load reductions from agricultural sources are minimized in the first alternative and reductions from urban lands are minimized in the second alternative. The recommended scenario balances the reductions from agricultural and urban sources by maintaining existing watershed loading characteristics. In each scenario, loadings from certain source categories were allocated according to their existing loads. For instance, sediment loads from forest lands represent the natural condition that would be expected to exist; therefore, the loading from forest lands was not reduced. Also, sediment loads were reduced for the MS4 permit, but no reductions were made to other point sources because these facilities are currently meeting their pollutant discharge limits and other permit requirements. Current permit requirements are expected to result in attainment of the WLAs as required by the TMDL. Note that the sediment WLA values presented in the following tables represent the sum of all point source WLAs.

Table 9.3 Recommended sediment allocations for Beaver Creek

Source Category	Existing Sediment Load (lbs/yr)	Sediment % Reduction	Sediment Load Allocation (lbs/yr)
Forest	95,932	0.0%	95,932
Water	0	0.0%	0
Pasture/Hay	6,672,577	54.9%	3,009,332
Cropland	2,477,641	55.4%	1,105,028
Barren/ Transitional/ Quarries	453,705	55.5%	201,899
Urban (pervious & impervious)	588,320	55.5%	261,802
Groundwater	0	0.0%	0
Point Sources (not incl. MS4)	14,868 *Private Residence = 91* *Bristol Ready Mix = 91* *Twin City Iron & Metal Co. = 1,783* *Visador Co. = 2,158* *General Shale Bristol Concrete = 1,077* *Carolina Steel = 8,725* *V&S Galvanizing = 375* *Federal Pacific Transformer Co. = 751*	0.0%	14,868 *Private Residence = 91* *Bristol Ready Mix = 91* *Twin City Iron & Metal Co. = 1,783* *Visador Co. = 2,158* *General Shale Bristol Concrete = 1,077* *Carolina Steel = 8,725* *V&S Galvanizing = 375* *Federal Pacific Transformer Co. = 751*
MS4 Permit (point source)	1,709,261	55.0%	769,168
TMDL Load (minus MOS)	N/A	54.6%	5,458,029

Table 9.4 Alternative sediment allocations for Beaver Creek

Source Category	Minimize Agricultural Reductions	Minimize Urban Reductions
Forest	0.0%	0.0%
Water	0.0%	0.0%
Pasture/Hay	42.0%	68.3%
Cropland	42.0%	68.2%
Barren/Transitional/Quarries	98.0%	68.2%
Urban (pervious & impervious)	98.0%	0.0%
Groundwater	0.0%	0.0%
Point Sources (WLA)	0.0%	0.0%
MS4 Permit	99.0%	0.0%

9.4 Consideration of Critical Conditions

The GWLF model is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is usually a significant lag time between the introduction of sediment to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective of the waterbody.

9.5 Consideration of Seasonal Variations

The continuous-simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season and hours of daylight for each month. The combination of these model features accounts for seasonal variability.

SECTION 10

REASONABLE ASSURANCE AND IMPLEMENTATION

10.1 TMDL Implementation

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

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

10.2 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

The iterative implementation of BMPs in the watershed has several benefits:

1. 1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in omputer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plans. While specific goals for BMP implementation will be established as part of the implementation plan development, for the bacteria TMDL the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

10.3 Stage 1 Scenario

The goal of the stage 1 scenario is to reduce the bacteria loadings from controllable sources, such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenario was generated with the same model setup as was used for the TMDL allocation scenarios. This scenario is presented with the other allocation scenarios in Section 8.

10.4 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. Several BMPs known to be effective in controlling bacteria have also been identified for implementation as part of the 2001 Interim Nutrient Cap

Strategy for the Shenandoah/Potomac basin. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of the strategy described under nonpoint source implementation mechanisms. (2001 Draft Interim Nutrient Cap Strategy for the Shenandoah/Potomac River Basins). The BMPs required for the implementation of the sediment allocations in the watersheds contribute directly to the sediment reduction goals set as part of the Chesapeake Bay restoration effort. A new tributary strategy is currently being developed for the Shenandoah-Potomac River Basin to address the nutrient and sediment reductions required to restore the health of the Chesapeake Bay. Up-to-date information can on tributary strategy development can be found at http://www.snr.state.va.us/Initiatives/TributaryStrategies/shenandoah.cfm.

10.5 Reasonable Assurance for Implementation

10.5.1 Follow-Up Monitoring

VADEQ will continue monitoring 6CBEV021.07and 6CBEV015.27 in accordance with its ambient monitoring program to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards. VADEQ will also continue monitoring 6CBEV023.99 and 6CBEV024.60 in accordance with its biomonitoring program. VADEQ will continue to use data from these monitoring stations and related ambient monitoring stations to evaluate improvements in the benthic community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

10.5.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plans, which will also be supported by regional and local offices of VADEQ, VADCR, and other cooperating agencies.

Once developed, VADEQ intends to incorporate the TMDL implementation plans into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

10.5.3 Stormwater Permits

It is the intention of the Commonwealth that the TMDLs will be implemented using existing regulations and programs. One of these regulations is the Virginia Pollutant Discharge Elimination System (VPDES) Permit Regulation (9 VAC 25-31-10 et seq.). Section 9 VAC 25-31-120 describes the requirements for storm water discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when:…(2) Numeric effluent limitations are infeasible,…".

Part of the Beaver Creek watershed is covered by Phase II VPDES permit VAR040048 for the small municipal separate storm sewer systems (MS-4) owned by the City of Bristol. The permit states, under Part II.A., that the "permittee must develop, implement, and enforce a storm water management program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP), to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act and the State Water Control Law."

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

For MS4/VPDES general permits, VADEQ expects revisions to the permittee's Stormwater Pollution Prevention Plans to specifically address the TMDL pollutants of concern. VADEQ anticipates that BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its BMPs to achieve the TMDL reductions. However, only failing to implement the required BMPs would be considered a violation of the permit. VADEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacteria TMDLs (see section 10.5.5 below). At some future time, it may therefore become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis. Any changes to the TMDL resulting from water quality standards change on Beaver Creek would be reflected in the permittee's Stormwater Pollution Prevention Plan required by the MS4/VPDES permit.

Additional information on Virginia's Storm Water Phase 2 program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.deq.state.va.us/water/bmps.html.

10.5.4 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

10.5.5 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. As is the case for Beaver Creek, these streams may not be able to attain standards without some reduction in wildlife load. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

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

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

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 7.1 above. VADEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

SECTION 11

PUBLIC PARTICIPATION

A stakeholder and TMDL study kickoff meeting was held April 9, 2003. A site visit to Beaver Creek was also conducted on this date. Important information regarding likely sources was discussed with state environmental personnel and local stakeholders.

The first public meeting on the development of TMDLs for Beaver Creek was held on June 25, 2003 from 7-10 p.m. at the Bristol City Hall Auditorium in Bristol, Virginia. Copies of the presentation materials were made available for public distribution at the meeting. Written comments were received and responded to by VADEQ.

The second public meeting on the development of TMDLs for Beaver Creek was held on February 11, 2004 from 7-10 p.m. at the Circuit Courtroom in the Bristol, Virginia Courthouse in Bristol, Virginia. Copies of the Draft TMDL presentation materials were made available for public distribution at the meeting. The Draft TMDL report was placed on the VADEQ website the following day for public distribution. Written comments were received and responded to by VADEQ.

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