

# **Total Maximum Daily Loads for Fecal Coliform for Bear Creek, North Carolina**

*[Waterbody IDs: 19-41-11a1; 19-41-11a2; 19-41-11a3; 19-41-11b1; 19-41-11b2]*

**Final Report**

**September 2011**

***White Oak River Basin***

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**List of Abbreviations**

BMP	Best Management Practice
CAC	Conditionally-approved closed shellfish growing area classification
CAO	Conditionally-approved open shellfish growing area classification
CFR	Code of Federal Regulations
CWA	Clean Water Act
EPA	Environmental Protection Agency
FC	Fecal Coliform Bacteria
HQW	High Quality Water supplemental classification
HUC	Hydrologic Unit Code
LA	Load Allocation
MF	MF is an abbreviation for the membrane filter procedure for bacteriological analysis.
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
NCAC	NC Administration Code
NCDEH	North Carolina Division of Environmental Health
NCDOT	North Carolina Department of Transportation
NCDWQ	North Carolina Division of Water Quality
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NSSP	National Shellfish Sanitation Program
ROW	NCDOT road right of way
SA	Class SA water body: suitable for commercial shellfishing and all other tidal saltwater use
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WLA	Waste Load Allocation

**SUMMARY**

**Total Maximum Daily Load (TMDL)**

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**1. 303(d) Listed Waterbody Information**

**State:** North Carolina

**County:** Onslow

**Major River Basin:** White Oak River Basin

**Watershed:** USGS HUC 03020106020070

**Impaired Waterbody (2010 303(d) List):**

Waterbody Name – [AU]	Description	Water Quality Classification	Acres
Bear Creek – [19-41-11a1]	From source to DEH closed area line	SA;HQW	88.1
Bear Creek – [19-41-11a2]	DEH CAC area along north shore of creek	SA;HQW	8.2
Bear Creek – [19-41-11a3]	DEH CAO area along south shore of creek	SA;HQW	19.2
Bear Creek – [19-41-11b1]	DEH CAC area along north shore of creek	SA;HQW	12.1
Bear Creek – [19-41-11b2]	DEH CAO area along south shore of creek	SA;HQW	179.8

**Constituent(s) of Concern:** Fecal Coliform Bacteria

**Designated Uses:** Shellfish harvesting, biological integrity, propagation of aquatic life, and recreation.

**Applicable Tidal Salt Water Quality Standards for Class SA Waters:**

“Organisms of coliform group: fecal coliform group not to exceed a median MF count of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.”

For the approval of shellfish growing areas “the median fecal coliform Most Probable Number (MPN) or the geometric mean MPN of water shall not exceed 14 per 100 milliliters, and not more than 10 percent of the samples shall exceed a fecal coliform MPN of 43 per 100 milliliters (per five tube decimal dilution) in those portions of areas most probably exposed to fecal contamination during most unfavorable hydrographic conditions” (15A NCAC 18A .0431 Standards for an Approved Shellfish Growing Area). In addition, “a minimum of the 30 most recent randomly collected samples from each sample station shall be used to calculate the median or geometric mean and 90th percentile to determine compliance with this standard” (NSSP, 2007).

## 2. TMDL Development

**Development Tools (Analysis/Modeling):** Steady-state tidal prism model

**Critical Conditions:** The 90th percentile concentration is the concentration exceeded only 10% of the time. Since the data used for model simulation spans 5 years, the critical condition is implicitly included in the value of the 90th percentile of model results.

**Seasonal Variation:** Given the long-term flow and water quality data record used to estimate the fecal coliform load, the seasonal variability is implicitly included in the analysis.

## 3. TMDL Allocation Summary

Waterbody	AUs	Fecal Coliform Load (MPN/day)					% Reduction
		Existing Load <sup>1</sup>	WLA <sup>2</sup>	LA	MOS	TMDL	
Lower Bear Creek	19-41-11b2	-	7.60E+09	6.07E+11	6.83E+10	6.83E+11	0%
Middle Bear Creek	19-41-11a2, 19-41-11a3, 19-41-11b1, 19-41-11b2	-	1.74E+09	1.39E+11	1.57E+10	1.57E+11	0%
Upper Bear Creek	19-41-11a1	3.67E+11	1.04E+09	1.02E+11	1.15E+10	1.15E+11	69%

1. For Lower Bear Creek and Middle Bear Creek, the calculated existing loads are less than the estimated TMDL, and hence no reduction is needed. The FC water quality standard will be met in segments m1 and m2 once the TMDL is implemented and loading is reduced from the watershed of segment m3.
2. WLA applies to NCDOT.

**4. Public Notice Date:** August 1, 2011

**5. Submittal Date:** September 7, 2011

**6. Establishment Date:** September 20, 2011

**7. EPA Lead on TMDL (EPA or blank):**

**8. Endangered Species (yes or blank):**

**9. MS4s Contributions to Impairment (Yes or Blank):**

**10. TMDL Considers Point Source, Nonpoint Source, or both:** Both

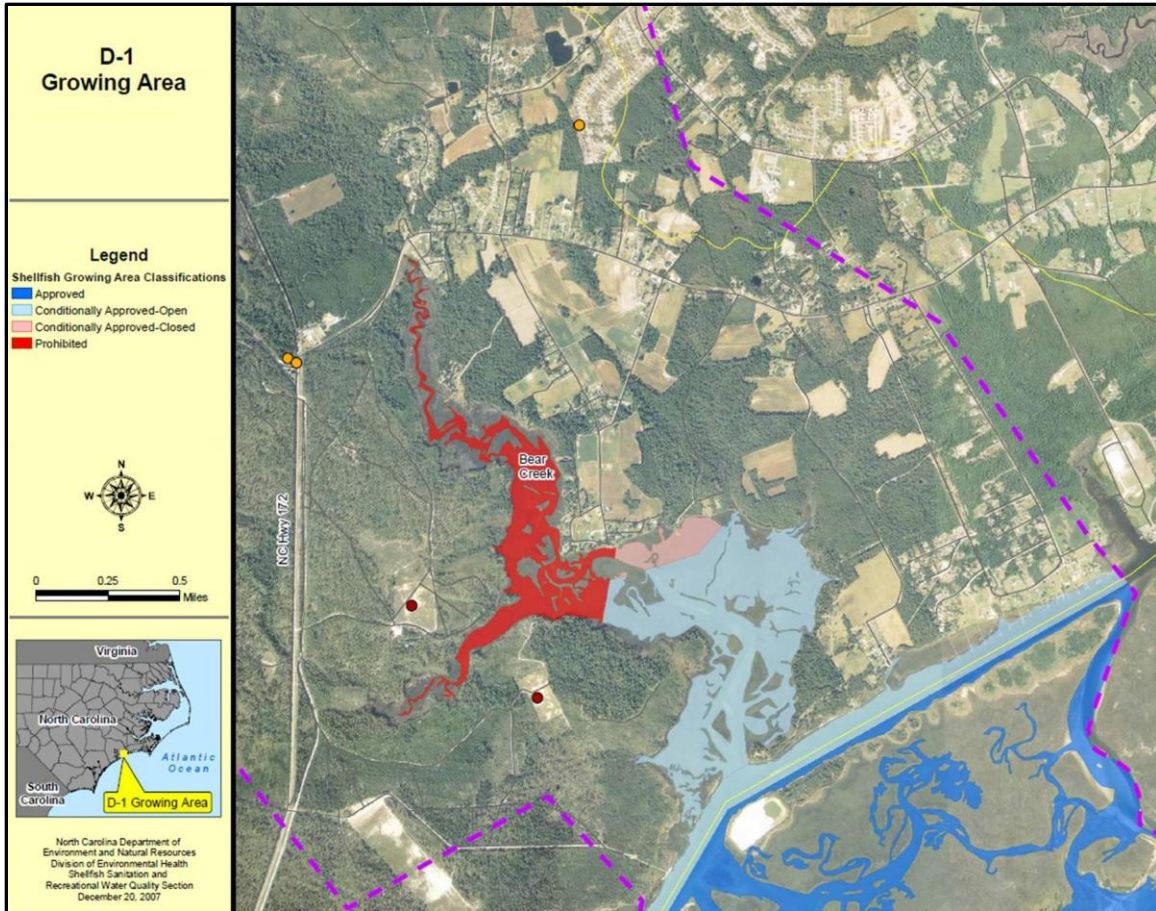
## 1 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each State to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment on the Section 303(d) list, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading that a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Bear Creek watershed is located in the White Oak River Basin (NC Subbasin 03-05-01 – HUC 03020106020070) along the North Carolina coast in Onslow County. The river is located within the shellfish area designated D-1 by the North Carolina Division of Environmental Health (NCDEH). All of the Bear Creek shellfish growing area is conditionally open or closed, or prohibited (Figure 1.1).

When shellfish harvesting is the designated use, the primary parameter of concern is fecal coliform bacteria (FC). Fecal coliform bacteria are found in the intestinal tract of humans and other warm-blooded animals. Few fecal coliform bacteria are pathogenic; however, the presence of elevated levels of fecal coliform in shellfish waters indicates recent sources of pollution. Some common waterborne diseases associated with the consumption of raw clams and oysters harvested from polluted water include viral and bacterial gastroenteritis and hepatitis A. Fecal coliform in surface waters may come from point sources (e.g., NPDES stormwater conveyances) and nonpoint sources.



**Figure 1.1 – Bear Creek Shellfish Growing Area (D-1) Classifications**

### 1.1 TMDL Components

The 303(d) process requires that a TMDL be developed for each of the waters appearing in Category 5 of a state’s Integrated Report. The objective of a TMDL is to estimate allowable pollutant loads and allocate to known sources so that actions may be taken to restore the water to its intended uses (USEPA, 1991). This TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving North Carolina’s water quality criteria for shellfish waters. Currently, TMDLs are expressed as a “mass per unit time, toxicity, or other appropriate measure” (40 CFR 130.2(i)). It is also important to note that the TMDLs presented herein are not literal daily limits. These loads are based on an averaging period that is defined by the water quality criteria.

Generally, the primary components of a TMDL, as identified by EPA (1991, 2000) and the Federal Advisory Committee (USEPA, 1998) are as follows:

*Target Identification* or selection of pollutant(s) and end-point(s) for consideration. The pollutant and end-point are generally associated with measurable water quality related characteristics that indicate compliance with water quality standards. North Carolina indicates known pollutants on the 303(d) list.

*Source Assessment.* All sources that contribute to the impairment should be identified and loads quantified, where sufficient data exist.

*Reduction Target.* Estimation or level of pollutant reduction needed to achieve water quality goal. The level of pollution should be characterized for the waterbody, highlighting how current conditions deviate from the target end-point. Generally, this component is identified through water quality modeling.

*Allocation of Pollutant Loads.* Allocating pollutant control responsibility to the sources of impairment. The wasteload allocation portion of the TMDL accounts for the loads associated with existing and future point sources. Similarly, the load allocation portion of the TMDL accounts for the loads associated with existing and future non-point sources, stormwater, and natural background.

*Margin of Safety.* The margin of safety addresses uncertainties associated with pollutant loads, modeling techniques, and data collection. Per EPA (USEPA, 2000), the margin of safety may be expressed explicitly as unallocated assimilative capacity or implicitly due to conservative assumptions.

*Seasonal Variation.* The TMDL should consider seasonal variation in the pollutant loads and end-point. Variability can arise due to stream flows, temperatures, and exceptional events (e.g., droughts, hurricanes).

*Critical Conditions.* Critical conditions indicate the combination of environmental factors that result in just meeting the water quality criterion and have an acceptably low frequency of occurrence.

Section 303(d) of the CWA requires EPA to review all TMDLs for approval or disapproval. Once EPA approves a TMDL, then the waterbody may be moved to Category 4a of the Integrated Report. Waterbodies remain in Category 4a until compliance with water quality standards is achieved. Where conditions are not appropriate for the development of a TMDL, management strategies may still result in the restoration of water quality.

TMDL is comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. The TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the



receiving waterbody, and in the scientific and technical understanding of water quality in natural systems.

## 1.2 Documentation of Impairment

The North Carolina Division of Water Quality (NCDWQ) Surface Water and Wetlands classification for these impaired waters is Class SA, HQW Waters – Shellfish Harvesting Waters (15A NCAC 02B.0221 Tidal Salt Water Quality Standards for Class SA Waters). Class SA waters are waterbodies suitable for commercial shellfishing and all other tidal saltwater use (NCAD, 2003).

Five segments, or assessment units (AUs), of Bear Creek have been included in Category 5 of the 2010 North Carolina Integrated Report, as shown below in Table 1.1.

**Table 1.1 – Bear Creek Impaired Assessment Units**

Waterbody Name – [AU]	Description	Water Quality Classification	Acres
Bear Creek – [19-41-11a1]	From source to DEH closed area line	SA;HQW	88.1
Bear Creek – [19-41-11a2]	DEH CAC area along north shore of creek	SA;HQW	8.2
Bear Creek – [19-41-11a3]	DEH CAO area along south shore of creek	SA;HQW	19.2
Bear Creek – [19-41-11b1]	DEH CAC area along north shore of creek	SA;HQW	12.1
Bear Creek – [19-41-11b2]	DEH CAO area along south shore of creek	SA;HQW	179.8

These restricted shellfish harvesting areas are identified as areas that do not meet their designated uses. Waters within this classification, according to 15A NCAC 02B.0221 (Tidal Salt Water Quality Standards for Class SA Waters), must meet the following water quality standard in order to meet their designated use:

*Organisms of coliform group: fecal coliform group not to exceed a median MF count of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.*

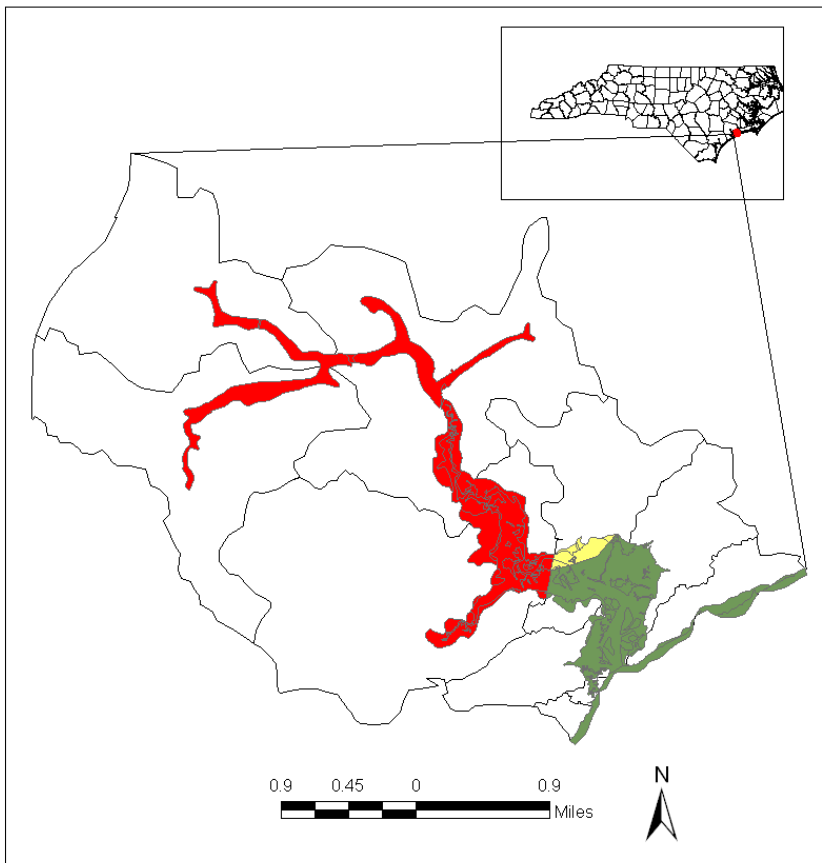
In addition, for approval of shellfish growing areas “the median fecal coliform Most Probable Number (MPN) or the geometric mean MPN of water shall not exceed 14 per 100 milliliters, and not more than 10 percent of the samples shall exceed a fecal coliform MPN of 43 per 100 milliliters (per five tube decimal dilution) in those portions

of areas most probably exposed to fecal contamination during most unfavorable hydrographic conditions” (15A NCAC 18A .0431 Standards for an Approved Shellfish Growing Area). In addition, “a minimum of the 30 most recent randomly collected samples from each sample station shall be used to calculate the median or geometric mean and 90<sup>th</sup> percentile to determine compliance with this standard” (NSSP, 2007).

For this report, the monitoring data averaging period was based on monitoring procedures for approval of SA water. The most recent five-year period of data was used, September 2005 – August 2010. A detailed analysis of the data used can be found in Appendix A.

### 1.3 Watershed Description

Bear Creek falls within the NCDEH D-1 Growing Area in Onslow County. The watershed was delineated using EPA BASINS (<http://water.epa.gov/scitech/datait/models/basins/>). The resulting watershed outline is provided below in Figure 1.2. The watershed area is less than 11 square miles.



**Figure 1.2 – Bear Creek watershed delineation overlaid with NCDEH shellfish growing area classifications (red: prohibited; yellow: CAC; green: CAO)**

The 2006 National Land Cover Database (NLCD) was used to obtain land cover characteristics of the watershed ([http://www.mrlc.gov/nlcd2006\\_downloads.php](http://www.mrlc.gov/nlcd2006_downloads.php)). Land cover distribution is shown in Figure 1.3 and land cover acreages are provided in Table 1.2. The dominant land covers in this watershed are shrub/scrub, forest, and wetlands.

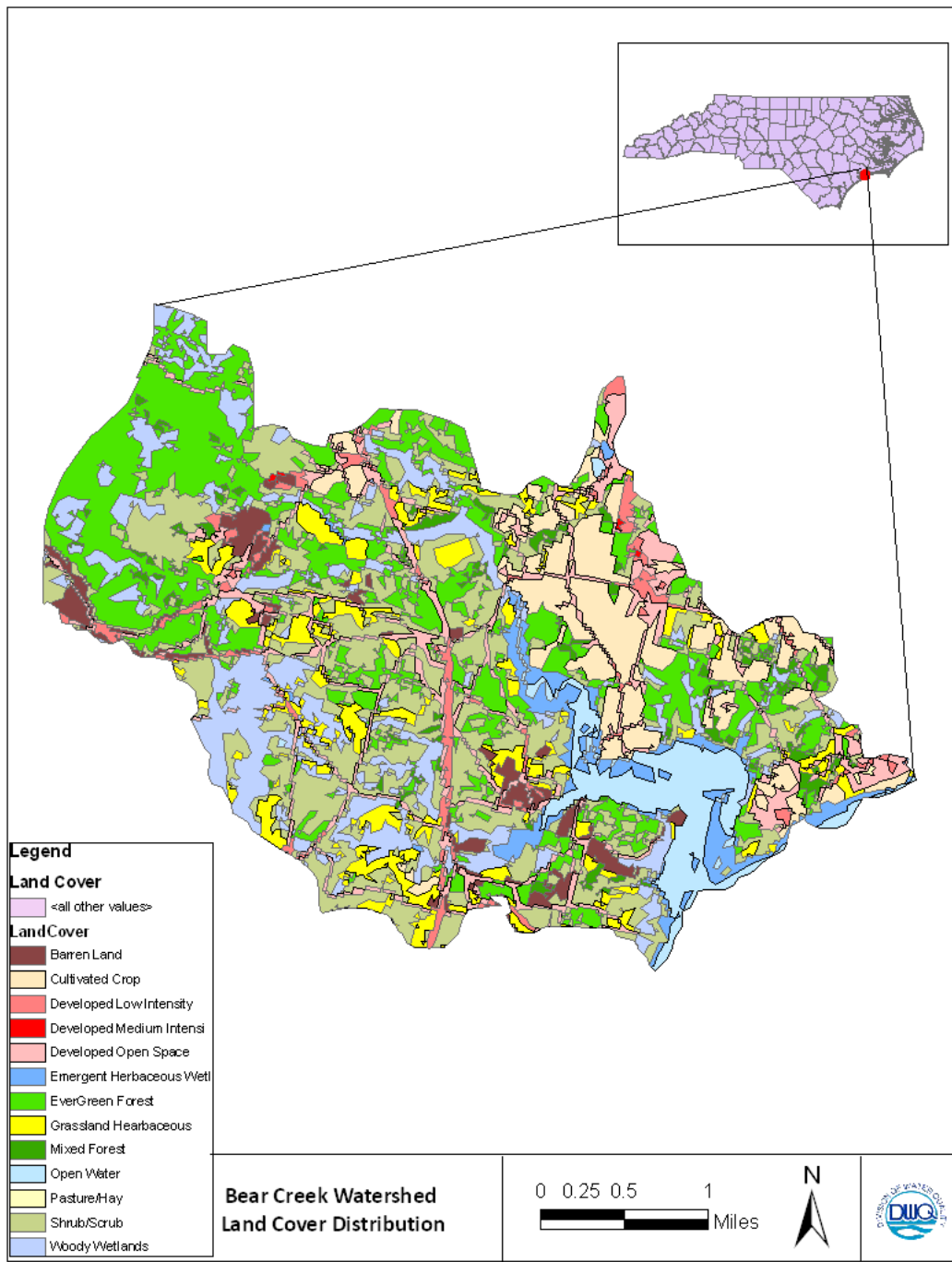


Figure 1.3 – 2006 NLCD Land Cover of the Bear Creek Watershed

**Table 1.2 – 2006 Land Cover Distribution of the Bear Creek Watershed**

Land Cover Category	Area (acres)	Percent Total
Developed Low Intensity	200.0	2.89%
Developed Medium Intensity	4.3	0.06%
Developed Open Space	593.5	8.56%
Cultivated Crop	612.7	8.84%
Pasture/Hay	2.4	0.03%
Evergreen Forest	1450.7	20.93%
Mixed Forest	169.0	2.44%
Herbaceous Grassland	511.1	7.37%
Shrub/Scrub	1672.6	24.13%
Emergent Herbaceous Wetland	253.6	3.66%
Woody Wetlands	879.6	12.69%
Barren Land	217.9	3.14%
Open Water	365.2	5.27%
Total Area	6932.8	100.00%

The D-1 growing area is not densely inhabited, with a total population of less than 1,900 according to US Census data from 2000. Residential development is isolated to the eastern shore of the Bear Creek. The entire western shore is part of the Camp LeJeune Marine Corps Base. This portion of the Base is used for training purposes.

The dominant tide in this region is the lunar semi-diurnal ( $M_2$ ) tide with a mean tidal range of 3.11 ft based on the NOAA station at Beaufort, NC (NOAA, 2010). Oysters and clams grow well throughout the area with clam production being the most significant commercial species.

#### **1.4 Water Quality Characterization**

The Shellfish Sanitation and Recreational Water Quality Section of the NCDEH is responsible for classifying shellfish harvesting waters to ensure oysters and clams are safe for human consumption. NCDEH adheres to the requirements of the National Shellfish Sanitation Program (NSSP), with oversight by the U.S. Food and Drug Administration. NCDEH conducts shoreline surveys and collects routine bacteria water quality samples in the shellfish-growing areas of North Carolina. The data are used to determine if the water quality criteria are being met. If the water quality criteria are exceeded, the shellfish areas are closed to harvest, at least temporarily, and consequently the designated use is not being achieved.

NCDEH has monitored shellfish growing regions throughout North Carolina for the past several decades. Bear Creek is sampled using the systematic random sampling strategy as outlined in the National Shellfish Sanitation Program's Model Ordinance and guidance document. In addition to the routine random monitoring of the areas, conditional area samples are collected after rainfall events for some stations.

There are 18 fecal coliform monitoring stations sampled by the NCDEH in the D-1 Growing Area, as shown in Figure 1.4. Most of the data available were collected through the random monitoring strategy, although five stations are regularly sampled under the conditional monitoring strategy after rainfall events (Stations 6, 7, 8, 8A, 9). NCDEH data from September 2005-August 2010 are summarized in Appendix A. The 2009 NCDEH Sanitary Survey Report notes one station did not meet standards for growing area criteria (NCDEH, 2009).

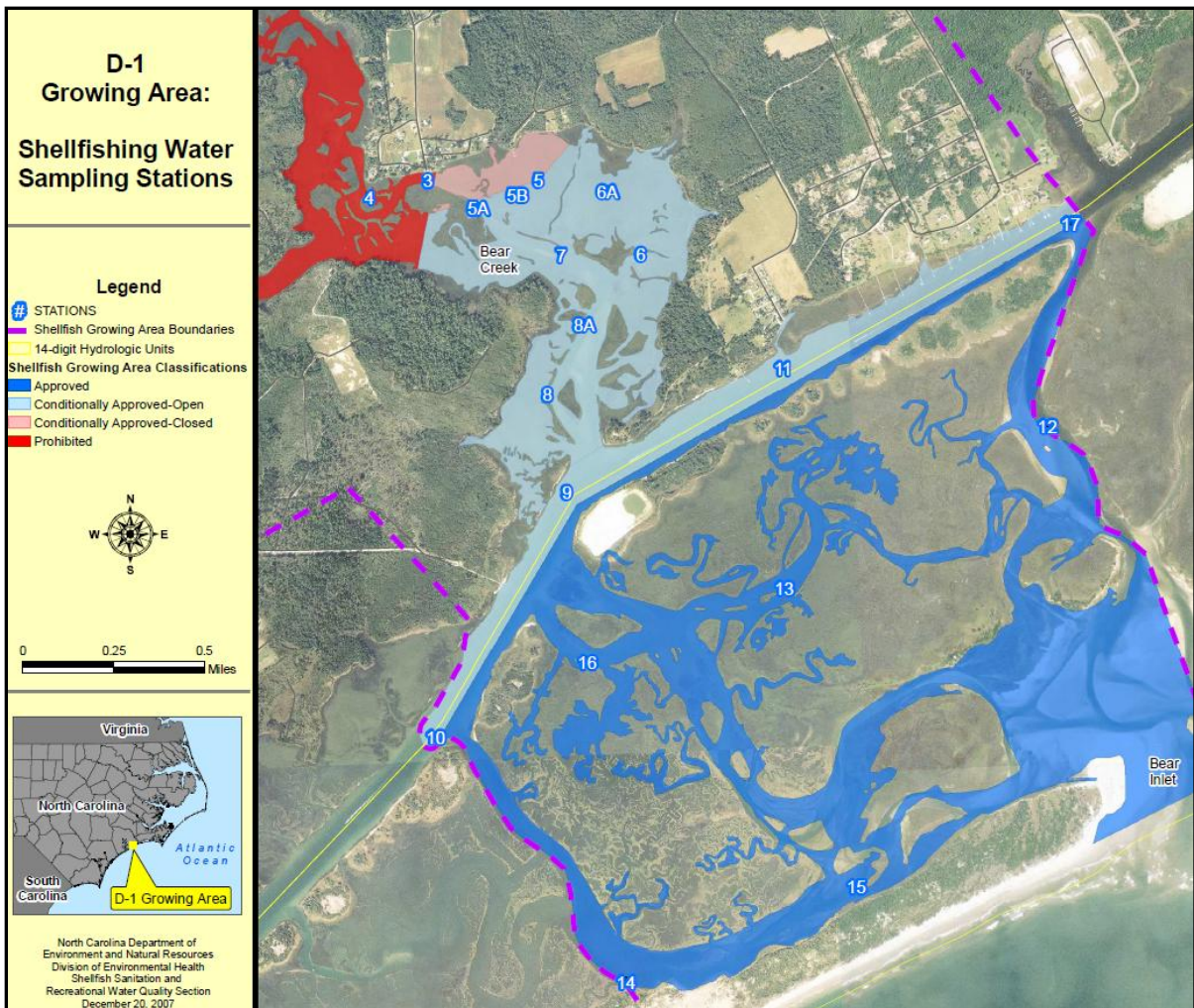


Figure 1.4 – NCDEH Fecal Coliform Monitoring Stations (note that station 4 has not been sampled since May 2005)



## **2 SOURCE ASSESSMENT**

### **2.1 Nonpoint Source Assessment**

Non-point sources are diffuse sources that typically cannot be identified as entering a water body at a single location. Nonpoint source loading typically occurs during rain events when surface runoff transports water carrying fecal coliform over the land surface and discharges it into the stream network. The transport of fecal coliform from the land to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

There are many types of nonpoint sources in watersheds that contribute to the restricted shellfish harvesting areas. The most recent NCDEH Shoreline Survey (NCDEH, 2009) documented and mapped potential sources of fecal coliform in Bear Creek. The survey found that stormwater draining off of agricultural lands, residential areas, and roadways into Bear Creek and its tributaries is of particular concern due to the steep grades along the shoreline throughout the area.

Nonpoint source contributions to the bacterial levels from human activities generally arise from malfunctioning or improperly-sited septic systems and their associated drain fields, or illicit connections of sanitary sewage to the stormwater conveyance system. The majority of onsite systems in the growing area were visited and inspected during the shoreline survey (NCDEH, 2009) and were found to be functioning properly. Pet waste can also be a significant source of fecal coliform bacteria loading.

Grazing animals contribute fecal coliform through either direct access to streams or runoff from deposition or manure spreading. According to the shoreline survey, there are several animal farms within the D-1 watershed, although none are particularly large. Land cover data for the watershed indicates that pasture/hay land area (grazing land) represents less than 1 percent of the watershed.

Agricultural fields are widespread in the D-1 watershed. Common crops include cotton, tobacco, hay, and corn. Several of these fields have drainages that reach either Bear Creek itself or have a tributary to Bear Creek and are likely to contribute fecal coliform bacteria to the creeks and waterways following rain events (NCDEH, 2009).

Wildlife in the watershed are considered to make up background concentrations of fecal coliform. There are various forested areas and agricultural fields scattered throughout the watershed, so wildlife is prevalent throughout the majority of this region. Large populations of deer, foxes, raccoons, and other small mammals are found in the area, as well as waterfowl and other birds. Waste from these animals can reach the creek either through direct deposition or through transportation through stormwater ditches.

## **2.2 Point Source Assessment**

All wastewater discharges to surface water in the State of North Carolina must receive a permit to control water pollution. Stormwater has previously been considered to be a nonpoint source; however, NPDES-permitted sources are to be included in the wasteload allocation (WLA) per EPA guidance (USEPA, 2002).

The only point source in the Bear Creek watershed is the NC Department of Transportation (NCDOT) which has a statewide Phase I NPDES stormwater permit (NCS000250).

### 3 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

#### 3.1 TMDL Objective

The TMDL objective is to meet North Carolina water quality fecal coliform standards of a median MF count of 14 per 100 ml and not more than 10 percent of the samples shall exceed an MF count of 43 per 100 ml. In addition, the National Shellfish Sanitation Program (NSSP) standard for the approved classification of growing areas requires that fecal coliform concentrations not exceed a median or geometric mean of a MPN of 14 per 100 ml and the 90<sup>th</sup> percentile of a MPN of 43 per 100 ml, with a minimum of the 30 most recent samples used to calculate compliance.

Both standards have the same numeric targets but the NSSP standard uses a minimum 30- sample averaging period. Data collected from September 2005 through August 2010 were used for the purpose of this TMDL.

#### 3.2 Modeling

##### 3.2.1 Approach

Bay and coastal waters such as Bear Creek are subject to the action of the tides. The ebb and flood of the tide serves to move water between locations exchanging and mixing with other water. The tide and amount of freshwater discharge into the embayment are the dominant influences on the transport of fecal coliform. Therefore, the TMDL was calculated using the spreadsheet-based steady-state tidal prism model. This modeling approach has been used in approved TMDLs in several other states (MDE, 2004; VADEQ, 2005).

The steady-state tidal prism model is spreadsheet-based and incorporates the influences of tidally induced transport, freshwater input, and removal of fecal coliform via decay. Depending on the geometry of the embayment, the model may have multiple segments. The model assumes that the embayment is well mixed within a single segment, and freshwater input, tidal range, and the first-order decay of fecal coliform are all constant. A brief description of the model is presented below.

The steady-state tidal prism model calculates fecal coliform load using equation 3.1:

$$L = [C(Q_b + kV) - Q_0C_0] \times Cf \quad (3.1)$$

where:

- $L$  = fecal coliform load (counts per day)
- $C$  = mean fecal coliform concentration (MPN /100ml) of the segment
- $k$  = the fecal coliform removal/decay rate (per tidal cycle)



$C_0$  = the fecal coliform concentration (MPN/100ml) entering the segment on the flood tide

$Q_0$  = the quantity of water that enters the segment on the flood tide that did not flow out of the segment on the previous ebb tide ( $m^3$  per tidal cycle)

$Q_b$  = the quantity of mixed water that leaves the segment on the ebb tide that did not enter the segment on the previous flood tide ( $m^3$  per tidal cycle)

$V$  = the mean volume of the segment ( $m^3$ )

$C_f$  = the unit conversion factor

The fecal coliform decay rate,  $k$ , was set at 0.36 per tidal cycle, which is considered a conservative estimate. The value of the decay rate varies from between 0.3 and 3.0 in salt water (Thomann and Mueller, 1987).  $Q_b$  and  $Q_0$  are estimated based on the steady state condition as follows:

$$\begin{aligned} Q_b &= Q_0 + Q_f \\ Q_0 &= \beta Q_T \end{aligned}$$

where:

$Q_f$  = mean freshwater input during one tidal cycle

$\beta$  = exchange ratio

$Q_T$  = the quantity of water that enters the segment on the flood tide

$Q_T$  is calculated based on the tidal range. The dominant tide in this region is the lunar semi-diurnal ( $M_2$ ) tide with a tidal period of 12.42 hours. The mean tidal range is assumed to be 3.11 ft, as monitored at a nearby NOAA station at Beaufort, NC. In general, the exchange ratio varies from 0.3 to 0.7, based on the previous model tests in coastal embayments (Kuo et al., 1998; Shen et al., 2002). A mean value of 0.5 was used for the exchange ratio.

The stream flow ( $Q_f$ ) used to represent the fresh water inflow was based on a ratio of the drainage area of the Bear Creek watershed as compared to the drainage area and the stream flows measured by the U.S. Geological Survey at the New River gaging station (USGS 02093000) near Gum Branch, NC. The selection of the gaging station for use in the model is determined by its similarity in watershed characteristics to the Bear Creek watershed and the proximity of the station to the TMDL study area. Appendix B provides model inputs and parameters used for the 90<sup>th</sup> percentile calculations.

### 3.2.2 Existing Load Calculation

Model segmentation is provided below in Figure 3.1. Existing median and 90<sup>th</sup> percentile concentrations for each segment are required as model inputs. These were calculated by combining monitoring data from all monitoring stations within each segment and calculating the overall median and the 90<sup>th</sup> percentile fecal coliform

concentrations. Table 3.1 provides the monitoring stations used in each model segment and the overall median and 90<sup>th</sup> percentile concentrations.

NCDEH conditional monitoring data were not used to calculate existing concentrations because conditional monitoring only takes place in a few stations close to the mouth of Bear Creek after rainfall events to see if waters can be reopened to shellfishing. These concentrations tend to be inconsistently higher compared to stations where conditional monitoring data were not collected (as shown in Appendix A, Table A.1). Therefore, to avoid creating bias in the model, conditional data were not used to calculate existing loads.

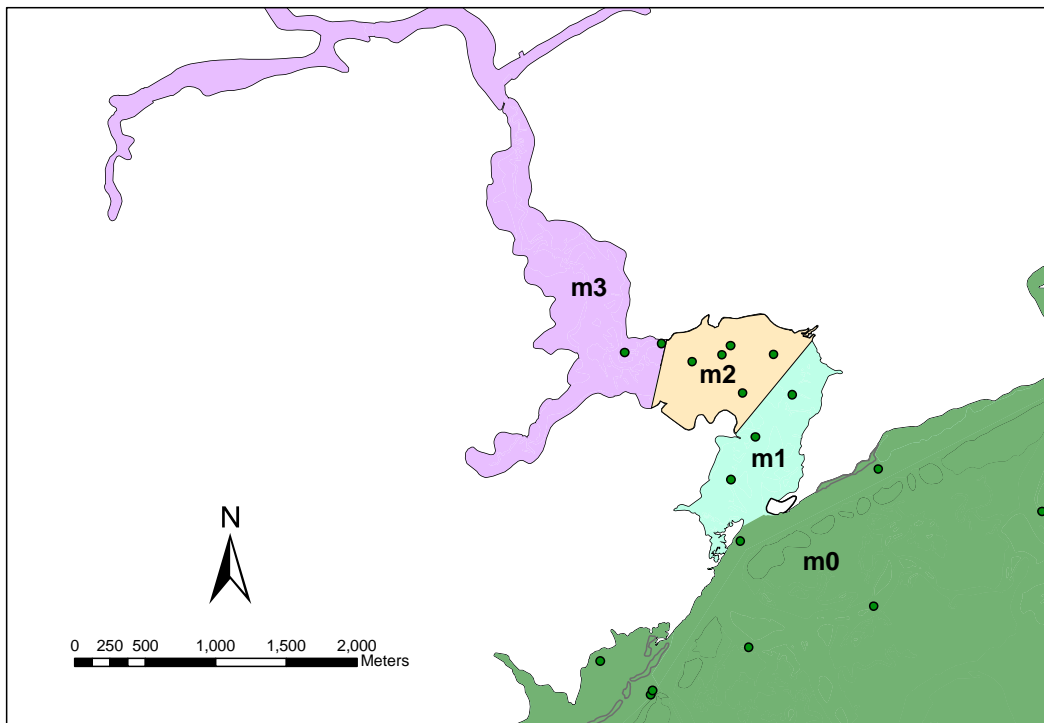


Figure 3.1 – Model Segmentation

Table 3.1 – Monitoring stations and assessment units associated with each model segment

Model Segment	Waterbody	AUs	NCDEH Monitoring Station(s)	Median FC (MPN/100 ml)	90 <sup>th</sup> Percentile FC (MPN/100ml)
m0	Ocean Boundary		9, 10, 11	2.0	8.0
m1	Lower Bear Creek	19-41-11b2	6, 8, 8A	2.0	18.0
m2	Middle Bear Creek	19-41-11a2, 19-41-11a3, 19-41-11b1, 19-41-11b2	5, 5A, 5B, 6A, 7	4.5	24.0
m3	Upper Bear Creek	19-41-11a1	3	7.8	75

The concentrations listed in Table 3.1 were then used in Equation 3.1 to calculate the existing fecal coliform loads associated with both the median and the 90<sup>th</sup> percentile concentrations. Table 3.2 presents the estimated existing loads for each segment.

### 3.2.3 TMDL Calculation

The TMDL was calculated by using Equation 3.1 and the North Carolina water quality fecal coliform standards of a median of 14 counts per 100 ml and a 90<sup>th</sup> percentile of 43 counts per 100 ml. Table 3.2 presents the estimated TMDL for each segment.

The percent load reduction needed to meet the fecal coliform standard was estimated using equation 3.2:

$$Reduction = (Existing\ Load - TMDL) / Existing\ Load \quad (3.2)$$

**Table 3.2 – Load reduction requirements under variations of standard criteria**

Standard Category	Segment	AUs	Standard (MPN/100ml)	Estimated Existing Load (MPN/day)	TMDL (MPN/day)	Percent Reduction Required
Median	m1	19-41-11b2	14	Less than TMDL	2.29E+11	0%
	m2	19-41-11a2, 19-41-11a3, 19-41-11b1, 19-41-11b2	14	Less than TMDL	5.11E+10	0%
	m3	19-41-11a1	14	Less than TMDL	3.74E+10	0%
90 <sup>th</sup> percentile	m1	19-41-11b2	43	Less than TMDL	6.83E+11	0%
	m2	19-41-11a2, 19-41-11a3, 19-41-11b1, 19-41-11b2	43	Less than TMDL	1.57E+11	0%
	m3	19-41-11a1	43	3.67E+11	1.15E+11	69%

Using median concentration and the corresponding median standard, the calculated existing loads are less than the TMDL in all segments. This is also reflected in the low median concentrations calculated from the monitoring data. In contrast, when 90<sup>th</sup> percentile concentrations and the corresponding 90<sup>th</sup> percentile water quality standard are used, a 69% load reduction is needed in the watershed of segment m3. No reduction in loading is needed from the watersheds of segment m1 and m2 due to their lower existing load than the TMDL. The FC water quality standard will be met in segments m1 and m2 once the TMDL is implemented and loading is reduced from the watershed of segment m3.

Required reductions in loading are higher for the 90<sup>th</sup> percentile model results (highlighted in orange in Table 3.2) and allow for both standards to be met. Therefore, the TMDL was calculated using the 90<sup>th</sup> percentile criterion.

### 3.3 TMDL Allocation

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source allocations (WLAs), nonpoint source allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 3.3.

$$TMDL = \sum WLAs + \sum LAs + MOS \quad (3.3)$$

The objective of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. The systematic procedures adopted to estimate TMDLs are described below.

#### 3.3.1 Margin of Safety (MOS)

A Margin of Safety (MOS) is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural water bodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

As a conservative estimate in the TMDL calculation, an explicit MOS of 10% is included. The explicit MOS was achieved by multiplying the TMDL by 10%. These loads are shown in Table 3.3.

**Table 3.3 – Margin of Safety Allocation**

Standard Category	Segment	Fecal Coliform Load (MPN/day)		
		TMDL	MOS	Allowable Load (TMDL – MOS)
90 <sup>th</sup> Percentile	m1	6.83E+11	6.83E+10	6.15E+11
	m2	1.57E+11	1.57E+10	1.41E+11
	m3	1.15E+11	1.15E+10	1.03E+11

**3.3.2 Waste Load Allocation (WLA)**

As described in Section 2.2, NCDOT is the only NPDES-permitted discharge in the watershed. Data is not available to calculate the existing load for the NCDOT.

The WLA for NCDOT land was isolated from other sources by multiplying the total load and the ratio of NCDOT road right of way (ROW) area to total subwatershed area. The NCDOT ROW area was calculated by multiplying the road length and width of US highways, NC roads, and state route roads within the watershed. The NCDOT ROW is only 1.0% of the total watershed area, as shown below in Table 3.4, and is therefore not considered to be a major source of fecal bacteria loading. The resulting WLA for NCDOT is provided below in Table 3.5.

NCDOT will continue to implement measures required by the permit, including illicit discharge detection and elimination, post-construction controls, management of hydraulic encroachments, sediment and erosion control, BMP retrofits, stormwater pollution prevention for industrial facilities, research, and education programs.

**Table 3.4 - Bear Creek Watershed NCDOT Contributing Area by Subwatershed**

Segment #	Total Sub-Watershed Area (acres)	NCDOT Land Area (acres)	NCDOT Land Area (% of total)
m1	696	8.6	1.2%
m2	644	7.9	1.2%
m3	5298	53.5	1.0%
Total	6638	70	1.0%

**Table 3.5 – NPDES Wasteload Allocations**

NPDES Permittee	Segment #	NCDOT Existing Permitted Load (MPN/day)	WLA (MPN/day)	Percent Reduction
NCDOT	m1	N/A	7.60E+09	0%
	m2	N/A	1.74E+09	0%
	m3	N/A	1.04E+09	0%

**3.3.3 Load Allocation (LA)**

All fecal coliform loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as LAs. The LA allocations were estimated by subtracting the MOS and WLA allocations from the TMDL. The estimated allocations of fecal coliform loading from nonpoint sources are presented in Table 3.6 and equate to the overall TMDL percent reduction.

**Table 3.6 – Nonpoint Source Allocation**

Segment #	LA (MPN/day)
m1	6.07E+11
m2	1.39E+11
m3	1.02E+11

**3.3.4 Critical Condition and Seasonal Variation**

The EPA Code of Federal Regulations (40 CFR 130.7 (c) (1)) requires TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The critical condition accounts for the hydrologic variation in the watershed over many sampling years whereas the critical period is the condition under which a waterbody is the most likely to violate the water quality standard(s).

The 90th percentile concentration is the concentration exceeded only 10% of the time. Since the data used for model simulation spans 5 years, the critical condition is implicitly included in the value of the 90th percentile of model results. Given the length of the monitoring record and the standard’s recognition of unusual and infrequent events, the 90th percentile is used instead of the absolute maximum.

The EPA also requires that these TMDL studies take into account seasonal variations. The consideration of critical condition and seasonal variation is to account for the hydrologic and source variations. Seasonal variations involve changes in surface runoff,

stream flow, and water quality as a result of hydrologic and climatologic patterns. For the Bear Creek TMDL study, variations due to changes in the hydrologic cycle as well as temporal variability in fecal coliform sources are accounted for by the use of the long-term data record to estimate the current load.

The seasonal fecal coliform distribution for the stations in Segment m1 of Bear Creek is presented in Figure 3.2 and includes both the random and conditional monitoring data. The seasonal distributions of fecal coliform concentrations for the other segments are presented in Appendix A. The results show that high fecal coliform levels occur throughout the year in the estuary. The largest standard deviation corresponds to the highest concentration for each station. These high concentrations result in a high 90<sup>th</sup> percentile concentration. Given the long-term flow and water quality data record used to estimate the fecal coliform load, the seasonal variability is implicitly included in the analysis.

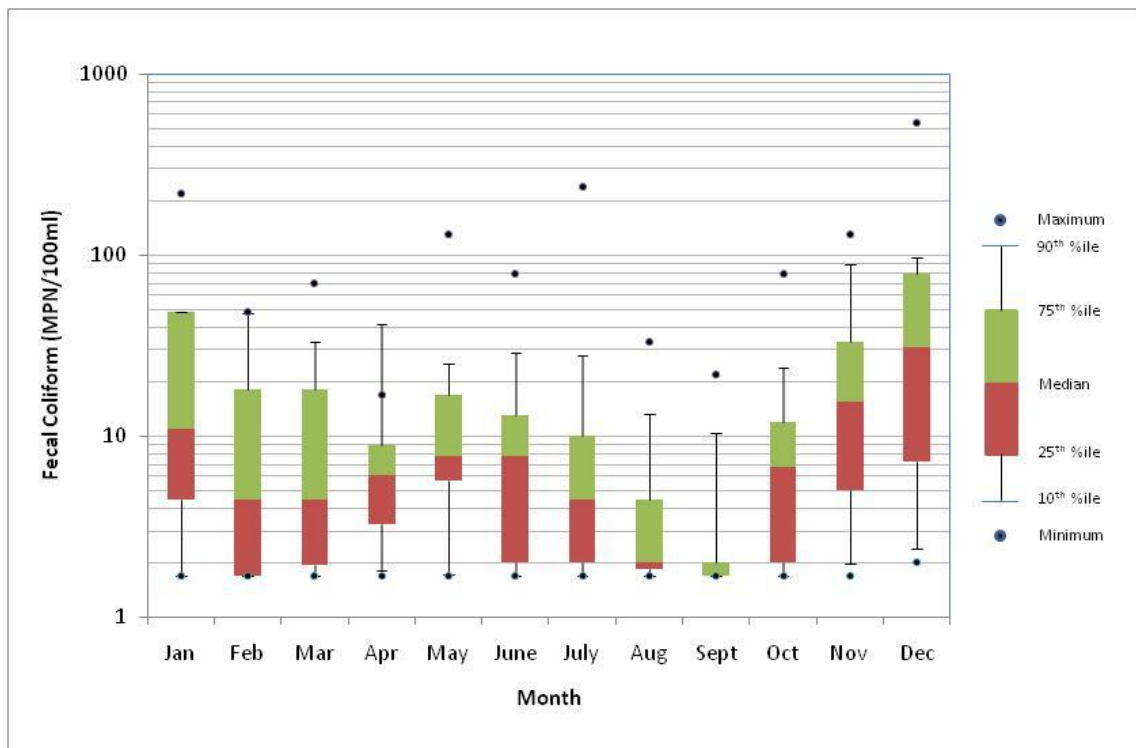


Figure 3.2 - Seasonal distribution of fecal coliform concentrations (random and conditional monitoring data combined) in Segment m1 (log scale)

### 3.3.5 TMDL Summary

A summary of the TMDL is provided below in Table 3.7. Reductions in fecal coliform loading are required for the Upper Bear Creek watershed (AU# 19-41-11a1). Upper Bear Creek corresponds to the NCDEH shellfish growing area classified as prohibited. As

shown above in Table 3.4, Upper Bear Creek receives drainage from about 80% of the total Bear Creek watershed and has the lowest calculated TMDL (Table 3.7). Reductions in loading from the Upper Bear Creek watershed allows for standards to be met throughout Bear Creek.

**Table 3.7 – Estimated TMDL and Load Allocation for Fecal Coliform for Bear Creek**

Waterbody	AUs	Fecal Coliform Load (MPN/day)					% Reduction
		Existing Load <sup>1</sup>	WLA <sup>2</sup>	LA	MOS	TMDL	
Lower Bear Creek (m1)	19-41-11b2	-	7.60E+09	6.07E+11	6.83E+10	6.83E+11	0%
Middle Bear Creek (m2)	19-41-11a2, 19-41-11a3, 19-41-11b1, 19-41-11b2	-	1.74E+09	1.39E+11	1.57E+10	1.57E+11	0%
Upper Bear Creek (m3)	19-41-11a1	3.67E+11	1.04E+09	1.02E+11	1.15E+10	1.15E+11	69%

1. For Lower Bear Creek and Middle Bear Creek, the calculated existing loads are less than the TMDL, and hence no reduction is needed. The FC water quality standard will be met in segments m1 and m2 once the TMDL is implemented and loading is reduced from the watershed of segment m3.
2. WLA applies to NCDOT.



#### **4 TMDL IMPLEMENTATION PLAN**

An implementation plan is not included in this TMDL. Local stakeholder groups, governments, and agencies are encouraged to develop an implementation plan and utilize funding sources for water quality improvement projects targeted at BMP construction and public outreach. Some potential funding sources include the North Carolina Clean Water Management Trust Fund, and Section 319 and 205j funds. Individual land owners may apply for the Community Conservation Assistance Program and Agriculture Cost Share Program to improve the condition of their property. The next NCDEH Sanitary Survey for the D-1 shellfish growing area will help further identify current sources of bacteria and drainage pathways that allow bacteria to enter Bear Creek.

NCDEH will continue to monitor water quality in Bear Creek using the systematic random sampling strategy as outlined in the National Shellfish Sanitation Program's Model Ordinance and guidance document. This data will be used to evaluate progress towards the goal of reaching water quality standards.

#### **5 PUBLIC PARTICIPATION**

A draft of the TMDL was publicly noticed through various means. NCDWQ electronically distributed the draft TMDL and public comment information to known interested parties. The announcement is provided in Appendix C. The TMDL was also available from the NCDWQ's website at <http://portal.ncdenr.org/web/wq/ps/mtu/tmdl/tmdls> during the comment period. The public comment period lasted from August 1 – September 1, 2011. NCDWQ received comments from NCDOT. A summary of their comments and NCDWQ's response is provided in Appendix D.

#### **6 FURTHER INFORMATION**

Further information concerning North Carolina's TMDL program can be found on the Internet at the Division of Water Quality website:  
<http://portal.ncdenr.org/web/wq/ps/mtu>

Technical questions regarding this TMDL should be directed to the following members of the NCDWQ Modeling/TMDL Unit:

Pam Behm  
e-mail: [pamela.behm@ncdenr.gov](mailto:pamela.behm@ncdenr.gov)

Kathy Stecker  
e-mail: [kathy.stecker@ncdenr.gov](mailto:kathy.stecker@ncdenr.gov)

## 7 REFERENCES

- Kuo, A., Park, K. 1994. A PC-based tidal prism water quality model for small coastal basins and tidal creeks. SRAMSOE No. 324, SMS/VIMS, CWM, VA, 119 pp.
- Kuo, A., Butt, A., Kim, S. and J. Ling. 1998. Application of a tidal prism water quality model to Virginia Small Coastal Basins. SRAMSOE No. 348.
- MDE. 2004. Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in the Potomac River Lower Tidal Basin in St. Mary's County, Maryland.
- NCAD. 2003. NC Administration Code.
- NCDEH. 2009. Report of Sanitary Survey, Area D-1, Bear Creek Area, May 2004 through March 2009. NC Division of Environmental Health Shellfish Sanitation and Recreational Water Quality.
- NOAA. 2010. Tides Online. National Oceanic and Atmospheric Administration/National Ocean Service. Website: <http://co-ops.nos.noaa.gov/>
- NSSP. 2007. National Shellfish Sanitation Program Guide for the control of Molluscan Shellfish 2007, Section IV, Chapter II (Bacteriological Standards). US Food and Drug Administration, 2007. Website: <http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/FederalStatePrograms/NationalShellfishSanitationProgram/UCM053698>
- Shen, J., H. Wang, and M. Sisson. 2002. Application of an Integrated Watershed and Tidal prism Model to the Poquoson Coastal Embayment (submitted to Department of Environmental Quality, Commonwealth of Virginia). Virginia Institute of Marine Science Special Report 380, Gloucester Point, VA.
- Thomann, R. V. and J. Mueller. 1987. Principles of surface water quality modeling and control. Harper Collins Publishers.
- USEPA. 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. Assessment and Watershed Protection Division, Washington, DC.
- USEPA. 1998. Draft Final TMDL Federal Advisory Committee Report. U.S. Environmental Protection Agency, Federal Advisory Committee (FACA). Draft final TMDL Federal Advisory Committee Report. 4/28/98.
- USEPA. 2000. Revisions to the Water Quality Planning and Management Regulation and Revisions to the National Pollutant Discharge Elimination System Program in

Support of Revisions to the Water Quality Planning and management Regulation; Final Rule. Fed. Reg. 65:43586-43670 (July 13, 2000).

USEPA. 2002. Wayland, Robert, H. and James A. Hanlon. "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs". Memo to Water Division Directors Regions 1-10. United States Environmental Protection Agency, Washington, D.C. 22 November 2002.

VADEQ. 2005. Total Maximum Daily Load Report for Shellfish Areas Listed Due to Bacterial Contamination.

**Appendix A: NCDEH Monitoring Data Summary**

**Table A.1 – Bear Creek NCDEH Monitoring Data Summary, September 2005 - August 2010**

Station	# Samples	Type of Sampling	Fecal Coliform Bacteria Concentration (MPN/100 ml)		
			Median	Geometric Mean	90th Percentile
3	31	Random	7.8	9.6	75
5	31	Random	6.8	8.0	36
5A	31	Random	4.5	6.0	31
5B	31	Random	4.5	6.2	25
6	31	Random	2.0	5.3	29
	78	Conditional	11	9.9	55
6A	31	Random	4.5	4.7	15
7	31	Random	4	4.8	20
	79	Conditional	11	11.4	56
8	31	Random	2.0	3.8	14
	86	Conditional	7.8	10.3	59
8A	31	Random	4	4.0	13
	77	Conditional	11	10.2	56
9	31	Random	2	3.5	10
	61	Conditional	6.8	8.2	54
10	31	Random	1.8	2.5	5
11	31	Random	2.0	3.6	10
12	31	Random	2	3.6	16
13	31	Random	1.8	2.9	8
14	31	Random	4	3.6	10
15	31	Random	2.0	4.1	17
16	31	Random	2	3.8	20
17	31	Random	2.0	3.1	9

Bear Creek Fecal Coliform TMDL

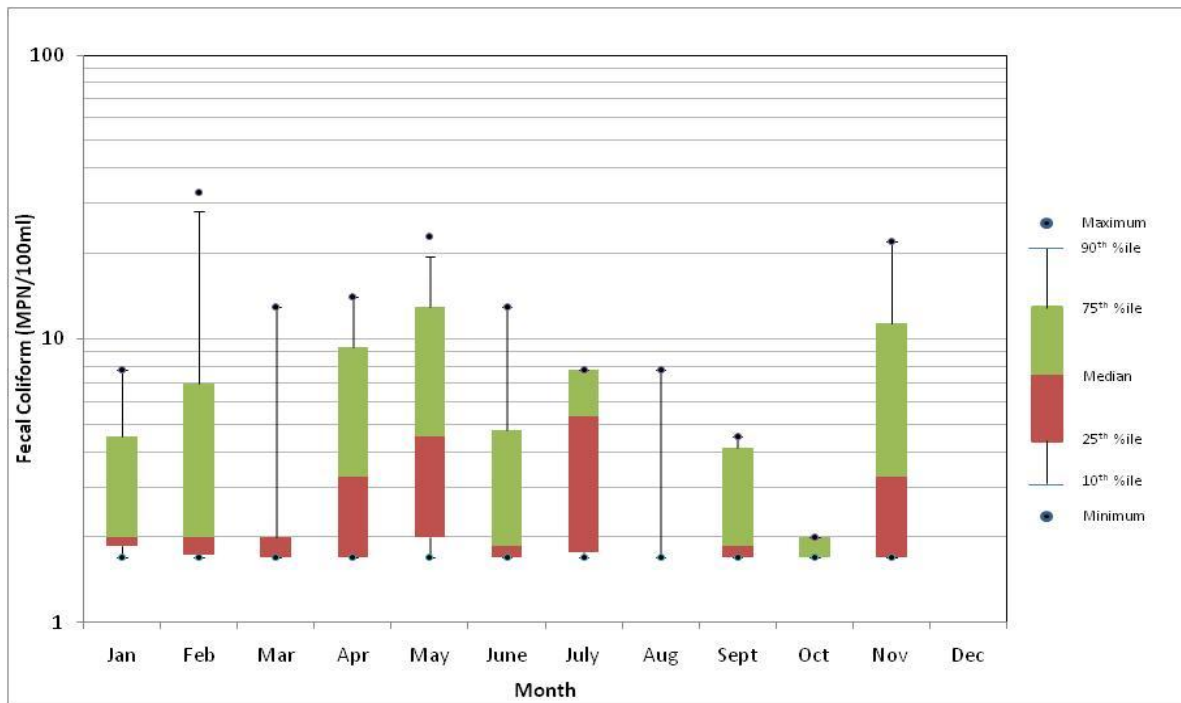


Figure A.1 - Seasonal distribution of fecal coliform concentrations (random monitoring data only) in Segment m0 (log scale)

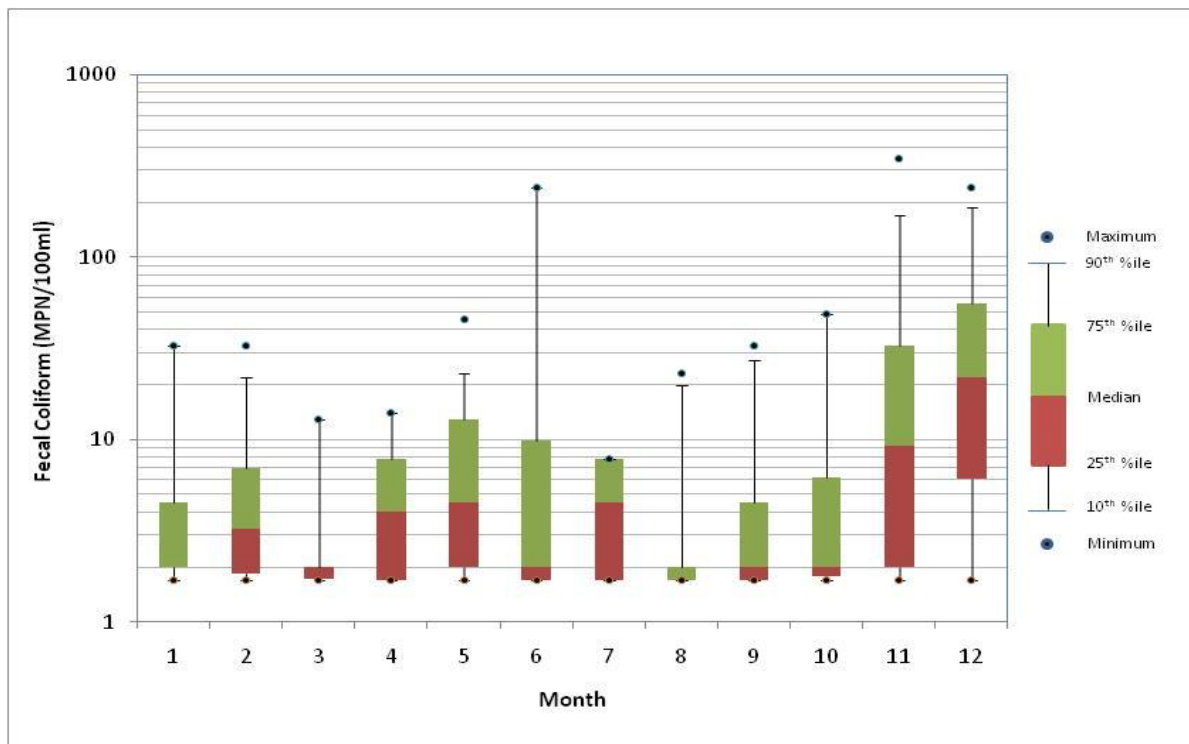


Figure A.2 - Seasonal distribution of fecal coliform concentrations (random and conditional monitoring data combined) in Segment m0 (log scale)

Bear Creek Fecal Coliform TMDL

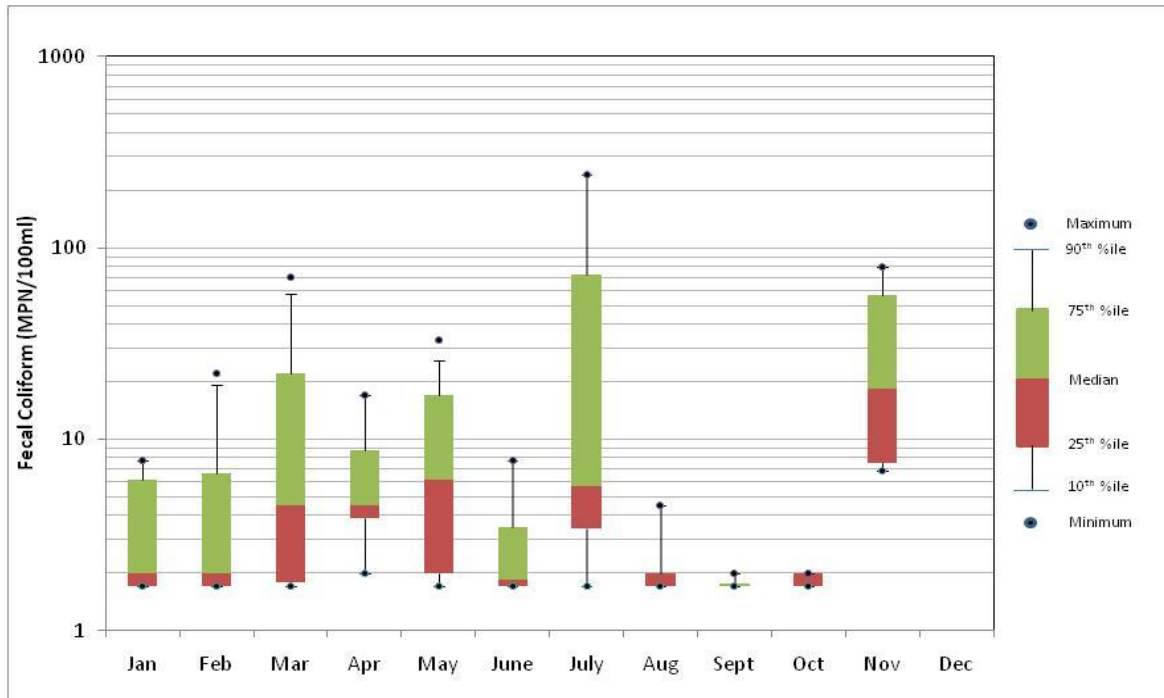


Figure A.3 - Seasonal distribution of fecal coliform concentrations (random monitoring data only) in Segment m1 (log scale)

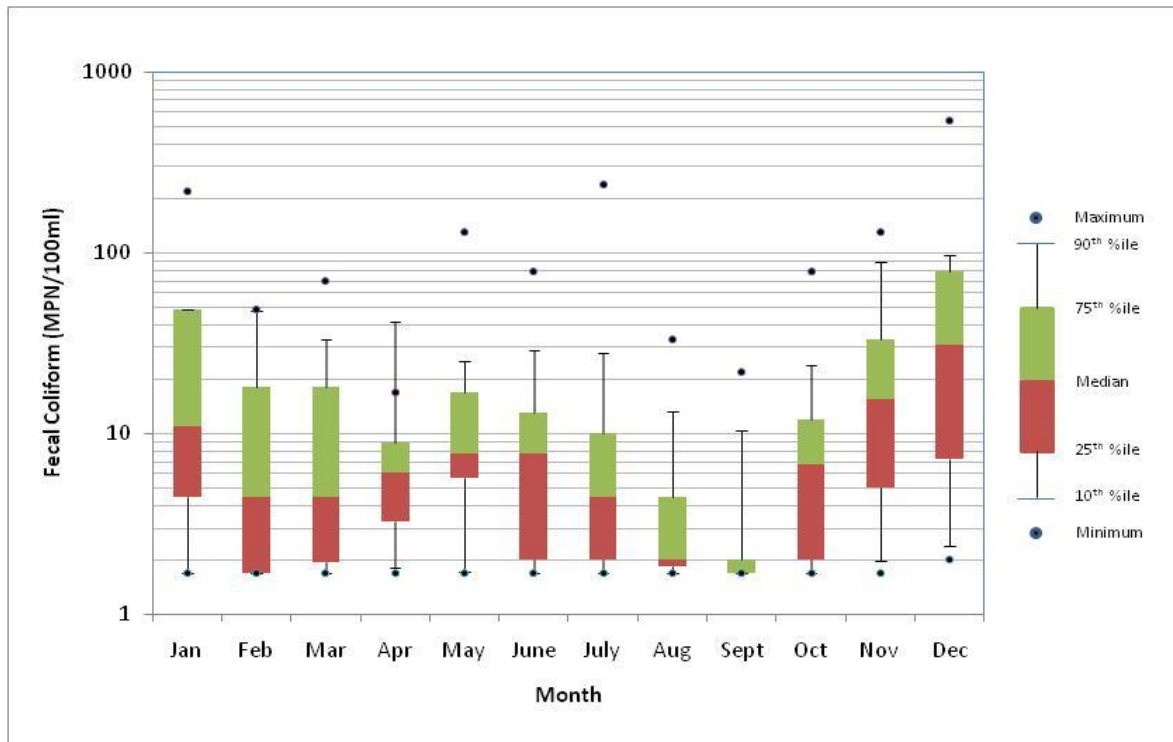


Figure A.4 - Seasonal distribution of fecal coliform concentrations (random and conditional monitoring data combined) in Segment m1 (log scale)

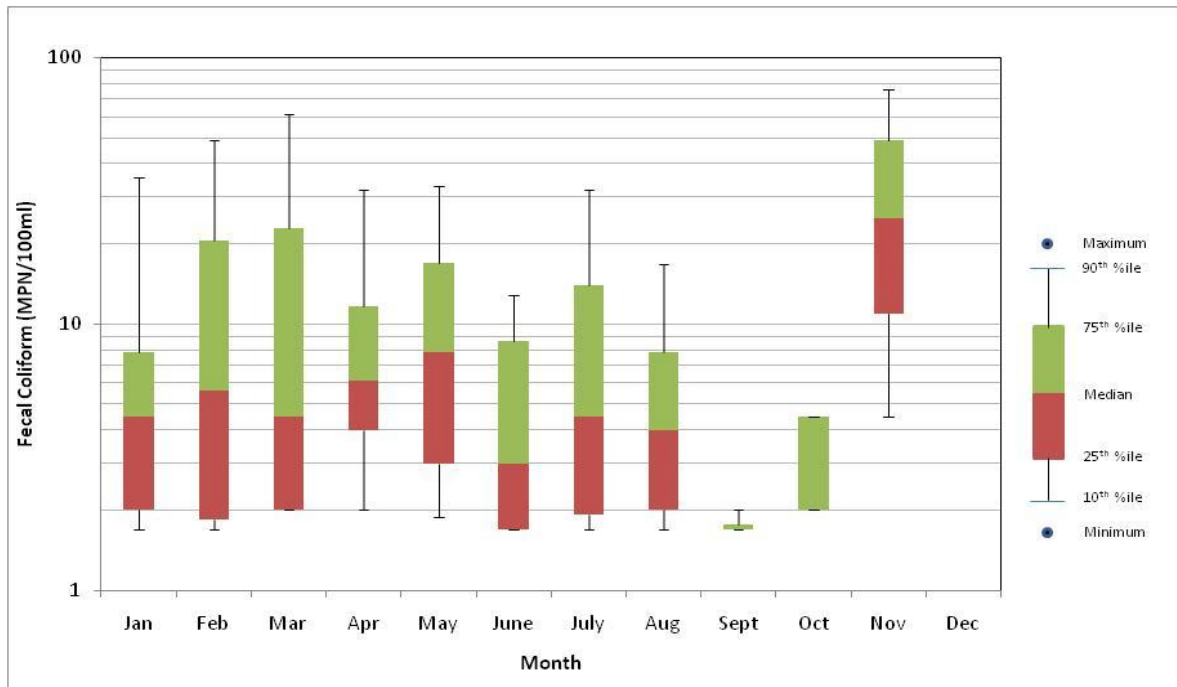


Figure A.5 - Seasonal distribution of fecal coliform concentrations (random monitoring data only) in Segment m2 (log scale)

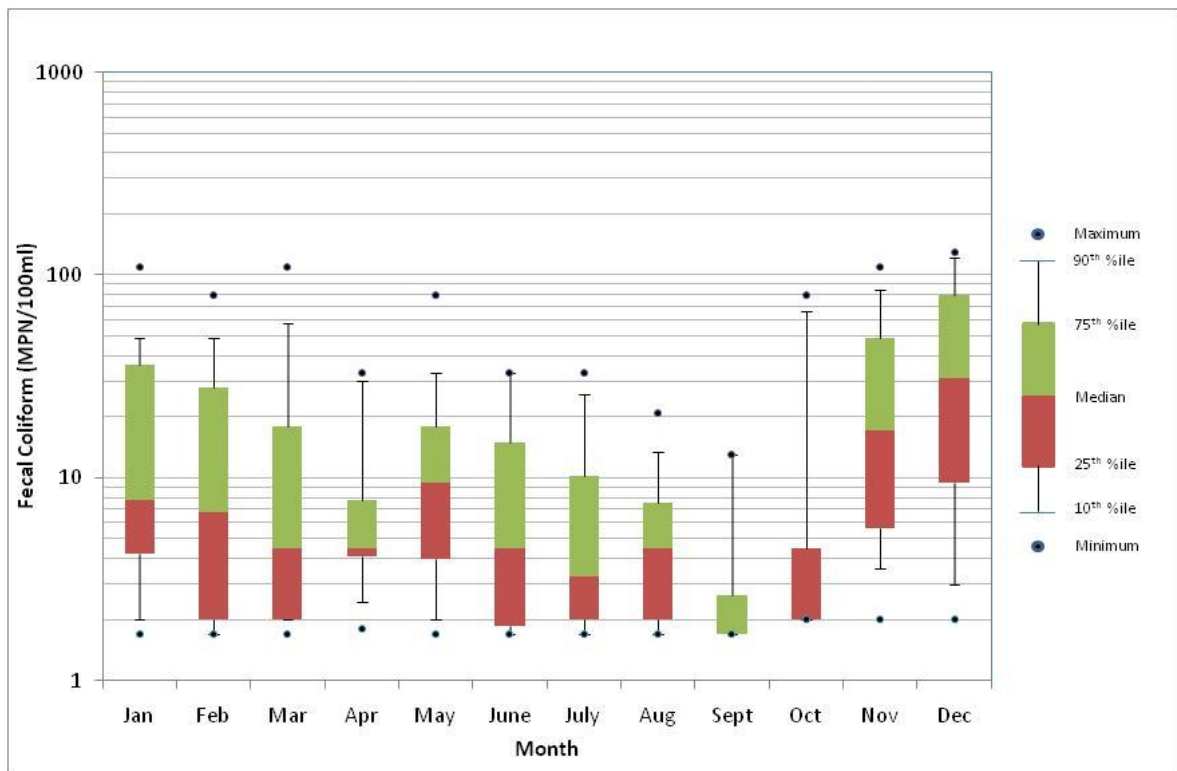


Figure A.6 - Seasonal distribution of fecal coliform concentrations (random and conditional monitoring data combined) in Segment m2 (log scale)

# Bear Creek Fecal Coliform TMDL

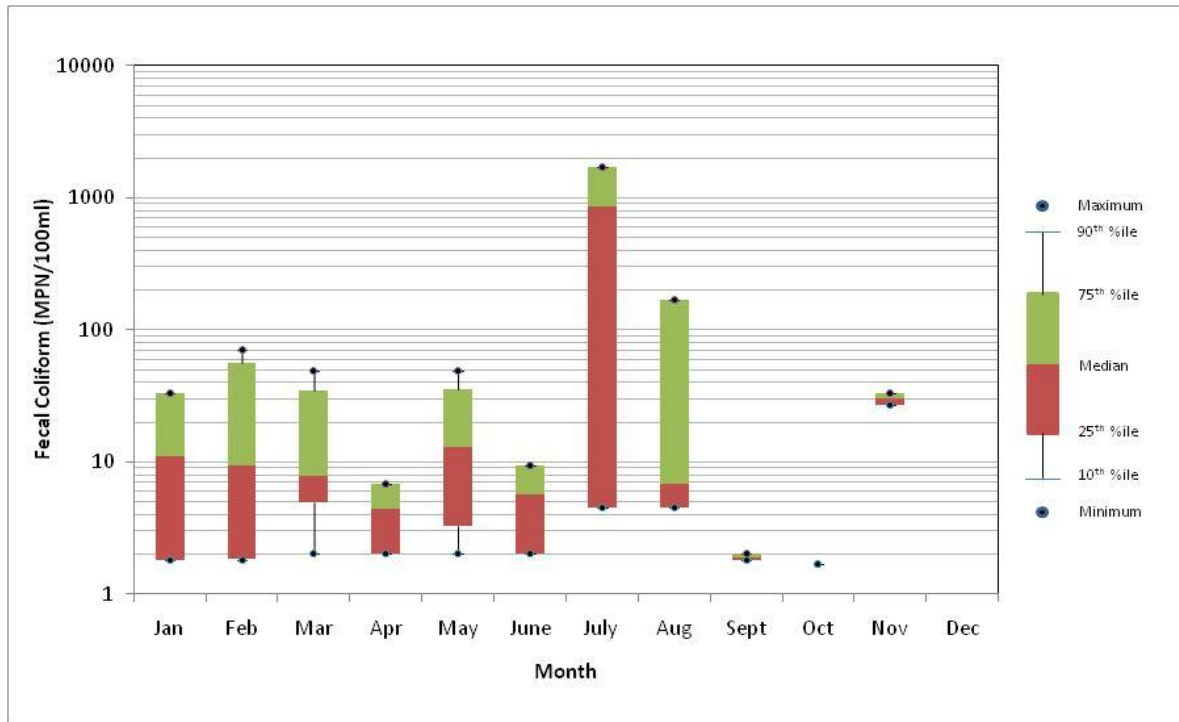


Figure A.7 - Seasonal distribution of fecal coliform concentrations (random monitoring data) in Segment m3 (log scale)



**Appendix B: Bear Creek Steady-State Tidal Prism Model Inputs and Parameters**

Table B-1. Model Parameters

Parameters	TR	$\beta$	k	Cf
<b>Description</b>	Mean tidal range	Exchange Ratio	Decay Rate	Unit Conversion Factor
<b>Unit</b>	m	N/A	Per Tidal Cycle (T <sup>-1</sup> )	T/day *100ml/m <sup>3</sup>
<b>Value</b>	0.95	0.5	0.36	19323.67

Table B-2. Model Inputs for 90<sup>th</sup> percentile Existing Loads Calculation

Parameters	V	C	C <sub>0</sub>	Q <sub>0</sub>	Q <sub>b</sub>	Q <sub>f</sub>
<b>Brief Description</b>	Mean Volume	Mean FC Conc. of the segment	FC Conc. enters the segment	Water Quantity enters the segment	Water Quantity leaves the segment	Fresh Water Input
<b>Unit</b>	m <sup>3</sup>	MPN/100ml	MPN/100ml	m <sup>3</sup> T <sup>-1</sup>	m <sup>3</sup> T <sup>-1</sup>	m <sup>3</sup> T <sup>-1</sup>
<b>M1</b>	941519	18	8 (from BC) 24(from m2)	590902 365132	957733	1700
<b>M2</b>	519969	24	18(from m1) 75(from m3)	350618 182292	534483	1573
<b>M3</b>	347615	75	24(from m2)	169351	182292	12941

Table B-3. Model Inputs for 90<sup>th</sup> percentile TMDL Loads Calculation

Parameters	V	C	C <sub>0</sub>	Q <sub>0</sub>	Q <sub>b</sub>	Q <sub>f</sub>
<b>Brief Description</b>	Mean Volume	Mean FC Conc. of the segment	FC Conc. enters the segment	Water Quantity enters the segment	Water Quantity leaves the segment	Fresh Water Input
<b>Unit</b>	m <sup>3</sup>	MPN/100ml	MPN/100ml	m <sup>3</sup> T <sup>-1</sup>	m <sup>3</sup> T <sup>-1</sup>	m <sup>3</sup> T <sup>-1</sup>
<b>M1</b>	941519	43	8 (from BC) 43(from m2)	590902 365132	957733	1700
<b>M2</b>	519969	43	43(from m1) 43(from m3)	350618 182292	534483	1573
<b>M3</b>	347615	43	43(from m2)	169351	182292	12941

**Appendix C: Public Announcement**

-----Original Message-----

From: wrri-news-owner@lists.ncsu.edu [mailto:wrri-news-owner@lists.ncsu.edu]  
Sent: Tuesday, August 02, 2011 4:22 AM  
To: wrri-news@lists.ncsu.edu  
Subject: [wrri-news] Digest (1 messages)

The WRRRI Daily Digest  
Volume 1 : Issue 787 : "text" Format

Messages in this Issue:

201108/2 : DRAFT Total Maximum Daily Load for fecal coliform for Bear Creek, White Oak River Basin, North Carolina  
"Behm, Pamela" <pamela.behm@ncdenr.gov>

-----  
Date: Mon, 1 Aug 2011 14:43:10 +0000  
From: "Behm, Pamela" <pamela.behm@ncdenr.gov>  
To: "wrri-news@lists.ncsu.edu" <wrri-news@lists.ncsu.edu>  
Subject: DRAFT Total Maximum Daily Load for fecal coliform for Bear Creek, White Oak River Basin, North Carolina  
Message-ID: <02CA0C092108494BA1EF9743399BEEE8BD0A@NCWITMXMBX33.ad.ncmail>

Now Available for Public Comment

DRAFT Total Maximum Daily Load for fecal coliform for Bear Creek, White Oak River Basin, North Carolina

8/1/11

North Carolina Department of Environment and Natural Resources, Division of Water Quality

This draft TMDL report was prepared as a requirement of the Federal Water Pollution Control Act, Section 303(d). Interested parties are invited to comment on the draft TMDL report by September 1, 2011. Comments concerning the report should be directed to Pam Behm at [pamela.behm@ncdenr.gov](mailto:pamela.behm@ncdenr.gov) or write to:

Pam Behm  
NC Division of Water Quality  
Planning Section  
1617 Mail Service Center  
Raleigh, NC 27699

The draft TMDL can be downloaded from the following website:  
<http://portal.ncdenr.org/web/wq/ps/mtu/tmdl/tmdls#Draft>

\*\*\*\*\*

Pam Behm  
NC DWQ Modeling and TMDL Unit  
1617 Mail Service Center  
Raleigh, NC 27699

Bear Creek Fecal Coliform TMDL

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Email: pamela.behm@ncdenr.gov  
Phone: 919-807-6419  
Fax: 919-807-6497

E-mail correspondence to and from this address may be subject to the North Carolina Public Records Law and may be disclosed to third parties.

[Attachment of type text/html removed.]

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End of [wrri-news] Digest (1 messages)  
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## Appendix D: Public Comments Responsiveness Summary

The public comment period lasted from August 1 - September 1, 2011. Comments were received from NCDOT. A summary of their comments and NCDWQ's response is provided below.

1. The modeling approach used to calculate the TMDLs is referred to on p. 11 as the "spreadsheet-based steady-state tidal prism model." Is this model maintained and distributed by EPA?

*NCDWQ Response: The tidal prism model is one of the models that have been used to estimate pollutant loading in tidal areas and is one of the tools recommended by USEPA. The original model is maintained by the Virginia Institute of Marine Sciences (VIMS). As stated in the TMDL report, the simplified spreadsheet based tidal prism model used for this TMDL was also used by States of Maryland and Virginia to develop bacteria TMDLs for shellfish growing areas.*

2. What is the version number and release date of the model used for these TMDLs?

*NCDWQ Response: There is no version number associated with the model. The simplified spreadsheet based tidal prism model used for the Bear Creek TMDL is the Bear Creek Version.*

3. Is the model in the public domain? How can the public obtain a copy of the model?

*NCDWQ Response: The simplified spreadsheet based tidal prism model used for the Bear Creek TMDL is implemented in Excel and can be obtained from NCDWQ Modeling and TMDL Unit.*

4. Is a user's manual/model documentation available for download on the internet? If so, please provide the URL. If not, can DWQ provide model documentation?

*NCDWQ Response: There is no separate manual for the model, but all the necessary guidelines to develop the model and the model description are included above in Section 3.2. The information included in this section is sufficient to setup the model. The spreadsheet is set-up to solve the equation given in Section 3.2 and there is no embedded code. A detailed description of the tidal prism model is published by VIMS researchers (Kuo et al., 1994).*

5. For each model segment (m1, m2, and m3) please provide all the parameter values that were used to calculate the existing load and the TMDLs. When estimates of the parameters were used as opposed to measured values, please explain the basis for why the estimate is believed to be reasonable and appropriate.

*NCDWQ Response: The TMDL report has been revised to include this information in Appendix B. The derivation of model inputs is fully described in Section 3.2.*

6. The existing fecal coliform loads for segments m1 and m2 are not reported. Please report the existing loads for these two segments.

*NCDWQ Response: As stated above in Section 3.2.3, these loads were estimated to be lower than the TMDL, thus there is no reduction required from sources draining into these segments.*

7. Assessment Unit (AU) 19-41-11b2 is listed as being within both segments m1 and m2 and thus is subject to 2 different TMDLs. Please clarify which TMDL applies to this AU. Also, the TMDL for AU 19-41-11b2 calculated based on the 90<sup>th</sup> percentile standard category is higher than the TMDL for this AU calculated based on the median standard category. Please clarify why DWQ believes the higher allowable loading is protective of water quality standards.

*NCDWQ Response: The model segmentation is not based on assessment units. For this reason, the part of assessment unit contained within m1 would have a TMDL allocation of m1 and similarly the other part of assessment unit contained in m2 would have a TMDL allocation of m2. However, neither segment m1 nor m2 has an assigned percent reduction. Had there been a required percent reduction for these segments, the TMDL would be based on the water quality standard (either median or 90<sup>th</sup> percentile) requiring the highest percent reduction, not necessarily the lowest allowable loading. By definition, the 90<sup>th</sup> percentile calculation of allowable load will always be higher than the median calculation.*

*A sentence has been added to the footnote of Table 3.7 in the report to reiterate that the FC water quality standard will be met in segments m1 and m2 once the TMDL is implemented and loading is reduced from the watershed of segment m3.*

8. Please describe the time period over which the NCDOT's load should be averaged and how this time period was derived.

*NCDWQ Response: The time period used to derive the TMDL and associated NCDOT's WLA was September 2005-August 2010. NCDEH will continue to monitor water quality in Bear Creek using the systematic random sampling strategy as outlined in the National Shellfish Sanitation Program's Model Ordinance and guidance document. This data will be used to evaluate progress towards the goal of reaching water quality standards.*