Total Maximum Daily Loads for Fecal Coliform for Embayments in Southeast White Oak River, North Carolina

[Waterbody ID 20-(18)c4, Waterbody ID 20-30, Waterbody ID 20-31]

Final Report: March 2009
EPA Approval Date: April 10, 2009

White Oak River Basin

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List of Abbreviations

BMP	Best Management Practice
CAFO	Confined Animal Feeding Operations
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
CWA	Clean Water Act
CWP	Center for Watershed Protection
DEH	Division of Environmental Health
DEM	Digital Elevation Model
EPA	Environmental Protection Agency
FA	Future Allocation
GIS	Geographic Information System
HSPF	Hydrological Simulation Program FORTRAN
HUC	Hydrologic Unit Code
LA	Load Allocation
LSPC	Loading Simulation Program in C^{++}
MF	MF is an abbreviation for the membrane filter procedure for bacteriological analysis.
ml	Milliliter(s)
MLW	Mean Low Water
MOS	Margin of Safety
MPN	Most Probable Number
MRLC	Multi-Resolution Land Cover
NOAA	National Ocean and Atmospheric Administration
NCAC	NC Administration Code
NCDWQ	North Carolina Department of the Environment
NCDENR	North Carolina Department of Environment and Natural Resources
NSSP	National Shellfish Sanitation Program
SA	Class SA water body: suitable for commercial shellfishing and all other tidal saltwater use
SSO	Sanitary Sewer Overflows
T^{-1}	Per Tidal Cycle
TMDL	Total Maximum Daily Load
TP	Tidal Prism model
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

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SUMMARY SHEET

Total Maximum Daily Load (TMDL)

1. 303(d) Listed Waterbody Information

State: North Carolina

County: Carteret

Major River Basin: White Oak River Basin

Watershed: Boathouse Creek, Dubling Creek, and White Oak River Embayment (HUC 03020106)

Impaired Waterbody (2002 303(d) List):

Waterbody Name – (ID)	Description	Water Quality Classification	Acres
Boathouse Creek - (20-31)	From source to White Oak River	SA HQW	15.8
Dubling Creek - (20-30)	From source to White Oak River	SA HQW	53.3
White Oak River – (20-(18)c4)	From DEH Conditionally Approved Closed Line to DEH Conditionally Approved Open Line	SA HQW	26.0*

*Only 15 acres of this is included in this TMDL document. The additional acres were added subsequent to this project.

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 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."

Note: The bacteria laboratory analysis used for all sampling in this area is based on most probably number (MPN) method instead of the membrane filter (MF) method. The National Shellfish Sanitation Program standards are a fecal coliform median or geometric mean of 14 MPN per 100ml and an estimated 90th percentile not to exceed 43 MPN per 100 ml for a five tube decimal dilution test.

2. TMDL Development

Development Tools (Analysis/Modeling):

The linked watershed and Tidal Prism modeling approach was used to estimate current fecal coliform load from watersheds and to simulate fecal coliform concentrations in the Bay. The long-term model results were used to establish allowable loads for each the restricted shellfish harvesting areas. Since real-time model simulation is used to establish TMDLs, it accounts for the seasonal variability and critical conditions, which thereby represents the hydrology, hydrodynamics, and water quality condition of each restricted shellfish harvesting area.

Critical Conditions:

The 90th percentile concentration of 43 MPN/100 ml is the concentration exceeded only 10% of the time. Since the model simulation period spans ten years (1998-2007), the critical condition is implicitly included in the value of the 90th percentile of model results. Given the length of the monitoring record and model simulation and the standard's recognition of unusual and infrequent events, the 90th percentile is used instead of the absolute maximum.

Seasonal Variation:

Seasonal variation in hydrology, climatic conditions, and watershed activities are represented through the use of continuous simulation. Observations and model simulations show that high fecal coliform concentrations occur throughout the year in each of the TMDL waterbodies. The primary driver of high concentrations is rainfall runoff and that occurs during all seasons, though it appears to be higher in the cooler months between October and April. Given the length of the model simulation, the seasonal variability is directly included in the model simulation.

3. TMDL Allocation Summary

Model results show that 90th percentile component of the standard, rather than the median component, requires the highest reduction. The allocation is established based on 90th percentile load.

Waterbody	Pollutant	Existing	WLA	LA	MOS[1]	Reduction Required[2]	TMDL
Boathouse Creek - (20-31)	Fecal coliform (counts/day)	6.17×10^{11}	9.91×10^{9}	1.75×10^{11}	2.41×10^{10}	66%	2.09×10^{11}
Dubling Creek - (20-30)	Fecal coliform (counts/day)	1.77×10^{11}	0.00	1.53×10^{11}	5.00×10^{9}	11%	1.58×10^{11}
White Oak River – (20-(18)c4)	Fecal coliform (counts/day)	2.88×10^{10}	6.60×10^{8}	1.24×10^{10}	1.44×10^{9}	50%	1.45×10^{10}

Notes: WLA = wasteload allocation, LA = load allocation, MOS = margin of safety

[1] Margin of safety (MOS) equivalent 11.6 percent of the target concentration in all embayments. Used a target of 38 instead of 43. MOS load in table represents the difference between total loading using those targets.

[2] The reduction required in this table includes the margin of safety. The actual reduction required should not count the margin of safety so the overall reductions required would be 70%, 14%, and 55%, respectively.

4. Contributing Municipalities TMDL Allocation Summary : N/A

5. Contributing NPDES Facilities TMDL Allocation Summary: NCDOT stormwater

6. Public Notice Information

Summary:	
Did notification contain specific mention of TMDL Proposal?	
Were comments received from the public?	
Was a responsiveness summary prepared?	

7. Public Notice Date:

8. Submittal Date:

9. Establishment Date:

10. EPA Lead on TMDL (EPA or blank):

11. DOT a Significant Contribution (Yes or Blank): Yes

12. Endangered Species (yes or blank):

13. MS4s Contributions to Impairment (Yes or Blank):

14. TMDL Considers Point Source, Nonpoint Source, or both: Nonpoint Source

EXECUTIVE SUMMARY

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 identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

The White Oak River embayments are located in the White Oak River Basin (NC Subbasin 30501 – HUC 03020106020030) in Carteret County, east of Swansboro along the North Carolina coast in the White Oak River Basin. The embayments are located within the shellfish area designated D-3 by the North Carolina Division of Environmental Health (NCDEH). The embayments of Boathouse Creek, Dubling Creek, and area south of Boathouse Creek (will be called Hills Bay embayment) are currently rated as Conditionally Approved Closed for shellfish harvesting according to Shellfish Sanitation (DEHSS).

The waterbody just northeast of the NC 24 bridge contains DEHSS station 20. According to the 2006 Sanitary Survey, this is one of the few areas that showed improvement in the D-3 growing area. The 90th percentile for this area was 27 colonies/100 ml as of March 2008. It last exceeded the 90th percentile standard in September 2003. However, the area just south of station 20 is (remains) classified as Prohibited (Closed) for shellfish harvesting. A TMDL has not been developed for this area because the hydrodynamics are not conducive to using the modeling approach used for the other TMDLs. This area will be addressed, however, in the included implementation strategies.

The Southeast White Oak fecal coliform TMDLs have been prioritized for TMDL development by the North Carolina Division of Water Quality (NCDWQ). This document addresses the fecal coliform impairment of these restricted shellfish harvesting areas within the White Oak River as listed in the following table.

305b_ID	Name	Description
20-31	Boathouse Creek	From source to White Oak River
20-30	Dubling Creek	From source to White Oak River
20-(18)c4	White Oak River	From DEH Conditionally Approved Closed Line to DEH Conditionally Approved Open Line (Hills Bay embayment)

This document proposes to establish TMDLs of fecal coliform for Boathouse Creek, Dubling Creek, and Hills Bay embayment. These restricted shellfish harvesting areas are impaired by levels of bacteria exceeding North Carolina's water quality standards for fecal coliform, which has resulted in closure of the waterbodies to shellfish harvesting.

Fecal coliform is an indicator organism used in water quality monitoring in shellfish waters to indicate sources of waste from warm-blooded animals. When the water quality standard for fecal coliform in shellfish waters is exceeded, waters are closed for shellfish harvesting to protect human health due to the potential risk from consuming raw molluscan shellfish from contaminated waters. The water quality goal of this TMDL is to reduce high fecal coliform concentrations to levels whereby the designated uses for these creeks will be met.

A variety of data at the watershed scale were used to identify potential fecal coliform contributions. The potential fecal coliform contributions were estimated using project monitoring data, landowner surveys, and Geographic Information Systems (GIS) data coverage including land use, property, and soils. The North Carolina Department of Transportation (NCDOT) is the lone NPDES permitted stormwater point source in the shellfish areas addressed in this report. NC Highway 24 is the largest road in the area and has a closed stormwater conveyance system. Other NCDOT roads in the area primary rely on open channels for stormwater drainage. Piped drainage is expected to host animals, such as raccoons, which are prime bacteria sources. Taken collectively, these data indicate the major contributions of fecal coliform load are nonpoint source runoff, including bacteria from wildlife and pets, and septic systems sited on marginal soils.

The linked watershed and Tidal Prism modeling approach was used to estimate current fecal coliform load from watersheds and to simulate fecal coliform concentrations in the embayments. This approach has been used for TMDLs in Maryland, Virginia, and Jarrett Bay in North Carolina. The long-term model results were used to establish allowable loads for each restricted shellfish harvesting area. Since the real-time model simulation is used to establish TMDLs, it accounts for the seasonal variability and critical conditions, which thereby represents the hydrology, hydrodynamics, and water quality condition of each selected restricted shellfish harvesting area. The load is then allocated to sources (land use) by determining the proportional contribution of each source based on animal/source density per land use acre times the fecal coliform production.

One of the critical tasks for these TMDLs is to determine current loads from all potential sources in the watershed. The procedure needs to account for temporal variability caused by the seasonal variation and the wet-dry hydrological conditions. Long-term model simulation was conducted to simulate fecal coliform concentration in the waterbodies. The long-term daily mean load is estimated for each watershed based on the watershed model results. These results were then used to estimate the current load condition. The allowable loads for each restricted shellfish harvesting area were then computed using both the median water quality standard for shellfish harvesting of 14 Most Probable Number (MPN)/100ml and the 90^{th} percentile standard of 43 MPN/100ml. An explicit Margin of Safety (MOS) of 12 percent was incorporated into the analysis to account for uncertainty by lowering the 90^{th} percentile target from 43 to 38. The TMDLs developed for the restricted shellfish harvesting areas for fecal coliform load are as follows:

Dubling Creek:
The fecal coliform TMDL = 1.58×10^{11} counts per day

Boathouse Creek:
The fecal coliform TMDL = 2.09×10^{11} counts per day

Embayment on Hills Bay:
The fecal coliform TMDL = 1.45×10^{10} counts per day

The goal of load allocation is to determine the estimated loads for each drainage area while ensuring that the water quality standard can be attained. For restricted shellfish harvesting areas, the 90th percentile criterion requires the greatest reduction. Therefore, the load reduction scenario is developed based on the 90th percentile water quality standard. The load reductions needed in the watershed of each restricted shellfish harvesting area to meet the shellfish criteria and the load allocations required to meet the TMDLs with a margin of safety are 14%, 70%, and 55%, respectively for Dubling Creek, Boathouse Creek, and the Hills Bay embayment. These are the loading reductions required from all sources taken collectively. More specific load reduction responsibilities are included in the TMDL load allocation (Sections 3.6 and 3.7).

Once the EPA has approved a TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. Implementation plans will be included in the appendices of the version of these TMDLs that goes to public notice. The North Carolina Department of Environment and Natural Resources (NCDENR) intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality, with consideration given to ease of implementation and cost.

1.0 INTRODUCTION

Section 303(d)(1)(C) 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 (WQLS) 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 White Oak River embayments are located in the White Oak River Basin (NC Subbasin 30501 – HUC 03020106020030) in Carteret County, east of Swansboro along the North Carolina coast in the White Oak River Basin. The embayments are located within the shellfish area designated D-3 by the North Carolina Division of Environmental Health (NCDEH). The embayments of Boathouse Creek, Dubling Creek, and Hills Bay are currently rated as Conditionally Approved Closed for shellfish harvesting according to Division of Health Shellfish Sanitation (DEHSS). Conditionally Approved Closed waters are closed except after extended dry periods when the areas may be opened for shellfish harvesting. Rainfall of 0.5 inches or greater within a 24-hour period or 0.75 inches within a 48-hour period immediately closes the waters to shellfish harvesting.

The waterbody just southeast of the NC 24 bridge contains DEHSS station 20. According to the 2006 Sanitary Survey, this is one of the few areas that showed improvement in the D-3 growing area. The 90th percentile for this area was 27 as of March 2008. It last exceeded the 90th percentile standard in September 2003. However, the area just south of station 20 is (remains) classified as Prohibited (Closed) for shellfish harvesting. A TMDL has not been developed for this area because the hydrodynamics are not conducive to the modeling approach used for the other TMDLs in this document. This area will be addressed, however, in the implementation strategies included in the Appendices.

When shellfish harvesting is the designated use, the problem parameter that might impair this use is fecal coliform bacteria. 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 (i.e., NPDES stormwater conveyances) and nonpoint sources.

1.1 TMDL Components

The 303(d) process requires that a TMDL be developed for each of the waters appearing in Category 5 of the Surface Water Integrated list. 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). A 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 (i.e., 30 samples per station). The averaging period used for development of these TMDLs requires at least 30 samples and uses the most recent 2.5-year window of data, assuming one sample per month. Generally, the primary components of a TMDL, as identified by EPA (1991, 1999) 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 (2000a), 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 and the Water Quality Planning and Management regulation (USEPA, 2000a) require 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. In addition, the TMDL may include a future allocation (FA) when necessary. Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS} + (\text{FA, where applicable})$$

These TMDLs do not include future allocations.

1.2 Documentation of Impairment

The North Carolina Division of Water Quality (DWQ) Surface Water and Wetlands classification for these restricted shellfish harvesting areas is Class SA Waters – Shellfish Harvesting Waters (15A NCAC 02B.0221 Tidal Salt Water Quality Standards for Class SA Waters). A Class SA water is a waterbody that is suitable for commercial shellfishing and all other tidal saltwater use (NCAD 2003).

Three segments of the Southeast White Oak basin have been included on the 2002 North Carolina Integrated Report. These restricted shellfish harvesting areas are identified as areas in this basin 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 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."** The bacteria laboratory analysis used for all sampling in this area is based on most probably number (MPN) method instead of the membrane filter (MF) method. The National Shellfish Sanitation Program standards are a fecal coliform median or geometric mean of 14 MPN per 100ml and an estimated 90^{th} percentile not to exceed 43 MPN per 100 ml for a five tube decimal dilution test.

For this report, the monitoring data-averaging period was based on monitoring procedures for classifying SA water, i.e. fecal coliform concentration cannot exceed a median or a geometric mean of an MPN of 14 per 100 ml and the 90^{th} percentile of an MPN of 43 per 100 ml, for six samples per year and 30 samples per station. The averaging period for the monitoring data required at least 30 samples. The water quality impairment was assessed using the geometric mean, median, and 90^{th} percentile concentrations.

1.3 Watershed Description

The Southeast White Oak River embayments are located in Carteret County, east of Swansboro along the North Carolina coast. Figure 1.3.1 shows the location of the embayments (NC Subbasin 30501 – HUC 03020106020030). The mean depth of all of the embayments is about 0.6 m (mean low water). The soils across the three watersheds are also similar. The USGS sediment inventory data shows that the dominant soil type in the wetland and riparian areas is hydrologic class D (U. S. Department of Agriculture (USDA), 1995), which is consistent with the location information. In most areas, the low elevations in the area along with a high water table do not provide adequate conditions for proper functioning of ground absorbing septic systems, especially in winter. In the upland area, the dominant soil is Wando, which is sandy and hydrologic class A. This soil is also considered to have 'very limited' use for septic tank absorption fields due to increased seepage and low filtering capacity.

The length of the Dubling Creek embayment is approximately 650 meters and the width is about 130 meters near the head and 280 meters near the mouth. The drainage area is about 246 acres (1.0 km^2). The land use is primarily wetland in the low-lying areas surrounding the embayments and forest in the uplands.

The length of the Boathouse Creek embayment is approximately 650 meters and the width is about 90 meters near the head and 180 meters near the mouth. The drainage area is about 546 acres (2.2 km^2). The land around the embayment and riparian areas is wetland, while the upland portion of the watershed is a mixture of commercial, residential, athletic park, and forest.

The length of the Hills Bay embayment is approximately 190 meters and the width is about 60 meters near the head and 300 meters near the mouth. The mean depth of the embayments is about 0.6 m (mean low water). The drainage area is about 152 acres (0.6 km^2). Wetlands surround the embayment, while the upland is a mix of herbaceous grassland, forest, residences, and commercial use around Highway 24.

The dominant tide in this region is the lunar semi-diurnal (M_2) tide with an assumed mean tidal range of 1.6 ft (based on the NOAA station at Bogue Inlet) with a tidal period of 12.42 hours (NOAA, 2004).

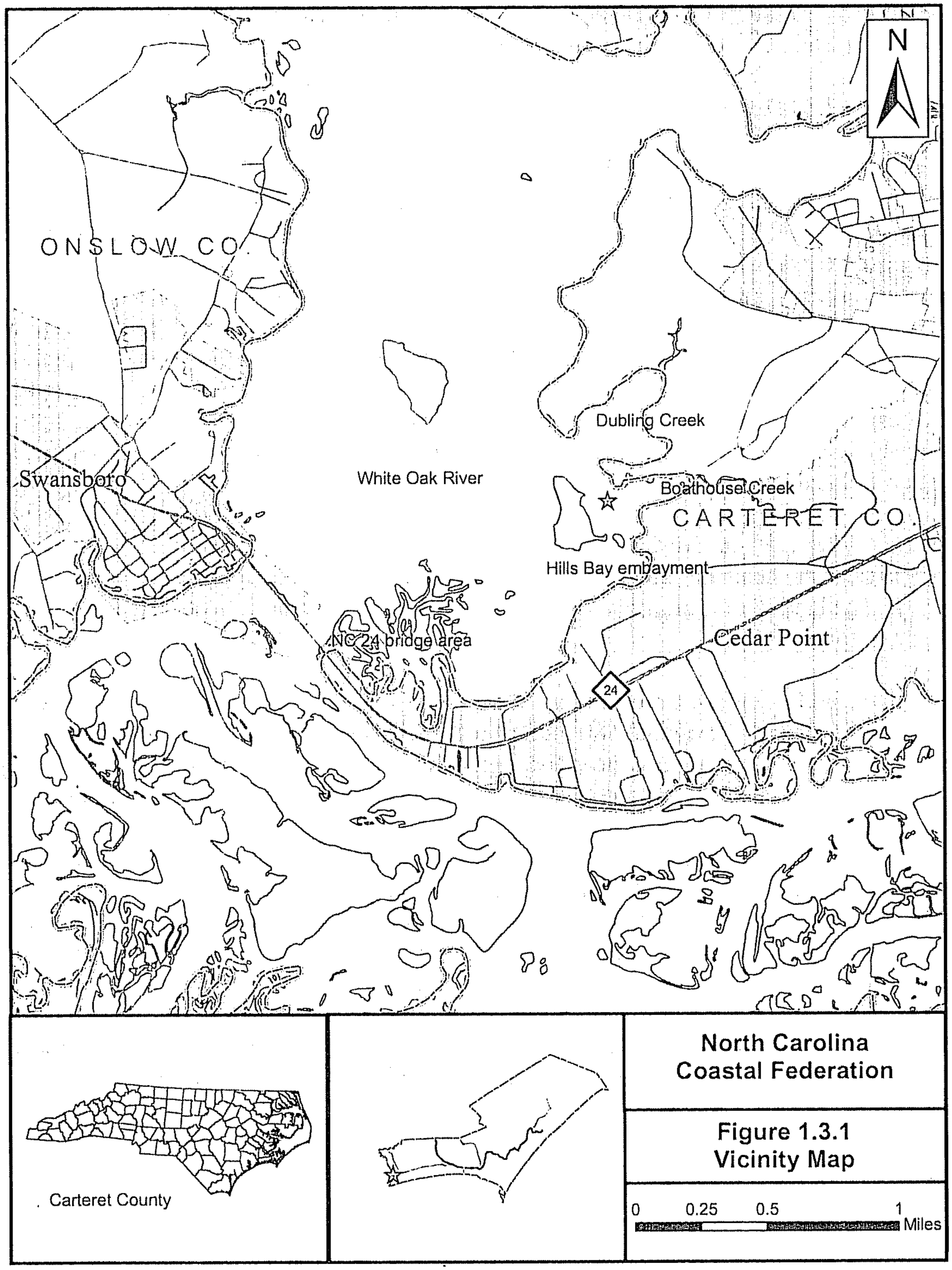


Figure 1.3.1: Location Map of the Southeast White Oak River Embayments

1.3.1 Land Use/Land Cover

A land use file unique to this project was created based on 2004 aerial orthophotography. For modeling purposes, the land use data were grouped into 5 categories: wetland, pasture/herbaceous, forest, urban, and NCDOT. No livestock are present on the pasture land and there is no cropland in the project area. The land use distribution is shown in Figure 1.3.2 and land use statistics are listed in Tables 1.3.1 through 1.3.3. In Dubling Creek, wetland and forest are the dominant land uses in the watershed. Boathouse Creek is more evenly distributed between urban, forest, wetland, and pasture/herbaceous cover. The Hills Bay embayment watershed has more pasture and forest but also has residential areas, as well as commercial land cover along NC 24.

Table 1.3.1: Land use distributions for Boathouse Creek Watershed

Land use	Area (acres)	Percent
Wetland	61.74	11.3
Pasture/Herbaceous	55.18	10.1
Forest	206.53	37.7
Urban	196.72	35.9
NCDOT	27.90	5.1
Total	548.07	100

Table 1.3.2: Land use distributions for Dubling Creek Watershed

Land use	Area (acres)	Percent
Wetland	119.44	48.5
Pasture/Herbaceous	16.49	6.7
Forest	101.25	41.2
Urban	8.74	3.6
NCDOT	0.1	0.04
Total	246.02	100

Table 1.3.3: Land use distributions for Hills Bay Embayment

Land use	Area (acres)	Percent
Wetland	11.54	7.6
Pasture/Herbaceous	67.82	44.8
Forest	37.76	25.0
Urban	26.55	17.6
NCDOT	7.55	5.0
Total	151.22	100

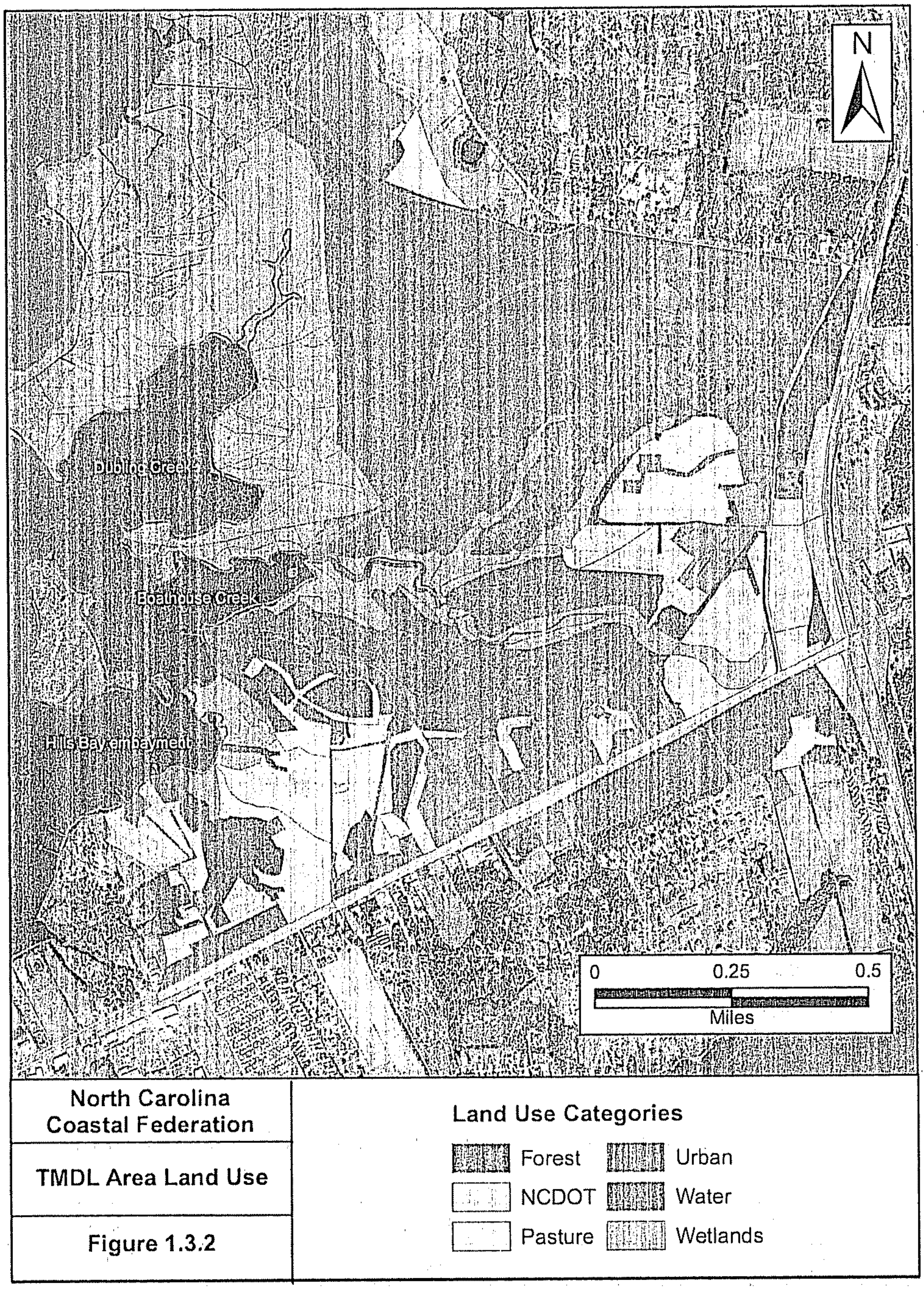


Figure 1.3.2: Land use distributions

1.4 Water Quality Characterization

The Shellfish Sanitation and Recreational Water Quality Section of the Division of Environmental Health (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, 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. The project embayments are 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 bacteriological monitoring of the areas, conditional area samples are collected after rainfall events for some stations. Water quality stations in and around the project area are mostly located in the embayment and most data were collected at least six times a year from 1991 (except Boathouse Cr. where sampling began in 2004) until the present. There are eight fecal coliform monitoring stations in the project area; at each embayment where one station is located within the closure line and a second station is located outside of the closure line (see Figure 1.4.1). The lone exception to this is the NC 24 Bridge Area, where both stations are outside of closure line. Consequently, Station 20A was discontinued in September 2006. The data collected from these observation stations are used for the water quality assessment for the TMDL study. The time series plots of the stations within the shellfish harvest areas are shown in Appendix A. Based on field measurements, the fecal coliform concentrations exceed the water quality standards at three stations: 19, 19A, and 56. Violations indicate that observed concentrations exceed the 90th percentile water quality standard of 43 MPN per 100 ml. Though the last 30 samples taken at station 56 are below the 90th percentile standard, the 90th percentile remained above 50 MPN/100ml from October 2004 through October 2007. Similarly, the 90th percentile exceeded the standard at station 20 as recently as September 2003.

Table 1.4.1: A Summary of Statistics of Observation Data (as of March 2008)

Station	Area	**Last 30 sample geometric mean** (MPN /100ml)	**Last 30 sample Median** (MPN /100ml)	**Last 30 sample 90%** (MPN/100ml)
56	Dubling Creek	7.1	7.8	36
56B	Outside Dubling	4.6	3.3	18
20	NC24 Bridge Area	6.9	5.6	27
20A	Outside NC24 Bridge Area	5.4	5.7	16
19A	Boathouse Creek	18.8	22	130
19C	Outside Boathouse	6.0	6.8	33
19	Hills Bay Embayment	17.7	19.5	91
19D	Outside Embayment	5.4	5.3	18.5

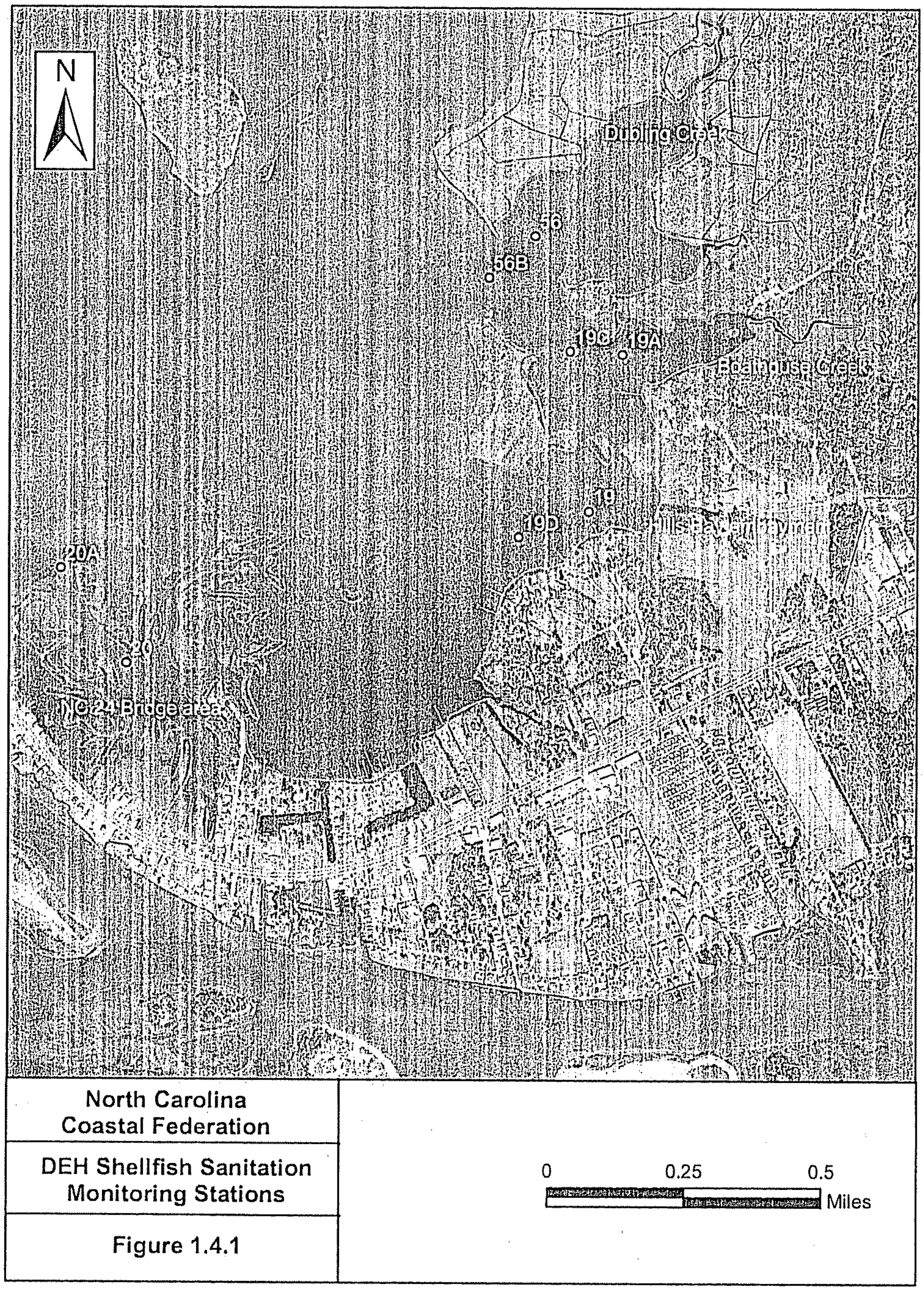


Figure 1.4.1: Locations of fecal coliform observation stations

2.0 SOURCE ASSESSMENT

2.1 Nonpoint Source Assessment

Nonpoint sources of fecal coliform bacteria do not have one discharge point but occur over the entire length of a stream or waterbody. There are many types of nonpoint sources in watersheds discharging to the restricted shellfish harvesting areas. Fecal coliform bacteria from the non-human sources originate from excretions from wildlife and pets. Fecal coliform inputs from livestock sources are negligible in the project area. Cows and goats have been known to graze in the area as recently as 2006 but none are currently present. Their numbers were believed to be very low and would not have had much impact on the overall loading.

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. A more direct path to the restricted areas occurs when wildlife defecate in the drainage network, including stream and wetland channels, and stormwater conveyance pipes. 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 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.

To improve our understanding of fecal coliform bacteria sources in the project area and to assist model calibration, a watershed survey was conducted as part of the project. The complete survey appears at the end of Appendix C. The survey included additional bacteria monitoring, a source assessment, and topographic surveys. It was designed to improve the accuracy of the TMDL modeling and to contribute to more effective implementation plans by identifying bacteria 'hot spots'.

The bacteria monitoring included 32 preliminary stations and was conducted by NC Coastal Federation and volunteers recruited by them. Additional sites were added to more specifically target bacteria sources, such as specific storm pipes or failing septic systems. All of the monitoring sites are shown in Figure 2.1.1. The samples were collected during wet and dry conditions, defined as follows:

- wet conditions – sample taken within 24 hours of a rainfall totaling at least 0.5" in 24 hours
- dry conditions – no rainfall in past 72 hours.

The purpose of the source assessment was to estimate the populations of pets, livestock, and wildlife and the number of septic systems in the project area. This work is based on that done for the Jarrett Bay TMDL by Dr. Bill Kirby-Smith and his student, Katie Wolff, from the Duke University Marine Lab (Kirby-Smith and Wolff, 2004).

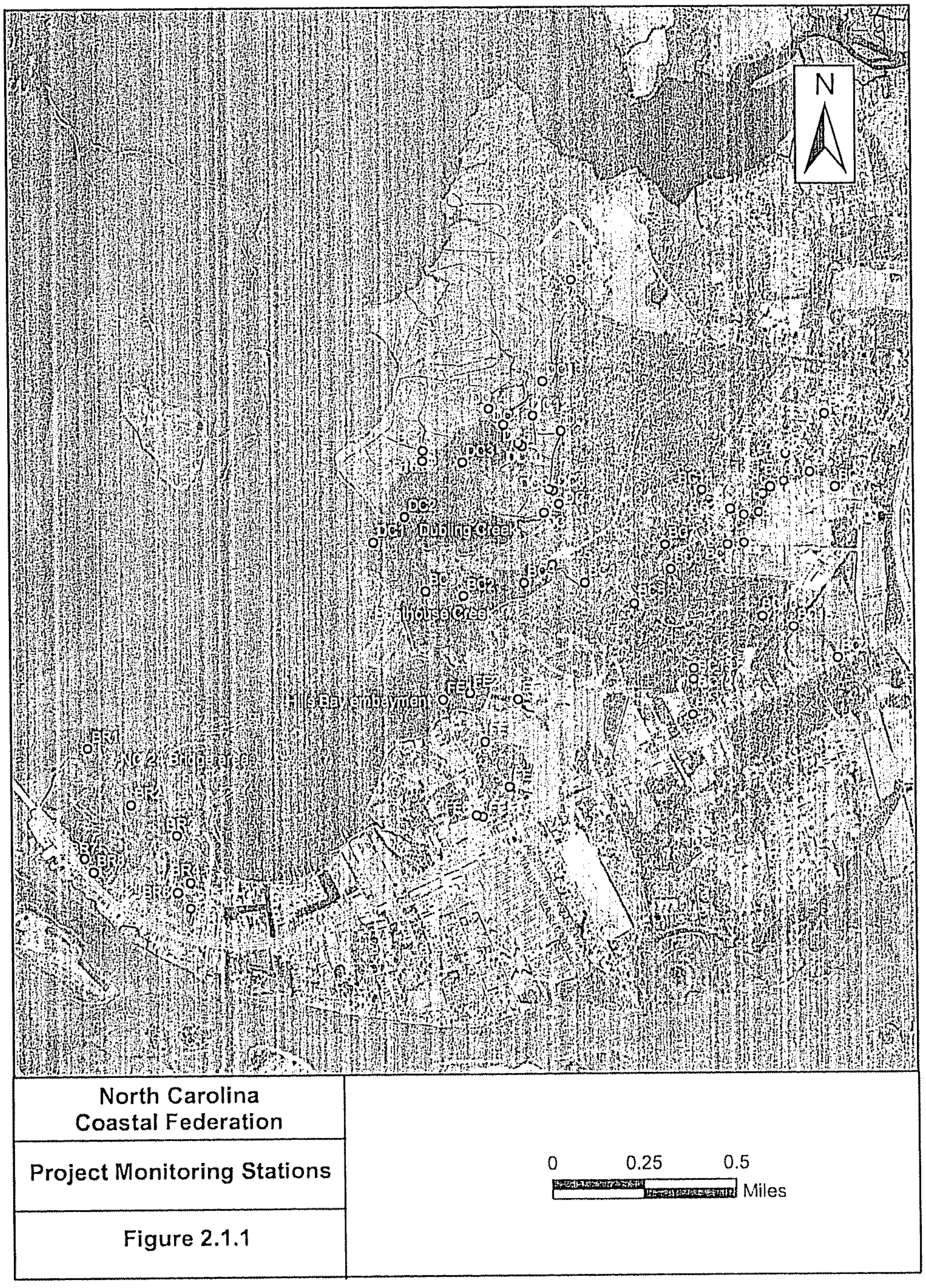
Using GIS parcel data, a database of landowners in the project watersheds was developed. There are approximately 230 parcels in the Boathouse Creek subwatershed, 30 parcels in Hills Bay embayment, and 55 parcels in the NC 24 Bridge subwatershed. Using this, NC Coastal

Federation conducted a telephone survey to estimate the number and types of pets and wildlife observed by residents in each subwatershed. The survey questions were:

1. Do you have pets and/or livestock?
2. If yes, what type(s) and how many? If you have cats, do they spend time outside?
3. Have you observed wildlife on or within the vicinity of your property? If yes, what type?

Wildlife
Estimates per hectare for birds, small mammals (rats, mice, voles, moles, squirrels, etc), medium mammals (raccoons, opossum, rabbits, etc), and large mammals (bear and beaver) have been provided by Dr. Kirby-Smith (Kirby-Smith and Wolff, 2004). Kirby-Smith contacted a wildlife biologist at NCSU for his best professional judgment and consulted NCSU wildlife information. Wildlife estimates were provided in densities per land use type, including marsh, agriculture, suburban, and forest.

Septic systems
It will be assumed that all parcels with a structure added have a septic system.



North Carolina Coastal Federation

Project Monitoring Stations

Figure 2.1.1

2.2 Point Source Assessment

NCDOT is considered to be the lone point source in the TMDLs because no sanitary sewer discharges are permitted in the project area. NCDOT has a number of roads in the project area, including Highways 24 and 58, which are covered under their statewide NPDES stormwater permit (NCS000250). Some of the project monitoring sites (e.g., FE5, BC11, BC26) are located at the outlets of stormwater pipes that drain NCDOT roads. These samples were used to calibrate the bacteria accumulation rates on NCDOT land.

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). Hence, NCDOT's contribution will be separately tracked from the remaining sources so that a specific load and reduction percentage can be assigned to it.

3.0 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

This section documents fecal coliform TMDL development and allocations for Dubling Creek, Boathouse Creek, and the Hills Bay embayment. In order to estimate existing load and allowable load for the creeks, a watershed model was used to simulate fecal coliform loads from the watershed. Once the fecal coliform is discharged to the receiving water, it will be transported to the different areas in the embayments due to interaction of tide and freshwater discharge and decay. Therefore, a tidal model was used to simulate fecal coliform concentrations in the embayments. The required load reduction was determined based on ten years of modeling results spanning from 1998 through 2007. The TMDL is presented as counts per day. The following sections present the detailed TMDL development and load allocations for the project area. The first section describes the watershed and tidal models used for the TMDL study, as well as model set up. The second section presents the model calibration and verification procedures. The third and fourth sections address the critical period and seasonal variability. The fifth section discusses TMDL loading caps. The sixth section presents the load allocation and the seventh section presents the margin of safety. Finally, the variables of the equation are combined in a summary accounting of the TMDL.

3.1 Modeling Approach

Based on the considerations of the influence of nonpoint sources and tidal-induced transport in the embayments, analysis of the monitoring data, review of the literature, and past pathogens modeling applications, a linked watershed and tidal modeling approach was used to simulate fecal coliform loading from the watershed and fecal coliform concentration in the embayments. A description of the modeling approach is provided in the following section.

3.1.1 Watershed Model Description

The watershed model selected for simulating fecal coliform load on the watershed is the Loading Simulation Program in C^{++} (LSPC). LSPC is a general watershed model developed by the U.S. Environmental Protection Agency (EPA) Region 3, with support from the West Virginia Department of Environmental Protection, and TetraTech, Inc. Continued development and refinement is supported by EPA Regions 3 and 4 (Henry et al., 2002; Shen et al., 2005). LSPC is a stand-alone, PC-based application with built-in GIS functionality. The dynamic watershed model simulates watershed hydrology and pollutant transport, as well as stream hydraulics and in-stream water quality. It is capable of dynamically simulating flow, sediments, metals, temperature, pH, as well as other conventional pollutants (fecal coliform) for pervious and impervious lands and waterbodies of varying order. The model is essentially a re-coded C^{++} version of selected Hydrological Simulation Program FORTRAN (HSPF) (Bicknell et al., 1996) modules. The numerical algorithms are identical to those in HSPF. The model has been successfully applied to TMDL studies for in-land watersheds and coastal basins (Henry et al., 2002; Shen et al., 2002; USEPA, 2001).

3.1.2 Tidal Prism Model

The Tidal Prism Model (TPM) simulates the tidal transport in terms of the concept of tidal flushing (Ketchum, 1951). The tidal prism, or inter-tidal volume, is the amount of water entering and leaving a coastal basin during each tidal cycle. During flood tide, a large amount of water (i.e., the tidal prism) floods into the coastal basin. This amount of water mixes with the lower tidal water within the basin. A portion of pollutant inside the basin will be transported out of the basin during ebb tide as water is transported out of the basin. The TPM can simulate pollutant transport in an embayment with multiple branches both temporally and spatially (Kuo and Neilson, 1988; Kuo et al., 1998). Because the TPM is capable of simulating pollutants both spatially and temporally, it can be applied to a coastal basin with a high degree of branching. The input data required to run the model includes tidal range, surface area, and depth of the water body. Thus, the tidal prism for each modeling area can be estimated based on the volume of the basins and the tidal range in the area.

3.1.3 Model Setup

Because the project area is located in a low-lying coastal area, the topographic maps and USGS Digital Elevation Model (DEM) data do not have sufficient vertical resolution showing variation of surface elevation. No historical watershed delineation information is available either. Hence, the watershed delineation was conducted based on all available information including DEM, United States Geological Survey (USGS) topographic maps, and aerial photos. To provide a better linkage between LSPC and TPM, the TPM segmentation was also used as a guideline for the watershed delineation. To represent watershed loadings and linkage between the watershed model and the TPM, the watershed was divided into 21 subwatersheds (10 in Dubling Creek, 9 in Boathouse Creek, and 2 in Hills Bay embayment). Figure 3.1.1 shows the watershed delineations.

Land use unique to this project was delineated based on 2004 aerial photography as described in Section 1.3.1.

The project embayments were divided into 10 segments based on the Tidal Prism Model theory (Kuo and Park, 1994), with 5 segments in Dubling Creek (4 in the main channel and 1 in a tributary), 3 segments in Boathouse Creek, and 2 segments in the Hills Bay embayment. The segmentation is shown in Figures 3.1.1 and 3.1.2. The volume of each segment was obtained from bathymetry transect surveys conducted for this project in November 2006. NOAA survey data for this area do not exist. The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal range of 0.49 meters based on NOAA station at Bogue Inlet (NOAA, 2002). The surface area of each segment together with tidal range was used to compute the high tide water volume and tidal prisms. Using mean tidal range and mean volume, the model provides the daily mean results, but not the instantaneous condition, which is consistent with the standard. The geometry information of the TPM is listed in Appendix B. A linkage table was generated to distribute subwatershed loads to their corresponding TPM segments. Since the TPM is on the scale of a tidal cycle (i.e., about 12.42 hours for the M_2 tide), the daily load was calculated from hourly loads generated from the watershed model. Then the load for each tidal cycle was calculated and fed to the segments. The simulation period of the TPM is the same as that of the watershed model.

3.1.4 Meteorological data

Meteorological data are a critical component of the watershed model. Appropriate representation of precipitation and temperature were acquired in an effort to develop the most representative dataset. In general, hourly precipitation data are recommended for nonpoint source modeling due to the storm sensitive processes and were used for this project. Potential evapotranspiration was calculated using the Jensen formula (Jensen and Haise, 1963), which is based on average daily temperature and monthly average solar radiation. Daily temperature values were calculated from hourly temperature in the project weather files and solar radiation came from monthly averages between 1961 and 1990 for Wilmington, NC. The meteorological data used in this study are the hourly data obtained from the NOAA weather station at Morehead City 2 WNW, NC for January 1998 through June 2001. The station at Beaufort Michael J. Smith Field was used for July 2001, when monitoring there began, through 2007 because the Morehead City station had many days of missing data in recent years.

Figure 3.1.1: Subwatershed delineation

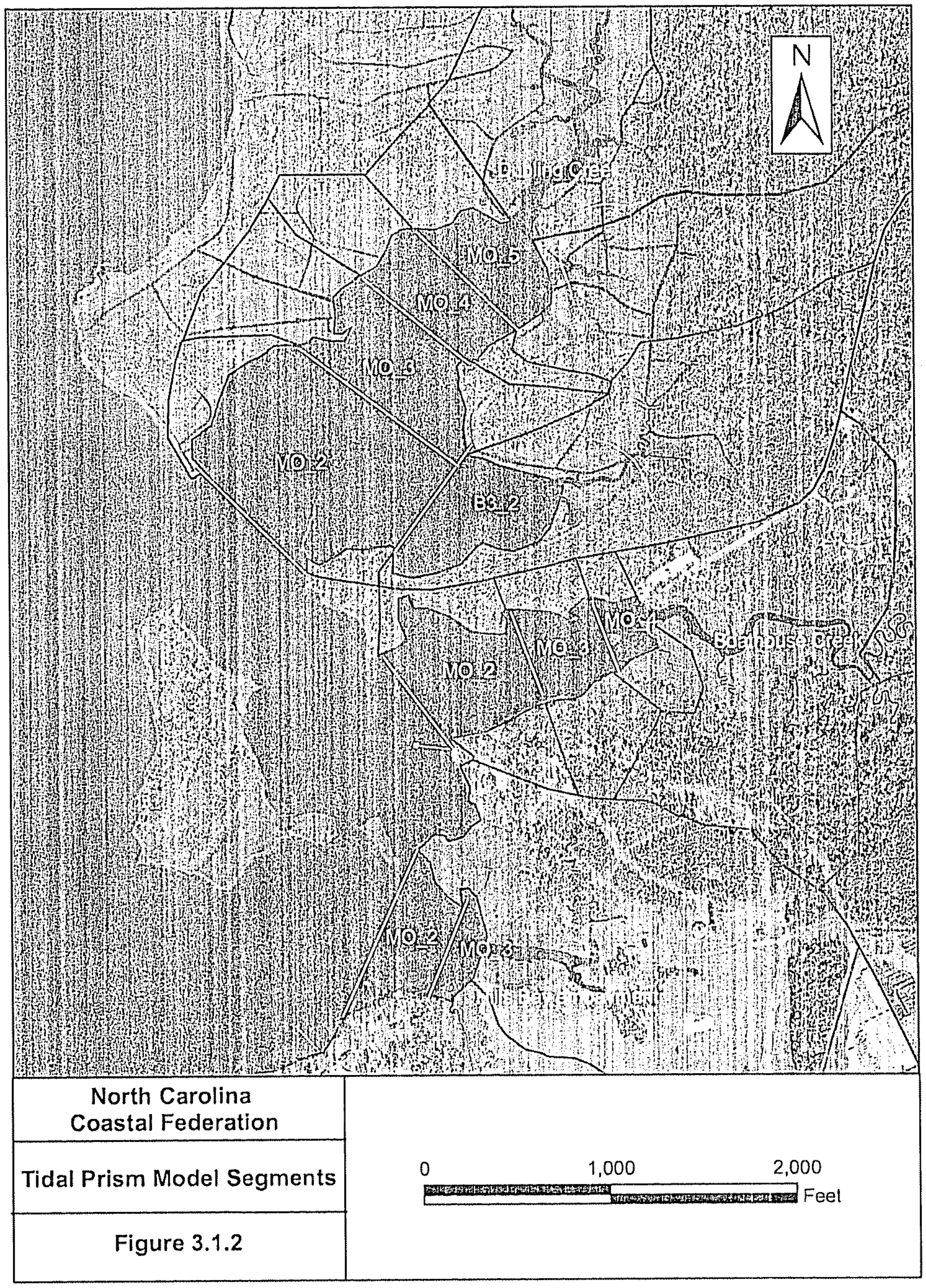


Figure 3.1.2: Tidal Prism Model segmentation

3.2 Model Calibration and Verification

Both watershed and Tidal Prism models are calibrated and verified based on observed data. A description of the model calibration and verification is presented in the following sections.

3.2.1 Watershed model calibration

The hydrological calibration developed for the Jarrett Bay TMDL (NCDWQ, 2007) was used for the Southeast White Oak TMDLs because the same streamflow gage is the closest to the project area and the topography and soil types are relatively similar. In fact, the Southeast White Oak watersheds are probably more similar to the gaged watershed because they both have sandier soils in the upland areas. The following paragraph explains the hydrologic calibration process for the Jarrett Bay TMDLs.

The hydrology of the LSPC model was calibrated and verified for water years from 1989 to 1990. Because there is no long-term USGS gage station in the drainage basin, the hydrology calibration was conducted by using a reference watershed calibration approach. The model hydrology parameters are calibrated based on the nearest USGS gage station in the upper part of the New River basin (USGS Gage 02093000), which is approximately 40 km west of the project area. The hydrology calibration involved adjustment of the model parameters used to represent the hydrologic cycle until acceptable agreement was achieved between simulated flows and historic stream flow data measured at the gage for the same period of time. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. The water years 1989 to 1990 were used for the model calibration. The calibrated parameters are in the same range as those parameters used in the Eastern Shore, a low-lying region of Virginia. These calibrated hydrological parameters were used for the project models. An example of model simulation of daily flow in 1990 is shown in Figure 3.2.1. The model was further verified by comparing the model simulation against the data at USGS gage station from water years 1991 to 1998. An example of model verification in year 1998 is shown in Figure 3.2.2. Results from a 10-year accumulative flow simulation results are shown in Figure 3.2.3. This shows that the long-term water budget is balanced and the hydrology simulation is satisfactory.

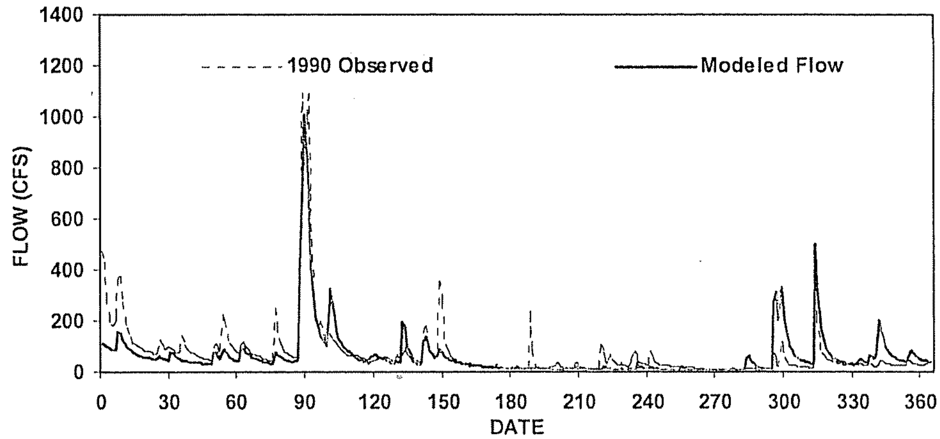


Figure 3.2.1: Example of hydrology model calibration (1990)

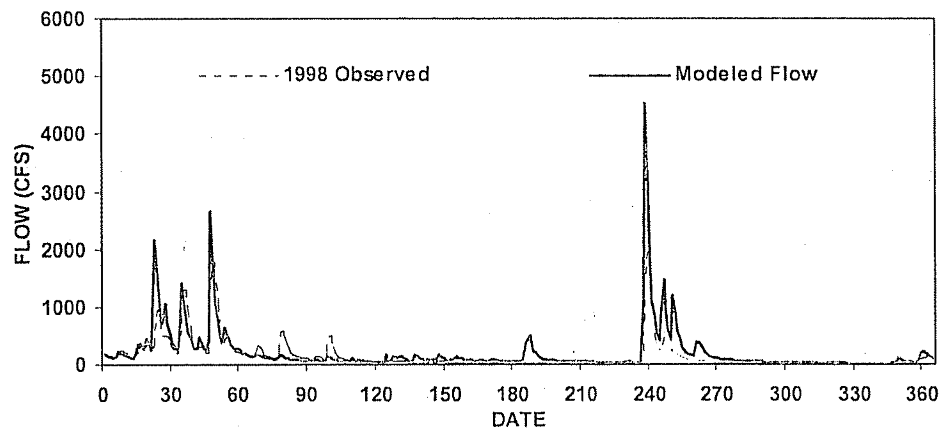


Figure 3.2.2: Example of hydrology model verification (1998)

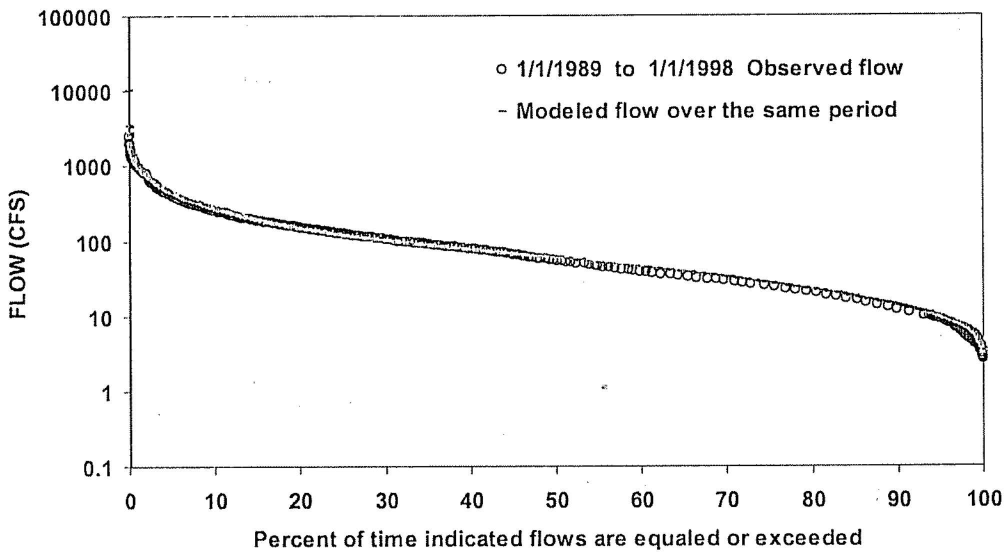


Figure 3.2.3: Comparison of long-term model results and USGS flow data

In modeling the fecal coliform processes, LSPC uses the same algorithm in HSPF that is based on the 'build-up and wash-off' approach with user-prescribed monthly build-up and wash-off rates for the fecal coliform sources for different land use categories (Shen et al., 2005). In this study, the 21 subwatersheds were given different parameter sets based on estimated fecal coliform accumulation rates. The accumulation rate of fecal coliform for each group was estimated based on the field survey data (e.g., numbers of septic systems, pets, and wildlife). The wildlife contributions were applied to forest, wetland, pasture, and urban land. However, exact wildlife numbers are impossible to obtain, and thus an estimation based on wildlife density and their habitat was used to estimate the rates. The bacteria contributions from pets were applied to residential lands and, to a lesser degree, other lands to represent feral cats or dogs at parks or on walking trails. These parameters were further calibrated during the Tidal Prism model calibration process, as necessary. Fecal coliform production rates of different kinds of source animals were based on the empirical numbers in previous studies and literature (see Appendix C). Detailed source estimation is presented in Appendix C. In this study, the fecal coliform storage limit varied according to its subwatershed and the corresponding decay rate. The maximum storage in counts/acre in the Hills Bay embayment subwatershed was set at 1.8 times the accumulation rate, and the watershed decay rate was set at 0.5 day^{-1}. For Boathouse Creek, the storage limit was set to be 3.3 times the accumulation rate, which represents a decay rate of 0.35 day^{-1}. For Dubling Creek, the storage limit was set to be 7.2 times the accumulation rate, which represents a decay rate of 0.15 day^{-1}. The openness of the canopy may be one factor in the disparity between watershed decay rates because sunlight is a primary determinant of bacteria decline.

Accumulation, storage, and decay rates were also calibrated based on project sampling within the watershed. For example, some of the project monitoring sites (e.g., FE5 and BC11) are located at the outlet of stormwater pipes that drain NCDOT roads. These samples were used to calibrate the bacteria accumulation rates on NCDOT land.

3.2.2 Tidal Prism Model calibration

The Tidal Prism Model calibration was conducted based on the comparison of model simulated fecal coliform in the embayments and observations. The only parameters that need to be calibrated are return ratio and fecal coliform decay rate in the TPM. The return ratio is the fraction of water leaving the embayment during the ebb tide that will be transported back to the embayment during the next flood tide. The return ratio ranges from 0 –1. Past studies of the TPM have demonstrated that the calculated salinity is relatively insensitive to the value of return ratio between 0.1 to 0.5 and the value of 0.3 works well for small creeks in Virginia (Kuo, et al., 1998). The selected return ratios were 0.5 for Dubling Creek, 0.4 for Boathouse Creek, and 0.2 for the embayment. The first order decay is used in the model to represent the fecal coliform die-off due to temperature, salinity, and solar radiation, and loss due to settling and other factors. A system with a higher decay rate has a higher assimilative capacity than the system with lower decay rate. The value of the decay rate varies from 0.7 to 3.0 per day in salt water (Mancini, 1978; Thomann and Mueller, 1987). A decay rate of 0.7 per day was used for Dubling and Boathouse Creeks as a conservative estimate in the TMDL calculation. A slightly higher decay rate of 0.8 per day was necessary to obtain better calibration results in Hills Bay embayment.

The water quality calibration is based on the simulation of fecal coliform concentration in the embayments using the linked watershed and Tidal Prism modeling approach. Figure 3.2.4 through Figure 3.2.6 show the 10-year simulation results for Dubling Creek, Boathouse Creek, and the Hills Bay embayment. The 10-year model simulations show that the model captured seasonal variability and peak fecal coliform concentrations. It is understandable that the model may fail to simulate some isolated events due to the high variability of the nature of fecal coliform, which has a quick response to an isolated event. The observed measurements show the lowest concentration is always 1.7 MPN/100ml. This is due to the laboratory methods used for determining the fecal coliform counts. The high concentration is more critical for determining the bacteria capacity.

The primary water quality calibration goal was to produce model results that reasonably approximated the observed 30-sample 90th percentile, which is used by Shellfish Sanitation for shellfish use ratings, as previously described in Section 1.4. Judging from long-term simulation results, the overall model performance is satisfactory. This is shown in Figures 3.2.7 through 3.2.9, which display the 90th percentile observations based on the previous 30 samples and the 90th percentile predictions based on 30 months of daily predictions (current 90% in figures).

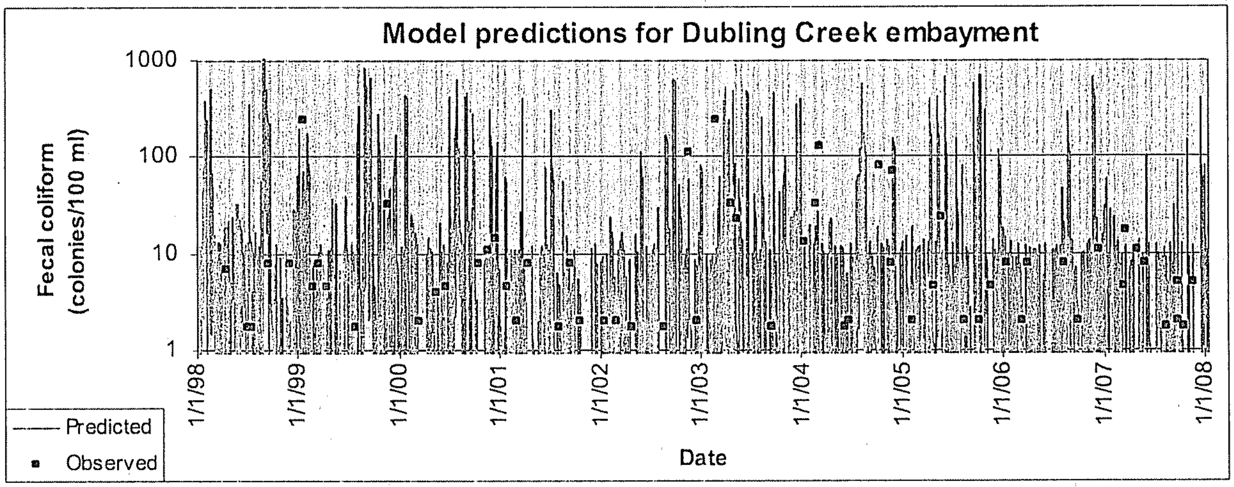


Figure 3.2.4: Comparisons of model simulation of fecal coliform and observations (Dubling Creek)

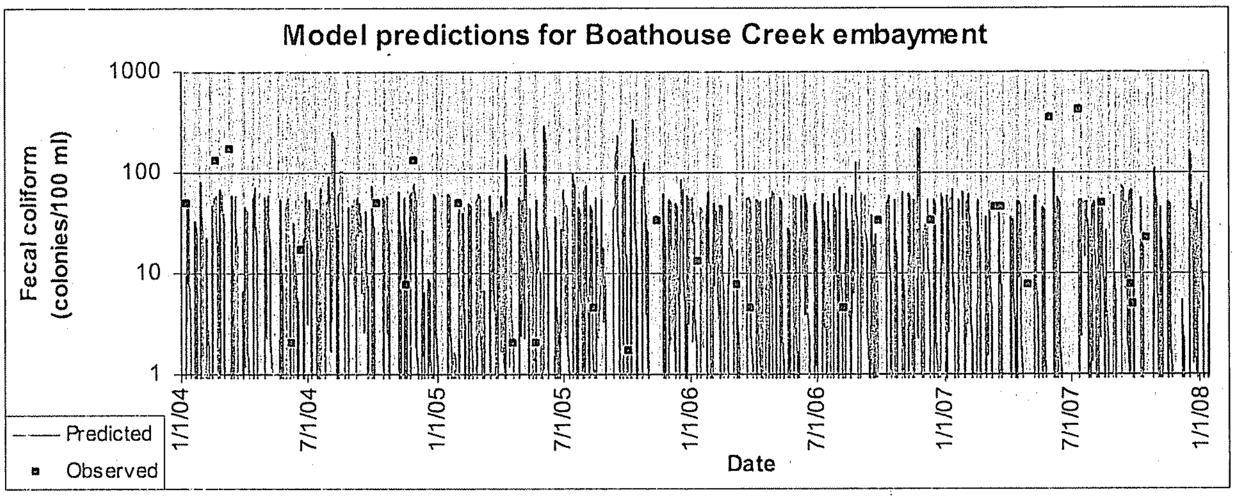


Figure 3.2.5: Comparisons of model simulation of fecal coliform and observations (Boathouse Creek)

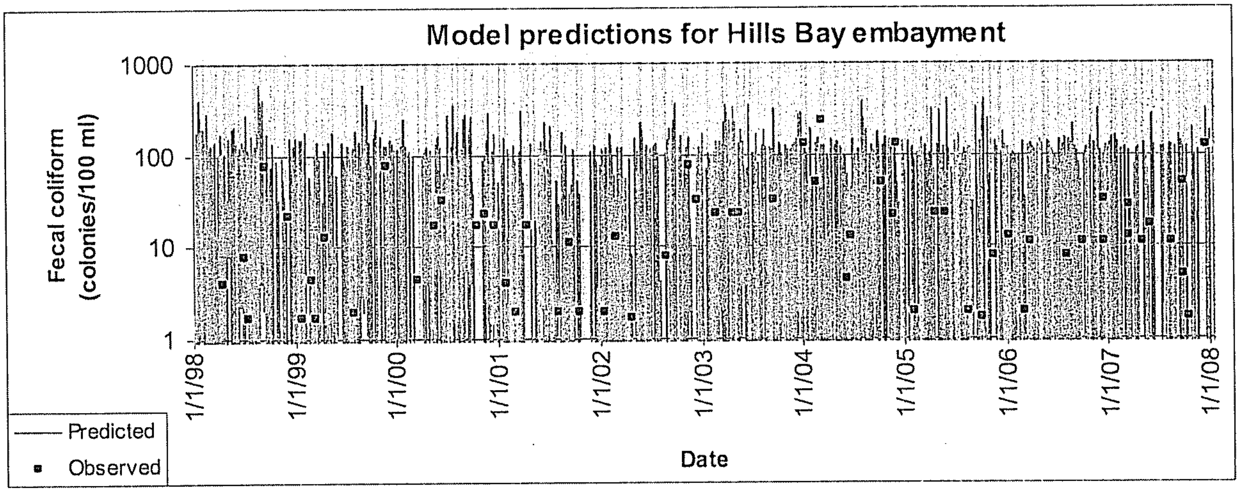


Figure 3.2.6: Comparisons of model simulation of fecal coliform and observations (Hills Bay Embayment)

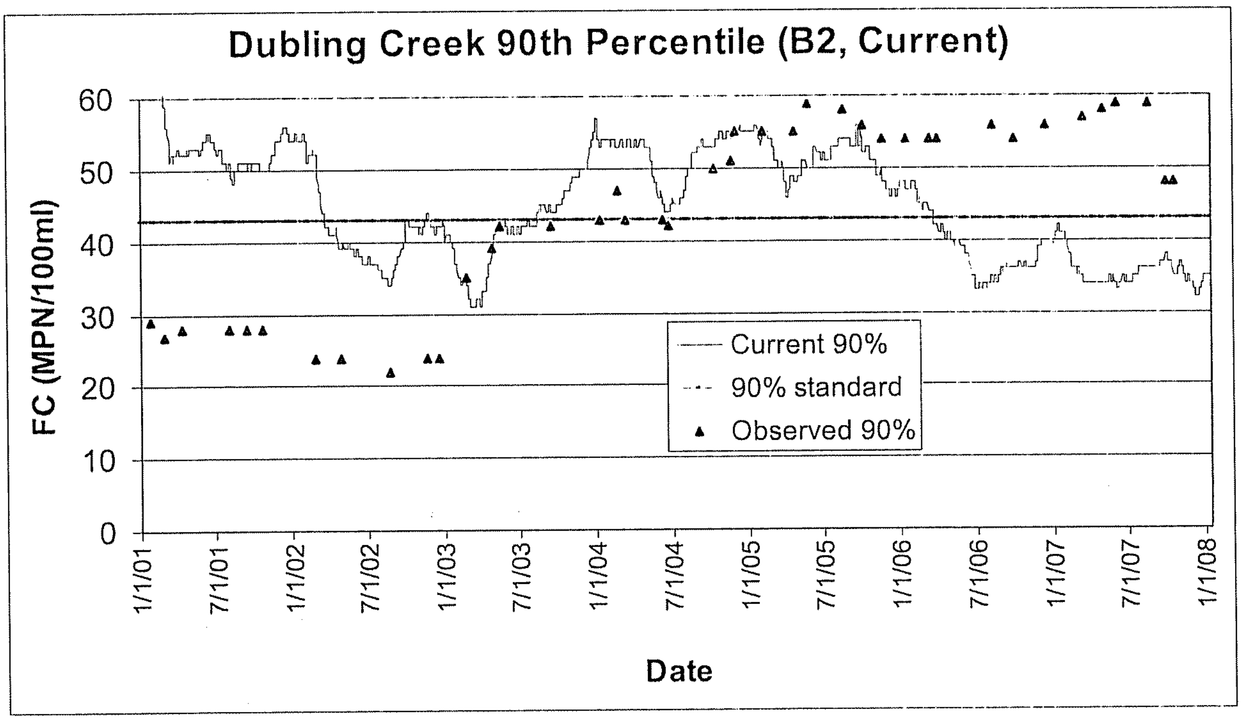


Figure 3.2.7: Comparison of 90th Percentile of fecal coliform from model simulation and observations (Dubling Creek)

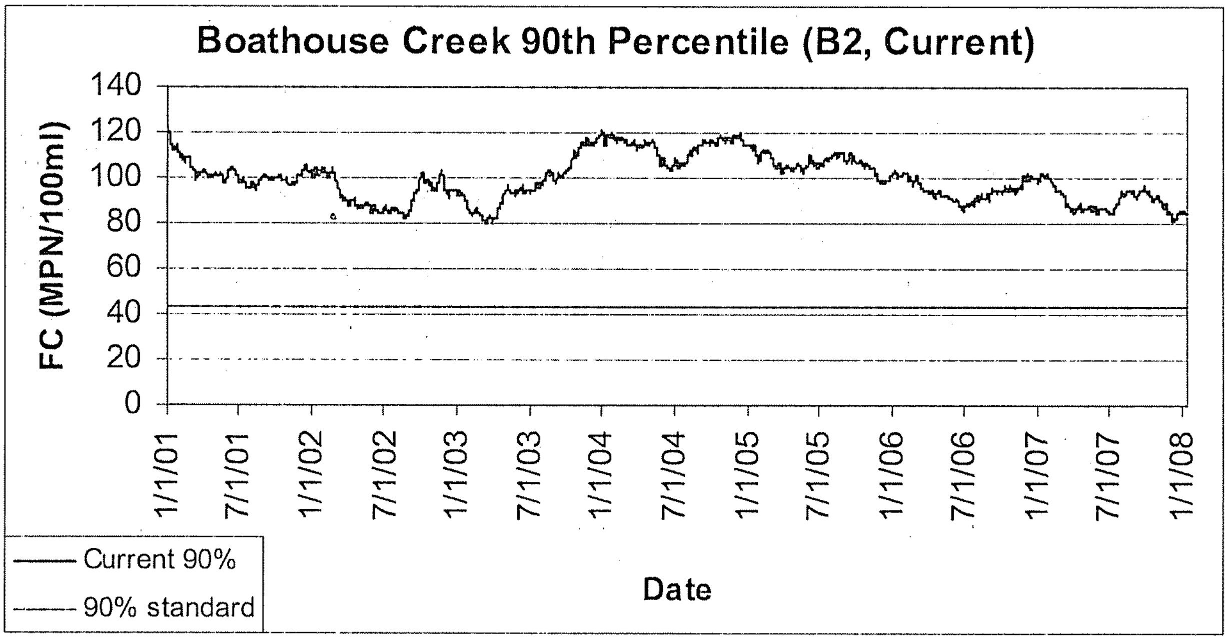


Figure 3.2.8: 90th Percentile of fecal coliform from model simulation (Boathouse Creek).
Note: Sampling began at this station in January 2004 so 30 samples on which to base Observed 90th percentile had not yet been collected. 90th percentile based on 27 samples was 119 in October 2007.

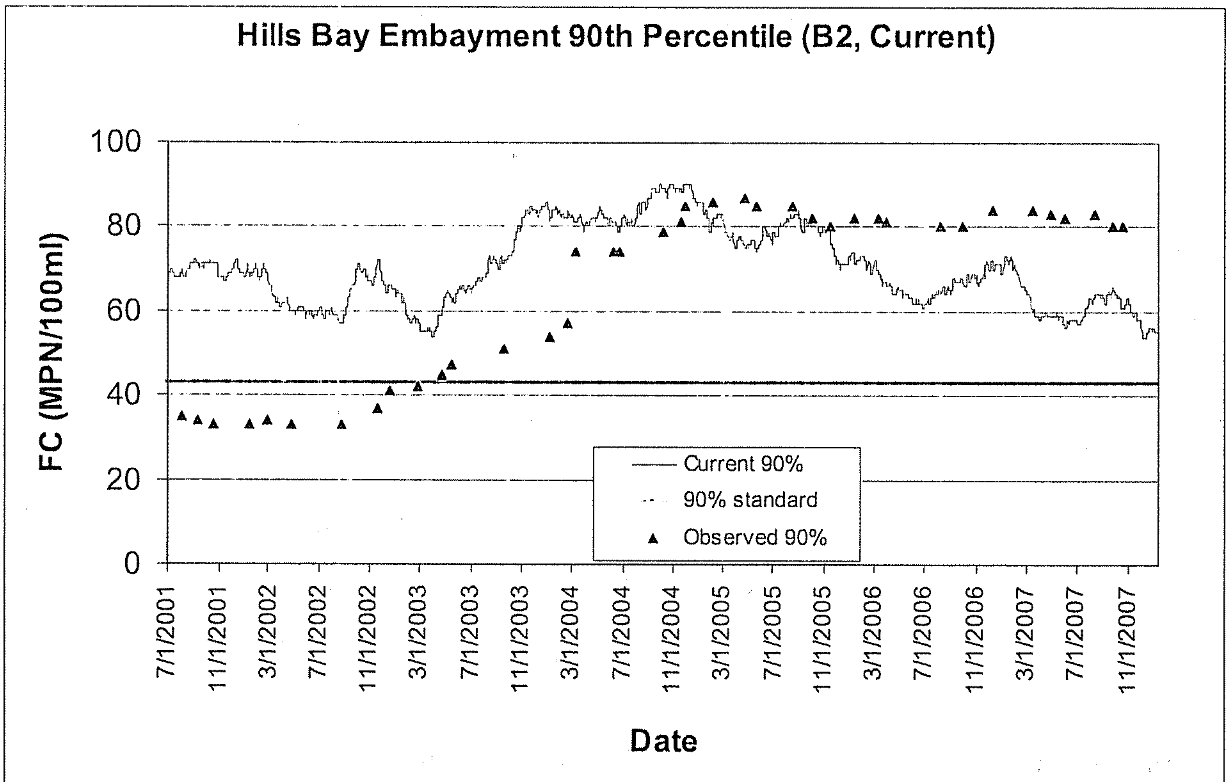


Figure 3.2.9: Comparison of 90th Percentile of fecal coliform from model simulation and observations (Hills Bay Embayment)

3.2.3 Accumulation Rates

The complete distributions of the accumulation rates for the drainage areas of Dubling Creek, Boathouse Creek, and the Hills Bay embayment are listed in Tables 3.2.1 to 3.2.3 in counts/day for each land use. These estimates are direct inputs on the land use and do not account for decay. The estimates were derived by multiplying the calibrated accumulation rates by the respective land use area for each watershed. Further details of the source estimate procedure can be found in Appendix C.

Table 3.2.1: Fecal Coliform Accumulation Rates from Boathouse Creek

Land use	Loading Counts/day	Loading Percent
Wetland	7.35E+11	10.8
Pasture/Herbaceous	1.96E+11	2.9
Forest	1.51E+12	22.1
Urban	4.17E+12	61.1
NCDOT	2.19E+11	3.2
Total	6.83E+12	100

Table 3.2.2: Fecal Coliform Accumulation Rates from Dubling Creek

Land use	Loading Counts/day	Loading Percent
Wetland	2.62E+12	68.4
Pasture/Herbaceous	5.85E+10	1.5
Forest	9.42E+11	24.6
Urban	2.10E+11	5.5
NCDOT	NA	0.0
Total	3.83E+12	100

Table 3.2.3: Fecal Coliform Accumulation Rates from Hills Bay Embayment

Land use	Loading Counts/day	Loading Percent
Wetland	3.21E+10	5.6
Pasture/Herbaceous	1.74E+11	30.2
Forest	9.81E+10	17.0
Urban	1.90E+11	33.0
NCDOT	8.15E+10	14.2
Total	5.76E+11	100

The loads shown above are for fecal coliform accumulation on the land surface only. They are not the loading delivered to the shellfish embayments. To get the delivered load, decay, maximum storage, and transport must be simulated. These processes are captured in the modeling.

3.2.4 TMDL Calculation

The existing load (or current condition) for each impaired embayment is estimated as the sum of all the loads from subwatersheds discharging into the embayments. The loading is expressed as counts per day. The TMDL calculation is based on the water quality criteria; in this case it is the median and 90th percentile for the most recent 30 samples. Since the samples are taken on an approximately monthly basis (i.e., samples can be taken in any month), the running 30-month median and 30-month estimated 90th percentile were calculated at TPM segments. The estimated 90th percentile is used by DEHSS and is calculated as follows:

1. Calculate the arithmetic mean and standard deviation of the sample result logarithms (base 10);
2. Multiply the standard deviation in (1) by 1.28;
3. Add the product from (2) to the arithmetic mean;
4. Taking the antilog (base 10) of the results in (3) to get the estimated 90th percentile; and
5. The MPN values that signify the upper or lower range of sensitivity of the MPN tests in the 90th percentile calculation shall be increased or decreased by one significant number.

The watershed loading was reduced until both water quality standards were met at all times during the model simulation period. Thus, the TMDL period for each watershed is the 30 months preceding the last prediction to meet the standard (i.e., reductions are made until all predictions meet the standard). The final loading input to the TPM from LSPC was computed as the TMDL for its corresponding watershed. The load reduction is computed based on the difference between the current condition and the TMDL loading. The existing and allowable loading for each project watershed is listed in Table 3.2.4. The time series plots of median and 90th percentile for each tidal segment under existing condition and after reduction are presented in Appendix D.

Table 3.2.4: Existing Load and TMDL By Watershed

Waterbody	Pollutant	Existing	WLA	LA	MOS[1]	Reduction Required[2]	TMDL
Boathouse Creek - (20-31)	Fecal coliform (counts/day)	6.17×10^{11}	9.91×10^{9}	1.75×10^{11}	2.41×10^{10}	66%	2.09×10^{11}
Dubling Creek - (20-30)	Fecal coliform (counts/day)	1.77×10^{11}	0.00	1.53×10^{11}	5.00×10^{9}	11%	1.58×10^{11}
White Oak River – (20-(18)c4)	Fecal coliform (counts/day)	2.88×10^{10}	6.60×10^{8}	1.24×10^{10}	1.44×10^{9}	50%	1.45×10^{10}

Notes: WLA = wasteload allocation, LA = load allocation, MOS = margin of safety

[1] Margin of safety (MOS) equivalent 11.6 percent of the target concentration in all embayments. Used a target of 38 instead of 43. MOS load in table represents the difference between total loading using those targets.

[2] The reduction required in this table includes the margin of safety. The actual reduction required should not count the margin of safety; the overall reductions required would be 70%, 14%, and 55%, respectively.

3.3 Critical Condition

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 model simulation period spans ten years (1998-2007), the critical condition is implicitly included in the value of the 90th percentile of model results. Given the length of the monitoring record and model simulation and the standard's recognition of unusual and infrequent events, the 90th percentile is used instead of the absolute maximum.

3.4 Seasonality

Fecal coliform distributions often show high seasonal variability, which is required to be considered in TMDL determinations. The seasonal fecal coliform distributions of observed data for Hills Bay embayment, Boathouse Creek, and Dubling Creek are presented in Figures 3.4.1, 3.4.2, and 3.4.3, respectively. The results show that high fecal coliform concentrations occur throughout the year, except perhaps during summer months. Also, the median monthly concentrations are relatively similar between months; the 75th percentile and maximums show disparity. For Hills Bay embayment, the highest concentrations occur in all but the warmest months. The pattern is similar for Boathouse Creek but the number of samples is much lower so the results are less robust. Concentrations measured in November and March are clearly higher than those measured in August and October. The period of higher concentrations in Dubling Creek extends from October to April. Overall, it appears the winter and shoulder seasons, which have less evapotranspiration and consequently relatively more runoff, are the periods with the highest bacteria concentrations.

The largest standard deviation corresponds to the highest concentration for each station. These high concentrations result in a high 90th percentile concentration. Given the length of the model simulation, the seasonal variability is directly included in the model simulation.

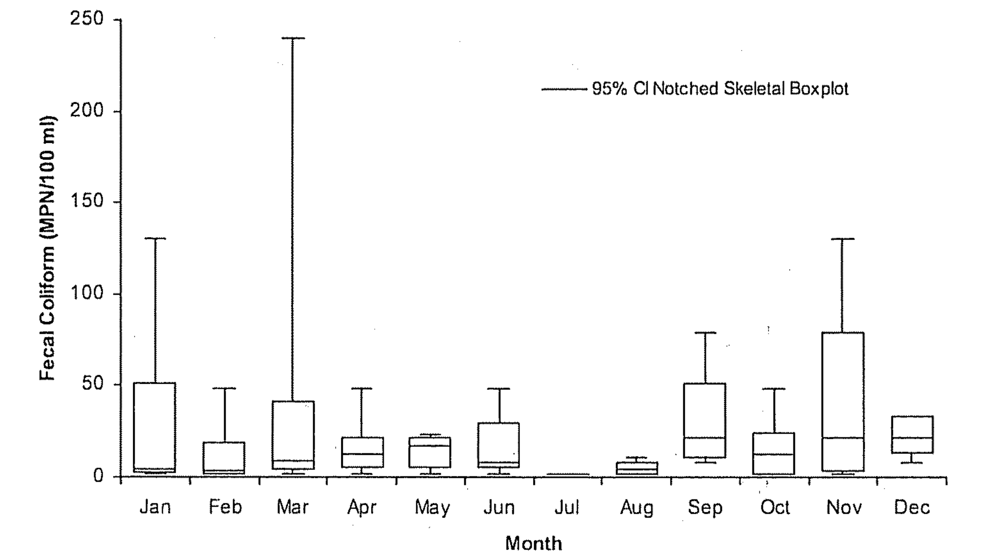


Figure 3.4.1: Seasonal distribution of observed fecal coliform in Hills Bay Embayment

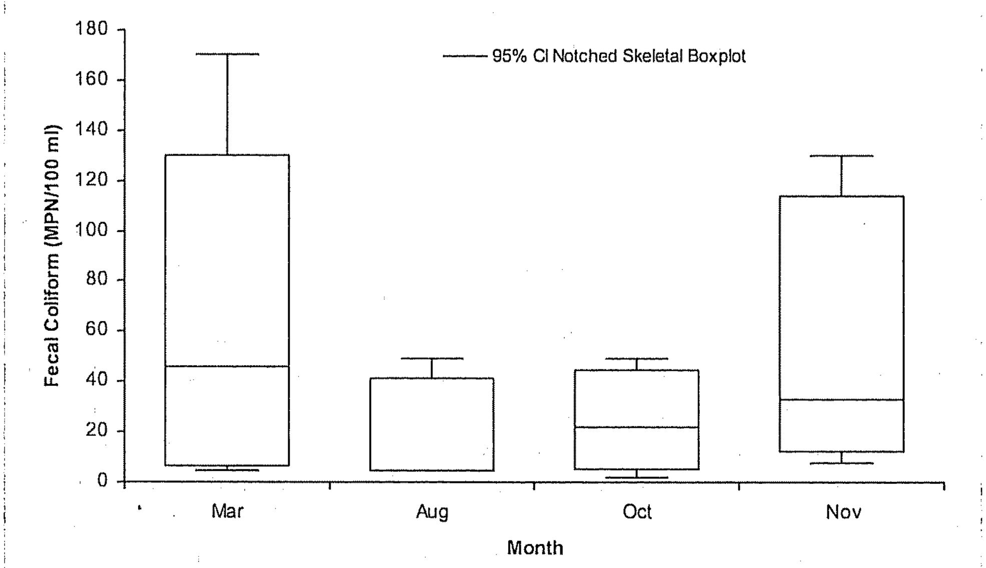


Figure 3.4.2: Seasonal distribution of observed fecal coliform in Boathouse Creek

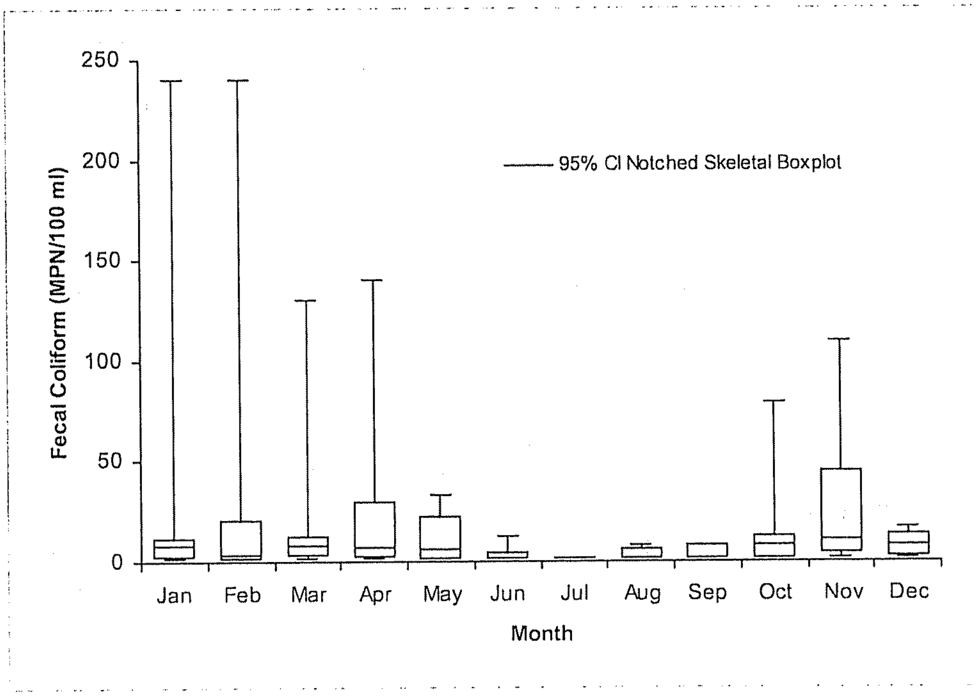


Figure 3.4.3: Seasonal distribution of observed fecal coliform in Dubling Creek

3.5 TMDL Loading Cap

This section presents the TMDL for the median and 90th percentile conditions for Dubling, Boathouse, and Hills Bay embayments. The TMDLs for shellfish harvesting areas, calculated based 1999-2007 model results, are as follows:

DublingCreek

The fecal coliform TMDL = 1.58×10^{11} counts per day
TMDL period is from 3/21/03 to 9/21/05

Boathouse Creek

The fecal coliform TMDL = 2.09×10^{11} counts per day
TMDL period is from 7/24/01 to 1/24/04

Hills Bay Embayment

The fecal coliform TMDL = 1.45×10^{10} counts per day
TMDL period is from 6/14/02 to 12/14/04

As described in Section 3.2.5, the TMDL period is the 30 months preceding the last daily prediction to meet the standard. The greater reduction required when comparing the median and the 90th percentile results was used for the TMDL. Based on the model results, the 90th percentile criterion requires the greatest reduction in all cases. The load reductions needed in the watershed to meet the shellfish criteria and the load allocations required to meet the TMDLs are 14%, 70%, and 55%, respectively, for Dubling Creek, Boathouse Creek, and Hills Bay embayment.

The reduction established based on the 90th percentile criterion indicates that the water body will meet the water quality standard requiring not more than 10% of the samples to exceed an MF count of 43/100 ml. Using the 90th percentile in this manner is consistent with the procedure used by DEHSS on their sample data for determining whether shellfish areas should be open, conditionally prohibited, or closed.

Management strategies to meet the proposed reduction will be implemented in an effort to achieve the control of fecal loads for all but the most extreme 10% of events (i.e. ensure that 90% of the concentrations are at or below the 90th percentile criterion). The extreme events are often due to precipitation patterns whereby extended dry periods are followed by high rainfall events. Bacteria builds up on the land surface during the dry weather and larger quantities are washed into the shellfish waters during the first significant rainfall event.

3.6 Load Allocation

The load allocations were determined using the same period as the TMDL calculation (see Section 3.2.4). Thus, the averaging period for the development of the TMDLs used daily predictions from the TMDL model runs for the 30 months preceding the highest 90th percentile concentration. Over this period, daily bacteria loading predictions were taken from each model subwatershed and subsequently summed across the watersheds. The daily average was then calculated; this serves as the basis for the load allocation. The wasteload allocation (WLA) must then be subtracted to determine the final load allocation (LA).

Model runs were conducted to determine what loading reductions are required to achieve the TMDLs with a margin of safety. For Boathouse Creek, reductions of 72% for both developed land (including Western Park) and NCDOT land are required to meet the TMDL. Additionally, septic systems in the Ocean Spray subdivision will need to be further evaluated. An initiative to upgrade these systems may be warranted if it is shown that bacteria from them is reaching the stream network in high concentration of surface runoff or ground water. In Dubling Creek much of the bacteria load originates from what has typically been considered uncontrollable sources (i.e., wildlife on wetlands and forest land). However, modeling indicates that the standard should be met if a 10% reduction is made on the wetland and forest area surrounding the walking trail (pet waste disposal should accomplish this) and a 48% reduction is made in the headwaters draining through the former mine pond. For Hills Bay embayment, reductions of 60% on NCDOT land and 57% on other built-upon land (i.e., residential and commercial) are estimated to be required to meet the standard.

3.7 Wasteload Allocation

NCDOT is the only NPDES-permitted discharger and consequently will be the lone entity receiving a WLA. Bacteria loading emanating from NCDOT property must be separated from all other sources. Using the delineated land use and calibrated models as a base, the models were rerun with the bacteria accumulation rate on NCDOT land use set at zero. The difference between the calibrated model and the run without NCDOT land use represents NCDOT's current delivered contribution to the embayments. For Boathouse Creek the result is 3.54×10^{10} bacteria counts per day and for Hills Bay Embayment the result is 1.65×10^{9}. To arrive at the WLA, the reduction specified in the TMDL model run is subtracted from the existing loads. A 72% reduction in Boathouse Creek results in a WLA of 9.91×10^{9}, and a 60% reduction in Hills Bay Embayment results in a WLA of 6.60×10^{8}. These values may then be subtracted from the load allocation basis described above (Section 3.6) to determine the final LA.

3.8 Margin of Safety

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.

For TMDL development, the MOS needs to be incorporated to account for uncertainty due to model parameter selection. Based on previous model sensitivity analysis, it has been determined that the most sensitive parameter is the decay rate. The value of the decay rate varies from 0.7 to 3.0 per day in salt water (Mancini, 1978; Thomann and Mueller, 1987, EPA 1985). Decay rates of 0.7 per day in Dubling and Boathouse and 0.8 per day in Hills Bay embayment were used.

As a conservative estimate in the TMDL calculation, an explicit MOS was also included. The explicit MOS was achieved by lowering the targeted 90^{th} percentiles to 38 MPN/100 ml. This is an 11.6% reduction from the standard 90^{th} percentile of 43 MPN/100 ml. The MOS, in terms of load, was calculated by subtracting the model loading needed to meet a 90^{th} percentile target of 38 from the model loading needed to meet a target of 43. These loads are shown in the Table 3.9.1.

3.9 Summary of Total Maximum Daily Loads

As explained in the previous sections, the TMDLs were calculated based on model runs that had a maximum 30-month 90^{th} percentile concentration of 38 MPN/100 ml. The target concentration was lowered from the standard of 43 MPN/100 ml to provide an explicit margin of safety.

NCDOT is the only NPDES-permitted source in the area so the allocation for it is in the WLA column. NCDOT has essentially no roads in the Dubling Creek watershed so a WLA was not provided in that case.

The TMDLs calculated based on the 30 months preceding the last highest 90th percentile concentration in the TMDL model runs are summarized as follows:

Table 3.9.1 The Fecal Coliform TMDL (counts per day)

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Dubling Creek	1.58×10^{11}	=	1.53×10^{11}	+	N/A	+	N/A	+	5.00×10^{9} (3.2%)
Boathouse Creek	2.09×10^{11}	=	1.75×10^{11}	+	9.91×10^{9}	+	N/A	+	**2.41×10^{10} (11.5%)**
Hills Bay embayment	1.45×10^{10}	=	1.24×10^{10}	+	6.60×10^{8}	+	N/A	+	**1.44×10^{9} (9.9%)**

Where:

TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
FA = Future Allocation
MOS = Margin of Safety (derived by using lower 90th percentile target concentration, 38 MPN/100ml versus standard of 43. MOS load reflects difference between model runs using targets of 38 and 43.)

4.0 TMDL IMPLEMENTATION PLAN

The TMDL analysis was performed using the best data available to specify the fecal coliform reductions necessary to achieve water quality criteria. The intent of meeting the criteria is to support the designated use classifications in the watershed. Implementation plans will be included in this TMDL. The Town of Cedar Point and the North Carolina Coastal Federation were involved in the development of the implementation plans. Potential funding sources for implementation include the North Carolina Clean Water Management Trust Fund, and Section 319 funds and 205(j) funds. These funds are expected to be used to construct BMPs and to host educational workshops and demonstrations.

Implementation plans will be included in Appendix E. Specific BMPs are proposed and reductions are estimated, as are the effects of those reductions on bacteria levels in the shellfish waters. There is a gap between what is required to meet standards and what reductions can be achieved from the identified BMP sites. This problem is primarily the result of having to retrofit the structural stormwater BMPs. Suitable sites for BMPs are limited for numerous reasons, including privately-held land, unavailable or inadequate space for BMPs before reaching jurisdictional waters, and limitations on construction and maintenance access.

The implementation plans will follow the Nine Key Elements for implementing watershed plans using incremental Section 319 funds. The nine elements include:

1. Identify the cause of impairment and pollutant sources.
2. Estimate the load reductions expected from management measures.
3. Describe the nonpoint source management measures that will need to be implemented to achieve the load reductions in 2 and the critical areas in which those measures will be needed to implement this plan.
4. Estimate the amount of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.
5. Include an information and educational component to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measure that will be implemented.
6. Provide a schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.
7. Describe the interim milestones for determining whether nonpoint source management measures or other control actions are being implemented.
8. Provide a set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.
9. Monitor to evaluate the effectiveness of the implementation efforts over time, measured against criteria established under 8 above.

Mechanisms for reducing fecal coliform will include implementation of appropriate structural BMPs, education on source reduction and individual homeowner BMP installation, and local regulations or ordinances related to zoning, land use, or stormwater runoff controls.

Following NCDENR recommendations, the required reductions will be implemented in an iterative process that first addresses those sources with the largest impact on water quality, with consideration given to ease of implementation and cost. The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

In terms of protecting people from ingesting contaminated shellfish, DEHSS has a conditional area management plan in place for White Oak River area. The Conditionally Approved Closed areas are usually closed to shellfish harvesting. If an extended period without rainfall occurs and the sample results indicate fecal coliform levels to be acceptable, recommendations will be made to Division of Marine Fisheries to temporarily reopen the area. The areas will be immediately closed to shellfishing after 0.5 inches or greater of rainfall within 24 hours.

The preliminary source assessment suggests that wild animals and pets are the major sources of fecal coliform loading to the TMDL waters. Therefore, reductions for fecal coliform should first be sought through installation and maintenance of BMPs to tackle loads from the primary sources. It is possible that in some waters for which TMDLs will be developed, the waterbody may still not meet water quality standards after all identified potential BMPs have been installed. However, neither the State of North Carolina nor EPA is proposing the elimination of wildlife to allow for the attainment of water quality standards. This is considered to be an impracticable and undesirable action. While managing the overpopulation of wildlife remains an option for State and local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

5.0 STREAM MONITORING

The Shellfish Sanitation Section of DEH should continue the systematic random sampling strategy in the TMDL waters, even if the waters are eventually permanently closed to shellfish harvesting. This system is well-suited for monitoring and classifying shellfish waters and it can serve to track the effectiveness of TMDL implementation and water quality improvements. DEHSS will continue to close the areas if levels of fecal coliform indicate that harvesting shellfish from those waters could cause a public health risk.

6.0 FUTURE EFFORTS

The North Carolina Coastal Federation and the Town of Cedar Point will take the primary lead in the TMDL implementation. Grant funds will be sought to implement the BMPs and programs recommended in this implementation strategy. Additionally, bacteria source tracking may be used to confirm the source estimates presented in this document and target major fecal coliform sources for reduction. The primary grant funding sources are expected to be the North Carolina Clean Water Management Trust Fund, the Section 319 fund administered by NCDWQ, and perhaps the North Carolina Division of Water Resources.

7.0 PUBLIC PARTICIPATION

A draft of the TMDL will be publicly noticed through various means, including two local newspapers, the Carteret County NEWS-TIMES and the New Bern Sun Journal, and the North Carolina Water Resources Research Institute email list-serve. The TMDL will be available on DWQ's website http://h2o.enr.state.nc.us/tmdl/ during the comment period.

A stakeholder process has been conducted as part of this project. An introductory meeting took place in January 2007, which introduced the project and educated attendees about DEHSS's work and TMDLs. Additional meeting have kept stakeholders informed of project progress and organized volunteer samplers. A final meeting will be held to present the TMDL and implementation strategies.

8.0 FURTHER INFORMATION

Further information concerning North Carolina's TMDL program can be found on the Internet at the Division of Water Quality website:
http://h2o.enr.state.nc.us/tmdl/

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

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Appendix A. Observation Time Series Plots and Water Quality Data

Fecal coliform observation data from 1996 to 2008 are analyzed and presented in the following figures. The time series together with 30-month median (Standard 1 in figures) and 90th percentile (Standard 2 in figures) are plotted in Figure A-1 to Figure A-4.

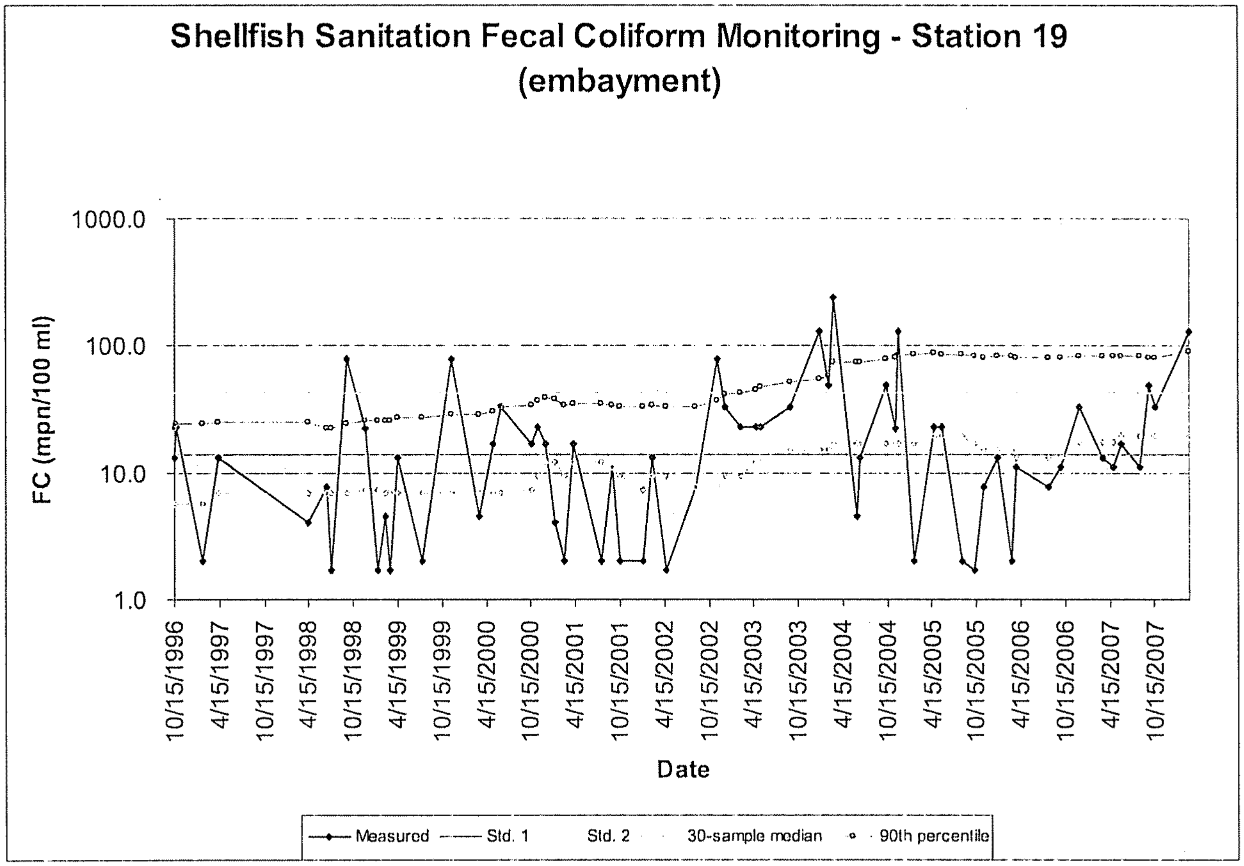


Figure A-1: Time series plots of fecal coliform observations in Hills Bay Embayment Station 19

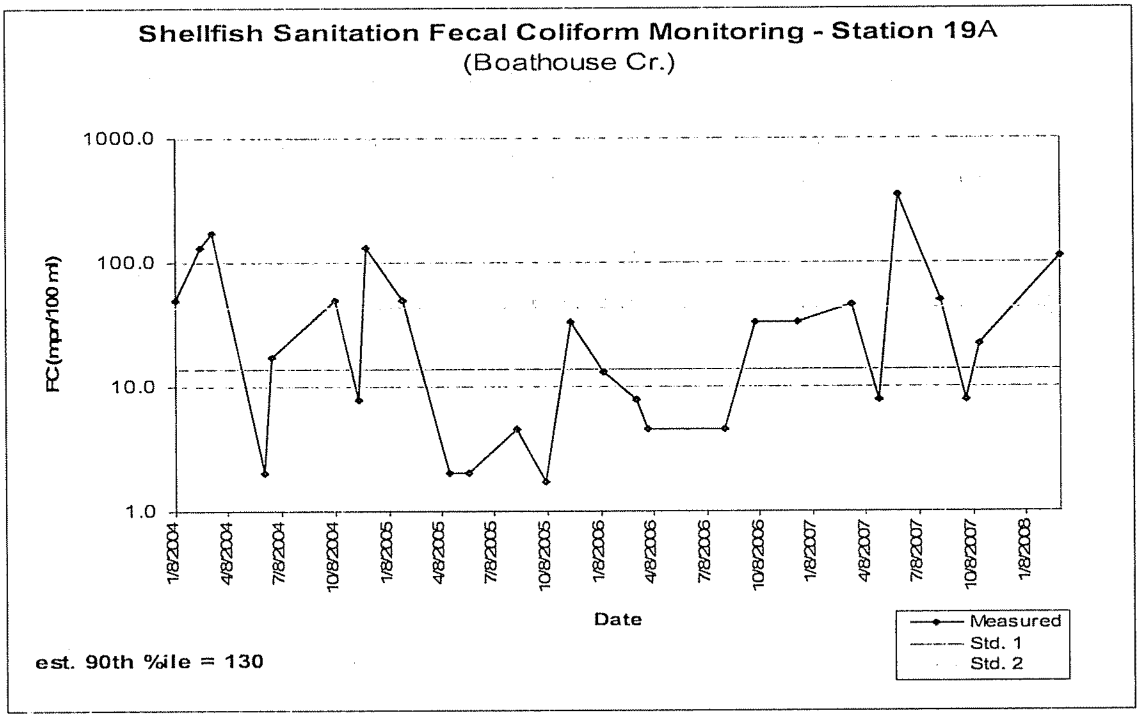


Figure A-2: Time series plots of fecal coliform observations in Boathouse Creek Station 19A

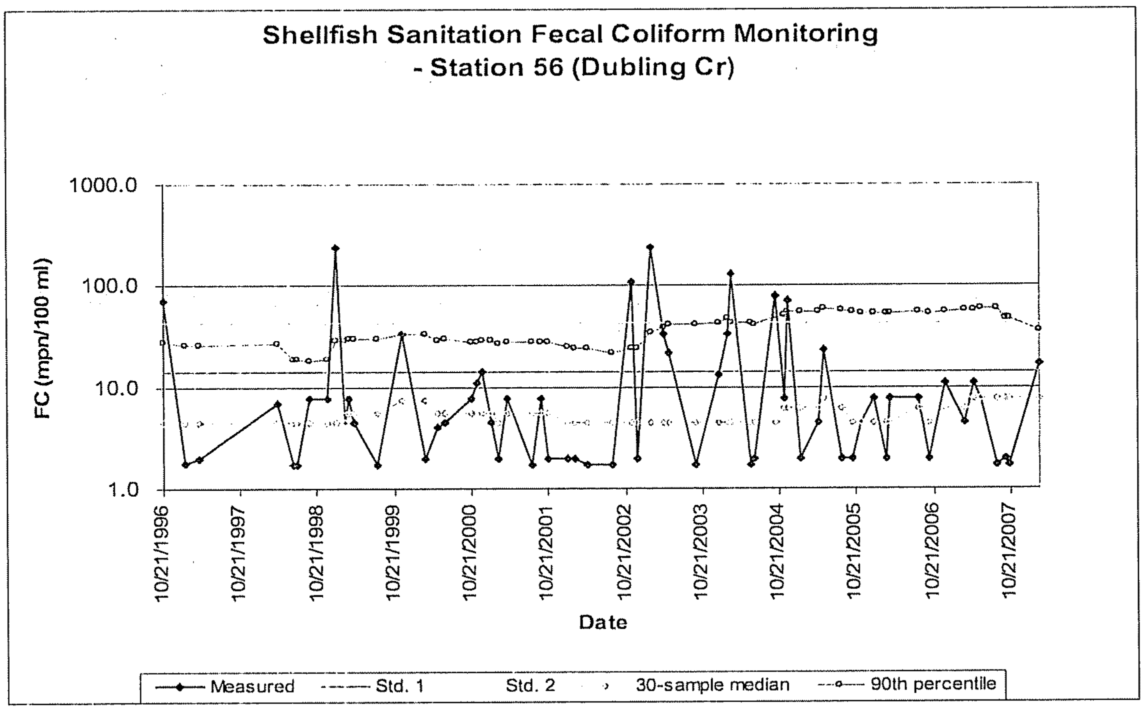


Figure A-3: Time series plots of fecal coliform observations in Dubling Creek Station 56

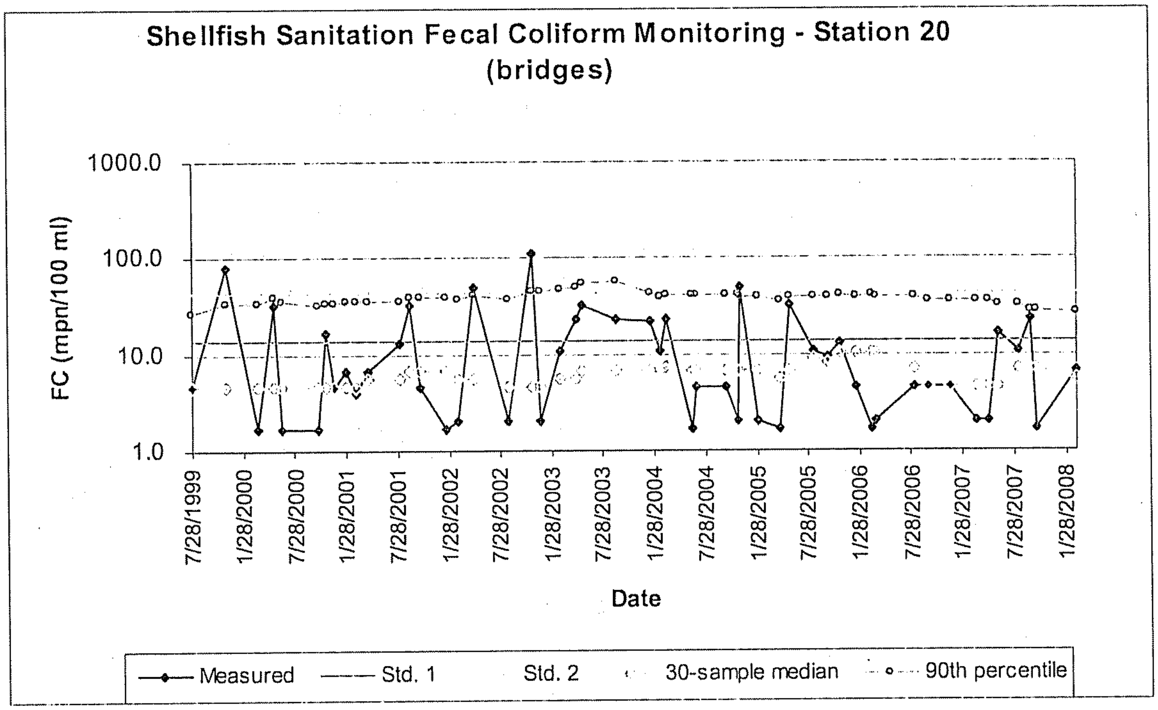


Figure A-4: Time series plots of fecal coliform observations in NC 24 Bridge Station 20

Appendix B. Watershed Delineation and Tidal Prism Model Segmentation

The land use delineation cited in Section 1.3.1 used similar categories to the USGS Multi-Resolution Land Cover (MRLC) data. There are 23 land use categories in the MRLC data. For modeling purposes, the land use categories were further grouped into eight categories. The land use categories are listed in Table B-1. The model group is used for the watershed model. The pervious and impervious land uses were estimated based on the perviousness, which are listed in Table B-1 in Pervious/impervious column. The number represents the percent of pervious land in that land use category.

Table B-1: MRLC land use categories and modeling land use categories

Model LUID	Model Grouping	Land Use Code	MRLC Category	Pervious / impervious
1	DOT_Impervious	NA	NA	0
2	DOT_Pervious	NA	NA	1.0
3	Forest	41	Deciduous Forest	1.0
3	Forest	42	Evergreen Forest	1.0
3	Forest	43	Mixed Forest	1.0
3	Forest	51	Deciduous Shrub land	1.0
3	Forest	52	Evergreen Shrub land	1.0
3	Forest	53	Mixed Shrub land	1.0
4	Pasture	71	Grasslands/Herbaceous (Natural/Semi Natural Herbaceous)	1.0
4	Pasture	81	Pasture/Hay	1.0
4	Pasture	85	Other Grasses/(Urban Grasses)	1.0
6	Urban Pervious	21	Low Intensity Residential	0.85
6	Urban Pervious	22	High Intensity residential	0.35
6	Urban Pervious	23	High Intensity Commercial/Industrial/Transportation	0.15
7	Wetlands	91	Woody Wetlands	1
7	Wetlands	92	Emergent Herbaceous Wetlands	1.0
21	Urban Impervious	21	Low Intensity Residential	0.15
21	Urban Impervious	22	High Intensity residential	0.65
21	Urban Impervious	23	High Intensity Commercial/Industrial/Transportation	0.85

The geometry information used for Tidal Prism model is listed in Table B-2.

Table B-2: Geometry information used for Tidal Prism model

Hills Bay Embayment

Segment	Distance from mouth (km)	High Water Volume ($m^3 \times 10^6$)	Tidal Prism ($m^3 \times 10^6$)	Depth (m)
M0_1	0.00	0.00	0.016	0.00
M0_2	0.09	0.016	0.007	0.73
M0_3	0.17	0.009	0.00	0.64
B2_1	0.00	0.00	0.001	0.00
B2_2	0.15	0.001	0.00	0.30

Boathouse Creek

Segment	Distance from Mouth (km)	High Water Volume ($m^3 \times 10^6$)	Tidal Prism ($m^3 \times 10^6$)	Depth (m)
M0_1	0.00	0.00	0.029	0.00
M0_2	0.20	0.028	0.014	0.66
M0_3	0.34	0.013	0.004	0.50
MO_4	0.42	0.005	0.00	0.43
B3_1	0.00	0.00	0.001	0.00
B3_2	0.05	0.001	0.00	0.30

Dubling Creek

Segment	Distance from Mouth (km)	High Water Volume ($m^3 \times 10^6$)	Tidal Prism ($m^3 \times 10^6$)	Depth (m)
M0_1	0.00	0.00	0.099	0.00
M0_2	0.25	0.099	0.071	0.80
M0_3	0.43	0.051	0.021	0.68
MO_4	0.53	0.021	0.010	0.67
MO_5	0.65	0.018	0.00	0.63
B3_1	0.00	0.00	0.011	0.00
B3_2	0.20	0.02	0.00	0.62

Appendix C. Source Assessment

Nonpoint Source Assessment

In order to determine the sources of fecal coliform contribution and reduction needed to achieve water quality criteria, and to allocate fecal coliform load among these sources, it is necessary to identify existing sources. The nonpoint source assessment was conducted using available data collected in the watershed. Multiple data sources were used to determine the potential sources of the fecal coliform load from the watershed. The data used for source assessment are:

1. Land use data created for this project based on 2004 aerial photography
2. Shoreline sanitary survey data (DEHSS)
3. Shoreline survey conducted by NC Coastal Federation
4. Pet survey results (NC Coastal Federation, 2007)
5. Fecal coliform monitoring data (DEHSS and NC Coastal Federation)
6. USGS digital elevation model (MDE) data
7. Stream GIS coverage (EPA, 1994)
8. Septic survey data (NC Coastal Federation, 2007)
9. Wildlife population estimates (NCSU, Duke University, 2004)

In the southeast White Oak River area, wildlife contributions, both mammalian and avian, are natural and may represent a background level of bacterial loading. Pet contributions usually occur through runoff from streets and land. Since there are no direct point source discharges to the embayment and there is a lack of information available for the discharge from boats, it is assumed that human loading results from failures in septic waste treatment systems or systems that are sited on soils that do not contain the waste. The major nonpoint source contributors assessed for this project are summarized in Table C-1. The potential nonpoint sources were grouped into three categories: wildlife, human, and pets. It should be noted that livestock are not a major source of fecal coliform in this area. Due to insufficient data sources, the source assessment method does not account for boat discharge, resuspension from bottom sediment, and the potential for regrowth of fecal coliform in the embayment.

Table C-1: Summary of Nonpoint Sources

Category	Source
Wildlife	raccoon, deer, goose, duck, rodents, and wild turkey
Human	septic systems
Pets	dogs and outdoor cats (including feral ones)

A. Human Contributions

Human loading can result from poorly functioning or failures in septic waste treatment systems. Poor septic system function in the Ocean Spray subdivision of the Boathouse Creek watershed is likely the result of soils that are not conducive to septic systems either because they are not permeable (i.e., clay rich) or highly permeable (i.e., very sandy). It is assumed that the failing of a septic system is a direct load contribution from humans. The estimation of human contribution is based on human population, properties, the number of septic systems in the watershed, and an estimated septic system failure rate. Also, to account for the poorly functioning systems due to local soils, the groundwater concentration was set in the residential areas of the Boathouse Creek watershed at 500 MPN/100 ml. This appears to be a conservative (i.e., high) estimate based on groundwater concentrations measured for the Charlotte fecal coliform TMDLs (2002). Other urban areas in the project were assigned groundwater concentrations of 300 MPN/100 ml. Non-urban areas were assigned groundwater concentrations of 30 MPN/100 ml.

The human population and the number of households were estimated from parcel data. The watershed survey identified which parcels were developed and would have a septic system. An average of 2.3 people per residence/septic system was assumed. A survey was conducted in the watersheds of Boathouse Creek, Hills Bay, and the NC 24 Bridge area in 2007. The number of households surveyed was 201, of which about 35% of the households returned the survey. The septic systems were counted during the survey. The results are shown in Table C-2. The mean ratios of septic and dog to the household obtained from survey results were used to estimate the number of dog and septic in the area.

Table C-2: Proportional Population, Households, and Septic Systems in the Project Area

	Parcels	Developed/ Septics	Responded to Survey	Dogs	Cats (outdoor)
Bridge Area	56	41	11	2.5	0
Boathouse	229	135	52	10	5
Embayment	32	25	7	2.5	0

Since there is no public sewer system in the project watersheds, the failing of septic is the main contribution of fecal coliform sources from human. It is assumed that the human contribution is attributed to septic systems (although recreational vessels might be a source, we have not attempted to quantify that source). The human contribution to the restricted shellfish harvesting areas was calculated using the number of septic systems, the average number of people per septic system, and the failure rate of the septic systems. The estimated fecal coliform loading from humans is calculated as follows:

$$\text{Load} = P\ S\ F_r\ C\ Q\ C_V$$

Where

P = number of people per septic system

S = number of septic systems in the restricted area

F_r = failure rate of septic systems
C = fecal coliform concentration of wastewater
Q = daily discharge of wastewater per person
C_V = unit conversion factor (37.854)

A septic system failure rate of 18 percent was assigned based on publications by NCDEH (2000) and USEPA (EPA600/R-00/008, Nelson et al., 1999). This is also a conservative estimate. Even so, the septic system portion of the total bacteria load is approximately one-tenth of 1 percent. This assumed failure rate is separate from the increased groundwater concentrations discussed above.

B. Pet Contributions

Pet contributions usually occur through runoff from either an urban or a low-density residential area. Dogs are the only domestic pets assumed to contribute fecal coliform. Dog license information can be obtained from the county; however, these data will not include unlicensed or feral animals. This is likely to cause an underestimation of the total population. Therefore, the dog populations for restricted shellfish harvesting areas in the project watersheds were estimated based on the number of households (see Table C-2) and ratio of dog to household obtained from the survey. The fecal coliform contribution from the dog population was estimated using a production rate of 4.09×10^9 counts/dog/day (ASAE, 1998). Using information from Table C-2, estimated fecal coliform loading from dogs is calculated as follows:

$$LOADING_{dog} = P\ R\ PR_{dog}$$

where:
P = number of households in specified restricted area
R = ratio of dogs per household in this region
PR_{dog} = average fecal coliform production rate for dogs

Outdoor cats were added to residential land in the same manner. The concentration used for fecal coliform in cat waste was 5×10^9 counts/cat/day (USEPA, 2001). Additionally, feral cats were noted in a number of the survey responses regarding observed wildlife so cats were added to pasture and forest land at a rate of 0.04 to 0.08 animals per acre.

C. Wildlife Contributions

According to the survey results, there are more than 15 wildlife species exist in the watershed. The most abundant wildlife species include deer, squirrel, raccoon, fox, possum, rabbit, goose, and duck. Fecal coliform from wildlife can be from excretions on land that are subject to runoff or direct deposition into the stream network or shellfish water. Wildlife populations within the watershed were estimated based on a combination of information from the Jarrett Bay survey conducted by Duke University with input from a wildlife biologist from North Carolina State University (Wolf and Kirby-Smith, 2004) and the North Carolina Wildlife Resources

Commission (2005) as listed in Table C-3. Information from the Maryland DNR Wildlife and Heritage Service (2003) was used in estimating duck and geese densities.

Table C-3: Wildlife Densities

Wildlife	Population Density (animals/acre)	Notes
Deer[2]	0.023 - 0.047	Higher density on forest and wetland.
Geese[3]	0.01 – 0.16	Entire watershed, usually lower density except for wetlands in Dubling and Boathouse
Duck[3]	0.01 – 0.16	See above for geese. Not as high as geese on urban land.
Raccoon[1]	0.2 – 1.5	Highest in Dubling Creek and urban portions of Boathouse Creek.
Rodents[1]	2.3 – 7.8	
Turkey[2]	0.016 – 0.023	Higher density on forest and wetland.

[1] Wolf and Kirby-Smith (2004); [2]NC WRC(2005); [3]MD DNR (2003)

The habitat areas for each species were determined using GIS land use developed for this project. Wildlife populations were obtained by applying assumed wildlife densities to these extracted areas. The populations of the wildlife were obtained by applying density factors to estimated habitat areas. The fecal coliform contributions were estimated based on the estimated number of wildlife and fecal coliform production rates, which are listed in Table C-4. To obtain the total wildlife contribution, population density is multiplied by the applicable acreage or stream mile and that product is multiplied by fecal coliform production rates for each animal.

Table C-4: Wildlife Fecal Coliform Production Rates (ASAE, 1998)

Source	Fecal Coliform Production (counts/animal/day)
Deer	5.00E+08
Goose	4.90E+10
Duck	2.43E+09
Rodent	3.40E+07
Raccoon	1.00E+10
Turkey	9.30E+07

All of the aforementioned source assessment data were entered into a spreadsheet called Fecal Tool, which calculates accumulation rates on the different land covers, and loading from direct sources such as leaking septic systems. TetraTech, Inc. developed Fecal Tool (2001). Output from this spreadsheet was used as the initial estimates for the corresponding parameters in the water quality model. Some of the input values calculated in spreadsheet were later altered through calibration (e.g., accumulation rates).

D. Livestock Contributions

The fecal coliform contribution from livestock is through the manure spreading processes and direct deposition during grazing. No livestock were included in the modeling because there is currently no livestock in the project area. Cows and goats were present as recently as 2006 but their numbers were believed to be very low and would not have had much impact on the overall loading.

E. Nonpoint Source Summary

The complete distributions of the source loads are listed in Tables C-7 and C-8, along with counts/day for each loading.

Table C-7: Estimated Distribution of Fecal Coliform Source Loads in the Watersheds

Creek	Pet	Septic	Wildlife	Total
Dubling	3.92E+10	0.00E+00	3.91E+12	3.95E+12
Boathouse	2.50E+11	1.48E+09	6.50E+12	6.75E+12
Hills Bay	6.98E+10	3.05E+08	5.01E+11	5.71E+11

Table C-8: Estimated Percent Distribution of Fecal Coliform Source Loads in the Watersheds

Creek	Pet	Septic	Wildlife	Total
Dubling	1.0	0.0	99.0	100.0
Boathouse	3.7	0.02	96.3	100.0
Hills Bay	12.2	0.1	87.7	100.0

Note: The septic contribution in the tables above is only from failing systems and does not include groundwater loading from poorly functioning systems.

The complete distributions of these source loads for the drainage areas of Dubling Creek, Boathouse Creek, and the Hills Bay Embayment are listed in Tables C-9 to C-11 in counts/day for each land use. These estimates are direct inputs on the land use and do not account for decay. The estimates were derived by multiplying the calibrated accumulation rates by the respective land use area for each watershed.

Table C-9: Distribution of Fecal Coliform Source Loads by Land Use (Boathouse Creek)

Land use	Loading Counts/day	Loading Percent
Wetland	7.35E+11	10.8
Pasture/Herbaceous	1.96E+11	2.9
Forest	1.51E+12	22.1
Urban	4.17E+12	61.1
NCDOT	2.19E+11	3.2
Total	6.83E+12	100

Table C-10: Distribution of Fecal Coliform Source Loads by Land Use (Dubling Creek)

Land use	Loading Counts/day	Loading Percent
Wetland	2.62E+12	68.4
Pasture/Herbaceous	5.85E+10	1.5
Forest	9.42E+11	24.6
Urban	2.10E+11	5.5
NCDOT	NA	0.0
Total	3.83E+12	100

Table C-11: Distribution of Fecal Coliform Source Loads by Land Use (Hills Bay Embayment)

Land use	Loading Counts/day	Loading Percent
Wetland	3.21E+10	5.6
Pasture/Herbaceous	1.74E+11	30.2
Forest	9.81E+10	17.0
Urban	1.90E+11	33.0
NCDOT	8.15E+10	14.2
Total	5.76E+11	100

The loads shown above are for fecal coliform accumulation on the land surface only. They are not the loading delivered to the shellfish embayments. To get the delivered load, decay, maximum storage, and transport must be simulated. These processes are captured in the modeling.

NCDOT is considered to be the lone point source in the TMDLs because no sanitary sewer discharges are permitted in the project area. NCDOT has a number of roads in the project area, including Highways 24 and 58, which are part of their statewide NPDES stormwater permit.

Stormwater has previously been considered to be a nonpoint source; however, NPDES-permitted sources are to be included in the wasteload allocation (WLA). Hence, NCDOT's contribution will be separately tracked from the remaining sources so that a specific load and reduction percentage can be assigned to it.

G. Watershed Survey for Project

White Oak Shellfish Restoration Project
Watershed Survey
May 21, 2007

This watershed survey includes bacteria monitoring, a bacteria source assessment, and topographic surveys. These programs are designed to improve the accuracy of the TMDL modeling and to contribute to more effective implementation plans. The North Carolina Coastal Federation will implement the programs in the watershed survey. Some of the procedures for this work are detailed in the Quality Assurance Project Plan (QAPP).

Bacteria Monitoring

32 preliminary monitoring stations have been identified by project staff. The monitoring stations are shown in the attached map (sampling_sites_100506.pdf) and are delineated in sampling_stns_100506.shp. The primary focus of the monitoring is to identify bacteria sources and the secondary focus is model calibration.

Samples should be collected during wet and dry conditions, defined as follows:

- wet conditions – sample taken within 24 hours of a rainfall totaling at least 0.5" in 24 hours
- dry conditions – no rainfall in past 72 hours.

The recent rainfall totals should be determined from a local rain gage that has been judged to be accurate.

Samples taken from shellfish waters (embayments, not creeks) should be collected within 1 hour of each other per subwatershed (e.g., samples from Frank's embayment should be collected within one hour, but the Boathouse Creek embayment samples can be collected within a separate hour).

Samples should be taken on an approximately monthly basis. The monitoring schedule can begin with a round of dry weather sampling whenever the Coastal Federation is ready. Once a dry weather round has been conducted, the focus should be on monitoring during wet conditions. Preliminarily, two dry rounds and three wet rounds will be targeted during the project.

Samples will be collected for a period of approximately 5-6 months. Some sites may be dropped and others may be added. Additional sampling may be conducted to identify individual sources, such as failing septic systems, specific drainage ditches or storm pipes, pet kennels, etc. If possible, Baker Engineering should be contacted prior to sampling to discuss weather conditions and sampling goals.

240 samples were budgeted in the grant proposal and replicates are required by the QAPP.

Safety is a primary concern so samplers should avoid being on open water in inclement weather. Also, if tide conditions do not allow access to all monitoring sites, some may be skipped.

The purpose of the source assessment is to estimate the populations of pets, livestock, and wildlife and the number of septic systems in the project area. This work is based on that done for the Jarrett Bay TMDL by Bill Kirby-Smith and his student Katie Wolff from the Duke University Marine Lab.

Landowner surveys
Using GIS parcel data, Baker Engineering will develop a database of landowners in the project watersheds. There are approximately 230 parcels in the Boathouse Creek subwatershed, 30 parcels in Frank's embayment subwatershed, and 55 parcels in the bridge subwatershed (see parcel spreadsheets). The database will include the landowners' names and addresses. Coastal Federation will identify the landowners' telephone numbers and missing addresses. They will then conduct a telephone survey to estimate the number and types of pets and wildlife observed by residents in each subwatershed. The survey questions will be:

1. Do you have pets and/or livestock?
2. If yes, what type(s) and how many? If you have cats, do they spend time outside?
3. Have you observed wildlife on or within the vicinity of your property? If yes, what type?

Residences identified as uninhabited will be removed from the contact list. For residences that are identified as vacation homes, the Coastal Federation will contact the real estate office to gage the properties' policies (e.g., no pets) and approximate rental history.

In-person interviews will be attempted if the landowner is unreachable by phone. If they are not home when visited, Coastal Federation will tape a paper survey to their door with contact info. The survey will have the questions listed above. The landowners will be noted as 'non-responsive' if telephone and in-person interviews prove unsuccessful.

NOTE: Residents contacted for this survey may want to know what these questions are for. The interviewer can tell them that the survey is for identifying bacteria sources as part of a study to clean up local water bodies. Residents should not be required to make changes as a result of the study but assistance may be available if they are interested in making changes to help water quality.

Wildlife
Estimates per hectare for birds, small mammals (rats, mice, voles, moles, squirrels, etc), medium mammals (raccoons, opossum, rabbits, etc), and large mammals (bear and beaver) have been provided by Bill Kirby-Smith. Kirby-Smith contacted a wildlife biologist at NCSU for his best professional judgment and consulted NCSU wildlife information. Wildlife estimates were provided in densities per land use type (marsh, agriculture, suburban, and forest). Baker Engineering will use these estimates and conduct some follow-up investigation, including results from the landowner surveys.

Septic systems
Coastal Federation will count the number of inhabited and uninhabited homes in each subwatershed. It will be assumed that all residences have a septic system. When a failing system is detected, it should be noted. The Coastal Federation will check with the Carteret County Health Department (252-728-8499) about known septic system failures within the project area and about the septic systems along NC Highway 24 in the bridge subwatershed.

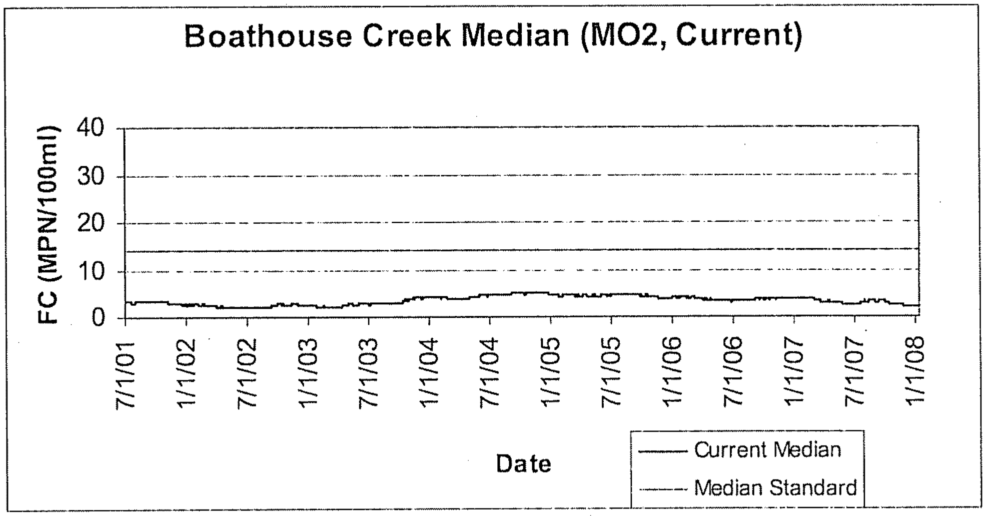
Topographic surveys

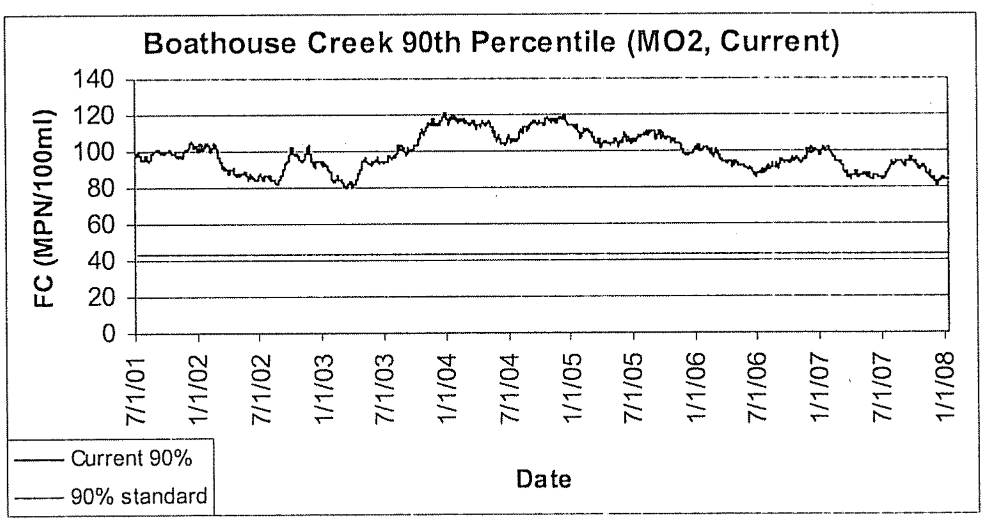
To improve the TMDL models of shellfish waters, we request that the Coastal Federation conduct longitudinal and lateral transects to id bathymetric (topographic) changes of 0.5 to 1.0 meters. The bathymetry surveys should be focused on the embayments in the project because the existing data have poor spatial resolution. See attached transect.pdf for the locations of the requested transects. GPS coordinates, the depth to bottom, the time, and approximate tide stage should be recorded for each station along a given transect. The goal of these surveys is to define a representative profile of the channel. If there is limited topographic relief then relatively few recordings will be needed for each transect.

The topographic surveys were completed in December 2006.

Appendix D. Model Results of Median and 90th Percentile

The 30-month median and 90th percentile were computed for Tidal Prism model segments. The time series plots of the existing condition and load reduction scenarios (if applicable) are presented in the following figures for Dubling Creek, Boathouse Creek, and Hills Bay embayment. MO2 is the Tidal Prism model segment that contains the DEHSS monitoring station.





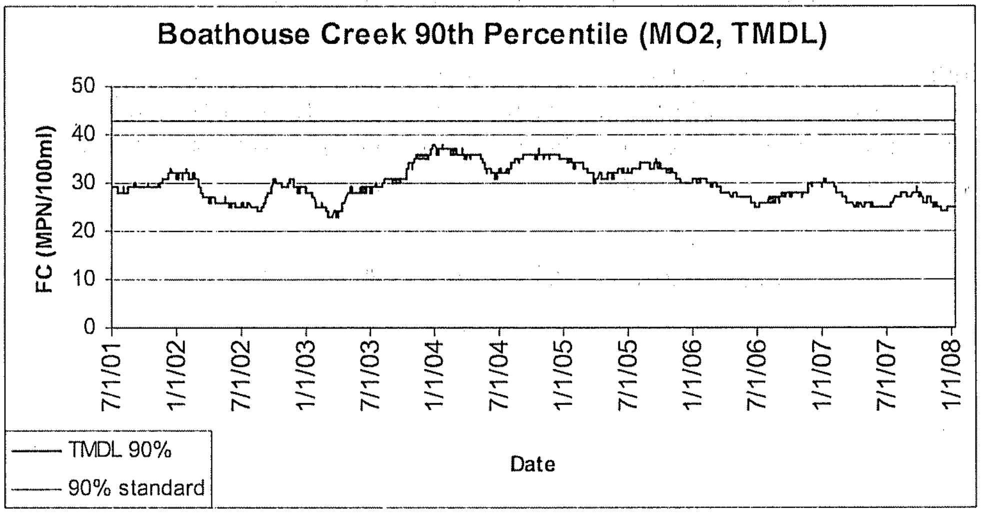
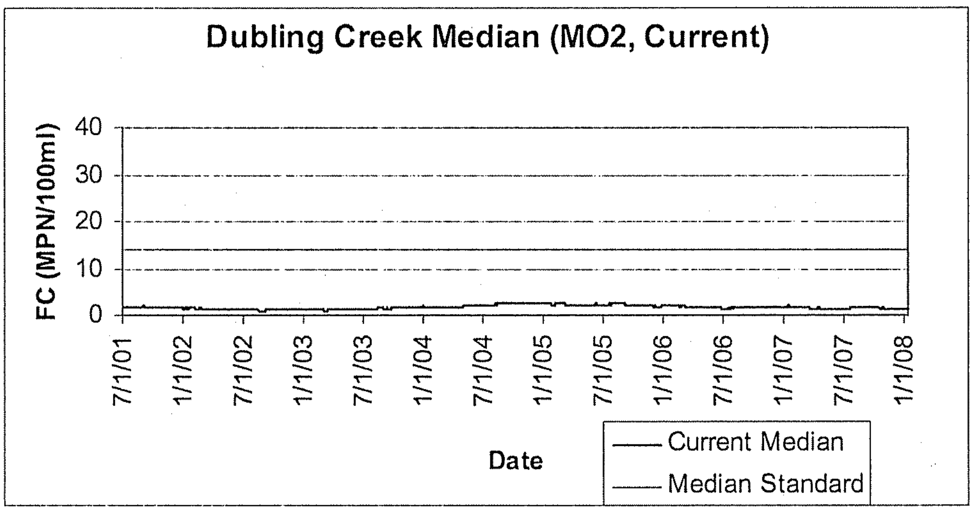
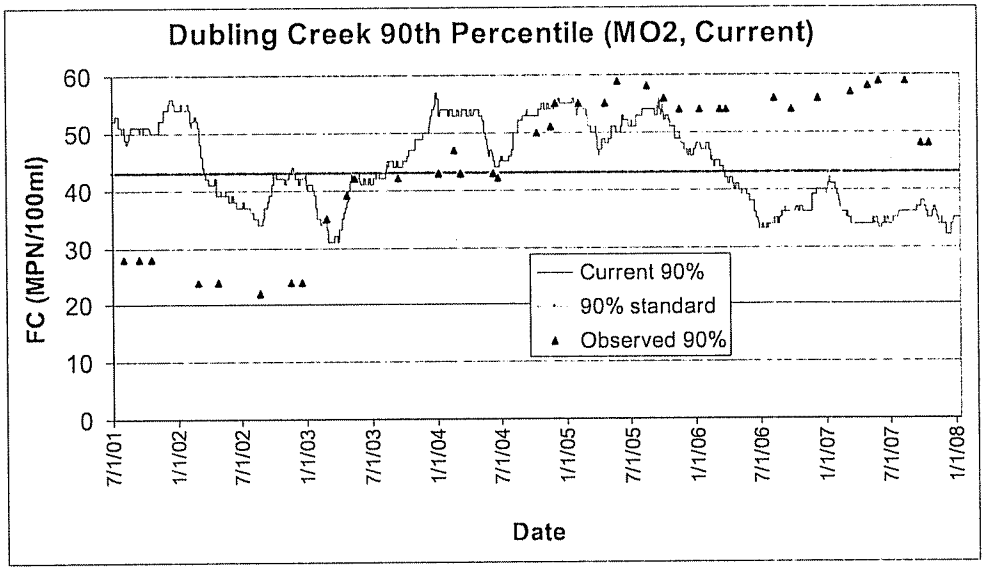


Figure D-1: Plots of 30-month Median and 90th percentiles for Boathouse Creek (MO2)





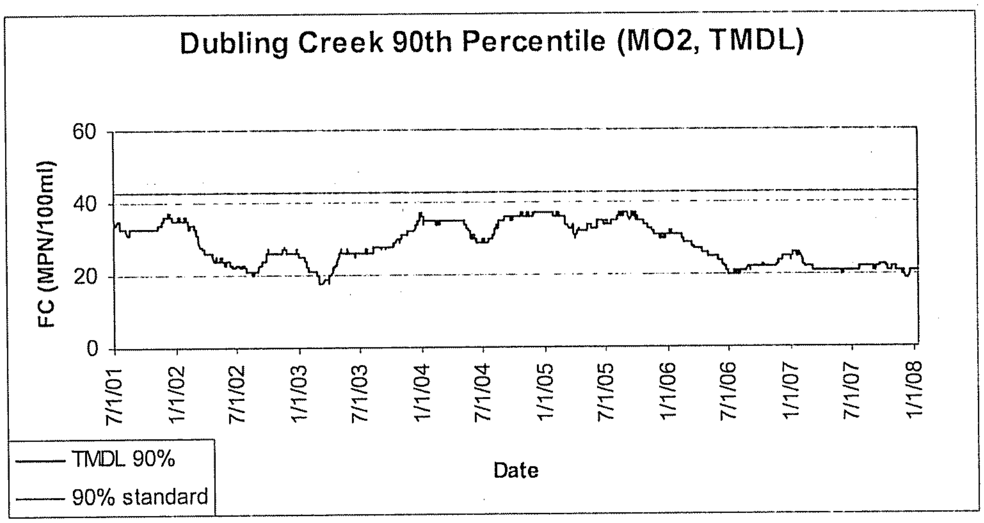
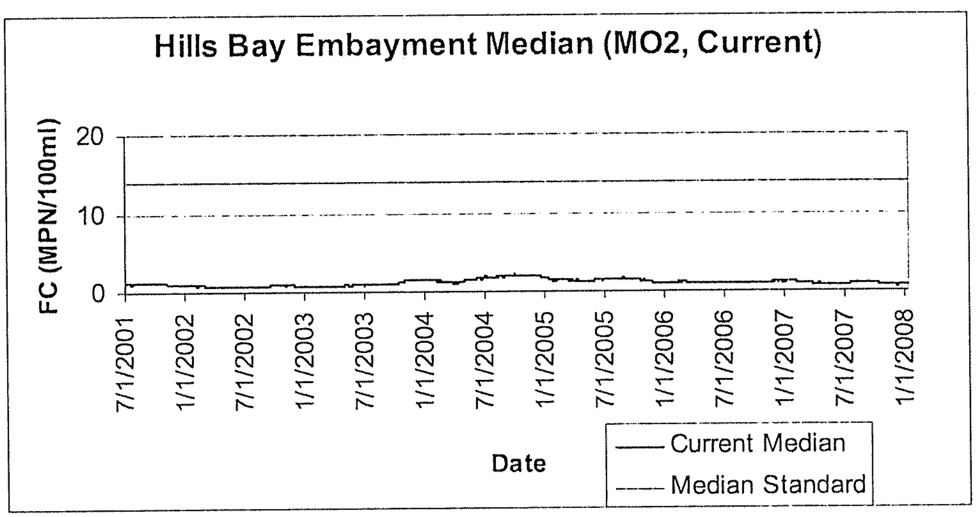
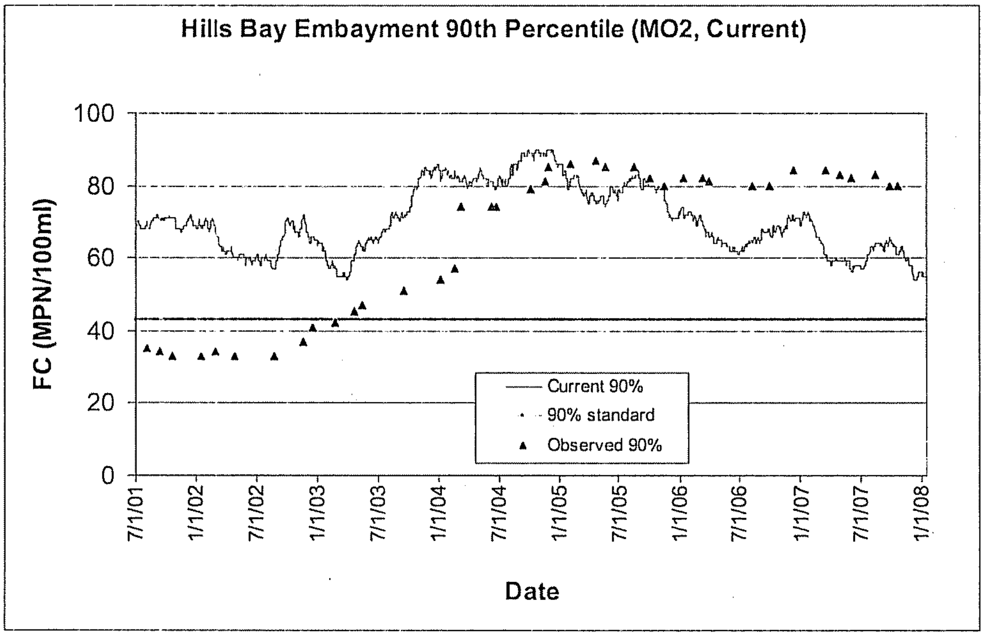


Figure D-2: Plots of 30-month Median and 90th percentiles for Dubling Creek (MO2)





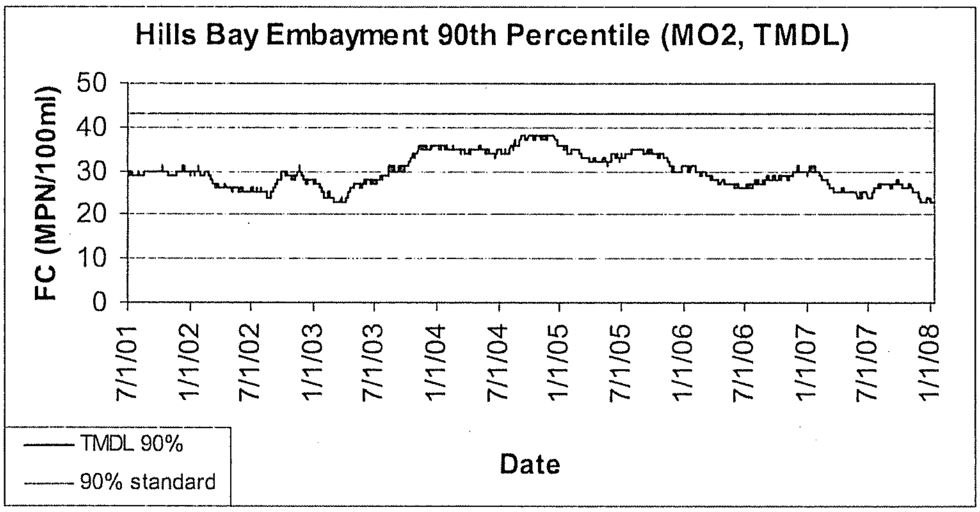


Figure D-3: Plots of 30-month Median and 90th percentiles for Hills Bay Embayment (MO2)

Appendix E. Implementation Plans

This appendix includes the watershed implementation plans developed in an effort to meet the specified TMDLs. These plans may be amended over time as part of an adaptive management approach as more information becomes available. Additional details for implementing the WLA will be submitted for DWQ's approval by NCDOT as per the requirements of that agency's NPDES stormwater management permit. The TMDLs developed in this project have the advantage of involving a small area, which allows for the consideration of most potential BMP locations and opportunities for reducing bacteria loading. Such detailed knowledge of TMDL watersheds can be difficult to obtain in larger areas.

In this document, a broad suite of integrated, site-specific stormwater BMPs, both structural and non-structural, will be outlined and described. The effects of these will be quantified with the aid of the TMDL models. This process will follow EPA's Nine Key Elements for implementing watershed plans using incremental Section 319 funds. The nine elements include:

1. Identify the cause of impairment and pollutant sources.
2. Estimate the load reductions expected from management measures.
3. Describe the nonpoint source management measures that will need to be implemented to achieve the load reductions in Element 2 and the critical areas in which those measures will be needed to implement this plan.
4. Estimate the amount of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.
5. Include an information and educational component to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measure that will be implemented.
6. Provide a schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.
7. Describe the interim milestones for determining whether nonpoint source management measures or other control actions are being implemented.
8. Provide a set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.
9. Monitor to evaluate the effectiveness of the implementation efforts over time, measured against criteria established under 8 above.

Mechanisms for reducing fecal coliform will include implementation of appropriate structural BMPs, education on source reduction, individual homeowner BMPs using low-impact development (LID) and other green infrastructure techniques, and local regulations or ordinances designed to more effectively control stormwater runoff.

This is a long-term, broad strategy that attempts to overcome the traditional failure of individual stormwater controls by employing varied integrated measures throughout the watershed. The structural steps outlined here are focused mainly on reducing the flow of runoff into the impaired waters by infiltrating or reusing runoff and not solely on source reduction. The National Research Council, in its report *Urban Stormwater Management in the United States*, recently identified the reliance on individual stormwater controls that attempt to reduce the sources of stormwater pollution as a general failure of stormwater TMDLs.

The overall percent load reductions required to meet the TMDLs are 55 percent for Hills Bay embayment, 70 percent for Boathouse Creek, and 14 percent for Dubling Creek. Dubling Creek's reductions could be achieved with several management actions, despite the fact that the sources are what typically have been considered to be uncontrollable. To reach such high reduction percentages in Hills Bay embayment and Boathouse Creek, local managers, residents, and visitors will need to do everything possible to meet the TMDLs. This may seem daunting but if the steps recommended in this document are implemented gradually over time, water quality will improve. There is considerable uncertainty in the TMDL targets, so implementation and continued monitoring may demonstrate that less bacteria reduction than predicted will allow the project waters to meet the designated use of shellfish harvesting.

The management strategies in this appendix will be organized first according to the 9 Key Elements and then geographically by shellfish water, including the NC 24 bridge area, which does not have a TMDL.

E1. Identify the cause of impairment and pollutant sources.

A more detailed examination of bacteria sources was provided in the source assessment in the TMDL (Section 2.0) and Appendix C. A recap is provided here for each watershed, as are figures that show the primary suspected bacteria sources in each area (Figures E1-E4). In general, bacteria transport to the shellfish waters is primarily the result of increased runoff due to alterations to watershed hydrology. The alterations include increases in impervious surfaces, piping, channel modification, pond construction, and swales. It is expected that if the natural, historic hydrology can be recreated to the maximum extent feasible, then surface runoff will be minimized and bacteria loading will be decreased.

Thus, recommended BMPs will first attempt to achieve runoff infiltration and where that is not practical, runoff detention or reuse will be the goal. BMPs such as infiltration basins or bioretention areas (also known as rain gardens) rely primarily on infiltration and filtration, respectively, while detention is the main treatment mechanism for wetlands or detention basins (also known as holding ponds). Of course, source reduction (e.g., pet waste disposal) is a necessary component of any strategy to reduce pollutant loading because it is typically the most cost effective.

Dubling Creek

Looking more specifically at the project watersheds, Dubling Creek is covered predominantly by forest and wetland and surrounded by the Croatan National Forest, and wildlife is expected to be the dominant bacteria source. These sources might at first appear to be uncontrollable. However, several human features make bacteria reductions possible. First, a walking trail has been constructed on the wetlands and forest area east of the shellfish embayments. People frequently walk their dogs on a trail that winds along the wetlands and forest east of the shellfish waters. Pet waste disposal stations are not present. The wetlands surrounding the shellfish waters are also intersected by an extensive series of mosquito ditches. Samples taken from the ditches as part of this project had high bacteria counts. The ditches allow bacteria to move from the wetlands to the embayment. Filling the ditches is not permitted because they are now considered to be fisheries habitat. On the other hand, allowing them to naturally fill by not maintaining them is a viable alternative. A pond dug in the headwaters of Dubling Creek to mine sand is likely to act as a better conductor of bacteria than a natural, forested landscape. The pond outlet could be retrofit to better and treat detain. Near the pond, a former mine site could be revegetated and an open field may benefit from a level spreader and filter strip. Finally, hundreds of acres of trees in the Croatan forest were destroyed during hurricanes more than a decade ago. Natural tree re-growth, possibly supplemented by plantings, will improve infiltration and evapo-transpiration.

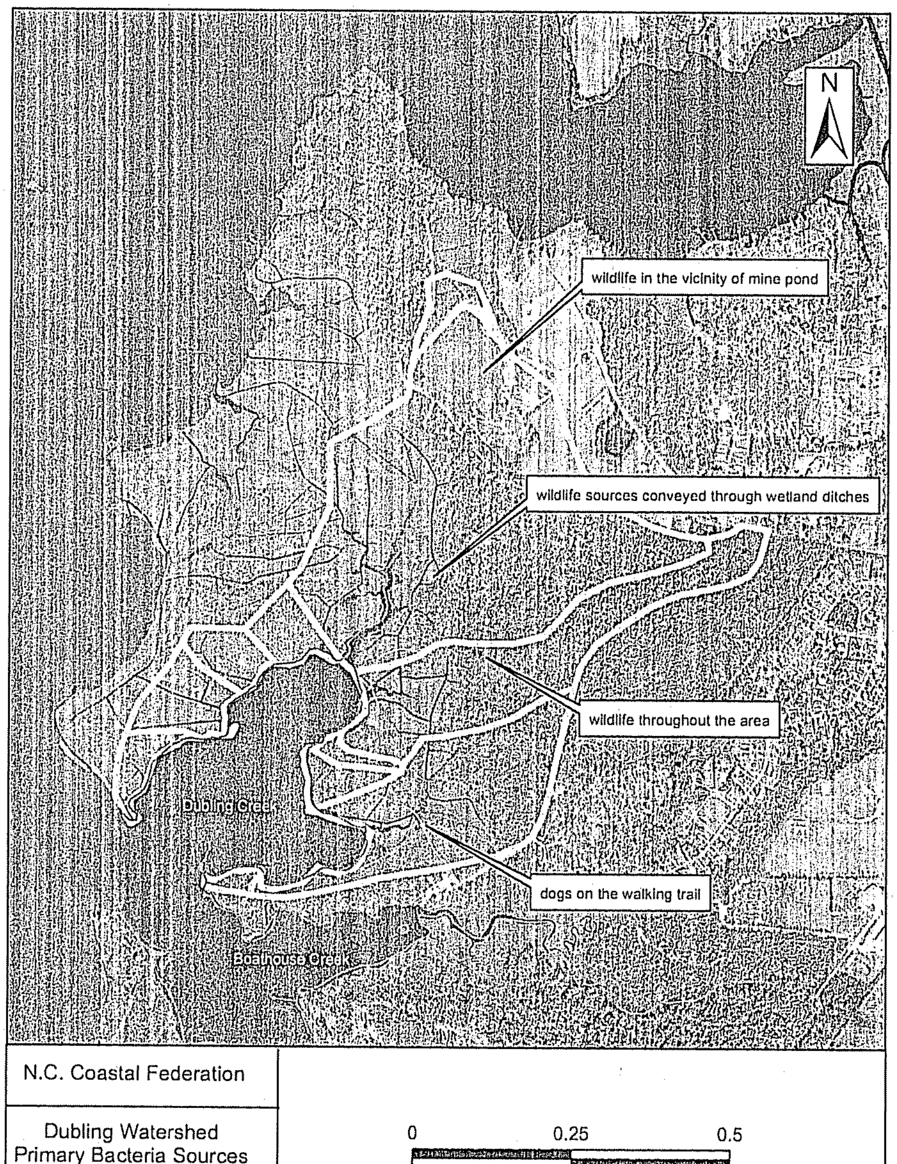
Boathouse Creek

Boathouse Creek is the most developed watershed, including commercial property along NC 24 and a sizable medium-density neighborhood (Ocean Spray). This development has mostly taken place under the stormwater paradigm of efficiently and quickly transporting rainfall offsite into the stream channel system via a network pipes and swales. These stormwater conveyance pipes can serve as habitat for bacteria-producing animals, including raccoons and rats.

The soils in the project area are not well-suited for septic systems because they are either very pervious or impervious. Consequently, septic waste is more likely to be transported to the drainage network than on sites with soils that allow for absorption. The Boathouse Creek watershed also has a large county park with open drainage swales. Pets are likely to be bacteria sources in this area, and the stormwater conveyance network is designed to collect runoff in the ditches and transport it to the riparian buffer surrounding upper Boathouse Creek. The U.S. Forest Service campground does not have pet waste disposal stations other than normal garbage disposal. NC 24 runoff has two primary exit locations: to the J-shaped ditch in the southern portion of the watershed and to a wetland area in the southeast. Project monitoring showed the former had considerably higher bacteria counts.

Hills Bay Embayment

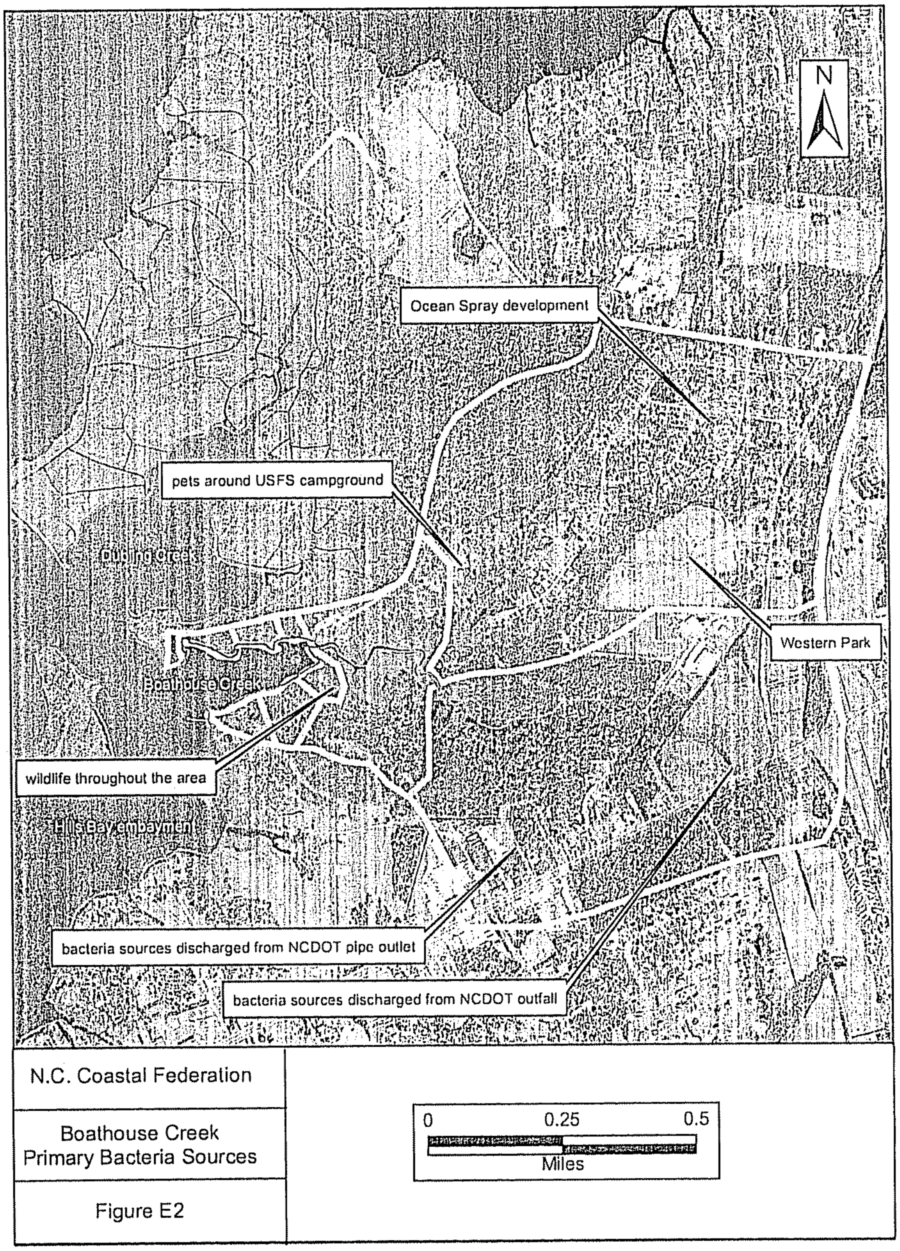
The Hills Bay embayment has a relatively small watershed. Much of it has been cleared of trees and low-density residential land surrounds west side of the creek. NC 24 runs along the south edge and is a significant stormwater source. Highway runoff has two primary exit locations. The first is a pipe outlet off Bluff Road. The conveyance is designed for all of the highway runoff in the watershed to go through this pipe. However, the road crown at the intersection of NC 24 and Masonic Drive was not constructed high enough, so highway runoff from this area goes down Masonic Drive instead of to the pipe network.



N.C. Coastal Federation

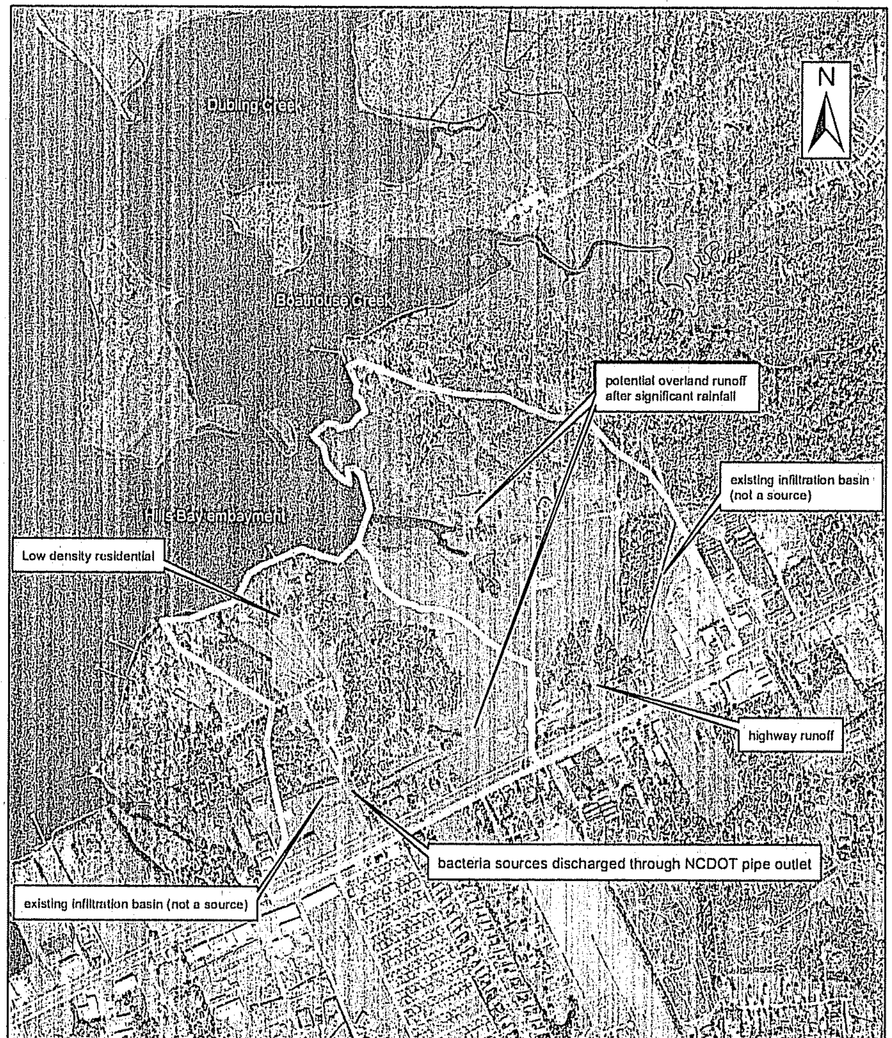
Dubling Watershed
Primary Bacteria Sources

Figure E1



Boathouse Creek
Primary Bacteria Sources

Figure E2



N.C. Coastal Federation

Hills Bay Embayment
Primary Bacteria Sources

Figure E3

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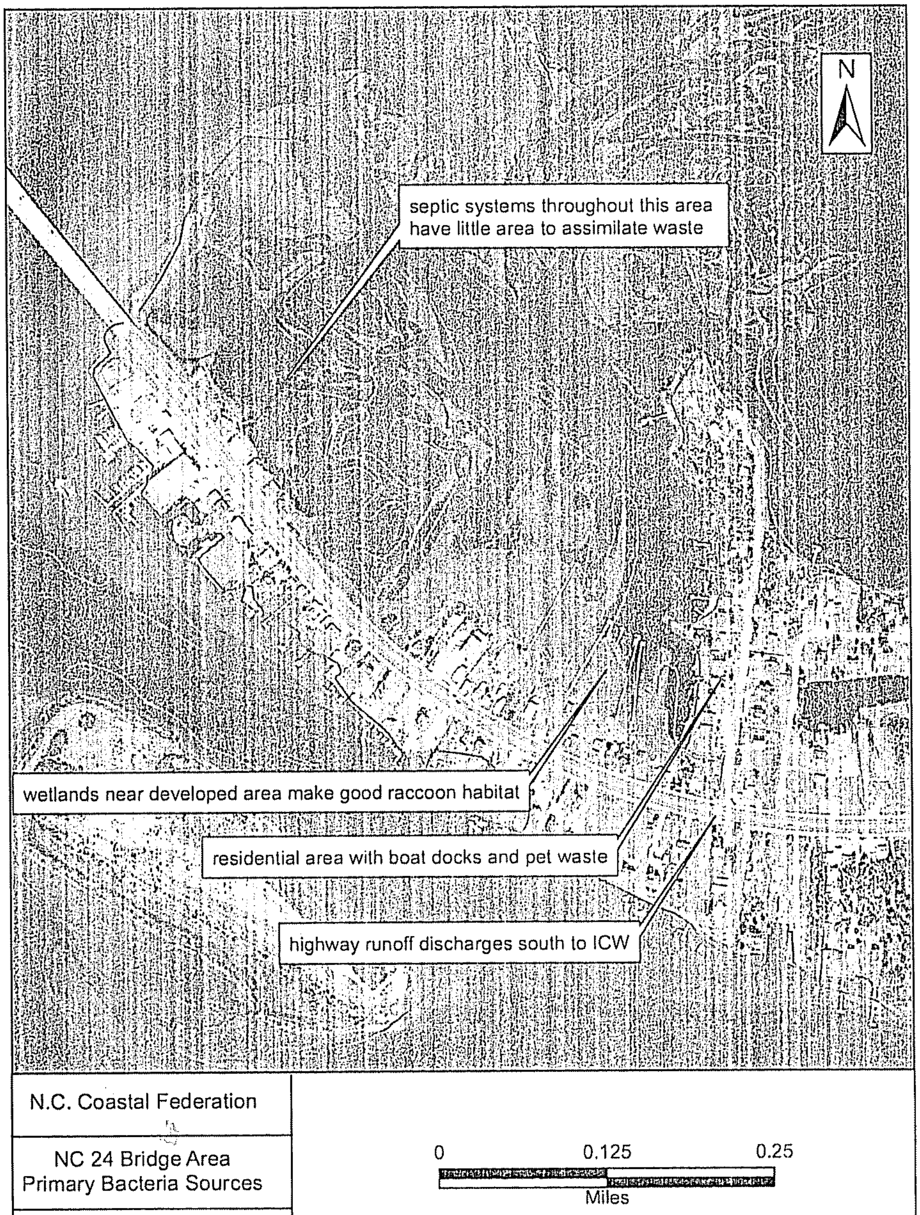
Miles



N.C. Coastal Federation

NC 24 Bridge Area
Primary Bacteria Sources

Figure E4

This drainage is captured in a blind ditch (no exit besides overflow) at the end of Masonic Drive and the fate of bacteria conveyed in the ditch is unknown. At Bluff Road, discharges of stormwater and the monitored bacteria concentrations have been high, particularly just after storms that follow longer periods of dry weather. The grassy areas throughout the Hills Bay embayment watershed are likely to host wildlife that produces fecal coliform bacteria. If overland flow is generated following heavy rains, as expected, the pastures are a notable source of bacteria.

NC 24 Bridge Area

The NC 24 Bridge shellfish waters have a small drainage area but it has a high degree of development, including businesses along NC 24 and residences along the east side. The septic systems have a short path to the waters and are likely older installations with uncertain operating performance. NC 24 runoff is piped underneath the road and discharged to the Intracoastal Waterway, which is immediately south of the project area, so it is likely not impacting water quality in the TMDL area. Runoff from the causeway bridge, though, drains directly to White Oak River. A medium-density residential area on Cedar Lane runs along the east side of the shellfish waters. In addition to septic system waste, pet waste is a leading potential bacteria source in this area.

As explained in Section 2.1 of the TMDL, this project included bacteria monitoring at 32 preliminary stations. The monitoring was conducted by NC Coastal Federation personnel and affiliated, trained volunteers. Additional sites were added to more specifically target bacteria sources, such as specific storm pipes, drainage ditches, or failing septic systems. All of the monitoring sites are shown in Figure 2.1.1. Generally, the project bacteria monitoring was helpful for identifying bacteria hot spots, and selecting and prioritizing BMP sites. Monitoring results are shown in Appendix F.

In Dubling Creek, the ditches surrounding the shellfish waters showed consistently high bacteria counts, particularly at sites DC5 and DC6, and DC8 through DC12. The ditches collect waste, which is then flushed into the shellfish waters with the tide, especially after rainfall. Wildlife throughout the watershed and dog waste from the walking trail appear to be the primary bacteria sources. In Boathouse Creek, there are a number of sites with high bacteria levels. All of the sites along Boathouse Creek are high, but there appears to be a hot spot in the vicinity of BC8. The source of contamination is unclear. It could be runoff from Western Park or Ocean Spray, or wildlife in the riparian corridor. The runoff is treatable, especially because there are good BMP sites nearby. These are described later in Section E3. The NCDOT pipes discharging runoff from NC 24 are also hot spots in the Boathouse watershed.

In Hills Bay embayment, the site with the highest bacteria concentrations was FE5, which is the NCDOT pipe off of Bluff Road. that discharges runoff from NC 24. FE3 and particularly FE4 are close to the shellfish waters and were also consistently high. FE4 is downstream of FE5 but it also drains grassland, forest, and areas along Bluff Road. that include a church and low-density residential development. FE6 drains properties along NC 24, including discharge from an infiltration basin that receives runoff from a hotel. Not many samples were collected from the Bridges watershed but the available results show low bacteria concentrations. The minor exceptions are BR6 and BR7, which are within the closed area and had samples of 18 and 40 MPN/100 ml, respectively.

The existing conditions were quantified in the modeling using a source assessment and fecal coliform accounting spreadsheet known as Fecal Tool, both of which are further explained in Appendix C. Generally, the source assessment involved a survey of residents to determine the number of outdoor pets and the types of wildlife seen in the area. The number of septic systems and the expected level of function were evaluated. These estimates were input to Fecal Tool and combined with literature values for daily fecal production per source. Fecal Tool then produces a predicted fecal coliform accumulation rate for each land use in loading counts per day. The results were input to the LSPC model and most uncertain values were altered in the calibration process.

The calibrated accumulation rates for each of the modeled watersheds are listed again in Tables E1 – E3. These estimates are direct inputs on the land use and do not account for decay. The estimates were derived by multiplying the calibrated accumulation rates by the respective land use area for each watershed.

Table E.1: Fecal Coliform Accumulation Rates from Boathouse Creek

Land use	Loading Counts/day	Loading Percent
Wetland	7.35E+11	10.8
Pasture/Herbaceous	1.96E+11	2.9
Forest	1.51E+12	22.1
Urban	4.17E+12	61.1
NCDOT	2.19E+11	3.2
Total	6.83E+12	100

Table E.2: Fecal Coliform Accumulation Rates from Dubling Creek

Land use	Loading Counts/day	Loading Percent
Wetland	2.62E+12	68.4
Pasture/Herbaceous	5.85E+10	1.5
Forest	9.42E+11	24.6
Urban	2.10E+11	5.5
NCDOT	NA	0.0
Total	3.83E+12	100

Table E.3: Fecal Coliform Accumulation Rates from Hills Bay Embayment

Land use	Loading Counts/day	Loading Percent
Wetland	3.21E+10	5.6
Pasture/Herbaceous	1.74E+11	30.2
Forest	9.81E+10	17.0
Urban	1.90E+11	33.0
NCDOT	8.15E+10	14.2
Total	5.76E+11	100

The loads shown above are for fecal coliform accumulation on the land surface only. They are not the loading delivered to the shellfish embayments. To get the delivered load, decay, maximum storage, and transport must be simulated by the model.

The final model estimates for nonpoint and point sources are listed below in Table E.4. The only point source is runoff from NCDOT roads. This is not typically thought of as a point source but because it is regulated by an NPDES permit, loading was calculated in isolation from other sources per EPA guidance (USEPA, 2002).

Table E.4: Existing Fecal Coliform Loading

Waterbody	Existing Load	Point Source	Nonpoint Source
Boathouse Creek	6.17×10^{11}	3.54×10^{10}	5.82×10^{11}
Dubling Creek	1.77×10^{11}	0.00	1.77×10^{11}
Hills Bay embayment	2.88×10^{10}	1.65×10^{9}	2.72×10^{10}

E2. Estimate the load reductions expected from management measures.

This Key Element addresses the TMDL or reduction required from the existing loading to meet the designated shellfish harvesting use. This determination is described in Section 3.2.4 of the TMDL. It then outlines the needed reductions from each land use in each watershed.

The TMDL calculation is based on the water quality criteria; in this case it is the median and 90th percentile for the most recent 30 samples. Since the samples are taken on an approximately monthly basis (i.e., samples can be taken in any month), the running 30-month median and 30-month 90th percentile were calculated at Tidal Prism Model (TPM) segments. The watershed loading was reduced until both water quality standards were met at all times during the model simulation period. Thus, the TMDL period for each watershed is the 30 months preceding the last prediction to meet the standard (i.e., reductions are made until all predictions meet the standard). The final loading input to the TPM from the watershed model (LSPC) was computed as the TMDL for its corresponding watershed. The load reduction is computed based on the difference between the current condition and the TMDL loading. The existing and allowable loading for each project watershed is listed in Table 3.2.4. The time series plots of the median and 90th percentile for each tidal segment under existing conditions and the TMDLs are presented in Appendix D.

The load allocations were determined using the same period as the TMDL calculation. Thus, the averaging period for the development of the TMDLs used daily predictions from the TMDL model runs for the 30 months preceding the highest 90th percentile concentration. Over this period, daily bacteria loading predictions were taken from each model subwatershed and subsequently summed across the watersheds. The daily average was then calculated; this serves as the basis for the load allocation. The wasteload allocation (WLA) must then be subtracted to determine the final load allocation (LA).

Model runs were conducted to determine what loading reductions are required to achieve the TMDLs with a margin of safety. For Boathouse Creek, reductions of 72 percent for both developed land (including Western Park) and NCDOT land are required to meet the TMDL. Additionally, septic systems in the Ocean Spray subdivision will need to be further evaluated. An initiative to upgrade these systems may be warranted if it is shown that septic waste is reaching the stream network in high concentration from ground water. In Dubling Creek, much of the bacteria load originates from what has typically been considered uncontrollable sources (i.e., wildlife on wetlands and forest land). However, modeling indicates that the standard should be met if a 10 percent reduction is made on the wetland and forest area surrounding the walking trail (pet waste disposal should accomplish this) and a 48 percent reduction is made in the headwaters draining through the former mine pond. For the Hills Bay embayment, reductions of 60 percent on NCDOT land and 57 percent on other built-upon land (i.e., residential and commercial) are estimated to be required to meet the standard.

NCDOT is the only NPDES-permitted discharger and consequently it will be the lone permittee in the WLA. Bacteria loading originating on NCDOT property must be separated from all other sources per EPA guidance (USEPA, 2002). Using the delineated land use and calibrated models as a base, the models were rerun with the bacteria accumulation rate on NCDOT land use set at zero. The difference between the calibrated model and the run without NCDOT land use represents NCDOT's current delivered contribution to the embayments. For Boathouse Creek the result is 3.54×10^{10} bacteria counts per day and for the Hills Bay embayment the result is 1.65×10^{9}. To arrive at the WLA, the reduction specified in the TMDL model run is subtracted from the existing loads. A 72 percent reduction in Boathouse Creek results in a WLA of 9.91×10^{9}, and a 60 percent reduction in Hills Bay Embayment results in a WLA of 6.60×10^{8}. These values may then be subtracted from the load allocation basis described above to determine the final LA.

Table E.5: Existing Fecal Coliform Loading

Waterbody	TMDL	WLA	NCDOT Reduction Required	LA	NPS Reduction Required
Boathouse Creek	2.09×10^{11}	9.91×10^{9}	72%	1.75×10^{11}	72%
Dubling Creek	1.58×10^{11}	0.00	0%	1.53×10^{11}	14%
Hills Bay embayment	1.45×10^{10}	6.60×10^{8}	60%	1.24×10^{10}	57%

Notes: WLA = wasteload allocation for point source (NCDOT), LA = load allocation for nonpoint sources. The margin of safety is not shown but is the difference between the TMDL and the WLA + LA.

The 90^{th} percentile for the NC 24 Bridge Area (DEHSS Station 20) last exceeded the 43 standard in September 2003. Monitoring results indicate a downward trend since then. It appears that the site will meet the standard in the next Sanitary Survey cycle, which concludes in 2011. Implementing the several BMPs recommended in this appendix should help the area to meet and maintain standards. One caveat is that this station is located outside of the closure area so no station exists inside of the closure area.

E3. Describe the nonpoint source management measures that will need to be implemented to achieve the load reductions in Element 2 and the critical areas in which those measures will be needed to implement this plan.

The project watersheds were explored in detail to identify potential stormwater BMP sites. Additionally, non-structural BMPs, including education and implementation of a stormwater ordinance by the Town of Cedar Point, were included. This effort produced 33 potential bacteria load reducing measures. These measures are shown in Table E6 and in Figures E11-E14.

A literature review was conducted to determine the amount of bacteria reduction that might be expected from structural stormwater BMPs (Schueler and Holland, 2000; NCDWQ, 2007; Boyer, 2007; Coyne et al., 1995). Three sources were combined using best professional judgment to produce one reduction percentage per BMP type. The results are shown in Table E7.

The drainage areas for each BMP were mapped in GIS and the resulting land use was tabulated. Bacteria reductions from BMPs were applied to the respective accumulation rates for each land use. Next, for each land use category in each subwatershed, a composite accumulation rate was calculated by summing the factor of land use area and accumulation rate for each polygon. The result was compared to the accumulation rate from the calibrated model and the resulting percent reduction was applied to that land use in the model. The accumulation rates were not directly changed in the model.

One exception to this practice of reducing loading according to BMP type applies to

NCDOT land. In this case, the reductions required by the TMDL were simply applied to NCDOT land. This assumes that NCDOT will obtain the reductions to meet their NPDES permit.

The modeled reductions do not include education or the stormwater ordinance. Education would help existing loading by reducing sources but the ordinance would presumably focus on future sources. Septic reductions were factored in the modeling.

Table E6. Potential BMP database

Dubling Creek Watershed

Potential BMP location (Id)	Severity of Bacteria Loading	Comments
Walking trail (DC_a)	High	Pet waste disposal stations and signs explaining the problem
Wetland ditches (DC_b)	High	Eliminate future maintenance of mosquito ditches so they are allowed to naturally fill in and revegetate
Mine pond (DC_c)	Moderate	Engineer outlet structure to retain high flows and gradually release runoff. Open tree canopy to allow greater exposure to sunlight.
Forest (DC_d)	Moderate	Allow reforestation to occur following hurricanes. Also, tree plantings in select locations.
Mine site (DC_e)	Moderate	Revegetate this area.
Roads (DC_f)	Moderate	Look for areas where runoff from roads accumulates and becomes channelized. Correct these problems.
Pasture (DC_g)	Moderate	Add a field edge buffer and possibly level spreader

Boathouse Creek Watershed

Potential BMP location	Severity of Bacteria Loading	Comments
Western Park near entrance (BC_a)	High	Wetland feature currently present. Could install an outlet structure and expand basin to detain flow and enhance the wetland.
Western Park near tennis courts (BC_b)	High	An infiltration basin/trench could be constructed along the wood line.
Western Park swale at southwestern corner (BC_c)	Moderate	The bacteria levels at this location are not very high but it could be a good future site if conditions change.
Western Park pet waste(BC_d)	High	Pet waste disposal stations and signs explaining the problem.
Ocean Spray septic systems (BC_e)	Moderate	Further monitor this potential source with piezometers/wells. Set up a septage authority and seek grant funds to update systems in need of replacement.
Ocean Spray ditch near BC21 (BC_f)	High	Could do a level spreader and filter strip or a terraced wetland here. Would need to purchase undeveloped lot.
Ocean Spray ditch near BC22 (BC_g)	Moderate	Swale running through backyard of numerous properties. Difficult access, might access below from Western Park.
Ocean Spray ditch near BC23 (BC_h)	High	Existing wetland feature could be enhanced. Difficult access and minimal space. Might consider site below that could be accessed through Western Park but would need to cross Boathouse Creek.
Cedar Point Town Hall (BC_i)	Low	Room for a small infiltration basin or bioretention area. Install cisterns at town hall and at planned maintenance building.
NCDOT pipe outlet at BC11 (BC_j)	High	Existing J-shaped open channel could be re-engineered to detain/infiltrate runoff discharged from pipe outlet. Pipe outlet and part of channel located on private property. May need to purchase additional land.
NCDOT outfall at BC26 (BC_k)	Moderate	This receiving channel is considered to be jurisdictional. Survey and engineering evaluation necessary to determine feasibility of a conventional stormwater BMP which would be located on private property due to very limited public ROW. Alternatively, source control measures and/or filter-type treatment within the closed conveyance system may be implemented.
Boat ramp at mouth of Boathouse Creek (BC_l)	Moderate	Good site to install a small BMP with educational signage.
USFS campground (BC_m)	Moderate-High	Check the septic system here. Add pet waste disposal stations and educational signs.
Marsh Harbour (BC_n)		Recommend LID in third phase. Incorporate voluntary LID and homeowner education in existing phases. Purchase large waterfront buffer from existing undeveloped lots.

Stormwater ordinance (BC_o)		Town of Cedar Point plans to make Low Impact Development an option for developers.

Table E6. continued

Hills Bay Embayment Watershed		
Potential BMP location	**Severity of Bacteria Loading**	**Comments**
NCDOT pipe outlet off Bluff Rd (HE_a)	High	Pipe outlet located on private property (church). Depth to seasonal high water table may influence BMP selection. Survey and engineering evaluation necessary in order to identify candidate BMPs due to site constraints. Little elevation difference between pipe and receiving channel inverts. Significant amounts of excavation may be required depending on BMP selection. Flow splitter will be required due to high runoff volumes. Alternatively, source control measures and/or filter-type treatment within the closed conveyance system may be implemented
Swale draining Octagon House prop. (HE_b)	Moderate-High	Work with Masons to ensure they develop property with water protection as a primary goal, use LID techniques. Or install a level spreader and filter strip if site is not developed.
Swale draining land adjacent to Octagon (HE_c)	Moderate-High	Install a level spreader and filter strip above the drainage to the tidal creek.
Swale draining Jones property (HE_d)	Moderate-High	Install a level spreader and filter strip above the drainage to the tidal creek.
Church off of Bluff Rd. (HE_e)	Moderate	Install level spreader and filter strip.
Bluff Rd across from church (HE_f)	Moderate	Install at bioretention area where this runoff concentrates.
NC 24 border in sws 201 (HE_g)	High	Install a level spreader and filter strip above existing pond.
Septic systems (HE_h)	Moderate	Might seek to upgrade these systems.
Bridges Watershed		
Potential BMP location	**Severity of Bacteria Loading**	**Comments**
Septic systems (BR_a)		Limited available space, soils, and proximity to the shellfish waters suggest that optimum systems are needed here.
Backyard rain gardens (BR_b)		Teach homeowners how to construct rain gardens to treat runoff from their property. Install neighborhood rain gardens as demonstration project.
Education (BR_c)		Educational campaign to inform limited number of residences bordering shellfish waters about pet waste, septic systems, and rain gardens.

The models were run using the expected reductions from the identified BMPs. The results for the 90th percentile are shown in Figures E5 to E7.

The results are positive for Dubling Creek. It appears that the shellfish waters will be able to meet the designated use if the identified measures are implemented. The results are not encouraging for Boathouse Creek and Hills Bay Embayment, however. The maximum 90th percentile dips slightly in both cases: from 120 to 110 in Boathouse Creek and from 90 to 70 in the embayment. However, the reductions may be closer to reaching standards than these results indicate because there is not a linear relationship between loading and bacteria concentrations in the embayment. This was observed in the modeling to determine the TMDLs.

The primary problem with reducing bacteria levels further is that an opportunity gap exists between available BMP sites and those that are needed to obtain the high reductions recommended by the TMDL. BMP sites are limited because of two factors: (1) a lack of space between the prime bacteria source areas and jurisdictional waters; and (2) an inability to address wildlife sources on undeveloped land (e.g., wetlands and forest).

As will be shown in Key Element 6, there are funding limitations to implementing BMPs, so the first several years of grant applications and project resources will be accounted for. In the meantime, further reductions to meet the TMDL may be identified and the need for them may be clarified.

Furthermore, it is difficult to precisely predict the result of management measures over time. A good start is to implement the most important sites and continue down the list. If monitoring is continued during this process, it should be possible to see the effect of the initial measures. This may allow modifications to the modeling and the implementation plans. This process is known as adaptive management.

Table E.7: Expected Fecal Coliform Bacteria Removal by BMP Type

BMP Type	NC BMP Manual	Center for Watershed Protection	Delaware Dept of Nat Res and Env Control	Removal based on BPJ
Bioretention	High		>99%	90%
Sw wetland	Med		78-90%	70%
Wet detention	Med	65% (n=10)	44-99%	65%
Sand filter	High	58% (n=9)	35-83%	70%
Filter strip	Med	57% (Coyne et al., 1995)		55%
Grassed swale	Low	-58% (n=5)		0%
Restored buffer	Med		43-57%	50%
Infiltration device	High			90%
Dry ext. detention	Med			70%
Permeable pavement	Low			30%
Green roof	Low			30%

Figure E5.

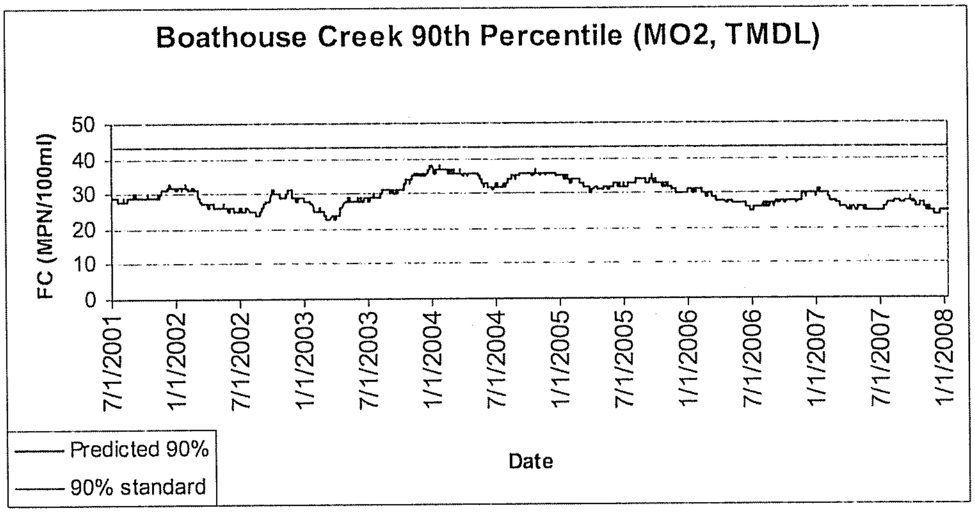


Figure E6.

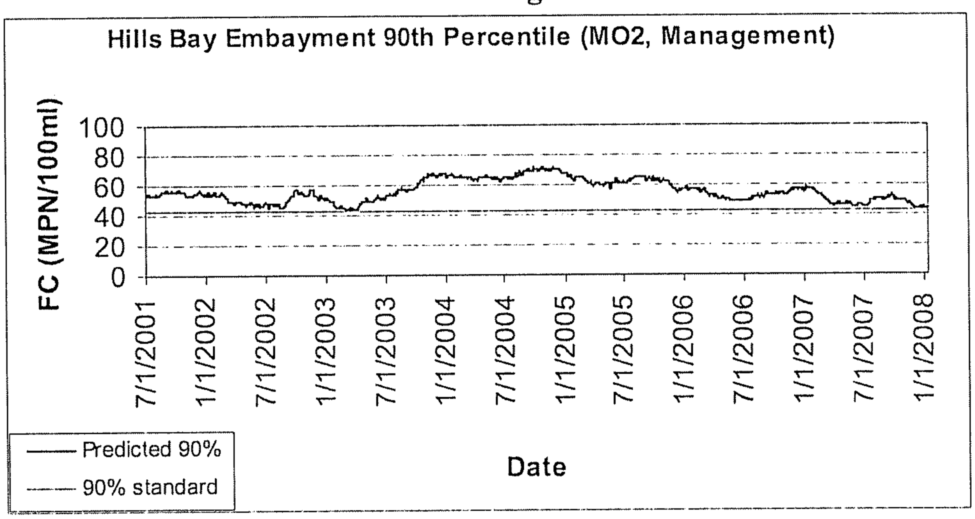
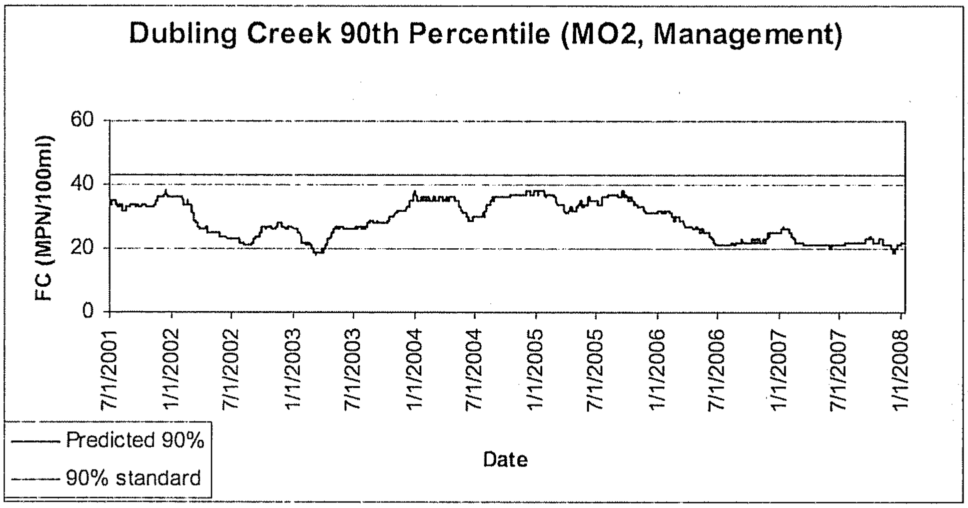


Figure E7.



Dubling Creek 90th Percentile (MO2, Management)
FC (MPN/100ml)
60
40
20
0
7/1/2001
1/1/2002
7/1/2002
1/1/2003
7/1/2003
1/1/2004
7/1/2004
1/1/2005
7/1/2005
1/1/2006
7/1/2006
1/1/2007
7/1/2007
1/1/2008
Date
Predicted 90%
90% standard

E4. Estimate the amount of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

Designing and constructing stormwater retrofit BMPs is an expensive undertaking. Design plans sealed by a professional engineer (PE) are needed to construct BMPs that will function properly over a BMP lifespan, which is typically on the order of 20 years. Heavy equipment, skilled labor, and specialized materials combine to make construction the highest BMP cost. Initial cost estimates were calculated for the majority of the recommended BMPs based on expected BMP type and size. Greater specificity will likely be necessary if these projects are further developed. Based on previous BMP installation experience, the project area wide cost of implementing the structural BMPs would approach $1.5 million. Specific cost estimates are provided in Table E8.

A small municipality like Cedar Point has an annual operating budget of approximately $0.5 million, so providing a cost share of 20-50 percent to obtain funding for BMP installation is a difficult proposition. NCCF will need to partner with Cedar Point on this and perhaps take the lead on most projects, much as they have for the TMDL. However, the support of both Cedar Point and NCCF staff will be needed to focus on the non-structural BMPs, including a stormwater ordinance and educational outreach. Additionally, a local entity will need to be responsible for long-term BMP maintenance. This is not a trivial task as it requires quarterly inspection and maintenance. In some cases, heavy equipment may be required to remove sediment and clean out drainage pipes.

A vital component of TMDL implementation is access to grant funds. Cedar Point and NCCF will need to apply for all available grant programs on a consistent basis for a number of years. The targeted grant programs are NC Clean Water Management Trust Fund and EPA Section 319 funds administered by NCDWQ. The Division of Water Resources grant fund may be another source but these awards are focused on water quantity (e.g., flooding), which is less of an issue in the project area. The Community Conservation Assistance Program (CCAP), a new statewide initiative of the Soil and Water Conservation Districts, is another potential source of revenue. The program helps pay to install LID techniques to alleviate existing stormwater pollution. If adequately funded by the N.C. General Assembly, CCAP offers great potential to educate citizens about stormwater pollution and to provide cost-share money to homeowners and businessmen for installation of low-cost BMPs. With tightening budgets as a result of slowing economic growth, the availability of grant funds and legislative appropriations may be reduced.

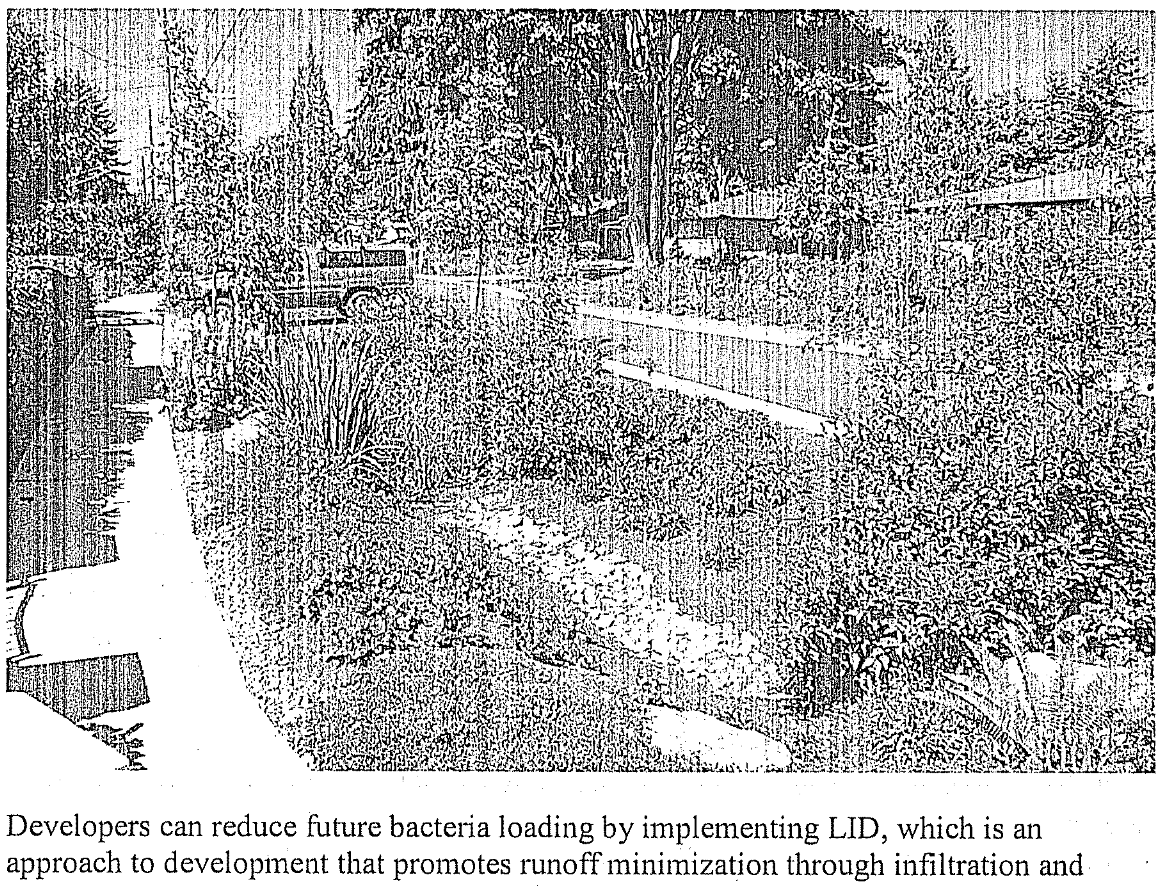
The BMPs that will be required to reduce bacteria contributions from land under NCDOT's jurisdiction should be mostly funded by NCDOT. The agency has the staff to address the technical aspects of the BMPs. Funding to construct the BMPs may be more difficult to obtain but reductions will be required to meet their NPDES permit, which will provide an incentive to install the necessary BMPs.

E5. An information and education component used to enhance the public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

The current project has had an information and education component that included meetings to explain the project, training for and implementation of volunteer monitoring, presentations to community groups and local governments, and a tabloid publication in the local newspapers to explain the results of the project.

Future efforts will build upon this foundation and are expected to include education for residents and developers. For residents, the primary objectives are expected to be focused on bacteria source reduction and backyard BMPs. Source reduction would include pet waste disposal and septic system improvements. Other potential topics include rain gardens to remove bacteria and reduce stormwater volume. A demonstration class would be a good educational tool for people who are interested in constructing a backyard rain garden.

Figure E8. Photo of rain garden from Seattle Public Utilities



Developers can reduce future bacteria loading by implementing LID, which is an approach to development that promotes runoff minimization through infiltration and limiting impervious footprint. Cedar Point's current regulations do not include an LID component, but the Town has expressed interest in adopting a stormwater ordinance that includes LID. Additionally, the developer of a large residential project in Boathouse Creek has expressed interest in using LID techniques.

Another aspect of education is appreciation of targeted land conservation. Informed landowners may sell a part of their land for BMPs or put it in a conservation easement if they know that it will benefit nearby water quality. Additionally, they may be more willing to have a BMP installed on their land if they understand and support the project.

E6. Provide a schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

The identified BMPs will be evaluated for the purpose of prioritizing them for implementation in this key element. They will then be added to a schedule for grant applications.

Sites that were potentially feasible areas for placement of a stormwater BMP were further investigated in the field. Potential site constraints, such as sanitary sewer lines, pipe elevations, and other site conditions, were identified. Potentially acceptable sites were further investigated using GIS and other analytical tools, as described below.

A preliminary ranking system was implemented based on the following parameters:

1. *Site conditions* – how suitable is the site for a BMP (e.g., would existing infrastructure need to be reconfigured or are soils conducive to expected BMP performance)?
2. *Pollutant removal quantity* – what are the expected bacteria loads and how effective would the prospective BMP at removing them from the stream network?
3. *Pollutant removal efficiency* – what is the cost per acre of drainage area? Bioretention areas are relatively expensive while constructed wetlands vary between being relatively inexpensive to moderately expensive.
4. *Construction feasibility* – would construction be a relatively straight-forward process or are there obvious difficulties to overcome?
5. *Maintenance access* – would permanent access for BMP maintenance be possible or is it expected to be problematic?
6. *Landowner status* – is the BMP area on public or private property? If public, is the land owned by Cedar Point, Carteret Count, or NCDOT? Is the landowner likely to be a willing project participant?
7. *Conflicts with adjacent land uses* – Might the BMP create a nuisance to adjacent land uses (e.g., hydrologic trespass, near residential areas, hazardous situations, etc)?
8. *Impacts on environmental resources* – would the BMP be situated in the path of jurisdictional waters, would forest need to be cut to install a BMP?
9. *Public education* – is the site appropriate for public education? If the site must be purchased then it is assumed that public education can be incorporated, provided there is sufficient space.

For each of the nine criteria, the sites were rated 1, 2, or 3, with 3 being the most favorable. The nine scores were averaged for a composite score and the potential BMPs were ranked on this basis. The results are shown in Table E9. The rankings are based on the nine criteria described above. The N.C. Coastal Federation and Cedar Point may choose to evaluate them differently.

Next, the Simple Method, which uses BMP drainage area and percent impervious cover, was used to determine targeted stormwater treatment volume. This was combined with the space available for treatment to estimate the dimensions of the prospective BMP. Dimensions, site conditions, and judgment from other project experience were used to produce rough cost estimates. The prospective sites and the associated drainage areas are shown in Figures E9- E12.

TABLE E8. Estimated BMP Costs

BMP Location	BMP_Id	BMP type	DA (acres)	Estimated Cost (in US Dollars, $)			
				Construction	Design	Other	Total
Entrance to Western Park	BC_a	enhance wetland	3.9	50,000	24,000	2,000	76,000
Western Park near tennis courts	BC_b	infiltration basin	7.5	71,000	35,000	2,000	108,000
Western Park swale at southwestern corner	BC_c	constructed wetland	10	100,000	35,000	2,000	137,000
Western Park pet waste	BC_d	pet waste disposal	NA			900	900
Ocean Spray septic systems	BC_e	monitor and upgrade	NA				-
Ocean Spray #1_ditch near BC21	BC_f	level spreader + filter strip	6.3	60,000	15,000	15,000	90,000
Ocean Spray #2_ditch near BC22	BC_g	constructed wetland	9.1	125,000	40,000	15,000	180,000
Ocean Spray #3_ditch near BC23	BC_h	constructed wetland	22	240,000	48,000	15,000	303,000
Cedar Point Town Hall	BC_i	bioretention area	0.6	20,000	15,000		35,000
NCDOT pipe outlet near BC11 (J ditch)	BC_j	infiltration trench	13.8				-
NCDOT outfall near BC26	BC_k	constructed wetland	47				-
Boat ramp at mouth of Boathouse Cr	BC_l	bioretention area	0.7	30,000	15,000		45,000
USFS campground	BC_m	pet waste disposal	NA			1,200	1,200
Marsh Harbour LID	BC_n	LID in Phase 3	NA				-
BOATHOUSE CREEK TOTAL							**975,825**
NCDOT pipe outlet off of Bluff Rd	HE_a	constructed wetland	8.1				-
Swale draining Octagon house	HE_b	level spreader + filter strip	4.6	25,000	10,000		35,000
Swale draining land adjacent to Octagon house	HE_c	level spreader + filter strip	3.9	20,000	10,000		30,000
Swale draining Mr. Jones' house	HE_d	level spreader + filter strip	9.4	40,000	10,000		50,000
Church on Bluff Rd.	HE_e	level spreader + filter strip	0.84	15,000	10,000		25,000
Bluff Rd. across from church	HE_f	bioretention area	4.7	50,000	20,000	3,000	73,000
NC 24 border in sws 201	HE_g	level spreader + filter strip	6.5	30,000	10,000		40,000
Septic systems	HE_h	monitor and upgrade	NA				-
HILLS BAY EMBAYMENT TOTAL							**253,000**

BMP Location	BMP_Id	BMP type	DA (acres)	Estimated Cost (in US Dollars, $)			
				Construction	Design	Other	Total
Dubling Creek walking trail	DC_a	pet waste disposal	-			1,800	1,800
Dubling Creek ditches	DC_b	no ditch maintenance	NA				-
Mine pond	DC_c	outlet structure	25	80,000	20,000		100,000
Forest	DC_d	tree re-growth	NA		-		-
Mine site	DC_e	revegetate	5.3	10,000	5,000		15,000
Roads	DC_f	manage runoff	NA	50,000	15,000		65,000
Pasture	DC_g	level spreader + filter strip	6.4	30,000	10,000		40,000
DUBLING CREEK TOTAL							**221,800**
NC 24 Bridge area septic systems	BR_a	monitor and upgrade	NA				-
Backyard rain gardens	BR_b	bioretention areas	NA				-
Education	BR_c	Pet waste disposal, etc.	NA				-
NC 24 BRIDGE TOTAL							-

*Confirmation of BC_k drainage area needed due to land development activities.

Table E9. BMP Priority Rankings	Suitability Rating for Criteria (3=good, 2=moderate, 1=low)*											
BMP Location (BMP Id)	Site Conditions	Construction Feasibility	Maintenance Access	Landowner Status	Conflicts with Adjacent Land Uses	Impacts on Environmental Resources	Pollutant Removal Quantity	Pollutant Removal Efficiency	Public Education	Composite Rating	BMP Rank	Watershed
Pet waste disposal (DC_a, BC_d, BR_c)	3	3	3	3	3	3	3	3	3	3.0	1	Multiple
USFS campground (BC_m)	3	3	3	3	3	3	3	3	3	3.0	2	Boathouse
Education	3	3	3	3	3	3	3	3	3	3.0	3	All
Dubling wetland ditches (DC_b)	3	3	3	3	3	2	3	3	3	2.9	4	Dubling
Walking trail (DC_a)	3	3	2	3	3	3	3	3	3	2.9	5	Dubling
Stormwater ordinance	3	3	3	2	3	3	2	2	3	2.7	6	All
Western Park near tennis courts (BC_b)	3	3	2	3	2	3	2	2	3	2.6	7	Boathouse
Croatan National Forest regrowth (DC_d)	3	2	3	3	3	2	2	3	2	2.6	8	Dubling
Western Park near entrance (BC_a)	2	2	2	3	2	3	3	2	3	2.4	9	Boathouse
Boat ramp at mouth of Boathouse Creek (BC_l)	3	3	3	3	2	2	2	1	3	2.4	10	Boathouse
Mine site (DC_e)	3	3	3	1	3	3	1	3	1	2.3	11	Dubling
Marsh Harbour LID (BC_n)	3	2	2	2	3	3	2	2	2	2.3	12	Boathouse
Cedar Point Town Hall (BC_i)	2	3	3	3	3	3	1	1	2	2.3	13	Boathouse
NCDOT pipe outlet at BC11 (BC_j)	3	2	2	2	2	2	3	2	2	2.2	14	Boathouse
Embayment pastures (HE_b, HE_c, HE_d, HE_e, HE_f)	2	2	3	1	3	2	2	3	2	2.2	15	Embayment
NCDOT pipe outlet off Bluff Rd (HE_a)	2	2	2	1	2	2	3	2	3	2.1	16	Embayment
Mine pond (DC_c)	3	2	3	1	2	2	2	3	1	2.1	17	Dubling
Ocean Spray ditch near BC21 (BC_f)	2	2	3	1	2	2	3	2	2	2.1	18	Boathouse
Bridges septic systems (BR_a)	3	1	2	1	2	3	3	2	2	2.1	19	Bridges
Western Park swale at southwestern corner (BC_c)	3	2	2	3	2	2	1	2	2	2.1	20	Boathouse
Dubling roads (DC_f)	2	2	3	2	2	2	2	2	2	2.1	21	Dubling
Dubling pasture (DC_g)	2	2	3	1	3	2	2	3	1	2.1	22	Dubling
Ocean Spray septic systems (BC_e)	3	1	2	1	2	3	2	2	2	2.0	23	Boathouse
Embayment septic systems (HE_h)	3	1	2	1	2	3	2	2	2	2.0	24	Embayment
NCDOT outfall at BC26 (BC_k)	1	2	1	1	1	2	3	2	3	1.8	25	Boathouse
Ocean Spray ditch near BC22 (BC_g)	1	1	1	1	1	2	3	2	2	1.6	26	Boathouse
Ocean Spray ditch near BC23 (BC_h)	1	1	1	1	1	2	3	2	2	1.6	27	Boathouse

The total estimated BMP costs are $1.5 million. Typical grant awards from NC Clean Water Management Trust Fund and EPA Section 319 for BMPs are $200,000 per project or less. If applications for each grant fund were made annually, it would take approximately four years to apply for funding for all of the BMPs. Not every proposal will be awarded and some of the BMPs toward the bottom of the list may not be fundable or cost effective. Further work may be needed to make them feasible. If the earlier projects are not funded it may be advisable to re-apply for them depending on what the funding agencies comments are.

Nevertheless, a five-year schedule for grant proposal applications might follow the outline in Table E8. NCDOT sites are not included because they will be the agency's responsibility.

Table E8. BMP Implementation Schedule

Year	CWMTF Proposal	319 Proposal
2009	Education, Embayment pasture sites	Pet waste disposal, stormwater ordinance, Western Park Phase I, Cedar Point Town Hall, neighborhood demonstration LID projects
2010	Mine Pond, Ocean Spray Phase I	Western Park Phase II
2011	Septic systems, Dubling pasture & roads	Boathouse boat ramp, mine site, Bluff Road sites
2012	Ocean Spray Phase II	Ocean Spray Phase III
2013	Remaining unfunded projects	Remaining unfunded projects

Western Park Phase I would include the BMP by the tennis courts and possibly the wetland near the entrance. If not in Phase I, the entrance wetland should be in Phase II, along with the BMP for the southwestern corner. Ocean Spray Phase I should treat the BC21 ditch using the open lot adjacent to it. The other Ocean Spray sites are less feasible but with further planning they may be addressed in a second phase.

It is unclear how much bacteria are contributed by the septic systems in the project watersheds. Thus, follow-up investigation, probably using wells, will be the next step. If it is determined that septic systems are significant contributors, they should be upgraded to the best available technology. Perhaps grant funding or other public funds can be obtained to pay for this.

The septic systems in the NC 24 Bridge watershed should be addressed first because of their proximity to the shellfish waters and apparent land-area limitations for treatment.

E7. Provide a description of the interim milestones for determining whether nonpoint source management or other control measures are being implemented.

The schedule provided in Key Element 6 provides a timetable for implementing management measures. Annually, NCCF and Cedar Point will assess progress relative to this schedule. While every effort should be made to adhere to the schedule, certain elements (such as obtaining grant funds) are beyond the control of the community. They will submit grant applications on a consistent basis to ensure they are optimizing their opportunities to receive cost share money.

The pet waste disposal stations, the education component, the stormwater ordinance, the Cedar Point Town Hall LID projects, and the neighborhood LID demonstration projects are relatively inexpensive measures that should be initiated within two years of this project's conclusion. They will likely be tied to another grant proposal so the two year time allowance is so that may be possible.

E8. Produce a set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

The Division of Environmental Health Shellfish Sanitation publishes a Sanitary Survey for each of the shellfish growing areas on a 5-year cycle. The next survey is scheduled to be completed in late 2011 and will include monitoring data from September 2006 through August 2011. This should include the effects of the first BMPs to be installed. In the reports, Shellfish Sanitation discusses whether water quality is improving or not based on the collected sample data. This is often not a straightforward exercise because unexpected (i.e., possibly high) bacteria results due to weather (for example, sampling after heavy rains preceded by an extended dry period) may occur even if reductions have been made. Consideration should be given to precipitation patterns during the monitoring period as shown in Stow et al. (2001). In this research, observed concentration was flow adjusted (normalized) to the long-term median flow. This produced different trends that are based on changes in surface conditions rather than annual riverine loading, which is highly dependent on annual precipitation. However, trends due to precipitation are more pronounced in the short-term; the longer the monitoring period, the more trends due to precipitation are minimized.

Table E9 shows potential interim targets for the 90^{th} percentile of the Shellfish Sanitation observation data. The short term goals are based on the BMP implementation recommended in this document. Longer term targets may require additional measures, depending on how processes respond in nature, outside of the modeling.

Table E.9 Management Objective: Reduce bacteria inputs shellfish waters to meet water quality standards				
Indicators to Measure Progress	Target Value or Goal	Interim Targets		
(MPN/100 ml) over last 30 samples		Short-term (2011)	Medium-term (2016)	Long-term (2021)
Dubling Creek 90th Percentile	<43	<50	<43	<43
Boathouse Creek 90th Percentile	<43	<110	<80	<43
Hills Bay Embayment 90th Percentile	<43	<80	<60	<43
NC 24 Bridge Area 90th Percentile	<43	<60	<50	<43

Using the 90th percentile as an interim target is preferable than looking at actual load reductions because the latter would require streamflow gages, which is probably an unnecessary expense when so many BMPs must be constructed.

Another approach would be a tiered interim use restoration strategy, as opposed to a numeric FC strategy. This was used in the Hewletts Creek watershed in the City of Wilmington. For example, an interim goal would be to upgrade from waters classified as Prohibited to Conditionally Approved Closed to Conditionally Approved Open, etc.

E9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against criteria established under Key Element 8 above.

DEHSS conducts monitoring at least six times per year at all of the shellfish areas addressed in this report. This monitoring should continue despite any changes to closure status. This will enable us to see the effects of BMP implementation. The results should continue to be published in the Sanitary Survey for Growing Area D-3.

Continued monitoring should allow for the use of adaptive management, whereby the TMDL model predictions can be compared to observations. If it appears that the shellfish waters are responding differently to the bacteria reductions than expected, it may be advisable to recalibrate the model based on the new monitoring data and update the TMDL. This might also change the course of the implementation plans. Perhaps more or less BMPs will be needed.

Additional monitoring may be done within the watersheds, perhaps as a requirement from the grant funding for BMP monitoring. BMP monitoring may be helpful to make adjustments to components such as water levels, as needed to maximize bacteria reduction.

CONCLUSION

A number of management measures have been identified and prioritized. It appears that if the measures in Dubling Creek are implemented, water quality standards will be met. The impairments in Hills Bay embayment and especially in Boathouse Creek are more intractable. The reductions required by the TMDL will need to be implemented on essentially every developed parcel in the watershed. This is very difficult in a retrofit situation because of constraints caused by a lack of available space and existing infrastructure. Where these constraints can be overcome, BMP sites have been recommended.

Over time, additional sites may be identified. In the meantime, there is plenty of work to implement the identified measures. A key component that has not been factored into the modeling is education. If this is instituted successfully, bacteria source reduction may be substantial. Source reduction is the most effective means of addressing bacteria from both a cost and quantity perspective

Source reduction would be critical in areas such as Ocean Spray and around the NC 24 Bridge Area. Rain gardens are also practical solutions in these areas because suitable retrofit BMP sites are, for the most part, not present.

Source reduction will not be effective at reducing bacteria from wildlife. However, hydrologic improvements may lower this by decreasing overland flow.

In conclusion, the shellfish impairments are difficult to manage because much of the bacteria come from wildlife. This may be managed if it occurs on developed land (e.g., a stormwater conveyance pipe) but the treatment options are reduced on forest and wetland. Where possible, this plan recommends alternative treatment measures, such as allowing mosquito ditches to naturally fill and promoting forest regrowth. Even with loading from developed land, retrofit BMPs are often not feasible. And when they are feasible, they are expensive. Nevertheless, this is the scenario for impaired shellfish waters along the North Carolina coast. This project may serve as a pilot for how to cost effectively manage the problem.

Appendix E References

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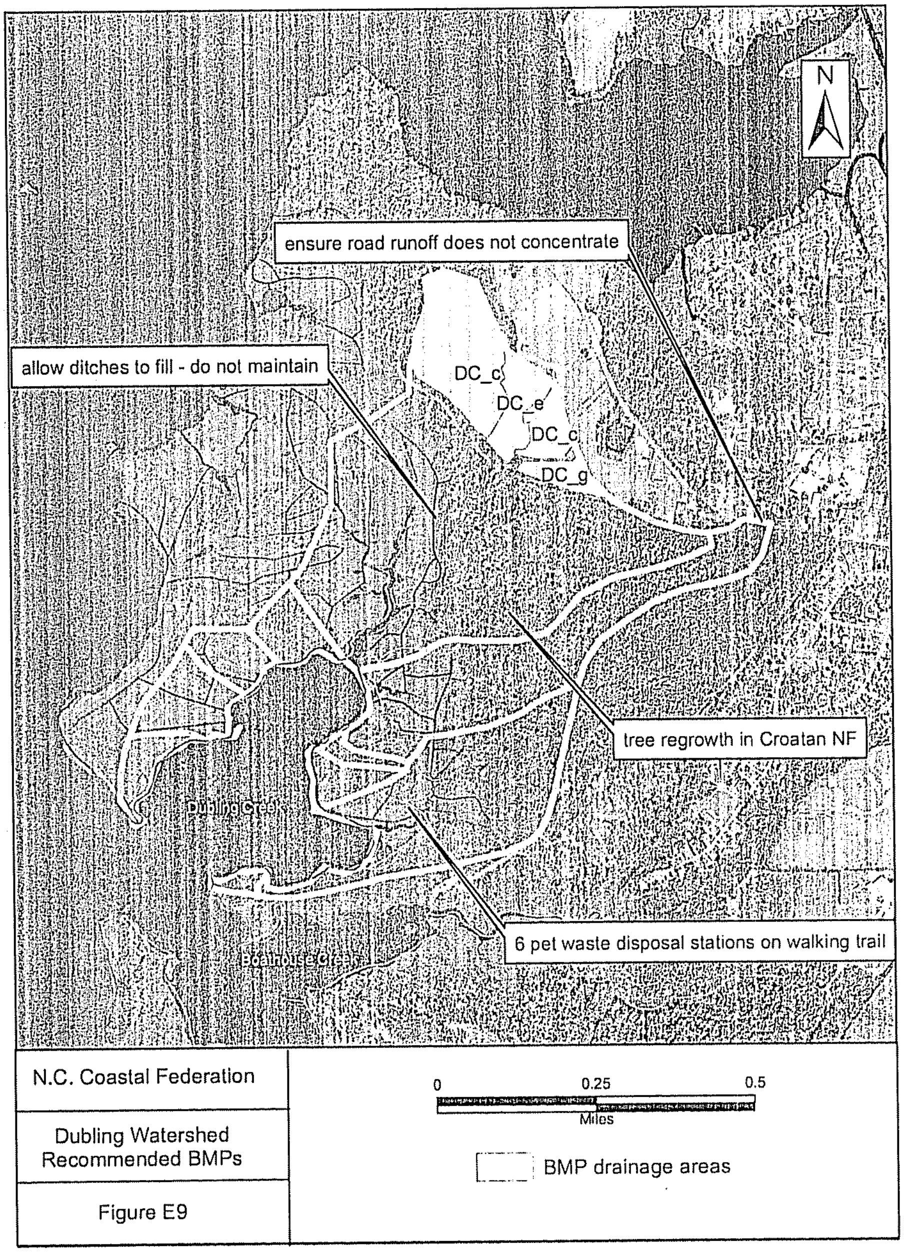
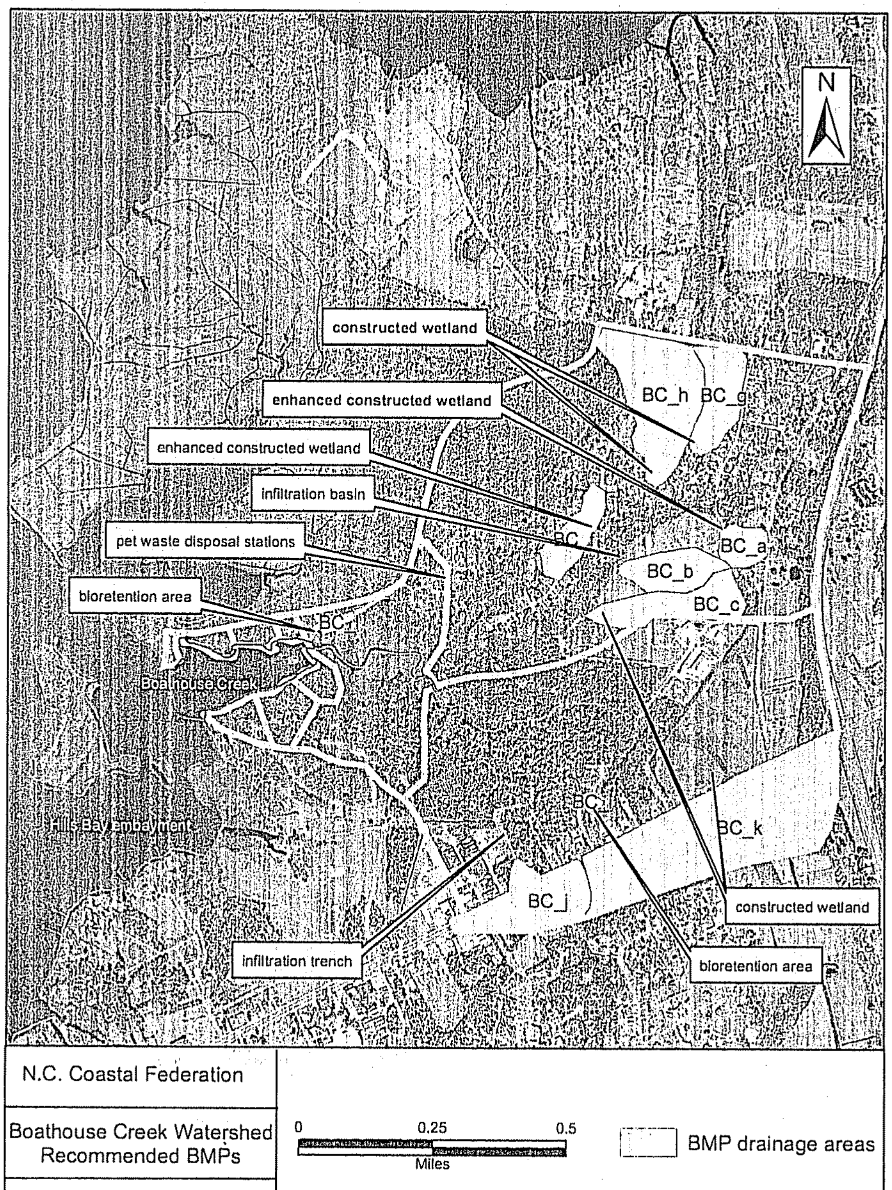
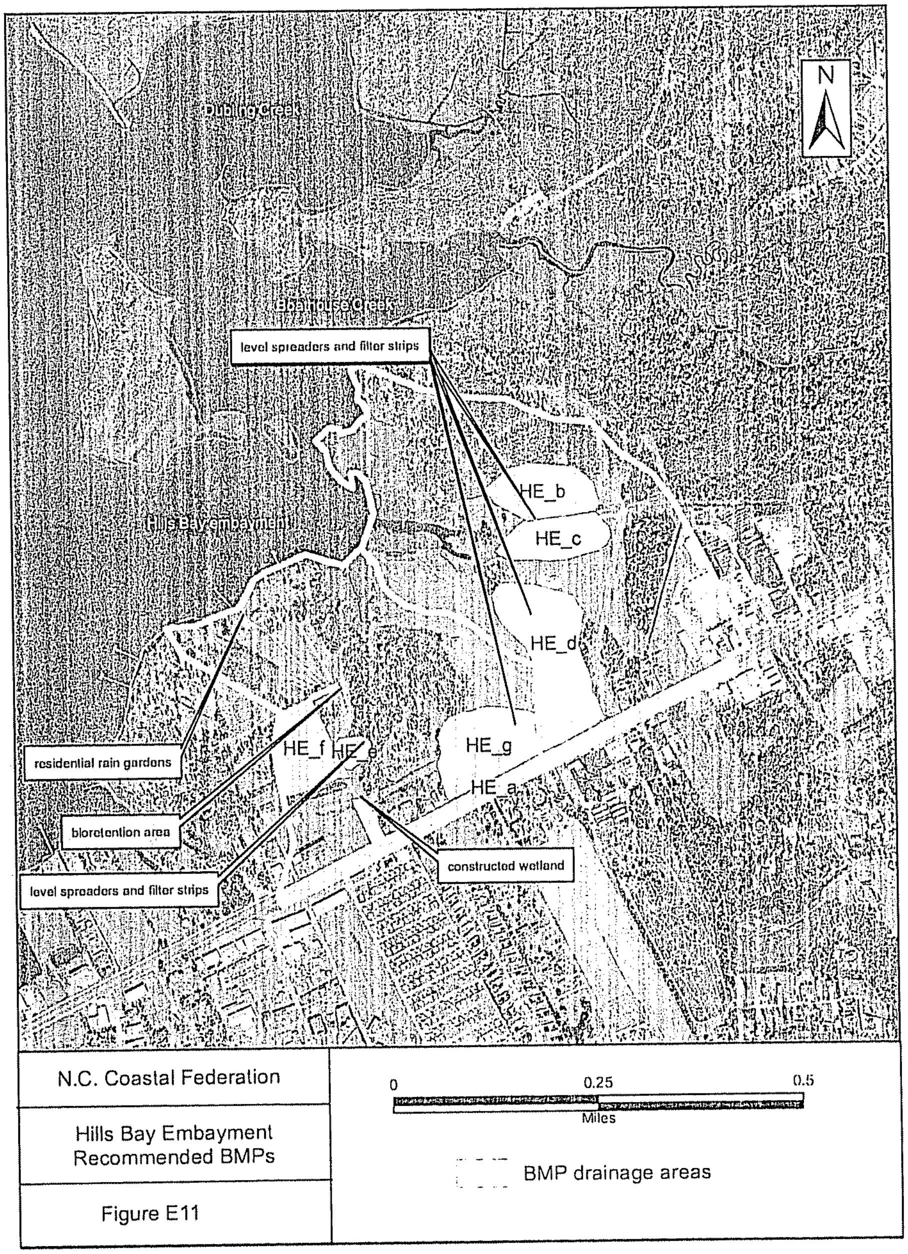

N
ensure road runoff does not concentrate
allow ditches to fill - do not maintain
DC_c
DC_e
DC_c
DC_g
tree regrowth in Croatan NF
Dubling Creek
6 pet waste disposal stations on walking trail
N.C. Coastal Federation
Dubling Watershed
Recommended BMPs
Figure E9
0
0.25
0.5
Miles
BMP drainage areas

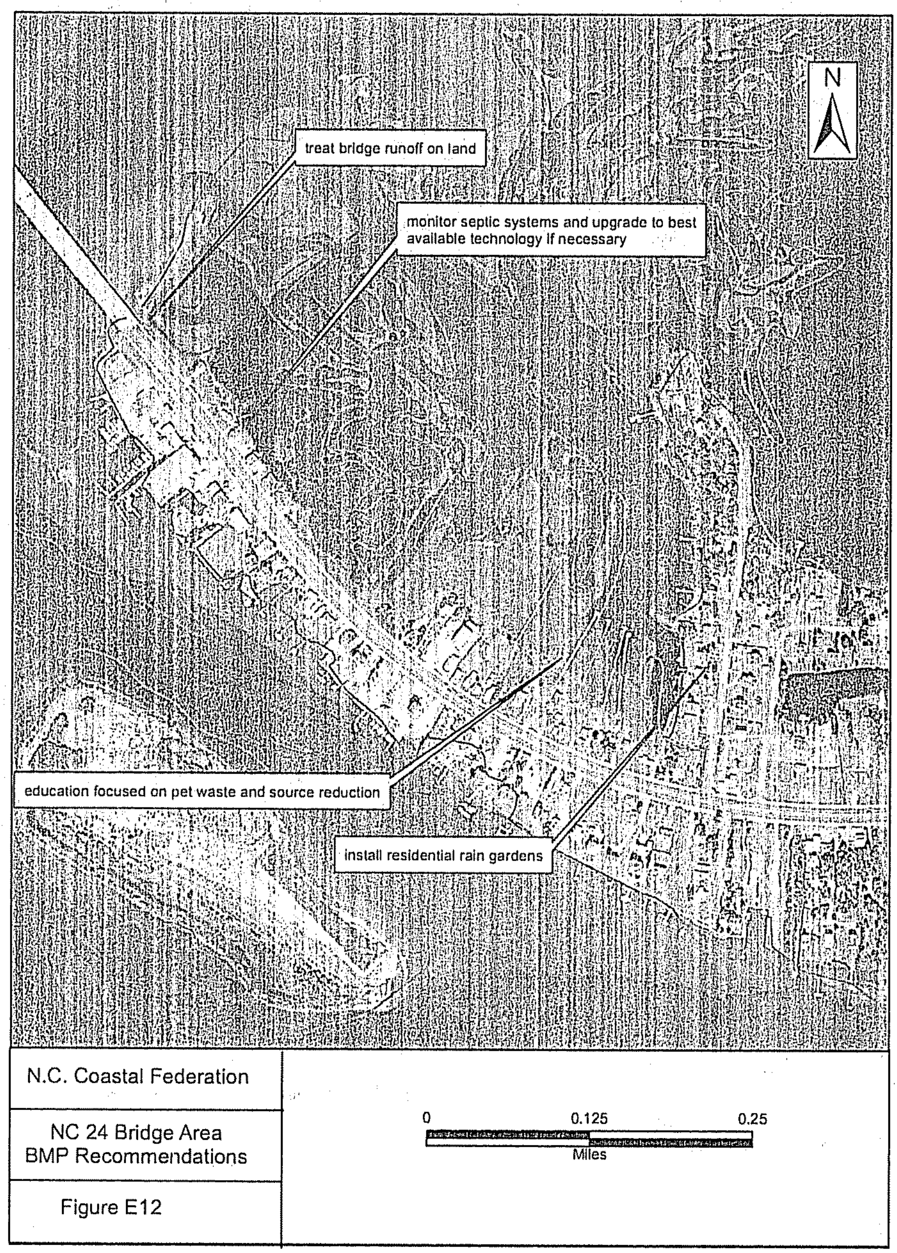


N.C. Coastal Federation

Boathouse Creek Watershed Recommended BMPs

Figure E10


N
level spreaders and filter strips
HE_b
HE_c
HE_d
HE_g
HE_a
HE_f
residential rain gardens
bioretention area
constructed wetland
level spreaders and filter strips
N.C. Coastal Federation
Hills Bay Embayment
Recommended BMPs
Figure E11
0
0.25
0.5
Miles
BMP drainage areas


N
treat bridge runoff on land
monitor septic systems and upgrade to best available technology if necessary
education focused on pet waste and source reduction
install residential rain gardens
N.C. Coastal Federation
NC 24 Bridge Area BMP Recommendations
0
0.125
0.25
Miles
Figure E12

Appendix F. Project Monitoring Data

Table F.1 Project Monitoring Results

Site	Date	Sample Type	Rain Amount	Last Rain	Qualifier	Result
BR1	3/13/07	Dry	0		<	2
BR2	3/13/07	Dry	0		<	2
BR3	3/13/07	Dry	0		<	2
BR4	3/13/07	Dry	0		est	5
BR5	3/13/07	Dry	0		est	5
BR6	3/13/07	Dry	0			18
BR7	5/18/07	Wet	0.97	5/17/07		40
BR7	9/10/07	Wet	1.12	9/9/07	est	18
BR8	3/9/07	Dry	0			3
BR8	5/18/07	Wet	0.97	5/17/07	est	13
BR8	9/10/07	Wet	1.12	9/9/07	est	11
FE1	5/30/07	Dry	0		est	8
FE1	9/10/07	Wet	1.12	9/9/07		26
FE1	9/27/07	Wet	0.51	9/26/07	<	5
FE1	9/27/07	Wet	0.51	9/27/07	<	5
FE1	12/17/07	Wet	3.51	12/16/07		72
FE2	5/30/07	Dry	0		est	28
FE2	9/10/07	Wet	1.12	9/9/07		57
FE2	9/27/07	Wet	0.51	9/26/07	<	5
FE2	9/27/07	Wet	0.51	9/27/07	<	5
FE2	12/17/07	Wet	3.51	12/16/07		123
FE3	3/14/07	Dry	0			274
FE3	6/4/07	Wet	0.57	6/3/07		586
FE3	6/4/07	Wet	0.57	6/3/04		580
FE3	9/10/07	Wet	1.12	9/9/07		786
FE3	12/17/07	Wet	3.51	12/16/07		1221
FE4	3/14/07	Dry	0		>	1510
FE4	6/4/07	Wet	0.57	6/3/07	>	1950
FE4	6/4/07	Wet	0.57	6/3/07	>	1950
FE4	9/10/07	Wet	1.12	9/9/07	>	1140
FE4	12/17/07	Wet	3.51	12/16/07		2000
FE4	2/13/08	Wet	1.16	2/13/08		
FE5	5/18/07	Wet	0.97	5/17/07	>	6170
FE5	6/4/07	Wet	0.57	6/3/07	>	1690
FE5	6/4/07	Wet	0.57	6/3/07	>	1690
FE5	9/10/07	Wet	1.12	9/9/07	>	18400
FE5	12/17/07	Wet	3.51	12/16/07		2400

Site	Date	Sample Type	Rain Amount	Last Rain	Qualifier	Result
FE6	3/14/07	Dry	0		est	8
FE6	6/4/07	Wet	0.57	6/3/07		414
FE6	6/4/07	Wet	0.57	6/3/07		428
FE6	9/10/07	Wet	1.12	9/9/07	>	1030
FE6	12/17/07	Wet	3.51	12/16/07		145
BC1	3/22/07	Dry	0		est	33
BC1	7/10/07	Wet	1.15	7/10/2007	est	49
BC1	9/27/07	Wet	0.51	9/26/2007	est	14
BC1	9/27/07	Wet	0.51	9/26/2007	est	16
BC2	3/22/07	Dry	0			46
BC2	7/10/07	Wet	1.15	7/10/2007		412
BC2	9/27/07	Wet	0.51	9/26/2007	<	5
BC2	9/27/07	Wet	0.51	9/26/2007	<	5
BC3	3/8/07	Dry	0			36
BC3	6/4/07	Wet	0.57	6/3/2007	>	1210
BC3	8/28/07	Wet	0.89	8/27/2007		386
BC3	8/28/07	Wet	0.89	8/27/2007		408
BC3	9/10/07	Wet	1.12	9/9/2007	>	1160
BC3	2/19/08	Wet	1.20	2/18/2007		857
BC4	3/8/07	Dry	0		>	242
BC4	6/4/07	Wet	0.57	6/13/2007	>	2870
BC4	8/28/07	Wet	0.89	8/27/2007		1300
BC4	8/28/07	Wet	0.89	8/27/2007		1311
BC4	9/10/07	Wet	1.12	9/9/2007	>	5440
BC4	2/19/08	Wet	1.2	2/18/2008		3600
BC5	3/8/07	Dry	0		>	733
BC5	6/4/07	Wet	0.57	6/3/2007	>	2650
BC5	8/28/07	Wet	0.89	8/27/2007		3400
BC5	8/28/07	Wet	0.89	8/27/2007		3290
BC5	9/10/07	Wet	1.12	9/9/2007	>	6760
BC5	2/19/08	Wet	1.2	2/18/2008		3500
BC6	3/9/07	Dry	0			729
BC6	5/3/07	Dry	0		>	2960
BC6	6/4/07	Wet	0.57	6/3/2007	>	3520
BC6	7/25/07	Dry	0			8200
BC6	8/28/07	Wet	0.89	8/27/2007	>	12600
BC6	9/10/07	Wet	1.12	9/9/2007	>	8840

Site	Date	Sample Type	Rain Amount	Last Rain	Qualifier	Result
BC6	12/17/07	Wet	3.51	12/16/07		5900
BC6	2/13/08	Wet	1.16	2/13/2008	>	10800
BC6A	7/25/07	Dry	0			10400
BC6A	8/28/07	Wet	0.89	8/27/2007		32200
BC7	3/9/07	Dry	0			225
BC7	5/3/07	Dry	0		>	2430
BC7	6/4/07	Wet	0.57	6/3/2007	>	2660
BC7	9/10/07	Wet	1.12	9/9/2007	>	8520
BC7	12/17/07	Wet	3.51	12/16/07		2300
BC7	2/13/08	Wet	1.16	2/13/2008	>	8590
BC8	3/14/07	Dry	0		est	844
BC8	3/27/07	Dry	0		>	2160
BC8	6/4/07	Wet	0.57	6/3/2007	>	2070
BC8	7/25/07	Dry	0			9000
BC8	8/6/07	Dry	0		>	18600
BC8	8/28/07	Wet	0.89	8/27/2007		4700
BC8	12/17/07	Wet	3.51	12/16/07		2000
BC8	2/13/08	Wet	1.16	2/13/2008	>	6090
BC8A	8/6/07	Dry	0		>	9300
BC8A	8/28/07	Wet	0.89	8/27/2007		6000
BC8B	8/6/07	Dry	0		>	3600
BC8B	8/28/07	Wet	0.89	8/27/2007		1260
BC8C	8/6/07	Dry	0		>	1640
BC8D	8/6/07	Dry	0		>	843
BC9	3/14/07	Dry	0		>	1240
BC9	3/27/07	Dry	0			843
BC9	6/4/07	Wet	0.57	6/3/2007	>	1780
BC9	7/25/07	Dry	0			71
BC9	12/17/07	Wet	3.51	12/16/07		743
BC9	2/13/08	Wet	1.16	2/13/2008		3000
BC9A	7/25/07	Dry	0			743
BC10	5/5/07	Dry	0			486
BC10	5/18/07	Wet	0.97	5/17/2007		514
BC10	6/4/07	Wet	0.57	6/3/2007		278
BC10	12/17/07	Wet	3.51	12/16/07		357
BC10	2/19/08	Wet	1.2	2/18/2008	est	25
BC11	7/9/07	Wet	0.65	7/9/2007	>	20200
BC11	10/24/07	Wet	0.67	10/24/2007		18600
BC11	10/25/07	Wet	0.5	10/25/2007	>	45700

Site	Date	Sample Type	Rain Amount	Last Rain	Qualifier	Result
BC11	1/11/08	Wet	0.5	1/11/2008		4200
BC11	1/17/08	Wet	0.57	1/17/2008		514
BC11	2/13/08	Wet	1.16	2/13/2008		543
BC11	2/22/08	Wet	1.06	2/22/2008		793
BC12	7/9/07	Wet	0.65	7/9/2007	>	19100
BC12	10/24/07	Wet	0.67	10/24/2007		20100
BC12	10/25/07	Wet	0.5	10/25/2007	>	24700
BC12	1/11/08	Wet	0.5	1/11/2008		4600
BC12	1/17/08	Wet	0.57	1/17/2008		4100
BC12	2/13/08	Wet	1.16	2/13/2008	>	1730
BC12	2/22/08	Wet	1.06	2/22/2008	>	17000
BC13	7/9/07	Wet	0.65	7/9/2007	>	13400
BC13	10/24/07	Wet	0.67	10/24/2007		30500
BC13	10/25/07	Wet	0.5	10/25/2007	>	24200
BC13	1/11/08	Wet	0.5	1/11/2008		2900
BC13	1/17/08	Wet	0.57	1/17/2008		2800
BC13	2/13/08	Wet	1.16	2/13/2008	>	1540
BC13	2/22/08	Wet	1.06	2/22/2008	>	13200
BC15	5/22/07	Dry	0			614
BC15	6/4/07	Wet	0.57	6/3/2007		99
BC15	12/17/07	Wet	3.51	12/16/07		293
BC15	2/19/08	Wet	1.2	2/18/2008		120
BC18	1/11/08	Wet	0.5	1/11/2008	est	1200
BC18	1/17/08	Wet	0.5	1/17/2008		400
BC18	2/13/08	Wet	1.16	2/13/2008		2100
BC18	2/22/08	Wet	1.06	2/22/2008	>	850
BC19	1/17/08	Wet	0.5	1/17/2008	<	5
BC19	2/13/08	Wet	1.16	2/13/2008	est	5
BC20	2/13/08	Wet	1.16	2/13/2008	est	175
BC20	2/22/08	Wet	1.06	2/22/2008	est	32
BC21	5/22/07	Dry	0		est	2
BC21	6/21/07	Wet	0.65	6/20/2007	>	1960
BC21	8/28/07	Wet	0.89	8/27/2007		175
BC21	2/13/08	Wet	1.16	2/13/2007		357
BC21	2/19/08	Wet	1.2	2/18/2008	est	11
BC23	2/13/08	Wet	1.16	2/13/2008	>	8480
BC23	2/22/08	Wet	1.06	2/22/2008	>	936
BC26	5/22/07	Dry	0			289
BC26	6/4/07	Wet	0.57	6/3/2007		548

Site	Date	Sample Type	Rain Amount	Last Rain	Qualifier	Result
BC26	12/17/07	Wet	3.51	12/16/07	est	82
BC26	2/19/08	Wet	1.2	2/18/2008	est	5
DC1	3/22/07	Dry	0			16
DC1	7/10/07	Wet	1.15	7/10/2007		50
DC1	9/27/07	Wet	0.51	9/26/2007	<	5
DC1	9/27/07	Wet	0.51	9/26/2007	<	5
DC1	11/16/07	Wet	0.52	11/15/2007	est	5
DC2	3/22/07	Dry	0		est	17
DC2	7/10/07	Wet	1.15	7/10/2007		0
DC2	9/27/07	Wet	0.51	9/26/2007	<	5
DC2	9/27/07	Wet	0.51	9/26/2007	<	5
DC2	11/16/07	Wet	0.52	11/15/2007	est	5
DC3	3/22/07	Dry	0		est	10
DC3	7/10/07	Wet	1.15	7/10/2007		32
DC3	9/27/07	Wet	0.51	9/26/2007	<	5
DC3	9/27/07	Wet	0.51	9/26/2007	<	5
DC3	11/16/07	Wet	0.52	11/15/2007	est	19
DC4	3/22/07	Dry	0		est	60
DC4	7/10/07	Wet	1.15	7/10/2007		79
DC4	11/16/07	Wet	0.52	11/15/2007	est	44
DC5	3/9/07	Dry	0			68
DC5	6/21/07	Wet	0.65	6/20/2007		771
DC5	8/28/07	Wet	0.89	8/27/2007		125
DC5	11/16/07	Wet	0.52	11/15/2007		657
DC5	11/16/07	Wet	0.52	11/15/2007		692
DC5A	10/2/07	Dry	0			10500
DC6	3/9/07	Dry	0		est	8
DC6	6/21/07	Wet	0.65	6/20/2007		103
DC6	8/28/07	Wet	0.89	8/27/2007		71
DC6	11/16/07	Wet	0.52	11/15/2007		417
DC6	11/16/07	Wet	0.52	11/15/2007		429
DC8	6/19/08	Dry	0			100
DC8	8/11/08	Wet	1.76	8/10/2008		3900
DC9	6/19/08	Dry	0		est	78
DC9	8/11/08	Wet	1.76	8/10/2008		4100
DC10	6/19/08	Dry	0			145
DC10	8/11/08	Wet	1.76	8/10/2008	est	1210
DC11	6/19/08	Dry	0			400
DC11	8/11/08	Wet	1.76	8/10/2008		2100

Site	Date	Sample Type	Rain Amount	Last Rain	Qualifier	Result
DC12	6/19/08	Dry	0		est	45
DC12	8/11/08	Wet	1.76	8/10/2008		>7800
DC13	8/14/08	Wet	0.98	8/13/2008		291
DC14	8/14/08	Wet	0.98	8/13/2008		43
DC15	8/14/08	Wet	0.98	8/13/2008		18
DC16	8/14/08	Wet	0.98	8/13/2008		32
DC16	8/14/08	Wet	0.98	8/13/2008	est	68

Attachment A

Public Notices

February 18, 2009 – Tideland News and Carteret County News Times

February 20 and 22, 2009 - Carteret County News Times

February 24, 2009 – Jacksonville Daily News (see article below)

February 25, 2009 – Tideland News

March 2, 2009 - Public meeting in Cape Carteret

From the Jacksonville Daily News

Study says White Oak River in danger

JANNETTE PIPPIN <mailto:jpippin@freedomenc.com>
February 24, 2009 - 5:56PM

CAPE CARTERET - The White Oak River is in trouble, and area citizens are invited to a meeting Monday March 2 to find out why and how they can help. The results of a three-year, federally funded study of bacteria levels in the river will be presented along with recommendations for voluntary steps the public can take to help reduce the flow of polluted stormwater into the waterways. The meeting will be held at White Oak Elementary School in Cape Carteret starting at 7 Monday night.

"We encourage everyone who cares about the White Oak to attend this important meeting," said Frank Tursi, the N.C. Coastal Federation's Cape Lookout CoastKeeper and the study's project leader. "This is a great opportunity to understand what is going on in our river and how we can begin to fix it."

The Coastal Federation partnered with the Town of Cedar Point and two state agencies on the study, which focused on the bacteria plaguing the White Oak and closing its oyster and clam beds. The study found very high levels of fecal coliform bacteria in four watersheds in the lower river near Cedar Point.

More than 200 water samples were drawn from almost 70 scattered sites, making the study the most extensive bacteria testing done river, Tursi said. When the results were in, 89 percent of the samples exceeded the federal health standard for shellfish waters. Of the 113 samples taken from the largest watershed, Boathouse Creek, all but three exceeded the standard.

Due to the high bacteria levels in the White Oak, particularly after moderate rains, the state closes much of the lower river to shellfishing because the oysters and clams would be unsafe to eat. About 2,200 acres, or almost two-thirds of the lower White Oak, are now permanently closed to shellfishing or close temporarily after a good rain, Tursi said. Under the federal Clean Water Act, the river is considered impaired and the state is obligated to take steps to reduce the contamination.

The partners received a federal EPA grant to conduct the study, and they are now holding the public hearing as part of that process. The study outlines a series of voluntary steps that can be taken to reduce the flow of stormwater into the river. While there is no requirement that they be followed, Tursi believes they are steps that the citizens and communities around the White Oak can follow, from reworking storm ditches to allow more runoff to soak into the ground to educating pet owners about the importance of picking up after their dogs.

Fecal coliform bacteria isn't generally harmful but can be an indicator of the presence of other harmful bacteria. The bacteria are found only in the digestive tract of warm-blooded animals, and genetic testing of some of the samples confirmed wildlife and pets are the primary sources of contamination. But that doesn't eliminate development as a contributor to the problems, Tursi said.

Wildlife has always been present; and in an undisturbed coastal landscape, the bacteria from animal droppings typically are absorbed into the ground with the rain. But much of the land in the study area is covered with hard surfaces such as roads and parking lots that increase the flow of stormwater.

Tursi said it wasn't realistic to reduce the source of pollution - pets and wildlife - so the focus of the recommendations is on reducing the flow of stormwater into the river. "It's not going to require anything of anybody, but we hope the study will educate people about what is going on and offer a reasonable roadway to solutions," Tursi said.

People can read the entire study at the N.C. Division of Water Quality's Web site at http://h20.enr.state.nc.us/tmdl/TMDL_list.htm#Draft_TMDLs. Written comments can be sent to Adugna Kebede of the Division's Planning Section at adugna.kebede@ncmail.net or to NCDWQ Planning Section, Attn: Adugna Kebede; 1617 Mail Service Center; Raleigh, NC 27699. Comments will be accepted until March 18.

Attachment B

Embayments in the Southeast White Oak TMDL Responsiveness Summary

The N.C. Coastal Federation (NCCF) and the Town of Cedar Point formed a partnership and received a 319 grant in 2006 to devise watershed implementation plans and TMDLs for three watersheds in the lower White Oak. A local public meeting in March 2009 included presentations on both the TMDL and the watershed implementation plan. Most of the comments received pertained to the watershed implementation plan, which is not a required component of the TMDL.

A total of seven individuals and one organization submitted comments for this TMDL: Henry Walsh, Richard Hunt, Charlie Holland, Al Fox, Linda McGowen, Richard Armstrong, Kenneth Cokey, and NC Department of Transportation. These public comments and the responses are listed below.

1). One comment. This effort to identify runoff of high bacteria levels into the White Oak is necessary and correct. Reliance on this study alone and its recommendations as the sole solution to the shellfish bacteria impairment is short sighted and will not, by itself, lead to a complete solution. The scope of the study should include salinity studies of the embayment waters, sampling of the sediment for bacteria levels over time, and recommendations as to ways in which tidal flows can be restored to these waters.

2). One comment. Install two culverts under Hwy 24 at the Flying Bridge restaurant to flush the Hills Bay area of White Oak River.

3). Five comments. Increased flow of the water out of mouth of the river will clean out the whole river and wash the bacteria out with it. Dredging is the only solution for this problem. This was a step in the right direction, at least people are starting to look at the problem and are looking for ways to remedy the situation.

4). One comment. Although better water flow (through dredging projects) would be helpful in improving water quality in the White Oak, much can be done through steps to control the amount of bacteria washing into the water in the first place. Please encourage the DOT and other state agencies to embrace preventive strategies such as those proposed by the NC Coastal Federation to keep our waterways clean for all the citizens to enjoy.

Response to comments 1-4. This project included a Total Maximum Daily Load (TMDL) under Section 303(d) of the Clean Water Act. The purpose of the TMDL is to identify pollutant sources and calculate reductions needed. We acknowledge that the TMDL goals will be met through adaptive management. The watershed implementation plan that was developed for this project includes recommendations for best management practices, local ordinances and outreach and education. We appreciate your input and *participation. We encourage you to continue involvement as the Town of Cedar Point implements the plan.*

5). One comment. Appreciate the opportunity to comment on the public review draft of the fecal coliform TMDL for the embayments in the southeast White Oak River. Development of this TMDL included a significant stakeholder component involving the Division, NCDOT, Town of Cedar Point, NC Coastal Federation, and local citizens. This effort, supported by a 319 grant administered by the Division started in August 2006 and concluded in March 2009. The strength of the TMDL technical analysis was significantly enhanced as a result of the stakeholder involvement. Our comments were addressed during this stakeholder process, and as such, we have no additional comments at this time.

Response: Thank you for your support.