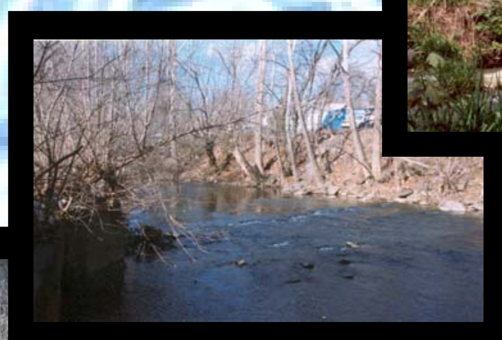
Fecal Coliform Total Maximum Daily Load Development

for
Glade Creek, Tinker Creek, Carvin Creek, Laymantown Creek and Lick Run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Fecal Coliform Impairment

Tinker Creek and Lick Run were placed on the Commonwealth of Virginia's 1996 Section 303(d) List of Impaired Waters because of violations of the fecal coliform bacteria water quality standard. Glade Creek was included in 1998 while Carvin and Laymantown Creeks were added in 2002. These listings are referenced in this document as the 'Tinker Creek watershed' and have resulted in the development of five Total Maximum Daily Loads (TMDLs). These TMDLs focus on fecal coliform impairments. Based on exceedances of the standard recorded at Virginia Department of Environmental Quality (VADEQ) monitoring stations, the stream does not support primary contact recreation (*e.g.*, swimming). In January 2003, Virginia adopted two new criteria to protect the primary contact recreational use. The new applicable fecal coliform state standard (Virginia Water Quality Standard 9 VAC 25-260-170) specifies that no more than 10% of the total samples taken during any calendar month exceed 400 colony forming units (cfu) per 100 milliliters (ml). Alternatively, if data is available, the geometric mean of two or more observations taken in a calendar month should not exceed 200 cfu/100 ml. A review of available monitoring data for the watershed indicated that fecal coliform bacteria were consistently elevated above the 400 cfu/100 ml standard.

The new *E.coli* criteria specifies that the number of *E. coli* bacteria shall not exceed a single sample maximum allowable level of 235 cfu/100 ml (Virginia Water Quality Standard 9 VAC 25-260-170). In addition, if data is available, the geometric mean of two or more observations taken in a calendar month should not exceed 126 cfu/100 ml. In TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126 cfu/100 ml and a single sample maximum of 235 cfu/100 ml. A translator developed by VADEQ was used to convert fecal coliform values to *E. coli* values.

Sources of Fecal Coliform

Potential sources of fecal coliform include both point source and nonpoint source contributions. Nonpoint sources include: grazing livestock; pets; land application of manure; land application of biosolids; urban/suburban runoff; failed, malfunctioning, and operational septic systems; uncontrolled discharges (straight pipes, dairy parlor waste, etc.), and wildlife. Permitted discharges in the Tinker Creek watershed include: ITT Industries - Night Vision, Roanoke City - Carvins Cove Water Filtration Plant, Norfolk Southern Railway Co. - East End Shops, Norfolk Southern Railway Co. - Shaffers Crossing, R W Bowers Commercial Development (VA0068497 and VAG402063), R W Bowers Parcel No. 6, R W Bowers Parcel No. 7, and locations covered by Virginia Pollutant Discharge Elimination System (VPDES) Phase Stormwater Permits. The list of permitted facilities is found in Table E.1. Of these, only R W Bowers Commercial Development, R W Bowers Parcel No. 6, and R W Bowers Parcel No. 7 are permitted to contain measurable amounts of fecal coliform. However, construction on these sites has not occurred.

Water Quality Modeling

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and perform TMDL allocations. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model.

Daily flows from the US Geological Survey gages #02055100 (Tinker Creek near Daleville), #02055000 (Roanoke River @ Roanoke) and #02056000 (Roanoke River @ Niagara) were used for direct calibration. The representative hydrologic period used for calibration ran from October 1993 through September 1998. The model was validated using daily flows recorded at the same gaging stations from October 1988 through September 1993.

The time periods covered by calibration and validation represent a broad range of hydrologic and climatic conditions and are representative of the long-term precipitation and discharge record. For purposes of modeling watershed inputs to in-stream water quality, the Tinker Creek drainage area was divided into eighteen subwatersheds. The model was calibrated for water quality predictions using data collected at VADEQ monitoring stations between October 1992 and September 1997, and validated using data collected between October 1997 and September 2001. All allocation model runs were conducted using precipitation data from October 1993 through September 1998.

Existing Loadings and Water Quality Conditions

Wildlife populations and ranges; biosolids application rates and practices; rate of failure, location, and number of septic systems; domestic pet populations; numbers of cattle and other livestock; and information on livestock and manure management practices for the Tinker Creek watershed were used to calculate fecal coliform load from land-based nonpoint sources in the watershed. The estimated fecal coliform production and accumulation rates due to these sources were calculated for the watershed and incorporated into the model. To accommodate the structure of the model, calculation of the fecal coliform accumulation and source contributions on a monthly basis accounted for seasonal variation in watershed activities such as wildlife feeding patterns and land application of manure. Also represented in the model were uncontrolled discharges, direct deposition by wildlife, and direct deposition by livestock.

Contributions from all of these sources were represented in the model to establish existing conditions for the watershed over a representative hydrologic period (1993-1998). Under existing conditions (2003), the HSPF model provided a comparable match to the VADEQ monitoring data, with output from the model indicating violations of both the instantaneous and geometric mean standards throughout the watershed.

Margin of Safety

In order to account for uncertainty in modeled output, a margin of safety (MOS) was incorporated into the TMDL development process. A margin of safety can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. An implicit MOS was used in the development of this TMDL through the use of conservative assumptions in model development. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will, in fact, succeed in meeting the water quality standards.

Load Allocation Scenarios

The next step in the TMDL process was to determine how to proceed from existing watershed conditions to reduce the various source loads to levels that would result in attainment of the water quality standards. Because Virginia's *E. coli* criteria does not permit any exceedances of the standard, modeling was conducted for a target value of 0% exceedance of the 126 cfu/100 ml geometric mean standard and 0% exceedance of the single sample maximum *E. coli* standard of 235 cfu/100 ml. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Modeling of these scenarios provided predictions of whether the reductions would achieve the target of 0% exceedance.

The final load allocation scenarios require a 100% reduction in direct deposition to the stream from livestock and a 100% reduction in uncontrolled discharges. These reductions apply to all five impairments.

Nonpoint source (indirect) load allocation scenarios from agricultural and urban areas required a 95% reduction in Laymantown Creek, a 96% reduction in Glade Creek, a 90% reduction in Carvin Creek, 91% and 99% reductions in Lick Run, respectively, and 99.8 and 98% reductions in Tinker Creek, respectively.

A 75% reduction in direct deposition to the stream from wildlife was required for Carvin Creek and Tinker Creek. Lick Run and Glade Creek required an 85% reduction in direct deposition from wildlife and Laymantown Creek required an 88% reduction in direct deposition from wildlife.

Nonpoint source (indirect) load allocation scenarios from wildlife required a 92% reduction in Laymantown Creek, a 91% reduction in Glade Creek, an 85% reduction in Carvin Creek, an 80% reduction in Lick Run, and a 95% reduction in Tinker Creek.

The average annual *E. coli* loads (cfu/year) modeled after TMDL allocation in the Laymantown Creek, Glade Creek, Carvin Creek, Lick Run, and Tinker Creek watersheds are shown in Table E.1.

It may be noted that in the previous TMDLs that have outlined wildlife reductions in their allocation scenarios, there has not been a clear mechanism for achieving these allocations. However, emerging programs aimed at the control of urban wildlife such as the one enacted by the City of Roanoke (City of Roanoke, 2003) will represent at least one mechanism for achieving some of these reductions in the Tinker Creek watershed.

Table E.1 Average annual *E. coli* loads (cfu/year) modeled after TMDL allocation in the Laymantown Creek, Glade Creek, Carvin Creek, Lick Run, and Tinker Creek watersheds.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Laymantown Creek	4.36E+11	6.15E+12	Implicit	6.58E+12
Botetourt County - VAR040023[1]	*4.36E+11*			
Glade Creek	4.00E+11	4.20E+13		4.24E+13
Vinton – VAR040026[1]	*8.78E+10*			
Roanoke County – VAR040022[1]	*8.02E+10*			
Roanoke City – VAR040004[1]	*1.13E+11*			
Botetourt County – VAR040023[1]	*1.19E+11*			
VAG402059[2]	*1.10E+10*			
VAG402061[2]	*1.10E+10*			
VAG402063[2]	*1.10E+10*			
Carvin Creek	5.24E+12	2.61E+13		3.14E+13
Roanoke County – VAR040022[1]	*4.07E+12*			
Roanoke City – VAR 040004[1]	*1.04E+12*			
Botetourt County - VAR040023[1]	*1.28E+11*			
Lick Run	7.17E+10	1.31E+13		1.31E+13
Roanoke County – VAR040022[1]	*3.29E+09*			
Roanoke City – VAR040004[1]	*6.84E+10*			
Tinker Creek	5.07E+12	7.56E+13		8.07E+13
Vinton - VAR040026[1]	*3.42E+11*			
Roanoke County – VAR040022[1]	*5.36E+11*			
Roanoke City – VAR040004[1]	*2.24E+12*			
Botetourt County - VAR040023[1]	*1.95E+12*			

[1] MS4 permits
[2] General permits

Recommendations for 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 bacteria impairments on Tinker Creek. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act states in section 62.1-44.19.7 that the "Board shall develop and implement a plan to achieve fully supporting status for impaired waters".

The TMDLs developed for the Tinker Creek watershed impairments provide allocation scenarios that will be a starting point for developing implementation strategies. A staged implementation plan is essential to the process of restoring water quality. The goal of the first stage is to foster local support for the implementation plan and to reduce the violations of the instantaneous standard to no more than 10% in the main stem of Tinker Creek. The model scenario developed for the first stage included a 100% reduction in loads from sewer overflows and uncontrolled residential discharges (straight pipes), a 75% reduction in direct in-stream loads from livestock and land-based loads from urban and agricultural sources.

A staged implementation plan is necessarily an iterative process. There is a measure of uncertainty associated with the final allocation development process. Continued monitoring can provide insight into the effectiveness of implementation strategies, the need for amending the plan, and/or progress toward the eventual removal of the impairment from the Section 303(d) list.

Also critical to the implementation process is public participation. While permitted point sources provide a limited contribution to the overall water quality problem, nonpoint direct deposition to streams is the critical factor in addressing the problem. These sources cannot be addressed without public understanding of, and support for, the implementation process. Stakeholder input will be critical from the onset of the implementation process in order to develop an implementation plan that is effective.

Public Participation

During development of the TMDL for the Tinker Creek watershed, public involvement was encouraged through three meetings. A basic description of the TMDL process and the agencies involved was presented at the kickoff meeting. The 1st public meeting was held to discuss the source assessment input, bacterial source tracking (BST), and model calibration data. The final model simulations and the TMDL load allocations were presented during the 2nd public meeting.

The meetings served to facilitate understanding of, and involvement in, the TMDL process. Posters that graphically illustrated the status of the watershed were on display at each meeting to provide an additional information component for the stakeholders. MapTech personnel were on hand to provide further clarification of the data as needed. Input from these meetings was utilized in the development of the TMDL and improved confidence in the allocation scenarios developed.

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1. INTRODUCTION

1.1 Background

The need for TMDLs to be conducted in the Tinker Creek watershed is based on provisions of the Clean Water Act. The document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA, 1999), states:

> *According to Section 303(d) of the Clean Water Act and EPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The waterbodies are considered water quality-limited and require TMDLs.*
> *…A TMDL is a tool for implementing State water quality standards, and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.*

The Tinker Creek watershed (USGS Hydrologic Unit Code #03010101) is located within Virginia's Botetourt and Roanoke Counties and Roanoke City (Figure 1.1). Tinker Creek drains to the Roanoke River, which flows southeast through a series of reservoirs (John H. Kerr Reservoir and Gaston Lake), eventually emptying into the Albemarle Sound. Impaired segments within the Tinker Creek basin include: Carvin Creek, Laymantown Creek, Glade Creek, Lick Run, and Tinker Creek (Figure 1.2). VADEQ has identified all of these segments as impaired with regard to fecal coliform.

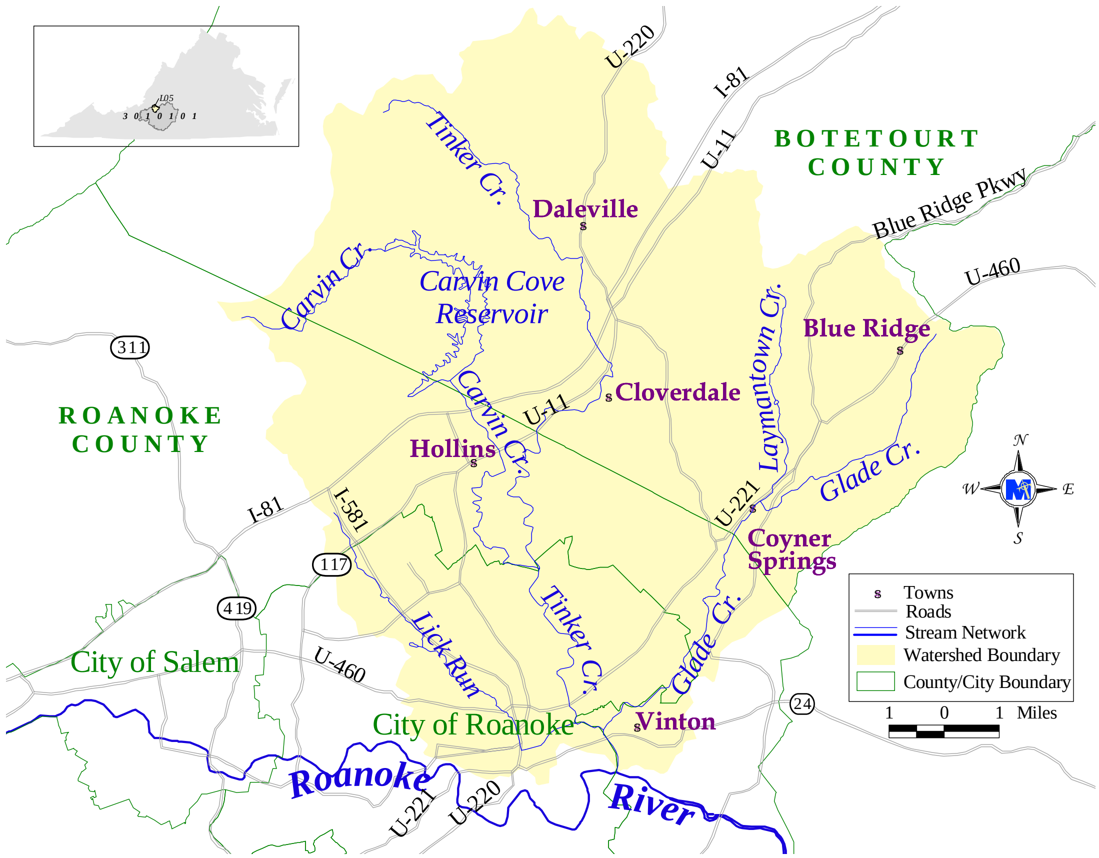

Figure 1.1 Location of the Tinker Creek watershed.

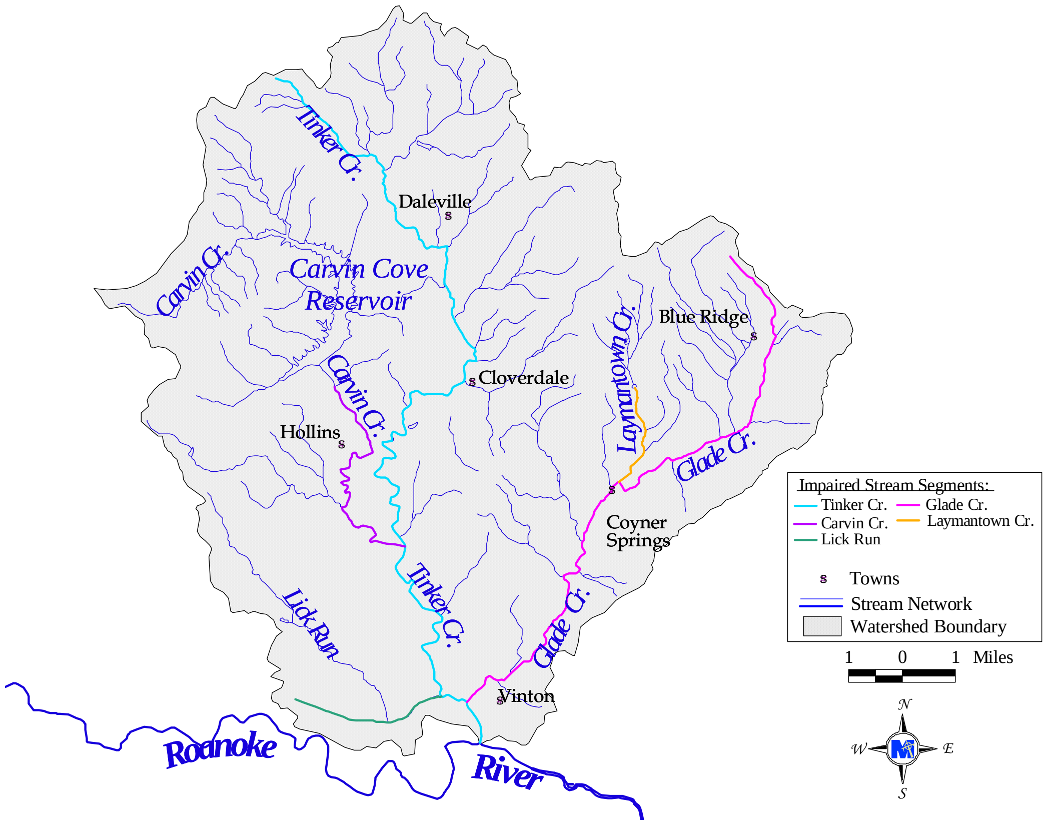

Figure 1.2 Impaired stream segments in the Tinker Creek watershed.

Table 1.1 lists the following information for each impairment: the VADEQ water quality monitoring station used for impaired waters assessment, the initial year that the segment was listed in the Section 303(d) TMDL Priority List and Report, the miles affected in listing, fecal coliform violation rate in 2002 Section 303(d) TMDL Priority List and Report, and the location of listing.

The land area of the Tinker Creek watershed is approximately 71,500 acres. Forest and pasture are the primary land uses with areas of heavy urbanization (Figure 1.3).

Table 1.1 Tinker Creek watershed's fecal coliform impairments and the monitoring stations used to list the waterbodies in the 2002 Section 303(d) TMDL Priority List and Report.

Stream Name	Station ID	Initial Listing	Miles Affected	1998 303(d) List FC Violations	2002 303(d) List FC Violations	Location
Carvin Creek	4ACRV000.28	2002	5.35	NL	IS = 2/7, GS = 2/2	Upstream of I-81 at mouth of unnamed tributary extends downstream to the mouth of Carvin Creek on Tinker Creek
Laymantown Creek	4ALAY000.37	2002	2.08	NL	GS 2/2	Upstream of Rt. 657 Bridge at a small pond ends at mouth of Laymantown Creek on Glade Creek
Glade Creek	4AGLA000.20 4AGLA001.60 4AGLA004.39 4AGLA005.75 4AGLA008.10	1998	12.61	IS = 3/8	IS = 4/7, GS = 2/2 IS = 2/7, GS = 2/2 IS = 4/7, GS = 2/2 IS = 3/7, GS = 2/2 IS = 1/6, GS = 1/2	Headwaters on the Stewartsville Quad downstream to its confluence with Tinker Creek at river mile 0.83
Lick Run	4ALCK000.38 Special Study (SS 975101)	1996	3.5	IS = 13/21	IS = 9/26 IS = 6/7, GS = 2/2	Shaffers Crossing rail yard - downstream limit is mouth of Lick Run on Tinker Creek at river mile 1.41
Tinker Creek	4ATKR000.69	1996	19.38	IS = 25/60	IS = 18/59	Headwaters of Tinker Creek downstream to its confluence with the Roanoke River

NL = not listed
IS = instantaneous standard (1,000 cfu/100 ml)
GS = geometric mean standard (200 cfu/100 ml)

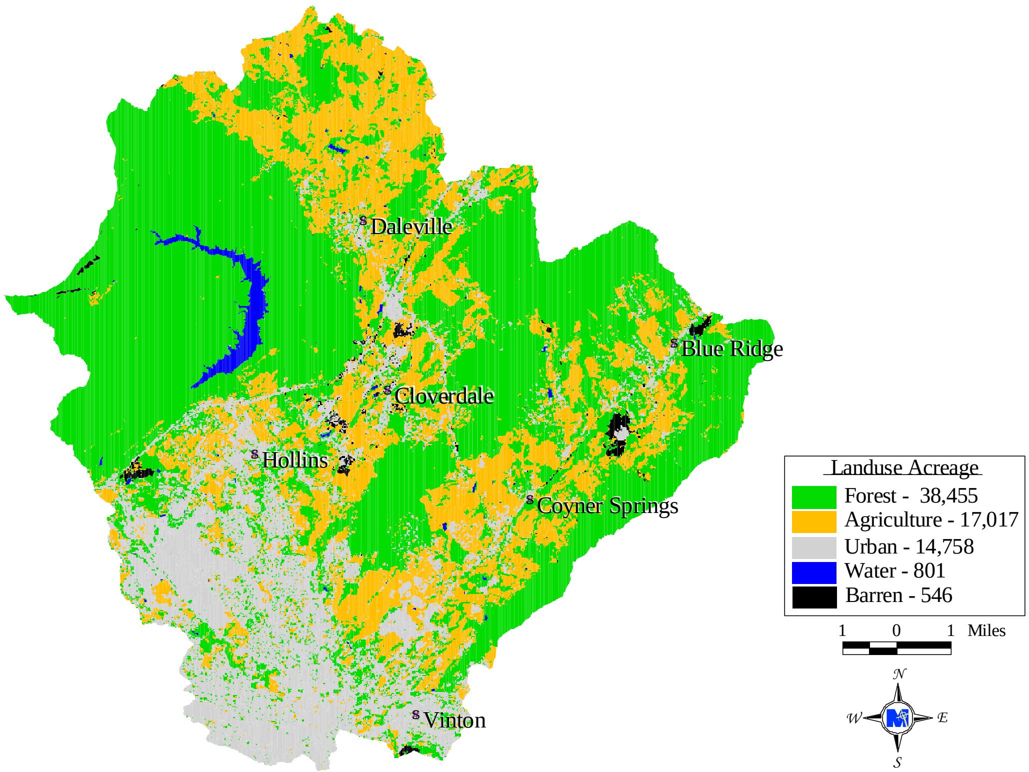

Figure 1.3 Land uses in the Tinker Creek watershed.

The National Land Cover Data (NLCD) produced cooperatively between USGS and EPA was utilized for this study. The collaborative effort to produce this dataset is part of a Multi-Resolution Land Characteristics (MRLC) Consortium project led by four U.S. government agencies: EPA, USGS, the Department of the Interior National Biological Service (NBS), and the National Oceanic and Atmospheric Administration (NOAA). Using 30-meter resolution Landsat 5 Thematic Mapper (TM) satellite images taken between 1990 and 1994, digital land use coverage was developed identifying up to 21 possible land use types. Classification, interpretation, and verification of the land cover dataset involved several data sources (when available) including: aerial photography; soils data; population and housing density data; state or regional land cover data sets; USGS land use and land cover (LUDA) data; 3-arc-second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief; and National Wetlands Inventory (NWI) data. Approximate acreages and land use proportions for each impaired segment are given in Table 1.2.

Table 1.2 Contributing land use area for impaired segments in the Tinker Creek watershed.

Impaired Segment	Land Use									
	Water (ac)	Residential (ac) Low	Residential (ac) High	Commercial & Services (ac)	Barren (ac)	Woodland (ac)	Pasture (ac)	Cropland (ac)	Wetlands (ac)	Livestock Access (ac)
Tinker Creek	61	3,283	22	726	235	11,676	8,801	173	14	524
Carvin Creek	665	1,838	34	605	105	13,605	1,217	29	16	76
Laymantown Creek	13	174	0	8	22	2,200	691	23	0	30
Glade Creek	23	1,922	0	608	193	10,404	4,486	113	6	192
Lick Run	4	3,228	158	2,015	0	740	532	8	2	9

The estimated human population within the drainage area in 2003 was 82,460 (calculated from 1990 and 2000 U.S. Census Bureau data) with 19,382 dogs and 21,706 cats (calculated from American Veterinary Medical Association Center for Information Management demographics) associated with this population. Table 1.3 lists agricultural production rankings for the counties and city in Tinker Creek basin compared to all counties in Virginia. Counties in the Tinker Creek basin are home to numerous species of wildlife, including mammals (*e.g.*, beaver, raccoon, white-tailed deer) and birds (*e.g.*, wood duck, wild turkey, Canada goose) (Table 1.4).

Table 1.3 Agricultural production rankings for counties in Tinker Creek basin compared to all counties in Virginia.[1]

County / City	Rankings Compared to Other Counties in Virginia			
	Cattle & Calves	*Dairy*	*Beef*	*Horses*
Botetourt County	29	18	29	14
Roanoke County	59	N/A	58	25
Roanoke City	N/A	N/A	N/A	N/A

[1]Virginia Agricultural Statistics Service.

Table 1.4 Number of wildlife species, mammal types, and bird types inhabiting counties and cities within Tinker Creek watershed.[1]

County / City	Number of Wildlife Species	Number of Mammal Types	Number of Bird Types
Botetourt County	496	53	214
Roanoke County	510	52	216
Roanoke City	479	52	212

[1]Virginia Department of Game and Inland Fisheries (http://www.dgif.state.va.us).

For the period from 1948 to 2000, the Tinker Creek watershed received average annual precipitation of approximately 40.7 inches, with 53% of the precipitation occurring during the May – October growing season (SERCC, 2003). Average annual snowfall is 23.2 inches with the highest snowfall occurring during February (SERCC, 2003). Average annual daily temperature is 56.3 ºF. The highest average daily temperature of 87.2 ºF occurs in July, while the lowest average daily temperature of 26.9 ºF occurs in January (SERCC, 2003).

1.2 Applicable Water Quality Standards

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

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

> *A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*
>
> ♦
>
> *D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*
>
> *G. The [State Water Control] board may remove a designated use which is not an existing use, or establish subcategories of a use, if the board can demonstrate that attaining the designated use is not feasible because:*
>
> 1. *Naturally occurring pollutant concentrations prevent the attainment of the use;*
> 2. *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;*
>
> ♦
>
> 6. *Controls more stringent than those required by §§301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.*

Section 9 VAC 25-260-170 is the applicable water quality criteria for fecal coliform impairments in the Tinker Creek watershed.

Prior to 2002, Virginia Water Quality Standards specified the following criteria for a non-shellfish supporting waterbody to be in compliance with Virginia's fecal standard for contact recreational use:

> *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.*

If the waterbody exceeded either criterion more than 10% of the time, the waterbody was classified as impaired and the development and implementation of a TMDL was indicated in order to bring the waterbody into compliance with the water quality criterion. Based on the sampling frequency, only one criterion was applied to a particular datum or data set. If the sampling frequency was one sample or less per 30 days, the instantaneous criterion was applied; for a higher sampling frequency, the geometric criterion was applied. These were the criteria used for listing the impairments included in this study. Sufficient fecal coliform bacteria standard violations were recorded at VADEQ water quality monitoring stations to indicate that the recreational use designations are not being supported.

EPA ultimately recommended that all states adopt an *E. coli* or *enterococci* standard for fresh water and *enterococci* criteria for marine waters by 2003. EPA is pursuing the states' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and *enterococci*) and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and *enterococci* standard is now in effect in Virginia.

The new criteria, outlined in 9 VAC 25-260-170, read as follows:

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

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

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

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

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

These criteria were used in developing the TMDLs included in this study.

2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Selection of a TMDL Endpoint and Critical Condition

EPA regulation 40 CFR 130.7 (c)(1) requires TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the impaired waterbody is protected during times when it is most vulnerable. This section describes selection of the TMDL endpoint, as well as establishment of critical conditions.

Lick Run and Tinker Creek were initially categorized as impaired in the Virginia 1996 Section 303(d) TMDL Priority List and Report. Glade Creek was initially placed on the Virginia 1998 Section 303(d) TMDL Priority List and Report. These segments remained on the 2002 Section 303(d) TMDL Priority List and Report and, in addition, Carvin Creek and Laymantown Creek were added (see Table 1.1). Elevated levels of fecal coliform bacteria recorded at VADEQ ambient water quality monitoring stations showed that these stream segments do not support the primary contact recreation use.

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the Tinker Creek TMDLs, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations (Section 1.2 of this document). In order to remove a water body from a state’s list of impaired waters, the Clean Water Act requires compliance with that state's water quality standard. Since modeling provided simulated output of *E. coli* concentrations at 1-hour intervals, assessment of TMDLs was made using both the geometric mean standard of 126 cfu/100 ml and the instantaneous standard of 235 cfu/100 ml. Therefore, the in-stream *E. coli* targets for these TMDLs were a monthly geometric mean not exceeding 126 cfu/100 ml and a single sample not exceeding 235 cfu/100 ml.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards. Fecal coliform sources within the Tinker Creek watershed are attributed to both point and non-point sources. Critical conditions for waters impacted by land-based non-point sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include non-point sources that are not precipitation driven (*e.g.,* fecal deposition to stream). Fecal coliform concentrations were plotted against the flow duration interval (Figures 2.1 through 2.9) based on Tinker Creek flows. Flows at the outlet of Tinker Creek watershed (*i.e.,* Tinker Creek flows) were calculated based on flows measured on the Roanoke River at USGS stations upstream (#02055000) and downstream (#02056000) of the Tinker Creek confluence with the Roanoke River. Data included in these figures were limited to data collected during the period from 1990 to 2002. More recent data has been collected, however, it was not available for this analysis.

At the time of this analysis, the data available for Carvin Creek, Laymantown Creek, and the upstream stations on Glade Creek were limited and did not provide a representative dataset for assessing violations with respect to different flow regimes. However, a graphical analysis of fecal coliform concentrations and flow duration interval at the downstream Glade Creek station showed that violations were more likely at high flows (Figure 2.7) while in Lick Run and Tinker Creek there was no obvious critical flow level (Figures 2.8 - 2.9). That is, the analysis showed no obvious dominance of either non-point sources or point sources. High concentrations were recorded in all flow regimes. Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons (Section 4.5). The resulting period for calibration was October 1993 through September 1998. For validation, the time period selected was October 1988 through September 1993.

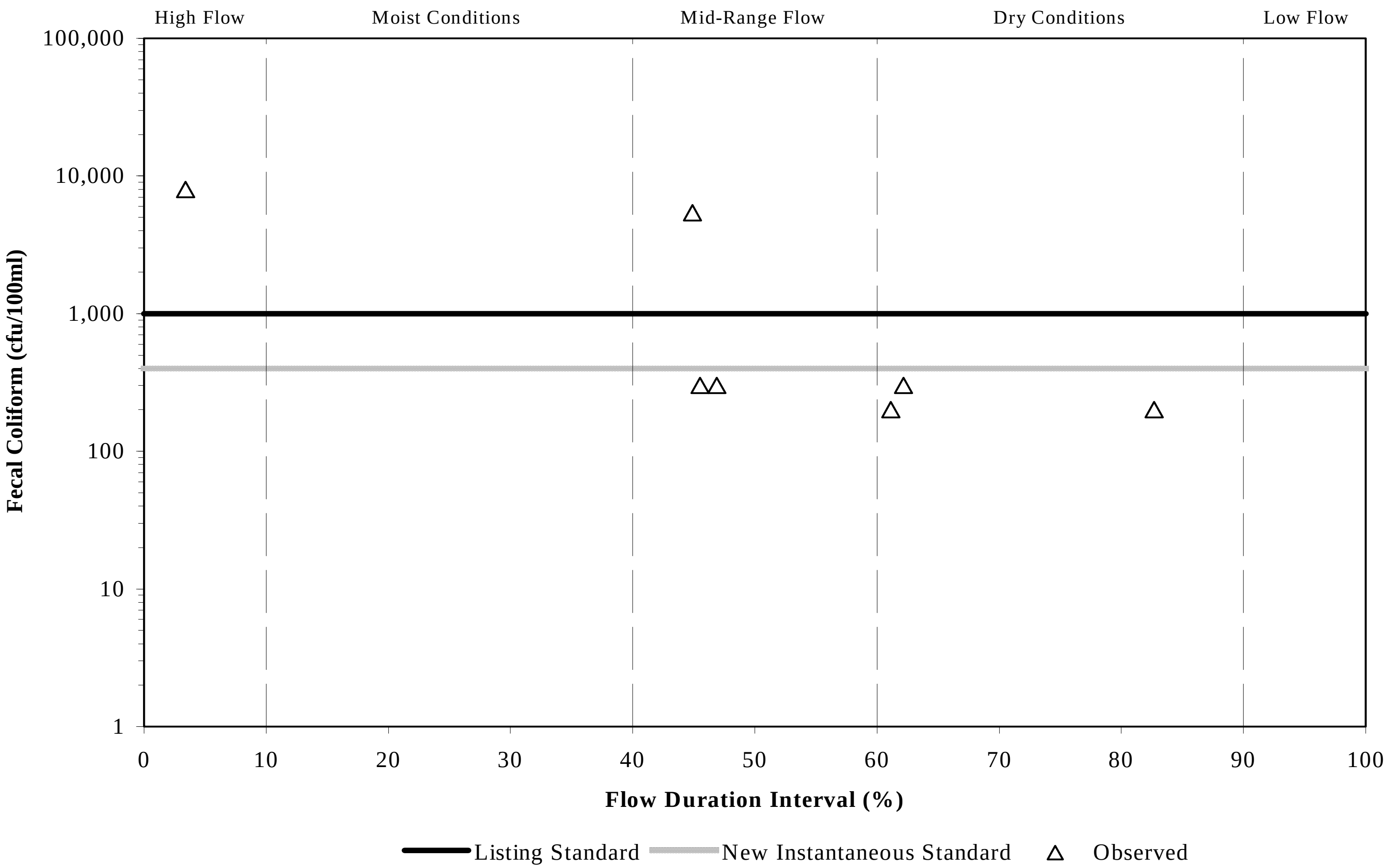

Figure 2.1 Relationship between fecal coliform concentrations (VADEQ Station 4ACRV000.28) and Tinker Creek discharge in the Carvin Creek impairment.

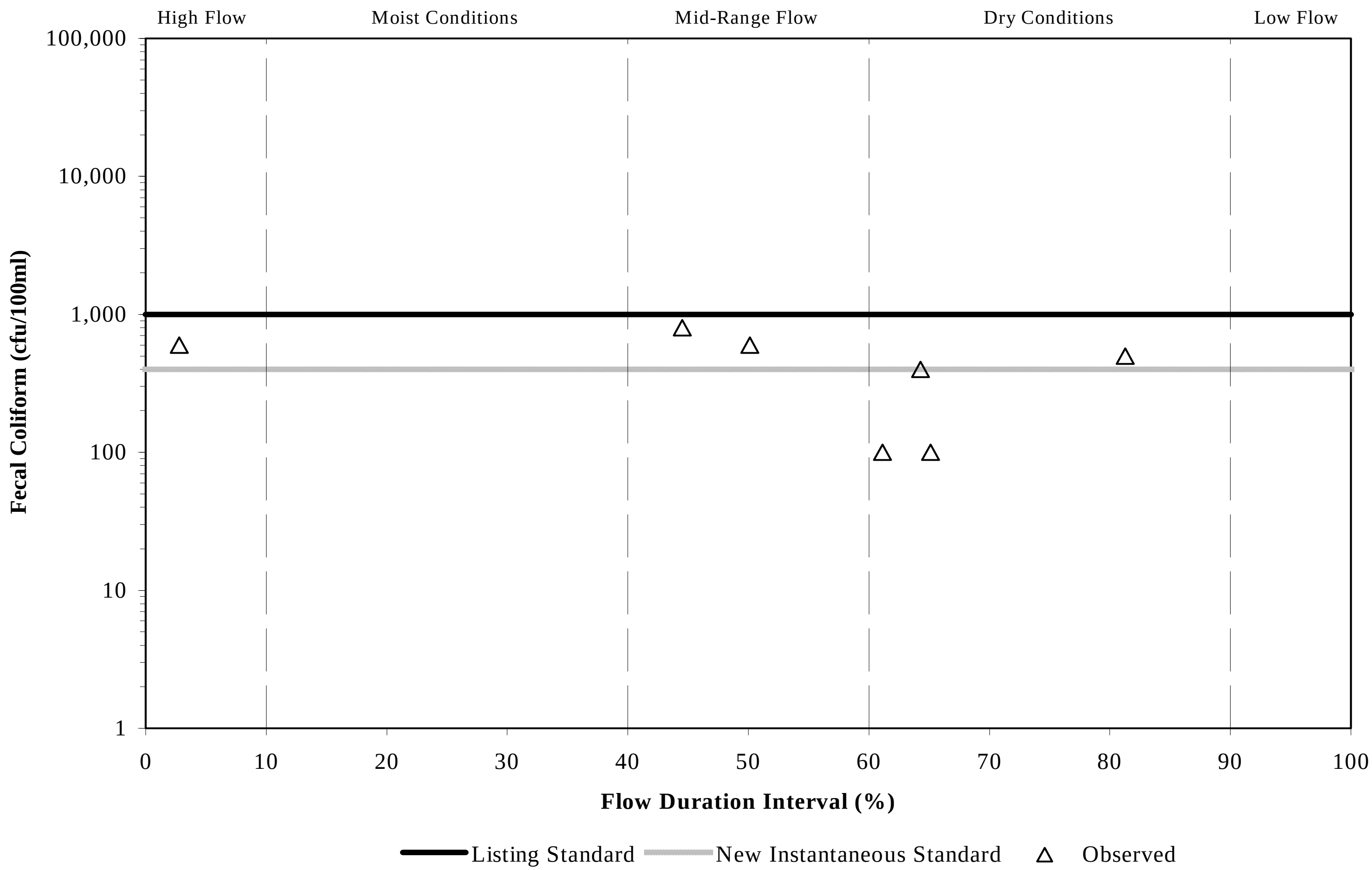

Figure 2.2 **Relationship between fecal coliform concentrations (VADEQ Station 4ALAY000.37) and Tinker Creek discharge in the Laymantown Creek impairment.**

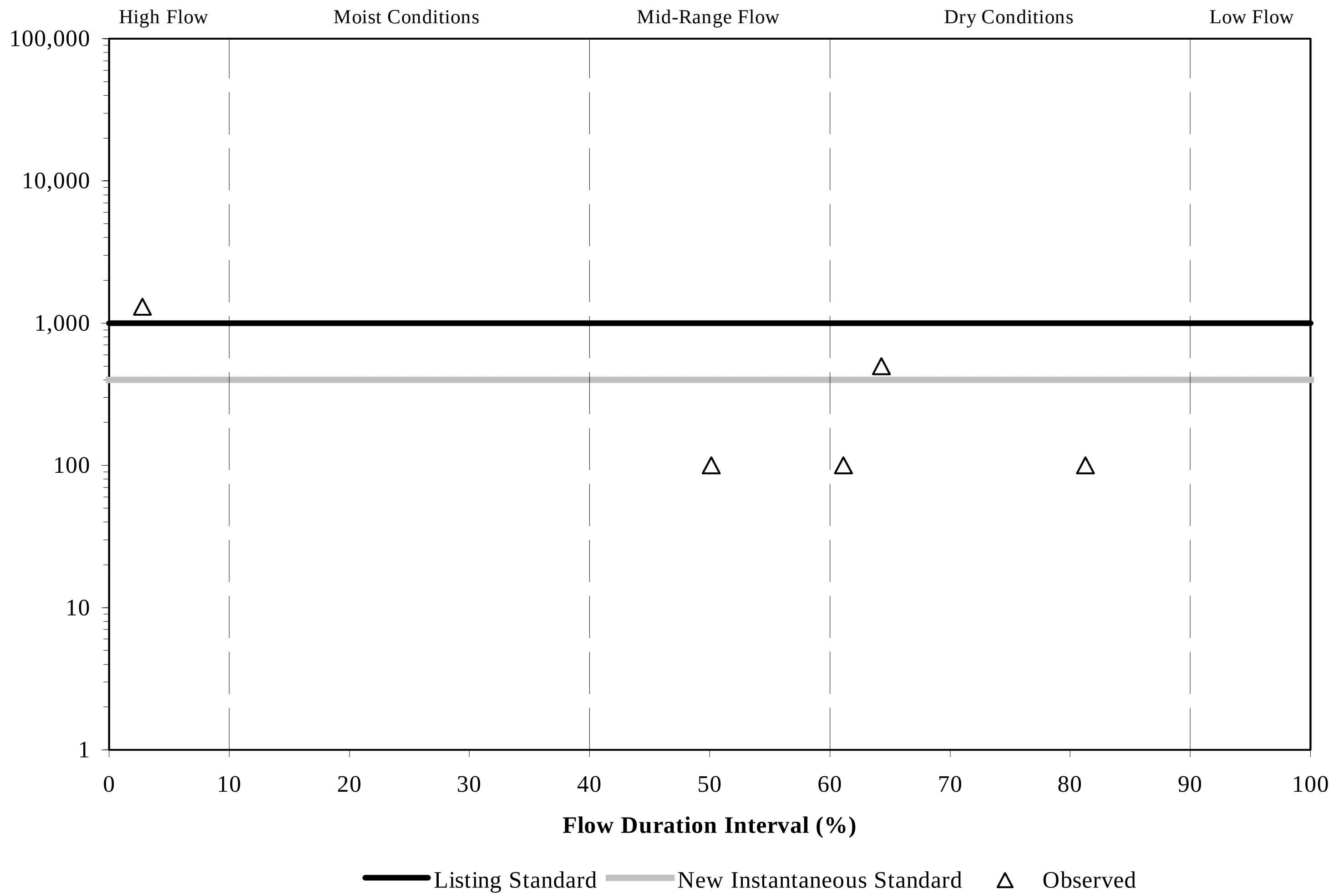

Figure 2.3 Relationship between fecal coliform concentrations (VADEQ Station 4AGLA008.10) and Tinker Creek discharge in the Glade Creek impairment.

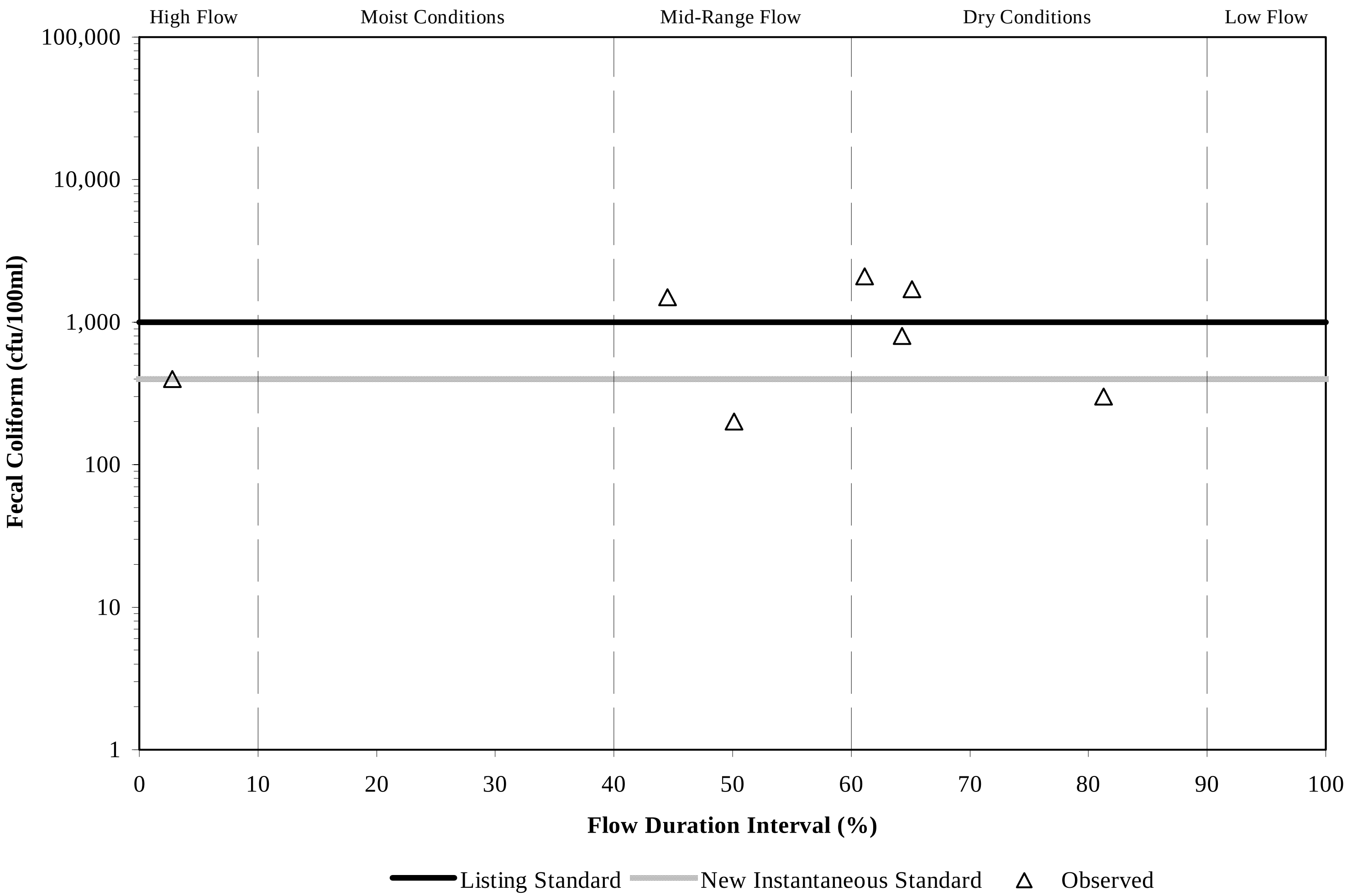

Figure 2.4 Relationship between fecal coliform concentrations (VADEQ Station 4AGLA005.75) and Tinker Creek discharge in the Glade Creek impairment.

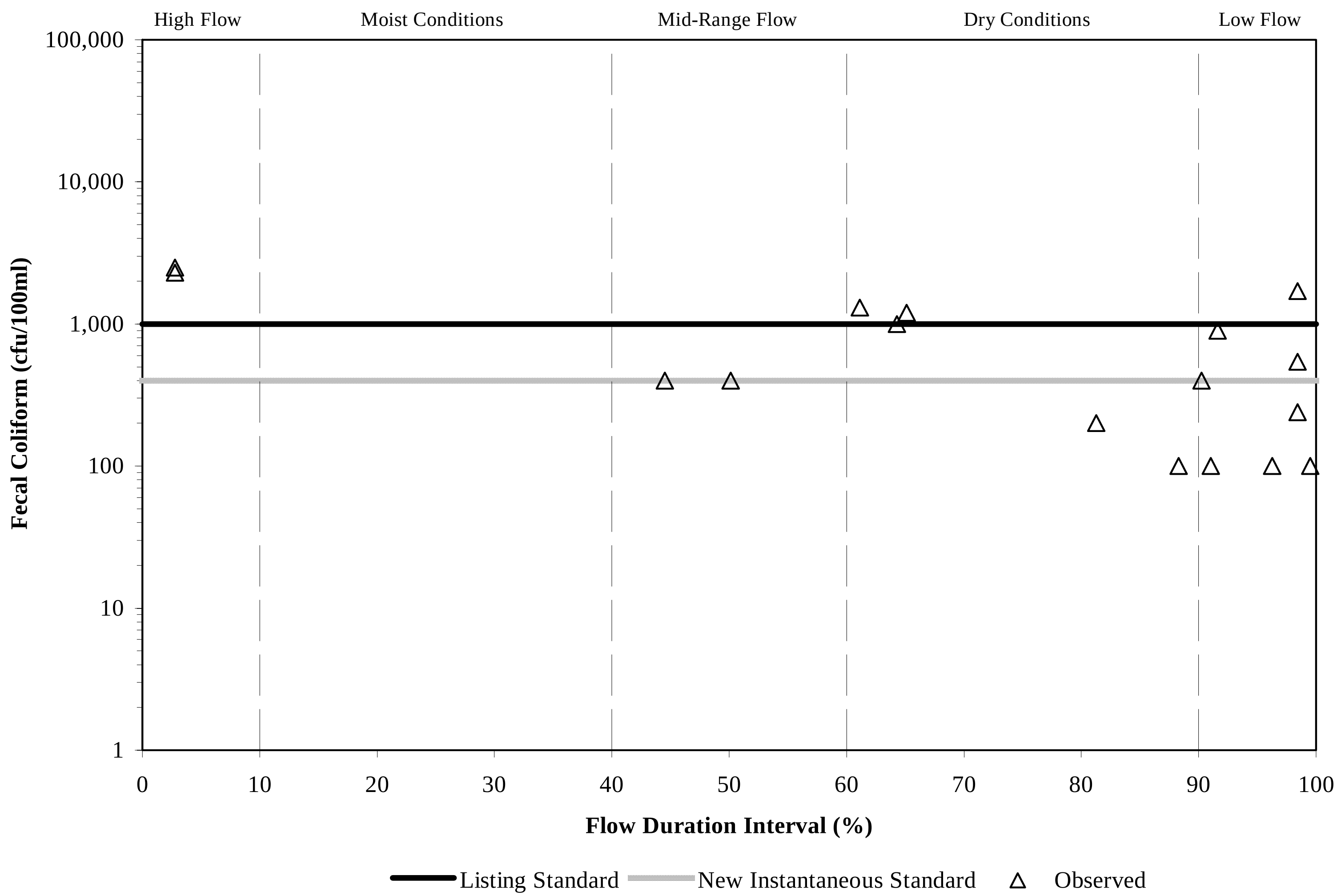

Figure 2.5 **Relationship between fecal coliform concentrations (VADEQ Station 4AGLA004.39) and Tinker Creek discharge in the Glade Creek impairment.**

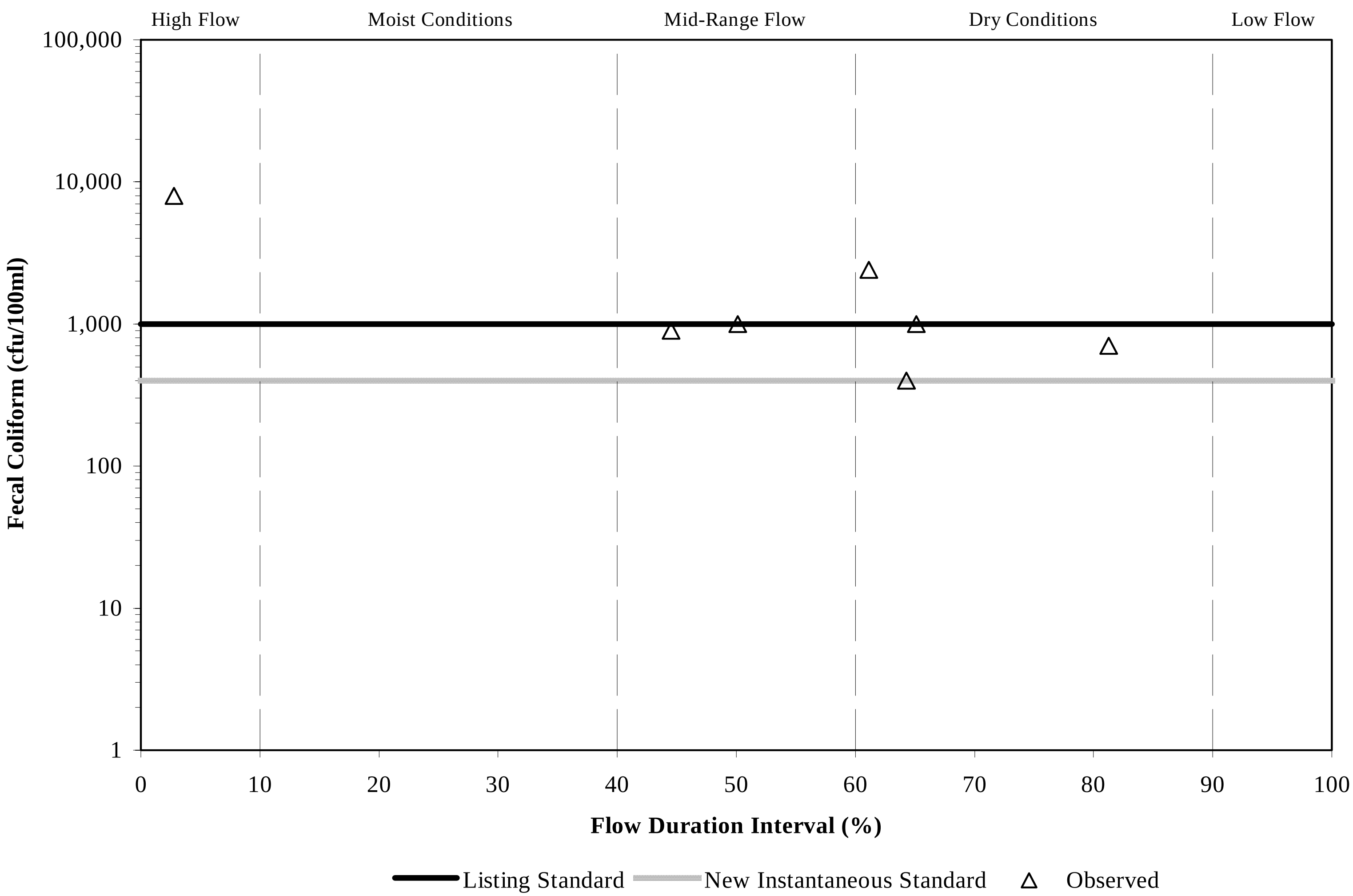

Figure 2.6 **Relationship between fecal coliform concentrations (VADEQ Station 4AGLA001.60) and Tinker Creek discharge in the Glade Creek impairment.**

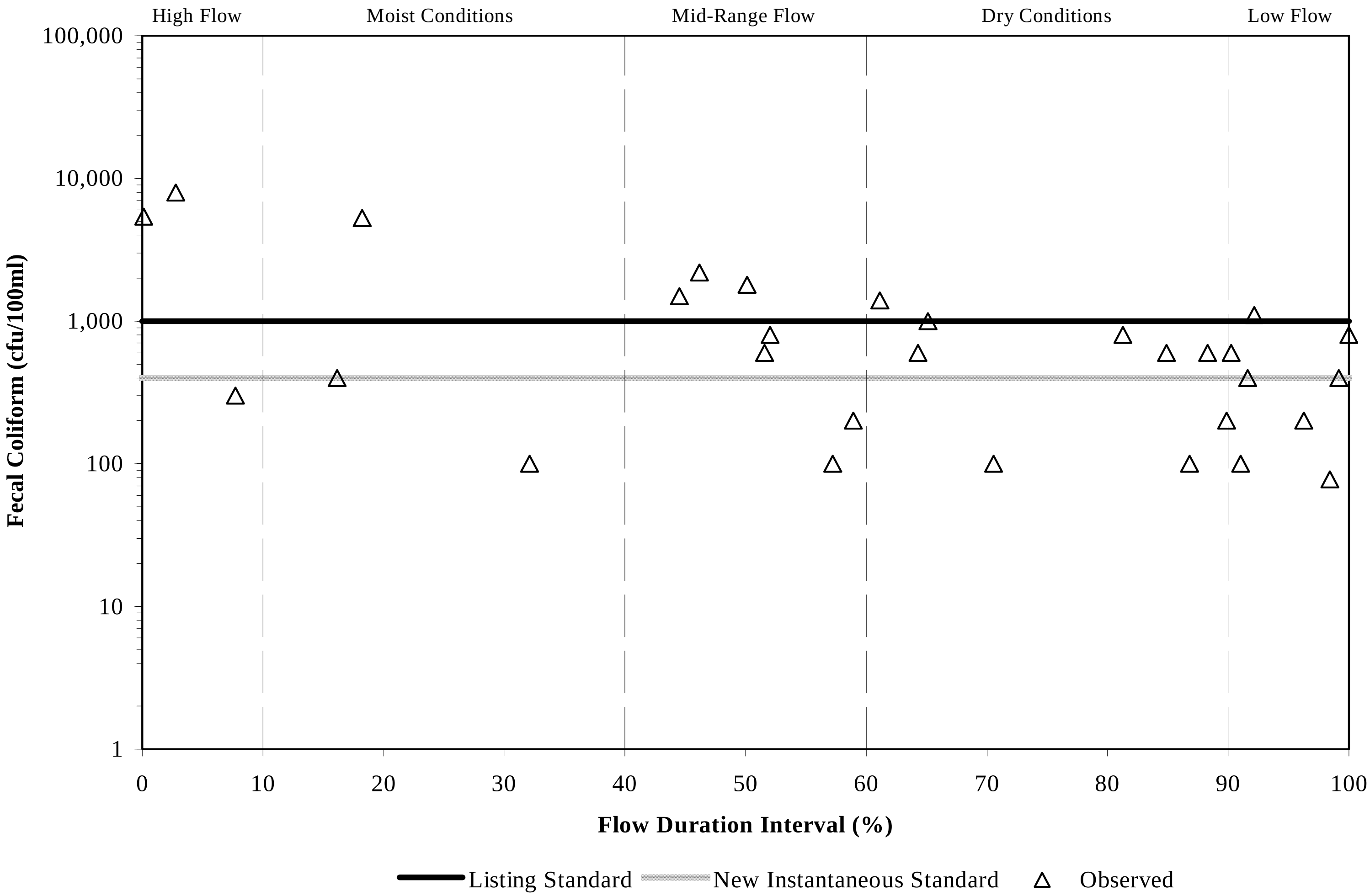

Figure 2.7 **Relationship between fecal coliform concentrations (VADEQ Station 4AGLA000.20) and Tinker Creek discharge in the Glade Creek impairment.**

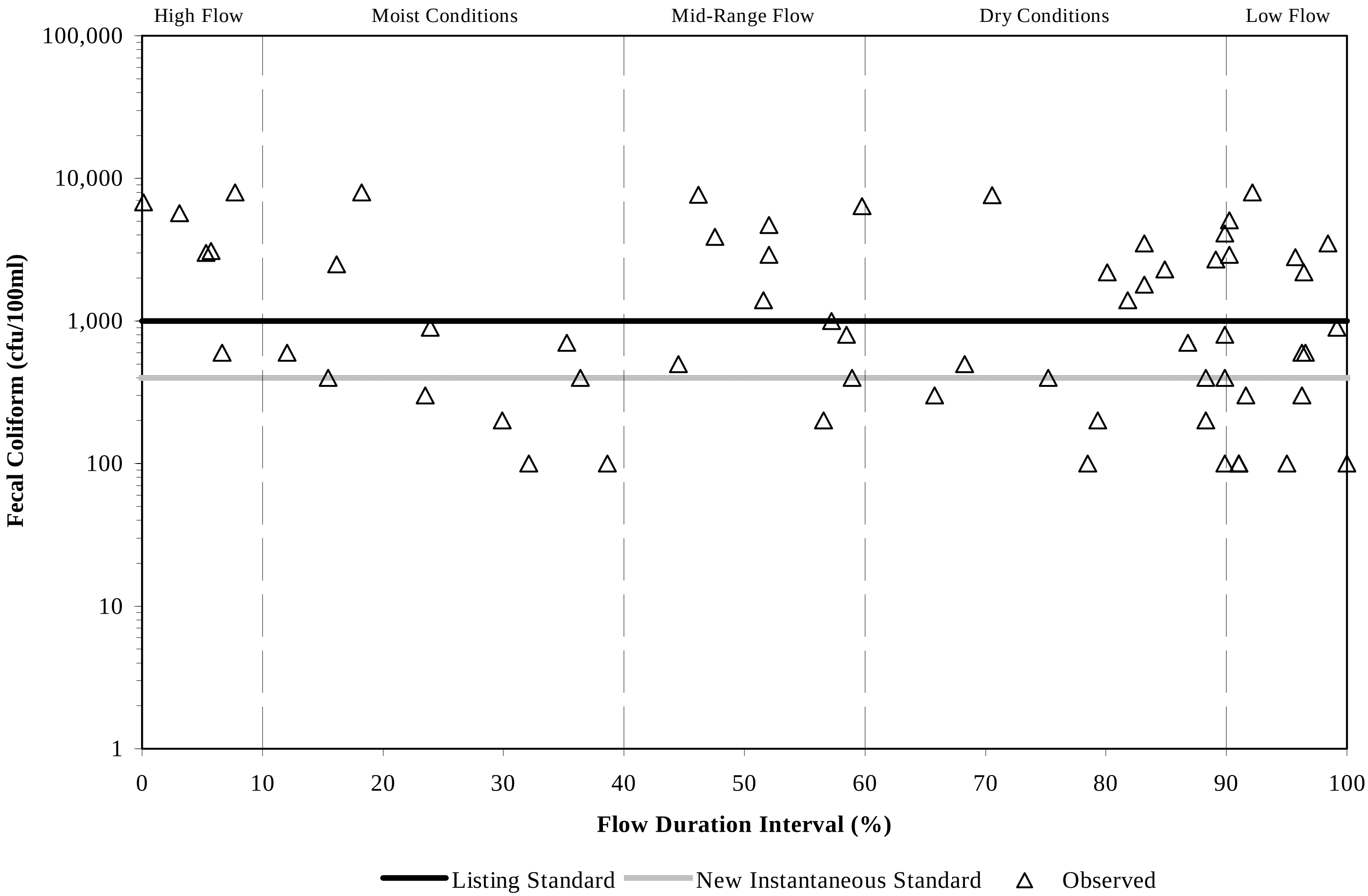

Figure 2.8 **Relationship between fecal coliform concentrations (VADEQ Station 4ALCK000.38) and Tinker Creek discharge in the Lick Run impairment.**

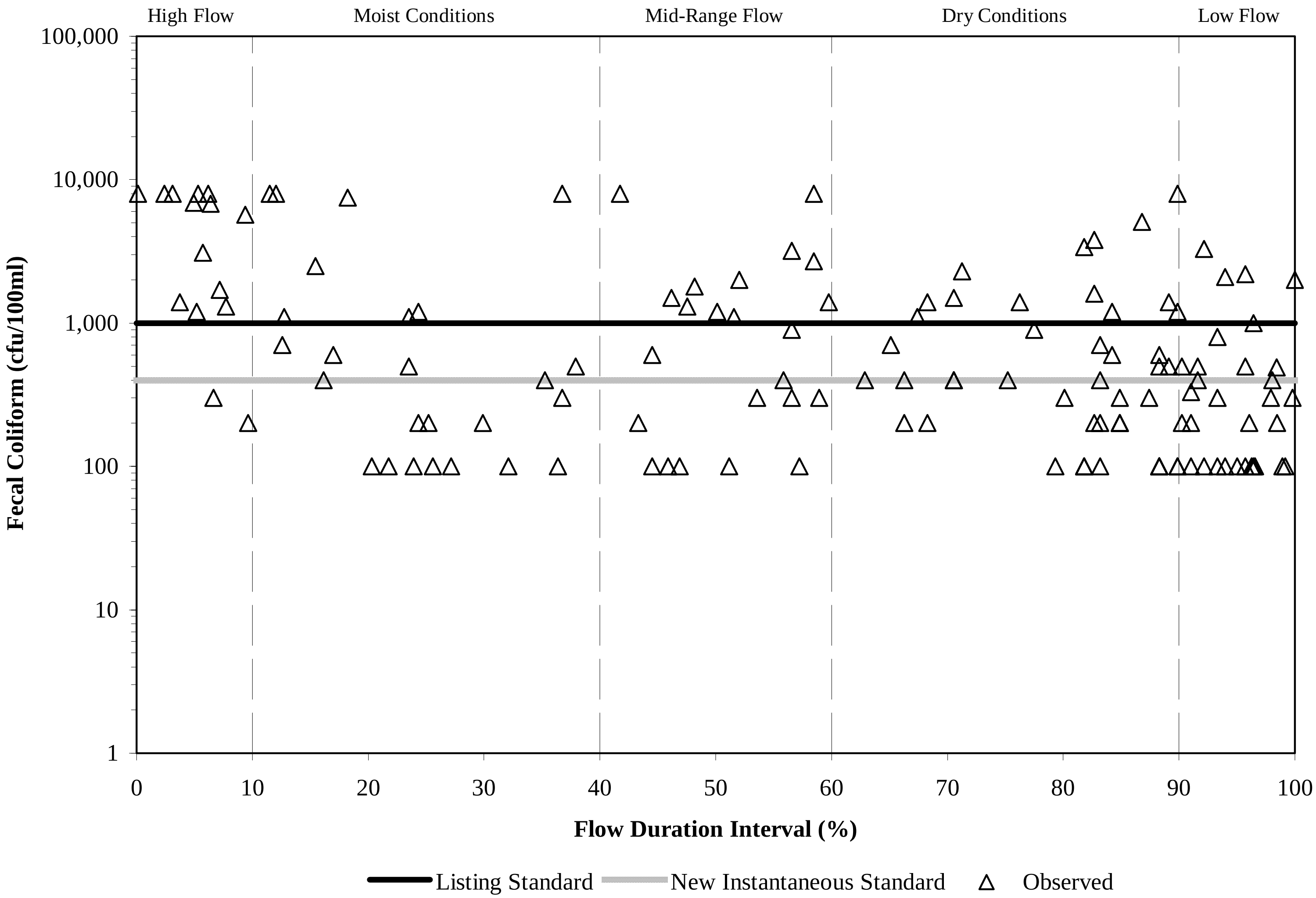

Figure 2.9 Relationship between fecal coliform concentrations (VADEQ Station 4ATKR000.69) and Tinker Creek discharge in the Tinker Creek impairment.

2.2 Discussion of In-stream Water Quality

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

2.2.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- bacteria enumerations from 9 VADEQ in-stream monitoring stations used for TMDL assessment; and
- bacteria enumerations and BST from seven VADEQ in-stream monitoring stations analyzed during TMDL development.

2.2.1.1 Water Quality Monitoring for TMDL Assessment

Data from in-stream fecal coliform samples, collected by VADEQ from January 1990 through September 2002, were analyzed (Figure 2.10) and are included in the analysis. Samples were taken for the expressed purpose of determining compliance with the state instantaneous standard limiting concentrations to less than 1,000 cfu/100 ml. Therefore, as a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 ml or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 ml, depending on the laboratory procedures employed for the sample) were not further analyzed to determine the precise concentration of fecal coliform bacteria. The result is that reported concentrations of 100 cfu/100 ml most likely represent concentrations below 100 cfu/100 ml, and reported concentrations of 8,000 or 16,000 cfu/100 ml most likely represent concentrations in excess of these values. Table 2.1 summarizes the fecal coliform samples collected at the in-stream monitoring stations used for TMDL assessment.

A special study was conducted by VADEQ at 8 stations in the Tinker Creek drainage, from May 1997 to August 1997. During this study, multiple samples were collected each month, allowing for assessment using the geometric mean standard. Table 2.2 gives a summary of the data including violation rates based on the geometric mean standard.

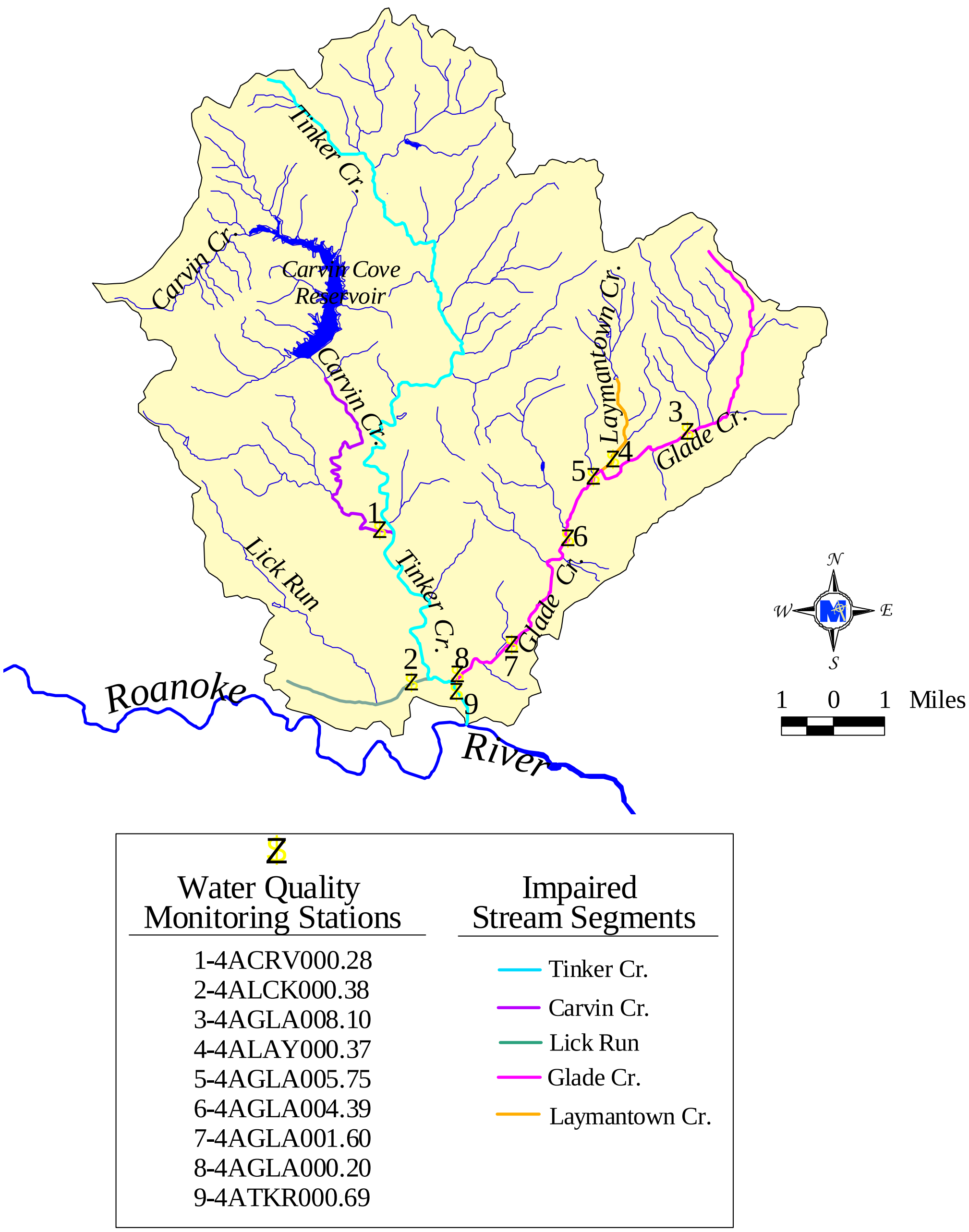

Figure 2.10 Location of VADEQ water quality monitoring stations used for TMDL assessment in the Tinker Creek watershed.

Table 2.1 Summary of water quality sampling conducted by VADEQ for period January 1990 through January 2003 used to assess violations of instantaneous standard. Fecal coliform concentrations (cfu/100 ml).

VADEQ Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Violations[1] (%)	Violations[2] (%)
4ACRV000.28	7	200	8,000	2,100	300	29	29
4AGLA000.20	32	78	9,200	1,416	600	28	56
4AGLA001.60	7	400	8,000	2,057	1,000	29	86
4AGLA004.39	17	100	16,000	1,735	790	35	44
4AGLA005.75	7	200	2,100	1,000	800	43	57
4AGLA008.10	5	100	1,300	420	100	20	40
4ALAY000.37	7	100	800	443	500	0	57
4ALCK000.38	64	100	9,200	2,170	850	45	66
4ATKR000.69	140	100	8,000	1,520	400	36	49

[1]Violations are based on the listing fecal coliform instantaneous standard (*i.e.*, 1,000 cfu/100ml)
[2]Violations are based on the new fecal coliform instantaneous standard (*i.e.*, 400 cfu/100ml)

Table 2.2 Summary of water quality sampling conducted by VADEQ for period May 1997 through August 1997 used to assess violations of geometric mean standard. Fecal coliform concentrations (cfu/100 ml).

VADEQ Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Violations[1] (%)
4ACRV000.28	7	173.22	1,549.19	791.41	734.85	100
4AGLA000.20	6	948.68	3,464.10	1,821.03	1,322.88	100
4AGLA001.60	6	600.00	2,828.43	1,598.25	1,422.67	100
4AGLA004.39	7	509.90	2,397.92	1,083.58	721.11	100
4AGLA005.75	6	400.00	1,095.45	756.08	784.16	100
4AGLA008.10	4	100.00	360.56	196.04	161.80	50
4ALAY000.37	6	223.61	692.82	410.32	367.42	100
4ALCK000.38	6	894.43	2,966.48	2,299.88	2,591.56	100

[1]Violations are based on the listing fecal coliform geometric mean standard (*i.e.*, 200 cfu/100ml)

2.2.1.2 *Water Quality Monitoring Conducted During TMDL Development*

Ambient water quality monitoring was performed from November 2002 through October 2003. Specifically, water quality samples were taken at seven sites throughout the Tinker Creek watershed (Figure 2.11). All samples were analyzed for fecal coliform and *E. coli* concentrations, and for bacteria source (*i.e.*, human, livestock, pets, wildlife) by the Environmental Diagnostics Laboratory (EDL) at MapTech. Tables 2.3 and 2.4 summarize the fecal coliform and *E. coli* concentration data, respectively, at the ambient stations. BST is presented and discussed in greater detail in Section 2.2.2.2.

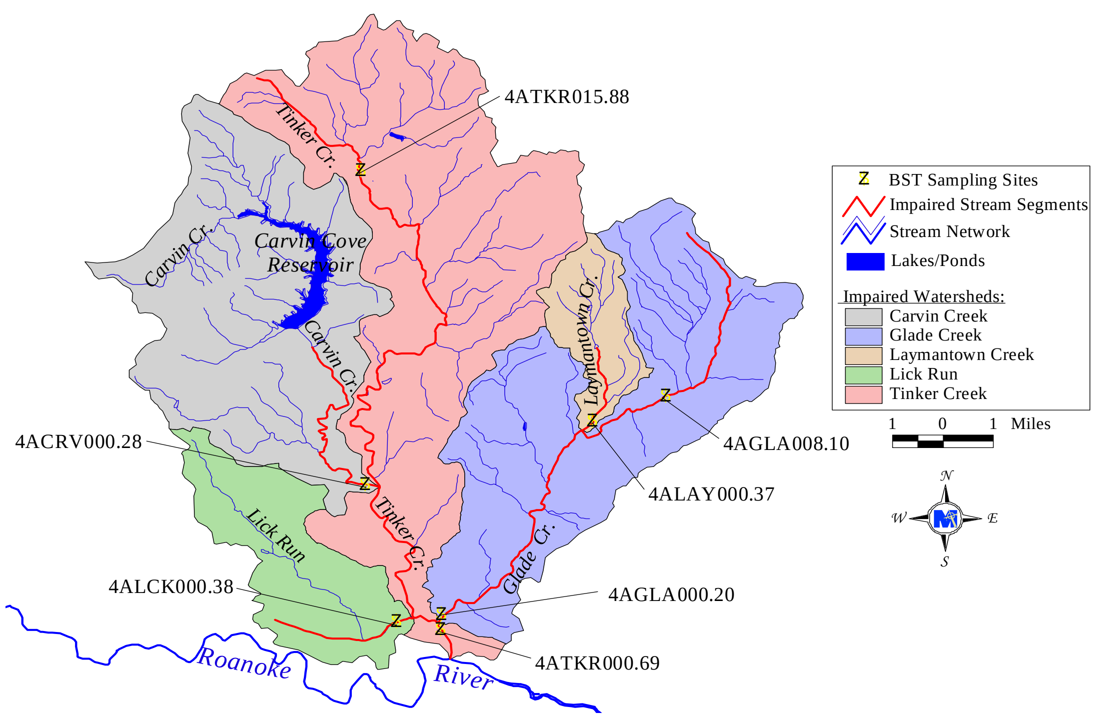

Figure 2.11 Location of BST water quality monitoring stations in the Tinker Creek watershed.

Table 2.3 Summary of water quality sampling conducted by VADEQ during TMDL development. Fecal coliform concentrations (cfu/100 ml).

Impairment	Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Violations[1] (%)	Violations[2] (%)
Carvin Creek	4ACRV000.28	12	100	2,200	464	280	8	33
Glade Creek	4AGLA000.20	11	150	2,800	730	440	18	55
	4AGLA008.10	12	50	2,000	490	335	8	42
Laymantown Creek	4ALAY000.37	9	91	2,300	613	320	11	44
Lick Run	4ALCK000.38	11	250	6,400	2,254	680	45	82
Tinker Creek	4ATKR000.69	12	20	3,400	1,484	1,300	50	83
	4ATKR015.88	12	130	5,900	1,138	555	25	67

[1]Violations based on listing fecal coliform instantaneous standard (*i.e.*, 1,000 cfu/100ml)
[2]Violations based on new fecal coliform instantaneous standard (*i.e.*, 400 cfu/100ml)

Table 2.4 Summary of water quality sampling conducted by VADEQ during TMDL development. *E. coli* concentrations (cfu/100 ml).

Impairment	**Station**	**Count (#)**	**Minimum (cfu/100ml)**	**Maximum (cfu/100ml)**	**Mean (cfu/100ml)**	**Median (cfu/100ml)**	**Violations[1] (%)**
Carvin Creek	4ACRV000.28	12	1	1,500	315	200	42
Glade Creek	4AGLA000.20	11	10	1,000	232	180	27
	4AGLA008.10	12	32	550	170	105	25
Laymantown Creek	4ALAY000.37	9	20	810	172	54	22
Lick Run	4ALCK000.38	11	46	3,000	498	280	55
Tinker Creek	4ATKR000.69	12	10	530	281	305	67
	4ATKR015.88	12	10	4,200	657	305	58

[1]Violations based on *E. coli* instantaneous standard (*i.e.*, 235 cfu/100ml)

2.2.1.3 *Summary of In-stream Water Quality Monitoring Data*

A wide range of fecal coliform concentrations have been recorded in the watershed. Concentrations reported during TMDL development were within the range of historical values reported by VADEQ during TMDL assessment. Exceedances of the instantaneous standard were reported in all flow regimes, leaving no apparent relationship between flow and water quality.

2.2.2 Analysis of Water Quality Monitoring Data

The data collected were analyzed for frequency of violations, patterns in fecal source identification, and seasonal impacts. Results of the analyses are presented in the following sections.

2.2.2.1 *Summary of Frequency of Violations at the Monitoring Stations*

Except for the special study described in section 2.2.1.1, water quality data were collected at a time-step of at least one month. The state standard of 1,000 cfu/100 ml and 400 cfu/100 ml was used to test for fecal coliform violations. For samples with *E. coli* concentrations, violations of the state standard of 235 cfu/100 ml were calculated. For the special study data, violations of the 200 cfu/100ml geometric-mean standard for fecal coliform are reported. Violation rates are listed in Tables 2.1 through 2.4. A distribution of fecal coliform and *E. coli* concentrations at each sampling station in the watershed can be found in Appendix A.

2.2.2.2 *Bacterial Source Tracking*

MapTech, Inc. was contracted to perform an analysis of fecal coliform and *E. coli* concentrations as well as BST. BST is intended to aid in identifying sources (i.e. human, pets, livestock, or wildlife) of fecal contamination in water bodies. Data collected provided insight into the likely sources of fecal contamination, aided in distributing fecal loads from different sources during model calibration, and will improve the chances for success in implementing solutions.

Several procedures are currently under study for use in BST. Virginia has adopted the Antibiotic Resistance Analysis (ARA) methodology implemented by MapTech's EDL. This method was selected because it has been demonstrated to be a reliable procedure for confirming the presence or absence of human, pet, livestock and wildlife sources in watersheds in Virginia. The results of sampling were reported as the percentage of isolates acquired from the sample that were identified as originating from either human, pet, livestock, or wildlife sources.

BST results of water samples collected at 7 ambient stations in the Tinker Creek drainage are reported in Tables 2.5 – 2.9. The *E. coli* enumerations are given to indicate the bacteria concentration at the time of sampling. The proportions reported are formatted to indicate statistical significance (*i.e.*, **BOLD** numbers indicate a statistically significant result). In general, the BST results indicate that all sources are contributing to the bacteria impairment.

Table 2.5 Summary of bacterial source tracking results from water samples collected in the Carvin Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as:			
				Human	Pets	Livestock	Wildlife
4ACRV000.28	11/25/02	130	1 BDL	--	--	--	--
	12/17/02	280	240	0%	0%	8%	**92%**
	1/29/03	100	62	**26%**	9%	**26%**	**39%**
	2/25/03	260	54	**13%**	**49%**	**17%**	**21%**
	3/31/03	150	110	**29%**	**13%**	**33%**	**25%**
	4/29/03	340	180	4%	**25%**	**25%**	**46%**
	5/28/03	280	90	**25%**	**37%**	**21%**	**17%**
	6/26/03	420	260	**96%**	0%	4%	0%
	7/22/03	660	500	**17%**	**21%**	**13%**	**49%**
	8/27/03	2,200	560	0%	**25%**	8%	**67%**
	9/22/03	610	1,500	0%	0%	**83%**	**17%**
	10/22/03	140	220	0%	0%	**50%**	**50%**

BOLD type indicates a statistically significant value.

Table 2.6 Summary of bacterial source tracking results from water samples collected in the Glade Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Human	Pets	Livestock	Wildlife
	12/17/02	170	78	**46%**	0%	**33%**	**21%**
	1/29/03	500	61	0%	6%	**69%**	**25%**
	2/25/03	150	48	**22%**	4%	**57%**	**17%**
	3/31/03	250	10 BDL	**--**	**--**	**--**	**--**
	4/29/03	380	74	**26%**	**17%**	**35%**	**22%**
4AGLA000.20	5/28/03	2,000	320	4%	8%	**42%**	**46%**
	6/26/03	520	230	**16%**	8%	**38%**	**38%**
	7/22/03	440	340	**33%**	**17%**	**17%**	**33%**
	8/27/03	2,800	210	0%	4%	4%	**92%**
	9/22/03	570	1,000	4%	**33%**	8%	**55%**
	10/22/03	250	180	5%	5%	**57%**	**33%**
	11/25/02	70	42	**37%**	**17%**	**33%**	**13%**
	12/17/02	220	200	**21%**	**13%**	8%	**58%**
	1/29/03	310	140	0%	0%	8%	**92%**
	2/25/03	130	32	**25%**	**37%**	**19%**	**19%**
	3/31/03	260	95	**46%**	**50%**	0%	4%
4AGLA008.10	4/29/03	360	100	**13%**	**30%**	**48%**	9%
	5/28/03	750	67	**13%**	**45%**	**25%**	**17%**
	6/26/03	460	110	8%	**13%**	**50%**	**29%**
	7/22/03	730	550	**21%**	**29%**	8%	**42%**
	8/27/03	2,000	250	0%	**25%**	**50%**	**25%**
	9/22/03	540	370	**38%**	8%	8%	**46%**
	10/22/03	50	80	0%	0%	**62%**	**38%**

BOLD type indicates a statistically significant value.

Table 2.7 Summary of bacterial source tracking results from water samples collected in the Laymantown Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Human	Pets	Livestock	Wildlife
	2/25/03	91	50	**29%**	**13%**	**29%**	**29%**
	3/31/03	270	33	**29%**	8%	**38%**	**25%**
	4/29/03	2,300	300	**36%**	**23%**	**23%**	**18%**
	5/28/03	260	100	8%	**38%**	**21%**	**33%**
4ALAY000.37	6/26/03	610	130	**79%**	0%	**13%**	8%
	7/22/03	600	48	8%	8%	0%	**84%**
	8/27/03	320	54	0%	**21%**	8%	**71%**
	9/22/03	900	810	0%	0%	**67%**	**33%**
	10/22/03	170	20	**49%**	0%	13%	**38%**

BOLD type indicates a statistically significant value.

Table 2.8 Summary of bacterial source tracking results from water samples collected in the Lick Run impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Human	Pets	Livestock	Wildlife
4ALCK000.38	11/25/02	64	32	**21%**	**21%**	**47%**	11%
	12/17/02	420	330	4%	**25%**	**38%**	**33%**
	1/29/03	6,400	3000	**13%**	**37%**	**33%**	**17%**
	2/25/03	2,800	320	**35%**	**26%**	**17%**	**22%**
	3/31/03	430	80	0%	0%	**96%**	4%
	4/29/03	500	68	0%	8%	**63%**	**29%**
	5/28/03	4,400	370	**29%**	**17%**	**21%**	**33%**
	6/26/03	680	110	**21%**	8%	**13%**	**58%**
	7/22/03	250	46	4%	**21%**	**17%**	**58%**
	8/27/03	5,400	280	0%	8%	0%	**92%**
	9/22/03	3,200	720	0%	**33%**	**25%**	**42%**
	10/22/03	310	150	**20%**	**15%**	**20%**	**45%**

BOLD type indicates a statistically significant value.

Table 2.9 Summary of bacterial source tracking results from water samples collected in the Tinker Creek impairment.

Station	Date	Fecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	Percent Isolates classified as: Human	Pets	Livestock	Wildlife
4ATKR000.69	11/25/02	20	15	11%	22%	**45%**	22%
	12/17/02	600	270	**42%**	0%	**16%**	**42%**
	1/29/03	3,300	200	**13%**	**22%**	9%	**56%**
	2/25/03	2,000	400	8%	**29%**	**42%**	**21%**
	3/31/03	2,700	10 BDL	**--**	**--**	**--**	**--**
	4/29/03	470	110	**13%**	**17%**	**53%**	**17%**
	5/28/03	3,400	480	**17%**	**33%**	**21%**	**29%**
	6/26/03	2,100	360	**38%**	0%	**41%**	**21%**
	7/22/03	510	250	8%	0%	0%	**92%**
	8/27/03	2,000	340	0%	**13%**	**13%**	**74%**
	9/22/03	140	530	0%	4%	**38%**	**58%**
	10/22/03	570	410	0%	**13%**	**38%**	**49%**
4ATKR015.88	11/25/02	130	10 BDL	**--**	**--**	**--**	**--**
	12/17/02	160	120	**42%**	**13%**	**45%**	0%
	1/29/03	270	200	**46%**	8%	**42%**	4%
	2/25/03	250	100	**13%**	8%	**71%**	8%
	3/31/03	1,300	10 BDL	**--**	**--**	**--**	**--**
	4/29/03	580	420	**17%**	0%	**17%**	**66%**
	5/28/03	5,900	4,200	**25%**	**17%**	**21%**	**37%**
	6/26/03	700	340	**92%**	0%	4%	4%
	7/22/03	560	410	**13%**	4%	4%	**79%**
	8/27/03	2,800	900	0%	**25%**	**33%**	**42%**
	9/22/03	550	900	0%	0%	**71%**	**29%**
	10/22/03	450	270	**21%**	0%	**54%**	**25%**

BOLD type indicates a statistically significant value.

2.2.2.3 *Trend and Seasonal Analyses*

In order to improve TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on precipitation, discharge, and fecal coliform concentrations. A Seasonal Kendall Test was used to examine long-term trends. The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends. This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed. For instance, the Seasonal Kendall Test can identify the trend (over many years) in discharge levels during a particular season or month.

A seasonal analysis of precipitation, discharge, and fecal coliform concentration data was conducted using the Mood Median Test. This test was used to compare median values of precipitation, discharge, and fecal coliform concentrations in each month. Significant differences between months within years were reported.

2.2.2.4 *Precipitation*

Total monthly precipitation measured at station Roanoke Airport #447285 in Roanoke, Virginia was analyzed, and no significant overall, long-term trend or seasonality was found. However, the highest precipitation occurred during the spring months, and the lowest precipitation occurred during the fall and winter months.

2.2.2.5 *Discharge*

Total monthly flow measured at two stations on the Roanoke River and one station on Tinker Creek (Stations #02055000 and #02056000 on the Roanoke River, and Station #02055100 on Tinker Creek) from January 1970 to September 2001 was analyzed. An overall, long-term decrease in flow was found at stations #02055000 and #02056000. The slope of this decrease was estimated at –0.72 cfs/year and –2.30 cfs/year, respectively (Table 2.10). No overall trend was observed at Station #02055100. Differences in mean monthly flow at each station are indicated in Tables 2.11 through 2.13. Flows in months with the same median group letter are not significantly different from each other at the 95% significance level. For example, February, March, and April are all in median group “C” and are not significantly different from each other. In general, flow in the winter-spring months tends to be higher than flow in the summer-fall months.

Table 2.10 Summary of trend analysis on flow (cfs).

Station	Mean	Median	Max	Min	SD[1]	N[2]	Significant Trend[3]
USGS #02055000	12.85	8.68	117.8	1.10	12.66	381	-0.72
USGS #02055100	376.55	250.71	2,557.9	43.55	349.82	381	No Trend
USGS #02056000	549.19	379.48	3,660.77	103.94	465.76	381	-2.30

[1]SD: standard deviation, [2]N: number of sample measurements, [3]A number in the significant trend column represents the Seasonal-Kendall estimated slope.

Table 2.11 Summary of the Mood Median Test on mean monthly flow at Roanoke River @ Roanoke USGS 02055000.

Month	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Median Groups		
January	14.31	2.08	35.86		B	C
February	18.66	3.78	82.64			C
March	22.45	3.16	69.26			C
April	20.65	3.21	87.87			C
May	9.18	1.10	117.80		B	C
June	9.96	1.67	39.02	A	B	
July	7.57	1.28	21.79	A	B	
August	6.38	1.10	29.80	A	B	
September	8.08	1.56	50.43	A		
October	8.71	2.09	34.19	A	B	
November	12.69	1.76	117.80	A	B	
December	11.00	2.67	32.61		B	

Table 2.12 Summary of the Mood Median Test on mean monthly flow at Tinker Creek near Daleville USGS 02055100.

Month	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Median Groups		
January	465.85	65.55	996.87		B	C
February	578.60	129.07	1,912.04			C
March	699.11	119.42	1,971.19			C
April	665.24	150.93	2,557.90		B	C
May	237.79	43.55	1,626.30		B	C
June	328.05	76.13	1,206		B	
July	164.79	65.13	470.19	A	B	
August	158.24	43.55	542.16	A		
September	189.41	54.63	992.23	A		
October	207.03	47.90	844.26	A		
November	289.93	55.13	1,626.30	A	B	
December	320.40	76.19	920.68		B	

Table 2.13 Summary of the Mood Median Test on mean monthly flow at Roanoke River @ Niagara USGS 02056000.

Month	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Median Groups		
January	645.86	136.16	1,406.23		B	C
February	801.87	201.46	2,805.36			C
March	969.39	209.71	2,846.26			C
April	927.42	240.80	3,660.77			C
May	373.63	103.94	2,100.43		B	C
June	492.04	135.30	1,550.27		B	
July	293.46	153.48	741.58	A	B	
August	282.80	103.94	805.71	A	B	
September	323.98	112.20	1,256.60	A		
October	329.50	138.74	1,170.77	A		
November	420.28	124.60	2,100.43	A	B	
December	466.80	154.52	1,307.45		B	

2.2.2.6 *Fecal Coliform Concentrations*

Water quality monitoring data collected by VADEQ were described in section 2.2.1.1. The trend analysis was conducted on data, if sufficient (*i.e.*, a minimum of 3 years of data for each month reported), collected at stations used in TMDL assessment. An overall trend in fecal coliform concentrations was detected at station 4ATKR000.69. The slope of this decrease was estimated at –22.90 cfu/100 ml/year. Remaining stations had no overall trend (Table 2.14). Differences in monthly fecal coliform concentration for station 4ATKR015.88 are indicated in Table 2.15. Fecal coliform concentrations in months with the same median group letter are not significantly different from each other at the 95% significance level. For example, February is in median group "A", and June is in median group "B"; therefore February and June are significantly different from each other. The remaining stations had no seasonality effect.

Table 2.14 Summary of trend analysis on fecal coliform (cfu/100 ml).

Station	Mean	Median	Max	Min	SD[1]	N[2]	Significant Trend[3]
4ATKR000.69	2,062.62	800	8,000	100	2,617.64	336	-22.90
4ALCK000.38	2,323.88	900	8,000	100	2,633.65	67	--
4AGLA000.20	1,353.60	500	8,000	78	2,037.65	30	--
4ATKR009.30	1,165.13	350	6,000	100	1,745.00	80	No Trend
4ATKR015.88	1,116.53	200	8,000	6	1,961.02	99	No Trend

[1]SD: standard deviation, [2]N: number of sample measurements, [3]A number in the significant trend column represents the Seasonal-Kendall estimated slope, "--" insufficient data

Table 2.15 Summary of the Mood Median Test on mean monthly fecal coliform at 4ATKR015.88 (p=0.038).

Month	Mean (cfu/100 ml)	Minimum (cfu/100 ml)	Maximum (cfu/100ml)	Median Groups	
January	562.5	100	3,000	A	B
February	150	100	200	A	
March	1,312.5	100	8,000	A	B
April	1,025	100	6,000	A	B
May	1,655.56	100	8,000	A	B
June	989.56	6	2,700		B
July	1,918.75	100	8,000	A	B
August	1,982.22	100	6,000	A	B
September	266.67	100	800	A	B
October	1,170	100	8,000	A	B
November	1,593.75	100	6,000	A	B
December	386.25	100	1,100	A	B

3. SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal bacteria in the Tinker Creek watershed. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local management agencies. This section documents the available information and interpretation for the analysis. The "Source Assessment" chapter is organized into point and non-point source sections. The representation of the following sources in the model is discussed in Chapter 4.

3.1 Assessment of Point Sources

Eight point sources are permitted to discharge in the Tinker Creek watershed through the VPDES. Figure 3.1 shows their discharge locations. Permitted point discharges that may contain pathogens associated with fecal matter have been required to maintain a fecal coliform concentration below 200 cfu/100 ml. Currently, these permitted dischargers are expected not to exceed the 126 cfu/100ml *E. coli* standard. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill off any pathogens. The monitoring method for ensuring the goal is to measure the concentration of total residual chlorine (TRC) in the effluent. If the concentration is high enough, pathogen concentrations, including fecal coliform concentrations, are considered reduced to acceptable levels. Typically, if minimum TRC levels are met, bacteria concentrations are reduced to levels well below the standard. Table 3.1 summarizes data from these point discharges.

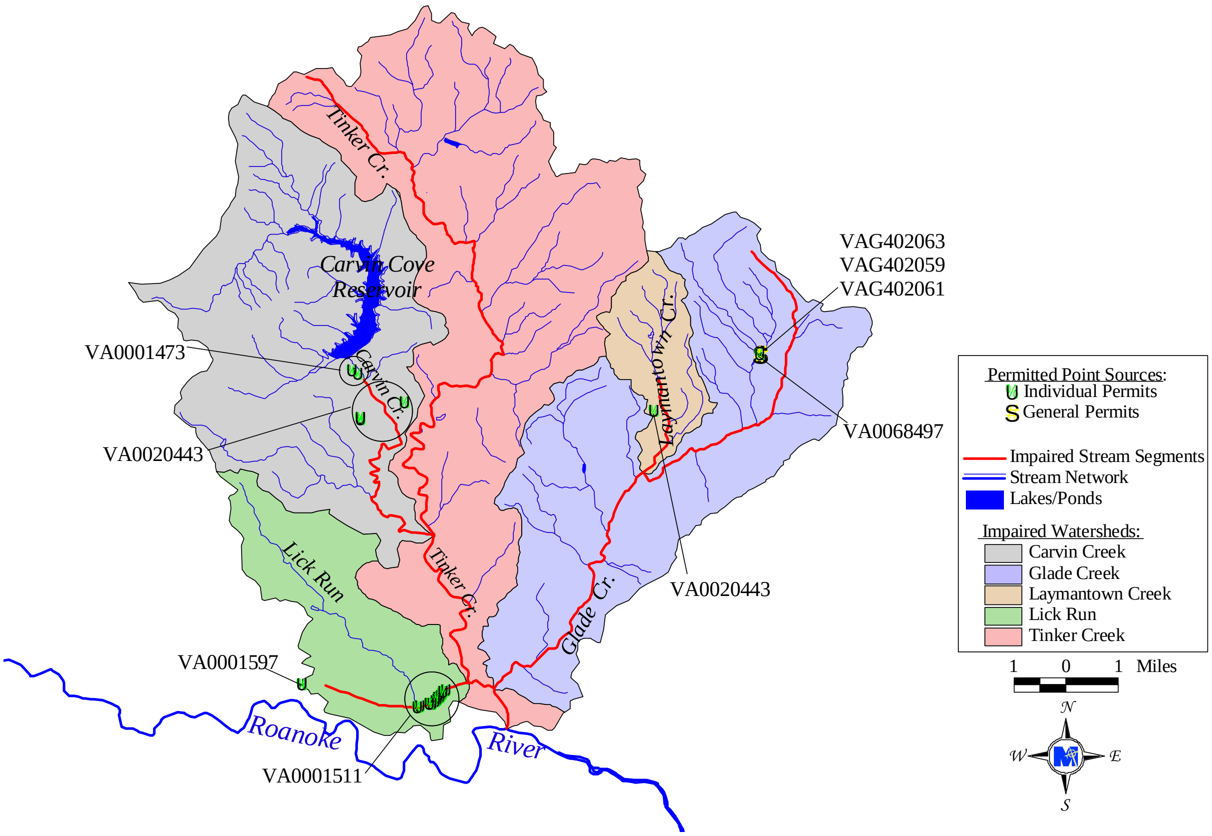

Figure 3.1 Location of VPDES permitted point sources in the Tinker Creek watershed.

Table 3.1 Summary of VPDES permitted point discharges in the Tinker Creek watershed.

Facility	VPDES #	Design Discharge (MGD)	Permitted For Fecal Control	Water Quality Data Availability
ITT Industries - Night Vision	VA0020443	0.058	No	N/A
Roanoke City - Carvins Cove Water Filtration Plant	VA0001473	0.474	No	N/A
Norfolk Southern Railway Co - East End Shops	VA0001511	N/A	No	N/A
Norfolk Southern Railway Co - Shaffers Crossing	VA0001597	0.05	No	N/A
R W Bowers Commercial Development	VA0068497	0.0005	Yes	ND
R W Bowers Commercial Development	VAG402063	0.0005	Yes	ND
R W Bowers Parcel No 6	VAG402059	0.0005	Yes	ND
R W Bowers Parcel No 7	VAG402061	0.0005	Yes	ND

N/A – not applicable.
ND – no data, facility not yet constructed.

3.2 Assessment of Nonpoint Sources

In the Tinker Creek watershed, both urban and rural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage treatment systems, land application of waste (livestock and biosolids), livestock, wildlife, and pets. Sources were identified and enumerated. MapTech collected samples of fecal coliform sources (*i.e.*, wildlife, livestock, pets, and human waste) and enumerated the density of fecal coliform bacteria to support the modeling process, and expanded the database of known fecal coliform sources for purposes of BST (Section 2.2.2.2). Where appropriate, spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

In 1990 U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank, or a cesspool; or sewage can be disposed of in other ways. The census category “Other Means” includes the houses that dispose of sewage other than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewage via straight pipes if located within 200 feet of a stream. U.S. Census Bureau statistics on population, housing units, and type of sewage treatment were calculated using geographic information systems (Table 3.2).

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge, or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant. When the flow of wastewater exceeds the design capacity, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows. Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system.

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

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

MapTech sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml. An average fecal coliform density for human waste of 642,000 cfu/g was calculated from samples collected from portable toilets. Geldreich (1978) reported a total waste load of 75 gal/day/person.

Table 3.2 Human population, housing units, houses on sanitary sewer, houses on septic systems, and houses on other treatment systems for 2003 in impaired segments within Tinker Creek watershed.[1]

Impaired Segment	Population	Housing Units	Sanitary Sewer	Septic Systems	Other *
Tinker Creek	23,804	10,449	7,423	3,006	20
Carvin Creek	13,879	6,210	5,497	709	4
Laymantown Creek	2,075	814	50	749	15
Glade Creek	17,835	7,320	3,778	3,502	40
Lick Run	24,867	11,503	11,239	259	5

* Houses with treatment systems other than sanitary sewer and septic systems.
[1]U.S. Census Bureau.

3.2.2 Biosolids

Between 1997 and 2003, a total of 752.30 acres were permitted by Virginia Department of Health for biosolids application in the Tinker Creek watershed; however, no biosolids applications on this permitted acreage was identified (Table 3.3). Figure 3.2 illustrates spatial distribution of permitted acreage. The application of biosolids to agricultural lands is strictly regulated in Virginia (VDH, 1997). Biosolids are required to be spread according to sound agronomic requirements and consideration for topography and hydrology. Class B biosolids may not have a fecal coliform density greater than 1,995,262 cfu/g (total solids). Application rates must be limited to a maximum of 15 dry tons/ac per three-year period.

Table 3.3 Acres permitted for biosolids application and number of acres biosolids applied to for impairments in the Tinker Creek watershed between 1997 and 2003.[1]

Impairment	Acres Permitted	Acres Applied
Tinker Creek	532.70	0.00
Carvin Creek	107.80	0.00
Laymantown Creek	0.00	0.00
Glade Creek	111.80	0.00
Lick Run	0.00	0.00

[1] Virginia Department of Health.

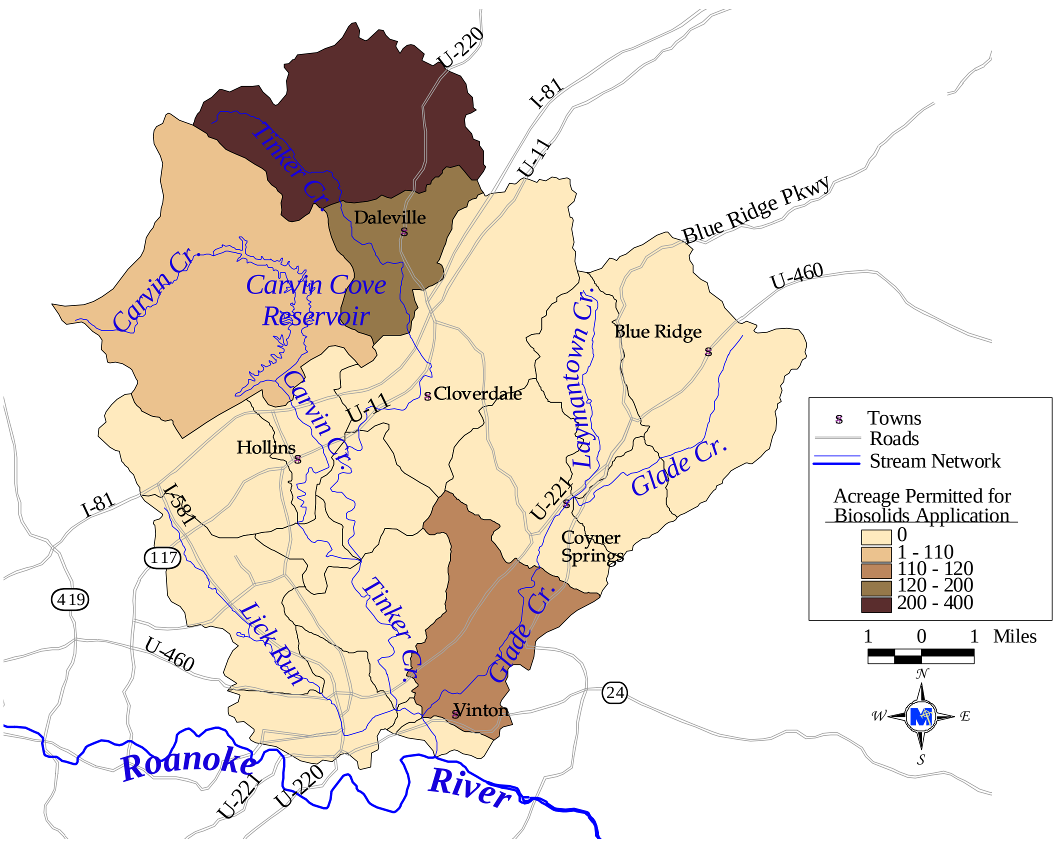

Figure 3.2 Location of acres permitted for biosolids application in the Tinker Creek watershed based on information provided by the Virginia Department of Health and the Virginia Department of Environmental Quality.

3.2.3 Pets

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

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

Type	Population Density[1] (an/house)	Waste load[2] (g/an-day)	FC Density[3] (cfu/g)
Dog	0.534	450	480,000
Cat	0.598	19.4	9

[1]American Veterinary Medical Association.
[2]Weiskel et al.
[3]MapTech.

Table 3.5 Domestic animal populations in impaired segments within Tinker Creek watershed.[1]

Impaired Segment	Dogs	Cats
Tinker Creek	5,580	6,249
Carvin Creek	3,316	3,714
Laymantown Creek	434	486
Glade Creek	3,909	4,378
Lick Run	6,143	6,879

[1]American Veterinary Medical Association.

3.2.4 Livestock

Although all types of livestock identified were considered in modeling the watershed, the predominant type of livestock in the Tinker Creek watershed is beef cattle. Animal populations were based on communication with Natural Resources Conservation Service (NRCS), Blue Ridge Soil and Water Conservation District (BRSWCD), Mountain Castles Soil and Water District (MCSWCD), watershed visits, and verbal communication with farmers. Table 3.6 gives a summary of livestock populations in the Tinker Creek watershed. Values of fecal coliform density of livestock sources were based on sampling performed by MapTech. Reported manure production rates for livestock were taken from ASAE, 1998. A summary of fecal coliform density values and manure production rates is presented in Table 3.7.

Table 3.6 Livestock populations in impaired segments within Tinker Creek watershed.[1]

Impairment	Dairy	Beef	Horse
Tinker Creek	280	890	80
Carvin Creek	0	40	40
Laymantown Creek	0	50	30
Glade Creek	0	600	120
Lick Run	0	15	3

[1]Natural Resources Conservation Service (NRCS), Blue Ridge Soil and Water Conservation District (BRSWCD), Mountain Castles Soil and Water District (MCSWCD), watershed visits, and verbal communication with farmers.

Table 3.7 Average fecal coliform densities and waste loads associated with livestock.[1]

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)
Dairy (1,400 lb)	120.4	271,000
Beef (800 lb)	46.4	101,000
Horse (1,000 lb)	51.0	94,000
Dairy Separator	N/A	32,000[1]000[2]
Dairy Storage Pit	N/A	44,600[1]600[2]

[1]American Society of Agricultural Engineers.
[21]units are cfu/100ml

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

Primarily, dairy waste is collected and spread on pasture and cropland. Time in confinement and estimates of the timing of applications throughout the year were based on data reported by NRCS, BRSWCD, and MCSWCD (Tables 3.8 - 3.10).

Table 3.8 Average percentage of collected dairy waste applied throughout year.[1]

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

[1] Natural Resources Conservation Service (NRCS), Blue Ridge Soil and Water Conservation District (BRSWCD), and Mountain Castles Soil and Water District (MCSWCD)

Table 3.9 Average time dairy milking cows spend in different areas per day.[1]

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot (hr)
January	2.4	0.5	21.1
February	2.4	0.5	21.1
March	3.5	0.8	19.7
April	5.5	1.2	17.3
May	6.4	1.4	16.2
June	6.9	1.5	15.6
July	7.6	1.6	14.8
August	7.6	1.6	14.8
September	7.7	1.5	14.8
October	7.3	1.3	15.4
November	6.4	1.1	16.5
December	4.7	0.8	18.5

[1] Natural Resources Conservation Service (NRCS), Blue Ridge Soil and Water Conservation District (BRSWCD), Mountain Castles Soil and Water District (MCSWCD), Virginia Department of Conservation and Recreation, and Virginia Cooperative Extension.

All livestock were expected to deposit some portion of waste on land areas. The percentage of time spent on pasture for dairy and beef cattle was based on research reported by the NRCS, VADCR, and VCE (Tables 3.9 through 3.11). Horses were assumed to be in pasture 100% of the time.

Based on discussions with BRSWCD, VCE, and NRCS, it was concluded that beef and dairy cattle were expected to make a significant contribution through direct deposition to streams. The average amount of time spent by dairy and beef cattle in stream access areas (*i.e.*, within 50 feet of the stream) for each month was based on a study entitled "Modeling Cattle Stream Access" conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR (Tables 3.9 through 3.11).

Table 3.10 Average time dry cows and replacement heifers spend in different areas per day.[1]

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

[1] Natural Resources Conservation Service (NRCS), Blue Ridge Soil and Water Conservation District (BRSWCD), Mountain Castles Soil and Water District (MCSWCD), Virginia Department of Conservation and Recreation, and Virginia Cooperative Extension.

Table 3.11 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day.[1]

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

[1] Natural Resources Conservation Service (NRCS), Blue Ridge Soil and Water Conservation District (BRSWCD), Mountain Castles Soil and Water District (MCSWCD),Virginia Department of Conservation and Recreation, and Virginia Cooperative Extension.

3.2.5 Wildlife

The predominant wildlife species in the watershed were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), citizens from the watershed, source sampling, and site visits. Population densities were provided by VDGIF and are listed in Table 3.12 (Bidrowski, 2003; Costanzo, 2003; Farrar, 2003; Knox, 2003; Norman and Lafon, 2002; and Rose and Cranford, 1987). The numbers of animals estimated to be in the Tinker Creek watershed are reported in Table 3.13. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were compiled from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996; and Yagow, 1999). Table 3.14 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife waste performed by MapTech. The only value that was not obtained from MapTech sampling in the watershed was for beaver. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development project (Yagow, 1999). Percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.*, within 50 feet of stream) are reported in Table 3.15.

Table 3.12 Wildlife population density.[1]

Wildlife	Botetourt Co. Density	Roanoke Co. Density	Roanoke City Density	Density Unit
Raccoon	0.0703	0.0703	0.0703	an/ac of habitat
Muskrat	2.26	2.26	2.26	an/ac of habitat
Beaver	4.8	4.8	4.8	an/mi of stream
Deer	0.048	0.032	0.032	an/ac of habitat
Turkey	0.01375	0.013750.	0.01375	an/ac of forest
Goose	0.0032	0.0032	0.0032	an/ac
Duck	0.0065	0.0065	0.0065	an/ac

[1]Virginia Department of Game and Inland Fisheries.

Table 3.13 Wildlife populations in the Tinker Creek watershed.

Impairment	Deer	Turkey	Goose	Duck	Muskrat	Raccoon	Beaver
Tinker Creek	956	159	82	166	278	149	77
Glade Creek	663	143	58	117	318	75	33
Laymantown Creek	141	30	10	21	30	8	3
Carvin Creek	618	187	58	118	1,664	103	58
Lick Run	39	9	21	44	39	1	4

Table 3.14 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	Primary = region within 600 ft of continuous streams Infrequent = region between 601 and 7,920 ft from continuous streams
Muskrat	100	Primary = region within 66 ft from continuous streams Less frequent = region between 67 and 308 ft
Beaver[1]	200	Continuous stream below 500 ft elevation (defined as distance in feet)
Deer	772	Primary = forested, harvested forest land, orchards, grazed woodland, open urban, cropland, pasture Infrequent = low density residential, medium density residential Seldom/None = rest of land use codes
Turkey[2]	320	Primary = forested, harvested forest land, grazed woodland Infrequent = open urban, orchards, cropland, pasture Seldom/None = Rest rest of land use codes
Goose[3]	225	Primary = region within 0-66 ft from ponds and continuous streams Infrequent = region between 67 and 308 ft from ponds and continuous streams
Mallard	150	Primary = region within 0-66 ft from ponds and continuous streams Infrequent = region between 67 and 308 ft from ponds and continuous streams

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

Table 3.15 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

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

4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Critical components of TMDL development include establishing the relationship between in-stream water quality and the source loadings, and establishing the critical conditions and seasonal factors that impact the water quality. A computer modeling framework addresses these critical components and allows for the evaluation of management options that will achieve the desired water quality standards. In the development of a TMDL for the Tinker Creek watershed, the relationship was defined through computer modeling based on data collected throughout the watershed. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration/validation, and model application are discussed.

4.1 Modeling Framework Selection

The USGS HSPF water quality model was selected as the modeling framework to simulate existing conditions and to perform TMDL allocations. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

The stream segment within each subwatershed is simulated as a single reach of open channel, referred to as an RCHRES. Water and pollutants from the pervious land segments (PERLNDs) and impervious land segments (IMPLNDs) are transported to the RCHRES using mass links. Mass links are also used to connect the modeled RCHRES segments in the same configuration in which the real stream segments are found in the physical world. The same mass link principle is applied when water and pollutants are conveyed to an RCHRES via a point discharge, or water is withdrawn from a particular RCHRES. On a larger scale, impaired stream segments are also linked to one another by mass links. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

4.2 Model Setup

To adequately represent the spatial variation in the watershed, the Tinker Creek drainage area was divided into eighteen subwatersheds (Figure 4.1). The rationale for choosing these subwatersheds was based on the availability of water quality data and the limitations of the HSPF model. Water quality data (*i.e.*, fecal coliform concentrations) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with these monitoring stations, since output from the model can only be obtained at the modeled subwatershed outlets (Figure 4.1 and Table 4.1). The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. Given this modeling constraint and the desire to maintain a spatial distribution of watershed characteristics and associated parameters, a one hour modeling time-step was determined to be required. 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.

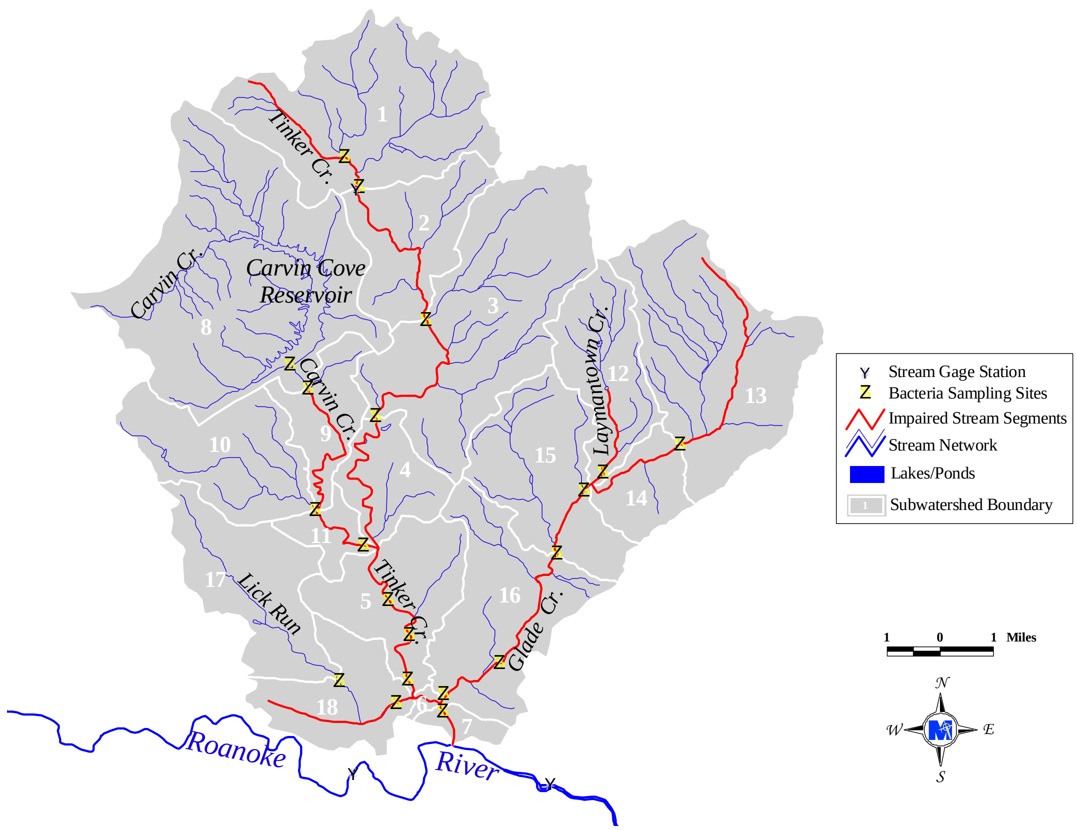

Figure 4.1 Subwatersheds delineated for modeling and location of VADEQ water quality monitoring stations and USGS Gaging Station in the Tinker Creek watershed.

Table 4.1 VADEQ monitoring stations and corresponding reaches in the Tinker Creek watershed.

Station Number	Reach Number
4ATKR000.69	7
4ACRV000.28	11
4ALAY000.37	12
4AGLA008.10	13
4AGLA004.39	15
4AGLA000.20	16
4ALCK002.17	17
4ALCK000.38	18

Using aerial photographs, MRLC identified 21 land use types in the watershed. The 21 land use types were consolidated into 10 categories based on similarities in hydrologic and waste application/production features (Table 4.2). Within each subwatershed, up to the ten land use categories were represented. Each land use had parameters associated with it that described the hydrology of the area (*e.g.*, average slope length) and the behavior of pollutants (*e.g.*, fecal coliform accumulation rate). Table 4.3 shows the consolidated land use types and the area existing in each impairment. These land use types are represented in HSPF as PERLNDs and IMPLNDs. Impervious areas in the watershed are represented in three IMPLND types, while there are nine PERLND types, each with parameters describing a particular land use (Table 4.2). Some IMPLND and PERLND parameters (*e.g.*, slope length) vary with the particular subwatershed in which they are located. Others vary with season (*e.g.*, upper zone storage) to account for plant growth, die-off, and removal.

Table 4.2 Consolidation of MRLC land use categories for the Tinker Creek watershed.

TMDL Land Use Categories	Pervious / Impervious (Percentage)	MRLC Land Use Classifications (Class No.)
Water	Impervious (100%)	Open Water (11)
Low Density Residential	Pervious (70%) Impervious (30%)	Low Intensity Residential (21) Urban/Recreational Grasses (85)
High Density Residential	Pervious (70%) Impervious (30%)	High Intensity Residential (22)
Commercial and Services	Pervious (70%) Impervious (30%)	Commercial/Industrial/Transportation (23)
Barren	Pervious (100%)	Transitional (33) Quarries/Strip Mines/Gravel Pits (32)
Woodland	Pervious (100%)	Evergreen Forest (42) Deciduous Forest (41) Mixed Forest (43)
Pasture	Pervious (100%)	Pasture/Hay (81)
Cropland	Pervious (100%)	Row Crops (82)
Wetlands	Pervious (100%)	Emergent Herbaceous Wetlands (92) Woody Wetlands (91)
Livestock Access	Pervious (100%)	Pasture/Hay (81)

Table 4.3 Spatial distribution of land use types in the Tinker Creek drainage area.

Land Use	Tinker Creek Acreage	Carvin Creek Acreage	Laymantown Creek Acreage	Glade Creek Acreage	Lick Run Acreage
Water	61	665	13	23	4
Residential – Low Density	3,283	1,838	174	1,922	3,228
Residential – High Density	22	34	0	0	158
Commercial & Services	726	605	8	608	2,015
Barren	235	105	22	193	0
Woodland	11,676	13,605	2,200	10,404	740
Pasture	8,801	1,217	691	4,486	532
Cropland	173	29	23	113	8
Wetlands	14	16	0	6	2
Livestock Access	524	76	30	192	9

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

4.3 Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.*, animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Direct depositions by nocturnal animals were modeled as being deposited from 6:00 PM to 6:00 AM, and direct depositions by diurnal animals were modeled as being deposited from 6:00 AM to 6:00 PM. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.*, population). Depending on the timeframe of the simulation being run, different numbers should be used. Data representing 1995 were used for the water quality calibration and validation period (1992-2001). Data representing 2003 were used for the allocation runs in order to represent current conditions. Additionally, data projected to 2008 were analyzed to assess the impact of changing populations.

4.3.1 Point Sources

There are eight permitted point discharges in the Tinker Creek drainage area. R W Bowers Commercial Development (VA0068497 and VAG402063), R W Bowers Parcel No. 6 (VAG402059), and R W Bowers Parcel No. 7 (VAG402061) are permitted for fecal control and each has a design discharge of 0.0005 MGD. R W Bowers Commercial Development obtained an individual permit (VA0068497) that was in effect from 1996 to 2001. In 2001, three general permits were obtained (VAG402063, VAG402059, and VAG402061), however, to date, construction has not taken place on any of these sites. ITT Industries – Night Vision Plant is not permitted for fecal control and is designed to discharge 0.058 MGD. Roanoke City – Carvins Cove Water Filtration Plant is not permitted for fecal control and is designed to discharge 0.474 MGD. Norfolk Southern Railway Co. – Shaffers Crossing is not permitted for fecal control and is designed to discharge 0.05 MGD. Norfolk Southern Railway Co. – East End Shops is not permitted for fecal control and the design discharge is not applicable. The design flow capacity was used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu/100 ml, where discharges were permitted for fecal control, to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels. For calibration and current condition runs, a lower value of fecal coliform concentration was used, based upon a regression analysis relating Total Residual Chlorine (TRC) levels and fecal coliform concentrations. Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

4.3.2 Private Residential Sewage Treatment

The number of septic systems in the eighteen subwatersheds modeled for the Tinker Creek watershed was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the watershed to enumerate the septic systems. Households were then distributed among low and high residential land use types. Septic divisions between low residential and high residential were based on GIS analysis. Each land use area was assigned a number of septic systems based on census data. A total of 6,760 septic systems were estimated in the Tinker Creek watershed in 1995. During allocation runs, the number of households was projected to 2003, based on current Botetourt and Roanoke County growth rates (USCB, 2000) resulting in 8,225 septic systems (Table 4.4). The number of septic systems was projected to increase to 9,141 by 2008.

Table 4.4 Estimated failing septic systems.

Impaired Segment	Total Septic Systems	Failing Septic Systems	Straight Pipes
Tinker Creek	3,006	634	6
Carvin Creek	709	176	1
Laymantown Creek	749	142	5
Glade Creek	3,502	647	9
Lick Run	259	85	0

4.3.2.1 *Failing Septic Systems*

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

4.3.2.2 *Uncontrolled Discharges*

Uncontrolled discharges were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category “other means” were assumed to be disposing sewage via uncontrolled discharges if located within 200 feet of a stream. Corresponding block data and subwatershed boundaries were intersected to determine an initial estimate of uncontrolled discharges in each subwatershed. A 200-foot buffer was created from the stream segments. The corresponding buffer and subwatershed areas were intersected resulting in uncontrolled discharges within 200 feet of the stream per subwatershed. Fecal coliform loads for each discharge were calculated based on the fecal density of human waste and the waste load for the average size household in the subwatershed. The loadings from uncontrolled discharges were applied directly to the stream in the same manner that point sources are handled in the model.

4.3.2.3 *Sewer System Overflows*

During the model calibration/validation period, October 1992 to September 2001, there were 61 reported sewer overflows, leading to a significant input of fecal bacteria into the watershed. It was assumed that additional occurrences of sewer overflows were likely undetected, and a procedure was determined to estimate the quantity of unreported overflows. Overflows were considered to occur during sufficiently wet periods, as based on the average rainfall over a three day period encompassing a reported overflow event. Additional three day wet periods exceeding this average value were considered to contain an unreported sewer overflow. The concentration of fecal bacteria discharged was considered to be equivalent to the concentration of septic tank effluent, and the magnitude of the discharge was estimated as the average discharge volume of reported sewer overflow events. As some biodegradation occurs in a septic system, it is felt that the estimate of concentration is conservative.

4.3.3 Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The number of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock numbers determined for 2003 were used for the allocation runs, while these numbers were projected back to 1995 for the calibration and validation runs. The numbers are based on data provided by BRSWCD, MCSWCD, and NRCS, as well as taking into account growth rates in Botetourt and Roanoke counties, as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1995 and VASS, 2003). Similarly, when growth was analyzed, livestock numbers were projected to 2008. For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.7). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

4.3.3.1 *Land Application of Collected Manure*

Significant collection of livestock manure occurs on dairy farms. For each farm in the drainage area, the average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Section 3.2.2. The amount of waste collected was first based on proportion of milking cows, as the milking herd represented the only cows subject to confinement and, therefore, waste collection. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. Finally, values for the percentage of loafing lot waste collected, based on data provided by BRSWCD, were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.8). Stored waste was spread on pastureland. It was assumed that 100% of land-applied waste is available for transport in surface runoff transport unless the waste is incorporated in the soil by plowing during seedbed preparation. Percentage of cropland plowed and amount of waste incorporated was adjusted using calibration for the months of planting.

4.3.3.2 *Deposition on Land*

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

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

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

4.3.3.3 *Direct Deposition to Streams*

Beef and dairy cattle are the primary sources of direct deposition by livestock in the Tinker Creek watershed. The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in “stream access” areas was calculated based on the “Modeling Cattle Stream Access” study. The proportion was calculated as follows:

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

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

4.3.4 Biosolids

Investigation of VDH data indicated that no biosolids applications have occurred within the Tinker Creek watershed. For model calibration, no biosolids were modeled. With urban populations growing, the disposal of biosolids will take on increasing importance. Class B biosolids have been measured with 68,467 cfu/g-dry and are permitted to contain up to 1,995,262 cfu/g-dry, as compared with approximately 240 cfu/g-dry for dairy waste. The sensitivity analysis provided insight into the effects that increased applications of biosolids could have on water quality.

4.3.5 Wildlife

For each species, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.5). An example of one of these layers is shown in Figure 4.2. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the waste load, fecal coliform densities, and number of animals for each species.

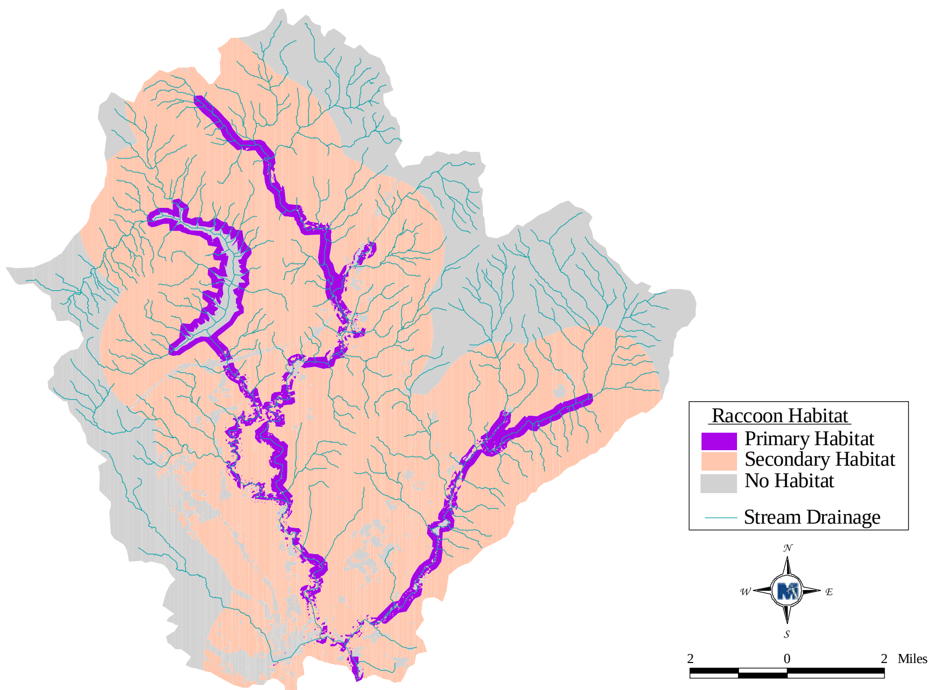

Figure 4.2 Example of raccoon habitat layer developed by MapTech in the Tinker Creek watershed.

Seasonal distribution of waste was determined using seasonal food preferences for deer and turkey. Goose and duck populations were varied based on migration patterns. No seasonal variation was assumed for the remaining species. For each species, a portion of the total waste load was considered to be land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.15). It was estimated that, for all animals other than beaver, 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams. No long-term (1995–2008) projections were made to wildlife populations, as there was no available data to support such adjustments.

4.3.6 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals/house), waste load, and fecal coliform density are reported in Section 3.2.3. Waste from pets was distributed in the low and high residential land uses. The location of households was taken from the 1990 and 2000 Census (USCB, 1990, 2000). The land use and household layers were overlaid, which resulted in number of households per land use. The number of animals per land use was determined by multiplying the number of households by the population density. The amount of fecal coliform deposited daily by pets in each land use segment was calculated by multiplying the waste load, fecal coliform density, and number of animals for both cats and dogs. The waste load was assumed not to vary seasonally. The populations of cats and dogs were projected from 1990 data to 1995, 2003, and 2008 based on housing growth rates.

4.4 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.*, stream geometry and resistance to flow). In order to determine a representative stream profile for each stream reach, cross-sections were surveyed at the subwatershed outlets. One outlet was considered the beginning of the next reach, when appropriate. In the case of a confluence, sections were surveyed above the confluence for each tributary and below the confluence on the main stream.

Most of the sections exhibited distinct flood plains with pitch and resistance to flow significantly different from that of the main channel slopes. The streambed, channel banks, and flood plains were identified. Once identified, the streambed width and slopes of channel banks and flood plains were calculated using the survey data. A representative stream profile for each surveyed cross-section was developed and consisted of a trapezoidal channel with pitch breaks at the beginning of the flood plain (Figure 4.3). With this approach, the flood plain can be represented differently from the streambed. To represent the entire reach, profile data collected at each end of the reach were averaged.

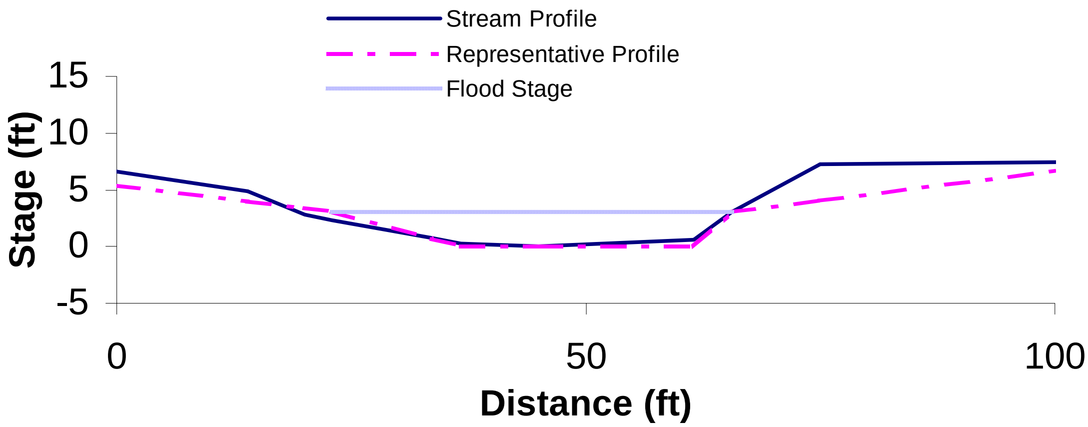

Figure 4.3 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with different values for resistance to flow (Manning's n) assigned to the flood plains and streambeds. The conveyance was calculated for each of the two flood plains and the main channel, then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth.

A key parameter used in the calculation of conveyance is the Manning's roughness coefficient, n. There are many ways to estimate this parameter for a section. The method first introduced by Cowan (1956) and adopted by the Soil Conservation Service (1963) was used to estimate Manning's n. This procedure involves a 6-step process of evaluating the properties of the reach, which is explained in more detail by Chow (1959). Field data describing the channel bed, bank stability, vegetation, obstructions, and other pertinent parameters were collected. Photographs were also taken of the sections while in the field. Once the field data were collected, they were used to estimate the Manning's roughness for the section observed. The pictures were compared to pictures contained in Chow (1959) for validation of the estimates of the Manning's n for each section.

The result of the field inspections of the reach sections was a set of characteristic slopes (channel sides and field plains), bed widths, heights to flood plain, and Manning's roughness coefficients. Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from Digital Elevation Models (DEMs) and a stream-flow network digitized from USGS 7.5-minute quadrangle maps (scale 1:24,000). These data were used to derive the Hydraulic Function Tables (F-tables) used by the HSPF model (Table 4.5). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and outflow (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. A maximum depth of 50 ft was used in the F-tables. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume of the flow in the reach, and is reported in acre-feet. The outflow is simply the stream discharge, in cubic feet per second.

Table 4.5 Example of an "F-table" calculated for the HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0.0	21.75	0.00	0.00
0.2	21.96	4.37	10.87
0.4	22.16	8.78	34.54
0.6	22.36	13.23	67.92
0.8	22.56	17.73	109.75
1.0	22.77	22.26	159.29
1.3	23.07	29.14	246.88
1.7	23.48	38.44	386.59
2.0	23.78	45.53	507.43
2.3	24.08	52.71	641.30
2.7	24.49	62.43	839.20
3.0	24.79	69.82	1,001.68
6.0	29.42	149.62	3,222.35
9.0	37.08	249.37	6,254.60
12.0	44.73	372.08	10,078.05
15.0	52.38	517.75	14,818.37
25.0	77.32	1,163.48	38,629.43
50.0	92.02	2,796.19	103,246.75

4.5 Selection of Representative Modeling Period

Selection of the modeling period was based on two factors: availability of data (discharge and water-quality), and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station #02055100 was available from January 1970 to September 2001. The modeling period was selected to include the VADEQ assessment period from July 1990 through June 2001 that led to the inclusion of the Carvin Creek, Laymantown Creek, Glade Creek, Lick Run, and Tinker Creek segments on the 1996, 1998, and 2002 Section 303 (d) lists. The fecal concentration data from this period were evaluated for use during calibration and validation of the model. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Using observed data that is reported at a shorter time-step improves this process and subsequently the performance of a time-dependent model. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration. During validation, no adjustments are made to model parameters. The goal of validation is to assess the capability of the model in hydrologic conditions other than those used during calibration.

High concentrations of fecal coliform were recorded in all flow regimes, and a period for calibration and validation was chosen based on the overall distribution of wet and dry seasons. The mean daily flow and precipitation for each season were calculated for the period January 1970 through September 2001. This resulted in 31 observations of flow and precipitation for the fall season and 32 observations for each of the other seasons. The mean and variance of these observations were calculated. Next, a representative period for modeling was chosen and compared to the historical data. The initial period was chosen based on the availability of mean discharge data closest to the period of available fecal coliform data (1/90-6/01). The representative period was chosen such that the mean and variance of each season in the modeled period was not significantly different from the historical data (Table 4.6). Therefore, the period was selected as representing the hydrologic regime of the study area, accounting for critical conditions associated with all potential sources within the watershed. The resulting period for hydrologic calibration was October 1993 through September 1998. For hydrologic validation, the period selected was October 1988 through September 1993.

Table 4.6 Comparison of modeled period to historical records.

	Mean Flow (cfs)				Precipitation (in/day)			
	Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**
				Historical Record (1971-2001)				
Mean	10.78	18.47	14.71	7.34	0.1015	0.1097	0.1237	0.1236
Variance	80.80	101.07	68.17	24.37	0.0017	0.0018	0.0013	0.0020
				Calibration & Validation Period (10/93 – 09/98, 10/88 – 09/93)				
Mean	9.70	24.12	14.93	7.95	0.0947	0.1068	0.1332	0.1225
Variance	54.77	170.16	31.17	23.32	0.0010	0.0017	0.0017	0.0030
				p-Values				
Mean	0.35	0.11	0.46	0.36	0.3009	0.4263	0.2674	0.4789
Variance	0.28	0.14	0.11	0.51	0.2478	0.5085	0.2701	0.1913

4.6 Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Qualities of fecal coliform sources were modeled as described in chapters 3 and 4. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

4.6.1 Hydrologic Calibration and Validation

Parameters that were adjusted during the hydrologic calibration represented the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the length of overland flow (LSUR), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), the amount of soil water contributing to interflow (INTFW), deep groundwater inflow fraction (DEEPER), baseflow PET (BASETP), forest coverage (FOREST), slope of overland flow plane (LSUR), groundwater recession flow (KVARY), maximum and minimum air temperature affecting PET (PETMAX, PETMIN, respectively), infiltration equation exponent (INFEXP), infiltration capacity ratio (INFILD), active groundwater storage PET (AGWETP), Manning's n for overland flow plane (NSUR), interception (RETSC), and the weighting factor for hydraulic routing (KS). Table 4.7 contains the typical range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions. Specific values for each calibrated parameter are given in the excerpt from the calibrated UCI in Appendix C.

The model was calibrated for hydrologic accuracy using daily flow data from USGS Stations #02055100, #02055000, and #02056000 for the period October 1993 through September 1998. Table 4.8 shows the hydrology calibration criteria and model performance for the flow gage at USGS Station #02055100, defined as the upper gage. Table 4.9 shows the hydrology calibration criteria and model performance for the area-weighted flow data from USGS Stations #02055000 and #02056000, defined as the lower gage. Graphical results of the hydrologic calibration are presented in Figures 4.4 through 4.11.

Results for the entire calibration period for the upper gage are plotted in Figure 4.4. Water year 1995 is represented in Figure 4.5 to portray the model performance for the upper gage on an annual scale and model accuracy for a single storm for the upper gage is plotted in Figure 4.6.

Results for the entire calibration period for the lower gage are plotted in Figure 4.8. Water year 1998 is represented in Figure 4.9 to portray the model performance for the lower gage on an annual scale, and model accuracy for a single storm for the lower gage is plotted in Figure 4.10.

Table 4.7 Model parameters utilized for hydrologic calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
FOREST	---	0.0 – 0.95	0.0	0.0
LZSN	in	2.0 – 15.0	1.5	2.0 – 3.0
INFILT	in/hr	0.001 – 0.50	0.01 – 0.354	0.006 – 0.296
LSUR	ft	100 – 700	1 – 1000	100 – 700
SLSUR	---	0.001 – 0.30	0.001 – 0.155	0.001 – 0.155
KVARY	1/in	0.0 – 5.0	0.0	0.05 – 0.12
AGWRC	1/day	0.85 – 0.999	0.97 – 0.98	0.989 – 0.994
PETMAX	deg F	32.0 – 48.0	40.0	40.0
PETMIN	deg F	30.0 – 40.0	35.0	35.0
INFEXP	---	1.0 – 3.0	2.0	2.0
INFILD	---	1.0 – 3.0	2.0	2.0
DEEPFR	---	0.0 – 0.50	0.1	0.0
BASETP	---	0.0 – 0.20	0.02	0.0315 – 0.0325
AGWETP	---	0.0 – 0.20	0.0	0.0
INTFW	---	1.0 – 10.0	0.75	1.0
IRC	1/day	0.30 – 0.85	0.5	0.3 – 0.85
MON-INT	in	0.01 - 0.40	0.1	0.01 – 0.4
MON-UZS	in	0.05 – 2.0	1.92 – 2.068	0.05 – 2.0
MON-LZE	---	0.1 – 0.9	0.2 – 0.65	0.1 – 0.9
MON-MAN		0.10 – 0.50	1.92 – 2.068	0.1 – 0.48
RETSC	in	0.0 – 1.0	0.1	0.1
KS	---	0.0 – 0.9	0.5	0.5

Table 4.8 Hydrology calibration criteria and model performance for upper gage period 10/1/93 through 9/30/98.

Criterion	Observed	Modeled	Percent Error
Total In-stream Flow	77.88	81.93	5.20
Upper 10% Flow Values (cfs)	32.49	33.76	3.91
Lower 50% Flow Values (cfs)	12.43	13.50	8.60
Winter Flow Volume (in)	39.88	39.54	-0.85
Spring Flow Volume (in)	17.21	20.06	16.54
Summer Flow Volume (in)	9.79	10.86	10.94
Fall Flow Volume (in)	11.00	11.47	4.28
Total Storm Volume (in)	65.11	70.26	7.90
Winter Storm Volume (in)	36.72	36.65	-0.20
Spring Storm Volume (in)	14.02	17.14	22.22
Summer Storm Volume (in)	6.59	7.92	20.22
Fall Storm Volume (in)	7.78	8.55	9.89

Table 4.9 Hydrology calibration criteria and model performance for lower gage period 10/1/93 through 9/30/98.

Criterion	Observed	Modeled	Percent Error
Total In-stream Flow	104.55	99.77	-4.56
Upper 10% Flow Values (cfs)	443.38	40.90	-5.72
Lower 50% Flow Values (cfs)	22.52	22.99	2.09
Winter Flow Volume (in)	44.96	41.17	-8.42
Spring Flow Volume (in)	24.19	24.53	1.37
Summer Flow Volume (in)	18.76	18.00	-4.03
Fall Flow Volume (in)	16.63	16.07	-3.37
Total Storm Volume (in)	74.56	68.29	-8.40
Winter Storm Volume (in)	37.54	33.39	-11.09
Spring Storm Volume (in)	16.70	16.67	-.22
Summer Storm Volume (in)	11.19	10.06	-10.04
Fall Storm Volume (in)	9.11	8.17	-10.31

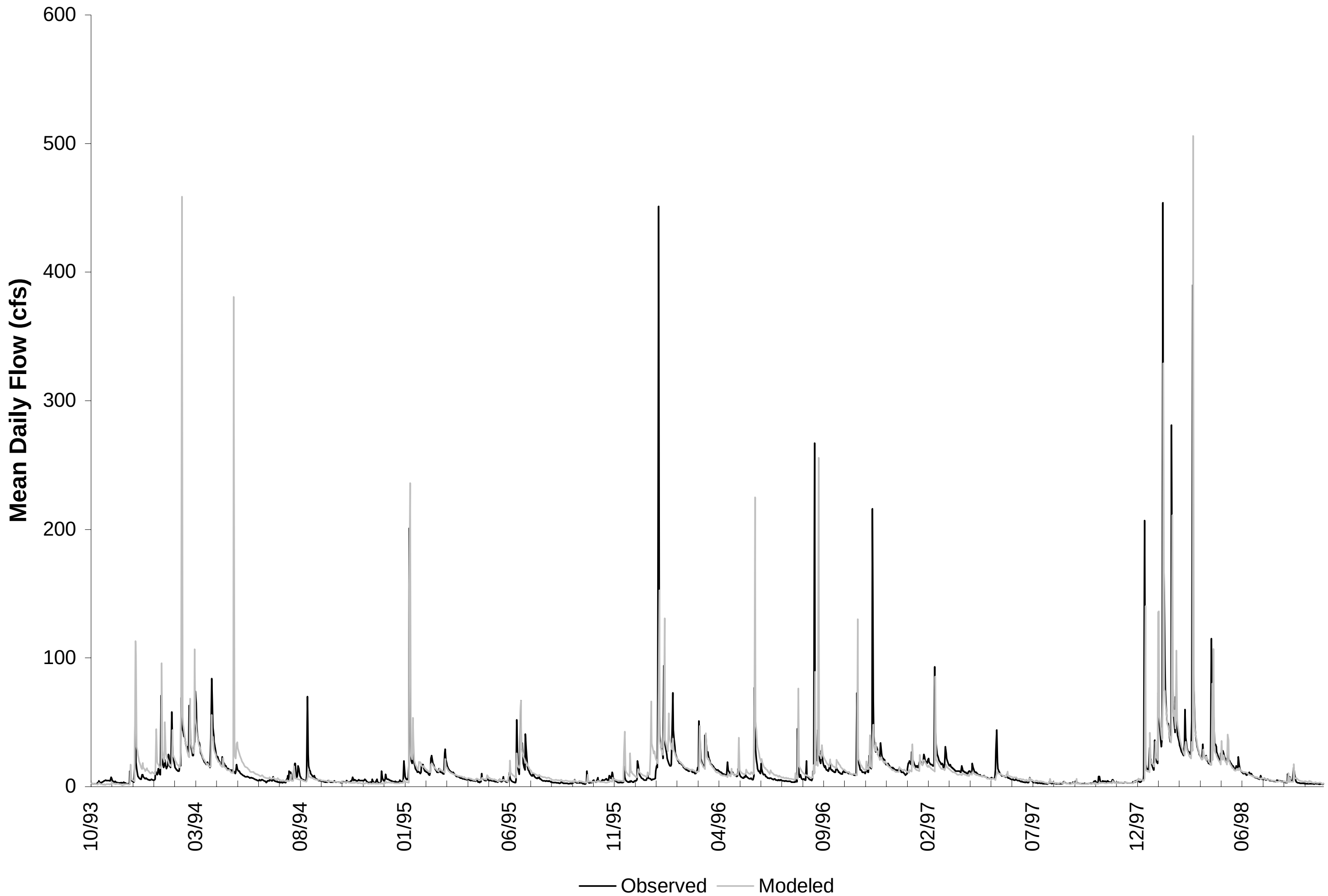

Figure 4.4 Calibration results for period 10/1/93 through 9/30/98 for upper gage.

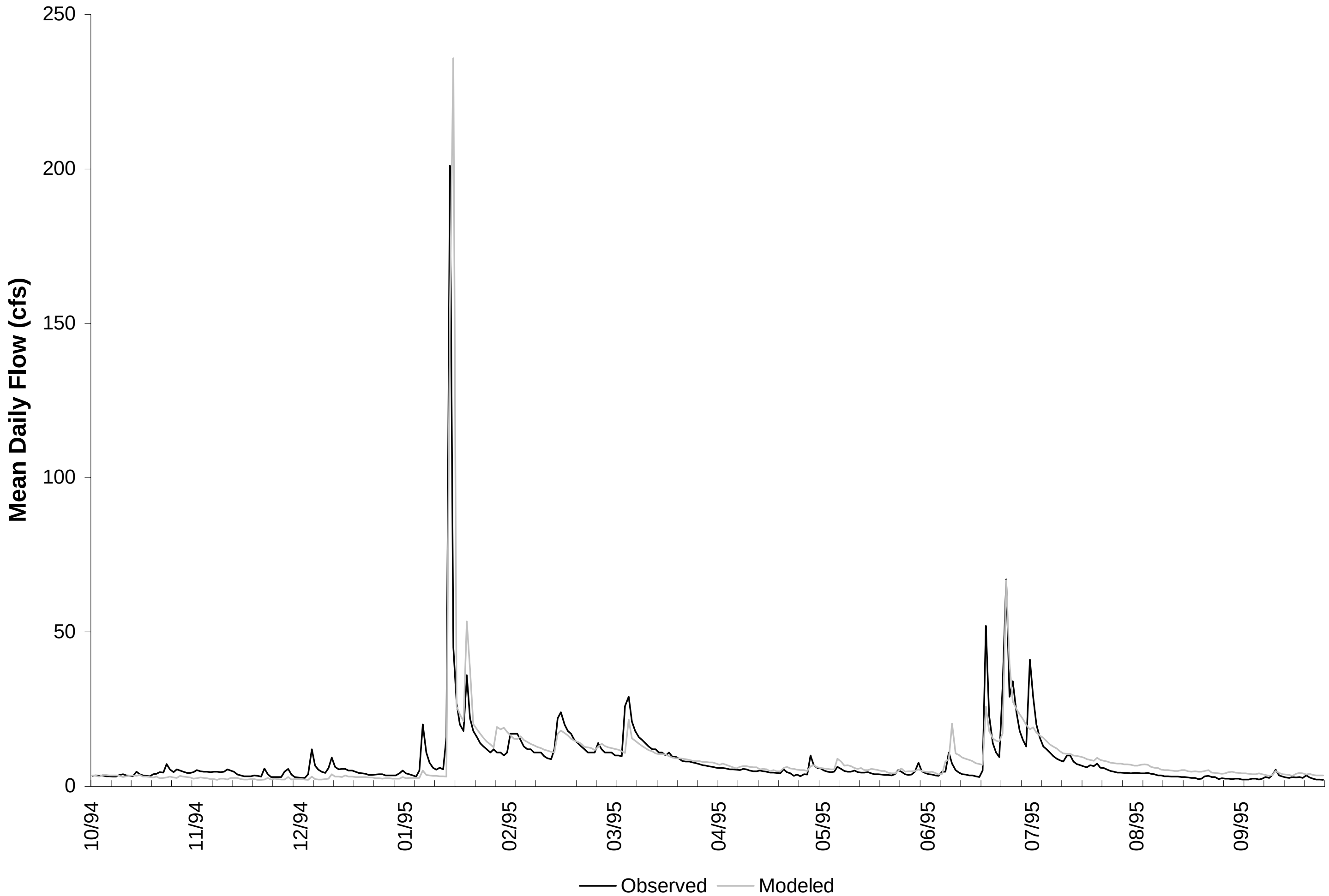

Figure 4.5 Calibration results for period 10/1/94 through 9/30/95 for upper gage.

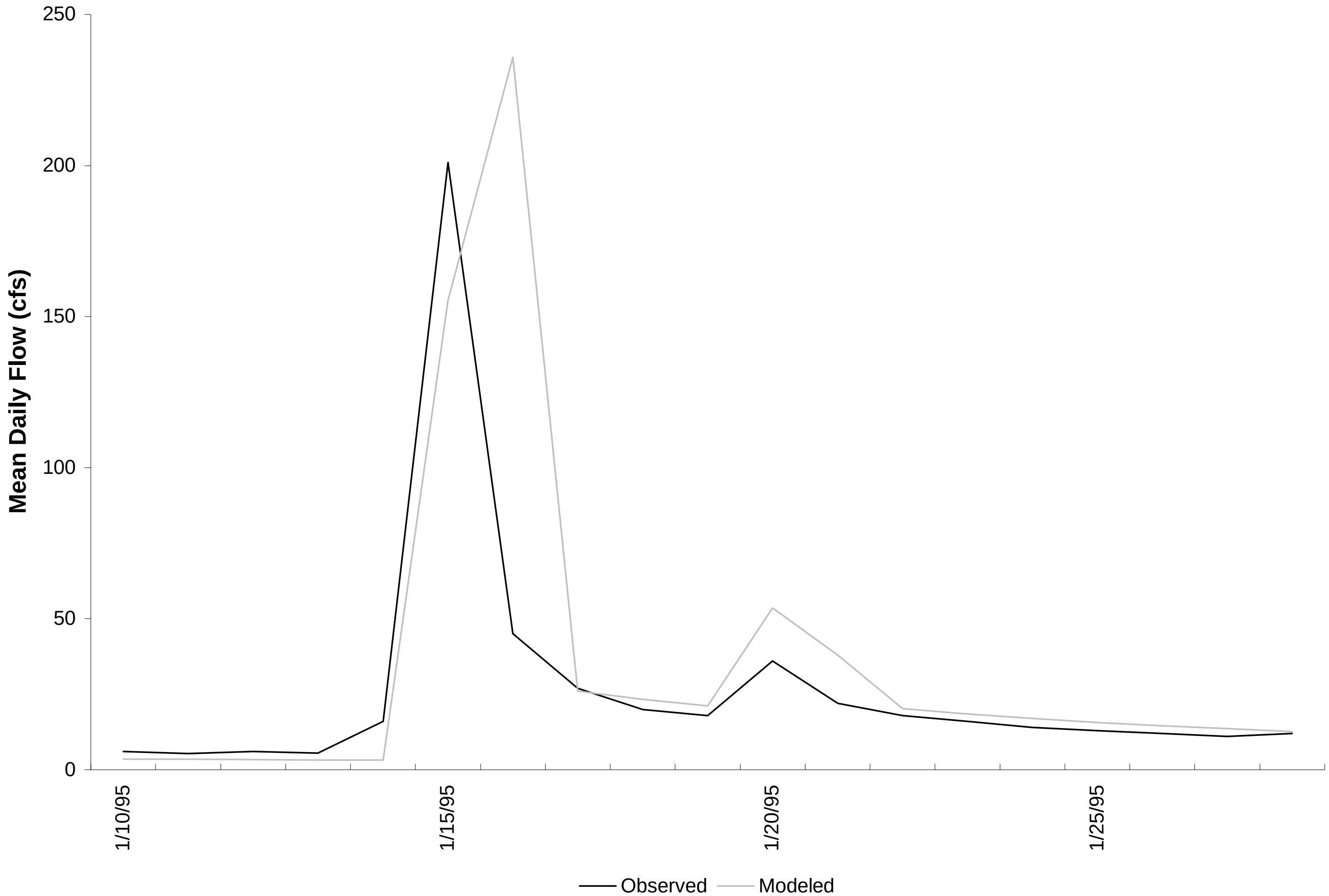

Figure 4.6 Calibration results for a single storm for upper gage.

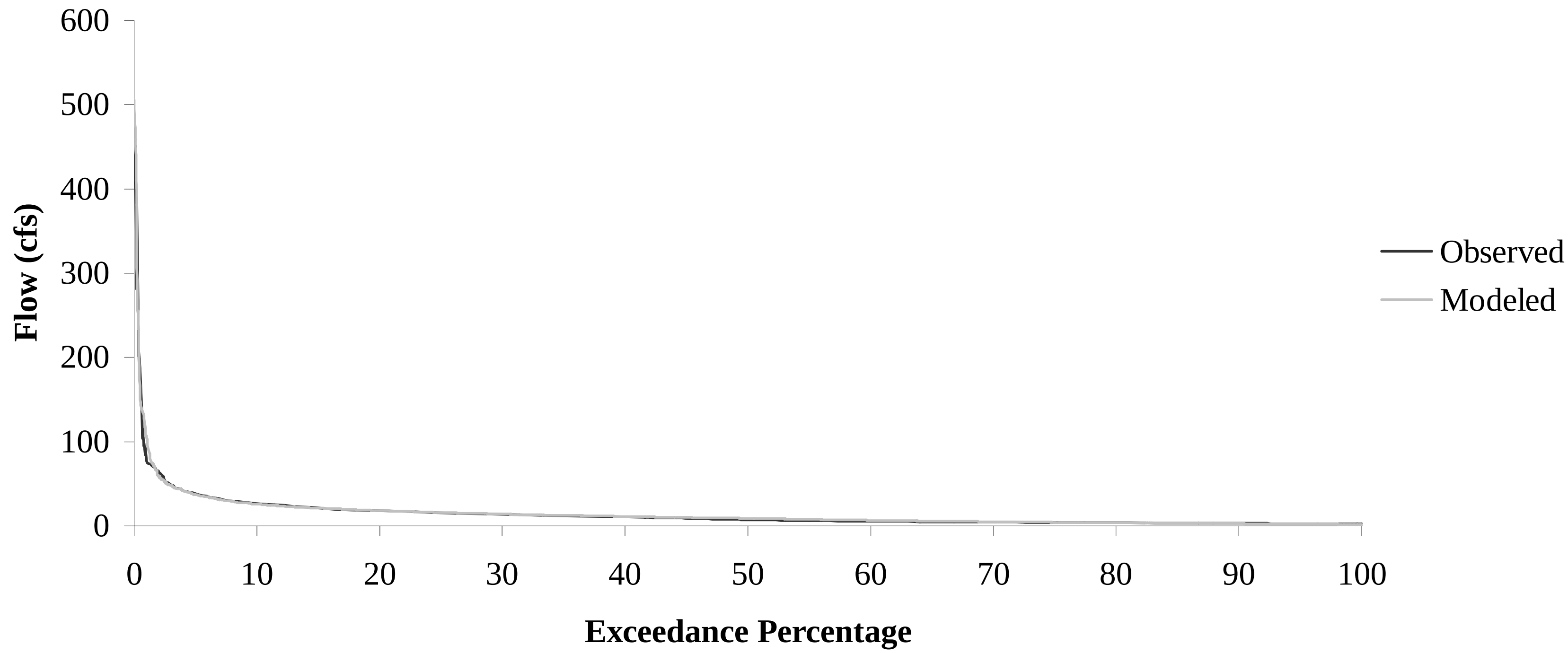

Figure 4.7 Tinker Creek upper gage flow duration for calibration period (10/01/1993 - 09/30/1998).

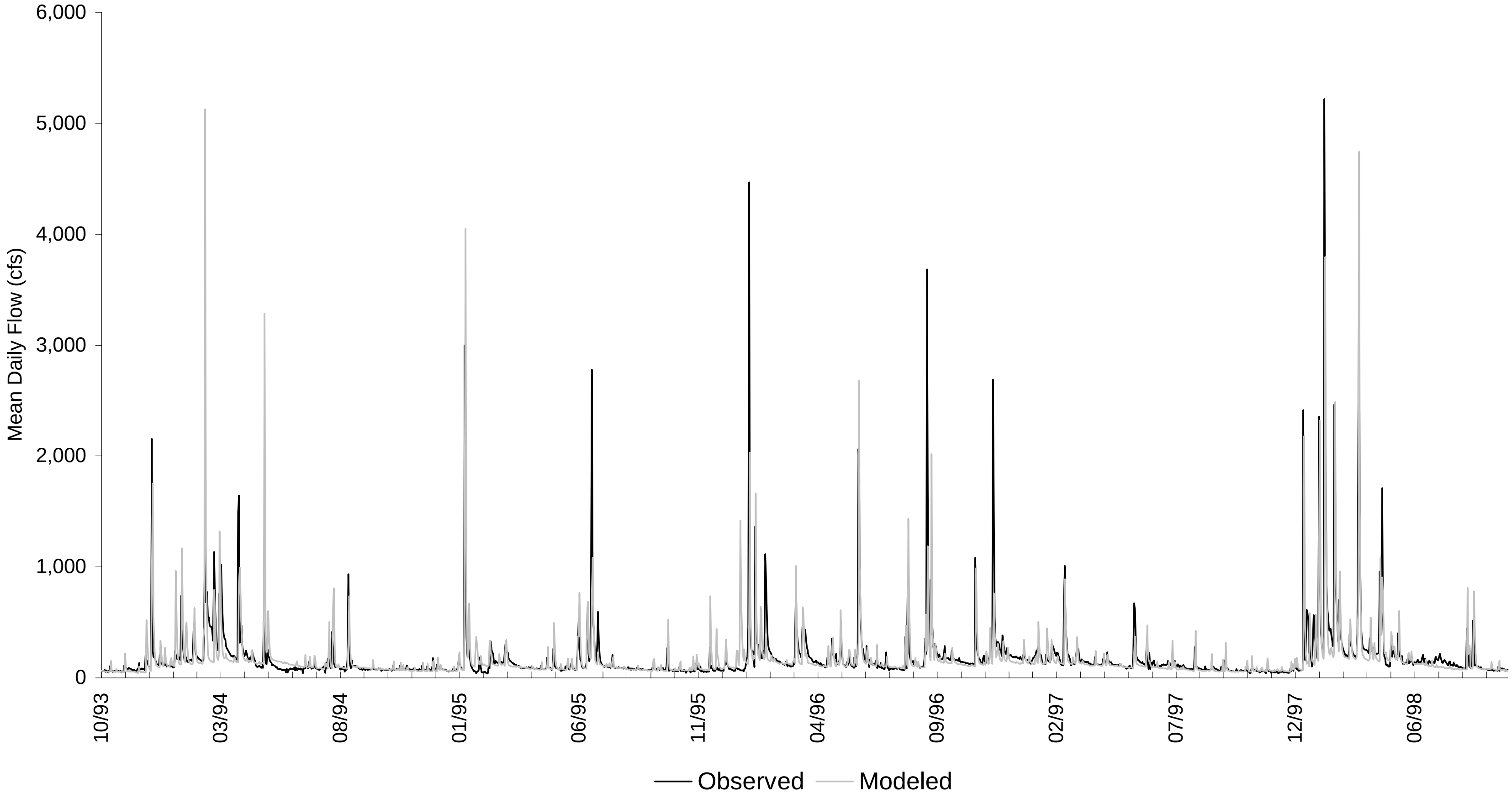

Figure 4.8 Calibration results for period 10/1/93 through 9/30/98 for lower gage.

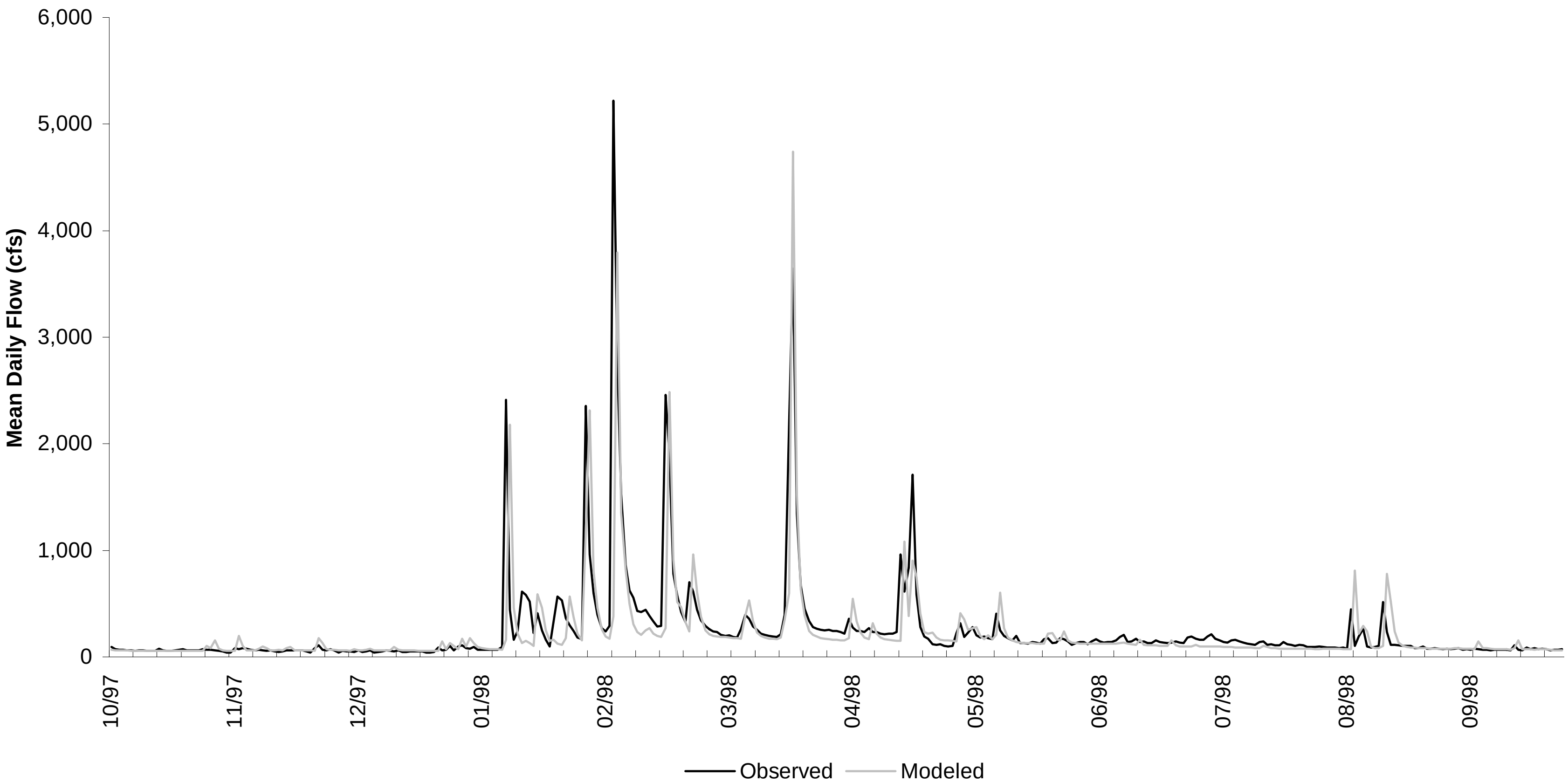

Figure 4.9 Calibration results for period 10/1/97 through 9/30/98 for lower gage.

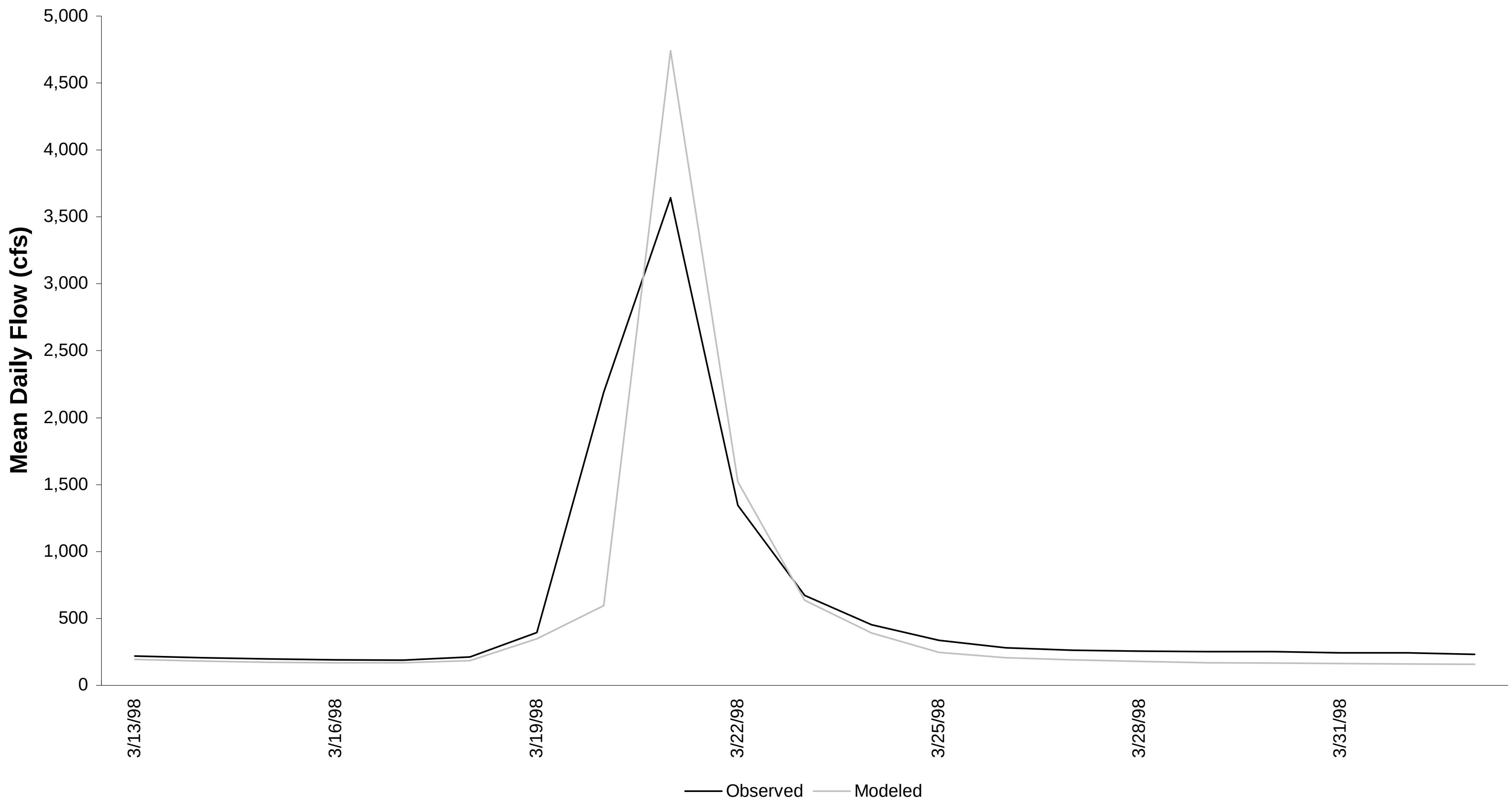

Figure 4.10 Calibration results for a single storm event for lower gage.

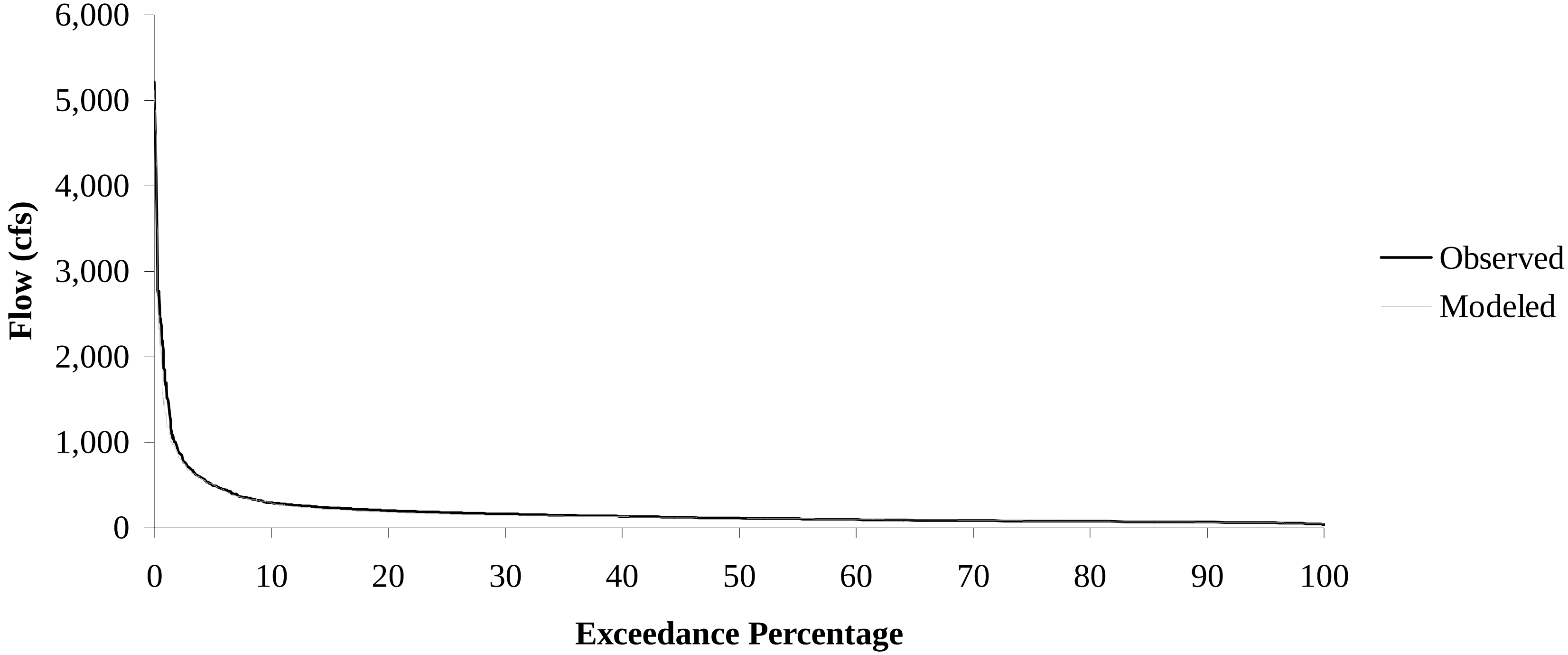

Figure 4.11 Tinker Creek lower gage flow duration for calibration period (10/01/1993 - 09/30/1998).

The model was validated for the period October 1988 through September 1993 (Tables 4.10 and 4.11). Graphical results of the hydrologic validation are presented in Figures 4.12 through 4.19. Results for the entire validation period for the upper gage are included in Figure 4.12. Water year 1990 is represented in Figure 4.13 to portray the model performance for the upper gage on an annual scale and validation results for a single storm for the upper gage is plotted in Figure 4.14.

Results for the entire validation period for the lower gage are included in Figure 4.16. Water year 1992 is represented in Figure 4.17 to portray the model performance for the lower gage on an annual scale and validation results for a single storm for the lower gage is plotted in Figure 4.18.

It was decided to use hourly precipitation during the validation period in order to make a comparable evaluation of the model response with respect to the model response during the hydrology calibration period. However, for some periods of record, only daily precipitation values were available. As a result, daily precipitation values for these periods were transformed to hourly values using a distribution developed from the available hourly precipitation data. For daily rainfall amounts less than 0.3 inches, the amount was assigned to the hour with the highest likelihood of rainfall, based on the historical hourly data. For daily rainfall amounts greater than or equal to 0.3 inches, the daily amount was distributed over the 24-hour period using a distribution developed from the available historical hourly data.

Table 4.10 Hydrology validation criteria and model performance for upper gage period 10/1/88 through 9/30/93.

Criterion	Observed	Modeled	Percent Error
Total In-stream Flow	86.18	77.24	-10.37
Upper 10% Flow Values (cfs)	33.62	28.88	-14.09
Lower 50% Flow Values (cfs)	15.03	14.15	-5.84
Winter Flow Volume (in)	29.31	26.16	-10.76
Spring Flow Volume (in)	26.00	24.34	-6.40
Summer Flow Volume (in)	13.48	10.86	-19.43
Fall Flow Volume (in)	17.39	15.82	-8.66
Total Storm Volume (in)	70.55	66.66	-5.52
Winter Storm Volume (in)	25.44	23.54	-7.47
Spring Storm Volume (in)	22.09	21.70	-1.80
Summer Storm Volume (in)	9.53	8.19	-14.06
Fall Storm Volume (in)	13.49	13.23	-1.89

Table 4.11 Hydrology validation criteria and model performance for lower gage period 10/1/88 through 9/30/93.

Criterion	Observed	Modeled	Percent Error
Total In-stream Flow	37.14	93.29	-3.96
Upper 10% Flow Values (cfs)	38.01	36.03	-5.19
Lower 50% Flow Values (cfs)	23.47	21.95	-6.47
Winter Flow Volume (in)	31.36	29.22	-6.82
Spring Flow Volume (in)	29.60	27.53	-7.02
Summer Flow Volume (in)	18.29	17.09	-6.57
Fall Flow Volume (in)	17.88	19.46	8.81
Total Storm Volume (in)	69.18	68.35	-1.21
Winter Storm Volume (in)	24.44	23.04	-5.72
Spring Storm Volume (in)	22.61	21.29	-5.85
Summer Storm Volume (in)	11.26	10.79	-4.24
Fall Storm Volume (in)	10.86	13.22	21.72

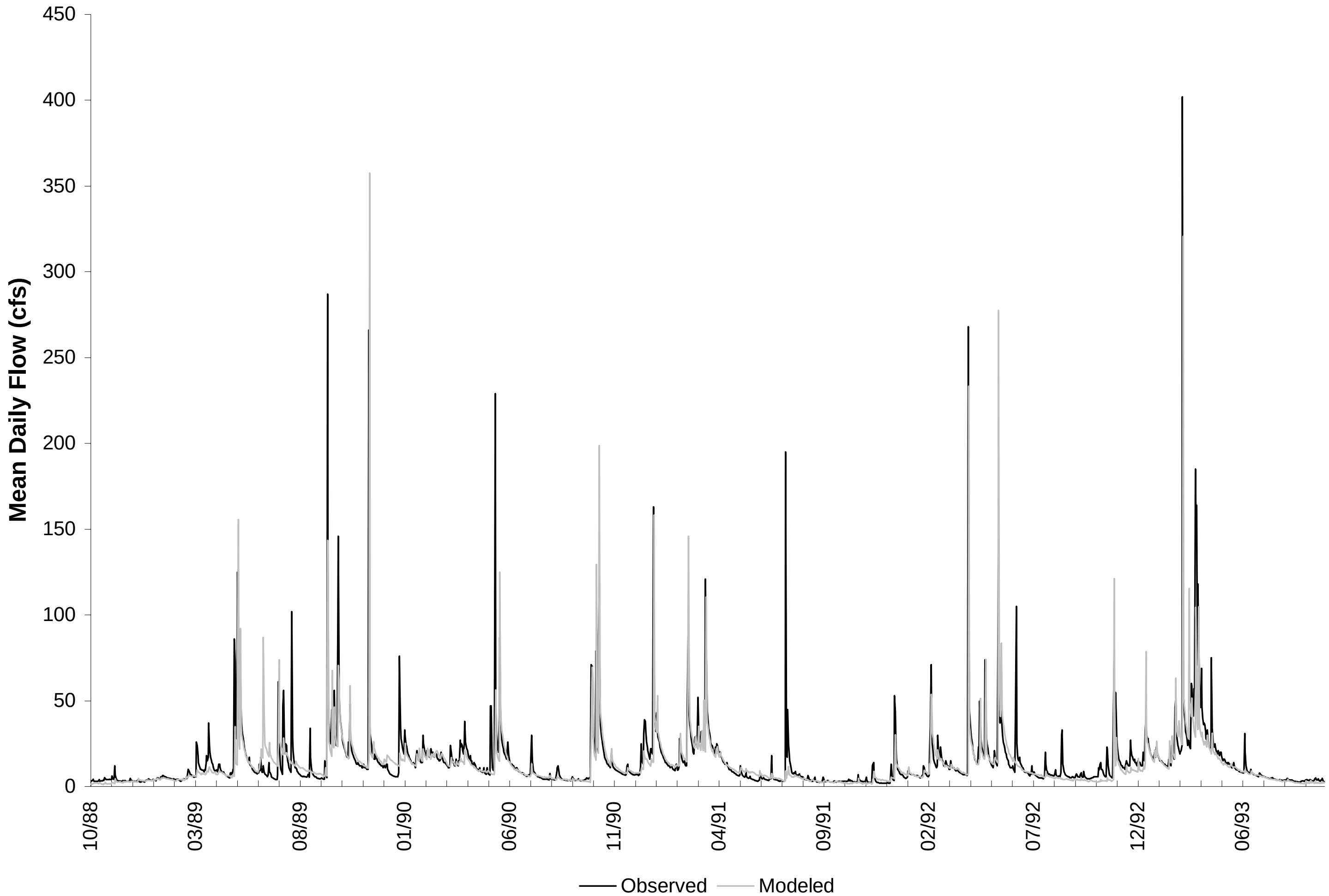

Figure 4.12 Validation results for period 10/1/88 through 9/30/93 for upper gage.

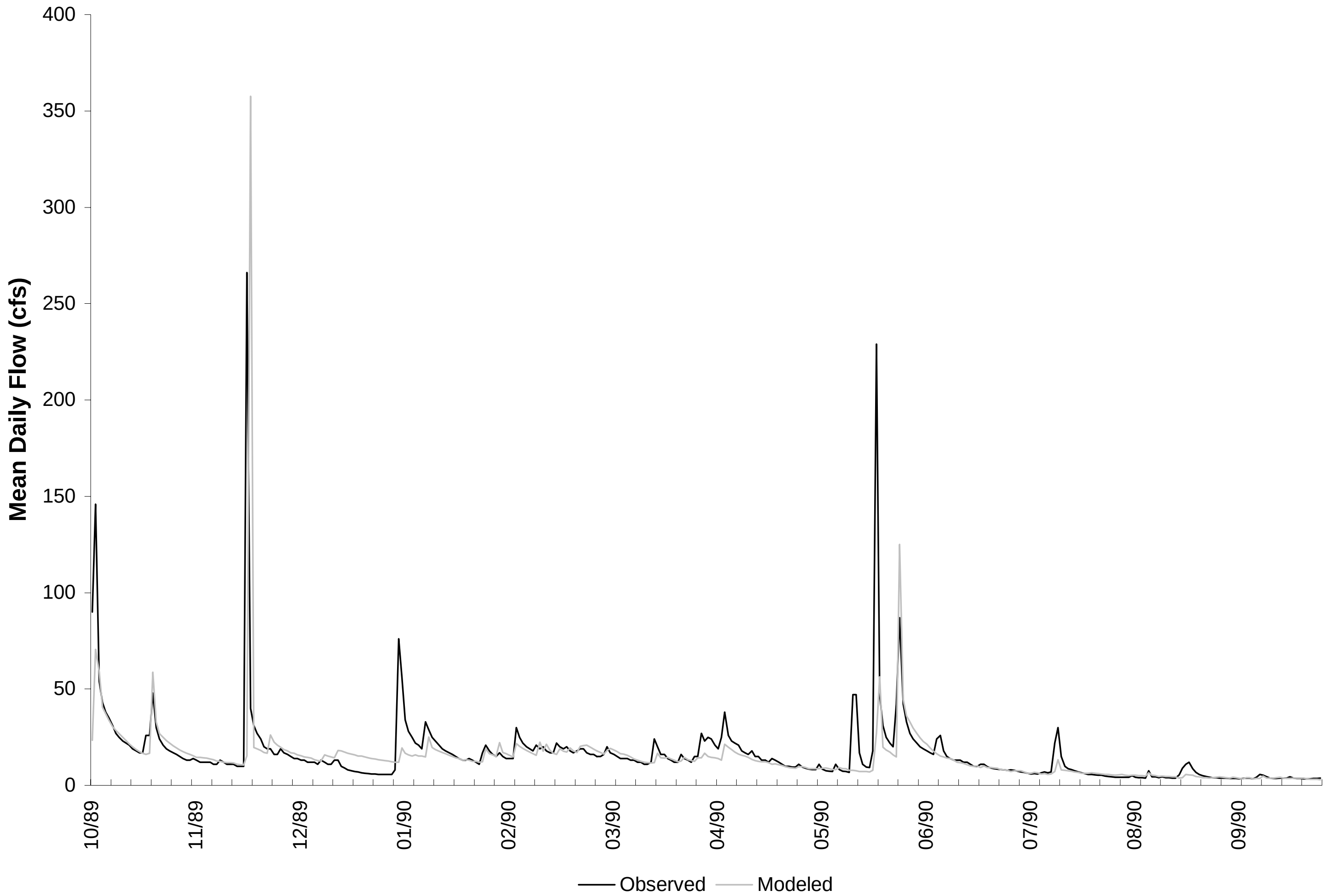

Figure 4.13 Validation results for period 10/1/89 through 9/30/90 for upper gage.

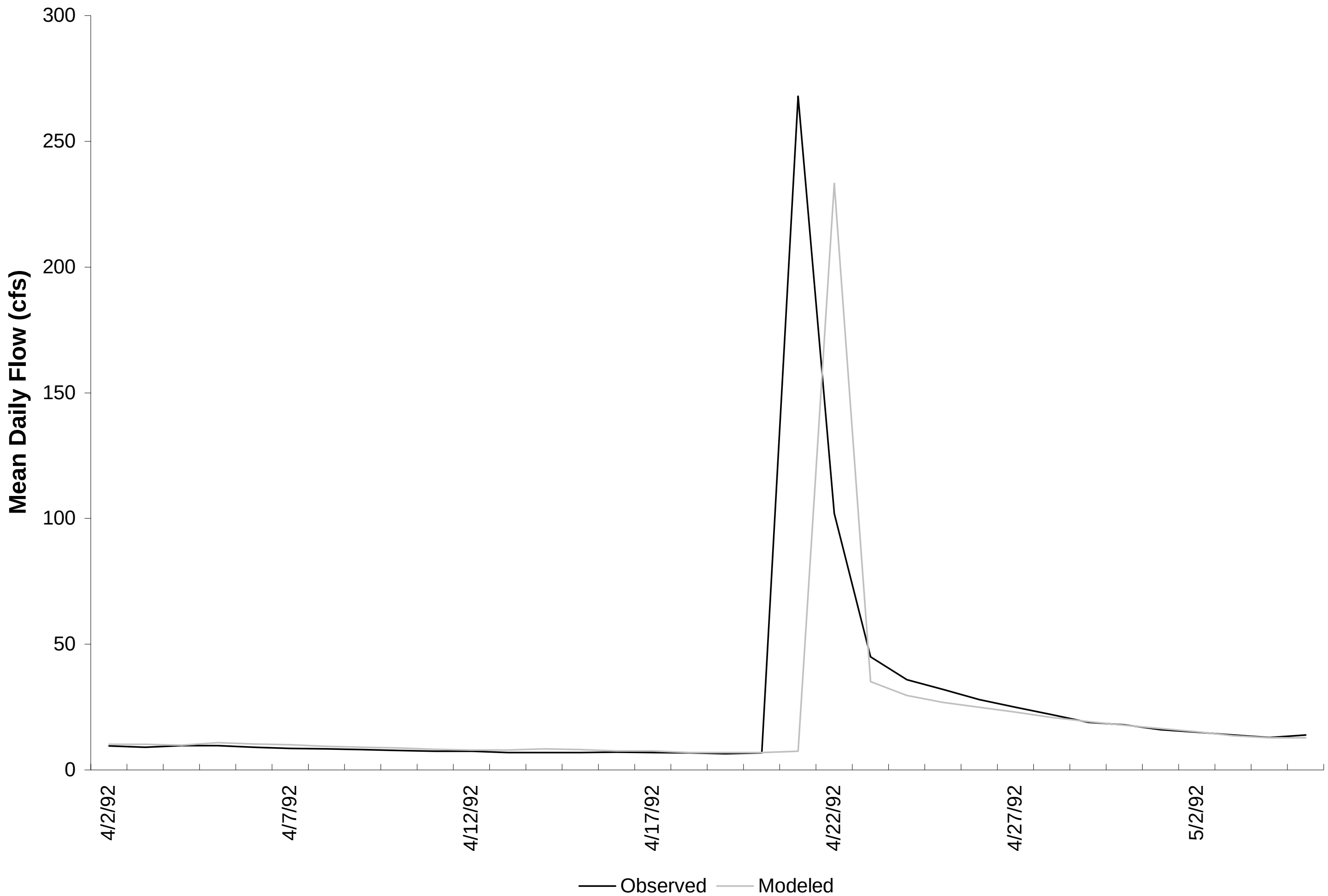

Figure 4.14 Validation results for a single storm for upper gage.

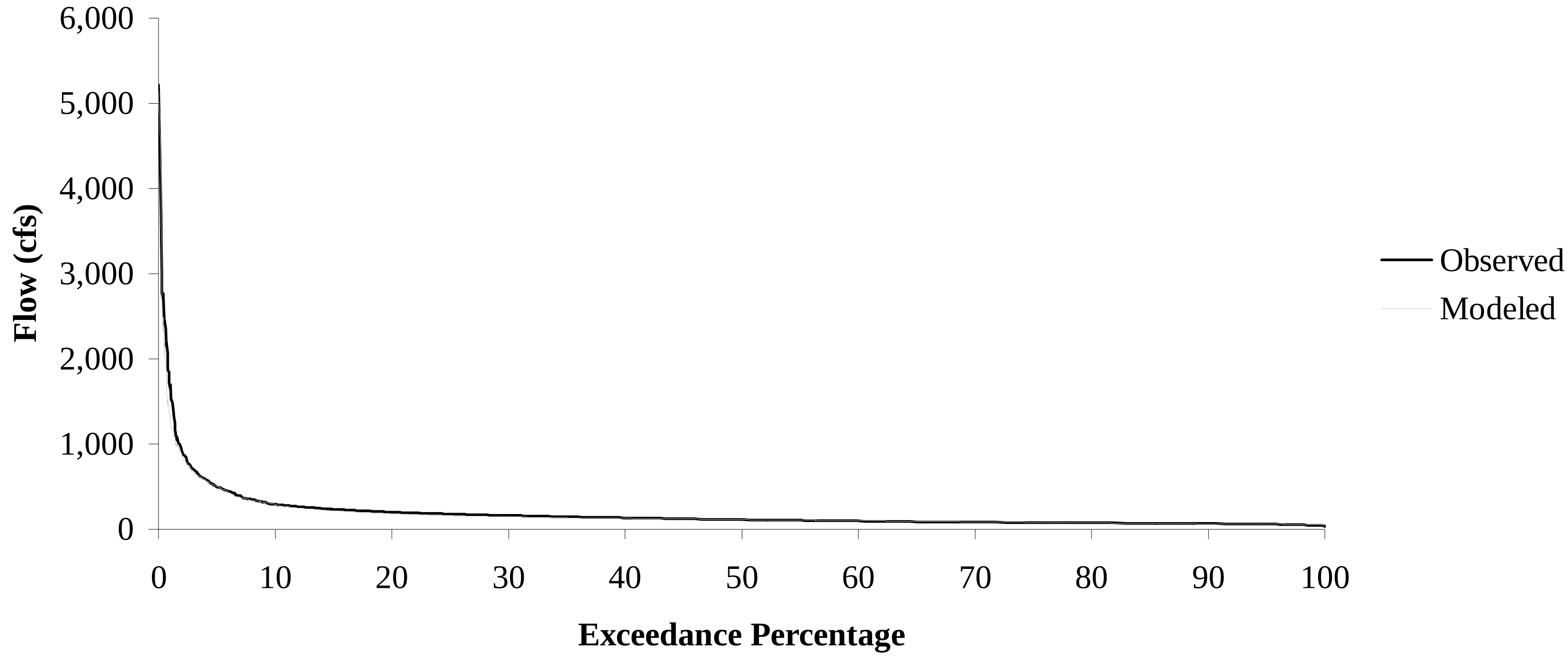

Figure 4.15 Tinker Creek upper end flow duration for validation period (10/01/1988 - 09/30/1993).

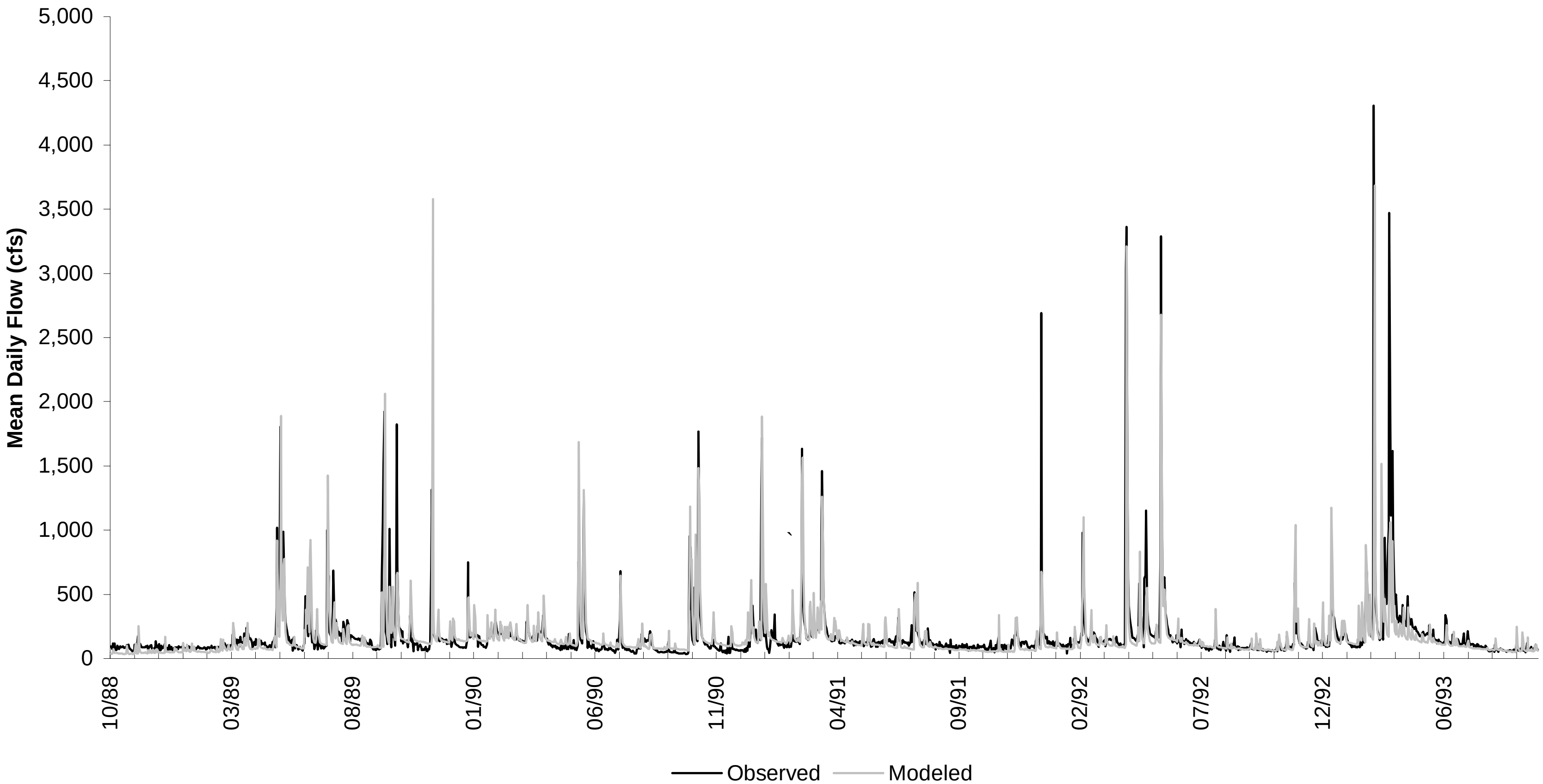

Figure 4.16 Validation results for period 10/1/88 through 9/30/93 for lower gage.

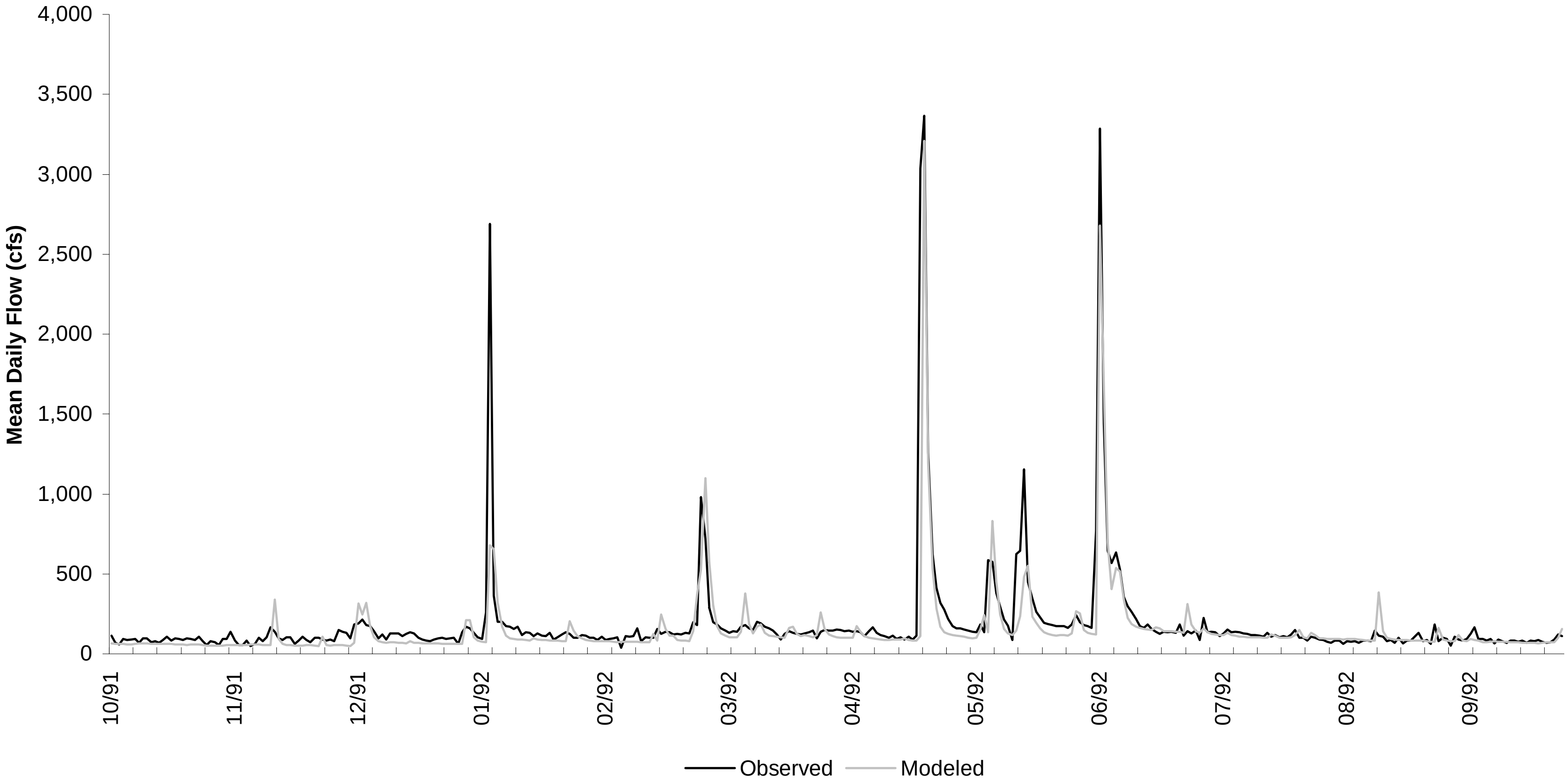

Figure 4.17 Validation results for period 10/1/91 through 9/30/92 for lower gage.

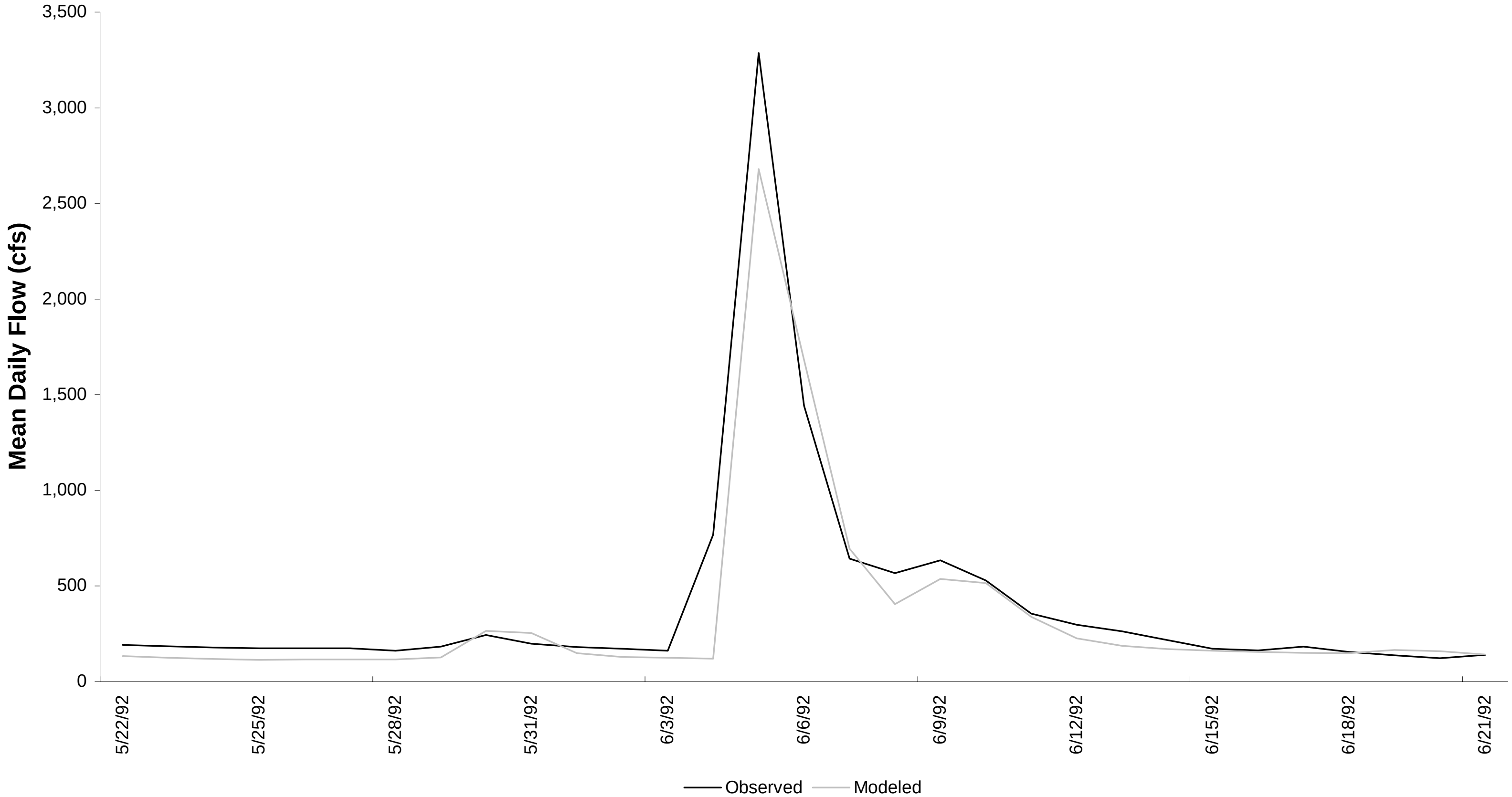

Figure 4.18 Validation results for a single storm for lower gage.

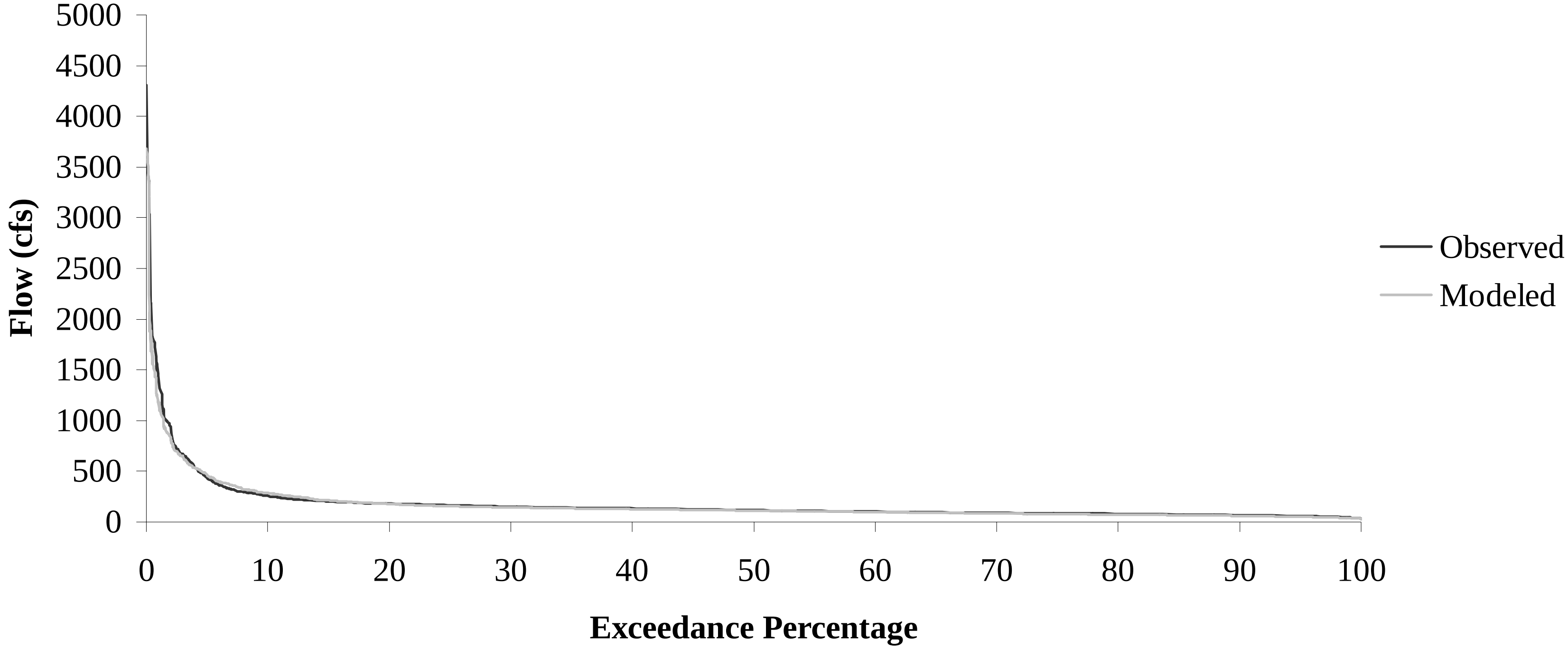

Figure 4.19 Tinker Creek lower end flow duration for validation period (10/01/1988 - 09/30/1993).

4.6.2 Water Quality Calibration and Validation

Water quality calibration is complicated by a number of factors, some of which are described here. First, water quality concentrations (*e.g.*, fecal coliform concentrations) are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters such as fecal coliform concentration. Second, the concentration of fecal coliform is particularly variable. Variability in location and timing of fecal deposition, variability in the density of fecal coliform bacteria in feces (among species and for an individual animal), environmental impacts on regrowth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling fecal coliform concentrations. Additionally, the limited amount of measured data for use in calibration and the practice of censoring both high (typically 8,000 or 16,000 cfu/100 ml) and low (under 100 cfu/100 ml) concentrations impede the calibration process.

One might expect the BST results could be used for direct calibration of the loads from the various contributing sources. This would be true if sufficient data over a sufficiently long period had been collected. For this study, only 12 data points were collected over the course of one year; therefore, it is not appropriate to use this data for calibration. However, the BST data was used to qualitatively validate

The water quality calibration was conducted from 10/1/92 through 9/30/97. Four parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), maximum accumulation on land (SQOLIM), rate of surface runoff that will remove 90% of stored fecal coliform per hour (WSQOP), and concentration of fecal coliform in interflow (IOQC). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled fecal coliform concentrations was established (Table 4.12). Specific values for each calibrated parameter are given in the excerpt from the calibrated UCI in Appendix C. Figures 4.20 - 4.25 show the results of calibration. Short-period fluctuations in the modeled data denotes the effective modeling of the variability within daily concentrations that was achieved through distributing direct depositions from wildlife, livestock, and uncontrolled discharges across each day (Section 4.3).

Table 4.12 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
MON-ACCUM	FC/ac*day	0.0E+00 – 1.0E+20	0.0E+00 – 2.2E+11	0.0E+00 – 2.2E+11
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0.0E+00 – 1.0E+12	0.0E+00 – 1.1E+13
WSQOP	in/hr	0.05 – 3.00	1.00	0.01- 3.0
IOQC	FC/ft^3	0.0E+00 – 1.0E+06	1.0E+03	1.0E+03
AOQC	FC/ft^3	0 – 10	0	0
DQAL	FC/100ml	0 – 1,000	200	200
FSTDEC	1/day	0.01 – 10.00	0. 50	0.01 – 10.00
THFST	---	1.0 – 2.0	1.07	1.07

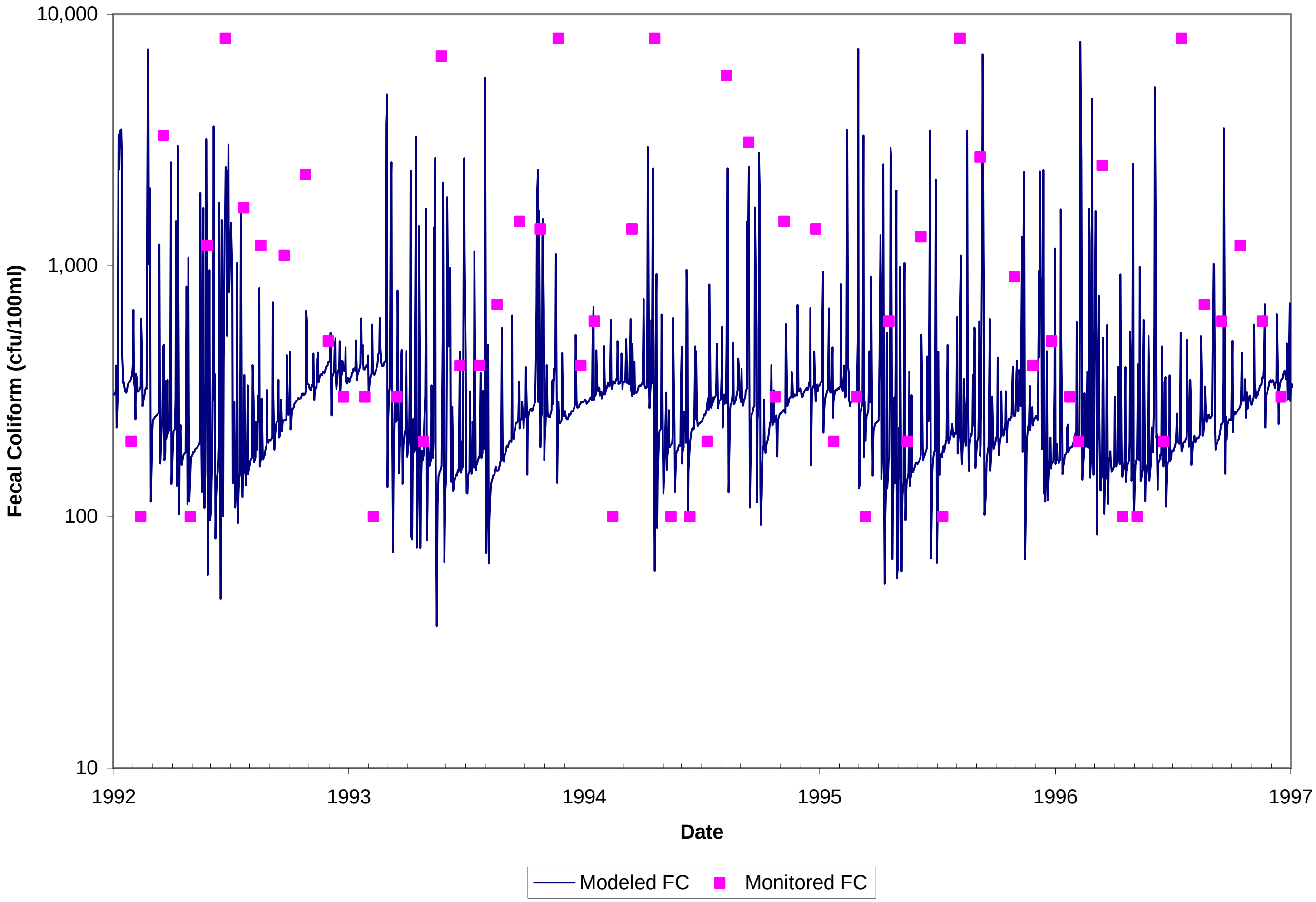

Figure 4.20 Simulated and Observed Fecal Coliform Concentration for Subwatershed 7 in Tinker Creek Calibration Scenario.

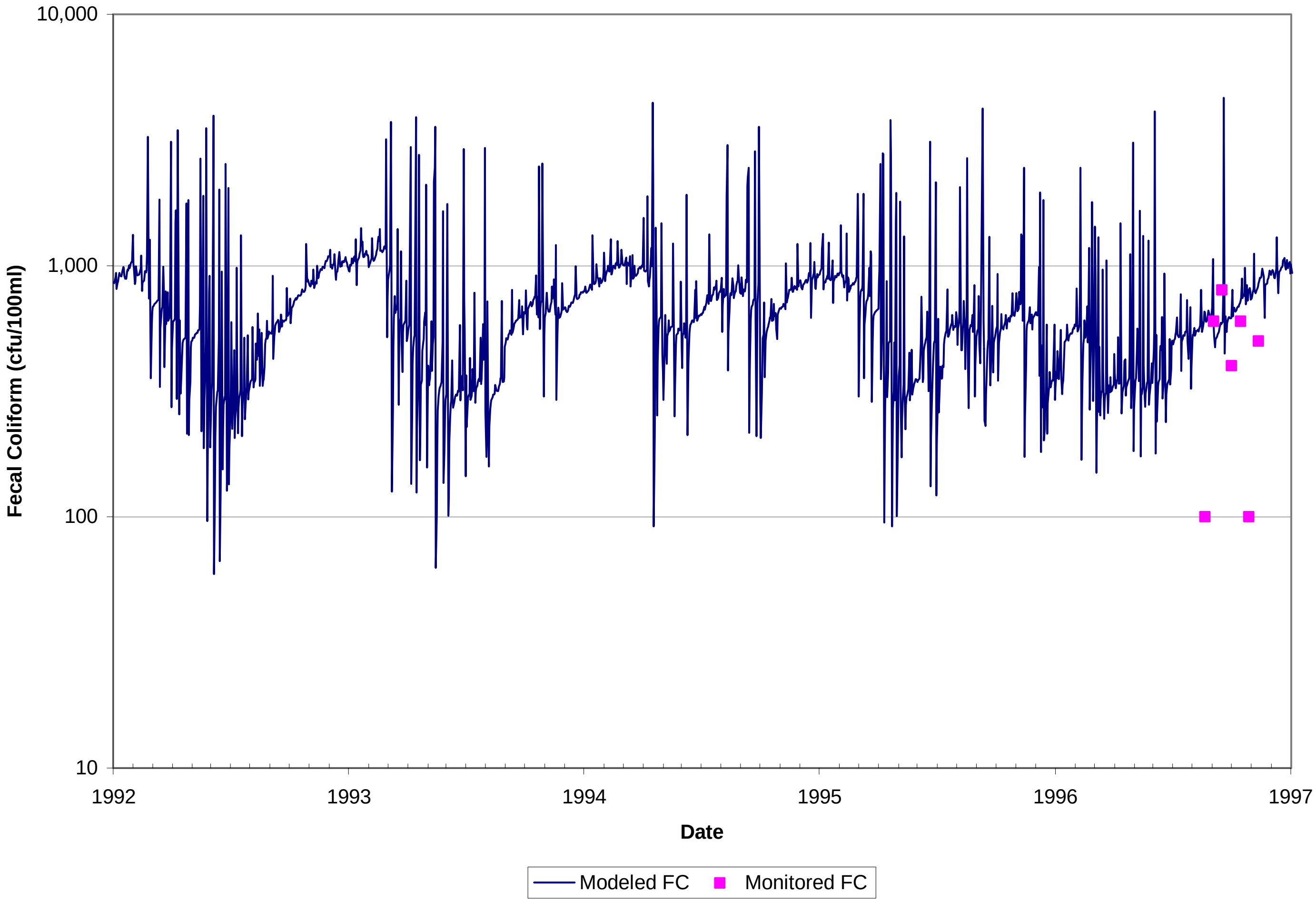

Figure 4.21 Simulated and Observed Fecal Coliform Concentration for Subwatershed 12 in Laymantown Creek Calibration Scenario.

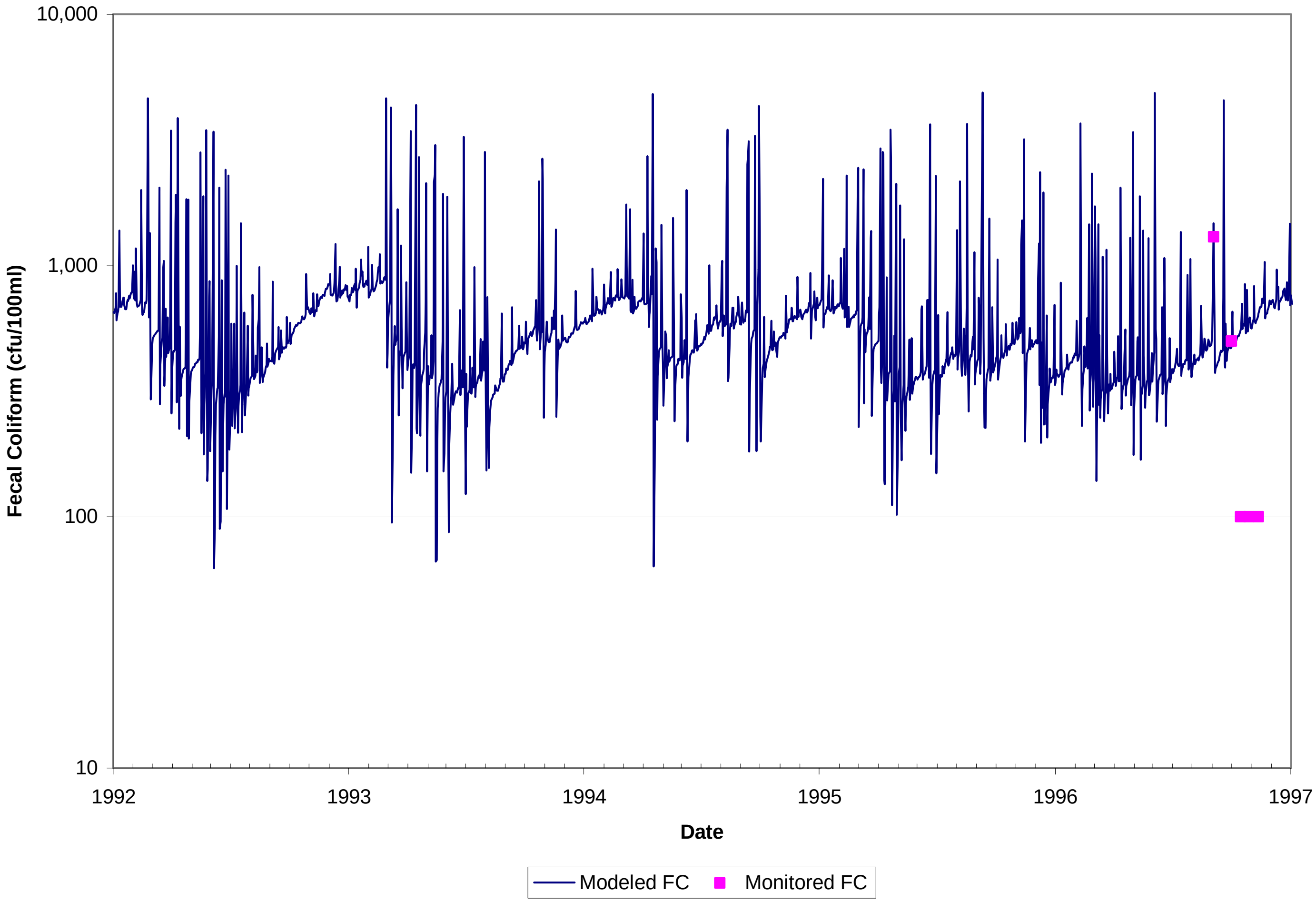

Figure 4.22 Simulated and Observed Fecal Coliform Concentration for Subwatershed 13 in Glade Creek Calibration Scenario.

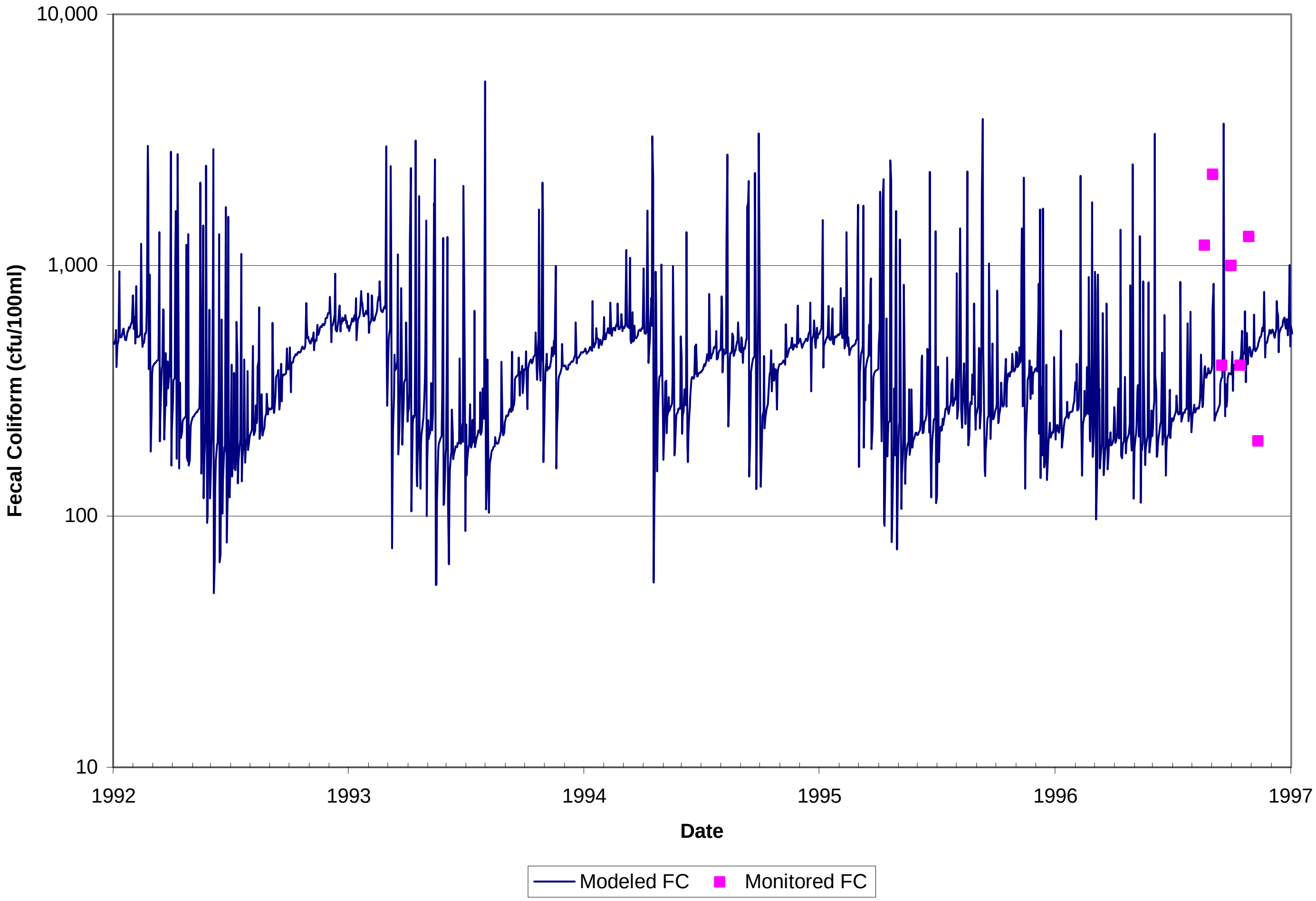

Figure 4.23 Simulated and Observed Fecal Coliform Concentration for Subwatershed 15 in Glade Creek Calibration Scenario.

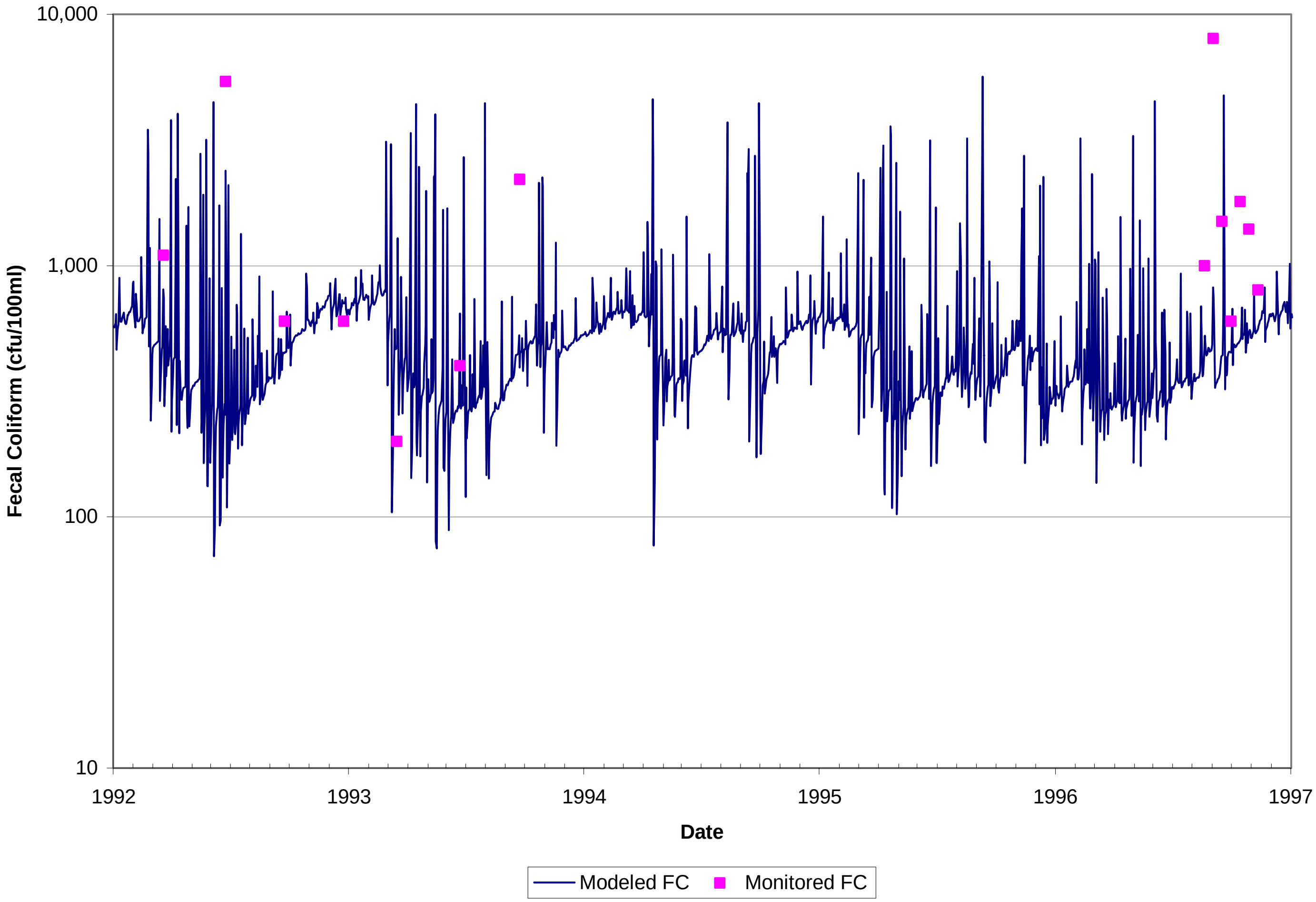

Figure 4.24 Simulated and Observed Fecal Coliform Concentration for Subwatershed 16 in Glade Creek Calibration Scenario.

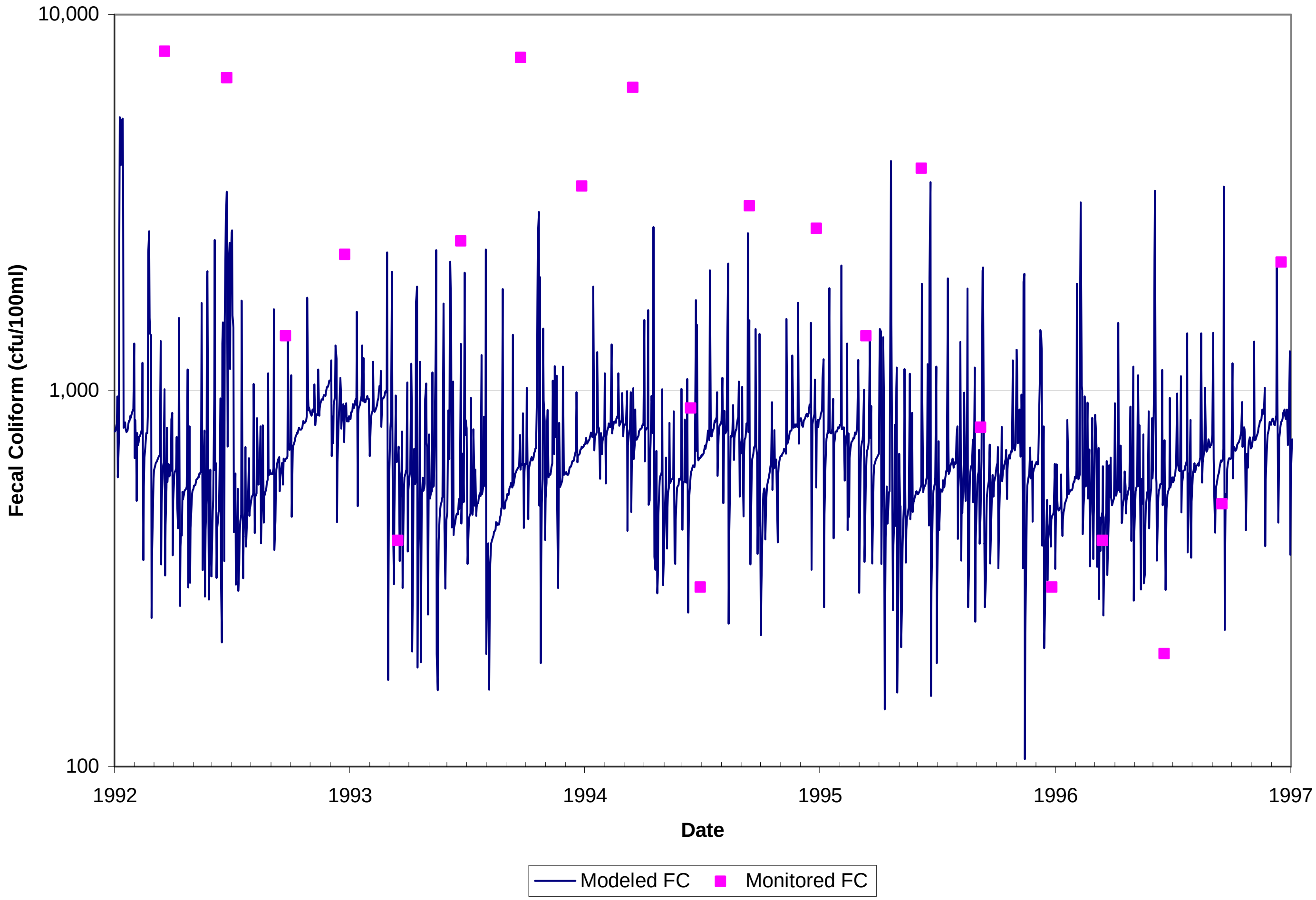

Figure 4.25 Simulated and Observed Fecal Coliform Concentration for Subwatershed 18 in Lick Run Calibration Scenario.

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. To provide a quantitative measure of the agreement between modeled and measured data while taking the inherent variability of fecal coliform concentrations into account, each observed value was compared with modeled concentrations in a 2-day window surrounding the observed data point. First, the minimum and maximum modeled values in each modeled window was determined. Figures 4.26 through 4.31 show the relationship between these extreme values and observed data. In addition, standard error in each observation window was calculated as follows:

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

where

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

This is a non-traditional use of standard error, applied here to offer a quantitative measure of model accuracy. In this context, standard error measures the variability of the sample mean of the modeled values about an instantaneous observed value. The use of limited instantaneous observed values to evaluate continuous data introduces error and, therefore, increases standard error. The mean of all standard errors for each station analyzed was calculated. Additionally, the maximum concentration values observed in the simulated data were compared with maximum values obtained from uncensored data (Section 2) and found to be at reasonable levels (Table 4.13).

In addition to these analyses, a comparison of the geometric mean of the modeled output for the calibration period and the geometric mean of the monitored data was performed (Table 4.14). In general, these numbers are fairly comparable. Some differences were expected due to factors such as model uncertainty, the limited amount of monitored data, and the fact that the monitored data is censored with regard to minimum and maximum values.

Table 4.13 Results of analyses on calibration runs.

WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)
4ATKR000.69	107	15,567
4ALAY000.37	33	23,157
4AGLA008.10	37	23,984
4AGLA004.39	49	14,762
4AGLA000.20	158	18,134
4ALCK000.38	200	20,332

Table 4.14 Comparison of Modeled and Observed Geometric Means.

		Modeled Existing Load Fecal Coliform				Monitored Fecal Coliform			
Reach ID	Station ID	*n*[1]	Geometric Mean (cfu/100ml)	Exceedances of Instantaneous Standard	Date Range	*n*[1]	Geometric Mean (cfu/100ml)	Exceedances of Instantaneous Standard	Date Range
7	4ARKR000.69	1,826	330.01	26%	10/92-9/97	150	581.23	52%	2/90-8/03
11	4ACRV000.28	1,826	321.71	24%	10/92-9/97	10	310.17	30%	11/02-8/03
12	4ALAY000.37	1,826	630.45	77%	10/92-9/97	14	372.52	50%	5/97-8/03
13	4AGLA008.10	1,826	530.55	71%	10/92-9/97	15	305.69	40%	5/97-1/03
15	4AGLA004.39	1,826	400.00	50%	10/92-9/97	17	609.66	53%	2/90-8/03
16	4AGLA000.20	1,826	538.06	66%	10/92-9/97	41	559.91	56%	2/90-8/03
18	4ALCK000.38	1,826	735.25	93%	10/92-9/97	73	992.69	68%	2/90-8/03

[1]Number of Observations

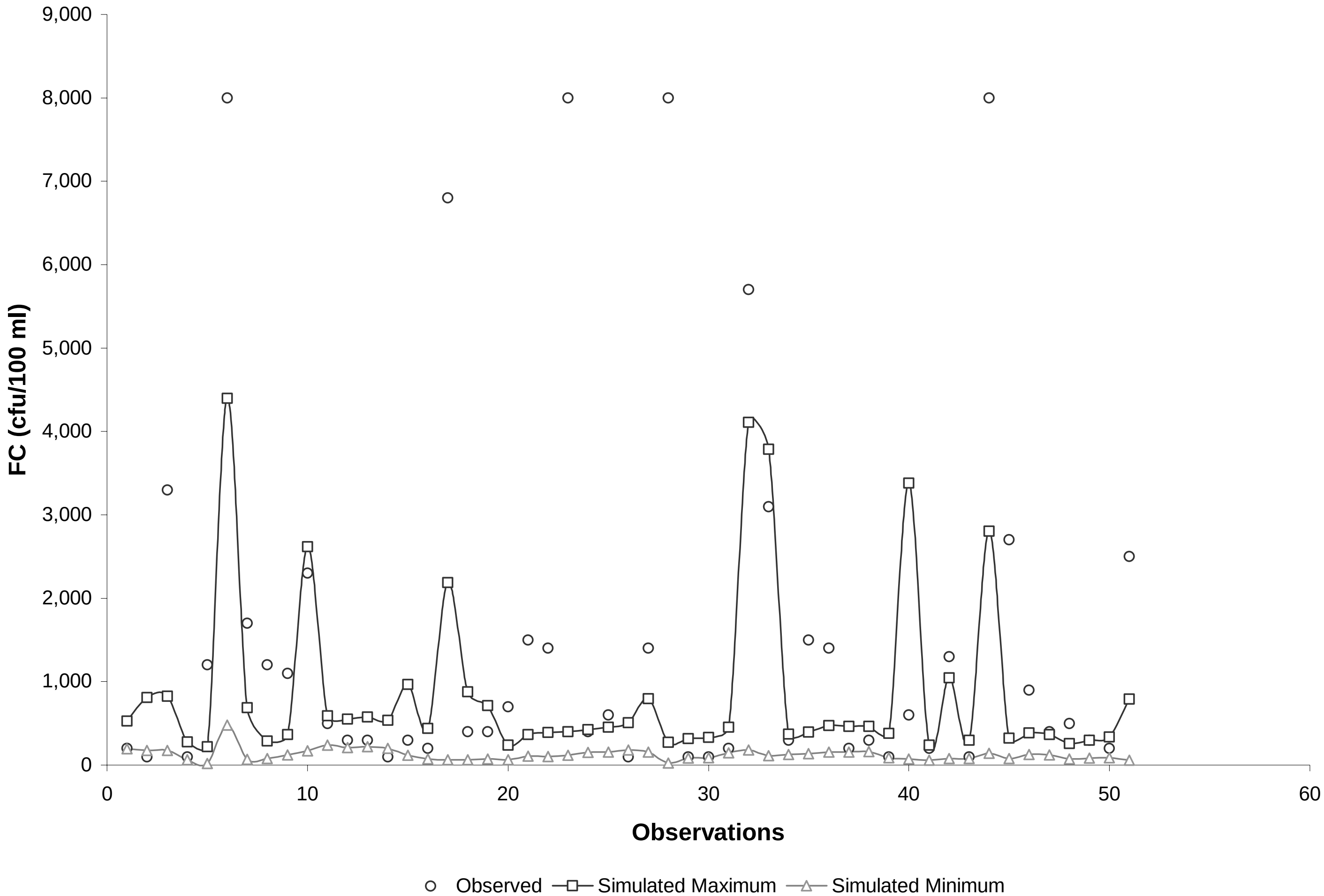

Figure 4.26 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 7 in Tinker Creek impairment.

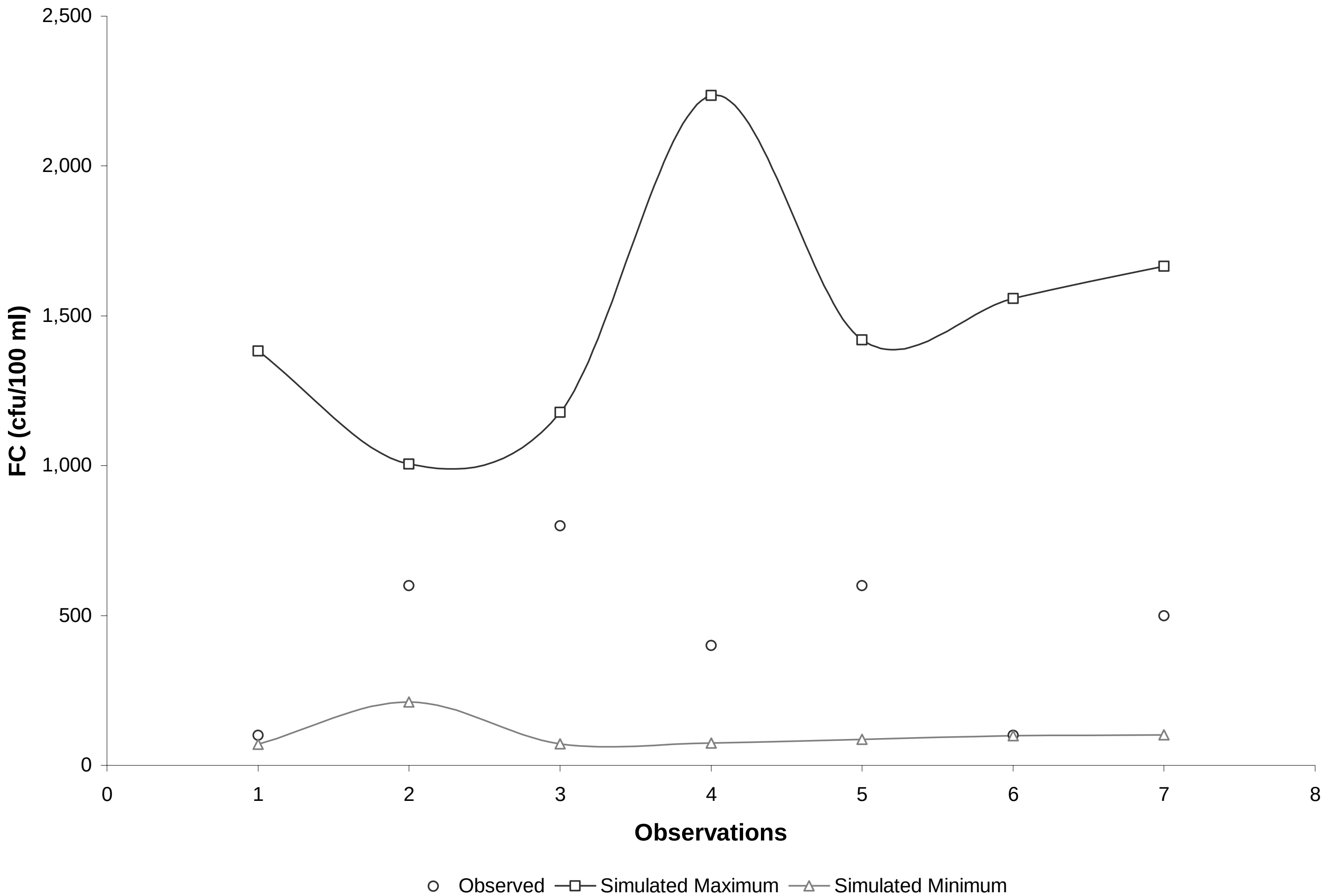

Figure 4.27 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 12 in Laymantown Creek impairment.

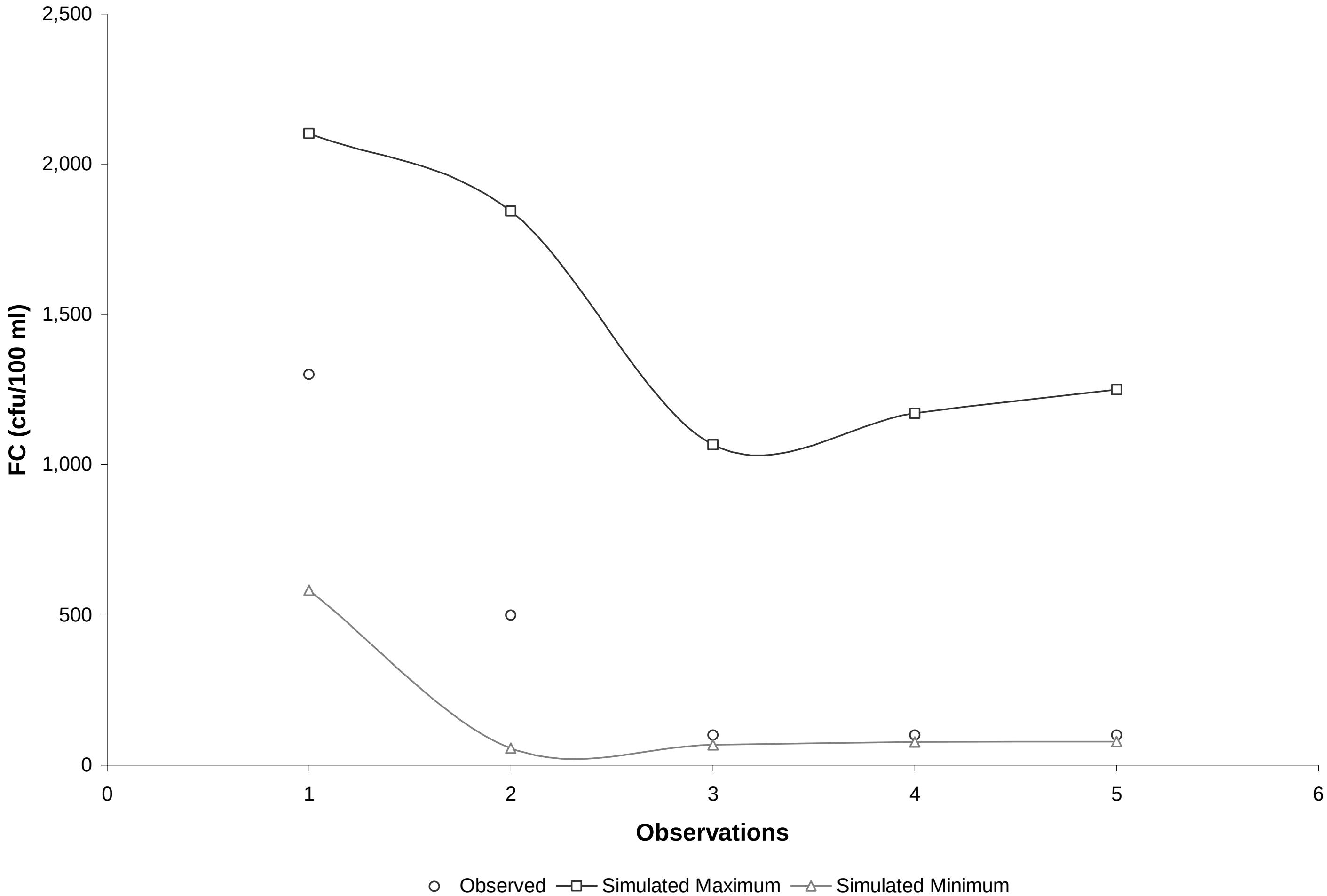

Figure 4.28 **Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 13 in Glade Creek impairment.**

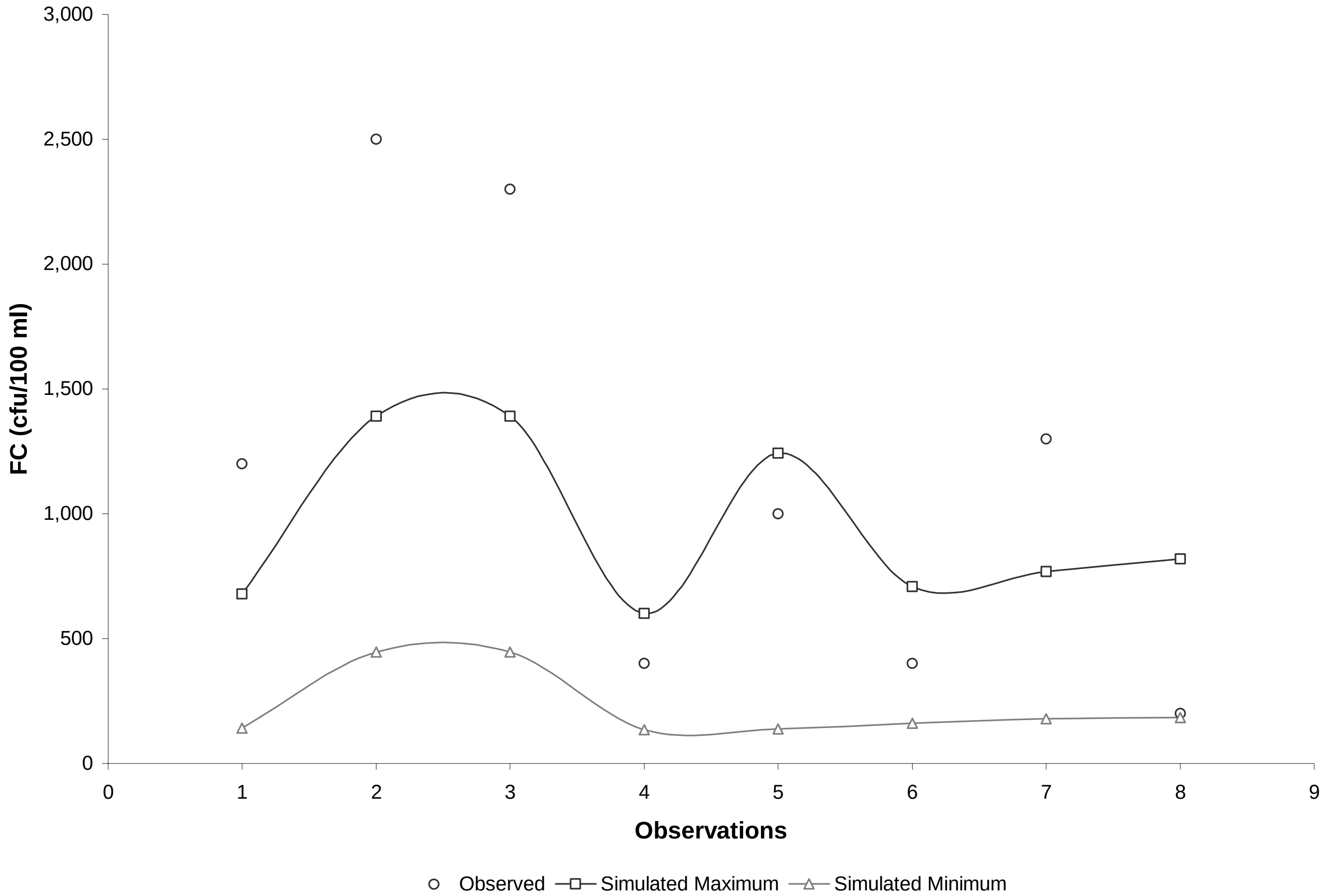

Figure 4.29 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 15 in Glade Creek impairment.

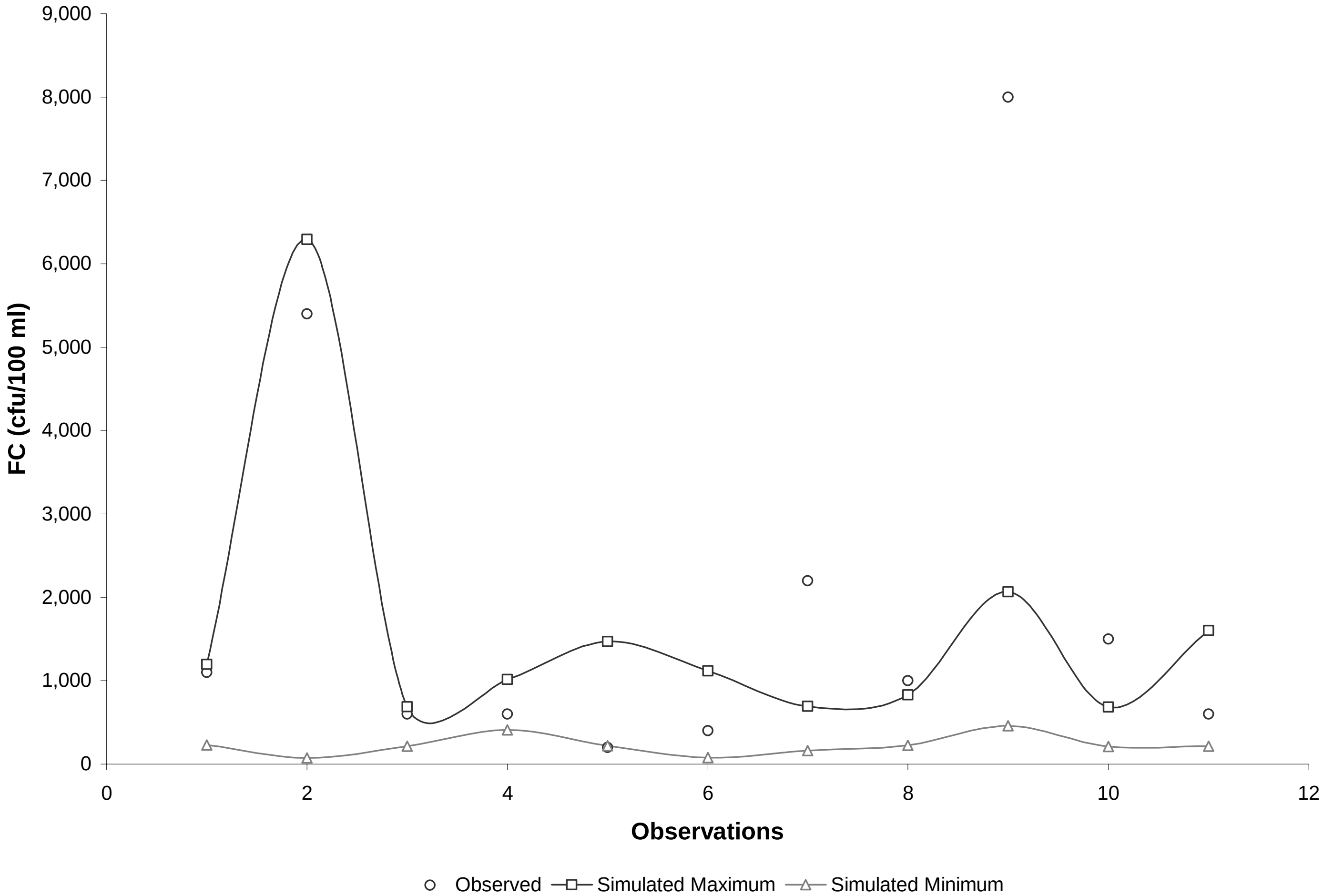

Figure 4.30 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 16 in Glade Creek impairment.

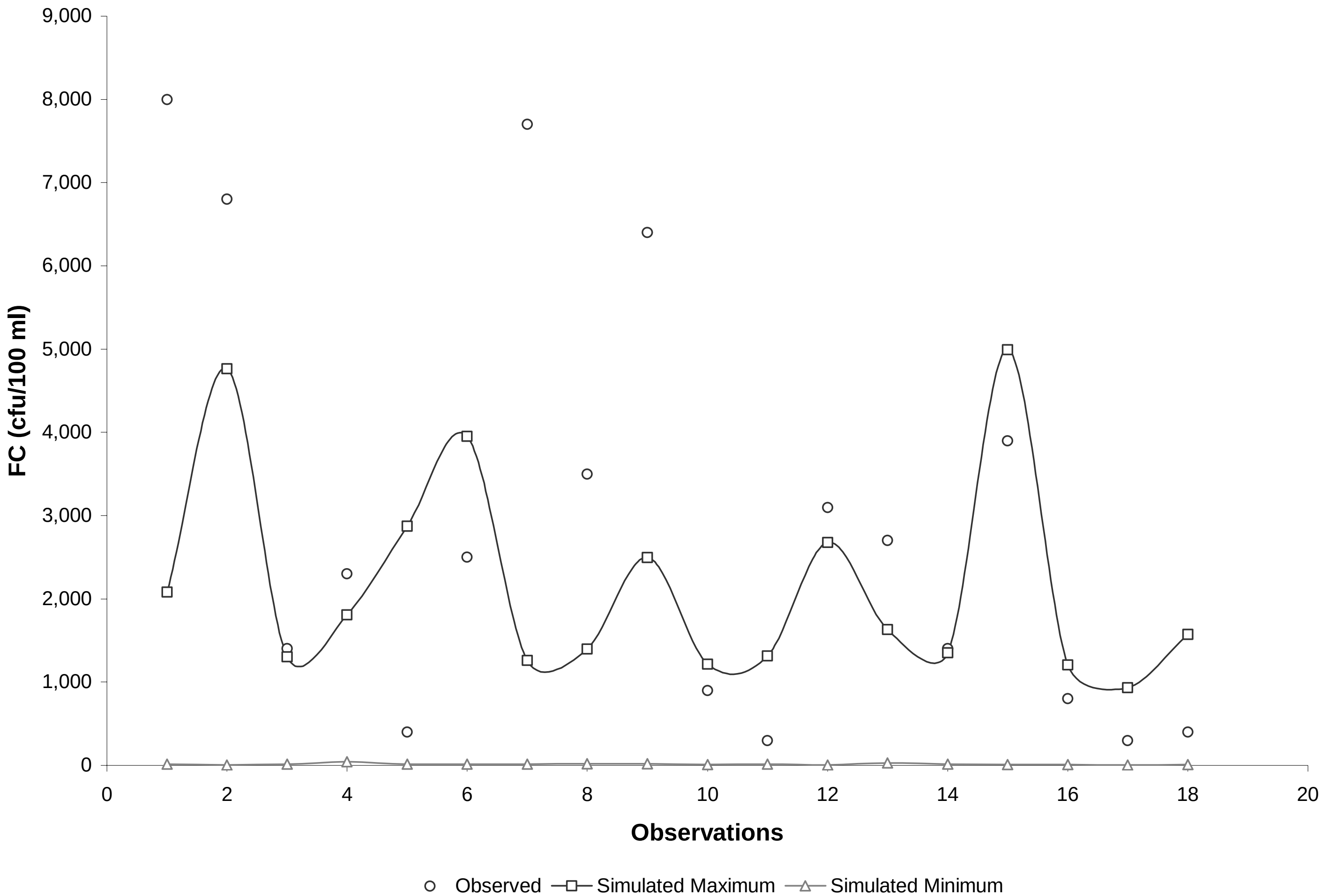

Figure 4.31 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 18 in Lick Run impairment.

The water quality validation was conducted for the time period from 10/1/97 to 9/30/01. The relationship between observed values and modeled values is shown in Figures 4.32 through 4.39. The results of standard error and maximum value analyses are reported in Table 4.15. Standard errors calculated from validation runs were comparable to standard errors calculated from calibration runs. Maximum simulated values were comparable to observed maximum values in the area (Section 2).

Table 4.15 Results of analyses on validation runs.

WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)
4ATKR000.69	83	13,876
4ALAY000.37	35	23,254
4AGLA008.10	38	24,062
4AGLA004.39	46	14,944
4AGLA000.20	114	18,151
4ALCK000.38	86	26,519

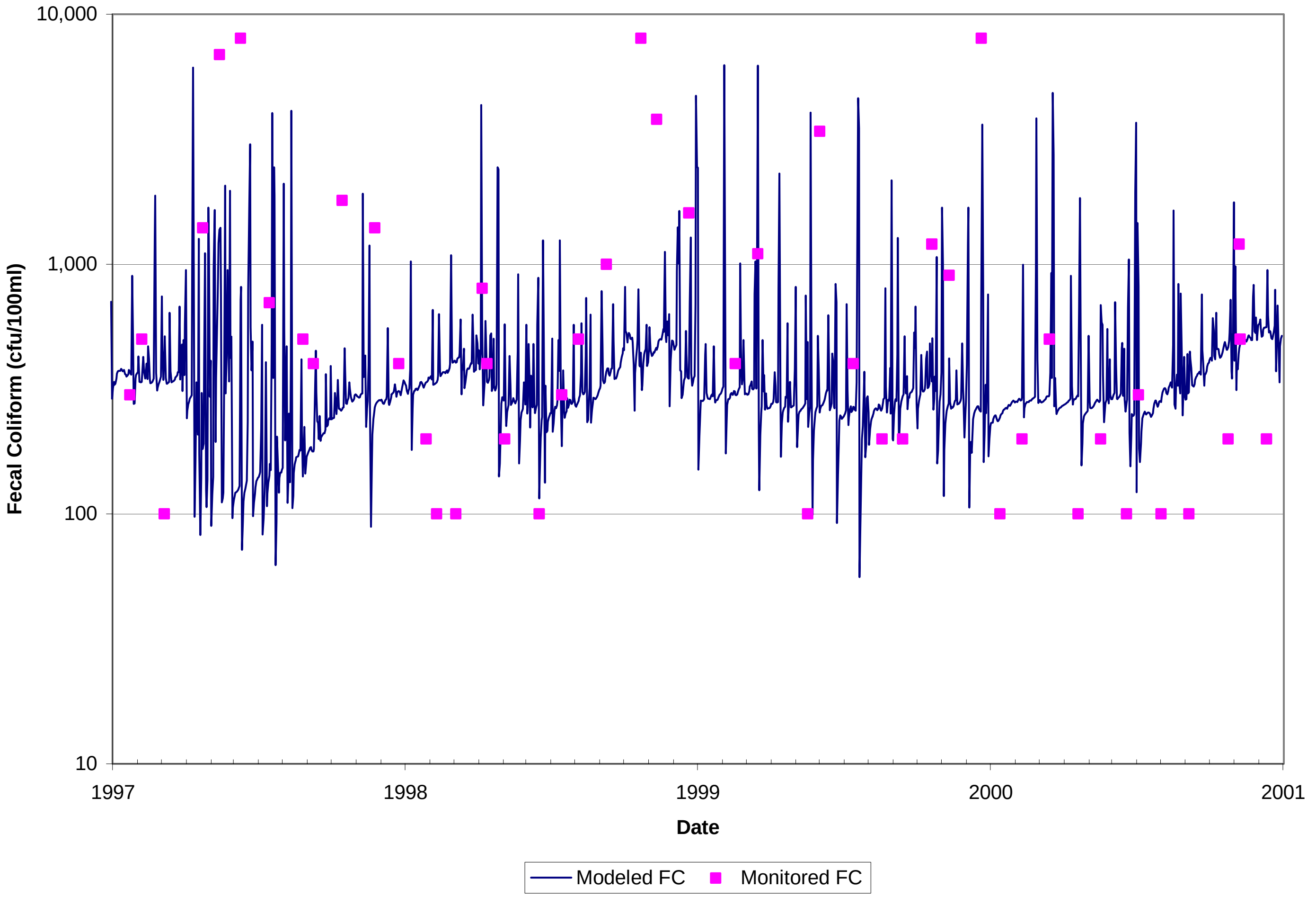

Figure 4.32 Simulated and Observed Fecal Coliform Concentration for Subwatershed 7 in Tinker Creek Validation Scenario.

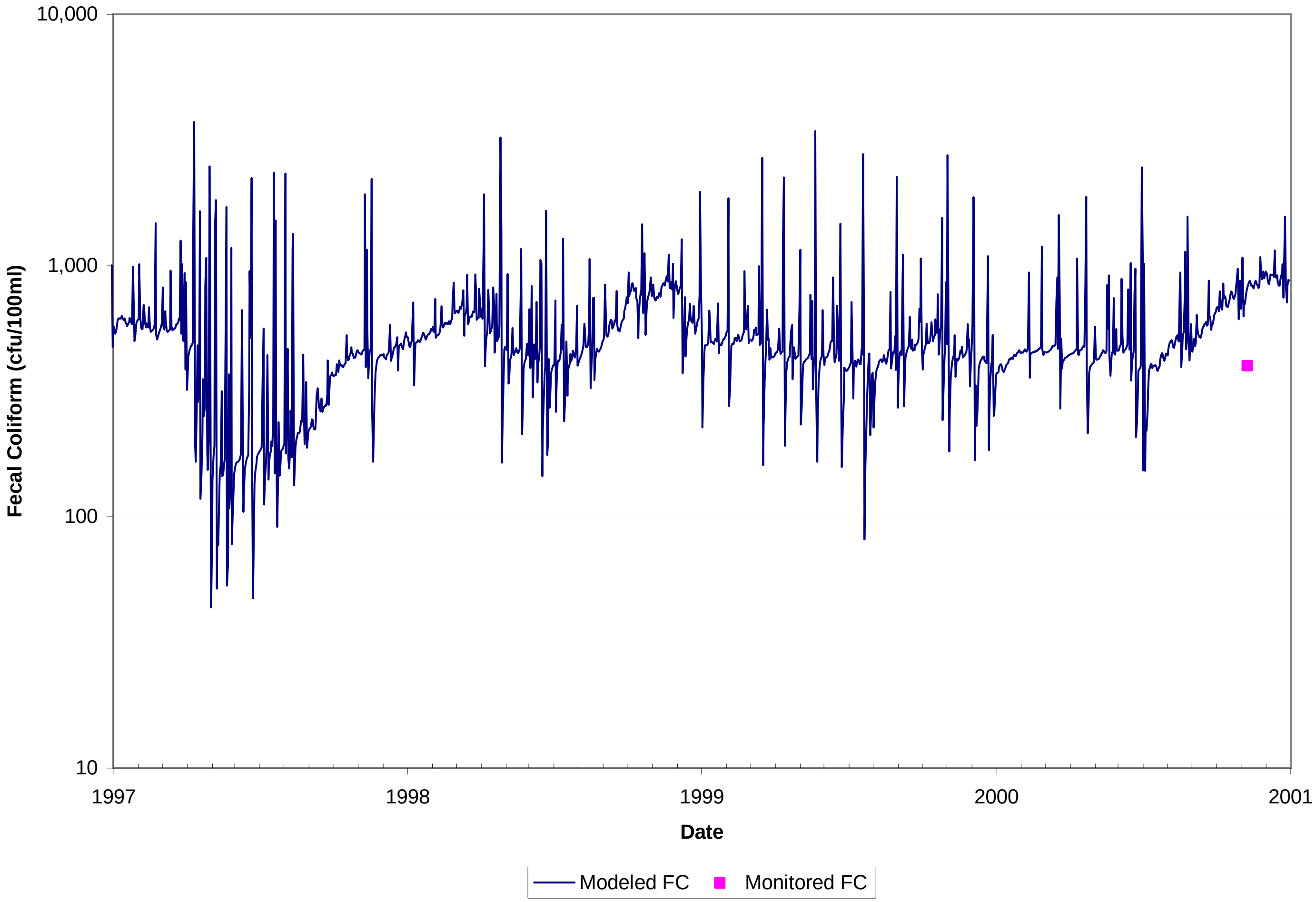

Figure 4.33 Simulated and Observed Fecal Coliform Concentration for Subwatershed 15 Glade Creek Validation Scenario.

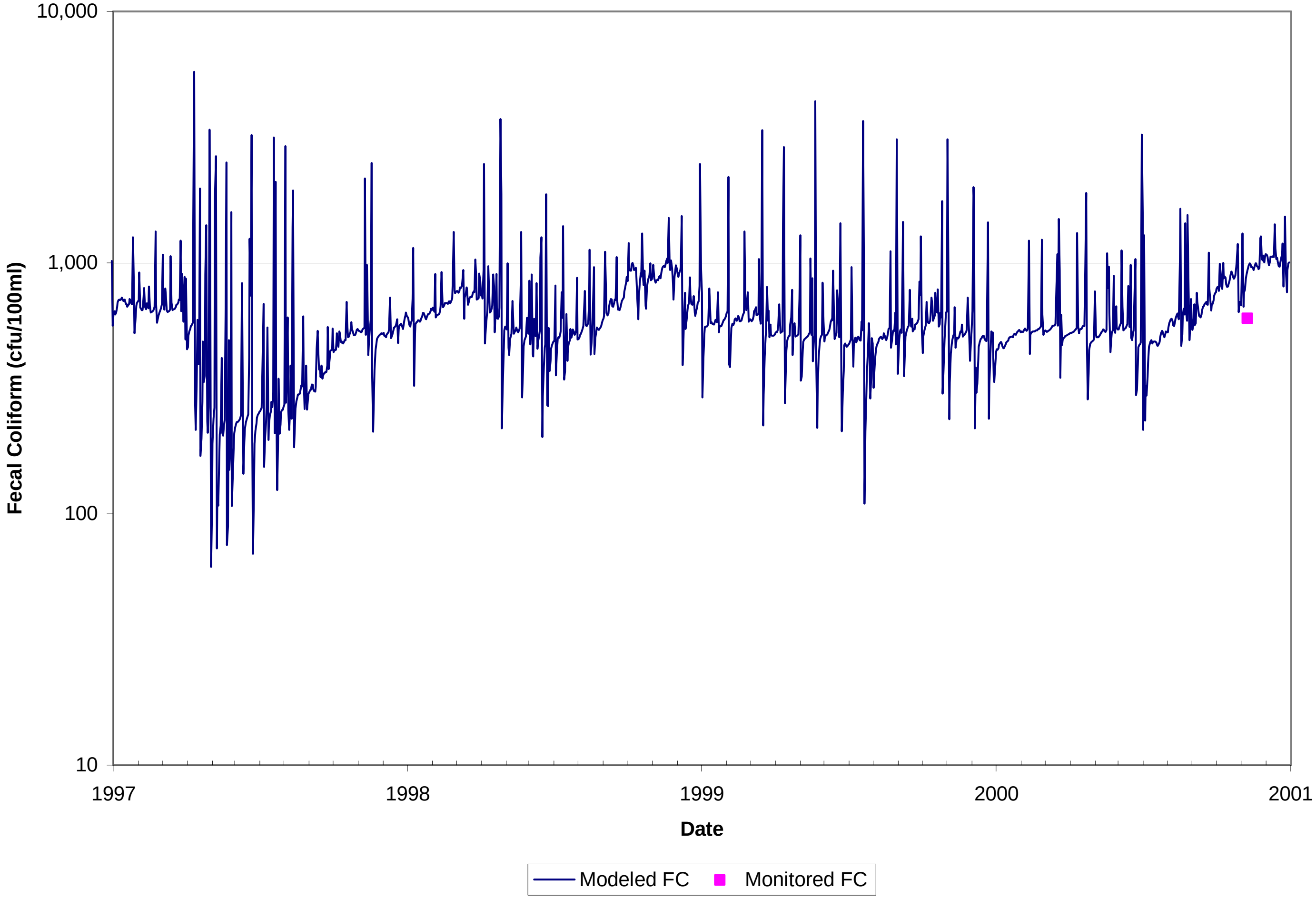

Figure 4.34 Simulated and Observed Fecal Coliform Concentration for Subwatershed 16 in Glade Creek Validation Scenario.

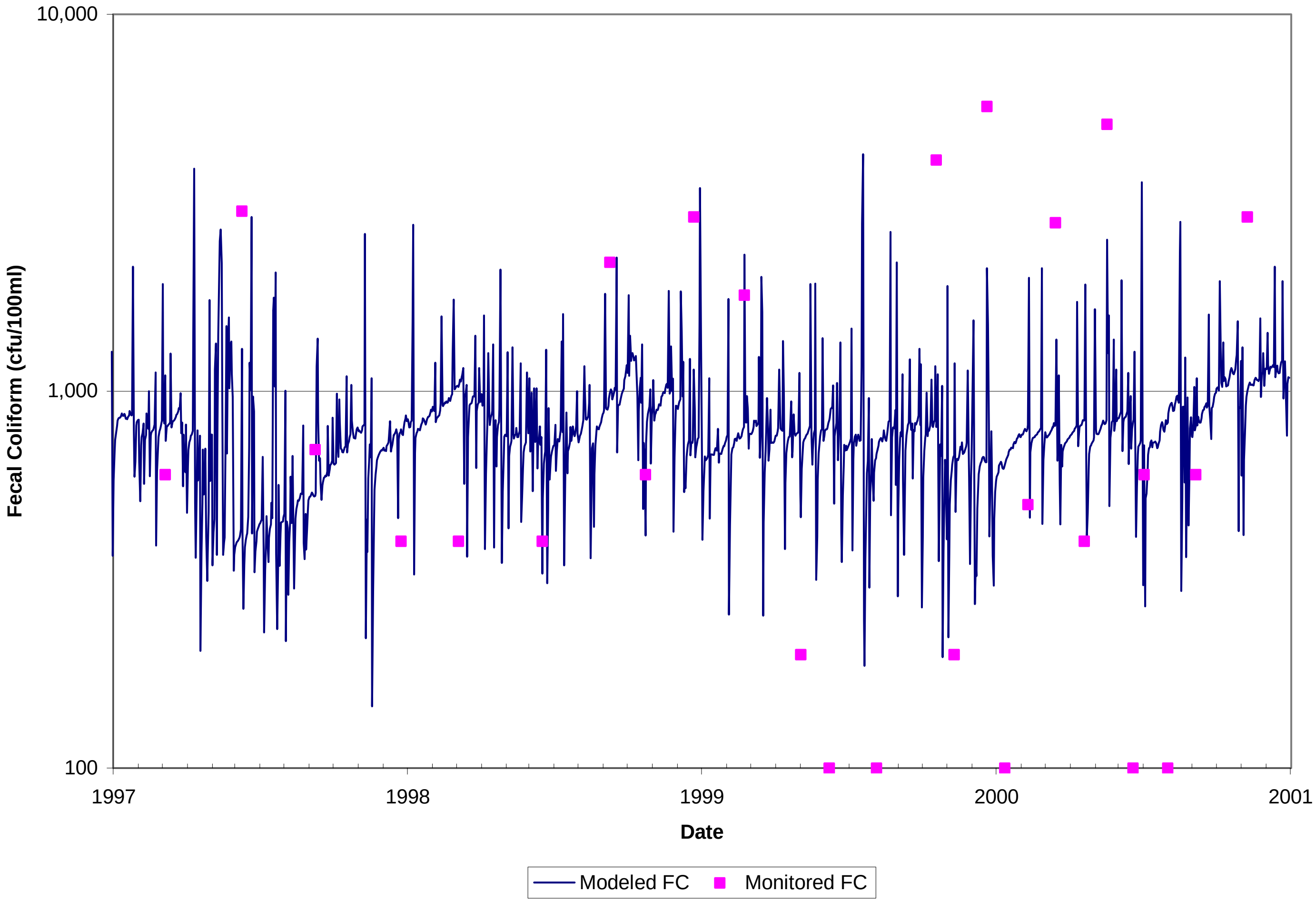

Figure 4.35 Simulated and Observed Fecal Coliform Concentration for Subwatershed 18 in Lick Run Validation Scenario.

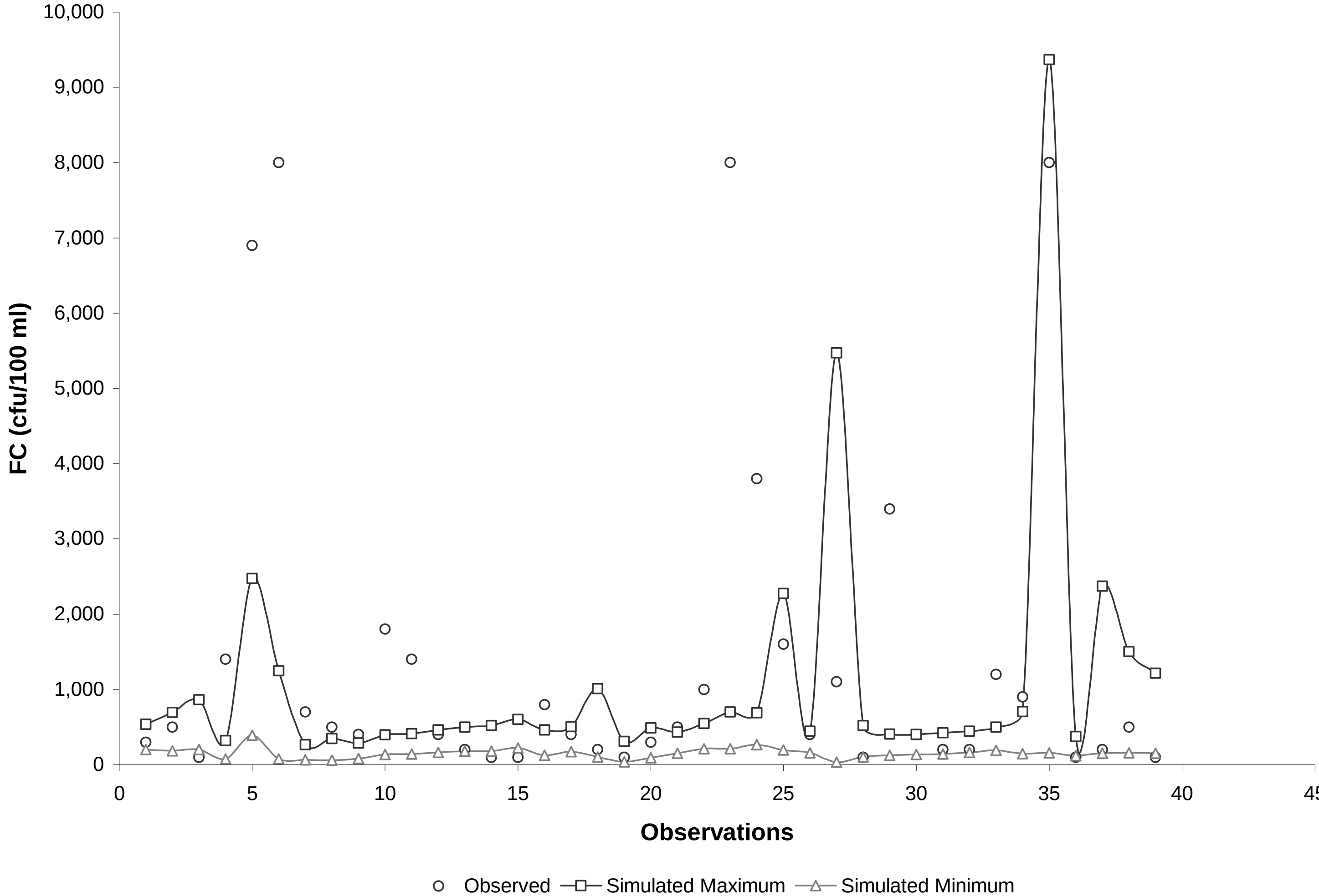

Figure 4.36 **Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 7 of the Tinker Creek impairment.**

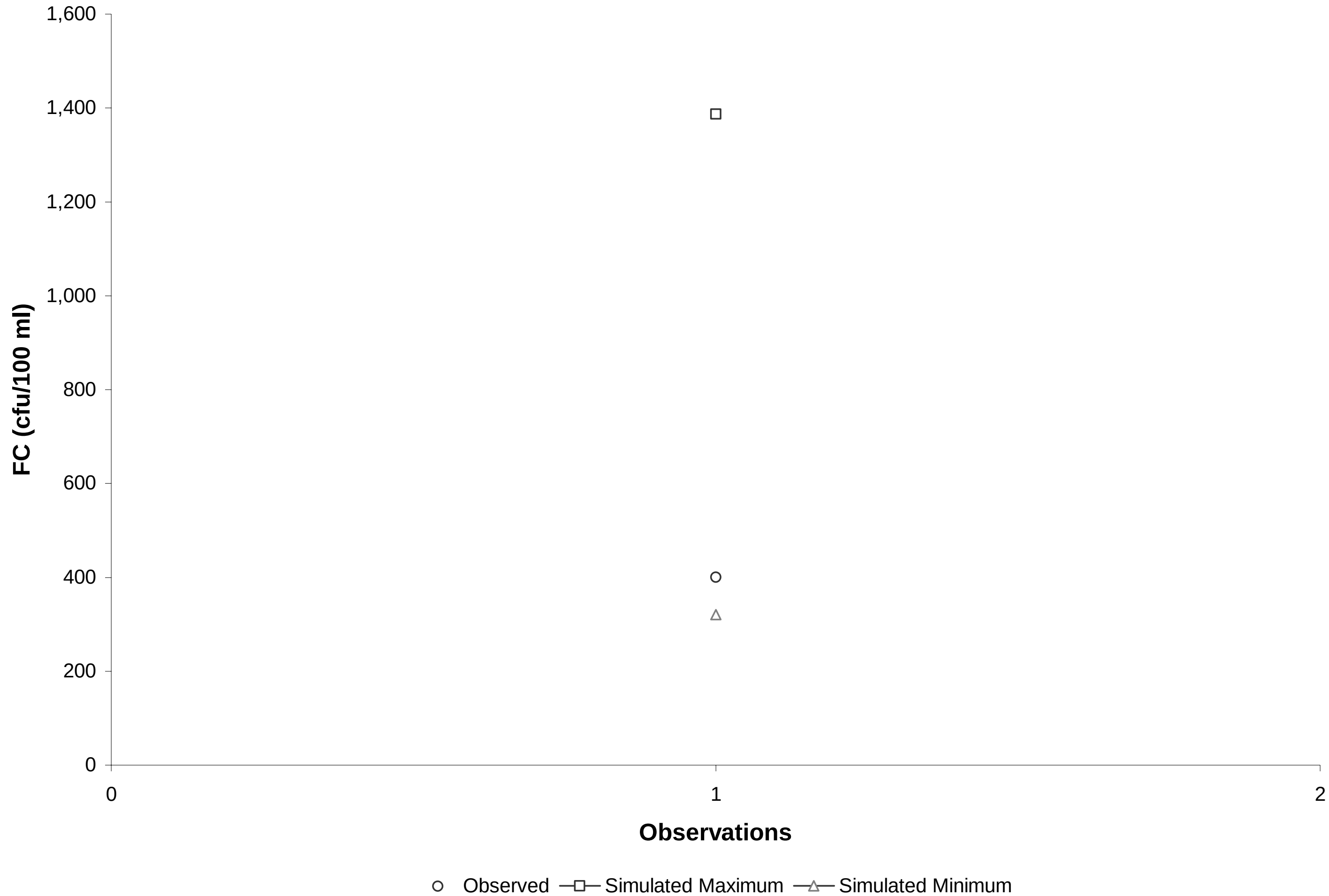

Figure 4.37 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 15 of the Glade Creek impairment.

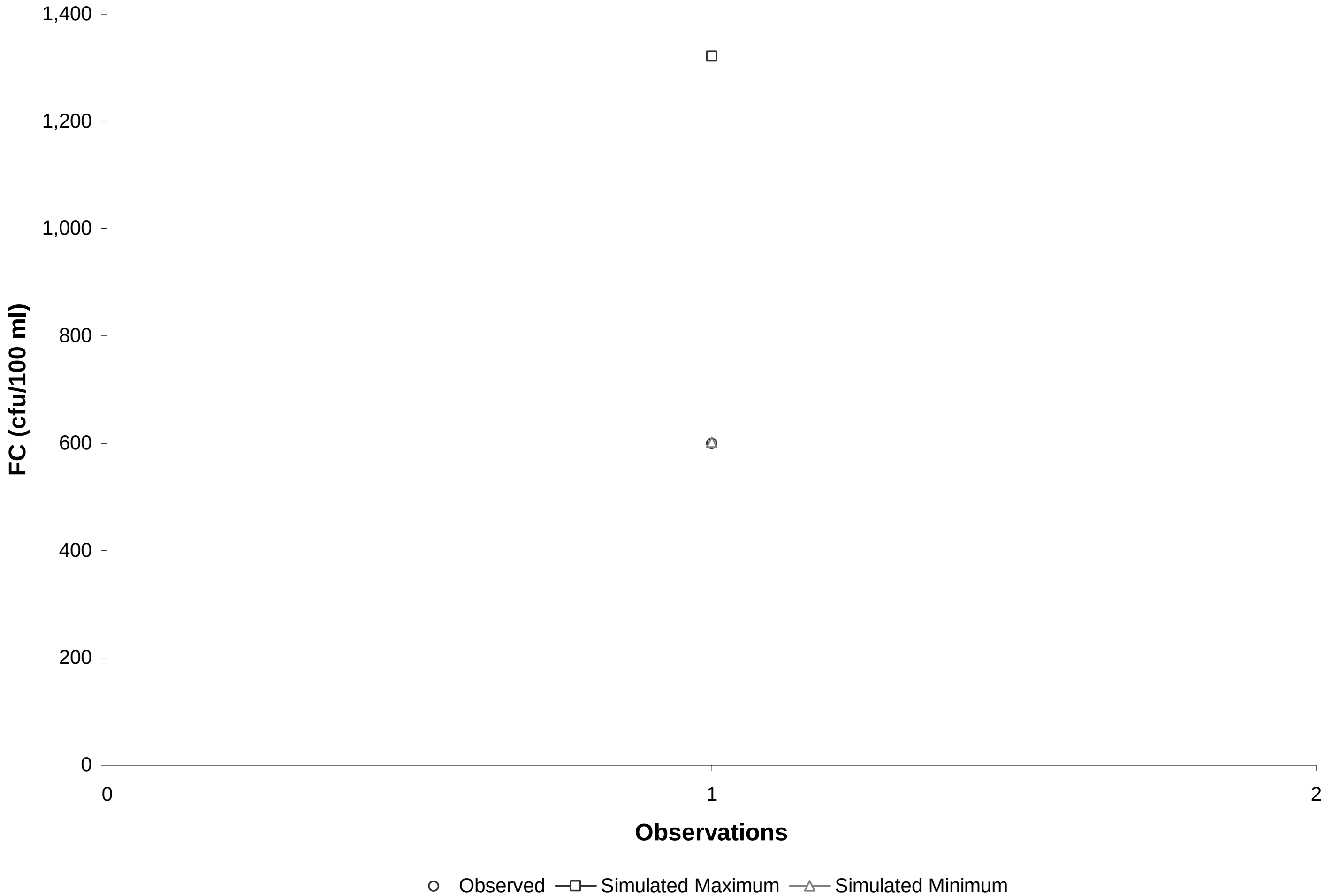

Figure 4.38 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 16 of the Glade Creek impairment.

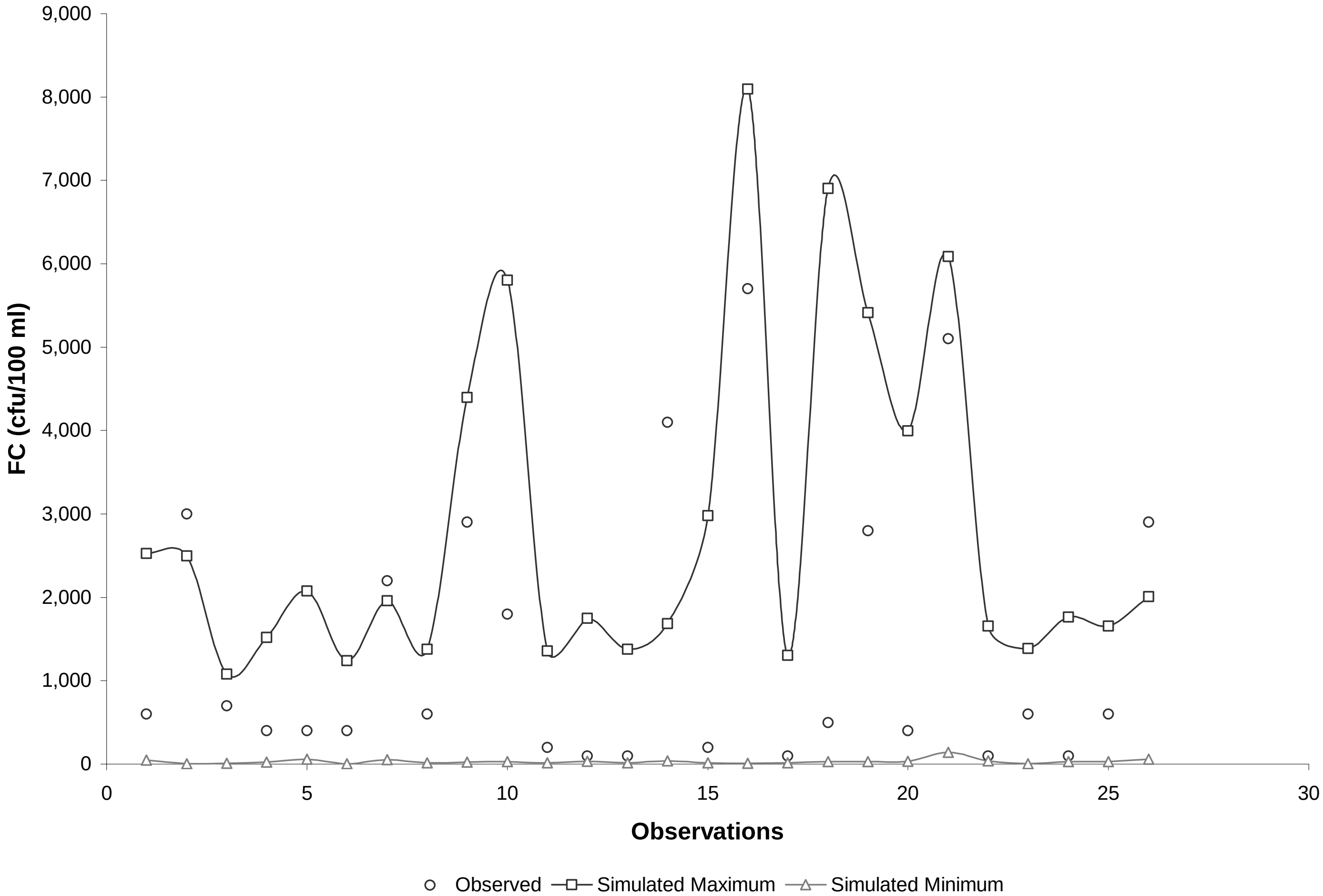

Figure 4.39 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 18 of the Lick Run impairment.

4.7 Existing Loadings

All appropriate inputs were updated to 2003 conditions, as described in Section 4. All model runs were conducted using precipitation data for a representative period used for hydrologic calibration (10/1/93 through 9/30/98). Figures 4.40 through 4.44 show the monthly geometric mean of *E. coli* concentrations in relation to the 126 cfu/100 ml standard. Figures 4.45 through 4.49 show the instantaneous values of *E. coli* concentrations in relation to the 235 cfu/100 ml standard. Appendix B contains tables with monthly loadings to the different land use areas in each subwatershed.

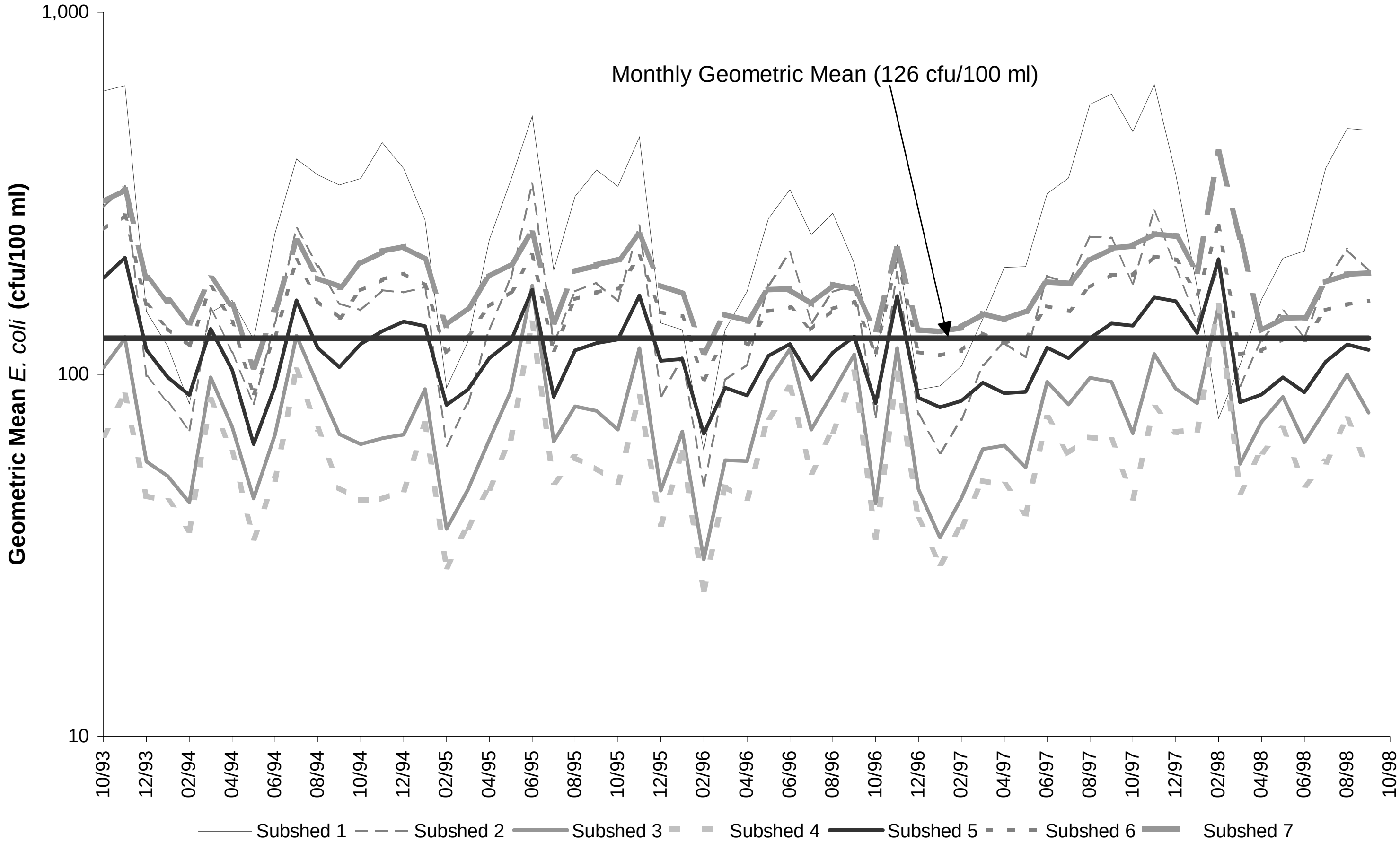

Figure 4.40 Existing conditions of *E. coli* concentrations in subwatersheds 1-7 in Tinker Creek impairment.

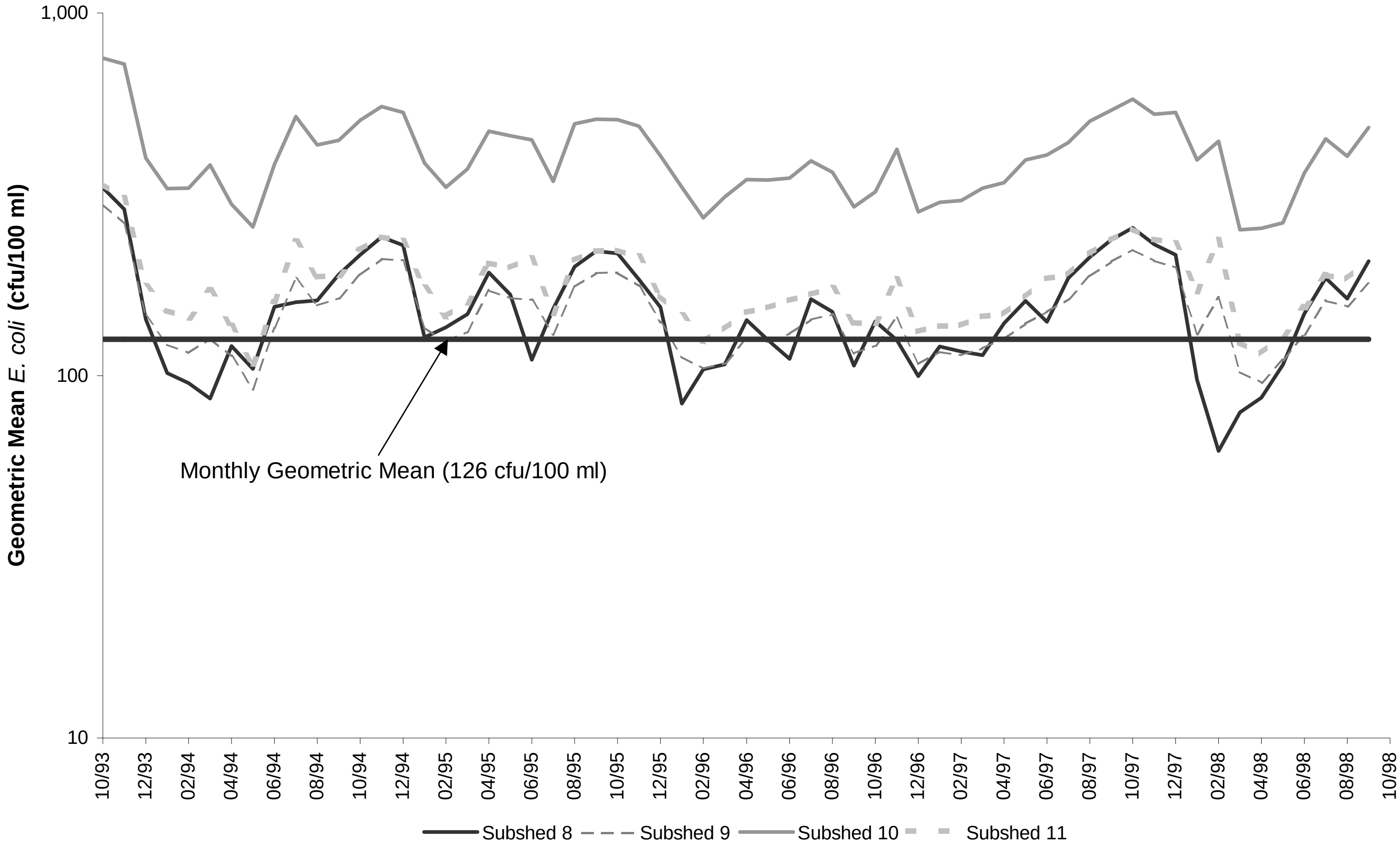

Figure 4.41 Existing conditions of *E. coli* concentrations in subwatersheds 8-11 in Carvin Creek impairment.

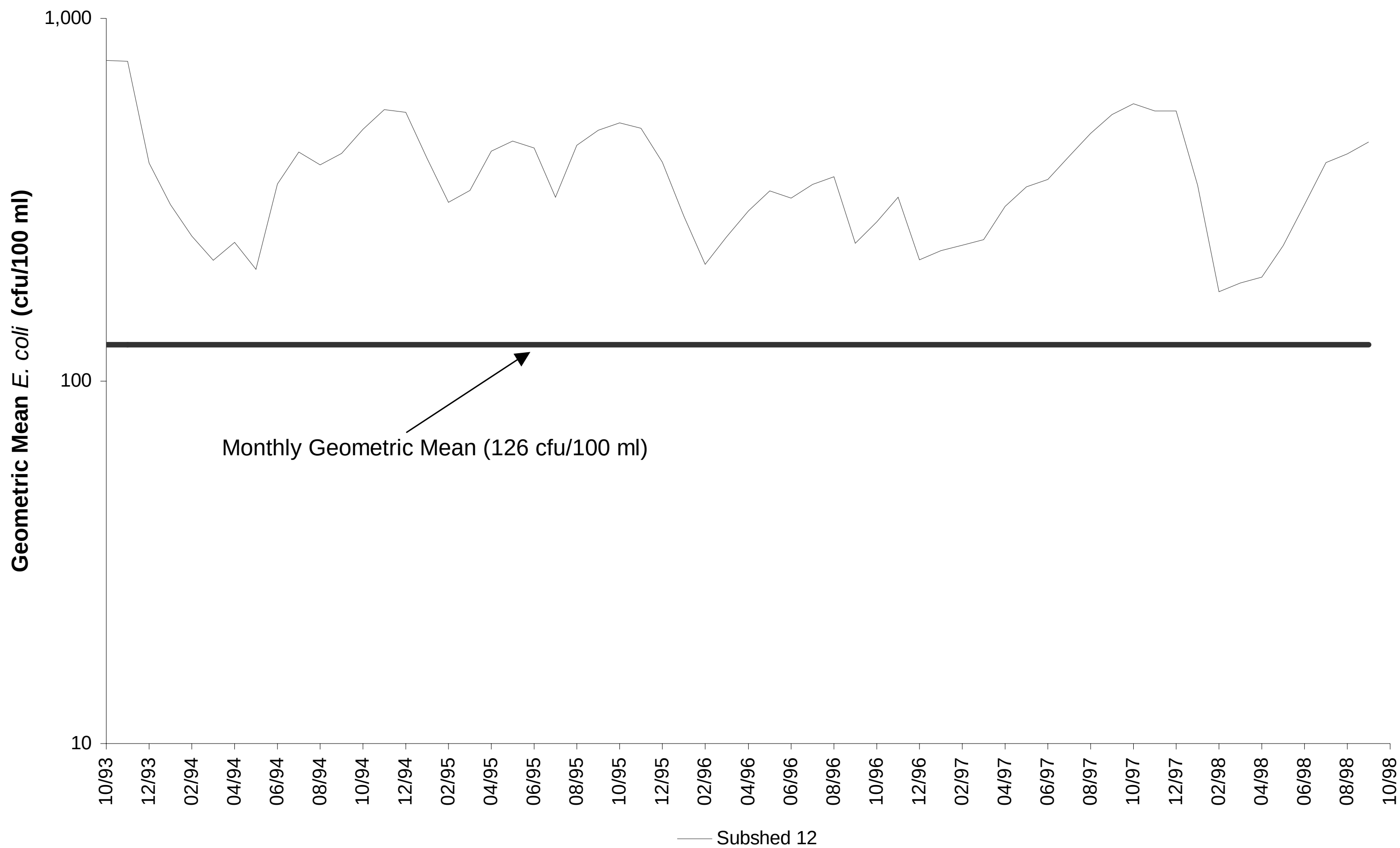

Figure 4.42 Existing conditions of *E. coli* concentrations in subwatershed 12 in Laymantown Creek impairment.

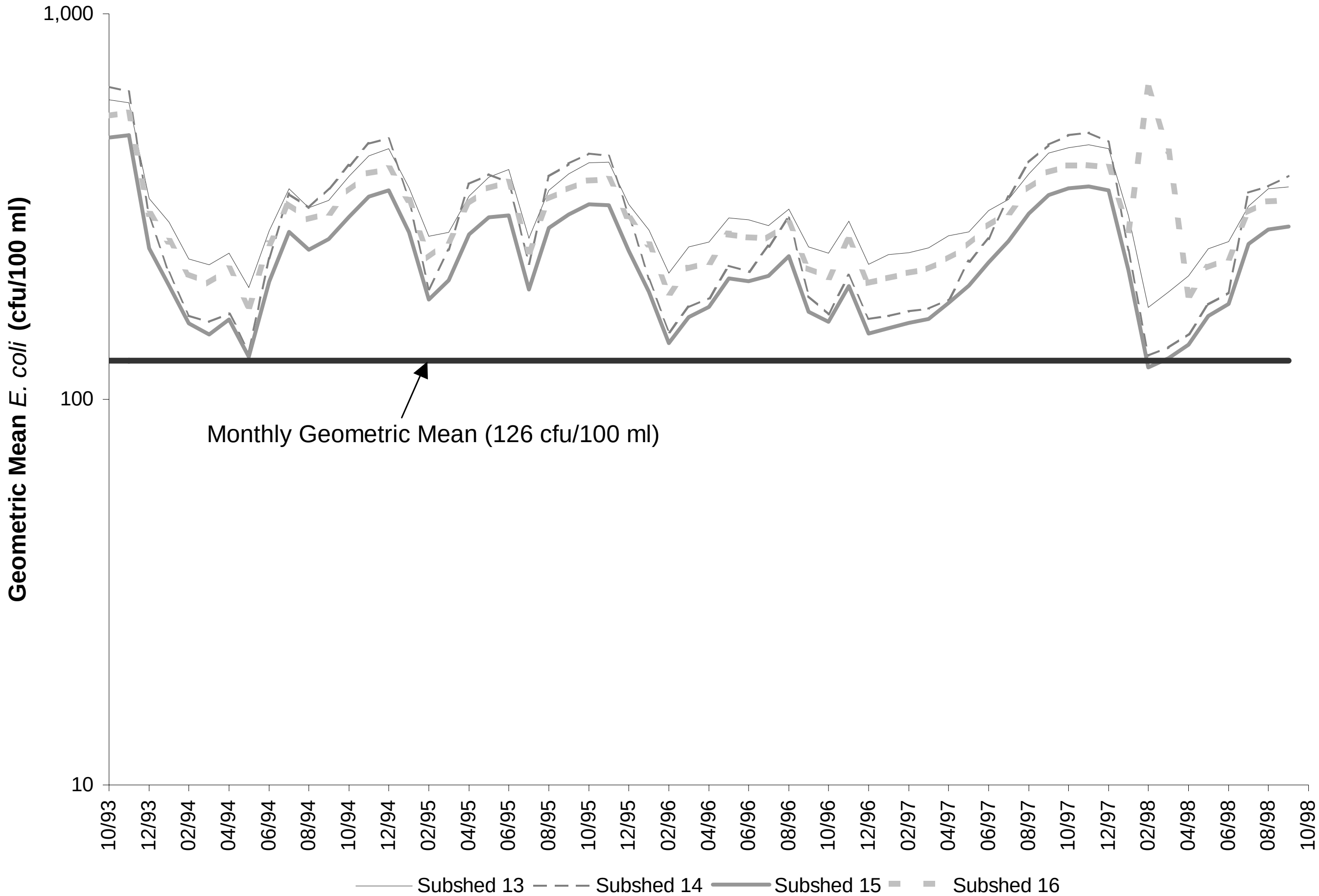

Figure 4.43 Existing conditions of *E. coli* concentrations in subwatersheds 13-16 of Glade Creek impairment.

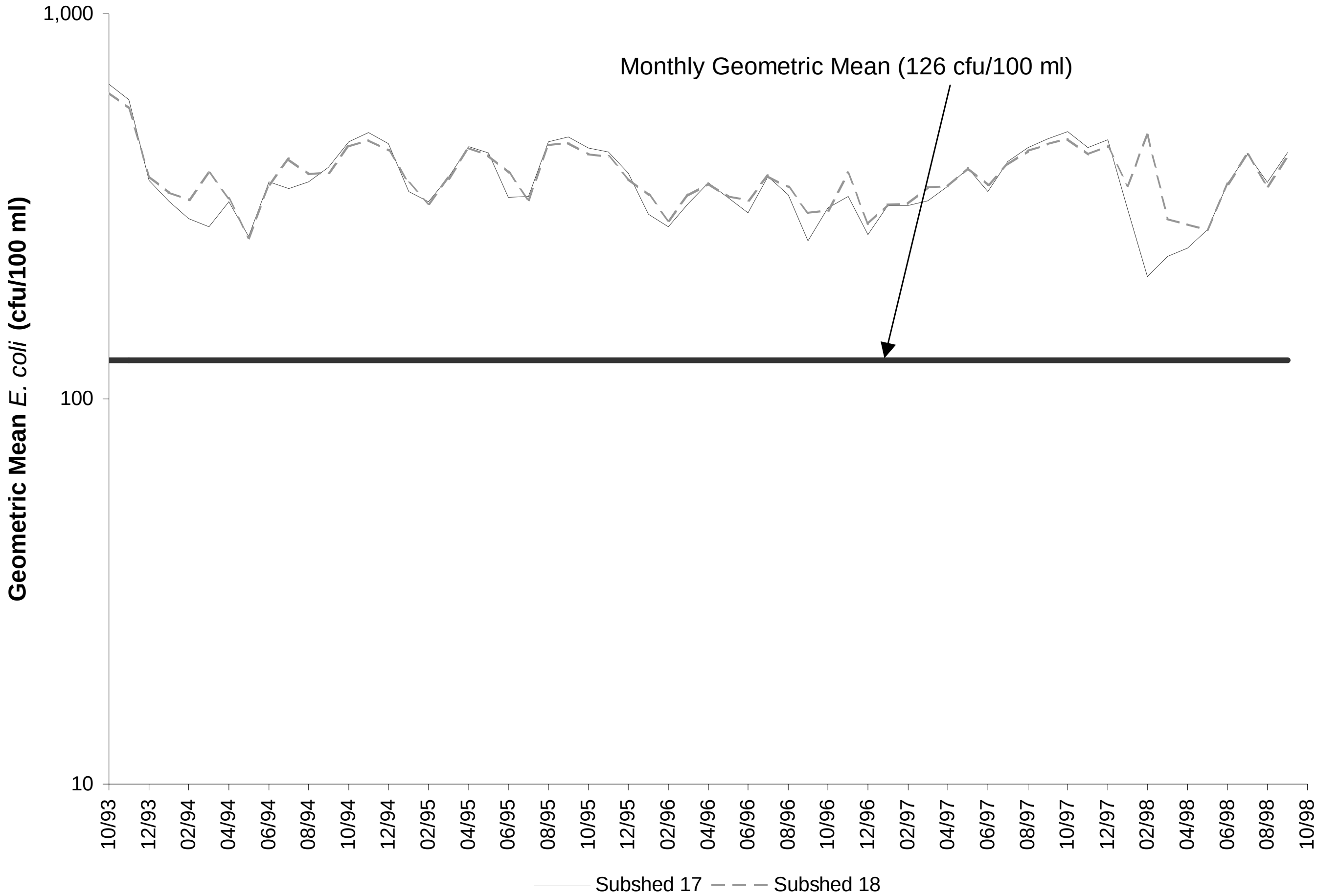

Figure 4.44 Existing conditions of *E. coli* concentrations in subwatersheds 17-18 of Lick Run impairment.

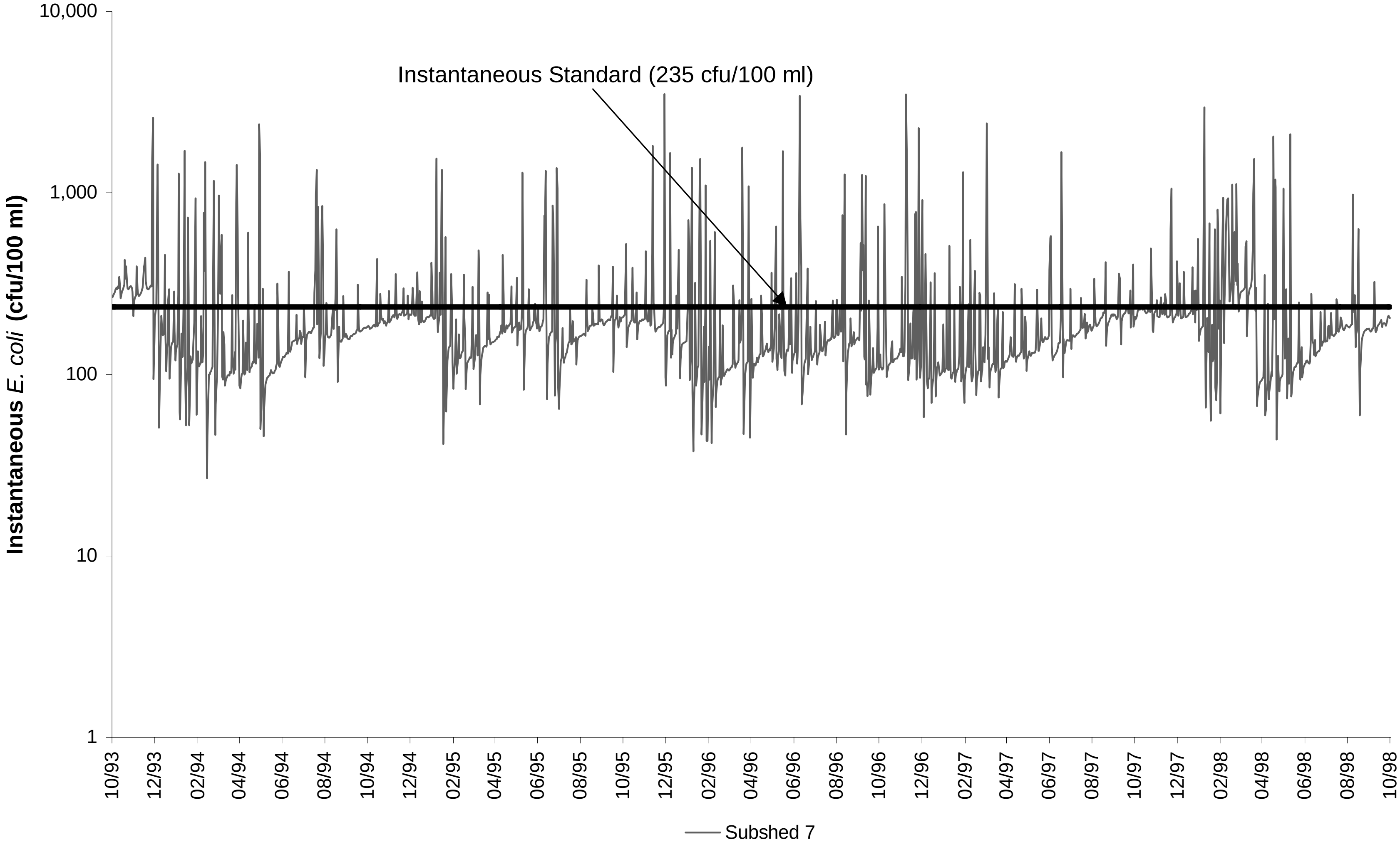

Figure 4.45 Existing conditions of *E. coli* concentrations in subwatershed 7 in Tinker Creek impairment.

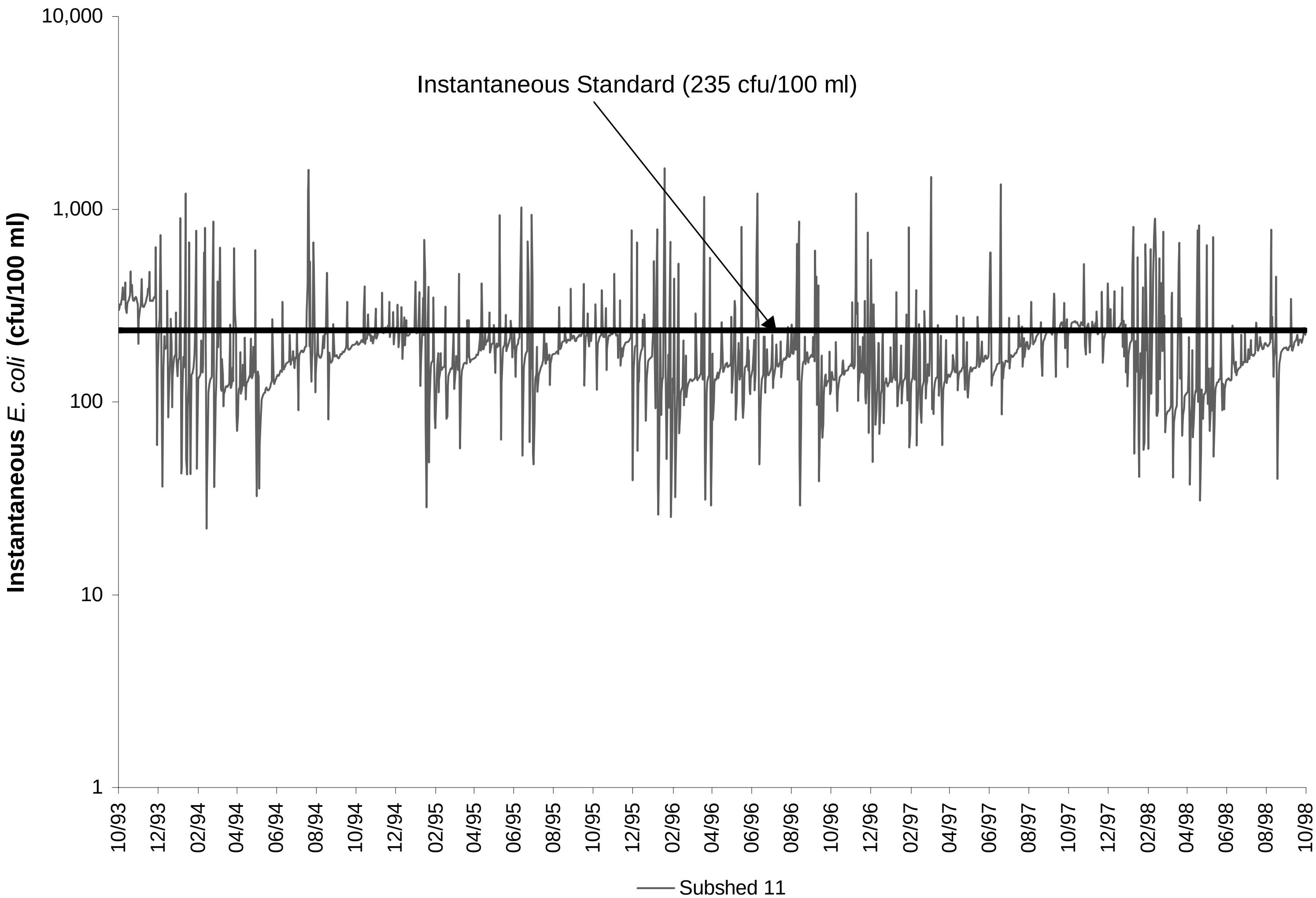

Figure 4.46 Existing conditions of *E. coli* concentrations in subwatershed 11 in Carvin Creek impairment.

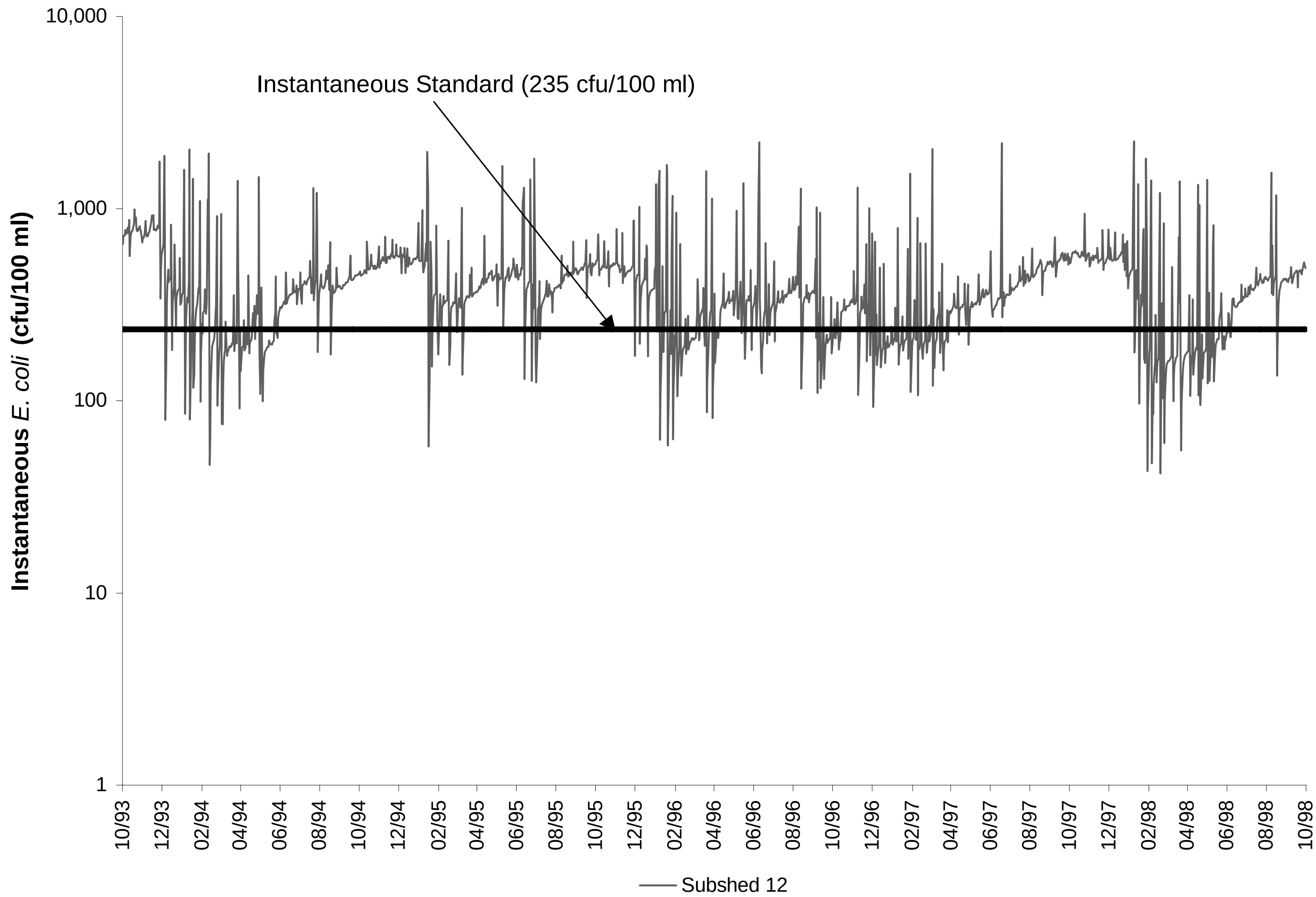

Figure 4.47 Existing conditions of *E. coli* concentrations in subwatershed 12 in Laymantown Creek impairment.

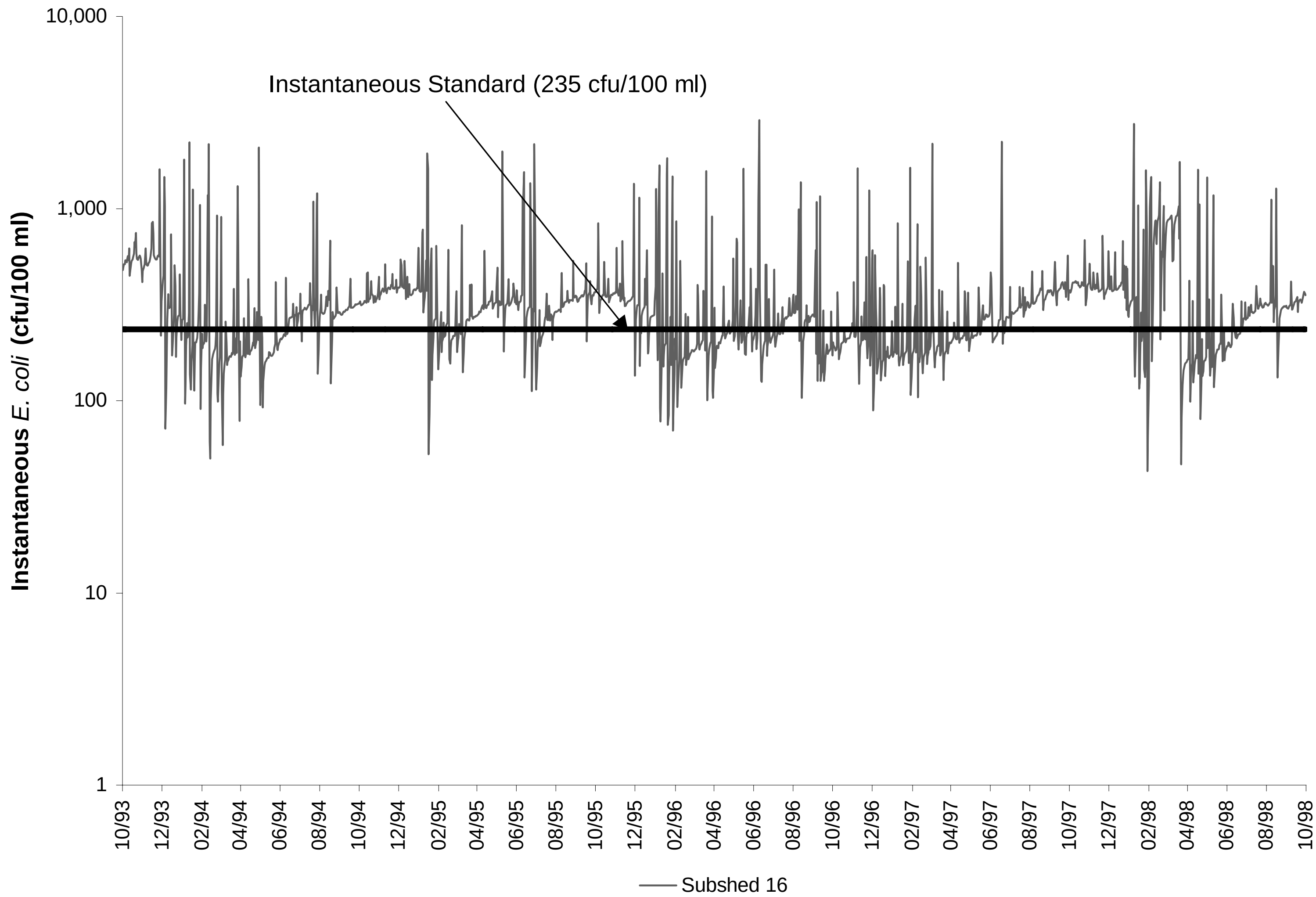

Figure 4.48 Existing conditions of *E. coli* concentrations in subwatershed 16 of Glade Creek impairment.

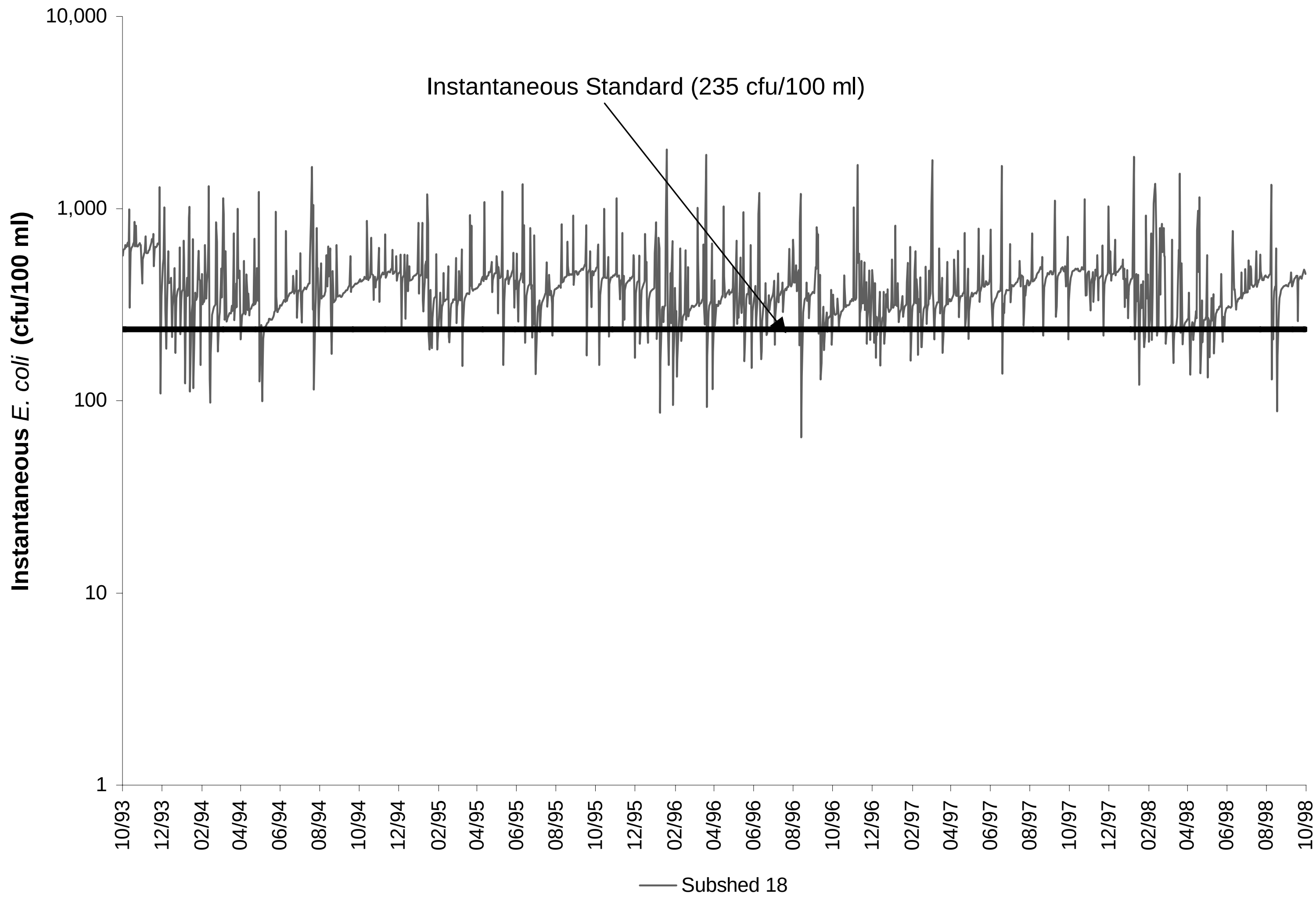

Figure 4.49 Existing conditions of *E. coli* concentrations in subwatershed 18 of Lick Run impairment.

5. ALLOCATION

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

$$TMDL = WLAs + LAs + MOS$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards. For fecal bacteria, TMDL is expressed in terms of colony forming units (or resulting concentration). A sensitivity analysis was performed to determine the impact of uncertainties in input parameters.

5.1 Sensitivity Analysis

Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.*, seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads). Additional analyses were performed to define the sensitivity of the modeled system to growth or technology changes that impact waste production rates.

Sensitivity analyses were run on both hydrologic and water quality parameters. The parameters adjusted for the hydrologic sensitivity analysis are presented in Table 5.1, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value, and the model was run for water years 1994 through 1998. Where an increase of 50% exceeded the maximum value for the parameter, the maximum value was used and the parameters increased over the base value was reported. The response of pertinent hydrologic outputs was recorded, and is reported in Table 5.2.

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 1994 through 1998 and model parameters established for 1995 conditions. The four parameters impacting the model's water quality response (Table 5.3) were increased and decreased by amounts that were consistent with the range of values for the parameter.

Since the water quality standard for fecal coliform bacteria is based on concentrations rather than loadings, it was considered necessary to analyze the effect of source changes on the monthly geometric-mean fecal coliform concentration. A monthly geometric mean was calculated for all months during the simulation period, and the value for each month was averaged. Deviations from the base run are given in Table 5.4 and plotted by month in Figures 5.1 and through 5.4.

In addition to analyzing the sensitivity of the model response to changes in model parameters, the response of the model to changes in land-based and direct loads was analyzed. The impacts of land-based and direct load changes on the annual load are presented in Figure 5.5, while impacts on the monthly geometric mean are presented in Figures 5.6 and 5.7.

Table 5.1 Base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
LZSN	Lower Zone Nominal Storage	in	2
INFILT	Soil Infiltration Capacity	in/hr	0.006-0.296
DEEPFR	Fraction of Deep Groundwater	---	0.1
BASETP	Base Flow Evapotranspiration	---	0.0325
INTFW	Interflow Inflow	---	1
MON-INTERCEP	Monthly Interception Storage Capacity	in	0.01-0.4
MON-UZSN	Monthly Upper Zone Nominal Storage	in	0.05-2
AGWRC	Active Groundwater Coefficient	1/day	0.994
KVARY	Groundwater Recession Coefficient	1/day	0.05
MON-MANNING	Monthly Manning's *n* for Overland Flow	---	0.1-0.48

Table 5.2 Sensitivity analysis results for hydrologic model parameters.

		% Change in							
Model Parameter	Parameter Change (%)	Total Flow	High Flows	Low Flows	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Winter Flow Volume	Total Storm Volume
BASETP	-50	1.61	-0.39	5.78	-0.08	2.40	5.39	0.66	-0.07
BASETP	-10	0.32	-0.08	1.16	-0.02	0.48	1.07	0.13	0.08
BASETP	10	-0.32	0.08	-1.17	0.02	-0.48	-1.07	-0.13	0.09
BASETP	50	-1.59	0.41	-5.89	0.09	-2.38	-5.34	-0.64	0.35
AGWRC	-50	2.51	51.39	-88.38	20.44	-9.09	-26.40	5.49	48.86
AGWRC	-10	1.37	19.98	-61.45	20.24	-9.63	-26.26	-0.44	46.35
AGWRC	0.5[1]	-3.75	-2.69	5.77	-6.42	-9.73	-1.07	9.22	-19.56
DEEPFR	-50	3.23	0.97	5.86	2.31	3.74	4.19	3.78	2.09
DEEPFR	-10	0.65	0.19	1.17	0.46	0.75	0.84	0.76	0.40
DEEPFR	10	-0.65	-0.19	-1.17	-0.46	-0.75	-0.84	-0.76	-0.40
DEEPFR	50	-3.23	-0.97	-5.88	-2.30	-3.74	-4.20	-3.79	-1.93
INFILT	-50	0.45	25.54	-25.68	8.57	-5.19	-9.12	-1.56	12.78
INFILT	-10	0.03	3.76	-3.92	1.40	-0.88	-1.48	-0.50	1.83
INFILT	10	-0.01	-3.34	3.52	-1.28	0.80	1.38	0.53	-1.52
INFILT	50	0.08	-13.62	14.66	-5.53	3.55	6.10	2.73	-6.42
MON-INTERCEP	-50	2.38	0.20	5.82	0.85	2.39	4.66	3.79	0.13
MON-INTERCEP	-10	0.43	0.03	1.03	0.16	0.45	0.81	0.67	0.10
MON-INTERCEP	10	-0.40	-0.03	-0.97	-0.15	-0.42	-0.75	-0.64	-0.08
MON-INTERCEP	50	-1.81	-0.22	-4.25	-0.70	-1.90	-3.31	-2.91	-0.19
MON-UZSN	-50	5.33	9.39	2.15	4.59	4.32	7.64	6.20	7.39
MON-UZSN	-10	0.89	1.61	0.30	0.81	0.78	1.15	0.93	1.25
MON-UZSN	10	-0.82	-1.51	-0.24	-0.78	-0.75	-1.00	-0.83	-1.09
MON-UZSN	50	-3.58	-6.63	-0.99	-3.61	-3.22	-4.09	-3.49	-5.04
KVARY	-50	-0.03	-0.35	1.59	-0.77	0.05	0.94	0.66	-1.24
KVARY	-10	-0.01	-0.07	0.31	-0.15	0.01	0.18	0.13	-0.25
KVARY	10	0.01	0.07	-0.31	0.15	-0.01	-0.18	-0.13	0.25
KVARY	50	0.03	0.33	-1.52	0.74	-0.06	-0.90	-0.62	1.37
LZSN	-50	4.94	11.53	-2.65	9.70	-2.59	1.67	7.57	9.02
LZSN	-10	0.82	1.79	-0.31	1.66	-0.26	0.02	1.15	1.49
LZSN	10	-0.76	-1.62	0.26	-1.56	0.18	0.07	-1.02	-1.16
LZSN	50	-3.20	-6.79	1.11	-6.77	0.39	0.94	-3.94	-5.58
INTFW	-50	-0.32	6.03	0.27	-0.51	-0.19	-0.37	0.04	-1.23
INTFW	-10	-0.05	0.61	0.10	-0.07	-0.04	-0.05	0.02	-0.17
INTFW	10	0.04	-0.51	-0.09	0.06	0.03	0.05	-0.01	0.15
INTFW	50	0.17	-1.77	-0.45	0.24	0.22	0.15	-0.07	0.60
MON-LZETP	-50	9.97	13.40	7.94	5.55	9.95	16.86	13.83	8.16
MON-LZETP	-10	3.11	4.27	2.56	1.14	5.65	4.56	2.80	2.96
MON-LZETP	10	0.68	1.39	0.09	-0.26	3.72	0.24	-0.98	1.01
MON-LZETP	50	-2.65	-2.44	-3.39	-2.18	0.59	-5.00	-6.17	-1.63
MON-MANNING	-50	0.26	2.36	-1.27	0.39	0.43	0.11	-0.17	0.73
MON-MANNING	-10	0.03	0.34	-0.17	0.04	0.06	0.02	-0.02	0.10
MON-MANNING	10	-0.03	-0.31	0.15	-0.03	-0.07	-0.01	0.03	-0.08
MON-MANNING	50	-0.11	-1.29	0.62	-0.20	-0.19	0.01	0.12	-0.33

[1]Maximum value used corresponds to the maximum allowable value for the parameter.

Table 5.3 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	0.00E+00 – 1.10E
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	1.00E-02 – 3.2E+0
MON-IFLW-CONC	FC Interflow Concentration	FC/ft^3	0 – 1.8E+06
FSTDEC	In-stream First Order Decay Rate	1/day	0.01 - 10

Table 5.4 Percent change in average monthly FC geometric mean for the years 1993-1998.

Model Parameter	Parameter Change (%)	Percent Change in Average Monthly FC Geometric Mean for the Years 1993-1998											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	20.8	20.9	20.8	20.7	20.3	20.5	19.4	18.8	18.0	15.8	18.0	19.9
FSTDEC	-10	3.5	3.6	3.5	3.5	3.5	3.5	3.3	3.1	3.0	2.6	3.0	3.4
FSTDEC	10	-3.3	-3.3	-3.3	-3.3	-3.2	-3.2	-3.0	-2.9	-2.8	-2.4	-2.8	-3.1
FSTDEC	50	-14.5	-14.7	-14.5	-14.3	-14.1	-14.2	-13.3	-12.7	-12.2	-10.5	-12.0	-13.6
MON-IFLW CONC	-100	-76.2	-78.1	-64.7	-42.7	-45.7	-43.1	-19.9	-24.7	-22.6	-7.5	-22.8	-51.9
MON-IFLW CONC	-50	-31.4	-34.6	-27.1	-18.6	-19.9	-17.9	-8.0	-9.9	-9.8	-3.3	-9.0	-22.5
MON-IFLW CONC	50	22.4	26.8	20.6	14.3	17.9	18.4	8.5	8.5	7.5	2.8	6.4	16.8
MON-IFLW CONC	100	64.5	70.1	51.4	35.0	39.3	34.6	13.6	16.8	18.0	5.4	15.6	45.8
SQOLIM	-50	-5.7	-2.5	-2.7	-2.1	-3.2	-6.1	-2.0	-2.4	-2.8	-1.5	-5.3	-5.6
SQOLIM	-25	-2.6	-1.0	-1.0	-0.9	-1.4	-2.6	-0.8	-0.9	-1.2	-0.5	-2.3	-2.7
SQOLIM	50	5.5	2.0	1.3	1.0	1.6	3.5	1.0	1.2	1.9	0.8	4.0	4.8
SQOLIM	100	10.4	3.7	2.2	1.6	2.7	5.8	1.6	2.0	3.3	1.3	6.6	8.2
WSQOP	-50	7.0	5.7	6.3	6.0	7.5	7.9	3.9	2.8	3.8	3.0	8.4	8.1
WSQOP	-10	1.0	0.8	0.9	0.8	1.0	1.1	0.5	0.4	0.6	0.4	1.2	1.2
WSQOP	10	-0.9	-0.8	-0.8	-0.7	-0.9	-1.0	-0.5	-0.4	-0.5	-0.4	-1.0	-1.0
WSQOP	50	-3.7	-3.1	-3.1	-2.9	-3.7	-4.0	-2.0	-1.6	-2.0	-1.5	-4.1	-4.1

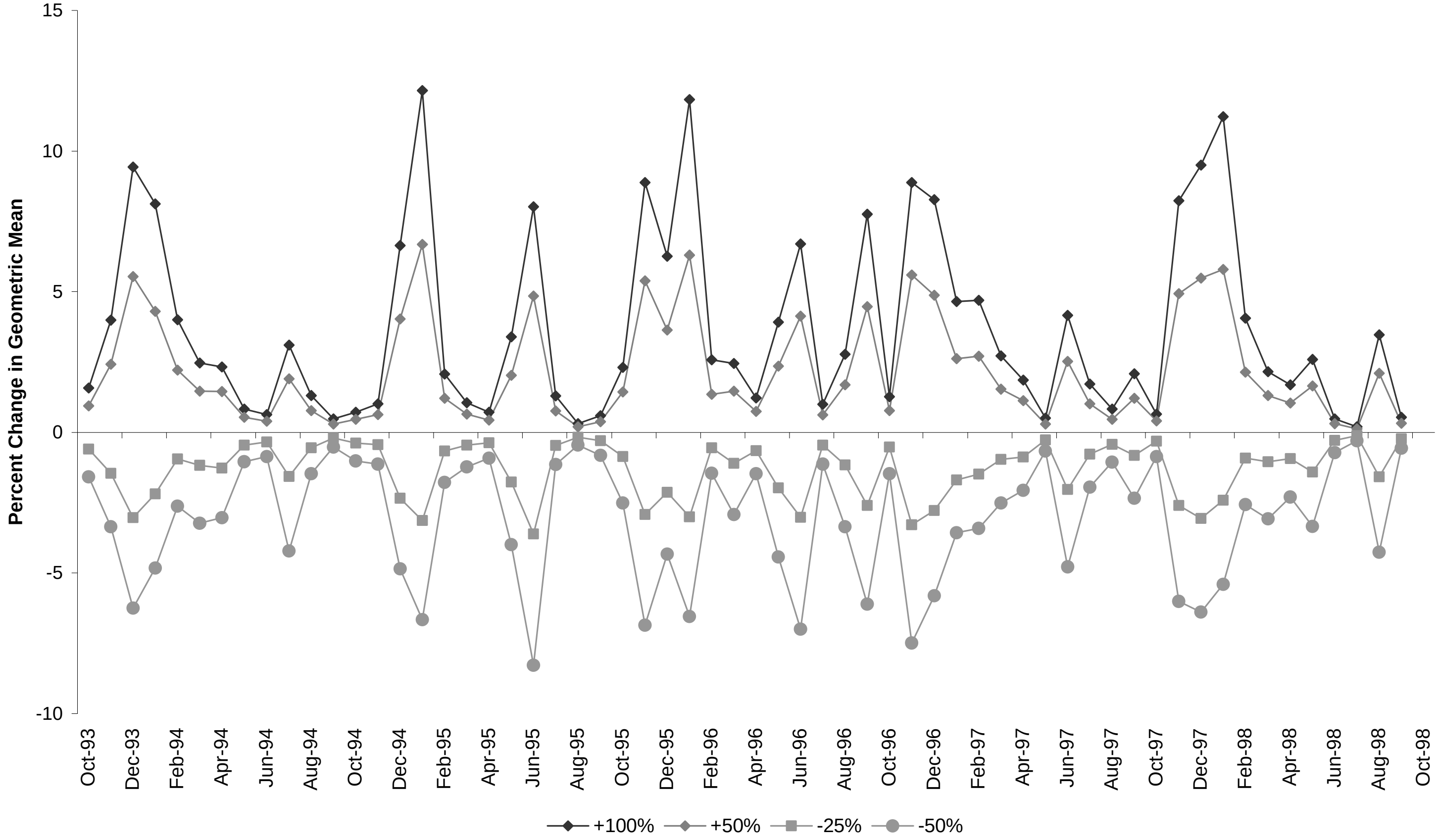

Figure 5.1 Results of sensitivity analysis on monthly geometric-mean concentrations in the Tinker Creek watershed, as affected by changes in maximum FC accumulation on land (MON-SQOLIM).

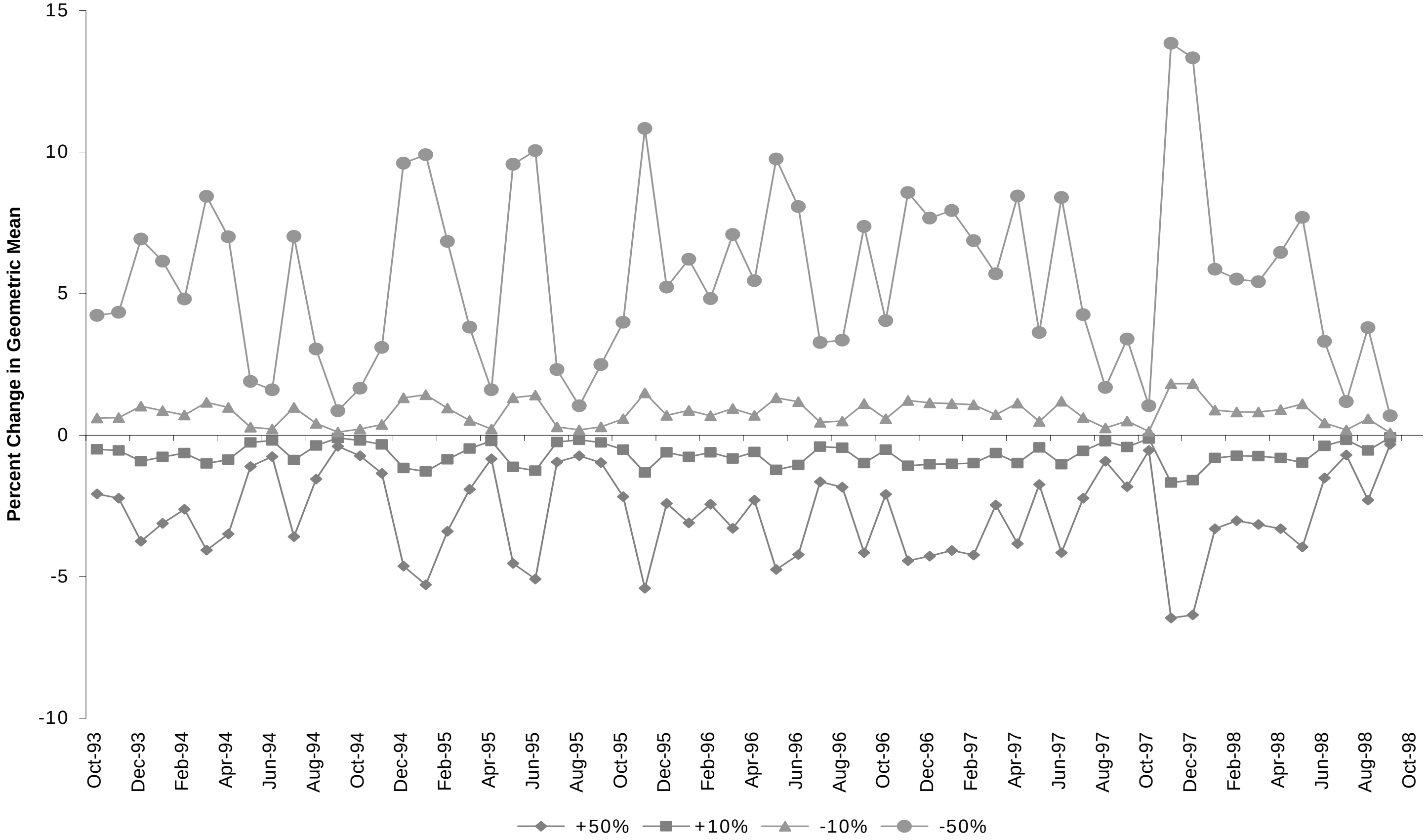

Figure 5.2 **Results of sensitivity analysis on monthly geometric-mean concentrations in the Tinker Creek watershed, as affected by changes in the wash-off rate for FC fecal coliform on land surfaces (WSQOP).**

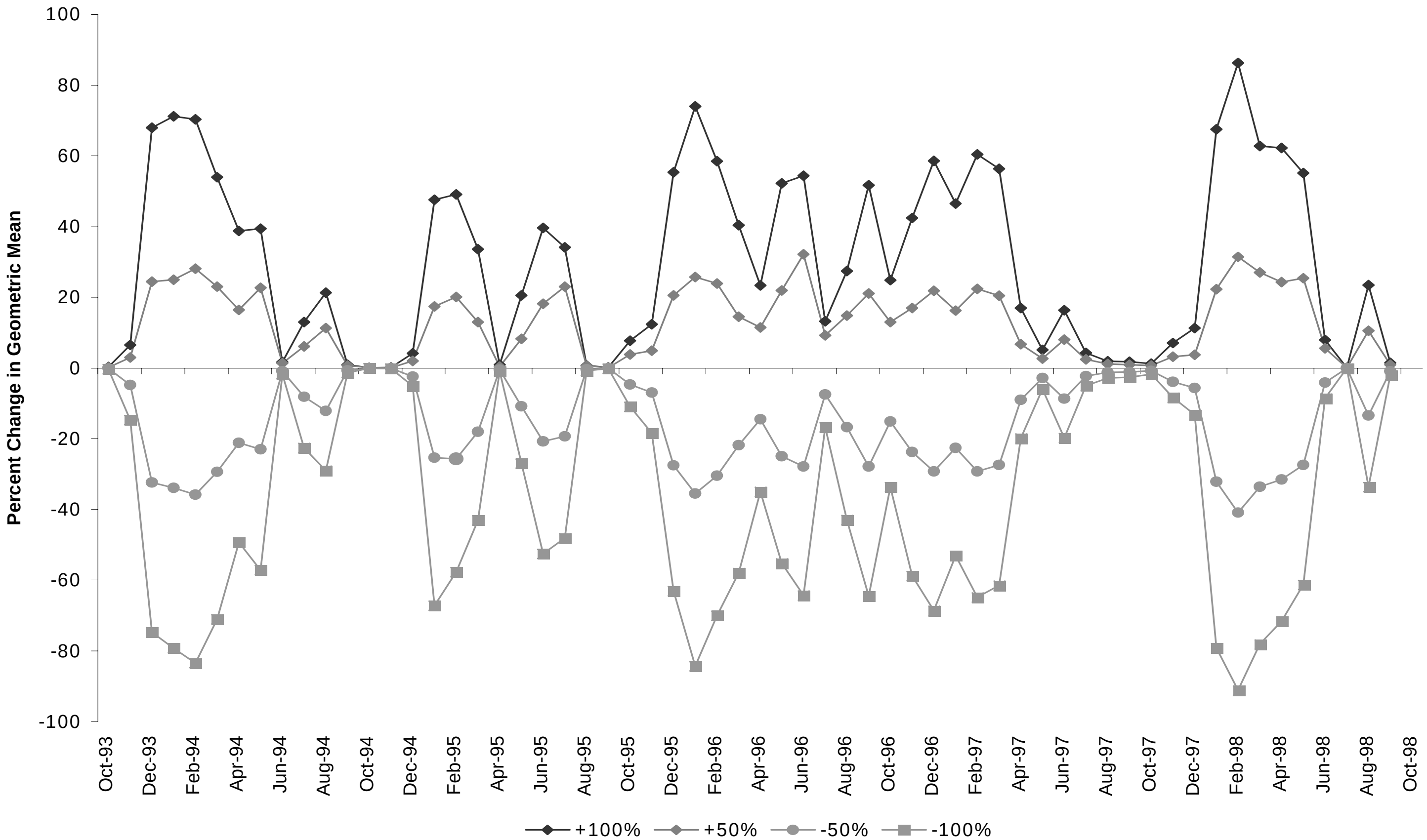

Figure 5.3 **Results of sensitivity analysis on monthly geometric-mean concentrations in the Tinker Creek watershed, as affected by changes in the concentration of fecal coliform in interflow (IFLW).**

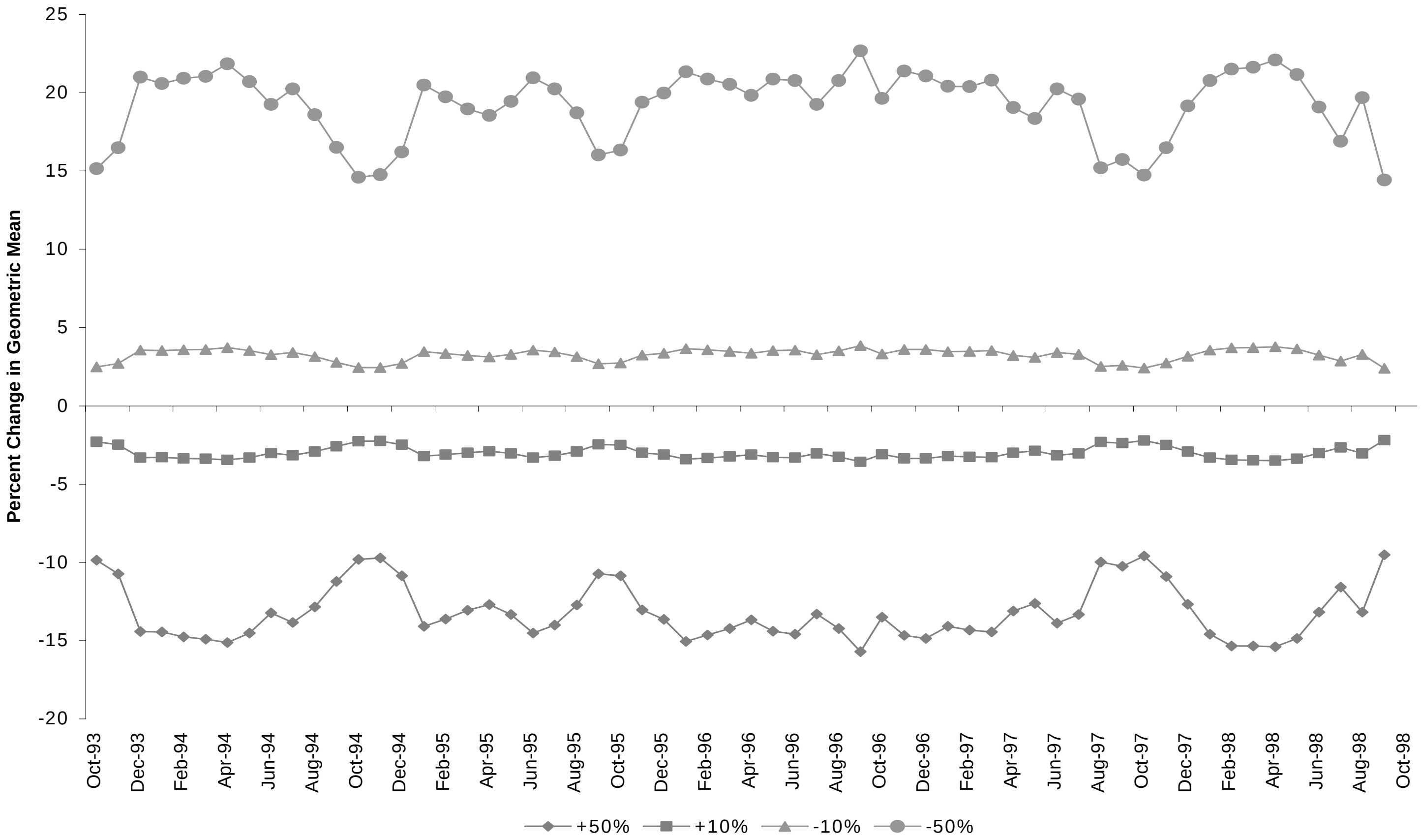

Figure 5.4 Results of sensitivity analysis on monthly geometric-mean concentrations in the Tinker Creek watershed, as affected by changes in the in-stream first-order decay rate (FSTDEC).

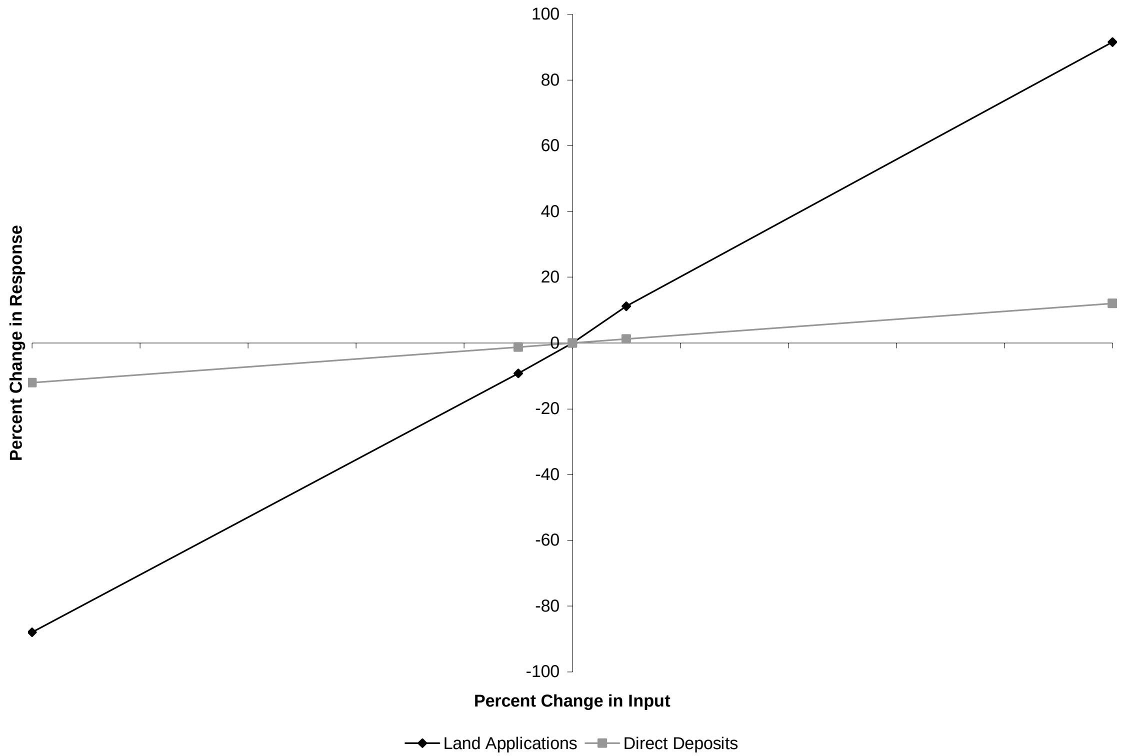

Figure 5.5 Total loading sensitivity to changes in direct and land-based loads for the Tinker Creek watershed.

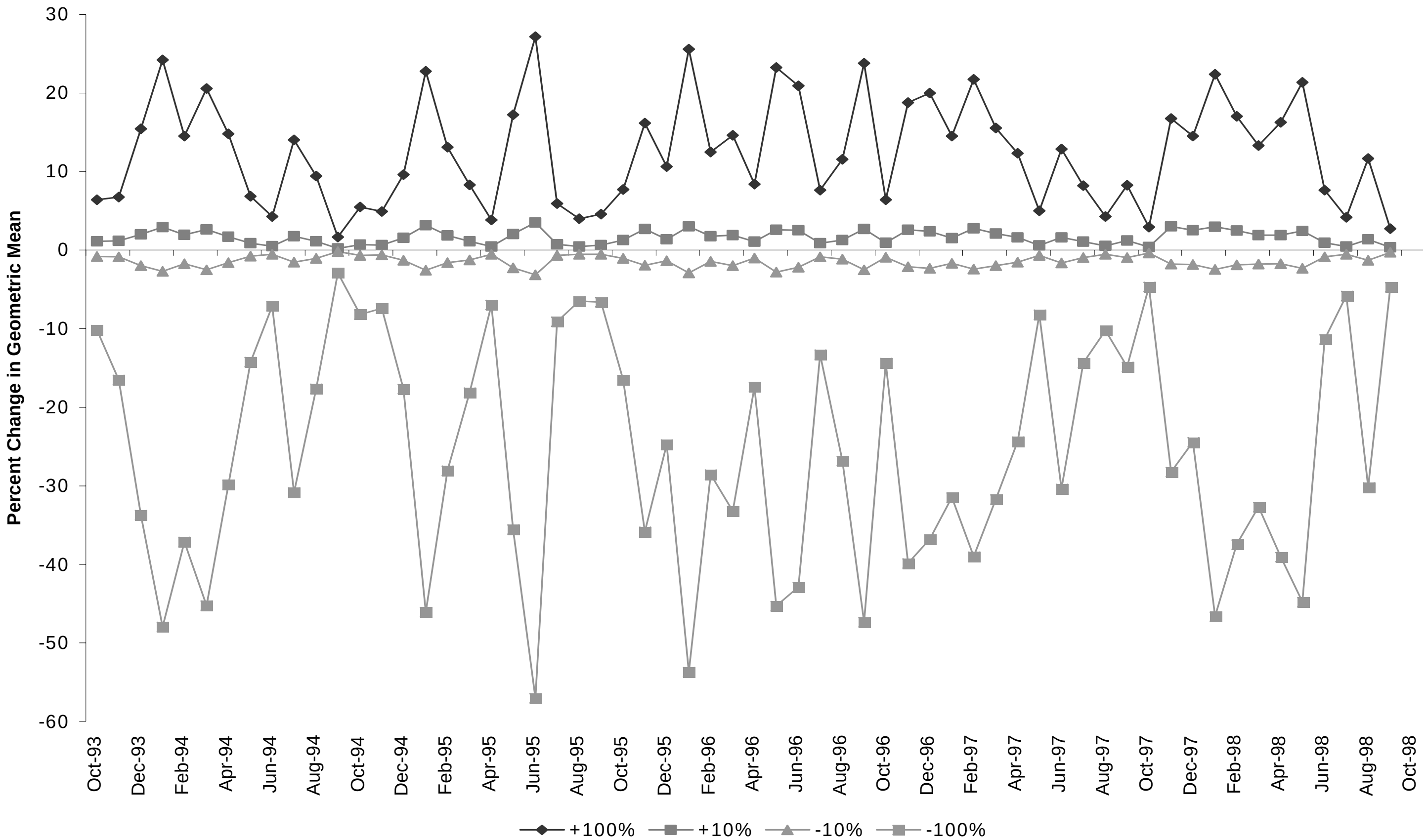

Figure 5.6 **Results of sensitivity analysis on monthly geometric-mean concentrations in the Tinker Creek watershed, as affected by changes in land-based loadings.**

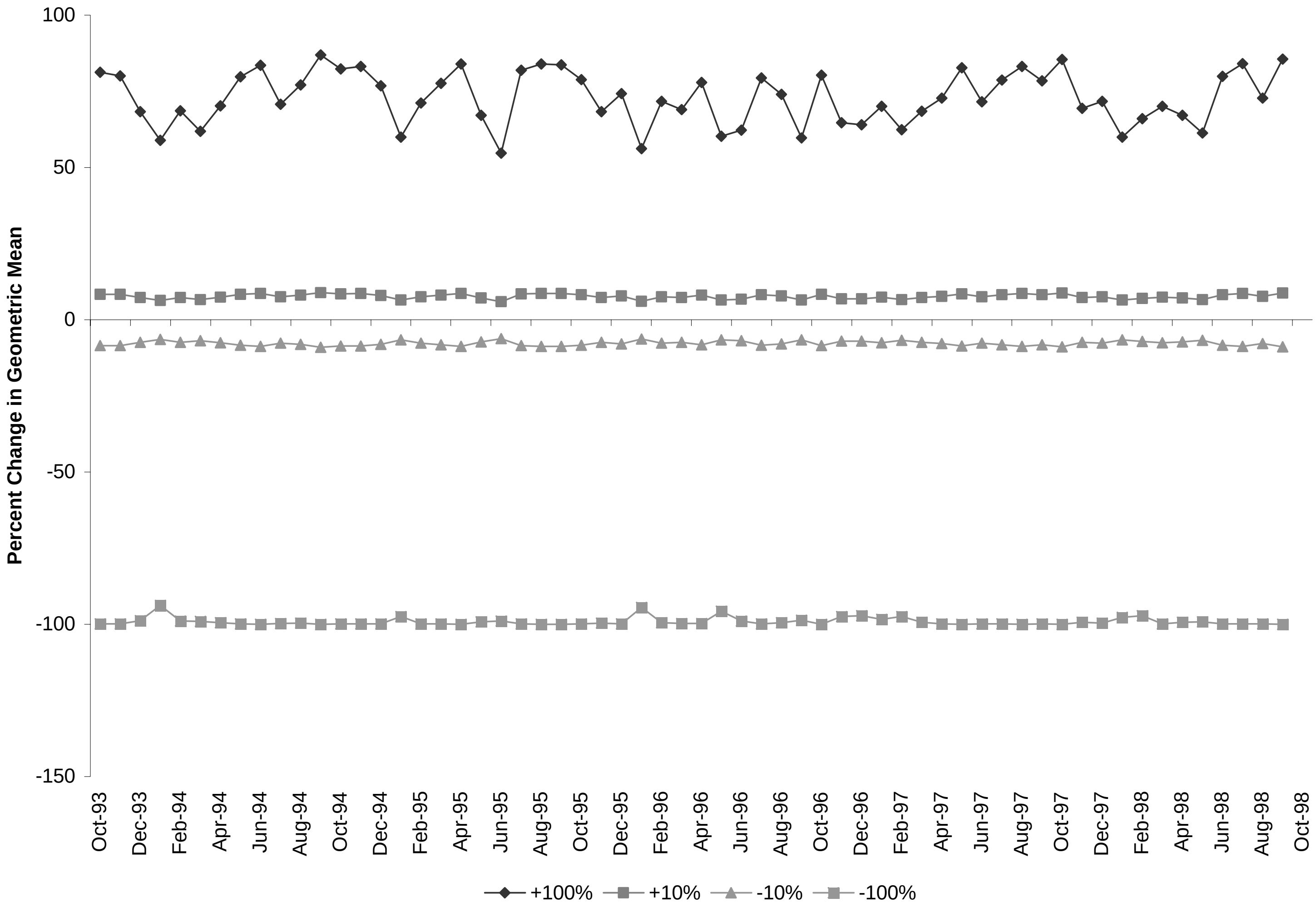

Figure 5.7 **Results of sensitivity analysis on monthly geometric-mean concentrations in the Tinker Creek watershed, as affected by changes in loadings from direct nonpoint sources.**

5.2 Incorporation of a Margin of Safety

An implicit margin of safety (MOS) was incorporated into the TMDL in an effort to account for scientific errors inherent to the TMDL development process, measurement uncertainty in model parameters, and to account for trends which might prevent the water quality goal, as targeted by the TMDL, from being achieved. Scientific errors arise from our inability to fully describe mathematically the processes and mechanisms through which pollutants are delivered to the stream. Model calibration is an attempt to address these errors through adjusting model parameters until a suitable fit to observed data is achieved. Measurement uncertainty also introduces errors in the model calibration, because model parameters that are adjusted to non-representative conditions result in model simulations being biased either low or high. For example, observed data used for model calibration were collected for the purpose of detecting violations of the state's water quality standards. As a result, sample analyses are arbitrarily censored at a level above the state standard. This introduces modeling uncertainty during events that produce high pollutant concentrations. The intention of an MOS in the development of a fecal coliform TMDL is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. A margin of safety can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. An implicit MOS was used in the development of this TMDL. By adopting an implicit MOS in estimating loads in the watershed, it is ensured that the recommended reductions will, in fact, succeed in meeting the water quality standard.

5.3 Scenario Development

Allocation scenarios were modeled using HSPF. Existing conditions were adjusted until the water quality standard was attained. The TMDLs developed for the Tinker Creek watershed were based on the Virginia State Standard for *E. coli*. As detailed in Section 1.2, the *E. coli* standard states that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml, and that a maximum single sample concentration of *E. coli* not exceed 235 cfu/100 ml. According to the guidelines put forth by the VADEQ (VADEQ, 2003) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation:

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

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

Pollutant concentrations were modeled over the entire duration of a representative modeling period, and pollutant loads were adjusted until the standard was met (Figures 5.8 through 5.17). The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the water quality target.

5.3.1 Wasteload Allocations

There are eight point sources currently permitted to discharge in the Tinker Creek watershed (Figure 3.1 and Table 3.1). Of these sources, only three are permitted for fecal control (Permit Nos. VAG402059, VAG402061 and VAG402063), and all three discharge into the Glade Creek impairment. For allocation runs, sources without fecal control permits were modeled as discharging the average recorded value of water, with no *E. coli*. The allocation for these sources is zero cfu/100 ml. The allocation for the sources permitted for fecal control is equivalent to their current permit levels (0.0005 MGD and 126 cfu/100 ml).

Within the Tinker Creek basin there are four Municipal Separate Storm Sewer System (MS4) permits requiring TMDL allocations (Table 5.16). Table 5.5 lists municipalities and receiving streams for these MS4 discharges. In allocating their TMDL, loads were based on each municipality's share of the contributing urbanized area of the impairment.

Table 5.5 Regulated small MS4 discharges in the Tinker Creek watershed.

Municipality	**Receiving Stream**
Roanoke County – VAR040022	Carvins Creek
	Deer Branch Creek
	Glade Creek
	Tinker Creek
	West Fork Carvins Creek
Roanoke City – VAR040004	Glade Creek
	Glade Creek X-Trib
	Lick Run
	Tinker Creek
	Tinker Creek X-Trib
	Trout Run
	West Fork Carvins Creek
Vinton, Town of – VAR040026	Glade Creek
	Tinker Creek
Botetourt County – VAR040023	Glade Creek
	Laymantown Creek
	Tinker Creek

5.3.2 Load Allocations

Load allocations to nonpoint sources are divided into land-based loadings from land uses and directly applied loads in the stream (*e.g.*, livestock, sewer overflows, and wildlife). Source reductions include those that are affected by both high and low flow conditions. Within this framework, however, initial criteria that influenced developing load allocations included how sources were linked for representing existing conditions, and results from BST in the area. Direct deposition nonpoint sources were modeled with consistent loadings to the stream regardless of flow regime and had a significant impact on low flow concentrations. BST during 2002-2003 sampling periods confirmed the presence of human, livestock and wildlife contamination.

Allocation scenarios were run in five parts, corresponding to the five impairments – Laymantown Creek, Glade Creek, Carvin Creek, Lick Run, and Tinker Creek. Tables 5.6 through 5.10 represent a small portion of the scenarios developed to determine the TMDL for each impairment. Scenario 1 in each table describes a baseline scenario that corresponds to the existing conditions in the watershed. Model results indicate that human, livestock, and in-stream depositions by wildlife are significant in all areas of the watershed. This is in agreement with the results of BST analysis presented in section 2.2.2.2.

Reduction scenarios exploring the role of anthropogenic sources in standards violations were explored first to determine the feasibility of meeting standards without wildlife reductions. Scenario 2 in each table contains reductions of 100% in all anthropogenic land-based loads, 100% reduction in sewer overflows and uncontrolled residential discharges, 100% reduction in direct livestock deposition and a 0% reduction in wildlife direct and land-based loading to the stream. In each case, the model predicts that water quality standards will not be met without reductions in wildlife loads.

Scenario 5 evaluates the impact of direct stream loads by eliminating 50% of direct deposition from wildlife, 100% of in-stream deposition by livestock, and 100% of sewer and straight-pipe discharges. All model segments show a large contribution to violations of the geometric mean standard by direct wildlife loadings, as well as being a source of instantaneous violations during dry periods. Land based loads also had a small impact on geometric mean standard, as well as dominating violations of the instantaneous standard during wet periods. As direct depositions from wildlife and livestock dominate the violations of the geometric mean standard, further scenarios all apply a reduction of 100% to livestock direct loadings, and progressively larger reductions in direct wildlife and land based loadings until both geometric mean and instantaneous standards are met. It may be noted that in the previous TMDLs that have outlined wildlife reductions in their allocation scenarios, there has not been a clear mechanism for achieving these allocations. However, emerging programs aimed at the control of urban wildlife such as the one enacted by the City of Roanoke (City of Roanoke, 2003) will represent at least one mechanism for achieving some of these reductions in the Tinker Creek watershed.

Scenario 5 in Table 5.6 for the Laymantown Creek segment shows that a 50% reduction in wildlife direct deposition, while sufficient to reduce instantaneous violations in dry periods substantially, is insufficient to make an impact on geometric mean standard violations. A 75% reduction in direct wildlife and all land based loads results in a substantial reduction in violations of the geometric mean standard, from 100% to 22%. A further reduction of 90% in all land-based categories brings the percentage of instantaneous violations down to 1%. Scenario 9 is the final TMDL scenario, and poses reductions of 92% in land-based wildlife deposition, and 95% reduction in anthropogenic land-based loads, and 88% in direct wildlife loads to achieve 0% violations of the instantaneous single sample standard. Due to the large proportion of woodlands in this segment, a final reduction of 88% for direct wildlife was required to meet the geometric mean standard.

Table 5.6 Allocation scenarios for bacterial concentration with current loading estimates in the Laymantown Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	100	77
2	0	0	100	100	100	100	100	73
3	0	100	100	100	100	100	100	68
4	20	20	75	75	75	100	100	69
5	50	0	100	0	0	100	100	37
6	75	75	100	75	75	100	22	3
7	75	90	100	90	90	100	22	1
8	80	90	100	90	90	100	1	0.60
9	88	92	100	95	95	100	0	0

The Glade Creek segment contains residential, agricultural, and wildlife sources contributing to standards violations, therefore scenarios 6, 7 and 8 of Table 5.7 explore equivalent reductions in all land-based loads. Scenario 7 shows that a 75% reduction in all land-based loads coupled with a 75% reduction in direct loading from wildlife will achieve a significant reduction in both geometric mean and instantaneous violations, bringing them down to 12% and 4% respectively. While a 90% reduction in land-based loads further reduces both instantaneous and geometric mean violations (due to the impact of land loads in smaller storm events), the model predicts that a final reduction of 96% of residential and agricultural land-based loads, 85% in direct wildlife, and 91% in land-based wildlife is needed to meet all water quality standards.

Table 5.7 Allocation scenarios for bacterial concentration with current loading estimates in the Glade Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	100	72
2	0	0	100	100	100	100	100	63
3	0	100	100	100	100	100	95	56
4	20	20	75	75	75	100	100	50
5	50	0	100	0	0	100	92	21
6	50	50	100	50	50	100	82	17
7	75	75	100	75	75	100	12	4
8	75	90	100	90	90	100	5	0.55
9	85	91	100	96	96	100	0	0

The Carvin Creek segment is a diverse segment, and requires significant reductions in all categories. Although woodland is by far the largest land-use, the impact of residential and urban land uses in the lower end can be seen, as significant reductions are required to human loads, and ultimately, reductions to direct wildlife loads were the smallest of all impaired segments in the Tinker Creek watershed as a whole. Scenario 7 in Table 5.8 shows that a 75% reduction in direct wildlife is sufficient to achieve the geometric mean standard. Scenario 8 explores a 90% reduction in all land-based loads, and achieves water quality standards. However, Scenario 9 predicts that the instantaneous standard can be achieved with reductions of 75% in direct wildlife, 90% in anthropogenic land sources, and a smaller reduction of 85% in wildlife land loads.

Table 5.8 Allocation scenarios for bacterial concentration with current loading estimates in the Carvin Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	93	21
2	0	0	100	100	100	100	67	11
3	0	100	100	100	100	100	55	7
4	20	20	75	75	75	100	43	6
5	50	0	100	0	0	100	13	7
6	50	0	100	0	100	100	13	5
7	75	75	100	75	75	100	0	0.33
8	75	90	100	90	90	100	0	0
9	75	85	100	90	90	100	0	0

The model scenarios for Lick Run shown in Table 5.9, while predicting a very significant role for wildlife in geometric mean standard violations, reflect the urban characteristics of this segment, and the subsequent dominance of residential and commercial land-based loads in instantaneous standards violations. Scenario 8 indicates that increasing the direct wildlife reduction from 50% to 75%, while holding all land-based reductions constant at 75%, reduces the geometric mean violations from 95% to 22%. The results of scenario 9 predict that a 99% reduction in residential and commercial land-based loads, a 91% reduction in agricultural loads, an 85% reduction in direct wildlife loads, and an 80% reduction in land-based wildlife loads will be sufficient to meet both water quality standards.

Table 5.9 Allocation scenarios for bacterial concentration with current loading estimates in the Lick Run impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	100	92
2	0	0	100	100	100	100	100	82
3	0	100	100	100	100	100	100	82
4	20	20	75	75	75	100	100	74
5	50	0	100	0	0	100	100	37
6	50	50	100	50	50	100	98	31
7	50	75	100	75	75	100	95	26
8	75	75	100	75	75	100	22	3
9	85	80	100	91	99	100	0	0

The runs in scenario Table 5.10 for the Tinker Creek impairment were performed with the upstream impairments of Lick Run, Laymantown Creek, Glade Creek, and Carvin Creek meeting both instantaneous and geometric mean water quality standards. The main stem of Tinker Creek contains significant agricultural lands in its headwaters (with pasture dominating), changing to a mixture of agricultural and woodland uses in its central portion, to predominantly urban types of land uses in its lower reaches. Significant reductions in the sources associated with all of these land uses will be required to meet water quality standards. Scenario 7 predicts that a reduction of 75% in direct wildlife deposition and in all land categories will be sufficient to meet the geometric mean standard; however, violations of the instantaneous standard are predicted to occur at a rate of 9%. Reducing all land-based loads by 90% brings the predicted instantaneous violations down to 5%. The final scenario shows that, in order to achieve 0% exceedences of the instantaneous standard, the following reductions are needed: 98% reduction in loads associated with urban land uses, 100% reduction in direct livestock loads, 99.8% reduction in loads from agricultural land uses, 75% reduction in direct wildlife loads, and 95% reduction in land-based wildlife loads.

Table 5.10 Allocation scenarios for bacterial concentration with current loading estimates in the Tinker Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	97	50
2	0	0	100	100	100	100	47	5
3	0	100	100	100	100	100	37	3
4	50	0	100	0	0	100	15	13
5	20	20	75	75	75	100	38	10
6	50	75	100	75	75	100	3	9
7	75	75	100	75	75	100	0	9
8	75	90	100	90	90	100	0	5
9	75	95	100	99.8	98	100	0	0

Figures 5.8 through 5.17 show graphically the existing and allocated conditions for the geometric-mean concentrations and instantaneous concentrations in each impairment.

Tables 5.11 through 5.15 indicate the land-based and direct load reductions resulting from the final allocation. Table 5.16 shows the final TMDL loads for all of the impairments.

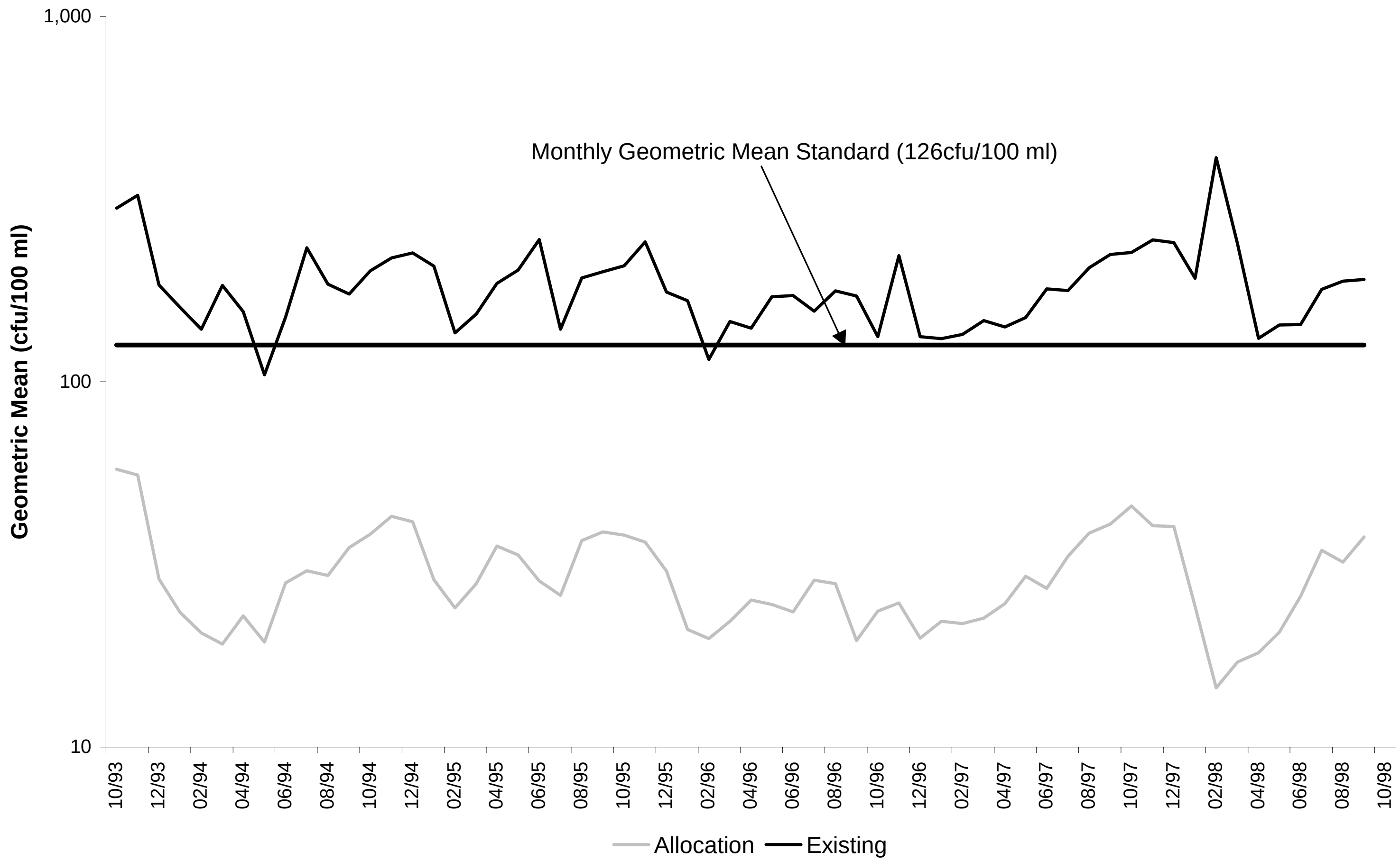

Figure 5.8 The monthly geometric mean standard (*E. coli)* of allocation and existing scenarios for the Tinker Creek impairment.

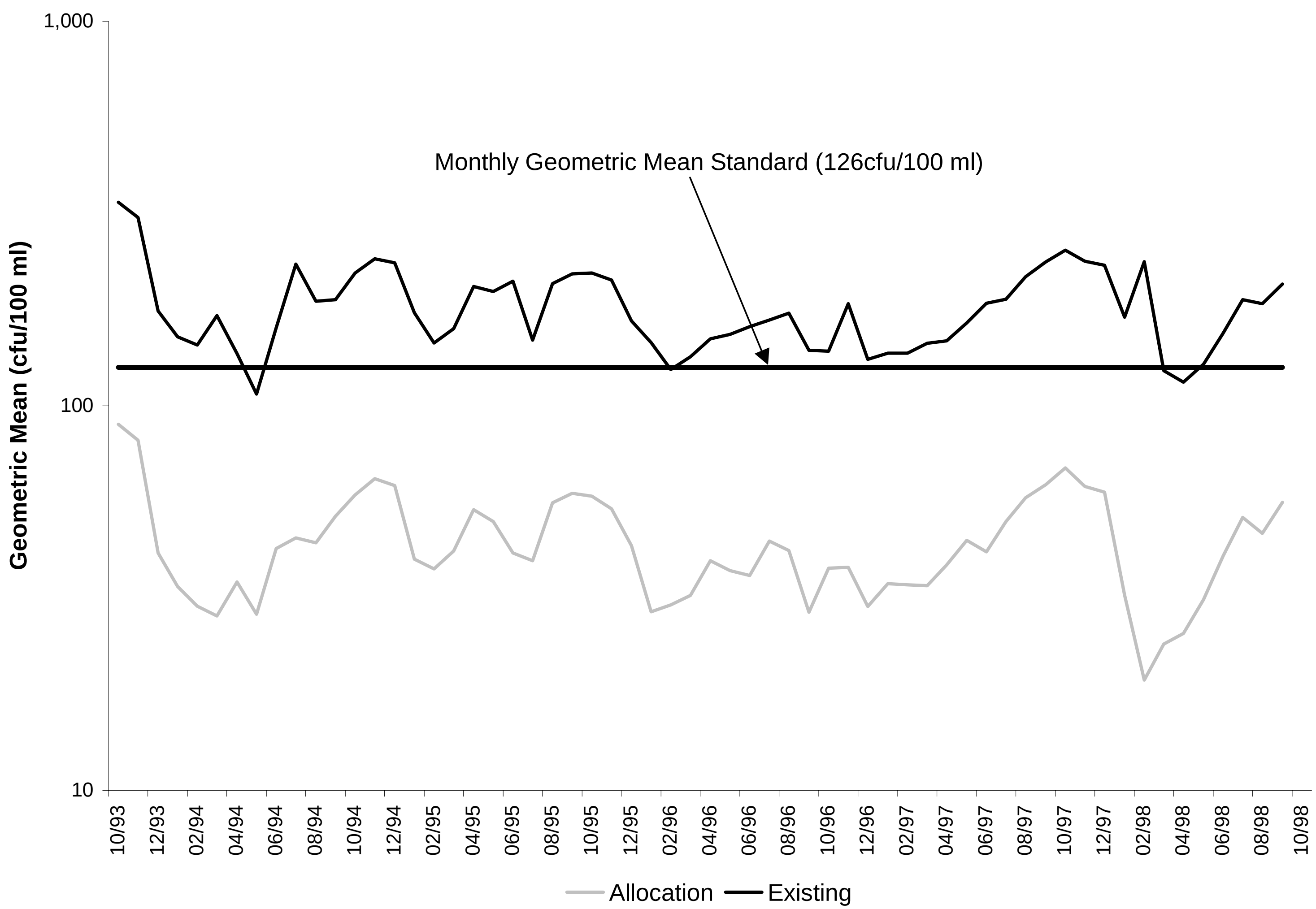

Figure 5.9 **The monthly geometric mean standard (*E. coli*) of allocation and existing scenarios for the Carvin Creek impairment.**

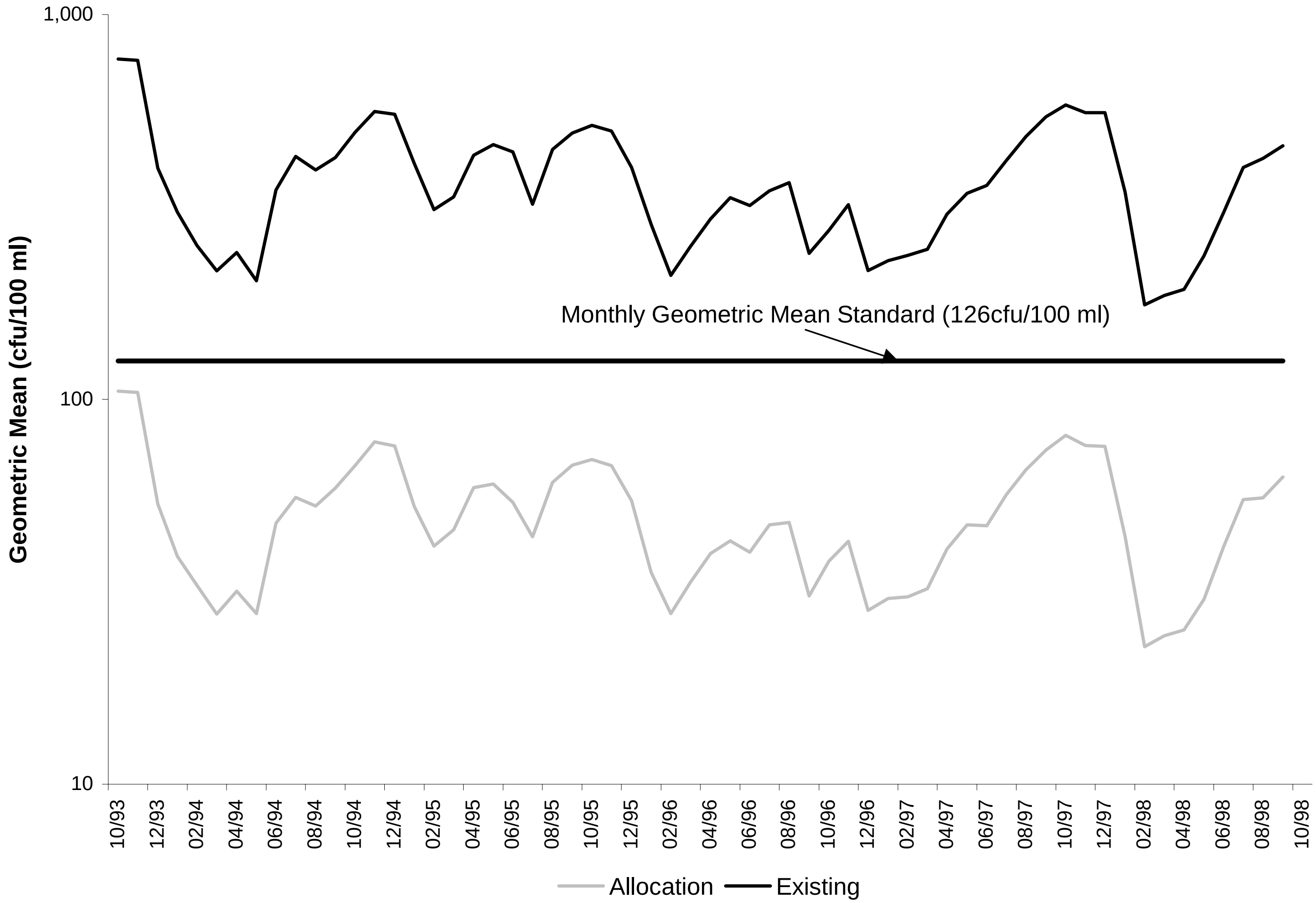

Figure 5.10 The monthly geometric mean standard (*E. coli)* of allocation and existing scenarios for the Laymantown Creek impairment.

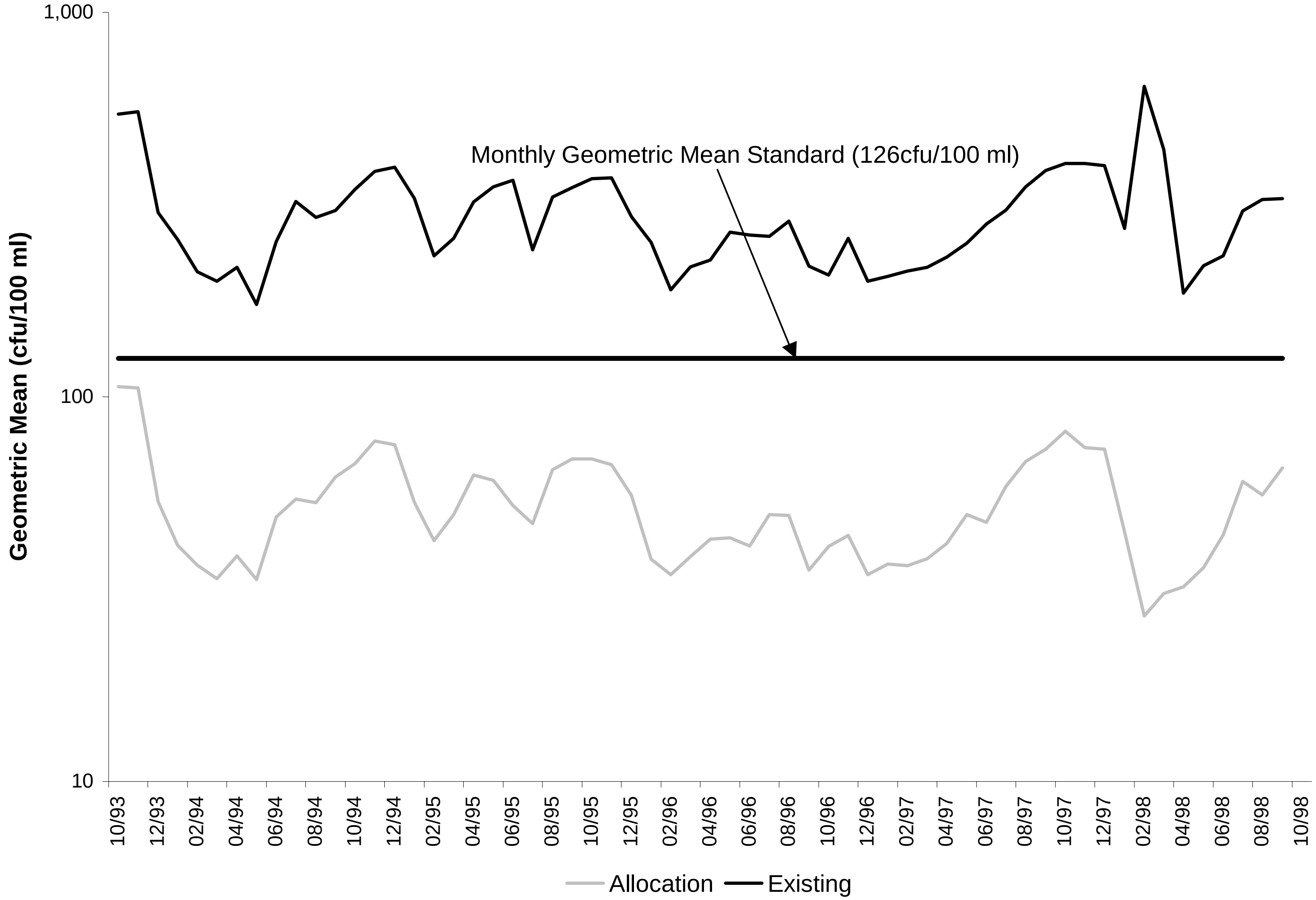

Figure 5.11 The monthly geometric mean standard (*E. coli)* of allocation and existing scenarios for the Glade Creek impairment.

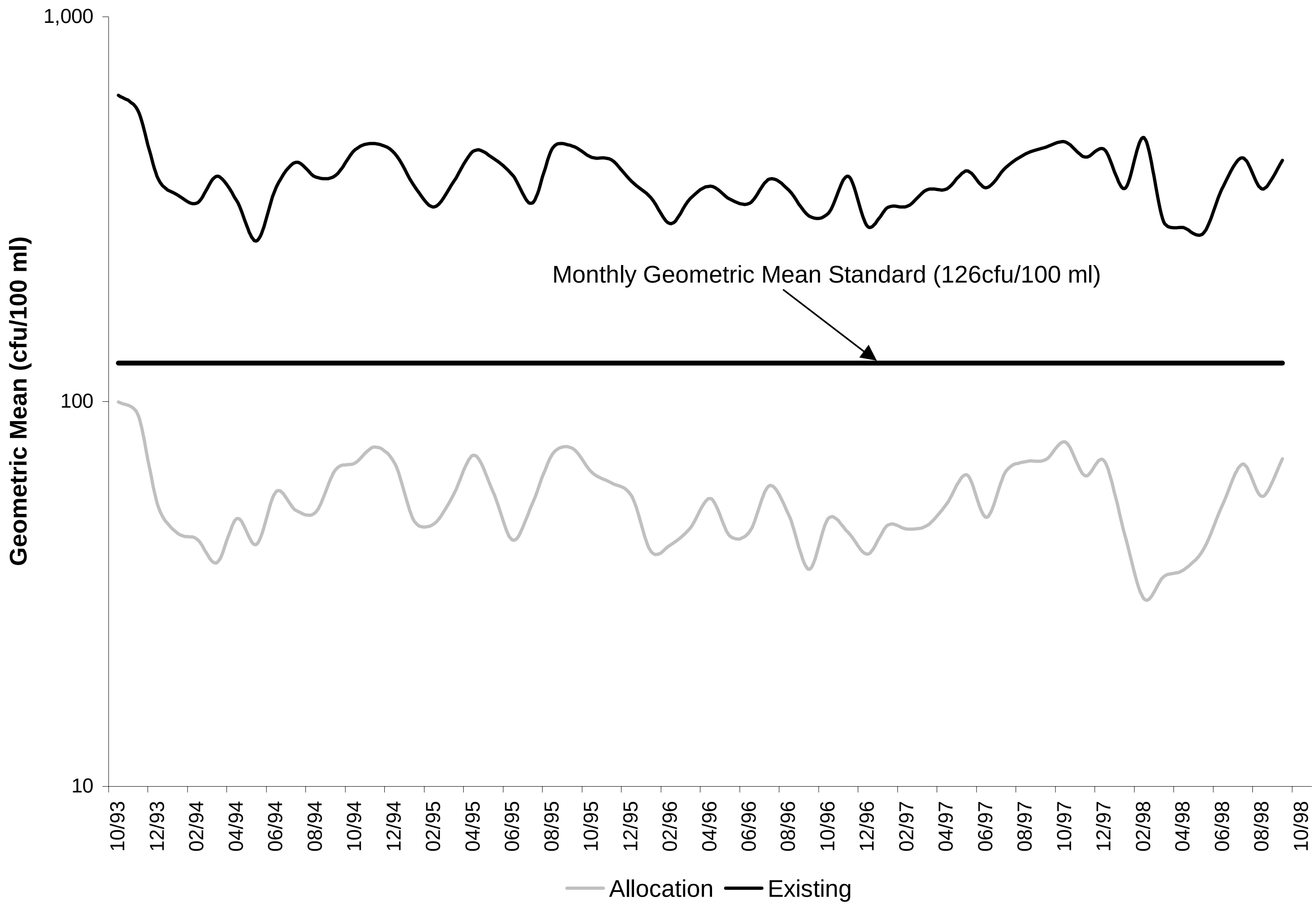

Figure 5.12 The monthly geometric mean standard (*E. coli*) of allocation and existing scenarios for the Lick Run impairment.

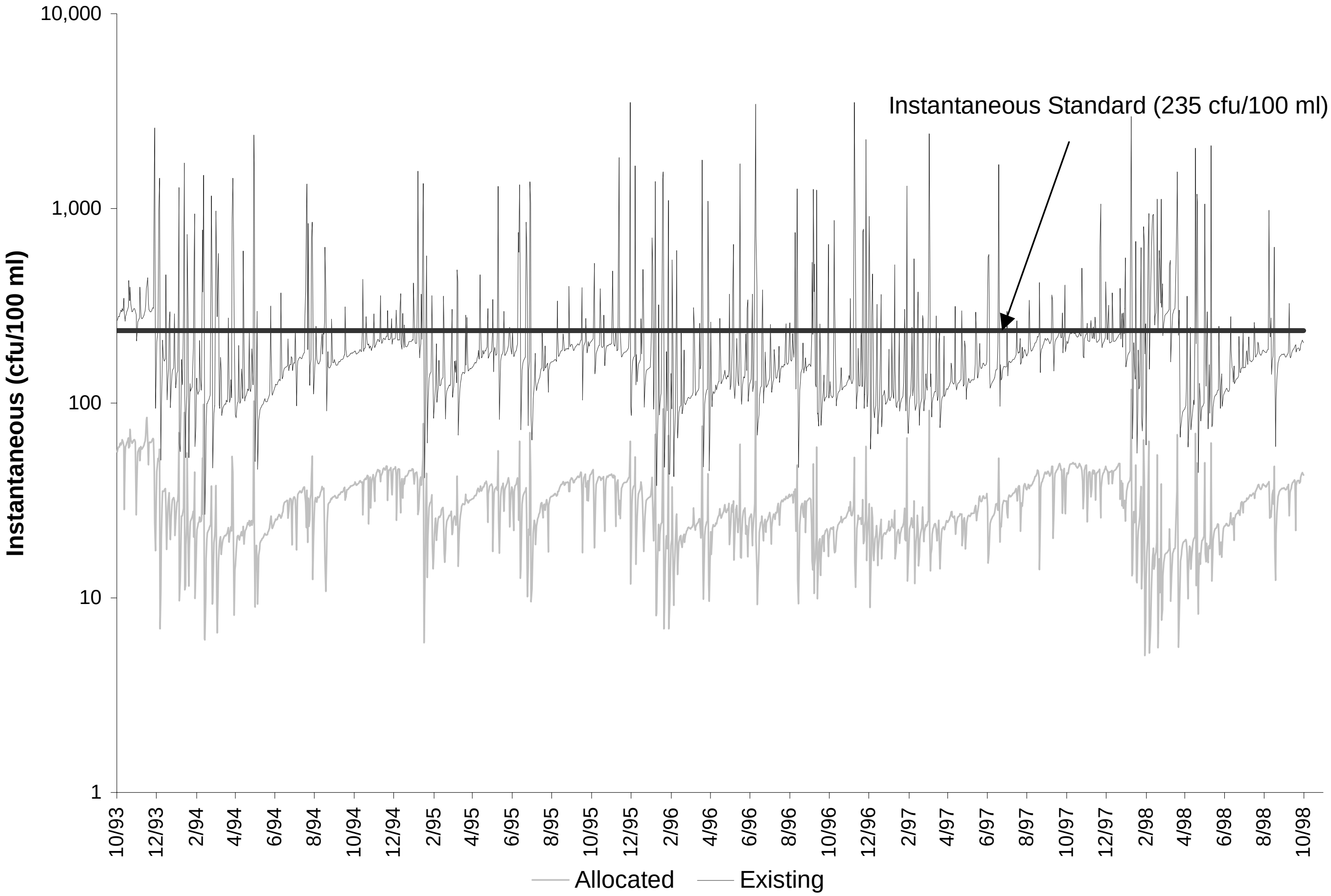

Figure 5.13 The instantaneous *E. coli* concentration of allocation and existing scenarios for the Tinker Creek impairment.

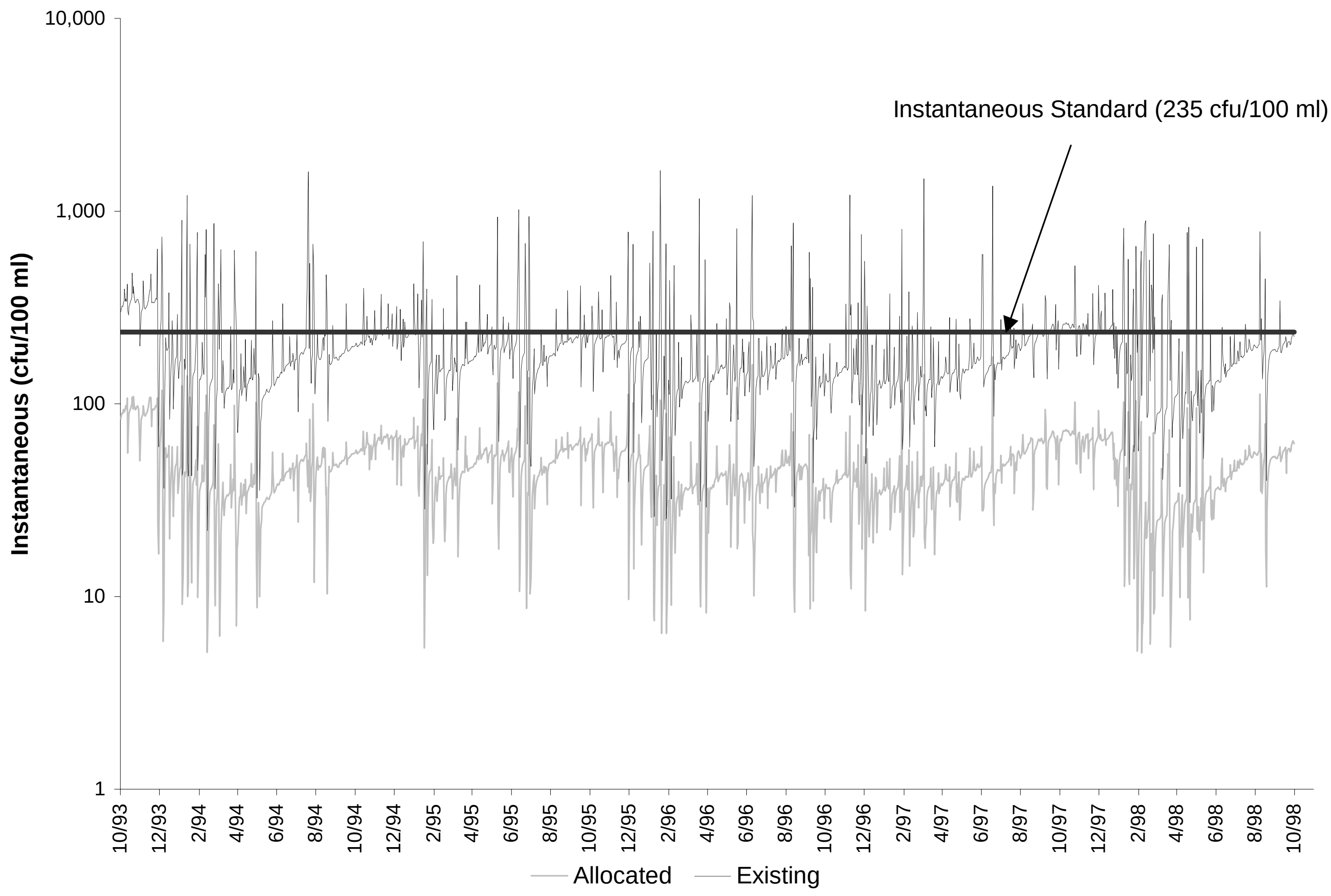

Figure 5.14 The instantaneous *E. coli* concentration of allocation and existing scenarios for the Carvin Creek impairment.

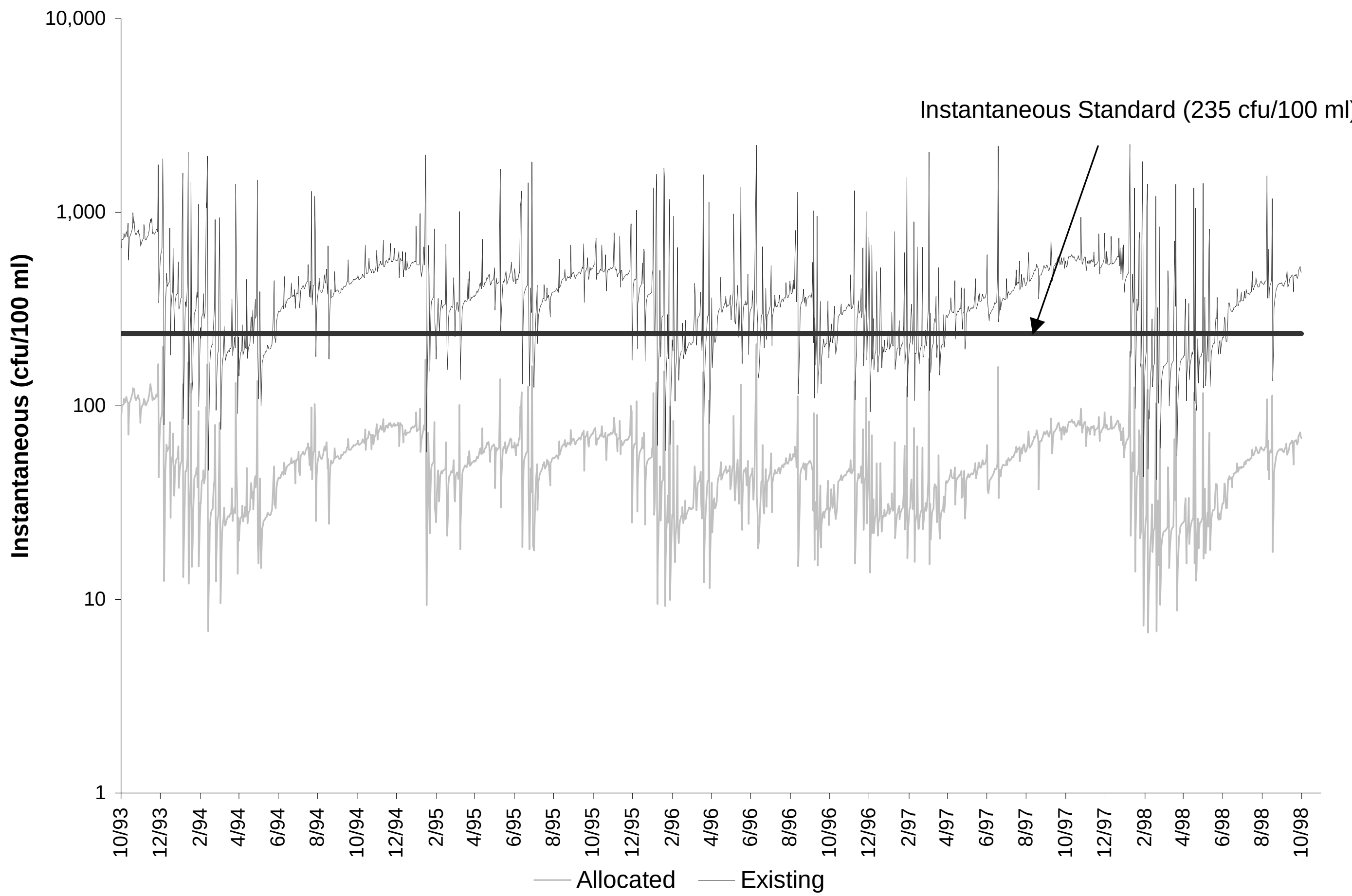

Figure 5.15 The instantaneous *E. coli* concentration of allocation and existing scenarios for the Laymantown Creek impairment.

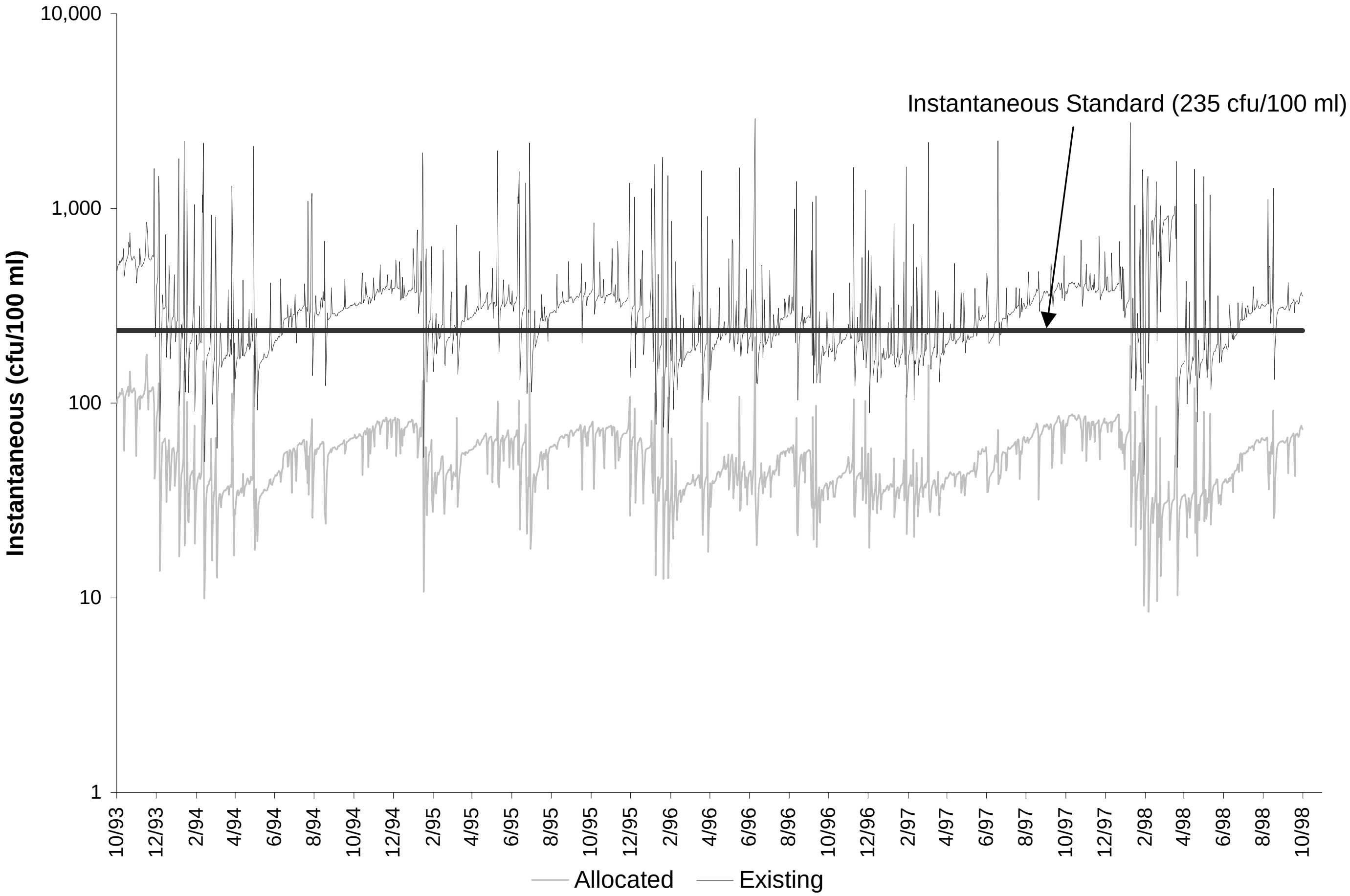

Figure 5.16 The instantaneous *E. coli* concentration of allocation and existing scenarios for the Glade Creek impairment.

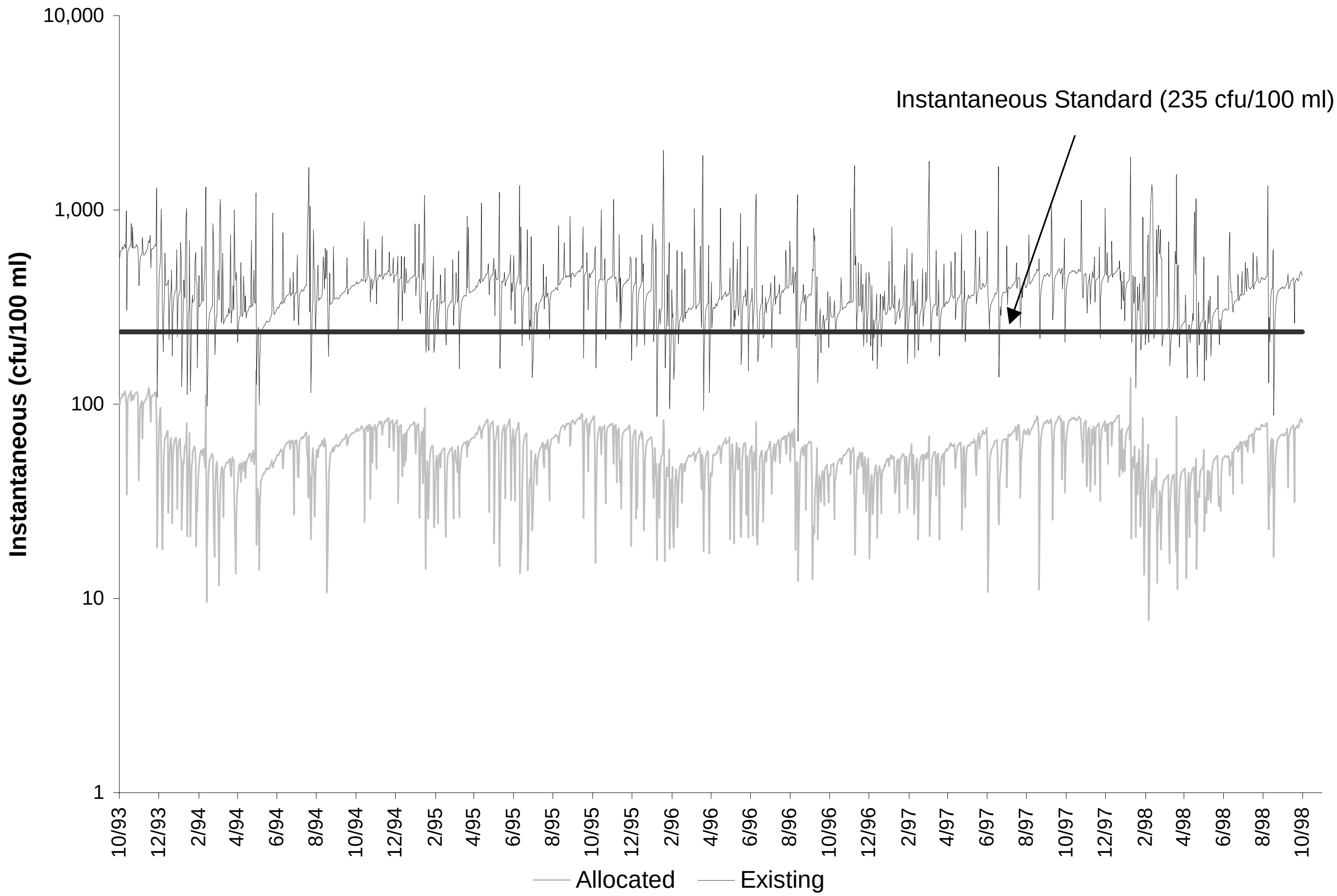

Figure 5.17 The instantaneous *E. coli* concentration of allocation and existing scenarios for the Lick Run impairment.

Table 5.11 Land-based and Direct nonpoint source load reductions in the Laymantown Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Barren	3.45E+12	1.73E+11	95
Commercial	1.36E+12	6.80E+10	95
Cropland	3.72E+12	1.86E+11	95
Forest	4.00E+14	3.20E+13	92
Livestock Access	7.23E+12	3.62E+11	95
Low Residential	9.75E+13	4.88E+12	95
Pasture	1.86E+14	9.30E+12	95
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	4.56E+11	0.00E+00	100
Wildlife	2.50E+13	3.00E+12	88
Straight Pipes and Sewer Overflows	4.29E+11	0.00E+00	100

Table 5.12 Land-based and Direct nonpoint source load reductions in the Glade Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land-Based			
Barren	3.66E+13	1.46E+12	96
Commercial	9.96E+13	3.98E+12	96
Cropland	2.07E+13	8.28E+11	96
Forest	1.96E+15	1.76E+14	91
Livestock Access	5.00E+13	2.00E+12	96
Low Residential	8.07E+14	3.23E+13	96
Pasture	1.31E+15	5.24E+13	96
Water	0.00E+00	0.00E+00	0
Wetlands	8.86E+11	7.97E+10	91
Direct			
Livestock	5.50E+12	0.00E+00	100
Wildlife	1.40E+14	2.10E+13	85
Straight Pipes and Sewer Overflows	1.47E+13	0.00E+00	100

Table 5.13 Land-based and Direct nonpoint source load reductions in the Carvin Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land-Based			
Barren	1.77E+13	1.77E+12	90
Commercial	1.02E+14	1.02E+13	90
Cropland	4.80E+12	4.80E+11	90
Forest	2.59E+15	3.89E+14	85
High Residential	2.30E+13	2.30E+12	90
Livestock Access	1.43E+13	1.43E+12	90
Low Residential	6.23E+14	6.23E+13	90
Pasture	2.87E+14	2.87E+13	90
Water	0.00E+00	0.00E+00	0
Wetlands	2.63E+12	3.95E+11	85
Direct			
Livestock	3.65E+11	0.00E+00	100
Wildlife	1.36E+14	3.40E+13	75
Straight Pipes and Sewer Overflows	3.84E+13	0.00E+00	100

Table 5.14 Land-based and Direct nonpoint source load reductions in the Lick Run impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land-Based			
Commercial	3.37E+14	3.37E+12	99
Cropland	1.32E+12	1.19E+11	91
Forest	1.25E+14	2.50E+13	80
High Residential	1.05E+14	1.05E+12	99
Livestock Access	1.73E+12	1.56E+11	91
Low Residential	1.03E+15	1.03E+13	99
Pasture	9.59E+13	8.63E+12	91
Water	0.00E+00	0.00E+00	0
Wetlands	4.54E+11	9.08E+10	80
Direct			
Livestock	0.00E+00	0.00E+00	100
Wildlife	5.34E+13	8.01E+12	85
Straight Pipes and Sewer Overflows	1.40E+13	0.00E+00	100

Table 5.15 Land-based and Direct nonpoint source load reductions in the Tinker Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Barren	6.30E+12	1.26E+11	98
Commercial	3.00E+12	6.00E+10	98
Cropland	2.92E+15	5.84E+12	99.8
Forest	3.45E+14	1.73E+13	95
High Residential	1.40E+13	2.80E+11	98
Livestock Access	7.28E+13	1.46E+11	99.8
Low Residential	6.53E+14	1.31E+13	98
Pasture	1.65E+15	3.30E+12	99.8
Water	0.00E+00	0.00E+00	0
Wetlands	1.14E+12	5.70E+10	95
Direct			
Livestock	2.26E+13	0.00E+00	100
Wildlife	4.11E+12	1.03E+12	75
Straight Pipes and Sewer Overflows	8.38E+13	0.00E+00	100

Table 5.16 Average annual *E. coli* loads (cfu/year) modeled after TMDL allocation in the Laymantown Creek, Glade Creek, Carvin Creek, Lick Run, and Tinker Creek watersheds.

Impairment	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Laymantown Creek	4.36E+11	6.15E+12	Implicit	6.58E+12
Botetourt County - VAR040023[1]	*4.36E+11*			
Glade Creek	4.00E+11	4.20E+13		4.24E+13
Vinton – VAR040026[1]	*8.78E+10*			
Roanoke County – VAR040022[1]	*8.02E+10*			
Roanoke City – VAR040004[1]	*1.13E+11*			
Botetourt County – VAR040023[1]	*1.19E+11*			
VAG402059[2]	*1.10E+10*			
VAG402061[2]	*1.10E+10*			
VAG402063[2]	*1.10E+10*			
Carvin Creek	5.24E+12	2.61E+13		3.14E+13
Roanoke County – VAR040022[1]	*4.07E+12*			
Roanoke City – VAR040004[1]	*1.04E+12*			
Botetourt County - VAR040023[1]	*1.28E+11*			
Lick Run	7.17E+10	1.31E+13		1.31E+13
Roanoke County – VAR040022[1]	*3.29E+09*			
Roanoke City – VAR040004[1]	*6.84E+10*			
Tinker Creek	5.07E+12	7.56E+13		8.07E+13
Vinton - VAR040026[1]	*3.42E+11*			
Roanoke County – VAR040022[1]	*5.36E+11*			
Roanoke City – VAR040004[1]	*2.24E+12*			
Botetourt County - VAR040023[1]	*1.95E+12*			

[1] MS4 permits
[2] General permits

6. 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 bacteria impairments on Tinker 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 *Guidance Manual for Total Maximum Daily Load Implementation Plans*, 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.

6.1 Staged Implementation

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

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

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

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

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

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

6.2 Stage 1 Scenarios

The goal of the Stage 1 scenarios is to reduce the bacteria loadings from controllable sources, excluding wildlife. The Stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios.

As presented in Chapter 5, scenarios were devised assuming reductions of 100% in all anthropogenic land-based loads, 100% reduction in sewer overflows and uncontrolled residential discharges, 100% reduction in direct livestock deposition, and a 0% reduction in wildlife direct and land-based loading to the stream. For all impairments, the model predicted violations of the water quality standards.

The Stage I water quality goal was to reduce the number of violations of the instantaneous standard in the main stem of Tinker Creek to less than 10%. Table 6.1 contains a set of reductions in land-based and direct loads that are projected to achieve this goal, along with a projected percent of violation occurrence. The Stage I allocation requires a 100% reduction in loads from sewer overflows and uncontrolled residential discharges (straight pipes), a 75% reduction in direct in-stream loads from livestock and land-based loads from urban and agricultural sources, and a 20% reduction in all wildlife loads. It is important to note that the Glade Creek impairment is fed by Laymantown Creek, and that the Tinker Creek impairment is fed by the Carvin, Glade, and Lick Run stream segments. The reduction values given for Glade Creek and Tinker Creek impairments assume that the recommended reductions in contributing streams have also been met.

Table 6.1 Reduction percentages for the Stage I implementation.

Impairment Name	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture / Livestock Access/ Cropland	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	% Single Samples Exceeding 235 cfu/ 100ml
Laymantown Creek	20	20	75	75	75	100	69.0
Lick Run	20	20	75	75	75	100	74.4
Glade Creek	20	20	75	75	75	100	49.8
Carvin Creek	20	20	75	75	75	100	5.9
Tinker Creek	20	20	75	75	75	100	9.6

Tables 6.2 through 6.6 detail the load reductions required to meet the Stage I Implementation.

Table 6.2 Nonpoint source allocations in the Tinker Creek impairment for Stage I implementation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land-Based			
Barren	6.30E+12	1.58E+12	75
Commercial	3.00E+12	7.50E+11	75
Cropland	2.92E+15	7.30E+14	75
Forest	3.45E+14	2.76E+14	20
High Residential	1.40E+13	3.50E+12	75
Livestock Access	7.28E+13	1.82E+13	75
Low Residential	6.53E+14	1.63E+14	75
Pasture	1.65E+15	4.13E+14	75
Water	0.00E+00	0.00E+00	0
Wetlands	1.14E+12	9.12E+11	20
Direct			
Livestock	2.26E+13	5.65E+12	75
Wildlife	4.11E+12	3.29E+12	20
Straight Pipes and Sewer Overflows	8.38E+13	0.00E+00	100

Table 6.3 Nonpoint source allocations in the Carvin Creek impairment for Stage I implementation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land-Based			
Barren	1.77E+13	4.43E+12	75
Commercial	1.02E+14	2.55E+13	75
Cropland	4.80E+12	1.20E+12	75
Forest	2.59E+15	2.07E+15	20
High Residential	2.30E+13	5.75E+12	75
Livestock Access	1.43E+13	3.58E+12	75
Low Residential	6.23E+14	1.56E+14	75
Pasture	2.87E+14	7.18E+13	75
Water	0.00E+00	0.00E+00	0
Wetlands	2.63E+12	2.10E+12	20
Direct			
Livestock	3.65E+11	9.13E+10	75
Wildlife	1.36E+14	1.09E+14	20
Straight Pipes and Sewer Overflows	3.84E+13	0.00E+00	100

Table 6.4 Nonpoint source allocations in the Laymantown Creek impairment for Stage I implementation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Barren	3.45E+12	8.63E+11	75
Commercial	1.36E+12	3.40E+11	75
Cropland	3.72E+12	9.30E+11	75
Forest	4.00E+14	3.20E+14	20
Livestock Access	7.23E+12	1.81E+12	75
Low Residential	9.75E+13	2.44E+13	75
Pasture	1.86E+14	4.65E+13	75
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	4.56E+11	1.14E+11	75
Wildlife	2.50E+13	2.00E+13	20
Straight Pipes and Sewer Overflows	4.29E+11	0.00E+00	100

Table 6.5 Nonpoint source allocations in the Glade Creek impairment for Stage I implementation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Barren	3.66E+13	9.15E+12	75
Commercial	9.96E+13	2.49E+13	75
Cropland	2.07E+13	5.18E+12	75
Forest	1.96E+15	1.57E+15	20
Livestock Access	5.00E+13	1.25E+13	75
Low Residential	8.07E+14	2.02E+14	75
Pasture	1.31E+15	3.28E+14	75
Water	0.00E+00	0.00E+00	0
Wetlands	8.86E+11	7.09E+11	20
Direct			
Livestock	5.50E+12	1.38E+12	75
Wildlife	1.40E+14	1.12E+14	20
Straight Pipes and Sewer Overflows	1.47E+13	0.00E+00	100

Table 6.6 Nonpoint source allocations in the Lick Run impairment for Stage I implementation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Commercial	3.37E+14	8.43E+13	75
Cropland	1.32E+12	3.30E+11	75
Forest	1.25E+14	1.00E+14	20
High Residential	1.05E+14	2.63E+13	75
Livestock Access	1.73E+12	4.33E+11	75
Low Residential	1.03E+15	2.58E+14	75
Pasture	9.59E+13	2.40E+13	75
Water	0.00E+00	0.00E+00	0
Wetlands	4.54E+11	3.63E+11	20
Direct			
Livestock	0.00E+00	0.00E+00	75
Wildlife	5.34E+13	4.27E+13	20
Straight Pipes and Sewer Overflows	1.40E+13	0.00E+00	100

The development of the implementation plan is expected to be an iterative process, with monitoring data refining its final design. Subsequent refinements will be made as the progress toward meeting milestones and the expressed TMDL goals is assessed. As practices are implemented, periodic analyses of water quality conditions will be conducted to evaluate the progress toward meeting end goals.

6.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will be integrated into on-going water quality improvement efforts aimed at restoring water quality in Tinker Creek and the Roanoke River basin. Several BMPs known to be effective in controlling bacteria have also been identified for implementation as part of this effort. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of a nonpoint source implementation strategy.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-up Monitoring

VADEQ will continue monitoring the Tinker Creek watershed in accordance with its ambient watershed monitoring program to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards.

The monitoring station on Tinker Creek (4ATKR000.69) is a trend station and will continue to be monitored on a bi-monthly basis. Watershed monitoring stations are designed to provide complete, census-based coverage of every watershed in Virginia. Two of the major data users in the Commonwealth (the Department of Environmental Quality and the Department of Conservation and Recreation) have indicated that this is an important function for ambient water quality monitoring.

Watershed stations are located at the mouth and within the watershed, based on a census siting scheme. The number of stations in the watershed is determined by the NPS priority ranking thus focusing our resources on known problem areas. Watersheds are monitored on a rotating basis such that, in the 6-year assessment cycle, all 493 watersheds are monitored. These stations will be sampled at a frequency of once every other month for a two-year period on a 6-year rotating basin basis.

6.4.2 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 plan, which will also be supported by the regional and local offices of VADEQ, VADCR, and other cooperating agencies.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP) in accordance with the CWA'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.

6.4.3 Stormwater Permits

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is the 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 National Pollutant Discharge Elimination System (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 Tinker Creek watershed is covered by Phase II VPDES permits VAR040004, VAR040022, VAR040023, and VAR040026 for the small municipal separate storm sewer systems (MS4s) owned by the City of Roanoke, County of Roanoke, County of Botetourt and the Town of Vinton, respectively. City of Roanoke (VAR040004) permit was issued on March 26, 2003. The effective date of coverage is December 9, 2002 until December 9, 2007. County of Roanoke (VAR040022) permit was issued on April 28,

2003. The effective date of coverage is April 28, 2003 until December 9, 2007. County of Botetourt (VAR040023) permit was issued on May 5, 2003. The effective date of coverage is December 9, 2002 until December 9, 2007. Town of Vinton (VAR040026) permit was issued on May 14, 2003. The effective date of coverage is December 9, 2002 until December 9, 2007. The permits state, 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 6.4.5 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 Tinker 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.

6.4.4 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.

6.4.5 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 Tinker 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.**

Although previous TMDLs for the Commonwealth have not addressed wildlife reductions in first stage goals, the city of Roanoke has already introduced wildlife management practices. 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 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 were approved by EPA and became effective in February 2004. Additional information 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 6.1 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.

7. PUBLIC PARTICIPATION

The development of the Tinker Creek TMDLs greatly benefited from public participation. Table 7.1 details the public participation throughout the project. The government kickoff meeting took place on February 12, 2003 at the VADEQ office in Roanoke with 18 people (2 from non-profit environmental groups and 16 government agents) attending. The kickoff meeting was publicized through direct mailing to local government agencies.

The first public meeting was held at Hollins University in Roanoke on June 24, 2003 to discuss the process for TMDL development; 35 people (16 citizens and 19 government agents) attended. Copies of the presentation materials were available for public distribution. The meeting was public noticed in the *Virginia Register* and letters were sent to over 1,000 property owners (residents and businesses) located at or near the impaired creeks. In addition, email notices were sent to all local environmental groups. There was a 30 day-public comment period and no written comments were received.

The second public meeting was held at Hollins University in Roanoke on December 16, 2003 to discuss the source assessment input, BST, and model calibration data; 21 (4 citizens and 17 government agents) people attended. Copies of the presentation materials were available for public distribution. The meeting was public noticed in the *Virginia Register* and publicized via direct mail to everyone who had attended either of the first two meetings, local elected officials, local government staff, and local environmental groups. A notice was placed on the local access cable network and an article also appeared in *Environmental News from the City of Roanoke*. In addition, an article featuring the Tinker Creek TMDL was printed in the *Roanoke Times* prior to the final public meeting on December 16, 2003. There was a 30 day-public comment period and no comments were received.

Table 7.1 Public participation during TMDL development for the Tinker Creek watershed.

Date	Location	Attendance[1]	Format
2/12/03	VADEQ office 3019 Peters Creek Road Roanoke, VA	18	Publicized to govt agencies, open to public at large
6/24/03	Hollins University 7916 Williamson Road Roanoke, VA	35	Open to public at large
12/16/03	Hollins University 7916 Williamson Road Roanoke, VA	21	Open to public at large

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

Public participation during the implementation plan development process will include the formation of stakeholders' committee and open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders' committee will have the expressed purpose of formulating the TMDL implementation plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from the Department of Environmental Quality, Department of Conservation and Recreation, Department of Health, local agricultural community, local urban community, and local governments. This committee will have responsibility for identifying corrective actions that are founded in practicality, establish a time line to insure expeditious implementation, and set measurable goals and milestones for attaining water quality standards.

APPENDIX A

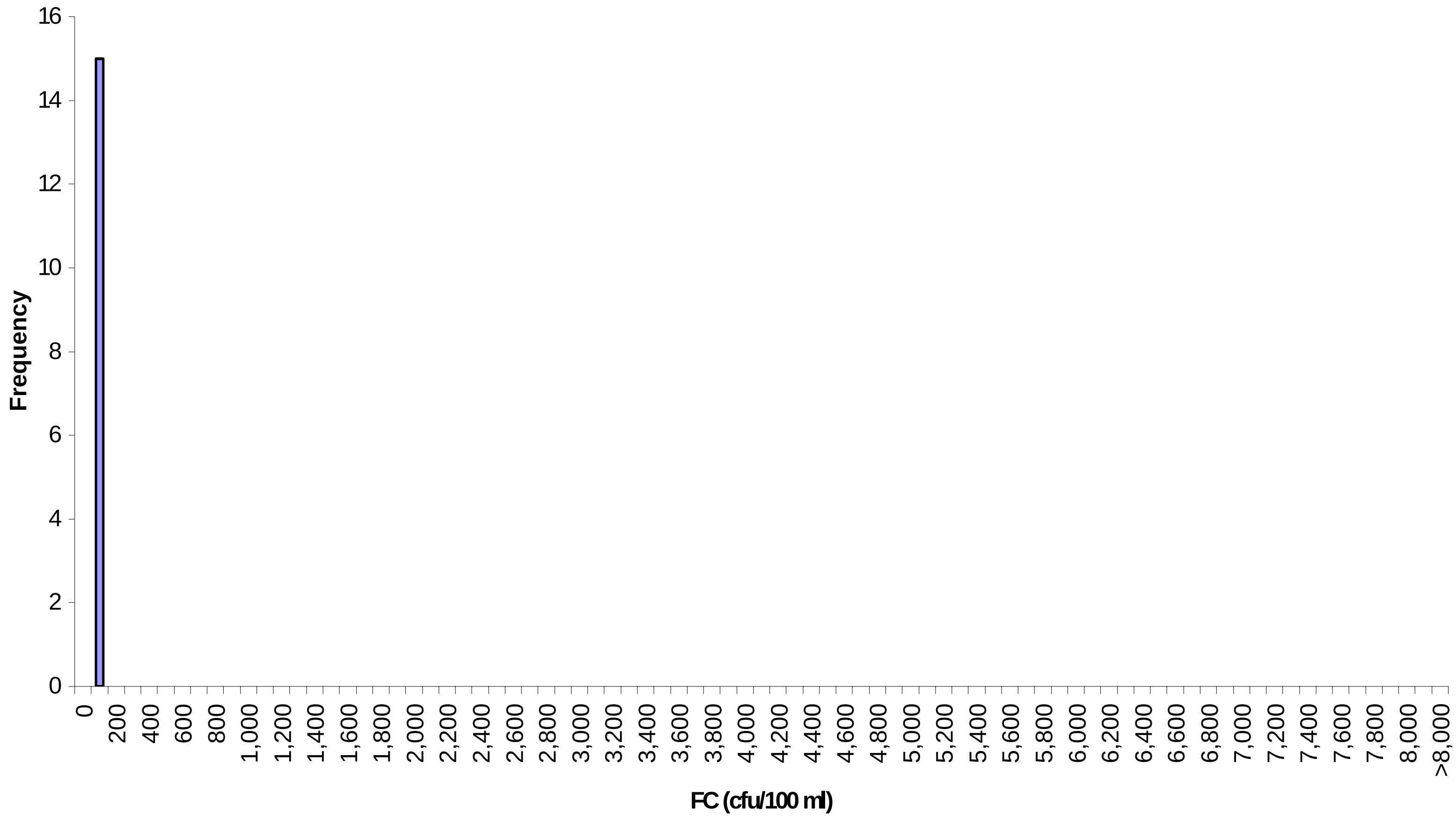

Figure A.1 **Frequency analysis of fecal coliform concentrations at station 4ACRV006.19 in the Tinker Creek impairment for period June 1977 and May 1999 to October 2000.**

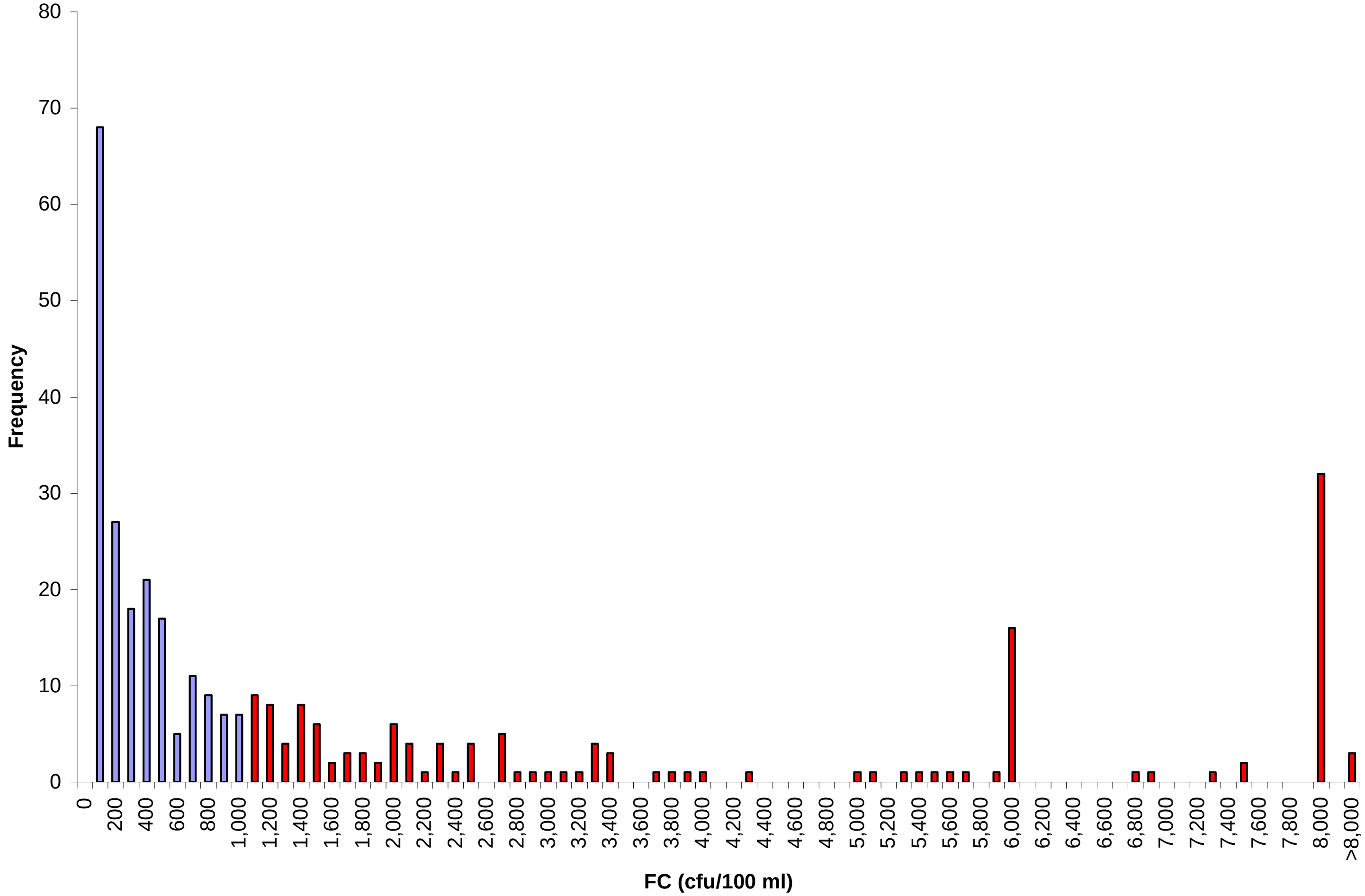

Figure A.2 Frequency analysis of fecal coliform concentrations at station 4ATKR000.69 in the Tinker Creek impairment for period November 1970 to December 2002.

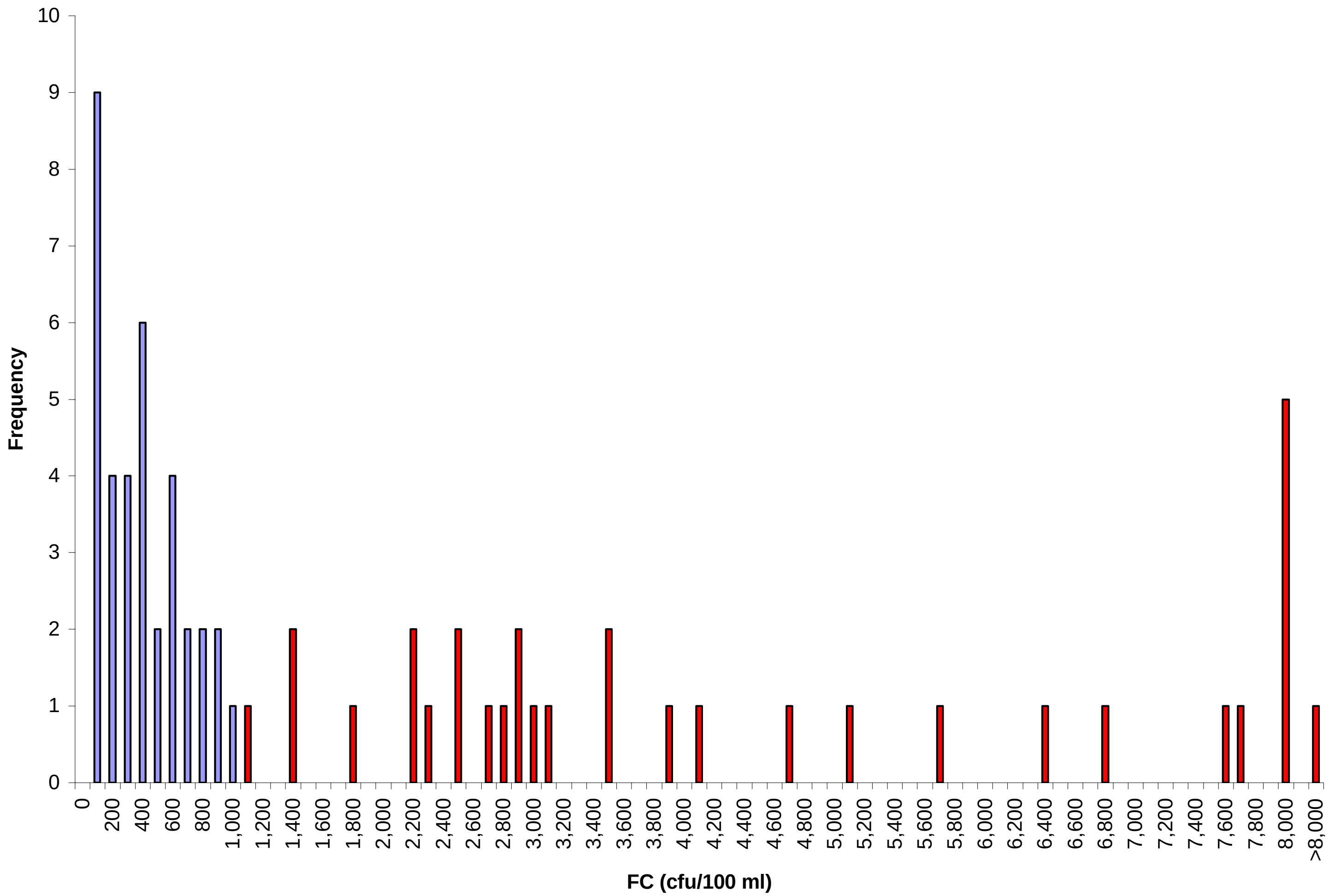

Figure A.3 Frequency analysis of fecal coliform concentrations at station 4ALCK000.38 in the Tinker Creek impairment for period November 1988 to December 2002.

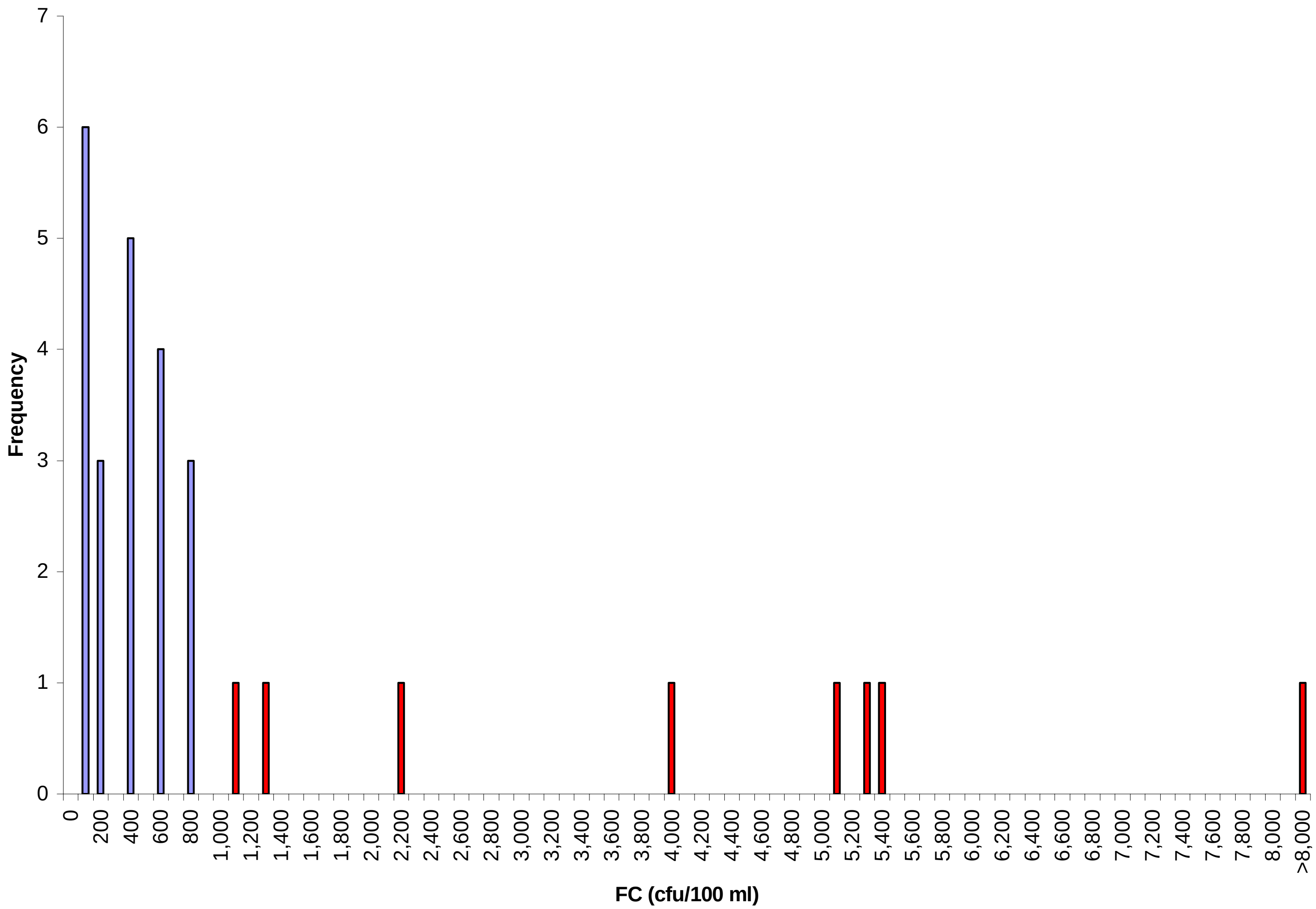

Figure A.4 Frequency analysis of fecal coliform concentrations at station 4AGLA000.20 in the Tinker Creek impairment for period August 1988 to June 1994 and August 2001 to December 2002.

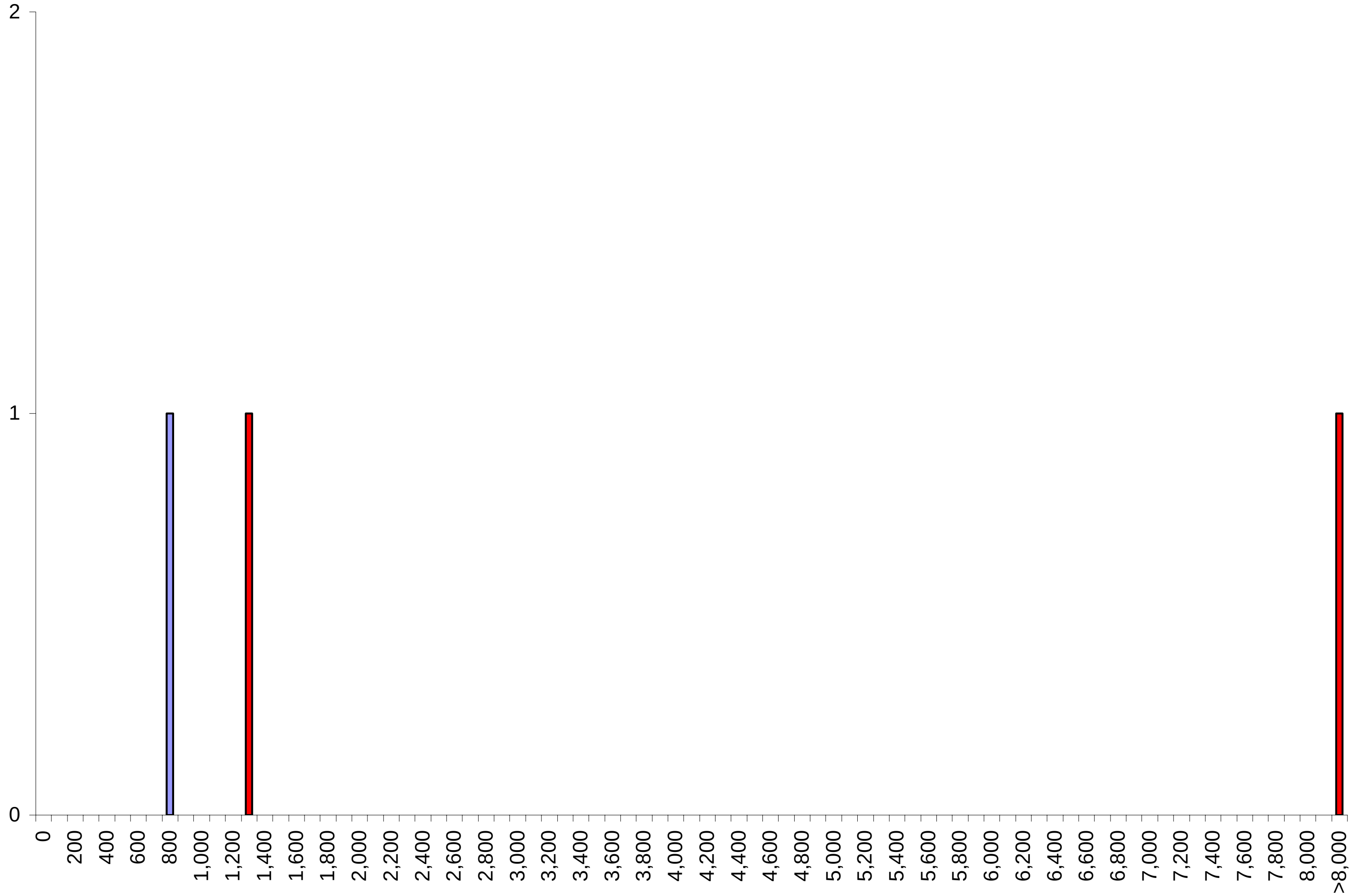

Figure A.5 Frequency analysis of fecal coliform concentrations at station 4ALCK002.17 in the Tinker Creek impairment for period August 2002 to December 2002.

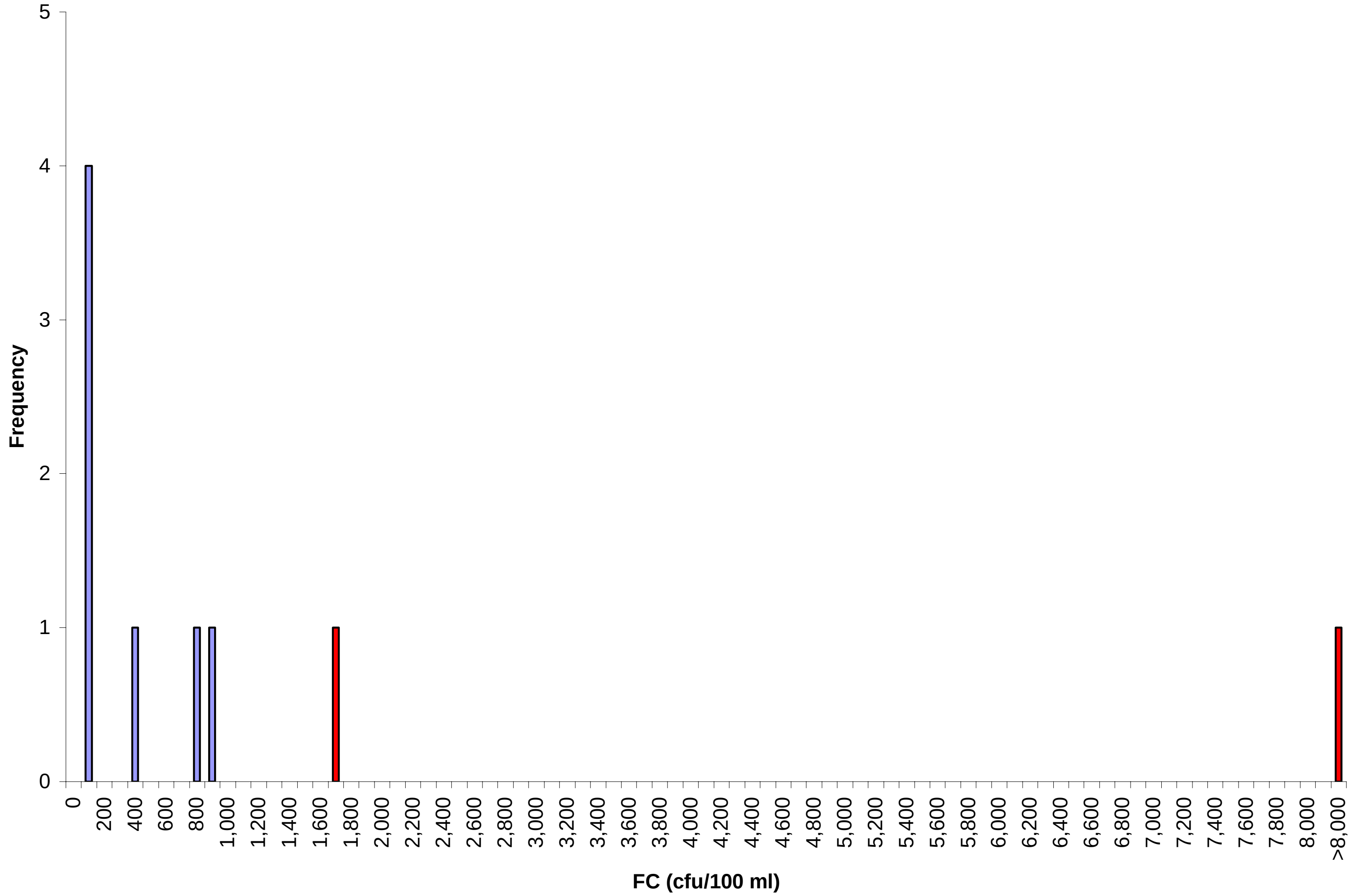

Figure A.6 Frequency analysis of fecal coliform concentrations at station 4AGLA004.39 in the Tinker Creek impairment for period August 2001 to January 2003.

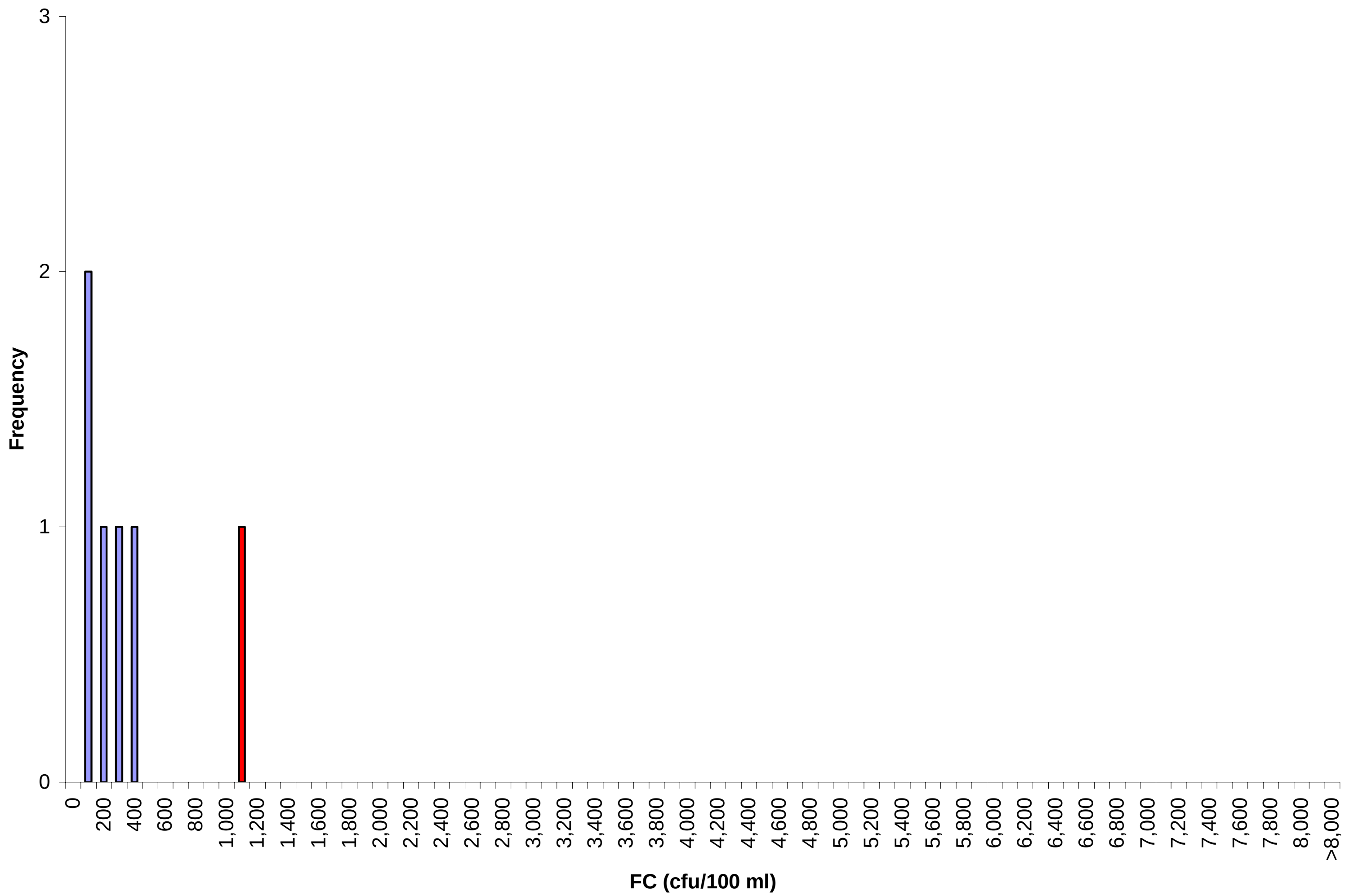

Figure A.7 Frequency analysis of fecal coliform concentrations at station 4ACRV001.88 in the Tinker Creek impairment for the period October 2001 to December 2002.

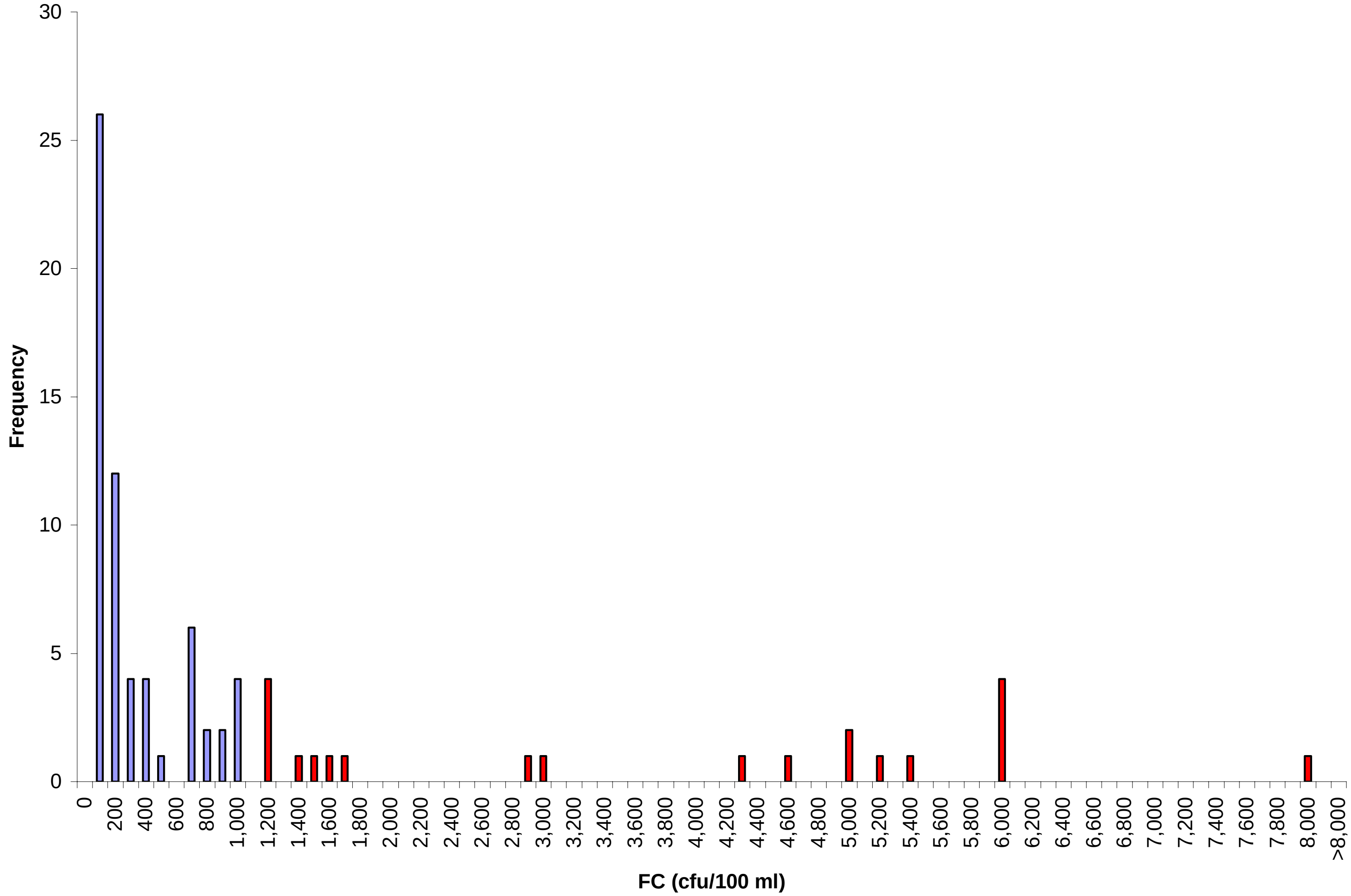

Figure A.8 Frequency analysis of fecal coliform concentrations at station 4ATKR009.30 in the Tinker Creek impairment for the period April 1973 to June 1979 and August 2001 to December 2002.

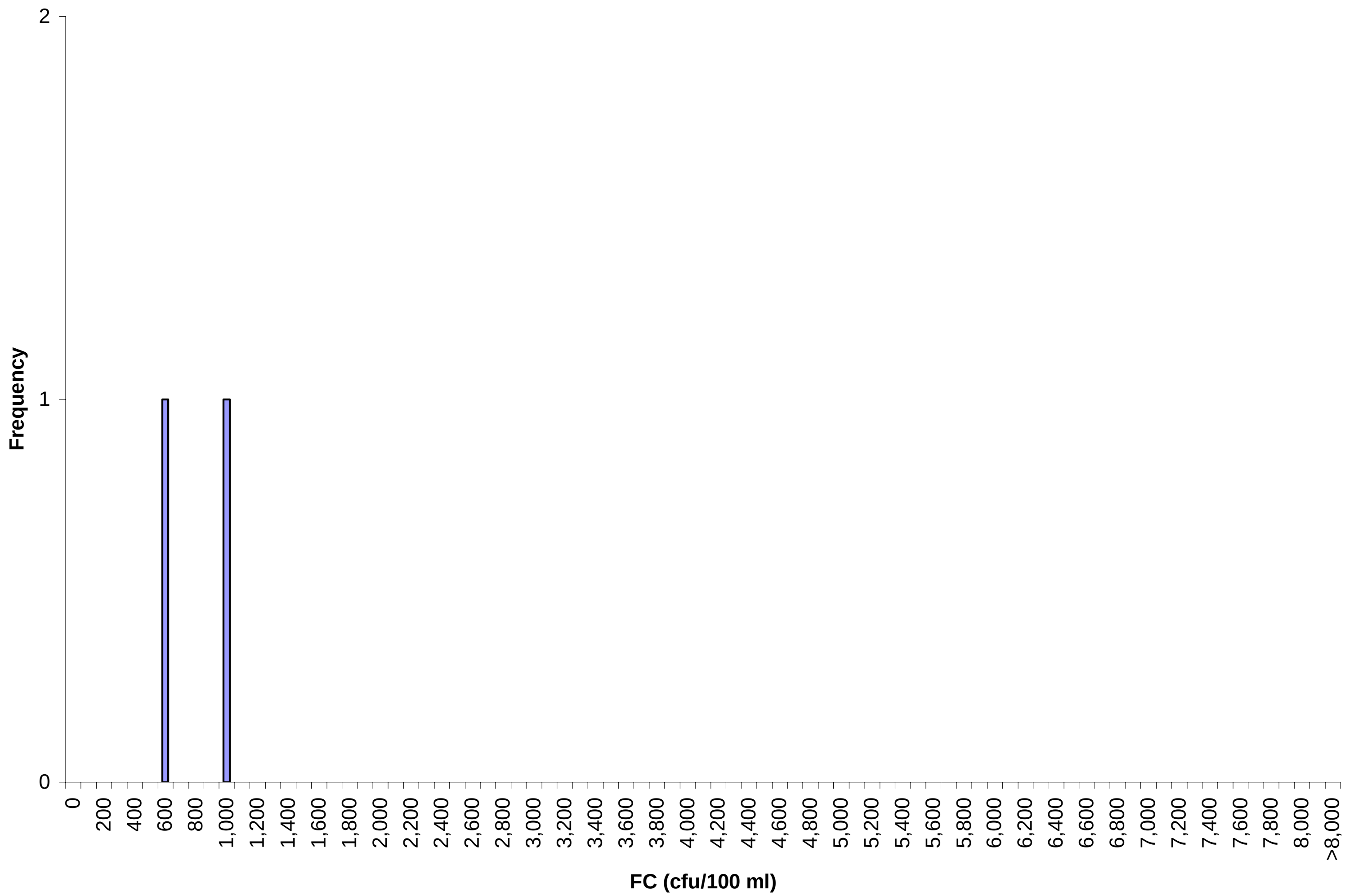

Figure A.9 Frequency analysis of fecal coliform concentrations at station 4ACRV005.58 in the Tinker Creek impairment for August 1992 and August 2001.

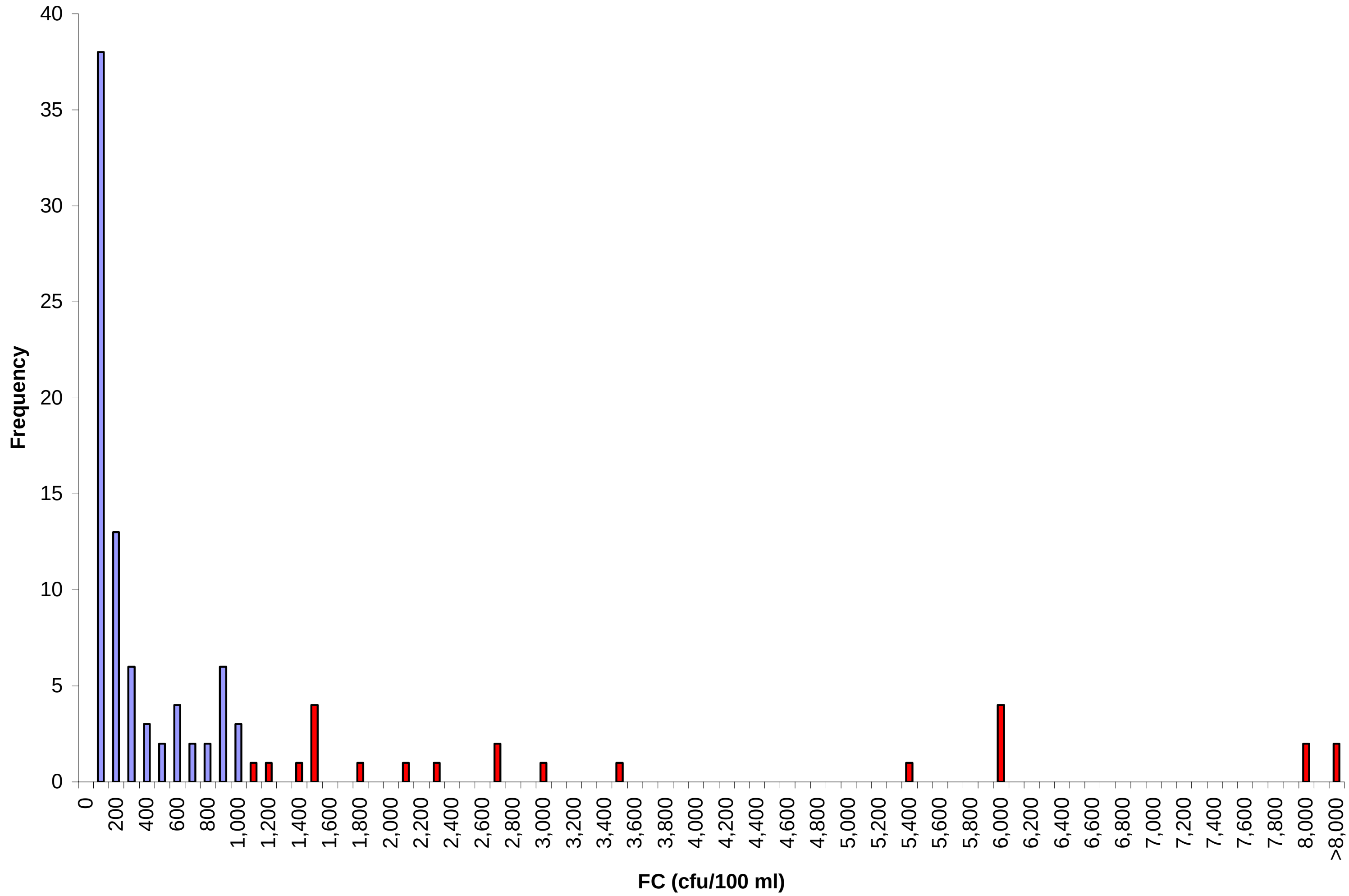

Figure A.10 Frequency analysis of fecal coliform concentrations at station 4ATKR015.88 in the Tinker Creek impairment for period November 1970 to June 1979 and August 2001 to December 2002.

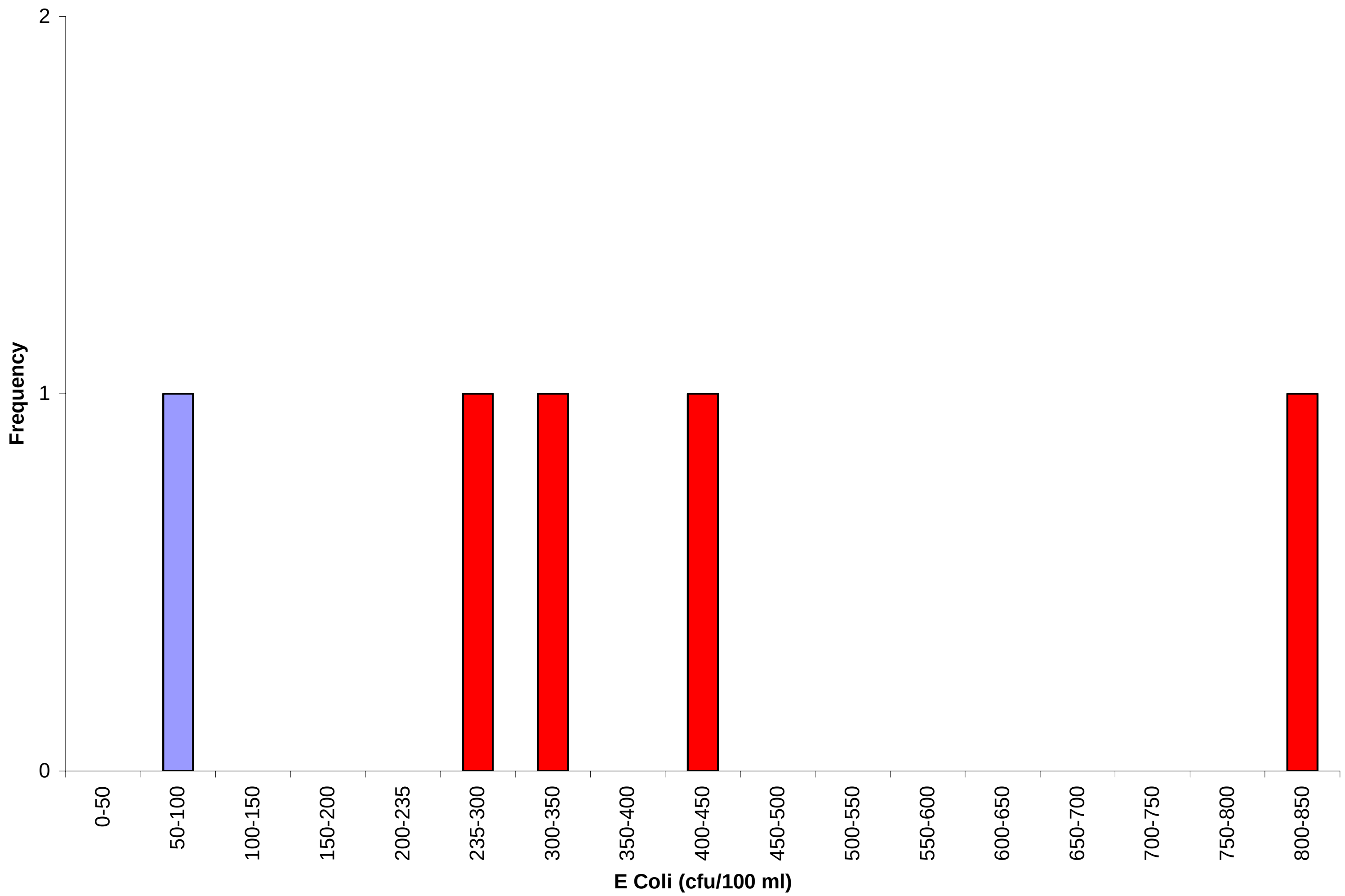

Figure A.11 Frequency analysis of *E. coli* concentrations at station 4ATKR000.69 in the Tinker Creek impairment.

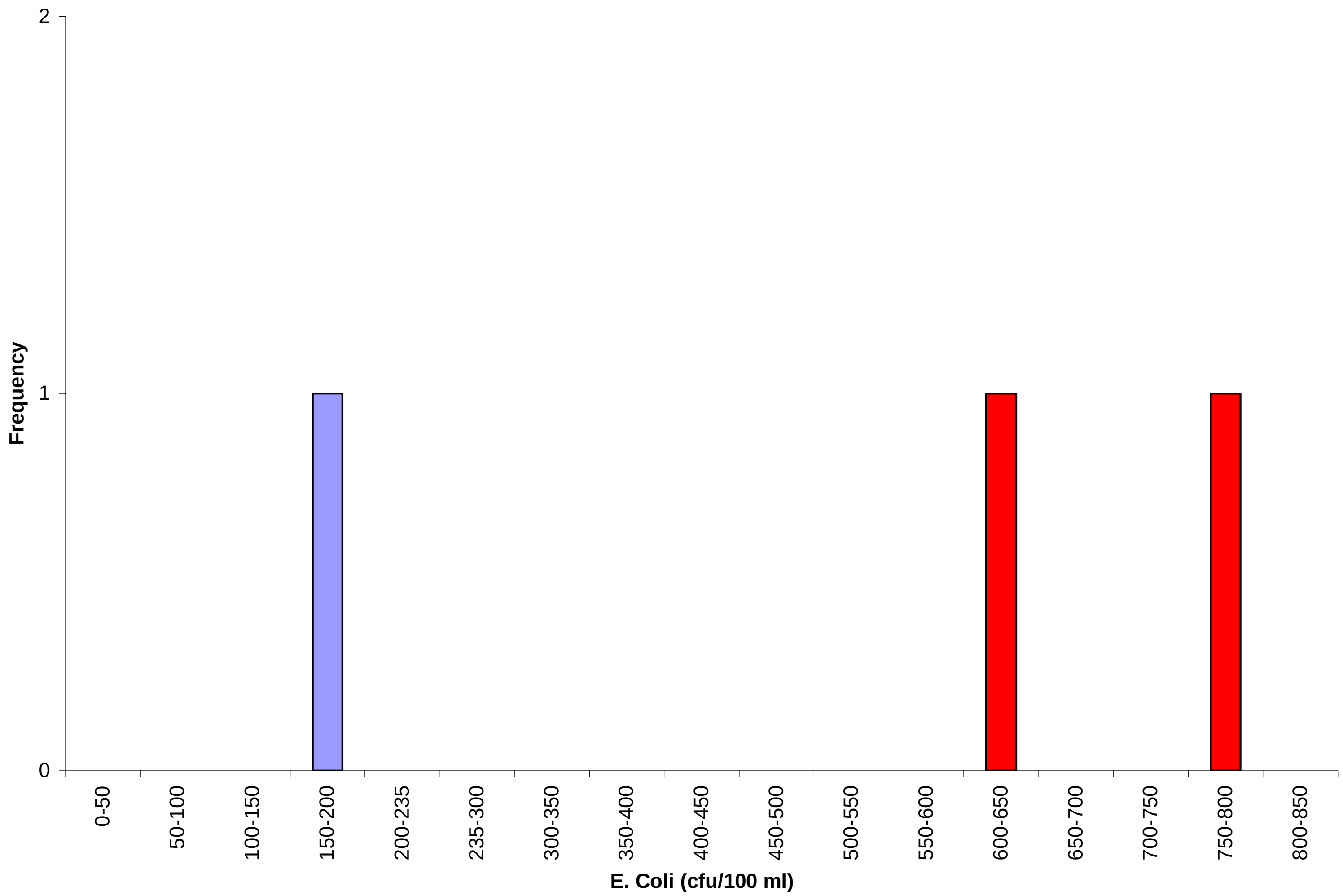

Figure A.12 Frequency analysis of *E. coli* concentrations at station 4ALCK000.38 in the Tinker Creek impairment.

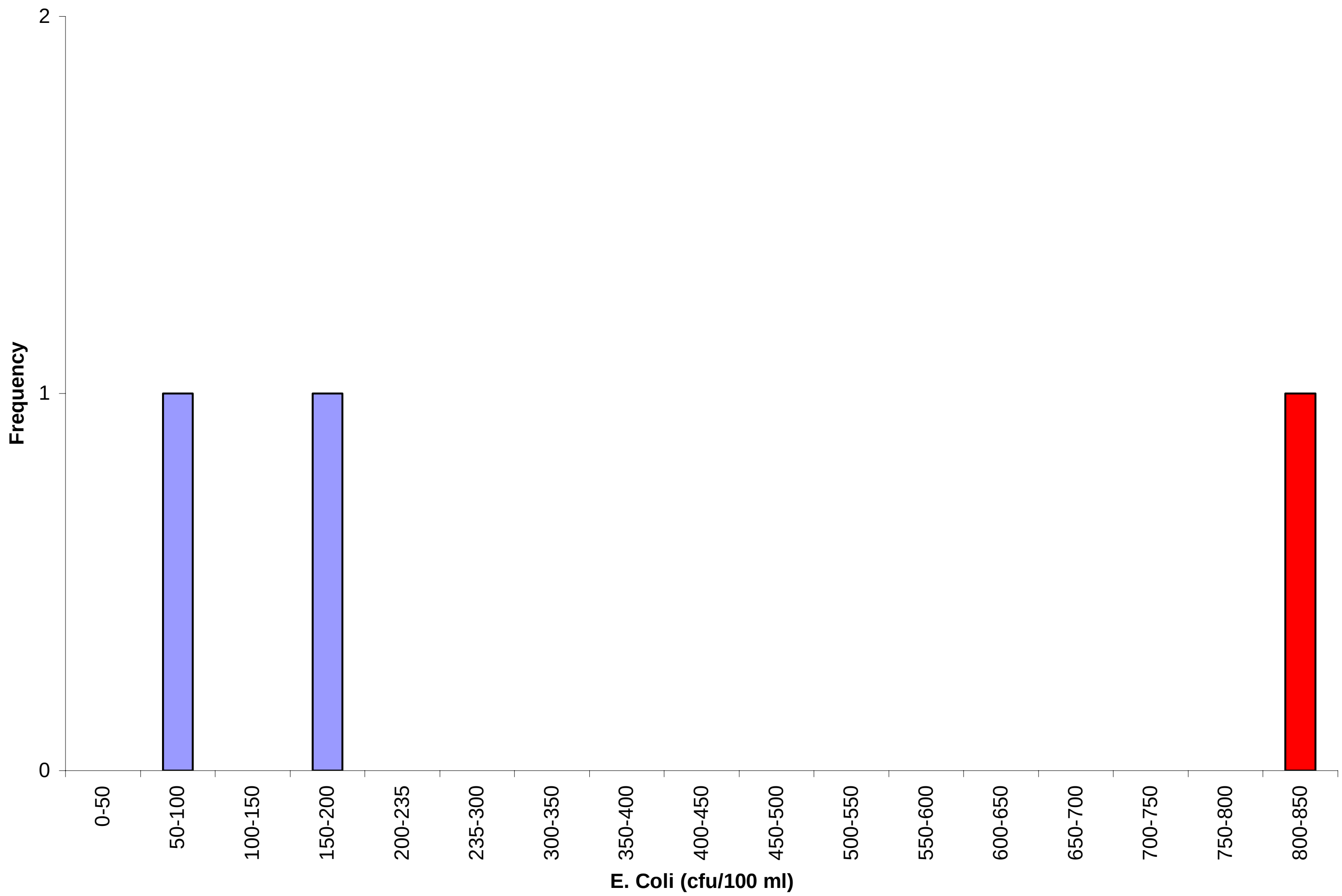

Figure A.13 Frequency analysis of *E. coli* concentrations at station 4AGLA000.20 in the Tinker Creek impairment.

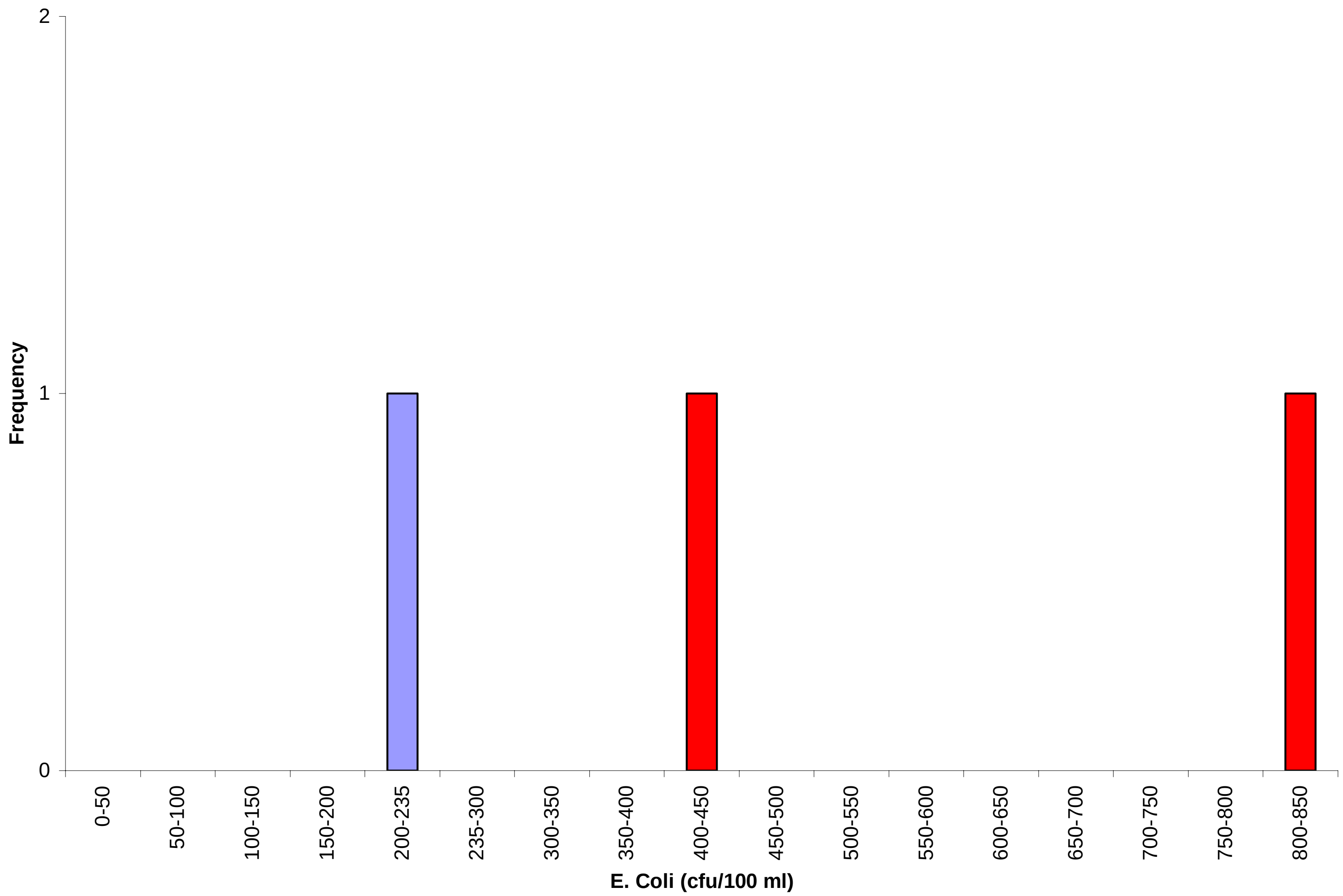

Figure A.14 Frequency analysis of *E. coli* concentrations at station 4ALCK002.17 in the Tinker Creek impairment.

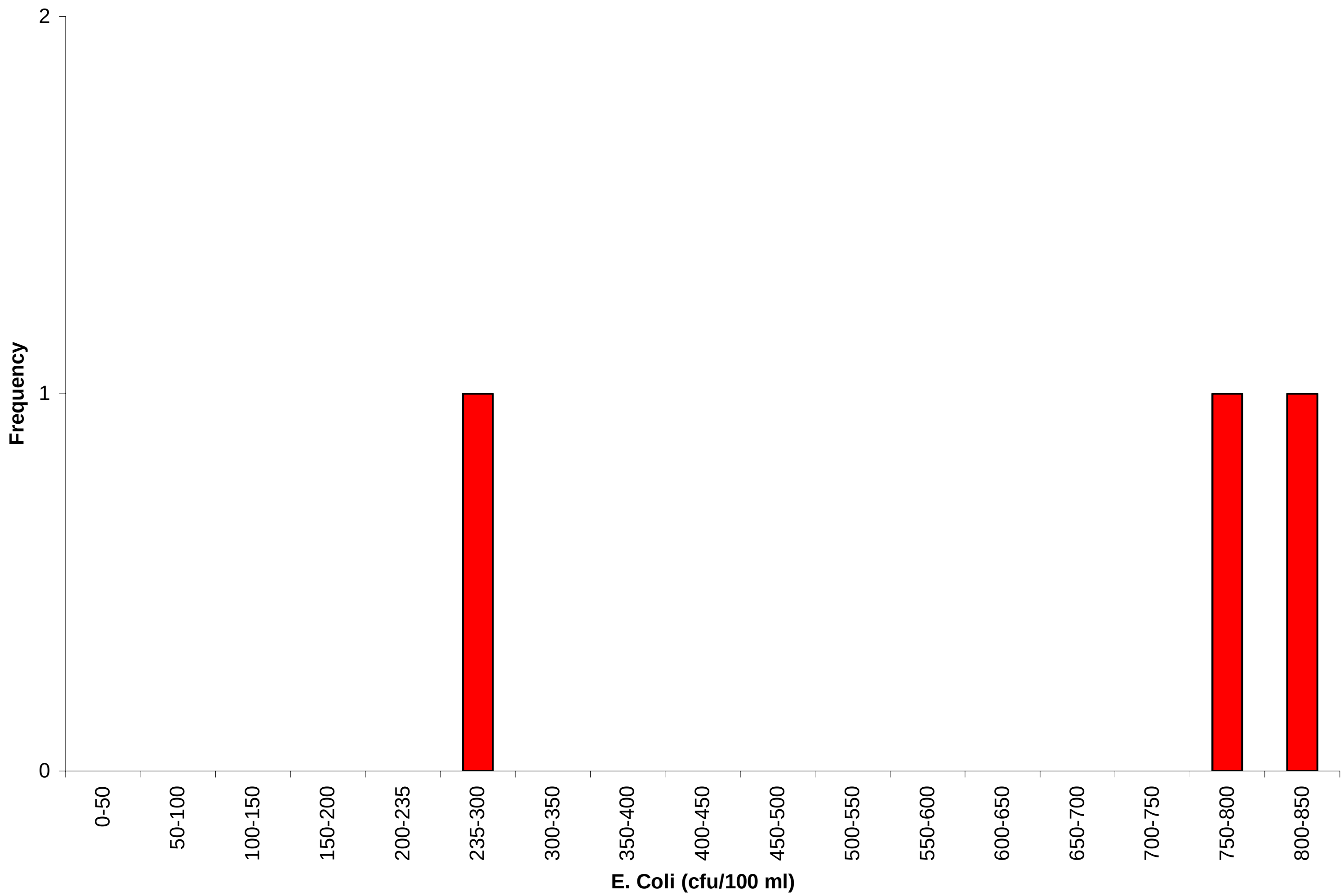

Figure A.15 Frequency analysis of *E. coli* concentrations at station 4AGLA004.39 in the Tinker Creek impairment.

APPENDIX B

FECAL COLIFORM LOADS IN EXISTING CONDITIONS

Table B.1 Current conditions (2003) of land applied fecal coliform load for Tinker Creek (Subsheds 1-18).

	Barren (cfu/ac*day)	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Forest (cfu/ac*day)	High Residential (cfu/ac*day)
January	3.17E+08	3.75E+08	4.65E+09	3.85E+08	1.86E+09
February	3.17E+08	3.75E+08	5.38E+09	3.85E+08	1.85E+09
March	3.17E+08	3.75E+08	4.98E+10	3.85E+08	1.84E+09
April	3.17E+08	3.75E+08	4.98E+10	3.85E+08	1.84E+09
May	3.17E+08	3.75E+08	4.98E+10	3.85E+08	1.84E+09
June	3.17E+08	3.75E+08	2.90E+08	3.85E+08	1.83E+09
July	3.17E+08	3.75E+08	2.90E+08	3.85E+08	1.82E+09
August	3.17E+08	3.75E+08	2.90E+08	3.85E+08	1.82E+09
September	3.17E+08	3.75E+08	1.48E+10	3.85E+08	1.82E+09
October	3.17E+08	3.75E+08	4.98E+10	3.85E+08	1.82E+09
November	3.17E+08	3.75E+08	4.98E+10	3.85E+08	1.82E+09
December	3.17E+08	3.75E+08	4.65E+09	3.85E+08	1.84E+09

Table B.1 Current conditions (2003) of land applied fecal coliform load for Tinker Creek (Subsheds 1-18) (Continued).

	Livestock Access (cfu/ac*day)	Low Residential (cfu/ac*day)	Pasture (cfu/ac*day)	Water (cfu/ac*day)	Wetlands (cfu/ac*day)
January	3.59E+08	8.68E+08	5.47E+08	0.00E+00	3.73E+08
February	3.74E+08	8.63E+08	5.86E+08	0.00E+00	3.73E+08
March	4.45E+08	8.53E+08	5.87E+08	0.00E+00	3.73E+08
April	5.25E+08	8.48E+08	5.92E+08	0.00E+00	3.73E+08
May	5.25E+08	8.43E+08	5.97E+08	0.00E+00	3.73E+08
June	5.96E+08	8.38E+08	7.08E+08	0.00E+00	3.73E+08
July	5.96E+08	8.28E+08	7.11E+08	0.00E+00	3.73E+08
August	5.96E+08	8.28E+08	7.11E+08	0.00E+00	3.73E+08
September	5.25E+08	8.28E+08	6.04E+08	0.00E+00	3.73E+08
October	4.45E+08	8.22E+08	6.08E+08	0.00E+00	3.73E+08
November	4.23E+08	8.28E+08	5.65E+08	0.00E+00	3.73E+08
December	3.59E+08	8.48E+08	5.60E+08	0.00E+00	3.73E+08

Table B.2 Current conditions (2003) of land applied fecal coliform load for Carvin Creek (Subsheds 8-11).

	Barren (cfu/ac*day)	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Forest (cfu/ac*day)	High Residential (cfu/ac*day)
January	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.92E+09
February	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.91E+09
March	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.90E+09
April	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.89E+09
May	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.88E+09
June	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.87E+09
July	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.86E+09
August	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.86E+09
September	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.86E+09
October	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.85E+09
November	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.86E+09
December	4.63E+08	4.64E+08	4.50E+08	5.21E+08	1.89E+09

Table B.2 Current conditions (2003) of land applied fecal coliform load for Carvin Creek (Subsheds 8-11) (Continued).

	Livestock Access (cfu/ac*day)	Low Residential (cfu/ac*day)	Pasture (cfu/ac*day)	Water (cfu/ac*day)	Wetlands (cfu/ac*day)
January	5.01E+08	9.44E+08	1.58E+06	0.00E+00	4.62E+08
February	5.05E+08	9.41E+08	1.57E+06	0.00E+00	4.62E+08
March	5.13E+08	9.35E+08	1.56E+06	0.00E+00	4.62E+08
April	5.24E+08	9.32E+08	1.55E+06	0.00E+00	4.62E+08
May	5.24E+08	9.29E+08	1.55E+06	0.00E+00	4.62E+08
June	5.32E+08	9.27E+08	1.54E+06	0.00E+00	4.62E+08
July	5.32E+08	9.21E+08	1.53E+06	0.00E+00	4.62E+08
August	5.32E+08	9.21E+08	1.53E+06	0.00E+00	4.62E+08
September	5.24E+08	9.21E+08	1.53E+06	0.00E+00	4.62E+08
October	5.13E+08	9.18E+08	1.52E+06	0.00E+00	4.62E+08
November	5.07E+08	9.21E+08	1.53E+06	0.00E+00	4.62E+08
December	5.01E+08	9.32E+08	1.55E+06	0.00E+00	4.62E+08

Table B.3 Current conditions (2003) of land applied fecal coliform load for Laymantown Creek (Subshed 12).

	Barren (cfu/ac*day)	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Forest (cfu/ac*day)
January	4.29E+08	4.37E+08	4.41E+08	4.99E+08
February	4.29E+08	4.37E+08	4.41E+08	4.99E+08
March	4.29E+08	4.37E+08	4.41E+08	4.99E+08
April	4.29E+08	4.37E+08	4.41E+08	4.99E+08
May	4.29E+08	4.37E+08	4.41E+08	4.99E+08
June	4.29E+08	4.37E+08	4.41E+08	4.99E+08
July	4.29E+08	4.37E+08	4.41E+08	4.99E+08
August	4.29E+08	4.37E+08	4.41E+08	4.99E+08
September	4.29E+08	4.37E+08	4.41E+08	4.99E+08
October	4.29E+08	4.37E+08	4.41E+08	4.99E+08
November	4.29E+08	4.37E+08	4.41E+08	4.99E+08
December	4.29E+08	4.37E+08	4.41E+08	4.99E+08

Table B.3 Current conditions (2003) of land applied fecal coliform load for Laymantown Creek (Subshed 12) (Continued).

	Livestock Access (cfu/ac*day)	Low Residential (cfu/ac*day)	Pasture (cfu/ac*day)	Water (cfu/ac*day)
January	6.08E+08	1.68E+09	7.20E+08	0.00E+00
February	6.22E+08	1.65E+09	7.48E+08	0.00E+00
March	6.47E+08	1.60E+09	7.46E+08	0.00E+00
April	6.81E+08	1.57E+09	7.44E+08	0.00E+00
May	6.81E+08	1.54E+09	7.44E+08	0.00E+00
June	7.06E+08	1.52E+09	7.43E+08	0.00E+00
July	7.06E+08	1.46E+09	7.43E+08	0.00E+00
August	7.06E+08	1.46E+09	7.43E+08	0.00E+00
September	6.81E+08	1.46E+09	7.44E+08	0.00E+00
October	6.47E+08	1.43E+09	7.46E+08	0.00E+00
November	6.28E+08	1.46E+09	7.19E+08	0.00E+00
December	6.08E+08	1.57E+09	7.20E+08	0.00E+00

Table B.4 Current conditions (2003) of land applied fecal coliform load for Glade Creek (Subsheds 12-16).

	Barren (cfu/ac*day)	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Forest (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	5.11E+08	4.48E+08	4.90E+08	5.13E+08	6.14E+08
February	5.11E+08	4.48E+08	4.90E+08	5.13E+08	6.37E+08
March	5.11E+08	4.48E+08	4.90E+08	5.13E+08	6.82E+08
April	5.11E+08	4.48E+08	4.90E+08	5.13E+08	7.41E+08
May	5.11E+08	4.48E+08	4.90E+08	5.13E+08	7.41E+08
June	5.11E+08	4.48E+08	4.90E+08	5.13E+08	7.85E+08
July	5.11E+08	4.48E+08	4.90E+08	5.13E+08	7.85E+08
August	5.11E+08	4.48E+08	4.90E+08	5.13E+08	7.85E+08
September	5.11E+08	4.48E+08	4.90E+08	5.13E+08	7.41E+08
October	5.11E+08	4.48E+08	4.90E+08	5.13E+08	6.82E+08
November	5.11E+08	4.48E+08	4.90E+08	5.13E+08	6.48E+08
December	5.11E+08	4.48E+08	4.90E+08	5.13E+08	6.14E+08

Table B.4 Current conditions (2003) of land applied fecal coliform load for Glade Creek (Subsheds 12-16) (Continued).

	Low Residential (cfu/ac*day)	Pasture (cfu/ac*day)	Water (cfu/ac*day)	Wetlands (cfu/ac*day)
January	1.25E+09	7.62E+08	0.00E+00	4.34E+08
February	1.24E+09	8.11E+08	0.00E+00	4.34E+08
March	1.21E+09	8.08E+08	0.00E+00	4.34E+08
April	1.20E+09	8.04E+08	0.00E+00	4.34E+08
May	1.19E+09	8.04E+08	0.00E+00	4.34E+08
June	1.17E+09	8.02E+08	0.00E+00	4.34E+08
July	1.15E+09	8.02E+08	0.00E+00	4.34E+08
August	1.15E+09	8.02E+08	0.00E+00	4.34E+08
September	1.15E+09	8.04E+08	0.00E+00	4.34E+08
October	1.14E+09	8.08E+08	0.00E+00	4.34E+08
November	1.15E+09	7.60E+08	0.00E+00	4.34E+08
December	1.20E+09	7.62E+08	0.00E+00	4.34E+08

Table B.5 Current conditions (2003) of land applied fecal coliform load for Lick Run (Subsheds 17-18).

	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Forest (cfu/ac*day)	High Residential (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	4.58E+08	4.52E+08	4.63E+08	1.83E+09	5.20E+08
February	4.58E+08	4.52E+08	4.63E+08	1.83E+09	5.20E+08
March	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
April	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
May	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
June	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
July	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
August	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
September	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
October	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
November	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08
December	4.58E+08	4.52E+08	4.63E+08	1.82E+09	5.20E+08

Table B.5 Current conditions (2003) of land applied fecal coliform load for Lick Run (Subsheds 17-18) (Continued).

	Low Residential (cfu/ac*day)	Pasture (cfu/ac*day)	Water (cfu/ac*day)	Wetlands (cfu/ac*day)
January	8.77E+08	4.94E+08	0.00E+00	5.66E+08
February	8.76E+08	4.94E+08	0.00E+00	5.66E+08
March	8.75E+08	4.94E+08	0.00E+00	5.66E+08
April	8.74E+08	4.94E+08	0.00E+00	5.66E+08
May	8.73E+08	4.94E+08	0.00E+00	5.66E+08
June	8.72E+08	4.94E+08	0.00E+00	5.66E+08
July	8.71E+08	4.94E+08	0.00E+00	5.66E+08
August	8.71E+08	4.94E+08	0.00E+00	5.66E+08
September	8.71E+08	4.94E+08	0.00E+00	5.66E+08
October	8.70E+08	4.94E+08	0.00E+00	5.66E+08
November	8.71E+08	4.94E+08	0.00E+00	5.66E+08
December	8.74E+08	4.94E+08	0.00E+00	5.66E+08

Table B.6 Monthly, directly deposited fecal coliform loads in each reach of the Tinker Creek impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
1	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	2.21E+10	2.36E+10	4.14E+10	5.99E+10	5.99E+10	7.77E+10
	Wildlife	2.67E+09	2.67E+09	2.67E+09	2.67E+09	2.67E+09	2.67E+09
2	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	1.42E+09	1.84E+09	2.63E+09	3.68E+09	3.68E+09	4.47E+09
	Wildlife	2.33E+09	2.33E+09	2.33E+09	2.33E+09	2.33E+09	2.33E+09
3	Human	1.29E+09	1.29E+09	1.29E+09	1.29E+09	1.29E+09	1.29E+09
	Livestock	3.03E+09	3.93E+09	5.62E+09	7.86E+09	7.86E+09	9.55E+09
	Wildlife	1.18E+09	1.18E+09	1.18E+09	1.18E+09	1.18E+09	1.18E+09
4	Human	9.28E+06	9.28E+06	9.28E+06	9.28E+06	9.28E+06	9.28E+06
	Livestock	9.32E+08	1.21E+09	1.73E+09	2.42E+09	2.42E+09	2.94E+09
	Wildlife	5.23E+08	5.23E+08	5.23E+08	5.23E+08	5.23E+08	5.23E+08
5	Human	4.29E+07	4.29E+07	4.29E+07	4.29E+07	4.29E+07	4.29E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	3.50E+09	3.50E+09	3.50E+09	3.50E+09	3.50E+09	3.50E+09
6	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	4.15E+08	4.15E+08	4.15E+08	4.15E+08	4.15E+08	4.15E+08
7	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	6.62E+08	6.62E+08	6.62E+08	6.62E+08	6.62E+08	6.62E+08

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
1	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	7.77E+10	7.77E+10	5.99E+10	4.14E+10	3.93E+10	2.21E+10
	Wildlife	2.67E+09	2.67E+09	2.67E+09	2.67E+09	2.67E+09	2.67E+09
2	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	4.47E+09	4.47E+09	3.68E+09	2.63E+09	2.03E+09	1.42E+09
	Wildlife	2.33E+09	2.33E+09	2.33E+09	2.33E+09	2.33E+09	2.33E+09
3	Human	1.29E+09	1.29E+09	1.29E+09	1.29E+09	1.29E+09	1.29E+09
	Livestock	9.55E+09	9.55E+09	7.86E+09	5.62E+09	4.33E+09	3.03E+09
	Wildlife	1.18E+09	1.18E+09	1.18E+09	1.18E+09	1.18E+09	1.18E+09
4	Human	9.28E+06	9.28E+06	9.28E+06	9.28E+06	9.28E+06	9.28E+06
	Livestock	2.94E+09	2.94E+09	2.42E+09	1.73E+09	1.33E+09	9.32E+08
	Wildlife	5.23E+08	5.23E+08	5.23E+08	5.23E+08	5.23E+08	5.23E+08
5	Human	4.29E+07	4.29E+07	4.29E+07	4.29E+07	4.29E+07	4.29E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	3.50E+09	3.50E+09	3.50E+09	3.50E+09	3.50E+09	3.50E+09
6	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	4.15E+08	4.15E+08	4.15E+08	4.15E+08	4.15E+08	4.15E+08
7	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	6.62E+08	6.62E+08	6.62E+08	6.62E+08	6.62E+08	6.62E+08

Table B.7 Monthly, directly deposited fecal coliform loads in each reach of the Carvin Creek impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
8	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	2.32E+11	2.32E+11	2.32E+11	2.32E+11	2.32E+11	2.32E+11
9	Human	2.68E+08	2.68E+08	2.68E+08	2.68E+08	2.68E+08	2.68E+08
	Livestock	2.10E+08	2.73E+08	3.89E+08	5.45E+08	5.45E+08	6.62E+08
	Wildlife	3.71E+10	3.71E+10	3.71E+10	3.71E+10	3.71E+10	3.71E+10
10	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	2.56E+08	3.33E+08	4.76E+08	6.66E+08	6.66E+08	8.09E+08
	Wildlife	8.54E+10	8.54E+10	8.54E+10	8.54E+10	8.54E+10	8.54E+10
11	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	1.73E+10	1.73E+10	1.73E+10	1.73E+10	1.73E+10	1.73E+10

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
8	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	2.32E+11	2.32E+11	2.32E+11	2.32E+11	2.32E+11	2.32E+11
9	Human	2.68E+08	2.68E+08	2.68E+08	2.68E+08	2.68E+08	2.68E+08
	Livestock	6.62E+08	6.62E+08	5.45E+08	3.89E+08	3.00E+08	2.10E+08
	Wildlife	3.71E+10	3.71E+10	3.71E+10	3.71E+10	3.71E+10	3.71E+10
10	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	8.09E+08	8.09E+08	6.66E+08	4.76E+08	3.66E+08	2.56E+08
	Wildlife	8.54E+10	8.54E+10	8.54E+10	8.54E+10	8.54E+10	8.54E+10
11	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	1.73E+10	1.73E+10	1.73E+10	1.73E+10	1.73E+10	1.73E+10

Table B.8 Monthly, directly deposited fecal coliform loads in each reach of the Laymantown Creek impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
12	Human	1.17E+09	1.17E+09	1.17E+09	1.17E+09	1.17E+09	1.17E+09
	Livestock	5.83E+08	7.57E+08	1.08E+09	1.51E+09	1.51E+09	1.84E+09
	Wildlife	6.84E+10	6.84E+10	6.84E+10	6.84E+10	6.84E+10	6.84E+10

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
12	Human	1.17E+09	1.17E+09	1.17E+09	1.17E+09	1.17E+09	1.17E+09
	Livestock	1.84E+09	1.84E+09	1.51E+09	1.08E+09	8.32E+08	5.83E+08
	Wildlife	6.84E+10	6.84E+10	6.84E+10	6.84E+10	6.84E+10	6.84E+10

Table B.9 Monthly, directly deposited fecal coliform loads in each reach of the Glade Creek impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
13	Human	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09
	Livestock	2.00E+09	2.60E+09	3.71E+09	5.20E+09	5.20E+09	6.31E+09
	Wildlife	1.56E+11	1.56E+11	1.56E+11	1.56E+11	1.56E+11	1.56E+11
14	Human	2.85E+08	2.85E+08	2.85E+08	2.85E+08	2.85E+08	2.85E+08
	Livestock	7.92E+08	1.02E+09	1.46E+09	2.05E+09	2.05E+09	2.48E+09
	Wildlife	3.27E+10	3.27E+10	3.27E+10	3.27E+10	3.27E+10	3.27E+10
15	Human	6.35E+08	6.35E+08	6.35E+08	6.35E+08	6.35E+08	6.35E+08
	Livestock	2.80E+09	3.63E+09	5.18E+09	7.26E+09	7.26E+09	8.81E+09
	Wildlife	9.46E+10	9.46E+10	9.46E+10	9.46E+10	9.46E+10	9.46E+10
16	Human	1.66E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08
	Livestock	1.44E+09	1.87E+09	2.67E+09	3.74E+09	3.74E+09	4.54E+09
	Wildlife	1.01E+11	1.01E+11	1.01E+11	1.01E+11	1.01E+11	1.01E+11

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
13	Human	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09
	Livestock	6.31E+09	6.31E+09	5.20E+09	3.71E+09	2.86E+09	2.00E+09
	Wildlife	1.56E+11	1.56E+11	1.56E+11	1.56E+11	1.56E+11	1.56E+11
14	Human	2.85E+08	2.85E+08	2.85E+08	2.85E+08	2.85E+08	2.85E+08
	Livestock	2.48E+09	2.48E+09	2.05E+09	1.46E+09	1.13E+09	7.92E+08
	Wildlife	3.27E+10	3.27E+10	3.27E+10	3.27E+10	3.27E+10	3.27E+10
15	Human	6.35E+08	6.35E+08	6.35E+08	6.35E+08	6.35E+08	6.35E+08
	Livestock	8.81E+09	8.81E+09	7.26E+09	5.18E+09	3.99E+09	2.80E+09
	Wildlife	9.46E+10	9.46E+10	9.46E+10	9.46E+10	9.46E+10	9.46E+10
16	Human	1.66E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08
	Livestock	4.54E+09	4.54E+09	3.74E+09	2.67E+09	2.06E+09	1.44E+09
	Wildlife	1.01E+11	1.01E+11	1.01E+11	1.01E+11	1.01E+11	1.01E+11

Table B.10 Monthly, directly deposited fecal coliform loads in each reach of the Lick Run impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
17	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	8.71E+10	8.71E+10	8.71E+10	8.71E+10	8.71E+10	8.71E+10
18	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	5.92E+10	5.92E+10	5.92E+10	5.92E+10	5.92E+10	5.92E+10

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
17	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	8.71E+10	8.71E+10	8.71E+10	8.71E+10	8.71E+10	8.71E+10
18	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	5.92E+10	5.92E+10	5.92E+10	5.92E+10	5.92E+10	5.92E+10

Table B.11 Existing annual fecal coliform loads from land-based sources for the Tinker Creek impairment (Subsheds 1-18).

Source	Forest (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Low Residential (cfu/yr)	High Residential (cfu/yr)	Cropland (cfu/yr)	Pasture (cfu/yr)	Livestock Access (cfu/yr)	Wetlands (cfu/yr)	Barren (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	0.00E+00	1.44E+15	1.08E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	3.72E+09	2.79E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	1.44E+15	1.08E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	3.63E+14	5.91E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E+15	5.73E+14	3.37E+13	0.00E+00	0.00E+00
Beef	3.04E+10	0.00E+00	5.54E+10	0.00E+00	0.00E+00	3.20E+10	1.18E+10	5.99E+10	1.46E+10	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E+14	0.00E+00	0.00E+00	0.00E+00
Total	3.04E+10	0.00E+00	5.54E+10	0.00E+00	0.00E+00	2.04E+15	7.25E+14	3.38E+13	1.46E+10	0.00E+00
Wildlife										
Raccoon	6.66E+14	0.00E+00	0.00E+00	1.64E+14	0.00E+00	7.29E+12	3.26E+14	1.99E+13	1.68E+12	9.76E+12
Muskrat	4.06E+15	0.00E+00	4.94E+14	1.10E+15	2.54E+13	2.42E+13	1.04E+15	4.66E+13	2.91E+12	4.77E+13
Deer	2.25E+14	0.00E+00	0.00E+00	1.55E+13	0.00E+00	1.89E+12	9.24E+13	5.07E+12	5.47E+10	7.90E+11
Turkey	1.06E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.24E+08	1.09E+10	5.99E+08	2.59E+07	0.00E+00
Goose	8.89E+10	0.00E+00	8.91E+09	3.43E+10	1.04E+09	1.22E+09	3.59E+10	1.04E+10	1.04E+09	1.29E+09
Duck	3.26E+09	0.00E+00	3.26E+08	1.26E+09	3.81E+07	4.48E+07	1.32E+09	3.82E+08	3.81E+07	4.74E+07
Unquantifiable	4.95E+14	0.00E+00	4.94E+13	1.28E+14	2.54E+12	3.34E+12	1.46E+14	7.16E+12	4.64E+11	5.83E+12
Total	5.44E+15	0.00E+00	5.43E+14	1.41E+15	2.79E+13	3.68E+13	1.61E+15	7.88E+13	9.61E+13	6.41E+13

Table B.12 Existing annual fecal coliform loads from land-based sources for Carvin Creek impairment (Subsheds 8-11).

Source	Forest (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Low Residential (cfu/yr)	High Residential (cfu/yr)	Cropland (cfu/yr)	Pasture (cfu/yr)	Livestock Access (cfu/yr)	Wetlands (cfu/yr)	Barren (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	0.00E+00	2.48E+14	1.69E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	6.40E+08	4.36E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	2.48E+14	1.69E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	3.60E+13	1.82E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.36E+09	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.23E+13	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.23E+13	5.36E+09	0.00E+00	0.00E+00
Wildlife										
Raccoon	2.62E+14	0.00E+00	0.00E+00	3.33E+13	0.00E+00	6.27E+11	3.09E+13	2.20E+12	6.05E+11	2.49E+11
Muskrat	2.02E+15	0.00E+00	9.33E+13	2.73E+14	3.94E+12	3.63E+12	1.75E+14	9.69E+12	1.76E+12	1.57E+13
Deer	7.94E+13	0.00E+00	0.00E+00	2.74E+12	0.00E+00	1.47E+11	7.04E+12	4.35E+11	2.27E+10	1.49E+11
Turkey	3.76E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.74E+07	8.32E+08	5.14E+07	1.07E+07	0.00E+00
Goose	3.24E+10	0.00E+00	1.27E+09	7.28E+09	1.20E+08	8.83E+07	3.64E+09	1.27E+09	2.33E+08	1.77E+08
Duck	1.19E+09	0.00E+00	4.67E+07	2.67E+08	4.39E+06	3.24E+06	1.33E+08	4.67E+07	8.55E+06	6.47E+06
Unquantifiable	2.36E+14	0.00E+00	9.33E+12	3.10E+13	3.94E+11	4.40E+11	2.13E+13	1.23E+12	2.39E+11	1.61E+12
Total	2.60E+15	0.00E+00	1.03E+14	3.40E+14	4.33E+12	4.84E+12	2.35E+14	1.36E+13	2.63E+12	1.77E+13

Table B.13 Existing annual fecal coliform loads from land-based sources for the Laymantown Creek impairment (Subshed 12).

Source	Forest (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Low Residential (cfu/yr)	High Residential (cfu/yr)	Cropland (cfu/yr)	Pasture (cfu/yr)	Livestock Access (cfu/yr)	Wetlands (cfu/yr)	Barren (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	0.00E+00	3.47E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	8.95E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	3.47E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	3.24E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.67E+13	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.67E+13	0.00E+00	0.00E+00	0.00E+00
Wildlife										
Raccoon	1.57E+13	0.00E+00	0.00E+00	2.55E+12	0.00E+00	3.07E+11	1.11E+13	5.69E+11	0.00E+00	4.98E+11
Muskrat	3.36E+14	0.00E+00	1.23E+12	2.49E+13	0.00E+00	2.95E+12	1.07E+14	4.85E+12	0.00E+00	2.61E+12
Deer	1.28E+13	0.00E+00	0.00E+00	2.43E+11	0.00E+00	1.24E+11	4.08E+12	1.91E+11	0.00E+00	2.92E+10
Turkey	6.06E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.46E+07	4.82E+08	2.26E+07	0.00E+00	0.00E+00
Goose	2.56E+09	0.00E+00	1.89E+07	5.68E+08	0.00E+00	1.77E+08	5.68E+08	1.07E+08	0.00E+00	1.83E+08
Duck	9.38E+07	0.00E+00	6.93E+05	2.08E+07	0.00E+00	6.47E+06	2.08E+07	3.93E+06	0.00E+00	6.70E+06
Unquantifiable	3.64E+13	0.00E+00	1.23E+11	2.77E+12	0.00E+00	3.38E+11	1.22E+13	5.61E+11	0.00E+00	3.13E+11
Total	4.01E+14	0.00E+00	1.36E+12	3.05E+13	0.00E+00	3.72E+12	1.34E+14	6.17E+12	0.00E+00	3.45E+12

Table B.14 Existing annual fecal coliform loads from land-based sources for the Glade Creek impairment (Subsheds 12-16).

Source	Forest (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Low Residential (cfu/yr)	High Residential (cfu/yr)	Cropland (cfu/yr)	Pasture (cfu/yr)	Livestock Access (cfu/yr)	Wetlands (cfu/yr)	Barren (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	0.00E+00	3.47E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	8.95E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	3.47E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	1.79E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	3.04E+10	0.00E+00	3.78E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.37E+13	0.00E+00	0.00E+00	0.00E+00
Total	3.04E+10	0.00E+00	3.78E+10	0.00E+00	0.00E+00	0.00E+00	8.37E+13	0.00E+00	0.00E+00	0.00E+00
Wildlife										
Raccoon	1.67E+14	0.00E+00	0.00E+00	3.56E+13	0.00E+00	2.44E+12	1.16E+14	6.09E+12	1.87E+11	4.07E+12
Muskrat	1.91E+15	0.00E+00	9.18E+13	3.06E+14	0.00E+00	1.91E+13	7.78E+14	3.20E+13	6.12E+11	3.20E+13
Deer	7.34E+13	0.00E+00	0.00E+00	3.05E+12	0.00E+00	7.58E+11	3.05E+13	1.39E+12	7.57E+09	3.12E+11
Turkey	3.47E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.97E+07	3.61E+09	1.65E+08	3.58E+06	0.00E+00
Goose	1.83E+10	0.00E+00	1.71E+09	7.26E+09	0.00E+00	5.05E+08	1.20E+10	3.06E+09	1.01E+08	3.72E+08
Duck	6.72E+08	0.00E+00	6.26E+07	2.66E+08	0.00E+00	1.85E+07	4.39E+08	1.12E+08	3.70E+06	1.36E+07
Unquantifiable	2.15E+14	0.00E+00	9.18E+12	3.44E+13	0.00E+00	2.23E+12	9.24E+13	3.95E+12	8.07E+10	3.64E+12
Total	2.37E+15	0.00E+00	1.01E+14	3.79E+14	0.00E+00	2.45E+13	1.02E+15	4.34E+13	8.88E+11	4.00E+13

Table B.15 Existing annual fecal coliform loads from land-based sources for the Lick Run impairment (Subsheds 17-18).

Source	Forest (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Low Residential (cfu/yr)	High Residential (cfu/yr)	Cropland (cfu/yr)	Pasture (cfu/yr)	Livestock Access (cfu/yr)	Wetlands (cfu/yr)	Barren (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	0.00E+00	4.09E+14	8.10E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	1.06E+09	2.09E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	4.09E+14	8.10E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	1.59E+13	4.37E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	1.76E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.67E+12	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	1.76E+10	0.00E+00	0.00E+00	0.00E+00	1.67E+12	0.00E+00	0.00E+00	0.00E+00
Wildlife										
Raccoon	4.69E+12	0.00E+00	0.00E+00	3.50E+13	0.00E+00	2.05E+11	2.49E+12	3.56E+10	8.89E+09	0.00E+00
Muskrat	1.06E+14	0.00E+00	3.07E+14	5.11E+14	2.14E+13	9.69E+11	8.06E+13	1.50E+12	4.02E+11	0.00E+00
Deer	4.02E+12	0.00E+00	0.00E+00	4.83E+12	0.00E+00	3.85E+10	3.03E+12	5.64E+10	3.78E+09	0.00E+00
Turkey	1.90E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.56E+06	3.59E+08	6.67E+06	1.79E+06	0.00E+00
Goose	1.05E+09	0.00E+00	2.88E+09	1.48E+09	8.58E+08	1.26E+07	8.83E+07	2.52E+07	1.01E+08	0.00E+00
Duck	3.86E+07	0.00E+00	1.06E+08	5.43E+07	3.14E+07	4.62E+05	3.24E+06	9.25E+05	3.70E+06	0.00E+00
Unquantifiable	1.15E+13	0.00E+00	3.07E+13	5.51E+13	2.14E+12	1.21E+11	8.61E+12	1.59E+11	4.15E+10	0.00E+00
Total	1.27E+14	0.00E+00	3.38E+14	6.06E+14	2.35E+13	1.33E+12	9.47E+13	1.75E+12	4.57E+11	0.00E+00

Table B.16 Existing annual loads from direct-deposition sources for the Tinker Creek impairment (subsheds 1-18).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	1.81E+12
Total	1.81E+12
Livestock	
Dairy	1.13E+15
Beef	2.83E+14
Horse	1.06E+14
Total	1.52E+15
Wildlife	
Raccoon	2.66E+12
Muskrat	3.23E+14
Beaver	6.92E+10
Deer	1.49E+11
Turkey	6.10E+09
Goose	5.92E+09
Duck	3.30E+08
Total	3.26E+14

Table B.17 Existing annual loads from direct-deposition sources for the Carvin Creek impairment (subsheds 8-11).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	9.80E+10
Total	9.80E+10
Livestock	
Dairy	0.00E+00
Beef	7.14E+12
Horse	9.57E+12
Total	1.67E+13
Wildlife	
Raccoon	8.42E+11
Muskrat	1.23E+14
Beaver	2.58E+10
Deer	4.50E+10
Turkey	0.00E+00
Goose	2.84E+09
Duck	1.58E+08
Total	1.24E+14

Table B.18 Existing annual loads from direct-deposition sources for the Laymantown Creek impairment (subshed 12).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	4.29E+11
Total	4.29E+11
Livestock	
Dairy	0.00E+00
Beef	8.93E+12
Horse	7.18E+12
Total	1.61E+13
Wildlife	
Raccoon	7.75E+10
Muskrat	2.27E+13
Beaver	1.41E+09
Deer	8.74E+09
Turkey	0.00E+00
Goose	1.25E+08
Duck	6.98E+06
Total	2.28E+13

Table B.19 Existing annual loads from direct-deposition sources for the Glade Creek impairment (subsheds 12-16).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	1.22E+12
Total	1.22E+12
Livestock	
Dairy	0.00E+00
Beef	1.16E+14
Horse	3.59E+13
Total	1.52E+14
Wildlife	
Raccoon	8.33E+11
Muskrat	1.50E+14
Beaver	1.62E+10
Deer	5.47E+10
Turkey	0.00E+00
Goose	1.16E+09
Duck	6.44E+07
Total	1.51E+14

Table B.20 Existing annual loads from direct-deposition sources for the Lick Run impairment (subsheds 17-18).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	0.00E+00
Total	0.00E+00
Livestock	
Dairy	0.00E+00
Beef	0.00E+00
Horse	7.18E+11
Total	7.18E+11
Wildlife	
Raccoon	1.06E+11
Muskrat	4.85E+13
Beaver	1.81E+09
Deer	5.99E+09
Turkey	0.00E+00
Goose	1.73E+08
Duck	9.64E+06
Total	4.86E+13

APPENDIX C

EXCERPT FROM UCI FILE USED FOR MODELING

```
PERLND
  ACTIVITY
*** <PLS >               Active Sections                               ***
*** x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  101  248    0    0    1    0    0    0    1    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
*** < PLS>                       Print-flags                           PIVL  PYR
*** x  - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC
  101  248    6    6    5    6    6    6    6    6    6    6    6    6    1    9
  END PRINT-INFO

  GEN-INFO
***             Name                Unit-systems   Printer BinaryOut
*** <PLS >                              t-series Engl Metr Engl Metr
*** x -  x                               in  out
  101     1Water                          1    1    0    0    0    0
  102     1Low Residential                1    1    0    0    0    0
  103     1Commercial                     1    1    0    0    0    0
  104     1Barren                         1    1    0    0    0    0
  105     1Forest                         1    1    0    0    0    0
  106     1Pasture                        1    1    0    0    0    0
  107     1Cropland                       1    1    0    0    0    0
  108     1Wetlands                       1    1    0    0    0    0
  109     1Livestock Access               1    1    0    0    0    0
  110     2Water                          1    1    0    0    0    0
  111     2Low Residential                1    1    0    0    0    0
  112     2High Residential               1    1    0    0    0    0
  113     2Commercial                     1    1    0    0    0    0
  114     2Barren                         1    1    0    0    0    0
  115     2Forest                         1    1    0    0    0    0
  116     2Pasture                        1    1    0    0    0    0
  117     2Cropland                       1    1    0    0    0    0
  118     2Wetlands                       1    1    0    0    0    0
  119     2Livestock Access               1    1    0    0    0    0
  120     3Water                          1    1    0    0    0    0
  121     3Low Residential                1    1    0    0    0    0
  122     3High Residential               1    1    0    0    0    0
  123     3Commercial                     1    1    0    0    0    0
  124     3Barren                         1    1    0    0    0    0
  125     3Forest                         1    1    0    0    0    0
  126     3Pasture                        1    1    0    0    0    0
  127     3Cropland                       1    1    0    0    0    0
  128     3Wetlands                       1    1    0    0    0    0
  129     3Livestock Access               1    1    0    0    0    0
  130     4Water                          1    1    0    0    0    0
  131     4Low Residential                1    1    0    0    0    0
  132     4High Residential               1    1    0    0    0    0
  133     4Commercial                     1    1    0    0    0    0
  134     4Barren                         1    1    0    0    0    0
  135     4Forest                         1    1    0    0    0    0
  136     4Pasture                        1    1    0    0    0    0
  137     4Cropland                       1    1    0    0    0    0
  138     4Wetlands                       1    1    0    0    0    0
  139     4Livestock Access               1    1    0    0    0    0
  140     5Water                          1    1    0    0    0    0
```

141	5Low Residential	1	1	0	0	0	0
142	5High Residential	1	1	0	0	0	0
143	5Commercial	1	1	0	0	0	0
144	5Forest	1	1	0	0	0	0
145	5Pasture	1	1	0	0	0	0
146	5Cropland	1	1	0	0	0	0
147	5Wetlands	1	1	0	0	0	0
148	5Livestock Access	1	1	0	0	0	0
149	6Low Residential	1	1	0	0	0	0
150	6Commercial	1	1	0	0	0	0
151	6Forest	1	1	0	0	0	0
152	6Pasture	1	1	0	0	0	0
153	7Low Residential	1	1	0	0	0	0
154	7Commercial	1	1	0	0	0	0
155	7Barren	1	1	0	0	0	0
156	7Forest	1	1	0	0	0	0
157	7Pasture	1	1	0	0	0	0
158	7Livestock Access	1	1	0	0	0	0
159	8Water	1	1	0	0	0	0
160	8Low Residential	1	1	0	0	0	0
161	8Commercial	1	1	0	0	0	0
162	8Barren	1	1	0	0	0	0
163	8Forest	1	1	0	0	0	0
164	8Pasture	1	1	0	0	0	0
165	8Cropland	1	1	0	0	0	0
166	8Wetlands	1	1	0	0	0	0
167	8Livestock Access	1	1	0	0	0	0
168	9Water	1	1	0	0	0	0
169	9Low Residential	1	1	0	0	0	0
170	9High Residential	1	1	0	0	0	0
171	9Commercial	1	1	0	0	0	0
172	9Barren	1	1	0	0	0	0
173	9Forest	1	1	0	0	0	0
174	9Pasture	1	1	0	0	0	0
175	9Cropland	1	1	0	0	0	0
176	9Livestock Access	1	1	0	0	0	0
177	10Water	1	1	0	0	0	0
178	10Low Residential	1	1	0	0	0	0
179	10High Residential	1	1	0	0	0	0
180	10Commercial	1	1	0	0	0	0
181	10Barren	1	1	0	0	0	0
182	10Forest	1	1	0	0	0	0
183	10Pasture	1	1	0	0	0	0
184	10Cropland	1	1	0	0	0	0
185	10Livestock Access	1	1	0	0	0	0
186	11Low Residential	1	1	0	0	0	0
187	11High Residential	1	1	0	0	0	0
188	11Commercial	1	1	0	0	0	0
189	11Forest	1	1	0	0	0	0
190	11Pasture	1	1	0	0	0	0
191	11Cropland	1	1	0	0	0	0
192	11Livestock Access	1	1	0	0	0	0
193	12Water	1	1	0	0	0	0
194	12Low Residential	1	1	0	0	0	0
195	12Commercial	1	1	0	0	0	0
196	12Barren	1	1	0	0	0	0
197	12Forest	1	1	0	0	0	0

```
  198     12Pasture                          1    1    0    0    0    0
  199     12Cropland                         1    1    0    0    0    0
  200     12Livestock Access                 1    1    0    0    0    0
  201     13Water                            1    1    0    0    0    0
  202     13Low Residential                  1    1    0    0    0    0
  203     13Commercial                       1    1    0    0    0    0
  204     13Barren                           1    1    0    0    0    0
  205     13Forest                           1    1    0    0    0    0
  206     13Pasture                          1    1    0    0    0    0
  207     13Cropland                         1    1    0    0    0    0
  208     13Wetlands                         1    1    0    0    0    0
  209     13Livestock Access                 1    1    0    0    0    0
  210     14Water                            1    1    0    0    0    0
  211     14Low Residential                  1    1    0    0    0    0
  212     14Commercial                       1    1    0    0    0    0
  213     14Barren                           1    1    0    0    0    0
  214     14Forest                           1    1    0    0    0    0
  215     14Pasture                          1    1    0    0    0    0
  216     14Cropland                         1    1    0    0    0    0
  217     14Livestock Access                 1    1    0    0    0    0
  218     15Water                            1    1    0    0    0    0
  219     15Low Residential                  1    1    0    0    0    0
  220     15Commercial                       1    1    0    0    0    0
  221     15Barren                           1    1    0    0    0    0
  222     15Forest                           1    1    0    0    0    0
  223     15Pasture                          1    1    0    0    0    0
  224     15Cropland                         1    1    0    0    0    0
  225     15Livestock Access                 1    1    0    0    0    0
  226     16Water                            1    1    0    0    0    0
  227     16Low Residential                  1    1    0    0    0    0
  228     16Commercial                       1    1    0    0    0    0
  229     16Forest                           1    1    0    0    0    0
  230     16Pasture                          1    1    0    0    0    0
  231     16Cropland                         1    1    0    0    0    0
  232     16Wetlands                         1    1    0    0    0    0
  233     16Livestock Access                 1    1    0    0    0    0
  234     17Water                            1    1    0    0    0    0
  235     17Low Residential                  1    1    0    0    0    0
  236     17High Residential                 1    1    0    0    0    0
  237     17Commercial                       1    1    0    0    0    0
  238     17Forest                           1    1    0    0    0    0
  239     17Pasture                          1    1    0    0    0    0
  240     17Cropland                         1    1    0    0    0    0
  241     17Wetlands                         1    1    0    0    0    0
  242     17Livestock Access                 1    1    0    0    0    0
  243     18Low Residential                  1    1    0    0    0    0
  244     18High Residential                 1    1    0    0    0    0
  245     18Commercial                       1    1    0    0    0    0
  246     18Forest                           1    1    0    0    0    0
  247     18Pasture                          1    1    0    0    0    0
  248     18Cropland                         1    1    0    0    0    0
  END GEN-INFO

  PWAT-PARM1
*** <PLS >                   Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC  HWT IRRG
  101  248    0    1    1    1    1    1    0    0    1    1    0    0
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  END PWAT-PARM1

  PWAT-PARM2
*** < PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x  - x                (in)   (in/hr)      (ft)              (1/in)   (1/day)
  101             0.        3.    0.0706    166.29     0.048      0.12     0.989
  102             0.        3.    0.0816    651.76     0.047      0.12     0.989
  103             0.        3.    0.1148      700.     0.055      0.12     0.989
  104             0.        3.    0.0774    478.14     0.066      0.12     0.989
  105             0.        3.    0.0944     443.7     0.101      0.12     0.989
  106             0.        3.    0.0791    376.46     0.058      0.12     0.989
  107             0.        3.    0.0816    289.41     0.056      0.12     0.989
  108             0.        3.    0.0604    225.32     0.042      0.12     0.989
  109             0.        3.    0.0689    104.57     0.025      0.12     0.989
  110             0.        2.     0.101    194.76     0.034      0.05     0.994
  111             0.        2.     0.217    437.09     0.045      0.05     0.994
  112             0.        2.     0.245    464.54     0.061      0.05     0.994
  113             0.        2.     0.241    472.92     0.037      0.05     0.994
  114             0.        2.     0.113     609.3      0.04      0.05     0.994
  115             0.        2.     0.129    469.43      0.12      0.05     0.994
  116             0.        2.     0.117    459.15     0.056      0.05     0.994
  117             0.        2.     0.127     337.9     0.055      0.05     0.994
  118             0.        2.     0.083    323.84     0.041      0.05     0.994
  119             0.        2.     0.165      101.      0.03      0.05     0.994
  120             0.        2.     0.097    193.99     0.026      0.05     0.994
  121             0.        2.     0.231    367.73     0.041      0.05     0.994
  122             0.        2.     0.265    265.37     0.013      0.05     0.994
  123             0.        2.     0.208    432.02     0.041      0.05     0.994
  124             0.        2.     0.117    353.77     0.042      0.05     0.994
  125             0.        2.     0.135    409.87     0.122      0.05     0.994
  126             0.        2.     0.124    395.75     0.055      0.05     0.994
  127             0.        2.     0.135     368.2     0.055      0.05     0.994
  128             0.        2.     0.116    162.01     0.019      0.05     0.994
  129             0.        2.     0.116      101.     0.041      0.05     0.994
  130             0.        2.     0.135    378.91      0.02      0.05     0.994
  131             0.        2.     0.275    676.57     0.067      0.05     0.994
  132             0.        2.     0.296    540.45      0.04      0.05     0.994
  133             0.        2.     0.286      700.     0.046      0.05     0.994
  134             0.        2.      0.16      700.     0.049      0.05     0.994
  135             0.        2.     0.166    371.44     0.098      0.05     0.994
  136             0.        2.     0.159    534.57     0.052      0.05     0.994
  137             0.        2.     0.151    479.79     0.052      0.05     0.994
  138             0.        2.     0.083      700.      0.01      0.05     0.994
  139             0.        2.      0.11      101.      0.03      0.05     0.994
  140             0.        2.     0.097    255.74     0.035      0.05     0.994
  141             0.        2.     0.257      700.     0.044      0.05     0.994
  142             0.        2.     0.227    569.36     0.037      0.05     0.994
  143             0.        2.      0.25      700.     0.033      0.05     0.994
  144             0.        2.     0.165      700.     0.073      0.05     0.994
  145             0.        2.      0.14    692.64     0.052      0.05     0.994
  146             0.        2.     0.132    566.64     0.066      0.05     0.994
  147             0.        2.     0.145    142.89      0.01      0.05     0.994
  148             0.        2.     0.165    237.73     0.021      0.05     0.994
  149             0.        2.     0.153    621.26     0.044      0.05     0.994
  150             0.        2.     0.163    353.02     0.038      0.05     0.994
  151             0.        2.     0.094     374.2     0.069      0.05     0.994
  152             0.        2.     0.078    654.65     0.046      0.05     0.994
```

153	0.	2.	0.202	614.25	0.06	0.05	0.994
154	0.	2.	0.213	530.97	0.048	0.05	0.994
155	0.	2.	0.101	655.68	0.13	0.05	0.994
156	0.	2.	0.119	374.32	0.095	0.05	0.994
157	0.	2.	0.087	520.3	0.044	0.05	0.994
158	0.	2.	0.006	101.	0.01	0.05	0.994
159	0.	2.	0.042	227.72	0.012	0.05	0.994
160	0.	2.	0.206	538.51	0.068	0.05	0.994
161	0.	2.	0.155	700.	0.043	0.05	0.994
162	0.	2.	0.195	700.	0.154	0.05	0.994
163	0.	2.	0.121	386.33	0.141	0.05	0.994
164	0.	2.	0.133	417.1	0.087	0.05	0.994
165	0.	2.	0.115	670.85	0.061	0.05	0.994
166	0.	2.	0.096	142.65	0.023	0.05	0.994
167	0.	2.	0.006	100.	0.001	0.05	0.994
168	0.	2.	0.124	290.4	0.01	0.05	0.994
169	0.	2.	0.246	457.02	0.056	0.05	0.994
170	0.	2.	0.232	415.77	0.028	0.05	0.994
171	0.	2.	0.189	461.38	0.041	0.05	0.994
172	0.	2.	0.083	336.49	0.075	0.05	0.994
173	0.	2.	0.114	326.6	0.097	0.05	0.994
174	0.	2.	0.111	389.65	0.057	0.05	0.994
175	0.	2.	0.112	600.66	0.051	0.05	0.994
176	0.	2.	0.006	100.	0.001	0.05	0.994
177	0.	2.	0.094	136.54	0.056	0.05	0.994
178	0.	2.	0.226	459.65	0.054	0.05	0.994
179	0.	2.	0.27	593.21	0.03	0.05	0.994
180	0.	2.	0.23	518.32	0.052	0.05	0.994
181	0.	2.	0.102	259.82	0.037	0.05	0.994
182	0.	2.	0.104	429.23	0.11	0.05	0.994
183	0.	2.	0.119	380.75	0.051	0.05	0.994
184	0.	2.	0.144	381.58	0.062	0.05	0.994
185	0.	2.	0.165	101.	0.01	0.05	0.994
186	0.	2.	0.295	700.	0.054	0.05	0.994
187	0.	2.	0.288	661.75	0.091	0.05	0.994
188	0.	2.	0.284	700.	0.056	0.05	0.994
189	0.	2.	0.162	658.4	0.076	0.05	0.994
190	0.	2.	0.161	700.	0.045	0.05	0.994
191	0.	2.	0.157	684.88	0.052	0.05	0.994
192	0.	2.	0.006	100.	0.001	0.05	0.994
193	0.	2.	0.113	154.56	0.022	0.05	0.994
194	0.	2.	0.225	309.29	0.083	0.05	0.994
195	0.	2.	0.174	246.71	0.057	0.05	0.994
196	0.	2.	0.104	398.65	0.078	0.05	0.994
197	0.	2.	0.138	347.47	0.149	0.05	0.994
198	0.	2.	0.134	439.36	0.073	0.05	0.994
199	0.	2.	0.144	330.87	0.088	0.05	0.994
200	0.	2.	0.165	202.	0.01	0.05	0.994
201	0.	2.	0.084	516.53	0.042	0.05	0.994
202	0.	2.	0.227	343.66	0.071	0.05	0.994
203	0.	2.	0.195	568.74	0.037	0.05	0.994
204	0.	2.	0.099	549.64	0.06	0.05	0.994
205	0.	2.	0.13	461.14	0.127	0.05	0.994
206	0.	2.	0.121	349.01	0.067	0.05	0.994
207	0.	2.	0.104	301.17	0.085	0.05	0.994
208	0.	2.	0.083	139.26	0.014	0.05	0.994
209	0.	2.	0.006	100.	0.001	0.05	0.994

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  210            0.        2.     0.124    319.71     0.055      0.05     0.994
  211            0.        2.     0.195     273.3     0.091      0.05     0.994
  212            0.        2.     0.225    286.02     0.155      0.05     0.994
  213            0.        2.     0.108      700.     0.084      0.05     0.994
  214            0.        2.     0.106    455.62     0.126      0.05     0.994
  215            0.        2.     0.105    374.56     0.061      0.05     0.994
  216            0.        2.     0.093    262.52     0.058      0.05     0.994
  217            0.        2.     0.006      100.     0.001      0.05     0.994
  218            0.        2.     0.126    357.85     0.031      0.05     0.994
  219            0.        2.      0.21    387.65     0.051      0.05     0.994
  220            0.        2.       0.2    577.02     0.048      0.05     0.994
  221            0.        2.     0.141     301.8     0.088      0.05     0.994
  222            0.        2.     0.146    603.77     0.116      0.05     0.994
  223            0.        2.     0.116    547.91      0.05      0.05     0.994
  224            0.        2.      0.13    522.84      0.04      0.05     0.994
  225            0.        2.     0.006      100.     0.001      0.05     0.994
  226            0.        2.     0.146    373.01     0.034      0.05     0.994
  227            0.        2.     0.195      700.     0.039      0.05     0.994
  228            0.        2.     0.218      700.     0.025      0.05     0.994
  229            0.        2.     0.129    541.15     0.097      0.05     0.994
  230            0.        2.     0.108      700.     0.036      0.05     0.994
  231            0.        2.     0.157    359.22     0.021      0.05     0.994
  232            0.        2.     0.094    309.23      0.01      0.05     0.994
  233            0.        2.     0.041    169.96     0.023      0.05     0.994
  234            0.        2.      0.16    256.82     0.046      0.05     0.994
  235            0.        2.     0.218      700.     0.031      0.05     0.994
  236            0.        2.     0.224      700.     0.009      0.05     0.994
  237            0.        2.     0.135      700.     0.034      0.05     0.994
  238            0.        2.     0.139      700.     0.043      0.05     0.994
  239            0.        2.     0.119      700.     0.035      0.05     0.994
  240            0.        2.     0.123    302.59     0.058      0.05     0.994
  241            0.        2.     0.125    588.49     0.015      0.05     0.994
  242            0.        2.      0.01      100.     0.001      0.05     0.994
  243            0.        2.     0.189      700.     0.014      0.05     0.994
  244            0.        2.     0.196      700.     0.014      0.05     0.994
  245            0.        2.     0.235      700.      0.01      0.05     0.994
  246            0.        2.      0.11      700.     0.016      0.05     0.994
  247            0.        2.     0.116      700.     0.013      0.05     0.994
  248            0.        2.     0.122      700.     0.009      0.05     0.994
  END PWAT-PARM2

  PWAT-PARM3
*** < PLS>    PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x  - x   (deg F)   (deg F)
  101  109       40.       35.        2.        2.        0.    0.0315        0.
  110  248       40.       35.        2.        2.        0.    0.0325        0.
  END PWAT-PARM3

  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                         (1/day)
  101           0.01      0.61      0.01        1.       0.3      0.01
  102           0.05     0.337       0.1        1.       0.3       0.1
  103           0.05     0.406       0.1        1.       0.3       0.1
  104           0.05     0.623       0.1        1.       0.3       0.1
  105           0.25     0.535       0.4        1.       0.3       0.7
  106            0.1      0.65       0.3        1.       0.3       0.5
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107	0.2	0.667	0.25	1.	0.3	0.6
108	0.1	0.51	0.4	1.	0.3	0.8
109	0.1	0.585	0.3	1.	0.3	0.5
110	0.01	0.609	0.01	1.	0.3	0.01
111	0.05	0.319	0.1	1.	0.3	0.1
112	0.05	0.351	0.1	1.	0.3	0.1
113	0.05	0.354	0.1	1.	0.3	0.1
114	0.05	0.655	0.1	1.	0.3	0.1
115	0.25	0.389	0.4	1.	0.3	0.7
116	0.1	0.648	0.3	1.	0.3	0.5
117	0.2	0.699	0.25	1.	0.3	0.6
118	0.1	0.504	0.4	1.	0.3	0.8
119	0.1	0.88	0.3	1.	0.3	0.5
120	0.01	0.63	0.01	1.	0.3	0.01
121	0.05	0.356	0.1	1.	0.3	0.1
122	0.05	0.456	0.1	1.	0.3	0.1
123	0.05	0.309	0.1	1.	0.3	0.1
124	0.05	0.656	0.1	1.	0.3	0.1
125	0.25	0.536	0.4	1.	0.3	0.7
126	0.1	0.709	0.3	1.	0.3	0.5
127	0.2	0.7	0.25	1.	0.3	0.6
128	0.1	0.726	0.4	1.	0.3	0.8
129	0.1	0.592	0.3	1.	0.3	0.5
130	0.01	1.138	0.01	1.	0.3	0.01
131	0.05	0.509	0.1	1.	0.3	0.1
132	0.05	0.55	0.1	1.	0.3	0.1
133	0.05	0.478	0.1	1.	0.3	0.1
134	0.05	1.032	0.1	1.	0.3	0.1
135	0.25	0.856	0.4	1.	0.3	0.7
136	0.1	1.041	0.3	1.	0.3	0.5
137	0.2	0.976	0.25	1.	0.3	0.6
138	0.1	1.395	0.4	1.	0.3	0.8
139	0.1	0.838	0.3	1.	0.3	0.5
140	0.01	0.118	0.01	1.	0.3	0.01
141	0.05	0.405	0.1	1.	0.3	0.1
142	0.05	0.243	0.1	1.	0.3	0.1
143	0.05	0.334	0.1	1.	0.3	0.1
144	0.25	1.045	0.4	1.	0.3	0.7
145	0.1	0.76	0.3	1.	0.3	0.5
146	0.2	0.737	0.25	1.	0.3	0.6
147	0.1	0.761	0.4	1.	0.3	0.8
148	0.1	0.8	0.3	1.	0.3	0.5
149	0.05	0.164	0.1	1.	0.3	0.1
150	0.05	0.198	0.1	1.	0.3	0.1
151	0.25	0.37	0.4	1.	0.3	0.7
152	0.1	0.33	0.3	1.	0.3	0.5
153	0.05	0.251	0.1	1.	0.3	0.1
154	0.05	0.271	0.1	1.	0.3	0.1
155	0.05	0.505	0.1	1.	0.3	0.1
156	0.25	0.556	0.4	1.	0.3	0.7
157	0.1	0.526	0.3	1.	0.3	0.5
158	0.1	0.025	0.3	1.	0.3	0.5
159	0.01	0.113	0.01	1.	0.3	0.01
160	0.05	0.315	0.1	1.	0.3	0.1
161	0.05	0.229	0.1	1.	0.3	0.1
162	0.05	0.236	0.1	1.	0.3	0.1
163	0.25	0.288	0.4	1.	0.3	0.7

164		0.1	0.48	0.3	1.	0.3	0.5
165		0.2	0.408	0.25	1.	0.3	0.6
166		0.1	0.419	0.4	1.	0.3	0.8
167		0.1	0.01	0.3	1.	0.3	0.5
168		0.01	1.07	0.01	1.	0.3	0.01
169		0.05	0.451	0.1	1.	0.3	0.1
170		0.05	0.468	0.1	1.	0.3	0.1
171		0.05	0.379	0.1	1.	0.3	0.1
172		0.05	0.51	0.1	1.	0.3	0.1
173		0.25	0.605	0.4	1.	0.3	0.7
174		0.1	0.768	0.3	1.	0.3	0.5
175		0.2	0.729	0.25	1.	0.3	0.6
176		0.1	0.01	0.3	1.	0.3	0.5
177		0.01	0.511	0.01	1.	0.3	0.01
178		0.05	0.418	0.1	1.	0.3	0.1
179		0.05	0.514	0.1	1.	0.3	0.1
180		0.05	0.375	0.1	1.	0.3	0.1
181		0.05	0.386	0.1	1.	0.3	0.1
182		0.25	0.586	0.4	1.	0.3	0.7
183		0.1	0.849	0.3	1.	0.3	0.5
184		0.2	0.89	0.25	1.	0.3	0.6
185		0.1	1.2	0.3	1.	0.3	0.5
186		0.05	0.531	0.1	1.	0.3	0.1
187		0.05	0.487	0.1	1.	0.3	0.1
188		0.05	0.459	0.1	1.	0.3	0.1
189		0.25	1.059	0.4	1.	0.3	0.7
190		0.1	0.957	0.3	1.	0.3	0.5
191		0.2	0.923	0.25	1.	0.3	0.6
192		0.1	0.01	0.3	1.	0.3	0.5
193		0.01	0.537	0.01	1.	0.3	0.01
194		0.05	0.364	0.1	1.	0.3	0.1
195		0.05	0.321	0.1	1.	0.3	0.1
196		0.05	0.789	0.1	1.	0.3	0.1
197		0.25	0.651	0.4	1.	0.3	0.7
198		0.1	0.795	0.3	1.	0.3	0.5
199		0.2	0.895	0.25	1.	0.3	0.6
200		0.1	0.275	0.3	1.	0.3	0.5
201		0.01	0.569	0.01	1.	0.3	0.01
202		0.05	0.356	0.1	1.	0.3	0.1
203		0.05	0.352	0.1	1.	0.3	0.1
204		0.05	0.689	0.1	1.	0.3	0.1
205		0.25	0.484	0.4	1.	0.3	0.7
206		0.1	0.645	0.3	1.	0.3	0.5
207		0.2	0.636	0.25	1.	0.3	0.6
208		0.1	0.575	0.4	1.	0.3	0.8
209		0.1	0.01	0.3	1.	0.3	0.5
210		0.01	0.49	0.01	1.	0.3	0.01
211	212	0.05	0.268	0.1	1.	0.3	0.1
213		0.05	0.578	0.1	1.	0.3	0.1
214		0.25	0.41	0.4	1.	0.3	0.7
215		0.1	0.494	0.3	1.	0.3	0.5
216		0.2	0.588	0.25	1.	0.3	0.6
217		0.1	0.01	0.3	1.	0.3	0.5
218		0.01	0.735	0.01	1.	0.3	0.01
219		0.05	0.368	0.1	1.	0.3	0.1
220		0.05	0.41	0.1	1.	0.3	0.1
221		0.05	0.539	0.1	1.	0.3	0.1

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  222          0.25     0.483       0.4        1.       0.3       0.7
  223           0.1     0.749       0.3        1.       0.3       0.5
  224           0.2     0.616      0.25        1.       0.3       0.6
  225           0.1      0.01       0.3        1.       0.3       0.5
  226          0.01     1.126      0.01        1.       0.3      0.01
  227          0.05     0.241       0.1        1.       0.3       0.1
  228          0.05     0.323       0.1        1.       0.3       0.1
  229          0.25       0.5       0.4        1.       0.3       0.7
  230           0.1     0.613       0.3        1.       0.3       0.5
  231           0.2      0.81      0.25        1.       0.3       0.6
  232           0.1     0.296       0.4        1.       0.3       0.8
  233           0.1     0.698       0.3        1.       0.3       0.5
  234          0.01     0.242      0.01        1.       0.3      0.01
  235          0.05     0.231       0.1        1.       0.3       0.1
  236          0.05     0.318       0.1        1.       0.3       0.1
  237          0.05     0.124       0.1        1.       0.3       0.1
  238          0.25     0.763       0.4        1.       0.3       0.7
  239           0.1      0.63       0.3        1.       0.3       0.5
  240           0.2     0.673      0.25        1.       0.3       0.6
  241           0.1     0.598       0.4        1.       0.3       0.8
  242           0.1      0.01       0.3        1.       0.3       0.5
  243          0.05     0.163       0.1        1.       0.3       0.1
  244          0.05     0.129       0.1        1.       0.3       0.1
  245          0.05     0.281       0.1        1.       0.3       0.1
  246          0.25     0.439       0.4        1.       0.3       0.7
  247           0.1     0.501       0.3        1.       0.3       0.5
  248           0.2     0.515      0.25        1.       0.3       0.6
  END PWAT-PARM4

  PWAT-STATE1
*** < PLS>  PWATER state variables (in)
*** x  - x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  101  248      0.01      0.01       0.3      0.01       1.5      0.01      0.01
  END PWAT-STATE1

  MON-INTERCEP
*** <PLS >  Interception storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101      0.01 0.01 0.01  0.4  0.40.017 0.01 0.01 0.01 0.01 0.01 0.01
  102  1030.0160.0160.0170.0230.023 0.060.0490.0650.065 0.02 0.020.015
  104     0.0120.0120.0120.0230.0230.0580.0480.0630.0630.0310.028 0.01
  105     0.0930.0930.093 0.18 0.18  0.40.359  0.4  0.40.2280.2070.047
  106     0.0850.0850.0850.1510.2020.3250.2880.2880.2880.1440.0550.043
  107     0.1080.1080.108 0.21 0.21  0.4  0.4  0.4  0.40.2660.2420.054
  108     0.0620.0620.0620.1210.1210.2860.2390.3130.3130.1520.1380.031
  109     0.0850.0850.0850.1510.2020.3250.2880.2880.2880.1440.0550.043
  110      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  111  1130.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
  114     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
  115     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
  116      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  117     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
  118     0.0240.0240.0240.0280.0280.0670.0960.1240.1240.121 0.110.024
  119      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  120      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  121  1230.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
  124     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
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125     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
126      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
127     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
128     0.0240.0240.0240.0280.0280.0670.0960.1240.1240.121 0.110.024
129      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
130      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
131   1330.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
134     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
135     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
136      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
137     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
138     0.0240.0240.0240.0280.0280.0670.0960.1240.1240.121 0.110.024
139      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
140      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
141   1430.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
144     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
145      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
146     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
147     0.0240.0240.0240.0280.0280.0670.0960.1240.1240.121 0.110.024
148      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
149   1500.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
151     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
152      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
153   1540.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
155     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
156     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
157   158 0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
159      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
160   1610.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
162     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
163     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
164      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
165     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
166     0.0240.0240.0240.0280.0280.0670.0960.1240.1240.121 0.110.024
167      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
168      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
169   1710.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
172     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
173     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
174      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
175     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
176      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
177      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
178   1800.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
181     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
182     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
183      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
184     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
185      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
186   1880.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
189     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
190      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
191     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
192      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
193      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
194   1950.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
196     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
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  197     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
  198      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  199     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
  200      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  201      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  202  2030.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
  204     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
  205     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
  206      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  207     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
  208     0.0240.0240.0240.0280.0280.0670.0960.1240.1240.121 0.110.024
  209      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  210      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  211  2120.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
  213     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
  214     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
  215      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  216     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
  217      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  218      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  219  2200.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
  221     0.0120.0120.0120.0140.0140.0270.038 0.05 0.050.0480.0440.012
  222     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
  223      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  224     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
  225      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  226      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  227  2280.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
  229     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
  230      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  231     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
  232     0.0240.0240.0240.0280.0280.0670.0960.1240.1240.121 0.110.024
  233      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  234      0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  235  2370.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
  238     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
  239      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  240     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
  241     0.0240.0240.0240.0280.0280.0670.0960.1240.1240.121 0.110.024
  242      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  243  2450.0160.0160.0170.0140.0140.0280.0390.0520.0520.0310.0320.024
  246     0.0490.0490.0490.0560.0560.1340.191 0.25 0.250.242 0.220.049
  247      0.04 0.04 0.040.0420.0560.0920.1380.1380.1380.1380.052 0.04
  248     0.0390.0390.0390.0450.0450.1080.152  0.2  0.20.1940.1760.039
  END MON-INTERCEP

  MON-UZSN
*** <PLS >  Upper zone storage at start of each month  (inches)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101     0.0830.0830.0830.1480.1480.1480.1240.1250.125 0.05 0.05 0.05
  102     0.2710.271 0.280.5040.5190.5190.4330.4340.434 0.140.1360.136
  103     0.3260.3260.3370.6060.6250.6250.5220.5220.5220.1680.1630.163
  104     0.4470.4470.467 0.841.0951.0950.9130.9140.9140.2330.2240.224
  105      0.46 0.460.4810.8651.1281.128 0.940.9410.941 0.24 0.23 0.23
  106     0.6240.6240.6481.1651.2091.2091.0081.0081.0080.3240.3120.312
  107     0.1070.1040.3530.9311.4851.584  1.5  1.5  1.50.4810.287 0.08
  108     0.4390.4390.4590.8251.0751.0750.8970.8970.8970.229 0.22 0.22
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109     0.5620.5620.5831.0481.0891.0890.9070.9080.9080.2910.2810.281
110     0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
111     0.2560.2560.2650.2650.2730.2730.2730.2730.2730.2650.2560.256
112     0.2820.2820.2910.2910.3010.3010.3010.3010.3010.2910.2820.282
113     0.2840.2840.2940.2940.3030.3030.3030.3030.3030.2940.2840.284
114     0.4690.4690.4910.491 0.64 0.64 0.64 0.64 0.640.4910.4690.469
115     0.2790.2790.2910.291 0.38 0.38 0.38 0.38 0.380.2910.2790.279
116     0.5180.5180.538   2.   2.   2.0.5580.5580.558   2.   2.   2.
117     0.0930.0910.3080.4520.7210.9610.9610.9610.9610.841  0.50.139
118     0.3610.3610.3770.3770.4920.4920.4920.4920.4920.3770.3610.361
119     0.7040.7040.731   2.   2.   2.0.7580.7580.758   2.   2.   2.
120     0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
121     0.2860.2860.2960.2960.3050.3050.3050.3050.3050.2960.2860.286
122     0.3670.3670.3790.3790.3910.3910.3910.3910.3910.3790.3670.367
123     0.2490.2490.2570.2570.2650.2650.2650.2650.2650.2570.2490.249
124      0.47 0.470.4910.4910.6410.6410.6410.6410.6410.491 0.47 0.47
125     0.3840.3840.4010.4010.5230.5230.5230.5230.5230.4010.3840.384
126     0.5670.5670.589   2.   2.   2.0.6110.6110.611   2.   2.   2.
127     0.0930.0910.3080.4530.7210.9620.9620.9620.9620.8410.5010.139
128      0.52 0.520.5440.5440.7090.7090.7090.7090.7090.544 0.52 0.52
129     0.4730.4730.491   2.   2.   2. 0.51 0.51 0.51   2.   2.   2.
130     0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
131      0.41 0.410.4230.4230.4370.4370.4370.4370.4370.423 0.41 0.41
132     0.4420.4420.4570.4570.4710.4710.4710.4710.4710.4570.4420.442
133     0.3840.3840.3970.397 0.41 0.41 0.41 0.41 0.410.3970.3840.384
134     0.7390.7390.7730.7731.0081.0081.0081.0081.0080.7730.7390.739
135     0.6130.6130.6410.6410.8360.8360.8360.8360.8360.6410.6130.613
136     0.8320.8320.864   2.   2.   2.0.8960.8960.896   2.   2.   2.
137      0.130.127 0.430.6321.0061.3421.3421.3421.3421.1740.6990.194
138     0.9990.9991.0451.0451.3631.3631.3631.3631.3631.0450.9990.999
139      0.67 0.670.696   2.   2.   2.0.7220.7220.722   2.   2.   2.
140     0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
141     0.3260.3260.3370.3370.3480.3480.3480.3480.3480.3370.3260.326
142     0.1960.1960.2020.2020.2090.2090.2090.2090.2090.2020.1960.196
143     0.2690.2690.2780.2780.2870.2870.2870.2870.2870.2780.2690.269
144     0.7490.7490.7830.7831.0211.0211.0211.0211.0210.7830.7490.749
145     0.6080.6080.631   2.   2.   2.0.6550.6550.655   2.   2.   2.
146     0.0980.0960.3250.4770.7591.0131.0131.0131.0130.8860.5270.147
147     0.5450.545 0.57 0.570.7430.7430.7430.7430.743 0.570.5450.545
148      0.64 0.640.665   2.   2.   2.0.6890.6890.689   2.   2.   2.
149     0.1320.1320.1360.136 0.14 0.14 0.14 0.14 0.140.1360.1320.132
150     0.1590.1590.1640.1640.1690.1690.1690.1690.1690.1640.1590.159
151     0.2650.2650.2770.2770.3610.3610.3610.3610.3610.2770.2650.265
152     0.2640.2640.2741.6441.7041.7040.2840.2840.2841.6441.5841.584
153     0.2020.2020.2090.2090.2160.2160.2160.2160.2160.2090.2020.202
154     0.2180.2180.2250.2250.2330.2330.2330.2330.2330.2250.2180.218
155     0.3620.3620.3780.3780.4930.4930.4930.4930.4930.3780.3620.362
156     0.3980.3980.4170.4170.5430.5430.5430.5430.5430.4170.3980.398
157     0.4210.4210.437   2.   2.   2.0.4530.4530.453   2.   2.   2.
158      0.05 0.05 0.050.1260.1320.132 0.05 0.05 0.050.126 0.12 0.12
159     0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
160     0.2530.2530.2610.261 0.27 0.27 0.27 0.27 0.270.2610.2530.253
161     0.1840.184 0.19 0.190.1960.1960.1960.1960.196 0.190.1840.184
162     0.1690.1690.1760.176 0.23 0.23 0.23 0.23 0.230.1760.1690.169
163     0.2060.2060.2160.2160.2810.2810.2810.2810.2810.2160.2060.206
164     0.3840.3840.398   2.   2.   2.0.4130.4130.413   2.   2.   2.
165     0.0540.053 0.180.2640.4210.5610.5610.5610.5610.4910.2920.081
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 166      0.3  0.30.3140.3140.4090.4090.4090.4090.4090.314  0.3  0.3
 167     0.05 0.05 0.05 0.06 0.06 0.06 0.05 0.05 0.05 0.06 0.06 0.06
 168    0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
 169    0.3630.3630.3750.3750.3870.3870.3870.3870.3870.3750.3630.363
 170    0.3770.3770.3890.3890.4020.4020.4020.4020.4020.3890.3770.377
 171    0.3040.3040.3150.3150.3250.3250.3250.3250.3250.3150.3040.304
 172    0.3660.3660.3820.3820.4980.4980.4980.4980.4980.3820.3660.366
 173    0.4340.4340.4530.4530.5910.5910.5910.5910.5910.4530.4340.434
 174    0.6140.6140.638   2.   2.   2.0.6610.6610.661   2.   2.   2.
 175    0.0970.0950.3210.4720.7521.0021.0021.0021.0020.8770.5220.145
 176     0.05 0.05 0.05 0.06 0.06 0.06 0.05 0.05 0.05 0.06 0.06 0.06
 177    0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
 178    0.3360.3360.3470.3470.3580.3580.3580.3580.3580.3470.3360.336
 179    0.4140.4140.4270.4270.4410.4410.4410.4410.4410.4270.4140.414
 180    0.3010.3010.3110.3110.3210.3210.3210.3210.3210.3110.3010.301
 181    0.2760.2760.2890.2890.3770.3770.3770.3770.3770.2890.2760.276
 182     0.42 0.420.4390.4390.5720.5720.5720.5720.5720.439 0.42 0.42
 183    0.6790.6790.705   2.   2.   2.0.7310.7310.731   2.   2.   2.
 184    0.1190.1160.3920.5760.9171.2231.2231.2231.223 1.070.6370.177
 185     0.96 0.960.997   2.1.0341.0341.0341.0341.034   2.   2.   2.
 186    0.4270.4270.4410.4410.4550.4550.4550.4550.4550.4410.4270.427
 187    0.3920.3920.4050.4050.4180.4180.4180.4180.4180.4050.3920.392
 188    0.3690.3690.3810.3810.3930.3930.3930.3930.3930.3810.3690.369
 189    0.7590.7590.7930.7931.0341.0341.0341.0341.0340.7930.7590.759
 190    0.7660.7660.795   2.   2.   2.0.8250.8250.825   2.   2.   2.
 191    0.123 0.120.4070.5970.9511.2681.2681.2681.268 1.11 0.660.184
 192     0.05 0.05 0.05 0.06 0.06 0.06 0.05 0.05 0.05 0.06 0.06 0.06
 193    0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
 194    0.2930.2930.3030.3030.3120.3120.3120.3120.3120.3030.2930.293
 195    0.2580.2580.2670.2670.2750.2750.2750.2750.2750.2670.2580.258
 196    0.5650.5650.5910.5910.7710.7710.7710.7710.7710.5910.5650.565
 197    0.4660.4660.4870.4870.6360.6360.6360.6360.6360.4870.4660.466
 198    0.6360.636 0.66   2.   2.   2.0.6850.6850.685   2.   2.   2.
 199    0.1190.1170.3950.5790.9231.2311.2311.2311.2311.0770.6410.178
 200     0.22 0.220.2281.3681.4221.4220.2370.2370.2371.368 1.32 1.32
 201    0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
 202    0.2860.2860.2960.2960.3050.3050.3050.3050.3050.2960.2860.286
 203    0.2830.2830.2920.2920.3020.3020.3020.3020.3020.2920.2830.283
 204    0.4940.4940.5160.5160.6730.6730.6730.6730.6730.5160.4940.494
 205    0.3470.3470.3630.3630.4730.4730.4730.4730.4730.3630.3470.347
 206    0.5160.5160.535   2.   2.   2.0.5550.5550.555   2.   2.   2.
 207    0.0850.083 0.280.4120.6560.8740.8740.8740.8740.7650.4550.127
 208    0.4120.412 0.43 0.430.5610.5610.5610.5610.561 0.430.4120.412
 209     0.05 0.05 0.05 0.06 0.06 0.06 0.05 0.05 0.05 0.06 0.06 0.06
 210    0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
 211    0.2150.2150.2220.2220.2290.2290.2290.2290.2290.2220.2150.215
 212    0.2160.2160.2230.223 0.23 0.23 0.23 0.23 0.230.2230.2160.216
 213    0.4140.4140.4330.4330.5640.5640.5640.5640.5640.4330.4140.414
 214    0.2940.2940.3070.3070.4010.4010.4010.4010.4010.3070.2940.294
 215    0.3950.395 0.41   2.   2.   2.0.4250.4250.425   2.   2.   2.
 216    0.0780.0770.259 0.380.6060.8080.8080.8080.8080.7070.4210.117
 217     0.05 0.05 0.05 0.06 0.06 0.06 0.05 0.05 0.05 0.06 0.06 0.06
 218    0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
 219    0.2960.2960.3060.3060.3160.3160.3160.3160.3160.3060.2960.296
 220     0.33 0.330.3410.3410.3520.3520.3520.3520.3520.341 0.33 0.33
 221    0.3860.3860.4040.4040.5270.5270.5270.5270.5270.4040.3860.386
 222    0.3460.3460.3620.3620.4720.4720.4720.4720.4720.3620.3460.346
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  223     0.5990.5990.622   2.   2.   2.0.6450.6450.645   2.   2.   2.
  224     0.082 0.080.2710.3980.6350.8460.8460.8460.846 0.740.4410.123
  225      0.05 0.05 0.05 0.06 0.06 0.06 0.05 0.05 0.05 0.06 0.06 0.06
  226     0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
  227     0.1940.194  0.2  0.20.2070.2070.2070.2070.207  0.20.1940.194
  228      0.26 0.260.2680.2680.2770.2770.2770.2770.2770.268 0.26 0.26
  229     0.3580.3580.3740.3740.4880.4880.4880.4880.4880.3740.3580.358
  230      0.49 0.490.509   2.   2.   2.0.5280.5280.528   2.   2.   2.
  231     0.1080.1060.3570.5240.8351.1131.1131.1131.1130.9740.5790.161
  232     0.2120.2120.2210.2210.2890.2890.2890.2890.2890.2210.2120.212
  233     0.5580.5580.579   2.   2.   2.0.6010.6010.601   2.   2.   2.
  234     0.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.0830.083
  235     0.1860.1860.1920.1920.1980.1980.1980.1980.1980.1920.1860.186
  236     0.2560.2560.2640.2640.2730.2730.2730.2730.2730.2640.2560.256
  237       0.1  0.10.1030.1030.1060.1060.1060.1060.1060.103  0.1  0.1
  238     0.5470.5470.5720.5720.7460.7460.7460.7460.7460.5720.5470.547
  239     0.5040.5040.523   2.   2.   2.0.5430.5430.543   2.   2.   2.
  240      0.090.0880.2970.4350.6940.9250.9250.9250.9250.8090.4820.134
  241     0.4290.4290.4480.4480.5840.5840.5840.5840.5840.4480.4290.429
  242      0.05 0.05 0.05 0.06 0.06 0.06 0.05 0.05 0.05 0.06 0.06 0.06
  243     0.1310.1310.1350.135 0.14 0.14 0.14 0.14 0.140.1350.1310.131
  244     0.1040.1040.1070.1070.1110.1110.1110.1110.1110.1070.1040.104
  245     0.2260.2260.2340.2340.2410.2410.2410.2410.2410.2340.2260.226
  246     0.3140.3140.3290.3290.4280.4280.4280.4280.4280.3290.3140.314
  247     0.4010.4010.416   2.   2.   2.0.4320.4320.432   2.   2.   2.
  248     0.0690.0670.2270.3330.5310.7070.7070.7070.7070.6190.3680.102
  END MON-UZSN

  MON-MANNING
*** <PLS >  Manning's n at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  102  104  0.1  0.1  0.1  0.1  0.10.1440.1440.1440.144  0.1  0.1  0.1
  105      0.14 0.14 0.28 0.28 0.28 0.42 0.42 0.42 0.42 0.28 0.28 0.14
  106      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  107       0.1  0.10.1730.2590.2590.3450.3450.3450.2590.173  0.1  0.1
  108      0.16 0.16 0.32 0.32 0.32 0.48 0.48 0.48 0.48 0.32 0.32 0.16
  109      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  110       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  111  114  0.1  0.1  0.1  0.1  0.10.1440.1440.1440.144  0.1  0.1  0.1
  115      0.14 0.14 0.28 0.28 0.28 0.42 0.42 0.42 0.42 0.28 0.28 0.14
  116      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  117       0.1  0.10.1730.2590.2590.3450.3450.3450.2590.173  0.1  0.1
  118      0.16 0.16 0.32 0.32 0.32 0.48 0.48 0.48 0.48 0.32 0.32 0.16
  119      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  120       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  121  124  0.1  0.1  0.1  0.1  0.10.1440.1440.1440.144  0.1  0.1  0.1
  125      0.14 0.14 0.28 0.28 0.28 0.42 0.42 0.42 0.42 0.28 0.28 0.14
  126      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  127       0.1  0.10.1730.2590.2590.3450.3450.3450.2590.173  0.1  0.1
  128      0.16 0.16 0.32 0.32 0.32 0.48 0.48 0.48 0.48 0.32 0.32 0.16
  129      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  130       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  131  134  0.1  0.1  0.1  0.1  0.10.1440.1440.1440.144  0.1  0.1  0.1
  135      0.14 0.14 0.28 0.28 0.28 0.42 0.42 0.42 0.42 0.28 0.28 0.14
  136      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  137       0.1  0.10.1730.2590.2590.3450.3450.3450.2590.173  0.1  0.1
```

138		0.16	0.16	0.32	0.32	0.32	0.48	0.48	0.48	0.48	0.32	0.32	0.16
139		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
140		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
141	143	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
144		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
145		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
146		0.1	0.1	0.173	0.259	0.259	0.345	0.345	0.345	0.259	0.173	0.1	0.1
147		0.16	0.16	0.32	0.32	0.32	0.48	0.48	0.48	0.48	0.32	0.32	0.16
148		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
149	150	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
151		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
152		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
153	155	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
156		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
157	158	0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
159		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
160	162	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
163		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
164		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
165		0.1	0.1	0.173	0.259	0.259	0.345	0.345	0.345	0.259	0.173	0.1	0.1
166		0.16	0.16	0.32	0.32	0.32	0.48	0.48	0.48	0.48	0.32	0.32	0.16
167		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
168		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
169	172	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
173		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
174		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
175		0.1	0.1	0.173	0.259	0.259	0.345	0.345	0.345	0.259	0.173	0.1	0.1
176		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
177		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
178	181	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
182		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
183		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
184		0.1	0.1	0.173	0.259	0.259	0.345	0.345	0.345	0.259	0.173	0.1	0.1
185		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
186	188	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
189		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
190		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
191		0.1	0.1	0.173	0.259	0.259	0.345	0.345	0.345	0.259	0.173	0.1	0.1
192		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
193		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
194	196	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
197		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
198		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
199		0.1	0.1	0.173	0.259	0.259	0.345	0.345	0.345	0.259	0.173	0.1	0.1
200		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
201		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
202	204	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
205		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
206		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
207		0.1	0.1	0.173	0.259	0.259	0.345	0.345	0.345	0.259	0.173	0.1	0.1
208		0.16	0.16	0.32	0.32	0.32	0.48	0.48	0.48	0.48	0.32	0.32	0.16
209		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
210		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
211	213	0.1	0.1	0.1	0.1	0.1	0.144	0.144	0.144	0.144	0.1	0.1	0.1
214		0.14	0.14	0.28	0.28	0.28	0.42	0.42	0.42	0.42	0.28	0.28	0.14
215		0.12	0.12	0.24	0.24	0.24	0.36	0.36	0.36	0.36	0.24	0.24	0.12
216		0.1	0.1	0.173	0.259	0.259	0.345	0.345	0.345	0.259	0.173	0.1	0.1

```
  217      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  218       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  219  221  0.1  0.1  0.1  0.1  0.10.1440.1440.1440.144  0.1  0.1  0.1
  222      0.14 0.14 0.28 0.28 0.28 0.42 0.42 0.42 0.42 0.28 0.28 0.14
  223      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  224       0.1  0.10.1730.2590.2590.3450.3450.3450.2590.173  0.1  0.1
  225      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  226       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  227  228  0.1  0.1  0.1  0.1  0.10.1440.1440.1440.144  0.1  0.1  0.1
  229      0.14 0.14 0.28 0.28 0.28 0.42 0.42 0.42 0.42 0.28 0.28 0.14
  230      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  231       0.1  0.10.1730.2590.2590.3450.3450.3450.2590.173  0.1  0.1
  232      0.16 0.16 0.32 0.32 0.32 0.48 0.48 0.48 0.48 0.32 0.32 0.16
  233      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  234       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  235  237  0.1  0.1  0.1  0.1  0.10.1440.1440.1440.144  0.1  0.1  0.1
  238      0.14 0.14 0.28 0.28 0.28 0.42 0.42 0.42 0.42 0.28 0.28 0.14
  239      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  240       0.1  0.10.1730.2590.2590.3450.3450.3450.2590.173  0.1  0.1
  241      0.16 0.16 0.32 0.32 0.32 0.48 0.48 0.48 0.48 0.32 0.32 0.16
  242      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  243  245  0.1  0.1  0.1  0.1  0.10.1440.1440.1440.144  0.1  0.1  0.1
  246      0.14 0.14 0.28 0.28 0.28 0.42 0.42 0.42 0.42 0.28 0.28 0.14
  247      0.12 0.12 0.24 0.24 0.24 0.36 0.36 0.36 0.36 0.24 0.24 0.12
  248       0.1  0.10.1730.2590.2590.3450.3450.3450.2590.173  0.1  0.1
  END MON-MANNING

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  102  103  0.1  0.1  0.10.1440.1440.192  0.1  0.1  0.1  0.1  0.1  0.1
  104       0.1  0.1  0.10.1060.1240.139  0.1  0.1  0.10.116  0.1  0.1
  105      0.64 0.640.649 0.79  0.9  0.90.4360.4360.4360.872 0.64 0.64
  106     0.4880.4880.507 0.630.7510.8630.3640.3640.3640.4880.4880.488
  107     0.2870.2870.3260.4280.614  0.9 0.38 0.380.3790.6220.2870.287
  108     0.6050.6050.6130.7450.877  0.90.4120.4120.4110.8230.6050.605
  109     0.4880.4880.507 0.630.7510.8630.3640.3640.3640.4880.4880.488
  110  114  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  115     0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
  116     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  117     0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
  118     0.3020.3020.306 0.310.3650.4110.4110.4110.4110.4110.3020.302
  119     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  120  124  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  125     0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
  126     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  127     0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
  128     0.3020.3020.306 0.310.3650.4110.4110.4110.4110.4110.3020.302
  129     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  130  134  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  135     0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
  136     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  137     0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
  138     0.3020.3020.306 0.310.3650.4110.4110.4110.4110.4110.3020.302
  139     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  140  143  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
```

```
144      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
145      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
146      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
147      0.3020.3020.306 0.310.3650.4110.4110.4110.4110.4110.3020.302
148      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
149  150  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
151      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
152      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
153  155  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
156      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
157  1580.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
159  162  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
163      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
164      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
165      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
166      0.3020.3020.306 0.310.3650.4110.4110.4110.4110.4110.3020.302
167      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
168  172  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
173      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
174      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
175      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
176      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
177  181  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
182      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
183      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
184      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
185      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
186  188  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
189      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
190      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
191      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
192      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
193  196  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
197      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
198      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
199      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
200      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
201  204  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
205      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
206      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
207      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
208      0.3020.3020.306 0.310.3650.4110.4110.4110.4110.4110.3020.302
209      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
210  213  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
214      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
215      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
216      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
217      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
218  221  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
222      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
223      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
224      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
225      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
226  228  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
229      0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
230      0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
231      0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
```

```
  232     0.3020.3020.306 0.310.3650.4110.4110.4110.4110.4110.3020.302
  233     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  234  237  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  238     0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
  239     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  240     0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
  241     0.3020.3020.306 0.310.3650.4110.4110.4110.4110.4110.3020.302
  242     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  243  245  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  246     0.2840.2840.2880.2920.3440.3870.3870.3870.3870.3870.2840.284
  247     0.1910.1910.199 0.75 0.75 0.750.2860.2860.286 0.75 0.75 0.75
  248     0.1190.1190.1360.1480.2130.3160.3160.3160.3160.2590.1190.119
  END MON-LZETPARM

  NQUALS
*** <PLS >
*** x -  xNQUAL
  101  248    1
  END NQUALS

  QUAL-PROPS
*** <PLS >  Identifiers and Flags
*** x -  x    QUALID      QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC
  101  248FECAL COLIFO       #    0    0    0    1    1    1    0    0    0
  END QUAL-PROPS

  QUAL-INPUT
***         Storage on surface and nonseasonal parameters
***            SQO   POTFW   POTFS   ACQOP  SQOLIM   WSQOP    IOQC    AOQC
*** <PLS >  qty/ac qty/ton qty/ton    qty/  qty/ac   in/hr qty/ft3 qty/ft3
*** x -  x                          ac.day
  101     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
  102     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
  103     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  104     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  105     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
  106     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
  107     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
  108     0.00E+000.00E+000.00E+001.00E+031.00E+00  2.50001.00E+030.00E+00
  109     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
  110     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
  111     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
  112     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  113     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  114     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  115     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
  116     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
  117     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
  118     0.00E+000.00E+000.00E+001.00E+031.00E+00  2.50001.00E+030.00E+00
  119     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
  120     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
  121     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
  122     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  123     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  124     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  125     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
  126     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
```

```
127    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
128    0.00E+000.00E+000.00E+001.00E+031.00E+00  2.50001.00E+030.00E+00
129    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
130    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
131    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
132    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
133    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
134    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
135    0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
136    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
137    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
138    0.00E+000.00E+000.00E+001.00E+031.00E+00  2.50001.00E+030.00E+00
139    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
140    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
141    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
142    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
143    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
144    0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
145    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
146    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
147    0.00E+000.00E+000.00E+001.00E+031.00E+00  2.50001.00E+030.00E+00
148    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
149    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
150    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
151    0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
152    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
153    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
154    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
155    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
156    0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
157    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
158    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
159    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
160    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
161    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
162    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
163    0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
164    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
165    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
166    0.00E+000.00E+000.00E+001.00E+031.00E+00  2.50001.00E+030.00E+00
167    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
168    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
169    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
170    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
171    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
172    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
173    0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
174    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
175    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
176    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
177    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
178    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
179    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
180    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
181    0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
182    0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
183    0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
```

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184     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
185     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
186     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
187     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
188     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
189     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
190     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
191     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
192     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
193     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
194     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
195     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
196     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
197     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
198     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
199     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
200     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
201     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
202     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
203     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
204     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
205     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
206     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
207     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
208     0.00E+000.00E+000.00E+001.00E+031.00E+00  2.50001.00E+030.00E+00
209     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
210     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
211     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
212     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
213     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
214     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
215     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
216     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
217     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
218     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
219     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
220     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
221     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
222     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
223     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
224     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
225     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
226     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
227     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
228     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
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234     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
235     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
236     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
237     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
238     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
239     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
240     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
```

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  242     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
  243     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
  244     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  245     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.40001.00E+030.00E+00
  246     0.00E+000.00E+000.00E+001.00E+031.00E+00  3.00001.00E+030.00E+00
  247     0.00E+000.00E+000.00E+001.00E+031.00E+00  1.20001.00E+030.00E+00
  248     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
  END QUAL-INPUT

  MON-ACCUM
*** <PLS >  Value at start of each month for accum rate of QUALOF (lb/ac.day)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
  102     09E0809E0808E0808E0808E0808E0807E0807E0807E0807E0807E0808E08
  103     01E0401E0401E0401E0401E0401E0401E0401E0401E0401E0401E0401E04
  104     19E0619E0619E0619E0619E0619E0619E0619E0619E0619E0619E0619E06
  105     71E0671E0671E0671E0671E0671E0671E0671E0671E0671E0671E0671E06
  106     06E0807E0807E0807E0808E0812E0812E0812E0808E0808E0807E0807E08
  107     02E1002E1022E1022E1022E1001E0801E0801E0807E1022E1022E1002E10
  108     02E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E08
  109     03E0803E0804E0806E0806E0807E0807E0807E0806E0804E0804E0803E08
  110     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
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  112     11E0810E0810E0810E0809E0809E0809E0809E0809E0809E0809E0810E08
  113     09E0209E0209E0209E0209E0209E0209E0209E0209E0209E0209E0209E02
  114     65E0665E0665E0665E0665E0665E0665E0665E0665E0665E0665E0665E06
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  119     02E0802E0803E0803E0803E0803E0803E0803E0803E0803E0802E0802E08
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  122     09E0809E0809E0808E0808E0808E0808E0808E0808E0807E0808E0808E08
  123     69E0269E0269E0269E0269E0269E0269E0269E0269E0269E0269E0269E02
  124     86E0686E0686E0686E0686E0686E0686E0686E0686E0686E0686E0686E06
  125     62E0662E0662E0662E0662E0662E0662E0662E0662E0662E0662E0662E06
  126     03E0803E0803E0803E0803E0803E0803E0803E0803E0803E0802E0803E08
  127     92E0692E0692E0692E0692E0692E0692E0692E0692E0692E0692E0692E06
  128     02E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E08
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  130     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
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  140     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
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149	02E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E08
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154	07E0607E0607E0607E0607E0607E0607E0607E0607E0607E0607E0607E06
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165	04E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E08
166	05E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E08
167	03E0803E0803E0803E0803E0803E0803E0803E0803E0803E0803E0803E08
168	00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
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170	09E0809E0808E0808E0808E0808E0808E0808E0808E0808E0808E0808E08
171	02E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E08
172	04E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E08
173	05E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E08
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188	02E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E08
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193	00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
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199	04E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E08
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201	00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00

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  202     08E0808E0808E0807E0807E0807E0807E0807E0807E0807E0807E0807E08
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  210     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
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  226     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
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  232     04E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E08
  233     06E0806E0807E0807E0807E0808E0808E0808E0807E0807E0806E0806E08
  234     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
  235     05E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E08
  236     11E0811E0810E0810E0810E0810E0810E0810E0810E0810E0810E0810E08
  237     02E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E08
  238     05E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E08
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  240     04E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E08
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  242     05E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E08
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  244     11E0811E0811E0811E0811E0811E0811E0811E0811E0811E0811E0811E08
  245     02E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E08
  246     04E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E0804E08
  247     05E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E08
  248     05E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E0805E08

  END MON-ACCUM

  MON-SQOLIM
*** <PLS >  Value at start of month for limiting storage of QUALOF (lb/ac)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
  102     02E1002E1002E1004E1004E1004E1004E1004E1004E1002E1001E1002E10
  103     23E0423E0435E0458E0458E0458E0458E0458E0458E0435E0423E0423E04
  104     04E0804E0806E0810E0810E0810E0810E0810E0810E0806E0804E0804E08
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105 14E0814E0821E0835E0835E0835E0835E0835E0835E0821E0814E0814E08
106 01E1001E1002E1004E1004E1006E1006E1006E1004E1002E1001E1001E10
107 39E1046E1007E1211E1211E1250E0850E0850E0803E1207E1204E1239E10
108 30E0830E0845E0875E0875E0875E0875E0875E0875E0845E0830E0830E08
109 56E0858E0801E1003E1003E1004E1004E1004E1003E1001E1085E0856E08
110 00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
111 61E0860E0887E0801E1001E1001E1001E1001E1001E1077E0852E0857E08
112 02E1002E1003E1005E1005E1005E1004E1004E1004E1003E1002E1002E10
113 02E0402E0403E0404E0404E0404E0404E0404E0404E0403E0402E0402E04
114 13E0813E0819E0832E0832E0832E0832E0832E0832E0819E0813E0813E08
115 21E0821E0832E0854E0854E0854E0854E0854E0854E0832E0821E0821E08
116 55E0863E0894E0802E1002E1002E1002E1002E1002E1094E0854E0855E08
117 16E0816E0824E0839E0839E0839E0839E0839E0839E0824E0816E0816E08
118 54E0854E0881E0801E1001E1001E1001E1001E1001E1081E0854E0854E08
119 45E0848E0881E0802E1002E1002E1002E1002E1002E1081E0849E0845E08
120 00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
121 51E0850E0873E0801E1001E1001E1001E1001E1001E1064E0844E0847E08
122 02E1002E1003E1004E1004E1004E1004E1004E1004E1002E1002E1002E10
123 14E0414E0421E0435E0435E0435E0435E0435E0435E0421E0414E0414E04
124 17E0817E0826E0843E0843E0843E0843E0843E0843E0826E0817E0817E08
125 12E0812E0819E0831E0831E0831E0831E0831E0831E0819E0812E0812E08
126 50E0859E0888E0801E1001E1001E1001E1001E1001E1088E0850E0850E08
127 18E0818E0828E0846E0846E0846E0846E0846E0846E0828E0818E0818E08
128 47E0847E0870E0801E1001E1001E1001E1001E1001E1070E0847E0847E08
129 29E0832E0856E0801E1001E1001E1001E1001E1001E1056E0833E0829E08
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132 02E1002E1003E1005E1005E1005E1005E1005E1005E1003E1002E1002E10
133 78E0278E0201E0402E0402E0402E0402E0402E0402E0401E0478E0278E02
134 12E0812E0818E0831E0831E0831E0831E0831E0831E0818E0812E0812E08
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137 24E0824E0836E0860E0860E0860E0860E0860E0860E0836E0824E0824E08
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139 38E0843E0878E0802E1002E1002E1002E1002E1002E1078E0845E0838E08
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141 58E0858E0886E0801E1001E1001E1001E1001E1001E1083E0856E0857E08
142 02E1002E1003E1005E1005E1005E1005E1005E1005E1003E1002E1002E10
143 01E0801E0802E0803E0803E0803E0803E0803E0803E0802E0801E0801E08
144 23E0823E0835E0859E0859E0859E0859E0859E0859E0835E0823E0823E08
145 20E0820E0830E0850E0850E0850E0850E0850E0850E0830E0820E0820E08
146 29E0829E0844E0873E0873E0873E0873E0873E0873E0844E0829E0829E08
147 70E0870E0801E1002E1002E1002E1002E1002E1002E1001E1070E0870E08
148 28E0828E0842E0871E0871E0871E0871E0871E0871E0842E0828E0828E08
149 40E0840E0860E0801E1001E1001E1001E1001E1001E1060E0840E0840E08
150 06E0806E0809E0816E0816E0816E0816E0816E0816E0809E0806E0806E08
151 62E0862E0893E0802E1002E1002E1002E1002E1002E1093E0862E0862E08
152 28E0828E0842E0871E0871E0871E0871E0871E0871E0842E0828E0828E08
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158 69E0869E0801E1002E1002E1002E1002E1002E1002E1001E1069E0869E08
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  END MON-SQOLIM

  MON-IFLW-CONC
*** <PLS >  Conc of QUAL in interflow outflow for each month (qty/ft3)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
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  107     02E0502E0518E0518E0518E0566E0466E0466E0405E0518E0518E0502E05
  108     64E0464E0464E0464E0464E0464E0464E0464E0464E0464E0464E0464E04
  109     02E0502E0503E0505E0505E0506E0506E0506E0505E0503E0503E0502E05
  110     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
  111     02E0502E0502E0502E0502E0502E0502E0502E0502E0502E0502E0502E05
  112     08E0508E0508E0508E0508E0507E0507E0507E0507E0507E0507E0508E05
  113     07E0007E0007E0007E0007E0007E0007E0007E0007E0007E0007E0007E00
  114     52E0452E0452E0452E0452E0452E0452E0452E0452E0452E0452E0452E04
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  116     02E0502E0502E0502E0502E0502E0502E0502E0502E0502E0502E0502E05
  117     62E0462E0462E0462E0462E0462E0462E0462E0462E0462E0462E0462E04
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  119     02E0502E0502E0502E0502E0502E0502E0502E0502E0502E0502E0502E05
  120     00E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E0000E00
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  240     82E0482E0482E0482E0482E0482E0482E0482E0482E0482E0482E0482E04
  241     71E0471E0471E0471E0471E0471E0471E0471E0471E0471E0471E0471E04
  242     72E0472E0472E0472E0472E0472E0472E0472E0472E0472E0472E0472E04
  243     02E0502E0502E0502E0502E0502E0502E0502E0502E0502E0502E0502E05
  244     07E0507E0507E0507E0507E0507E0507E0507E0507E0507E0507E0507E05
  245     24E0424E0424E0424E0424E0424E0424E0424E0424E0424E0424E0424E04
  246     87E0487E0487E0487E0487E0487E0487E0487E0487E0487E0487E0487E04
  247     92E0492E0492E0492E0492E0492E0492E0492E0492E0492E0492E0492E04
  248     01E0501E0501E0501E0501E0501E0501E0501E0501E0501E0501E0501E05

  END MON-IFLW-CONC

END PERLND

IMPLND
  ACTIVITY
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  101  145    0    0    1    0    0    1
  END ACTIVITY

  PRINT-INFO
*** <ILS > ******** Print-flags ******** PIVL  PYR
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  101  145    6    6    5    6    6    6    1    9
  END PRINT-INFO

  GEN-INFO
***             Name             Unit-systems   Printer BinaryOut
*** <ILS >                           t-series Engl Metr Engl Metr
*** x -  x                            in  out
  101     1Low Residential            1    1    0    0    0    0
  102     1Commercial                 1    1    0    0    0    0
  103     2Low Residential            1    1    0    0    0    0
  104     2High Residential           1    1    0    0    0    0
  105     2Commercial                 1    1    0    0    0    0
  106     3Low Residential            1    1    0    0    0    0
  107     3High Residential           1    1    0    0    0    0
  108     3Commercial                 1    1    0    0    0    0
  109     4Low Residential            1    1    0    0    0    0
  110     4High Residential           1    1    0    0    0    0
  111     4Commercial                 1    1    0    0    0    0
  112     5Low Residential            1    1    0    0    0    0
  113     5High Residential           1    1    0    0    0    0
  114     5Commercial                 1    1    0    0    0    0
  115     6Low Residential            1    1    0    0    0    0
  116     6Commercial                 1    1    0    0    0    0
  117     7Low Residential            1    1    0    0    0    0
  118     7Commercial                 1    1    0    0    0    0
  119     8Low Residential            1    1    0    0    0    0
  120     8Commercial                 1    1    0    0    0    0
  121     9Low Residential            1    1    0    0    0    0
  122     9High Residential           1    1    0    0    0    0
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  123     9Commercial                 1    1    0    0    0    0
  124     10Low Residential           1    1    0    0    0    0
  125     10High Residential          1    1    0    0    0    0
  126     10Commercial                1    1    0    0    0    0
  127     11Low Residential           1    1    0    0    0    0
  128     11High Residential          1    1    0    0    0    0
  129     11Commercial                1    1    0    0    0    0
  130     12Low Residential           1    1    0    0    0    0
  131     12Commercial                1    1    0    0    0    0
  132     13Low Residential           1    1    0    0    0    0
  133     13Commercial                1    1    0    0    0    0
  134     14Low Residential           1    1    0    0    0    0
  135     14Commercial                1    1    0    0    0    0
  136     15Low Residential           1    1    0    0    0    0
  137     15Commercial                1    1    0    0    0    0
  138     16Low Residential           1    1    0    0    0    0
  139     16Commercial                1    1    0    0    0    0
  140     17Low Residential           1    1    0    0    0    0
  141     17High Residential          1    1    0    0    0    0
  142     17Commercial                1    1    0    0    0    0
  143     18Low Residential           1    1    0    0    0    0
  144     18High Residential          1    1    0    0    0    0
  145     18Commercial                1    1    0    0    0    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  101  143    0    1    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (in)
  101         651.76     0.047      0.05       0.1
  102         735.86     0.055      0.05       0.1
  103         437.09     0.045      0.05       0.1
  104         464.54     0.061      0.05       0.1
  105         472.92     0.037      0.05       0.1
  106         367.73     0.041      0.05       0.1
  107         265.37     0.013      0.05       0.1
  108         432.02     0.041      0.05       0.1
  109         676.57     0.067      0.05       0.1
  110         540.45      0.04      0.05       0.1
  111          1000.     0.046      0.05       0.1
  112          1000.     0.044      0.05       0.1
  113         569.36     0.037      0.05       0.1
  114          1000.     0.033      0.05       0.1
  115         621.26     0.044      0.05       0.1
  116         353.02     0.038      0.05       0.1
  117         614.25      0.06      0.05       0.1
  118         530.97     0.048      0.05       0.1
  119         538.51     0.068      0.05       0.1
  120          1000.     0.043      0.05       0.1
  121         457.02     0.056      0.05       0.1
  122         415.77     0.028      0.05       0.1
  123         461.38     0.041      0.05       0.1
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  124         593.21      0.03      0.05       0.1
  125         518.32     0.052      0.05       0.1
  126         459.65     0.054      0.05       0.1
  127          1000.     0.054      0.05       0.1
  128         661.75     0.091      0.05       0.1
  129          1000.     0.056      0.05       0.1
  130         309.29     0.083      0.05       0.1
  131         246.71     0.057      0.05       0.1
  132         343.66     0.071      0.05       0.1
  133         568.74     0.037      0.05       0.1
  134          273.3     0.091      0.05       0.1
  135         286.02     0.155      0.05       0.1
  136         387.65     0.051      0.05       0.1
  137         577.02     0.048      0.05       0.1
  138         877.53     0.039      0.05       0.1
  139          1000.     0.025      0.05       0.1
  140          1000.     0.031      0.05       0.1
  141          1000.     0.009      0.05       0.1
  142          1000.     0.034      0.05       0.1
  143  144     1000.     0.014      0.05       0.1
  145          1000.      0.01      0.05       0.1
  END IWAT-PARM2

  IWAT-PARM3
*** <ILS >    PETMAX    PETMIN
*** x -  x   (deg F)   (deg F)
  101  145       40.       35.
  END IWAT-PARM3

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  101  145      0.01      0.01
  END IWAT-STATE1

  NQUALS
*** <ILS >
*** x -  xNQUAL
  101  145    1
  END NQUALS

  QUAL-PROPS
*** <ILS >    Identifiers and Flags
*** x -  x      QUALID    QTID  QSD VPFW  QSO  VQO
  101  145FECAL COLIFO       #    0    0    1    1
  END QUAL-PROPS

  QUAL-INPUT
***         Storage on surface and nonseasonal parameters
***           SQO   POTFW   ACQOP  SQOLIM   WSQOP
*** <ILS >  qty/ac qty/ton    qty/  qty/ac   in/hr
*** x -  x                  ac.day
  101     0.00E+000.00E+000.00E+000.00E+00  0.1000
  102     0.00E+000.00E+000.00E+000.00E+00  0.1000
  103     0.00E+000.00E+000.00E+000.00E+00  0.1000
  104     0.00E+000.00E+000.00E+000.00E+00  0.1000
  105     0.00E+000.00E+000.00E+000.00E+00  0.1000
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  106     0.00E+000.00E+000.00E+000.00E+00  0.1000
  107     0.00E+000.00E+000.00E+000.00E+00  0.1000
  108     0.00E+000.00E+000.00E+000.00E+00  0.1000
  109     0.00E+000.00E+000.00E+000.00E+00  0.1000
  110     0.00E+000.00E+000.00E+000.00E+00  0.1000
  111     0.00E+000.00E+000.00E+000.00E+00  0.1000
  112     0.00E+000.00E+000.00E+000.00E+00  0.1000
  113     0.00E+000.00E+000.00E+000.00E+00  0.1000
  114     0.00E+000.00E+000.00E+000.00E+00  0.1000
  115     0.00E+000.00E+000.00E+000.00E+00  0.1000
  116     0.00E+000.00E+000.00E+000.00E+00  0.1000
  117     0.00E+000.00E+000.00E+000.00E+00  0.1000
  118     0.00E+000.00E+000.00E+000.00E+00  0.1000
  119     0.00E+000.00E+000.00E+000.00E+00  0.1000
  120     0.00E+000.00E+000.00E+000.00E+00  0.1000
  121     0.00E+000.00E+000.00E+000.00E+00  0.1000
  122     0.00E+000.00E+000.00E+000.00E+00  0.1000
  123     0.00E+000.00E+000.00E+000.00E+00  0.1000
  124     0.00E+000.00E+000.00E+000.00E+00  0.1000
  125     0.00E+000.00E+000.00E+000.00E+00  0.1000
  126     0.00E+000.00E+000.00E+000.00E+00  0.1000
  127     0.00E+000.00E+000.00E+000.00E+00  0.1000
  128     0.00E+000.00E+000.00E+000.00E+00  0.1000
  129     0.00E+000.00E+000.00E+000.00E+00  0.1000
  130     0.00E+000.00E+000.00E+000.00E+00  0.1000
  131     0.00E+000.00E+000.00E+000.00E+00  0.1000
  132     0.00E+000.00E+000.00E+000.00E+00  0.1000
  133     0.00E+000.00E+000.00E+000.00E+00  0.1000
  134     0.00E+000.00E+000.00E+000.00E+00  0.1000
  135     0.00E+000.00E+000.00E+000.00E+00  0.1000
  136     0.00E+000.00E+000.00E+000.00E+00  0.1000
  137     0.00E+000.00E+000.00E+000.00E+00  0.1000
  138     0.00E+000.00E+000.00E+000.00E+00  0.1000
  139     0.00E+000.00E+000.00E+000.00E+00  0.1000
  140     0.00E+000.00E+000.00E+000.00E+00  0.1000
  141     0.00E+000.00E+000.00E+000.00E+00  0.1000
  142     0.00E+000.00E+000.00E+000.00E+00  0.1000
  143     0.00E+000.00E+000.00E+000.00E+00  0.1000
  144     0.00E+000.00E+000.00E+000.00E+00  0.1000
  145     0.00E+000.00E+000.00E+000.00E+00  0.1000
  END QUAL-INPUT

  MON-ACCUM
*** <ILS >  Value at start of each month for accum rate of QUALOF (qty/ac.day)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101     98E0695E0691E0689E0687E0685E0680E0680E0680E0678E0680E0689E06
  102     13E0213E0213E0213E0213E0213E0213E0213E0213E0213E0213E0213E02
  103     34E0634E0632E0632E0631E0630E0629E0629E0629E0628E0629E0632E06
  104     01E0801E0801E0801E0801E0801E0897E0697E0697E0695E0697E0601E08
  105     96E0096E0096E0096E0096E0096E0096E0096E0096E0096E0096E0096E00
  106     28E0628E0627E0626E0626E0625E0624E0624E0624E0624E0624E0626E06
  107     01E0899E0695E0693E0690E0688E0684E0684E0684E0682E0684E0693E06
  108     08E0208E0208E0208E0208E0208E0208E0208E0208E0208E0208E0208E02
  109     33E0633E0632E0632E0631E0631E0630E0630E0630E0630E0630E0632E06
  110     01E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E08
  111     43E0043E0043E0043E0043E0043E0043E0043E0043E0043E0043E0043E00
  112     32E0632E0632E0632E0631E0631E0631E0631E0631E0631E0631E0632E06
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  113     01E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E08
  114     74E0474E0474E0474E0474E0474E0474E0474E0474E0474E0474E0474E04
  115     22E0622E0622E0622E0622E0622E0622E0622E0622E0622E0622E0622E06
  116     03E0603E0603E0603E0603E0603E0603E0603E0603E0603E0603E0603E06
  117     30E0630E0630E0630E0630E0630E0630E0630E0630E0630E0630E0630E06
  118     77E0477E0477E0477E0477E0477E0477E0477E0477E0477E0477E0477E04
  119     02E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E0802E08
  120     16E0616E0616E0616E0616E0616E0616E0616E0616E0616E0616E0616E06
  121     47E0647E0647E0646E0646E0646E0646E0646E0646E0645E0646E0646E06
  122     97E0696E0694E0693E0692E0691E0690E0690E0690E0689E0690E0693E06
  123     26E0626E0626E0626E0626E0626E0626E0626E0626E0626E0626E0626E06
  124     57E0657E0657E0656E0656E0656E0656E0656E0656E0655E0656E0656E06
  125     01E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E08
  126     27E0627E0627E0627E0627E0627E0627E0627E0627E0627E0627E0627E06
  127     61E0661E0660E0660E0660E0660E0660E0660E0660E0660E0660E0660E06
  128     01E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E08
  129     26E0626E0626E0626E0626E0626E0626E0626E0626E0626E0626E0626E06
  130     01E0899E0695E0693E0692E0690E0687E0687E0687E0685E0687E0693E06
  131     25E0625E0625E0625E0625E0625E0625E0625E0625E0625E0625E0625E06
  132     89E0688E0685E0683E0681E0680E0677E0677E0677E0675E0677E0683E06
  133     27E0627E0627E0627E0627E0627E0627E0627E0627E0627E0627E0627E06
  134     86E0685E0682E0680E0679E0677E0674E0674E0674E0673E0674E0680E06
  135     13E0613E0613E0613E0613E0613E0613E0613E0613E0613E0613E0613E06
  136     73E0672E0670E0669E0669E0668E0666E0666E0666E0665E0666E0669E06
  137     25E0625E0625E0625E0625E0625E0625E0625E0625E0625E0625E0625E06
  138     61E0660E0660E0659E0659E0659E0658E0658E0658E0658E0658E0659E06
  139     26E0626E0626E0626E0626E0626E0626E0626E0626E0626E0626E0626E06
  140     53E0653E0653E0653E0653E0653E0653E0653E0653E0653E0653E0653E06
  141     01E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E08
  142     27E0627E0627E0627E0627E0627E0627E0627E0627E0627E0627E0627E06
  143     56E0656E0656E0656E0656E0656E0656E0656E0656E0656E0656E0656E06
  144     01E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E0801E08
  145     26E0626E0626E0626E0626E0626E0626E0626E0626E0626E0626E0626E06

  END MON-ACCUM

  MON-SQOLIM
*** <PLS >  Value at start of month for limiting storage of QUALOF (#/ac)***
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  101     20E0819E0818E0818E0817E0817E0816E0816E0816E0816E0816E0818E08
  102     03E0403E0403E0403E0403E0403E0403E0403E0403E0403E0403E0403E04
  103     07E0807E0810E0816E0815E0815E0815E0815E0815E0809E0806E0806E08
  104     23E0823E0833E0854E0852E0851E0849E0849E0849E0828E0819E0821E08
  105     19E0219E0229E0248E0248E0248E0248E0248E0248E0229E0219E0219E02
  106     06E0806E0808E0813E0813E0813E0812E0812E0812E0807E0805E0805E08
  107     20E0820E0828E0846E0845E0844E0842E0842E0842E0825E0817E0819E08
  108     02E0402E0402E0404E0404E0404E0404E0404E0404E0402E0402E0402E04
  109     07E0807E0810E0816E0816E0815E0815E0815E0815E0809E0806E0806E08
  110     24E0823E0834E0856E0855E0854E0853E0853E0853E0831E0821E0822E08
  111     09E0209E0213E0222E0222E0222E0222E0222E0222E0213E0209E0209E02
  112     06E0806E0810E0816E0816E0816E0815E0815E0815E0809E0806E0806E08
  113     22E0822E0833E0855E0855E0854E0854E0854E0854E0832E0821E0822E08
  114     15E0615E0622E0637E0637E0637E0637E0637E0637E0622E0615E0615E06
  115     04E0804E0807E0811E0811E0811E0811E0811E0811E0807E0804E0804E08
  116     70E0670E0601E0802E0802E0802E0802E0802E0802E0801E0870E0670E06
  117     06E0806E0809E0815E0815E0815E0815E0815E0815E0809E0806E0806E08
  118     15E0615E0623E0638E0638E0638E0638E0638E0638E0623E0615E0615E06
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  119     04E0804E0804E0804E0804E0804E0804E0804E0804E0803E0804E0804E08
  120     32E0632E0632E0632E0632E0632E0632E0632E0632E0632E0632E0632E06
  121     09E0809E0814E0823E0823E0823E0823E0823E0823E0814E0809E0809E08
  122     19E0819E0828E0847E0846E0846E0845E0845E0845E0827E0818E0819E08
  123     05E0805E0808E0813E0813E0813E0813E0813E0813E0808E0805E0805E08
  124     11E0811E0817E0828E0828E0828E0828E0828E0828E0817E0811E0811E08
  125     24E0824E0835E0859E0858E0858E0857E0857E0857E0834E0823E0823E08
  126     05E0805E0808E0814E0814E0814E0814E0814E0814E0808E0805E0805E08
  127     12E0812E0818E0830E0830E0830E0830E0830E0830E0818E0812E0812E08
  128     27E0827E0840E0867E0867E0867E0867E0867E0867E0840E0827E0827E08
  129     05E0805E0808E0813E0813E0813E0813E0813E0813E0808E0805E0805E08
  130     20E0820E0829E0847E0846E0845E0843E0843E0843E0825E0817E0819E08
  131     05E0805E0807E0812E0812E0812E0812E0812E0812E0807E0805E0805E08
  132     18E0818E0825E0842E0841E0840E0838E0838E0838E0823E0815E0817E08
  133     05E0805E0808E0814E0814E0814E0814E0814E0814E0808E0805E0805E08
  134     17E0817E0825E0840E0839E0839E0837E0837E0837E0822E0815E0816E08
  135     03E0803E0804E0807E0807E0807E0807E0807E0807E0804E0803E0803E08
  136     15E0814E0821E0835E0834E0834E0833E0833E0833E0820E0813E0814E08
  137     05E0805E0807E0812E0812E0812E0812E0812E0812E0807E0805E0805E08
  138     12E0812E0818E0830E0830E0829E0829E0829E0829E0817E0812E0812E08
  139     05E0805E0808E0813E0813E0813E0813E0813E0813E0808E0805E0805E08
  140     11E0811E0816E0827E0827E0826E0826E0826E0826E0816E0811E0811E08
  141     23E0823E0835E0858E0858E0858E0857E0857E0857E0834E0823E0823E08
  142     05E0805E0808E0813E0813E0813E0813E0813E0813E0808E0805E0805E08
  143     11E0811E0817E0828E0828E0828E0828E0828E0828E0817E0811E0811E08
  144     23E0823E0835E0858E0858E0858E0858E0858E0858E0835E0823E0823E08
  145     05E0805E0808E0813E0813E0813E0813E0813E0813E0808E0805E0805E08

  END MON-SQOLIM

END IMPLND

RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    1   18    1    1    0    0    0    1    0    0    0    0
  END ACTIVITY

  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    1   18    5    6    6    6    6    6    6    6    6    6    1    9
  END PRINT-INFO

  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                               t-series  Engl Metr LKFG
*** x -  x                                 in  out
    1   18                        1         1    1   91    0    0    0    0
  END GEN-INFO

  HYDR-PARM1
***         Flags for HYDR section
***RC HRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
*** x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    1   18   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
```

```
  END HYDR-PARM1

  HYDR-PARM2
*** RCHRES FTBW FTBU        LEN     DELTH     STCOR        KS      DB50
*** x -  x              (miles)      (ft)      (ft)                (in)
    1        0.   1.       1.57       72.       3.2       0.5      0.01
    2        0.   2.       3.63       68.       3.2       0.5      0.01
    3        0.   3.       6.29      249.       3.2       0.5      0.01
    4        0.   4.        4.1      119.       3.2       0.5      0.01
    5        0.   5.       4.13       81.       3.2       0.5      0.01
    6        0.   6.       0.59        4.       3.2       0.5      0.01
    7        0.   7.       0.86        5.       3.2       0.5      0.01
    8        0.   8.       6.28      191.       3.2       0.5      0.01
    9        0.   9.       3.62       65.       3.2       0.5      0.01
   10        0.  10.       2.84      126.       3.2       0.5      0.01
   11        0.  11.        1.8       23.       3.2       0.5      0.01
   12        0.  12.       2.64      180.       3.2       0.5      0.01
   13        0.  13.       2.46      130.       3.2       0.5      0.01
   14        0.  14.        2.2       60.       3.2       0.5      0.01
   15        0.  15.       1.71       40.       3.2       0.5      0.01
   16        0.  16.       4.37       80.       3.2       0.5      0.01
   17        0.  17.       2.93      102.       3.2       0.5      0.01
   18        0.  18.       2.13       41.       3.2       0.5      0.01
  END HYDR-PARM2

  MON-CONVF
*** RCHRES  Monthly f(VOL) adjustment factors
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1   18 0.97 0.89 0.89 0.91 0.93 0.93 0.94 0.95 0.95 0.98 0.98 0.97
  END MON-CONVF

  HYDR-INIT
***         Initial conditions for HYDR section
***RC HRES       VOL  CAT Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft      for each possible   exit  for each possible exit,ft3
    1   18      0.01       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
  END HYDR-INIT

  ADCALC-DATA
*** RCHRES  Data for section ADCALC
*** x -  x     CRRAT       VOL (ac-ft)
    1   18       1.7      100.
  END ADCALC-DATA

  GQ-GENDATA
*** RCHRES NGQL TPFG PHFG ROFG CDFG SDFG PYFG  LAT
*** x -  x                                     deg
    1   18    1    2    2    2    2    2    2    0
  END GQ-GENDATA

  GQ-QALDATA
*** RCHRES                GQID      DQAL    CONCID      CONV     QTYID
*** x -  x                        concid
    1     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
    2     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
    3     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
    4     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
```

```
    5     FECAL COLIFORM      200.0E+000         # 3.52E-003         #
    6     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
    7     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
    8     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
    9     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   10     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   11     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   12     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   13     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   14     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   15     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   16     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   17     FECAL COLIFORM      200.0E+000         # 3.53E-003         #
   18     FECAL COLIFORM      200.0E+000         # 3.53E-003         #

  END GQ-QALDATA

  GQ-QALFG
*** RCHRES HDRL OXID PHOT VOLT BIOD  GEN SDAS
*** x -  x
    1   18    0    0    0    0    0    1    0
  END GQ-QALFG

  GQ-FLG2
*** RCHRES HDRL OXID PHOT VOLT BIOD  GEN SBMS
*** x -  x
    1   18    0    0    0    0    0    0    2
  END GQ-FLG2

  GQ-GENDECAY
*** RCHRES    FSTDEC     THFST
*** x -  x    (/day)
    1           1.85      1.07
    2           1.85      1.07
    3           1.85      1.07
    4           1.85      1.07
    5           1.85      1.07
    6           1.85      1.07
    7           1.85      1.07
    8          10.00      1.07
    9           1.85      1.07
   10           1.85      1.07
   11           1.85      1.07
   12           3.00      1.07
   13           3.00      1.07
   14           3.00      1.07
   15          10.00      1.07
   16           0.01      1.07
   17           0.01      1.07
   18           0.01      1.07

  END GQ-GENDECAY

END RCHRES

MUTSIN
  MUTSINFO
```

```
  <-range><mfl><npt><nmn><nli><mis> ***
    # -   #  MFL  NPT  NMN  NLI MSFG ***
    1         60    2    0    3    3
    2         61    2    0    3    3
    3         62    2    0    3    3
    4         63    2    0    3    3
    5         64    2    0    3    3
    6         65    2    0    3    3
    7         66    2    0    3    3
    8         67    2    0    3    3
   11         41    0    1   25    3
   12         42    0    1   25    3
   13         43    0    1   25    3
   14         44    0    1   25    3
   15         45    0    1   25    3
   16         46    0    1   25    3
   17         47    0    1   25    3
   18         48    0    1   25    3
   19         49    0    1   25    3
   20         50    0    1   25    3
   21         51    0    1   25    3
   22         52    0    1   25    3
   23         53    0    1   25    3
   24         54    0    1   25    3
   25         55    0    1   25    3
   26         56    0    1   25    3
   27         57    0    1   25    3
   28         58    0    1   25    3
   30         70    0    1   25    3
   31         71    0    1   25    3
   32         72    0    1   25    3
   33         73    0    1   25    3
   34         77    0    1   25    3
   35         75    0    1   25    3
   36         76    0    1   25    3
   37         77    0    1   25    3
   38         78    0    1   25    3
   39         68    0    1   25    3
   40         69    0    1   25    3
  END MUTSINFO
END MUTSIN

FTABLES

  FTABLE      1
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      5.56        0.        0.
      0.17      5.62      0.93      4.08
      1.66      6.19     19.77    188.14
      2.08      7.14    112.38    272.78
       2.6     19.13    122.21    353.86
      3.12     19.52    132.26    649.13
     53.53     57.83  11981.82 289128.28
    103.93     96.14  15862.46 1245981.5
  END FTABLE  1
```

```
  FTABLE      2
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      16.2        0.        0.
      0.19     16.37      3.14       4.2
      1.93      17.9     32.86    193.68
      2.41     20.44     41.58    280.78
      3.01     55.18      74.5    362.69
      3.61     56.24    108.05    664.69
     62.04    159.11   6398.47 287181.34
    120.46    261.98  18698.72  1220084.
  END FTABLE  2

  FTABLE      8
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      6.78        0.        0.
      0.13      6.87      0.88      1.78
      1.29      7.67     19.34     82.03
      1.62        9.    111.85    118.97
      2.02     23.79    121.35    155.58
      2.42     24.35    131.07    285.91
      41.6      78.2  12039.68 134692.03
     80.77    132.06  16157.91 594684.94
  END FTABLE  8

  FTABLE      3
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      29.3        0.        0.
       0.2     29.61      5.84      5.86
      1.98     32.32     61.12    270.38
      2.48     36.86     77.33    391.96
       3.1     99.62    138.49    505.89
      3.72     101.5    200.82    926.98
     63.84    284.63  11808.56 398209.84
    123.96    467.76  34426.421687073.12
  END FTABLE  3

  FTABLE     12
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      9.83        0.        0.
      0.23      9.92      2.24      7.93
      2.27     10.77     123.4    366.07
      2.84     12.18    129.58    530.63
      3.55     33.13    152.89     682.4
      4.26     33.72    176.62   1249.43
     73.12     90.72  14361.16 522827.78
    141.98    147.73  112571.22186191.75
  END FTABLE 12
```

```
  FTABLE     13
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      6.08        0.        0.
      0.12      6.17      0.72      1.17
      1.18      6.92     17.67     53.87
      1.47      8.18     19.74     78.14
      1.84      21.5    117.56    102.52
      2.21     22.02    125.58    188.53
     37.95     72.87  11721.36   90746.1
      73.7    123.71  15234.51 404143.22
  END FTABLE 13

  FTABLE      9
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      8.62        0.        0.
      0.18      8.71      1.54      3.85
      1.77      9.56    116.11     177.8
      2.22     10.98     120.4    257.77
      2.77     29.51    136.58    333.75
      3.32      30.1    153.09    611.98
     57.05      87.4  13209.89 268948.81
    110.78    144.71  19445.451151877.12
  END FTABLE  9

  FTABLE     10
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.     27.91        0.        0.
      0.25     28.16       7.1     12.57
      2.53     30.42     73.85    580.11
      3.17      34.2      93.3    840.86
      3.96     93.47    166.64   1078.45
      4.75     95.04    241.23    1973.4
      81.5    247.59  13390.54 809473.19
    158.26    400.13  38248.743349658.75
  END FTABLE 10

  FTABLE     14
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.     43.31        0.        0.
      0.33     43.64     14.56     25.24
      3.35     46.66    150.63    1165.5
      4.19     51.69    190.04   1689.21
      5.23    142.92     338.5   2152.82
      6.28    145.02    489.15   3934.01
    107.78    348.47  25534.291538889.25
    209.28    551.92  71230.45  6200498.
  END FTABLE 14

  FTABLE      4
```

```
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.     40.13        0.        0.
      0.24      40.5      9.79     12.84
      2.43     43.83    101.96    592.72
      3.04     49.39    128.85    859.14
      3.79    134.74    230.23   1103.02
      4.55    137.06    333.36   2018.82
     78.17    361.48  18683.04 834386.75
    151.78    585.91  53553.64 3466608.5
  END FTABLE  4

  FTABLE     11
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.     11.17        0.        0.
      0.24     11.28      2.68      6.92
      2.39     12.21    127.92    319.18
      2.98     13.77    135.28    462.65
      3.73     37.55    163.06    594.23
      4.48      38.2    191.32    1087.7
     76.85    101.27    15138. 450966.41
    149.22    164.33 114748.931876713.25
  END FTABLE 11

  FTABLE     15
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      6.75        0.        0.
      0.36       6.8      2.41     17.42
      3.56      7.25      24.9    804.57
      4.45      8.01     31.41    1166.1
      5.56      22.2     55.92   1484.26
      6.67     22.51     80.78   2711.57
    114.55     53.18   4163.491050574.25
    222.43     83.85  11554.65  4208794.
  END FTABLE 15

  FTABLE     17
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.     12.32        0.        0.
      0.41     12.41      5.08      27.4
      4.11     13.18    152.42   1265.85
      5.14     14.46    166.07   1834.61
      6.42     40.29   1117.48   2328.53
      7.71     40.83   1169.57   4251.41
     132.3      92.7  18487.29  1611776.
    256.89    144.57 123267.72 6370863.5
  END FTABLE 17

  FTABLE      5
 rows cols                               ***
```

```
    8    4
     depth      area    volume  outflow1 ***
        0.      5.53        0.        0.
      0.12      5.61      0.66      1.68
      1.19      6.29      7.02     77.42
      1.48      7.43      8.92    112.29
      1.86     19.54     16.08    147.28
      2.23     20.01     23.42    270.84
     38.23     66.07   1572.99 130162.16
     74.23    112.13   4780.86 579328.88
  END FTABLE  5

  FTABLE     18
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      7.22        0.        0.
      0.16      7.31      1.17       2.4
      1.61      8.06     12.33     110.8
      2.02      9.31     15.63    160.64
      2.52      24.9     28.06    208.58
      3.03     25.43     40.76    382.69
     51.96     76.03   2523.21  171537.8
     100.9    126.63   7482.07 741349.44
  END FTABLE 18

  FTABLE     16
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.     29.58        0.        0.
      0.25     29.85       7.5      9.88
      2.52     32.25       78.    456.12
      3.15     36.26     98.55    661.13
      3.94     99.09    176.02    848.01
      4.73    100.76     254.8   1551.76
     81.21    262.76  14155.37 636924.12
    157.69    424.76   40445.42636530.75
  END FTABLE 16

  FTABLE      6
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      8.43        0.        0.
      0.16      8.53      1.38      4.09
      1.63       9.4     14.51    188.54
      2.03     10.85     18.38    273.36
      2.54     29.05       33.    354.84
      3.05     29.65     47.93    651.01
     52.39     88.43   2960.78 291280.78
    101.72    147.21   8773.541257825.12
  END FTABLE  6

  FTABLE      7
 rows cols                               ***
    8    4
```

```
     depth      area    volume  outflow1 ***
        0.     18.58        0.        0.
      0.21     18.77      3.94      5.52
      2.11     20.43     41.15    254.72
      2.64     23.21     52.05    369.24
       3.3     62.91     93.15    475.78
      3.96     64.07    135.01    871.48
     67.91    176.31   7821.25 369866.81
    131.86    288.55  22685.181557690.25
  END FTABLE  7
END FTABLES
```

GLOSSARY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Deterministic model. *A model that does not include built-in variability: same input will always result in the same output.*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Empirical model. *Use of statistical techniques to discern patterns or relationships underlying observed or measured data for large sample sets. Does not account for physical dynamics of waterbodies.*

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

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

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

Existing use. *Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

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

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

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

First-order kinetics. *The type of relationship describing a dynamic reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.*

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

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

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

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

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

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

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

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

Hyetograph. *Graph of rainfall rate versus time during a storm event.*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Mathematical model. *A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one or more individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Raw sewage. *Untreated municipal sewage.*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

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

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

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

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

Water quality-based effluent limitations (WQBEL). *Effluent limitations applied to dischargers when technology-based limitations alone would cause violations of water quality standards. Usually WQBELs are applied to discharges into small streams.*

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

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

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

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

WQIA. Water Quality Improvement Act.

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