South Carolina
Department of Health and Environmental Control

Total Maximum Daily Load Development for Beaverdam Creek: Station CW-153 Fecal Coliform Bacteria

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Bureau of Water

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South Carolina Department of Health
and Environmental Control

Abstract

Beaverdam Creek (03050101-180-030) in York County, South Carolina, is a small stream that is impaired for primary and secondary contact recreational uses by fecal coliform bacteria. The creek is a tributary to Crowders Creek, just upstream of where Crowders Creek flows into Lake Wylie and the Catawba River. This watershed (48.8 km^2) is mostly forested, with nearly one third of the land in crop and pasture land, and a small urbanized area. Farming is declining as the area is being converted to low density residential uses. During the 1994-98 assessment period 33 % of samples exceeded the water quality standard of 400 counts/100ml.

This TMDL was based on a mass-balance method whereby the load from each source was estimated and summed for the TMDL. The principal source of fecal coliform loading to the stream was estimated to be runoff from grazed pasture land. The second largest source was runoff from built-up land. The total maximum daily load for fecal coliform bacteria was determined to be $1.08 \cdot 10^{11}$ counts/day. A reduction of 77 % in the current load to Beaverdam Creek would be required to meet this TMDL. Several TMDL implementation strategies to bring about this reduction are suggested.

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Tables and Figures

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(HUC 03050101-180-030)

1.0 INTRODUCTION:

1.1 Background

Levels of fecal coliform bacteria can be elevated in water bodies as the result of both point and nonpoint sources of pollution. 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).

1.2 Watershed Description

Beaverdam Creek is a small creek located in York County, SC and drains into Crowders Creek which in turn drains into Lake Wylie (Catawba River) (Figure 1). The drainage area of concern for this TMDL is almost all of watershed 03050101-180-030 inYork County and consists of the area of land draining to station CW-153. All references to the Beaverdam Creek watershed in this TMDL refer specifically to the area draining to CW-153. This watershed comprises an area of 48.8 km^2 (18.8 mi^2) in the Piedmont region of South Carolina.

A separate TMDL has been developed for a small tributary of Beaverdam Creek, Brown Creek. This small creek flows out of Clover, SC, and is also impaired by fecal coliform.

The land use (Table 1 and Figure 2) in the watershed is predominantly forested (64%), with significant areas of cropland (18%), pasture (13%) and urban (4%) (MRLC 1992 data). The urban land use is mostly in the upper part of the watershed (Clover), however the lower part of the watershed near Lake Wylie is being urbanized rapidly. Agricultural land is being replaced by homesites and 'hobby farms'. The number of cattle is decreasing, while the number of horses and goats is increasing (Maryann Trent, NRCS county conservationst, personal communication, 2000 and 2001).

1.3 Water Quality Standard

The impaired stream segment, Beaverdam Creek, is designated as Class Freshwater. Waters of this class are described as follows:

> '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.61-68)

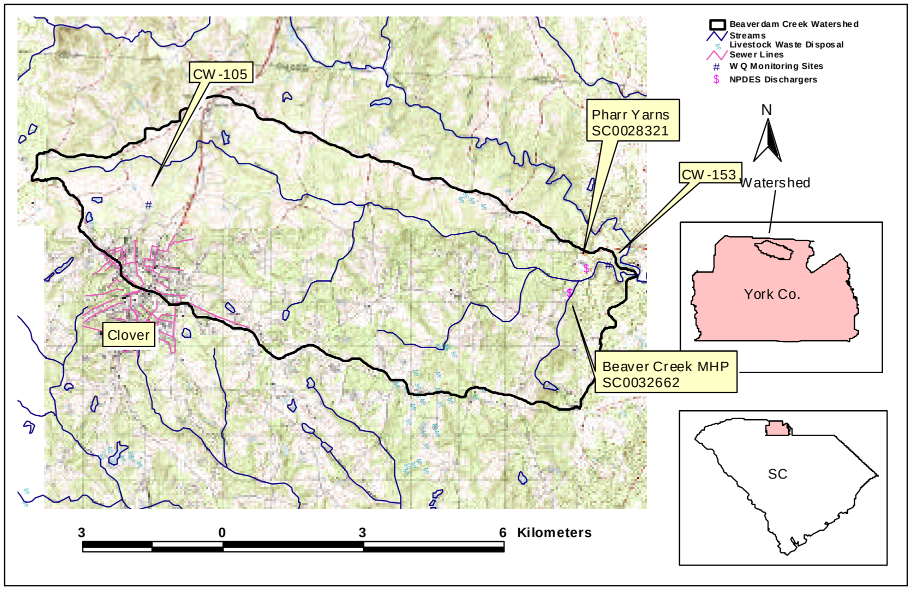

Figure 1. Map of the Beaverdam Creek watershed, York County, showing Clover sewer lines.

South Carolina's standard for fecal coliform 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)

Table 1. Beaverdam Creek Watershed Land Use.

Land Use Category		**Area (hectares)**	**Percent**		**Area (acres)**
Open Water		**18.7**	**0.4%**		46.3
Low Intensity Residential		118.3	2.4%		292.2
High Intensity Residential		32.4	0.7%		80.1
High Intensity Commercial, Industrial		52.0	1.1%		128.5
Total Built-up		**202.7**	**4.2%**		500.8
Bare Rock, Sand, Clay		**19.6**	**0.4%**		48.5
Deciduous Forest		1,694.3	34.8%		4,186.5
Evergreen Forest		715.1	14.7%		1,767.1
Mixed Forest		626.0	12.8%		1,546.7
Woody Wetlands		68.2	1.4%		168.6
Emergent Herbaceous Wetlands		3.4	0.1%		8.5
Total Forest		**3,107.0**	**63.7%**		7,677.3
Pasture/Hay		**629.6**	**12.9%**		1,555.8
Row Cropland		**884.8**	**18.1%**		2,186.3
Parks, urban grasslands		**12.9**	**0.3%**		31.8
Total		**4,875.3**	**100.0%**		**12,046.9**

2.0 WATER QUALITY ASSESSMENT

The Watershed Water Quality Management Strategy Catawba Basin (SCDHEC 1999) was used to identify this stream segment as impaired and for listing the water body on the 2000 South Carolina 303(d) list. Beaverdam Creek was also included on the 1998 303(d) list. Waters in which no more than 10% of the samples collected over a five year period are greater than 400 fecal coliform counts/ 100 ml are considered to comply with the South Carolina water quality standard for fecal coliform bacteria. Waters with more than 10 percent of samples greater than 400 fecal coliforms/ 100 ml are considered impaired and listed for fecal coliform bacteria on South Carolina's 303(d) List. There are two SCDHEC ambient monitoring stations, CW-696 and CW-153, on Beaverdam Creek. Aquatic life uses are supported at both stations, however CW-153 (located at S-46-152 in York County) does not support recreational uses due to violations of the 400/100 ml fecal coliform criterion. During the assessment period (1994-1998), 33% of the samples did not meet the fecal coliform criterion. CW-153 on Beaverdam Creek is a secondary station which means it is sampled only during the warm months. Fecal coliform data for CW-153 is in Appendix A.

3.0 SOURCE ASSESSMENT AND LOAD ALLOCATION

Fecal coliform bacteria enter surface waters from both point and nonpoint sources. Poorly treated municipal sewage has been a major source of fecal coliform, but with improved treatment and enforcement is not usually the case not now. All point sources must have a NPDES permit. In South Carolina NPDES permittees that discharge sanitary wastewater must meet the state standard for fecal coliform.

Nonpoint sources are diffuse sources that have multiple routes of entry into surface waters. Some sources are related to land use activities that accumulate fecal coliform on the land surface which then runs off during storm events. Other sources are more or less continuous. Potential nonpoint sources of fecal coliform bacteria are: wildlife, land application of manure, grazing animals, failing septic systems, urban storm runoff, and leaking or overflowing sewer collection systems**.**

3.1 Point Sources in the Beaverdam Creek Watershed

There are two point sources in the Beaverdam Creek watershed. Pharr Yarns operates a wastewater treatment facility on Beaverdam Creek. This facility has a permited discharge of 0.014 mgd (53,000 l/day). This facility is approximately 400 m upstream of the impaired stream station. Beaver Creek Mobile Home Park operates a wastewater treatment facility on a tributary of Beaverdam Creek. It is permitted to discharge 0.015 mgd (56,800 l/day) of wastewater. This outfall is approximately 900 m upstream of CW-153. The total load for these two facilities at point of discharge and permit limits is 2.2×10^7 counts/day. A review of the DMR data for these two locations indicates their treated wastewater is not a cause of the impairment.

3.2 Nonpoint Sources in Beaverdam Creek Watershed

3.2.1 Wildlife

Wildlife (mammals and birds) contribute a low level of fecal coliform to surface waters. Wildlife wastes are carried into nearby streams by runoff during rainfall. Deer are used as a surrogate for all wildlife. The SC Department of Natural Resources has estimated a density of 30 deer/mi^2 for this area. Deer habitat includes forest, cropland, and pasture land. Deer are assumed to be distributed evenly throughout their habitat and the population uniform during the modeling period. Loading of fecal coliform bacteria from wildlife is considered background.

3.2.2 Land Application of Manure

Manure from confined animal operations is usually collected and then distributed on crop and pasture land. Livestock population estimates are based on the Census of Agriculture 1997 and NRCS (Maryann Trent, NRCS county conservationst, personal communication, 2000 and 2001). While this watershed has no confined animal operations; a nearby dairy is permitted to apply waste to pastureland in the watershed.

3.2.3 Grazing Animals

Livestock such as cattle, goats, and horses spend most of their time grazing on pasture land. Runoff from rainfall washes some of the manure deposited in the pastures into nearby by streams. For this TMDL loading from pastureland (grazing and manure applications) was calculated from estimated runoff and a concentration value from the literature (USEPA, 2001). Runoff from pasture land was estimated to be the primary source of fecal coliform bacteria in Beaverdam Creek, accounting for 84 % of the load.

Frequently cattle and other animals are allowed access to streams and ponds. Manure deposited directed into streams and ponds can be a significant source of fecal coliform. Loading from this source is estimated from the number of beef cattle and the percentage of time they spend in streams.

3.2.4 Untreated Wastewater Inputs

Using a GIS we overlayed the census layer over the sewer line theme and estimated the number of persons without access to have municipal sewer lines. Based on Horsley and Witten (1996) the average waste flow per person was assumed to be 70 gal/capita/day. The average household consisted of 2.5 persons. Septic systems were assumed to have a failure rate of 20 % (Schueler, 1999). Other assumptions were that all wastewater reached the stream and the concentration of fecal coliform in that wastewater was 10^4 counts/100ml (Horsley and Witten, 1996). Other potential sources of fecal coliform include leaking sanitary sewers, illicit discharges, and overflows of sanitary sewers. For this TMDL these sources are included in the failing septic systems estimate.

3.2.5 Urban Storm Runoff

Urbanized or developed land typically generates an increased loading for pollutants relative to forest and other undeveloped land uses. Dogs, cats, and other pets are the primary source of fecal coliform deposited on the urban landscape. Storm runoff washes some of this fecal material into streams directly or through the storm sewers. This source is estimated by the ‘simple method’ of Schueler (1987) using a concentration for fecal coliform from the literature (USEPA, 2001). This source is the second largest contributor to the load going into Beaverdam Creek, though it is only 12 % of the existing load.

4.0 TMDL DEVELOPMENT

This TMDL was developed using a simple mass balance approach as suggested in the USEPA (2001) Protocol for Developing Pathogen TMDLs. The estimated loads were added up to calculate the existing load. For the TMDL the average warm weather flow was multiplied by the target fecal coliform concentration (175 counts/ 100ml). The average warm weather flow for Beaverdam Creek, which is not gauged, was calculated from the generation coefficient determined for an adjacent gauged stream, Clarks Fork Creek (USGS 02153780).

4.1 Critical Conditions

Novotny & Olem (1994) found statistically lower fecal coliform counts in cold weather urban runoff samples than in warmer weather urban runoff. To substantiate this, winter and summer fecal coliform values were compared at ambient water quality monitoring stations in the Piedmont Region in South Carolina impacted by nonpoint sources. This analysis reveals similar or higher values in the summer than the winter. Therefore, the warm season (May-October), which is also the most likely time for contact recreation, is considered critical conditions. This can be explained by the nature of storm events in the summer versus the winter. Thunderstorms are typical in the summer months. This pattern of rainfall allows for the accumulation and washing off of fecal coliforms into the streams resulting in spikes of fecal coliform concentrations. In the winter, long slow rain events are more typical. This pattern of rainfall does not allow for the high build-up of coliform that characterizes the summer. Rather, coliform bacteria are washed into the stream at a more even rate. This, coupled with the increased winter flows that provide more dilution, results in lower fecal coliform concentrations.

4.2 Margin of Safety

There are two basic methods for incorporating the MOS (USEPA 1991): 1) implicitly incorporate the MOS using conservative model assumptions to develop allocations, or 2) explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The MOS for this TMDL is an explicit 25 counts/ 100 ml. This MOS is created by establishing a target concentration of 175 counts/ 100 ml. By setting the target based on the geometric mean of 200 counts/ 100 ml we have some assurance that the stream can meet the criterion ‘not more than 10% of samples exceed 400/100 ml’. A review of water quality data in South Carolina by SCDHEC (unpublished data) showed that over 75% of waters having a fecal coliform concentration less than 175counts/ 100ml also meet the 10% less than 400 counts/ 100ml criterion.

4.3 Seasonal Variability

The discussion of critical conditions indicated that the warm weather months tend to have higher fecal coliform concentrations. Basing this TMDL on the warm weather months will also protect the stream during the cold weather months.

4.4 Existing Load

The existing load in Beaverdam Creek is the sum of the point sources, nonpoint sources, and background. These loads have been reduced to account for decay of the fecal coliform bacteria population before the load reaches the sampling point (CW-153). The amount of decay for point sources is a function of the travel time from the point of discharge to the sampling site. For the nonpoint sources the travel time was estimated by measuring travel time from a point in the watershed that was figured as the center point of that land use or source. The decay rate was assumed to be 0.5 counts/day. These calculations are provided in Appendix B.

Point source loading is simply the product of the daily flow times the concentration (the permit limit of 200 counts/ 100ml):

Loading from Point Sources = 1.7×10^{7} counts/day

The loading from runoff is calculated by Schueler's (1987) 'simple method' which estimates the quantity of runoff based on percentage of impervious surface. Multiplying the runoff depth times the drainage area times a concentration value times a units correction factor yields loading from each land use:

Loading from Runoff = 3.97×10^{11} counts/day

Other nonpoint source loadings, which include failing septic systems and cattle-in-streams, are determined from an estimated flow times concentration. The estimated flow is calculated from the estimated population using failing septic systems or the number of cattle times a percentage of the day they a assumed to be standing in the stream:

Other Nonpoint Sources = 1.59×10^{10} counts/day

Background loading is estimated by multiplying the $^{7}Q_{10}$ flow times a concentration value (from USEPA, 2001):

Background = 2.44×10^{8} counts/day

All these component loads are summed for the total loading:

Total Existing Load = 4.14×10^{11} counts/day

5.0 TOTAL MAXIMUM DAILY LOAD

A total maximum daily load (TMDL) for a given pollutant and water body is comprised 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), either 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 the 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 water quality standards. 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 bacteria, however, TMDLs are expressed in terms of organism counts (or resulting concentration), in accordance with 40 CFR 130.2(l).

5.1 Waste Load Allocations

Beaverdam Creek has two NPDES permitted dischargers with sanitary wastewater - Pharr Yarns and Beaver Creek Mobile Home Park. The wasteload allocations for these two facilities are based on their permitted flows and permitted fecal coliform limit (200 counts/100ml). The combined WLA for these two facilities is 2.2×10^{8} counts/day.

5.2 Load Allocations

The load allocation for Beaverdam Creek is 9.45×10^{10} counts/day.

5.3 Margin of Safety

The margin of safety is 25 counts/ 100ml or 1.35×10^{10} counts/day.

5.4 TMDL

$$TMDL = \sum WLA + LA + MOS$$

$$TMDL = 2.2 \times 10^{8} + 9.45 \times 10^{10} \text{ counts/day} + 1.35 \times 10^{10} \text{ counts/day.}$$

TMDL = 1.08×10^{11} counts/day

Target Loading = 9.46×10^{10} counts/day

The target loading value is the load to the creek that it can receive and meet the water quality standard. It is simply the TMDL minus the MOS. The target loading for Beaverdam Creek requires a reduction of 77 % from the current load of 4.14×10^{11} counts/day.

6.0 IMPLEMENTATION

As discussed in the *Implementation Plan for Achieving Total Maximum Daily Load Reductions From Nonpoint Sources for the State of South Carolina* (SCDHEC,1998), South Carolina has several tools available for implementing this nonpoint source TMDL. Specifically, SCDHEC's animal agriculture permitting program addresses animal operations and land application of animal wastes. In addition, SCDHEC will work with the existing agencies in the area to provide nonpoint source education in the Beaverdam Creek watershed. Local sources of nonpoint source education include Clemson Extension Service, the Natural Resource Conservation Service (NRCS) and the South Carolina Department of Natural Resources. 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. NRCS can provide cost share money to land owners installing BMPs. SCDHEC employs a nonpoint source educator who can also provide BMP information.

SCDHEC is empowered under the State Pollution Control Act to perform investigations of and pursue enforcement for activities and conditions which threaten the quality of waters of the state. In addition, other interested parties (universities, local watershed groups, etc.) may apply for section 319 grants to install BMPs that will reduce fecal coliform loading to Beaverdam Creek.

In conjunction with county efforts related to the storm water NPDES permit SCDHEC will work with existing agencies in this area to provide nonpoint source education in the Beaverdam Creek watershed. Local sources of nonpoint source education include Clemson Extension Service, the Natural Resource Conservation Service (NRCS), the Chester County Soil and Water Conservation District, and the South Carolina Department of Natural Resources. In addition, Clemson Extension has developed a Home-A-Syst handbook that can help urban or rural homeowners reduce sources of NPS pollution on their property. This document guides homeowners through a self-assessment, including information on proper maintenance practices for septic tanks. SCDHEC also employs a nonpoint source educator who can assist with distribution of these tools as well as provide additional BMP information.

Using existing authorities and mechanisms, these measures will be implemented in the Beaverdam Creek Watershed in order to bring about a 74 % reduction in fecal coliform bacteria loading to Beaverdam Creek. DHEC will continue to monitor, according to the basin monitoring schedule, the effectiveness of implementation measures and evaluate stream water quality as the implementation strategy progresses.

7.0 REFERENCES

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APPENDIX A Fecal Coliform Data for CW-153

Fecal Coliform Bacteria Concentrations (counts/100ml) in Beaverdam Creek at SR-91-152, 8 mi E of Clover

Date	Time	FC
5/19/93	1140	4400
6/22/93	1315	380
7/15/93	1317	310
8/3/93	1200	110
9/2/93	1310	100
10/6/93	1245	350
6/1/94	1130	330
6/21/94	1248	120
8/3/94	1352	480
9/29/94	1125	320
11/3/94	1120	280
5/2/95	1255	6600
6/27/95	1210	1800
7/20/95	1110	140
8/29/95	1218	900
9/26/95	1438	210
10/25/95	1040	340
5/28/96	1117	1600
5/27/97	1225	210
6/24/97	1140	420
7/14/97	1215	290
8/27/97	1130	140
9/18/97	1100	40
10/13/97	1145	150
5/6/98	1045	200
6/8/98	1220	370
7/22/98	1430	880
8/13/98	1250	310
9/30/98	1145	990
10/26/98	1400	190

Appendix B Calculations

Load Calculations for Beaverdam Creek at CW-153 (HUC 03050101-180-030) **Decay Rate:** **0.5** (counts/day)
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Existing Loading

Sources:	Type	Permit #		Flow (cfs)	(L/sec)	Conc (counts/ 100ml)		Load (counts /day)	Method of calc Loading	Load at CW-153 (counts /day)	Travel Time (days)
Pharr Yarns	PS	SC0028321		0.0217	0.614	200		1.06E+08	Permit limits	8.69E+07	0.4
Beaver Ck MHP	PS	SC0032662		0.0233	0.660	200		1.14E+08	Permit limits	8.45E+07	0.6
Failing Septic Systems	NPS	N/A		0.0345	0.977	10000		8.44E+09	% of septic systems	6.25E+09	0.6
Animals-in-streams	NPS	N/A		1.1E-06	0.000			1.30E+10	Spreadsheet	9.63E+09	0.6
Stormwater - Built-up	NPS							2.37E+11	Schueler's Simple Method	5.03E+10	3.1
Stormwater - Cropland	NPS							0.00E+00		0.00E+00	1.7
Stormwater - Pasture	NPS							9.44E+11	Schueler's Simple Method	3.47E+11	2
Stormwater - Wooded	NPS							NA		NA	2
Background				1.1	31.149	100		2.69E+09	Flow x Conc	2.44E+09	0.2

Total Loading (counts/day) **4.16E+11**

TMDL Loading

Allocations				Flow (cfs)	(L/sec)	Conc (counts/ 100ml)		Load (counts /day)
Load Allocations				22.15	627.2	175		9.48E+10
Wasteload Allocations				0.045	1.3	200		2.20E+08

Total Loading (counts/day) **9.51E+10** **Percent Reduction:** **77.2%**

Calculation of Runoff (from Schueler, 1987)

Runoff - Warm Season	=	Rainfall -warm season	*	Fraction of events producing runoff	*	Runoff Coeffi-cient *		
in		in						
Runoff built-up		21.5		0.9		0.4	**7.74**	**inches**
Runoff pasture		21.5		0.9		0.07	**1.35**	**inches**

*** Note: Runoff Coeff is function of % impervious surface as follows:**

Rc = 0.05 + 0.009 x I

Calculation of Loading from Runoff (from Schueler, 1987)

Loading daily	**=**	**Conversion Factor ***	**=**	**Warm Season Runoff ** (in)**	*****	**Conc (counts/ 100 ml)**	*****	**Area (acres)**		**Loading (counts / day)**	
Existing:											
Loading Built-up		5.60E-06		7.74		10,000		547.1		2.37E+11	
Loading Pasture		5.60E-06		1.35		80,000		1556		9.44E+11	
		* Conversion factor changes units and Load to counts/day									
		** Number of days represented by runoff (eg annual = 365):									184

Appendix C Public Notification