Total Maximum Daily Load Document
Gills Creek Watershed
SCDHEC Monitoring Stations: C-001, C-017
(Hydrologic Unit Codes: 03050110-0201, -0202, -0203)
Fecal Coliform Bacteria, Indicator for Pathogens

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C*over photo courtesy of Jessica Artz, Gills Creek Watershed Association*

Abstract

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for water bodies that are not meeting designated uses under technology-based pollution controls. A TMDL is the maximum amount of pollutant a water body can assimilate while meeting water quality standards for the pollutant of concern. All TMDLs include a wasteload allocation (WLA) for all National Pollutant Discharge Elimination System (NPDES) permitted discharges, a load allocation (LA) for all nonpoint sources, and an explicit and/or implicit margin of safety (MOS).

A fecal coliform TMDL was developed for two impaired stations within the Gills Creek watershed in Richland County, South Carolina. Two stations along the creek are included as impaired on the state's 2008 §303(d) list of impaired water bodies due to excessive fecal coliform counts documented during the 2002–2006 assessment period. In addition, 35 percent and 25 percent of the samples collected by the South Carolina Department of Health and Environmental Control (SCDHEC or the Department) between 1999 and 2006 at monitoring stations C-001 and C-017, respectively, exceeded the water quality standard.

There are currently no active continuous NPDES-permitted dischargers of fecal coliform bacteria in the watershed. The probable sources of fecal contamination include but are not limited to: wildlife, failing septic systems, illicit connections, leaking sewers, sanitary sewer overflows, pet wastes and stormwater runoff. The watershed modeling system Loading Simulation Program in C++ (LSPC) was used to calculate existing and TMDL loads for each impaired station. The existing pollutant loadings and proposed TMDL reductions for critical hydrologic conditions are presented in Table Ab-1. Critical hydrologic conditions were defined as moist, mid-range, or dry depending on which condition demonstrated the highest load reductions necessary to meet water quality standards. To achieve the target load (slightly below water quality standards) for Gills Creek and tributaries, reductions in the existing loads of up to 97 percent will be necessary at some stations. For SCDOT and existing and future NPDES MS4 permittees, compliance with terms and conditions of its NPDES MS4 permit is effective implementation of the WLA to the Maximum Extent Practicable (MEP). For existing and future NPDES construction and Industrial stormwater permittees, compliance with terms and conditions of its permit is effective implementation of the WLA. The required load reductions in the LA portion of the TMDL can be implemented through voluntary measures.

The Department recognizes that **adaptive management/implementation** of this TMDL might be needed to achieve the water quality standard, and we are committed towards targeting the load reductions to improve water quality in the Gills Creek watershed. As additional data and/or information becomes available, it may become necessary to revise and/or modify the TMDL target accordingly.

Table Ab-1. Total Maximum Daily Loads for the Gills Creek Watershed

				Wasteload Allocation (WLA)		Load Allocation (LA)	
Station	**Existing Load (cfu/day)**	**TMDL (cfu/day)**	**Margin of Safety (MOS) (cfu/day)**	**Continuous Sources[1] (cfu/day)**	**Non-Continuous Sources[2,3,4] (% Reduction)**	**Load Allocation (cfu/day)**	**% Reduction to Meet LA[3]**
C-001	8.31E+13	2.13E+12	1.06E+11	See Note Below	97%	2.02E+12	97%
C-017	4.37E+13	3.93E+12	1.96E+11	See Note Below	91%	3.73E+12	91%

Table Notes:

1. WLAs are expressed as a daily maximum. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern. Loadings were developed based upon permitted flow and assuming an allowable permitted maximum concentration of 400cfu/100ml.
2. Percent reduction applies to all NPDES-permitted stormwater discharges, including current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction due to the uncertain

nature of non-continuous discharge volumes and recurrence intervals. Stormwater discharges are required to meet the percentage reduction or the existing instream standard for the pollutant of concern in accordance with their NPDES Permit.
3. Percent reduction applies to existing instream load; where Percentage Reduction = (Existing Load - Load Allocation) / Existing Load
4. By implementing the best management practices that are prescribed in either the SCDOT annual SWMP or the SCDOT MS4 Permit to address fecal coliform, the SCDOT will comply with this TMDL and its applicable WLA to the maximum extent practicable (MEP) as required by its MS4 permit.

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1.0 Introduction

1.1. BACKGROUND

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for water bodies that are not meeting designated uses under technology-based pollution controls. 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 and restore and maintain the quality of water resources (USEPA 1991).

SCDHEC has identified the Gills Creek watershed (03050110-02), Richland County (Figure 1-1), upstream of two ambient water quality monitoring stations as impacted by fecal coliform bacteria. These monitoring stations, shown in Figure 1-2, are C-001 (Gills Creek at US-76, Garners Ferry Road) and C-017 (Gills Creek at SC-48, Bluff Road South of I-77). Accordingly, the stations have been included on South Carolina's 2008 §303(d) list due to excessive fecal coliform counts documented during the 2002–2006 assessment period.

Fecal coliform (FC) bacteria can be elevated in surface water as the result of both point and nonpoint sources of pollution. It is assumed that water bodies with high concentrations of FC bacteria might also be contaminated by pathogens, or disease-producing bacteria or viruses, which may exist in fecal material. Waterborne diseases associated with fecal material include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal contamination is, therefore, an indicator of a potential health risk to individuals exposed to the contaminated water.

1.2. WATERSHED DESCRIPTION

The Gills Creek watershed is in Richland County, South Carolina, and includes over 70 miles of streams in three 12-digit Hydrologic Unit Codes (HUCs), within one 10-digit HUC (0305011002). The watershed consists primarily of Gills Creek and its tributaries—Jackson Creek, Bynum Creek, Rose Creek, Mack Creek, Wildcat Creek, Windsor Lake, Carys Lake, and Spring Lake. The Gills Creek watershed covers 74.5 square miles (47,681 acres), including parts of Columbia, Forest Acres, and Fort Jackson, a U.S. Army basic combat training center. The project watershed, upstream of monitoring station C-017, is 66.3 square miles. Originating near Sesquicentennial State Park, Gills Creek flows through the northeastern section of the city of Columbia and eventually drains into the Congaree River. In Columbia, the Broad and Saluda rivers join to form the Congaree River. Downstream, the Congaree River joins the Wateree River, forming the Santee River, which ultimately discharges into the Atlantic Ocean.

Figure 1-3 and Table 1-1 show the 2001 National Land Cover Database (NLCD) land use coverage in square miles and by percentage for the Gills Creek watershed. About 55 percent of the watershed is developed; the remaining area is largely composed of forest. Agriculture represents a small percentage of the watershed, about 2 percent.

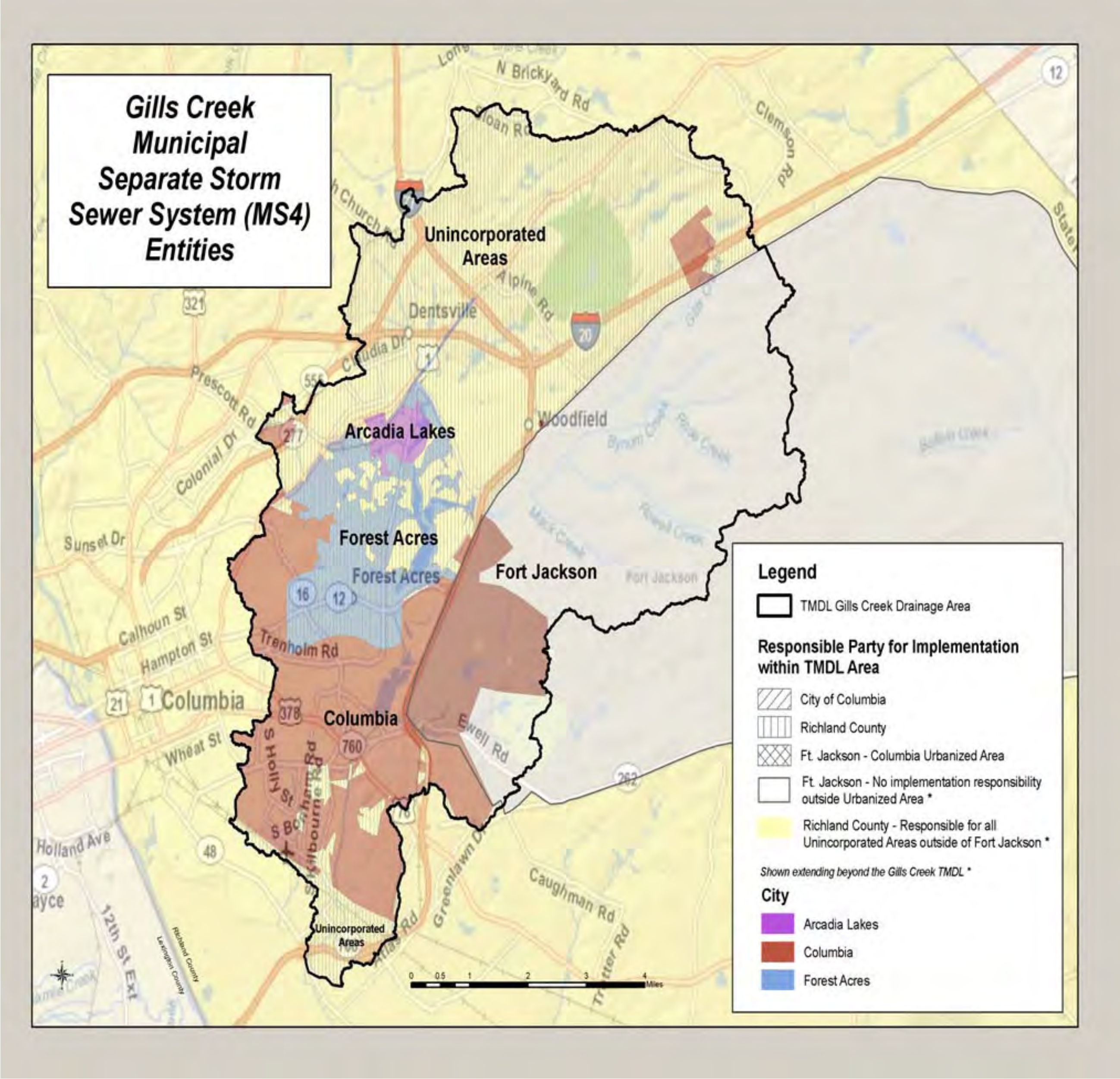

Figure 1-1. **Gills Creek watershed in Richland County, South Carolina.**

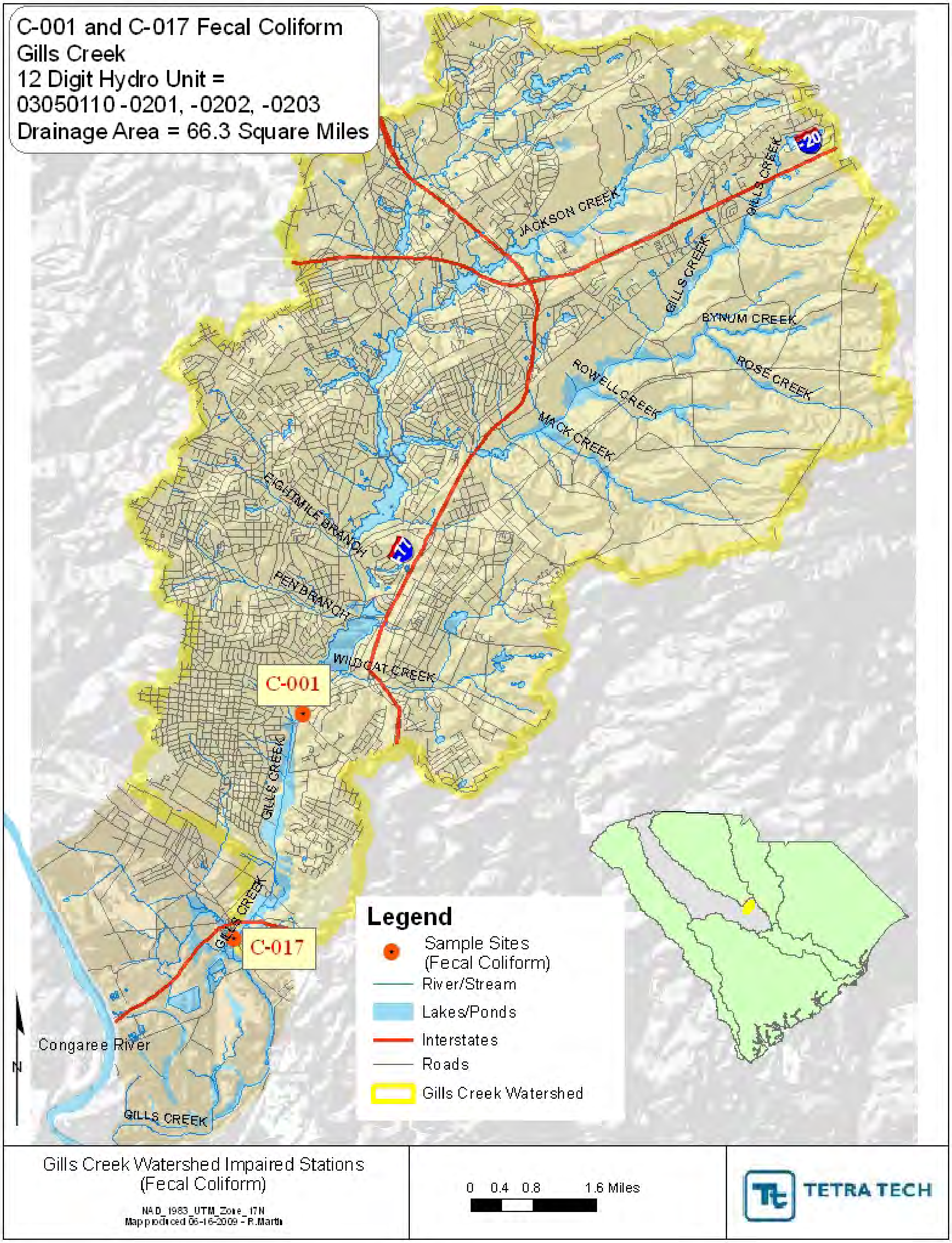

Figure 1-2. Gills Creek watershed stations indicating fecal coliform impairment.

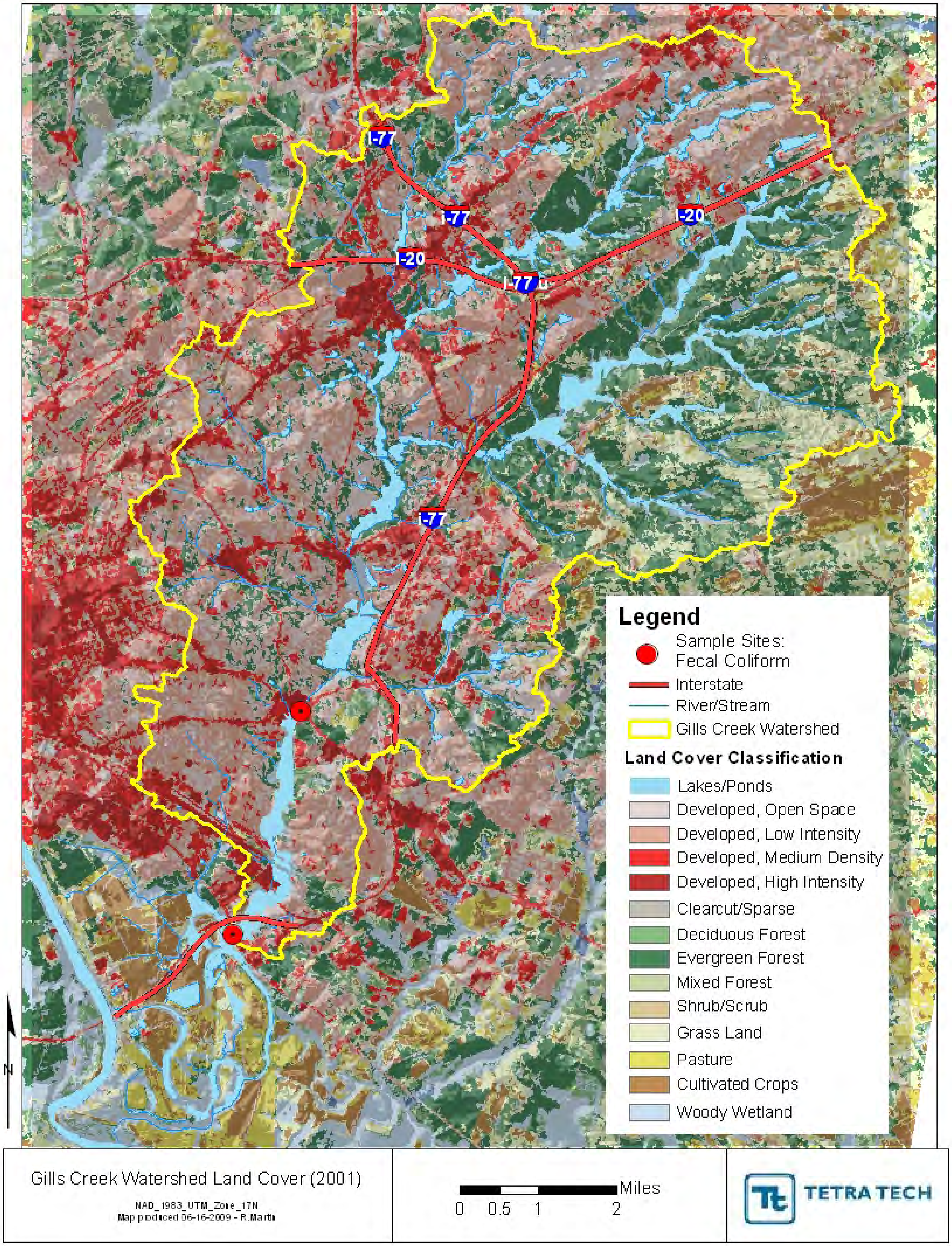

Figure 1-3. Gills Creek watershed land cover.

Table 1-1. Gills Creek Watershed Land Use/ Land Cover to C-017 (USGS 2001)

2001 NLCD	Area (mi^2)	Percent (%)
Open Water	1.4	2%
Developed, Open Space	12.1	18%
Low Intensity Development	16.1	24%
Medium Intensity Development	6.2	9%
High Intensity Development	2.1	3%
Barren	0.0	0%
Deciduous Forest	2.7	4%
Evergreen Forest	13.9	21%
Mixed Forest	1.1	2%
Shrubland	0.1	0%
Grassland	4.4	7%
Pasture and Hay	0.6	1%
Cropland	1.2	2%
Woody Wetland	4.1	6%
Emergent Wetland	0.2	0%
Watershed Total	66.3	

Soil types within or near the Gills Creek watershed in Richland County vary according to the location within the watershed. In the northeastern section of the watershed, the predominant soils are Lakeland soils, which are gently sloping to steep soils and are found within the Southern Piedmont Ecoregion. Lakeland soils are excessively drained soils that are sandy throughout. Soils in the central portion of the watershed are predominately Pelion-Johnston-Vaucluse soils. These soils are also gently sloping to steep soils found within the Southern Piedmont Ecoregion, and they can be moderately well drained soils that have a sandy surface layer and a loamy subsoil, very poorly drained soils that are loamy throughout, and/or well-drained soils that have a sandy surface layer and a fragipan in the loamy subsoil. In the southernmost part of the Gills Creek watershed, the soils are the nearly level to sloping soils found within the floodplains in the Coastal Plain Ecoregion. The three soil types in this area are Orangeburg-Norfolk-Marlboro, Persanti-Cantey-Goldsboro, and Congaree-Tawcaw-Chastain. Orangeburg-Norfolk-Marlboro soils are well drained soils that have a sandy or loamy surface layer and can have a loamy or clayey subsoil. Persanti-Cantey-Goldsboro soils are moderately well drained soils that have a loamy surface layer and a clayey or loamy subsoil and/or poorly drained soils that have a loamy surface layer and a clayey subsoil. The Congaree-Tawcaw-Chastain soils, which are nearly level soils on floodplains, are well-drained to moderately well drained soils that are loamy throughout. These soils can also be somewhat poorly drained soils that have a loamy surface layer and a clayey subsoil.

1.3. WATER QUALITY STANDARD

The impaired stream segments of the Gills Creek watershed are classified as Freshwaters, according to SCDHEC R.61-69 (SCDHEC 2008). Waters of this class are described as follows:

> Freshwaters (FW) are freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses. [R.61-69]

South Carolina's Water Quality Standard (WQS) for FC bacteria in freshwater is

> Not to exceed a geometric mean of 200/100 mL, based on five consecutive samples during any 30 day period; nor shall more than 10 percent of the total samples during any 30 day period exceed 400/100 mL. [R.61-68; SCDHEC 2008]

Primary contact recreation is not limited to large streams and lakes. Even streams that are too small to swim in allow small children the opportunity to play and immerse their hands and faces. Therefore, essentially all perennial streams should be protected from pathogen impairment.

2.0 Water Quality Assessment

Waters in which no more than 10 percent of the samples collected over a five-year period have FC bacteria counts greater than 400 colony-forming units (cfu) per 100 mL are considered to be meeting the South Carolina WQS for FC bacteria. Waters with more than 10 percent of samples[1] greater than 400 cfu/100 mL are considered impaired for FC bacteria and are placed on South Carolina's §303(d) list. For the purpose of this TMDL document, only the instantaneous water quality criterion was targeted because there are insufficient data to evaluate against the 30-day geometric mean.

Two locations in the watershed are considered impaired due to exceedances of FC bacteria WQS. Table 2-1 provides a summary of the number of samples collected, number of exceedances, and exceedance percentage. Figure 2-1 illustrates samples exceeding the water quality standard for monitoring conducted at C-001 and C-017 between 1999 and 2006, as well as rainfall. Appendix A presents fecal coliform monitoring data at C-001 and C-017 between 1999 and 2006 in Tables A-1 and A-2.

For C-001, correlations between observed FC bacteria and rain and FC bacteria and flow are weak (R^2 = 0.006 and 0.02, respectively). For C-017, the correlations between FC bacteria and rain and FC bacteria and flow are also weak (R^2 = 0.006 and 0.047, respectively). Appendix A illustrates these relationships in Figures A-1 through A-4.

Table 2-1. Fecal Coliform Bacteria Data Summary for Impaired Stations (1999–2006)

Station	Waterbody	Number of Samples	Number Samples > 400/100 mL	% Samples Exceeding WQS
C-001	Gills Creek at US76 (Garners Ferry Road)	48	17	35%
C-017	Gills Creek at SC48 (Bluff Road S of I-77)	96	24	25%
Total		**144**	**41**	**28%**

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[1] The frequency of sampling was fewer than five samples within a 30 day period, therefore the water quality assessment was based on the 10% standard (400/100 mL).

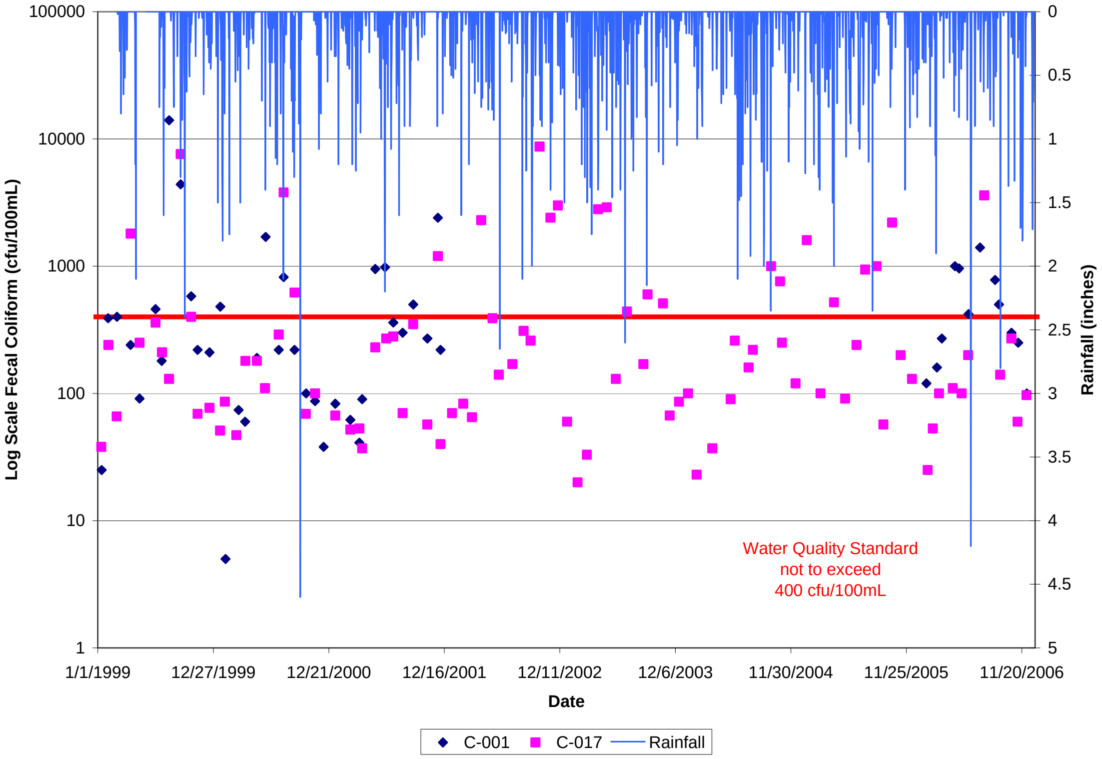

Figure 2-1. Samples exceeding fecal coliform bacteria standards at stations C-001 and C-017.

Further analysis looked at seasonal variations in FC bacteria at the two impaired monitoring locations. Forty-eight samples were available at C-001 for the period from 1999 through 2006. One sample per month was available at C-017 for the period from 1999 through 2006, for a total of 96 samples. There is some indication that concentrations of FC bacteria are higher during the summer months, but the variations do not confirm that generalization.

Table 2-2. Percent of Monthly Samples Exceeding 400 cfu/100 mL (Exceeding WQS)

Month	C-001	C-017
Jan	25%	13%
Feb	0%	0%
Mar	0%	0%
Apr	25%	63%
May	50%	13%
Jun	100%	0%
Jul	25%	38%
Aug	75%	38%
Sep	75%	50%
Oct	25%	50%
Nov	25%	25%
Dec	0%	14%

Evaluation of available data from the impaired monitoring locations does not explicitly point to a single source causing the FC bacteria impairment at C-001 and C-017. The major sources of bacteria likely contribute loads across varying hydrologic events and seasons.

3.0 Source Assessment

The source assessment phase of this study involved identifying and quantifying FC bacteria loads as applied to the land surface or directly to the stream. The accuracy and precision of estimated loading rates may be reduced by many sources of uncertainty and environmental variability. However, local knowledge, a large body of previous studies, and existing tools provide a basis for assessing the potential order of magnitude of various bacterial sources.

There are many sources of pathogen pollution in surface waters. In general, these sources can be classified as point and nonpoint sources. With the implementation of technology-based controls, pollution from continuous point sources, such as factories and wastewater treatment facilities, has been greatly reduced. The Clean Water Act requires these point sources to obtain a National Pollutant Discharge Elimination System (NPDES) permit. In South Carolina NPDES permits require that dischargers of sanitary wastewater must meet the state FC standard at the point of discharge.

Municipal and private sanitary wastewater treatment facilities may occasionally be sources of pathogen or FC bacteria pollution. However, if these facilities are discharging wastewater that meets their permit limits, they are not causing impairment. If any of these facilities is not meeting its permit limits, enforcement actions/mechanisms are required.

Other non-continuous point sources required to obtain NPDES permits that may be a source of pathogens include municipal separate storm sewer systems (MS4s) and stormwater discharges from industrial or construction sites. MS4s may require NPDES discharge permits for industrial and construction activities under the NPDES stormwater regulations. These sources are also required to comply with the state standard for the pollutant(s) of concern. If MS4s and discharges from construction sites meet the percentage reduction or the water quality standard as prescribed in Section 5 of this TMDL document and required in their MS4 permit(s), they should not be causing or contributing to an instream FC bacteria impairment.

The Bacterial Indicator Tool (BIT) developed by EPA as part of its BASINS family of software was used to quantify the FC bacteria loading rates from various nonpoint sources (USEPA 2001). The BIT is a spreadsheet that calculates loading factors for various animal sources, including wildlife and unconfined livestock. The spreadsheet requires the user to define the number of animals present in the watershed, as well as the area (in acres) of the forest, pastureland, cropland and built-up land components of the watershed.

Richland County and the Gills Creek Watershed Association (GCWA) recently developed a watershed management plan for Gills Creek, prepared by Tetra Tech, Inc., and BP Barber and Associates, Inc. (Tetra Tech and BP Barber 2009). The plan contains a source assessment with detailed discussions and maps of potential sources of pollutants, including bacteria. A summary of the findings of that source assessment (referred to hereafter as “the WMP”) follows.

3.1. POINT SOURCES

3.1.1. Continuous-Discharge Point Sources

Figure 3-1 and Table 3-1 show the location of NPDES-permitted facilities with both active and inactive permits. There are currently two active continuous NPDES discharges to surface waters in the watershed. The active NPDES discharges are not permitted to discharge FC bacteria and therefore not subject to the WLA. None of the active NPDES permits during the model period (1997–2004) included limits for FC bacteria. Future NPDES discharges in the referenced watershed are required to comply with the load reductions prescribed in the WLA and demonstrate consistency with the assumptions and requirements of the TMDL.

Table 3-1. NPDES Continuous Dischargers in the Gills Creek Watershed.

Facility Name	NPDES Permit #	Current Status	Waterbody
Amphenol Corporation	SC0046264	Active	Ephemeral tributary to Jackson Creek
Aramark Uniform Services	SC0046566	Inactive	Tributary to Tributary G-1
Central Products*	SCG250180	Active	Gills Creek
Fort Jackson	SC0003786 – Pipe 002	Inactive	Wildcat Creek
Fort Jackson	SC0003786 – Pipe 004	Inactive	Wildcat Creek
Fort Jackson**	SC0003786 – Pipe 006	Inactive	Lake Katherine
Fort Jackson**	SC0003786 – Pipe 007	Inactive	Gills Creek
Fort Jackson	SC0003786 – Pipe 008	Inactive	Wildcat Creek
Fort Jackson	SC0003786 – Pipe 009	Inactive	Gills Creek
Furon Company/ Helico Components	SC0046418	Inactive	Unnamed Tributary to Gills Creek
Tenneco Direct Service Station	SC0043770	Inactive	Eight Mile Branch

*Formerly Intertape Polymer Group, SC0002101.

** On 10-27-08, NPDES permit SC0003786 was cancelled. Certification (#SCR001892) was issued by SCDHEC for these Fort Jackson outfalls 006 and 007 under the industrial stormwater general permit SCR000000. Therefore, after 10-27-08, these two outfalls were no longer classified as continuous point sources; they are non-continuous point sources.

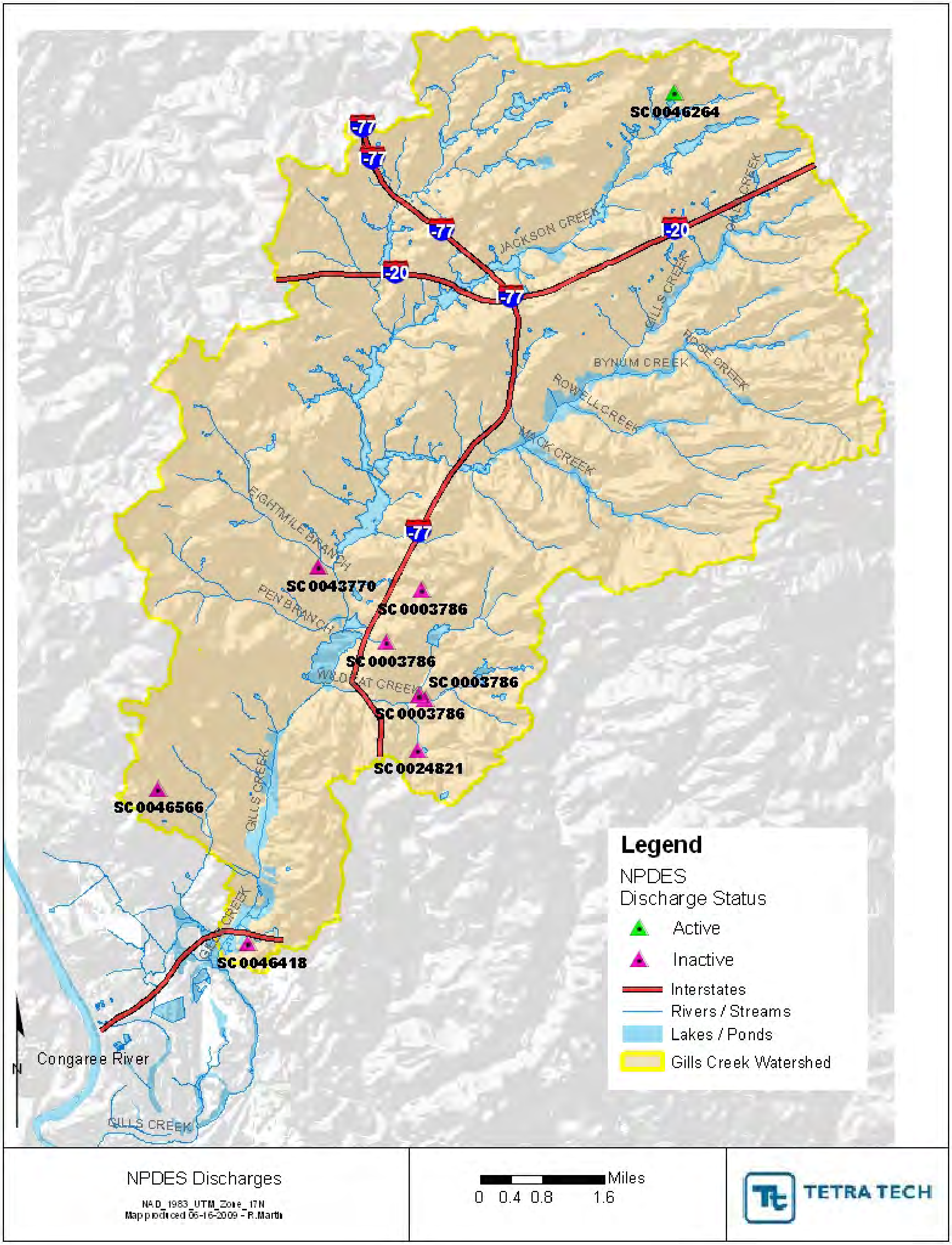

Figure 3-1. NPDES point source discharges in Gills Creek watershed.

3.1.2. Non-continuous Point Sources

Non-continuous point sources include all NPDES-permitted stormwater discharges, including current and future MS4s, construction, and industrial discharges covered under permits SCS and SCR and regulated under South Carolina Water Pollution Control Permits Regulation 122.26(b)(14 and 15). All regulated MS4 entities have the potential to contribute FC pollutant loadings in the delineated drainage area used in the development of this TMDL.

The South Carolina Department of Transportation (SCDOT) is designated as an MS4 within the Gills Creek watershed. SCDOT operates under NPDES MS4 SCS040001 and owns and operates roads in the watershed. However, the Department recognizes that SCDOT is not a traditional MS4 in that it does not possess statutory taxing or enforcement powers. SCDOT does not regulate land use or zoning, issue building or development permits.

The following additional jurisdictions are regulated MS4 entities within the Gills Creek watershed: Richland County, the City of Columbia, the Town of Arcadia Lakes, the City of Forest Acres, and the US Army/Fort Jackson (Figure 3-3). Of these jurisdictions, Richland County and the City of Columbia are designated Phase I MS4s. The Town of Arcadia Lakes and the City of Forest Acres are Phase II MS4s currently covered under the jurisdiction of the Richland County Phase I MS4 permit, and they will not be considered separate MS4 entities for the purposes of this TMDL document. If future MS4 permits are applicable to this watershed, those discharges will be subject to the assumptions and requirements of the wasteload allocation (WLA) portion of this TMDL.

At any time, industrial or construction activities that could produce stormwater runoff might be going on. Industrial facilities that have the potential to cause or contribute to a violation of a water quality standard are covered by the NPDES Storm Water Industrial General Permit (SCR000000). Construction activities are usually covered by the NPDES Storm Water Construction General Permit from SCDHEC (SCR100000). Where construction activities have the potential to affect water quality of a water body with a TMDL, the Storm Water Pollution Prevention Plan (SWPPP) for the site must address any pollutants of concern and adhere to any WLAs in the TMDL.

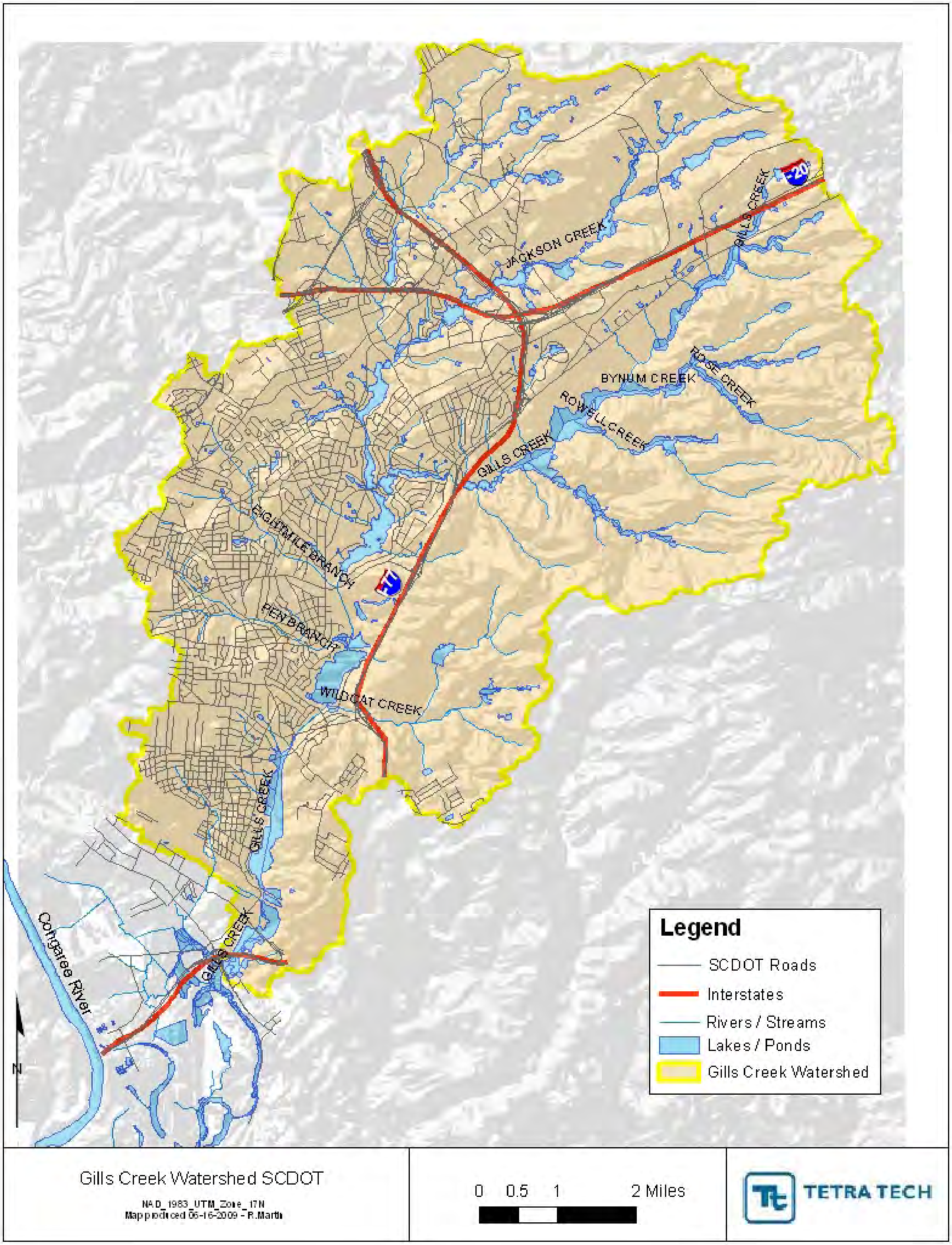

Figure 3-2. South Carolina Department of Transportation roads in Gills Creek watershed.

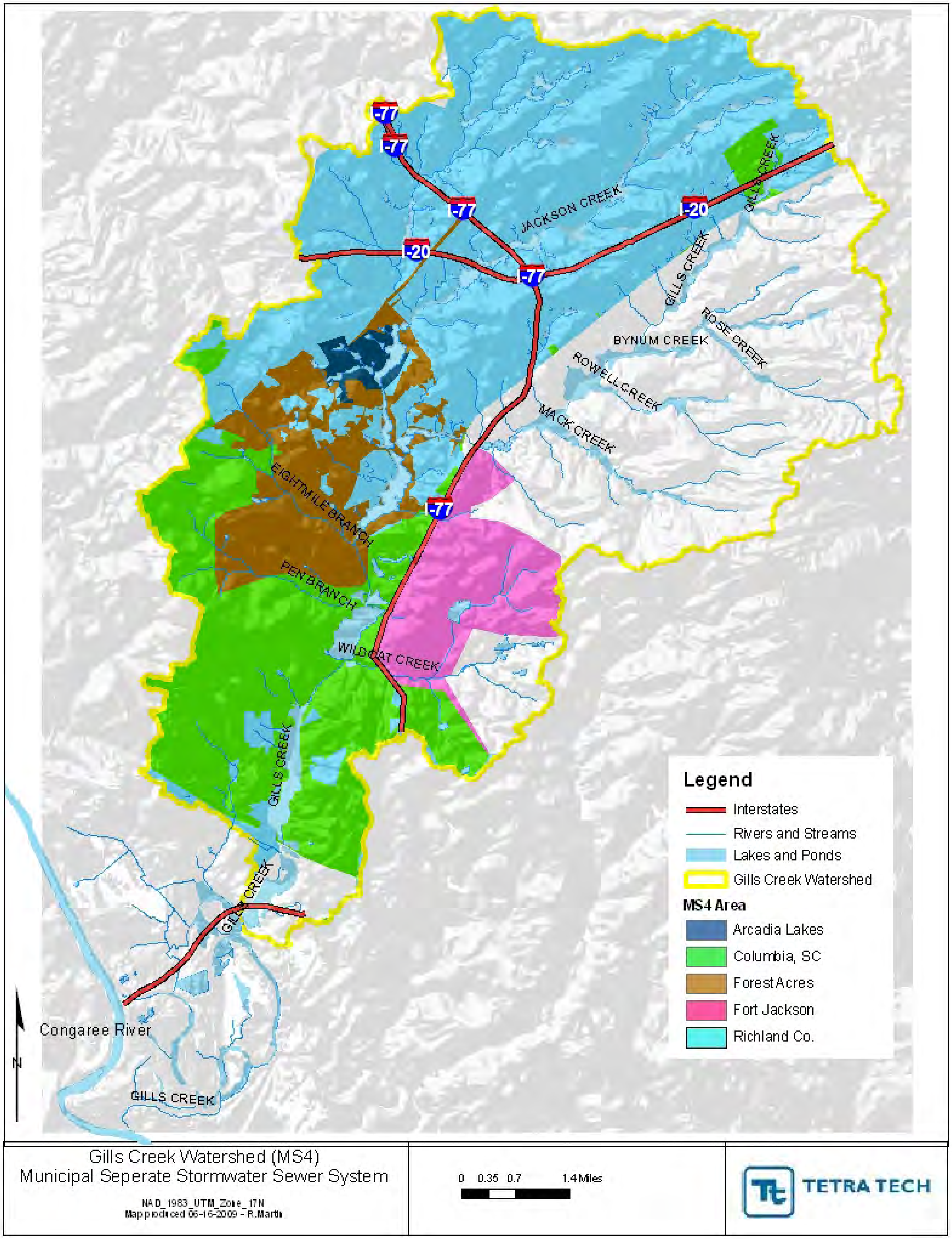

Figure 3-3. Regulated municipal separate storm sewer systems in Gills Creek watershed.

3.2. NONPOINT SOURCES

The Department recognizes that there may be wildlife, agricultural activities, grazing animals, septic tanks, and/or other nonpoint source contributors located within unregulated areas (outside the permitted area) of the Gills Creek watershed. Nonpoint sources located in unregulated areas are subject to the load allocation (LA) and not the WLA of the TMDL document.

3.2.1. Wildlife

The watershed contains about 33 percent forest and wetland, where wildlife is likely to exist. Wildlife in this area typically includes deer, squirrels, raccoons, and other mammals as well as a variety of birds. Wildlife wastes are carried into nearby streams by runoff following rainfall or deposited directly in streams. Most of the natural forest and wetland areas are in the upper, northeast portion of the watershed. Wildlife within these areas likely contribute bacteria loads to downstream water bodies.

The deer population for the Gills Creek watershed was estimated as 760, based on an approximate density of less than 15 deer per square mile from the South Carolina Department of Natural Resources (SCDNR) 2008 Deer Density Map (SCDNR 2008) and input from SCDNR wildlife biologist Charles Ruth (C. Ruth, SCDNR, personal communication to H. Fisher, May 18, 2009). Data on density estimates for other wildlife were not available. Based on the BIT, the FC bacteria loading rates for the deer population were estimated as an average of 1.64×10^7 counts/acre/day from forest and herbaceous land covers.

About 2 percent of the Gills Creek watershed (1.4 square miles) is in open water, and ponds and lakes encompass most of this area. This large area of open water is likely to attract waterfowl during migratory seasons and throughout the year, and waterfowl are likely to be a source of bacteria. Density estimates for waterfowl were not available.

3.2.2. Agricultural Activities

Agricultural activities that involve livestock, animal wastes, or unstabilized surfaces are potential sources of FC contamination to surface waters. Owners/operators of most commercial animal growing operations are required by SC Regulation 61-43, Standards for the Permitting of Agricultural Animal Facilities, to obtain permits for the handling, storage, treatment (if necessary) and disposal of the manure, litter, and dead animals generated at their facilities (SCDHEC 2002). The requirements of R. 61-43 are designed to protect water quality; therefore, we have a reasonable assurance that facilities operating in compliance with this regulation should not contribute to downstream water quality impairments. South Carolina currently does not have any confined animal feeding operations (CAFOs) under NPDES coverage; however, the State does have permitted animal feeding operations (AFOs) covered under R. 61-43. These permitted operations are not allowed to discharge to waters of the State and are covered under ‘no discharge’ (ND) permits. Discharges from these operations to waters of the State are illegal and are subject to enforcement actions by SCDHEC. There are currently no AFOs in the Gills Creek watershed.

There are individually owned horse farms in the upper, northeastern portion of the watershed, and a few additional operations may be present throughout the less developed portions (H. Caldwell, Richland County Soil and Water Conservation District, personal communication to H. Fisher, September 2008). All of these operations are expected to be small farms with low densities of livestock. Livestock operations might contribute some bacteria loading to the watershed but are not expected to be a major source. FC bacteria loadings from these sources are considered negligible in the Gills Creek watershed.

3.2.3. Leaking Sanitary Sewers and Illicit Discharges

Leaking sewer pipes and illicit sewer connections represent a direct threat to public health because they result in discharge of partially treated or untreated human wastes to the surrounding environment. Quantifying these sources is extremely speculative without direct monitoring of the source because the magnitude is directly proportional to the volume and its proximity to the surface water. Typical values of

FC bacteria in untreated domestic wastewater range from 10^4 to 10^6 most probable number/100 mL (Metcalf and Eddy 1991).

At the time of TMDL development, data on the condition of sewer pipes were not available from the two major municipal sewer districts in the watershed, the City of Columbia and the East Richland County Public Service District (ERCPSD). Some pipes within ERCPSD date back to the 1940s, and the District continually repairs leaks in the infrastructure (Donny Way, ERCPSD, personal communication to H. Fisher, May 14, 2009). Portions of the City of Columbia system are likely to be of similar age and condition. In the future, comprehensive studies of infiltration and inflow in both districts would provide an estimate of impacts due to these sources.

Illicit discharges that might be occurring in the watershed include, but are not limited to:

- Sewer pipes wrongly connected to storm sewers, including pipes from restaurants (which can happen intentionally or unintentionally and can be identified through dye tests and infrared imaging)
- Septic systems emptying into storm drains (which an owner might do after a drain field malfunctions).

Monitoring of storm drain outfalls during dry weather is needed to document the presence or absence of sewage in the drainage systems. Dye tests and infrared imaging, as noted above, would allow identifying specific sources.

3.2.4. Failing Septic Systems

Failing septic systems are potential sources of bacteria in surface water and groundwater. Data collected in the watershed show that the entire watershed is serviced by municipal sewer systems. This indicates that new or recent developments are likely to be serviced by municipal sewer systems and not septic systems. Older developments may be serviced by septic systems. U.S. Census data indicate that in 1990 onsite wastewater system density in the watershed ranged from 3 to 1,100 systems per square mile. It is likely that since the 1990 census some septic systems in developing areas have been replaced with sanitary sewers. The Richland County Public Health Department is not aware of any septic systems within the watershed (Robert Deyo, Richland County Public Health Department, personal communication to H. Fisher, November 2008). The WMP stakeholder survey indicated that there is at least one remnant septic system in the lower portion of the watershed, between US-76 and SC-48 (Bluff Road). BP Barber estimated that about 1 percent of the ERCPSD is served by septic tanks (T. Thain, BP Barber, personal communication, July 2008).

To estimate the approximate loading from remnant septic systems, about 1 percent of the ERCPSD by area was assumed to be served by septic tanks. For areas within the watershed where no current estimate of septic density was available, it was assumed that half of the systems present in 1990 are still in use, which represents the midpoint within the range of potential values for this estimate. This is a gross estimate that could be refined if geospatial data on sanitary sewer lines become available in the future. It was also assumed that each system serves about three persons per household and that the average failure rate of the systems is 20 percent (Schueler 1999). Based on the 1990 census data and these assumptions, it was estimated that 1,071 septic systems are active in the watershed and that 214 of those systems are failing.

3.2.5. Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) contribute high concentrations of bacteria during short time intervals. About 71 overflows have been recorded at 60 locations in the watershed since 2000. These overflows represent 308,025 gallons released, and approximately 93 percent of this volume was released to surface waters. Additional SSOs might have occurred in the watershed but could not be geolocated because of insufficient information. The overflows do not appear to be concentrated in a single portion of the watershed. The locations that contribute the greatest bacteria loads to surface waters are likely those that occur directly adjacent to waterbodies, such as the locations directly upstream of Lake Katherine. SCDHEC is not aware of any combined sewer overflows (CSOs) in the watershed and does not expect that any CSOs have occurred (G. Trofatter, SCDHEC Bureau of Water, personal communication to H. Fisher, September 2008).

The Department acknowledges that only limited data are available to quantify the location of SSOs and the quantity of spills that reach surface waters. The assumptions of the TMDL are expected to be a fraction of the number of spills actually occurring in the watershed.

3.2.6. Urban/Suburban Runoff

A significant portion of the Gills Creek watershed has been developed into suburban and urban lands (~36.5 mi^2). The amount of developed land within the watershed (55 percent) is approximately the same as undeveloped lands (45 percent). This development is scattered throughout most of the watershed—with the exception of Fort Jackson lands (mostly forested). Impacts from urban/suburban land are likely to occur throughout the watershed due to the sprawling nature of this development (see Figure 1-2).

The developed areas outside the MS4 jurisdictions are considered nonpoint pollutant sources, although runoff is a concern for bacteria both within and outside MS4 jurisdictions. Fecal matter from pets and wildlife can be a major contributor of bacteria loads from urban and suburban areas.

Dogs, cats and other domesticated pets are likely a contributing source of FC deposited on the urban landscape. According to a 2002 study conducted by the American Veterinary Medical Association (AVMA 2002), there are 0.58 dogs and 0.66 cats on average per each household within an urban setting. Based on U.S. census data (U.S. Census Bureau 2000), it is estimated that there are 120,101 households in Richland County, of which 13,967 are estimated to be within the Gills Creek watershed. This results in approximately 8,100 dogs in the delineated area. It has been shown that dogs produce approximately 0.32 pounds of fecal waste per day (Geldrich et al. 1962), which results in an estimated 2,592 pounds of waste deposited by domesticated dogs in the watershed per day. Based on the AVMA study and observations by Geldrich and others, there are approximately 9,218 cats in the drainage area producing 1,382 pounds of waste per day. There is also “urban” wildlife—squirrels, raccoons, pigeons, and other birds—in the watershed, all of which contribute to the FC bacteria load.

The following information on potential pollutant sources has been summarized from a nonscientific public survey conducted for the Richland County WMP in October and November 2008, which included questions on pets and wildlife. This information is included for informational purposes only and was not used in developing or calculating the referenced TMDL:

> *The survey results pertain to the Gills Creek watershed, including both regulated MS4 and unregulated MS4 areas). Of the 67 respondents, 16 percent said they owned a dog, and 8 percent said they owned more than one dog. Several respondents also own cats or both a cat and a dog, while 44 percent of respondents said they did not own a pet. For further details on the response of the pet owners in the watershed, please see Appendix A of the WMP. Even when owners clean up after their pets, bacteria loading may occur prior to clean up or from residue following clean up.*
>
> *The public survey also asked respondents whether they observe wildlife feces in their yards. Of the 67 respondents, 38 percent said that they had observed wildlife feces, 28 percent responded that they had not, and 34 percent did not answer. Therefore, these results indicate that areas in the watershed are likely to contribute bacteria loading from wildlife, pets, etc.* (Tetra Tech and BP Barber 2009)

4.0 Modeling Methodology

To develop TMDLs for the Gills Creek watershed, SCDHEC contracted Tetra Tech to update a watershed model developed by the Richland County Department of Public Works (Richland County). The Loading Simulation Program C++ (LSPC) was selected to address all the modeling needs in the Gills Creek watershed. LSPC is a version of the Hydrologic Simulation Program–FORTRAN (HSPF) model that has been ported to the C++ programming language to improve efficiency and flexibility.

LSPC was configured to simulate the Gills Creek watershed as a series of hydrologically connected subbasins. The delineated subbasins from Richland County’s HSPF model were the basis for further delineation at the U.S. Geological Survey (USGS) flow gauge (USGS 02169570) and SCDHEC water quality assessment points. The subbasins were configured to model streams and lakes in the Gills Creek watershed. The simulation period, a 7-year period from January 1, 1998, through December 31, 2004, was chosen to correspond with Richland County’s HSPF model.

The LSPC model is driven by precipitation and other climatological data (e.g., air temperature, evapotranspiration, dew point, cloud cover, wind speed, solar radiation). Of the four available stations, two stations used for Richland County’s HSPF model—National Oceanic and Atmospheric Administration’s (NOAA) Columbia Metropolitian Airport weather station (KCAE) located approximately 11 miles southwest from the centroid of the Gills Creek watershed and the Sandhill Research Elgin weather station located approximately 8.5 miles northeast from the centroid of the Gills Creek watershed—were selected as rainfall stations for this modeling effort.

The basis for distributing hydrologic and pollutant loading parameters throughout the watershed is correlated to soil characteristics and land practices. Land use used in watershed modeling for the Gills Creek watershed was compiled from two land use data sources: Richland County’s HSPF modeled land use and the 2001 National Land Cover Database (NLCD) program (Homer et al. 2004). HSPF’s modeled land use was used for most of the LSPC subbasins. However, the additional delineation for the new water quality assessment points and the USGS flow gauge location required redistribution and processing of the existing HSPF modeled land use. For the subbasins that required modification of the delineation line, a redistribution of the existing modeled land use was conducted. Modeled land use was reassigned to each new delineated subbasin using NLCD GIS data. NLCD land use categories were combined to match the current HPSF-modeled land use categories. The HSPF modeling land use areas were then redistributed using a ratio of the NLCD land use for the new smaller subbasins and the HSPF modeled land use for the original larger watershed.

Additional sources of pollutant loads were defined in the watershed model as point sources. Continuous point source discharges, sanitary sewer overflows, and failing septic systems were input to the model and quantified as described in Appendix B. Appendix B also includes additional details of the methods used to set up the watershed model. The resulting hydrologic calibration and water quality calibrations are presented in Figures 4-1 through 4-3.

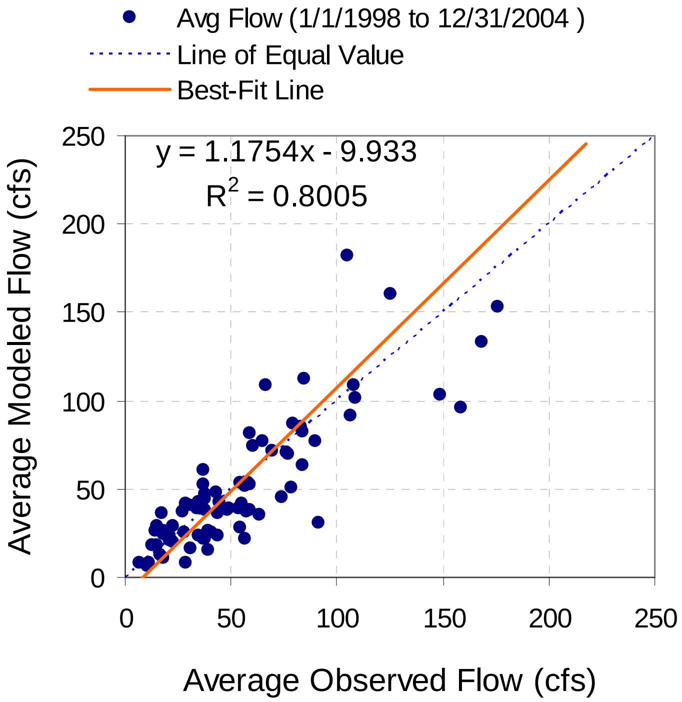

Figure 4-1. Comparison of monthly average observed and modeled flows at USGS 02169570.

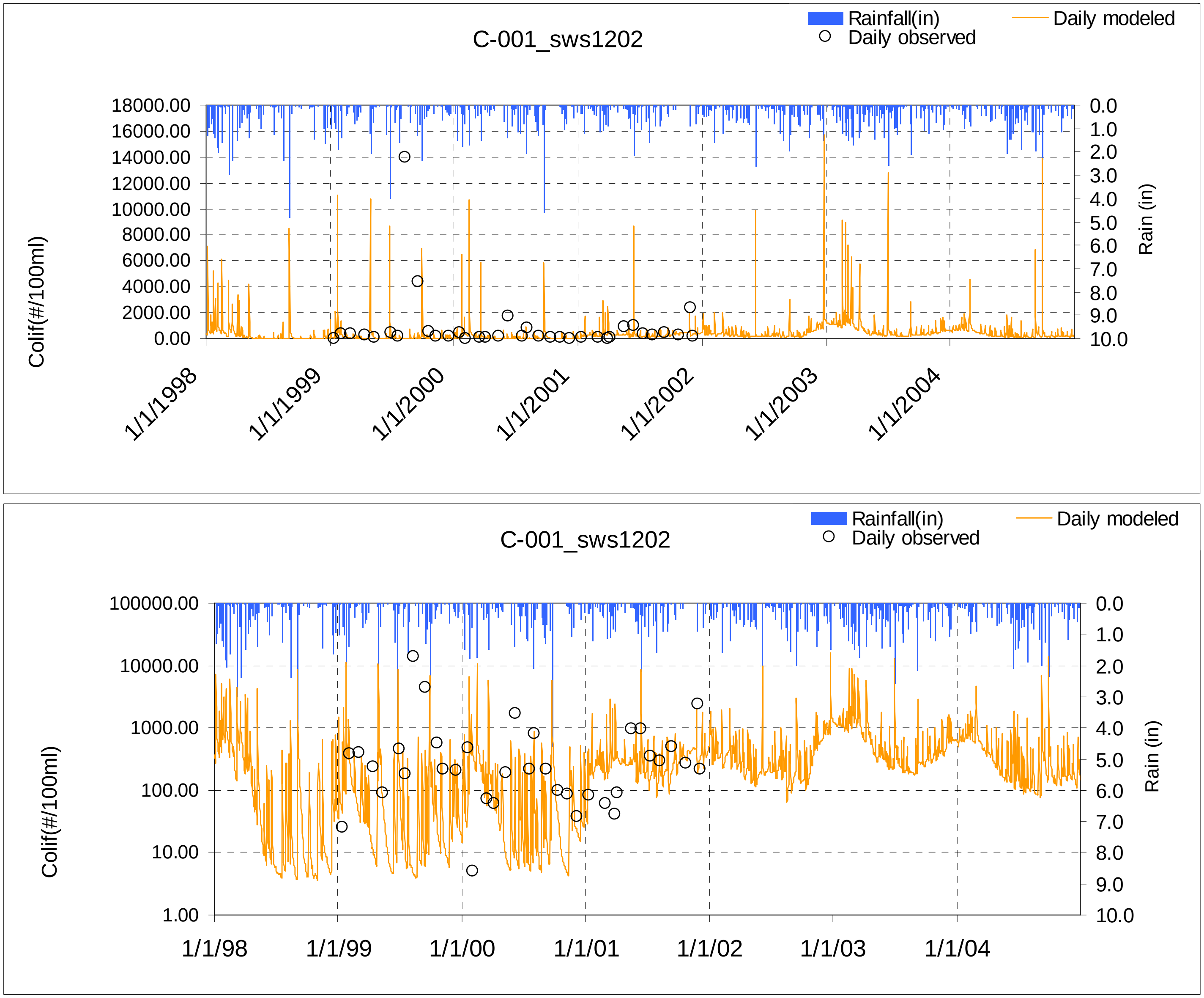

Figure 4-2. Comparison of observed and modeled fecal coliform results at C-001.

Figure 4-3. Comparison of observed and modeled fecal coliform results at C-017.

5.0 Development of Total Maximum Daily Load

A total maximum daily load (TMDL) for a given pollutant and water body is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by an equation:

$$TMDL = \sum WLAs + \sum LAs + MOS \ .$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving water body while still achieving compliance with water quality standards (WQS). In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established and thereby provide the basis to establish water quality-based controls. For most pollutants, TMDLs are expressed as a mass load (e.g., kilograms per day). For fecal coliform (FC) bacteria, however, TMDLs are expressed in terms of number (#), cfu, organism counts (or resulting concentration), or MPN (most probable number), in accordance with 40 CFR 130.2(l).

5.1. CRITICAL CONDITIONS

This TMDL is based on the greatest violations of the instantaneous and geometric mean standard. The model outputs daily average concentrations over the simulation period. The highest violations of the standard were targeted as the critical conditions. The critical condition stations impaired for FC bacteria in Gills Creek are illustrated in Figures 5-1 and 5-2.

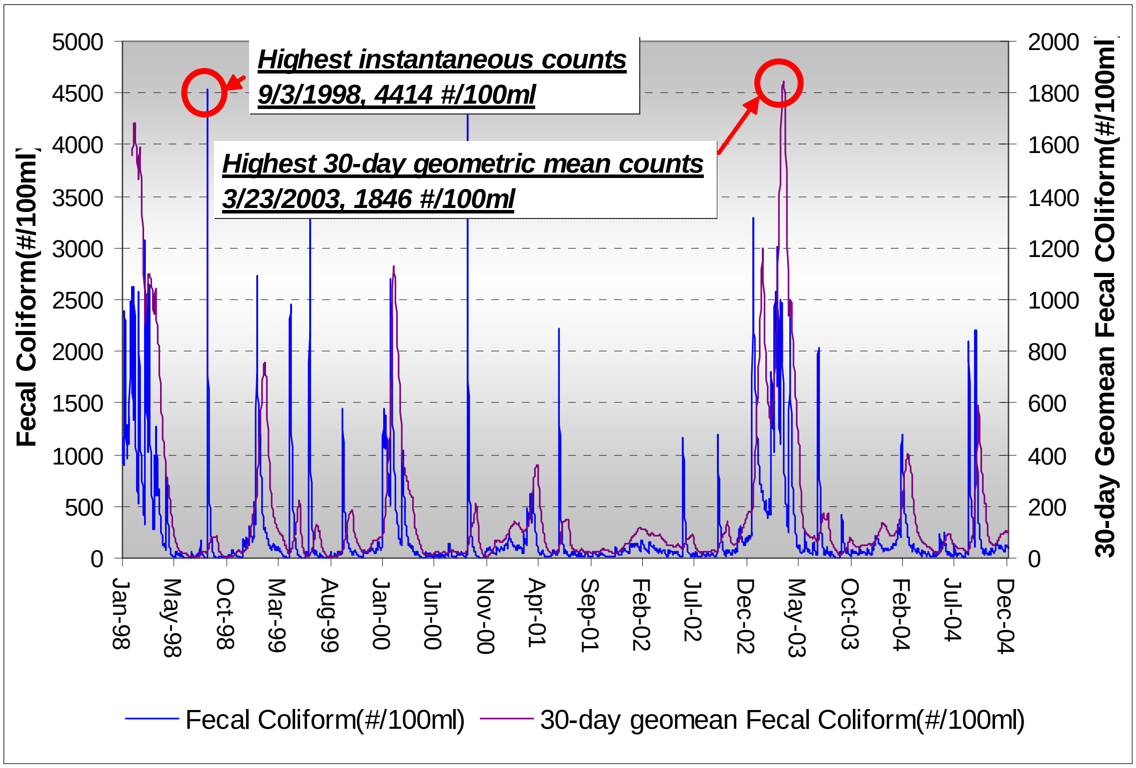

Figure 5-1. Critical conditions modeled at C-001.

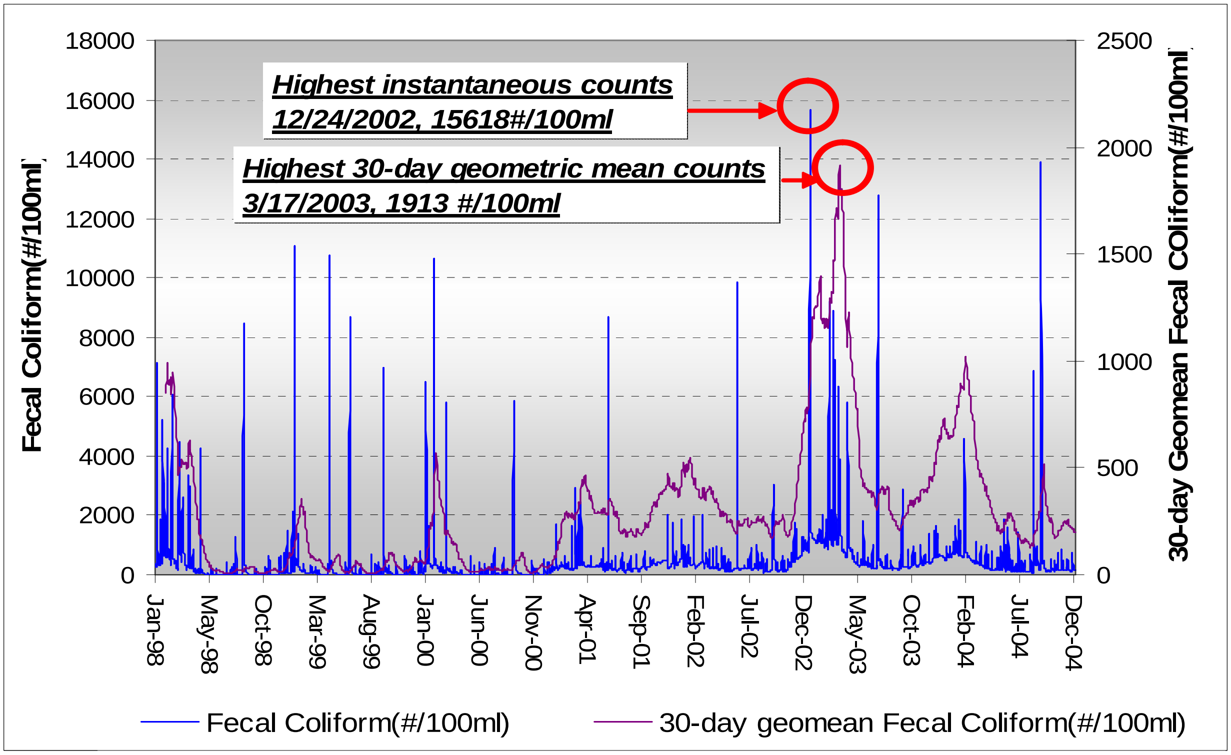

Figure 5-2. Critical conditions modeled at C-017.

5.2. EXISTING LOAD

An existing load was determined using the WQS and modeled flows during the critical condition, described earlier in Section 5.1. Loadings from both urban and nonurban sources are included in this value.

5.3. WASTELOAD ALLOCATION

The WLA is the portion of the TMDL allocated to NPDES-permitted point sources (USEPA 1991). The WLA summation is determined by subtracting the MOS and the sum of the LAs from the TMDL. Note that all illicit dischargers, including SSOs, are illegal and not covered under the WLA of this TMDL.

5.3.1. Continuous Point Sources

There are currently no continuous permitted dischargers contributing FC bacteria to the Gills Creek watershed. Future continuous discharges are required to meet the prescribed loading for the pollutant of concern, based on permitted flow and assuming an allowable permitted maximum concentration of 400 cfu/100ml.

5.3.2. Non-continuous Point Sources

Non-continuous point sources include all NPDES-permitted stormwater discharges, including current and future MS4s, construction, and industrial discharges covered under permits SCS and SCR and regulated under South Carolina Water Pollution Control Permits Regulation 122.26(b)(14) and (15). Illicit discharges, including SSOs, are not covered under any NPDES permit and are subject to enforcement mechanisms. All areas defined as “Urbanized Area” by the U.S. Census are required under the NPDES Stormwater Regulations to obtain a permit for the discharge of stormwater. Other non-urbanized areas may be required under the NPDES Phase II Stormwater Regulations to obtain a permit for the discharge of stormwater.

Based on the available information at this time, the portion of the watershed that drains directly to a regulated MS4 and that which drains through the unregulated MS4 has not been clearly defined within the MS4 jurisdictional area. Loading from both types of sources (regulated and unregulated) typically occurs in response to rainfall events, and discharge volumes as well as recurrence intervals are largely unknown. Therefore, the regulated MS4 is assigned the same percent reduction as the unregulated sources in the watershed. The regulated MS4 entity is only responsible for implementing the TMDL WLA in accordance with their MS4 permit requirements.

As appropriate information is made available to further define the pollutant contributions for the permitted MS4, an effort can be made to revise these TMDLs. This effort will be initiated as resources permit and if deemed appropriate by the Department. For the Department to revise these TMDLs the following information should be provided, but not limited to:

1. An inventory of service boundaries of the MS4 covered in the MS4 permit, provided as ARCGIS compatible shape files.
2. An inventory of all existing and planned stormwater discharge points, conveyances, and drainage areas for the discharge points, provided as ARCGIS compatible shape files. If drainage areas are not known, any information that would help estimate the drainage areas should be provided. The percentage of impervious surface within the MS4 area should also be provided.
3. Appropriate and relevant data should be provided to calculate individual pollutant contributions for the MS4 permitted entities. At a minimum, this information should include precipitation, water quality, and flow data for stormwater discharge points.

WLAs for stormwater discharges are expressed as a percentage reduction instead of as a numeric loading due to the uncertain nature of discharge volumes and recurrence intervals. Regulated stormwater discharges are required to meet the percentage reduction or the existing instream standard for the pollutant of concern. The percent reduction is based on the maximum percent reduction (critical condition) within any hydrologic category necessary to achieve target conditions. Table 5-1 and Figure 5-3 present the reduction needed for each of the impaired stations. The reduction percentages in this TMDL also apply to the FC waste load attributable to those areas of the watershed that are covered or will be covered under NPDES MS4 permits. Compliance by an entity with responsibility for the MS4 with the terms of its individual MS4 permit may fulfill any obligations it has toward implementing this TMDL.

Table 5-1. Regulated MS4 Entity(ies) Currently Responsible for Meeting Percentage Reduction or WQS by Monitoring Station.

Station	WLA % Reduction	Existing Regulated MS4 Entity(ies) in Watershed
C-001	97%	City of Arcadia Lakes SCS400001
	97%	City of Columbia
	97%	City of Forest Acres SCS400001
	97%	Fort Jackson SCR037901
	97%	Richland County SCS400001
	97%	SC DOT SCS040001
C-017	91%	City of Columbia
	91%	Richland County SCS400001
	91%	SC DOT SCS040001

It should be noted that in order to meet the WQS for FC bacteria, prescribed load reductions must be targeted from all sources including NPDES permitted and nonpoint sources.

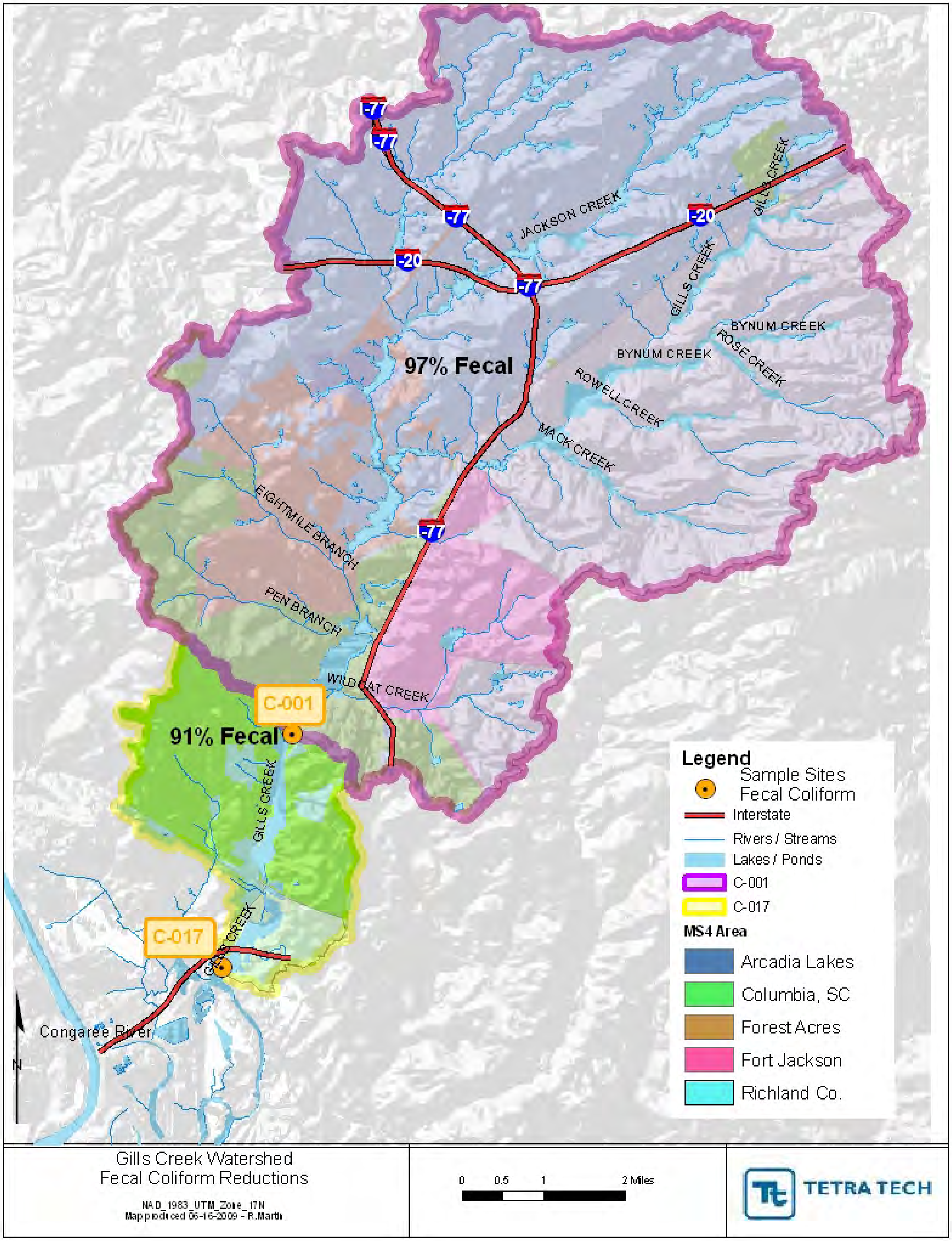

Figure 5-3. Gills Creek Percent Reductions

5.4. LOAD ALLOCATION

The LA applies to the nonpoint sources of fecal coliform bacteria. In watersheds covered under an MS4 permit, it is assumed that some contribution of the total load is not being conveyed through storm water sewers. This contribution is considered the LA, and it is expressed as a percent reduction equal to the percent reduction for the non-continuous WLA. There may be unregulated MS4s located in the watershed that are subject to the LA component of this TMDL. At such time that the referenced entities, or other future unregulated entities become regulated NPDES MS4 entities and subject to applicable provisions of SC Regulation 61-68D, they will be required to meet load reductions prescribed in the WLA component of the TMDL. This also applies to future discharges associated with industrial and construction activities that will be subject to SC R. 122.26(b)(14)(15) (SCDHEC 2003).

Table 5-2. Percentage Reduction Necessary to Achieve Target Load.

Station	LA % Reduction
C-001	97%
C-017	91%

5.5. SEASONAL VARIABILITY

Federal regulations require that TMDLs take into account the seasonal variability in watershed loading. Seasonal variability in this TMDL is accounted for by using a 7-year simulation period and 12-month water quality sampling data set, which includes data collected from all seasons.

5.6. MARGIN OF SAFETY

The MOS may be explicit and/or implicit. This TMDL considers an explicit MOS at 5 percent of the water quality standard load or 20 counts/100 mL of the instantaneous criterion of 400 cfu/100 mL (380 cfu/100 mL) and 190 cfu/100 mL for the geometric mean.

5.7. TOTAL MAXIMUM DAILY LOAD

TMDLs are expressed in terms of colony-forming units (cfu) or organism counts (or resulting concentration), in accordance with 40 CFR 130.2(l). The TMDL is defined as the load (from point and nonpoint sources) that a stream segment can assimilate while meeting the WQS. The TMDL value is the median target load within the critical condition (i.e., the middle value within the hydrologic category that requires the greatest load reduction) plus WLA and MOS. The target load, which takes into account perceived uncertainty in the TMDL, is the TMDL minus the MOS. Values for each component of the TMDL for the impaired stations of the Gills Creek watershed are provided in Table 5-3.

Figures 5-4 and 5-5 show modeled results that confirm reductions to meet both the instantaneous and geometric standards. The terms and conditions of NPDES permits for continuous discharges require facilities to demonstrate compliance with both geometric mean and instantaneous water quality criteria for FC bacteria in treated effluent. The MS4 entity(ies) are responsible for meeting the percentage reduction or the existing instream standard for the pollutant of concern by individual water quality monitoring station. Note that all future regulated NPDES-permitted stormwater discharges will also be required to meet the prescribed percentage reduction, or the water quality standard, to the maximum extent practicable, where applicable. It should be noted that in order to meet the WQS for fecal coliform bacteria, prescribed load reductions must be targeted from all sources, including NPDES permitted and nonpoint sources.

Table 5-3. Total Maximum Daily Loads for the Gills Creek Watershed

Station	Existing Load (cfu/day)	TMDL (cfu/day)	Margin of Safety (MOS) (cfu/day)	Wasteload Allocation (WLA)		Load Allocation (LA)	
				Continuous Sources[1] (cfu/day)	Non-Continuous Sources[2,3,4] (% Reduction)	Load Allocation (cfu/day)	% Reduction to Meet LA[3]
C-001	8.31E+13	2.13E+12	1.06E+11	See Note Below	97%	2.02E+12	97%
C-017	4.37E+13	3.93E+12	1.96E+11	See Note Below	91%	3.73E+12	91%

Table Notes:

1. WLAs are expressed as a daily maximum. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern. Loadings were developed based upon permitted flow and assuming an allowable permitted maximum concentration of 400cfu/100ml.
2. Percent reduction applies to all NPDES-permitted stormwater discharges, including current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction due to the uncertain nature of non-continuous discharge volumes and recurrence intervals. Stormwater discharges are required to meet the percentage reduction or the existing instream standard for the pollutant of concern.
3. Percent reduction applies to existing instream load; where Percentage Reduction = (Existing Load - Load Allocation) / Existing Load
4. By implementing the best management practices that are prescribed in either the SCDOT annual SWMP or the SCDOT MS4 Permit to address fecal coliform, the SCDOT will comply with this TMDL and its applicable WLA to the maximum extent practicable (MEP) as required by its MS4 permit.

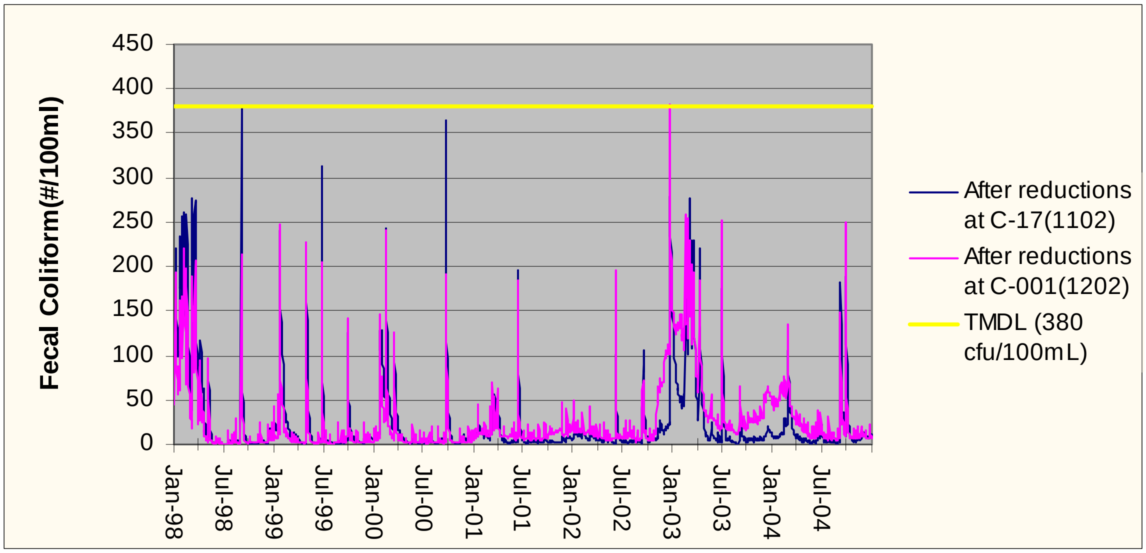

Figure 5-4. Confirmation of fecal coliform load reductions to meet instantaneous standard.

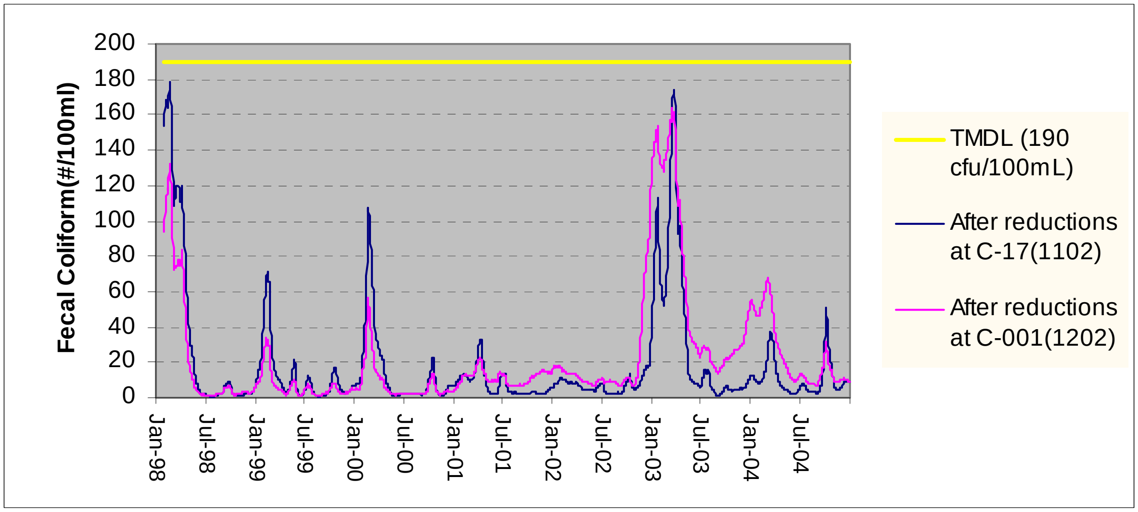

Figure 5-5. Confirmation of fecal coliform load reductions to meet geometric standard.

6.0 Implementation

The implementation of both point (WLA) and non-point (LA) source components of the TMDL are necessary to bring about the required reductions in FC bacteria loading to Gills Creek and its tributaries in order to achieve the water quality standard. Using existing authorities and mechanisms, an implementation plan providing information on how point and non-point sources of pollution are being abated or may be abated in order to meet water quality standards is provided. Sections 6.1.1-6.1.7 presented below correspond with sections 3.1.1-3.2.6 of the source assessment presented in the TMDL document. As the implementation strategy progresses, SCDHEC may continue to monitor the effectiveness of implementation measures and evaluate water quality where deemed appropriate.

Point sources are discernible, confined, and discrete conveyances of pollutants to a water body including but not limited to pipes, outfalls, channels, tunnels, conduits, man-made ditches, etc. The Clean Water Act's primary point source control program is the National Pollutant Discharge Elimination System (NPDES). Point sources can be broken down into continuous and non-continuous point sources. Some examples of a continuous point source are wastewater treatment facilities (WWTF) and industrial facilities. Non-continuous point sources are related to stormwater and include municipal separate storm sewer systems (MS4), construction activities, etc. Current and future NPDES discharges in the referenced watershed are required to comply with the load reductions prescribed in the wasteload allocation (WLA).

Nonpoint source pollution originates from multiple sources over a relatively large area. It is diffuse in nature and indistinct from other sources of pollution. It is generally caused by the pickup and transport of pollutants from rainfall moving over and through the ground. Nonpoint sources of pollution may include, but are not limited to: wildlife, agricultural activities, illicit discharges, failing septic systems, and urban runoff. Nonpoint sources located in unregulated portions of the watershed are subject to the load allocation (LA) and not the WLA portion of the TMDL document.

South Carolina has several tools available for implementing the non-point source component of this TMDL. The *Implementation Plan for Achieving Total Maximum Daily Load Reductions From Nonpoint Sources for the State of South Carolina* (SCDHEC 1998) document is one example. Another key component for interested parties to control pollution and prevent water quality degredation in the watershed would be the establishment and administration of a program of Best Management Practices (BMPs). Best management practices may be defined as a practice or a combination of practices that have been determined to be the most effective, practical means used in the prevention and/or reduction of pollution.

SCDHEC will also work with the existing agencies in the area to provide nonpoint source education in the Gills Creek watershed. Local sources of nonpoint source education and assistance include the Natural Resource Conservation Service (NRCS), the Richland County Soil and Water Conservation Services, the Clemson University Cooperative Extension Service, and the South Carolina Department of Natural Resources.

The Department recognizes that **adaptive management/implementation** of this TMDL might be needed to achieve the water quality standard and we are committed towards targeting the load reductions to improve water quality in the Gills Creek Watershed. As additional data and/or information becomes available, it may become necessary to revise and/or modify the TMDL target accordingly.

6.1. IMPLEMENTATION STRATEGIES

The strategies presented in this document for implementation of the referenced TMDL are not inclusive and are to be used only as guidance. The strategies are informational suggestions which may lead to the required load reductions being met for the referenced watershed while demonstrating consistency with the assumptions and requirements of the TMDL. Application of certain strategies provided within may be voluntary and are not a substitute for actual NPDES permit conditions.

6.1.1. Continuous Point Sources

There are no Continuous point source WLA reductions at this time. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern and demonstrate consistency with the assumptions and requirements of the TMDL. Loadings are developed based upon permitted flow and assume an allowable permitted maximum concentration of 400 cfu/100ml.

6.1.2. Non-Continuous Point Sources

An iterative BMP approach as defined in the general stormwater NPDES MS4 permit is expected to provide significant implementation of the WLA. Permit requirements for implementing WLAs in approved TMDLs will vary across waterbodies, discharges, and pollutant(s) of concern. The allocations within a TMDL can take many different forms – narrative, numeric, specific BMPs – and may be complimented by other special requirements such as monitoring.

The level of monitoring necessary, deployment of structural and non-structural BMPs, evaluation of BMP performance, and optimization or revisions to the existing pollutant reduction goals of the SWMP or any other plan is TMDL and watershed specific. Hence, it is expected that NPDES permit holders evaluate their existing SWMP or other plans in a manner that would effectively address implementation of this TMDL with an acceptable schedule and activities for their permit compliance. The Department staff (permit writers, TMDL project managers, and compliance staff) is willing to assist in developing or updating the referenced plan as deemed necessary. Please see Appendix C which provides additional information as it relates to evaluating the effectiveness of an MS4 Permit as it related to compliance with approved TMDLs. For SCDOT and existing and future NPDES MS4 permittees, compliance with terms and conditions of its NPDES NS4 permit is effective implementation of the WLA to the MEP. For existing and future NPDES construction and Industrial stormwater permittees, compliance with terms and conditions of its permit is effective implementation of the WLA.

The Department acknowledges that progress with the assumptions and requirements of the TMDL by MS4s is expected to take one or more permit iteration. Achieving the WLA reduction for the TMDL may constitute MS4 compliance with its SWMP, provided the maximum extent practicable definition is met, even where the numeric percent reduction may not be achieved in the interim.

Regulated MS4 entities are required to develop a SWMP that includes the following: public education, public involvement, illicit discharge detection & elimination, construction site runoff control, post construction runoff control, and pollution prevention/good housekeeping. These measures are not exhaustive and may include additional criterion depending on the type of NPDES MS4 permit that applies. The following examples are recognized as acceptable stormwater practices and may be applied to unregulated MS4 entities or other interested parties in the development of a stormwater management plan.

An informed and knowledgeable community is crucial to the success of a stormwater management plan (USEPA 2005). MS4 entities may implement a public education program to distribute educational materials to the community, or conduct equivalent outreach activities about the impacts of stormwater discharges on local waterbodies and the steps that can be taken to reduce stormwater pollution. Some appropriate BMPs may be brochures, educational programs, storm drain stenciling, stormwater hotlines, tributary signage, and alternative information sources such as web sites, bumper stickers, etc (USEPA 2005).

The public can provide valuable input and assistance to a stormwater management program and they may have the potential to play an active role in both the development and implementation of the stormwater program where deemed appropriate by the entity. There are a variety of practices that can involve public participation such as public meetings/citizens panels, volunteer water quality monitoring, volunteer educators, community clean-ups, citizen watch groups, and "Adopt a Storm Drain" programs which encourage individuals or groups to keep storm drains free of debris and monitor what is entering local waterways through storm drains (USEPA 2005).

Illicit discharge detection and elimination efforts are also necessary. Discharges from MS4s often include wastes and wastewater from non-stormwater sources. These discharges enter the system through either direct connections or indirect connections. The result is untreated discharges that contribute high levels of pollutants, including heavy metals, toxics, oil and grease, solvents, nutrients, viruses, and bacteria to receiving waterbodies (USEPA 2005). Pollutant levels from these illicit discharges have been shown in EPA studies to be high enough to significantly degrade receiving water quality and threaten aquatic, wildlife, and human health. MS4 entities may have a storm sewer system map which shows the location of all outfalls and to which waters of the US they discharge for instance. If not already in place, an ordinance prohibiting non-stormwater discharges into a MS4 with appropriate enforcement procedures may also be developed. Entities may also have a plan for detecting and addressing non-stormwater discharges. The plan may include locating problem areas through infrared photography, finding the sources through dye testing, removal/correction of illicit connections, and documenting the actions taken to illustrate that progress is being made to eliminate illicit connections and discharges.

A program might also be developed to reduce pollutants in stormwater runoff to the MS4 area from construction activities. An ordinance or other regulatory mechanism may exist requiring the implementation of proper erosion and sediment controls on applicable construction sites. Site plans should be reviewed for projects that consider potential water quality impacts. It is recommended that site inspections should be conducted and control measures enforced where applicable. A procedure might also exist for considering information submitted by the public (USEPA 2005). For information on specific BMPs please refer to the SCDHEC Stormwater Management BMP Handbook online at: http://www.scdhec.com/environment/ocrm/pubs/docs/SW/BMP_Handbook/Erosion_prevention.pdf

Post-construction stormwater management in areas undergoing new development or redevelopment is recommended because runoff from these areas has been shown to significantly affect receiving waterbodies. Many studies indicate that prior planning and design for the minimization of pollutants in post-construction stormwater discharges is the most cost-effective approach to stormwater quality management (USEPA 2005). Strategies might be developed to include a combination of structural and/or non-structural BMPs. An ordinance or other regulatory mechanism may also exist requiring the implementation of post-construction runoff controls and ensuring their long term-operation and maintenance. Examples of non-structural BMPs are planning procedures and site-based BMPs (minimization of imperviousness and maximization of open space). Structural BMPs may include but are not limited to stormwater retention/detention BMPs, infiltration BMPs (dry wells, porous pavement, etc.), and vegetative BMPs (grassy swales, filter strips, rain gardens, artificial wetlands, etc.).

Pollution prevention/good housekeeping is also a key element of stormwater management programs. Generally this requires the MS4 entity to examine and alter their programs or activities to ensure reductions in pollution are occurring. It is recommended that a plan be developed to prevent or reduce pollutant runoff from municipal operations into the storm sewer system and it is encouraged to include employee training on how to incorporate and document pollution prevention/good housekeeping techniques. To minimize duplication of effort and conserve resources, the MS4 operator can use training materials that are available from EPA or relevant organizations (USEPA 2005).

MS4 communities are encouraged to utilize partnerships when developing and implementing a stormwater management program. Watershed associations, educational organizations, and state, county, and city governments are all examples of possible partners with resources that can be shared. For additional information on partnerships contact the SCDHEC Watershed Manager for the waterbody of concern online at: http://www.scdhec.gov/environment/water/shed/contact.htm For additional information on stormwater discharges associated with MS4 entities please see SCDHEC's NPDES web page online at http://www.scdhec.gov/environment/water/swnpdes.htm as well as the USEPA NPDES website online at http://cfpub.epa.gov/npdes/home.cfm?program_id=6 for information pertaining to the National Menu of BMPs, Urban BMP Performance Tool, Outreach Documents, etc.

As part of the modeling effort for this TMDL, reduction sequencing was simulated from the headwaters-downstream to establish potential reductions at a subbasin scale in the Gills Creek watershed. These reductions, presented here, are made to use as a guide to implementing BMPs in the Gills Creek watershed. Any implementation efforts focused on specific subbasins may not meet compliance at SCDHEC's existing water quality monitoring stations or be consistent with the assumptions and requirements of the TMDL as defined section 5 of this document. Therefore, it should be noted that compliance is measured at SCDHEC's existing water quality monitoring stations and not at the subbasin level, unless a plan has been developed, reviewed, approved, and demonstrates consistency with the assumptions and requirements of the TMDL. Implementation will need to occur throughout the watershed as a collaborative effort between multiple stakeholders to ensure compliance at SCDHECs existing monitoring stations. Table 6-1 and Figure 6-1 present the results of reductions by subbasin from the headwaters-downstream for FC bacteria.

Table 6-1. Guidance for Implementing Reductions to Watershed Subbasins from the Headwaters Downstream

Modeled Subbasin	130	140	150	160	170	200	300	320	330	400	410	500	1102	1201	1202	1203	3101	3102
Fecal Coliform Percentage Reductions	82%	40%	21%	71%	61%	85%	45%	98%	51%	99%	71%	93%	92%	84%	97%	99%	35%	25%

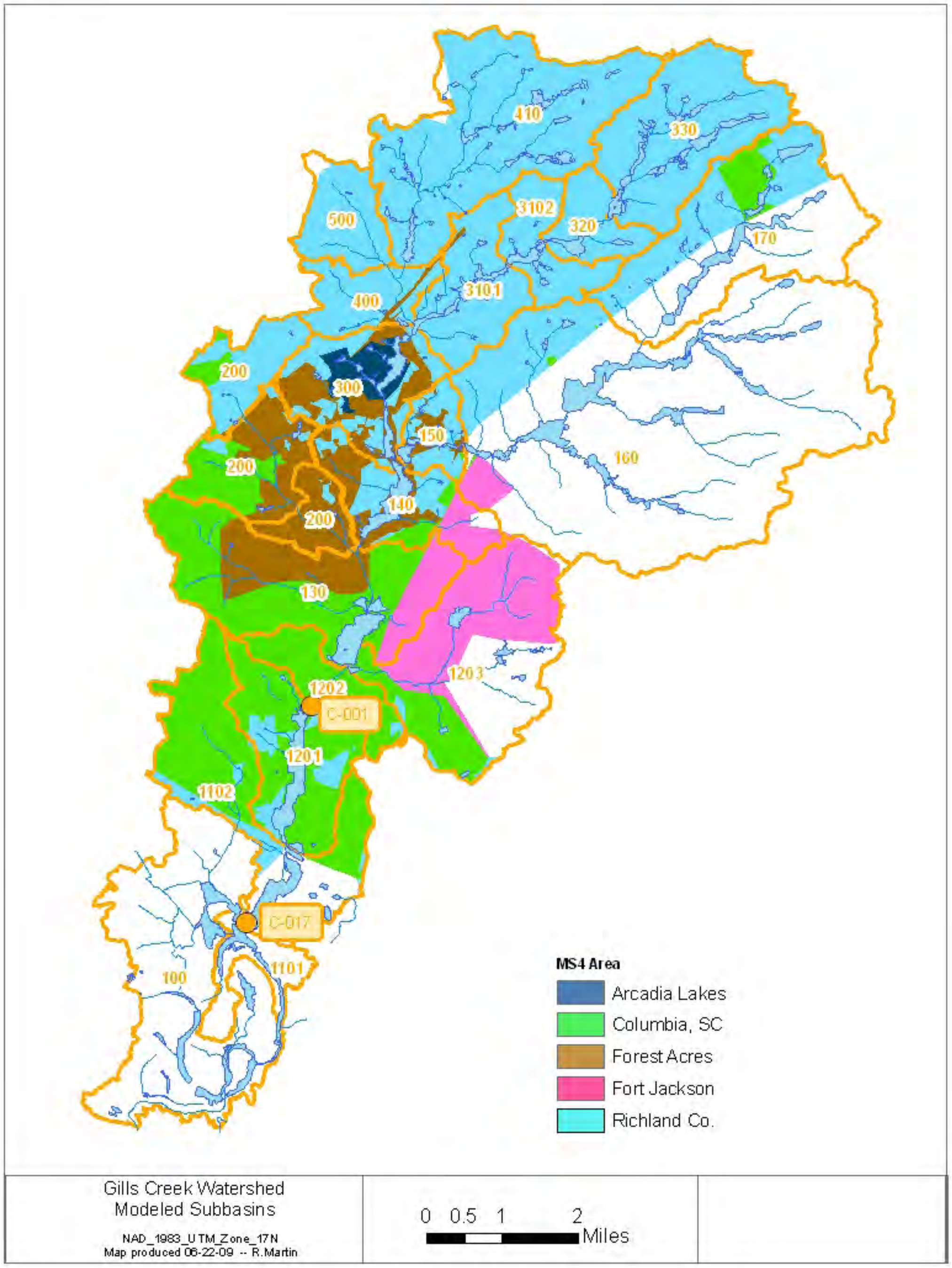

Figure 6-1. Guidance for Implementing Reductions to Watershed Subbasins from the Headwaters Downstream

6.1.3. Wildlife

Suggested forms of implementation for wildlife will vary widely due to geographic location and species. There are many forms of acceptable wildlife BMPs in practice and development at the present time. For example, contiguous forested areas could be set up and managed to keep wildlife from bedding down and defecating near surface waters. This management practice relies on concentrating wildlife away from water bodies to minimize their impact to pollutant loading. Additionally, contributions from wildlife could be reduced in protected areas by developing a management plan which would allow hunting access during certain seasons. Although this strategy might not work in all situations, it would decrease FC loading from wildlife in areas where wildlife may be a significant contributor to the overall watershed.

Deterrents may also be used to keep wildlife away from docks and lawns in close proximity to surface waters. Non-toxic spray deterrents, decoys, eagles, kites, noisemakers, scarecrows, and plastic owls are a sample of what is currently available. Given the large area of open water in the Gills Creek watershed, it is likely that waterfowl are present, though density estimates are not available. Many waterfowl species are deterred by foreign objects on lawns and the planting of a shrub buffer along greenways adjacent to impoundments may also be effective.

In addition, homeowners and the hunting community should be educated on the impacts of feeding wildlife or planting wildlife food plots in close proximity to surface waters. Please check local and federal laws before applying deterrents or harassing wildlife. Additional information may be obtained from the *Managing Pet and Wildlife Waste to Prevent Contamination of Drinking Water* bulletin provided by USEPA (2001).

6.1.4. Agricultural Activities

Suggested forms of implementation for agricultural activities will vary based on the activity of concern. Agricultural BMPs can be vegetative, structural or management oriented. When selecting BMPs, it is important to keep in mind that nonpoint source pollution occurs when a pollutant becomes available, is detached and then transported to nearby receiving waters. Therefore, for BMPs to be effective, the transport mechanism of the pollutant, fecal coliform, needs to be identified. For livestock in the referenced watershed, installing fencing along the streams within the watershed and providing an alternative water source where livestock are present would eliminate direct contact with the streams. Very few livestock are present in the watershed at the time of this study. If fencing is not feasible, it has been shown that installing water troughs within a pasture area reduced the amount of time livestock spent drinking directly from streams by 92% (ASABE 1997). An indirect result of this was a 77% reduction in stream bank erosion by providing an alternative to accessing the stream directly for water supply.

For row crop farms in the referenced watershed, many common practices exist to reduce FC contributions. Unstable soil directly adjacent to surface waters can contribute to FC loading during periods of runoff after rain events. Agricultural field borders and filter strips (vegetative buffers) can provide erosion control around the border of planted crop fields. These borders can provide food for wildlife, may possibly be harvested (grass and legume), and also provide an area where farmers can turn around their equipment (SCDNR 1997). A study conducted in 1998 by the American Society of Agricultural and Biological Engineers (ASABE 1998) has shown that a vegetative buffer can reduce fecal runoff concentrations from 2.0E+7 to an immeasurable amount once filtered through the buffer. The buffer in this study was also shown to reduce phosphorous and nitrogen concentrations by 75%.

The agricultural BMPs listed above are a sample of the many accepted practices that are currently available. Many other techniques such as conservation tillage, responsible pest management, and precision agriculture also exist and may contribute to an improvement in overall water quality in the watershed. Education should be provided to local farmers on these methods as well as acceptable manure spreading and holding (stacking sheds) practices.

For additional information on accepted agricultural BMPs you can obtain a copy of the *Farming for Clean Water in South Carolina* handbook by contacting Clemson University Cooperative Extension Service at (864) 656-1550. In addition, Clemson Extension Service offers a *Farm-A-Syst* package to farmers. *Farm-A-Syst* allows the farmer to evaluate practices on their property and determine the nonpoint source impact they may be having. It recommends best management practices (BMPs) to correct nonpoint source problems on the farm. You can access *Farm-A-Syst* by going onto the Clemson Extension Service website: http://www.clemson.edu/waterquality/FARM.HTM.

NRCS provides financial and technical assistance to help South Carolina landowners address natural resource concerns, promote environmental quality, and protect wildlife habitat on property they own or control. The cost-share funds are available through the Environmental Quality Incentives Program (EQIP). EQIP helps farmers improve production while protecting environmental quality by addressing such concerns as soil erosion and productivity, grazing management, water quality, animal waste, and forestry concerns. EQIP also assists eligible small-scale farmers who have historically not participated in or ranked high enough to be funded in previous sign ups. Please visit www.sc.nrcs.usda.gov/programs/ for more information, including eligibility requirements.

Also available through NRCS, the Grassland Reserve Program (GRP) is a voluntary program offering landowners the opportunity to protect, restore and enhance grasslands on their property. NRCS and the Farm Service Agency (FSA) coordinate implementation of the GRP, which helps landowners restore and protect grassland, rangeland, pastureland, shrubland and certain other lands and provides assistance for rehabilitating grasslands. The program will conserve vulnerable grasslands from conversion to cropland or other uses and conserve valuable grasslands by helping maintain viable grazing operations. A grazing management plan is required for participants. NRCS has further information on their website for the GRP as well as additional programs such as the Conservation Reserve Program, Conservation Security Program, Farm and Ranch Lands Protection Program, etc. You can visit the NRCS website by going to: www.sc.nrcs.usda.gov/programs/.

6.1.5. Leaking Sanitary Sewers and Illicit Discharges

Leaking sanitary sewers and illicit discharges, although illegal and subject to enforcement, may be occurring in regulated or unregulated portions of the watershed at any time. Due to the high concentration of pollutant loading that is generally associated with these discharges, their detection may provide a substantial improvement in overall water quality in the Gills Creek watershed. Detection methods may include, but are not limited to: dye testing, air pressure testing, static pressure testing, and infrared photography.

SCDHEC recognizes illicit discharge detection and elimination activities are conducted by regulated MS4 entities as pursuant to compliance with existing MS4 permits. Note that these activities are designed to detect and eliminate illicit discharges that may contain FC bacteria. It is the intent of SCDHEC to work with the MS4 entities to recognize FC load reductions as they are achieved. SCDHEC acknowledges that these efforts to reduce illicit discharges and SSOs are ongoing and some reduction may already be accountable (i.e., load reductions occurring during TMDL development process). Thus, the implementation process is an iterative and adaptive process. Regular communication between all implementation stakeholders will result in successful remediation of controllable sources over time. As designated uses are restored, SCDHEC will recognize efforts of implementers where their efforts can be directly linked to restoration.

6.1.6. Failing Septic Systems

A septic system, also known as an onsite wastewater system, is defined as failing when it is not treating or disposing of sewage in an effective manner. The most common reason for failure is improper maintenance by homeowners. Untreated sewage water contains disease-causing bacteria and viruses, as well as unhealthy amounts of nitrate and other chemicals. Failed septic systems can allow untreated sewage to seep into wells, groundwater, and surface water bodies, where people get their drinking water and recreate. Pumping a septic tank is probably the single most important thing that can be done to protect the system. If the buildup of solids in the tanks becomes too high and solids move to the drainfield, this could clog and strain the system to the point where a new drainfield will be needed.

SCDHEC's Office of Coastal Resource Management (OCRM) has created a toolkit for homeowners and local governments which includes tips for maintaining septic systems. These septic system Do's and Don't's are as follows:

Do's:

- Conserve water to reduce the amount of wastewater that must be treated and disposed of by your system. Doing laundry over several days will put less stress on your system.
- Repair any leaking faucets or toilets. To detect toilet leaks, add several drops of food dye to the toilet tank and see if dye ends up in the bowl.
- Divert down spouts and other surface water away from your drainfield. Excessive water keeps the soil from adequately cleansing the wastewater.
- Have your septic tank inspected yearly and pumped regularly by a licensed septic tank contractor.

Don'ts:

- Don't drive over your drainfield or compact the soil in any way.
- Don't dig in your drainfield or build anything over it, and don't cover it with a hard surface such as concrete or asphalt.
- Don't plant anything over or near the drainfield except grass. Roots from nearby trees an shrubs may clog and damage the drain lines.
- Don't use your toilet as a trash can or poison your system and the groundwater by pouring harmful chemicals and cleansers down the drain. Harsh chemicals can kill the bacteria that help purify your wastewater.

For additional information on how septic systems work, how to properly plan and maintain a septic system, or to link to the OCRM toolkit mentioned above, please visit the SCDHEC Environmental Health Onsite Wastewater page at the following link: http://www.scdhec.gov/health/envhlth/onsite_wastewater/septic_tank.htm.

6.1.7. Urban Runoff

Urban runoff is surface runoff of rainwater created by urbanization outside of regulated areas which may pick up and carry pollutants to receiving waters. Pavement, compacted areas, roofs, reduced tree canopy and open space increase runoff volumes that rapidly flow into receiving waters. This increase in volume and velocity of runoff often causes stream bank erosion, channel incision and sediment deposition in stream channels. In addition, runoff from these developed areas can increase stream temperatures that along with the increase in flow rate and pollutant loads negatively affect water quality and aquatic life (USEPA 2005). This runoff can pick up FC bacteria along the way. Many strategies currently exist to reduce FC loading from urban runoff and the USEPA nonpoint source pollution website provides extensive resources on this subject which can be accessed online at: http://www.epa.gov/nps/urban.html.

Some examples of urban nonpoint source BMPs are street sweeping, stormwater wetlands, pet waste receptacles (equipped with waste bags), and educational signs which can be installed adjacent to receiving waters in the watershed such as parks, common areas, apartment complexes, trails, etc. Low impact development (LID) may also be effective. LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treats stormwater as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements (USEPA 2009).

Some additional urban BMPs that can be adopted in public parks are doggy dooleys and pooch patches. Doggy dooleys are disposal units, which act like septic systems for pet waste, and are installed in the ground where decomposition can occur (USEPA 2001). This requires that pet owners place the waste into the disposal units. Education should be provided to individual homeowners in the referenced watershed on the contributions to FC loading from pet waste. Education to homeowners in the watershed on the fate of substances poured into storm drain inlets should also be provided. For additional information on urban runoff please see the SCDHEC Nonpoint Source Runoff Pollution homepage at http://www.scdhec.gov/environment/water/npspage.htm.

Clemson Extension's *Home-A-Syst* handbook can also help homeowners reduce sources of non-point source pollution on their property. This document guides homeowners through a self-assessment of their property and can be accessed online at: http://www.clemson.edu/waterquality/HOMASYS.HTM

7.0 Resources for Pollutant Management

This section provides a list of available resources to aid in the mitigation and control of pollutants. There are examples from across the nation, most of which are easily accessible on the Internet.

7.1. GENERAL FOR URBAN AND SUBURBAN STORMWATER MITIGATION

- *National Management Measures to Control Nonpoint Source Pollution from Urban Area.* Draft. 2002. EPA842-B-02-003. Available at http://www.epa.gov/owow/nps/urbanmm/index.html
- *Stormwater Management Volume Two: Stormwater Technical Manual*. 1997. Massachusetts Department of Environmental Management. Available at http://www.mass.gov/dep/brp/stormwtr/stormpub.htm
- Fact Sheets for the six minimum control measures for storm sewers regulated under Phase I or Phase II. Available at http://cfpub1.epa.gov/npdes/stormwater/swfinal.cfm?program_id=6
- *A Current Assessment of Urban Best Management Practices*. 1992. Metropolitan Washington Council of Governments. Washington, DC
- *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*. 1987. Metropolitan Washington Council of Governments. Washington, DC
- *2004 Stormwater Quality Manual*. Connecticut Department of Environmental Protection 2004. Available at http://dep.state.ct.us/wtr/stormwater/strmwtrman.htm
- *Stormwater Treatment BMP New Technology Report*. 2004. California Department of Transportation. SW-04-069-.04.02 Available at http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/_pdfs/new_technology/CTSW-RT-04-069.pdf
- Moonlight Beach Urban Runoff Treatment Facility: Using Ultraviolet Disinfection to Reduce Bacteria Counts. J. Rasmus and K. Weldon. 2003. *StormWater*, May/June 2003. Available at http://www.forester.net/sw_0305_moonlight.html
- *Operation, Maintenance, and Management of Stormwater Management Systems*. Livingston, Shaver, Skupien, and Horner. August 1997. Watershed Management Institute. Call (850) 926-5310.
- Model Ordinances to Protect Local Resources – Stormwater Control Operation and Maintenance. USEPA Web page: http://www.epa.gov/owow/nps/ordinance/stormwater.htm
- Stormwater O & M Fact Sheet: Preventive Maintenance. 1999. U.S. Environmental Protection Agency. EPA 832-F-99-004. Available at http://www.epa.gov/owm/mtb/prevmain.pdf
- *The MassHighway Stormwater Handbook*. 2004. Massachusetts Highway Department. 2004. Available at http://166.90.180.162/mhd/downloads/projDev/swbook.pdf

- University of New Hampshire Stormwater Center Web site: http://www.unh.edu/erg/cstev/index.htm#

- U.S. Environmental Protection Agency's Stormwater Web site: http://www.epa.gov/region1/topics/water/stormwater.html

7.2. ILLICIT DISCHARGES

- *Illicit Discharge Detection and Elimination Manual—A Handbook for Municipalities*. 2003. New England Interstate Water Pollution Control Commission. Available at http://www.neiwpcc.org/PDF_Docs/iddmanual.pdf

- Model Ordinances to Protect Local Resources – Illicit Discharges. U.S. Environmental Protection Agency Web page: http://www.epa.gov/owow/nps/ordinance/discharges.htm

7.3. PET WASTE

- *National Management Measures to Control Non Point Source Pollution from Urban Areas.* Draft. 2002. U.S. Environmental Protection Agency. EPA 842-B-02-2003. Available at http://www.epa.gov/owow/nps/urbanmm/index.html
- Septic Systems for Dogs? *Nonpoint Source News-Notes* 63.

- *Pet Waste: Dealing with a Real Problem in Suburbia*. J. Kemper. 2000. New Jersey Department of Environmental Protection. Available at http://www.state.nj.us/dep/watershedmgt/pet_waste_fredk.htm

- Stormwater Manager's Resource Center. T. Schueler, Center for Watershed Protection, Inc. http://www.stormwatercenter.net

- *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. 1993. U.S. Environmental Protection Agency, Office of Water. Washington, DC.

- *National Menu of Best Management Practices for Stormwater Phase II*. 2002. U.S. Environmental Protection Agency. Available at http://www.epa.gov/npdes/menuofbmps/menu.htm

- Welcome to NVRC'S Four Mile Run Program. 2001. Northern Virginia Regional Commission. Available at http://www.novaregion.org/fourmilerun.htm

- Boston's ordinance on dog waste. City of Boston Municipal Codes, Chapter XVI. 16-1.10A Dog Fouling. Available at http://www.amlegal.com/boston_ma

- Pet Waste and Water Quality. J.A. Hill and D. Johnson. 1994. University of Wisconsin Extension Service. Available at http://cecommerce.uwex.edu/pdfs/GWQ006.pdf

- *Source Water Protection Practices Bulletin: Managing Pet and Wildlife Waste to Prevent Contamination of Drinking Water*. 2001. U.S. Environmental Protection Agency. EPA 916-F-01-027. Available at http://www.epa.gov/safewater/protect/pdfs/petwaste.pdf

7.4. WILDLIFE

- An example of a bylaw prohibiting the feeding of wildlife: Prohibiting Feeding of Wildlife. Town of Bourne Bylaws Section 3.4.3. Available at http://www.townofbourne.com/Town%20Offices/Bylaws/chapter__3.htm
- Integrated Management of Urban Canadian Geese. M. Underhill. 1999. *Conference Proceedings*, Waterfowl Information Network.
- Urban Canadian Geese in Missouri. *Missouri Conservationist* online. Available at http://www.conservation.state.mo.us/conmag/2004/02/20.htm

7.5. SEPTIC SYSTEMS

- *National Management Measures to Control Nonpoint Source Pollution from Urban Areas.* Draft. Chapter 6. New and Existing Onsite Wastewater Treatment Systems. 2002. U.S. Environmental Protection Agency. EPA842-B-02-003. Available at http://www.epa.gov/owow/nps/urbanmm/index.html

- Septic Systems. U.S. Environmental Protection Agency Web page: http://cfpub.epa.gov/owm/septic/home.cfm

7.6. FEDERAL AGRICULTURE RESOURCES: PROGRAM OVERVIEWS, TECHNICAL ASSISTANCE AND FUNDING

- The U.S. Department of Agriculture's National Resources Conservation Service (USDA-NRCS) assists landowners with planning for the conservation of soil, water and natural resources. Local, state and federal agencies and policymakers also rely on NRCS expertise. Cost sharing and financial incentives are available in some cases. Most work is done with local partners. The NRCS is the largest funding source for agricultural improvements. To find out about potential funding, see http://www.ma.nrcs.usda.gov/programs. To pursue obtaining funding, contact a local NRCS coordinator. Contact information is available at http://www.ma.nrcs.usda.gov/contact/employee_directory.html

- CORE4 Conservation Practices. The common sense approach to natural resource conservation. 1999. USDA-NRCS. This manual is intended to help USDA-NRCS personnel and other conservation and nonpoint source management professionals implement effective programs using core conservation practices: nutrient management, pest management, and conservation buffers. Available at http://www.nrcs.usda.gov/technical/ECS/agronomy/core4.pdf

- County soil survey maps are available from NRCS at http://soils.usda.gov

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Appendix A. Fecal Coliform Data Analysis

Table A-1. Fecal Coliform measured data at C-001

Sample Date	Fecal Coliform (cfu/day)
1/13/1999	25
2/2/1999	390
3/2/1999	400
4/13/1999	240
5/11/1999	91
6/30/1999	460
7/19/1999	180
8/11/1999	14000
9/16/1999	4400
10/19/1999	580
11/8/1999	220
12/15/1999	210
1/18/2000	480
2/3/2000	5
3/15/2000	74
4/4/2000	60
5/11/2000	190
6/7/2000	1700
7/18/2000	220
8/2/2000	820
9/5/2000	220
10/11/2000	100
11/8/2000	87
12/5/2000	38
1/10/2001	83
2/26/2001	62
3/26/2001	41
4/4/2001	90
5/15/2001	950
6/14/2001	980
7/10/2001	360
8/8/2001	300
9/10/2001	500
10/24/2001	270
11/26/2001	2400
12/4/2001	220
1/26/2006	120
2/28/2006	160
3/15/2006	270
4/25/2006	1000
5/8/2006	960
6/6/2006	420
7/12/2006	1400
8/28/2006	780
9/9/2006	500
10/18/2006	300
11/8/2006	250
12/5/2006	100

Table A-2. Fecal Coliform measured data at C-017

Sample Date	Fecal Coliform (cfu/day)
1/12/1999	38
2/3/1999	240
3/1/1999	66
4/13/1999	1800
5/11/1999	250
6/30/1999	360
7/20/1999	210
8/11/1999	130
9/16/1999	7600
10/19/1999	400
11/8/1999	69
12/15/1999	77
1/17/2000	51
2/1/2000	86
3/8/2000	47
4/5/2000	180
5/11/2000	180
6/5/2000	110
7/18/2000	290
8/2/2000	3800
9/5/2000	620
10/10/2000	69
11/8/2000	100
12/5/2000	0
1/10/2001	67
2/26/2001	52
3/26/2001	53
4/4/2001	37
5/15/2001	230
6/18/2001	270
7/10/2001	280
8/8/2001	70
9/10/2001	350
10/24/2001	57
11/26/2001	1200
12/4/2001	40
1/9/2002	70
2/13/2002	83
3/12/2002	65
4/10/2002	2300
5/15/2002	390
6/4/2002	140
7/16/2002	170
8/20/2002	310
9/11/2002	260
10/9/2002	8700
11/12/2002	2400
12/5/2002	3000
1/2/2003	60
2/4/2003	20
3/5/2003	33
4/9/2003	2800
5/6/2003	2900

Sample Date	Fecal Coliform (cfu/day)
6/3/2003	130
7/8/2003	440
8/28/2003	170
9/10/2003	600
10/28/2003	510
11/18/2003	67
12/17/2003	86
1/14/2004	100
2/10/2004	23
3/30/2004	37
4/27/2004	1000
5/26/2004	90
6/8/2004	260
7/21/2004	160
8/3/2004	220
9/29/2004	1000
10/27/2004	760
11/2/2004	250
12/14/2004	120
1/18/2005	1600
2/8/2005	10
3/2/2005	100
4/13/2005	520
5/18/2005	91
6/22/2005	240
7/19/2005	940
8/24/2005	1000
9/14/2005	57
10/11/2005	2200
11/7/2005	200
12/12/2005	130
1/30/2006	25
2/15/2006	53
3/6/2006	100
4/18/2006	110
5/16/2006	100
6/5/2006	200
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8/9/2006	1200
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10/18/2006	270
11/6/2006	60
12/4/2006	97

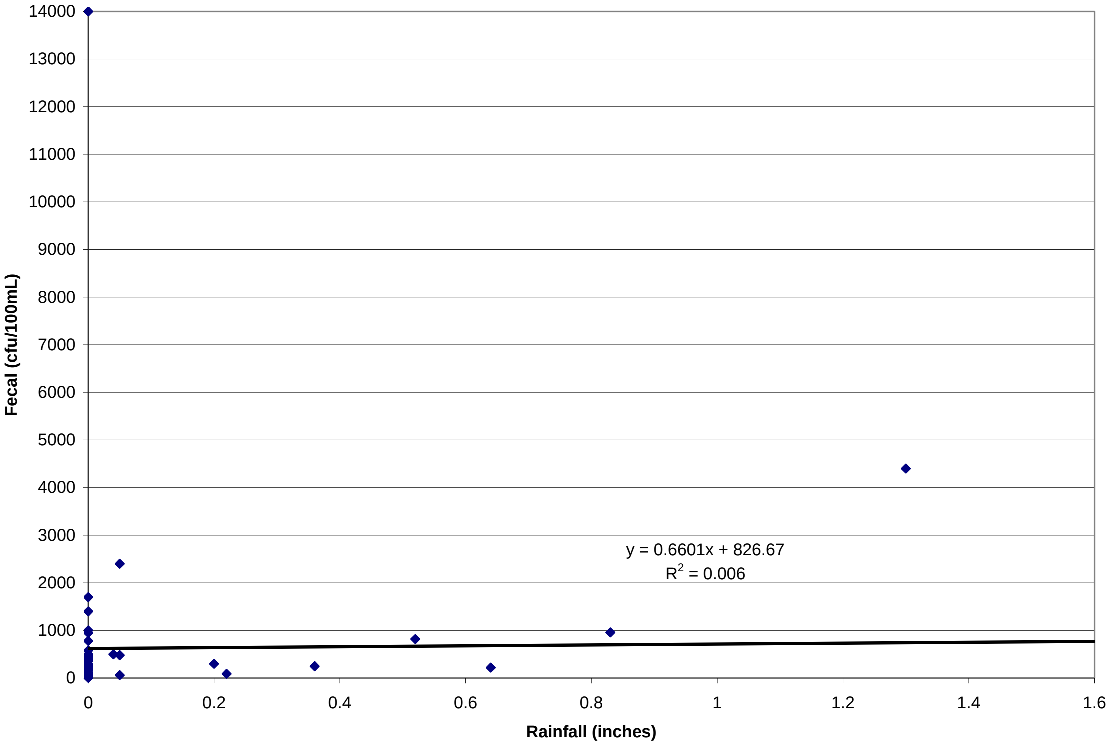

Figure A-1. C-001 relationship between fecal coliform and rainfall.

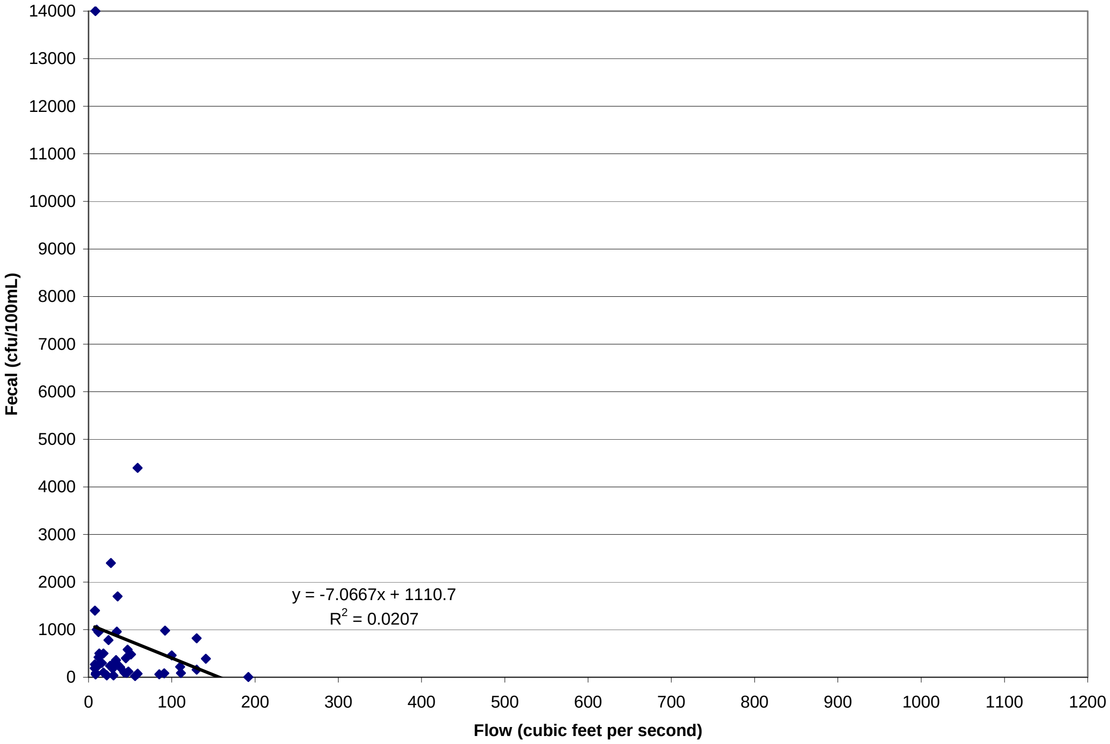

Figure A-2. C-001 relationship between fecal coliform and flow.

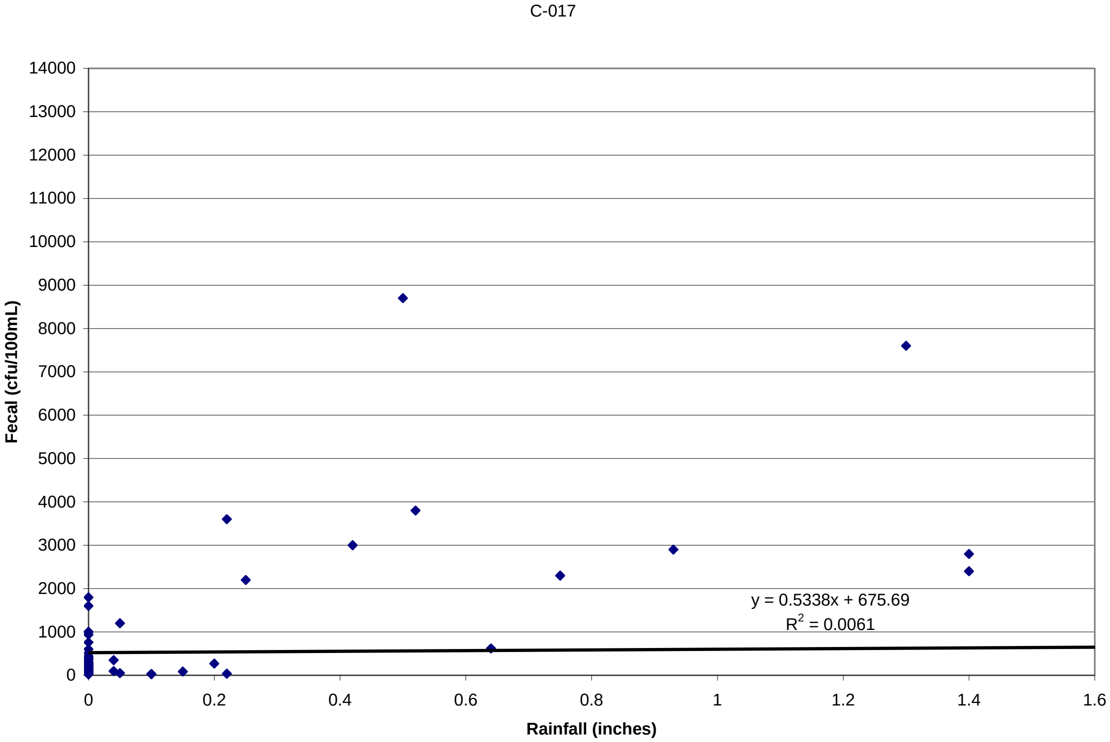

Figure A-3. C-017 relationship between fecal coliform and rainfall.

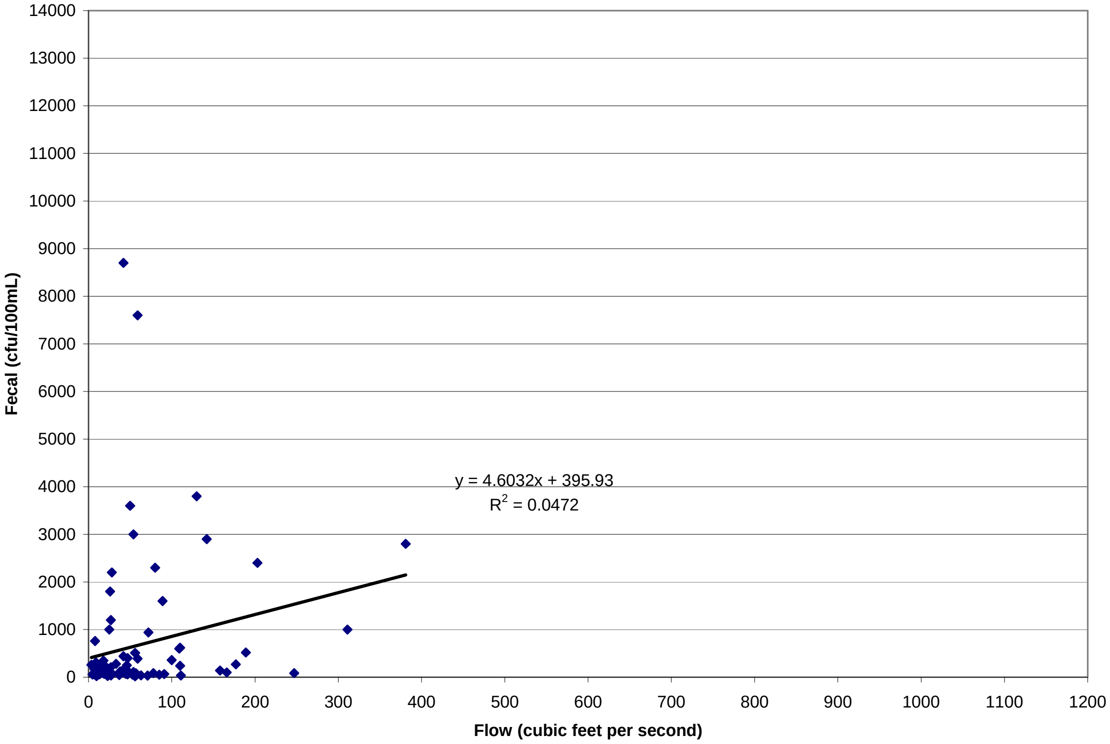

Figure A-4. C-017 relationship between fecal coliform and flow.

Appendix B. Evaluating the Progress of MS4 Programs

Evaluating the Progress of MS4 Programs:

Meeting the Goals of TMDLs and Attaining Water Quality Standards

Bureau of Water

August 2008

Described below are potential approaches that may be used by MS4 permit holders. These are recommendations and examples only, as SCDHEC-BOW recognizes that other approaches may be utilized or employed to meet compliance goals.

1. Calculate pollutant load reduction for each best management practice (BMP) deployed:
   - Retrofitting stormwater outlets
   - Creation of green space
   - LID activities (e.g., creation of porous pavements)
   - Creations of riparian buffers
   - Stream bank restoration
   - Scoop the poop program (how many pounds of poop were scooped/collected)
   - Street sweeping program (amount of materials collected etc.)
   - Construction & post-construction site runoff controls
2. Description & documentation of programs directed towards reducing pollutant loading
   - Document tangible efforts made to reduce impacts to urban runoff
   - Track type and number of structural BMPs installed
   - Parking lot maintenance program for pollutant load reduction
   - Identification and elimination of illicit discharges
   - Zoning changes and ordinances designed to reduce pollutant loading
   - Modeling of activities & programs for reducing pollutant reductions
3. Description & documentation of social indicators, outreach, and education programs
   - Number/Type of training & education activities conducted and survey results
   - Activities conducted to increase awareness and knowledge – residents, business owners. What changes have been made based on these efforts? Any measured behavior or knowledge changes?
   - Participation in stream and/or lake clean-up events or activities
   - Number of environmental action pledges
4. Water quality monitoring: A direct and effective way to evaluate the effectiveness of stormwater management plan activities.
   - Use of data collected from existing monitoring activities (e.g., SCDHEC data for ambient monitoring program available through STORET; water supply intake testing; voluntary watershed group’s monitoring, etc)

- Establish a monitoring program for permitted outfalls and/or waterbodies within MS4 areas as deemed necessary– use a certified lab
- Monitoring should focus on water quality parameters and locations that would both link pollutant sources and BMPs being implemented

5. Links:

- Evaluating the Effectiveness of Municipal Stormwater Programs. September 2007. EPA 833-F-07-010
- The BMP database - http://www.bmpdatabase.org/BMPPerformance.htm (this link is specifically to the BMP performance page, and lot more)
- EPA's STORET data warehouse - http://www.epa.gov/storet/dw_home.html
- EPARegion 5: STEPL – Spreadsheet tool for estimating pollutant loads http://it.tetratech-ffx.com/stepl/
- Measurable goals guidance for Phase II Small MS4 - http://cfpub.epa.gov/npdes/stormwater/measurablegoals/index.cfm
- Environmental indicators for sotrmwater program- http://cfpub.epa.gov/npdes/stormwater/measurablegoals/part5.cfm
- National menu of stormwater best management practices (BMPs) - http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm
- SCDHEC – BOW: 319 grant program has attempted to calculate the load reductions for the following BMPs:

  - Septic tank repair or replacement
  - Removing livestock from streams (cattle, horses, mules)
  - Livestock fencing
  - Waste Storage Facilities (aka stacking sheds)
  - Strip cropping
  - Prescribed grazing
  - Critical Area Planting
  - Runoff Management System
  - Waste Management System
  - Solids Separation Basin
  - Riparian Buffers

Appendix C. Watershed Hydrology and Water Quality Monitoring Report

Watershed Hydrology and Water Quality Modeling Report

for the

Gills Creek Watershed, Richland County, South Carolina

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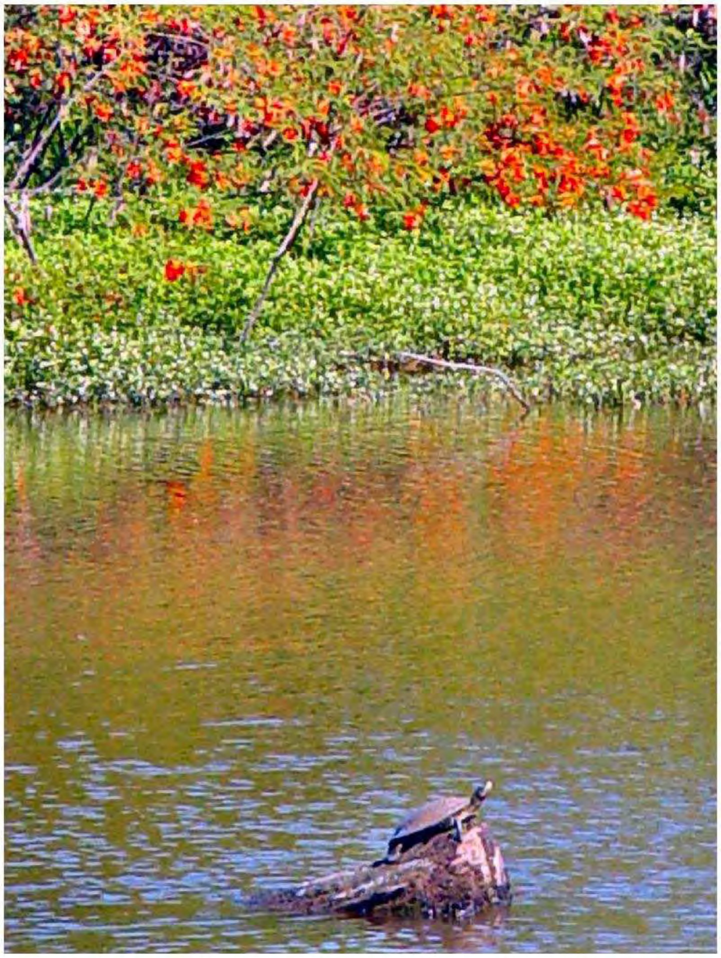

Cover photo courtesy of Elliott Powell, Gills Creek Watershed Association

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1.0 INTRODUCTION

The South Carolina Department of Health and Environmental Control (SCDHEC) contracted Tetra Tech to update a watershed model originally developed by the Richland County Department of Public Works (Richland County) to develop total maximum daily loads (TMDLs) for the Gills Creek watershed. The model was originally calibrated for hydrology for the period from 1998 through 2004. This report details the work completed to convert the existing Hydrologic Simulation Program–FORTRAN (HSPF) to the Loading Simulation Program C++ (LSPC). Following model conversion, hydrologic calibration was confirmed and the model was calibrated to establish loadings for pollutants causing fecal coliform and dissolved oxygen impairments in Gills Creek.

2.0 WATERSHED MODEL DEVELOPMENT

2.1 OVERVIEW

The LSPC was selected to address all the modeling needs in the Gills Creek watershed. LSPC is a version of the HSPF model that has been ported to the C++ programming language to improve efficiency and flexibility. LSPC integrates a geographic information system (GIS), comprehensive data storage and management capabilities, the original HSPF algorithms, and a data analysis/post-processing system into a convenient PC-based windows interface. LSPC's algorithms are identical to a subset of those in the HSPF model. LSPC is currently maintained by the EPA Office of Research and Development in Athens, Georgia. A brief overview of the HSPF model is provided below, and a detailed discussion of HSPF's simulated processes and model parameters is available in the HSPF User's Manual (Bicknell et al. 2001).

HSPF is a comprehensive, public-domain watershed and receiving water quality modeling framework. It was originally developed in the mid-1970s and is supported by EPA and the U.S. Geological Survey (USGS). During the past several years, the model has been used to develop hundreds of EPA-approved TMDLs, and it is generally considered the most advanced hydrologic and watershed loading model available. The hydrologic portion of HSPF is based on the Stanford Watershed Model (Crawford and Linsley 1966), which was one of the pioneering watershed models developed in the 1960s. The HSPF framework is developed in a modular fashion with many different components that can be assembled in different ways, depending on the objectives of the individual project. The model includes three major modules:

- PERLND for simulating watershed processes on pervious land areas
- IMPLND for simulating processes on impervious land areas
- RCHRES for simulating processes in streams and vertically mixed lakes.

All three of these modules include many submodules that calculate the various hydrologic and water chemistry processes in the watershed. Many options are available for both simplified and complex process formulations. Spatially, the watershed is divided into a series of subbasins representing the drainage areas that contribute to each of the stream reaches. These subbasins are then further subdivided into segments representing different land uses. For the developed areas, the land use segments are further divided into the pervious (PERLND) and impervious (IMPLND) fractions. The stream network (RCHRES) links the surface runoff and groundwater flow contributions from each of the land segments and subbasins and routes them through the water bodies using storage routing techniques. The stream model includes precipitation and evaporation from the water surfaces, as well as flow contributions from the watershed, tributaries and upstream stream reaches. Flow withdrawals can also be accommodated. The stream network is constructed to represent all the major tributary streams, as well as different portions of stream reaches where significant changes in water chemistry occur.

Advantages to choosing LSPC for this application include:

- LSPC simulates all the necessary constituents and applies to different land use types.
- It is capable of simulating both stream and simple lake processes.
- A comprehensive modeling framework using the proposed LSPC approach facilitates development of TMDLs not only for this project but also for potential future projects to address other impairments throughout the basin.
- The time-variable nature of the modeling enables a straightforward evaluation of the cause-effect relationship between source contributions and water body response and direct comparison to relevant water quality criteria.
- The proposed modeling tools are free and publicly available. This is advantageous for distributing the model to interested stakeholders and amongst government agencies.

- The model simulates both surface and subsurface impacts on flow and water quality.
- LSPC provides storage of all geographic, modeling and point source permit data in a Microsoft Access database and text file formats to provide for efficient data manipulation.
- LSPC presents no inherent limitations regarding the size and number of watersheds and streams that can be modeled.
- LSPC provides post-processing and analytical tools designed specifically to support TMDL development and reporting requirements.

The watershed model represented the variability of nonpoint source contributions through dynamic representation of hydrology and land practices. The watershed model included all point and nonpoint source contributions. Key components of the watershed modeling included:

- Watershed segmentation
- Simulation period
- Soils
- Meteorological data
- Reach characteristics
- Land use representation
- Point source discharges
- Hydrologic representation
- Observed flow data
- Hydrology calibration and validation
- Temperature modeling
- Sediment modeling
- Fecal coliform modeling
- Nitrogen modeling
- Five-day biochemical oxygen demand (BOD5) /dissolved oxygen (DO) modeling
- Model limitations

The hydrologic representation and the hydrology calibration and validation are presented in Chapter 3. The water quality representation and the water quality calibration and validation are presented in Chapter 4.

2.2 WATERSHED SEGMENTATION

LSPC was configured to simulate the Gills Creek watershed as a series of hydrologically connected subbasins. The spatial subdivision of the watersheds allowed for a more refined representation of pollutant sources and a more realistic description of hydrologic factors. Each subbasin was modeled as a defined land area draining to a single waterbody (stream or lake), with land area made up of modeled land uses. The output from LSPC is for the most downstream point of each subbasin (sometimes referred to as the “pour point”).

The delineated subbasins from Richland County’s HSPF model were the basis for further delineation at the USGS flow gage (USGS 02169570) and SCDHEC water quality assessment points. Wild Cat Creek, which is a tributary to the lower segment of Gills Creek, was also separated into an individual watershed to ensure more accurate flow response/timing and pollutant loadings to Gills Creek. The delineation was conducted by hand digitizing using grid-based national elevation data (NED) (10 m by10 m) and the National Hydrography Dataset (NHD) stream line and waterbody coverage. The final delineation of the Gills Creek watershed with NED data for the LSPC model is shown in Figure 2-1.

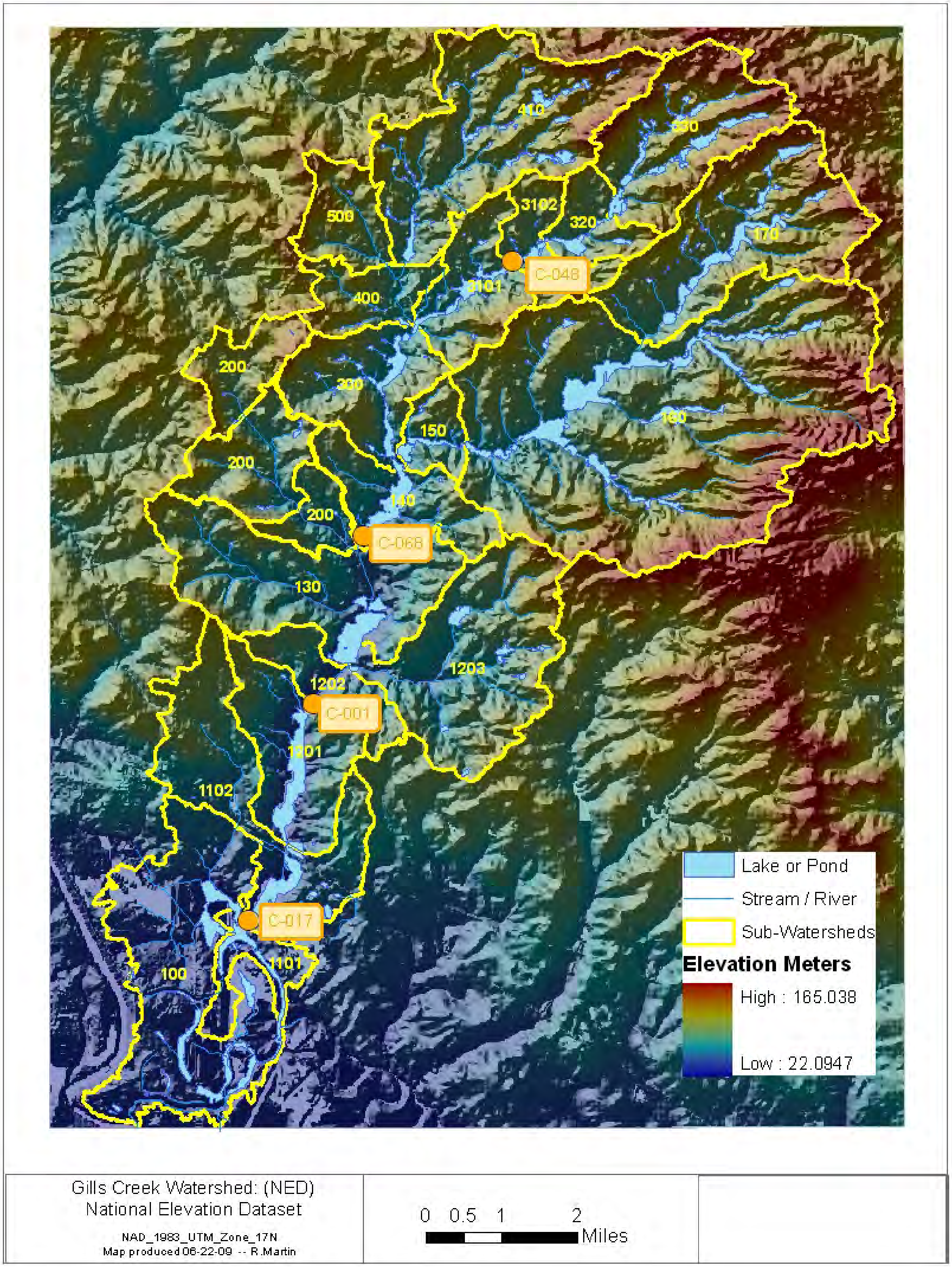


Figure 2-1. Subbasin delineations.

Table 2-1, lists the USGS flow gage and SCDHEC water quality assessment points used in calibration and validation of the Gills Creek watershed model.

Table 2-1. Monitoring stations in the Gills Creek Watershed

Station ID	Station Description	Impairment
C-017	Gills Creek at SC48	Dissolved Oxygen and Fecal Coliform
C-001 / USGS 02169570	Gills Creek at US76	Fecal Coliform
C-068	Forest Lake downstream of dam	None
C-048	Windsor Lake Spillway on Windsor Lake Blvd. (Jackson Creek)	Dissolved Oxygen

2.3 SIMULATION PERIOD

The LSPC model was simulated for a 7-year period from January 1, 1998, through December 31, 2004. This simulation period was chosen to correspond with Richland County's HSPF model. This time period was originally selected because it captured a drought year (2001) and a wet year (2003) and represented all the hydrologic conditions that could affect pollutant generation/loadings. To stabilize the hydrologic and water quality component of the model, the model was run for a full year (1997) before the simulation period as a "spin-up" period.

2.4 SOILS

Soil data for the Gills Creek watershed were obtained from the U.S. Department of Agriculture's (USDA) State Soil Geographic (STATSGO) database. The STATSGO data show that there are five soil types in the watershed. Based on the data, the hydrologic soil groups in the Gills Creek watershed can be categorized as mainly group B (Figure 2-2). A small portion of the lower end of the watershed is categorized as group D. Hydrologic group B soils have moderate infiltration rates when thoroughly wetted. The USDA soil textures normally included in this soil group are silt loam and loam. The transmission rate of the soil is usually between 0.38 to 0.76 cm/h (Maidment 1993). Group D soils have high runoff potential. They have low infiltration rates when thoroughly wetted. USDA soil textures normally included in this group are clay loam, silt clay loam, sandy clay, silty clay and clay. These soils have a low transmission rate of 0 to 0.13 cm/h (Maidment 1993).

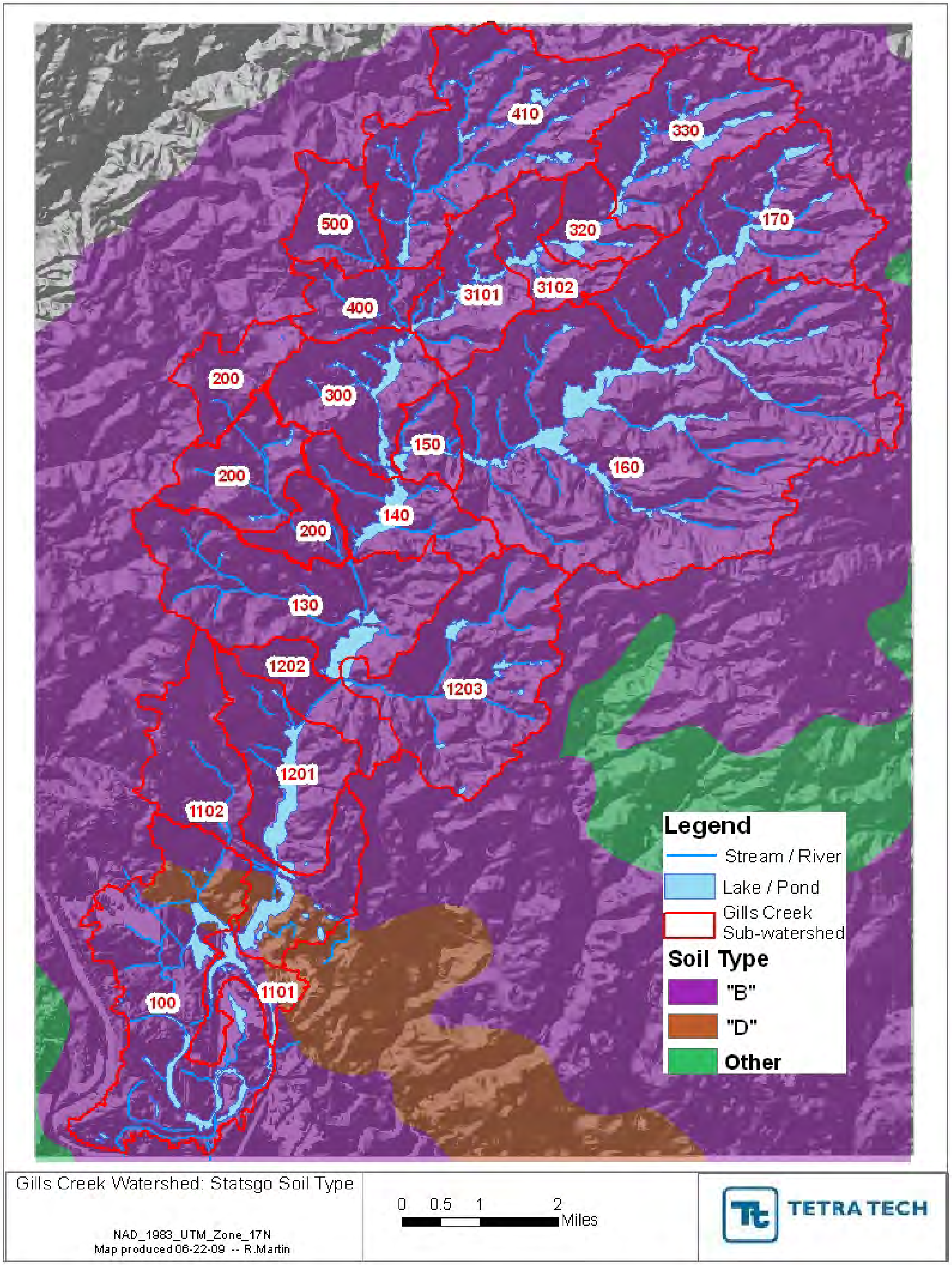


Figure 2-2. Hydrologic soil groups.

2.5 METEOROLOGICAL DATA

The LSPC model is driven by precipitation and other climatological data (e.g., air temperature, evapotranspiration, dew point, cloud cover, wind speed, solar radiation). As a result, meteorological data are a critical component of the watershed modeling effort. Appropriate representation of precipitation, wind movement, solar radiation, potential evapotranspiration, cloud cover, temperature, and dew point are required to develop a valid model. Ideally, these data should be represented on an hourly time step to allow the model to better predict hydrologic response. The most critical inputs are precipitation, air temperature, solar radiation, and potential evapotranspiration. Table 2-2 shows the available weather stations.

Table 2-2. Available Weather Stations Near Gills Creek Watershed

Available Weather Stations
Cedar Creek (rainfall station)
University of South Carolina (rainfall station)
Sandhill Research Elgin (rainfall station)
Columbia Metro Airport (climatological data)

Of the four available stations, two stations previously used for Richland County’s HSPF model were also chosen to be used for LSPC modeling. One of these stations is the National Oceanic and Atmospheric Administration’s (NOAA) Columbia Metropolitan Airport weather station (KCAE) located approximately 11 miles southwest from the centroid of the Gills Creek watershed (Figure 2-3). The other station chosen for modeling is the Sandhill Research Elgin weather station located approximately 8.5 miles northeast from the centroid of the Gills Creek watershed (Figure 2-3). The reasons these two stations were selected as rainfall stations for modeling are described in a technical memorandum, “Water Quality Evaluation of the Gills Creek watershed, Richland County, SC” (Wagner 2007) as follows.

> *Of these, only the Columbia Metro Airport had hourly rainfall records, while the others had daily rainfall records. Because hourly records are more desirable for water quality simulation, the Columbia Metro Airport data were considered the best source initially. However, comparison of the rainfall at that gage showed it was significantly different than the rainfall at the other gages, and the annual rainfall totals at the gage did not seem reasonable when compared to the streamflow measured at the USGS gage in the watershed. Ultimately, the Sandhill Research gage records were used as the input to the HSPF model.*

The following paragraph , extracted from the same document, explains how other climatological data were processed. The same climatological data set used for the HSPF was also used for LSPC modeling.

> *Sandhill Research gage records were used as the precipitation data input to the HSPF model. A disaggregation approach included in the WDMUtil utility program was used to convert daily rainfall to hourly rainfall records. The dissagregation used daily Sandhill rainfall and the hourly distribution of rainfall at the Metro Columbia Airport. The PET input to HSPF was developed using another WDMUtil computing option that estimates PET as a function of minimum and maximum daily temperature, station latitude, and monthly coefficients. Hourly values from the Metro Columbia Airport were used directly for air temperature, dew point temperature, and wind speed. Cloud cover values were estimated based on sky condition data from the airport gage. Solar radiation data were estimated using a WDMUtil option that computes solar radiation as a function of cloud cover and latitude.*

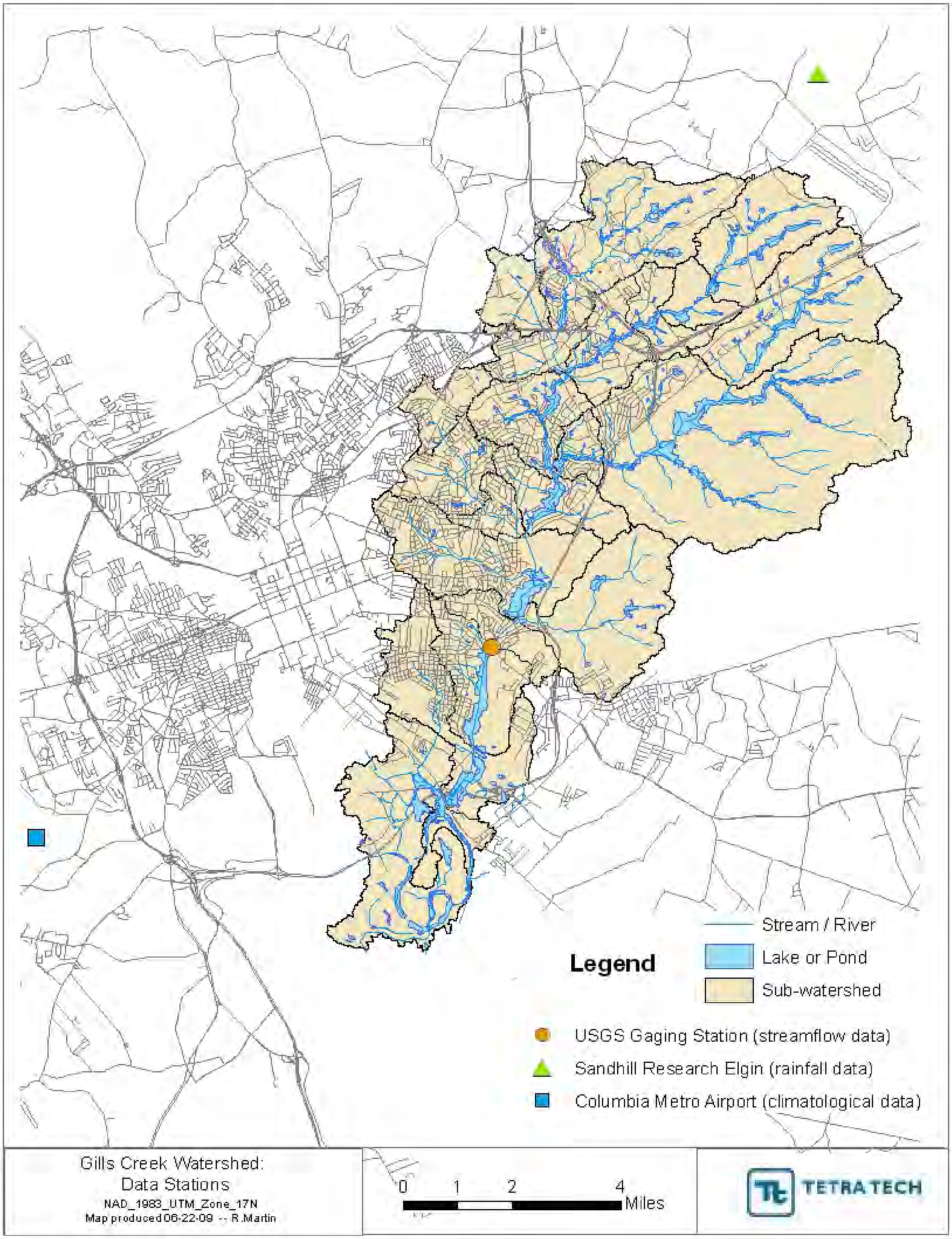


Figure 2-3. Location of meteorological stations used in the Gills Creek watershed model.

2.6 REACH CHARACTERISTICS

LSPC was configured to model streams and lakes in the Gills Creek watershed. Each subbasin in LSPC was represented with a single stream assumed to be a completely mixed, one-dimensional segment with a trapezoidal cross section (Figure 2-4). Input parameters for the reaches include initial depth, length, depth, width, slope, Manning's roughness coefficient, and coefficients to describe the shape of the stream channel. The methodology for determining these parameters is described below:

- IDEPTH (reach initial water depth) – Assumed to be half the bankfull depth.
- LENGTH (reach length) – Determined from the National Hydrography Dataset (NHD) medium-resolution stream reach network (available online at http://nhd.usgs.gov/).
- DEPTH (reach bankfull depth) – Reach bankfull depth values were estimated based on equation 1 (below). The default coefficients used for "a" and "b" were: a = 1.4995, b=0.2838.

$$eq.1 : BankfullDepth(ft) = a \times (WatershedArea)^{b}$$

- WIDTH (reach bankfull width) – Reach bankfull width values were estimated based on equation 2. The default coefficients used for "c" and "d" were c=14.49, d=0.4.

$$eq.2 : BankfullWidth(ft) = c \times (WatershedArea)^{d}$$

- SLOPE (reach slope) – Calculated based on elevation data from the USGS 10-meter National Elevation Dataset (USGS 2009).
- MANN (Manning's roughness coefficient for the stream channel) – Estimated coefficient of 0.02 was applied to each representative stream reach based on typical literature values (Schwab et al. 1993)
- R1 (reach ratio of bottom width to bankfull width) – 0.5
- R2 (reach side slope of floodplain) – 0.5
- W1 (reach floodplain width factor) – 1.5

This estimation method for reach dimensions was used for only Wild Cat Creek in the Gills Creek watershed. All other streams and lakes were represented using the F-table. The F-table basically describes the hydrology of a river reach or reservoir/lakes segment by defining the functional relationship between water depth, surface area, water volume, and outflow in the segment. The relationship described in the F-table is independent of the shape of the reach or waterbody; thus, LSPC makes no assumptions regarding the shape of a stream channel. F-table information for all streams and lakes segments, except Wild Cat Creek, was transferred from Richland County's HSPF model. Table 2-3 shows how each reach associated with subbasins was represented in the LSPC model.

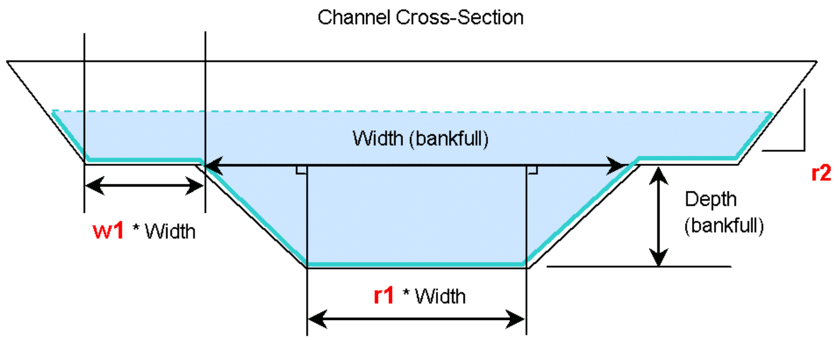


Figure 2-4. Stream channel representation in the LSPC model.

Table 2-3. Reach Representation in the LSPC Model

Modeled Subbasin	Reach Representation
100	Stream
130	Lake
140	Lake
150	Lake
160	Lake
170	Lake
200	Lake
300	Lake
320	Stream
330	Lake
400	Stream
410	Lake
500	Stream
1101	Stream
1102	Lake
1201	Lake
1202	Stream
1203	Stream
3101	Lake
3102	Lake

2.7 LAND USE REPRESENTATION

LSPC requires a basis for distributing hydrologic and pollutant loading parameters. This is necessary to appropriately represent hydrologic variability throughout each watershed, which is influenced by land surface and subsurface characteristics. It is also necessary to represent variability in pollutant loading, which is highly correlated to soil characteristics and land practices.

Land use data used in watershed modeling for the Gills Creek watershed (Table 2-4) were compiled from two land use data sources: Richland County's HSPF modeled land use and the 2001 National Land Cover Database (NLCD) program (Homer et al. 2004). NLCD is developed under a national program overseen by the Multi-Resolution Land Characteristics Consortium, a group of federal agencies that cooperate to create a consistent land cover GIS grid-based product for the entire United States. The 2001 data are based on interpolation of multi-seasonal Landsat satellite images into 30-meter grid cells.

HSPF's modeled land use was used for most of the LSPC subbasins. However, the additional delineation for the new water quality assessment points and the USGS flow gage location required redistribution and processing of the existing HSPF modeled land use. For the subbasins that required modification of the delineation line, the existing modeled land use was redistributed. Modeled land use was reassigned to each new delineated subbasin using NLCD GIS data. NLCD land use categories were combined to match the current HPSF modeled land use categories. The HSPF modeling land use areas were then redistributed using a ratio of the NLCD land use for the new smaller subbasins and the HSPF modeled land use for the original larger watershed.

Table 2-4. LSPC's Land Use Category and Area (Acres)

Sub-basin	Bare Soil	Cultivated	Evergreen Upland Forest	Forested Wetland	Herbaceous	Impervious Urban	Mixed Upland Forest	Non Forested Wetland	Pervious Urban	Sand	Total
100	118	1,476	72	114	115	209	654	799	487	54	4,097
130	110	27	78	90	48	534	601	166	1245	35	2,934
140	73	50	76	16	33	175	279	96	409	36	1,242
150	7	1	15	9	2	89	114	60	207	0	504
160	507	17	2,118	464	595	595	3,831	499	1,388	71	10,085
170	221	3	720	138	216	252	932	150	587	27	3,245
200	124	12	81	34	59	488	538	132	1,138	22	2,626
300	70	6	57	34	19	254	337	133	593	17	1,519
320	8	0	261	57	14	26	230	31	62	0	690
330	201	27	260	64	113	239	550	82	558	87	2,181
400	56	2	36	5	29	183	70	18	427	14	840
410	178	46	284	96	116	532	993	118	1,240	56	3,659
500	51	11	101	29	35	107	237	57	249	7	884
1101	13	171	41	5	83	34	164	19	80	3	614
1102	201	22	53	68	49	538	213	290	1,254	50	2,737
1201	76	4	67	77	25	314	298	120	734	24	1,740
1202	63	23	45	63	18	116	199	99	271	20	917
1203	178	92	169	180	130	446	751	282	1,040	57	3,325
3101	84	2	93	37	20	215	189	87	502	15	1,245
3102	52	2	93	23	43	105	191	54	246	9	820
Total	2,389	1,995	4,719	1,602	1,761	5,451	11,372	3,290	12,718	605	45,902

2.8 POINT SOURCE DISCHARGES

2.8.1 Continuous Discharge Point Sources

Facilities permitted under the National Pollutant Discharge Elimination System (NPDES) are, by definition, considered point sources. The NPDES GIS coverage provided by SCDHEC was adopted as the starting point for the evaluation of point sources for the Gills Creek watershed model. Figure 2-5 shows the locations of continuous NPDES discharge locations. Table 2-5 lists the names of the continuous NPDES dischargers and available DMR data and permit limits.

Table 2-5. Summary of Continuous Point Source Discharges to the Gills Creek Watershed

Name	NPDES ID	Waterbody	Current Status	Dates during Model Period for Which Data Are Available	Chemical Permit Limits
Amphenol Corporation	SC0046264	Ephemeral tributary to Jackson Creek	Active	01-31-97 through 12-31-04	Trichloroethene – 0.005 mg/L daily maximum 1,1-Dichloroethylene[1] – 0.007 mg/L daily maximum pH – within 6.0 to 8.5 daily Must monitor and report 6 other organic chemicals.
Aramark Uniform Services	SC0046566	Tributary to Tributary G-1	Inactive	No data available.	BOD5 – 10.0 mg/L daily average and 20 mg/L daily maximum pH – within 6.0 to 8.5 daily Limits for 7 organic chemicals
Central Products[2]	SCG250180	Gills Creek	Active	01-31-97 through 12-31-04	*Following 10-31-98:* The previous limits as stated below. TDS – 500 mg/L daily maximum (if boiler blowdown is discharged) Total residual chlorine – calculated based on flow using equation in permit. *On or prior to 10-31-98:* Water temperature – 90 degree F daily max BOD5 – 20 mg/L daily maximum TSS – 40 mg/L daily maximum pH – within 6.0 to 8.5 daily
Fort Jackson	SC0003786 – Pipe 002	Wildcat Creek	Inactive	01-31-97 through 03-31-98	Total organic carbon – 110 mg/L daily maximum Oil and Grease – 10 mg/L monthly average and 15 mg/L daily maximum pH – within 6.0 to 8.5 daily
Fort Jackson	SC0003786 – Pipe 004	Wildcat Creek	Inactive	03-31-97 through 03-31-98	Total organic carbon – 110 mg/L daily maximum Oil and grease – 10 mg/L monthly average and 15 mg/L daily maximum pH – within 6.0 to 8.5 daily
Fort Jackson[3]	SC0003786 – Pipe 006	Lake Katherine	Inactive	09-30-97 through 09-30-04	Total organic carbon – 110 mg/L daily maximum Oil and grease – 10 mg/L monthly average and 15 mg/L daily maximum pH – within 6.0 to 8.5 daily
Fort Jackson[3]	SC0003786 – Pipe 007	Gills Creek	Inactive	09-30-97 through 12-31-04	Total organic carbon – 110 mg/L daily maximum Oil and grease – 10 mg/L monthly average and 15 mg/L daily maximum pH – within 6.0 to 8.5 daily
Fort Jackson	SC0003786 – Pipe 008	Wildcat Creek	Inactive	03-31-97 through 11-30-97	Total organic carbon – 110 mg/L daily maximum Oil and grease – 10 mg/L monthly average and 15 mg/L daily maximum pH – within 6.0 to 8.5 daily

Name	NPDES ID	Waterbody	Current Status	Dates during Model Period for Which Data Are Available	Chemical Permit Limits
Fort Jackson	SC0003786 – Pipe 009	Gills Creek	Inactive	03-31-97 through 02-28-99	Total organic carbon – 110 mg/L daily maximum Oil and grease – 10 mg/L monthly average and 15 mg/L daily maximum pH – within 6.0 to 8.5 daily
Furon Company/ Helico Components	SC0046418	Unnamed Tributary to Gills Creek	Inactive	01-31-97 through 06-30-97	12 chemical parameters including: BOD5 – 10 mg/L monthly average; 20 mg/L daily maximum TSS – 30 mg/L monthly average; 60 mg/L daily maximum pH – within 6.0 to 8.5 daily
Tenneco Direct Service Station	SC0043770	Eight Mile Branch	Inactive	03-31-97 through 03-31-97	BOD5 – 10 mg/L monthly average and 20 mg/L daily maximum pH – within 6.0 to 8.5 daily Lead – 0.05 mg/L daily maximum Limits for 12 organic chemicals.

1 Parameter was dichloroethene through 6-30-98.

2 Formerly Intertape Polymer Group, SC0002101

3 On 10-27-08, NPDES permit SC0003786 was cancelled. Certification (#SCR001892) was issued by SCDHEC for these Fort Jackson outfalls 006 and 007 under the industrial stormwater general permit SCR000000. Therefore, after 10-27-08, these two outfalls were no longer classified as continuous point sources; they are non-continuous point sources.

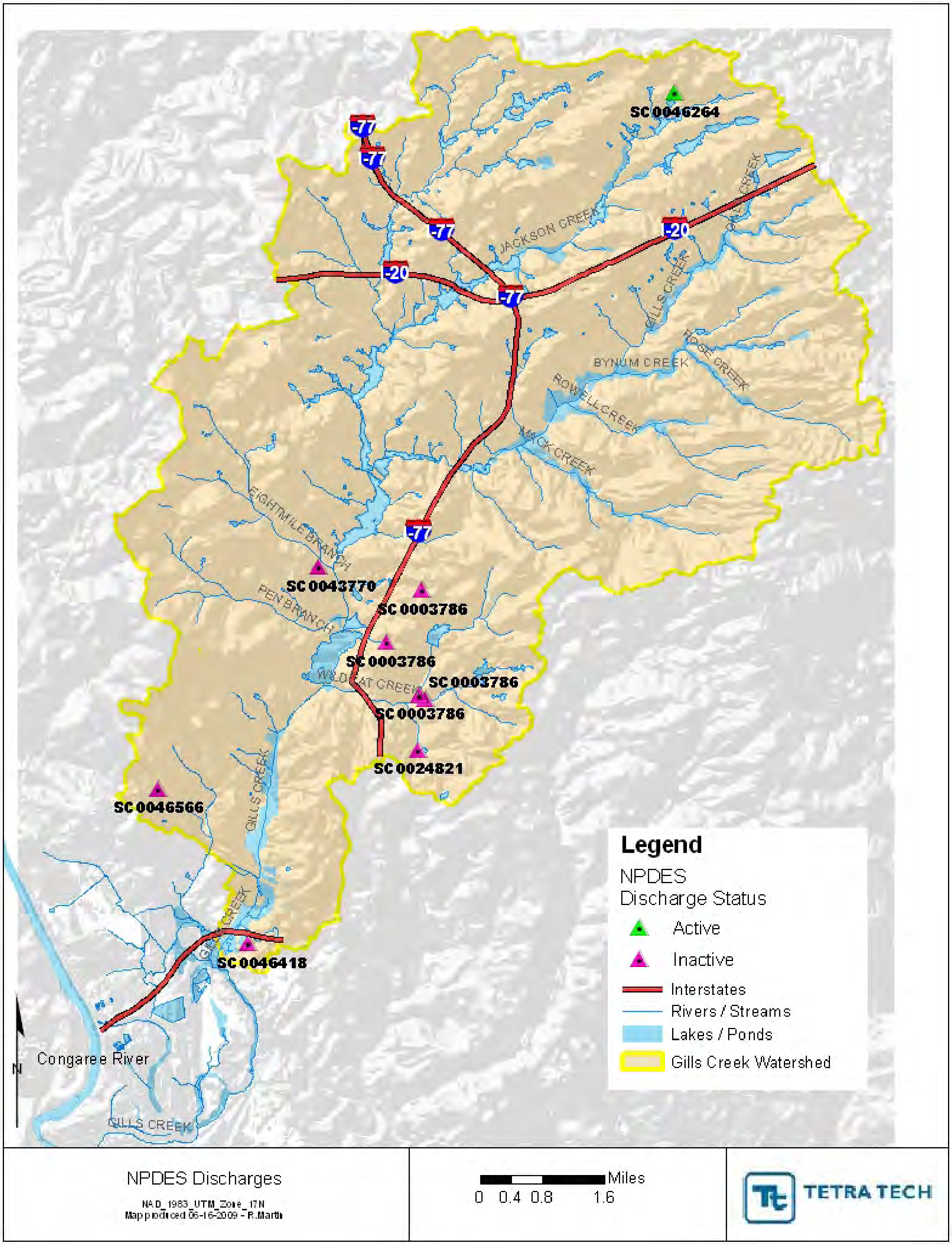


Figure 2-5. Continuous Permitted Discharges to the Gills Creek watershed

2.8.2 Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) can also be considered point source discharges for modeling because the outlets are defined at their specific location and they flow directly into streams. Table 2-6 shows each SSO occurrence, by subbasin, and its discharged volume. The information is based on DHEC incident data available at the time of model development.

Table 2-6. SSO Occurrence Locations and Discharged Volume Used in Modeling

Subbasin	Volume (gallons)
100	550
130	216,000
200	22,700
400	500
1101	4,000
1102	325
1201	2,000
1202	500
1203	11,500

2.8.3 Failing Septic Systems

The loadings from failing septic systems were also treated as point source discharges in LSPC; the loadings were directly added to streams. Details of the methods used to estimate loadings are documented in the TMDL source assessment (SCDHEC 2009). Table 2-7 shows the estimated septic flow reaching each modeled subbasin.

Table 2-7. Estimation of Septic System Failures and Their Flows

Subbasins	Number of Failing Septic Systems	Total Number of People Served	Septic System Flow (cfs)
100	13	39	0.004232
130	3	9	0.000977
140	2	6	0.000651
150	1	3	0.000326
160	11	33	0.003581
170	8	24	0.002604
200	2	6	0.000651
200	3	9	0.000977
200	1	3	0.000326
300	4	12	0.001302
320	1	3	0.000326
330	3	9	0.000977
400	2	6	0.000651
410	7	21	0.002279
500	2	6	0.000651
1101	8	24	0.002604
1102	31	93	0.010091
1201	20	60	0.006510
1202	10	30	0.003255
1203	37	111	0.012044
3101	3	9	0.000977
3102	2	6	0.000651

3.0 Watershed Hydrology Model

3.1 HYDROLOGIC REPRESENTATION

Watershed hydrology plays an important role in the determination of nonpoint source flow and ultimately nonpoint source loadings to a water body. The watershed model must appropriately represent the spatial and temporal variability of hydrological characteristics within a watershed. Key hydrological characteristics include interception storage capacities, infiltration properties, evaporation and transpiration rates, and watershed slope and roughness. LSPC's algorithms are identical to those in the HSPF.

Initial values for the LSPC hydrological parameters were taken from Richland County's HSPF model. During the calibration process, previously set values for lower zone evapotranspiration (LZETP) in the HSPF model were increased within the recommend range (USEPA 2000) so that modeled flow was better simulated at flow gage, USGS 02169570.

3.2 OBSERVED FLOW DATA

Figures 3-1 and 3-2 show the statistical evaluation of the observed flow. Figure 3-1 presents the trend of flow and rainfall showing the annual average flow (cfs) and annual sum of rainfall (in) from 1998 through 2004. As the figure shows, the lowest annual rainfall was recorded in 2001 and the highest annual rainfall record was observed during 2003. Not surprisingly, the average flow trends also follow the rainfall patterns. The highest average flow was recorded in 1999 and the lowest average flow occurred during 2001. Although the average flow during 1999 was the highest, the coefficient of variation (CV) was among the lowest values for the 7-year period. This shows that the flow variance during 1997 was small, which indicates that the differences between high and low flow conditions were relatively small compared with the high CV in 2004.

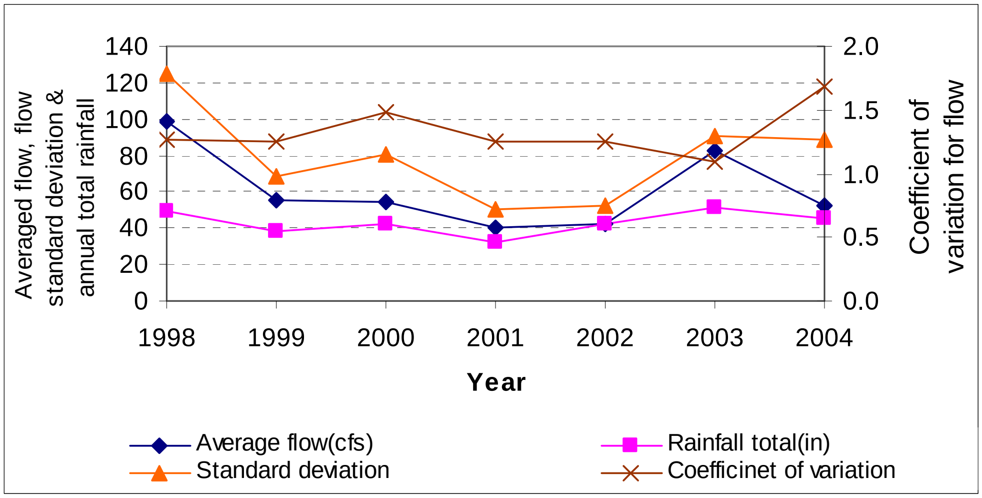


Figure 3-1. Flow (USGS 02169570) and rainfall (Sandhill Research Elgin) statistics.

Figure 3-2 and Table 3-1 shows the result of Richard Baker's flashiness index for each year (Baker 2004). The index reflects the frequency and rapidity of short-term changes in stream flow, especially during runoff events. Flashiness is an important component of a stream's hydrologic regime. A variety of land use and land management changes can lead to increased or decreased flashiness. The index is calculated by dividing the path length of flow oscillations for a time interval (i.e., the sum of the absolute values of day-to-day changes in mean daily flow) by the total discharge during that time interval. The trend line of the index value shows the upward trend. This could be an indication of land use changes within the Gills Creek watershed and also could be a sign of urban development over the years.

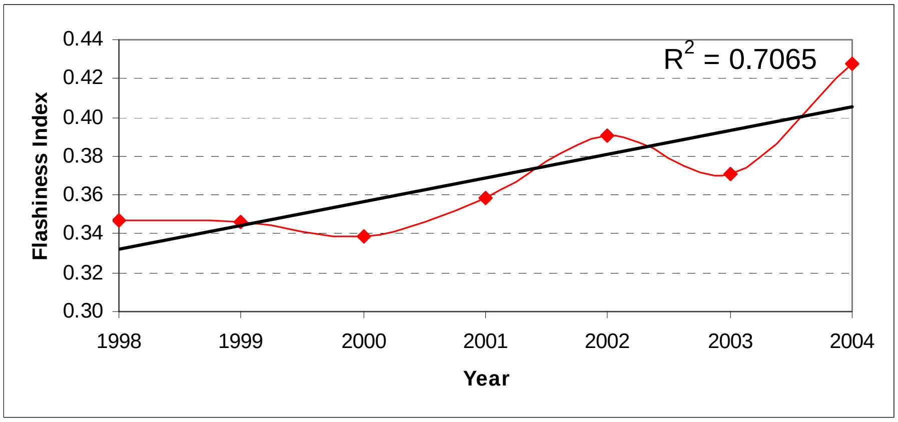


Figure 3-2. Yearly flashiness index from flow (USGS 02169570).

Table 3-1. Yearly Flashiness Index Results

Year	Flashiness
1998	0.35
1999	0.35
2000	0.34
2001	0.36
2002	0.39
2003	0.37
2004	0.43

3.3 HYDROLOGY MODEL CALIBRATION

Calibration is defined as "the process of adjusting model parameters within physically defensible ranges until the resulting predictions give the best possible fit to the observed data" (USEPA 2003). For LSPC, calibration is required for both hydrology (flow) and water chemistry. It is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values at specified locations in a watershed. Calibration is required for parameters that cannot be deterministically and uniquely evaluated from topographic, climatic, physical and chemical characteristics of the watershed and compounds of interest. Because these characteristics vary throughout a watershed, calibration usually occurs at more than one site. Also, calibration typically covers several years to capture a variety of climatic conditions. The calibration procedure results in parameter values that produce the best overall agreement between simulated and observed values throughout the calibration period.

Several different methods were employed to judge the adequacy of the model fit to the observed data. The hydrologic calibration followed the standard operating procedures for the model described in Donigian et al. (1984) and Lumb et al. (1994). Daily, monthly, seasonal, and total modeled flows were compared to observed data, and error statistics were calculated for the percent difference (i.e., [Modeled – Observed]/[Observed] *100). The percent errors were then compared to recommended tolerance targets from Donigian et al. (1984) and Lumb et al. (1994). Tolerance targets for the flow simulation were modified slightly from the literature values to better assess the Gills Creek watershed calibration.

Donigian et al. (1984) and Lumb et al. (1994) recommend seasonal targets (e.g., spring, summer) of ±30 percent; the targets are shown in Table 3-2. Model results were also visually compared to observed data, and daily and monthly data were plotted as scatter plots with regression analyses.

Table 3-2. Recommended Criteria for the Gills Creek Watershed Hydrology Calibration

Category	Recommended Criteria (%)
Error in total volume	**±10**
Error in the mean of the 10% lowest flows	**±10**
Error in the mean of the 10% highest flows	**±15**
Error in monthly volumes	**±30**
Error in growing season volumes	**±30**
Error in non-growing season volumes	**±30**

Source: Modified from Lumb et al. 1994 and Donigian et al. 1984.

Results of the hydrologic model calibration are presented in Appendix A.

3.4 HYDROLOGY MODEL VALIDATION

An important step of the modeling process is model validation. Model validation is the process of taking the hydrological parameters that have been calibrated, applying those parameters to other watersheds, and comparing the simulated flow to measured flow from a USGS stream gaging station for the same period. Model validation is sometimes called model verification because it essentially validates or verifies that hydrological parameters calibrated in one watershed will produce acceptable results in another watershed. When selecting watersheds to perform validations, it is important that those watersheds represent a wide variety of land uses as well as drainage areas. This helps to ensure that the hydrological parameters that were calibrated apply to a wide range of conditions. The validation of the hydrological parameters was performed for 2001 through 2004. Results of the model validation are presented in Appendix A.

4.0 Water Quality Model Calibration and Validation

4.1 CALIBRATION AND VALIDATION PERIOD

The periods of water quality model calibration and validation were selected to correspond with the hydrology calibration and validation periods—calibration from 1998 through 2001, validation from 2002 through 2004. The selection of the two periods was determined based on the available water quality data and an ability to evaluate critical conditions under wet and dry weather conditions within the 7-year time span.

4.2 MODELED PARAMETERS

The LSPC water quality model was set up to model water temperature, DO, BOD5, total nitrogen (TN), ammonia (NH3), nitrate+nitrite (NOx), total suspended solids (TSS) and fecal coliform bacteria. Phytoplankton and benthic algae were not modeled due to data unavailability. As a result, DO was simulated with an assumption that carbon biochemical oxygen demand (CBOD) and nitrogen biochemical oxygen demand (NBOD) were the only biogeochemical reactions affecting DO concentration in the Gills Creek watershed, and the daily net oxygen production/deficit from algal activities due to respiration and photosynthesis in water bodies was assumed to be zero.

4.3 WATER TEMPERATURE

In-stream temperature is an important parameter for simulating biochemical transformations and DO. Because temperature plays an important role in all water quality constituents, it was the first water quality constituent calibrated after hydrology.

Soil temperatures are simulated using three layers. The surface layer is the portion of the land segment that affects overland flow water temperature. The upper subsurface layer affects interflow temperature, while the groundwater subsurface layer affects groundwater temperature. The upper-layer temperature was estimated by a regression equation as a function of air temperature. The groundwater subsurface temperature was supplied directly as temperature. All values for all layers were input into the model as monthly values. LSPC also considers the effect of radiation on stream temperature. A stream can either gain or lose heat due to atmospheric conduction and short- and long-wave radiation. The results of the temperature calibration/validation are provided in Appendix B.

4.4 SEDIMENT

Important aspects of sediment modeling within a watershed system include the following:

- Loading and erosion sources
- Delivery of these eroded sediment sources to streams, drains and other pathways
- Subsequent in-stream transport, scour and deposition processes.

High concentrations of sediment in streams and lakes are not only a problem for aesthetic reasons and for keeping healthy benthic biology. Concentrations of sediment are also critical because sediment provides surfaces for pollutants to be adsorbed and transported downstream. For these reasons, estimating sediment loadings to streams and simulating sediment in-stream behavior are an important initial step in water quality calibration. Sediment calibrations in the LSPC model can be divided into two processes: (1) estimating sediment delivery parameters from the landscape and (2) adjusting parameters to represent in-stream transport mechanisms.

One of the uncertainties for modeling sediments with a watershed model is to predict reasonable upland sediment loading rates from different land uses represented in the model. The upland loadings can be obtained from local studies, previous modeling results from the area, or literature values. For the Gills Creek watershed, local studies were sought at first. However, no specific studies were found, and EPA's

Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) was selected to set estimating target (or expected) sediment loading rates from the landscape. STEPL employs algorithms to calculate nutrient and sediment loads from different land uses. The tool computes surface runoff and sediment delivery based on various land uses. The surface runoff was estimated using curve numbers and local weather data. The land uses considered in the tool are urban land, cropland, pastureland, feedlot, forest, and sand and bare soil type. In the tool, the annual sediment load (from sheet and rill erosion only) is calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio.

To derive more site-specific sediment loading rates from STEPL, K-factors (erodibility factors) and the area of each land use for all subbasins were updated with the specific data from the Gills Creek watershed. The local K-factors were originally obtained from the STASGO database and then modified by a weighted average of land use and K-factor within each subbasin. The estimated range of derived K-factors was from 0.1 to 0.3, with higher K-factors close to the outlet of the Gills Creek watershed. The crop management factor (C-factor) for sand and bare soil was assigned as 1, with an assumption of no covering management. Any other parameter values assigned in the tool were either built-in local NRCS data or built-in default literature values, and those values remained unchanged during the calculation process. Because LSPC's modeled land use categories were different from STEPL's land use categories, reassignment of the modeled land use categories was necessary. Table 4-1 shows the LSPC land use grouping to match land uses provided in STEPL.

Table 1. Table 4-1. Matched Land Use between LSPC and STEPL

LSPC Modeled Land Use	STEPL Land Use
Non-Forested Wetland	Wetland
Forested Wetland	Wetland
Evergreen Upland Forest	Forest
Cultivated	Crop
Mixed Upland Forest	Forest
Herbaceous	Pasture
Bare Soil	Soil & Sand
Sand	Soil & Sand
Pervious Urban	Urban
Impervious Urban	Urban

Estimated annual unit area field loading rates (before applying sediment delivery ratio) from the tool were compared to the ones from LSPC to verify that the assigned erosion-related model parameters were reasonable. The comparison results are shown in Figure 4-1.

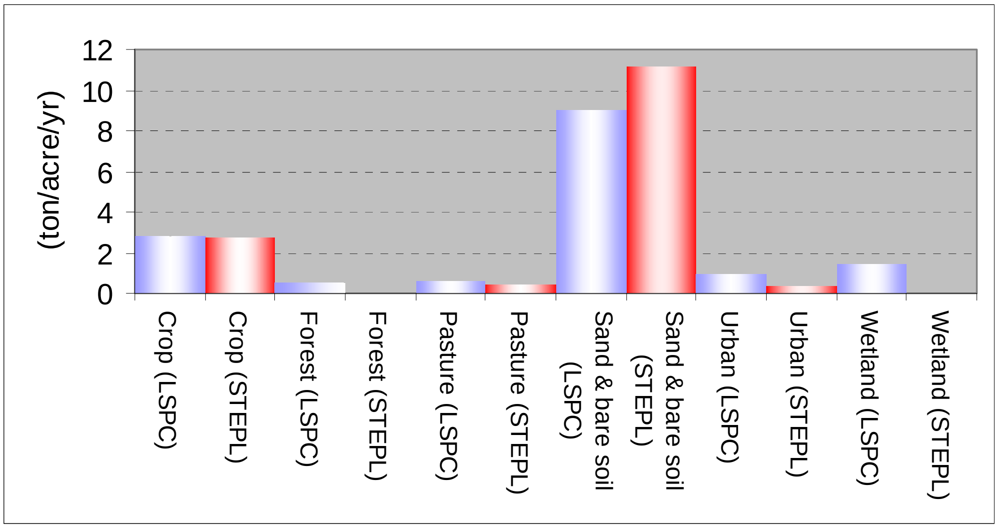


Figure 4-1. Sediment unit area loading rates from LSPC and STEPL.

Once all of the upland sediment loading parameters in LSPC were established and calibrated to the unit area loading rates from STEPL, the calibration moved on to representing in-stream sediment processes. Upland sediment loading in LSPC is represented as single model-represented sediment, but it is split into more specific sand, silt and clay components when the sediment is transferred to the stream. Relative contribution of sand, silt and clay (40%:40%:20%) were estimated as loam from STATSGO data. The USLE estimates field sediment loadings to address sediment loadings that are ultimately delivered to the receiving stream. The trapping factor of 0.96 was determined during the calibration process. The trapping factor represents the sediment that was not transported to the modeled reach or was deposited to the streambed in smaller streams (streams of lower order) that are not explicitly represented in the LSPC model.

In addition to the nonpoint sources represented by land-based sediment loadings, SSO sediment loadings were added directly into streams as a point source. The estimated sediment concentration was assumed to be the same as that of raw domestic sewage, and the literature value of 200 mg/L was used (USEPA 1997). The SSO incident information provided by SCDHEC was used to determine subbasins where SSOs had occurred. SSO discharges were reported as gallons without any time unit associated with the data; thus, the recorded SSO volumes were assumed to be a daily sum of SSO flow discharges.

For the sediment to reach the streams from nonpoint sources and be added as point sources, in-stream sediment calibration was conducted using parameters related to scour and deposition and the results were compared with in-stream solids (mg/L) data. Physical characteristics of sediment particles and other calibration parameters were selected from the ranges provided in EPA’s BASINS technical note No 8 (USEPA 2006).

The results of sediment calibration/validation are provided in Appendix B.

4.5 FECAL COLIFORM

Simulation of fecal coliform bacteria concentrations often presents a challenge for watershed modelers. Observed concentrations tend to be highly variable in both space and time due to natural variability and analytical uncertainty. Furthermore, in-stream concentrations may be elevated by sources that are not explicitly included in the model (e.g., waterfowl, uncounted wildlife, illicit connections to storm sewers, or illegal dumping into storm drain systems) or by sources that are included in the model in a general way but have large and unmonitored variability (e.g., occasional loads from wastewater pumping station spills or malfunctioning septic tanks). The watershed models represent average loads from the land surface as a wash-off process. In addition, background loading is represented as a groundwater concentration.

The basis for setup of bacteria export from land surfaces was EPA's Fecal Coliform Loading Estimation spreadsheet tool. During the calibration process, however, the source represented in the tool was found to be significantly underestimating the observed fecal coliform conditions in streams. Thus, during the model calibration process, the accumulation loadings from urban land use were increased and modified. Table 4-2 shows the accumulation and buildup limits derived from the tool and the updated values selected during the calibration process.

Table 4-2. Original and Updated ACQOP and SQOLIM Parameters for Fecal Coliform in LSPC

	Original Urban Pervious	Original Urban Impervious	Updated Urban Pervious	Updated Urban Impervious
Accumulation rate(#/ac/day)	8.50E+06	8.50E+06	1.28E+10	8.50E+08
Buildup limit (#/ac)	1.28E+07	1.28E+07	1.275E+11	8.50E+09

The assumptions and best professional judgment used during this adjustment were as follows:

- According to Figure 4-2, the cumulative land use distributions at the two assessment points impaired for fecal coliform (C-017 and C-001) show the majority of the modeled land uses were mixed upland forest and pervious urban land uses.
- The majority of the forest land use is located in the upper northeast of the Gills Creek watershed. Due to the longer travel time from the clustered forest area to the assessment points, the loading impact of fecal coliform from the forest area would be small due to bacteria die-off.
- The limited available wildlife data used for the tool does not support the large loadings from forest land use.
- Pervious urban is the land use with the largest area at these assessment points. These pervious urban land use areas are in close proximity to nearby streams, so there are fewer opportunities for the die-off mechanisms to take effect and reduce fecal coliform concentrations.

Observed concentrations of fecal coliform bacteria in-stream are strongly affected by the die off rate of fecal coliform bacteria. Die-off rates are increased by a variety of factors, including temperature, sunlight, salinity, settling, and predation. Based on trial and error, a loss rate of 0.6 per day appeared to provide a reasonable fit to observations.

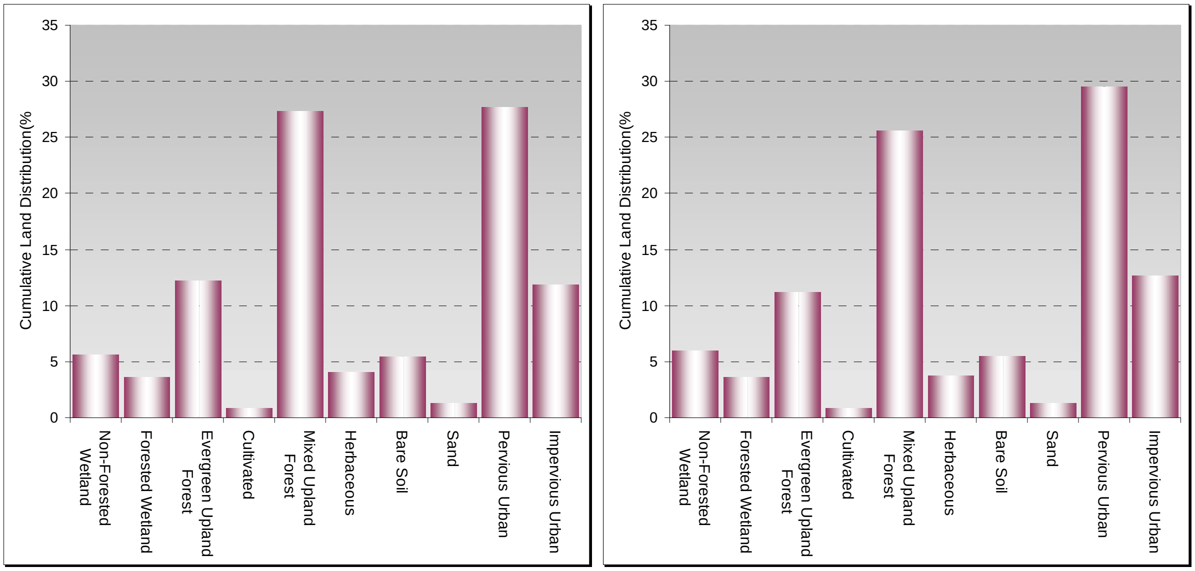


Figure 4-2. Cumulative land use distributions at C-017(left) and C-001(right).

Sorption to sediment might also play an important role in observed fecal coliform concentrations. It is well established (Thomann and Mueller 1987) that coliform bacteria can be stored in stream sediment, where they experience a lower die-off rate and diffuse back into the water column, resulting in a slower recovery of stream concentrations to baseflow levels after wash-off events. Accordingly, fecal coliform bacteria within stream reaches were simulated as weakly sediment-associated with the silt and clay fraction and simulated as less prone to mortality factors such as light with a lower decay rate while in storage in the streambed.

In addition to the estimated nonpoint sources, point sources were directly added to streams. There were two types of added point sources: SSO fecal coliform loadings and estimated failing septic system-related fecal coliform loadings. There are no continuous NPDES point sources discharging fecal coliform in the Gills Creek watershed. SSO loadings were assigned in the same way as described in the previous sediment section. The concentration assigned for fecal coliform was 8.3×10^6 counts/100 mL based on the available literature value of domestic sewage (Thomann and Mueller 1987). The details of fecal coliform loadings from failing septic systems were provided in the *Gills Creek Fecal Coliform TMDL Source Assessment* (Tetra Tech 2009). Fecal coliform loadings from failing septic systems tend to affect the concentrations during low-flow conditions because they are contributing a larger percentage of the load to the stream at such times. Other loadings that could affect low-flow conditions were loadings associated with interflow and groundwater flows. The fecal coliform concentrations for these flows were adjusted to the observed data during the calibration process.

The results of fecal coliform calibration/validation are provided in Appendix B.

4.6 NITROGEN

Depending on species, nitrogen can be an indirect source or a direct sink for DO. NH3 and nitrate indirectly influence oxygen through consumption and production. BOD reduction due to denitrification is also an indirect source. Direct sinks include nitrification and respiration of algal growth. In the Gills Creek LSPC model, nitrogen loading from upland sources was modeled as TN. Target unit area loading rates of TN for different land uses were estimated by STEPL. The estimated local animal counts (the same counts used in the fecal tool in Section 4.5) were used in STEPL as a part of nitrogen sources. Additional land loadings of TN from different land uses were calculated using default built-in TN values in the tool. The purpose of using STEPL was to estimate relative TN loadings contributions from different land uses. LSPC's surface runoff buildup and wash-off parameters were estimated by comparing the upland loading rates from STEPL as described in the sediment section. A comparison of results between STEPL's and LSPC's TN unit area loading rates is shown in Figure 4-3.

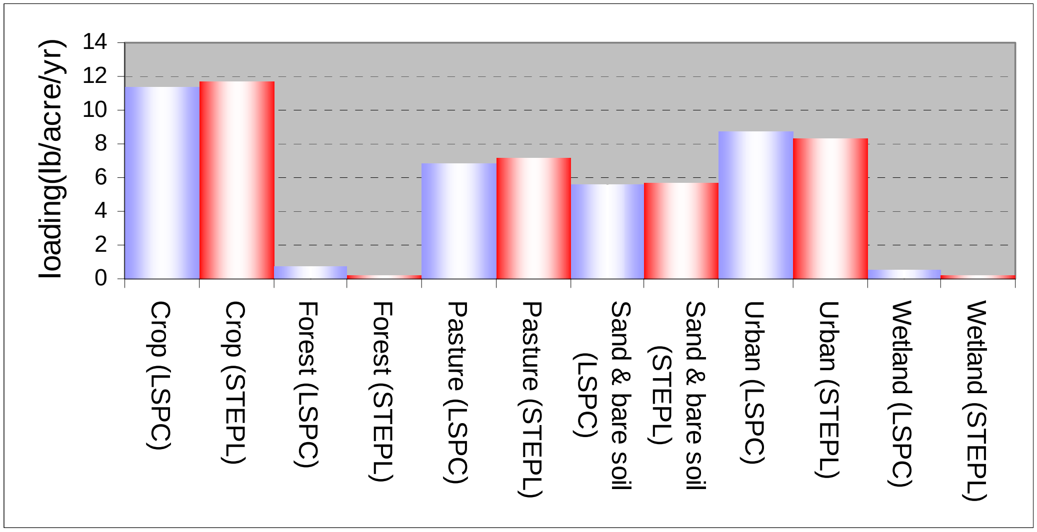


Figure 4-3. Total nitrogen unit area loading rates from LSPC and STEPL.

In LSPC, TN distributes into NOx, NH3, and organic nitrogen (ON) between the land surface to stream reach interface. In the Gills Creek watershed model, NOx and total ammonia were simulated because ON is not directly associated with DO reaction without simulating the PLANKTON routine. Some water quality models require that the simulation of ON as ON contributes to NH3 due to the hydrolysis reaction of ON. In LSPC, this reaction is represented in BOD decay. BOD decay generates nitrogen based on internal ratio and contributes to nitrification and, thus, eventual DO consumption.

Initial distribution ratios of TN between NOx and NH3 were estimated to be 8 percent for NOx and 17 percent for NH3 from in-stream observed data of those nitrogen species. This ratio was modified during the calibration process to 1 percent for NOx and 15 percent for NH3. These selected percentages were still within the percentage ranges for the observed concentrations. Interflow and groundwater could potentially contribute to nitrogen loading, especially NOx loading due to the low adsorption capability of clays and other soil particles. Initial values for seasonal interflow and groundwater concentrations for TN were assigned based on previous LSPC applications in the United States, but they were varied during in-stream calibration to match observed conditions. Subsequently, the assigned monthly TN for interflow and groundwater flow was redistributed into NOx and NH3, assuming that 75 percent of TN was considered ON (mainly dissolved ON). Due to the affinity of positively charged ammonium for clays and other inorganic/organic particles in soil, a higher nitrate ratio was applied to TN for interflow (15 percent for TN, 10 percent for NH3) and groundwater flow (20% of TN, 5% for NH3).

In addition to the estimated nonpoint sources, point sources were directly added to streams. There were three types of the added point sources: continuous NPDES discharges, SSO NH3 loadings and estimated failing septic system NH3 loadings. Discharge monitoring reports were used to simulate continuous NPDES discharges. SSO loadings were assigned in the same way as described in the previous sediment section. The concentration assigned for NH3 was 50 mg/L based on the available literature value for domestic sewage (USEPA 1997). The estimated flows for the failing septic systems were the same as the flows used to derive the fecal coliform loadings in Section 4.6. Nitrate values were estimated to be not significant for the domestic sewage (USEPA 1997); thus, no loadings of nitrate were assigned for these two sources.

Atmospheric nitrogen deposition data were retrieved from the National Atmospheric Deposition Program's (NADP) Web site (NADP 2009). The monthly wet deposition (mg/L) data from 1997 through 2004 were retrieved for ammonium and nitrate from Santee National Wildlife Refuge (SC06) (NADP 2009). The average monthly concentrations for these parameters were calculated using the data and were input into the model. Table 4-3 shows the averaged ammonium and nitrate concentrations added to the model.

Table 4-3. Wet Deposition Included in LSPC Model

Pollutant	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Ammonium(mg/L)	0.16	0.23	0.25	0.29	0.27	0.16	0.19	0.16	0.09	0.17	0.23	0.12
Nitrate(mg/L)	0.95	0.96	1.07	1.11	1.07	1.04	1.4	1.22	0.62	0.67	0.73	0.65

Since the dry deposition data were not available from NADP, Clean Air Status and Trends Network (CASTNET) data were retrieved (CASTNET 2009). The CASTNET station closest to the Gills Creek watershed was the Candor station (CND125) in Montgomery County, North Carolina. The data provided both annual wet and dry areal rates of TN. From this data set, the ratio of dry deposition to wet deposition of TN was estimated to be 0.54. In deriving this ratio, the assumption was made that TN consisted mainly of ammonium and nitrate. This could overestimate the contribution of these two species because ON was not considered. The derived ratio was applied to the available annual wet deposition rates from NADP data to estimate the dry deposition for the Gills Creek watershed. The derived values, 0.0141 lb/acre/day (ammonium) and 0.0729 lb/acre/day (nitrate), were assigned as constant values throughout the modeling period.

Nitrogen species entering into streams were further modified through biogeochemical reactions within the LSPC model. The reactions considered in the model were ammonium sorption to sediment and nitrification/denitrification. The nitrification rate (0.1 /day) and other kinetic rates were selected to be within the ranges of literature values (Bicknel et al. 2001; USEPA 1985, 1997).

The results of nitrogen calibration/validation are provided in Appendix B.

The calibration and validation results for NH3 indicated a good simulation capability of the model. However, the model generally overestimated NOx compared to the observed data. The discrepancy between the modeled and the observed data could mean the current model setups were not representing the processes affecting NOx in the system well. Two processes—algal nitrate uptake and denitrification in the sediment—were not included in the LSPC modeling. Although the model overestimated nitrate concentrations, because the magnitude of the nitrate concentrations was very low, the differences between the observed and modeled were small enough to not significantly affect the current DO modeling.

4.7 DISSOLVED OXYGEN AND 5-DAY BIOCHEMICAL OXYGEN DEMAND CALIBRATION

DO is influenced by oxidation of organic carbon, nitrification, and respiration and replenished by surface exchange and photosynthesis. Oxygen enters the water by reaeration from the atmosphere and by plant photosynthesis. Water temperature also affects DO saturation in streams and lakes. The Gills Creek LSPC model was configured to simulate all of those mechanisms listed above except the respiration and photosynthesis process due to a lack of sampling data.

LSPC simulates BOD5 and DO relations using BOD5 decay rate, BOD5 release from sediment based on aerobic and anaerobic condition of water column, and benthic BOD5 release due to scouring of the sediment. BOD5 simulated in the modeling was assumed to be the labile (non-refractory) and dissolved organic carbon portion of total organic carbon (TOC). Labile particulate organic carbon and dissolved organic carbon have a decomposition time scale of days to weeks and decay rapidly in the water column or sediment bed as opposed to the decomposition time scale of months to seasons for refractory particulate organic carbon (Ji 2007). Thus, labile (non-refractory) and dissolved organic carbon, which can be measured by BOD5, and nitrification of ammonium can be a sink for DO through the decomposition/transformation by bacteria, and their mechanisms were simulated in the Gills Creek LSPC model.

DO contributions from subsurface flows were incorporated into LSPC by assigning monthly DO concentrations from interflow and groundwater flows. The DO concentrations were determined during the calibration processes.

The target area loading rate of BOD5 for different land uses was estimated by STEPL. The estimated local animal counts were used in STEPL as a part of BOD5 sources. Additional land loadings of BOD5 from different land uses were calculated using default built-in BOD5 values in the tool. LSPC's surface runoff buildup and wash-off parameters were estimated by comparing the upland loadings rates from STEPL as described in the sediment section. The comparison results between STEPL and LSPC's BOD5 unit area loadings rates are presented in Figure 4-4.

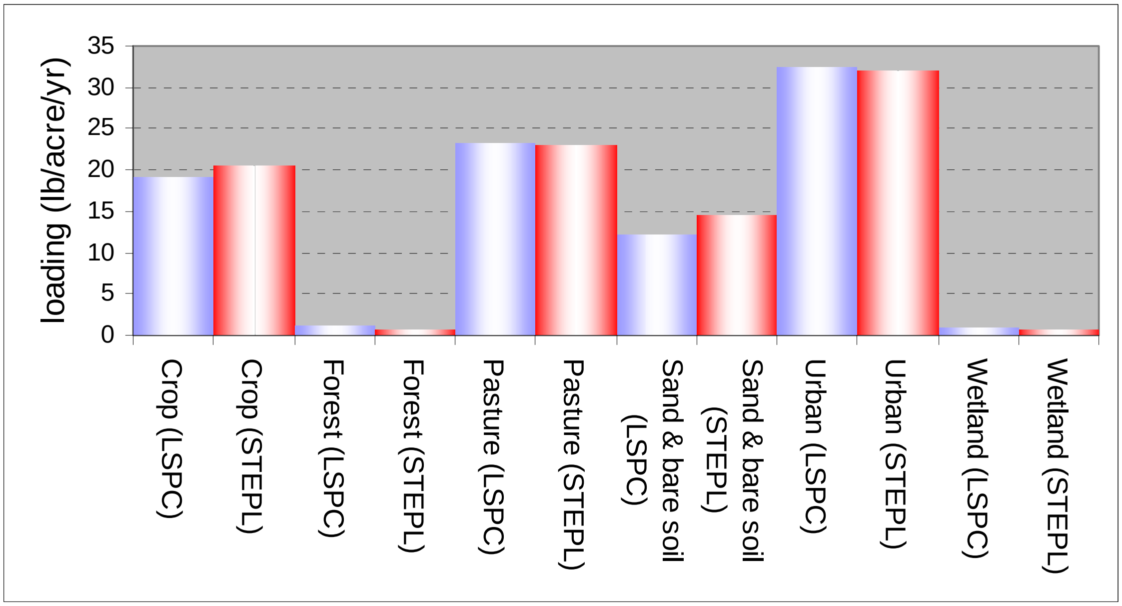


Figure 4-4. BOD5 unit area loading rates from LSPC and STEPL.

BOD5 has been monitored in the Gills Creek watershed using APHA (1998) Standard Method 5210B. This yields estimates of 5-day (short-term) BOD (BOD5) from whole-water samples. The lowest observed BOD5 among the samples was 0.8 mg/L, and the lower-than-detection limit samples were assigned half of the lowest observed value, 0.4mg/L. In-stream calibration efforts for BOD5 were focused on concentrations measured above the detection limit.

LPSC offers user-defined parameters for three main coefficients for reaeration calculation for streams: REAK (empirical constant for reaeration equation (/hour)), EXPREV (exponent to velocity function), and EXPRED (exponent to depth function). These coefficients values were selected to be 0.906 for REAK, 0.67 for EXPREV and -1.85 for EXPRED based on the HSPF manual (USEPA 2001). The basis of the selection was the modeled average depth. All the modeled stream average depths were under or around 2 feet, which was the value suggested in the manual as the selection criterion for the coefficients. The reaeration of the lakes was calculated internally in the model using the modeled depths, the velocities, and the correction factor to the reaeration coefficient for lakes (CFOREA). The value of 1 was selected for CFOREA.

An sediment oxygen demand (SOD) value of 0.9 g O_2/m^2/day was determined during the DO calibration process for all reaches in the model. This value was selected during the calibration processes based on the literature value range provided by Chapra (1997): 0.06 - 2 g O_2/m^2/day of SOD for lakes and by EPA(1997): 0.33 to 1.1 g O_2/m^2/day for southeastern U.S. rivers.

The kinetic rate of carbonaceous BOD decay (0.1 /day for streams and lakes) and other kinetic rates were selected to be within the ranges of literature values (USEPA 1985, 1997; Bicknel et al. 2001).

The results of BOD5 and DO calibration/validation are provided in Appendix B.

DO modeling results at C-068 showed an overestimation of DO deficit during the summer. This might have been caused by not including the activities of algae in the slow-moving lake system in the model. If algae were simulated in the model, oxygen generated by the algal photosynthesis might have offset the simulated DO deficit. In Appendix B, BOD5 observed data at C-068 also shows higher concentrations than the simulated results. It is possible that BOD5 samples during the summers contained algal biomass reflected as higher BOD5 data that were not captured in the modeling.

Figure 4-5 shows the calculated DO saturation values based on the modeled water temperatures, the observed DO, and the simulated DO results at C-068. In Figure 4-5, comparing the observed DO data to the DO saturation values shows some indication of potential DO sinks during the summers.

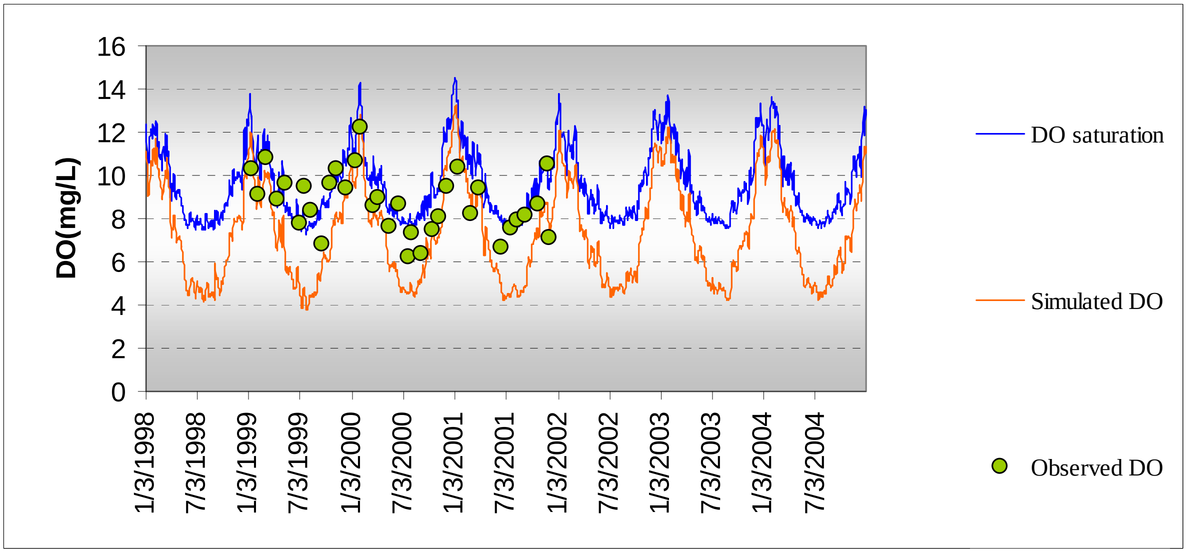


Figure 4-5. Simulated DO, the observed DO data, and calculated DO saturation values at C-068.

To further investigate potential causes of the differences between the observed DO data and the temperature-based DO saturation during summers, potential oxygen production and oxygen consumption by algal activity were calculated. The following steps were taken to quantify the values.

1. Calculated the averaged *modeled* ammonium concentration during summer seasons (June through September) to be 0.043mg/L. The selection of the months as summer season was mainly based on the high water temperature and the discrepancy between the observed and molded data because the model overestimated DO deficit during the high water temperature of the summers.
2. Calculated averaged observed total phosphorus data (based on three available data at C-068) during summer season (June through September) to be 0.023 mg/L.
3. Estimated the nutrient-to-chlorophyll a ratio to be 7 ug nitrogen/ug chlorophyll a and 1ug phosphorus/ug chlorophyll a (USEPA 1997).

4. Assumed that all total phosphorus was soluble reactive phosphorus available for algal uptake. This assumption could overestimate the phosphorus available for algae to grow, but the assumption enabled the modelers to give the potential maximum chlorophyll a to the calculation processes.
5. Estimated the maximum potential chlorophyll a concentration as follows:

   (43 ug N/L) / 7 ug N/ug Chl a) = 6.14 ug chl a/L for nitrogen

   (24 ug N/L) / 1 ug N/ug Chl a) = 24 ug chl a/L for phosphorus

   Since nitrogen and phosphorus control algal growth, the lower of the two, 6.14 ug chl a/L, was assumed to be the maximum chlorophyll a concentration that can be generated from the nutrient condition.
6. Used the following equations to estimate potential oxygen production and depletion by algal activity:

   Oxygen production $P = r_{oa} G_{\max} 1.066^{T-20} a$ (Chapra 1997, Thomann and Mueller 1987)

   Oxygen depletion $R = r_{oa} k_{ra} 1.08^{T-20} a$ (Chapra 1997, Thomann and Mueller 1987)

   r_{oa}= oxygen generated per unit mass of plant biomass produced; 0.125 g/mg was selected based on the reference

   k_{ra} = respiration rate for the plants; 0.25 /day was based on the reference

   G_{max} = maximum plant growth rate for optimal light condition and excess nutrients; 2 /day for the plant growth rate was selected based on the reference.

The required temperature input for the equations was derived by averaging the modeled water temperature during the summer periods. Inputting all the data to the equations, maximum oxygen production and maximum oxygen depletion were estimated to be 2.25 and 0.32 mg/L/day. As a result, the net oxygen production by algal activity was estimated to be 1.92 mg/L/day.

Figure 4-6 shows that 1.92 mg/L of the net potential oxygen was added to the LSPC simulated DO to examine the potential algal DO generation. As the figure shows, the lower simulated DO during the summers was improved and showed DO conditions similar to the observed data during the summer of 2000. However, the model still overestimated DO deficit during the summers of 1999 and 2001.

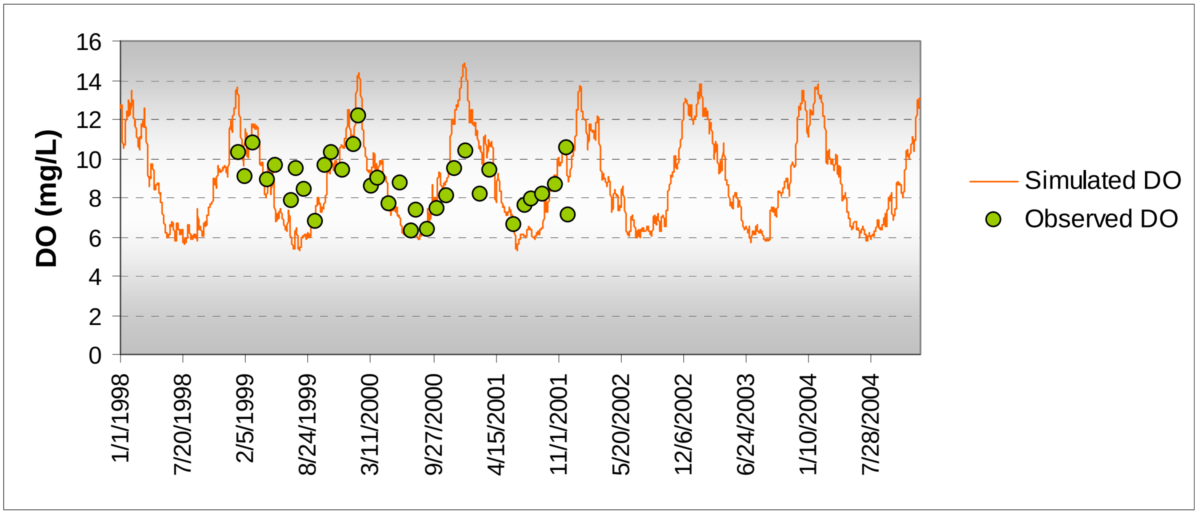


Figure 4-6. Estimated algal DO addition to LSPC results.

Figure 4-7 shows the simulated LSPC DO with the lowest recommended SOD value of 0.06 g O_2/m^2/day (Chapra 1997) without adding the net DO production by algae. The results showed results similar to those in Figure 4-6.

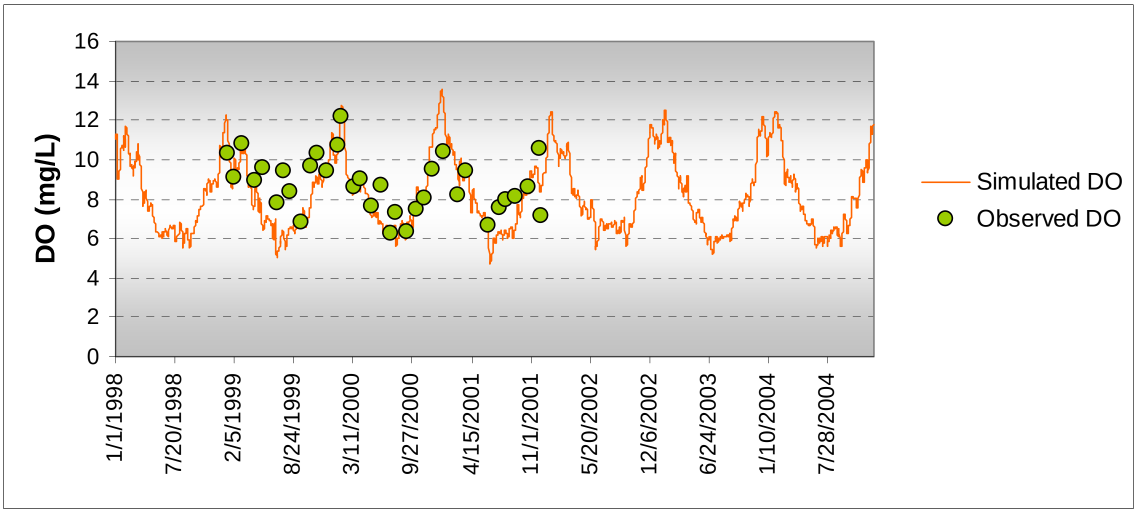


Figure 4-7. 0.06 g O_2/m^2/day SOD value assigned at the C-068 reach.

The last figure, Figure 4-8, shows that 1.92 mg/L of the net potential oxygen was added to LSPC's simulated DO, including SOD of 0.06 g O_2/m^2/day at C-068. The result shows a better match of the simulated DO with the observed DO during the summer of 1999 and 2001 but an underestimate of the DO deficit during the summer of 2000.

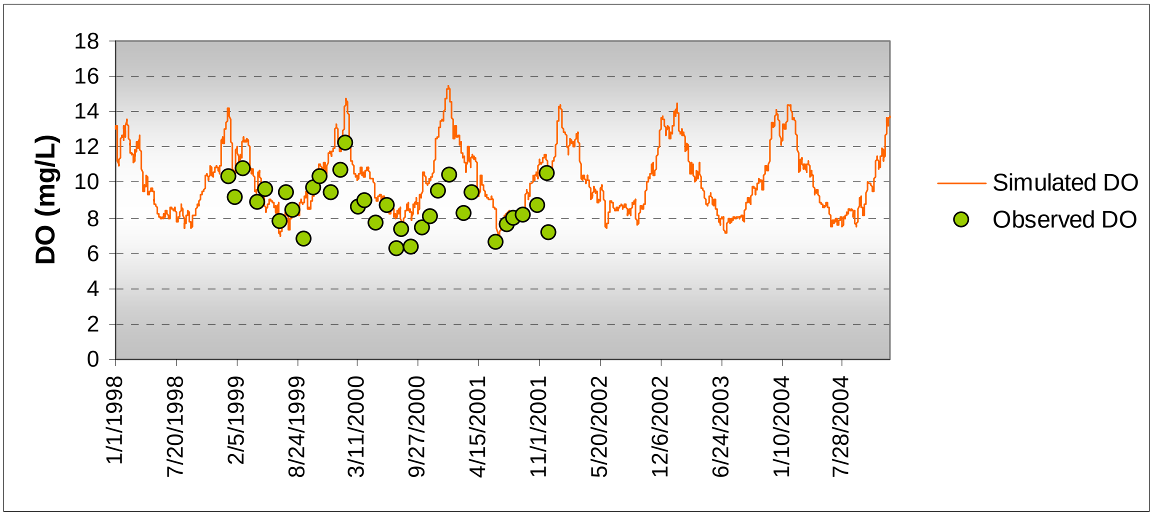


Figure 4-8. Addition of the estimated net algal DO generation to LSPC results with a consideration of 0.06 g O_2/m^2/day SOD value.

Although the calculation of algal photosynthesis and respiration was static, not dynamic as LSPC would have modeled, and the estimated algal generation and consumption of DO were maximum values due to not considering light extinction, light attenuation by meteorological factors, and other assumptions, the calculation still gave some insights to the potential DO sinks, As the three figures above indicate, DO conditions at C-068 could be controlling by the combination of algal activities and SOD. By simulating dynamic algal interaction with nutrient and DO and possibly setting a lower SOD value than the current 0.9 g O_2/m^2/day at C-068, the DO result at C-068 could be improved. However, actual future sampling would need to support the existence of algae at this site and its influence on DO.

5. 0 Model Limitations

The Gills Creek LSPC model is capable of representing only processes that are captured from the model input data. Events that are unknown to the model, such as undocumented point source discharges or undocumented flow alterations, cannot be replicated. Therefore, limitations in the input data drive the limitations, error and uncertainty in the LSPC model outputs. The following sections summarize the known limitations in the model input data, and how these data limitations potentially affect model output.

5.1 WEATHER DATA

As discussed in Section 2.5, weather data (e.g., temperature, precipitation, potential evapotranspiration) are critical for running the LSPC model. Precipitation data are ultimately the source for all modeled flows, while other weather data control temperature and evaporation processes. Therefore, the accuracy of modeled flows (and, indirectly, water quality) tends to increase as the number of weather gauges increases. The quality of the weather data also affects the accuracy of the modeled flow. Only one disaggregated daily precipitation data set was used for the Gills Creek watershed because of the availability and reliability of the data, as described in Section 2.5 of this document. Daily Sandhill Research Elgin rainfall data were disaggregated using hourly rainfall data from NOAA's Columbia Metropolitan Airport weather station (KCAE).

5.2 POINT SOURCES DISCHARGES

The LSPC model can account for point sources by using time-series inputs of flow and concentrations. However, the point source data were not available for the entire modeling time period, and only the available data were input into the model. The pollutant loads from these point sources might not affect the impairments of Gills Creek. SSOs are likely to influence the storm event portion of the simulation, especially for bacteria. Uncertainty in the volume of water and uncertainty in the water quality concentrations in the SSOs could result in over- or underestimating the effects of the SSO events.

5.3 PHYSIOGRAPHIC CHARACTERISTICS

LSPC is driven by the basic physiographic characteristics that make up a watershed. Therefore, physiographic data must be accurate and complete for each watershed. Potential errors were introduced into the model because several of these physiographic characteristics were simplified to facilitate modeling. Also, physiographic characteristics change over time, and they might or might not be represented by the available data and the chosen calibration period. However, this process most likely does not introduce modeling error when compared to the other potential sources of error.

5.4 OBSERVATION DATA

There is always the possibility of analytical uncertainty in any reported observations. These errors are derived from the inherent imprecision of analytical techniques and, occasionally, from laboratory analysis and reporting errors. Perhaps more important, grab samples submitted for chemical analysis represent a specific location and point in time that is not entirely consistent with the spatial and temporal support of the model. LSPC represents water bodies as discrete reaches that are assumed to be fully mixed. Real water bodies vary continuously in both the longitudinal and lateral dimensions, as well as in time. A sample taken from a specific location might not be representative of the average concentration across the stream cross section and may be even less representative of the average across an entire model reach. Furthermore, a sample taken at a discrete point in time might not be representative of the average concentration that would be observed across a modeling time step, particularly when the sample is taken near a discharge location or during the course of a runoff event. This phenomenon most likely introduces model error during storm events or during periods with short-term discharges.

5.5 HYDROLOGY CALIBRATION DATA

One flow gauge was available in Gills Creek watershed. Although the watershed does not have a large drainage area, ideally, the calibration should be conducted with more gauges. Many existing lakes in the watershed could contribute some error to the hydrology calibration. However, the hydrology is well represented on a larger watershed scale in the Gills Creek watershed.

5.6 WATER CHEMISTRY CALIBRATION DATA

DO was simulated without explicit consideration of the effect of nutrients and daily DO fluctuations from algal activities. Chlorophyll a data were not available to quantify algal activity at the compliance points in the watershed. If the data are measured in the Gills Creek watershed in the future, the DO sinks and sources in the model should be updated to represent these algal activities.

6. 0 Modeling Scenarios

The Gills Creek LSPC model was used to determine pollutant reductions to meet water quality standards for fecal coliform bacteria and DO. The existing conditions model was used to establish critical conditions based on the greatest violation of the water quality standards. Reductions were made to both point and nonpoint source pollutant loads to ensure that water quality standards will be meet during the period of critical conditions. The following sections describe the modeling scenarios completed to establish the reductions necessary to meet the total maximum daily loads for fecal coliform, BOD5, and NH3.

6.1 FECAL COLIFORM

The existing conditions model was used to determine when the greatest violations of the instantaneous and geometric mean standard occurred for fecal coliform. The LSPC model outputs daily average concentrations over the simulation period. The highest violations of the fecal coliform instantaneous and geometric mean standard were targeted as the critical conditions. The critical condition stations impaired for fecal coliform bacteria in Gills Creek are illustrated in Figures 6-1 and 6-2.

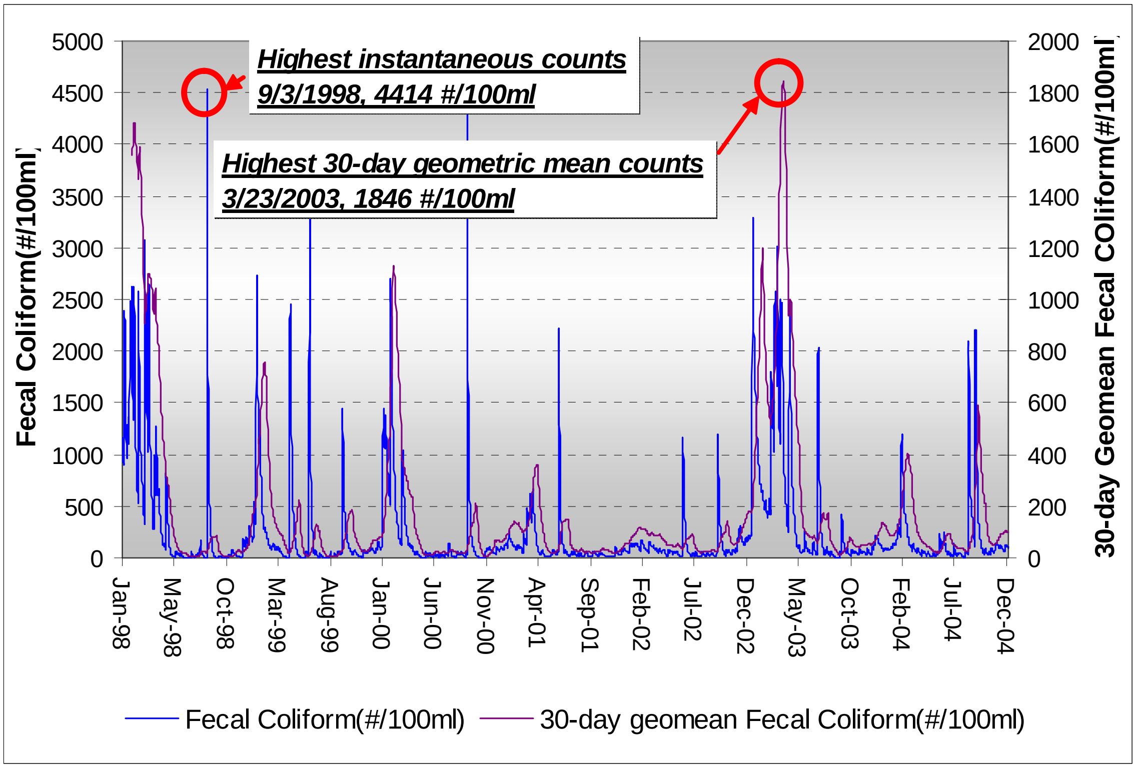
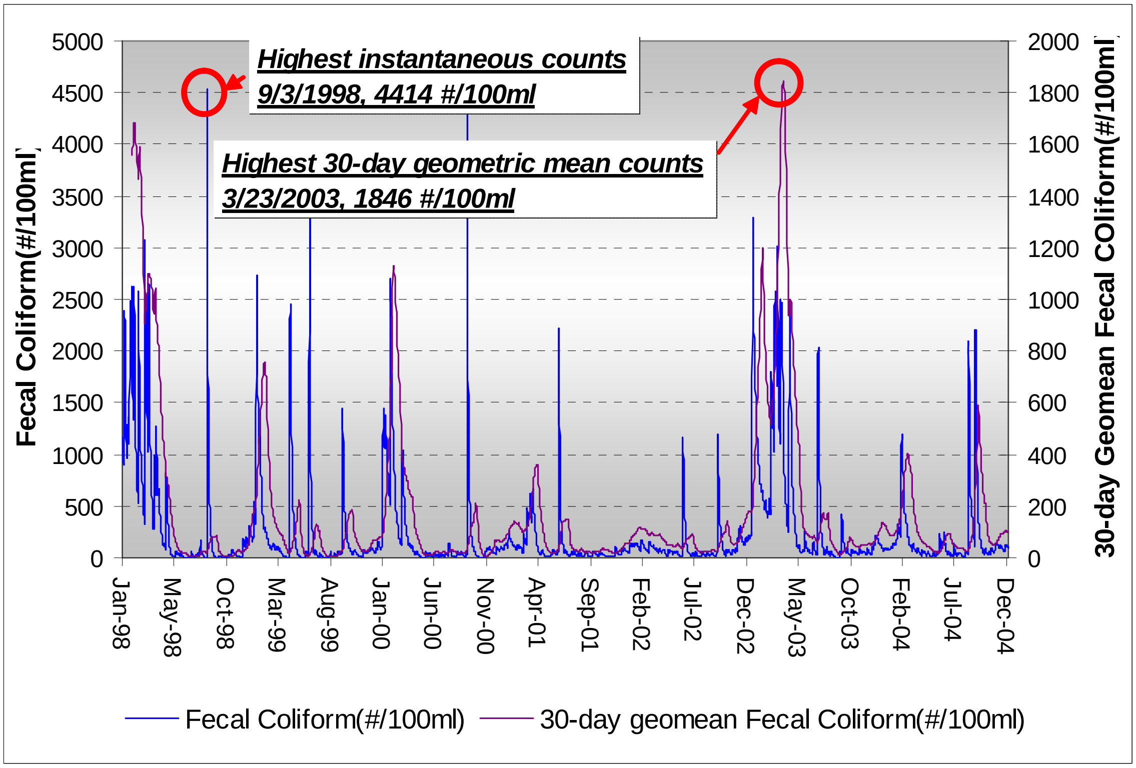


Figure 6-1. Critical conditions modeled at C-001.


Highest instantaneous counts 9/3/1998, 4414 #/100ml

Highest 30-day geometric mean counts 3/23/2003, 1846 #/100ml

Figure 6-2. Critical conditions modeled at C-017.

These critical periods were used to calculate existing conditions in the watershed. Point and nonpoint source loadings of fecal coliform bacteria were reduced equally throughout the modeled land uses to determine the allowable loading to meet water quality standards at impaired SCDHEC monitoring stations. Figure 6-3 and 6-4 verified that the instantaneous and chronic geometric mean (30-day average) standards were met after the reductions were made. As Figure 6-4 indicates, the reductions that meet the instantaneous standard also meet the geometric mean standard.

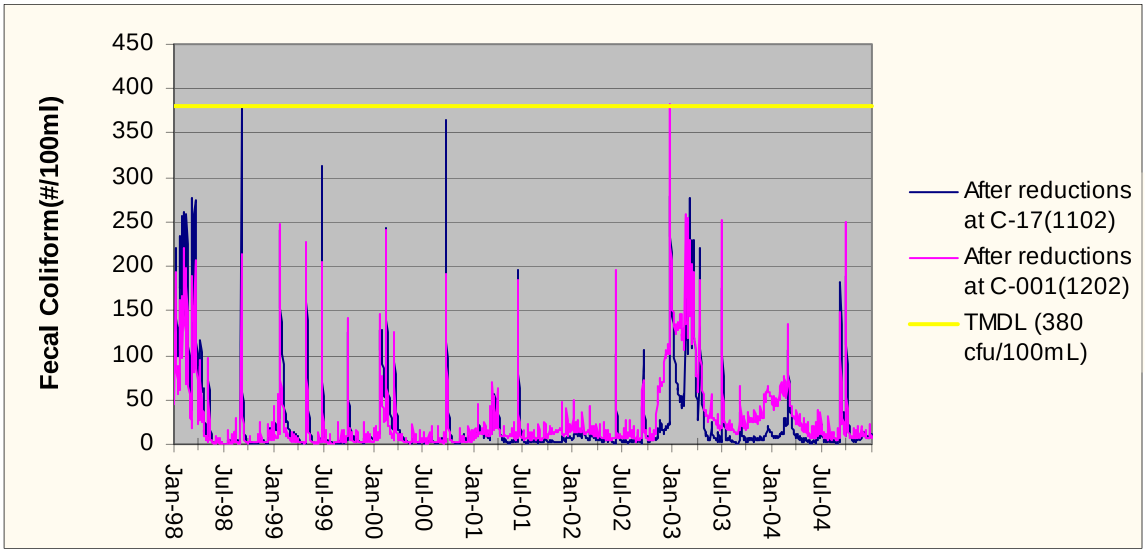


Figure 6-3. Visual confirmation of fecal coliform loading reduction to meet South Carolina's instantaneous standard (380 counts/100 mL), including 5% margin of safety.

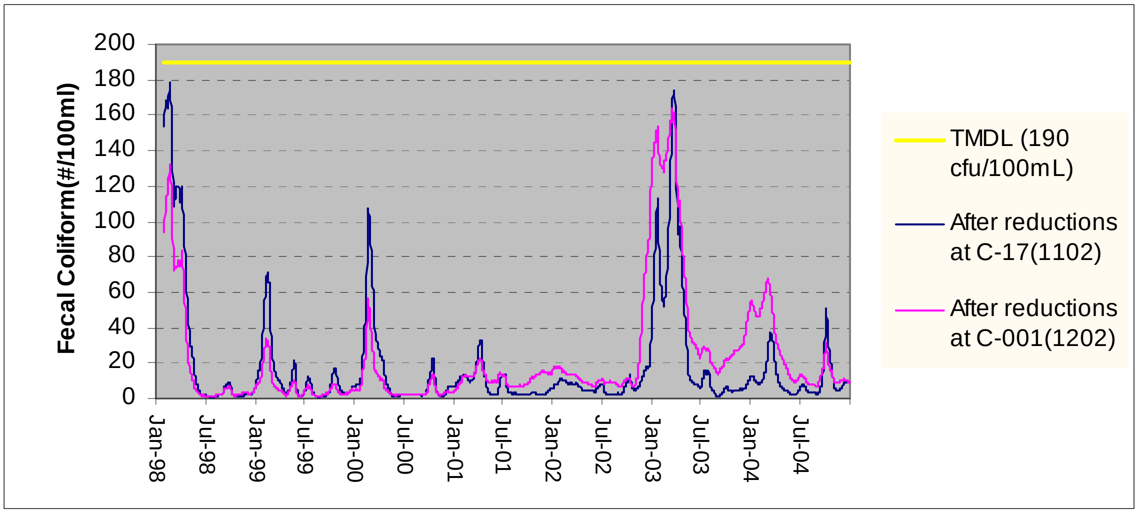


Figure 6-4. Visual confirmation of fecal coliform loading reduction to meet South Carolina's chronic standard (190 counts/100 mL), including 5% margin of safety.

Additional model scenarios were simulated to guide implantation of BMPs. Reduction sequencing was simulated from the headwaters-downstream to establish potential reductions at a subbasin scale in the Gills Creek watershed. These reductions were made to use **as a guide to implementing BMPs** from the headwaters downstream. Table 6-1 presents the results of reductions by subbasin from the headwaters-downstream.

Table 6-1. Total Reductions Required from Each Watershed to Meet Criterion at Each Watershed

Modeled subbasin	Fecal Coliform percentage reductions
100	NA
130	82%
140	40%
150	21%
160	71%
170	61%
200	85%
300	45%
320	98%
330	51%
400	99%
410	71%
500	93%
1101	NA
1102	92%
1201	84%
1202	97%

1203	99%
3101	35%
3102	25%

6.2 DISSOLVED OXYGEN

Critical conditions for DO were based on the greatest violations of the DO standard. The LSPC model outputs daily average concentrations over the simulation period, distinguishing the most critical daily average DO from the existing conditions model. The critical conditions for DO in Gills Creek are illustrated in Figures 6-5 and 6-6.

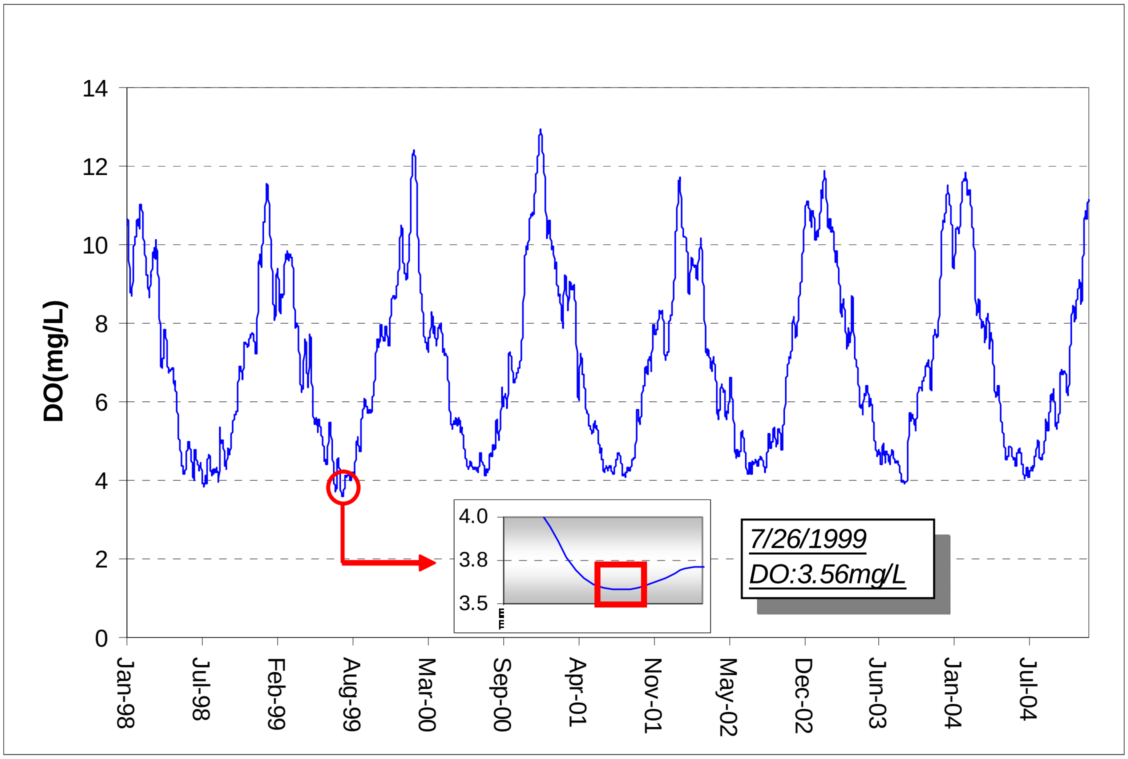


Figure 6-5. Critical conditions modeled at C-048.

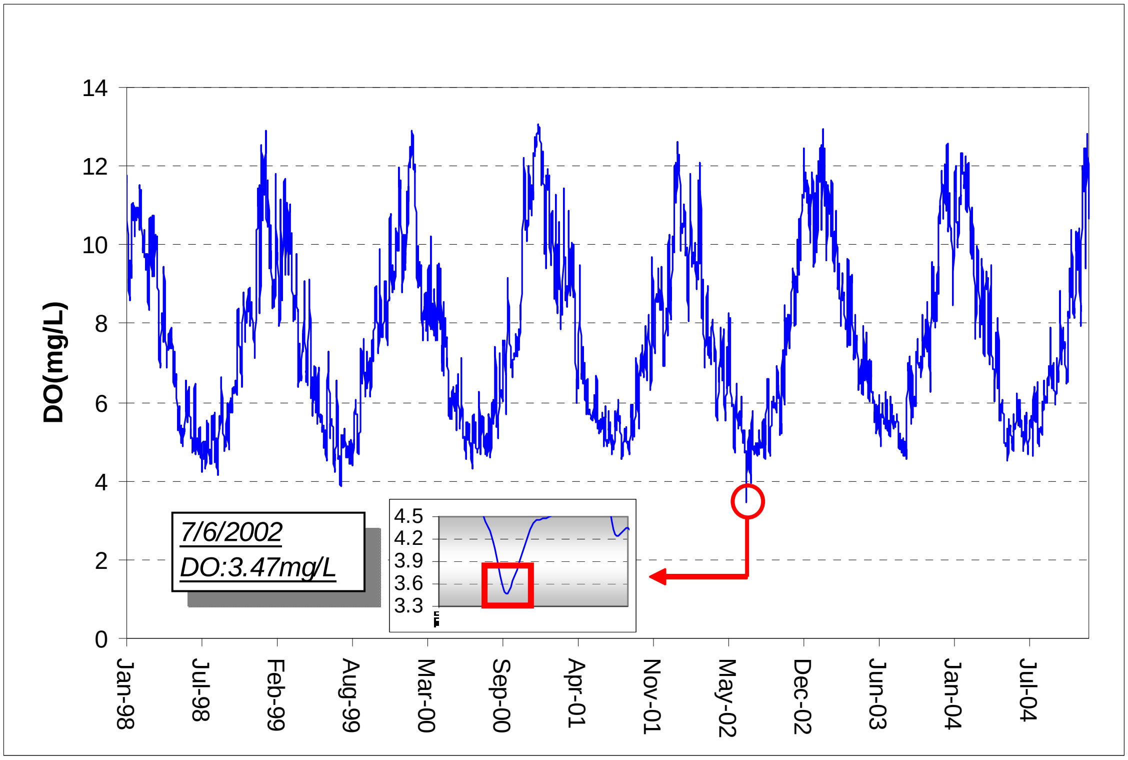


Figure 6-6. Critical conditions modeled at C-017.

Reductions were made to both point and nonpoint source pollutant loads to ensure that water quality standards will be meet during the period of critical conditions. There are three continuous NPDES point sources permitted for pollutants that influence DO; TOC and BOD5. The permitted concentrations for these discharges were included in the model scenarios to establish pollutant reductions. Permitted concentrations of TOC were converted to BOD5 and concentrations of NH3 were assumed equal to 0.11 mg/L if no data was available or assumed equal to half of the Total Kjeldahl Nitrogen (TKN); TKN = ON+NH3.

Figures 6-7 and 6-8 confirm that after load reductions, DO conditions meet the criterion of 5 mg/L of DO at the critical condition on July 26, 1999, for C-048 and July 6, 2002, for C-017. The loading reductions were assigned equally throughout the modeled land uses. The higher loading reduction rate for BOD5 and the lesser reduction rate for ammonia were determined after conducting sensitivity analyses on in-stream DO conditions by reducing different ratios of these two oxygen-consuming materials.

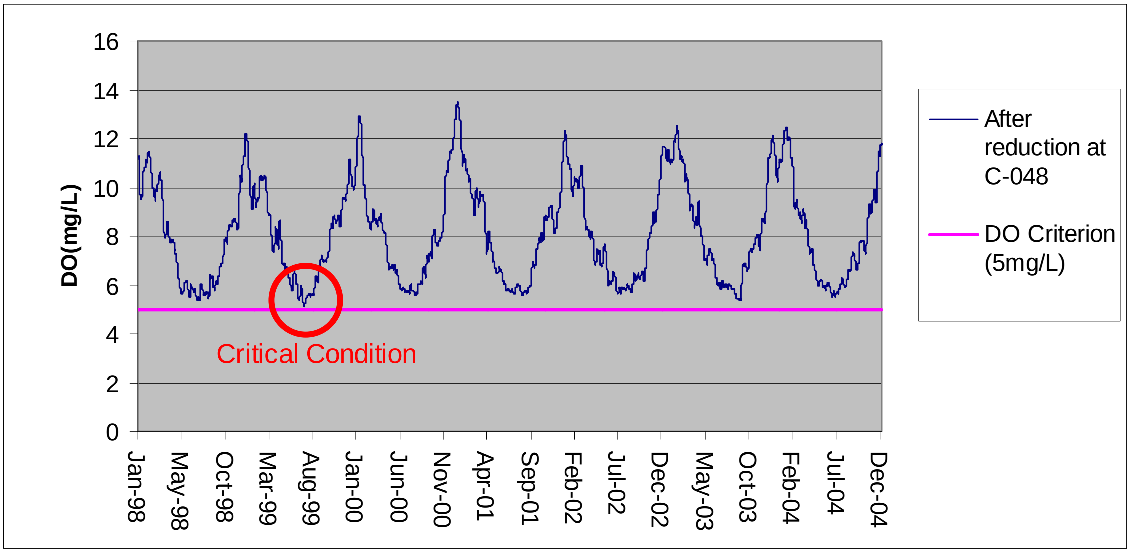


Figure 6-7. DO conditions after load reductions at the critical condition at C-048.

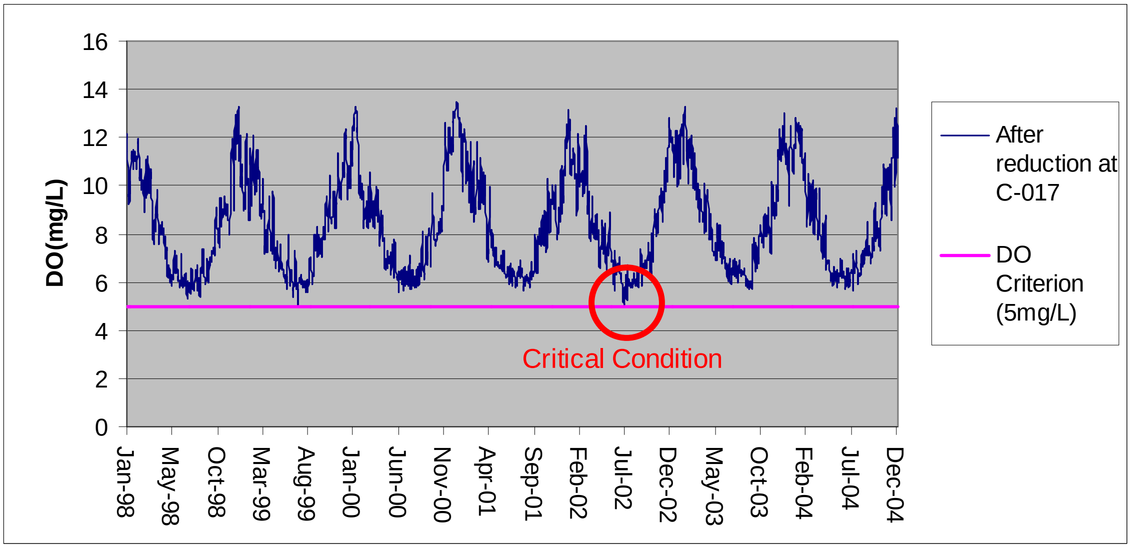


Figure 6-8. DO conditions after load reductions at the critical condition at C-0017.

DO was still violating water quality standards after reducing the BOD5 and ammonia loadings to zero using the calibrated SOD (0.9 g O_2/m^2/day). The model indicated that SOD reductions were needed to meet the DO standard. SOD is generally accumulated oxygen consumption materials, mainly particulate and dissolved organic matter from the upland loadings deposited onto the streambed or lake bed. So reductions of BOD5 and ammonia would translate (be linked) to SOD reductions. Ultimately, BOD5/nutrient reductions and SOD reductions were conducted simultaneously. For example, after reducing 20 percent of BOD5/nutrient, the corresponding SOD value was derived from the fitted line shown in Figure 6-9 and the LSPC model was run. This process was repeated until the DO standard was met at all reaches. Reductions were made to BOD5/nutrients and SOD for each subbasin to ensure that the DO standard was achieved.

During the process of the loading reductions, it was apparent that loading reductions to point and nonpoint sources of ammonia and BOD5 were not enough to meet the criterion at the assessment points. Thus, additional SOD reductions were applied to meet the criterion. The following paragraphs explain how SOD reductions were determined.

LSPC/HSPF does not include an explicit function of sediment digenesis within the modeling framework but allows a constant SOD input for each modeled reach. The calibrated model has 0.9 g O_2/m^2/day SOD assigned to all the modeled reaches. To directly link the reductions in BOD5 and ammonia with the associated SOD reductions, the Sediment Flux model, developed by Quantitative Environmental Analysis and Mississippi State University, was used.

The Sediment Flux model requires hydraulics information such as water volume, depth, flow rates, and sediment surface area. It also requires nutrient inputs (nitrogen, phosphorus, and carbon), water column DO, and water temperature. These values were directly taken from LSPC outputs and converted, if necessary, based on the available water quality data to required input parameters in the sediment flux model. For example, LSPC modeled BOD5 results were converted to total organic carbon (TOC) using the observed data ratio between these two parameters. The unknown sediment surface area was adjusted from the average of LSPC's water surface area results as a starting sediment surface area. Sediment surface area was selected as the calibration parameter because clear delineation and estimation of the SOD-contributing active sediment area was not feasible and the estimate of the area was more uncertain compared to the required physical parameters of water volumes and depths for the sediment flux model. The sediment surface area was reduced to generate the current sediment condition of 0.9 g O_2/m^2/day that was set in LSPC model.

Once the Sediment Flux model was calibrated, the in-stream loadings at the assessment points, based on all contributing sources, were input to the model and subsequently reduced in a stepwise manner (25 percent to 90 percent). This method quantified the relationship between loading reductions and calculated SOD at the assessment points C-017 and C-048. The average calculated SOD, based on the reduction percentages to the BOD5/nutrients at the two locations, was used for the TMDL reduction scenarios for the Gills Creek watershed (Figure 6-9). As illustrated in Figure 6-9, varying the load of BOD5 and ammonia by making reductions varies the SOD. The relationship between SOD and BOD5 and ammonia reductions was fitted to a second-order polynomial line. This relationship was used to determine how reductions in BOD5 and ammonia would influence SOD, which influences DO. The TMDL modeling considers how reductions to BOD5 and ammonia reduce SOD in each of the modeled reaches.

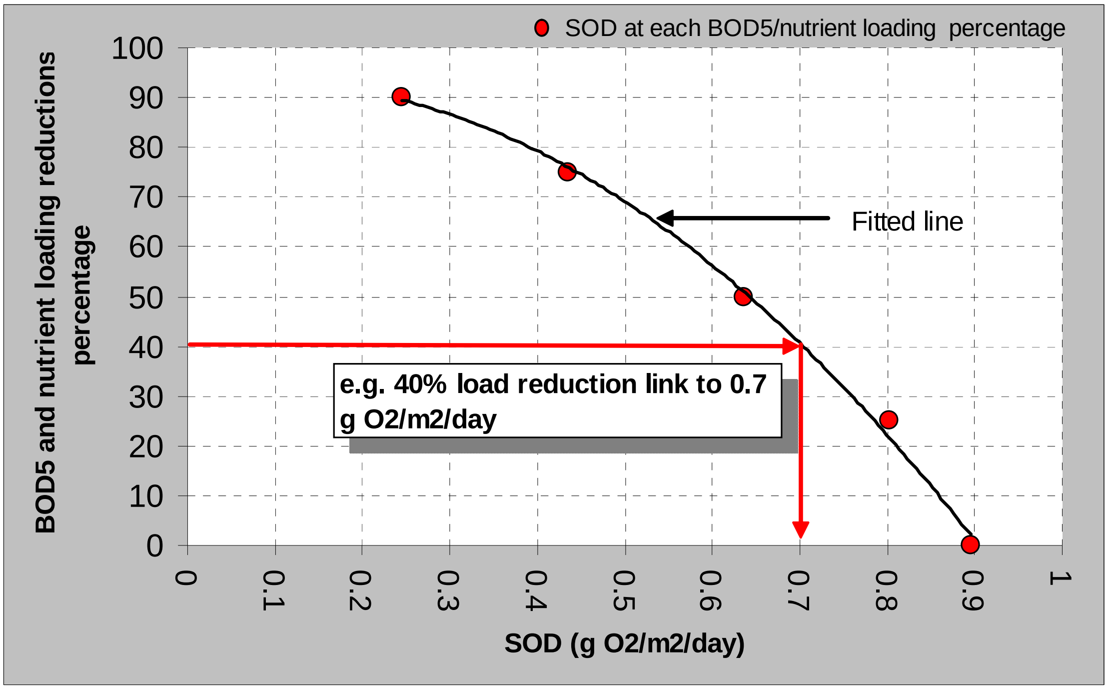


Figure 6-9. Reduced SOD, estimated from reductions.

In addition to the upland loadings and SOD reductions, the release rate of BOD5 material from the reach bed was also reduced by the same percentage as that of the BOD5 loading reduction. In LSPC/HSPF, BOD5 materials are released from the bed depending on the DO condition of the water column and the stream/lake velocity. This is intended to mimic the redox reactions that occur in the bed. More specifically, metal hydroxide, especially iron, can be dissolved during anoxic conditions, converting from ferric iron (Fe3+) to ferrous iron (Fe2+), and simultaneously release adsorbed materials (such as BOD5).

Table 6-2 shows the upland loading reductions required from each subbasin to meet the DO criterion at the assessment points during the critical conditions and also meet the criterion at the end of each subbasin reach.

Additional model scenarios were simulated to guide implantation of BMPs. Reduction sequencing was simulated from the headwaters-downstream to establish potential reductions at a subbasin scale in the Gills Creek watershed. These reductions were made to use **as a guide to implementing BMPs** from the headwaters downstream. Table 6-2 presents the results of reductions by subbasin from the headwaters-downstream.

Table 6-2. Reduction Percentage Required from Each Subbasin to Meet Dissolved Oxygen Water Quality Criterion

Subbasin	Reduction Percentage of BOD5	Reduction Percentage of NH3
100	NA	NA
130	55	11
140	55	11
150	55	11
160	55	11
170	55	11
200	75	15
300	55	11
320	55	11
330	70	14
400	0	0
410	65	13
500	0	0
1101	NA	NA
1102	65	13
1201	45	9
1202	85	17
1203	0	0
3101	55	11
3102	60	12

7.0 References

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APPENDIX A
Watershed Hydrology Calibration

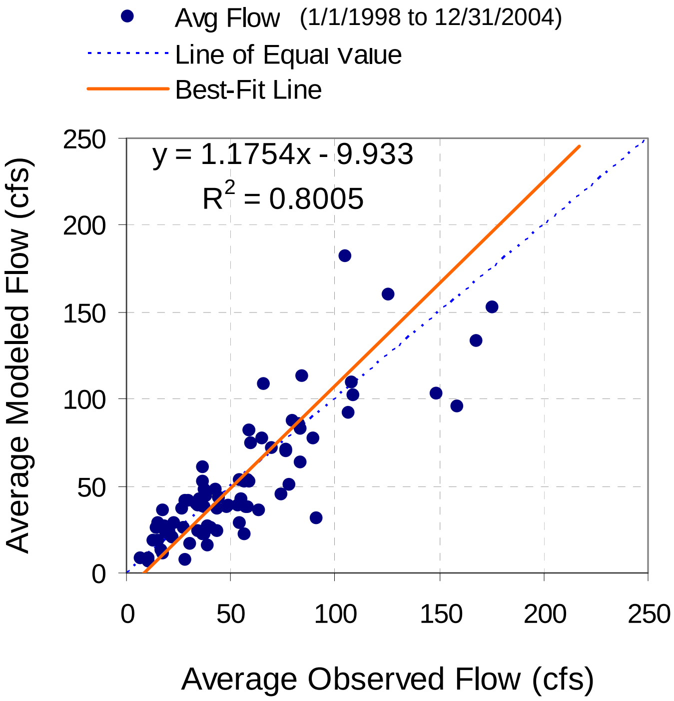


Figure A-1. Comparison of averaged observed and modeled flows.

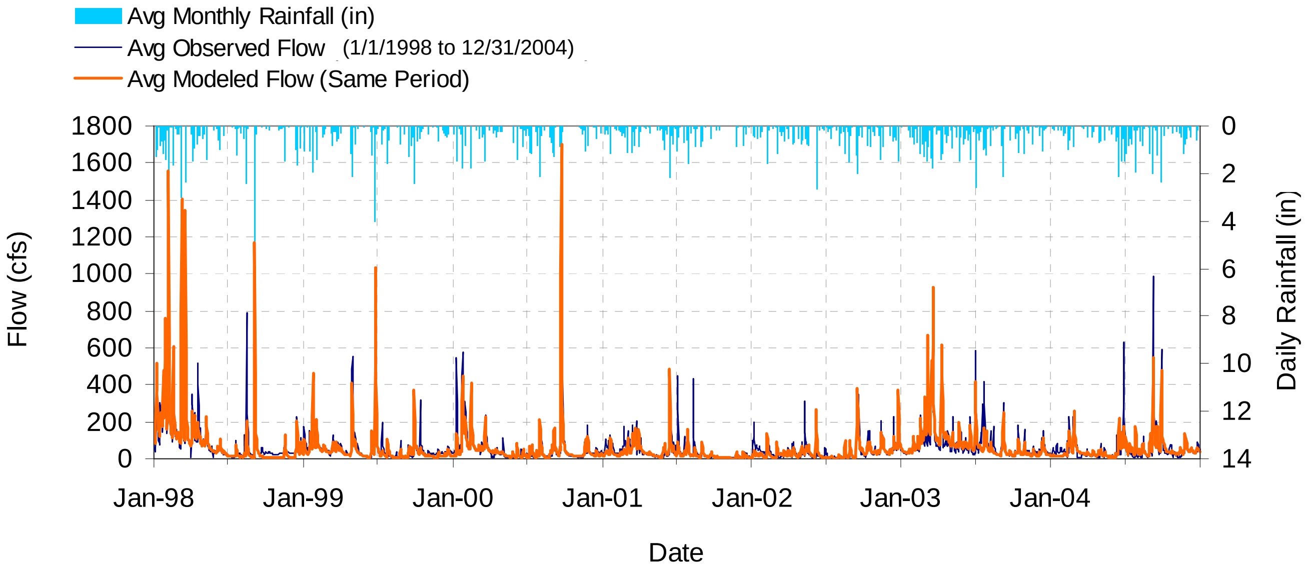


Figure A-2. Comparison of daily observed and modeled flows.

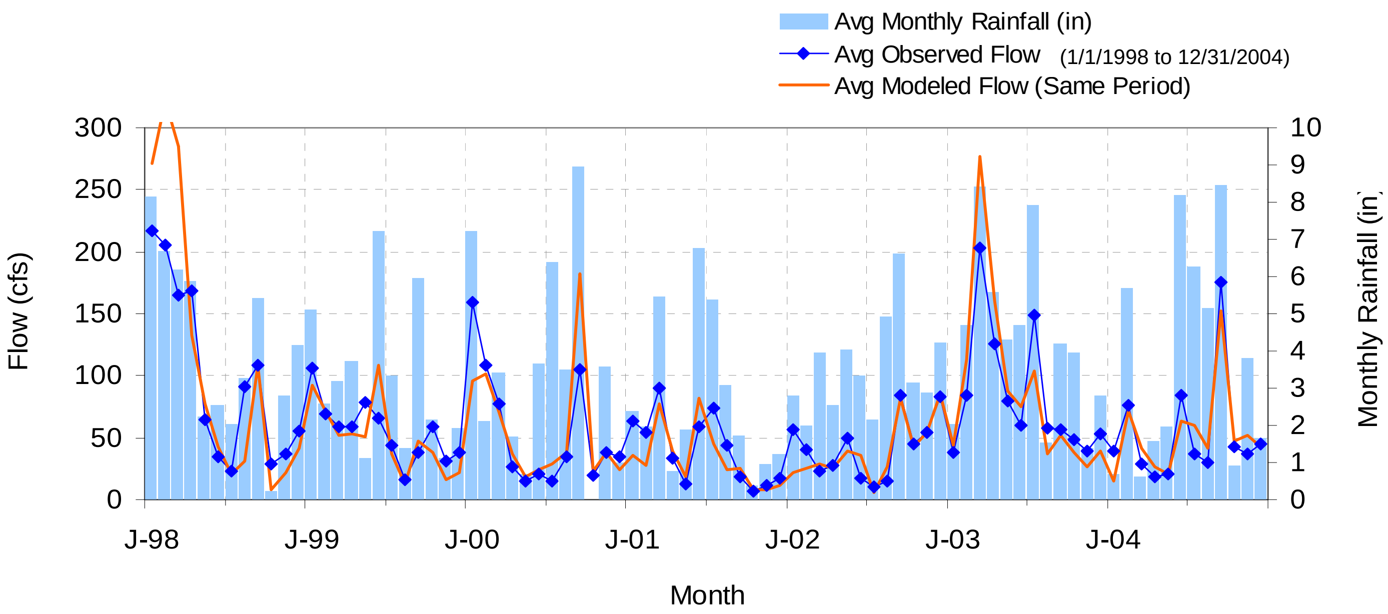


Figure A-3. Comparison of weekly average observed and modeled flows.

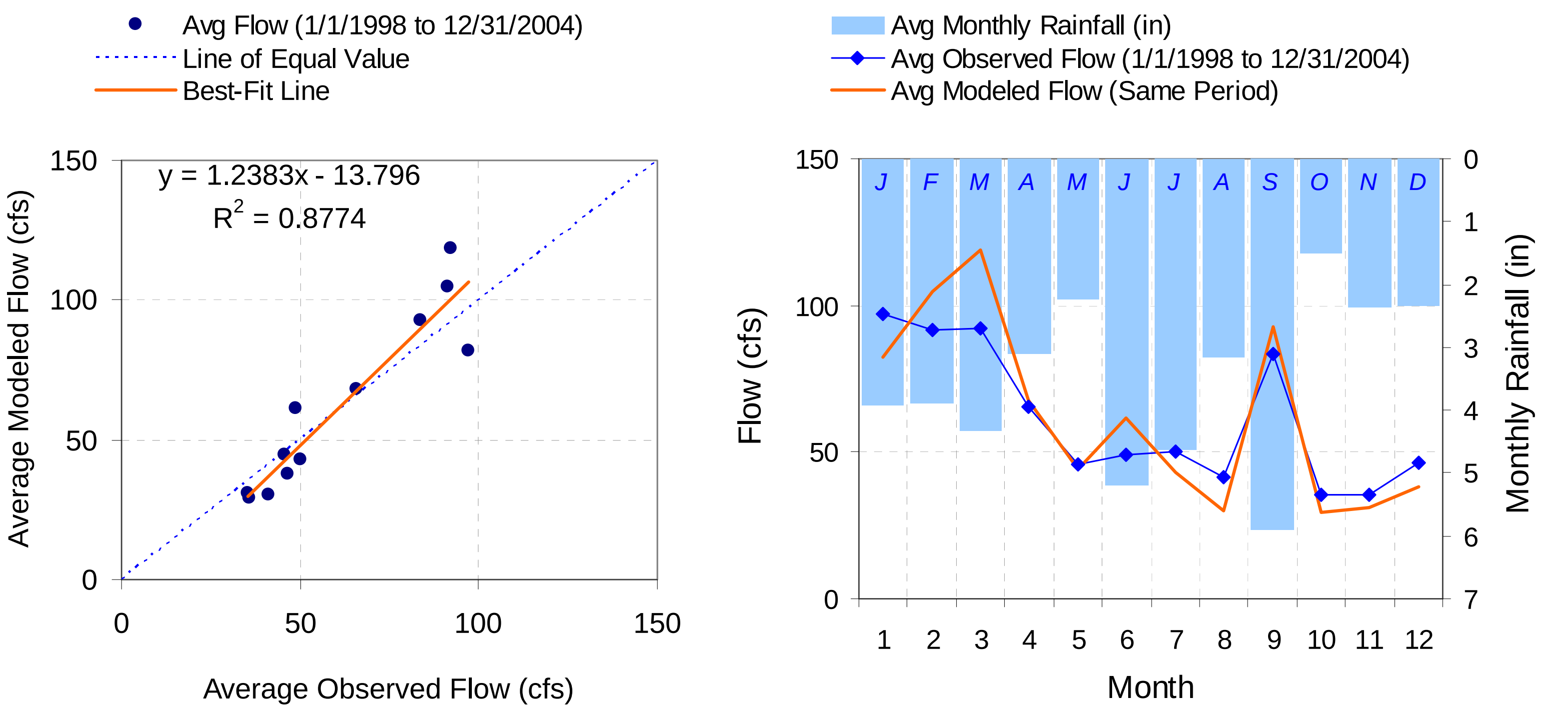


Figure A-4. Comparison of monthly average observed and modeled flows.

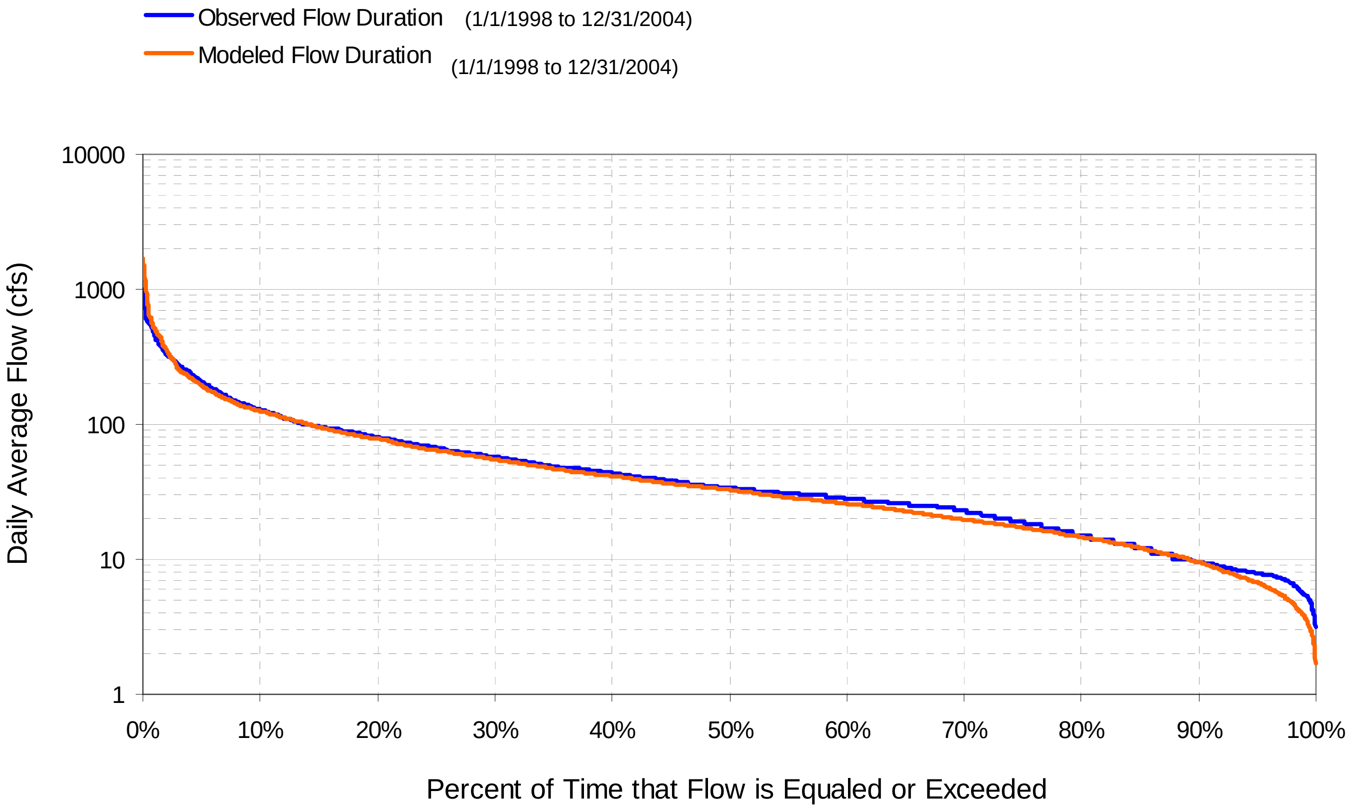


Figure A-5. Comparison of observed and measured flow duration curves.

Table A-1. Statistical Comparison of Observed and Modeled Flows

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 1202 7-Year Analysis Period: 1/1/1998 - 12/31/2004 Flow volumes(inches/year) are for upstream drainage area		**USGS02169570**	
Total Simulated In-stream Flow:	**14.04**	Total Observed In-stream Flow:	**13.90**
Total of simulated highest 10% flows:	**6.43**	Total of Observed highest 10% flows:	**5.93**
Total of Simulated lowest 50% flows:	**2.00**	Total of Observed Lowest 50% flows:	**2.18**
Simulated Summer Flow Volume (months 7-9):	**3.15**	Observed Summer Flow Volume (7-9):	**3.34**
Simulated Fall Flow Volume (months 10-12):	**1.88**	Observed Fall Flow Volume (10-12):	**2.25**
Simulated Winter Flow Volume (months 1-3):	**5.73**	Observed Winter Flow Volume (1-3):	**5.28**
Simulated Spring Flow Volume (months 4-6):	**3.28**	Observed Spring Flow Volume (4-6):	**3.03**
Total Simulated Storm Volume:	**5.16**	Total Observed Storm Volume:	**5.26**
Simulated Summer Storm Volume (7-9):	**1.48**	Observed Summer Storm Volume (7-9):	**1.66**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	1.05	10		
Error in 50% lowest flows:	-8.07	10		
Error in 10% highest flows:	8.45	15		
Seasonal volume error - Summer:	-5.56	30		
Seasonal volume error - Fall:	-16.38	30		
Seasonal volume error - Winter:	8.59	30		
Seasonal volume error - Spring:	8.18	30		
Error in storm volumes:	-1.93	20		
Error in summer storm volumes:	-10.93	50		

APPENDIX B
Watershed Water Quality Calibration

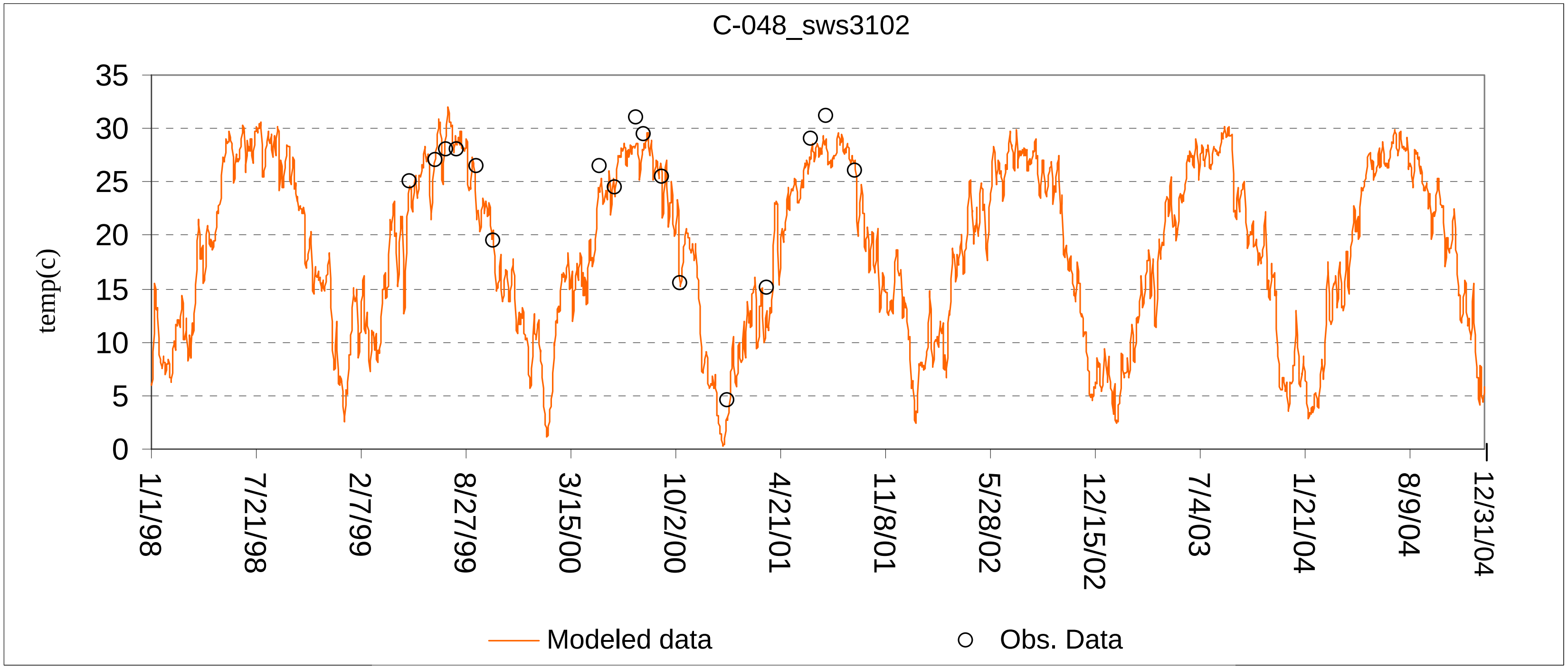


Figure B-1. Temperature comparison at C-048.

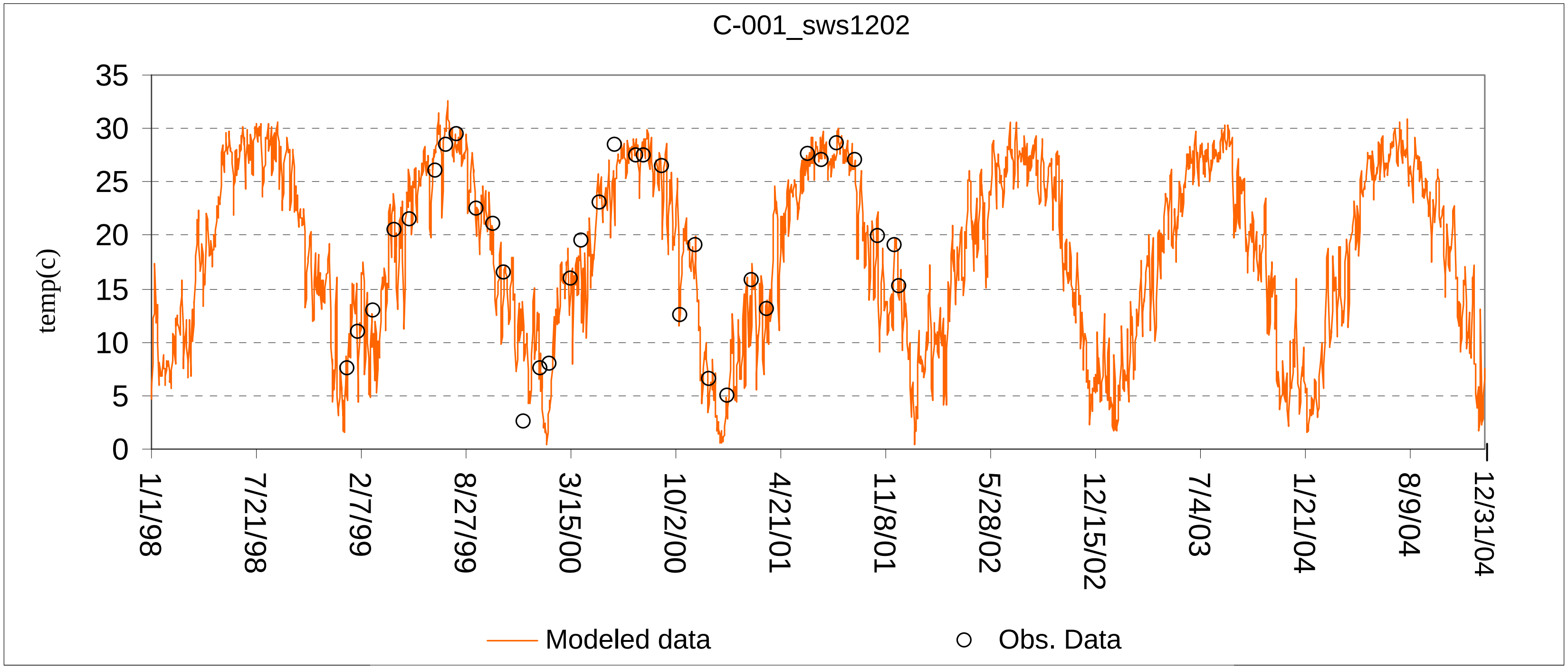


Figure B-2. Temperature comparison at C-001.

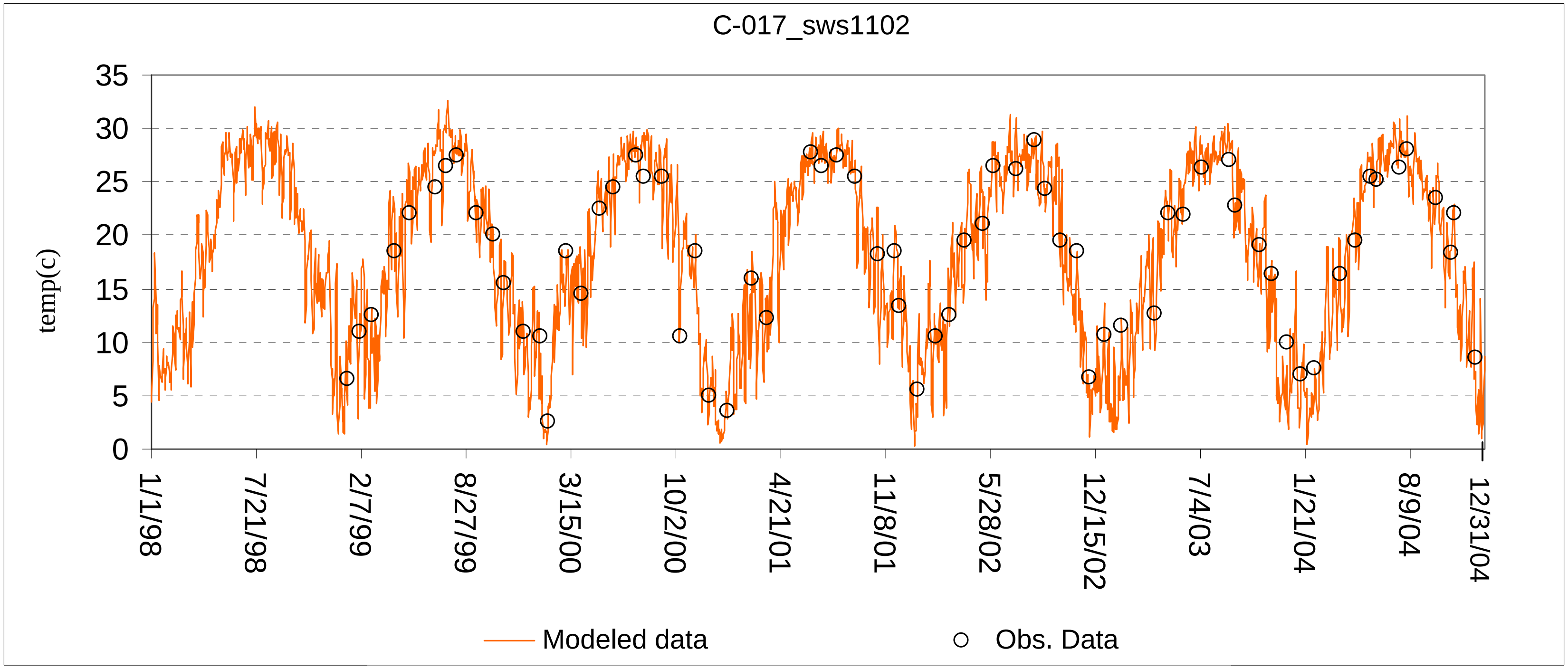


Figure B-3. Temperature comparison at C-017.

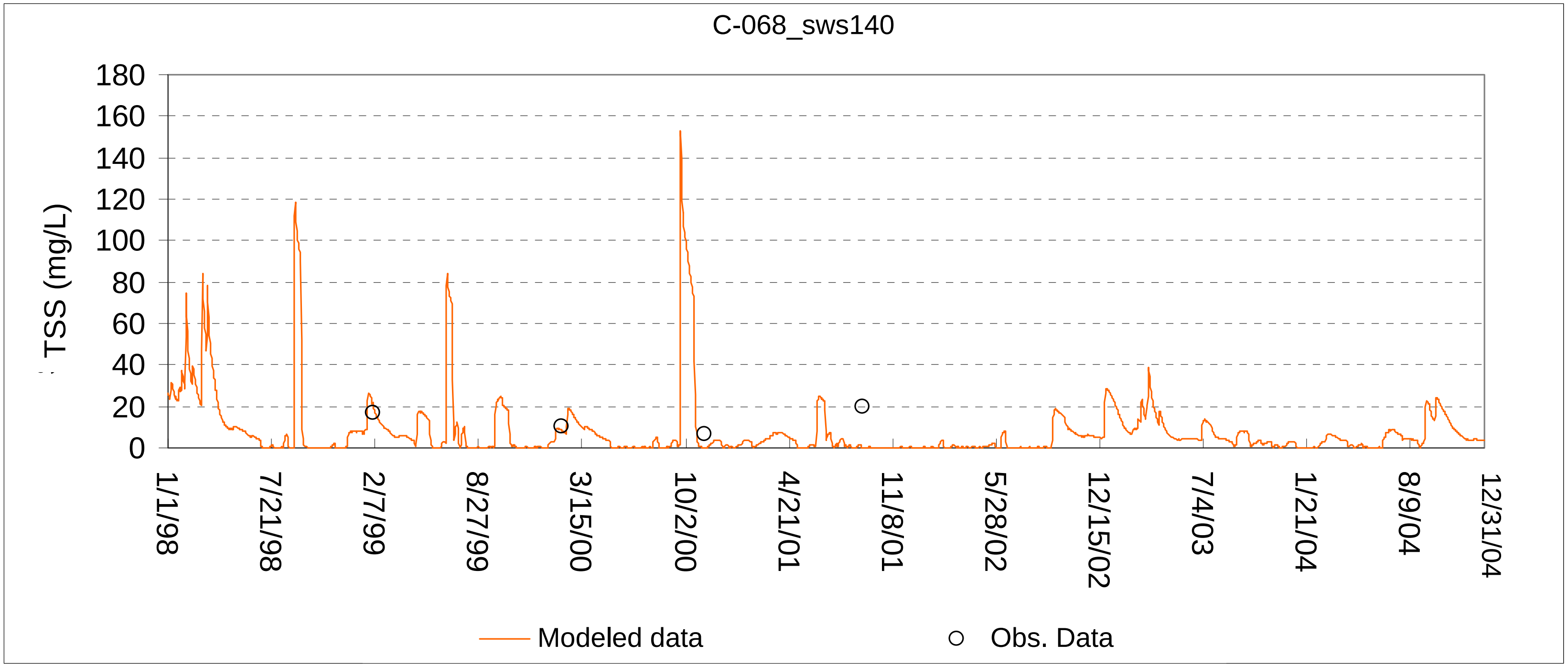


Figure B-4. Total suspended solids comparison at C-068.

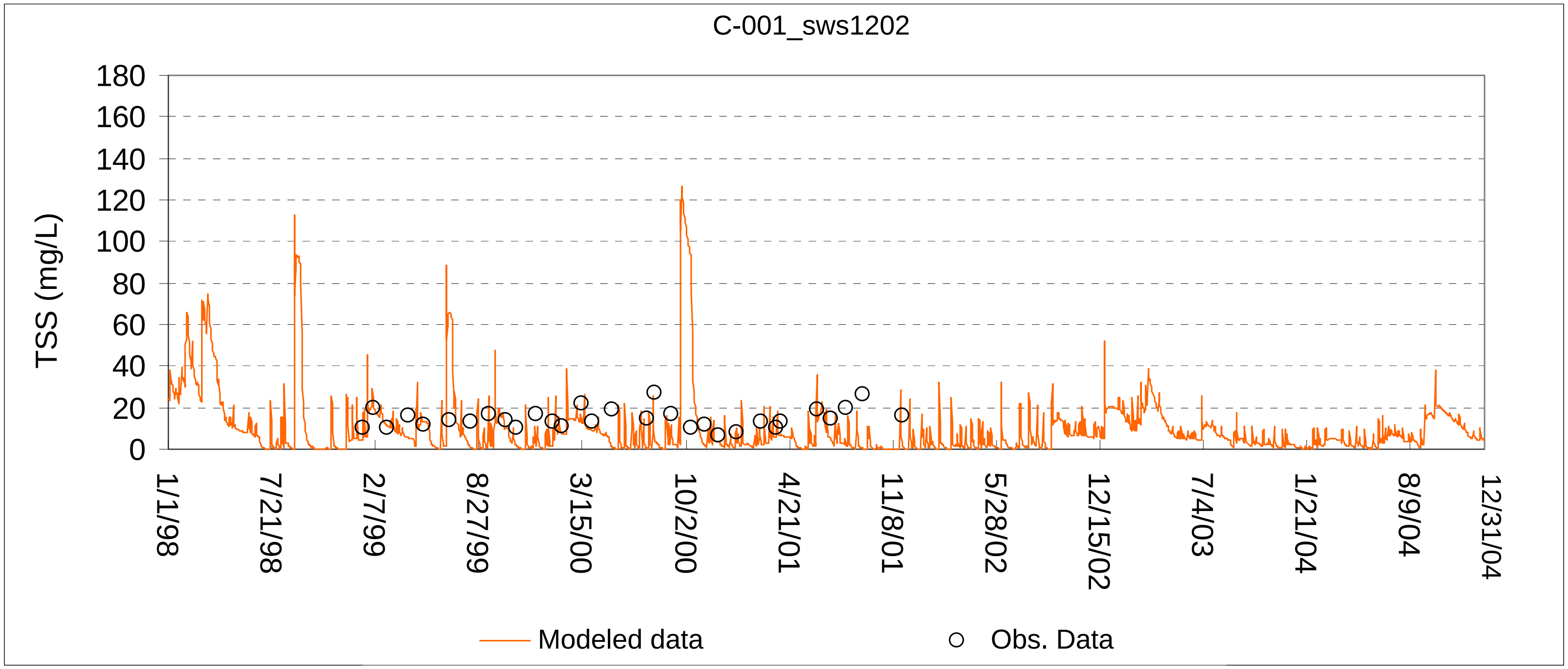


Figure B-5. Total suspended solids comparison at C-001.

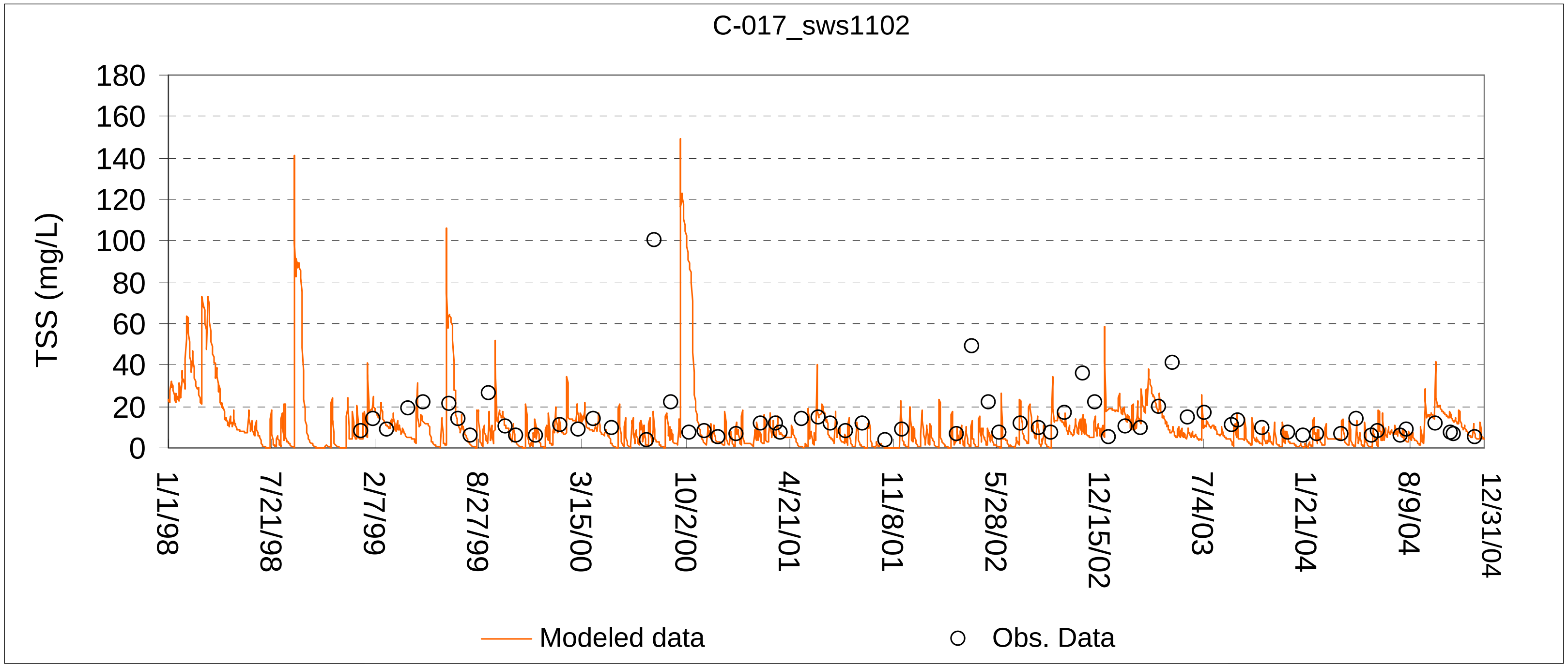
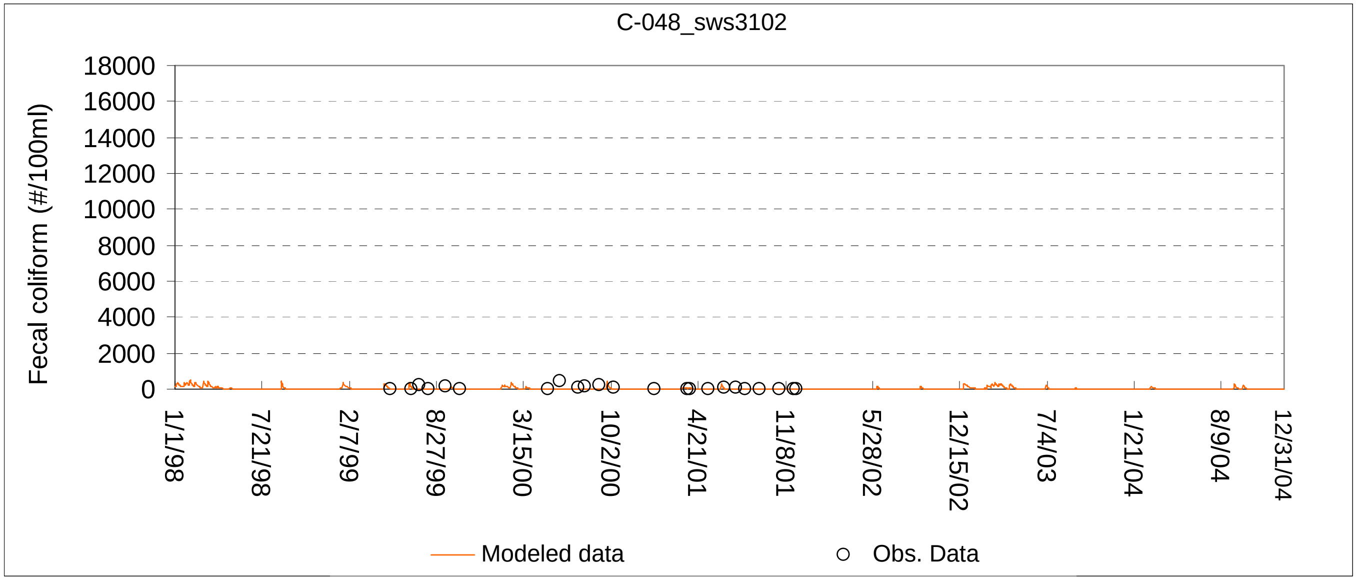


Figure B-5. Total suspended solids comparison at C-017.



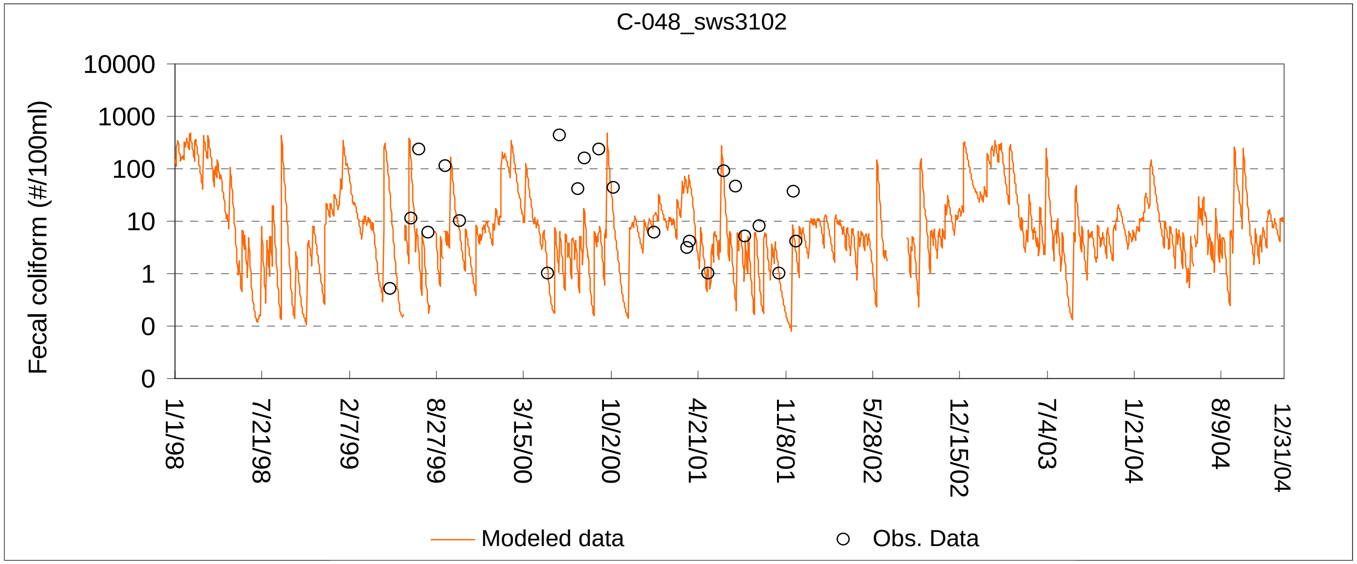
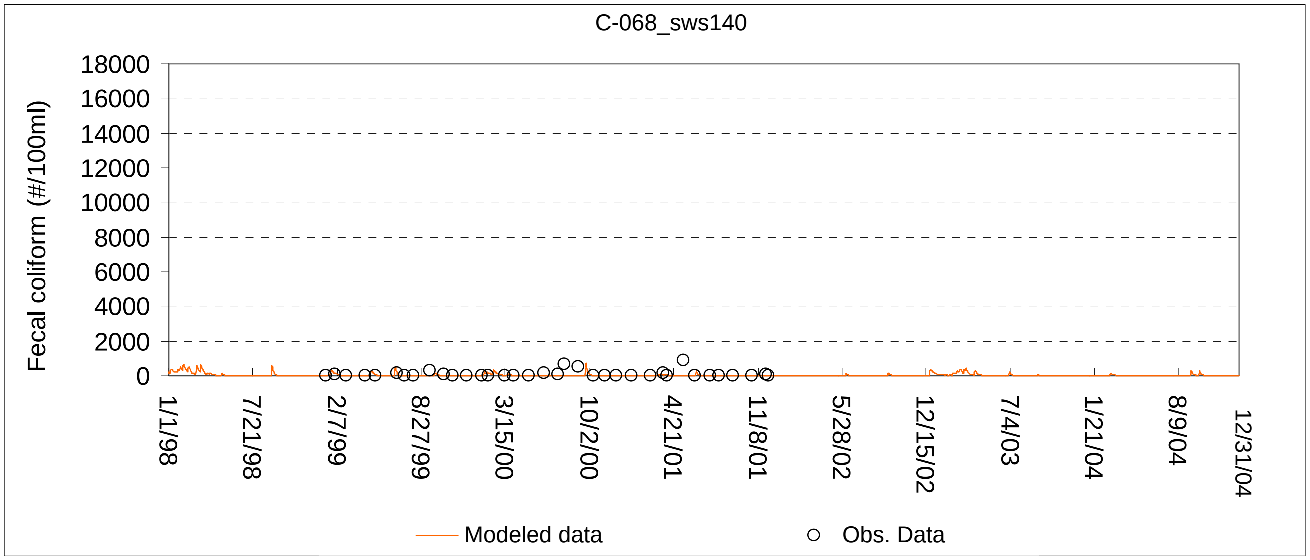


Figure B-6. Fecal coliform comparison at C-048.



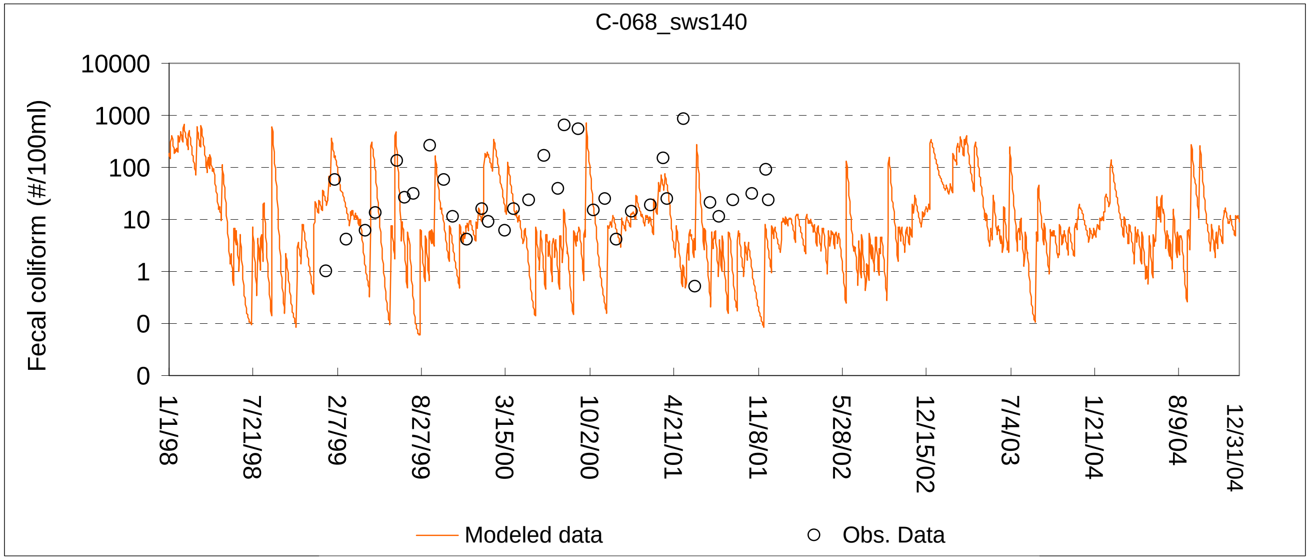


Figure B-7. Fecal coliform comparison at C-068.

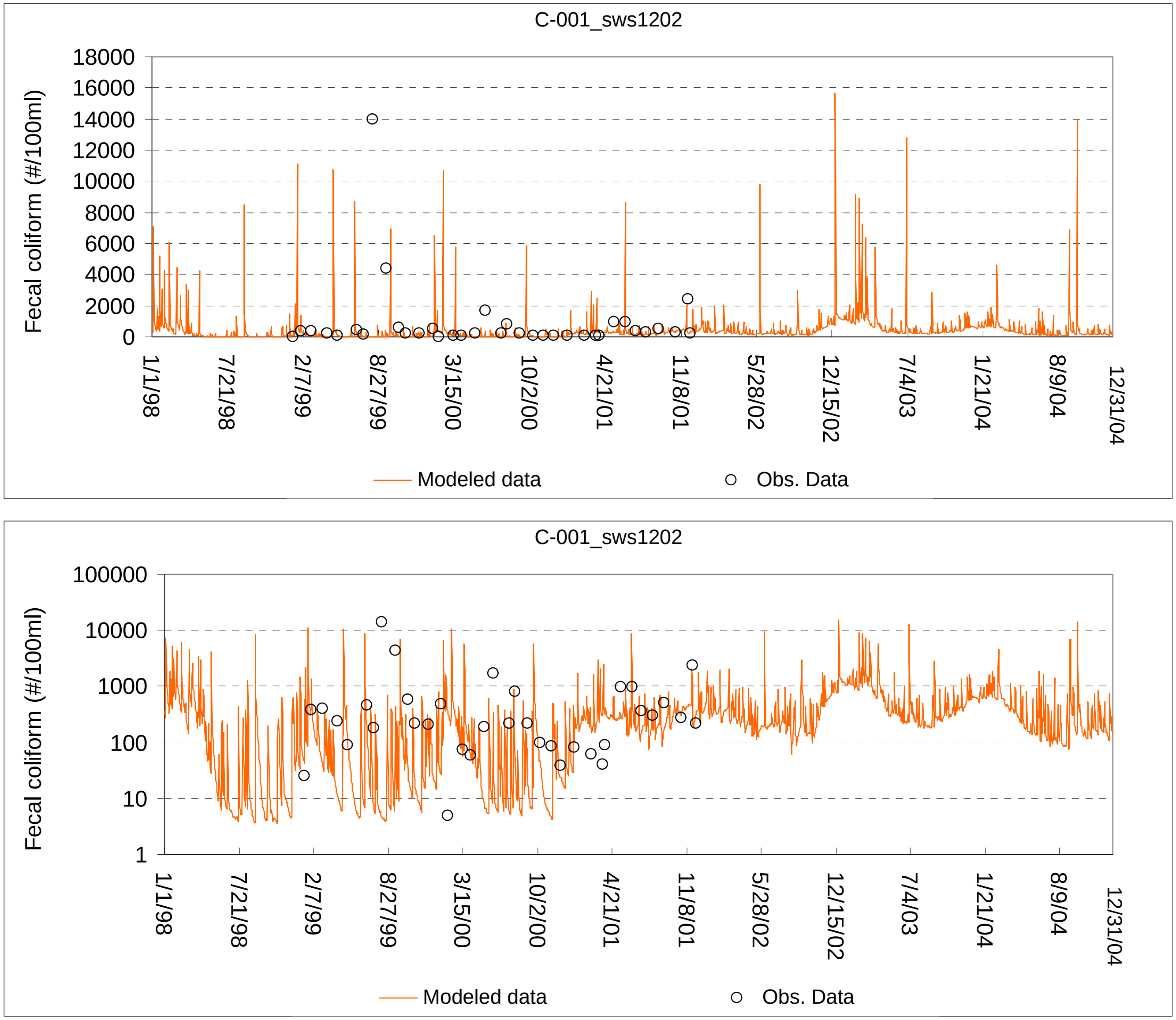
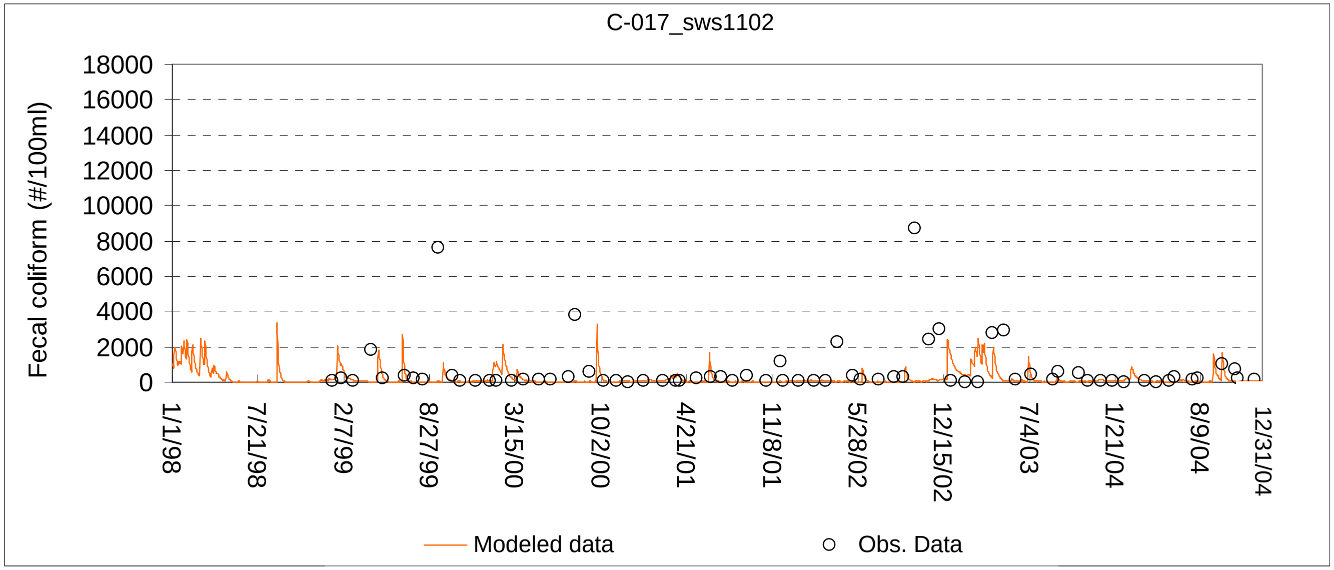


Figure B-8. Fecal coliform comparison at C-001.



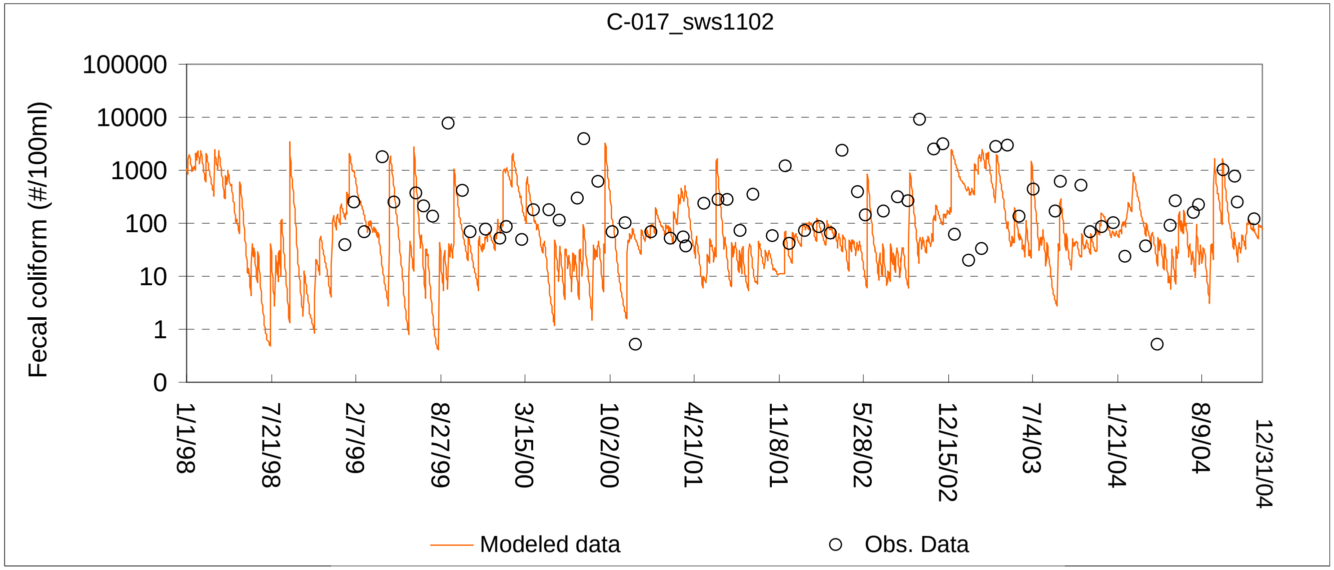


Figure B-9. Fecal coliform comparison at C-017.

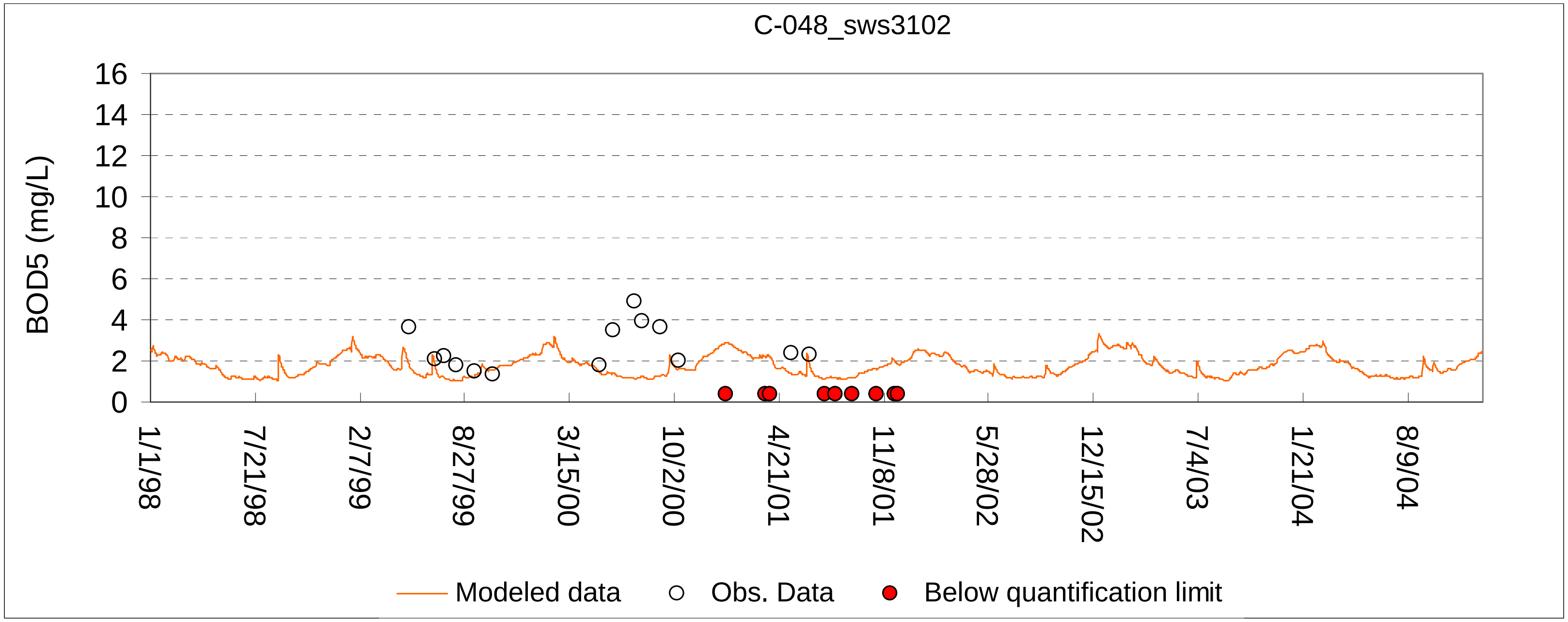


Figure B-10. BOD5 comparison at C-048 (Below QLs are shown as 0.4 mg/L: the lowest observed value of 0.8/2 = 0.4).

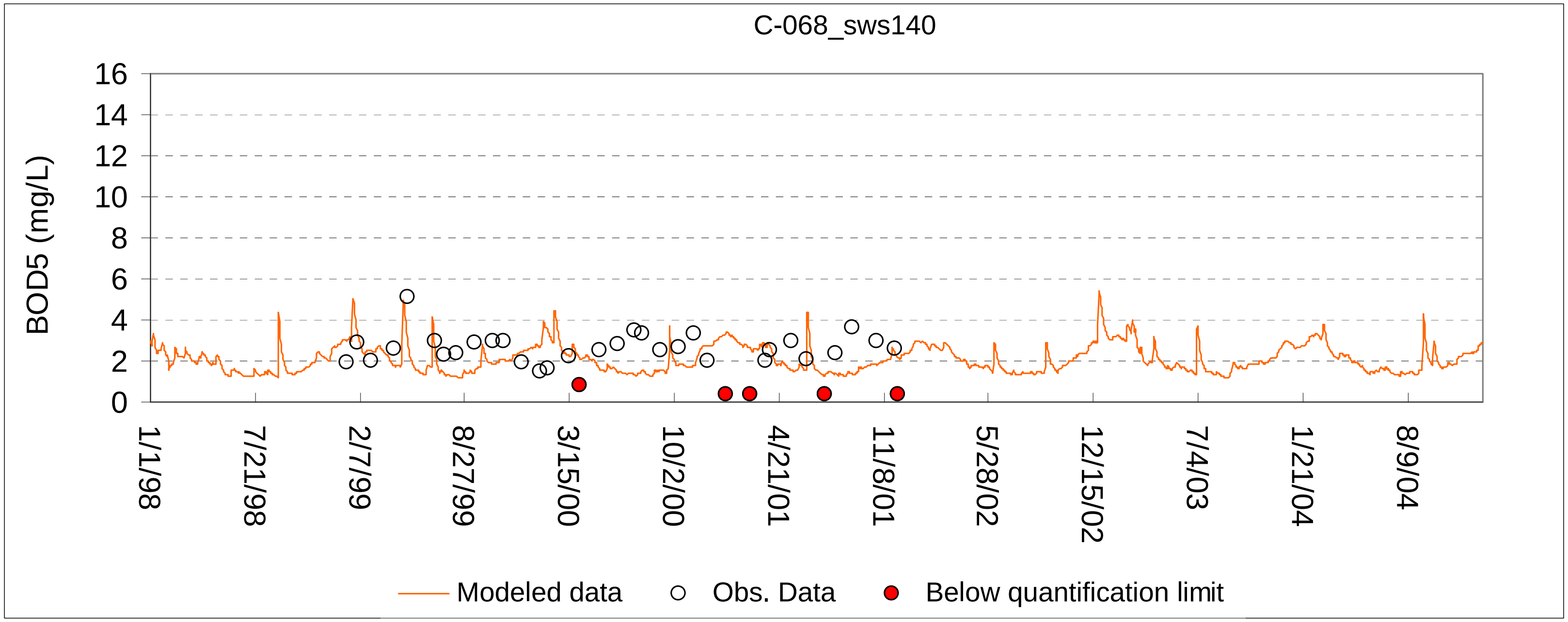


Figure B-11. BOD5 comparison at C-068 (Below QLs are shown as 0.4 mg/L: the lowest observed value of 0.8/2 = 0.4).

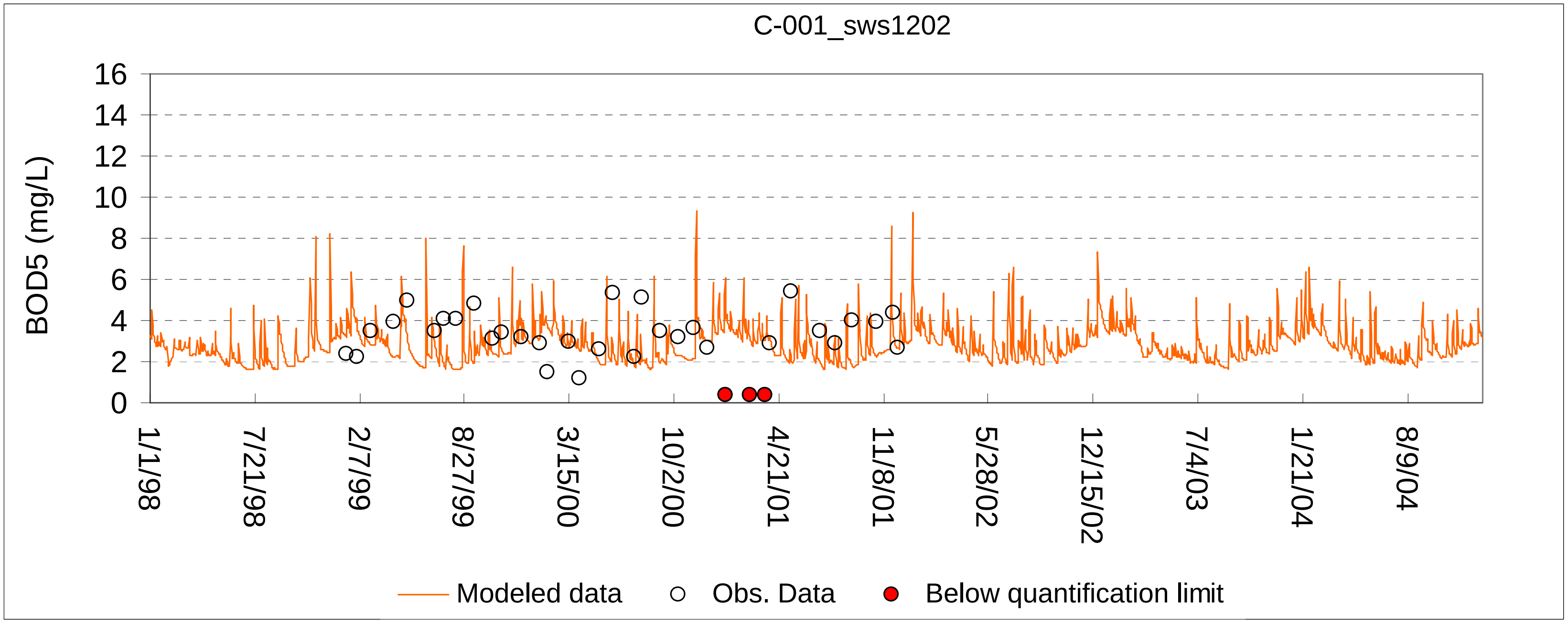


Figure B-12. BOD5 comparison at C-001 (Below QLs are shown as 0.4 mg/L: the lowest observed value of 0.8/2 = 0.4).

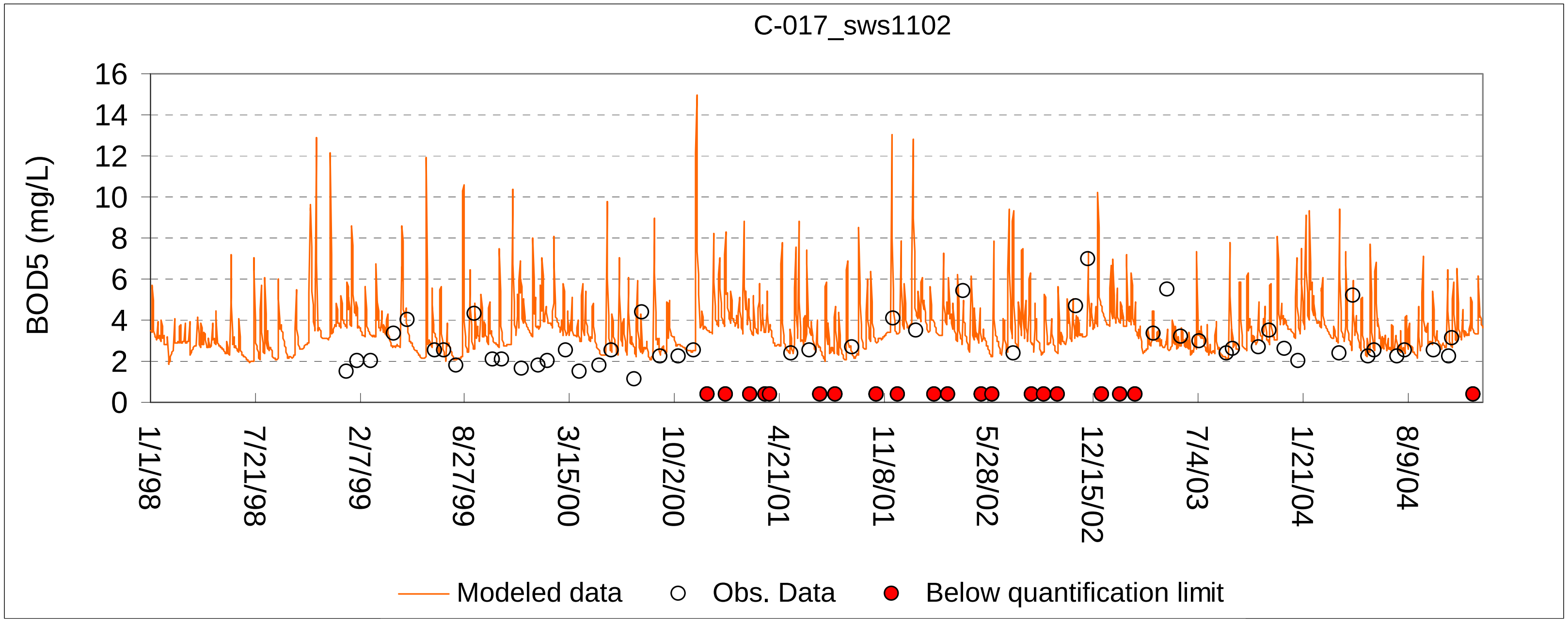


Figure B-13. BOD5 comparison at C-017 (Below QLs are shown as 0.4 mg/L: the lowest observed value of 0.8/2 = 0.4).

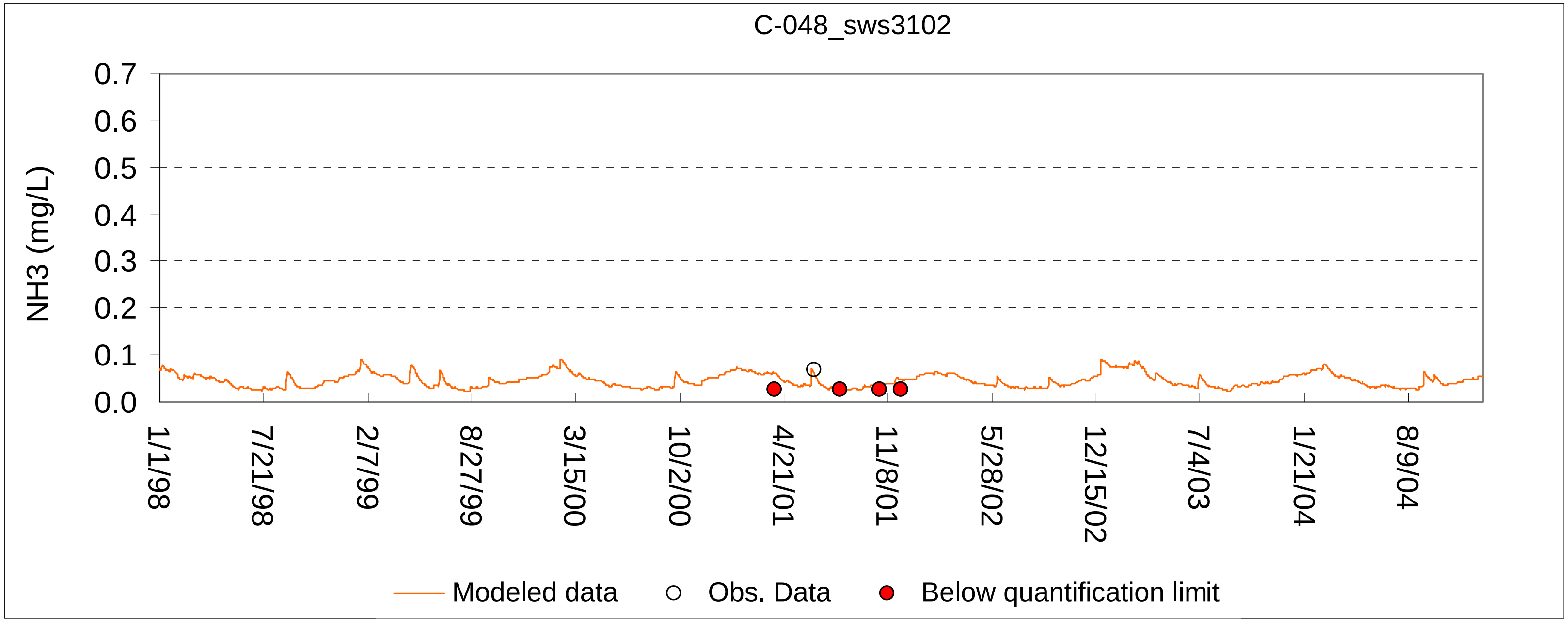


Figure B-14. Ammonia comparison at C-048 (Below QLs are shown as 0.025 mg/L: the lowest observed value of 0.05/2 = 0.025).

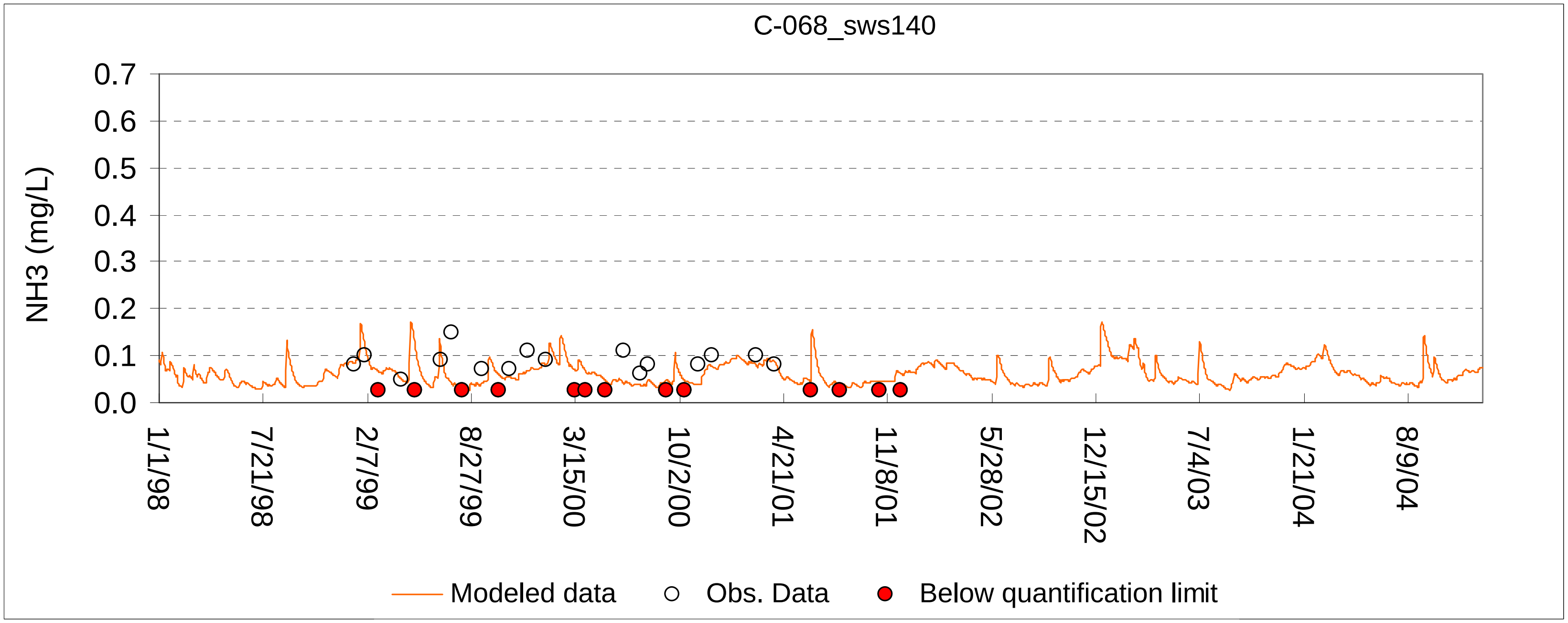


Figure B-15. Ammonia comparison at C-068 (Below QLs are shown as 0.025 mg/L: the lowest observed value of 0.05/2 = 0.025).

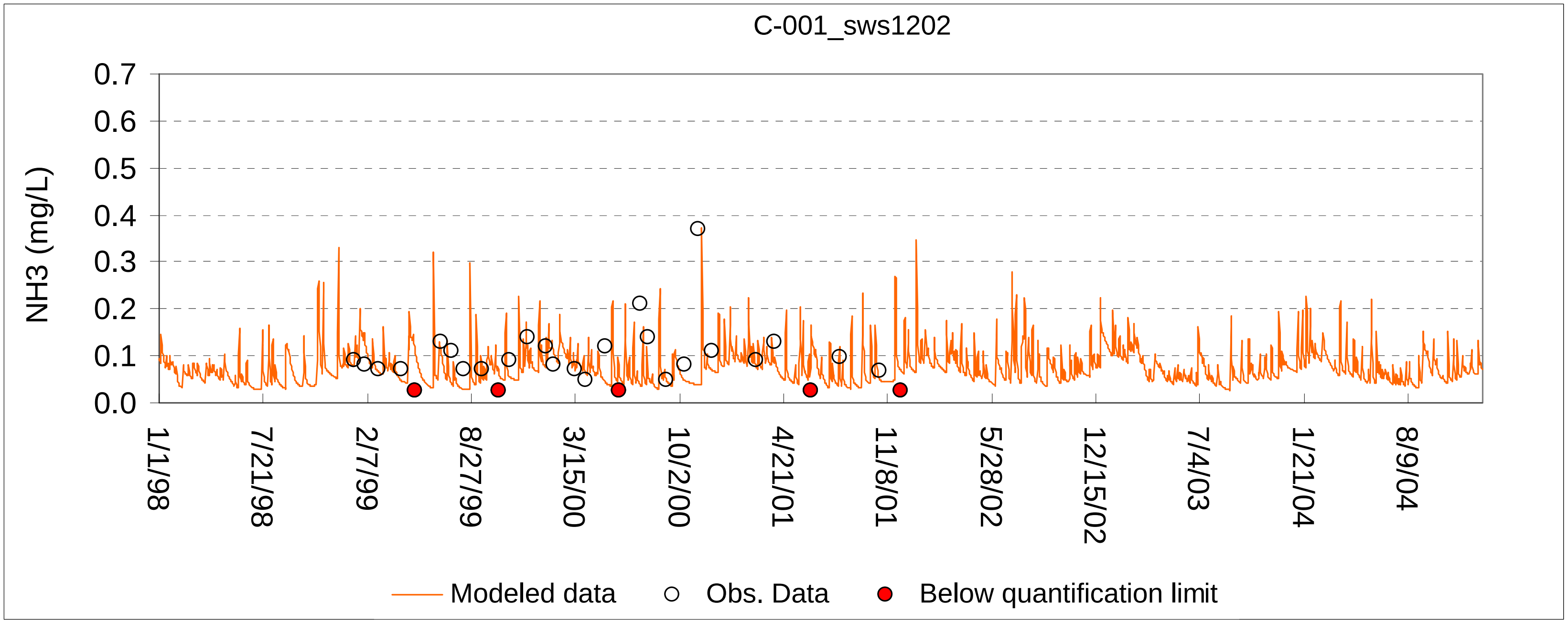


Figure B-16. Ammonia comparison at C-001 (Below QLs are shown as 0.025 mg/L: the lowest observed value of 0.05/2 = 0.025).

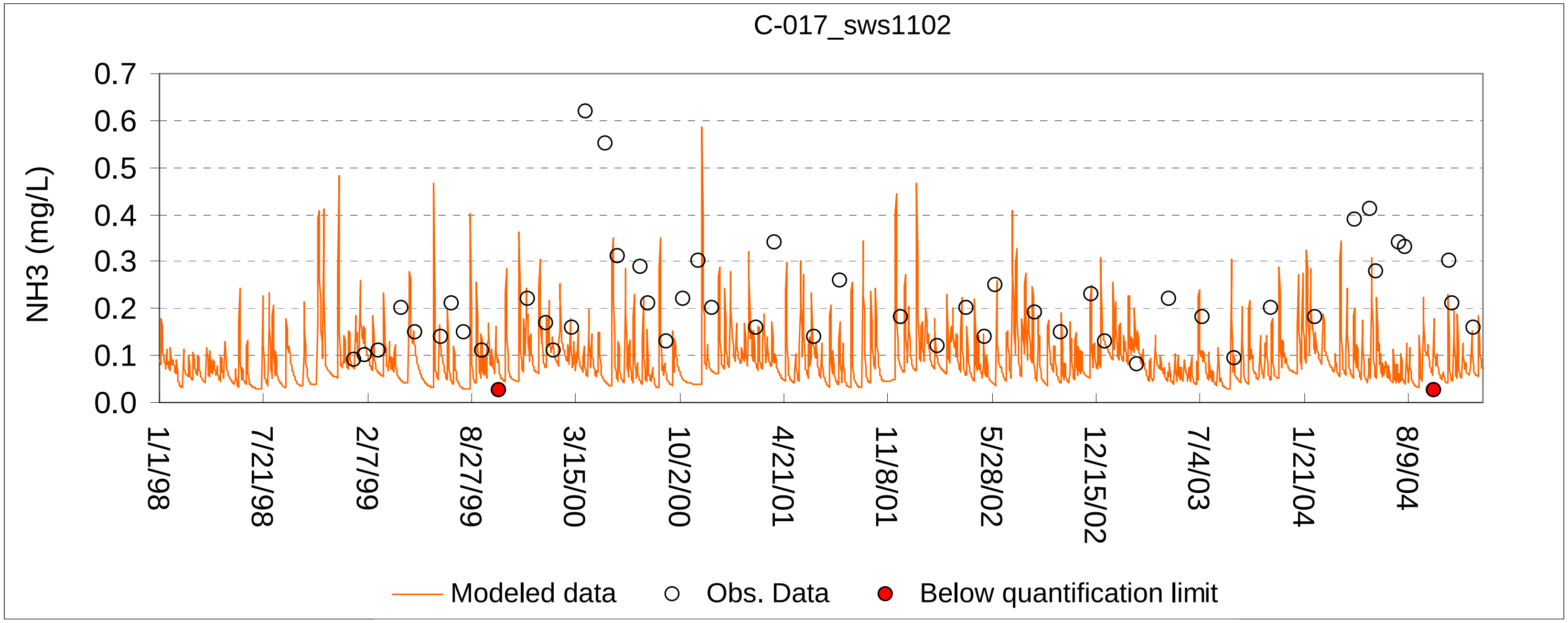


Figure B-17. Ammonia comparison at C-017 (Below QLs are shown as 0.025 mg/L: the lowest observed value of 0.05/2 = 0.025).

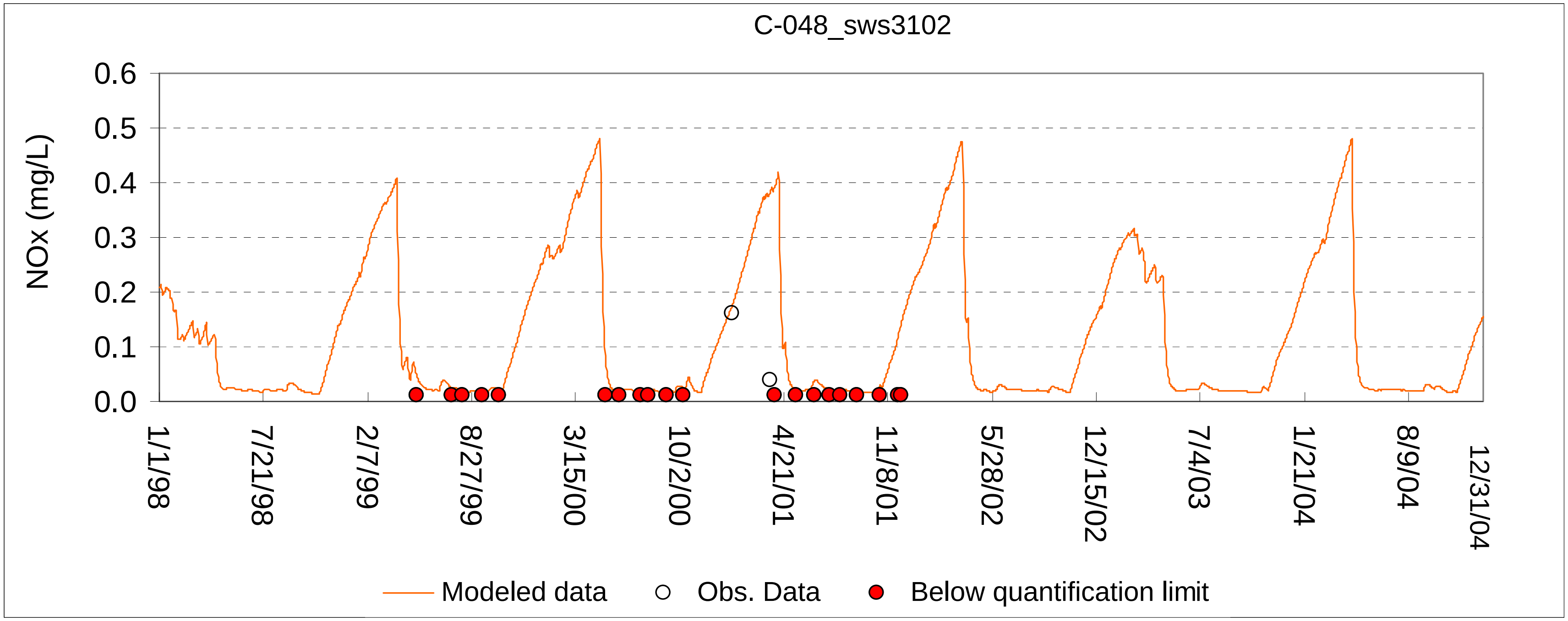


Figure B-18. NOx comparison at C-048 (Below QLs are shown as 0.01mg/L: the lowest observed value of 0.02/2 = 0.01).

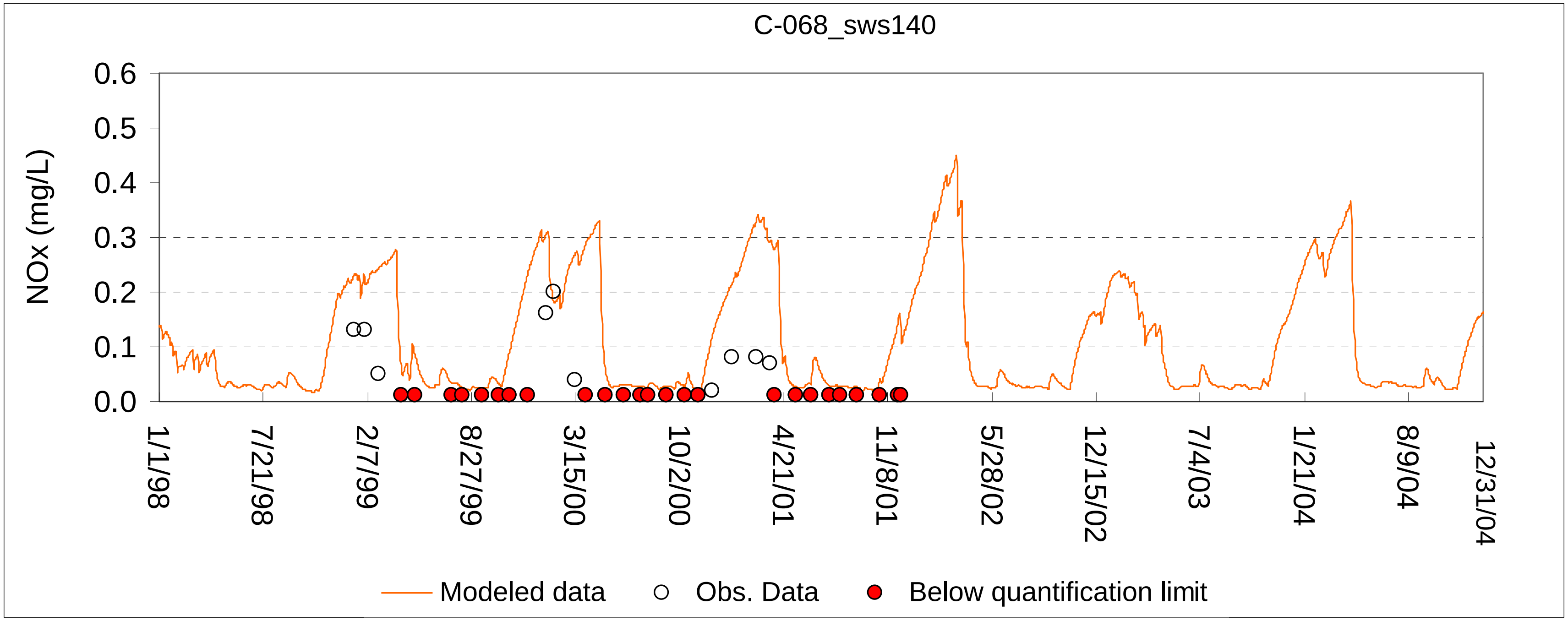


Figure B-19. NOx comparison at C-068 (Below QLs are shown as 0.01 mg/L: the lowest observed value of 0.02/2 = 0.01).

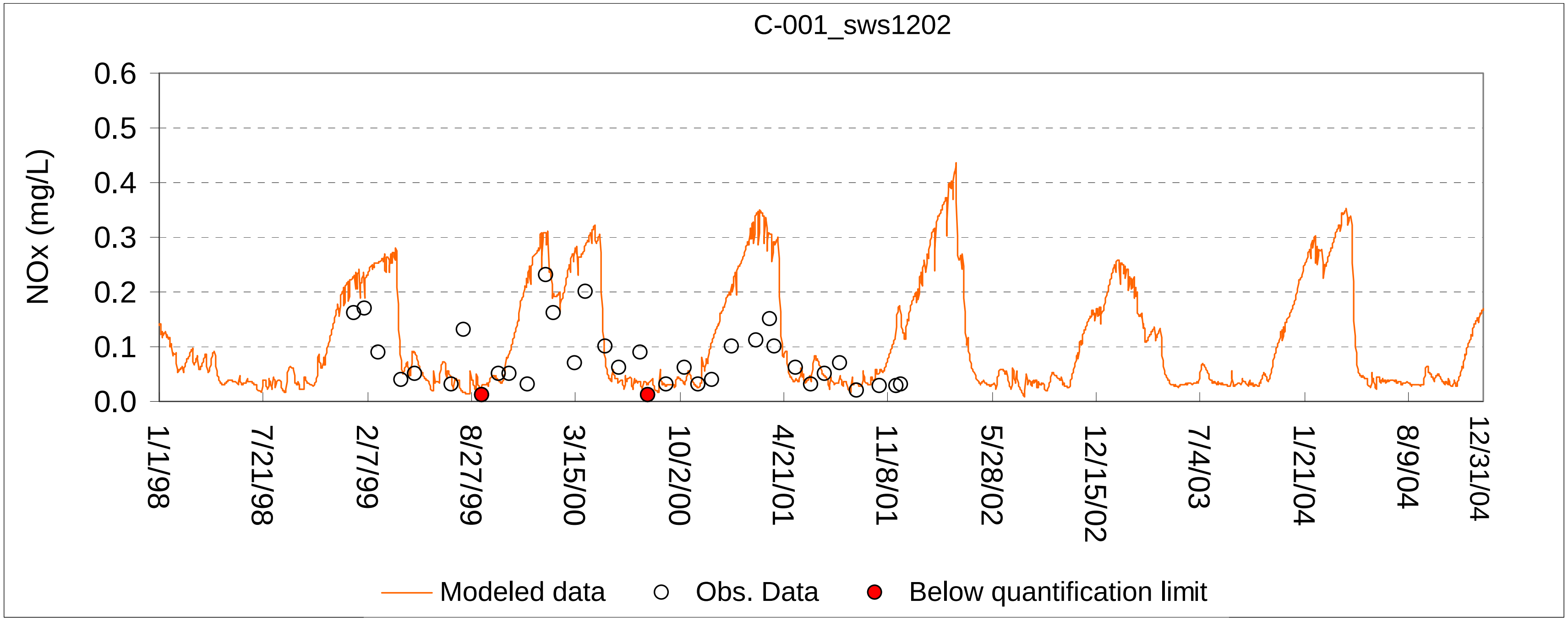


Figure B-20. NOx comparison at C-001 (Below QLs are shown as 0.01 mg/L: the lowest observed value of 0.02/2 = 0.01).

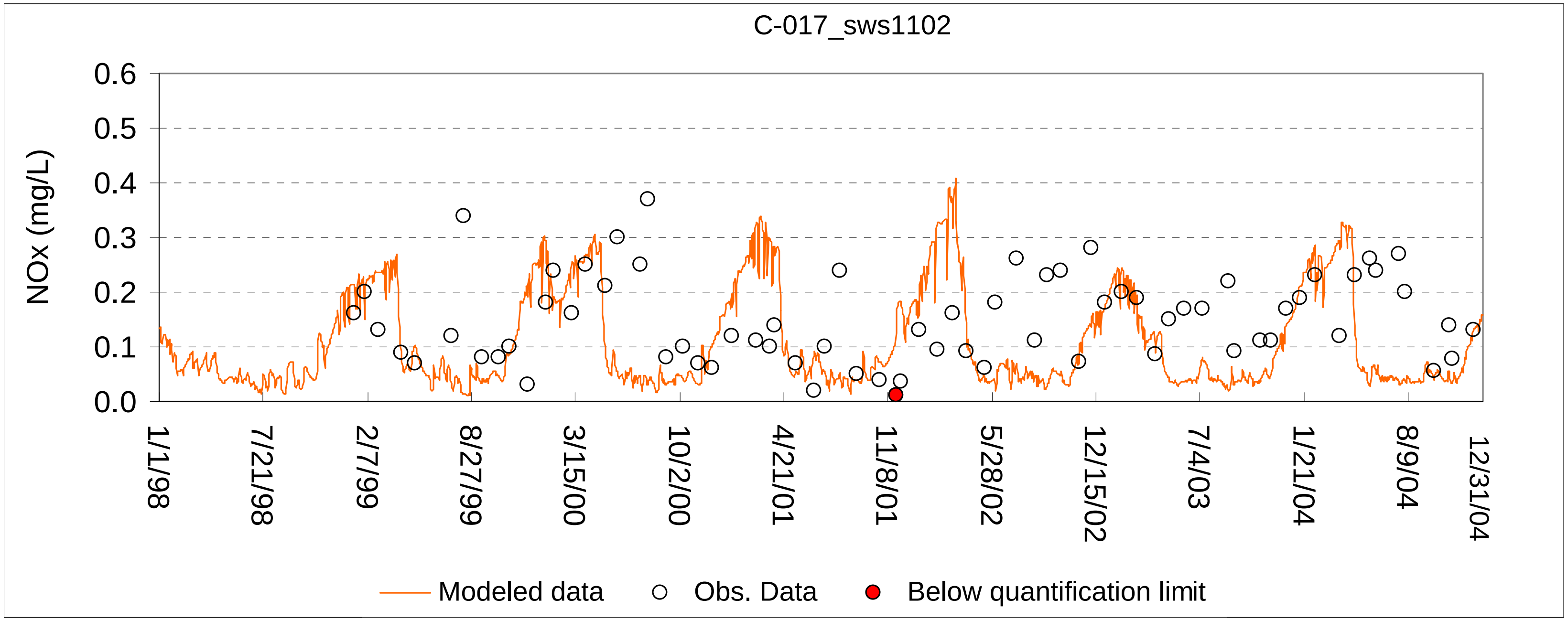


Figure B-21. NOx comparison at C-017 (Below QLs are shown as 0.01 mg/L: the lowest observed value of 0.02/2 = 0.01).

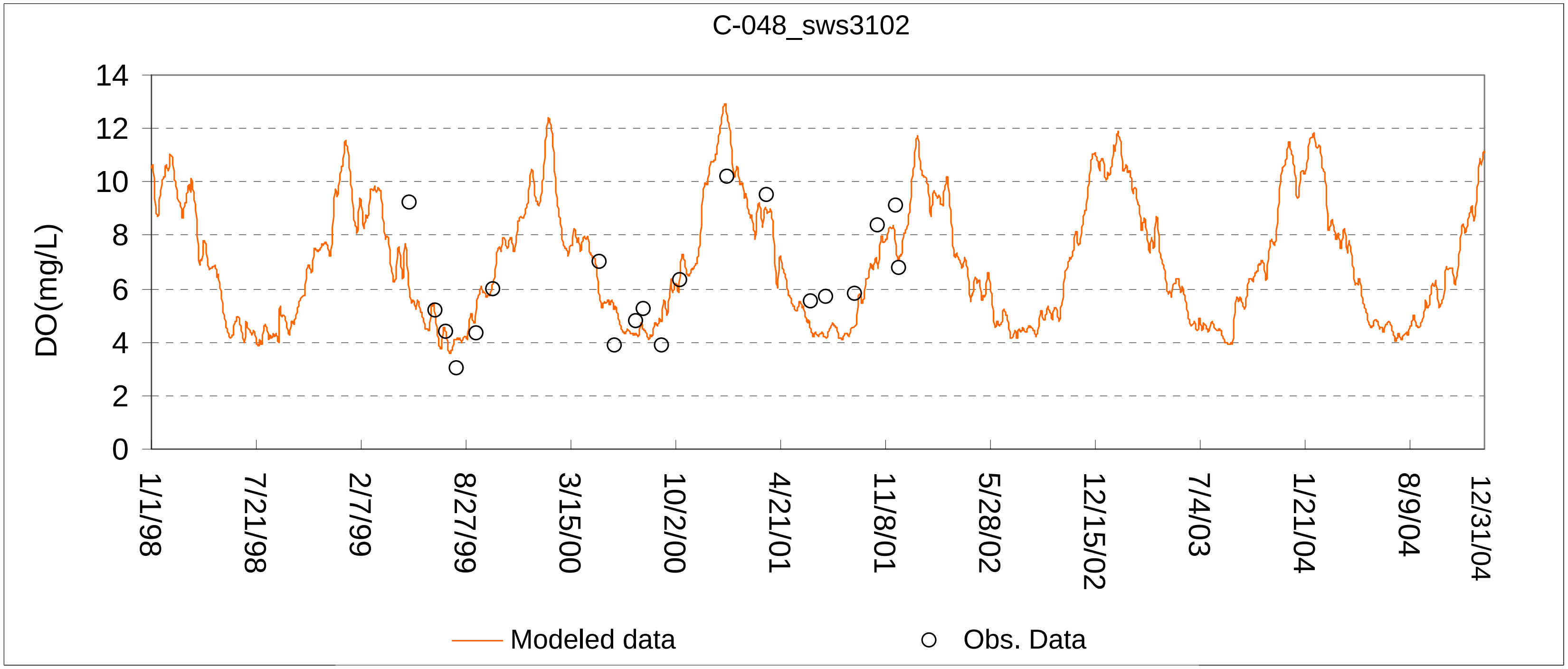


Figure B-22. Dissolved oxygen comparison at C-048.

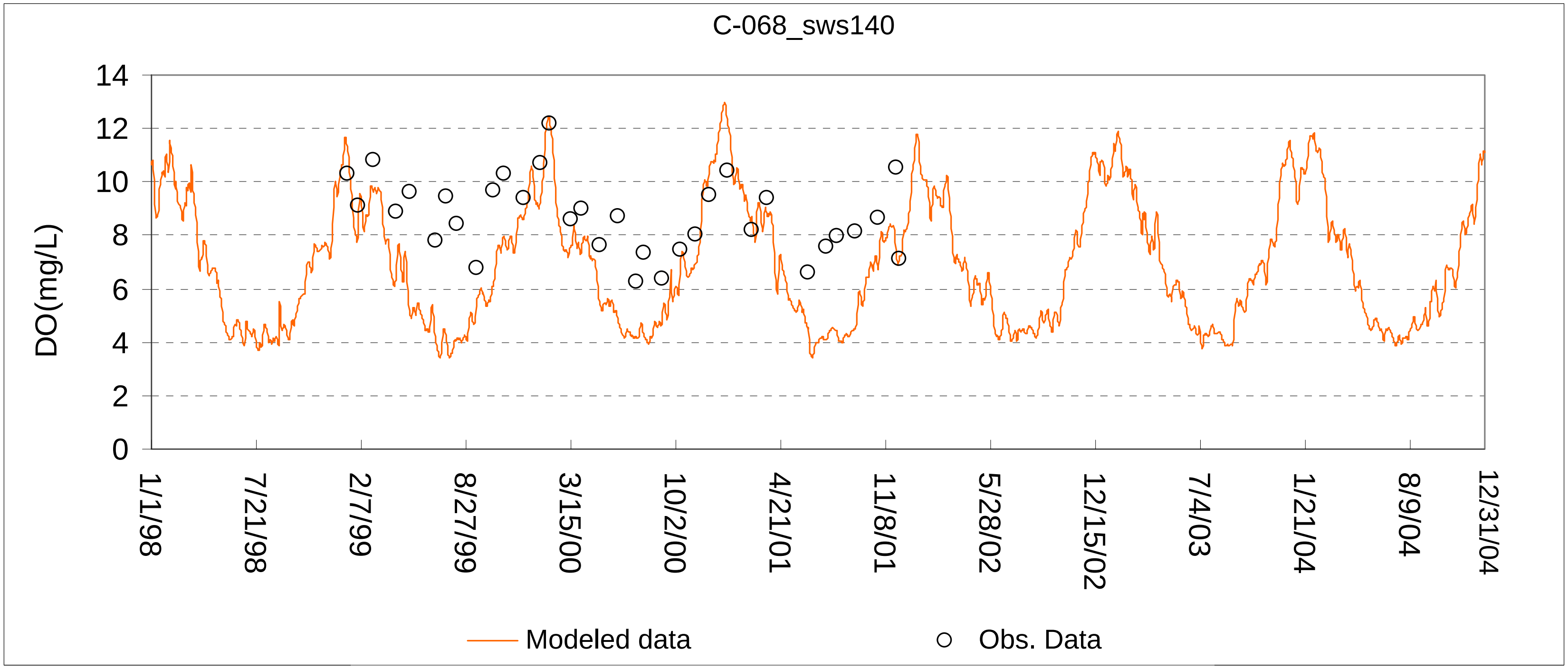


Figure B-23. Dissolved oxygen comparison at C-068.

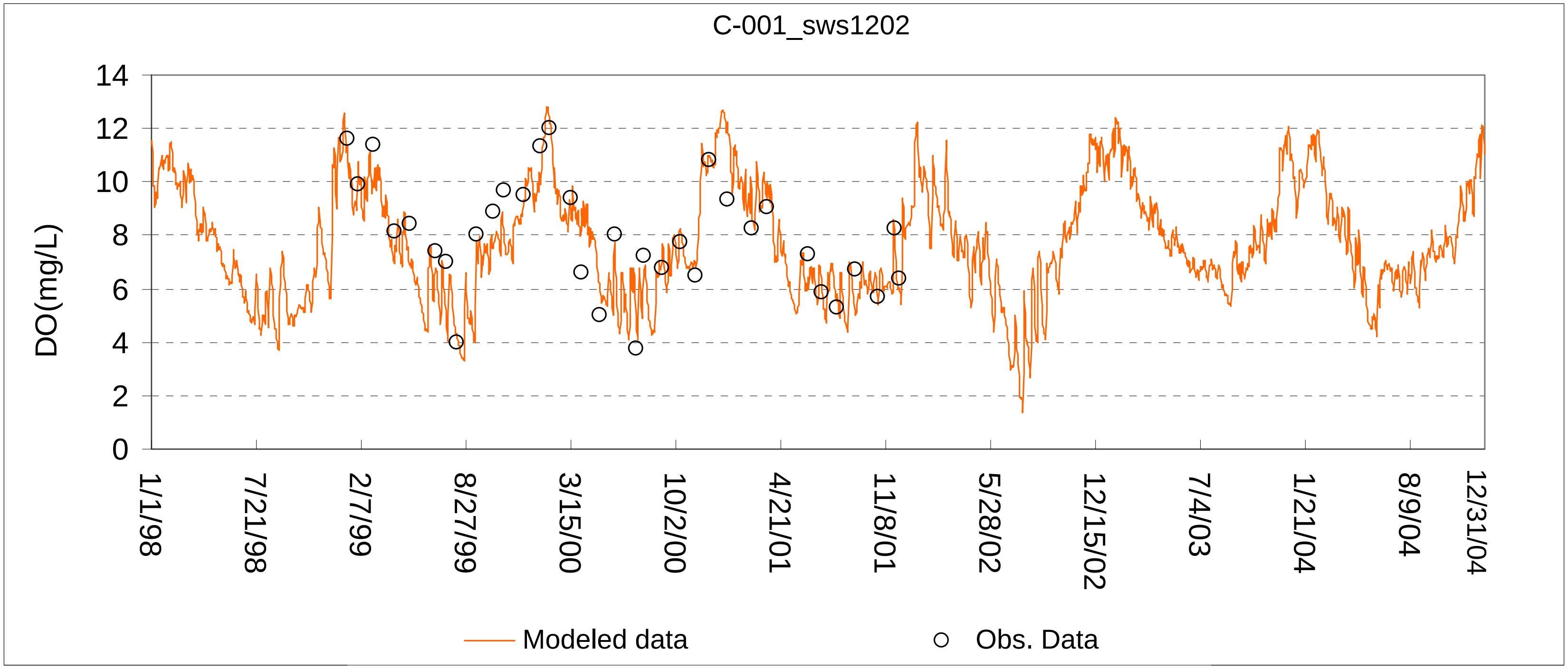


Figure B-24. Dissolved oxygen comparison at C-001.

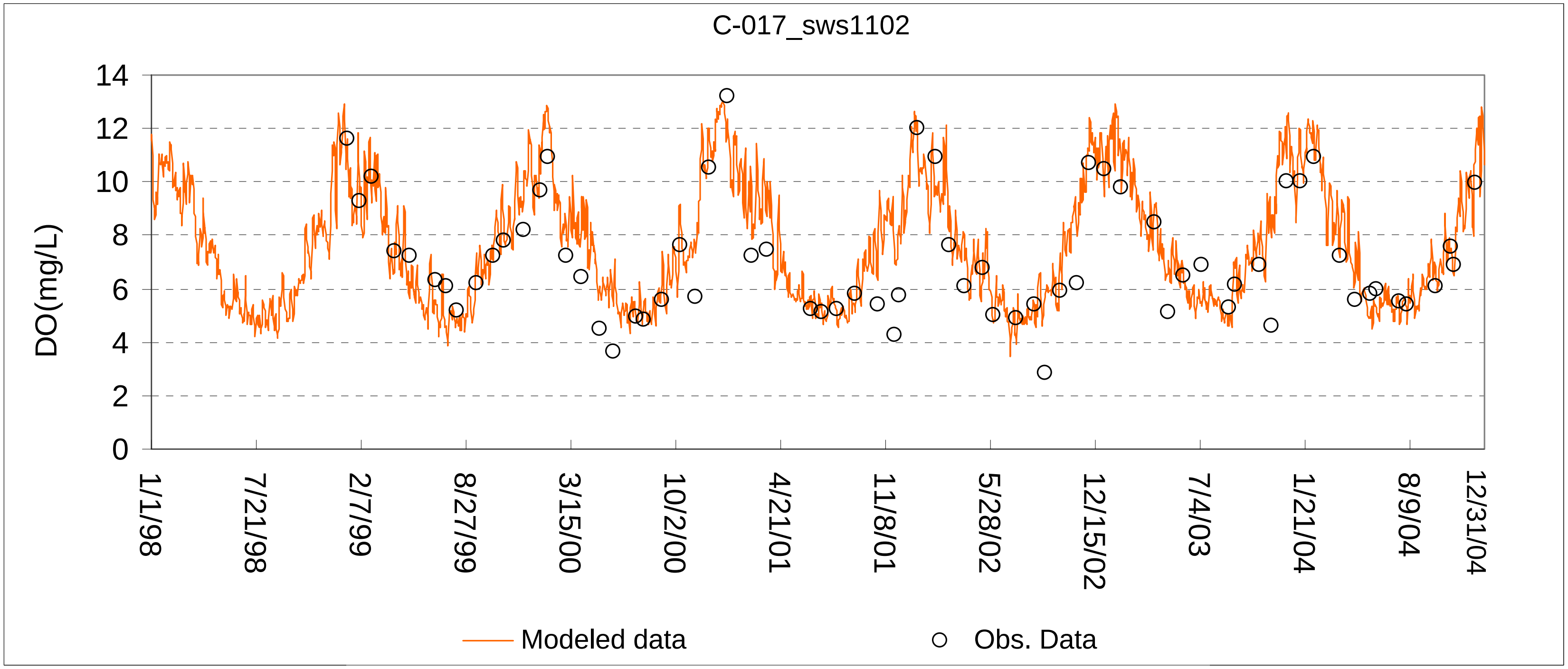


Figure B-25. Dissolved oxygen comparison at C-017

Responsiveness Summary
Gills Creek FC TMDL Document

Comments were received from the following:
Gills Creek Watershed Association
Friends of Congaree Swamp
City of Forest Acres
City of Columbia
South Carolina Department of Transportation

Comments from Gills Creek Watershed Association

Comment 1:

"Based on the data contained in the TMDL documents, there should be little doubt that nonpoint sources (NPS) of pollution, sanitary sewer overflows (SSOs), leaky sanitary sewers and other illicit discharges comprise the greatest sources contributing to water quality violations. However, the water quality sampling data collected by the SC Department of Health and Environmental Control (DHEC) has limited wet weather and elevated-flow sampling. The GCWA Board is concerned that the TMDLs may therefore significantly underestimate NPS pollutant concentrations and loadings. By definition, the "TMDL is the maximum amount of pollutant a water body can assimilate while meeting water quality standards for the pollutant of concern." Therefore, if high-flow conditions are not adequately sampled when the greatest loading of NPS pollutants occur, the load allocation (LA) and margin of safety (MOS) assumptions will be incorrect. The GCWA Board is also concerned that without adequate sampling of the high-flow conditions, the calibrations conducted for the water quality modeling in both TMDL documents **may** be biased towards lower concentrations and loadings sampled by DHEC."

"In support of this comment, please refer Figures 4.2 and 4.3 (pp. 21-22) of the FC TMDL which compares observed v. modeled FC counts. Sampled FC counts appear to exceed the modeled FC counts on six to eight occurrences at Station C-001 (Gills Ck at US 76, Garner's Ferry Rd.) and approximately 18 to 20 occurrences at Station C-017 (Gills Ck at Hwy 48, Bluff Road).[1] It is true that some sampled FC counts are less than the modeled FC counts. However, differences equal to an order of magnitude are observed between the sampled FC counts which exceed the modeled FC counts. Further, as shown in Figures 5.1 and 5.2 (pp. 23-24), the critical condition for the highest [modeled] instantaneous count equals 4414 counts/100ml at Stations C-001 and C-017 which are significantly lower than the sampled maximum FC counts. This is especially true for Station C-001 where the maximum sampled FC count is approximately 14,000 counts/100 ml. Due to limited elevated flow sampling, which would capture NPS runoff and SSOs, the sampled maximum FC counts may not represent "true critical conditions" in the Gills Creek watershed.

Response 1:

Based on the data contained in the TMDL documents, the Department acknowledges that nonpoint sources of pollution, sanitary sewer overflows, leaky sanitary sewers and other illicit discharges are some of the contributing sources to water quality standard violations. In addition to these sources, urban runoff, continuous/non-continuous point sources, agricultural activities, atmospheric deposition, etc., may also be contributing to fecal coliform, BOD5, and NH3 loading in the Gills Creek watershed.

The Department's ambient monitoring program network is not designed to target a specific climatic event or specific stream flow. Instead, samples are collected during a wide range of climatic events and various conditions instream. For more information, an electronic copy of the State of South Carolina Water Quality Monitoring Strategy approved by the USEPA can be found at the following link: **http://www.scdhec.gov/environment/water/docs/strategy.pdf**

The referenced water quality data were considered for use in development of the 2008 303(d) lists (as required by 40 CFR Part 130) and, subsequently, the data was used for development of the referenced TMDL in the Gills Creek watershed. The Department believes the methods used and presented in the referenced TMDL document, with concurrence from EPA Region 4, are valid and scientifically defensible.

Comment 2:

"Regarding the DO TMDL, the differences between sampled [measured] DO and modeled DO, shown in Figures 4.2 and 4.3 (p. 37), are much less pronounced compared with the FC TMDL. However, the GCWA Board also has additional concerns and questions regarding the sampled and reported concentrations for Total Kjeldahl Nitrogen (TKN), Total Nitrogen (TN) and Total Phosphorus (TP) referenced in Table 2.4 (pp.17-18) of the DO TMDL. The footnote on Table 2.4 states "Outliers greater than 70 mg/L were removed from the TKN, TN, and TP data; for most of these outliers, a second measurement on the same date provided a value with an expected range for the parameter." Further explanation is needed in the DO TMDL document to support and justify the elimination of "outliers." For example, was the sample deemed an outlier due to sampling error, lab error or the assumption that TKN, TN and TP concentrations should not be greater than 70 mg/l? As discussed previously, elimination of such "outliers" from the data set or inadequate sampling of elevated flow conditions could underestimate the "true" pollutant concentrations and loadings.

In order to address the above "sampling" issue, the GCWA Board strongly recommends that DHEC and the various MS4 entities in the Gills Creek Watershed reevaluate their sampling programs. This recommendation is consistent with both TMDL documents which conclude "As additional data and/or information becomes available, it might become necessary to revise and/or modify the TMDL target accordingly." In particular, additional focus should be placed on detailed elevated flow (wet weather) sampling to better characterize and quantify pollutant concentrations and loadings. The GCWA Board believes that additional statistical "blocking" of rising and falling limb hydrographs could yield important information on how to best target and implement best management practices (BMPs) and NPDES Permit compliance and enforcement efforts. For example, improved correlation between SSOs and FC violations could be utilized to better target other FC controls in sub-watersheds."

Response 2:

All available data from the modeling period (1998-2004) were used in model development. As the modeling report describes, nitrogen species were calibrated for total ammonia and NOx. Details of the modeling assumptions and procedures can be found in section 4.6. Although TP can be an important parameter to evaluate the effect on algal photosynthesis/respiration, TP is not a chemical component directly related to DO generation/consumption; thus, it was omitted from the modeling parameter related to DO modeling.

The Department's ambient monitoring program network is not designed to target a specific climatic event or specific stream flow. Instead, samples are collected during a wide range of climatic events and various conditions instream. For more information, an electronic copy of the State of South Carolina Water Quality Monitoring Strategy approved by the USEPA can be found at the following link: **http://www.scdhec.gov/environment/water/docs/strategy.pdf**

Comments from Friends of Congaree Swamp

Comment 1:

“Board members have reviewed the TMDL documents and support the findings of both. Due to the limited numbers and types of continuous point source discharges with NPDES permits, we concur that the primary sources of pollution come from non-continuous point sources (regulated storm water) and nonpoint sources.

“The TMDL document for fecal coliform bacteria proposes significant reductions in fecal coliform bacteria in the watershed. Because there are no continuous point sources with NPDES permits contributing fecal coliform, it is critical that storm water management plans for the regulated entities in the watershed be developed and implemented. There are at least six distinct entities with MS4 permits for storm water. These entities should work in concert to achieve the necessary reductions. Water quality monitoring programs and development of storm water plans are integral to the MS4 permit. But it will be imperative that these stormwater management plans actually be implemented to expect to obtain the desired reductions.”

“Although SCDHEC must finalize this TMDL and USEPA must approve it, the MS4 entities should proceed with their permit requirements.”

Response 1:

The Department agrees that the percentage reductions from all sources, including point (WLA) and nonpoint (LA), will be required to meet the water quality standard and implement the referenced TMDL.

The Department agrees that implementation from all sources in the watershed, including point (WLA) and nonpoint (LA) sources, are required to meet the percentage reductions. SCDHEC encourages a collaborative effort amongst MS4 entities in addressing stormwater issues and meeting the percentage reductions in this watershed.

The Department recognizes that **adaptive management/implementation** of this TMDL (i.e. WLA and LA) might be needed to achieve the water quality standard and we are committed towards targeting the load reductions to improve water quality in the Gills Creek watershed.

Comments from the City of Forest Acres

Comment 1:

“A detailed sensitivity analysis of the model is not provided. The importance of critical model assumptions (e.g., decay rate of0.6 day"1, loading rate for urban pervious land increased from the default value by a factor of 1,500, etc.) should be evaluated with a sensitivity analysis. Therefore, insufficient information is provided in the TMDL document to support the model application and TMDL development.”

Response 1:

The assumptions and the modeling parameters were selected using available data and literature values, as described in Sections 3 and 4 of the modeling document. The best available data was used in development of the models. Unfortunately more detailed site specific data, like a fecal tracking study, was not available to quantify loads, but literature values and fecal spreadsheet were available and therefore were used.

Section 4.5 specifies that “Observed concentrations of fecal coliform bacteria in-stream are strongly affected by the die off rate of fecal coliform bacteria. Die-off rates are increased by a variety of factors, including temperature, sunlight, salinity, settling, and predation. Based on trial and error, a loss rate of 0.6 per day appeared to provide a reasonable fit to observations.”

Comment 2:

“The TMDL study does not sufficiently establish a relationship between the source loadings and the water quality standard. The non-point source loading for urban areas was simply increased to match the approximate order of magnitudes of the range on instream concentrations (the loading rate for urban pervious land increased from the default value by a factor of 1,500); however, the analysis of measured data fails to establish sufficient understanding of the pollutant sources and justification for an increase in the urban loading by three orders of magnitude. The modeling itself does not appear to provide any additional insight to help explain the linkage between pollutant sources and the instream concentrations.”

Response 2:

Reasoning and justification for the adjustment are provided in Section 4.5 (pages 22 and 23) of the modeling report. Similar values have been used for other studies. For example, the recent study done by Tetra Tech for Water Quality Calibration and Validation Results for the Menomonee River Modeling prepared for the Milwaukee Metropolitan Sewerage District has the maximum build up and wash off rate of 2.9E+10 and 5.4E+10.

Comment 3:

“The model calibration does not demonstrate an ability to predict daily variations in FC concentrations. Therefore, the application of the model should not be used to assess instantaneous FC concentrations. Additional comparisons should be provided to demonstrate that the model is capable of reasonably predicting longer time-averaged concentrations (even annual geometric mean concentrations) to show that the model is reasonably reproducing the instream concentrations.”

Response 3:

The below table includes statistics when comparing all available observed data with the modeled results.

Assessment locations	Water quality parameter name	Obs. Data number	Modeled mean (mg/L or #/100ml)	Obs. Mean (mg/L or #/100ml)	Mean abs.Error (mg/L or #/100ml)	RMS Error (mg/L or #/100ml)	Relative RMS Error(%)
C-068	BOD5 (mg/L)	35	2.10	2.35	1.13	1.32	28.00
C-068	DO (mg/L)	33	6.89	8.73	2.14	2.54	42.63
C-068	Fecal Coliform (#/100ml)	35	21.53	93.26	94.06	211.14	24.57
C-068	NO3/NO2 (mg/L)	34	0.12	0.03	0.08	0.12	64.34
C-068	Sediment (mg/L)	3	8.94	13.45	2.98	3.37	33.04
C-068	Total ammonia (mg/L)	28	0.06	0.06	0.03	0.04	30.58
C-017	BOD5 (mg/L)	70	3.43	2.15	1.58	2.08	31.52
C-017	DO (mg/L)	68	7.65	7.11	0.98	1.24	11.97

C-017	Fecal Coliform (#/100ml)	71	250.70	669.50	704.01	1637.84	18.83
C-017	NO3/NO2 (mg/L)	70	0.12	0.15	0.10	0.13	35.18
C-017	Sediment (mg/L)	65	10.83	13.63	10.08	18.48	19.17
C-017	Temperature ©	68	18.42	18.25	1.71	2.16	8.16
C-017	Total ammonia (mg/L)	50	0.09	0.21	0.13	0.18	29.66
C-001	BOD5 (mg/L)	34	2.64	3.17	1.46	1.76	35.11
C-001	DO (mg/L)	33	7.80	7.98	0.81	1.03	12.44
C-001	Fecal Coliform (#/100ml)	35	178.70	873.50	838.77	2533.42	18.10
C-001	NO3/NO2 (mg/L)	34	0.13	0.08	0.07	0.09	42.80
C-001	Sediment (mg/L)	30	11.11	14.80	12.90	20.80	102.98
C-001	Temperature ©	33	18.35	18.84	2.24	2.89	10.71
C-001	Total ammonia (mg/L)	29	0.07	0.09	0.05	0.08	23.81
C-048	BOD5 (mg/L)	22	1.58	1.76	1.30	1.60	35.53
C-048	DO (mg/L)	19	5.89	6.20	1.13	1.37	19.01
C-048	Fecal Coliform (#/100ml)	22	15.04	64.28	69.47	122.91	28.62
C-048	NO3/NO2 (mg/L)	21	0.07	0.02	0.05	0.12	77.54
C-048	Temperature ©	16	23.09	24.26	1.57	1.94	7.27
C-048	Total ammonia (mg/L)	4	0.05	0.03	0.02	0.02	44.90

- Mean absolute errors (MAE): the mean absolute value of the difference between observed and predicated values. It indicates the average deviation between model predictions and observed data. Zero means that the predications match the observation perfectly.

- RMS error: the average of the squared differences between observed and predicted values. It is more rigorous measure of model performance than MAE. It is a weighted equivalent to MAE with larger observation-predication differences given larger weightings. An RMS error of zero is ideal.

- Relative RMS error: percentage error based on RMS error and observed change. It is used to measure model performance in the water quality modeling.

Comment 4:

“There is an unexplained change in the model behavior at the end of2001 (an increase in minimum FC concentrations) that is not supported by the measured data. This curious model behavior should be either explained or corrected before the model is used to establish a TMDL.”

Response 4:

Several SSO data became available from 2001. Due to this input of the data, the model generates higher concentrations than previous years.

Comment 5:

“In the ‘wildlife’ section of the report, loading from deer population was estimated for forest and herbaceous land covers, and loading from other wildlife such as raccoons, …was not estimated. Raccoons and opossums can occur throughout the watershed, and these should be included in the loading estimate. The “urban/suburban runoff” section describes urban wildlife, but it does not estimate loads from these sources. Waterfowl are a potential significant source of bacteria that should be included in the loading estimate as well.”

Response 5:

Specific data for waterfowl were not available. Model fecal loads were assumed using the EPA Fecal tool based on literature values. The EPA Fecal tool was developed for use in TMDL development. Known animal counts, landuse, and application rates for various types of manure can be input to the spreadsheet and fecal loads are estimated based on literature values.

Comment 6:

"The source assessment should describe when and where the sanitary sewer overflows (SSOs) occurred, and if there is any correlation between the high FC concentrations and the SSO events."

Response 6:

Due to the limited information currently available for SSO events occurring in the Gills Creek watershed it is not feasible to attempt to correlate SSO events with the existing ambient monitoring conducted for fecal coliform concentrations.

Comment 7:

"A flow duration curve type analysis should be completed to see if this provides any additional insight to the relationship between flow and FC concentration."

Response 7:

An analysis was conducted to provide insight into the relationship between flow and FC concentration. The following table is included in the Gills Creek TMDL document:

Station	R^2 for FC and rain	R^2 for FC and flow
C-001	0.006	0.02
C-017	0.006	0.047

In addition, figures A-2 and A-4 show the relationship between fecal coliform and flow at water quality monitoring stations C-001 and C-017.

Comment 8:

"Given the fact that water quality data for all 4 monitoring stations was presented through 2006, the LSPC model should be extended through 2006. This would provide significantly more data for model calibration/validation. This would also provide complete overlap with the 200-2006 TMDL measured data assessment period."

Response 8:

Time and resources restricted the ability to extend the model through 2006. The modeled period did include both wet and dry periods to account for variations in climate and therefore adequate for the development of TMDLs.

Comment 9:

“The water quality standard is as follows: *"Not to exceed a geometric mean of 2001100 mL, based on five consecutive samples during any 30 day period; nor shall more than 10percent of the total samples during any 30 day period exceed 4001100 ml.*. [R.61-68; SCDHEC 2008]." Why then is a single instantaneous 4001100mL criterion used to determine the TMDL based on the model simulation? This is not consistent with the standard of"... 1*0 percent of the total samples during any 30 day period. . ."* A criterion of not exceeding 400/100 mL more than 3 days out of 30 is more appropriate.”

Response 9:

The Gills Creek Watershed LSPC model predicts daily FC bacteria output during the 1999-2004 time-frame. The FC bacteria TMDLs are based upon ‘critical conditions’. In this case, the highest predicted violations of both the instantaneous and geometric mean standard represent ‘critical conditions’. The Department also believes this approach for using modeling predictions is appropriate as an implicit margin of safety (MOS) in TMDL development.

Note that the definition of a $TMDL = \Sigma WLAs + \Sigma LAs + MOS$

Comment 10:

“The model study does not demonstrate the ability of the model to reliably predict instantaneous concentrations. Therefore, the predicted 30-day geometric mean is a more reasonable standard to apply when using the model to determine the TMDL.”

Response 10:

The TMDL was developed using the most critical event to be protective of all the standards.

Comment 11:

“For the model calibration comparisons, the geomean of simulated FC for the entire simulation should be compared to geomean of observed FC for the entire period.”

Response 11:

As stated in Section 2.0 “there are insufficient data to evaluate against the 30-day geometric mean,” so no geomean data is available for comparison.

Comment 12:

“The report should describe how the FTABLES were developed in greater detail. Are they based on field surveyed cross-sections, or based on DEMS?”

Response 12:

FTables were set up in the previous modeling effort completed by Richland County. Contact the Richland County Department of Public Works for more information on modeling work they have completed in the watershed.

Comment 13:

"Additional detail should be provided describing the FC concentrations of groundwater and interflow determined during the calibration process."

Response 13:

Reasoning and justification for the adjustment are provided in the modeling report. Section 2.8.3 presents the failing septic system loading assumptions and their reasoning. Similar values have been used for other studies. For example, the recent study done by Tetra Tech for Water Quality Calibration and Validation Results for the Menomonee River Modeling prepared for the Milwaukee Metropolitan Sewerage District has the maximum build up and wash off rate of 2.9E+10 and 5.4E+10.

Comment 14:

"The minimum predicted FC concentration increases by an order of magnitude between 2000 and 2001. The model study report should explain the cause of this change in concentration."

Response 14:

Several SSO data became available from 2001. Due to this input of the data, the model generates higher concentrations than previous years.

Comment 15:

"The pollutant accumulation rate for urban pervious areas was increased from the default values by a factor of 1,500, and the buildup limit was increased by nearly a factor of 10,000. The study must demonstrate that these are reasonable values. Have these accumulation and buildup limits been found elsewhere in the literature, as documented by monitoring data?"

Response 15:

The similar values have been used for other studies. For example, the recent study done by Tetra Tech for Water Quality Calibration and Validation Results for the Menomonee River Modeling prepared for the Milwaukee Metropolitan Sewerage District has the maximum build up and wash off rate of 2.9E+10 and 5.4E+10.

Comment 16:

"A sensitivity analysis should be provided to show the effects of the model assumptions. The urban pervious area loading rates were dramatically increased, but it is not clear if similar results could be obtained by increasing other loading rates (other land uses, SSO events, leaking sanitary sewers, illicit discharges, failing septic systems, wildlife, groundwater and interflow loads) or modifying model coefficients within the range of uncertainty."

Response 16:

SSO events, leaking sanitary sewers, failing septic systems, and wildlife information were input into the model based on local, US census, or literature data. Groundwater and interflow loads were started from values that used in other modeling studies and modified during calibration processes. Landuse loadings for fecal were set using EPA's Fecal Tool. However, with insufficient detailed animal counts information, the build-up and the wash-off rates were increased through calibration process. The range of the selected rates was still similar to the ranges used in other studies. An example was listed in response 11. The die-off rates were also selected within literature values. The different combination of selected values for these inputs could still potentially generate the same result but using the available data and the professional judgments described in the modeling document, we tried to reduce the uncertainty associated with simulating complex nature with a mathematical model through modeling process.

Comment 17:

"The report should clarify if SSO events were included only for model calibration and if they were included in the application of simulations."

Response 17:

SSO events were included during both calibration and validation periods.

Comments from the City of Columbia

Comment 1:

"On pg. 6, the TMDL quotes South Carolina's Water Quality Standard for fecal coliform (FC) bacteria in freshwater as "[n]ot to exceed a geometric mean of 200/100 ml, based on five consecutive samples during any 30 day period; nor shall more than 10 percent of the total samples during any 30 day period exceed 400/100ml." Since DHEC does not collect a sufficient number of samples to determine the geometric mean per the standards, DHEC relies on the 10% criteria. Yet since DHEC only pulls approximately one sample each 30 day period, should any of those samples exceed 400/100 ml, that sample fails the 10% criteria. Thus DHEC's sampling strategy is heavily skewed towards over-estimating fecal load. This approach would be completely unacceptable for a permit holder."

Response 1:

The data used in the development of the referenced TMDL document consists of up to 96 individual data points from 1999 - 2006. Sampling is conducted under an approved Quality Assurance Project Plan (QAPP), which must be approved by the State Quality Assurance Management Officer (SQAMO) or Quality Assurance (QA) Officer. In addition, a SCDHEC EQC (Environmental Quality Control) standard operating procedures (SOP) and quality assurance manual is also used. Ambient monitoring is covered under section 7, part 2 of the SOP and QA manual. The Department believes, with concurrence from EPA region 4, that the data collected is valid, scientifically defensible, and adequate for TMDL development. Federal regulations also require that TMDLs take into account the seasonal variability in watershed loading. The variability in this TMDL is accounted for by using a 7-year hydrological data set and 12 month water quality sampling data set, which includes data collected from all seasons.

Comment 2:

"In support of the above concern, Figure 4-2 for C-001 shows only one sample greater than 5000 CFU/100 ml, even though the model predicts 20 peaks greater than this amount. If the sample strategy is overestimating fecal loading, then the model is likely overestimating the critical condition. The single measured peak suggests the sampling strategy gives undue weight to outliers, thus skewing the model. If a better sampling strategy was used, it may be that the number of predicted peaks would have been fewer."

Response 2:

The data used in the development of the referenced TMDL document consists of up to 96 individual data points from 1999 - 2006. Sampling is conducted under an approved Quality Assurance Project Plan (QAPP), which must be approved by the State Quality Assurance Management Officer (SQAMO) or Quality Assurance (QA) Officer. In addition, a SCDHEC EQC (Environmental Quality Control) standard operating procedures (SOP) and quality assurance manual is also used. Ambient monitoring is covered under section 7, part 2 of the SOP and QA manual. The Department believes, with concurrence from EPA region 4, that the data collected is valid, scientifically defensible, and adequate for TMDL development. Federal regulations also require that TMDLs take into account the seasonal variability in watershed loading. The variability in this TMDL is accounted for by using a 7-year hydrological data set and 12 month water quality sampling data set, which includes data collected from all seasons.

Comment 3:

"The TMDL lacks scientific basis for concluding that the water quality standards have been breached. The City questions the entire basis for this TMDL. The City requests more frequent base-line sampling to determine the fecal counts in this water body and whether or not they are related to stormwater discharges."

Response 3:

The data used in the development of the referenced TMDL document consists of up to 96 individual data points from 1999 - 2006. Sampling is conducted under an approved Quality Assurance Project Plan (QAPP), which must be approved by the State Quality Assurance Management Officer (SQAMO) or Quality Assurance (QA) Officer. In addition, a SCDHEC EQC (Environmental Quality Control) standard operating procedures (SOP) and quality assurance manual is also used. Ambient monitoring is covered under section 7, part 2 of the SOP and QA manual. The Department believes, with concurrence from EPA region 4, that the data collected is valid, scientifically defensible, and adequate for TMDL development. Federal regulations also require that TMDLs take into account the seasonal variability in watershed loading. The variability in this TMDL is accounted for by using a 7-year hydrological data set and 12 month water quality sampling data set, which includes data collected from all seasons.

Based on the available information at this time, the portion of the watershed that drains directly to a regulated MS4 and that which drains through the non-regulated MS4 has not been clearly defined for the MS4 jurisdictional area. Loading from both types of sources (regulated and non-regulated) typically occur in response to rainfall events, and discharge volumes as well as reoccurrence intervals are largely unknown. Therefore, the regulated MS4 is assigned the same percent reduction as the non-regulated sources in the watershed. The regulated MS4 entity is only responsible for implementing the TMDL WLA in accordance with MS4 permit requirements.

It should be further acknowledged that implementation from all sources in the watershed, including point (WLA) and nonpoint (LA) sources, are required to meet the percentage reduction. As additional data and/or information becomes available, it may become necessary to revise and/or modify the TMDL target accordingly.

Comment 4:

"On pg. 35, the TMDL lists a series of sub-basins with load reductions based solely on modeling since water quality data were not available. Of note is that the overall station reductions are over 90% while the estimated load reductions for many of the sub-basins are under 90% and as low as 40% or even 25%. The load reductions for the sub-basins are inconsistent with the over-all load reductions suggesting problems with the overall modeling strategy. If this is not correct, please include the calculations that support the reductions outlined in the TMDL."

Response 4:

As part of the modeling effort for this TMDL, reduction sequencing was simulated from the headwaters-downstream to establish potential reductions at a subbasin scale in the Gills Creek watershed. These reductions, presented on page 35 of the referenced TMDL document, are made to use as a guide to prioritize and for implementing BMPs in the Gills Creek watershed. Any implementation efforts focused on specific subbasins may not meet compliance at SCDHEC's existing water quality monitoring stations or be consistent with the assumptions and requirements of the TMDL as defined in section 5 of the referenced TMDL document. Therefore, it should be noted that compliance is measured at SCDHEC's existing water quality monitoring stations and not at the subbasin level. Implementation will need to occur throughout the watershed as a collaborative effort between multiple stakeholders to ensure compliance at SCDHECs existing monitoring stations.

Comment 5:

"The City is also concerned about the impact stormwater management can have on FC bacteria given no statistically significant correlations between FC bacteria and rain and FC bacteria and flow. On pg. 7, the correlations between FC bacteria and rain and FC bacteria and flow at the stations are as follows:

Station	R^2 for FC and rain	R^2 for FC and flow
C-001	0.006	0.02
C-017	0.006	0.047

This information is also presented on pp. 49 and 50, Figures A-2 and A5. All correlations are so weak as to be effectively non-existent. This data does not support stormwater as being a statistically significant source of fecal loading in the watershed. Since illicit discharges are considered illegal and not subject to load or waste load allocations, there seems to be no merit to additional fecal coliform management responsibilities beyond identifying and addressing potential illegal discharges to the maximum extent practicable on MS4s in the Gills Creek watershed. The City requests that the TMDL be based on proven scientific data since the TMDL document has regulatory impacts on MS4s."

Response 5:

Section 3.0 of the TMDL document attempts to inventory all potential source of FC bacteria in the Gills Creek watershed. Illicit discharges are recognized as a potential source, in addition to other potential sources in the watershed. Note that a reduction from all sources in necessary in order achieve the water quality standard.

A lack of correlation between FC bacteria, rain and instream flow does not preclude regulated MS4 from meeting all requirements of their MS4 permit. Illicit discharge detection and elimination is only one MS4 permit requirement. Elimination of these illicit discharges may not result in attainment of the FC bacteria standard in Gills Creek unless reductions from all other sources are achieved. Stormwater discharges covered under an MS4 permit are required to meet percentage reduction or the existing instream standard for pollutant of concern in accordance with their NPDES permit to the MEP.

Comment 6:

"On pg. 16, the TMDL states that "waterfowl are likely to be a source of bacteria" due to the open water attracting migratory birds. Yet, it goes on to state that "[d]ensity estimates for waterfowl were not available" (pg. 16). If waterfowl are a likely source, then they should be accounted for in the model. However, pg. 21 of the Watershed Hydrology and Water Quality Modeling Report for the Gills Creek Watershed states that waterfowl are not part of the model. If the model does not account for waterfowl, it is then underestimating their contribution to FC bacterial loading in the watershed. Please also explain how waterfowl estimates are not available. Shouldn't the S.C. Department of Natural Resources be able to provide such information? With these estimates, the City requests that the model be re-run accounting for waterfowl population estimates."

Response 6:

The source assessment did not identify specific locations where waterfowl gather. Therefore, specific counts of waterfowl could not be explicitly input to the Fecal tool. In-stream fecal coliform concentrations may be elevated by sources that are not explicitly included in the model (e.g., waterfowl) or by sources that are included in the model in a general way but have large and unmonitored variability. The watershed models represent average loads from the land surface as a wash-off process. In addition, background loading is represented as a groundwater concentration. During the calibration process, however, the source represented in the tool was found to be significantly underestimating the observed fecal coliform conditions in streams. Thus, during the model calibration process, the accumulation loadings from urban land use were increased and modified. Table 4-2 shows the accumulation and buildup limits derived from the tool and the updated values selected during the calibration process.

Comment 7:

"For Figure 4-1, Comparison of the monthly average observed and modeled flows at USGS 02169570, the TMDL uses R^2 to evaluate average model flow. Recent studies (Harmel and Smith, 2007; Legates and McCabe, 1999) advocate the use of numeric errors other than R^2 such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and the Nash-Sutcliffe coefficient. Figure 4-1 should reflect use of the Nash-Sutcliffe coefficient since R^2 is insensitive to additive and proportional differences between model simulations and observations (Legates and McCabe, 1999)."

Response 7:

Comparing the accepted error range for hydrologic modeling calibration, the results show the model is calibrated adequately at the gage; the modeled results can be compared to Table 3-2 in the modeling report.

Comment 8:

"Under Section 3.2.2 - Agricultural Activites, the TMDL does not consider manure application sites as a potential source of FC bacteria. The City requests DHEC evaluate whether manure application sites may be a concern for FC bacterial loading."

Response 8:

Manure application sites are covered under No Discharge (ND) permits and therefore any discharge of fecal coliform to waters of the State is illegal, subject to compliance and enforcement actions, and not covered under a wasteload or load allocation.

Comment 9:

"The TMDL relies heavily on personal communications to establish livestock agricultural activity beyond that permitted by DHEC. H. Caldwell is cited as the source for estimating livestock ownership. More scientifically robust sources of information exist to estimate livestock ownership. The USDA Census of Agriculture includes information on for-profit farming in the region. The American Veterinary Association's pet ownership survey also includes information on livestock kept as pets. The South Carolina Department of Agriculture and the South Carolina Farm Bureau are also sources of more definitive information. The City requests that the model be re-run using these sources of information to estimate livestock impact on FC bacteria in the watershed."

Response 9:

As a representative of the county and active watershed stakeholder, H. Caldwell appears to be the most knowledgeable source of information for this TMDL. The counts he provided were used in the Fecal tool developed by EPA. The Fecal tool uses literature values to quantify loads of fecal coliform based on animal counts, landuse, and manure application. This was described in Section 4.5 of the modeling report.

Comment 10:

"Section 3.2.4 - Failing Septic Systems estimates that there are 214 failing septic systems in the watershed. This estimate seems to be based on one reported resident claiming to still have a septic system on his or her property and 1990 census data with the assumption that half the systems reported in the census are still in use. Within the City limits, it is illegal to maintain or use a septic tank where a public sewer is accessible for connection, and any houses found to be on a septic system are required to tie on to public sewer within 30 days of being identified (City of Columbia Code of Ordinances, Section 23-151). This law has been in effect since 1979. Therefore, to assume even half of the 1990 septic tank systems are still in operation, at least within the City limits, is likely an overestimation. The City requests that unless physical evidence shows there are septic tank systems within the City limits, this load be removed from any WLA estimates."

Response 10:

To estimate the approximate loading from remnant septic systems, about 1 percent of the ERCPSD by area was assumed to be served by septic tanks. For areas within the watershed where no current estimate of septic density was available, it was assumed that half of the systems present in 1990 are still in use, which represents the midpoint within the range of potential values for this estimate. It was also assumed that each system serves about three persons per household and that the average failure rate of the systems is 20 percent (Schueler 1999). Based on the 1990 census data and these assumptions, it was estimated that 1,071 septic systems are active in the watershed and that approximately 214 of those systems are failing. The Department feels that as an assumption, the amount of septic tank systems estimated to still be in operation may be an underestimate just as well as it may be an overestimate.

If the City of Columbia has more accurate information on the number of septic systems in the Gills Creek watershed the Department invites the submittal of such information for review and possible revision of the referenced TMDL document where the Department deems it to be appropriate and as resources permit.

Comment 11:

“Section 3.0 is the Source Assessment used for constructing the model. Any information included in this Section should be relevant to how the values for the model were determined. Yet, Section 3.2.6 - Urban/Suburban Runoff includes an excerpt from an admittedly “nonscientific public survey” (pg. 18). Based on how the surveys were collected, no real conclusions can be drawn from the data to help better understand this source assessment. Why is this “information” included? Is DHEC promoting the use of “nonscientific” data? The City requests the last three paragraphs from page 18 be removed from the TMDL as they are irrelevant and promote poor data collection techniques.”

Response 11:

The information on potential pollutant sources in the Gills Creek watershed was summarized from a nonscientific public survey conducted for the Richland County watershed management plan (WMP) in Octover and November of 2008, which included questions on pets and wildlife. This information, as well as some other information provided within the referenced TMDL document, is presented for informational purposes only and was not used in developing or calculating the referenced TMDL. The Department has deemed this information may be helpful in identifying and addressing potential fecal coliform sources in the Gills Creek watershed.

Comment 12:

“Only **one** station was used for hydrologic calibration for the entire watershed. Considering spatial variability, multiple sites should have been used for model hydrology calibration since inaccurate hydrology can skew loadings. Please clarify why this was not done.”

Response 12:

This was the only station available and required to do calibration.

Comment 13:

“In light of our concerns about the TMDL underestimating agricultural loading in Section 1.E. above, it is also internally inconsistent in this regard. Considering Section 6.1.4 - Agricultural Activities is devoted to implementation strategies for agricultural sources, this is inconsistent with a TMDL that supposedly has very limited agricultural contributions. Why then are agricultural activities mentioned when they are not considered in the source assessment? If agricultural impacts are not a significant source of loading, then this information is not helpful and should be removed. If this information is useful in addressing pollutant loadings in Gills Creek Watershed, then agricultural impacts are significant and the model should be re-run accordingly. Please explain why this section is included.”

Response 13:

Agricultural activities that involve livestock, animal wastes or unstablized surfaces are potential sources of FC contamination to surface waters. These activities might contribute some bacteria to the Gills Creek watershed but are not expected to be a major contributing source. Section 6.1.4 is included in the referenced document to aid in implementation of agricultural activities. Although there may only be a small amount of agricultural activities in the watershed at present, additional activies may become prevalent in the future. The included information not only helps to address implementation concerns of today but also prepares for any future activities.

Comment 14:

“On pg. 21, the labels appear to be the same for both graphs in Figure 4-2, yet the graphs are quite different. This same problem is found on pg. 22 in Figure 4-3. Please confirm that the labels are correct.”

Response 14:

These figures present flows in two ways to better understand how well the model is simulating the range of high and low flows. The top figure y-axis is linear and the bottom figure y-axis is based on a log scale.

Comment 15:

“On pg. 23, the TMDL states, “[t]his TMDL is based on the greatest violations of the instantaneous and geometric mean standard.” Yet, DHEC did not pull enough samples to use the geometric mean standard. Please clarify what DHEC is basing the TMDL on.”

Response 15:

South Carolina’s Water Quality Standard (WQS) for FC bacteria in freshwater is:

> Not to exceed a geometric mean of 200/100 mL, based on five consecutive samples during any 30 day period; nor shall more than 10 percent of the total samples during any 30 day period exceed 400/100 mL. [R.61-68; SCDHEC 2008]

While the Department does not collect enough FC data to assess against the geometric mean criterion, the LSPC model predicts daily output for FC. As a consequence, it is possible to utilize model output to evaluate against the geometric mean criterion. The reductions presented in the referenced TMDL document are based on the predicted highest violations of the instantaneous water quality standard and the geometric mean criteria.

The model outputs daily average concentrations over the simulation period. The predicted highest violations of both the instantaneous and geometric mean criteria were targeted for as the critical conditions for TMDL development. The critical condition stations impaired for FC bacteria in Gills Creek are illustrated in Figures 5-1 and 5-2 on pages 23-24.

Comment 16:

“On pp. 23 and 24, Figures 5-1 and 5-2 are exactly the same yet represent two different stations. Please revise the TMDL to include the correct figure. Also, please confirm that the percent reductions were calculated using the correct FC concentrations.”

Response 16:

The concentrations used in calculating the percentage reduction at each water quality monitoring station are correct. The Department however acknowledges that Figures 5-1 and 5-2 are the same. The referenced TMDL document will be revised to include the correct figure.

Comment 17:

"According to Section 5.5 - Seasonal Variability, only a 12 month water quality sampling data set was used with the 7 year simulation period to account for seasonality. Why wasn't the average of the 36 month water quality data set used? That data would have provided a better statistical representation."

Response 17:

The Gills Creek TMDL is based on 48-96 data points collected from 1999-2006. The 12 month water quality sampling data set reference referred to in comment 17 has to do with the fact that data was collected from every month of the year to provide variability across the seasons.

Comment 18:

"Also, for Section 5.5 - Seasonal Variability, it is unclear which 12 month data set is used. Please clarify."

Response 18:

The Gills Creek TMDL is based on 48-96 data points collected from 1999-2006. The 12 month water quality sampling data set reference referred to in comment 17 has to do with the fact that data was collected from every month of the year to provide variability across the seasons.

Comment 19:

"On page 31, the TMDL states "[i]nterested parties (local stakeholder groups, universities, local governments, etc.) may be eligible to apply for CWA 319 grants to install BMPs that will implement the LA portion of this TMDL and reduce nonpoint source FC loading to Gills Creek and its tributaries." Please confirm that such grant moneys are available within the Gills Creek Watershed, clarify what they may be used for, and clarify who is eligible for such moneys."

Response 19:

CWA 319 grants are currently not available in the Gills Creek TMDL watershed area. The referenced language will be removed from the draft document to avoid confusion to the reader with regard to CWA 319 grant opportunities in the Gills Creek Watershed.

Comment 20:

"On pg. 34, the TMDL references the modeled sub-basins for Gills Creek Watershed. What was the criterion used to segment the watershed into sub-watersheds? Please clarify."

Response 20:

Table 6-1 on page 34 has been included in the Gills Creek TMDL document as a guide to help prioritize and implement BMPs in the watershed. Any implementation efforts focused on specific subbasins may not meet compliance at SCDHEC's existing water quality monitoring stations or be consistent with the assumptions and requirements of the TMDL as defined in section 5 of the referenced TMDL document. In Table 6-1, the Gills Creek watershed is segmented in sub-watersheds based on connectivity. Water is routed through the watershed based on connections between subwatersheds. The subwatersheds were delineated at stream confluences to ensure the timing of flows moving through the watershed was adequately modeled.

Comment 21:

“There is no information on what parameters were used to calibrate the model. Without such information, it is difficult to judge if those parameters are appropriate to accurately represent watershed conditions. Please provide such information.”

Response 21:

The following information is presented in section 4.2 of the modeling report:

> The LSPC water quality model was set up to model water temperature, DO, BOD5, total nitrogen (TN), ammonia (NH3), nitrate+nitrite (NOx), total suspended solids (TSS) and fecal coliform bacteria. Phytoplankton and benthic algae were not modeled due to data unavailability. As a result, DO was simulated with an assumption that carbon biochemical oxygen demand (CBOD) and nitrogen biochemical oxygen demand (NBOD) were the only biogeochemical reactions affecting DO concentration in the Gills Creek watershed, and the daily net oxygen production/deficit from algal activities due to respiration and photosynthesis in water bodies was assumed to be zero.

Comment 22:

“Throughout the TMDL document, Sanitary Sewer Overflows (SSO) are considered both point source and non-point sources. Please clarify which category SSOs fall.”

Response 22:

For the purposes of this TMDL document, SSOs may be described as either a point source or non-point source. The document characterizes these discharges as a non-point source (Section 3.2.5) as well as a non-continuous discharge that is illegal and should not occur (Section 5.3.2).

Illicit discharges, including SSOs, not covered under any NPDES permit and are subject to enforcement mechanisms. Because these discharges are illegal they are not prescribed a TMDL WLA or LA in this document.

Comment 23:

“On page 8, the TMDL states "[t]here is some indication that concentrations of FC bacteria are higher during the summer months, etc." Please define what months constitute summer months.”

Response 23:

The referenced statement reads as follows:

> There is some indication that concentrations of FC bacteria are higher during the summer months, but the variations do not confirm that generalization.

This statement is a generalization that has been included in the referenced TMDL document for informational purposes only. Generally speaking, the summer months run from June through September. At station C-001, three of the four largest percentages presented in table 2 occur during the summer months. At station C-017, three of the five largest occur from June to September.

Comments from the South Carolina Department of Transportation

Comment 1:

Pg 7. "For the purpose of this TMDL document, only the instantaneous water quality criterion was targeted because there are insufficient data to evaluate against the 30-day geometric mean."

"In the TMDL, only the instantaneous water quality data was considered and DHEC acknowledges that there were insufficient data to evaluate against the 30-day geometric mean. Thus the TMDL is defective."

Response 1:

South Carolina's Water Quality Standard (WQS) for FC in freshwater is:

> "Not to exceed a geometric mean of 200/100 mL, based on five consecutive samples during any 30 day period; nor shall more than 10% of the total samples during any 30 day period exceed 400/100 mL." (R.61-68).

The Department does not collect sufficient data to evaluate against the 30-day geometric mean. During assessment of data, the WQS for FC in freshwater allows the Department to use either standard to base impairments on in the absence of one or the other. If information is available to evaluate against a 30-day instantaneous mean (not to exceed 200/100 mL) and determine whether 10% of the total samples during any 30 day period exceeds 400/100 mL then the Department will evaluate against both criteria. The reference to 'insufficient data' is *only* related to collection and assessment of ambient FC data in Section 2.0 of the TMDL document.

While the Department does not collected enough FC data to assess against the geometric mean criterion, the LSPC model predicts daily output for FC. As a consequence, it is possible to utilize model output to evaluate against the geometric mean criterion. The reductions presented in the referenced TMDL document are based on the predicted highest violations of the instantaneous water quality standard and the geometric mean criteria. The approach for developing these TMDLs is outlined in Section 5.0 of the TMDL document.

Comment 2:

Pg 7. "For C-100, correlations between observed FC bacteria and rain and FC bacteria and flow are weak (R^2 = 0.006 and 0.02, respectively). For C-017, the correlations between FC bacteria and rain and FC bacteria and flow are also weak (R^2 = 0.006 and 0.047, respectively).

"The R2 values calculated show no mathematical correlation between FC bacteria and rainfall and no mathematical correlation between FC bacteria and flow. There also needs to be a relationship established between flow and FC bacteria when grouped by season. In addition a relationship needs to be established between rainfall and FC in all seasons. Because no critical flow condition can be established the TMDL is defective."

Response 2:

The Department believes that this further justifies use of a dynamic model. Dynamic models can be used when sources and stressors to water quality come from a variety of sources that cannot easily be defined.

Comment 3:

Pg 8 Figure 2-1

Why are there no FC samples from C-001 from 2002 to 2005?

Response 3:

“Prior to 2001, C-001 was sampled once/month every year. Beginning in 2001, C-001 was sampled once/month every fifth year and, consequently, 2006 data are the only data available during the 2001-2006 time-frame.

The Department’s ambient water quality monitoring strategy was revised in 2000 and the changes became effective beginning in 2001. Site C-001 became a watershed water quality monitoring site in 2001 and was scheduled to be sampled once/month every fifth year.”

Comment 4:

“Pg. 8 “There is some indication that concentrations of FC bacteria are higher during the summer months, but the variations do not confirm that generalization

The document states that higher fecal concentrations were observed during summer months, but there is no information on how the seasons are defined. What months constitute what season? The concentrations appeared erratic with respect to month/season”

Response 4:

For the purposes of the Gills Creek TMDL document the summer season is defined from June to August.

Comment 5:

Pg 9. “Evaluation of available data from the impaired monitoring locations does not explicitly point to a single source causing the FC bacteria impairment at C-001 and C-017. The major sources of bacteria likely contribute loads across varying hydrologic events and season.”

“No efforts were made to conduct an extensive spatio-temporal sampling at different land uses before the development of the TMDL, therefore, the TMDL is defective.”

Response 5:

The best available data was used in the development of these TMDLs. In other parts of the country, less data has been used to develop TMDLs. Assessing impairment to water quality standards is a continuous process, the purpose of TMDLs is to progress toward meeting water quality standards. If future data becomes available to more precisely define the source of pollutants and the processes that influence pollutants, the allowable loads can be revisited.

Comment 6:

Pg 10. “There are currently two active continuous NPDES discharges to surface waters in the watershed. The active NPDES discharges are not permitted to discharge FC bacteria and *therefore not subject to the WLA. None of the active NPDES permits during the model period (1997-2004) included limits for FC bacteria."*

"The active NPDES dischargers are not permitted to discharge FC bacteria and therefore were not subject to the WLA. Just because an entity has an NPDES permit does not mean that fecal is not present in its discharge. The true fecal concentrations being contributed by NPDES permit holders should be determined to ensure that the model outputs valid loadings."

Response 6:

If future data becomes available to more precisely define the source of pollutants and the processes that influence pollutants, the allowable loads can be revisited.

Comment 7:

Pg 13. "Based on current information, as well as the physically interconnected nature of SCDOT owned or operated properties in relation to urbanized area and the potential for growth in the referenced watershed, SCDOT is considered to be a contributing source of FC bacteria in the delineated drainage area used in the development of this TMDL document."

"DHEC has not provided "current information" to show that SCDOT is a potential source."

Response 7:

Based on previous discussions with SCDOT the referenced statement has been removed from the final draft version of the referenced TMDL document.

Comment 8:

Pg 16. "About 2 percent of the Gills Creek watershed (1.4 square miles) is in open water, and ponds and lakes encompass most of this area. This large area of open water is likely to attract waterfowl during migratory seasons and throughout the year, and waterfowl are likely to be a source of bacteria. Density estimates for waterfowl were not available."

"While the TMDL acknowledges waterfowl as a potential source of FC bacteria, the model does not account for contributions from waterfowl. Therefore the model does not accurately depict how FC is being contributed within the watershed."

Response 8:

The fecal tool and STEPL, developed by EPA using literature values, were used to develop loads for this modeling effort. The best available data was used in the development of these TMDLs. If future data becomes available to more precisely define the source of pollutants and the processes that influence pollutants, the allowable loads can be revisited.

Comment 9:

Pg 17. Failing Septic Systems

"The approximate loadings from septic systems were given as approximately 214 failing systems. None of these systems are being maintained by permitted MS4s. The TMDL never states that failing septic systems are considered to be a contributing source of FC in the watershed even though they are explicitly included in the model as a source."

Response 9:

Failing septic systems are included in the TMDL source assessment section 3.2.4 titled "Failing Septic Systems." Failing septic systems are nonpoint sources of pollution and have the potential to contribute to fecal coliform loading in the Gills Creek watershed. Their contribution is included in the load allocation portion of the TMDL document.

Comment 10:

Pg 17 Sanitary Sewer Overflows

"Sanitary Sewer Overflows (SSOs) were included as point sources in the development of the TMDL. SSOs have a significant impact on the model and this is based on reported, not predicted or unregulated SSOs. The TMDL should begin with proper sampling and documentation of SSOs and a 100% reduction of SSOs."

Response 10:

The Department acknowledges that SSOs are illegal and should not occur. Illicit discharges, including SSOs, are not covered under any NPDES permit and are subject to enforcement mechanisms.

SSOs may be reported to the Department in the form of a complaint from the public. However, a larger number of SSOs go unreported and the actual SSO contributions are unknown for the purposes of this modeling application.

Comment 11:

Pg 18. "This information is included for informational purposes only and was not used in developing or calculating the referenced TMDL:"

"Why is this included?"

Response 11:

The Department believes that any additional information gathered and presented may be deemed useful by interested entities during the implementation process. The Department has included information for "informational purposes only" many times throughout the referenced TMDL document.

Comment 12:

Pg 21. Figure 4-2

"Only one sample is greater than 5000 CFU/100mL yet the model predicts 20 peaks greater than this amount.

After the time span of observed values (calibration period) is over, the low end of the model predictions increases by an order of magnitude and the variability of the model's predictions decreases significantly while the frequency of high peaks increases. This behavior suggests inconsistency with the time varying model inputs.

Data was collected between 1999 and 2006, but the modelers only plotted data for station C-001 until 2002. Also, why was the model only run until 2004 and not until 2006? Running the model for a longer duration would give more time for model calibration and model validation, especially when there is available data for the referenced period.

The critical condition predicted by the model is higher than the highest observed value. This is two orders of magnitude higher than the water quality standard. This suggests that the data of approximately 14000 cfu/100ml is an outlier (invalid test results) and should not be controlling the TMDL. Therefore the model results appear inconsistent and not an appropriate basis to determine required reductions for the TMDL."

Response 12:

Based on current resources the ability to extend the model through 2006 was restricted. The modeled period did include both wet and dry periods to account for variations in climate and therefore adequate for the development of TMDLs. The TMDL was developed to be protective of the most critical conditions in the watershed.

Comment 13:

Pg 22. "The majority of the forest land use is located in the upper northeast of the Gills Creek watershed. Due to the longer travel time from the clustered forest area to the assessment points, the loading impact of fecal coliform from the forest area would be small due to bacteria die-off."

"It is known that forested riparian areas are suitable for generation and maintenance of bacterial population. Sunlight kills bacteria, therefore, urban areas without canopy or shade will kill more bacteria. Furthermore, riparian areas will likely export more bacteria because of the presence of organic matter that will provide a flourishing environment for the FC bacteria to reproduce. The TMDL is not based on current facts."

Response 13:

The fecal tool and STEPL, developed by EPA using literature values, were applied as described in the modeling report.

Comment 14:

Pg 23 "This TMDL is based on the greatest violations of the instantaneous and geometric mean standard."

"This contradicts the statement on page 7 which states, 'For this TMDL document, only the instantaneous water quality criterion was targeted because there are insufficient data to evaluate against the 30-day geometric mean.

Why are both the geometric and instantaneous values reported and which one is used to calculate the percent reduction?"

Response 14:

South Carolina’s Water Quality Standard (WQS) for FC in freshwater is:

> “Not to exceed a geometric mean of 200/100 mL, based on five consecutive samples during any 30 day period; nor shall more than 10% of the total samples during any 30 day period exceed 400/100 mL.” (R.61-68).

As stated the Department does not have sufficient data to evaluate against the 30-day geometric mean. The WQS for FC in freshwater allows the Department to use either standard to base impairments on in the absence of one or the other. If information is available to evaluate against a 30-day instantaneous mean (not to exceed 200/100 mL) and determine whether 10% of the total samples during any 30 day period exceeds 400/100 mL then the Department will evaluate against both criteria. The percentage reduction presented in the Gills Creek TMDL document is based off of the instantaneous WQS of no more than 10% of the total samples during any 30 day period exceeding 400/100 mL.

Comment 15:

Pg 23. “The model outputs daily average concentrations over the simulation period. The highest violations of the standard were targeted as the critical conditions.”

“Since the instantaneous criterion is being evaluated in this TMDL document, the highest PREDICTED violation should not be used to determine the existing load. According to R.61-68 no more than 10% of the total samples during any 30 day period can exceed 400/100mL. The model output should be examined for the worst case 30 day period and the percent reduction should be used.”

Response 15:

The TMDL was developed to be protective of the most critical conditions in the watershed.

Comment 16:

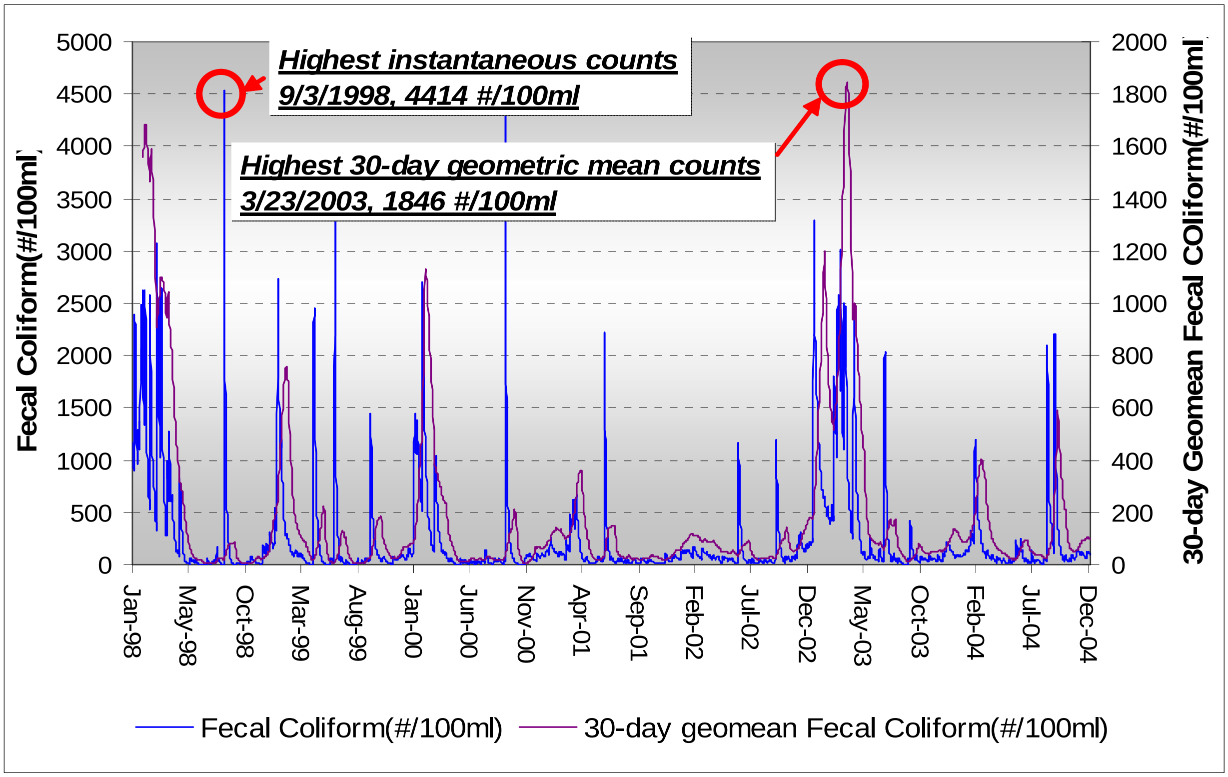
Pg 23. Figures 5-1 & 5-2

“These figures are exactly the same yet represent two different stations. Please revise to include the correct figure. Were the percent reductions calculated using the appropriate/correct FC concentrations?”

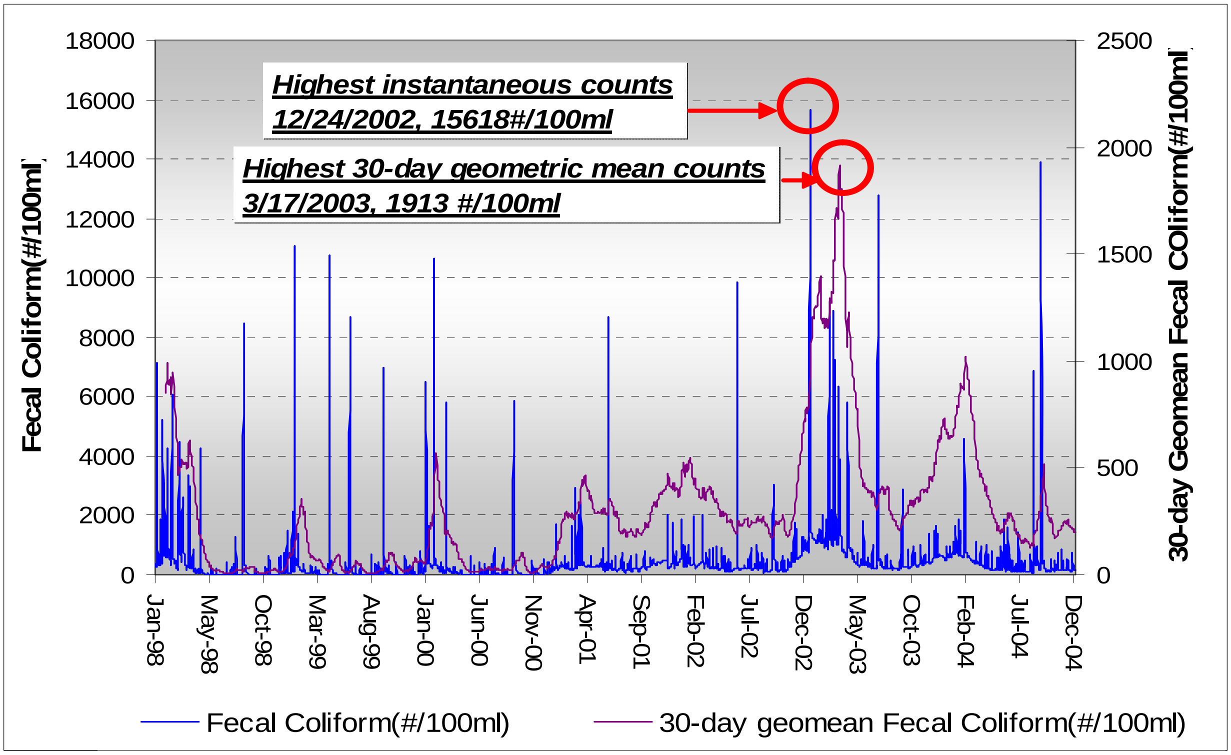
Response 16:

These figures will be updated with the following figures in the Gills Creek TMDL document:

C-001



C-017



Comment 17:

Pg 24. "Note that all illicit dischargers, including SSOs, are illegal and not covered under the WLA of this TMDL."

"These SSOs are included under the LA portion of the TMDL and are specified in the model as point sources. Since SSOs are illegal, and apparently do not occur within the watershed, SSO contributions into the model should be removed when determining the critical conditions. The SSO inputs should not be included when calculating the existing load."

Response 17:

Several SSO data became available from 2001. Due to this input of the data, the model generates higher concentrations than previous years.

Comment 18:

Pg 28. "Federal regulations require that TMDLs take into account the seasonal variability in watershed loading. Seasonal variability in this TMDL is accounted for by using a 7-year simulation period and 12-month water quality sampling data set, which includes data collected from all seasons."

"Seasonal variability in the TMDL was accounted for by using a 7-year simulation period and 12 month water quality sampling data set. Why wasn't the average of the 36 month water quality data used? That data would have provided a better statistical representation. It is unclear which data set was used."

Response 18:

Data is presented in the Gills Creek TMDL document for stations C-001 and C-017 in appendix A. For water quality monitoring station C-001, 48 samples were collected between 1999 and

2006. For water quality monitoring station C-017, 96 samples were collected between 1999 and 2006. All of the data points were used in calculating the load reductions presented. The data was collected during all 12 months of the year for each sampling year, which provides seasonal variability.

Comment 19:

P*g 36. Section 6.1.4. Agricultural Activities*

"Why are agricultural activities considered in the BMP implementation when they are not considered in the modeling or source assessment portions of the report?"

Response 19:

Fecal coliform loading from agricultural activities in the Gills Creek watershed, although present, are considered not to be significant. A section for agricultural activities in the implementation plan is included to aid interested parties in implementing BMPs where these activities do occur. This section is also included should agricultural activities become prominent in the Gills Creek watershed at a later date.

Comment 20:

Pg 49 and 50. Figure A-2. C-001 relationship between fecal coliform and flow. And Figure A-4. C-017 relationship between fecal coliform and flow.

"What is the explanation of the -ve and +ve trend (correlation) between fecal coliform and flow at site C-001 and C-017."

Response 20:

The Department believes this further justifies use of a dynamic model. Dynamic models can be used when sources and stressors to water quality come from a variety of sources that can not easily be defined.

Comment 21:

"What was the criterion while conducting watershed segmentation? Was it similar soil? Was it similar land use? Both?"

Response 21:

Section 2.2 of the modeling report; done by Richland Counties modeling effort by CDM. Generally, watershed segmentation is developed from USGS national hydragraphy data and elevation are used in developing watershed segments with outfalls where measured data is collected. Model parameters are categorized by soil type and land use.

Comment 22:

"Why was only one year used for model warm up (spin off)?"

Response22:

This is a common practice for HSPF/LSPC calibration among watershed modelers to have one year spin-up period prior to the beginning of calibration to allow internal model processes to reach equilibrium such as soil moisture conditions, etc.

Comment 23:

“Only one station was used for hydrologic calibration for the entire watershed. Considering spatial variability, multiple sites should have been used for model hydrology calibration since inaccurate hydrology can skew loadings.”

Response 23:

Only this station had continuous flow data.

Comment 24:

“There is no information on what parameters were used to calibrate the model. There is no basis to demonstrate that those parameters accurately represent watershed conditions.”

Response 24:

Recommended hydrologic parameters for HSPF/LSPC are listed in BASINS Technical note 6 from EPA. In a water quality model, parameters quantify the relationships in the major dynamic processes. The values of parameters are generally obtained through the model calibration process while constrained by a range of reasonable values documented in literature. Assumptions and litruture sued to determine the selected parameters values were described in the modeling document.

Comment 25:

“The TMDL uses R2 to evaluate average model flow. What about other numeric errors such as Mean Absolute Error (MAE), and Root Mean Square Error (RMSE), and Nash-Sutcliffe coefficient? Recent studies are advocating the use of numeric errors other than just R2. MAE measures random error, whereas RMSE measures total error. RMSE is useful when large errors are undesirable. Since, large errors cause large loadings, the RMSE should be used. No information on these numeric errors are available in the report.”

Response 25:

Comparing the accepted error range for hydrologic modeling calibration, the results show the model is calibrated adequately at the gage; the modeled results can be compared to Table 3-2 in the modeling report.
Here are stats comparing all available observed data with the modeled results.

Assessment locations	Water quality parameter name	Obs. Data number	Modeled mean (mg/L or #/100ml)	Obs. Mean (mg/L or #/100ml)	Mean abs.Error (mg/L or #/100ml)	RMS Error (mg/L or #/100ml)	Relative RMS Error(%)
C-068	BOD5 (mg/L)	35	2.10	2.35	1.13	1.32	28.00
C-068	DO (mg/L)	33	6.89	8.73	2.14	2.54	42.63
C-068	Fecal Coliform (#/100ml)	35	21.53	93.26	94.06	211.14	24.57
C-068	NO3/NO2 (mg/L)	34	0.12	0.03	0.08	0.12	64.34

C-068	Sediment (mg/L)	3	8.94	13.45	2.98	3.37	33.04
C-068	Total ammonia (mg/L)	28	0.06	0.06	0.03	0.04	30.58
C-017	BOD5 (mg/L)	70	3.43	2.15	1.58	2.08	31.52
C-017	DO (mg/L)	68	7.65	7.11	0.98	1.24	11.97
C-017	Fecal Coliform (#/100ml)	71	250.70	669.50	704.01	1637.84	18.83
C-017	NO3/NO2 (mg/L)	70	0.12	0.15	0.10	0.13	35.18
C-017	Sediment (mg/L)	65	10.83	13.63	10.08	18.48	19.17
C-017	Temperature ©	68	18.42	18.25	1.71	2.16	8.16
C-017	Total ammonia (mg/L)	50	0.09	0.21	0.13	0.18	29.66
C-001	BOD5 (mg/L)	34	2.64	3.17	1.46	1.76	35.11
C-001	DO (mg/L)	33	7.80	7.98	0.81	1.03	12.44
C-001	Fecal Coliform (#/100ml)	35	178.70	873.50	838.77	2533.42	18.10
C-001	NO3/NO2 (mg/L)	34	0.13	0.08	0.07	0.09	42.80
C-001	Sediment (mg/L)	30	11.11	14.80	12.90	20.80	102.98
C-001	Temperature ©	33	18.35	18.84	2.24	2.89	10.71
C-001	Total ammonia (mg/L)	29	0.07	0.09	0.05	0.08	23.81
C-048	BOD5 (mg/L)	22	1.58	1.76	1.30	1.60	35.53
C-048	DO (mg/L)	19	5.89	6.20	1.13	1.37	19.01
C-048	Fecal Coliform (#/100ml)	22	15.04	64.28	69.47	122.91	28.62
C-048	NO3/NO2 (mg/L)	21	0.07	0.02	0.05	0.12	77.54
C-048	Temperature ©	16	23.09	24.26	1.57	1.94	7.27
C-048	Total ammonia (mg/L)	4	0.05	0.03	0.02	0.02	44.90

- Mean absolute errors (MAE): the mean absolute value of the difference between observed and predicated values. It indicates the average deviation between model predictions and observed data. Zero means that the predications match the observation perfectly.

- RMS error: the average of the squared differences between observed and predicted values. It is more rigorous measure of model performance than MAE. It is a weighted equivalent to MAE with larger observation-predication differences given larger weightings. An RMS error of zero is ideal.

- Relative RMS error: percentage error based on RMS error and observed change. It is used to measure model performance in the water quality modeling.

Amendments to the Gills Creek FC TMDL Document

As a result of comments received by the Department during the public comment period from November 5th, 2009 to December 7th, 2009 the following amendments have been made to the Gills Creek TMDL Document. Changes are shown as bold font and are reflected in the most recent version of the referenced TMDL document.

Amendment Location 1:

Abstract

Amendment:

The following paragraph has been revised:

> **For SCDOT and existing and future NPDES MS4 permittees, compliance with terms and conditions of its NPDES MS4 permit is effective implementation of the WLA to the Maximum Extent Practicable (MEP). For existing and future NPDES construction and Industrial stormwater permittees, compliance with terms and conditions of its permit is effective implementation of the WLA.** The required load reductions in the LA portion of the TMDL can be implemented through voluntary measures.

Amendment Location 2:

Table Ab-1 and Table 5-3

Amendment:

The wasteload allocation column has been revised as follows:

Table 5-1. Total Maximum Daily Loads for the Gills Creek Watershed

Station	Existing Load (cfu/day)	TMDL (cfu/day)	Margin of Safety (MOS) (cfu/day)	Wasteload Allocation (WLA)		Load Allocation (LA)	
				Continuous Sources[1] (cfu/day)	Non-Continuous Sources[2,3,4] (% Reduction)	Load Allocation (cfu/day)	% Reduction to Meet LA[3]
C-001	8.31E+13	2.13E+12	1.06E+11	See Note Below	97%	2.02E+12	97%
C-017	4.37E+13	3.93E+12	1.96E+11	See Note Below	91%	3.73E+12	91%

Amendment Location 3:

Table Ab-1 and Table 5-3 Footnote

Amendment:

Table notes 1, 2, and 4 have been revised as follows:

Table Notes:

1. WLAs are expressed as a daily maximum Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern. Loadings were developed based upon permitted flow and an allowable permitted maximum concentration of 400cfu/100ml.
2. Percent reduction applies to all NPDES-permitted stormwater discharges, including current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction due to the uncertain nature of stormwater discharge volumes and recurrence intervals. Stormwater discharges are required to meet percentage reduction or the existing instream standard for pollutant of concern **in accordance with their NPDES Permit.**
3. Percent reduction applies to existing instream load
4. **By implementing the best management practices that are prescribed in either the SCDOT annual SWMP or the SCDOT MS4 Permit to address fecal coliform, the SCDOT will comply with this TMDL and its applicable WLA to the maximum extent practicable (MEP) as required by its MS4 permit.**

Amendment Location 4:

Section 3.1.2, Page 13

Amendment:

Section 3.1.2 has been revised to read as follows:

> Non-continuous point sources include all NPDES-permitted stormwater discharges, including current and future MS4s, construction and industrial discharges covered under permits numbered SCS and SCR and regulated under SC Water Pollution Control Permits Regulation 122.26(b)(14)&(15). **All regulated MS4 entities have the potential to contribute FC pollutant loadings in the delineated drainage area used in the development of this TMDL.**
>
> **The South Carolina Department of Transportation (SCDOT) is designated as an MS4 within the Gills Creek watershed. SCDOT operates under NPDES MS4 SCS040001 and owns and operates roads in the watershed (Figure 4). However, the Department recognizes that SCDOT is not a traditional MS4 in that it does not possess statutory taxing or enforcement powers. SCDOT does not regulate land use or zoning, issue building or development permits.**

Amendment Location 5:

Section 5.3.2, Page 25

Amendment:

The first paragraph of section 3.2.5 has been revised to read as follows:

> Non-continuous point sources include all NPDES-permitted stormwater discharges, including current and future MS4s, construction and industrial discharges covered under permits numbered SCS & SCR and regulated under SC Water Pollution Control Permits Regulation 122.26(b)(14) & (15). Illicit discharges, including SSOs, are not covered under any NPDES permit and are subject to enforcement mechanisms. All areas defined as “Urbanized **Area**” by

> the US Census are required under the NPDES Stormwater Regulations to obtain a permit for the discharge of stormwater. Other non-urbanized areas may be required under the NPDES Phase II Stormwater Regulations to obtain a permit for the discharge of stormwater.

Amendment Location 6:

Section 6.0, Page 32

Amendment:

The following paragraph in the implementation section of the Gills Creek TMDL document has been revised to read as follows:

> **For SCDOT and existing and future NPDES MS4 permittees, compliance with terms and conditions of its NPDES MS4 permit is effective implementation of the WLA to the MEP. For existing and future NPDES construction and Industrial stormwater permittees, compliance with terms and conditions of its permit is effective implementation of the WLA.**