Total Maximum Daily Load
for
Fecal Coliform
in
Cash Hollow Creek

Watauga River Watershed, Tennessee

(HUC 06010103)

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SUMMARY SHEET

Total Maximum Daily Load (TMDL) for Fecal Coliform in Cash Hollow Creek

1. <u>303(d) Listed Waterbody Information</u>

State: Tennessee
County: Washington

Major River Basin: Holston River Basin
Watershed (Hydrologic Unit Code): Watauga River (06010103)

Location: Tributary to Knob Creek above Boone Lake (Watauga River mile 11.4)
Impaired Stream Length: 3.4 miles
Watershed Area: 3.3 square miles
Waterbody ID: TN06010103CASHHOLLOWCR

Constituent of Concern: Fecal Coliform

Designated Uses: Fish and Aquatic Life, Recreation, Livestock Watering and Wildlife, and Irrigation

Applicable Fecal Coliform Water Quality Standard for Recreation (more stringent of two standards):

> The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

2. <u>TMDL Development</u>

Analysis/Modeling: The Non-Point Source Model (NPSM)/Hydrologic Simulation Program – Fortran (HSPF) was used to develop this TMDL. Daily and hourly timesteps were used to simulate hydrologic and water quality conditions. The model was developed for the entire 303(d)-listed segment.

Critical Conditions: A continuous simulation period of 10 years, representing a wide range of hydrologic and meteorological conditions, was used to assess the water quality standards for this TMDL.

Seasonal Variation: A continuous simulation period of 10 years was used to assess the water quality standards for this TMDL. This period includes seasonal variations.

3. <u>Watershed/Stream Reach Allocation</u>

Waste Load Allocation: 0.0 counts per 30 days

> Note: All future permitted discharges shall meet end-of-pipe criteria of 200 counts/100 ml as a 30-day geometric mean for fecal coliform.

Load Allocation: 1.060×10^{11} counts per 30 days

Margin of Safety: Implicit (conservative modeling assumptions)

Total Maximum Daily Load (TMDL): 1.060×10^{11} counts per 30 days

TABLE OF CONTENTS

				Page
EXECUTIVE SUMMARY				v
1.0	INTRODUCTION			1
	1.1	Background		1
	1.2	Watershed Description		1
	1.3	Water Quality Target		4
	1.4	Water Quality Monitoring Program		4
2.0	SOURCE ASSESSMENT			4
	2.1	Point Source Assessment		5
	2.2	Nonpoint Source Assessment		5
		2.2.1	Wildlife	5
		2.2.2	Livestock Estimates	6
		2.2.3	Land Application of Agricultural Manure	6
		2.2.4	Grazing Animals	6
		2.2.5	Failing Septic Systems	6
		2.2.6	Urban Development	7
3.0	MODELING APPROACH			7
	3.1	Model Selection		7
	3.2	Model Setup		8
	3.3	Fecal Coliform Source Representation		8
		3.3.1	Wildlife	9
		3.3.2	Land Application of Agricultural Manure	9
		3.3.3	Grazing Animals	9
		3.3.4	Urban Development	9
		3.3.5	Other Sources	9
	3.4	Model Calibration		10
	3.5	Critical Conditions		10
4.0	MODEL RESULTS			11
	4.1	Existing Conditions		11
	4.2	Critical Conditions		11
5.0	ALLOCATION			11
	5.1	Total Maximum Daily Load		11
	5.2	Waste Load Allocations		13
	5.3	Load Allocations		13
	5.4	Seasonal Variation		14
	5.5	Margin of Safety		14
6.0	IMPLEMENTATION STRATEGY			14
	6.1	Monitoring		14
	6.2	Field Surveys		15
	6.3	Phase 2 NPDES Stormwater Permit and Storm Water Management Plan		15
	6.4	Future Efforts		16
7.0	FURTHER INFORMATION			16
REFERENCES				17

LIST OF APPENDICES

Appendix		Page
A	Water Quality Data ……………………………………………………………………….	18
B	Hydrologic Calibration ……………………………………………………………………..	24
C	Water Quality Calibration …………………………………………………………………..	27
D	TMDL Allocation Results …………………………………………………………………..	30
E	Public Notice of Proposed Total Maximum Daily Load (TMDL) for Fecal Coliform in Cash Hollow Creek ……………………………………………………………….	35
F	Public Comments for Proposed Total Maximum Daily Load (TMDL) for Fecal Coliform In Cash Hollow Creek ………………………………………………………….	37

LIST OF FIGURES

Figure		Page
1	Location of the Watauga River and Cash Hollow Creek watersheds …..………………………	2
2	Cash Hollow Creek watershed ……………………………………………………………….	3
3	Cash Hollow Creek model simulation of existing conditions (30-day geometric mean) ………	12
C1	Cash Hollow Creek water quality model simulation of fecal coliform concentration versus observed data at Austin Springs Road (001), July 18-August 31, 1994 ………………	28
C2	Cash Hollow Creek water quality model simulation of fecal coliform concentration versus observed data (log scale) at Austin Springs Road (001), July 18-August 31, 1994 ….	28
C3	Cash Hollow Creek water quality model simulation of fecal coliform concentration versus observed data at Lakeview Drive (002), July 18-August 31, 1994 ……………….…	29
C4	Cash Hollow Creek water quality model simulation of fecal coliform concentration versus observed data (log scale) at Lakeview Drive (002), July 18-August 31, 1994 …...…	29
D1	Cash Hollow Creek model simulation of existing conditions versus TMDL allocation at Austin Springs Road (001), (30-day geometric means) ……………………………..	33
D2	Cash Hollow Creek model simulation of existing conditions versus TMDL allocation (log scale) at Austin Springs Road (001), (30-day geometric means) ………………….…...	33
D3	Cash Hollow Creek model simulation of existing conditions versus TMDL allocation at Lakeview Drive (002), (30-day geometric means) …………………..……………	34
D4	Cash Hollow Creek model simulation of existing conditions versus TMDL allocation (log scale) at Lakeview Drive (002), (30-day geometric means) ………….…………………	34

LIST OF TABLES

Table		Page
1	MRLC Landuse Distribution by Subwatershed ………………………………..…………..	4
2	Water Quality Monitoring Station Fecal Coliform Data Analysis ……….………………….	5
3	Livestock Distribution by Subwatershed ……………………..…..……………………………	6
4	Septic Systems in the Cash Hollow Creek Watershed ……………..………………………….	7
5	Land Use Distribution in the Cash Hollow Creek Watershed ………………………………..	8
6	Cash Hollow Creek watershed simulated maximum 30-day geometric mean fecal coliform concentrations for existing (1989-1998) conditions …………….………………………..	11
A1	Cash Hollow Creek Water Quality (Fecal Coliform) Data ……………………………..….	19
B1	NPSM/HSPF Hydrology Parameters and Value Ranges ………………………………………	25
D1	Cash Hollow Creek Water Quality Allocation Analysis ………………………………………	31
D2	Cash Hollow Creek Water Quality Loading Analysis: Existing Conditions ………………….	32
D3	Cash Hollow Creek Water Quality Loading Analysis: TMDL Allocation ……………………	32

EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries that do not meet minimum water quality standards for designated use classifications. States are required to develop Total Maximum Daily Loads (TMDLs) for these waterbodies. The TMDL process establishes the maximum amount of a pollutant that a waterbody can assimilate without exceeding water quality standards and allocates this load between all contributing pollutant sources. The purpose of the TMDL is to establish water quality objectives required to reduce pollution from both point and nonpoint sources, and to restore and maintain the quality of water resources.

Tennessee's 1998 303(d) list identified Cash Hollow Creek (TN06010103CASHHOLLOWCR) as a water quality limited stream impaired by pathogens and not supporting its designated use for Recreation. Waters of this use classification must meet the following quality standards for fecal coliform:

> The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

For this TMDL evaluation, the water quality standard of the 30-day geometric mean fecal coliform concentration of 200 counts/100 ml defines the target endpoint.

The analysis performed to develop the TMDL for fecal coliforms in Cash Hollow Creek utilized dynamic hydrologic and water quality modeling techniques that incorporated physical characteristics of the watershed, meteorology, hydrologic response parameters, and water quality source loading, transport, and decay parameters. Land use in the watershed was characterized from Landsat Thematic Mapper digital images collected during the period 1990-1993. Fecal coliform contributions represented in model simulations were derived from land use activities and direct in-stream contributions and included septic systems, cattle grazing, manure application, urban development, and wildlife. Initial model parameterization values for urban, agricultural, and forest land uses were provided by EPA. No National Pollutant Discharge Elimination System (NPDES) permitted dischargers were included in the modeling analysis.

A simulation period of ten years (1/1/89 - 12/31/98) was used to develop the fecal coliform TMDL. This ten-year period included a wide range of hydrologic conditions including low and high streamflows. The range of hydrologic conditions was considered adequate to identify the conditions critical to fecal coliform concentrations in Cash Hollow Creek as well as determining the 30-day geometric mean concentration for TMDL calculation. To achieve the TMDL, load reductions were applied until the simulated 30-day geometric mean of fecal coliform concentrations did not exceed the water quality standard of 200 counts per 100 ml. Modeling assumptions were considered conservative to constitute an implied margin of safety.

Model results indicate that there are two significant categories of sources impacting fecal coliform loading in the Cash Hollow Creek watershed under existing conditions. Urban sources provide the greatest source contribution in the winter wet season when storm runoff events dominate streamflow. Direct in-stream sources (failing septic systems, leaking sewer lines, straight pipes [illicit connections], animals [including cattle], and unknown sources) provide the greatest source contribution during the summer dry season when seasonal low flow dominates and dilution of direct sources is minimized. Direct in-stream sources are the most significant in terms of contribution to exceedances of water quality criteria.

A possible allocation scenario that would meet in-stream water quality standards on all segments of Cash Hollow Creek includes nonpoint source loading reductions of 90% to urban land use loading and 50-98.4% to direct in-stream sources. Reductions to direct in-stream sources consist of 50-90% reduction in failing septic systems and 95.1-98.4% reduction to other direct in-stream sources. Recommended strategies for subsequent reduction of sources causing impairment of water quality are targeted toward field surveys for improved source delineation and identification, reduction of septic system failure rates, establishment of an urban stormwater management program to identify and eliminate sources related to urban stormwater runoff, and additional monitoring to support model refinement and re-evaluation of load reductions.

The Total Maximum Daily Load for fecal coliform in Cash Hollow Creek, at the Austin Springs Road monitoring station (most downstream monitored location in the watershed), is 1.060 x 10^{11} counts per 30 days. This is consistent with the fecal coliform water quality standard of 200 counts/100 ml as a 30-day geometric mean.

1.0 INTRODUCTION

1.1 Background

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology-based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not meeting designated uses. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and in-stream water quality conditions so that states can establish water quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA, 1991).

Tennessee's 303(d) list was approved by EPA Region IV on September 17, 1998. The list identified Cash Hollow Creek (TN06010103CASH HOLLOWCR) as a water body that does not meet the minimum water quality standard for fecal coliform, due to urban runoff/stormwater and Pastureland. The objective of this study is to develop a fecal coliform TMDL for Cash Hollow Creek.

1.2 Watershed Description

The Watauga River watershed (HUC 06010103) is in the northeast region of Tennessee and northwest North Carolina (Figure 1). Cash Hollow Creek is a tributary to Knob Creek, which drains to the Watauga River at approximately river mile 11.4. The Cash Hollow Creek watershed lies in the Level III Ridge and Valley (67) ecoregion. Cash Hollow Creek (Figure 2) is approximately 3.4 miles long and drains an area of 3.3 square miles, partially located within the Johnson City, Tennessee city limits.

The land use characteristics of the Cash Hollow Creek watershed were determined using data from Tennessee's Multiple Resolution Land Coverage (MRLC). This coverage is based on Digital Landsat Thematic Mapper imagery for 1990-1993. The classification is based on a modified Anderson level one and two system. Table 1 presents land use distribution in the watershed. The dominant land use in the watershed is forest (76.8%), followed by urban (16.9%), with approximately 6.3% agricultural (primarily pasture).

Designated beneficial uses and water quality standards are established by the State of Tennessee in the *State of Tennessee Water Quality Standards*, *Chapters 1200-4-3*, *General Water Quality Criteria*, and *1200-4-4*, *Use Classifications for Surface Waters*, *October, 1999.* The impaired water body has two designated use classifications that comprise fecal coliform criteria: 1) Fish and Aquatic Life and 2) Recreation.

For the purposes of TMDL development, the most stringent of the applicable water quality criteria is designated as the water quality objective for impaired waters. The Recreation use classification is the most stringent for pathogens (fecal coliform). Waters of this class must meet the following quality standards for fecal coliform:

> The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

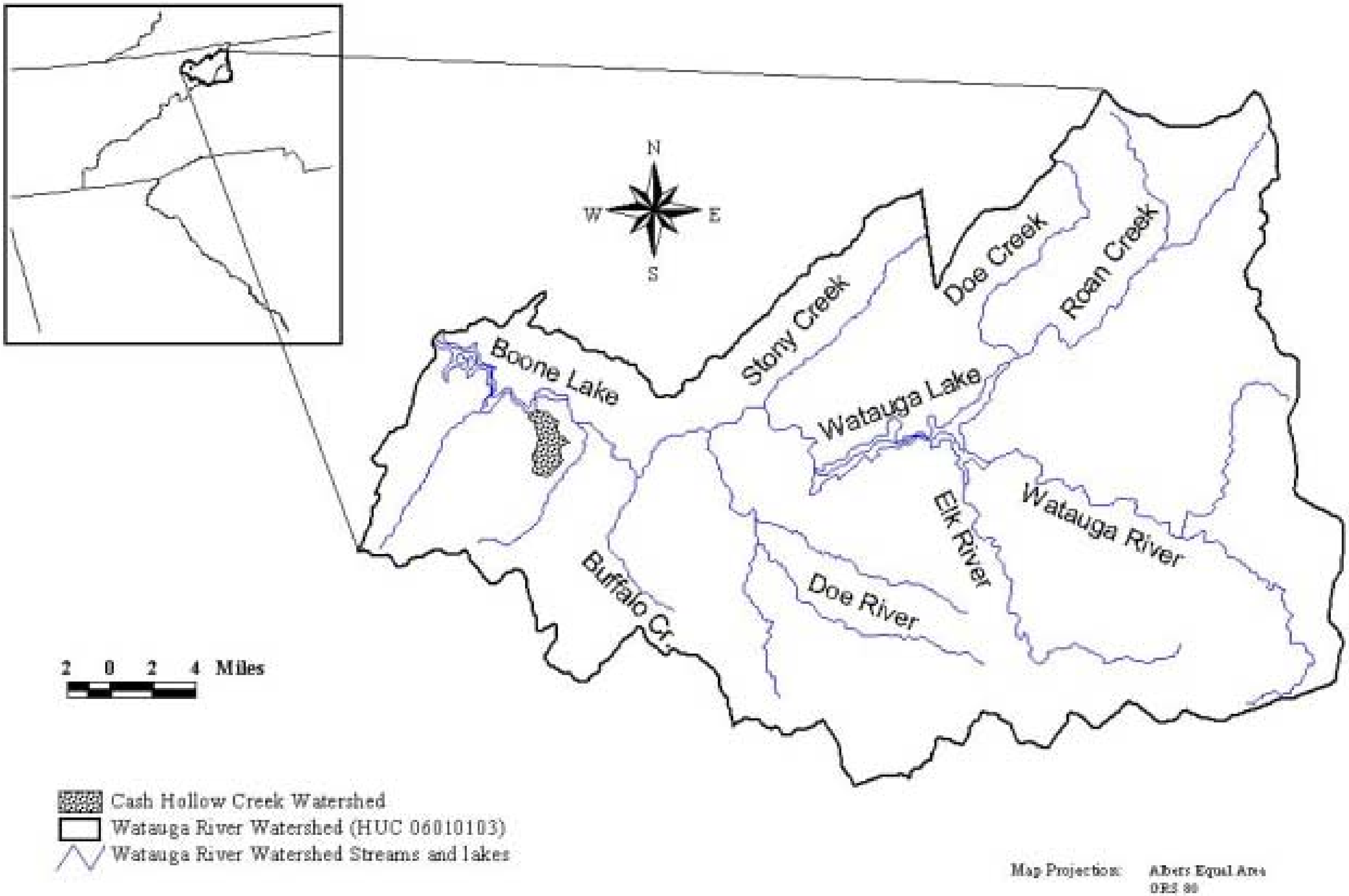

Figure 1. Location of Watauga River and Cash Hollow Creek watersheds.

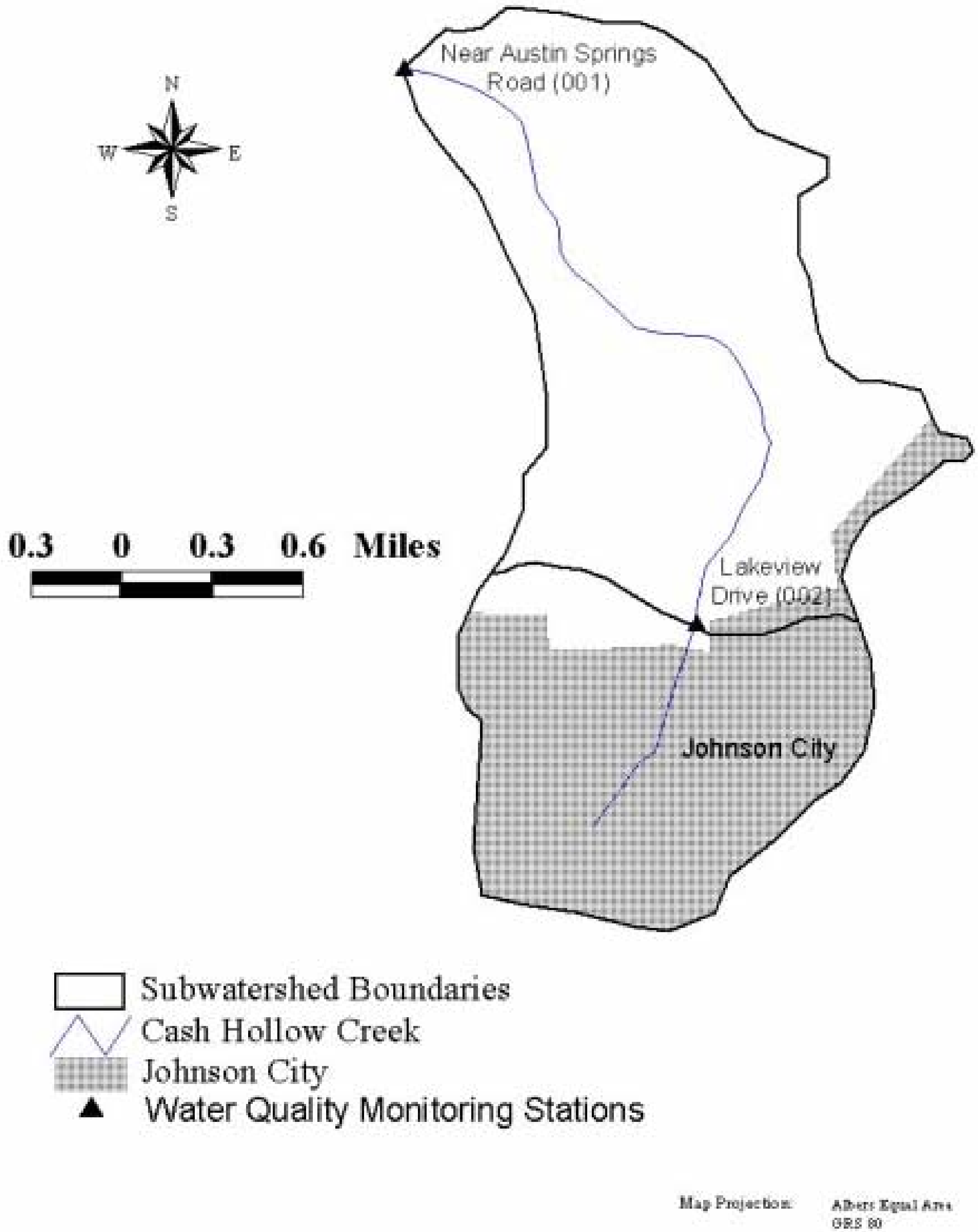

Figure 2. Cash Hollow Creek watershed.

Table 1. MRLC Landuse Distribution by Subwatershed.

	001		002		Watershed Totals	
Landuse	Area (ac)	%	Area (ac)	%	Area (ac)	%
Bare Rock/Sand/Clay	2	0.1	1	0.1	3	0.1
Deciduous Forest	833	60.8	135	17.8	968	45.5
Evergreen Forest	198	14.5	100	13.2	298	14.0
High Intensity Commercial/Industrial/ Transportation	2	0.1	25	3.3	27	1.3
High Intensity Residential	2	0.l	30	4.0	32	1.5
Low Intensity Residential	44	3.2	257	33.9	301	14.1
Mixed Forest	235	17.2	75	9.9	310	14.6
Open Water	2	0.1	0	0	2	0.l
Other Grasses (Urban/recreational; e.g. parks, lawns)	7	0.5	46	6.1	53	2.5
Pasture/Hay	31	2.3	75	9.9	106	5.0
Row Crops	13	0.9	15	2.0	28	1.3
Woody Wetlands	1	0.1	0	0	1	*
Total	1370	100	759	100	2129	100

* Less than 0.1%.

1.3 Water Quality Target

A major component of the TMDL is the establishment of in-stream numeric endpoints, or targets, used to evaluate the attainment of water quality meeting designated use criteria. The target represents the restoration objective expected to be achieved by implementation of load reductions specified by the TMDL evaluation. In addition, the target serves to facilitate evaluation of progress toward attainment of water quality standards by allowing comparison to observed in-stream conditions. For this TMDL, the fecal coliform 30-day geometric mean standard for Recreation (200 counts/100 ml) is the target level to evaluate impairment and establish the TMDL.

1.4 Water Quality Monitoring Program

Data from five water quality sampling sites on Cash Hollow Creek (Appendix A) were used to determine water body impairment and for listing the water on the Tennessee 1998 303(d) list. Geometric means of monthly intensive fecal coliform samples, for the three periods 5/13-6/10/93, 8/1-31/94, and 9/19-10/18/95 range from 161 to 1555 colonies per 100 ml. Concurrently, at the five sampling locations, 53% to 100% of samples had fecal coliform concentrations exceeding 200 colonies per 100 ml and 7% to 57% of samples had fecal coliform concentrations exceeding 1,000 colonies per 100 ml. Table 2 presents fecal coliform data statistics for the five water quality sampling sites.

2.0 SOURCE ASSESSMENT

Potential sources of fecal coliform are numerous and often occur in combination. Untreated or inadequately treated municipal sewage commonly constitutes a major source of fecal coliform in impaired surface waters. Urban stormwater runoff, sanitary and combined sewer overflows, and failing septic systems can be sources of fecal coliform. Rural stormwater runoff can contribute significant loads of fecal coliform from livestock pastures, animal feedlots, and cropland where manure application is practiced. Wildlife can also contribute fecal coliform. Sources of fecal coliform loads can be assigned to two broad classes: point source loads and nonpoint source loads. Point sources of fecal coliform are identified as entering a water body from discrete, identifiable locations, usually pipes. Nonpoint sources of fecal coliform are diffuse sources usually not identified as entering a water body at discrete locations. These sources generally involve land activities that contribute fecal coliform to streams during rainfall runoff events.

Table 2. Water Quality Monitoring Station Fecal Coliform Data Analysis.

Subwatershed[1]	Water Quality Station	Samples (#)	Concentrations (Counts/100 ml)			
			Minimum	Maximum	Mean	Median
001 (RM 0.1)	Near Austin Springs Road	46	310	13900	2358	1100
002 (RM 2.7)	Lakeview Drive	46	72	1060000[2]	23472[2]	390

[1] RM = Cash Hollow Creek River Mile.
[2] A pump station failure resulted in high fecal coliform sample counts on August 15, 1994. Therefore, the mean is not representative of typical conditions.

2.1 Point Source Assessment

There are no National Pollutant Discharge Elimination System (NPDES) permitted facilities discharging to Cash Hollow Creek.

Municipal Publicly Owned Treatment Works (POTWs) service urban areas located in the Cash Hollow Creek watershed, including portions of north Johnson City, TN. These POTWs discharge to water bodies outside the Cash Hollow Creek watershed and therefore are not a consideration for the Cash Hollow Creek TMDL evaluation.

Unidentified point sources (e.g., illicit connections to the storm sewer system and straight pipes to the stream) are considered to be potential contributors of fecal coliform loading in the Cash Hollow Creek watershed. These have been considered in the TMDL analysis.

2.2 Nonpoint Source Assessment

In the absence of permitted point source dischargers contributing fecal coliform loading to Cash Hollow Creek, nonpoint sources are believed to be the primary source of fecal coliform contamination. Land use in the watershed (in 1990-1993) consisted of approximately 16.9% urban, 6.3% agricultural (primarily pasture), and 76.8% forested. Nonpoint sources of fecal coliform loading contributing to water quality impairment in the Cash Hollow Creek watershed are largely attributable to direct inputs to the waterbody (including leaking septic systems, cattle in streams, and undefined sources) and urban runoff/stormwater.

2.2.1 Wildlife

Deer population data were provided by the Tennessee Wildlife Resources Agency (TWRA) for the state of Tennessee. However, no county-specific data were available for east Tennessee counties nor were statistics available for other animals. Therefore, deer were assumed to populate the Cash Hollow Creek watershed according to the upper limit of available population data of 36 per square mile. In addition, in order to account for other wildlife sources of fecal coliform in the watershed, the number of deer per square mile was increased to 45 for water quality model simulations. It is assumed that the wildlife population remains constant throughout the year and that wildlife is uniformly distributed on all land classified in the MRLC database as forest, pasture, cropland, and wetlands.

2.2.2 Livestock Estimates

Table 3 shows agricultural livestock distribution in the watershed. The livestock data are based on the 1997 Agricultural Census compiled and reported by county and distributed to the subwatersheds based on the percentages of agricultural areas in each subwatershed classified as pasture/hay. Therefore, in a small watershed such as Cash Hollow Creek, the level of uncertainty in livestock distribution on the basis of county populations is high.

Table 3. Livestock Distribution by Subwatershed.

Livestock (individuals)	Beef Cows	Dairy Cows	Total Cattle	Chickens (Layers)	Hogs	Sheep	Goats	Horses
001	15	4	34	0	1	0	4	2
002	37	8	85	0	0	1	1	1
Total	52	12	119	0	1	1	5	3

2.2.3 Land Application of Agricultural Manure

Processed agricultural manure from confined hog, dairy cattle, and poultry operations is generally collected in lagoons and applied to land surfaces during the months March through October. There are no poultry operations in the Cash Hollow Creek watershed and, according to county census data and subwatershed areas, proportionally, there is only one hog and it is located in subwatershed 001. In addition, dairy cattle account for only 10% of the total cattle in the watershed. It is assumed that dairy cattle are kept in feed lots; therefore, 100% of dairy cattle waste is collected and applied equally to pasture and cropland in the watershed.

2.2.4 Grazing Animals

Beef cattle spend time grazing on pastureland and depositing manure onto the land. During rainfall runoff events, this manure is available for washoff and is transported to surface streams. It is assumed that animal access to the pastures is unlimited year-round, resulting in uniform fecal coliform loading rates throughout the year. The percentage of manure deposited during grazing on the land versus access to streams is used to estimate the fecal coliform loading rates from pastureland.

Grazing cattle usually have direct access to streams flowing through pastures as a drinking water source. Manure deposited in these streams by grazing animals is considered a direct point source in the water quality model. The input is considered as a constant flow and concentration according to the percentage of time spent in-stream.

2.2.5 Failing Septic Systems

Table 4 shows estimates from county census data of people in the Cash Hollow Creek watershed on septic systems. In the Johnson City area, there are approximately 2.37 people per household on septic systems. However, the census data do not delineate between urban (Johnson City) and non-urban (Washington County) areas. The majority of the population within the city limits is on city sewer service while virtually all of the population outside city limits (in Washington County) is on septic systems. Assumed septic failure rates vary from 10 to 50%, in part to account for discrepancies in the census data. Failing septic systems are represented in the water quality model as point sources (summed by subwatershed) having constant flow and concentration.

Table 4. Septic Systems in the Cash Hollow Creek Watershed.

Subwatershed	Septic Systems	Population Served	Failing Septic Systems*
001	196	464	98
002	22	52	2

* Estimated/assumed.

2.2.6 Urban Development

Fecal coliform loading from urban areas is potentially attributable to multiple sources including stormwater runoff, leaks and overflows from the sanitary sewer system, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, and domestic animals. Urban runoff and stormwater processes are considered to be significant contributors to fecal coliform impairment in Cash Hollow Creek. Unidentified (unverified) urban sources with direct input to the stream (e.g., leaking sanitary collection lines, illicit discharges, straight pipe connections to the stream) are included as point source inputs in water quality model simulations. Overflowing sanitary sewers, leaking collection lines, and straight pipe (illicit) connections to the stream are considered as possible sources of fecal coliform bacteria in the Cash Hollow Creek watershed. A number of these sources have been documented at various times in the Cash Hollow Creek watershed in the past and some (e.g., overflows) are known to have been corrected.

3.0 MODELING APPROACH

Establishing the relationship between in-stream water quality and source loadings is an important component of TMDL development. It provides for the identification of sources and their relative contributions (links sources to impairment) and supports examination of potential water quality improvements resulting from various remediation scenarios designed to meet water quality criteria. For the Cash Hollow Creek fecal coliform TMDL evaluation, a dynamic loading model was utilized to develop this relationship. Fecal coliform source delineation methodology and the modeling techniques used to simulate dynamic loading, transport, and fate in the Cash Hollow Creek watershed follow.

3.1 Model Selection

The Nonpoint Source Model (NPSM) is a Windows and ArcView geographic information system (GIS) based interface to the EPA watershed model Hydrologic Simulation Program - Fortran (HSPF). HSPF is a spatially distributed, lumped parameter, continuous simulation model used to analyze the dynamic hydrologic and water quality characteristics of watersheds and river basins. HSPF calculates nonpoint source loadings of selected pollutants for specified land use categories in the watershed, represents subsequent pollutant runoff response to hydrologic influences (i.e., precipitation, evapotranspiration, etc.), simulates point sources as constant or variable flow and concentration, and simulates flow and pollutant routing through a stream network to the outlet at the pour point of the watershed. The NPSM/HSPF watershed model was utilized to link the sources of fecal coliform to impacts and to characterize the processes (loading, transport, decay) contributing to exceedances of fecal coliform concentrations in the Cash Hollow Creek watershed.

In addition to the NPSM/HSPF, the Watershed Characterization System (WCS), a GIS tool, was used to display, analyze, and compile GIS information to support water quality model simulations for the Cash Hollow Creek watershed. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics. Results of the WCS characterization are input to a spreadsheet designed by EPA to estimate NPSM/HSPF input parameters associated with fecal coliform buildup (loading rates) and washoff from land surfaces. In addition, the spreadsheet estimates direct loadings to water bodies due to cattle in streams and septic system failures. Computed loading rates from the WCS and spreadsheet tools were used in the NPSM/HSPF to simulate the loading and transport of fecal coliform and the resulting water quality response.

3.2 Model Setup

The Cash Hollow Creek watershed was delineated into two subwatersheds (Figure 2), corresponding to the two water quality monitoring stations representing significantly different (with respect to landuse) contributing areas, in order to characterize the relative fecal coliform contributions from various land uses and point source-type discharges. Subwatershed 001, located almost totally within Johnson City boundaries, is highly urbanized while subwatershed 002 lies almost entirely outside the city limits and is characterized as predominantly forested and rural in nature. Subwatershed delineation was based on EPA's River Reach Files Version 3 (RF3) segmented stream coverage and elevation data (USEPA, 1998). This discretization allows for management and load reduction alternatives to be varied by subwatershed. Stream geometry and hydraulic characteristics data (hydrologic function table) from nearby Brush Creek (a stream of similar size, drainage area, and geology) were used in model simulations for streamflow routing. These detailed stream parameters are not available in the RF3 coverage. In addition, for a simplified approach to modeling landuse loading of fecal coliform, the MRLC landuse data were combined into the following four categories: urban, forest, cropland, and pasture (Table 5).

A continuous simulation period from January 1, 1988 to December 31, 1998 was used in the water quality analysis for Cash Hollow Creek. The period from January 1, 1988 to December 31, 1988 was used to allow the model results to stabilize. The period from July 18 to August 31, 1994 was used to calibrate the water quality model. Therefore, the model results had more than adequate simulation time to stabilize prior to the occurrence of available observed water quality data. A ten-year simulation period, January 1, 1989 to December 31, 1998, was used to identify the critical period from which to develop the TMDL (see Sect. 3.5).

Table 5. Land Use Distribution in the Cash Hollow Creek Watershed.

Subwatershed	Urban		Forest		Pasture		Cropland		Total	
	acres	%	acres	%	acres	%	acres	%	acres	%
001	48.4	3.5	1278	93.3	31	2.3	13	0.9	1370.4	64.4
002	311.6	41.1	357	47.1	75	9.9	15	2.0	758.6	35.6
Total	360	16.9	1635	76.8	106	5.0	28	1.3	2129	100

3.3 Fecal Coliform Source Representation

Both point and nonpoint sources are represented in the water quality model. A number of nonpoint source categories are not associated with land loading processes and are represented as direct, in-stream source contributions in the model. These include, but are not limited to, failing septic systems, cattle in streams, leaking sewer lines, and undefined sources. All other nonpoint sources are land loading sources and therefore rainfall runoff generated. These sources are only partially available to streams due to the mechanisms of washoff (efficiency), decay, and incorporation into soil (adsorption, absorption, filtering) before being transported to the stream. Therefore, land-loading nonpoint sources are represented as indirect contributions to the stream. Buildup, washoff, and die-off rates are dependent on seasonal and hydrologic processes. The following sections describe the assumptions used for the various sources described in Section 2.0.

3.3.1 Wildlife

Fecal coliform loading from wildlife is represented in water quality model simulations based on deer population. In the model, deer are uniformly distributed to forest, pasture, cropland, and wetland areas at a density of 45 per square mile to account for other forms of wildlife other than deer. The fecal coliform loading rate applied for deer, 5.0 x 10^8 counts/day/deer, was derived from the EPA spreadsheet described in Section 3.1.

3.3.2 Land Application of Agricultural Manure

Fecal coliform accumulation and buildup rates resulting from land application of hog and cattle manure can be represented in model simulations as monthly input values or constants when uniform loading rates are assumed year-round. Manure application rates for cropland were represented as monthly variable. Hog manure is assumed to be applied only to cropland. Dairy cattle manure is assumed to be applied equally and uniformly to pastureland and cropland. The animal fecal loading rates are: 1.08 x 10^{10} counts/day/hog (ASAE) and 1.83 x 10^{11} counts/day/dairy cow (ASAE).

3.3.3 Grazing Animals

Beef cattle deposit fecal coliform directly to pastureland during grazing. It is assumed there is no monthly variation in access to pastures; therefore, fecal coliform loading rates are considered to be uniform throughout the year. Contributions of fecal coliform from wildlife are included in the pasture loading rate. The animal fecal loading rates are: 5.71 x 10^{10} counts/day/beef cattle (ASAE) and 5.0 x 10^8 counts/day/deer.

3.3.4 Urban Development

Urban areas are represented in the model as two components: pervious and impervious. Initially, a single area-weighted loading rate for urban areas, based on buildup and accumulation rates referenced in Horner (1992), was used in the model. Urban loading rates were adjusted as primary calibration parameters in model simulations and remained constant throughout the year for both subwatersheds.

It was apparent, in calibrating the water quality model to reproduce existing conditions, that dry weather phenomena (exclusive of rainfall runoff generated loading) were responsible for the critical conditions in the Cash Hollow Creek watershed. Significant contributions to high concentrations of fecal coliform at low flows, from urban sources, are probable. These sources may include leaking sewer lines, illicit connections, and improper disposal of wastes. Point source loads were included for each subwatershed in model simulations to account for these direct in-stream sources. They are included with cattle in streams and unknown sources.

3.3.5 Other Sources

The peak 30-day geometric mean fecal coliform concentration at the outlet of the watershed (001) nearly doubled relative to 002 while subwatershed 002 has nearly 87% of the urban area and over 70% of the pasture area in the watershed. Critical 30-day geometric mean concentrations occur during seasonal low flows in the summer and fall. Therefore, direct in-stream sources appear to be largely responsible for the high fecal coliform concentrations during low-flow conditions. A point source load was included in each subwatershed in model simulations to account for direct in-stream loading of fecal coliform including cattle in streams (see Sect. 2.2.4) and unidentified (unknown) sources (see Sect. 2.2.6).

3.4 Model Calibration

Calibration of a dynamic loading model involves both hydrologic and water quality components. The model must be calibrated to appropriately represent hydrologic response in the watershed before reasonable water quality simulations and subsequent calibration can be performed. The hydrologic calibration involves comparison of simulated streamflows to historic continuous streamflow data from a stream gaging station in the watershed. Simulated streamflows are generated from input and adjustment of model parameters, including meteorological (precipitation, evapotranspiration, temperature), physical (areas, overland flowpath lengths, slopes, Manning's roughness coefficients, stream cross-sections), and hydrologic response (infiltration; upper zone, lower zone, and groundwater storage; recession and interflow parameters) to represent the hydrologic cycle. Parameters are adjusted according to and within reasonable constraints until an acceptable agreement is achieved between simulated and observed results. Due to the absence of a USGS stream gaging station in the Cash Hollow Creek watershed, hydrologic calibration of the Cash Hollow Creek model consisted of modification of the Sinking Creek hydrologic model. All physical parameters were adjusted accordingly and best professional judgement was used to adjust other parameters as necessary.

Fecal coliform data are available from five water quality monitoring stations in the Cash Hollow Creek watershed for intensive monthly (summer) sampling periods (10 samples each) during each of years 1993, 1994, and 1995. A limited number of samples were also collected during 1996 with additional intensive monitoring again in 1999. However, precipitation data were not available for 1999 in a usable format for NPSM/HSPF model input; therefore, these recent data could not be used for model calibration. Because no data were available during the winter wet season and few samples were collected during highflow conditions, the uncertainty of the model calibration increases. Graphical representation of model calibration results shows that the model adequately simulates baseflow concentrations and storm runoff response where samples are available for comparison.

3.5 Critical Conditions

Fecal coliform contributions to Cash Hollow Creek may be attributed exclusively to the nonpoint category of sources. There are no point source dischargers located in the Cash Hollow Creek watershed. Critical conditions for waters impaired by nonpoint sources generally occur during periods of wet-weather storm runoff. However, among the categories of nonpoint sources to Cash Hollow Creek are sources that have the potential to occur as direct input to the stream as well as sources whose primary transport mechanism is groundwater, thus being more significant, relative to flow, during dry-weather periods.

The critical condition for fecal coliform impairment from nonpoint, land-loading sources is a rainfall runoff (storm) event preceded by an extended period of dry weather. An extended period of dry weather on the order of nine days or more allows for the maximum buildup of fecal coliform on the land surface, according to Cash Hollow Creek watershed water quality model analyses. This fecal coliform accumulated on the land is then available for washoff by precipitation events. Critical conditions for direct contributions to the stream, represented as point sources in model simulations, occur during low flow and subsequent reduced dilution of available fecal coliform. Both conditions are simulated in the NPSM/HSPF model.

Observed fecal coliform sample concentration versus flow analyses were conducted for all sampling locations on Cash Hollow Creek. These analyses indicated that there were no significant correlations in the relationships at any of the sampling locations. This suggests that fecal coliform impairment is not strictly a storm runoff phenomenon. In fact, according to the water quality model calibration, the critical condition occurs during periods of dry weather low flow. The highest 30-day geometric mean concentrations of fecal coliform occur during the summer and fall at all water quality sampling locations on an annual basis. However, it is important to note that, according to modeling results, storm-driven processes contribute significantly to impairment and must be addressed in the allocation and subsequent reduction of fecal coliform loadings to Cash Hollow Creek.

The ten-year simulation period from January 1, 1989 to December 31, 1998 was used to calibrate the water quality model and identify the critical conditions from which to base the fecal coliform TMDL. This ten-year period contained a range of hydrologic conditions including low and high streamflows. The range of hydrologic conditions was considered adequate to identify the conditions critical to fecal coliform in Cash Hollow Creek as well as determining the 30-day geometric mean concentration and subsequent loading for TMDL calculation. The critical period was determined to be during seasonal low flows occurring in the summer and fall.

4.0 MODEL RESULTS

4.1 Existing Conditions

Model results indicate that the primary sources of fecal coliform contamination in the Cash Hollow Creek watershed are urban sources (both runoff-generated and direct input to the stream) and direct input of fecal coliform to the stream from various sources (e.g., failing septic systems, cattle, illicit dischargers, other animals having access to streams, and other unknown sources) in non-urban areas.

4.2 Critical Conditions

Results of the ten-year simulation of the 30-day geometric mean concentration for existing conditions at the outlet of the Cash Hollow Creek watershed (001) are shown in Figure 3. Critical conditions can be determined from this figure. The 30-day critical period, according to the model simulation, is the time period preceding and including the highest simulated exceedance of the 30-day geometric mean standard. Achieving the water quality criteria for this period ensures that water quality criteria will be achieved for the remainder of the ten-year period and suggests that water quality criteria will be achieved for a very high percentage of time beyond the simulation period. For Cash Hollow Creek, the highest exceedance of the 30-day geometric mean fecal coliform concentration standard occurred on December 8, 1998 at both impaired subwatersheds modeled. Therefore, the critical period is November 9, 1998 through December 8, 1998. Table 6 shows the maximum 30-day geometric mean fecal coliform concentrations at each of the two modeled segments/subwatersheds and the corresponding levels of reduction required to achieve the 30-day geometric mean standard of 200 counts/100 ml at each.

Table 6. Cash Hollow Creek watershed simulated maximum 30-day geometric mean fecal coliform concentrations for existing (1989-1998) conditions.

Subwatershed	Max. 30-day Geometric Mean Fecal Coliform Concentration (Counts/100 ml)	Percent Reduction Required to Achieve Water Quality Standard
002	2706	92.6
001	4683	95.7

5.0 ALLOCATION

5.1 Total Maximum Daily Load

The TMDL process quantifies the amount of pollutant that can be assimilated in a water body, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations [WLAs]), nonpoint source loads (Load Allocations [LAs]), and an appropriate margin of safety (MOS) which takes into account any lack of knowledge concerning the relationship between the effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

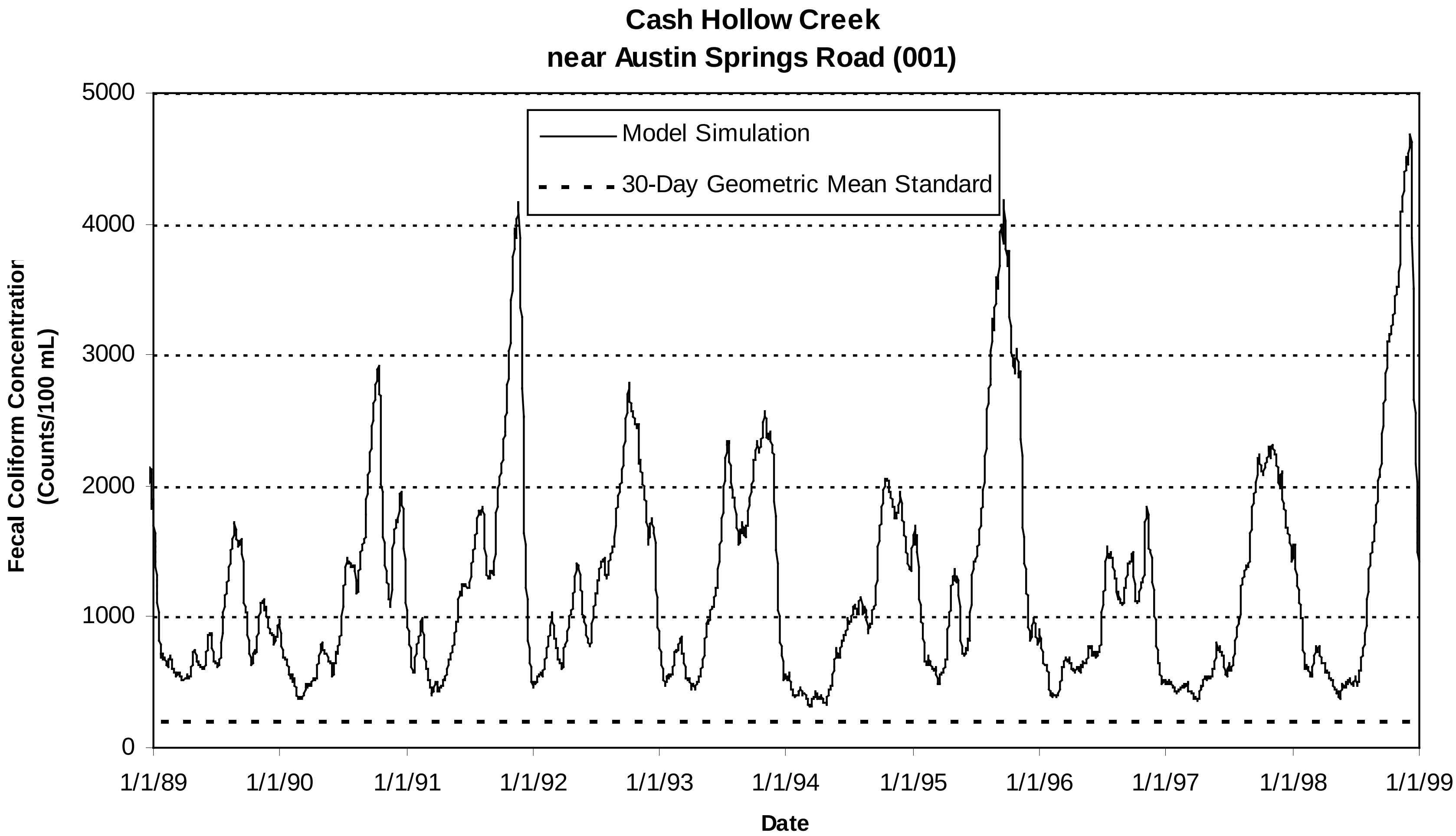

Figure 3. Cash Hollow Creek model simulation of existing conditions (30-day geometric mean).

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (I) states that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure.

The total maximum daily load of fecal coliform was determined by adding the WLA and the LA. The MOS was implicitly included in the TMDL analysis (as described in Sect. 3.5) and does not factor directly in the TMDL equation as shown above. The TMDL for Cash Hollow Creek at the water quality monitoring station near Austin Springs Road (most downstream monitored point in the watershed) is 1.060 x 10^{11} counts per 30 days.

5.2 Waste Load Allocations

Since there are no NPDES fecal coliform-permitted discharges in the Cash Hollow Creek watershed, the WLA for Cash Hollow Creek is zero. All future NPDES facilities will be required to meet end-of-pipe criteria for fecal coliform discharge.

5.3 Load Allocations

Modeling results indicate dual impacts to fecal coliform loading in the Cash Hollow Creek watershed. Urban sources provide the greatest source contribution in the winter wet season when storm runoff events dominate streamflow. Direct in-stream sources (failing septic systems, leaking sewer lines, cattle in streams, and other animals and unknown sources) provide the greatest source contribution during the summer dry season when seasonal low flow dominates and dilution of direct sources is minimized. Direct in-stream sources are the most significant in terms of contribution to exceedances of water quality criteria.

Reducing loading from agricultural practices in the Cash Hollow Creek watershed had a limited impact in allocation modeling simulations (what-if scenarios). In fact, the difference between a 100% reduction and a 100% increase in agricultural loading, exclusive of direct in-stream loading by cattle (and other sources), was approximately 20 counts per 100 ml. Since the maximum simulated 30-day geometric mean fecal coliform concentration, for existing conditions, was on the order of 4683 counts/100 ml at the watershed outlet (001), impacts from agricultural land use loading are considered to be negligible and reductions are unnecessary. In addition, no loading reduction was considered for forested land.

The allocation strategy for Cash Hollow Creek nonpoint source load reduction consisted of applying reductions to fecal coliform loading to both impaired subwatersheds until subwatershed 002 (headwaters subwatershed) was adjusted to meet water quality standards. Next, further reductions were applied to subwatershed 001 until the concentrations approached water quality standards.

Allocation modeling scenarios were investigated in order to meet fecal coliform Recreational Use in-stream water quality criteria at water quality monitoring locations in Cash Hollow Creek. The final allocation scenario included nonpoint source loading reductions to urban land use loading and direct in-stream sources. Reductions to loading were applied uniformly to all land uses in both subwatersheds. Reductions applied to sources in the subwatersheds consisted of the following: 90% reduction in urban land use loading rates and 50-98.4% reduction in direct in-stream loading (50-90% reduction in failing septic systems and 95.1-98.4% reduction to loading from other direct in-stream sources, including cattle in streams and unknown sources). The lower rates of reduction were for subwatershed 002 and the higher rates were for the downstream subwatersheds where impairment is greatest. See Appendix D for detailed allocation information by subwatershed.

5.4 Seasonal Variation

Seasonal variation is accounted for in the dynamic water quality model by simulations covering ten years. Changes in meteorologic inputs and hydrology indicate distinctive seasonal changes and variability in modeled watershed response. In addition, different sources dominate water quality during different seasons (see Sect. 5.3, paragraph 1, above).

5.5 Margin of Safety

The MOS is a required component of TMDL development. There are two basic methods for incorporating the MOS (USEPA, 1991): 1) implicitly incorporate the MOS using conservative model assumptions to develop allocations, or 2) explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations. For the Cash Hollow Creek fecal coliform TMDL, the MOS was implicitly incorporated into the modeling analysis by incorporation of the critical period based on the results of a ten-year simulation including extreme wet and dry periods.

6.0 IMPLEMENTATION STRATEGY

The TMDL analysis was performed using the best data available to specify Load Allocations that will meet the water quality criteria for fecal coliform in Cash Hollow Creek so as to support its designated use classifications. The following recommendations and strategies are targeted toward source delineation, collection of data to support additional modeling and evaluation, and subsequent reduction in sources causing impairment of water quality.

6.1 Monitoring

Tennessee’s watershed management approach specifies a five-year cycle for planning and assessment. Each watershed will be examined (or re-examined) on a rotating basis. Generally, in years two and three of the five-year cycle, water quality data are collected in support of water quality assessment (including TMDL development) and planning activities. Therefore, a watershed TMDL is developed one to two years prior to commencement of the next cycle’s monitoring period.

Continued monitoring of the fecal coliform concentration at multiple water quality sampling points in the watershed is critical in characterizing sources of fecal coliform contamination and documenting future reduction of loading. Current monitoring methodology has focused on intensive sampling for one month (10 samples in 30 days) each summer. This type of sampling supports stream posting for water quality impairment and, according to model simulations, correctly targets the critical low flow season. In the next watershed cycle, monitoring should be expanded to provide water quality information to characterize seasonal trends and refined source identification and delineation.

Recommended monitoring for the Cash Hollow Creek watershed includes monthly grab samples and intensive sampling for one month during the wet season (January-March). In addition, monitoring efforts may be refined and enhanced in order to characterize dry and wet season baseflow conditions (concentrations) and promote selective storm response (hydrograph) characterization. Lastly, stream discharge should be measured with the collection of each fecal coliform sample in order to characterize the dynamics of fecal coliform transport within the surface-water system. Consideration should be given to installation of a USGS continuous stream gage or development of a partial stage-discharge relationship to support improved model calibration. A single gage could serve as an index site for all water quality monitoring stations in the Cash Hollow Creek watershed. This information will support future dynamic modeling efforts yielding meaningful results and reduced uncertainty.

6.2 Field Surveys

Many of the model input parameters utilized in dynamic water quality simulations in support of this TMDL development were based on estimations and assumptions. Therefore, a significant component of the implementation strategy for addressing fecal coliform exceedances in Cash Hollow Creek is collection of data by field reconnaissance. Information on current manure management methods in the watershed is needed to verify the modeling assumptions or to adjust simulations accordingly. Input in this area should be coordinated with the Tennessee Department of Agriculture (TDA), University of Tennessee Agricultural Extension Service, and the NRCS.

In addition, a number of field surveys are recommended to verify or refine estimates of sources of fecal coliform to Cash Hollow Creek. Efforts supported by the City of Johnson City, the Washington County Health Department, the Tennessee Department of Environment and Conservation (TDEC), TDA, TWRA, NRCS, and others should be initiated for collecting these data and conducting the following surveys:

1. Septic system data (population serviced by, age of, proximity to stream, etc.) including failure rates by county or subwatershed

2. Cattle access to streams (and other agricultural animals, feeding operations, etc.)

3. Livestock populations by subwatersheds (including horses, sheep, and other agricultural animals)

4. Unidentified sources: domestic animals, leaking sewer lines, illicit discharges, improper waste disposal, etc.

5. Wildlife population estimates by county (in east Tennessee) or subwatershed (deer, waterfowl, etc.)

6.3 Phase 2 NPDES Stormwater Permit and Storm Water Management Plan

The City of Johnson City, TN will be issued an NPDES Phase 2 Stormwater permit by the State of Tennessee, TDEC. Applications are due by March 10, 2003. In accordance with the permit, the City of Johnson City must develop a Storm Water Quality Management Program (SWQMP). The management program will cover the duration of the permit (5-year renewable) and will comprise a comprehensive planning process which involves public participation and intergovernmental coordination to reduce the discharge of pollutants to the maximum extent practicable using management practices, control techniques, public education, and other appropriate methods and provisions. Components of the SWQMP will include, but will not be limited to, the following (USEPA, 2000):

> *Public Education and Outreach:* Distributing educational materials and performing outreach to inform citizens about the impacts polluted stormwater runoff discharges can have on water quality.
>
> *Public Participation/Involvement:* Providing opportunities for citizens to participate in program development and implementation, including effectively publicizing public hearings and/or encouraging citizen representatives on a stormwater management panel.
>
> *Illicit Discharge Detection and Elimination:* Developing and implementing a plan to detect and eliminate illicit discharges to the storm sewer system (includes developing a system map and informing the community about hazards associated with illegal discharges and improper disposal of waste).
>
> *Post-Construction Runoff Control:* Developing, implementing, and enforcing a program to address discharges of post-construction stormwater runoff from new development and redevelopment areas. Applicable controls could include preventative actions such as protecting sensitive areas (e.g., wetlands) or the use of structural BMPs such as grassed swales or porous pavement.

Pollution Prevention/Good Housekeeping: Developing and implementing a program with the goal of preventing or reducing pollutant runoff from municipal operations. The program must include municipal staff training on pollution prevention measures and techniques (e.g., regular street sweeping, reduction in the use of pesticides or street salt, or frequent catch basin cleaning.

Additional activities and programs conducted by city, county, and state agencies are recommended to support the SWQMP: field screening and monitoring programs to identify the types and extent of fecal coliform water quality problems, relative degradation or improvement over time, areas of concern, and source identification; requirements that all new and replacement sanitary sewage systems be designed to minimize discharges from the system into the storm sewer system; and mechanisms for reporting illicit connections, breaks, surcharges, and general sanitary sewer system problems with potential to release to the storm sewer system.

6.4 Future Efforts

This TMDL represents the first phase of a long-term restoration project to reduce fecal coliform loading to acceptable levels (meeting water quality standards) in the Cash Hollow Creek watershed. TDEC will evaluate the progress of implementation strategies and refine the TMDL as necessary in the next phase (next five-year cycle). This will include recommending specific implementation plans for delineated and as yet undefined sources and causes of pollution. Cooperation will be maintained with TDA (for possible 319 nonpoint source grants) and NRCS for developing BMPs. The dynamic loading model will be upgraded and refined in the next phase to more effectively link sources (including background and agricultural) to impacts and characterize the processes (loading, transport, decay, etc.) contributing to exceedances of fecal coliform concentrations (loading) in impacted water bodies. The phased approach will assure progress toward water quality standards attainment in the future.

7.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the internet at the Tennessee Department of Environment and Conservation website:

www.state.tn.us/environment/wpc/tmdl.htm

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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APPENDIX A

WATER QUALITY DATA

Table A1. Cash Hollow Creek Water Quality (Fecal Coliform) Data.

Water Quality Monitoring Station[1]	Date	FC[2]	FC (30-d GM)[3]
Near Austin Springs Road (001)	5/13/93	2300	
Near Austin Springs Road (001)	5/17/93	1100	
Near Austin Springs Road (001)	5/20/93	1200	
Near Austin Springs Road (001)	5/24/93	1900	
Near Austin Springs Road (001)	5/27/93	2500	
Near Austin Springs Road (001)	6/2/93	1070	
Near Austin Springs Road (001)	6/3/93	2700	
Near Austin Springs Road (001)	6/7/93	1500	
Near Austin Springs Road (001)	6/9/93	1200	
Near Austin Springs Road (001)	6/10/93	1100	1554.68
Near Austin Springs Road (001)	7/18/94	900	
Near Austin Springs Road (001)	7/20/94	790	
Near Austin Springs Road (001)	7/25/94	890	
Near Austin Springs Road (001)	8/1/94	1570	
Near Austin Springs Road (001)	8/4/94	5900	
Near Austin Springs Road (001)	8/8/94	910	
Near Austin Springs Road (001)	8/10/94	1100	
Near Austin Springs Road (001)	8/15/94	10400	
Near Austin Springs Road (001)	8/22/94	940	
Near Austin Springs Road (001)	8/23/94	8200	
Near Austin Springs Road (001)	8/25/94	600	
Near Austin Springs Road (001)	8/29/94	1300	
Near Austin Springs Road (001)	8/31/94	420	1732.41
Near Austin Springs Road (001)	9/19/95	10000	
Near Austin Springs Road (001)	9/20/95	640	
Near Austin Springs Road (001)	9/27/95	1400	
Near Austin Springs Road (001)	9/28/95	620	
Near Austin Springs Road (001)	10/2/95	1090	
Near Austin Springs Road (001)	10/3/95	520	
Near Austin Springs Road (001)	10/9/95	1000	
Near Austin Springs Road (001)	10/11/95	1290	
Near Austin Springs Road (001)	10/16/95	470	
Near Austin Springs Road (001)	10/18/95	310	948.89
Near Austin Springs Road (001)	10/28/96	13600	
Near Austin Springs Road (001)	10/30/96	2200	
Near Austin Springs Road (001)	11/4/96	490	
Near Austin Springs Road (001)	11/5/96	980	
Near Austin Springs Road (001)	11/6/96	13900	
Near Austin Springs Road (001)	8/18/99	1800	
Near Austin Springs Road (001)	8/19/99	750	
Near Austin Springs Road (001)	8/24/99	1800	
Near Austin Springs Road (001)	8/26/99	2700	
Near Austin Springs Road (001)	8/31/99	790	
Near Austin Springs Road (001)	9/2/99	470	
Near Austin Springs Road (001)	9/7/99	570	
Near Austin Springs Road (001)	9/9/99	570	
Cash Hollow Road Bridge	5/13/93	2200	
Cash Hollow Road Bridge	5/17/93	780	
Cash Hollow Road Bridge	5/20/93	850	

Water Quality Monitoring Station[1]	Date	FC[2]	FC (30-d GM)[3]
Cash Hollow Road Bridge	5/24/93	440	
Cash Hollow Road Bridge	5/27/93	380	
Cash Hollow Road Bridge	6/2/93	240	
Cash Hollow Road Bridge	6/3/93	240	
Cash Hollow Road Bridge	6/7/93	310	
Cash Hollow Road Bridge	6/9/93	1000	
Cash Hollow Road Bridge	6/10/93	600	551.71
Cash Hollow Road Bridge	7/18/94	700	
Cash Hollow Road Bridge	7/20/94	920	
Cash Hollow Road Bridge	7/25/94	860	
Cash Hollow Road Bridge	8/1/94	460	
Cash Hollow Road Bridge	8/4/94	4700	
Cash Hollow Road Bridge	8/8/94	950	
Cash Hollow Road Bridge	8/10/94	960	
Cash Hollow Road Bridge	8/15/94	7700	
Cash Hollow Road Bridge	8/22/94	730	
Cash Hollow Road Bridge	8/23/94	510	
Cash Hollow Road Bridge	8/25/94	470	
Cash Hollow Road Bridge	8/29/94	490	
Cash Hollow Road Bridge	8/31/94	460	950.01
Cash Hollow Road Bridge	9/19/95	6600	
Cash Hollow Road Bridge	9/20/95	340	
Cash Hollow Road Bridge	9/27/95	1100	
Cash Hollow Road Bridge	9/28/95	360	
Cash Hollow Road Bridge	10/2/95	530	
Cash Hollow Road Bridge	10/3/95	200	
Cash Hollow Road Bridge	10/9/95	850	
Cash Hollow Road Bridge	10/11/95	830	
Cash Hollow Road Bridge	10/16/95	44	
Cash Hollow Road Bridge	10/18/95	160	464.53
Cash Hollow Road Bridge	10/28/96	440	
Cash Hollow Road Bridge	10/30/96	80	
Cash Hollow Road Bridge	11/4/96	50	
Cash Hollow Road Bridge	11/5/96	230	
Cash Hollow Road Bridge	11/6/96	10200	
Cash Hollow Road Bridge	8/18/99	178	
Cash Hollow Road Bridge	8/19/99	178	
Cash Hollow Road Bridge	8/24/99	380	
Cash Hollow Road Bridge	8/26/99	240	
Cash Hollow Road Bridge	8/31/99	280	
Cash Hollow Road Bridge	9/2/99	146	
Cash Hollow Road Bridge	9/7/99	320	
Cash Hollow Road Bridge	9/9/99	170	
Morning Star Church	5/13/93	1200	
Morning Star Church	5/17/93	840	
Morning Star Church	5/20/93	840	
Morning Star Church	5/24/93	380	
Morning Star Church	5/27/93	580	
Morning Star Church	6/2/93	210	
Morning Star Church	6/3/93	400	
Morning Star Church	6/7/93	39000	

Water Quality Monitoring Station[1]	Date	FC[2]	FC (30-d GM)[3]
Morning Star Church	6/9/93	560	
Morning Star Church	6/10/93	320	801.61
Morning Star Church	7/18/94	1100	
Morning Star Church	7/20/94	710	
Morning Star Church	10/1/94	470	
Morning Star Church	8/1/94	3400	
Morning Star Church	8/4/94	800	
Morning Star Church	8/8/94	2300	
Morning Star Church	8/10/94	800	
Morning Star Church	8/15/94	12900	
Morning Star Church	8/22/94	1010	
Morning Star Church	8/23/94	610	
Morning Star Church	8/25/94	290	
Morning Star Church	8/29/94	630	
Morning Star Church	8/31/94	320	1088.06
Morning Star Church	9/19/95	880	
Morning Star Church	9/20/95	310	
Morning Star Church	9/27/95	1300	
Morning Star Church	9/28/95	650	
Morning Star Church	10/2/95	470	
Morning Star Church	10/3/95	300	
Morning Star Church	10/9/95	260	
Morning Star Church	10/11/95	240	
Morning Star Church	10/16/95	360	
Morning Star Church	10/18/95	180	409.14
Morning Star Church	10/28/96	130	
Morning Star Church	10/30/96	110	
Morning Star Church	11/4/96	110	
Morning Star Church	11/5/96	110	
Morning Star Church	11/6/96	4300	
Morning Star Church	8/18/99	410	
Morning Star Church	8/19/99	650	
Morning Star Church	8/24/99	770	
Morning Star Church	8/26/99	800	
Morning Star Church	8/31/99	150	
Morning Star Church	9/2/99	180	
Morning Star Church	9/7/99	870	
Morning Star Church	9/9/99	260	
Convenience Center	5/13/93	150	
Convenience Center	5/17/93	750	
Convenience Center	5/20/93	200	
Convenience Center	5/24/93	150	
Convenience Center	5/27/93	260	
Convenience Center	6/2/93	60	
Convenience Center	6/3/93	40	
Convenience Center	6/7/93	88	
Convenience Center	6/9/93	260	
Convenience Center	6/10/93	240	160.81
Convenience Center	7/18/94	7500	
Convenience Center	7/20/94	510	
Convenience Center	7/25/94	2600	

Water Quality Monitoring Station[1]	Date	FC[2]	FC (30-d GM)[3]
Convenience Center	8/1/94	190000	
Convenience Center	8/4/94	270	
Convenience Center	8/8/94	10400	
Convenience Center	8/10/94	380	
Convenience Center	8/15/94	176000	
Convenience Center	8/22/94	100	
Convenience Center	8/23/94	360	
Convenience Center	8/25/94	90	
Convenience Center	8/29/94	1200	
Convenience Center	8/31/94	260	
Convenience Center	9/19/95	510	
Convenience Center	9/20/95	1150	
Convenience Center	9/27/95	130	
Convenience Center	9/28/95	60	
Convenience Center	10/2/95	176	
Convenience Center	10/3/95	80	
Convenience Center	10/9/95	590	
Convenience Center	10/11/95	760	
Convenience Center	10/1695	60	
Convenience Center	10/18/95	30	186.89
Convenience Center	10/28/96	10	
Convenience Center	10/30/96	8400	
Convenience Center	11/4/96	10	
Convenience Center	11/5/96	10	
Convenience Center	11/6//96	10	
Lakeview Drive (002)	5/13/93	210	
Lakeview Drive (002)	5/17/93	72	
Lakeview Drive (002)	5/20/93	670	
Lakeview Drive (002)	5/24/93	350	
Lakeview Drive (002)	5/27/93	400	
Lakeview Drive (002)	6/2/93	240	
Lakeview Drive (002)	6/3/93	200	
Lakeview Drive (002)	6/7/93	500	
Lakeview Drive (002)	6/9/93	900	
Lakeview Drive (002)	6/10/93	1000	353.69
Lakeview Drive (002)	7/18/94	1500	
Lakeview Drive (002)	7/20/94	1050	
Lakeview Drive (002)	7/25/94	540	
Lakeview Drive (002)	8/1/94	710	
Lakeview Drive (002)	8/4/94	530	
Lakeview Drive (002)	8/8/94	490	
Lakeview Drive (002)	8/10/94	790	
Lakeview Drive (002)	8/15/94	1060000	
Lakeview Drive (002)	8/22/94	930	
Lakeview Drive (002)	8/23/94	560	
Lakeview Drive (002)	8/25/94	270	
Lakeview Drive (002)	8/29/94	320	
Lakeview Drive (002)	8/31/94	190	
Lakeview Drive (002)	9/19/95	620	
Lakeview Drive (002)	9/20/95	250	
Lakeview Drive (002)	9/27/95	420	

Water Quality Monitoring Station[1]	Date	FC[2]	FC (30-d GM)[3]
Lakeview Drive (002)	9/28/95	340	
Lakeview Drive (002)	10/2/95	390	
Lakeview Drive (002)	10/3/95	230	
Lakeview Drive (002)	10/9/95	630	
Lakeview Drive (002)	10/11/95	390	
Lakeview Drive (002)	10/16/95	600	
Lakeview Drive (002)	10/18/95	560	418.27
Lakeview Drive (002)	10/28/96	90	
Lakeview Drive (002)	10/30/96	180	
Lakeview Drive (002)	11/4/96	270	
Lakeview Drive (002)	11/5/96	280	
Lakeview Drive (002)	11/6/96	200	
Lakeview Drive (002)	8/18/99	122	
Lakeview Drive (002)	8/19/99	88	
Lakeview Drive (002)	8/24/99	240	
Lakeview Drive (002)	8/26/99	150	
Lakeview Drive (002)	8/31/99	180	
Lakeview Drive (002)	9/2/99	340	
Lakeview Drive (002)	9/7/99	310	
Lakeview Drive (002)	9/9/99	400	

[1] Near Austin Springs Road (RM = 0.1)
Cash Hollow Road Bridge (RM = 0.8)
Morning Star Church (RM = 1.5)
Convenience Center (RM = 1.9)
Lakeview Drive (RM = 2.7)
[2] Fecal Coliform Concentration (Counts/100 ml)
[3] Fecal Coliform 30-day Geometric Mean Concentration (Counts/100 ml)

APPENDIX B

HYDROLOGIC CALIBRATION

Table B1. NPSM/HSPF Hydrology Parameters and Value Ranges

			Range of Values							
			Typical		Possible		Sinking Creek	Cash Hollow Creek		
Name	**Definition**	**Units**	**Min**	**Max**	**Min**	**Max**	**Starter**	**Calibration**	**Function of:**	**Comments**
PWAT-PARM2										
FOREST	Fraction forest cover	none	0	0.5	0	0.95	0.284-0.394	0.246-0.389	Forest cover	% evergreen (forest land use only)
LZSN	Lower zone nominal soil moisture storage	inches	3	8	2	15	5	5	Soils, climate	Calibration
INFILT	Index to infiltration capacity of the soil	in/hr	0.01	0.25	0.001	0.5	0.05	0.05	Soils, land use	Calibration, divides surface/subsurface flow
LSUR	Length of overland flow plane	feet	200	500	100	700	500	300-500	Topography	Estimate from maps or GIS
SLSUR	Slope of overland flow plane	none	0.01	0.15	0.001	0.3	0.029-0.15	0.05-0.125	Topography	Estimate from maps or GIS
KVARY	GW recession flow parameter	1/inches	0	3	0	5	0	0	Baseflow recession variation	Used when recession rate varies w/ GW levels
AGWRC	Basic GW recession rate	none	0.92	0.99	0.85	0.999	0.98	0.98	Baseflow recession	Calibration
PWAT-PARM3										
PETMAX	Temperature below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation	Reduces ET near freezing, when SNOW is active
PETMIN	Temperature below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation	Reduces ET near freezing, when SNOW is active
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soils variability	Usually default to 2.0
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soils variability	Usually default to 2.0
DEEPFR	Fraction of GW inflow to deep recharge	none	0	0.2	0	0.5	0.35	0.05-0.2	Geology, GW recharge	Calibration: Cash Hollow Creek is a losing reach
BASETP	Fraction of remaining ET from baseflow	none	0	0.05	0	0.2	0	0	Riparian vegetation	Direct ET from riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0	0.05	0	0.2	0	0	Marsh/wetlands extent	Direct ET from shallow GW
PWAT-PARM4										
CEPSC	Interception storage capacity	inches	0.03	0.2	0.01	0.4	monthly	Monthly	Vegetation type/density, land use	Monthly values usually used
UZSN	Upper zone nominal soil moisture storage	inches	0.1	1	0.05	2	0.7	0.7	Surface soil conditions, land use	Accounts for near surface retention
NSUR	Manning's n (roughness) for overland flow	none	0.15	0.35	0.1	0.5	0.3	0.2-0.3	Surface conditions, land use	Monthly values often used for croplands
INTFW	Interflow inflow parameter	none	1	3	1	10	5	5	Soils, topography, land use	Calibration, based on hydrograph separation
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.5	0.5	Soils, topography, land use	Often start with a value of 0.7, then adjust
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	Monthly	monthly	Vegetation type/density, root depth	Monthly values usually used
MON-INTERCEPT	Monthly interception storage capacity	inches	0.03	0.2	0.01	0.4			Vegetation type/density, land use	Monthly values usually used
	January						0.01	0.01		
	February						0.01	0.01		
	March						0.03	0.03		
	April						0.08	0.08		
	May						0.12	0.12		
	June						0.12	0.12		
	July						0.12	0.12		
	August						0.12	0.12		
	September						0.12	0.12		
	October						0.06	0.06		
	November						0.03	0.03		
	December						0.01	0.01		
MON-LZETPARM	Monthly lower zone ET parameter	none	0.2	0.7	0.1	0.9			Vegetation type/density, root depth	Monthly values usually used
	January						0.2	0.2		
	February						0.2	0.2		
	March						0.2	0.2		
	April						0.3	0.3		

	May						0.4	0.4		
	June						0.4	0.4		
	July						0.4	0.4		
	August						0.3	0.3		
	September						0.3	0.3		
	October						0.2	0.2		
	November						0.2	0.2		
	December						0.2	0.2		

GW = groundwater
ET = evapotranspiration

APPENDIX C

WATER QUALITY CALIBRATION

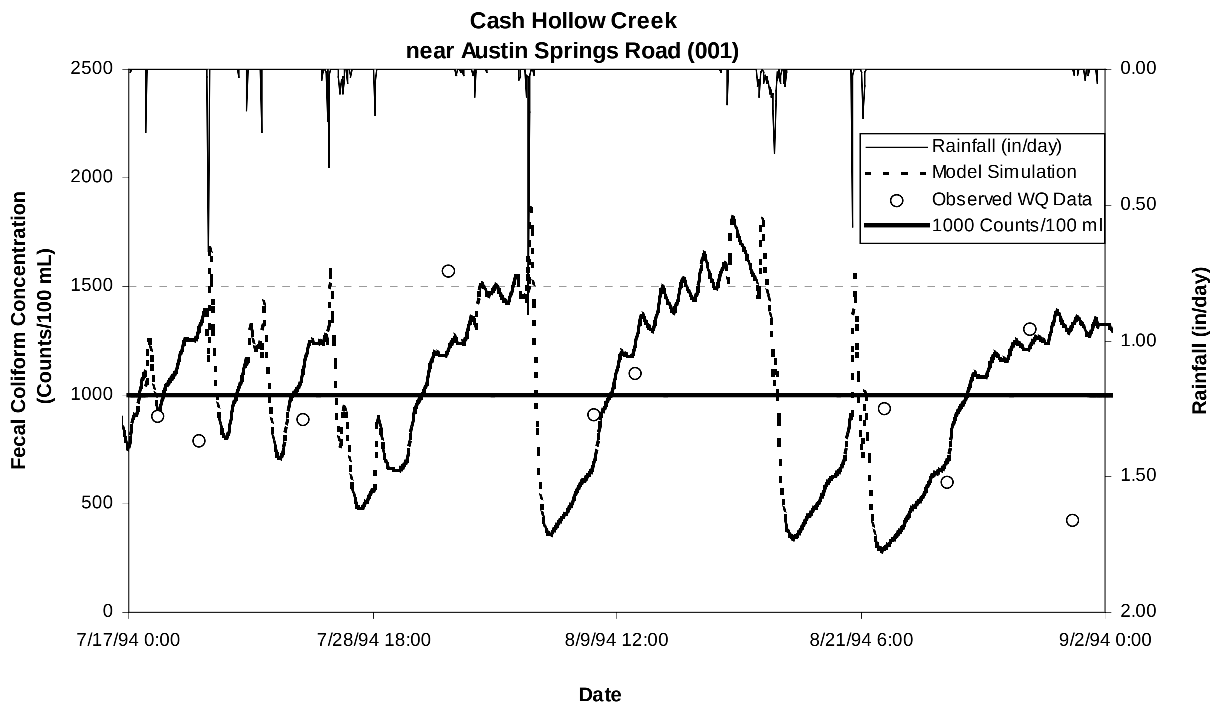

Figure C1. Cash Hollow Creek water quality model simulation of fecal coliform concentration versus observed data at Austin Springs Road (001), July 18-August 31, 1994.

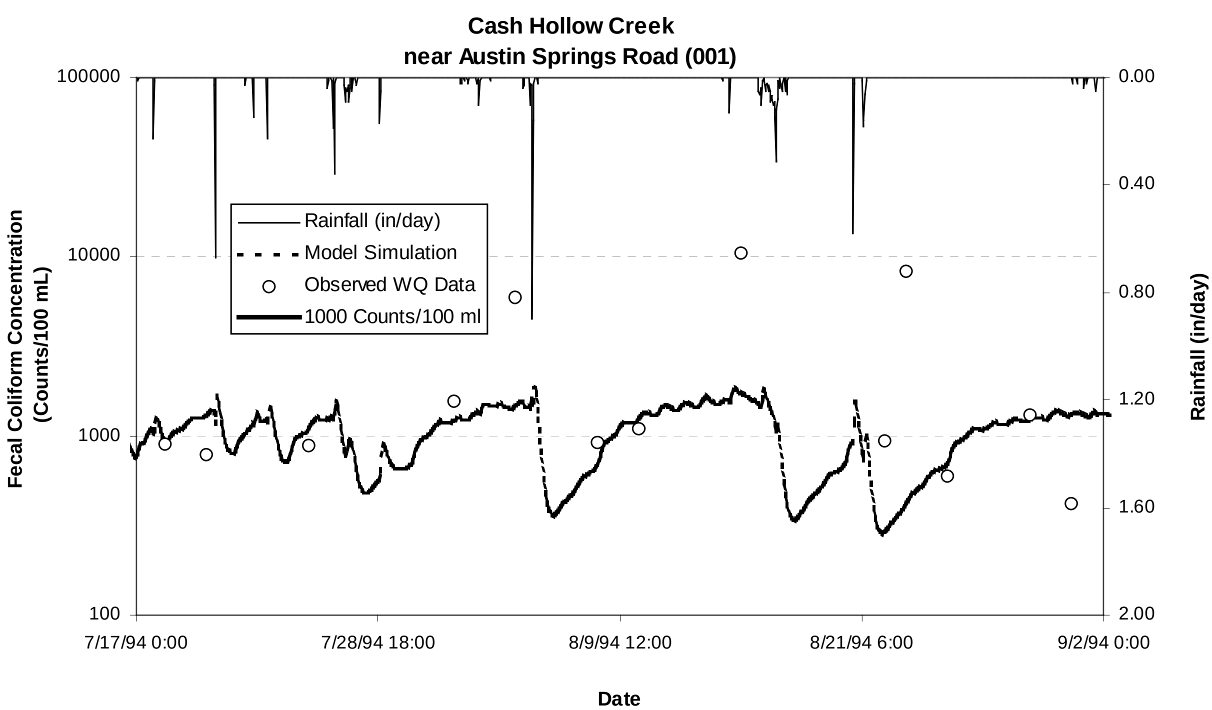

Figure C2. Cash Hollow Creek water quality model simulation of fecal coliform concentration versus observed data (log scale) at Austin Springs Road (001), July 18-August 31, 1994.

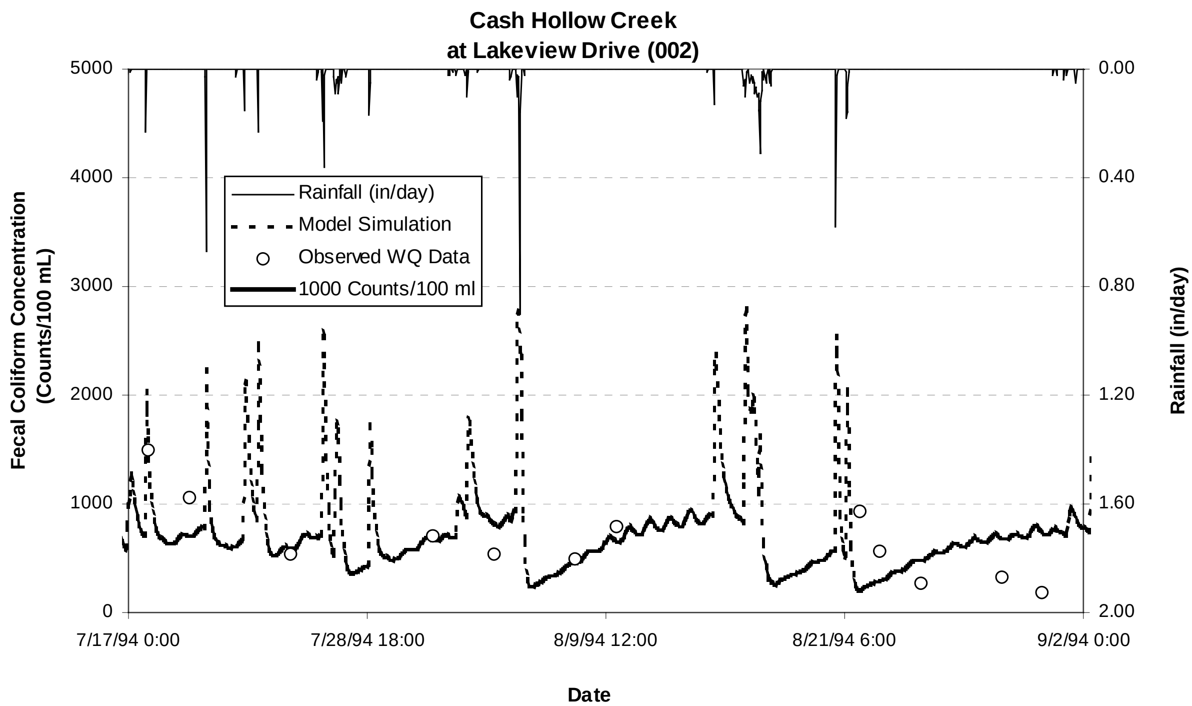

Figure C3. Cash Hollow Creek water quality model simulation of fecal coliform concentration versus observed data at Lakeview Drive (002), July 18-August 31, 1994.

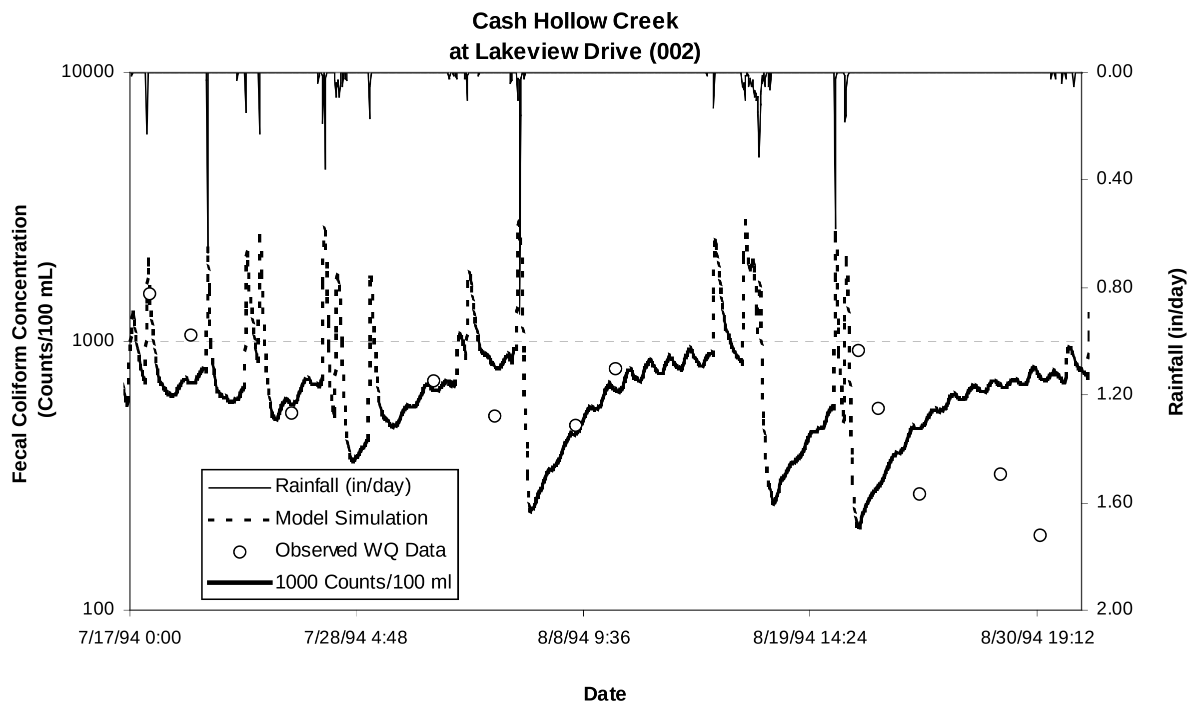

Figure C4. Cash Hollow Creek water quality model simulation of fecal coliform concentration versus observed data (log scale) at Lakeview Drive (002), July 18-August 31, 1994.

APPENDIX D

TMDL ALLOCATION RESULTS

Table D1. Cash Hollow Creek Water Quality Allocation Analysis

Calibrated Water Quality model parameters:

SW#	% SSF	% OIS	Urb (Perv) SQO/ACQOP	Urb (Perv) SQOLIM	Urb (Imp) SQO/ACQOP	Urb (Imp) SQOLIM	Urb IOQC/AOQC	Pas SQO/ACQOP	Pas SQOLIM	Pas IOQC/AOQC	Calibrated model max. 30-d geo. mean
002	10	0.235	1.09E+09	1.744E+09	1.09E+09	1.74E+09	56640	5.44E+10	8.704E+10	29800	**2706**
001	50	3	1.09E+09	1.744E+09	1.09E+09	1.74E+09	56640	5.36E+10	8.576E+10	29800	**4683**

Allocation Water Quality model parameters:

SW#	% SSF	% OIS	Urb (Perv) SQO/ACQOP	Urb (Perv) SQOLIM	Urb (Imp) SQO/ACQOP	Urb (Imp) SQOLIM	Urb IOQC/AOQC	Pas SQO/ACQOP	Pas SQOLIM	Pas IOQC/AOQC	Allocated model max. 30-d geo. mean
002	5	0.0115	1.09E+08	1.744E+08	1.09E+08	1.74E+08	8496				**197.5**
001	5	0.048	1.09E+08	1.744E+08	1.09E+08	1.74E+08	8496				**199.0**

Note: only parameter values that have been adjusted are listed (i.e., parameter values not listed were not adjusted)

Allocation Water Quality model; **Percent Reductions** (relative to calibrated model) to meet criteria:

SW#	% SSF	% OIS	Urb (Perv) SQO/ACQOP	Urb (Perv) SQOLIM	Urb (Imp) SQO/ACQOP	Urb (Imp) SQOLIM	Urb IOQC/AOQC	Pas SQO/ACQOP	Pas SQOLIM	Pas IOQC/AOQC	% Reduction*
002	50	95.1	90	90	90	90	85				**92.7**
001	90	98.4	90	90	90	90	85				**95.8**

* Percent reduction at subwatershed outlet required to meet criteria (30-day geometric mean less than or equal to 200 counts/100 ml) according to calibrated model 30-day geometric mean concentration.

SW# = Subwatershed number
SSF = Septic System Failure
OIS = Other direct In-Stream sources (including unidentified sources)
Urb = Urban
Perv = Pervious
Imp = Impervious
Pas = Pasture

Table D2. Cash Hollow Creek Water Quality Loading Analysis: Existing Conditions

Subwatershed #	Land Loading (Counts/30 days)		Direct In-Stream Loading (Counts/30 days)		Total (Counts/30 days)
	Pervious	Impervious	Septic Systems	OIS[1]	
002	1.560E+10	2.698E+11	4.102E+09	2.765E+11	5.660E+11
001	1.097E+10	3.554E+10	1.846E+11	1.435E+12	1.666E+12
Total	2.657E+10	3.054E+11	1.887E+11	1.711E+12	**2.232E+12**

[1] OIS = Other direct In-Stream sources (including unidentified sources)

Table D3. Cash Hollow Creek Water Quality Loading Analysis: TMDL Allocation

Subwatershed #	Land Loading (Counts/30 days)		Direct In-Stream Loading (Counts/30 days)		Total (Counts/30 days)	TMDL (Counts/30 days)
	Pervious	Impervious	Septic Systems	OIS[1]		
002	8.740E+09	2.698E+10	2.051E+09	1.357E+10	5.134E+10	5.134E+10
001	9.654E+09	3.554E+09	1.846E+10	2.296E+10	5.463E+10	**1.060E+11**
Total	1.839E+10	3.054E+10	2.051E+10	3.653E+10	1.060E+11	

[1] OIS = Other direct In-Stream sources (including unidentified sources)

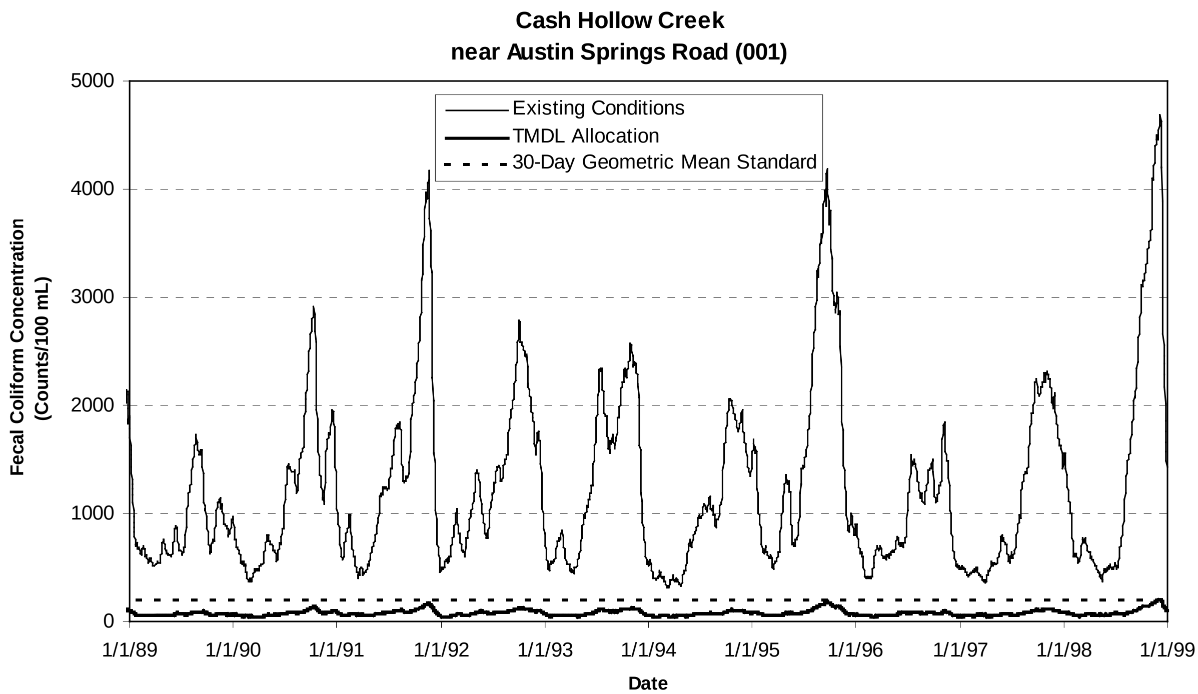

Figure D1. Cash Hollow Creek model simulation of existing conditions versus TMDL allocation at Austin Springs Road (001), (30-day geometric means).

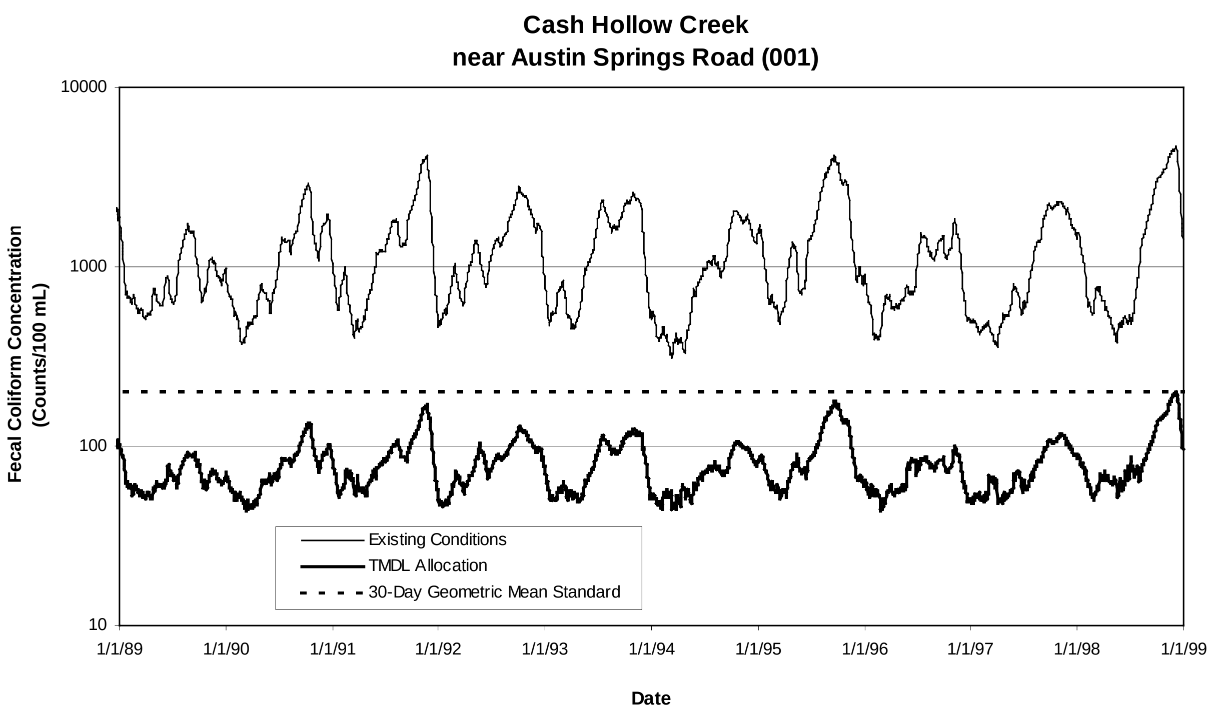

Figure D2. Cash Hollow Creek model simulation of existing conditions versus TMDL allocation (log scale) at Austin Springs Road (001), (30-day geometric means).

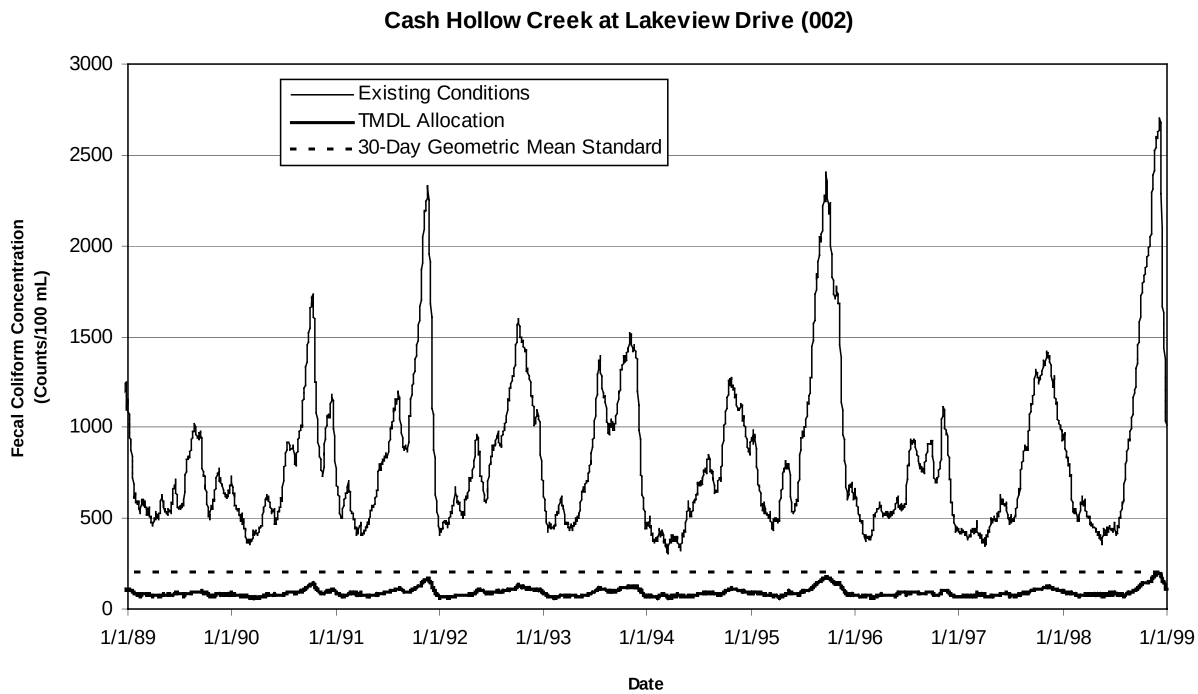

Figure D3. Cash Hollow Creek model simulation of existing conditions versus TMDL allocation at Lakeview Drive (002), (30-day geometric means).

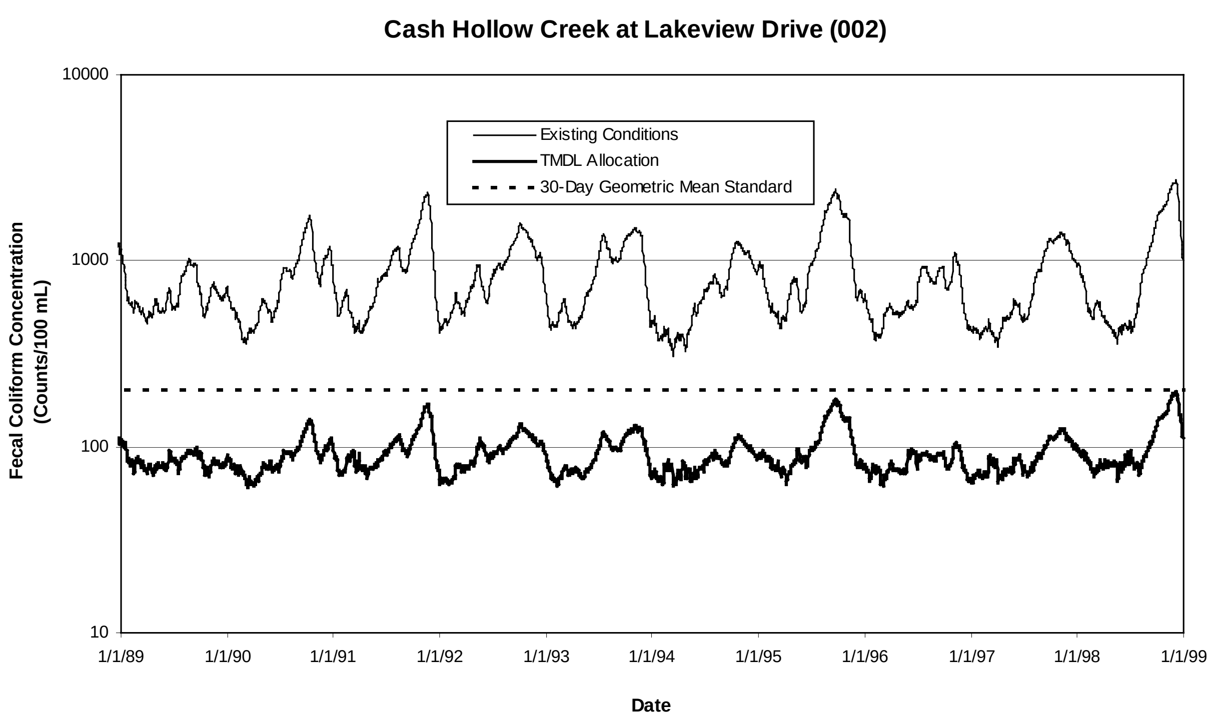

Figure D4. Cash Hollow Creek model simulation of existing conditions versus TMDL allocation (log scale) at Lakeview Drive (002), (30-day geometric means).

APPENDIX E

PUBLIC NOTICE OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR FECAL COLIFORM IN CASH HOLLOW CREEK

DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR FECAL COLIFORM IN CASH HOLLOW CREEK, WATAUGA RIVER WATERSHED (HUC 06010103), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed total maximum daily load (TMDL) for fecal coliform in the Cash Hollow Creek watershed, which drains to Watauga River at approximately river mile 11.4. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

Cash Hollow Creek is listed on Tennessee's final 1998 303(d) list as not supporting its designated use classifications due, in part, to discharge of fecal coliforms resulting from Urban runoff/stormwater and Pastureland. The TMDL utilizes Tennessee's general water quality criteria, recently collected site specific water quality data, continuous flow data from a USGS discharge monitoring station located in proximity to the watershed, and a calibrated dynamic water quality model to establish allowable loadings of fecal coliform which will result in reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of approximately 95% for Cash Hollow Creek.

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

Dennis M. Borders, P.E., Watershed Management Section
Telephone: 615-532-0706

Sherry H. Wang, Ph.D., Watershed Management Section
Telephone: 615-532-0656

Persons wishing to comment on the proposed TMDL are invited to submit their comments in writing no later than November 13, 2000 to:

Division of Water Pollution Control
Watershed Management Section
7th Floor L & C Annex
401 Church Street
Nashville, TN 37243-1534

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Pollution Control, 7th Floor L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.

APPENDIX F

PUBLIC COMMENTS FOR PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR FECAL COLIFORM IN CASH HOLLOW CREEK

Comments received on the Proposed TMDL for Fecal Coliform in Sinking Creek

The following constitutes the comments received during the public notice period. It has been transcribed, verbatim, from the original hardcopy transmittal.

November 9, 2000

Comments relating to Proposed Total Maximum Daily Load for Fecal Coliform in Cash Hollow Creek, Watauga River Watershed (HUC 06010103), Tennessee:

Dear Sirs:

I strongly support reductions of coliform levels in Cash Hollow Creek. I, and many others, use the Johnson City Boat Dock near where Cash Hollow Creek empties into the lake. The City is making major efforts to clean up around its household waste site near the Creek and provide buffers. Thus, the area has some potential for environmental health and that should be pursued on all fronts.

Sincerely,

Michael D. Everette
Associate Professor of Economics
1322 Centenary Rd.
Kingsport, TN 37663