TOTAL MAXIMUM DAILY LOADS

FOR

FECAL COLIFORM IN SHELLFISH WATERS OF THE LITCHFIELD-PAWLEY'S ISLAND ESTUARY, SOUTH CAROLINA

HYDROLOGIC UNIT CODE: 03040207

(STATIONS 04-09, 04-10, 04-11, 04-12, 04-13, 04-14, 04-19, 04-21)

July 2005

SCDHEC Technical Report Number: 024-05

EPA United States Environmental Protection Agency

Region 4 serving the southeast

Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION 4, ATLANTA, GEORGIA

AND

THE SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL, BUREAU OF WATER

CONTRACT 68-C-02-111

Prepared by:

QUANTITATIVE ENVIRONMENTAL ANALYSIS, LLC

APRIL 2005

In compliance with the provisions of the Federal Clean Water Act, 33 U.S.C §1251 et.seq., as amended by the Water Quality Act of 1987, P.L. 400-4, the U.S Environmental Protection Agency is hereby establishing a Total Maximum Daily Load (TMDL) for Fecal Coliform for Litchfield-Pawley's Island Estuary in the Pee Dee River Basin. Subsequent actions must be consistent with this TMDL.

_____________________________ _____________________________

James D. Giattina, Director Date

Water Management Division

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
cfu	Colony forming units
CWA	Clean Water Act
FCLES	Fecal Coliform Loading Estimator Spreadsheet
GDNR	Georgia Department of Natural Resources
GIS	Geographic Information System
HUC	Hydrologic unit code
ISTD	Individual sewage treatment and disposal system
LA	Load allocation
mL	Milliliter
MA	Management Area
MAR	Multiple antibiotic resistance
MOS	Margin of safety
MPN	Most Probable Number
MS4	Municipal separate storm sewer system
NCDC	National Climatic Data Center
NLCD	National Land Cover Data
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPDES	National Pollutant Discharge Elimination System
ppt	Parts per thousand
%	Percent
SCDHEC	South Carolina Department of Health and Environmental Control
SFH	Shellfish Harvesting Water
TMDL	Total maximum daily load
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WCS	Watershed Characterization System
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard

SECTION 1
INTRODUCTION

1.1 Background

The State of South Carolina is required to develop total maximum daily loads (TMDLs) for water bodies not meeting water quality standards (WQS) in accordance with Section 303(d) of the Clean Water Act (CWA) and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130). The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions so that states can establish water quality-based controls to reduce pollution and restore and maintain the quality of water resources (USEPA 1991).

The South Carolina Department of Health and Environmental Control (SCDHEC) currently classifies approximately 571,010 acres of estuarine and riverine growing area habitat suitable for the cultivation and harvesting of molluscan shellfish (SCDHEC 2003c). For classification purposes, these habitat areas are divided into 25 Shellfish Management Areas (MAs). The Litchfield-Pawley's Island Estuary, which is the focus of this report, is located within MA 04.

Water quality standards for the State of South Carolina were promulgated in the South Carolina Pollution Control Act, Section 48-1-10 *et seq*. Chapter 61, R61-68 (SCDHEC 2004b). The waterbodies within the Litchfield-Pawley's Island system are designated as Class Shellfish Harvesting Waters (SFH). Waters of this class are defined in Regulation 61-68, *Water Classifications and Standards* as:

> *Tidal saltwaters protected for shellfish harvesting and uses listed in Class SA and SB. Suitable for primary and secondary contact recreation, crabbing and fishing. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.*

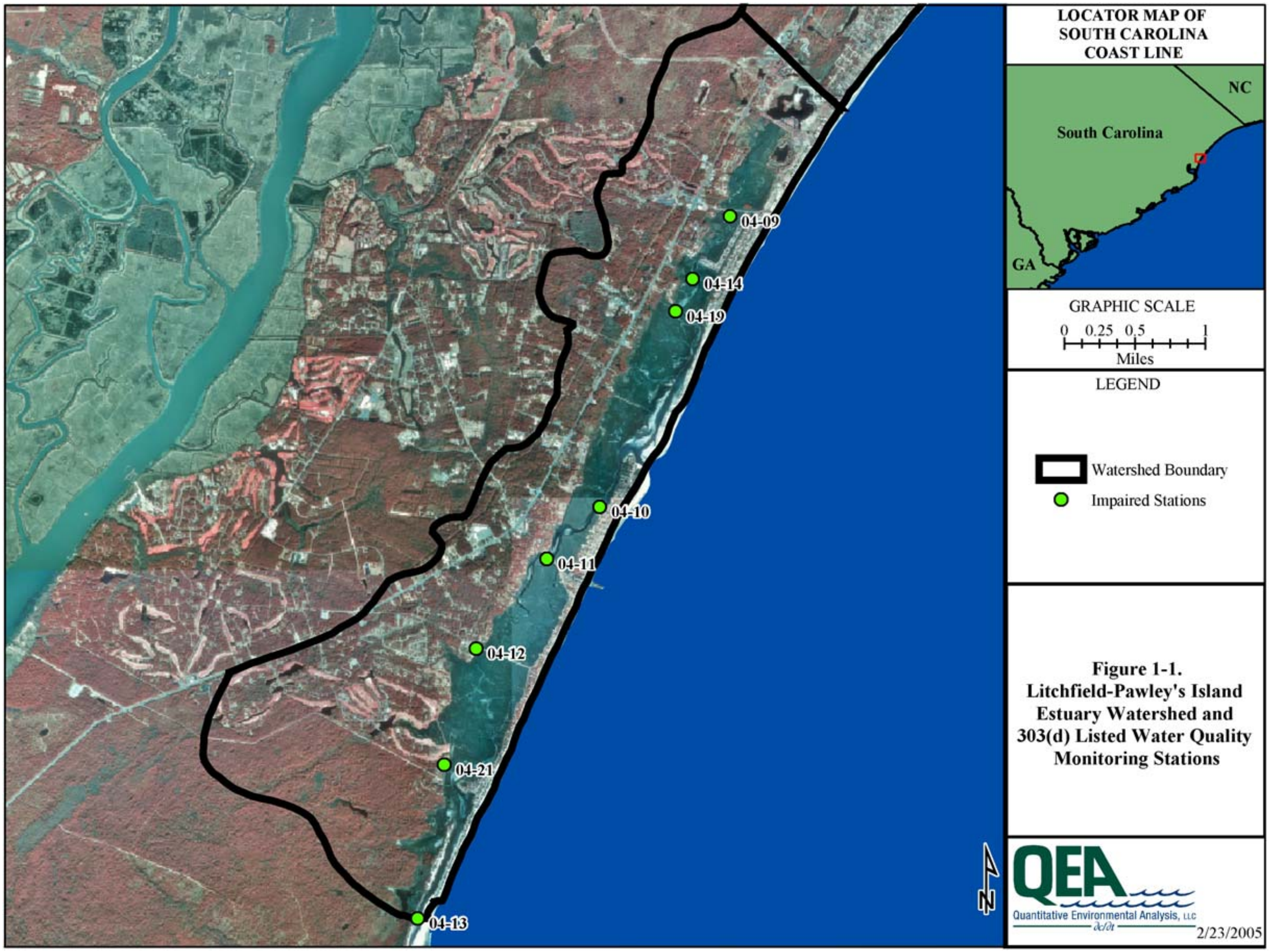
South Carolina's numeric criteria for fecal coliform bacteria in SFH are:

- *Not to exceed a Most Probable Number (MPN) geometric mean of 14/100 milliliters (mL), and*
- *No more than 10 percent (%) of the samples exceed an MPN of 43/100 mL.*

For the purposes of this report, these standards will be referred to herein as the geometric mean standard and the 10% exceedance standard, respectively.

The State of South Carolina has placed eight water quality monitoring (WQM) stations within the Litchfield-Pawley's Island Estuary (Hydrologic Unit Code [HUC] 03040207) on its 2004 Section 303(d) list due to fecal coliform impairments (SCDHEC 2004a; Figure 1-1 and Table 1-1). That is, fecal coliform levels at these locations exceed one or both water quality criteria for fecal coliform in shellfish harvesting waters. The presence of fecal coliform bacteria at these locations indicates that the water has been contaminated with the fecal material

Figure 1-1 Litchfield-Pawley's Island Estuary Watershed and 303(d) Listed Water Quality Monitoring Stations



of humans and/or other animals, which may have originated from point and/or nonpoint sources of pollution.

Table 1-1 Water Quality Monitoring Stations in the Litchfield-Pawley's Island Estuary on the 2004 303(d) List for Fecal Coliform

SCDHEC WQM Station	WQM Station Locations	SCDHEC Shellfish Water Classification
Clubhouse Creek (HUC 03040207040)		
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	Restricted
04-14	Clubhouse Creek at Dock End of Sportsmen Boulevard	Restricted
04-19	Clubhouse Creek, First Bend South of Salt Marsh Cove	Restricted
Pawley's Island Creek (HUC 03040207040)		
04-12	South Causeway Bridge at Pawley's Island Creek	Restricted
04-11	North Causeway Bridge at Pawley's Island Creek	Restricted
04-10	Shell Avenue at Pawley's Island Creek	Restricted
South Pawley's Island (HUC 03040207040)		
04-21	Pawley's Island Sound, Inlet South Boat Landing	Restricted
04-13	Pawley's Inlet	Restricted

The eight stations listed in Table 1-1 are classified as Restricted, indicating that shellfish harvesting for direct marketing is not allowed due to unpredictable fluctuations in water quality at these locations. Shellfish harvesting at Restricted stations is allowed only by special permit for the purposes of depuration and relaying. Wet weather sources have been identified as the general cause of the impairments at these stations; acceptable water quality is observed during prolonged dry weather periods (SCDHEC 2003b). Studies of specific rainfall amounts on water quality within the estuary are currently being considered.

The purpose of this report is to establish pollutant load allocations for the impaired waterbodies listed in Table 1-1. This information will assist SCDHEC develop and implement a management plan to mitigate fecal coliform bacteria loadings and facilitate the re-opening of the shellfish harvesting beds in these waterbodies.

1.2 Watershed Description

The Litchfield-Pawley's Island system is a saltwater, tidally-dominated waterbody situated in the Pee Dee River Basin along the northeastern shoreline of South Carolina (SCDHEC 2003b). This system is comprised of small meandering creeks that are characterized by ebb and flood tidal deltas, intertidal mudflats, intertidal oyster reefs, and high marshes. The system is situated within Georgetown County, extending from North Litchfield to approximately one mile south of Pawley's Inlet. The system contains approximately 1,256 acres (29%) of the habitat suitable for shellfish production that exists within MA 04.

The Litchfield-Pawley's Island system drains approximately 5,250 acres of land comprised of forest (44%), open water/beach (23%), wetlands (20%), urban buildup (9%), and urban/recreational grasses (3%) (Figure 1-2). Approximately 4,886 acres (93%) of the total watershed drain through the eight WQM stations listed on the 303(d) list. The general land use categories and associated acreages for the sub-watersheds draining through each of the WQM stations, as derived from 1992 United States Geological Survey (USGS) National Land Cover Data (NLCD) land use data, are presented in Table 1-2. The percentages that each land use constitutes within the respective sub-watersheds are presented in Table 1-3.

The estuary is approximately 5.5 nautical miles in length and has an average width of less than 0.5 nautical miles. Water depths in this system are generally less than 2.5 meters (SCDHEC 2003b). Salinity in the system is generally above 30 parts per thousand (ppt), as significant freshwater input to this area is generally limited to precipitation and resulting runoff. Annual precipitation for the region, as measured at Brookgreen Gardens (1993 to present), averages about 57 inches.

Figure 1-2 Land Use Distribution within the Litchfield-Pawley's Island Estuary Watershed

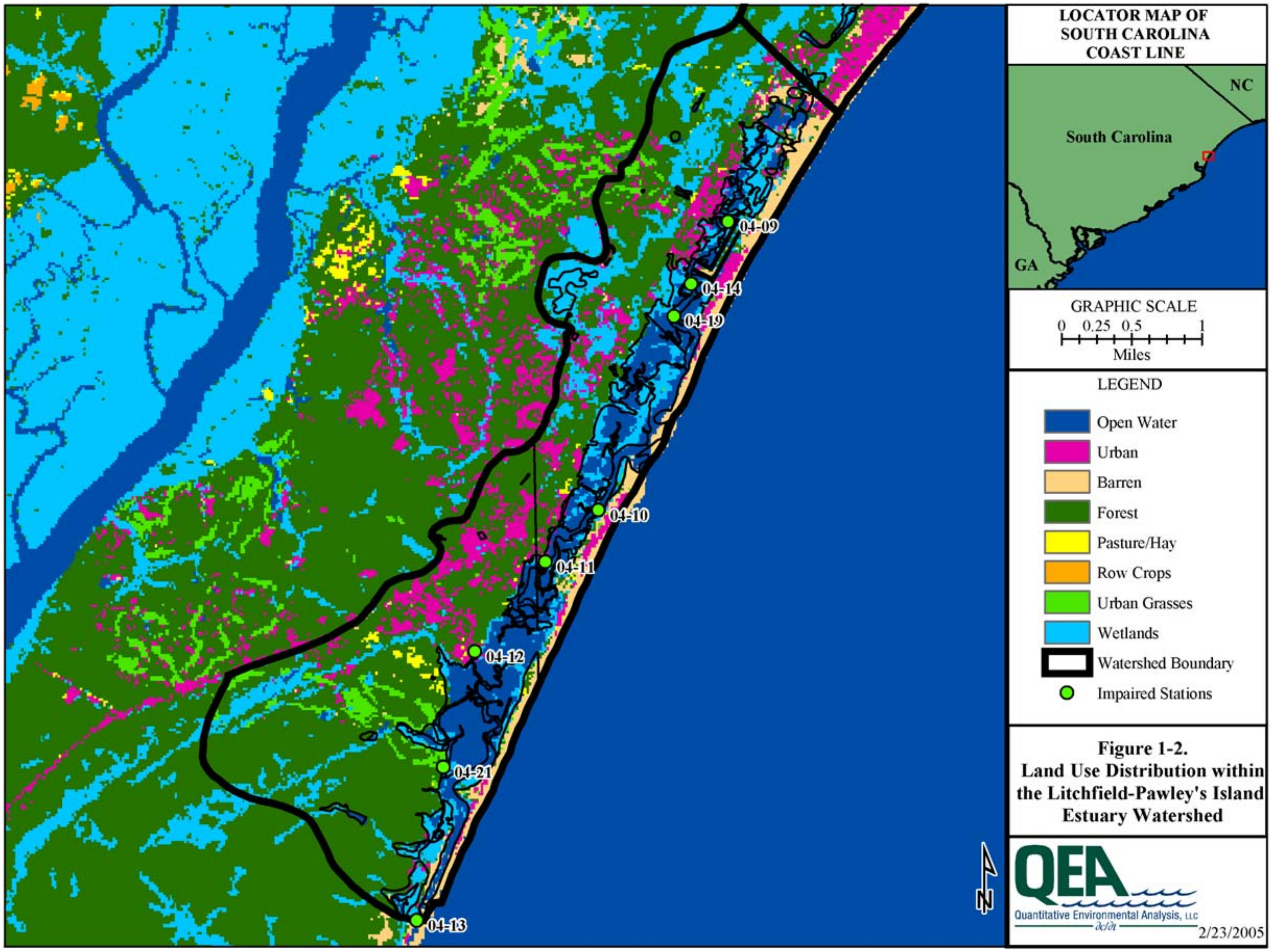


Table 1-2 Land Use Distribution (in Acres) for the Sub-watersheds of the 303(d) Listed Water Quality Monitoring Stations within the Litchfield-Pawley's Island Estuary

Land Use Description	Acreages in Each Sub-Watershed							
	04-09	04-14	04-19	04-12	04-11	04-10	04-21	04-13
Barren	131.3	19.3	20.1	19.7	19.1	28.4	31.0	35.6
Forest	370.6	152.7	93.4	216.3	201.0	166.2	242.3	852.9
Open water	80.2	40.9	70.7	117.4	91.6	103.7	174.2	51.4
Pasture/hay	8.7	0.0	0.0	17.5	4.8	3.8	7.2	0.2
Urban buildup	100.5	45.1	29.2	68.3	116.0	52.6	15.3	13.7
Urban grasses	18.7	5.4	0.2	0.4	2.0	2.2	72.9	27.4
Wetlands	300.3	64.2	126.9	47.3	31.4	81.8	66.9	225.8
Totals	1,010.3	327.6	340.5	486.9	465.9	438.7	609.8	1,207.0

Table 1-3 Land Use Distribution (in Percentages) for the Sub-watersheds of the 303(d) Listed Water Quality Monitoring Stations within the Litchfield-Pawley's Island Estuary

Land Use Description	Percentage in Each Sub-Watershed							
	04-09	04-14	04-19	04-12	04-11	04-10	04-21	04-13
Barren	13.0	5.9	5.9	4.0	4.1	6.5	5.1	2.9
Forest	36.8	46.6	27.4	44.5	43.2	37.8	39.6	70.7
Open water	7.9	12.5	20.8	24.1	19.7	23.6	28.6	4.3
Pasture/hay	0.9	0.0	0.0	3.6	1.0	0.9	1.2	0.0
Urban buildup	9.9	13.8	8.6	14.0	24.9	12.0	2.5	1.1
Urban grasses	1.8	1.6	0.1	0.1	0.4	0.5	12.0	2.3
Wetlands	29.7	19.6	37.2	9.7	6.7	18.7	11.0	18.7
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SECTION 2
WATER QUALITY ASSESSMENT

2.1 Assessment of Existing Water Quality Data

A water quality assessment was performed for each impaired station using data obtained from several sources, including:

- USEPA Watershed Characterization System (WCS) – land use type, stream characteristics, and locations of point source dischargers,
- USEPA STORET database – water quality monitoring information collected between September 2001 and August 2004,
- National Oceanic and Atmospheric Administration (NOAA) National Climactic Data Center (NCDC) – daily precipitation records for Brookgreen Gardens in Georgetown County, and
- NOAA National Ocean Service (NOS) – tide stage information.

The water quality assessment focused on understanding: (1) which fecal coliform standard, the geometric mean or the no more than 10% exceedance, caused the listing; (2) the source(s) of the fecal coliform causing these exceedances; and (3) the relationships between measured fecal coliform levels and various environmental variables (e.g., precipitation, salinity). This assessment was performed using a weight-of-evidence approach. That is, all pertinent information was examined in a holistic fashion in order to understand water quality impacts associated with potential fecal coliform sources to and fecal coliform levels within the impaired systems; no one data set carried more weight than another. A summary of the water quality data collected for the three year period between September 2001 and August 2004 (since SCDHEC shellfish harvesting classifications are established using data from a three year period) and used in this assessment are provided for each impaired station in Table 2-1. Individual ambient fecal coliform bacteria measurements for each WQM during this period are provided in Appendix A.

Eight stations within the Litchfield-Pawley's Island system exceed the State's water quality standards for fecal coliform (see Table 1-1). Six of the eight stations (04-09, 04-10, 04-11, 04-12, 04-14, and 04-19) are on the State's Section 303(d) list because fecal coliform levels at these locations exceed both the geometric mean (i.e., 14/100 mL) and no more than 10% exceedance (43/100 mL) standards. The other two stations (04-13 and 04-21) are listed as impaired because fecal coliform levels at these locations exceed the no more than 10% exceedance standard.

Relationships between measured in-stream fecal coliform levels and several environmental variables were examined to understand the conditions in which these fecal coliform exceedances occur. Environmental variables considered in this assessment included water temperature, tidal stage, total 24-hour precipitation, and salinity. Seasonal variations in fecal coliform levels were also examined. Individual fecal coliform measurements are presented as a function of salinity in Figure 2-1. Although variable, relationships between in-stream fecal coliform levels and salinity are evident. This trend is more evident in Figure 2-2, where in-stream fecal coliform measurements are grouped

Table 2-1 Summary of Fecal Coliform Data (September 2001 – August 2004) for the 303(d) Listed Stations within the Litchfield-Pawley's Island Estuary

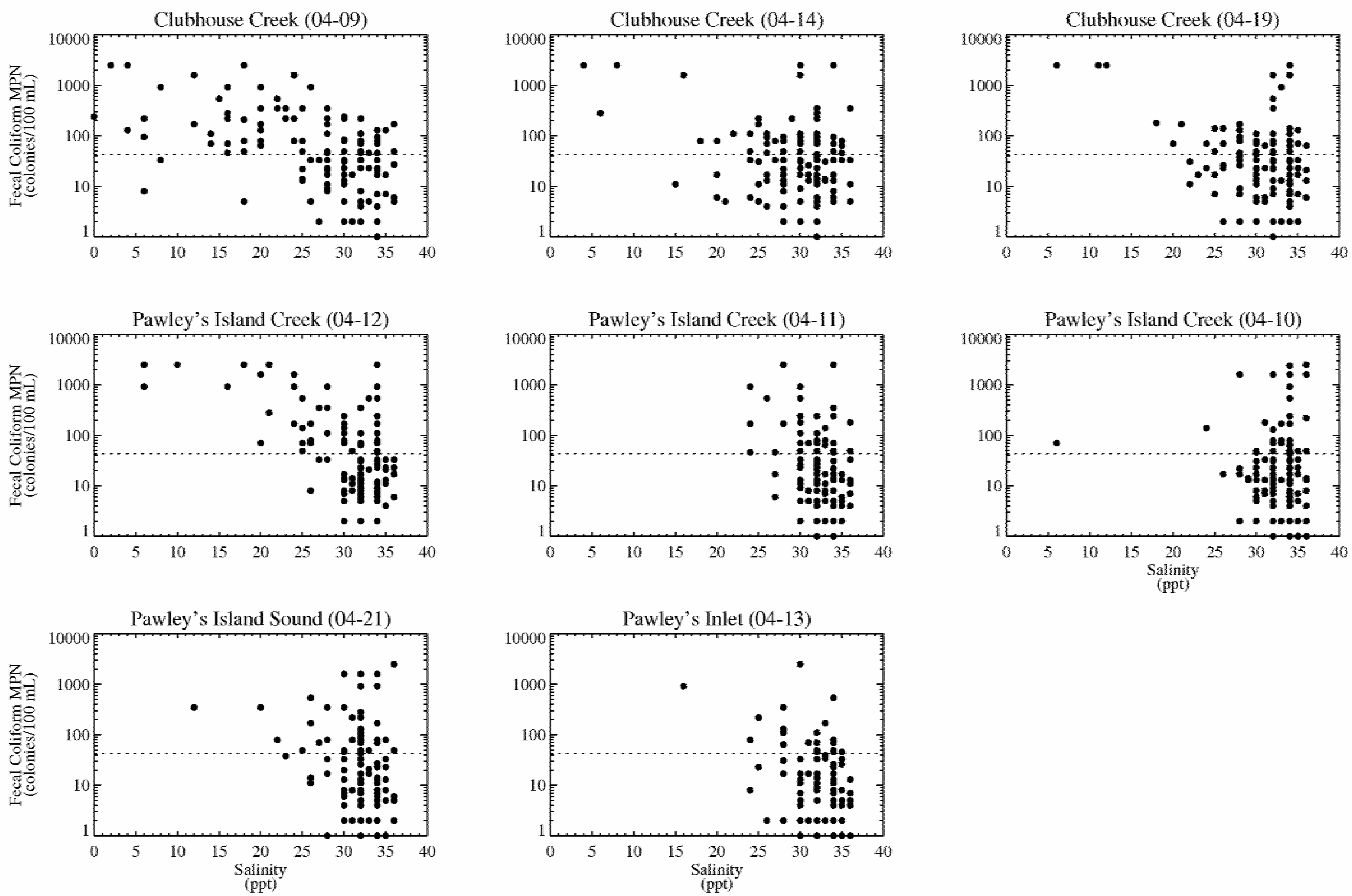
WQM Station	Number of Measurements	Geometric Mean	Samples >43/100 mL		Listing Cause	
			Number	Percent	Violates Geo. Mean Standard	Violates > 10% Standard
Clubhouse Creek (HUC 03040207040)						
04-09	36	54.3	21	58%	Yes	Yes
04-14	36	48.5	19	53%	Yes	Yes
04-19	36	43.8	15	42%	Yes	Yes
Pawley's Island Creek (HUC 03040207040)						
04-12	36	35.5	13	36%	Yes	Yes
04-11	36	14.2	10	28%	Yes	Yes
04-10	37	22.3	15	41%	Yes	Yes
South Pawley's Island (HUC 03040207040)						
04-21	37	17.3	12	32%	No	Yes
04-13	37	9.5	8	22%	No	Yes

and averaged in 5 ppt salinity bins. At most locations, average in-stream fecal coliform levels are highest during times with the greatest freshwater influence (i.e., less than 20 ppt) and decline with increasing salinity (Figure 2-2). Average fecal coliform counts at each station generally measure in the hundreds to thousands at salinity levels less than 20 ppt, in the tens to hundreds at salinities of 20 to 30 ppt, and in the ones to tens above salinities of 30 ppt. The consistent relationship between in-stream fecal coliform levels and salinity indicate that wet weather (i.e., freshwater) inputs are significant contributors to the fecal coliform contamination within the Litchfield-Pawley's Island Estuary. This finding is consistent with observations made during shoreline surveys of MA 04 performed by the SCDHEC (SCDHEC 2003b).

Fecal coliform levels exhibit a weaker relationship to total 24-hour precipitation than salinity (Figures 2-3 and 2-4). This is understandable considering: (1) fecal coliform measurements were primarily collected during relatively dry periods (i.e., days with 0.5 inches of precipitation or less); (2) the time of concentration (i.e., the time required for storm runoff to travel through the basin and reach the receiving waterbody) was not necessarily considered during collection of the in-stream water samples after precipitation events; and (3) fecal coliform bacteria are subject to decay during transport of storm runoff from the basin to the receiving waterbody.

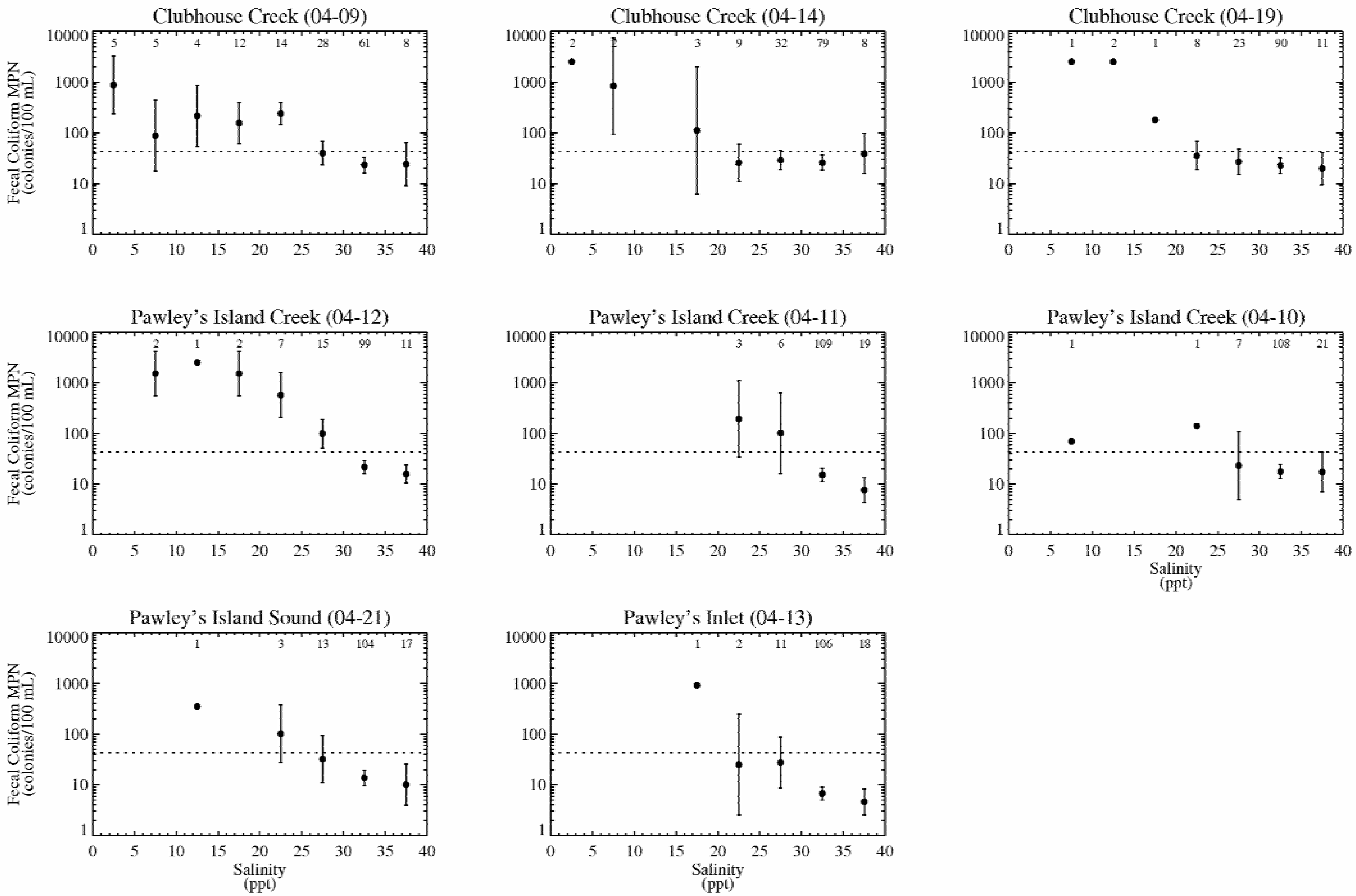
No consistent relationship was observed between in-stream fecal coliform levels and water temperature, tidal stage, and season.

Figure 2-1 Fecal Coliform Levels as a Function of Salinity for the 303(d) Listed Stations within the Litchfield-Pawley's Island Estuary: Individual Measurements



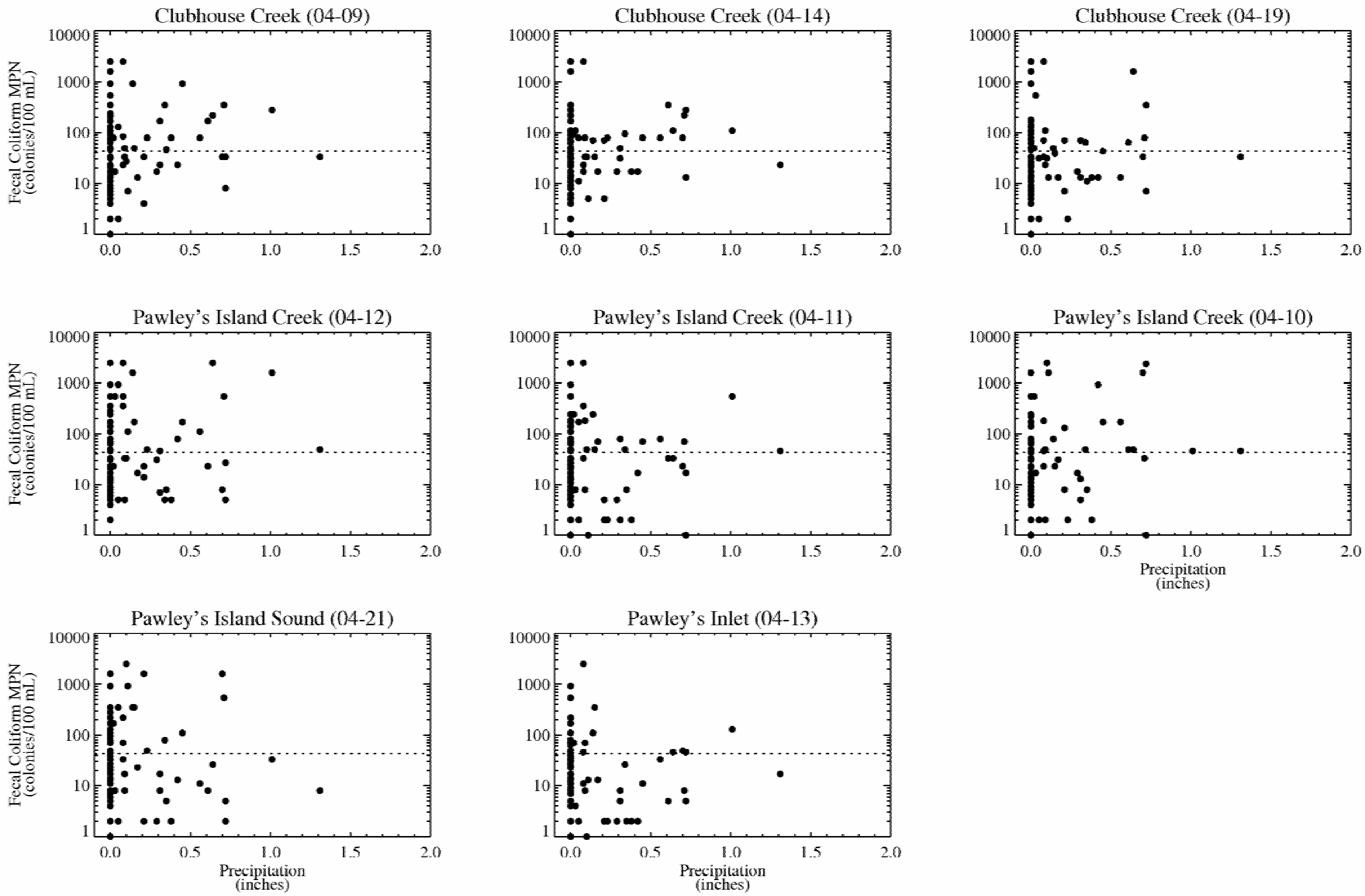
Dashed horizontal lines indicate the 10% not to exceed standard of 43 colonies/100 mL.
Data collected between 1993 and 2004.

Figure 2-2 Average Fecal Coliform Levels as a Function of Salinity for the 303(d) Listed Stations within the Litchfield-Pawley's Island Estuary: By Salinity Bin



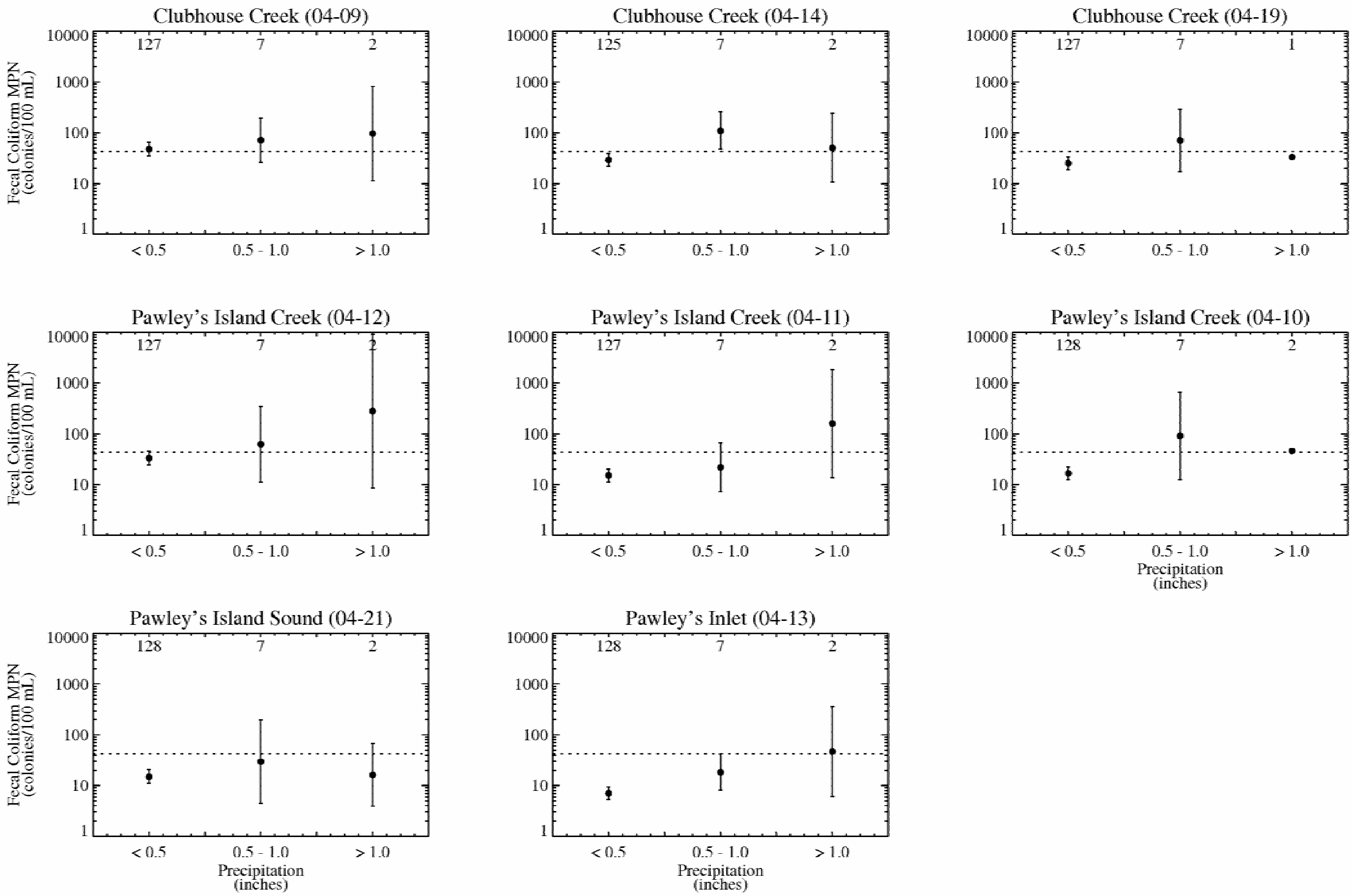
Data shown as geometric means +/- two standard errors of mean (1993 - 2004).
Data grouped into 5 ppt salinity intervals. Geometric means plotted at center of 5 ppt salinity interval.
Dashed horizontal lines indicate the 10% not to exceed standard, 43 colonies/100 mL.

Figure 2-3 Fecal Coliform Levels as a Function of Precipitation for the 303(d) Listed Stations within the Litchfield-Pawley's Island Estuary: Individual Measurements



Data from 1993 to 2004. Precipitation represents 24-hour totals as measured at Brookgreen Gardens.
Dashed horizontal lines indicate the 10% not to exceed standard for fecal coliforms (43 colonies/100 mL).

Figure 2-4 Average Fecal Coliform Levels as a Function of Precipitation for the 303(d) Listed Stations within the Litchfield-Pawley's Island Estuary: By Precipitation Bin



Data from 1993 to 2004. Precipitation represents 24-hour totals as measured at Brookgreen Gardens.
Data shown as geometric means +/- two standard errors of mean.
Dashed horizontal lines indicate the 10% not to exceed standard for fecal coliforms (43 colonies/100 mL).

SECTION 3
POLLUTANT SOURCE ASSESSMENT

Fecal coliform are bacteria that are present in the digestive tract of warm-blooded animals and are excreted in the feces. Although fecal coliform themselves do not generally pose a danger to humans and animals, their presence in waterbodies is indicative of other disease-causing bacteria and viruses. For this reason, fecal coliform bacteria are often used as indicators of the health of recreational, drinking and shellfish waters.

Fecal coliform bacteria enter surface water from both point and nonpoint sources. Point sources are discharges that originate from a single known location, such as pipes, outfalls and conveyance channels from either municipal or industrial wastewater treatment facilities. Facilities that discharge treated (removed) human waste are permitted through the National Pollutant Discharge Elimination System (NPDES) program, and are required to monitor fecal coliform bacteria in their effluent in accordance with their NPDES permit. Nonpoint sources are diffuse sources that originate and enter waterbodies from a relatively large area (i.e., cannot be attributable to a specific location). Nonpoint sources include various land activities that contribute fecal coliform bacteria to waterbodies as a result of runoff producing storm events. Potential point and nonpoint sources of fecal coliform contamination that may affect water quality within the Litchfield-Pawley's Island system are discussed below.

As was done for the water quality assessment, the pollutant source assessment presented herein was performed using a weight-of-evidence approach. That is, all pertinent information was examined in a holistic fashion in order to understand water quality impacts associated with potential fecal coliform sources to the impaired systems; no one data set carried more weight than another.

3.1 Point Source Discharges

Potential point sources of fecal contamination include permitted dischargers (e.g., wastewater and other NPDES-regulated dischargers), municipal separate storm sewer systems (MS4s), and marinas and docking facilities. Wastewater dischargers can contribute to fecal coliform pollution of a waterbody if disinfection processes at the facility are not properly maintained or the capacities of these systems are exceeded. MS4s collect stormwater runoff that may contain elevated levels of fecal coliform bacteria and convey this runoff directly to a waterbody during storm events. The accidental or intentional dumping of raw or poorly treated sewage in waters at marinas and docking facilities also can contribute to elevated fecal coliform levels within a waterbody.

3.1.1 Permitted Dischargers

Two wastewater treatment facilities provide service to communities within MA 04: (1) Grand Strand Water and Sewer Authority; and (2) Georgetown Water and Sewer Authority. Of the two authorities, only the Georgetown Water and Sewer Authority provides wastewater disposal service within the watershed (Litchfield Beach and Pawley's Island communities). The Georgetown Water and Sewer Authority manages 37 lift stations within the watershed (Hardy 2005), which help to transport untreated and treated wastewater to the treatment facility. Treated wastewater from this treatment facility is discharged to the Waccamaw River, which is located outside of the Litchfield-Pawley's Estuary watershed.

Failure of these lift stations has the potential to adversely affect water quality in the Litchfield-Pawley's system. In order to ensure adequate response in the event of lift station failure, the stations are provided with emergency power, audible and visual alarms, and telemetry systems which alert repair crews to any failure that could impact water quality. The lift stations within the Litchfield-Pawley's watershed are not believed to be significant sources of fecal coliform contamination, as the SCDHEC has inspected the lift stations and has found them to be well maintained and in good working order (SCDHEC 2003b). The Authority is responsible for notifying SCDHEC in the event of a spillage that may adversely impact the shellfish waters within MA 04 (SCDHEC 2003b).

One NPDES-permitted discharger exists within the Litchfield-Pawley's Island Estuary (Inlet Point South Phase II – ND0074616). This discharger is a domestic package plant that is permitted to discharge to an inland golf course only; it does not discharge directly to the estuary.

3.1.2 Municipal Separate Storm Sewer Systems (MS4s)

In 1990, USEPA implemented the Phase I Stormwater NPDES program to regulate discharges to local waterbodies associated with MS4s. These regulations categorized MS4s into three classifications, based on the populations each system serves: large; medium; or small. This phase of the program required large and medium MS4s to apply for NPDES permits; small MS4s were not regulated until 1999 when USEPA implemented the second phase (Phase II) of the program. Phase II extended regulation of the NPDES stormwater program to small MS4s (SCDHEC undated).

No MS4s exist within the Litchfield-Pawley's Island system.

3.1.3 Marinas and Docking Facilities

Marinas and docking facilities are not located within the Litchfield-Pawley's Island Estuary due to the shallow waters within the system. For this reason, watercraft using the estuary are limited to approximately 16 feet in length (SCDHEC 2004c).

3.2 Nonpoint Sources

Nonpoint sources are diffuse sources that originate and enter waterbodies from a relatively large area (i.e., cannot be attributable to a specific location) and, thus, may originate from both rural and urbanized areas. Based on the land use distribution within the Litchfield-Pawley's Island watershed, potential nonpoint sources of fecal coliform contamination include urban and suburban stormwater runoff, agricultural runoff, individual sewage treatment and disposal (ISTD) systems, wild and domestic animal populations, and boat traffic.

3.2.1 Urban and Suburban Runoff

Stormwater runoff from urban and suburban areas has been identified as a significant problem within MA 04 due to the dense development of the surrounding area (SCDHEC 2003b). Undisturbed tracts of forested land exist within the watershed; however, an increase in the population density has resulted in the construction of single and multi-family housing developments, golf courses, shopping centers, and associated development (SCDHEC 2004c).

3.2.2 Agricultural Runoff

Agricultural runoff is not considered a significant source of fecal coliform contamination due to limited commercial crop production in the area and land use economics (SCDHEC 2004c).

3.2.3 Individual Sewage Treatment and Disposal Systems (ISTDs)

Malfunctioning or improperly installed septic systems or ISTDs can serve as a source of fecal coliform contamination to the Litchfield-Pawley's Estuary. ISTDs within MA 04 are generally being replaced by central sewer systems; however, septic systems are still in use. Central sewer systems have less potential to impact shellfish harvesting waters than ISTDs, although occasional discharges of untreated wastewater to adjacent waterbodies can occur during system malfunctions (SCDHEC 2004c). A survey of the Pawley's Island mainland in 2001 was conducted by the State's Division of Environmental Sanitation and the Waccamaw District Shellfish Program. This survey identified overt malfunctions of ISTDs in the Maryville community in the southern portion of the survey area. This community is separated from the marsh by a golf course; a distance of approximately one mile between the community and the estuary (SCDHEC 2004c). Therefore, ISTDs are not believed to be significant sources of fecal coliform contamination to the system.

3.2.4 Wildlife

Fecal coliform bacteria originating from domestic animals and wildlife accumulate on the land surface and are transported to receiving waterbodies via runoff during precipitation events. The South Carolina Department of Natural Resources estimates that, where suitable habitat exists, there are between 15 and 30 white-tailed deer per square mile within the watershed (South Carolina Deer Density Map 2000). The watershed also contains suitable habitat for a wide variety of shorebirds. In addition, substantial populations of wildlife are supported within MA 04. These wildlife include rabbit, raccoon, opossum, rodents, songbirds, shorebirds and migratory waterfowl (SCDHEC 2004c). As such, wildlife may be a significant source of fecal coliform to the Litchfield-Pawley's system.

The predominant domestic animal populations within the watershed consist of dogs and cats (SCDHEC 2004c). Many of these animals spend at least a portion of their time outdoors and, therefore, can deposit fecal matter that is then available to be washed into the waterbody during precipitation events. The national average for dog and cat ownership is 0.66 cats and 0.58 dogs per household (American Veterinary Medical Association 2004). Using these averages and the 1997 population estimates for the appropriate portions of Georgetown County located within the Litchfield-Pawley's watershed, it is estimated that approximately 138 cats and 122 dogs reside within the watershed. Domestic pets are not believed to be a significant source of fecal coliform to the Litchfield-Pawley's system.

3.2.5 Boat Traffic

Although marinas and docking facilities are not found within the Litchfield-Pawley's Island Estuary due to its shallow waters, the system does support recreational boat traffic. As indicated above, watercraft using the estuary are limited to approximately 16 feet in length

(SCDHEC 2004c). The discharge of onboard septage to the waterbodies in the Litchfield-Pawley's system is strictly forbidden by law. Although not believed to be a significant source, illegal dumping of onboard septage is a potential source of fecal coliform to the system.

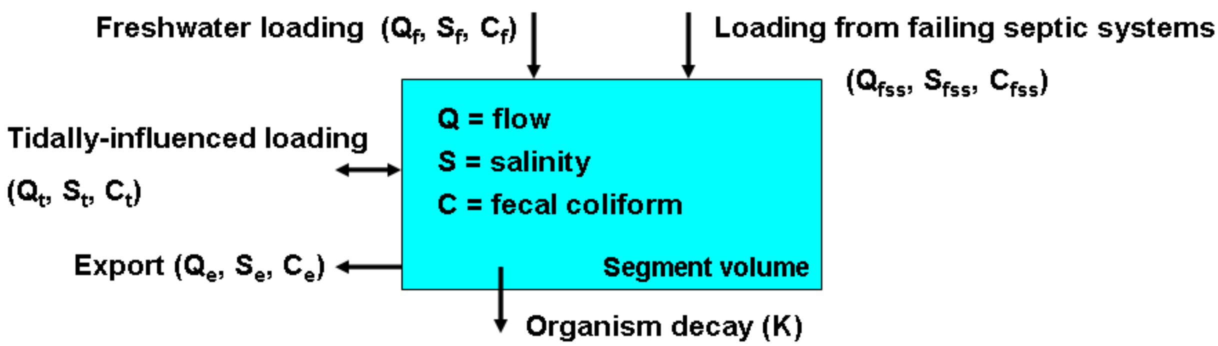
3.3 Summary of Fecal Coliform Sources and Impaired WQM Stations

The available water quality data indicate that six of the eight WQM stations are on the Section 303(d) list due to exceedances of the geometric mean standard, while all eight stations violate the no more than 10% exceedance standard. Relationships between in-stream fecal coliform levels and salinity, as well as the lack of major point sources of fecal coliform pollution within the watershed, indicate that stormwater runoff from nonpoint sources are the primary contributors to fecal coliform contamination in the impaired waterbodies.

SECTION 4
SOURCE LOAD ASSESSMENT

The primary purpose of the source load assessment is to develop estimates of point and non-point source loadings that contribute to the observed fecal coliform concentrations within the impaired water segment. Fecal coliform loadings enter the impaired system primarily via two routes: (1) wet weather (i.e., freshwater) loadings, which are derived from precipitation events and subsequent runoff; and (2) tidally-influenced loadings, which are introduced during the diurnal tidal fluctuations that occur in the system. Fecal coliform are lost with the net estuarine flow from the system and through natural decay (i.e., death). A generalized schematic of the source and sink terms to the impaired system is presented in Figure 4-1.

Figure 4-1 Sources and Sinks of Fecal Coliform to the Litchfield-Pawley's Island Estuary



A weight-of-evidence approach was employed to assess the importance of the various sources of fecal coliform bacteria to in-stream levels measured within each of the impaired systems. Results of this evaluation indicate that freshwater inputs represent the most important loading to each system. These freshwater loadings were quantified through the development and application of a simple fecal coliform mass balance model. Mathematical modeling has been used extensively to support the development of TMDLs for fecal coliform bacteria in aquatic environments (SCDHEC 2003c; SCDHEC 2004d; Georgia Department of Natural Resources [GDNR] 2000). The complexity of these modeling applications have ranged from simple tidal prism approaches to highly mechanistic fate and transport modeling. Due to the limited physical and hydraulic information for the individual creeks within the Litchfield-Pawley's Island Estuary, as well as the observation that the impairments to these systems are driven by wet weather sources, a simple multi-segment box model approach was employed. For each impaired system, the model that extended from the most upstream impaired station within the system to the open ocean boundary, where possible, was developed using the principles of conservation of mass, and considered the various sources and sinks discussed in Section 3 and presented in Figure 4-1. Each system was divided into multiple segments; the number of model segments was based on the number of WQM stations within each system. Table 4-1 summarizes the average dimensions of the model segments for each of the modeled systems. Model simulations covered the three year period from September 1, 2001 through August 31, 2004. The simple multi-segment model was then used to estimate the total freshwater source loading to the entire system.

Table 4-1 Model Segment Characteristics for Each Fecal Coliform Model

Impaired System	Number of Model Segments	Average Dimensions of Modeled Segments		
		Length (feet)	Width (feet)	Surface Area (acres)
Clubhouse Creek	4	4,663	141	14
Pawley's Island Creek	3	4,633	145	15
South Pawley's Island	2	5,409	122	16

4.1 Model Development

Three unique multi-segment models were developed, one for each impaired system within the Litchfield-Pawley's Island Estuary: (1) Clubhouse Creek (stations 04-09, 04-14 and 04-19); (2) Pawley's Island Creek (stations 04-12, 04-11 and 04-10); and (3) South Pawley's Island (stations 04-21 and 04-13). The following discussion provides a summary of the approach employed in developing the models for each impaired system. These mathematical models were then used to support the development of the fecal coliform TMDLs presented in Section 5 of this report.

Step 1: Delineate shorelines and sub-watersheds for each impaired system. Each impaired system was divided into multiple model segments, with the total number of segments created for each model depending on the number of WQM stations (impaired and un-impaired) situated within the system. For example, the model developed for Clubhouse Creek included four model segments that extended from the most upstream station (04-09) to the open ocean boundary. The sub-watersheds for each model segment were then delineated using an aerial photograph of the system and a Geographic Information System- (GIS) based coverage of the Litchfield-Pawley's Island Estuary watershed. Maps showing the land use and sub-watershed delineations for each impaired system are provided in Appendix B.

Step 2: Estimate freshwater and tidally-influenced flows for the system. Freshwater runoff entering each model segment was estimated using the rational method (McCuen 1989). For these calculations, daily freshwater flows were estimated from precipitation records at Brookgreen Gardens and runoff coefficients determined from NLCD land cover data for the sub-watersheds draining into each model segment. These flows were estimated on a daily basis. Tidally-influenced flows for each model segment were estimated as the product of the typical tidal range of the system, as measured at the nearest tide gage (Litchfield Beach Bridge gage was used for Clubhouse Creek, Bennett's Dock gage was used for Pawley's Island Creek and Ward's Dock gage was used for South Pawley's Island; NOAA/NOS 2004), and the surface area of each respective model segment. Since a complete tidal cycle occurs every 12.42 hours, the tidally-influenced flows were multiplied by 1.93 (i.e., 24 hours/day divided by 12.42 hours/tidal cycle) to obtain the tidal exchange over the course of a day.

Step 3: Conduct flow balance for the system using salinity data. A salinity balance was performed and checked against monitoring data as a means of corroborating the relative proportion of freshwater and saltwater flow within the system. To accomplish this, salinity data measured during each sampling period was used as a conservative tracer to determine the flow balance of each impaired system. The salinity balance is based on the principle of conservation of mass; the mass of salt in each model segment (Q_eS_e) must equal the mass of salt entering the model segment (in freshwater runoff [Q_fS_f] and incoming tides [$Q_{ti}S_{ti}$]) minus the mass of salt leaving the model segment (in the outgoing tide [$Q_{to}S_{to}$]). The salinity balance calculation is represented mathematically as:

$$\mathbf{Q_eS_e = Q_fS_f + Q_{ti}S_{ti} - Q_{to}S_{to}} \qquad \textbf{(4-1)}$$

where: Q_e = net estuarine (i.e., export) flow ($L^3\ T^{-1}$)

Q_f = freshwater flow ($L^3\ T^{-1}$)

Q_{ti} = tidally-influenced flow into the model segment ($L^3\ T^{-1}$)

Q_{to} = tidally-influenced flow out of the model segment ($L^3\ T^{-1}$)

S_e = salinity of net estuarine flow ($M\ L^{-3}$)

S_f = salinity of freshwater inputs ($M\ L^{-3}$)

S_{ti} = salinity of tidally-influenced flow into the model segment ($M\ L^{-3}$)

S_{to} = salinity of tidally-influenced flow out of the model segment ($M\ L^{-3}$)

The freshwater (Q_f) and tidally-influenced (Q_{ti} and Q_{to}) flows estimated in Step 2 above were used in the salinity balance. Salinity (S_f) in the freshwater flow was set to zero since this component is the direct result of precipitation. The average salinity measured at each of the WQM stations was used to define the initial salinity level in each model segments. A salinity of 35 ppt was assumed for the downstream boundary (i.e., ocean). The export flow (Q_e) was computed as the sum of the freshwater and tidally-influenced flows (i.e., $Q_f + Q_{ti} - Q_{to}$). Using the above information, Equation 4-1 was solved for the salinity in the export flow (S_e). The computed salinity levels were then compared to the salinity measurements collected at each WQM station within the system to ensure flows within the system were accurately represented.

Step 4: Conduct mass balance for fecal coliform. Upon corroboration of the salinity balance, a mass balance on fecal coliform within the system was computed. The number of fecal coliform in each model segment (Q_eC_e) was computed as the number of fecal coliform entering the model segment (in the freshwater runoff from nonpoint source areas [Q_fC_f], incoming tides [$Q_{ti}C_{ti}$], and seepage from failing septic systems [$Q_{fss}C_{fss}$]) minus the number of fecal coliform leaving the model segment (lost due to decay [KVC_e] and leaving in the outgoing tide [$Q_{to}C_{to}$]). The mass balance calculation is represented mathematically as:

$$\mathbf{Q_eC_e = (Q_{ti}C_{ti} - Q_{to}C_{to}) + Q_fC_f + Q_{fss}C_{fss} - KVC_e} \qquad \textbf{(4-2)}$$

where: Q_e = net estuarine flow determined by the flow balance ($L^3\ T^{-1}$)

Q_{ti} = tidally-influenced flow into the model segment ($L^3\ T^{-1}$)

Q_{to} = tidally-influenced flow out of the model segment ($L^3\ T^{-1}$)

Q_f = freshwater flow ($L^3\ T^{-1}$)

Q_{fss} = seepage flow from failing septic systems ($L^3\ T^{-1}$)

C_e = fecal coliform level in net estuarine flow ($M\ L^{-3}$)

C_{ti} = fecal coliform level in tidally-influenced flow entering the model segment ($M\ L^{-3}$)

C_{to} = fecal coliform level in tidally-influenced flow leaving the model segment ($M\ L^{-3}$)

C_f = fecal coliform level in freshwater flow ($M\ L^{-3}$)

C_{fss} = fecal coliform level in seepage flow from failing septic systems ($M\ L^{-3}$)

K = fecal coliform decay rate (T^{-1})

V = volume of model segment (L^3)

Flows determined during the flow balance (Step 3) were used in the fecal coliform mass balance. The average fecal coliform level measured at each of the WQM stations was used to define the initial conditions in each model segment. A fecal coliform level of zero was assumed for the downstream boundary (i.e., ocean). For impaired segments that are not modeled down to the ocean boundary, the average fecal coliform level at the nearest downstream WQM station was used to define appropriate boundary conditions.

Fecal coliform loadings from each land use category were estimated as the product of the freshwater flows (as determined during the flow balance) and source-specific fecal coliform concentrations reported in the literature (and summarized in USEPA 2001). Fecal coliform concentrations in runoff from forest, barren land, urban grasses, wetlands, pastures and urban areas specified and adjusted within the range of reported values during model calibration. The loadings from the individual land use categories were then summed to represent the total fecal coliform loading entering the modeled waterbodies from all nonpoint sources.

Fecal coliform loadings from failing septic systems were computed using septic system usage information contained within the WCS and from values reported from the literature. The number of failing septic systems was determined based on the estimated number of active septic systems, the population density within the watershed, and an assumed septic system failure rate of 20%. An hourly loading rate to the receiving waterbody was then estimated assuming a density of 2.5 people per septic system, an average fecal coliform concentration of 1.0×10^6/100 mL in the septic overcharge (Horsely and Whitten 1996), and a septic overcharge rate of 70 gallons per person per day (Horsely and Whitten 1996). Resultant loading rates varied among WQM stations due to differences in land uses and ranged from 3.6×10^8 to 2.1×10^9 fecal coliform per hour. These loading rates were multiplied by 24 to convert them to daily loading rates, and were used as inputs to the model. Unlike the loadings from the nonpoint freshwater sources, fecal coliform loadings from failing septic systems were not adjusted during model calibration.

Salinity is one of several factors that influence the survival/decay of fecal coliform bacteria in aquatic systems. Fecal coliform decay rates in estuarine/saltwater environments are higher than those in freshwaters systems, primarily due to osmotic effects (i.e., excess salinity draws water out of the bacterial cells, causing death/decay). A constant fecal coliform decay rate of 3 per day was selected based on reported decay rates for waters with salinities ranging from 2 to 18 ppt (0.4 to 3.0 per day; Mancini 1978; Thomann and Mueller 1987). The upper end of the range of these reported decay rates was selected for the modeling since the waters within the

Litchfield-Pawley's Island Estuary generally contain more than 30 ppt salinity, and studies have shown that fecal coliform decay rates increase with increasing salinity; as high as 37 to 110 per day have been reported in sunlit seawater (Fujioka et al., 1981).

4.2 Model Calibration

The first step to model calibration consisted of comparing predicted and observed salinities to ensure that the freshwater flows within the system were accurately represented. Cumulative probability distributions of measured and predicted salinity levels for each impaired station are compared in Figure 4-2. Comparisons of the spatial distributions of average predicted and observed salinity for each impaired system are provided in Figure 4-3. These comparisons indicated that the flow balance for each system, as described in Step 3 above, yields salinities that compare well to the observed salinities, and captures the observed salinity gradient within each of the impaired systems. For this reason, the estimated freshwater flows to the system were deemed realistic and the flow balance was considered calibrated. Time series of observed and predicted salinity levels for each impaired WQM station are provided in Appendix C.

The fecal coliform model was calibrated by adjusting the fecal coliform concentrations in runoff from nonpoint sources within the watershed (i.e., forest, urban buildup, etc.) within the range of the reported values until the cumulative probability distributions of fecal coliform levels predicted by the model matched those of the in-stream measurements. The final set of fecal coliform concentrations used to calibrate the model, along with the range of concentrations reported in the literature, is presented in Table 4-2. The fecal coliform concentrations in runoff from each of the different land uses were held constant among the impaired systems (i.e., Clubhouse Creek, Pawley's Island Creek, etc.).

Table 4-2 Fecal Coliform Levels in Runoff Estimated During Model Calibration

Land Use	Level Estimated During Model Calibration (number per 100 mL)	Range of Levels Reported in Literature (number per 100 mL)	Source
Barren Land, Forest, Urban Grasses, Wetlands	3.9×10^3	1.5×10^1 to 4.5×10^5	Overcash and Davidson 1980
Pasture/hay	1.2×10^2	1.2×10^2 to 1.3×10^6	Doran et al. 1981
Urban buildup	2.2×10^3	9.6×10^2 to 4.3×10^6	Doran et al. 1981

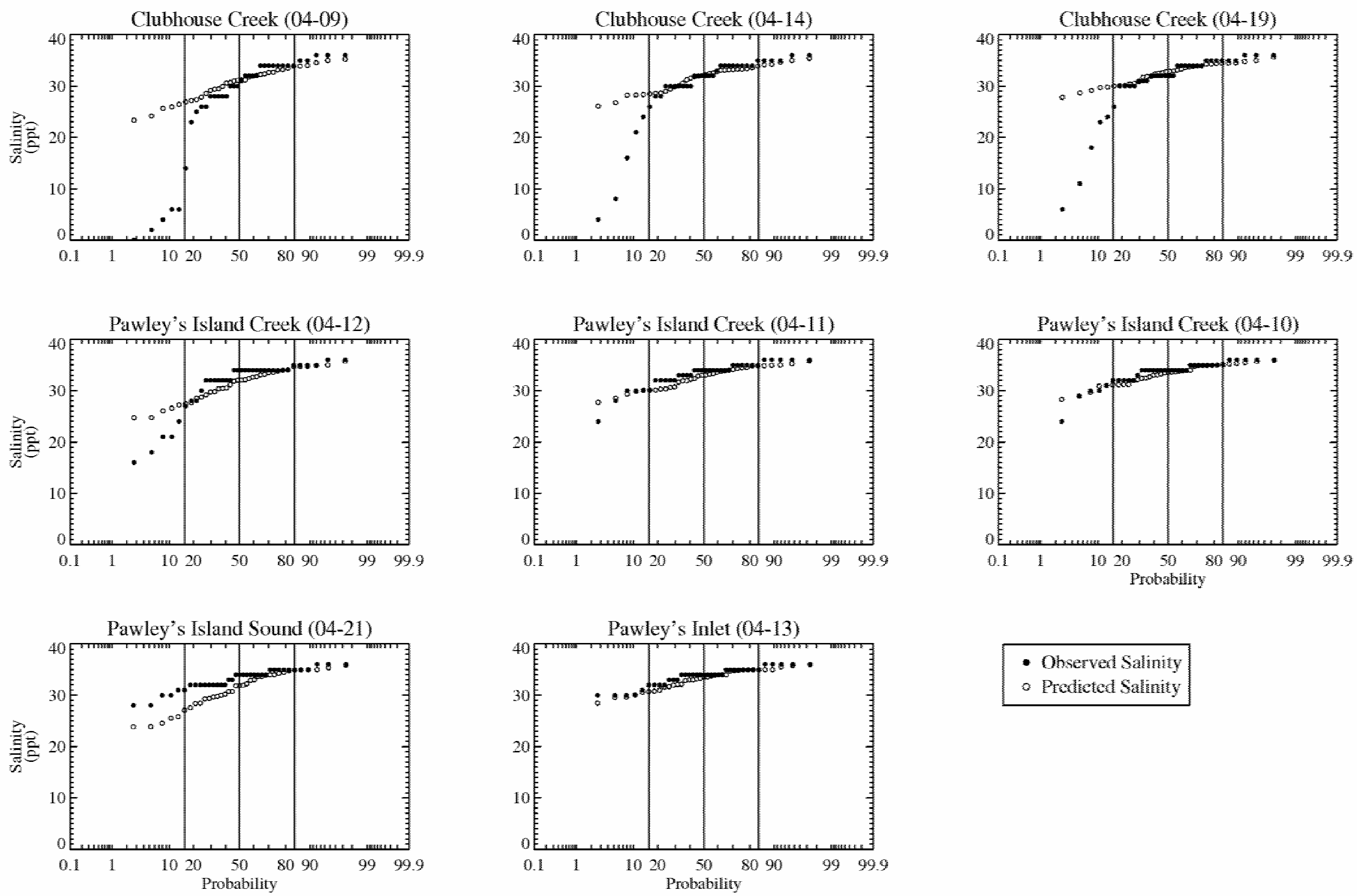
Cumulative probability distributions of observed and predicted fecal coliform levels for each impaired station are presented in Figure 4-4. Comparisons of the spatial distributions of average predicted and observed fecal coliform levels for each impaired system are provided in Figure 4-5. Time series of observed and predicted fecal coliform levels for each impaired WQM station are provided in Appendix C. Overall, the model predicts fecal coliform distributions that capture the general variability and shape of the observed data, and reproduces the observed spatial distribution within each of the impaired systems. However, the model does not consistently reproduce the fecal coliform levels observed at the upper end of the distributions (i.e., upper 10 to 20 percentiles; see Figure 4-4). This was expected, as the model assumes the instantaneous mixing of freshwater runoff within each model segment; it does not consider the time required for the runoff to accumulate and move along the land surface before entering the waterbody or the bacterial decay that occurs during this transport. This assumption results in more rapid mixing of freshwater runoff (containing fecal coliform) within the modeled system than what is actually occurring in the receiving waterbody and, thus, the model cannot capture fluctuations of fecal coliform levels on a day-to-day basis. Nonetheless, the general agreement between the observed and predicted probability distributions and spatial gradients indicates the model is a useful tool for evaluating achievement of the WQS under average conditions.

Average fecal coliform loadings to each of the impaired systems, as predicted by the model for the September 2001 to August 2004 period, are presented in Table 4-3.

Table 4-3 Estimated Average Existing Fecal Coliform Loadings to the Impaired Systems by Source Area (September 2001 to August 2004)

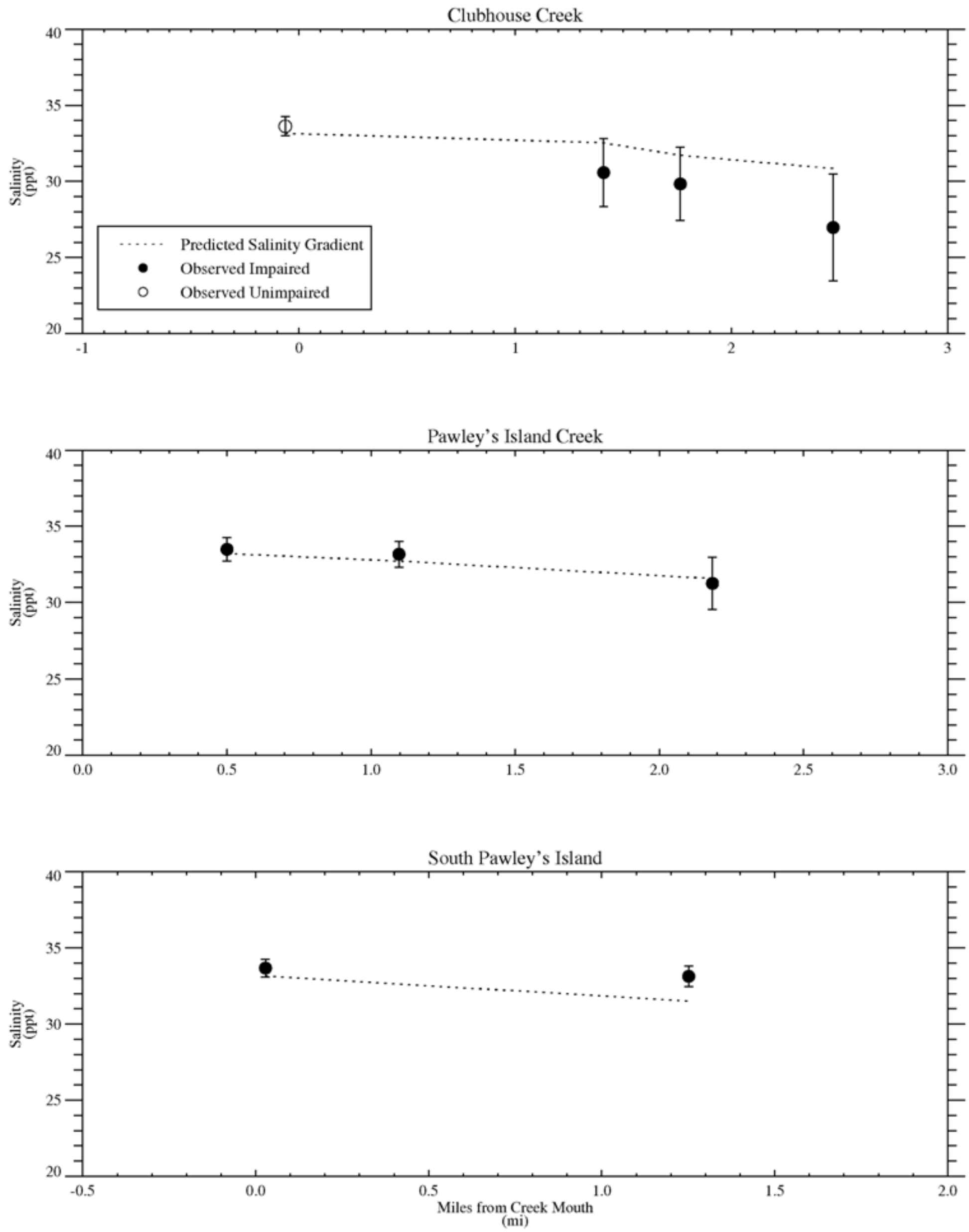
Impaired System	Average Existing Loadings By Source Area (counts/day)		
	Nonpoint Sources	Septic Systems	Total Loading
Clubhouse Creek	$4.5x10^{11}$	$5.0x10^{10}$	$5.0x10^{11}$
Pawley's Island Creek	$3.2x10^{11}$	$2.6x10^{10}$	$3.4x10^{11}$
South Pawley's Island	$3.9x10^{11}$	$1.0x10^{11}$	$4.9x10^{11}$

Figure 4-2 Cumulative Probability Distributions of Predicted and Observed Salinity Levels for 303(d) Listed Stations in the Litchfield-Pawley's Island Estuary



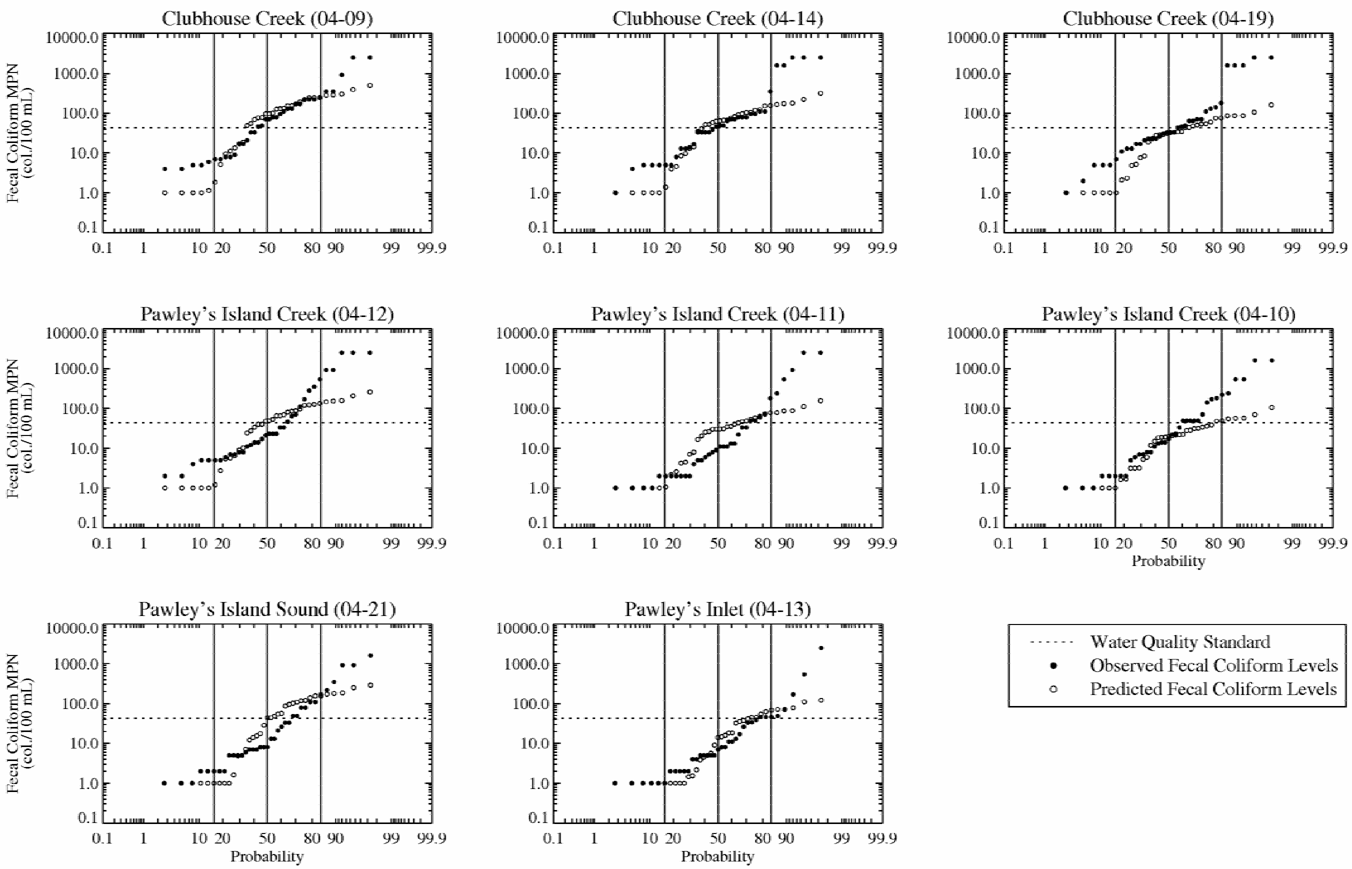
Data collected between September 1, 2001 and August 31, 2004.

Figure 4-3 Spatial Distributions of Average Predicted and Observed Salinity Levels in the Impaired Systems within the Litchfield-Pawley's Island Estuary



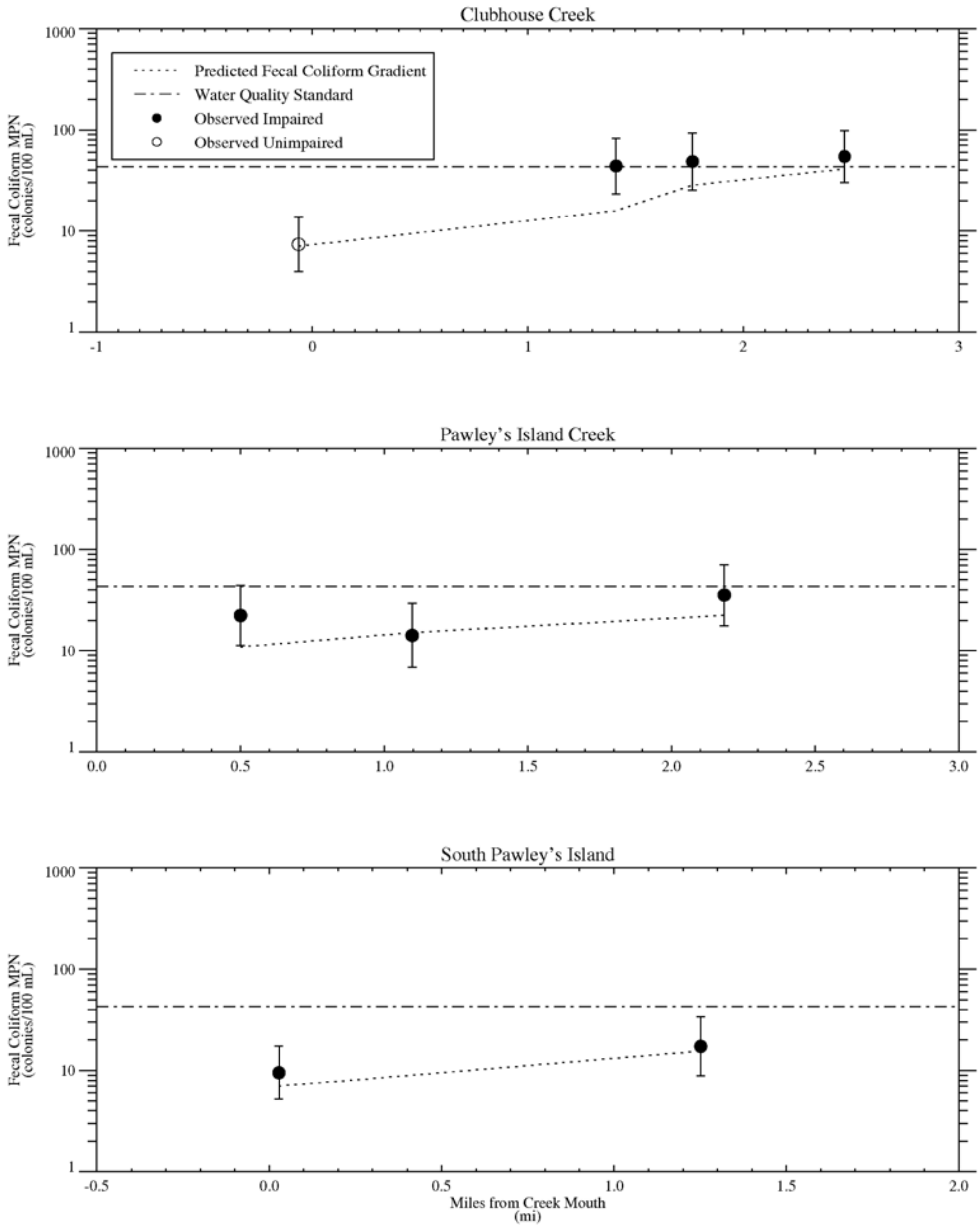
Data from impaired stations plotted as filled circles. Data from unimpaired stations plotted as open circles.
Data shown as arithmetic means +/- two standard errors of mean.
Data collected between September 1, 2001 and August 31, 2004.

Figure 4-4 Cumulative Probability Distributions for Predicted and Observed Fecal Coliform Levels for 303(d) Listed Stations within Litchfield-Pawley's Island



Dashed horizontal lines indicate the 10% exceedance standard of 43 colonies/100 mL.
Data collected between September 1, 2001 and August 31, 2004.

Figure 4-5 Spatial Distributions of Average Predicted and Observed Fecal Coliform Levels in the Impaired Systems within the Litchfield-Pawley's Island Estuary



Dashed horizontal lines are 10% not to exceed standard (43 col./100 mL).
Data shown as geometric means +/- two standard errors of mean. Data collected between 9/1/2001 and 8/31/2004.
Data from impaired stations plotted as filled circles. Data from unimpaired stations plotted as open circles.

SECTION 5
TMDL CALCULATIONS

5.1 TMDLs

A TMDL is the maximum amount of pollutant that can be assimilated by a receiving waterbody without exceeding WQS, and consists of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for both non-point sources and background levels. In addition, the TMDL must include a margin of safety (MOS) to account for the uncertainty associated with the relationship between pollutant loading and receiving water quality. This relationship is illustrated mathematically in Equation 5-1.

$$\mathbf{TMDL} = \Sigma\ \mathbf{WLA} + \Sigma\ \mathbf{LA} + \mathbf{MOS} \qquad \mathbf{(5\text{-}1)}$$

The objective of the TMDL is to estimate allowable pollutant loads and to allocate these loads to the known pollutant sources in the watershed so the appropriate control measures can be implemented and the WQS achieved. 40 CFR §130.2 (1) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure. For fecal coliform, TMDLs are expressed as colony forming units (cfu) per day, where possible, or as percent reductions, and represent the maximum 1-day load which the stream can assimilate and still maintain the water quality criterion.

TMDLs for each impaired watershed were developed by estimating the reductions in fecal coliform loadings predicted by the model (as described in Section 4) needed to achieve the geometric mean standard at each impaired station. Due to the tidal nature of the Litchfield-Pawley's Estuary, which results in the upstream movement of fecal coliform bacteria through the system with the tidal flows, this evaluation was performed on a watershed basis. That is, a single percent reduction was assigned to a watershed having multiple impaired stations such that the prescribed reduction results in the attainment of water quality standards at all stations within the system. Similarly, cumulative probability distributions of the measured fecal coliform data for each of the impaired WQM stations were used to determine average percent reductions in instantaneous source loadings to the system needed to satisfy the not to exceed 10% standard. In both instances, an explicit MOS of 5% was assumed. The more stringent (i.e., higher) of the two percent reductions for each watershed was then selected in the final TMDL determination to ensure that both State standards will be achieved.

5.2 Critical Conditions

USEPA regulations at 40 CFR 130.7(c) (1) require TMDLs to take into account critical conditions for stream flow, loading and water quality parameters. Critical conditions are used in the TMDL evaluation to ensure that established uses of the stream are protected. All eight stations within the Litchfield-Pawley's Estuary are classified as Restricted, six exceed the geometric mean standard of 14/100 mL, and all violate the not to exceed 10% standard of 43/100 mL. This suggests that critical conditions for fecal coliform at these locations occur over a range of flow conditions. Therefore, for the purposes of establishing TMDLs for the impaired stations, critical conditions were defined as periods of low tidal flows, which result in the least amount of dilution of fecal coliform entering the system. For the TMDL determination, the 10th percentile values of the daily tidally-influenced flows computed during the flow balance (from the NOS tide data) were used to define critical conditions.

5.3 Waste Load Allocation

Only one NPDES-permitted discharger exists within the Litchfield-Pawley's Island Estuary; however, it does not discharge directly to the estuary and, therefore, the WLA is zero. No MS4s exist within the Litchfield-Pawley's Island Estuary.

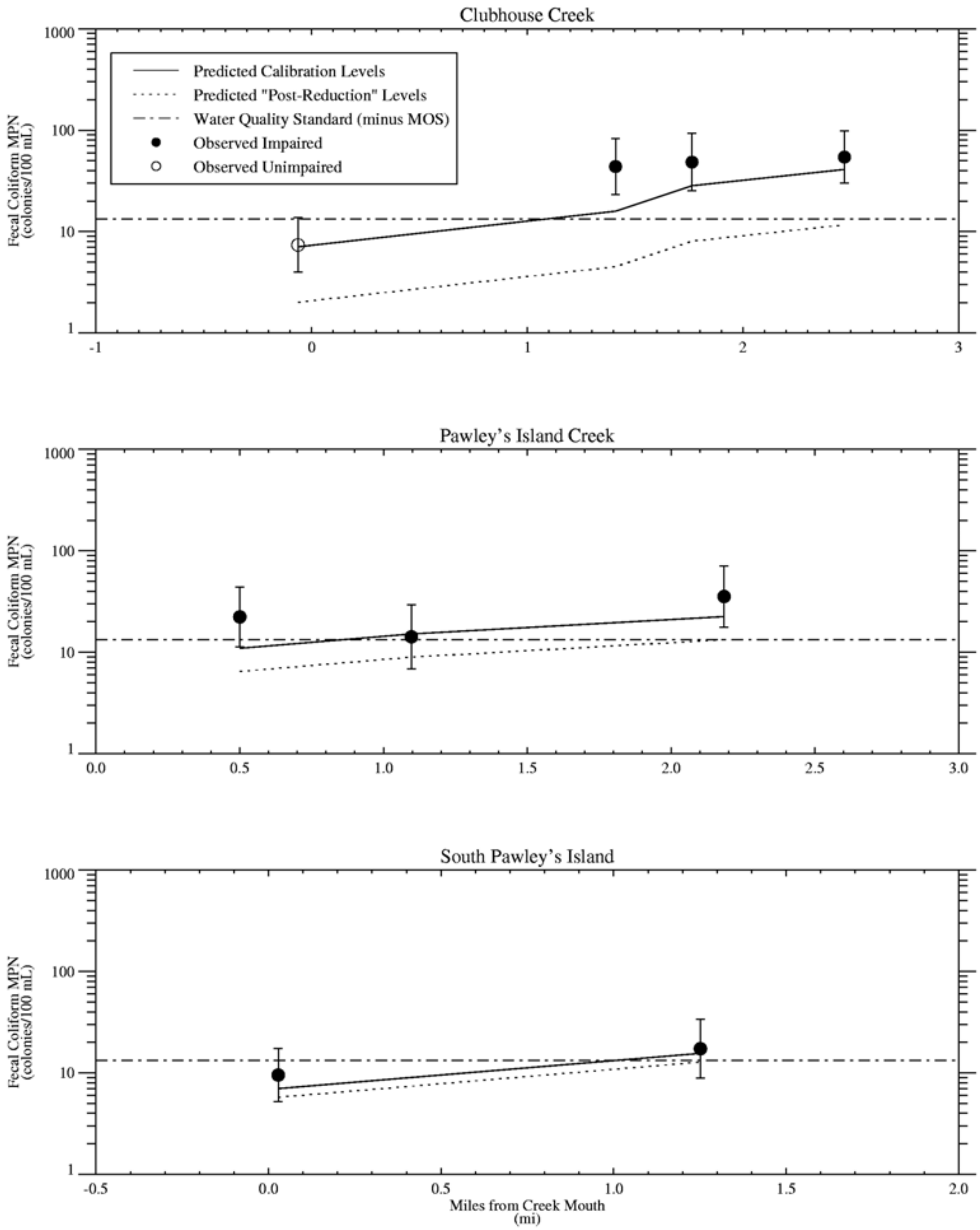
5.4 Load Allocation

Nonpoint fecal coliform loading to the receiving streams of each WQM station originate from various sources. These nonpoint source loadings were estimated using the mass balance approach described in Section 4. The fact that many of the WQM stations exceed the geometric mean standard indicates that evaluating mean source inputs (i.e., under mean conditions) via the mass balance approach may be sufficient to ascribe load allocations for many, but not all, of the affected waters. Model calibration results discussed in Section 4.2 indicate the model is limited in terms of its ability to address exceedances caused by instantaneous inputs to the stations where the no more than 10% exceedance standard is not met. Therefore, a two-pronged approach to the load allocation component of the TMDL determination was employed.

The first step involved computing the percent reduction in the daily freshwater loadings estimated during the source load assessment (Section 4) that is required to achieve the State's water quality standards. To accomplish this, the daily load estimates for the period of record was reduced until the geometric mean standard, minus the 5% explicit MOS (see Section 5.5), was met (i.e., 13.3/100 mL). As stated above, a single percent reduction was assigned to a watershed having multiple impaired stations such that the prescribed reduction results in the attainment of geometric mean standard at all stations within the system. The resultant predicted post-reduction fecal coliform levels are presented for each system in Figure 5-1.

The second step addresses the exceedances resulting from instantaneous source loadings to the system. This step uses the cumulative probability distributions of the measured fecal coliform data for each of the WQM stations to determine the percent reductions needed to satisfy the not to exceed 10% standard. To determine the required percent reduction, the cumulative probability distributions for each WQM station were reduced by a constant such that the 90th percentile value of the resulting distribution for each station is less than 40.9/100 mL (43/100 mL standard minus the 5% explicit MOS). These station-specific reductions were then used to estimate a single average percent reduction for each watershed. This was considered reasonable as the in-stream fecal coliform measurements are influenced by sources originating both upstream and downstream of the impaired WQM station and, thus, direct use of the data on a station-by-station basis would result in overly conservative percent reductions needed to meet the not to exceed 10% standard. The cumulative probability distributions of the observed data, and the associated distributions of the "reduced" levels, are presented for each WQM station in Figure 5-2. Average percent reductions for each watershed are provided in Table 5-1.

Figure 5-1 Spatial Distributions of Average Predicted Post-Reduction Fecal Coliform Levels in the Impaired Systems within the Litchfield-Pawley's Island Estuary



Horizontal lines represent the geometric mean standard minus the MOS (i.e., 13.3/100 mL).
Solid lines represents model calibration. Dashed lines represent predicted "post-reduction" levels.
Data from impaired stations plotted as filled circles. Data from unimpaired stations plotted as open circles.
Data shown as geometric means +/- two standard errors of mean. Data collected between 9/1/2001 and 8/31/2004.

This two-pronged approach results in two estimates of fecal coliform loading reductions for each WQM station: one that satisfies the MPN geometric mean standard and one that satisfies the no more than 10% exceedance standard. In order to achieve both State standards for each WQM station, the greater of the two percent reductions was selected for the load allocation component of the TMDL (see Table 5-1).

5.5 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include a MOS to account for the uncertainty associated with calculating the allowable fecal coliform pollutant loadings to ensure water quality standards are attained. USEPA (1991) guidance identifies two options for incorporating the MOS into the TMDL evaluation: (1) implicitly incorporate the MOS through the use of conservative assumptions (e.g., nonpoint source loadings are not subject to decay during transport from the basin and are instantaneously mixed with the receiving waterbody); and (2) explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocation purposes. For the TMDLs in this report, an explicit MOS of 5% was used. Therefore, the water quality targets were set at 13.3/100 mL and 40.9/100 mL for the MPN geometric mean and not to exceed 10% standards, respectively. Other conservative assumptions were employed in the development of the TMDLs for these watersheds. Most notably, the more stringent of the two percent reductions required to satisfy each of the respective WQS was used to determine the TMDL for each watershed.

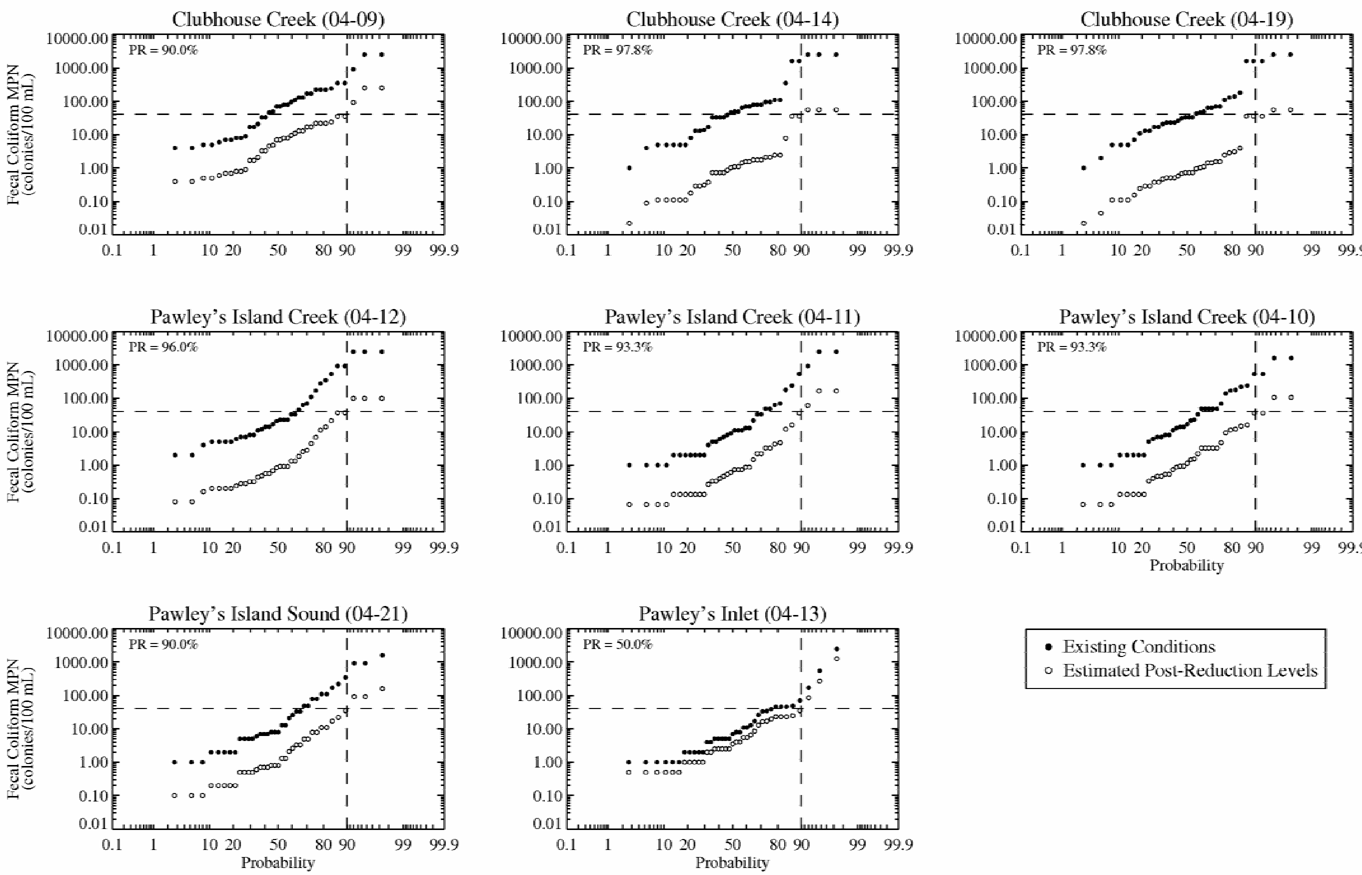
5.6 Seasonal Variability

The fecal coliform model simulations extended for the three year period between September 1, 2001 and August 31, 2004. Mass balance calculations were performed on a daily basis for the duration of the simulation period and, thus, captured the range of seasonal conditions (i.e., wet and dry periods) experienced within the system.

5.7 TMDL Calculations

The fecal coliform TMDLs for the impaired watersheds covered in this report were derived using a mass balance approach. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for uncertainty concerning the relationship between effluent limitations and water quality. Equation 5-1 was used to determine the various components of the TMDL calculation for each impaired watershed. Results of these calculations are provided in Table 5-1. "Post-reduction" geometric mean fecal coliform levels for each WQM station (both impaired and unimpaired) under critical conditions, based on the observed levels measured between September 1, 2001 and August, 31 2004 period and the watershed-based percent reductions (see Table 5-1), are presented in Appendix D.

Figure 5-2 Cumulative Probability Distributions of Observed and Post-Reduction Fecal Coliform Levels for 303(d) Listed Stations within the Litchfield-Pawley's Island Estuary



Vertical lines indicate upper 10th percentile of distribution. Horizontal lines indicate 10% exceedance standard of 43 colonies/100 mL.
Percent reduction to achieve 10% exceedance standard in upper left corner of plot panels.
Data collected between September 1, 2001 and August 31, 2004.

Table 5-1 TMDL Summary for Impaired Watersheds within the Litchfield-Pawley's Estuary

TMDL[1] (counts/day)	WLAs (counts/day)	MS4 WLA[2] (% Reduction)	LA[2] (% Reduction)	Explicit MOS	Percent Reduction	
					Model[3]	Distribution[4]
Clubhouse Creek (Impaired Stations 04-09, 04-14, 04-15 and 04-19)						
3.7×10^{10}	N/A	N/A	95.2%	5%	71.6%	95.2%
Pawley's Island Creek (Impaired Stations 04-10, 04-11 and 04-12)						
3.8×10^{10}	N/A	N/A	94.2%	5%	40.9%	94.2%
South Pawley's Island (Impaired Stations 04-13 and 04-21)						
2.4×10^{10}	N/A	N/A	70.0%	5%	17.9%	70.0%

N/A – not applicable

1 – Represents the TMDL estimated as the product of the critical flow conditions (i.e., 10th percentile tidal flow) and the geometric mean standard (minus the MOS). This value cannot be directly compared to the existing load to derive the percent reductions because the percent reductions are based upon the statistical distribution of the fecal coliform levels under critical conditions that meet the geometric mean standard.

2 - The more stringent of the two percent reductions (i.e., model vs. distribution) applied to both MS4 WLA and LA components of TMDL.

3 - The percent reduction needed to achieve the geometric mean standard at all stations within the impaired system. This value is based on the fecal coliform levels predicted by the model and, thus, will deviate from the measured in-stream values due to the simplifying assumptions made during model calibration.

4 - The average percent reduction (computed from station-specific percent reductions) needed to achieve the not to exceed 10% standard.1 - The more stringent of the two percent reductions (i.e., model vs. distribution) applied to both MS4 WLA and LA components of TMDL.

SECTION 6
REFERENCES

American Veterinary Medical Association, 2004. Veterinary Market Statistics, 2004. http://www.avma.org/membshp/marketstats/formulas.asp.

Doran J.W., J.S. Schepers, and N.P. Swanson, 1981. Chemical and Bacteriological Quality of Pasture Runoff. *Journal of Soil and Water Conservation* 36(3):166-171.

Fujioka, R.S., H.H. Hashimoto, E.B. Siwak, and R.H.F. Young, 1981. Effect of Sunlight on Survival of Indicator Bacteria in Seawater. *Appl. Environ. Micro.* 41(3):690-696.

Georgia Department of Natural Resources (GDNR), 2000. *Total Maximum Daily Load Evaluation of Fecal Coliform for Oquina Creek, Ochlockonee River Basin.* Environmental Protection Division, Georgia.

Hardy, Edward (Georgetown Water and Sewer Authority). Personal Communication. March 2005.

Horsely and Whitten Inc., 1996. *Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, New Brunswick and Freeport, Maine.* Final Report. Casco Bay Estuary Project, Portland, ME.

Mancini, J.J., 1978. Numerical Estimation of Coliform Mortality Rates Under Various Conditions. *Journal of Water Pollution Control Federation,* 50 (11). p2477.

McCuen, R.H. 1989. *Hydrologic Analysis and Design*. Englewood Cliffs: Prentice Hall.

National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS), 2004. http://co-ops.nos.noaa.gov/tides04/tab2ec3a.html#64.

Overcash, M.R. and J.M. Davidson, 1980. *Environmental Impact of Nonpoint Source Pollution.* Ann Arbor, MI: Ann Arbor Science Publishers, Inc.

South Carolina Department of Environmental Health and Control (SCDHEC), undated. *Regulated Small Municipal Separate Storm Sewer System (MS4).*

http://www.scdhec.gov/water/html/swnsms4.html.

SCDHEC, 2003a. *Total Maximum Daily Load Development for Twelve Mile Creek Watershed, South Carolina*. June 2003.

SCDHEC, 2003b. *Shellfish Management Area 04: 2003 Annual Update*. Shellfish Sanitation Program, Water Monitoring, Assessment and Protection Division, Environmental Quality Control – Bureau of Water. July 2003.

SCDHEC, 2003c. *2003 Shellfish Growing Area Status Report*. Shellfish Sanitation Program, Water Monitoring, Assessment and Protection Division, Environmental Quality Control – Bureau of Water. December 2003.

SCDHEC, 2004a. *The State of South Carolina's 2004 Integrated Report, Part I: Listing of Impaired Waters*. http://www.scdhec.gov/water/pubs/303d2004.pdf.

SCDHEC, 2004b. Department of Health and Environmental Control, Chapter 61. Statutory Authority: 1976 Code Section 48-1-10 et seq. R.61-68, *Water Classifications and Standards*.

SCDHEC, 2004c. *Shellfish Management Area 04: 2004 Annual Update.* Shellfish Sanitation Program, Water Monitoring, Assessment and Protection Division, Environmental Quality Control – Bureau of Water. July 2004.

SCDHEC, 2004d. *Total Maximum Daily Load Development for Fecal Coliform Bacteria, Lower Saluda River and Tributaries.* Bureau of Water. September 2004.

Thomann, R.V. and J.A. Mueller, 1987. *Principles of Surface Water Quality Modeling and Control.* , New York: Harper & Row Publishers, Inc. p644.

United States Environmental Protection Agency (USEPA), 1991. *Guidance for Water Quality-Based Decisions: The TMDL Process.* Office of Water, EPA 440/4-91-001.

USEPA, 2001. *Protocol for Developing Pathogen TMDLs, First Edition.* Office of Water, EPA 841-R-00-002.

APPENDIX A
FECAL COLIFORM DATA COLLECTED AT 303(D) LISTED STATIONS BETWEEN SEPTEMBER 1, 2001 AND AUGUST 31, 2004

Station ID	Station Name	Date	Fecal Coliform MPN (colonies/100 mL)	Salinity (ppt)
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	09/12/2001	95	6
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	10/08/2001	79	34
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	11/13/2001	21	34
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	12/19/2001	4	34
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	01/07/2002	220	23
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	02/19/2002	17	28
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	03/05/2002	8	6
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	04/08/2002	5	36
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	05/14/2002	170	36
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	06/11/2002	130	35
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	07/15/2002	170	28
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	08/05/2002	350	25
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	09/10/2002	33	30
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	10/07/2002	6	36
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	11/12/2002	2500	4
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	12/04/2002	79	34
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	01/21/2003	4	32
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	02/24/2003	5	26
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	03/05/2003	49	30
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	04/08/2003	2500	2
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	05/19/2003	110	32
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	06/02/2003	17	31
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	07/23/2003	220	30
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	08/12/2003	350	28
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	09/09/2003	220	32
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	10/06/2003	130	34
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	11/12/2003	7	35
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	12/10/2003	8	32
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	01/05/2004	70	34
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	02/10/2004	33	28
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	03/03/2004	70	14
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	04/12/2004	920	26
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	05/25/2004	9	28
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	06/14/2004	46	34
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	07/06/2004	7	34
04-09	Clubhouse Creek at Litchfield Boulevard Bridge	08/16/2004	240	0
04-14	Dock - End of Sportsman Boulevard	09/12/2001	70	26
04-14	Dock - End of Sportsman Boulevard	10/08/2001	49	34
04-14	Dock - End of Sportsman Boulevard	11/13/2001	8	34
04-14	Dock - End of Sportsman Boulevard	12/19/2001	5	34
04-14	Dock - End of Sportsman Boulevard	01/07/2002	39	32
04-14	Dock - End of Sportsman Boulevard	02/19/2002	17	34

04-14	Dock - End of Sportsman Boulevard	03/05/2002	33	24
04-14	Dock - End of Sportsman Boulevard	04/08/2002	5	36
04-14	Dock - End of Sportsman Boulevard	05/14/2002	350	36
04-14	Dock - End of Sportsman Boulevard	06/11/2002	33	35
04-14	Dock - End of Sportsman Boulevard	07/15/2002	49	28
04-14	Dock - End of Sportsman Boulevard	08/05/2002	95	30
04-14	Dock - End of Sportsman Boulevard	09/10/2002	33	34
04-14	Dock - End of Sportsman Boulevard	10/07/2002	79	35
04-14	Dock - End of Sportsman Boulevard	11/12/2002	1600	16
04-14	Dock - End of Sportsman Boulevard	12/04/2002	95	32
04-14	Dock - End of Sportsman Boulevard	01/21/2003	1.9	32
04-14	Dock - End of Sportsman Boulevard	02/24/2003	4	28
04-14	Dock - End of Sportsman Boulevard	03/05/2003	79	30
04-14	Dock - End of Sportsman Boulevard	04/08/2003	2500	8
04-14	Dock - End of Sportsman Boulevard	05/19/2003	1600	30
04-14	Dock - End of Sportsman Boulevard	06/02/2003	33	32
04-14	Dock - End of Sportsman Boulevard	07/23/2003	110	30
04-14	Dock - End of Sportsman Boulevard	08/12/2003	110	32
04-14	Dock - End of Sportsman Boulevard	09/09/2003	13	34
04-14	Dock - End of Sportsman Boulevard	10/06/2003	14	33
04-14	Dock - End of Sportsman Boulevard	11/12/2003	64	35
04-14	Dock - End of Sportsman Boulevard	12/10/2003	13	32
04-14	Dock - End of Sportsman Boulevard	01/05/2004	70	34
04-14	Dock - End of Sportsman Boulevard	02/10/2004	5	30
04-14	Dock - End of Sportsman Boulevard	03/03/2004	5	21
04-14	Dock - End of Sportsman Boulevard	04/12/2004	79	30
04-14	Dock - End of Sportsman Boulevard	05/25/2004	2500	30
04-14	Dock - End of Sportsman Boulevard	06/14/2004	46	35
04-14	Dock - End of Sportsman Boulevard	07/06/2004	5	34
04-14	Dock - End of Sportsman Boulevard	08/16/2004	2500	4
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	09/12/2001	26	26
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	10/08/2001	33	34
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	11/13/2001	21	36
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	12/19/2001	5	34
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	01/07/2002	23	31
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	02/19/2002	11	34
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	03/05/2002	23	24
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	04/08/2002	13	36
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	05/14/2002	64	36
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	06/11/2002	33	35
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	07/15/2002	70	30
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	08/05/2002	64	31
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	09/10/2002	2	35
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	10/07/2002	130	35
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	11/12/2002	180	18
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	12/04/2002	49	32
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	01/21/2003	1.9	32

04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	02/24/2003	5	30
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	03/05/2003	33	30
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	04/08/2003	2500	11
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	05/19/2003	1600	34
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	06/02/2003	46	32
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	07/23/2003	1600	32
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	08/12/2003	31	32
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	09/09/2003	140	34
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	10/06/2003	23	35
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	11/12/2003	70	35
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	12/10/2003	7	32
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	01/05/2004	110	34
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	02/10/2004	5	31
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	03/03/2004	17	23
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	04/12/2004	43	30
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	05/25/2004	1600	32
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	06/14/2004	17	35
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	07/06/2004	13	34
04-19	Clubhouse Creek - First Bend south of Salt Marsh Cove	08/16/2004	2500	6
04-12	South Causeway Bridge at Pawley's Island Creek	09/12/2001	920	28
04-12	South Causeway Bridge at Pawley's Island Creek	10/08/2001	17	32
04-12	South Causeway Bridge at Pawley's Island Creek	11/13/2001	2	34
04-12	South Causeway Bridge at Pawley's Island Creek	12/19/2001	12	34
04-12	South Causeway Bridge at Pawley's Island Creek	01/07/2002	350	27
04-12	South Causeway Bridge at Pawley's Island Creek	02/19/2002	8	34
04-12	South Causeway Bridge at Pawley's Island Creek	03/05/2002	14	30
04-12	South Causeway Bridge at Pawley's Island Creek	04/08/2002	5	34
04-12	South Causeway Bridge at Pawley's Island Creek	05/14/2002	23	36
04-12	South Causeway Bridge at Pawley's Island Creek	06/11/2002	6	36
04-12	South Causeway Bridge at Pawley's Island Creek	07/15/2002	7	32
04-12	South Causeway Bridge at Pawley's Island Creek	08/05/2002	5	34
04-12	South Causeway Bridge at Pawley's Island Creek	09/10/2002	23	35
04-12	South Causeway Bridge at Pawley's Island Creek	10/07/2002	21	35
04-12	South Causeway Bridge at Pawley's Island Creek	11/12/2002	2500	18
04-12	South Causeway Bridge at Pawley's Island Creek	12/04/2002	23	34
04-12	South Causeway Bridge at Pawley's Island Creek	01/21/2003	14	32
04-12	South Causeway Bridge at Pawley's Island Creek	02/24/2003	33	28
04-12	South Causeway Bridge at Pawley's Island Creek	03/05/2003	7	32
04-12	South Causeway Bridge at Pawley's Island Creek	04/08/2003	2500	21
04-12	South Causeway Bridge at Pawley's Island Creek	05/19/2003	64	32
04-12	South Causeway Bridge at Pawley's Island Creek	06/02/2003	2	34
04-12	South Causeway Bridge at Pawley's Island Creek	07/23/2003	2500	34
04-12	South Causeway Bridge at Pawley's Island Creek	08/12/2003	46	34
04-12	South Causeway Bridge at Pawley's Island Creek	09/09/2003	33	34
04-12	South Causeway Bridge at Pawley's Island Creek	10/06/2003	8	34
04-12	South Causeway Bridge at Pawley's Island Creek	11/12/2003	4	35
04-12	South Causeway Bridge at Pawley's Island Creek	12/10/2003	5	32

04-12	South Causeway Bridge at Pawley's Island Creek	01/05/2004	70	32
04-12	South Causeway Bridge at Pawley's Island Creek	02/10/2004	5	34
04-12	South Causeway Bridge at Pawley's Island Creek	03/03/2004	280	21
04-12	South Causeway Bridge at Pawley's Island Creek	04/12/2004	170	24
04-12	South Causeway Bridge at Pawley's Island Creek	05/25/2004	540	34
04-12	South Causeway Bridge at Pawley's Island Creek	06/14/2004	11	35
04-12	South Causeway Bridge at Pawley's Island Creek	07/06/2004	110	34
04-12	South Causeway Bridge at Pawley's Island Creek	08/16/2004	920	16
04-11	North Causeway Bridge at Pawley's Island Creek	09/12/2001	64	33
04-11	North Causeway Bridge at Pawley's Island Creek	10/08/2001	2	34
04-11	North Causeway Bridge at Pawley's Island Creek	11/13/2001	11	33
04-11	North Causeway Bridge at Pawley's Island Creek	12/19/2001	2	34
04-11	North Causeway Bridge at Pawley's Island Creek	01/07/2002	2	33
04-11	North Causeway Bridge at Pawley's Island Creek	02/19/2002	2	35
04-11	North Causeway Bridge at Pawley's Island Creek	03/05/2002	5	33
04-11	North Causeway Bridge at Pawley's Island Creek	04/08/2002	5	35
04-11	North Causeway Bridge at Pawley's Island Creek	05/14/2002	33	36
04-11	North Causeway Bridge at Pawley's Island Creek	06/11/2002	13	35
04-11	North Causeway Bridge at Pawley's Island Creek	07/15/2002	2	35
04-11	North Causeway Bridge at Pawley's Island Creek	08/05/2002	49	34
04-11	North Causeway Bridge at Pawley's Island Creek	09/10/2002	11	36
04-11	North Causeway Bridge at Pawley's Island Creek	10/07/2002	180	36
04-11	North Causeway Bridge at Pawley's Island Creek	11/12/2002	540	30
04-11	North Causeway Bridge at Pawley's Island Creek	12/04/2002	240	34
04-11	North Causeway Bridge at Pawley's Island Creek	01/21/2003	1.9	32
04-11	North Causeway Bridge at Pawley's Island Creek	02/24/2003	9	30
04-11	North Causeway Bridge at Pawley's Island Creek	03/05/2003	1.9	32
04-11	North Causeway Bridge at Pawley's Island Creek	04/08/2003	2500	28
04-11	North Causeway Bridge at Pawley's Island Creek	05/19/2003	2500	34
04-11	North Causeway Bridge at Pawley's Island Creek	06/02/2003	49	34
04-11	North Causeway Bridge at Pawley's Island Creek	07/23/2003	33	30
04-11	North Causeway Bridge at Pawley's Island Creek	08/12/2003	7	36
04-11	North Causeway Bridge at Pawley's Island Creek	09/09/2003	8	34
04-11	North Causeway Bridge at Pawley's Island Creek	10/06/2003	13	36
04-11	North Causeway Bridge at Pawley's Island Creek	11/12/2003	2	35
04-11	North Causeway Bridge at Pawley's Island Creek	12/10/2003	1.9	32
04-11	North Causeway Bridge at Pawley's Island Creek	01/05/2004	2	34
04-11	North Causeway Bridge at Pawley's Island Creek	02/10/2004	4	34
04-11	North Causeway Bridge at Pawley's Island Creek	03/03/2004	11	30
04-11	North Causeway Bridge at Pawley's Island Creek	04/12/2004	70	32
04-11	North Causeway Bridge at Pawley's Island Creek	05/25/2004	22	32
04-11	North Causeway Bridge at Pawley's Island Creek	06/14/2004	6	35
04-11	North Causeway Bridge at Pawley's Island Creek	07/06/2004	1.9	34
04-11	North Causeway Bridge at Pawley's Island Creek	08/16/2004	920	24
04-10	Shell Avenue and Pawley's Island Creek	09/12/2001	70	33
04-10	Shell Avenue and Pawley's Island Creek	10/08/2001	22	34
04-10	Shell Avenue and Pawley's Island Creek	11/13/2001	2	34

04-10	Shell Avenue and Pawley's Island Creek	12/19/2001	240	34
04-10	Shell Avenue and Pawley's Island Creek	01/07/2002	14	32
04-10	Shell Avenue and Pawley's Island Creek	02/19/2002	2	34
04-10	Shell Avenue and Pawley's Island Creek	02/25/2002	7	35
04-10	Shell Avenue and Pawley's Island Creek	03/05/2002	2	34
04-10	Shell Avenue and Pawley's Island Creek	04/08/2002	14	36
04-10	Shell Avenue and Pawley's Island Creek	05/14/2002	49	36
04-10	Shell Avenue and Pawley's Island Creek	06/11/2002	33	35
04-10	Shell Avenue and Pawley's Island Creek	07/15/2002	5	35
04-10	Shell Avenue and Pawley's Island Creek	08/05/2002	49	34
04-10	Shell Avenue and Pawley's Island Creek	09/10/2002	8	36
04-10	Shell Avenue and Pawley's Island Creek	10/07/2002	220	36
04-10	Shell Avenue and Pawley's Island Creek	11/12/2002	1600	32
04-10	Shell Avenue and Pawley's Island Creek	12/04/2002	540	34
04-10	Shell Avenue and Pawley's Island Creek	01/21/2003	1.9	32
04-10	Shell Avenue and Pawley's Island Creek	02/24/2003	6	30
04-10	Shell Avenue and Pawley's Island Creek	03/05/2003	2	30
04-10	Shell Avenue and Pawley's Island Creek	04/08/2003	180	31
04-10	Shell Avenue and Pawley's Island Creek	05/19/2003	540	34
04-10	Shell Avenue and Pawley's Island Creek	06/02/2003	49	34
04-10	Shell Avenue and Pawley's Island Creek	07/23/2003	49	32
04-10	Shell Avenue and Pawley's Island Creek	08/12/2003	7	35
04-10	Shell Avenue and Pawley's Island Creek	09/09/2003	11	34
04-10	Shell Avenue and Pawley's Island Creek	10/06/2003	2	35
04-10	Shell Avenue and Pawley's Island Creek	11/12/2003	17	35
04-10	Shell Avenue and Pawley's Island Creek	12/10/2003	1.9	32
04-10	Shell Avenue and Pawley's Island Creek	01/05/2004	1.9	34
04-10	Shell Avenue and Pawley's Island Creek	02/10/2004	23	35
04-10	Shell Avenue and Pawley's Island Creek	03/03/2004	13	29
04-10	Shell Avenue and Pawley's Island Creek	04/12/2004	170	34
04-10	Shell Avenue and Pawley's Island Creek	05/25/2004	8	34
04-10	Shell Avenue and Pawley's Island Creek	06/14/2004	49	35
04-10	Shell Avenue and Pawley's Island Creek	07/06/2004	1600	36
04-10	Shell Avenue and Pawley's Island Creek	08/16/2004	140	24
04-21	South Pawley's Island Boat Landing	09/12/2001	110	32
04-21	South Pawley's Island Boat Landing	10/08/2001	2	34
04-21	South Pawley's Island Boat Landing	11/13/2001	33	32
04-21	South Pawley's Island Boat Landing	12/19/2001	5	34
04-21	South Pawley's Island Boat Landing	01/07/2002	7	32
04-21	South Pawley's Island Boat Landing	02/19/2002	1.9	34
04-21	South Pawley's Island Boat Landing	02/25/2002	5	35
04-21	South Pawley's Island Boat Landing	03/05/2002	21	33
04-21	South Pawley's Island Boat Landing	04/08/2002	5	36
04-21	South Pawley's Island Boat Landing	05/14/2002	8	35
04-21	South Pawley's Island Boat Landing	06/11/2002	1.9	35
04-21	South Pawley's Island Boat Landing	07/15/2002	8	35
04-21	South Pawley's Island Boat Landing	08/05/2002	79	31

04-21	South Pawley's Island Boat Landing	09/10/2002	6	36
04-21	South Pawley's Island Boat Landing	10/07/2002	49	36
04-21	South Pawley's Island Boat Landing	11/12/2002	1600	32
04-21	South Pawley's Island Boat Landing	12/04/2002	170	34
04-21	South Pawley's Island Boat Landing	01/21/2003	2	30
04-21	South Pawley's Island Boat Landing	02/24/2003	1.9	28
04-21	South Pawley's Island Boat Landing	03/05/2003	7	32
04-21	South Pawley's Island Boat Landing	04/08/2003	220	31
04-21	South Pawley's Island Boat Landing	05/19/2003	920	32
04-21	South Pawley's Island Boat Landing	06/02/2003	49	33
04-21	South Pawley's Island Boat Landing	07/23/2003	26	32
04-21	South Pawley's Island Boat Landing	08/12/2003	79	35
04-21	South Pawley's Island Boat Landing	09/09/2003	13	34
04-21	South Pawley's Island Boat Landing	10/06/2003	8	35
04-21	South Pawley's Island Boat Landing	11/12/2003	33	35
04-21	South Pawley's Island Boat Landing	12/10/2003	2	32
04-21	South Pawley's Island Boat Landing	01/05/2004	2	34
04-21	South Pawley's Island Boat Landing	02/10/2004	5	34
04-21	South Pawley's Island Boat Landing	03/03/2004	7	30
04-21	South Pawley's Island Boat Landing	04/12/2004	110	32
04-21	South Pawley's Island Boat Landing	05/25/2004	2	34
04-21	South Pawley's Island Boat Landing	06/14/2004	13	35
04-21	South Pawley's Island Boat Landing	07/06/2004	920	34
04-21	South Pawley's Island Boat Landing	08/16/2004	350	28
04-13	Pawley's Inlet	09/12/2001	170	33
04-13	Pawley's Inlet	10/08/2001	49	34
04-13	Pawley's Inlet	11/13/2001	5	34
04-13	Pawley's Inlet	12/19/2001	1.9	34
04-13	Pawley's Inlet	01/07/2002	34	33
04-13	Pawley's Inlet	02/19/2002	1.9	35
04-13	Pawley's Inlet	02/25/2002	2	35
04-13	Pawley's Inlet	03/05/2002	1.9	34
04-13	Pawley's Inlet	04/08/2002	5	36
04-13	Pawley's Inlet	05/14/2002	5	36
04-13	Pawley's Inlet	06/11/2002	8	35
04-13	Pawley's Inlet	07/15/2002	5	35
04-13	Pawley's Inlet	08/05/2002	26	34
04-13	Pawley's Inlet	09/10/2002	7	36
04-13	Pawley's Inlet	10/07/2002	46	35
04-13	Pawley's Inlet	11/12/2002	2	32
04-13	Pawley's Inlet	12/04/2002	70	34
04-13	Pawley's Inlet	01/21/2003	1.9	32
04-13	Pawley's Inlet	02/24/2003	5	30
04-13	Pawley's Inlet	03/05/2003	1.9	30
04-13	Pawley's Inlet	04/08/2003	2500	30
04-13	Pawley's Inlet	05/19/2003	540	34
04-13	Pawley's Inlet	06/02/2003	2	34

04-13	Pawley's Inlet	07/23/2003	46	32
04-13	Pawley's Inlet	08/12/2003	4	36
04-13	Pawley's Inlet	09/09/2003	2	34
04-13	Pawley's Inlet	10/06/2003	8	35
04-13	Pawley's Inlet	11/12/2003	39	33
04-13	Pawley's Inlet	12/10/2003	46	32
04-13	Pawley's Inlet	01/05/2004	11	34
04-13	Pawley's Inlet	02/10/2004	1.9	35
04-13	Pawley's Inlet	03/03/2004	17	31
04-13	Pawley's Inlet	04/12/2004	11	34
04-13	Pawley's Inlet	05/25/2004	2	34
04-13	Pawley's Inlet	06/14/2004	4	35
04-13	Pawley's Inlet	07/06/2004	13	36
04-13	Pawley's Inlet	08/16/2004	33	30

APPENDIX B
LAND USE AND SUB-WATERSHED DELINEATIONS FOR THE IMPAIRED SYSTEMS OF LITCHFIELD-PAWLEY'S ISLAND ESTUARY

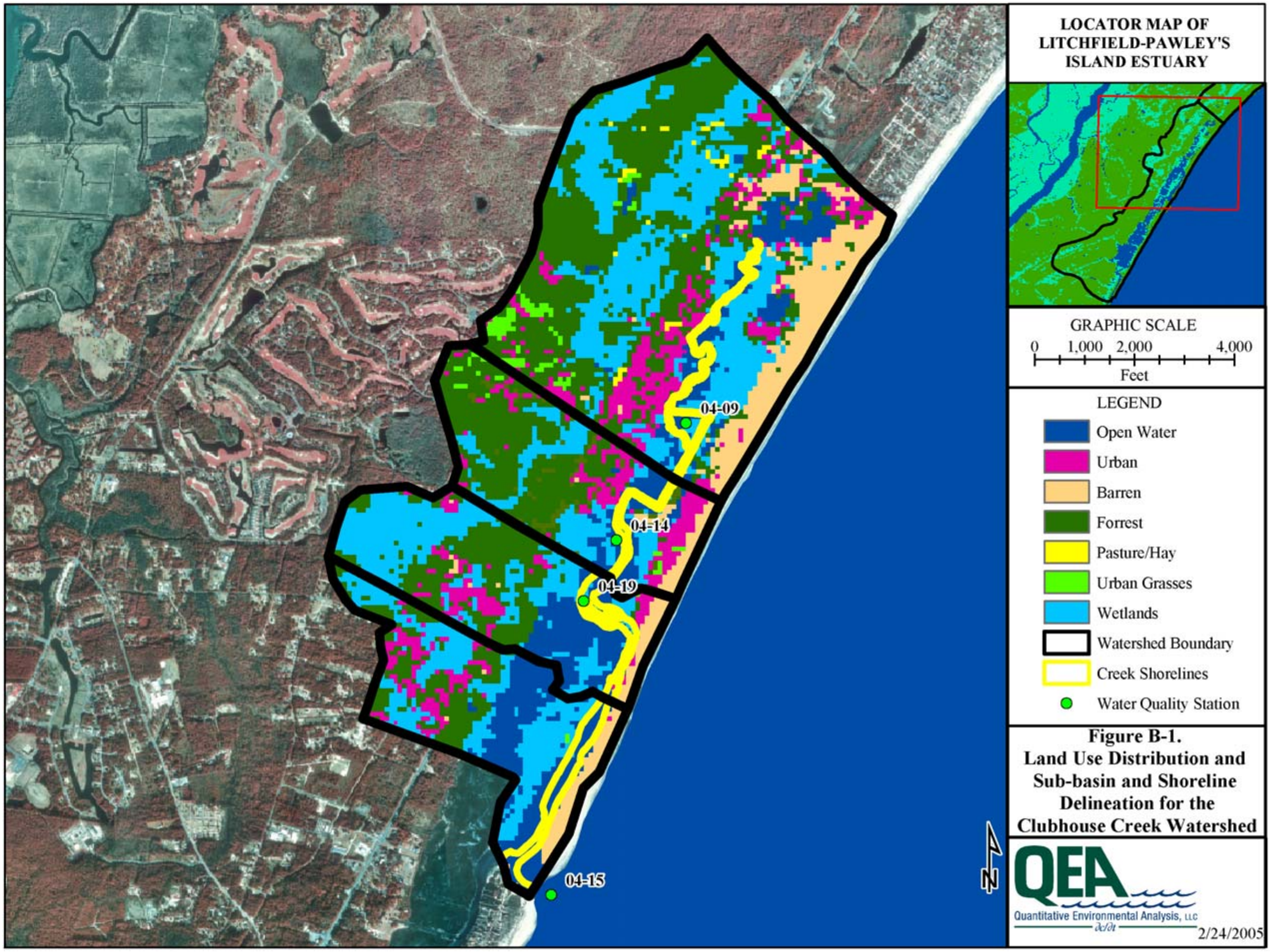


Figure B-1. Land Use Distribution and Sub-basin and Shoreline Delineation for the Clubhouse Creek Watershed

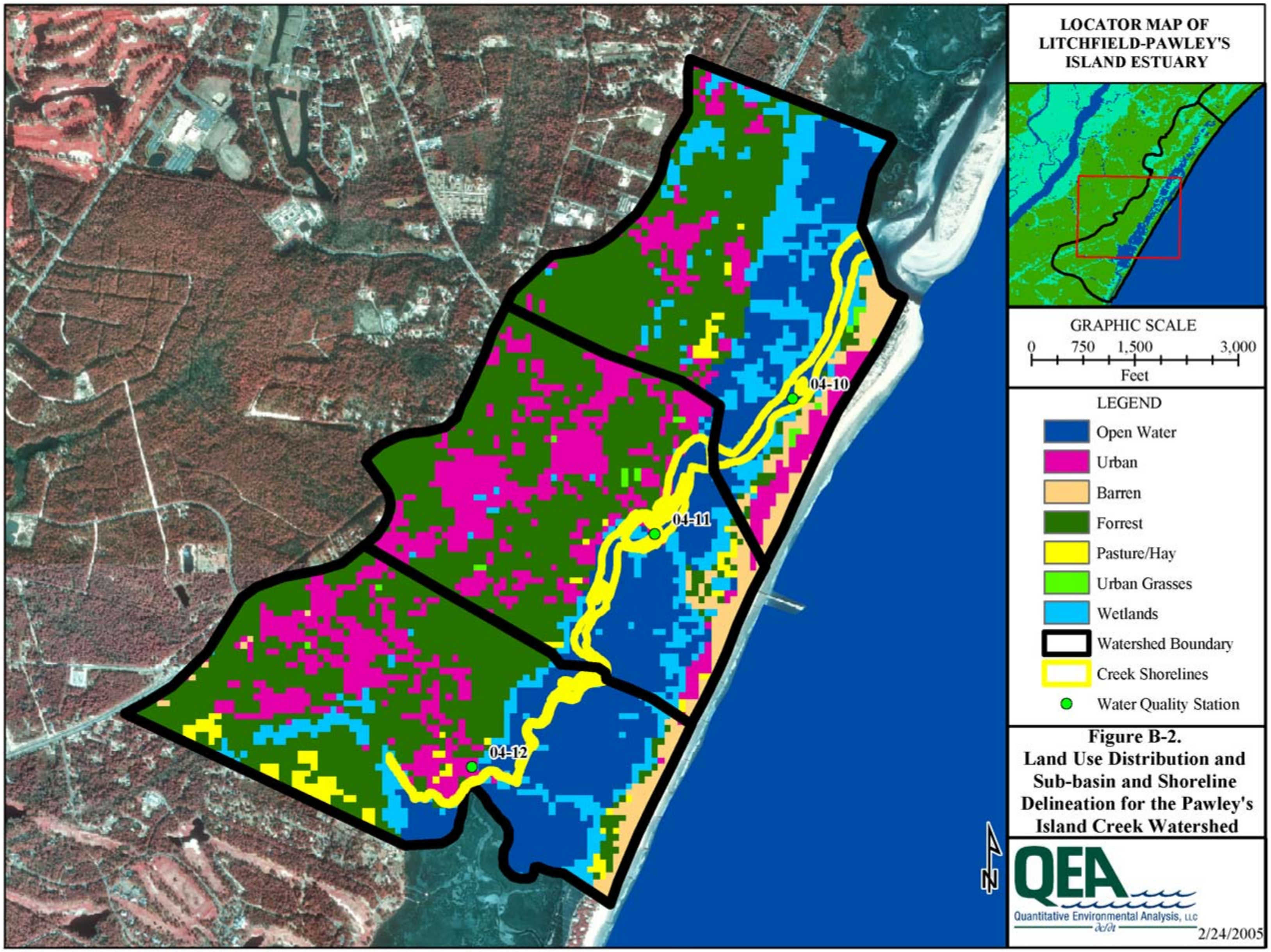


Figure B-2. Land Use Distribution and Sub-basin and Shoreline Delineation for the Pawley's Island Creek Watershed

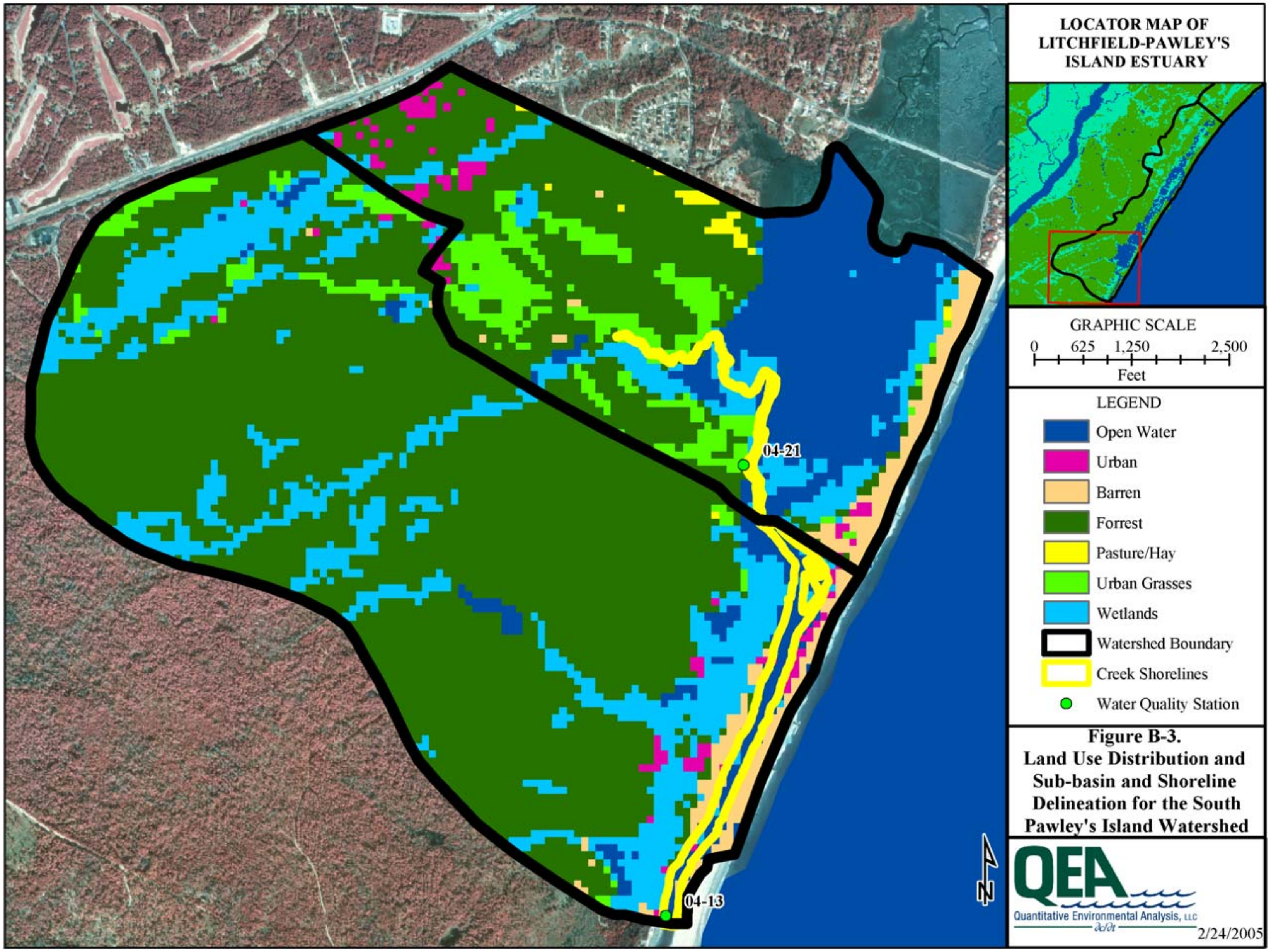


Figure B-3. Land Use Distribution and Sub-basin and Shoreline Delineation for the South Pawley's Island Watershed

APPENDIX C
TIME SERIES OF PREDICTED AND OBSERVED SALINITY AND FECAL COLIFORM LEVELS AT EACH 303(D) LISTED STATION

(SEPTEMBER 2001 TO AUGUST 2004)

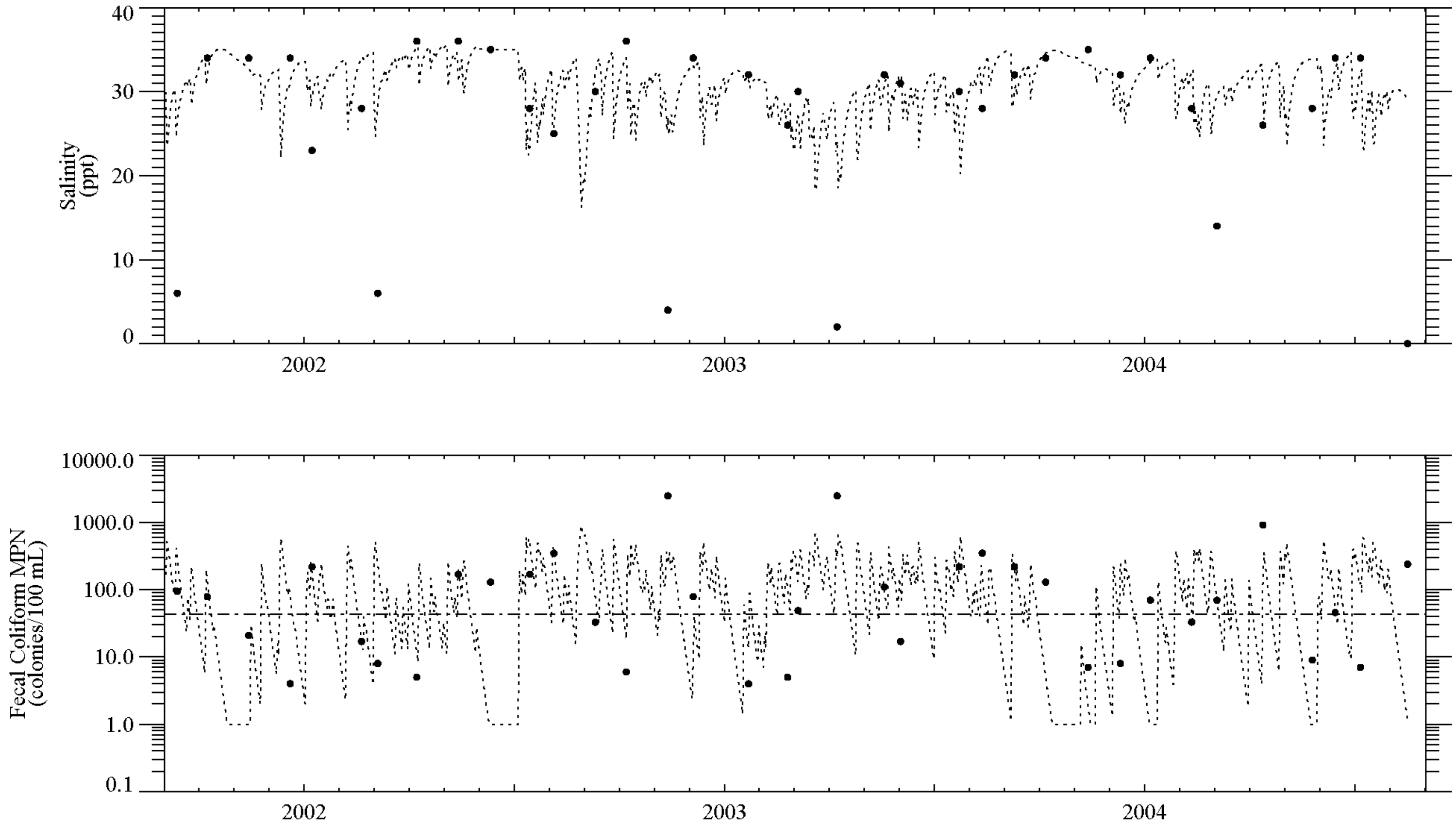
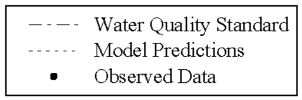


Figure C-1. Predicted and Observed Fecal Colfiorm and Salinity for Clubhouse Creek at Litchfield Boulevard Bridge (Station 04-09).

Dashed horizontal lines are 10% not to exceed standard (43 colonies/100 mL).



sfh - D:\Jobs\PARbac\Analysis\Water\f_coli_temporal\fcoli_temporal_final_figs.pro
Mon Apr 04 11:14:53 2005

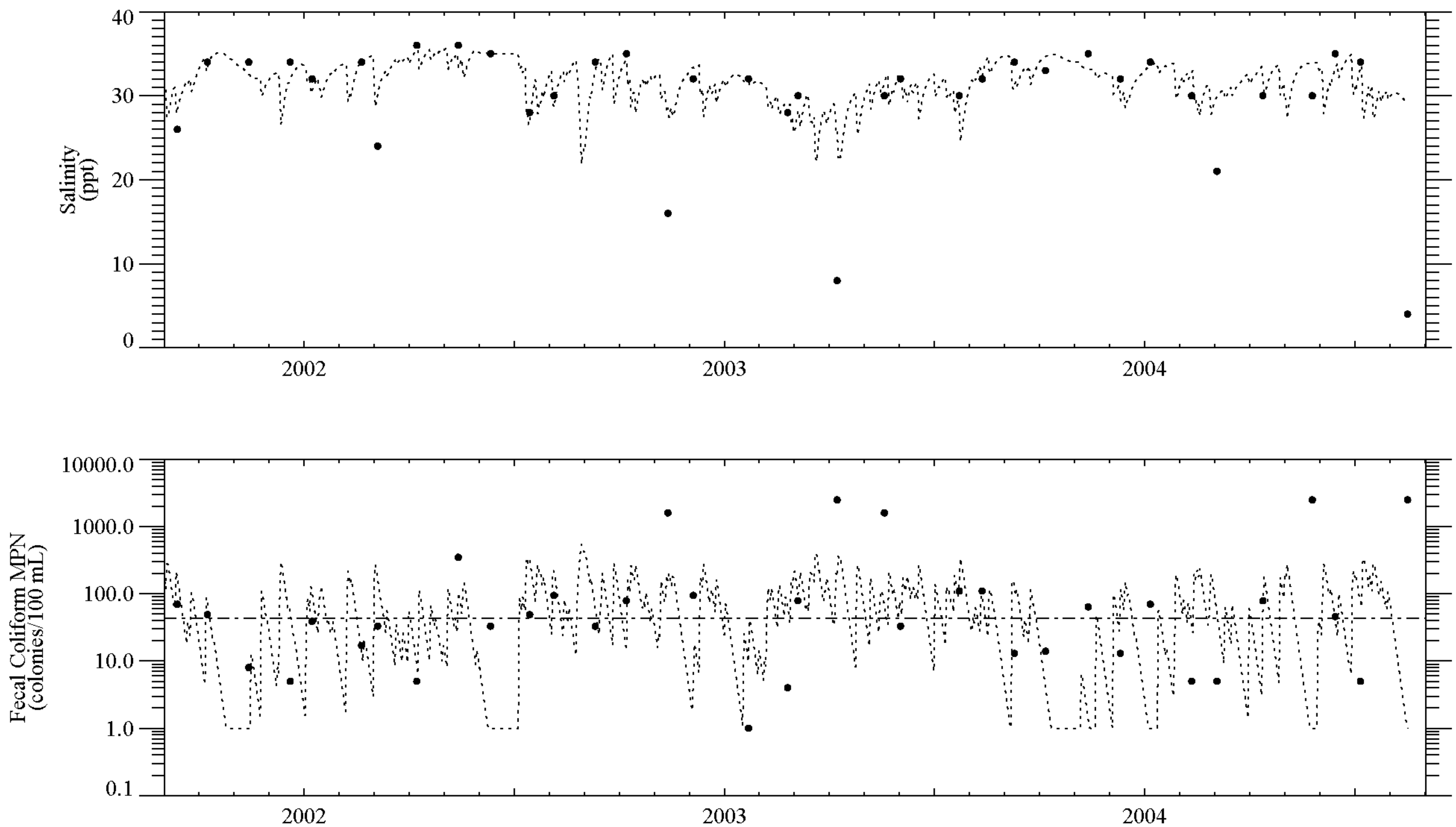


Figure C-2. Predicted and Observed Fecal Colfiorm and Salinity for Dock - End of Sportsman Boulevard (Station 04-14).

Dashed horizontal lines are 10% not to exceed standard (43 colonies/100 mL).

sfh - D:\Jobs\PARbac\Analysis\Water\f_coli_temporal\fcoli_temporal_final_figs.pro
Mon Apr 04 11:14:56 2005

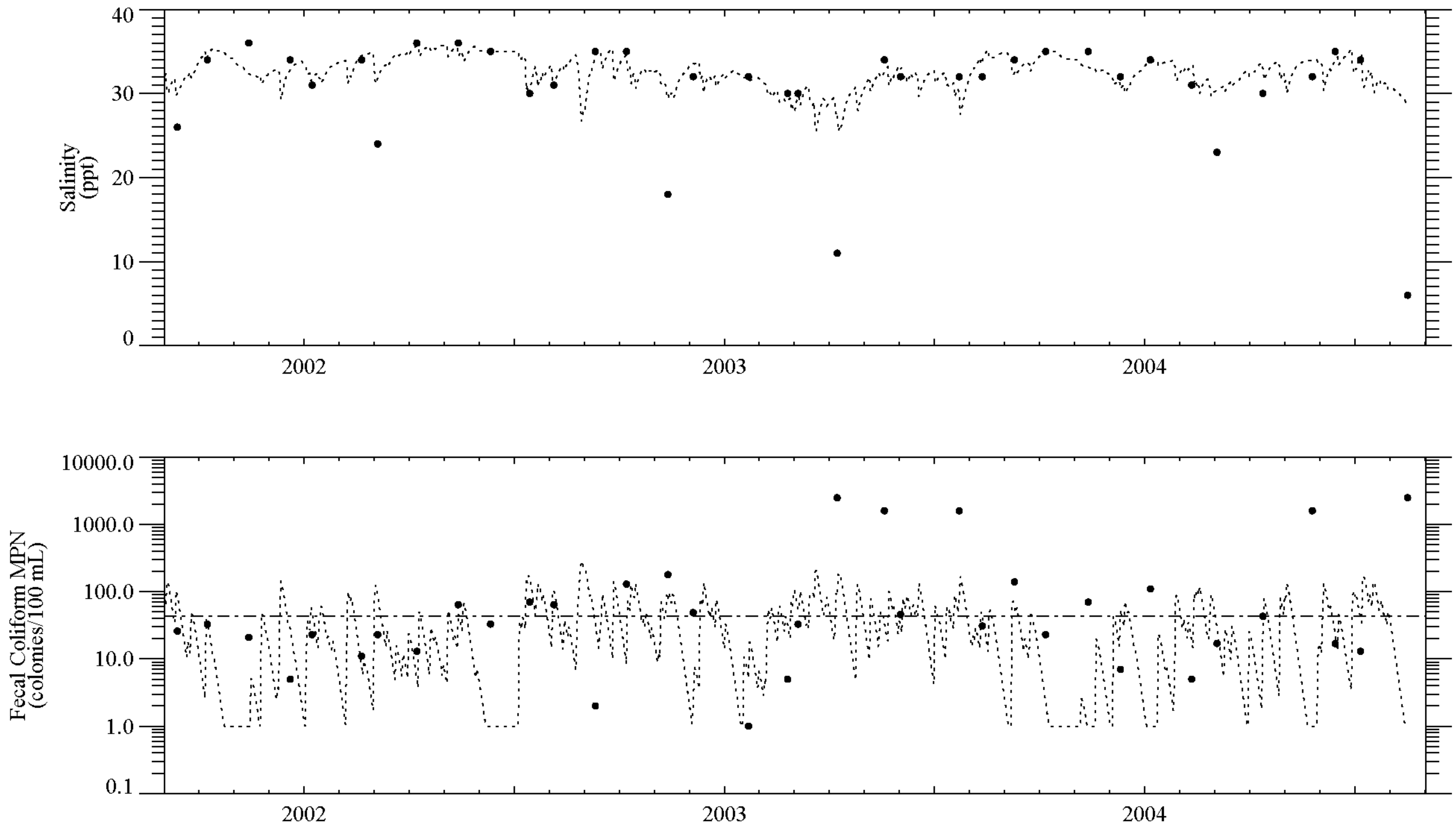
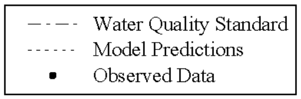


Figure C-3. Predicted and Observed Fecal Colfiorm and Salinity for Clubhouse Creek - First Bend South of Salt Marsh Cove (04-19).
Dashed horizontal lines are 10% not to exceed standard (43 colonies/100 mL).



sfh - D:\Jobs\PARbac\Analysis\Water\f_coli_temporal\fcoli_temporal_final_figs.pro
Mon Apr 04 11:14:58 2005

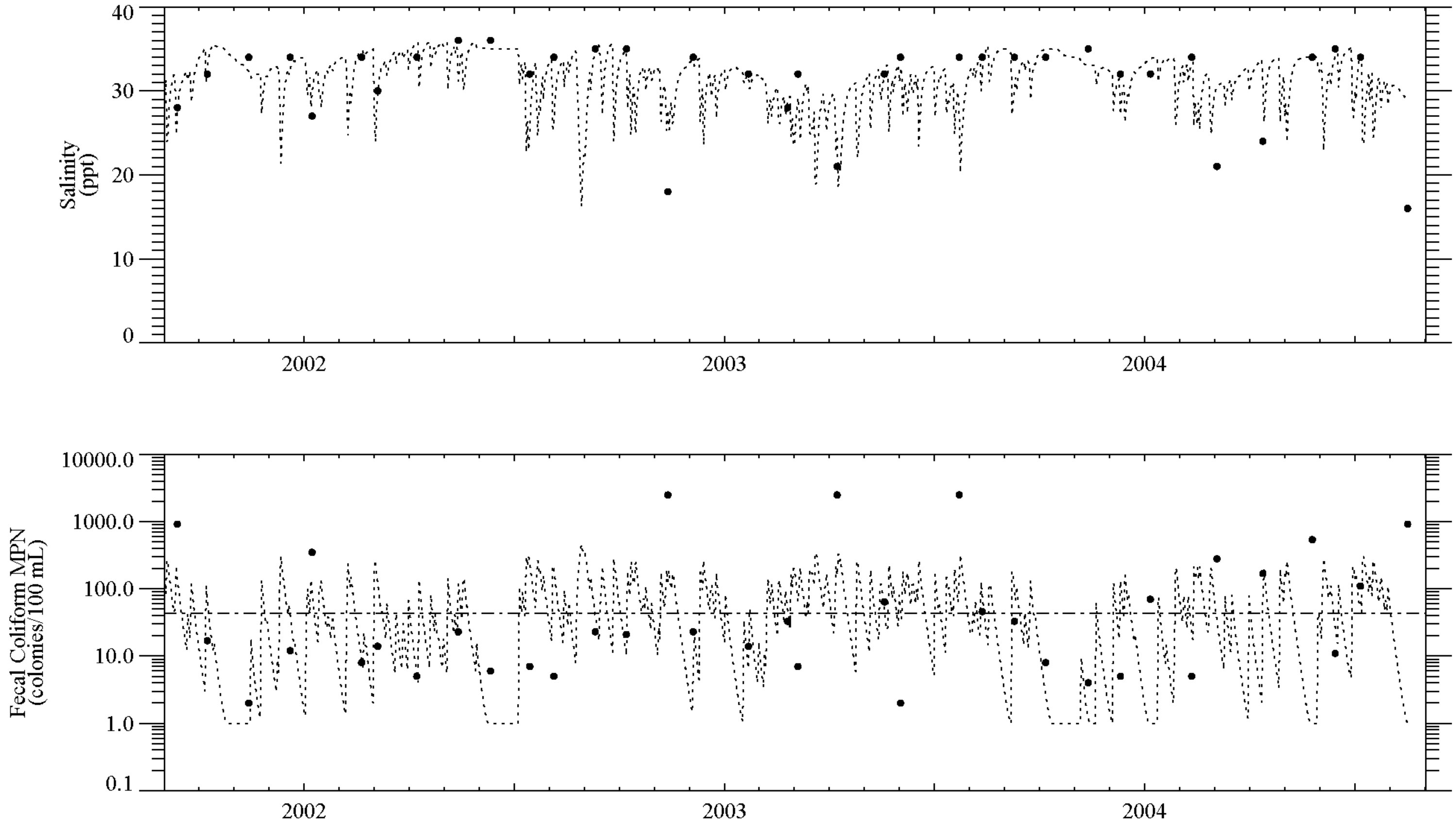


Figure C-4. Predicted and Observed Fecal Colfiorm and Salinity for South Causeway Bridge at Pawley's Island Creek (Station 04-12).

Dashed horizontal lines are 10% not to exceed standard (43 colonies/100 mL).

Water Quality Standard
Model Predictions
Observed Data

sfh - D:\Jobs\PARbac\Analysis\Water\f_coli_temporal\fcoli_temporal_final_figs.pro
Mon Apr 04 11:15:01 2005

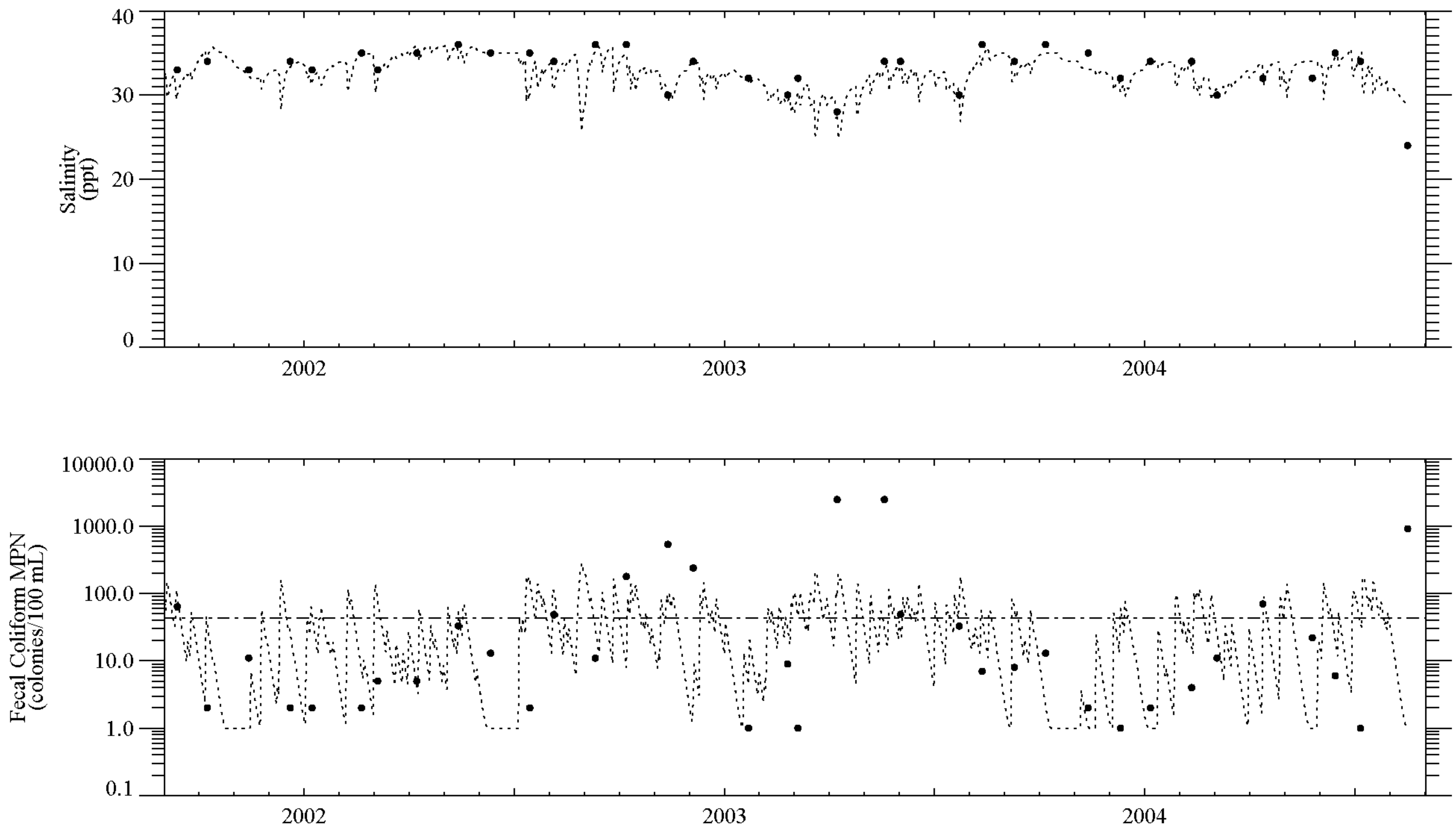


Figure C-5. Predicted and Observed Fecal Colfiorm and Salinity for North Causeway Bridge at Pawley's Island Creek (Station 04-11).

Dashed horizontal lines are 10% not to exceed standard (43 colonies/100 mL).

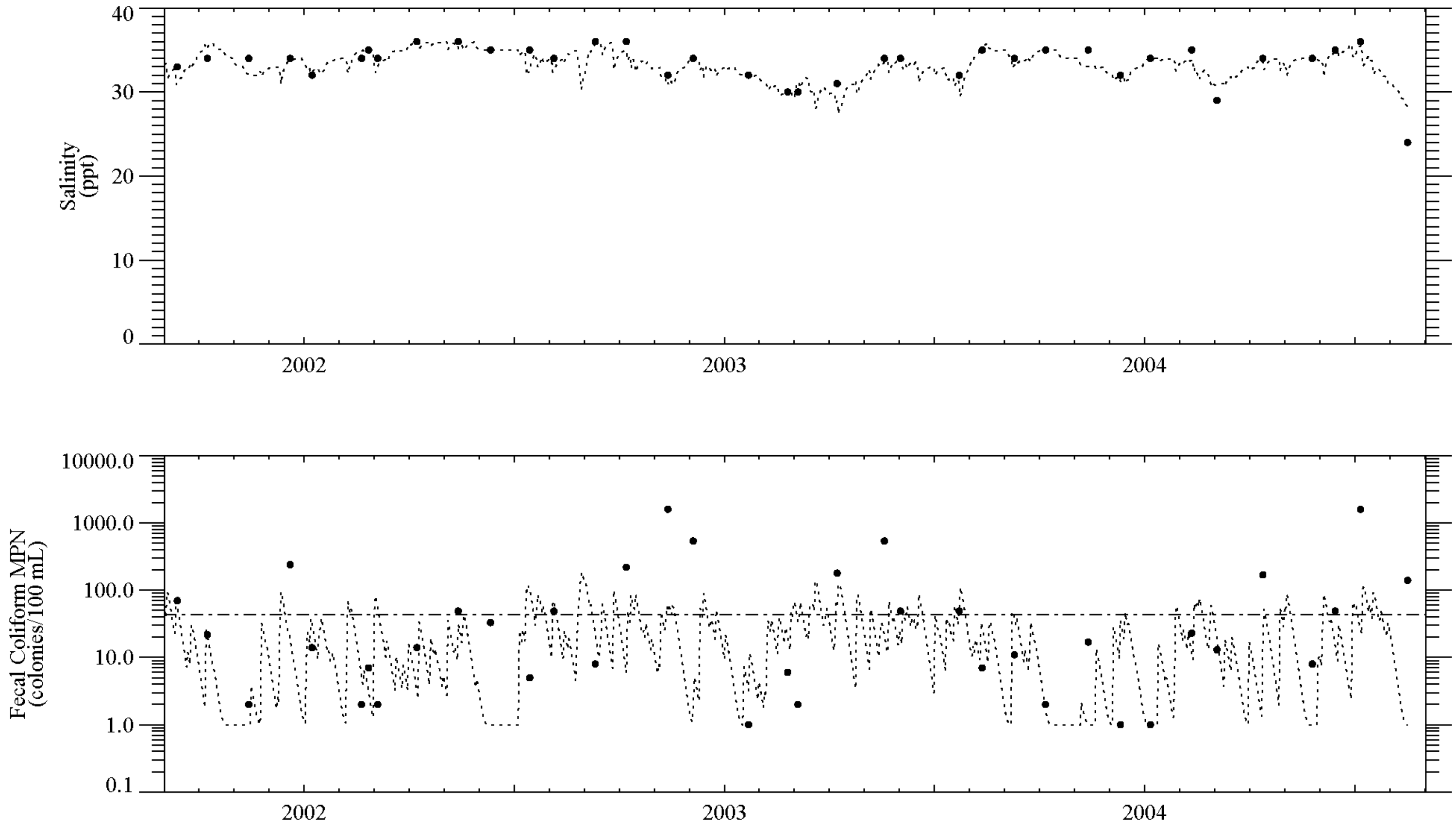
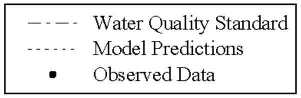


Figure C-6. Predicted and Observed Fecal Colfiorm and Salinity for Shell Avenue and Pawley's Island Creek (Station 04-10).
Dashed horizontal lines are 10% not to exceed standard (43 colonies/100 mL).



sfh - D:\Jobs\PARbac\Analysis\Water\f_coli_temporal\fcoli_temporal_final_figs.pro
Mon Apr 04 11:15:06 2005

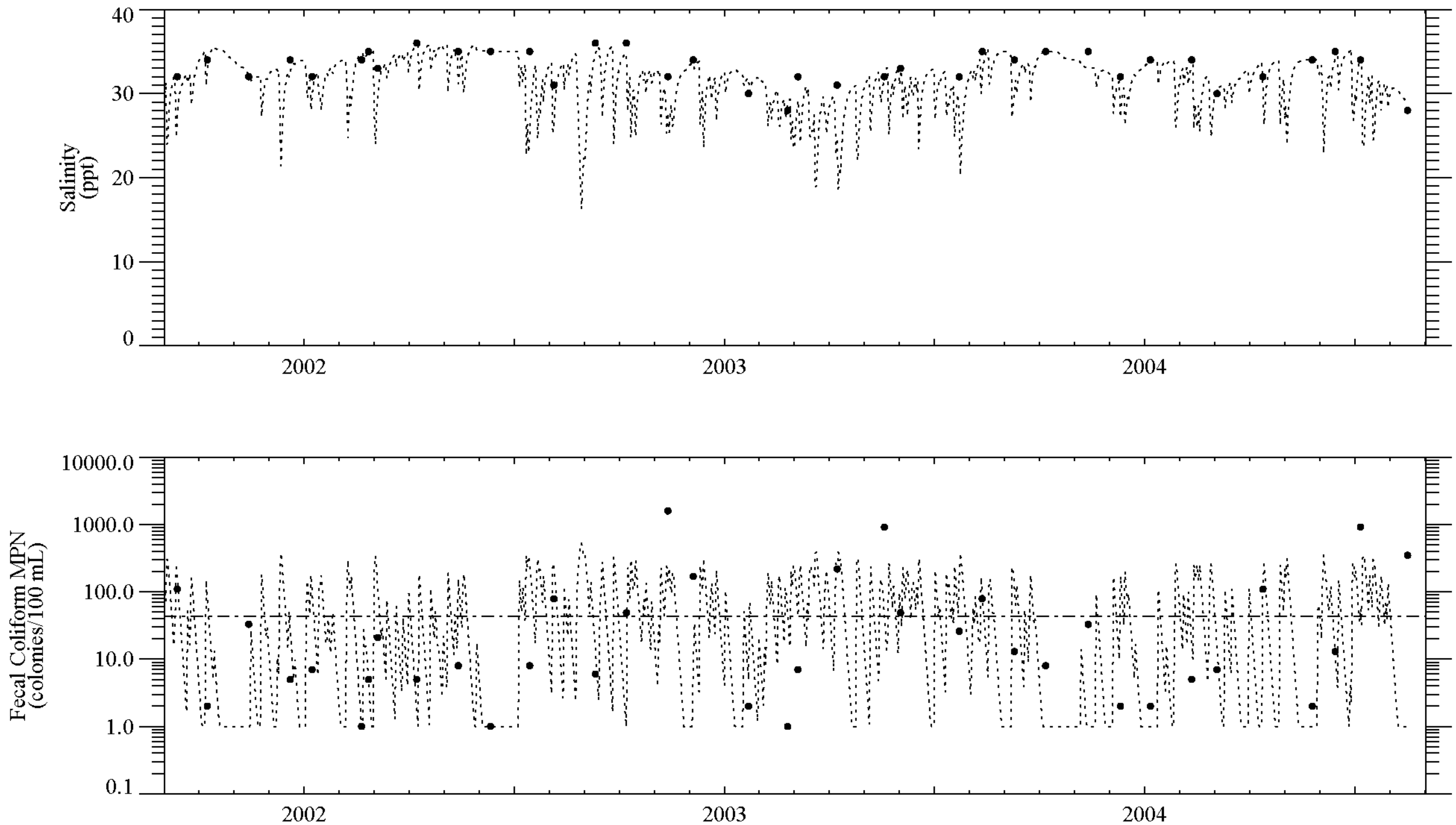
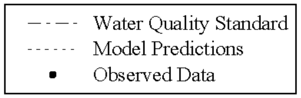


Figure C-7. Predicted and Observed Fecal Colfiorm and Salinity for South Pawley's Island Boat Landing (Station 04-21).
Dashed horizontal lines are 10% not to exceed standard (43 colonies/100 mL).



sfh - D:\Jobs\PARbac\Analysis\Water\f_coli_temporal\fcoli_temporal_final_figs.pro
Mon Apr 04 11:15:09 2005

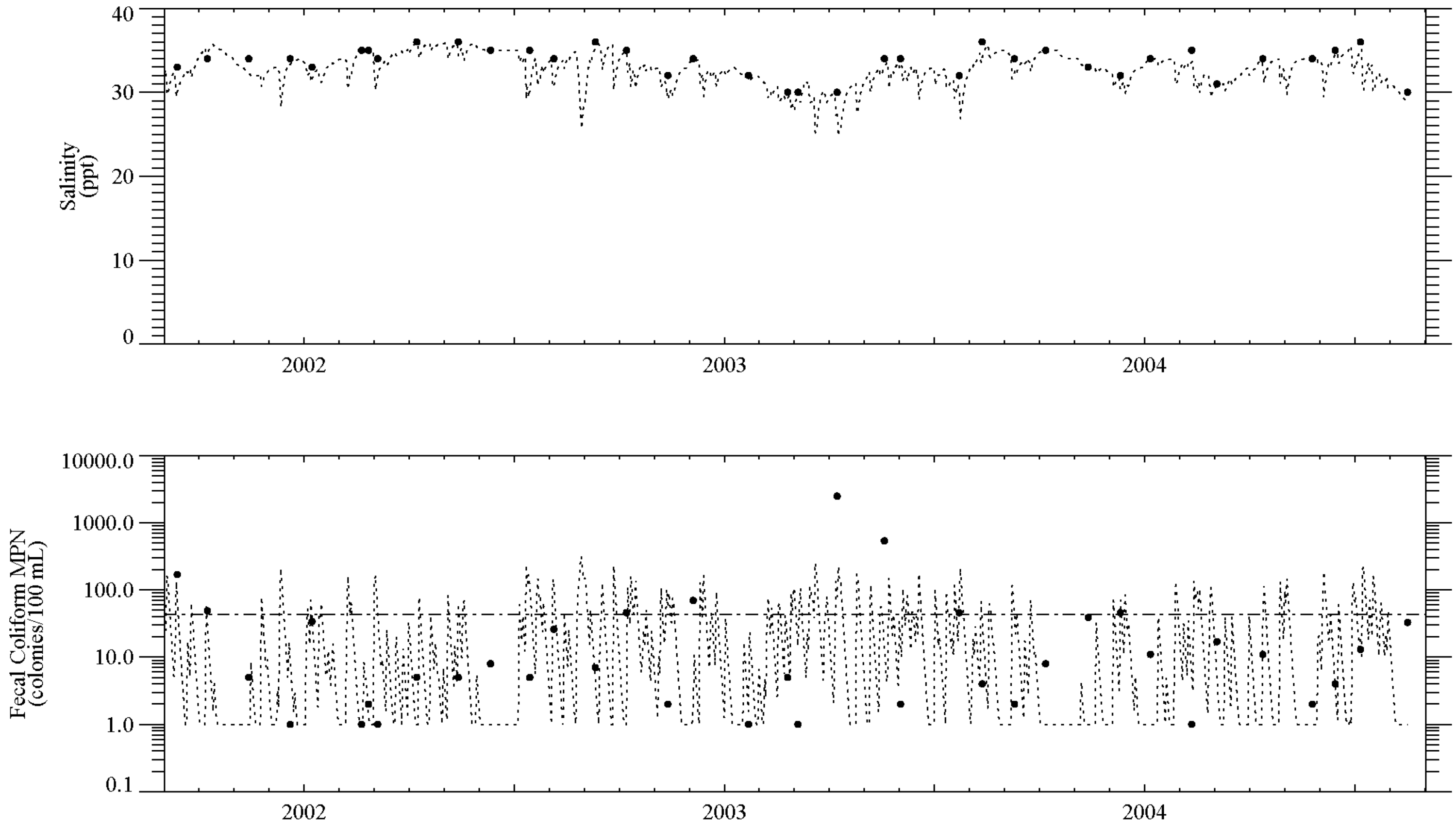
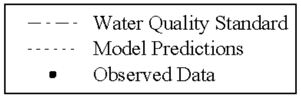


Figure C-8. Predicted and Observed Fecal Colfiorm and Salinity for Pawley's Inlet (Station 04-13).

Dashed horizontal lines are 10% not to exceed standard (43 colonies/100 mL).



sfh - D:\Jobs\PARbac\Analysis\Water\f_coli_temporal\fcoli_temporal_final_figs.pro
Mon Apr 04 11:15:11 2005