Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in St. Clements Bay in St. Mary's County, Maryland

FINAL

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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
COMAR	Code of Maryland Regulations
CSO	Combined Sewer Overflow
CWA	Clean Water Act
CWP	Center for Watershed Protection
EPA	Environmental Protection Agency
FA	Future Allocation
GIS	Geographic Information System
LA	Load Allocation
LMM	Long-term Moving Median
MACS	Maryland Agricultural Cost Share Program
MASS	Maryland Agricultural Statistic Service
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MRLC	Multi-Resolution Land Cover
MSSCC	Maryland State's Soil Conservation Committee
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
RID	MDE Restricted Area Identification
SSO	Sanitary Sewer Overflows
T^{-1}	Per Tidal Cycle
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

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.

St. Clements Bay (basin number 02-14-01-05) was first identified on the 1996 303(d) list submitted to the U.S. Environmental Protection Agency (EPA) by Maryland Department of the Environment (MDE) as being impaired by nutrients, sediments and fecal coliform, with listings of biological impacts in non-tidal portions added in 2002. On the draft 2004 303(d) List, specific restricted shellfish harvesting areas were identified. This document addresses the fecal coliform impairment listings of three restricted shellfish harvesting areas St. Clements Bay Basin: St. Clements Bay (RID 44A), Canoe Creek (RID 44B) and St. Patrick Creek (RID 44C). The nutrient, suspended sediment and biological impairments within St. Clements Bay basin will be addressed at a future date.

This document proposes to establish TMDLs of fecal coliform for three restricted shellfish harvesting areas in St. Clements Bay Basin - St. Clements Bay; Canoe Neck Creek, and St. Patrick Creek – which are located within the St. Clements Bay basin and drain south into the Potomac River. These restricted shellfish harvesting areas are impaired by levels of bacteria exceeding Maryland's water quality standards for fecal coliform, which has resulted in closure of the areas to shellfish harvesting.

Fecal coliform are indicator organisms used in water quality monitoring in shellfish waters to indicate fresh sources of pollution from human waste. When the water quality standard for fecal coliform in shellfish waters is exceeded, waters are closed to shellfish harvesting to protect human health due to the potential risk from consuming raw molluscan shellfish from sewage contaminated waters. The water quality goal of these TMDLs is to reduce high fecal coliform concentrations to levels whereby the designated uses for these restricted shellfish harvesting areas will be met. The nutrient, sediment, biological, and any remaining bacteria impairments within the basin will be addressed at a future date.

A variety of data at the watershed scale, including shoreline sanitary survey data, was used to identify potential fecal coliform contributions. The potential fecal coliform contributions were estimated using Geographic Information System (GIS) data coverage including land use, septic distribution, property, and stream data, concurrently with local agriculture census data. There are no permitted point source facilities in any of the restricted shellfish harvesting areas addressed in this report. From these estimates, the major contributions of fecal coliform load are

nonpoint sources, including livestock, wildlife, pets, and failing septic systems. Estimated sources will be revisited once laboratory analysis, using bacteria source tracking, is completed.

A steady state tidal prism model was used to estimate current fecal coliform load based on volume and concentration, and to establish allowable loads for each restricted shellfish harvesting area in St. Clements Bay. The tidal prism model incorporates both influences of freshwater discharge and tidal flushing for each restricted shellfish harvesting area, which thereby represents the hydrodynamics of each selected area. The load is then allocated to sources (human, livestock, pets, and wildlife) 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. In order to accomplish this, data available from the most recent five-year period (i.e., 1999-2003) were used to calculate a median and 90th percentile values were 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 90th percentile standard of 49 MPN/100ml. An implicit Margin of Safety (MOS) was incorporated in the analysis to account for uncertainty. The TMDLs developed for the restricted shellfish harvesting area of St. Clements Bay Basin for fecal coliform median load and 90th percentile load are as follows:

St. Clements Bay (RID 44A):
The median load of fecal coliform TMDL = 7.78×10^{11} counts per day
The 90th percentile of fecal coliform TMDL = 2.72×10^{12} counts per day

Canoe Neck Creek (RID 44B):
The median load of fecal coliform TMDL = 1.58×10^{11} counts per day
The 90th percentile of fecal coliform TMDL = 5.54×10^{11} counts per day

St. Patricks Creek (RID 44C):
The median load of fecal coliform TMDL = 6.15×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 2.15×10^{11} counts per day

For the restricted shellfish harvesting areas in St. Clements Bay Basin, the 90th percentile criterion requires the greater reduction. Therefore, the source reduction scenario is developed based on the 90th percentile load TMDL. The source contributions estimated from the watershed analysis were used to determine the percent contribution for each source. The percent distributions of these sources were used to partition the load allocation that would meet water quality standards at restricted shellfish harvesting areas in St. Clements Bay Basin. The reduction for each source was calculated based on differences of the current loads and the allowable loads. The reduction for each source was calculated based on differences of the current loads and the allowable loads. The reductions needed in each restricted shellfish harvesting area to meet the shellfish criteria and the load allocations required to meet the TMDLs are shown in the table below.

Load Allocations and Reductions

RID	Source	Current Load Distribution (% of Total)	Required Reduction	TMDL Load Allocation (% of Total)
St. Clements Bay				
44A	Total	100.0%	21.0%	100.0%
	Wildlife	12.3%	0.0%	15.5%
	Human	0.1%	24.0%	0.1%
	Pets	2.6%	24.0%	2.5%
	Livestock	85.0%	24.0%	81.9%
Canoe Neck Creek				
44B	Total	100.0%	30.6%	100.0%
	Wildlife	11.3%	0.0%	16.2%
	Human	0.1%	34.4%	0.1%
	Pets	2.4%	34.4%	2.3%
	Livestock	86.2%	34.4%	81.4%
St. Patrick Creek				
44C	Total	100.0%	80.0%	100.0%
	Wildlife	3.5%	0.0%	17.4%
	Human	0.1%	82.9%	0.0%
	Pets	1.3%	82.9%	1.2%
	Livestock	95.1%	82.9%	81.4%

Once the EPA has approved these TMDLs, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. MDE 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. To confirm the bacteria source allocations, MDE is conducting a one-year bacteria source tracking study for each restricted shellfish harvesting area identified in this report. There is an ongoing effort for continued monitoring by MDE's Shellfish Certification Division.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to 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.

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.

St. Clements Bay (basin number 02-14-01-05) was first identified on the 1996 303(d) list submitted to the EPA by Maryland Department of the Environment (MDE) as being impaired by nutrients, sediments, and bacteria, with listings of biological impacts in non-tidal portions added in 2002. On the draft 2004 303(d) List, specific restricted shellfish harvesting areas were identified. This document proposes to establish TMDLs of fecal coliform for identified restricted shellfish harvesting areas in St. Clements Bay. The nutrient, sediment and biological impairments within the basin will be addressed at a future date.

In both the 1996 and 1998 Maryland 303(d) lists of impaired waterbodies, many 8-digit watersheds were identified as being impaired since these waterbodies are closed to shellfish harvesting due to elevated fecal coliform concentrations. Monitoring is ongoing in shellfish areas, and openings and closings occur routinely. The draft 2004 303(d) List indicates currently restricted shellfish harvesting areas within an 8-digit watershed, that require a TMDLs.

Fecal coliform are found in the intestinal tracts of humans and other warm-blooded animals. Few fecal coliform are pathogenic; however, the presence of elevated levels of fecal coliform in shellfish waters indicate recent sources of pollution. Some common waterborne diseases associated with the consumption of raw clams and oysters harvested from polluted waters include viral and bacterial gastroenteritis and hepatitis A. Fecal coliform may occur in surface waters from point and nonpoint sources.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

St. Clements Bay Basin is situated approximately 45 km upriver from the mouth of the Potomac River along its northeast shoreline. St. Clements Bay extends about 11 km from its headwaters to the mouth of the river where it discharges into the Potomac River. The shellfish waters include the tidal waters of the St. Clements Bay Basin and its tributaries in St. Mary's County, Maryland from the headwaters near Dynard, Maryland to its confluence with the Potomac River.

St. Clements Bay (RID 44A), Canoe Neck Creek (RID 44B), and St. Patrick Creek (RID 44C) drain south to the Lower Potomac River, as shown in Figure 2.1.1. The drainage basin for St. Clements Bay is approximately 22.5 km in the north-south direction by 4 km in the east-west direction with a drainage area of approximately 386,718 acres (1,565 km^2). Soils mainly consist of silt (42.9%), sand (37.6%), and clay (19.5%) (U.S. Department of Agriculture (USDA), 1995). The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal range of 0.5 m and tidal period of 12.42 hours. Please refer to Table 2.1.1 for the mean volumes and mean water depths of each restricted shellfish harvesting area.

Table 2.1.1: Physical Characteristics of the St. Clements Bay Restricted Shellfish Harvesting Areas

Restricted Shellfish Harvesting Area (RID)	Mean Water Volume in m^3	Mean Water Depth in m
St. Clements Bay (44A)	7,891,224	2.41
Canoe Neck Creek (44B)	1,612,090	1.61
St. Patrick Creek (44C)	626,211	0.84

The 2000 Maryland Department of Planning (MDP) land use/land cover data show the St. Clements Bay watershed can be characterized as rural. The land use information for the restricted shellfish harvesting areas in the St. Clements Bay watershed is shown in Table 2.1.2 to Table 2.1.4 and Figure 2.1.2 to Figure 2.1.4. Feedlots identified in the figures are MDP land use types, not permitted confined animal feeding operations (CAFOs).

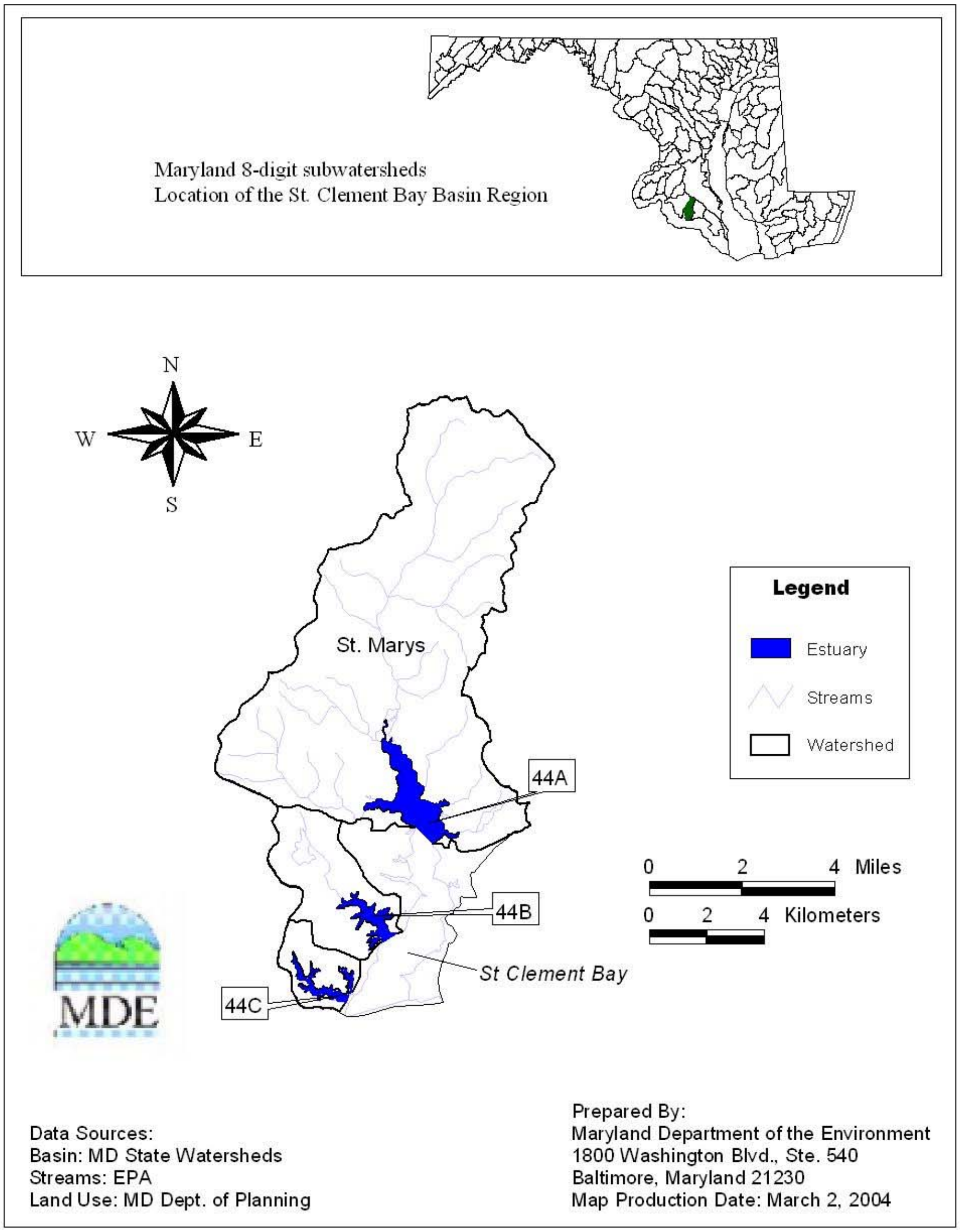

Figure 2.1.1: Location Map of St. Clements Bay Basin

Table 2.1.2: Land Use Percentage Distribution for St. Clements Bay (RID 44A)

Land Type	Acreage	Percentage
Urban	2,113.2	8.9
Forest	11,638.3	48.8
Agriculture	9,078.8	38.0
Wetlands	213.4	0.9
Water	825.9	3.4
Totals	**23,869.7**	**100.0**

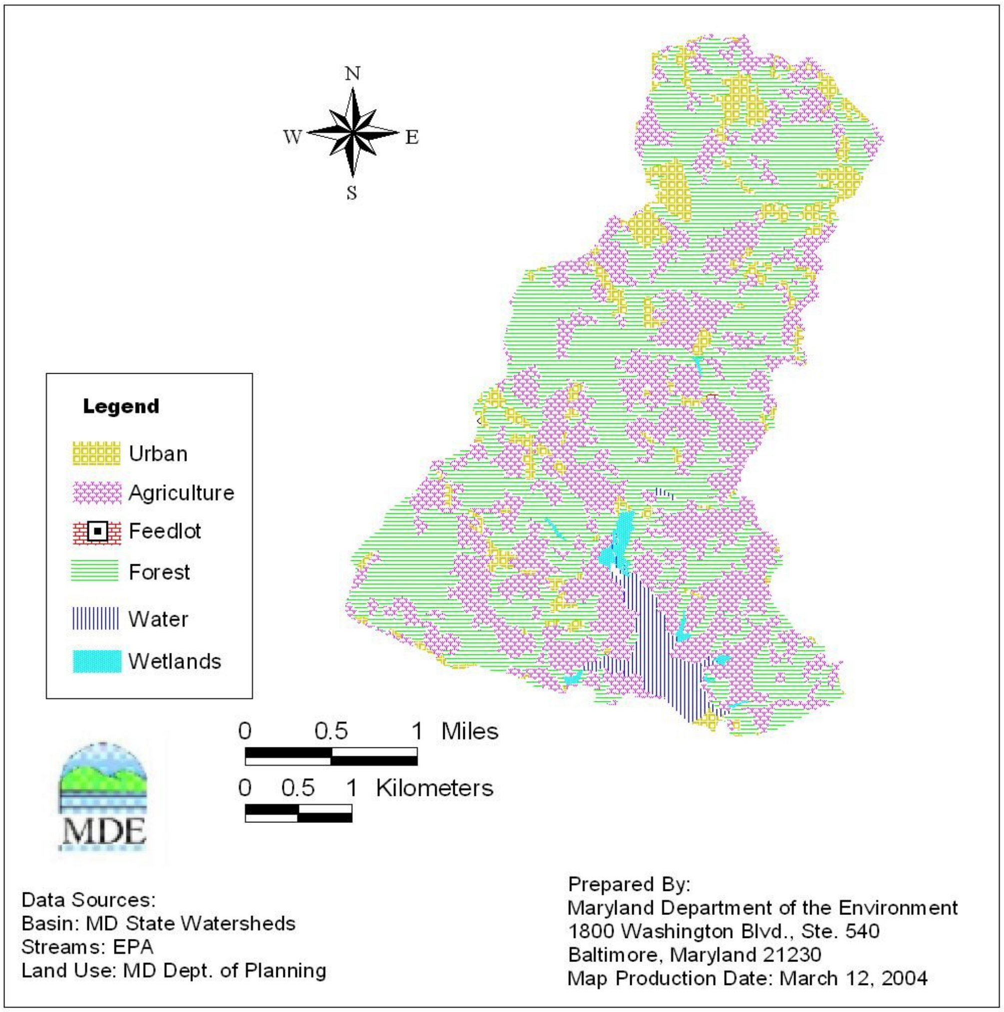

Figure 2.1.2: Land Use in the St. Clements Bay Subbasin

Table 2.1.3: Land Use Percentage Distribution for Canoe Neck Creek (RID 44B)

Land Type	Acreage	Percentage
Urban	324.8	9.7
Forest	1,975.8	58.7
Agriculture	815.3	24.2
Wetlands	0.0	0.0
Water	247.9	7.4
Totals	**3,363.8**	**100.0**

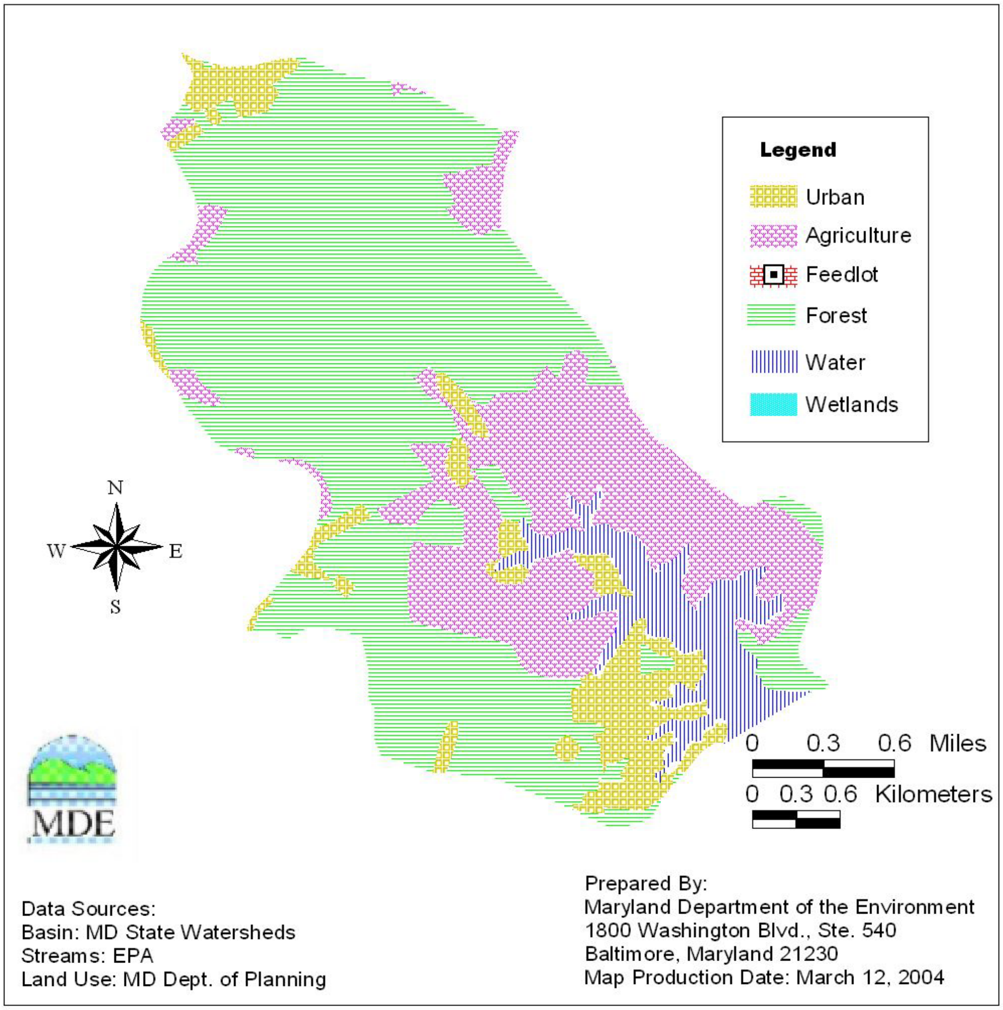

Figure 2.1.3: Land Use in the Canoe Neck Creek Basin

Table 2.1.4: Land Use Percentage Distribution for St. Patrick Creek (RID 44C)

Land Type	Acreage	Percentage
Urban	177.4	13.2
Forest	573.8	42.6
Agriculture	400.3	29.7
Wetlands	9.2	0.7
Water	185.8	13.8
Totals	**1,346.4**	**100.0**

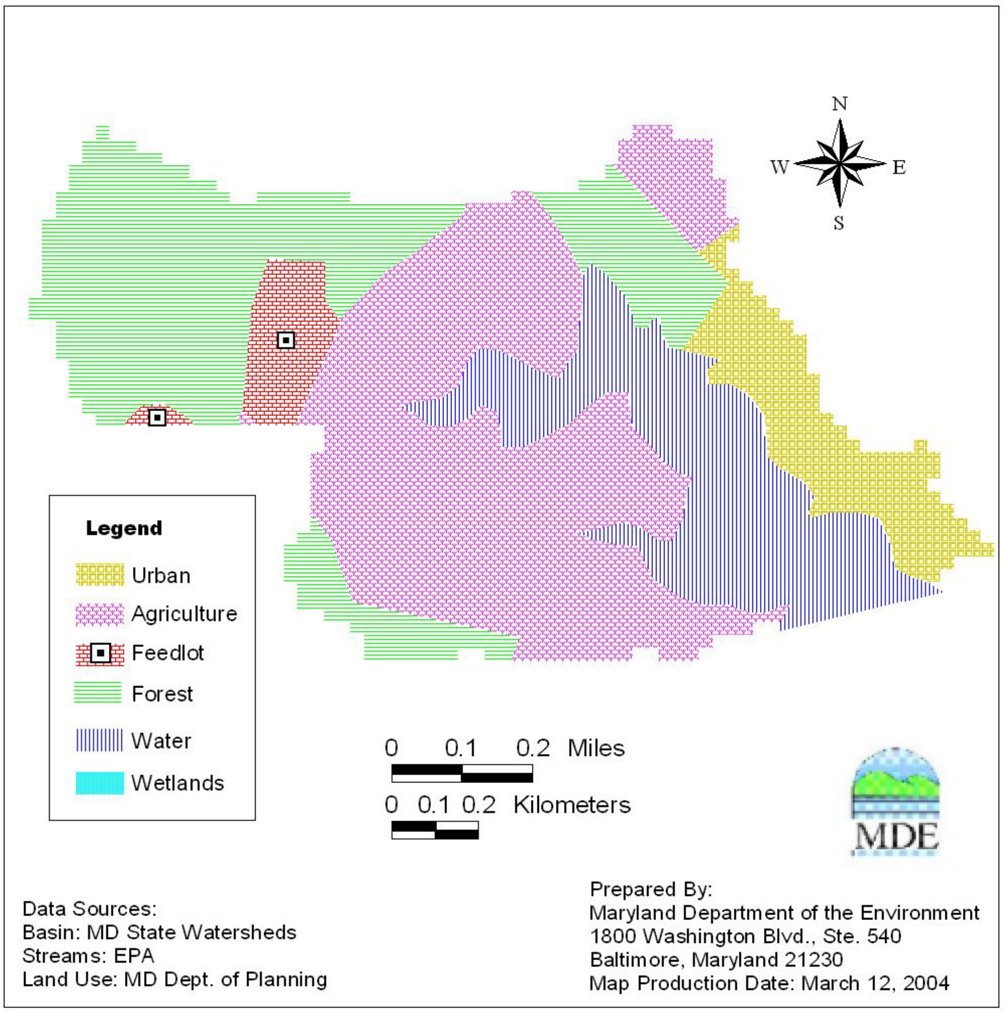

Figure 2.1.4: Land Use in the St. Patrick Creek Basin

2.2 Water Quality Characterization

MDE's Shellfish Certification Program is responsible for classifying shellfish harvesting waters to ensure oysters and clams are safe for human consumption. MDE adheres to the requirements of the National Shellfish Sanitation Program (NSSP), with oversight by the U.S. Food and Drug Administration. MDE conducts shoreline surveys and collects routine bacteria water quality samples in the shellfish-growing areas of Maryland. These 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 and the designated use is not being achieved.

MDE's Shellfish Certification Division has monitored shellfish growing regions throughout Maryland for the past several decades. There are six shellfish monitoring stations, in the restricted shellfish areas in St. Clements Bay. The monitoring stations and observations recorded during the period of 1999 – 2003 are provided in Table 2.2.1 to Table 2.2.3 and Figure 2.2.1 to Figure 2.2.9. In general, based on Statewide shellfish monitoring data, fecal coliform concentrations are higher in the headwaters.

Table 2.2.1: Locations of Shellfish Monitoring Stations in St. Clements Bay

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
13-02-001	1999-2003	54	38 17 43.0	76 43 14.0
13-02-004	1999-2003	54	38 17 12.0	76 42 55.0

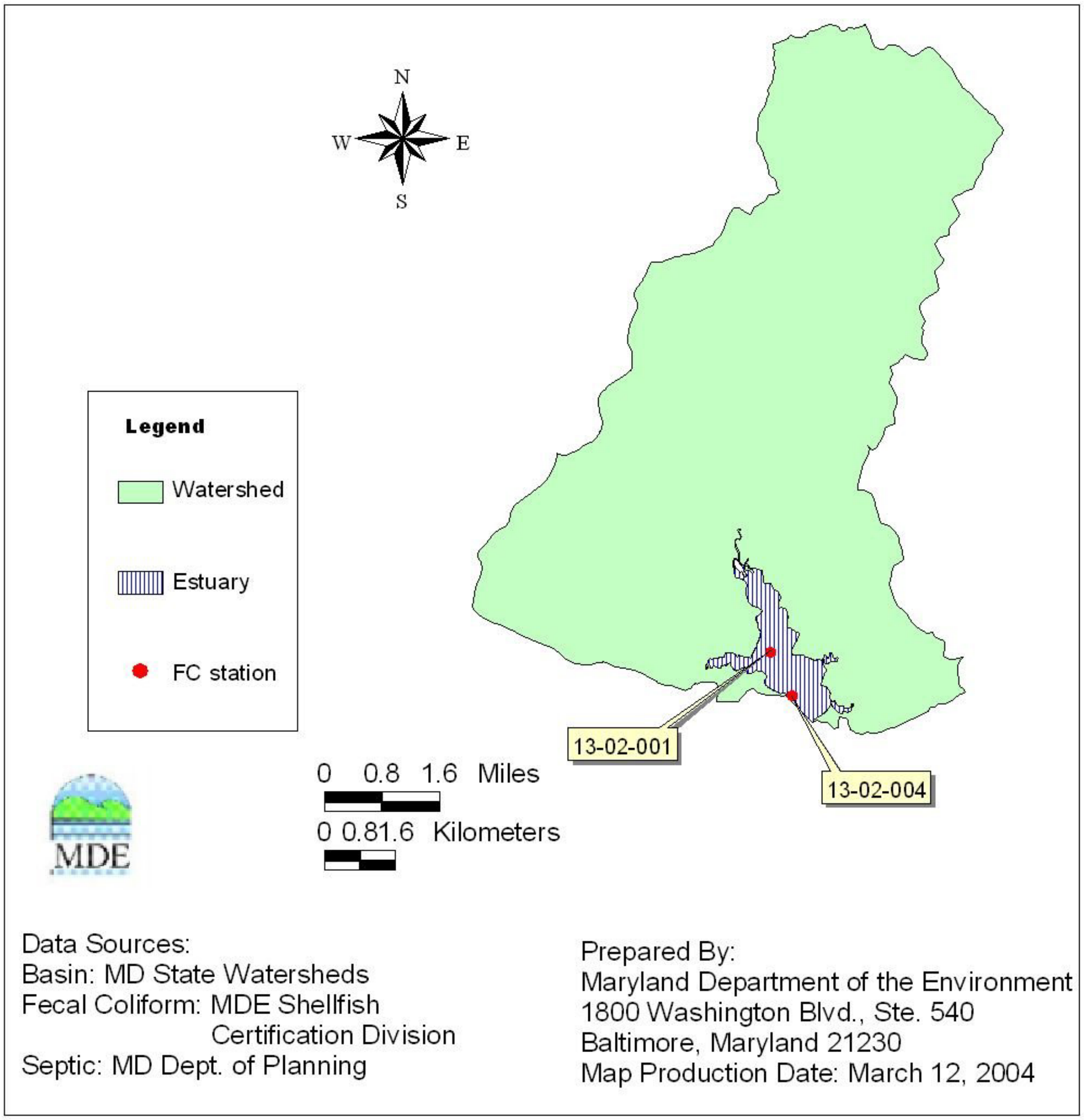

Figure 2.2.1: Shellfish Monitoring Stations in St. Clements Bay

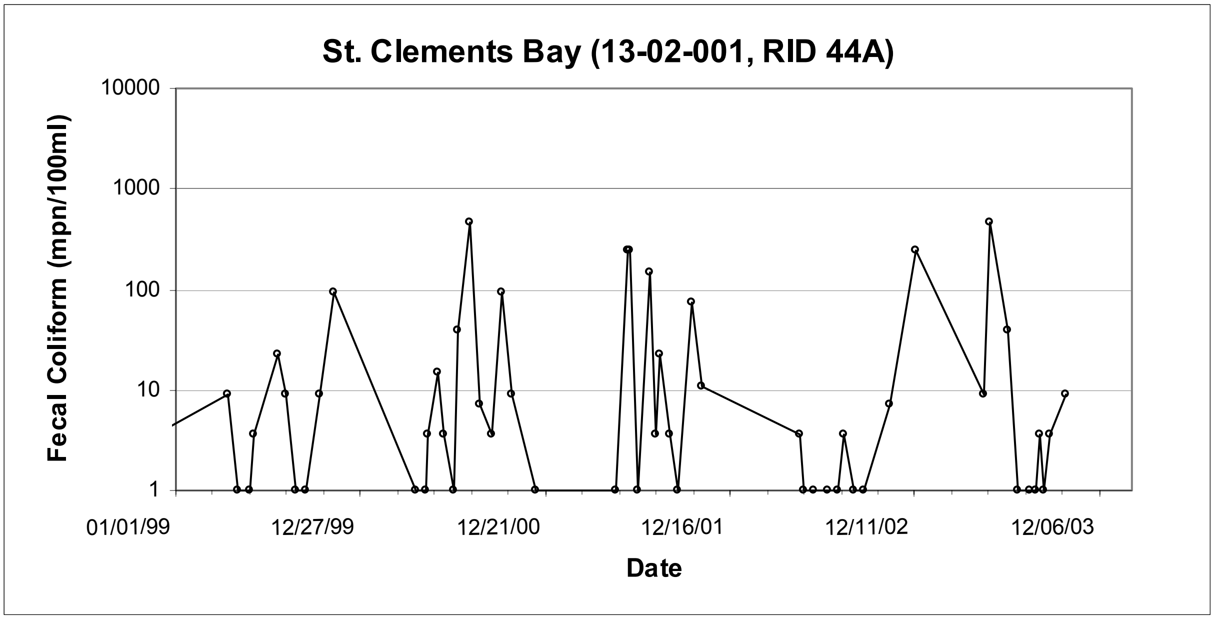

Figure 2.2.2: Observed Fecal Coliform at Station 13-02-001

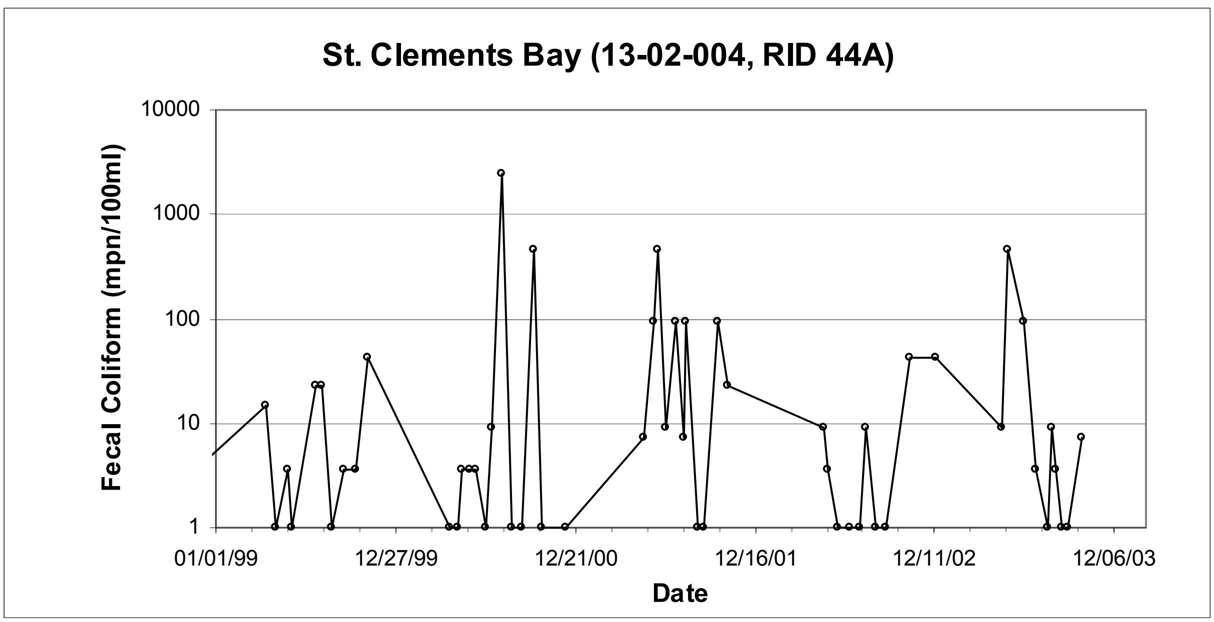

Figure 2.2.3: Observed Fecal Coliform at Station 13-02-004

Table 2.2.2: Locations of Shellfish Monitoring Stations in Canoe Neck Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
13-02-009A	1999-2003	54	38 15 09.0	76 43 45.0
13-02-010	1999-2003	53	38 15 26.0	76 44 00.0

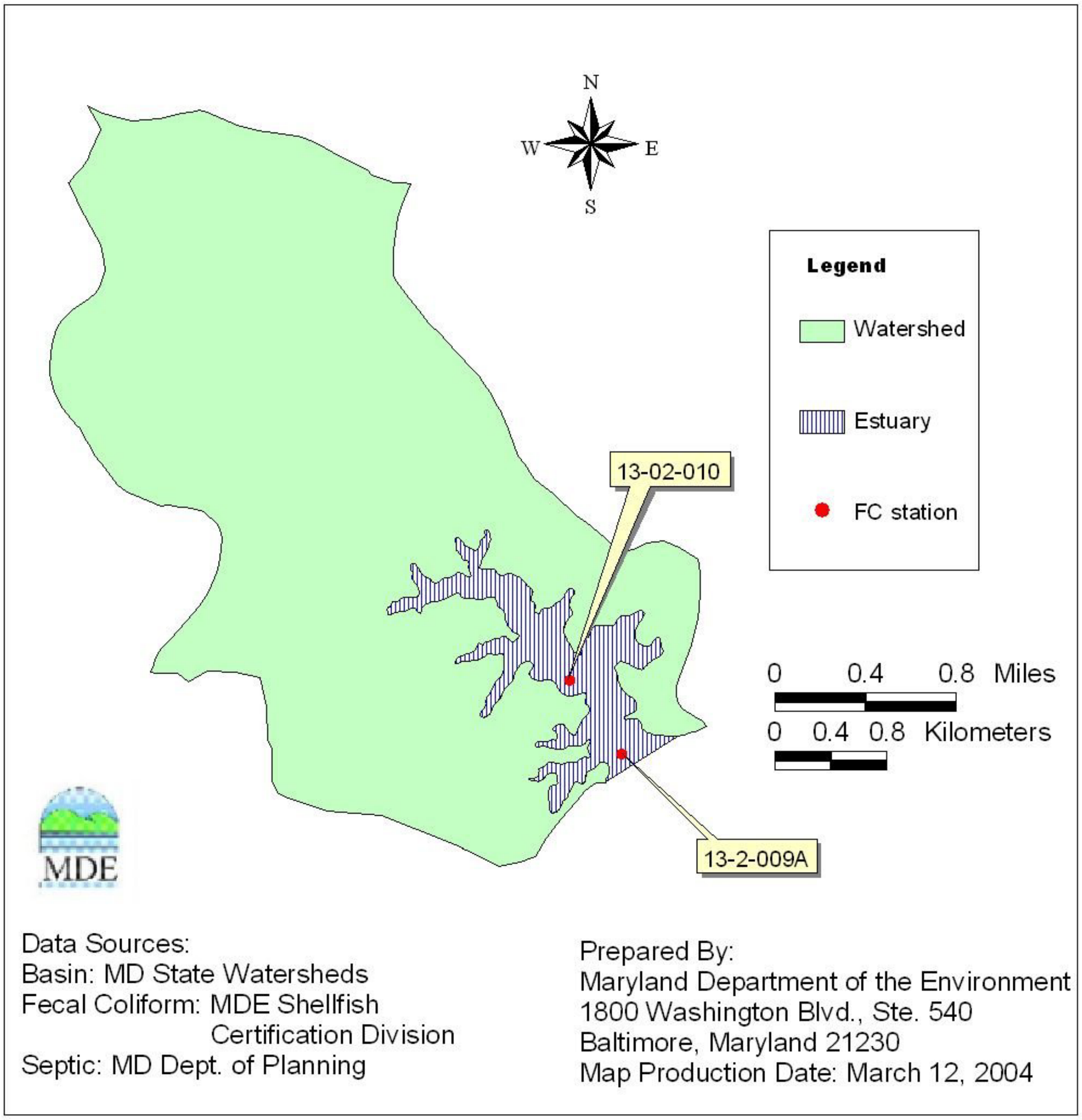

Figure 2.2.4: Shellfish Monitoring Stations in Canoe Neck Creek

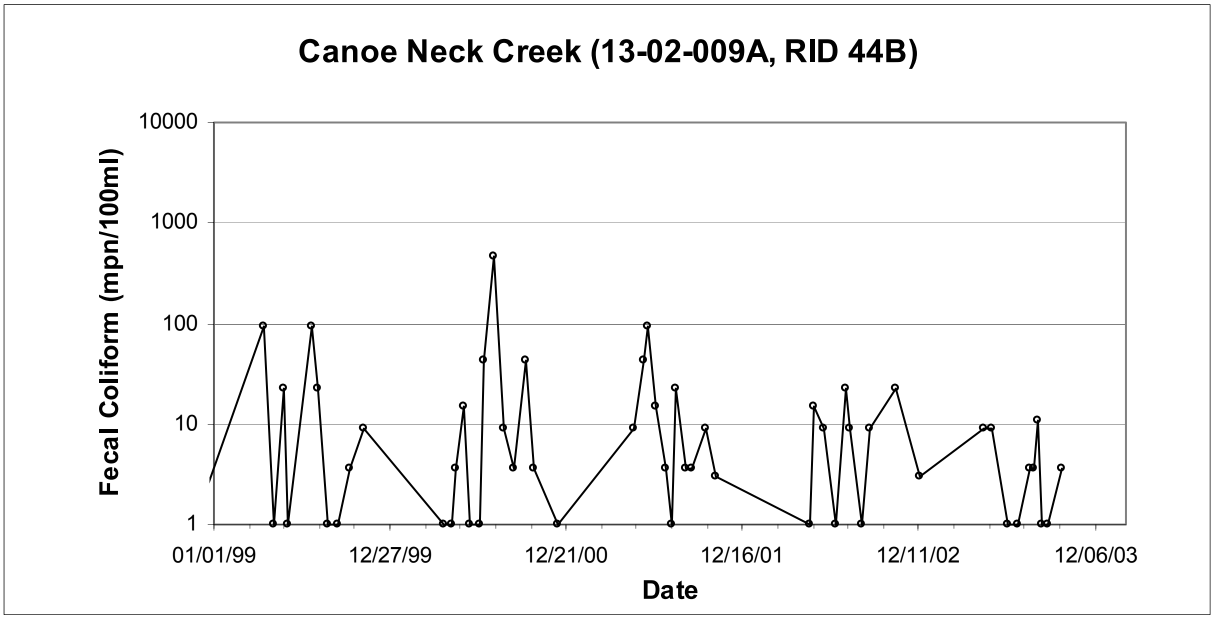

Figure 2.2.5: Observed Fecal Coliform at Station 13-02-009A

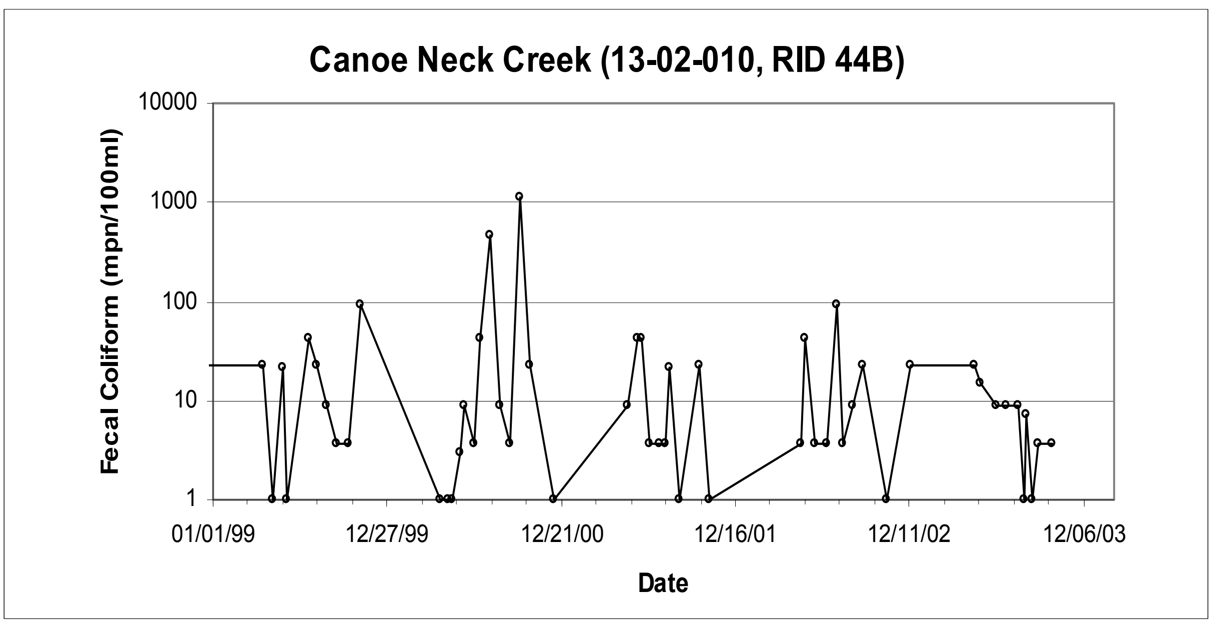

Figure 2.2.6: Observed Fecal Coliform at Station 13-02-010

Table 2.2.3: Locations of Shellfish Monitoring Stations in St. Patrick Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
13-02-014	1999-2003	59	38 13 58.0	76 44 39.0
13-02-014C	1999-2003	59	38 14 06.0	76 45 10.0

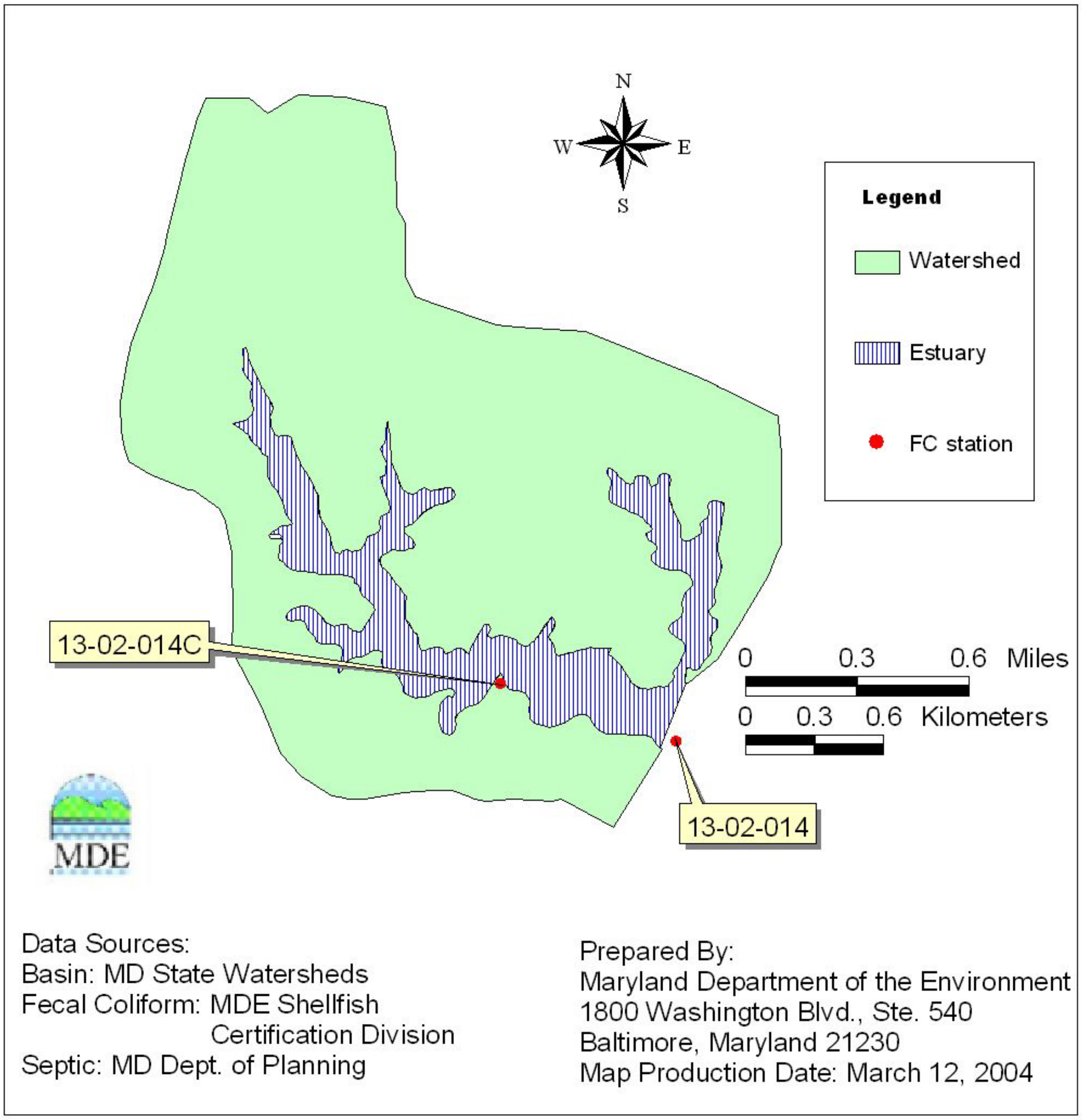

Figure 2.2.7: Shellfish Monitoring Stations in St. Patrick Creek

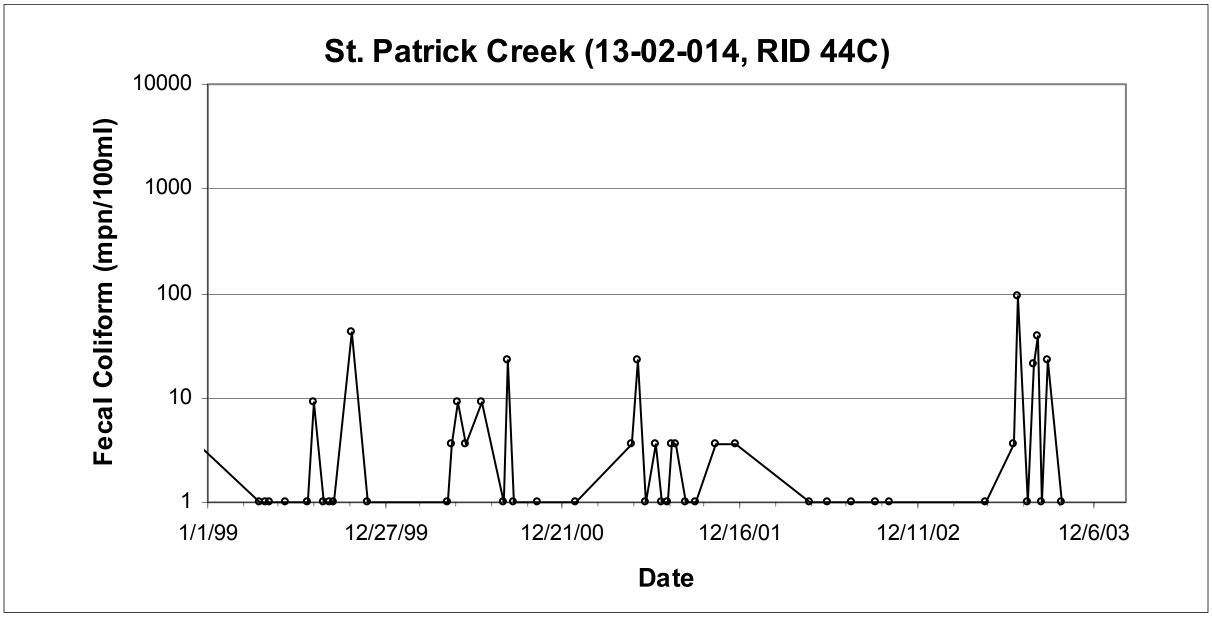

Figure 2.2.8: Observed Fecal Coliform at Station 13-02-014

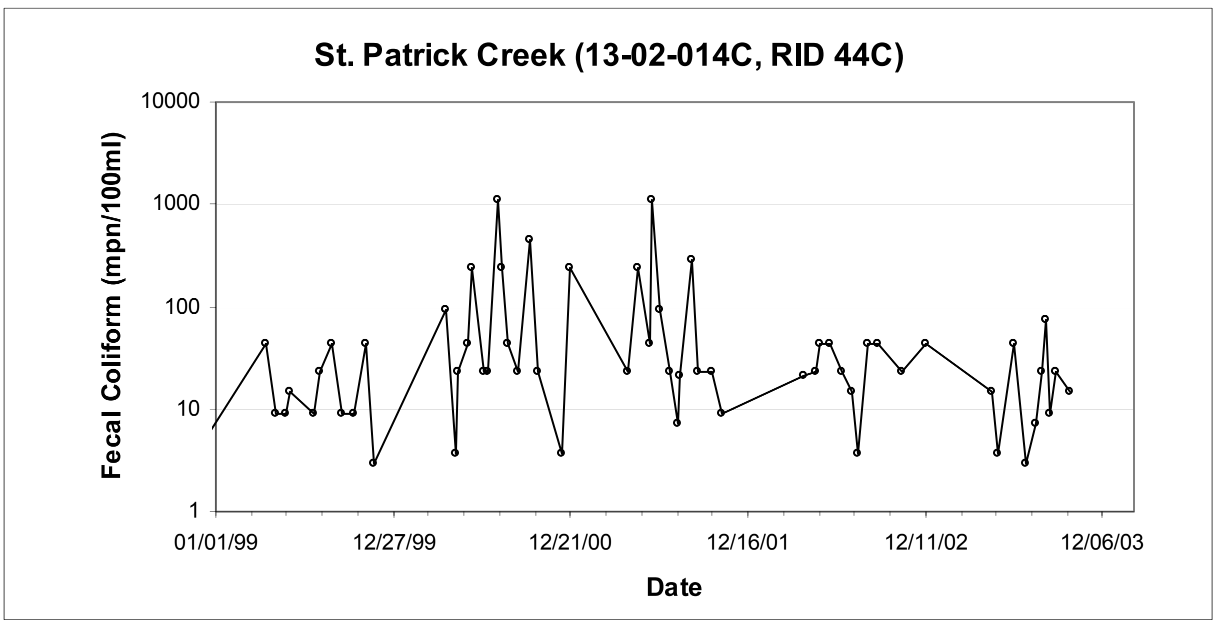

Figure 2.2.9: Observed Fecal Coliform at Station 13-02-014C

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation for these restricted shellfish harvesting areas is Use II- Shellfish Harvesting Waters (Code of Maryland Regulations (COMAR) 26.08.02.08M). St. Clements Bay (basin number 02-14-01-05) has been included on the draft 2004 Integrated 303(d) List as impaired by fecal coliform. The restricted shellfish harvesting areas located in the St. Clements Bay Basin are identified as areas in this basin that do not meet shellfish water quality standards. Waters within this classification, according to COMAR Section 26.08.02.03-3C, **"means that the median fecal coliform MPN of at least 30 water sample results taken over a three year period to incorporate inter-annual variability shall not exceed 14 per 100 milliliters, and**

(i) In areas affected by point source discharges, not more than 10 percent of the samples shall exceed an MPN of 43 per 100 ml for a five tube decimal dilution test or 49 MPN per 100 ml for a three tube decimal dilution test; or

(ii) In other areas, the 90^{th} percentile of water sample results shall not exceed an MPN of 43 per 100 ml for a five tube decimal dilution test or 49 MPN per 100 ml for a three tube decimal dilution test."

For this report, the monitoring data averaging period was based on a combination of management objectives and monitoring data requirements for determination of shellfish harvesting area water quality standards attainment. The averaging period for the monitoring data required least 30 samples and used all data within the most recent five year period.
The water quality impairment was assessed using the median and 90^{th} percentile concentrations. Descriptive statistics of the monitoring data and the water quality criterion are shown in Table 2.3.1. Water quality impairments are demonstrated in restricted shellfish harvesting areas.

Table 2.3.1: St. Clements Bay Shellfish Monitoring Stations (1999-2003) - Median and 90th Percentile

RID	Restricted Shellfish Harvesting Area	Station	Median		90th Percentile	
			Monitoring Data	Criterion	Monitoring Data	Criterion
			MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
44A	St. Clements Bay	13-02-001	3.6	14	67.9	49
		13-02-004	3.6	14	88.6	49
44B	Canoe Neck Creek	13-02-009A	3.6	14	39.1	49
		13-02-010	9.1	14	61.1	49
44C	St. Patrick Creek	13-02-014	9.1	14	55.2	49
		13-02-014C	23.0	14	159.4	49

2.4 Source Assessment

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. The possible introductions of fecal coliform bacteria to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and discharges to the restricted shellfish harvesting area. The deposition of non-human fecal coliform directly to the restricted shellfish area occurs when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions to the bacterial levels from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreation vessel discharges. The transport of fecal coliform from land surface to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

The complete distributions of these source loads are also listed in Tables 2.4.1 to 2.4.3, along with counts/day for each loading. Details of the source estimate procedure can be found in Appendix B. The Bacteria Source Tracking (BST) data will be used to further confirm the source distribution when it becomes available.

Table 2.4.1: Distribution of Fecal Coliform Source Loads in the St. Clements Bay Subasin

Fecal Coliform Source	**Loading Counts/day**	**Loading Percent**
Livestock	2.32E+13	85.0%
Pets	7.12E+11	2.6%
Human	2.89E+10	0.1%
Wildlife	3.34E+12	12.3%
Total	2.73E+13	100.0%

Table 2.4.2: Distribution of Fecal Coliform Source Loads in the Canoe Neck Creek Basin

Fecal Coliform Source	**Loading Counts/day**	**Loading Percent**
Livestock	3.40E+12	86.2%
Pets	9.71E+10	2.4%
Human	4.08E+09	0.1%
Wildlife	4.44E+11	11.3%
Total	3.95E+12	100.0%

Table 2.4.3: Distribution of Fecal Coliform Source Loads in the St. Patrick Creek Basin

Fecal Coliform Source	**Loading Counts/day**	**Loading Percent**
Livestock	5.21E+12	95.1%
Pets	7.50E+10	1.3%
Human	2.96E+09	0.1%
Wildlife	1.91E+11	3.5%
Total	5.48E+12	100.0%

Point Source Assessment

There are no permitted point source facilities discharging directly into any of the restricted shellfish areas, based on the point source permitting information.

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal coliform TMDLs established in this document is to establish the loading caps needed to assure attainment of water quality standards in the restricted shellfish harvesting areas. These standards are described fully in Section 2.3 Water Quality Impairment.

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section documents detailed fecal coliform TMDL and source allocation developments for the restricted shellfish harvesting areas of St. Clements Bay Basin. The required load reduction was determined based on the most recent five-year data spanning the years 1999 to 2003. The TMDL is presented as counts/day. The second section describes the analysis framework for simulating fecal coliform concentration in areas of St. Clements Bay Basin. The third section addresses the critical period. The fourth section presents the TMDL calculation. The fifth section discusses TMDL loading caps. The sixth section presents the load allocation. The margin of safety is discussed in Section 4.7. Finally, the variables of the equation are combined in a summary accounting of the TMDL.

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality criteria, in this case Maryland's water quality criteria for shellfish waters. Currently, TMDLs are expressed as a "mass per unit time, toxicity, or other appropriate measure" (40 Code of Federal Regulation (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 defined by the water quality criteria (i.e., at least 30 samples). The averaging period used for development of these TMDLs requires at least 30 samples and uses the most recent five-year period.

TMDLs are 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:

$$TMDL = WLAs + LAs + MOS + FA$$

4.2 Analysis Framework

In general, tidal waters are exchanged through their connecting boundaries. The tide and amount of freshwater discharge into the restricted shellfish harvesting area are the dominant influences on the transport of fecal coliform. The methodology used assumes that freshwater input, tidal range, and the first-order decay of fecal coliform are all constant. The TMDL is calculated based on the steady state tidal prism model. Compared to the volumetric method (EPA Shellfish Workshop, 2002), the steady state tidal prism model provides improvements incorporating the influences of tidal induced transport, freshwater, and decay of fecal coliform in the restricted shellfish harvesting area. A detailed description of the model is presented in Appendix A.

The most recent five-year median and 90th percentile values were used to estimate the current loads. Using the steady state tidal prism model, the loads can be estimated according to the equation as follows (see also Appendix A):

$$L = \left[C(Q_b + kV) - Q_0 C_0\right] \times Cf \qquad (1)$$

where:
L = fecal coliform load (counts per day)
C = fecal coliform concentration (MPN /100ml) of embayment
Q_b = the quantity of mixed water that leaves the embayment on the ebb tide that did not enter the embayment on the previous flood tide (m^3 per tidal cycle)
k = the fecal coliform decay rate (per tidal cycle)
V = the mean volume of the embayment (m^3)
Q_0 = the quantity of water that enters the embayment on the flood tide through the ocean boundary that did not flow out of the embayment on the previous ebb tide (m^3 per tidal cycle)
C_0 = the fecal coliform concentration (MPN/100ml) at the oceanside boundary
Cf = the unit conversion factor.

Q_b and Q_0 are estimated based on the steady state condition as follows:

$$Q_b = Q_0 + Q_f$$

where Q_f is mean freshwater discharge during the tidal cycle

$$Q_0 = \beta Q_T$$

where β is an exchange ratio and Q_T is the total ocean water entering the bay on the flood tide, which is calculated based on tidal range. The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal period of 12.42 hours; therefore, the M_2 tide is used for the representative tidal cycle. In general, the exchange ratio varies from 0.3 to 0.7, based on the previous model tests in Virginia coastal restricted shellfish harvesting areas (Kuo et al., 1998; Shen et al., 2002). The observed salinity data were also used to estimate the exchange ratio. The estimated values range from 0.3 to 0.8; therefore, a value of 0.5 is used for the exchange ratio. The stream flow used for the estimation of Q_f was based on the flows of the U.S. Geological Survey (USGS) gage # 02060006, located nearby in Calvert County, MD. For each restricted shellfish harvesting area, the average long-term flow for this USGS gage (i.e., 4.99 cfs) was adjusted by the ratio of the drainage basin area to that of the gage basin (i.e., 4,307.5 acres) to derive estimates of the long-term flows. See Table 4.2.1 below.

Table 4.2.1: Drainage Acres and Long-Term Flows in the St. Clement's Bay Basin

Restricted Shellfish Harvesting Area (RID)	Drainage Area in Acres	Average Long-Term Flow in cfs
St. Clements Bay (44A)	23,059.41	27.64
Canoe Neck Creek (44B)	3,116.48	3.90
St. Patrick Creek (44C)	1,161.27	1.56

4.3 Critical Condition and Seasonality

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 exceed the water quality standard(s).

The 90th percentile concentration is the concentration exceeded only 10% of the time. Since data collected during the most recent five-year period of data were used to calculated the 90th percentile, the critical condition is implicitly included in the value of the 90th percentile. Given the length of the monitoring record used and the limited applicability of best management practices to extreme conditions, the 90th percentile is utilized instead of the absolute maximum.

A comparison of the median values and the 90th percentile values against the water quality criteria determines which represents the more critical condition or higher percent reduction. If the median values dictate the higher reduction, this suggests that, on average, water sample counts are very high with limited variation around the mean. If the 90th percentile criterion requires a higher reduction, this suggests an occurrence of the high fecal coliform due to the variation of hydrological conditions.

Similar to the critical condition, seasonality is also implicitly included in the analysis due the averaging required in the water quality standards. It is possible that during colder season the bacteria levels will be less however this is not always true when reviewing monitoring data. The shellfish monitoring program uses a systematic random sampling design which was developed to cover inter-annual variability.

4.4 TMDL Computation

According to the water quality standard for fecal coliform in shellfish waters, computation of a TMDL requires analyses of both the median and 90th percentile. These analyses are described below.

For the analyses, the most recent five-year period of monitoring data (at least 30 samples), specifically fecal coliform concentrations were used to estimate the current loads. This was conducted for median and 90th percentile conditions. Since two monitoring stations exist in each restricted shellfish harvesting area, the station(s) closest to the headwaters were used to represent the restricted shellfish harvesting area concentration and the downstream station(s) were used to represent boundary conditions.

The allowable loads were calculated based on the water quality criteria of a median 14 MPN/100ml and a 90th percentile of 49 MPN/100ml. The load reductions needed for the attainment of the criteria is determined by subtracting the allowable loads from the current loads. The TMDL calculations are presented in Appendix A. The calculated results are listed in Table 4.4.1 and Table 4.4.2.

Table 4.4.1: Median Loading Analysis of Current Load and Estimated Load Reduction

Area	Mean Volume m^3	Fecal Coliform Concentration Median MPN/100mL	Decay Rate per tidal cycle	Estimated Residence Time day	Current Load counts/day	Allowable Load Counts/day	Required Percent Reduction (%)
St. Clements Bay	7891224	3.6	0.36	4.8	2.001E+11	7.78E+11	0.00
Canoe Neck Creek	1612090	9.1	0.36	3.3	1.295E+11	1.583E+11	0.00
St. Patrick Creek	626211	23.0	0.36	1.7	1.514E+11	6.152E+10	59.36

Table 4.4.2: 90th Percentile Loading Analysis of Current Load and Estimated Load Reduction

Area	Mean Volume m^3	Fecal Coliform Concentration 90th percentile MPN/100mL	Decay Rate per tidal cycle	Estimated Residence Time day	Current Load counts/day	Allowable Load Counts/day	Required Percent Reduction (%)
St. Clements Bay	7891224	67.9	0.36	4.8	3.448E+12	2.723E+12	21.03
Canoe Neck Creek	1612090	61.1	0.36	3.3	7.981E+11	5.542E+11	30.56
St. Patricks Creek	626211	159.4	0.36	1.7	1.077E+12	2.153E+11	80.02

4.5 TMDL Loading Caps

This section presents the TMDLs for the median and the 90th percentile conditions. The TMDLs for restricted shellfish harvesting areas of St. Clements Bay Basin are as follows:

St. Clements Bay (RID 44A):
The median load of fecal coliform TMDL = 7.78×10^{11} counts per day
The 90th percentile of fecal coliform TMDL = 2.72×10^{12} counts per day

Canoe Neck Creek (RID 44B):
The median load of fecal coliform TMDL = 1.58×10^{11} counts per day

The 90th percentile of fecal coliform TMDL = 5.54×10^{11} counts per day

St. Patricks Creek (RID 44C):
The median load of fecal coliform TMDL = 6.15×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 2.15×10^{11} counts per day

The greater reduction required when comparing the median and the 90th percentile results (see Table 4.4.1 and Table 4.4.2), was used for load allocations. It is also important to note that the TMDLs presented herein are not literal daily limits. These loads are based on an averaging period defined by the water quality criteria (i.e., at least 30 samples). The averaging period used for development of these TMDLs is five years.

4.6 Load Allocation

The allocations described in this section demonstrate how the TMDL can be implemented to achieve water quality standards. However, the State reserves the right to revise these allocations provided the allocations are consistent with the achievement of water quality standards.

Source reductions were assigned by first managing controllable sources (human, livestock and pets) and then determining if the TMDL could be achieved. If the total required reduction was not achieved then the wildlife source was then reduced. Given the non-point source characteristics of the wildlife contribution, it was assumed that best management practices applied to controllable sources may also reduce some wildlife sources contributing to the restricted shellfish harvesting area. Based on these assumptions, the source allocation for the watershed for each of the major source categories is estimated. Results are presented in Table 4.6.1.

Table 4.6.1: Load Allocations and Reductions

RID	Source	Current Load Distribution (% of Total)	Required Reduction	TMDL Load Allocation (% of Total)
St. Clements Bay				
44A	Total	100.0%	21.0%	100.0%
	Wildlife	12.3%	0.0%	15.5%
	Human	0.1%	24.0%	0.1%
	Pets	2.6%	24.0%	2.5%
	Livestock	85.0%	24.0%	81.9%
Canoe Neck Creek				
44B	Total	100.0%	30.6%	100.0%
	Wildlife	11.3%	0.0%	16.2%
	Human	0.1%	34.4%	0.1%
	Pets	2.4%	34.4%	2.3%
	Livestock	86.2%	34.4%	81.4%
St. Patrick Creek				
44C	Total	100.0%	80.0%	100.0%
	Wildlife	3.5%	0.0%	17.4%
	Human	0.1%	82.9%	0.0%
	Pets	1.3%	82.9%	1.2%
	Livestock	95.1%	82.9%	81.4%

4.7 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 analysis (VIMS, 2004), it was 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). A decay rate of 0.7 per day was used as a conservative estimate in the TMDL calculation. Further literature review supports this assumption as a conservative estimate of the decay rate (MDE, 2004). Therefore, the MOS is implicitly included in the calculation.

4.8 Summary of Total Maximum Daily Loads

Since there are no permitted point sources in the watershed, all allocations are to nonpoint sources. The TMDLs are summarized as follows:

The median TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
St. Clements Bay	7.78×10^{11}	=	7.78×10^{11}	+	**N/A**	+	**N/A**	+	**Implicit**
Canoe Neck Creek	1.58×10^{11}	=	1.58×10^{11}	+	**N/A**	+	**N/A**	+	**Implicit**
St. Patricks Creek	6.15×10^{10}	=	6.15×10^{10}	+	**N/A**	+	**N/A**	+	**Implicit**

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
St. Clements Bay	2.72×10^{12}	=	2.72×10^{12}	+	**N/A**	+	**N/A**	+	**Implicit**
Canoe Neck Creek	5.54×10^{11}	=	5.54×10^{11}	+	**N/A**	+	**N/A**	+	**Implicit**
St. Patricks Creek	2.15×10^{11}	=	2.15×10^{11}	+	**N/A**	+	**N/A**	+	**Implicit**

Where:

TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
FA = Future Allocation
MOS = Margin of Safety

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the fecal coliform TMDL will be achieved and maintained. The appropriate measures to reduce pollution levels in the impaired segments include, where appropriate, the use of better treatment technology or installation of best management practices (BMPs). Details of these methods are to be described in the implementation plan.

In general, MDE 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. 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.

Potential funding sources for implementation include the Maryland's Agricultural Cost Share Program (MACS) which provides grants to farmers to help protect natural resources and the Environmental Quality and Incentives Program which focuses on implementing conservation practices and BMPs on land involved with livestock and production. Additional funding available for local governments include the State Water Quality Revolving Loan Fund and the Stormwater Pollution Cost Share Program. Details of these programs and additional funding sources can be found at http://www.dnr.state.md.us/bay/services/summaries.html.

Regulatory enforcement of potential bacteria sources may include MDE's routine sanitary surveys of shellfish growing areas and through National Pollutant Discharge Elimination System (NPDES) permitting activities such as confined animal feeding operations (CAFOs). Though not directly linked, it is assumed that the nutrient management plans from the Water Quality Improvement Act of 1998 (WQIA) will have some reduction of bacteria from manure application practices.

As part of Maryland's commitment to the NSSP, MDE will continue to monitor shellfish waters and classify harvesting areas. Those waters meeting shellfish water quality standards may be reclassified as open to harvesting and can serve to track the effectiveness of TMDL implementation and water quality improvements. Additional monitoring will also include bacteria source tracking that will be used to confirm the source estimates presented in this document. Bacteria source tracking will be completed according to MDE's schedule posted on MDE's website, http://www.mde.state.md.us:8001/assets/document/BST_schedule.pdf.

Implementation and Wildlife Sources

It is expected that in some waters for which TMDLs will be developed, the bacteria source analysis will indicate that after controls are in place for all anthropogenic sources, the waterbody does not meet water quality standards. However, neither the State of Maryland 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 and option for state and local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

After developing and implementing, to the maximum extent possible, a reduction goal based on the anthropogenic sources identified in the TMDL, Maryland is considering the following TMDL strategy to address wildlife issues. It is possible that implementation to reduce the nonpoint controllable sources may also reduce some wildlife inputs to the shellfish waters. Following this first implementation stage, MDE would re-assess the water quality to determine if the designated use is being achieved. If the water quality standards are not attained, then MDE would consider developing either a risk based adjusted water quality assessment or a Use Attainability Analysis to reflect the presence of naturally high bacteria levels from uncontrollable sources.

6.0 PUBLIC PARTICIPATION

Public notification of the State's intent to address the bacteria listing was conducted in a variety of ways. Identified stakeholders (including local government contacts, tributary team chairs, and interested parties) were formally notified of MDE's intent to develop bacteria TMDLs in March 2004.

Following this initial contact, these stakeholders were again notified on June 23, 2004 when the document began Interagency Review. The document went through a public comment period from August 11, 2004 to September 9, 2004 where the document was placed in the St. Mary's County Library, MDE's website and notices were published in the St. Mary's Enterprise. Following the public comment period, comments were reviewed and addressed through a comment response document. The documents were then submitted to EPA Region III at which time stakeholders were notified of this action. Once the document was approved by EPA Region III, stakeholders were notified of the action and the finalized document was posted on MDE's website.

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Appendix A

Tidal Prism Model

A detailed description of the tidal flushing model is presented in this section. It is assumed that a single volume can represent a waterbody, and that the pollutant is well mixed in the waterbody system, as shown in Figure A-1.

The mass balance of water can be written as follows (Guo and Lordi, 2000):

$$\frac{dV}{dT} = (Q_0 - Q_b + Q_f) \qquad (1)$$

where Q_0 is the quantity of water that enters the embayment on the flood tide through the ocean boundary (m^3T^{-1}); Q_b is the quantity of mixed water that leaves the bay on the ebb tide that did not enter the bay on the previous flood tide (m^3 per tidal cycle); Q_f is total freshwater input over the tidal cycle (m^3); V is the volume of the bay (m^3); T is the dominant tidal period (hours).

It is further assumed that Q_0 is the pure ocean water that did not flow out of the embayment on the previous ebb tide, and that Q_b is the embayment water that did not enter into the system on the previous flood tide. The mass balance for the fecal coliform can then be written as follows:

$$\frac{dVC}{dT} = Q_0C_0 - Q_bC + L_f + L_l - kVC \qquad (2)$$

where L_f is the loading from upstream; L_l is the additional loading from the local area within the tidal cycle, k is the fecal coliform decay rate (or a damped parameter for the net loss of fecal coliform), C is fecal coliform concentration in the embayment, and C_0 is the fecal coliform concentration from outside the embayment.

In a steady-state condition, the mass balance equations for the water and the fecal coliform concentration can be written as follows:

$$Q_b = Q_0 + Q_f \qquad (3)$$

$$Q_bC + kVC = Q_0C_0 + L_f + L_l \qquad (4)$$

The fecal coliform concentration in the embayment can be calculated as follows:

$$C = \frac{Q_0C_0 + L_f + L_l}{Q_b + kV} \qquad (5)$$

From Equation (4), assuming $L_f + L_l = Load_t$ and letting C_c be the criterion of fecal coliform in the embayment, the loading capacity can be estimated as:

$$Load_T = C_c(Q_b + kV) - Q_0 C_0 \tag{6}$$

The daily load can be estimated based on the dominant tidal period in the area. For the upper Chesapeake Bay the dominant tide is lunar semi-diurnal (M_2) tide with a tidal period of 12.42 hours. If fecal coliform concentration is in MPN/100ml, the daily load (counts day^{-1}) can be estimated as:

$$Load = Load_T \times \frac{24}{12.42} \times 10000 \tag{7}$$

In practice, one may not know Q_0 *a priori*. Instead, one is given the tidal range of the tidal embayment. From that, Q_T, the total ocean water entering the bay on the flood tide, can be calculated. From this, Q_0, the volume of new ocean water entering the embayment on the flood tide can be determined by the use of the ocean tidal exchange ratio β as:

$$Q_0 = \beta Q_T \tag{8}$$

where β is the exchange ratio and Q_T is the total ocean water entering the bay on the flood tide. The exchange ratio can be estimated from salinity data (Fischer et al., 1979):

$$\beta = \frac{S_f - S_e}{S_0 - S_e} \tag{9}$$

where S_f is the average salinity of ocean water entering the bay on the flood tide, S_e is the average salinity of the bay water leaving the bay, and S_0 is the salinity at the ocean side. The numerical value of β is usually smaller than 1, and it represents the fraction of new ocean water entering the embayment. Once Q_0 is known, then Q_b can be calculated from equation (3).

The residence time, T_L, is an estimate of time required to replace the existing pollutant concentration in a system; it can be calculated as follows:

$$T_L = \frac{V_b}{Q_b} \tag{10}$$

where V_b is mean volume of the embayment. From the definition, the denominator can either be Q_T or Q_b. However, using Q_T assumes that the ocean water enters into the embayment during the flood tide is 100% new, whereas using Q_b takes into consideration that a portion of water is not entirely new. The latter is more realistic. If Q_b is used in the residence time calculation, it will result in a longer time scale than if Q_T is used (Ketchum, 1951; Guo and Lordi, 2000).

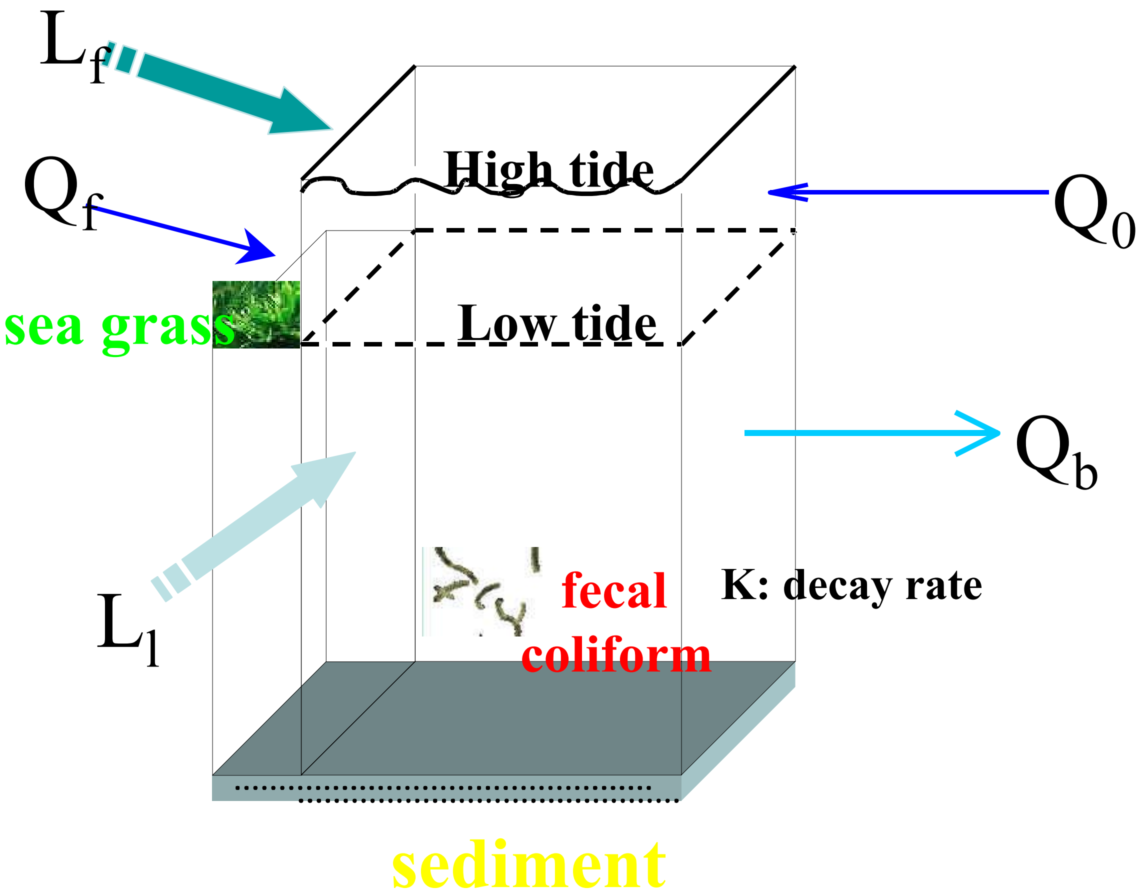


Figure A-1: The schematic diagram for the tidal prism model

A Tidal Prism Model Calculation for St. Clements Bay (RID 44A)

Case I: The most recent five-year fecal coliform median concentration is used.

The median load calculation is illustrated as follows:

V = Mean volume of the embayment = 7891223.8(m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 27.6435 cfs = 27.6435 × 0.0283×86400×12.42÷24 = 34978.7 (m^3T^{-1})
Q_0 = 819743.8 (m^3T^{-1})
Q_b = 854722.5 (m^3 T^{-1})
C_c = water quality criterion = 14 MPN/100ml
C = current fecal coliform 5-year median concentration = 3.6 (MPN/100ml)
C_0 = fecal coliform 5-year median outside of the embayment = 3.6 (MPN/100ml)
T = tidal cycle =12.42 hours
Cf = the unit conversion factor

For allowable calculation, C_c is used as fecal coliform concentration (i.e., 14 MPN/100ml). The fecal coliform concentration at the outside of the embayment also uses 14 MPN/100ml. The allowable load is calculated as follows:

Allowable Load =
$$Load = [C_c \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$
= [14× (854722.5 +0.36×7891223.8) - 819743.8× 14] ×24÷12.42×10000
=7.780×10^{11}

For the current load estimation, the most recent five-year median fecal coliform concentration is used for the calculation. The current load is calculated as follows:

Current condition =
$$Load = [C \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$
[(3.6) × (854722.5 +0.36×7891223.8) - 819743.8 × (3.6)] ×24÷12.42×10000
=2.001×10^{11}

The load reduction is estimated as follows:

$$\textbf{Load Reduction} = \frac{\textbf{Current Load} - \textbf{Allowable Load}}{\textbf{Current Load}} \times 100\%$$

$$\text{Load Reduction} = \frac{2.001 \times 10^{11} - 7.780 \times 10^{11}}{2.001 \times 10^{11}} = 0\%$$

A Tidal Prism Model Calculation for St. Clements Bay (RID 44A)

Case II: The most recent five-year fecal coliform 90th percentile concentration is used.

The 90th percentile load calculation is illustrated as follows:

V = Mean volume of the embayment = 7891223.8(m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 27.6435 cfs = 27.6435 × 0.0283×86400×12.42÷24 = 34978.7 (m^3T^{-1})
Q_0 = 819743.8 (m^3T^{-1})
Q_b = 854722.5 (m^3 T^{-1})
C_c = water quality criterion = 49 MPN/100ml
C = current fecal coliform 5-year 90th percentile concentration = 67.94 (MPN/100ml)
C_0 = fecal coliform 5-year 90th percentile at the outside of the embayment
= 88.6 (MPN/100ml)
T = tidal cycle =12.42 hours
Cf = the unit conversion factor

For allowable calculation, C_c is used as fecal coliform concentration (i.e., 49 MPN/100ml). The fecal coliform concentration at the outside of the embayment also uses 49 MPN/100ml. The allowable load is calculated as follows:

Allowable Load =
$$Load = [C_c \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$
= [49× (854722.5 +0.36×7891223.8) - 819743.8× 49] ×24÷12.42×10000
=2.723×10^{12}

For the current load estimation, the most recent five-year 90th percentile fecal coliform concentration is used for the calculation. The current load is calculated as follows:

Current condition =
$$Load = [C \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$
[(67.94) × (854722.5 +0.36×7891223.8) - 819743.8 × (88.6)] ×24÷12.42×10000
=3.448×10^{12}

The load reduction is estimated as follows:

$$\textbf{Load Reduction} = \frac{\textbf{Current Load} - \textbf{Allowable Load}}{\textbf{Current Load}} \times 100\%$$

$$\text{Load Reduction} = \frac{3.448\times10^{12} - 2.723\times10^{12}}{3.448\times10^{12}} = 21.03\%$$

Sample calculations load reductions for both the median and 90th percentiles have been presented for the first embayment in this report (i.e., RID 44A). The following table lists the parameter values needed for these calculations at all other embayment in this report. Please refer to the sample calculations for a full description of each parameter, as well as constants required.

Table A-1: Parameter values required for TMDL calculations for each restricted shellfish area

St. Clements Bay		V	k	Q_f	Q_0	Q_b	Median		90th Percentile	
RID	Area Name						C	C_0	C	C_0
44A	St. Clements Bay	7891223.8	0.36	34978.7	819743.8	854722.5	3.6	3.6	67.94	88.6
44B	Canoe Neck Creek	1612090.0	0.36	4929.3	250210.0	255139.3	9.1	3.6	61.1	39.1
44C	St. Patrick Creek	626211.4	0.36	1973.0	187281.4	189254.4	23	9.1	159.4	55.2

The values attained using the sample calculation are listed below:

Table A-2: TMDL calculation results for each restricted shellfish harvesting area

St. Clements Bay		Median			90th Percentile		
RID	Area Name	Allowable Load Counts/day	Current Load Counts/day	Percent Reduction	Allowable Load Counts/day	Current Load Counts/day	Percent Reduction
44A	St. Clements Bay	7.78E+11	2.001E+11	0.00	2.723E+12	3.448E+12	21.03
44B	Canoe Neck Creek	1.583E+11	1.295E+11	0.00	5.542E+11	7.981E+11	30.56
44C	St. Patrick Creek	6.152E+10	1.514E+11	59.36	2.153E+11	1.077E+12	80.02

Appendix B

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. The possible introductions of fecal coliform bacteria to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and discharges to the restricted shellfish harvesting area. The deposition of non-human fecal coliform directly to the restricted shellfish area occurs when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions to the bacterial levels from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreation vessel discharges. The transport of fecal coliform from land surface to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

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 all 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 of 2000 Maryland Department of Planning (MDP) land use/land cover data
2. Livestock inventory by 8-digit Hydrologic Unit Code (Maryland States Soil Conservation Committee (MSSCC); USDA, 1997; MASS, 2002a; MASS, 2002b; Brodie and Lawrence, 1996)
3. GIS 2000 Census of Human population (MDP)
4. Pet survey results from The Center for Watershed Protection (Swann, 1999)
5. Fecal coliform monitoring data (MDE Shellfish Certification Division)
6. The shoreline sanitary survey data (MDE Shellfish Certification Division)
7. Stream GIS coverage (EPA, 1994)
8. Septic GIS Coverage (MDP, 2003)
9. Wildlife population (Maryland DNR, 2003)

In the St. Clements Bay Basin, wildlife contributions, both mammalian and avian, are natural conditions and may represent a background level of bacterial loading. Livestock contributions, such as those from mammalian and avian livestock, mainly result from surface runoff. 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. The major nonpoint source contributions assessed for restricted shellfish areas in the St. Clements Bay Basin are summarized in Table B-1. The potential nonpoint sources were grouped into four categories: wildlife; human; pets; and livestock. 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 B-1: Summary of Nonpoint Sources

Category	Source
Wildlife	Beaver, deer, goose, duck, muskrat, raccoon and wild turkey
Human	Septic
Pets	Dog
Livestock	cattle, sheep, chicken, and horse

A. Wildlife Contributions

In general it is assumed that the wildlife species existent in the watershed include beaver, deer, goose, duck, muskrat, raccoon and wild turkey. Fecal coliform from wildlife can be from excretion on land that is subject to runoff or direct deposition into the stream. Wildlife populations within the watershed were estimated based on a combination of information from the Maryland DNR Wildlife and Heritage Service and from habitat information listed in Virginia bacteria TMDL report (VA DEQ, 2002). Habitat density results were reviewed by the Maryland Department of Natural Resources, and are listed in Table B-2.

Table B-2: Wildlife Habitat and Densities

Wildlife Type	Population Density	Habitat Requirements
Beaver[1]	4.8 animals/ mile of stream	Tidal and non-tidal regions
Deer[2]	0.047 animals/acre	Entire watershed
Goose[2]	0.087 animals/acre	Entire watershed
Duck[2]	0.039 animals/acre	Entire watershed
Muskrat[1]	2.75 animals/acre	Within 66 feet of streams and ponds
Raccoon[1]	0.07 animals/acre	Within 600 feet of streams and ponds
Wild Turkey[1]	0.01 animals/acre	Entire watershed excluding farmsteads and urban

[1] VA DEQ (2002); [2]MD DNR (2003)

The habitat areas for each species were determined using ArcView GIS with the 2000 MDP land use data and EPA reach coverage in the watershed. The GIS tool was applied to the land use coverage to create a habitat area according to Table B-2. For the deer, goose and duck estimates the entire watershed was used as the density estimates were developed using watershed area as the ratio estimator. 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 B-3. 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 B-3: Wildlife Fecal Coliform Production Rates

Source	Fecal Coliform Production (counts/animal/day)
Beaver[1]	2.50E+08
Deer[1]	5.00E+08
Goose[2]	2.43E+09
Duck[1]	2.43E+09
Muskrat[3]	3.40E+07
Raccoon[3]	1.00E+09
Wild turkey[4]	9.30E+07

[1]USEPA (2000); [2]Use duck rate (USEPA, 2000);
[3]Kator and Rhodes (1996); [4]ASAE (1998)

B. Human Contributions

Human loading can result from failures in septic waste treatment systems or through pollution from recreation vessel discharges in the identified restricted shellfish areas. 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.

The human population was estimated from the GIS 2000 Census Block that includes the St. Clements Bay watershed. Since the subwatersheds throughout the St. Clements Bay Basin are sub-areas of the Census Block, the GIS tool was used to extract these areas from the 2000 Census Block. The percentage of the subwatershed area relative to the total area of the 2000 Census Block was calculated. This percentage was applied to partition the total census block population and the total census block number of households to proportion the population within the area of the subwatersheds. The results are shown in Table B-4.

Table B-4: Proportional Population, Households, and Septic Systems in St. Clements Bay

RID	Area Name	Proportional Population	Proportional Septic Systems	Proportional Households	Public Sewer
44A	St. Clements Bay	4,395	1,561	1,511	Partial
44B	Canoe Neck Creek	513	317	206	No
44C	St. Patrick Creek	372	316	159	No

The distributions of septic systems in the identified restricted shellfish areas of St. Clements Bay are shown in Figure B-1 to Figure B-3. Based on GIS property coverage, a point is assumed to represent a septic system. The total number of septic systems in each restricted shellfish area is shown in Table B-4. According to GIS coverage, there are no public sewer systems in the restricted shellfish area watersheds.

It is assumed that the human contribution is attributed to septic systems. The human contribution to the restricted shellfish areas was calculated using the number of septic systems, the average number of people using the septic systems, and the failure rate of the septic systems. The estimated fecal coliform loading from humans is calculated as follows:

$$Load = P\ S\ F_r\ C\ Q\ C_V$$

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)

The number of people using each septic system is estimated by the ratio of the population to the number of septic systems. According to shoreline sanitary survey data in the St. Clements Bay watershed and other watersheds, an estimated failing rate of 3% was used for the total number of failing septic systems. This rate is in the same range as that in the upper Chesapeake Bay (De Walle, 1981; EPA Stormwater Management Center). It was assumed that wastewater for each person was 70 gallons per day with a fecal coliform concentration of 1×10^5 most probable number (MPN)/100ml. The estimated load due to failures of septic systems is about 2%.

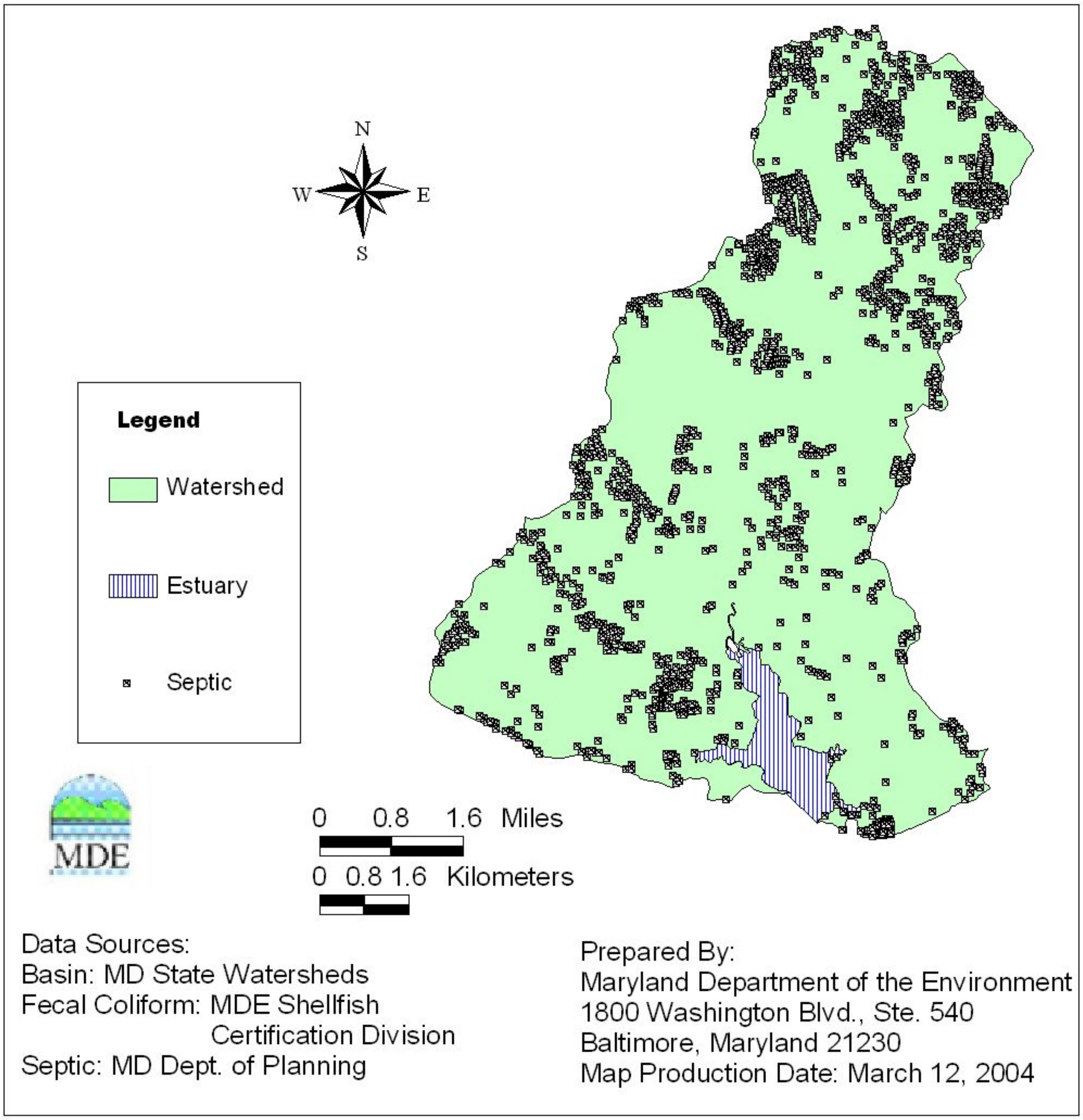


Figure B-1: Distribution of Septic Systems in the St. Clements Bay Subbasin

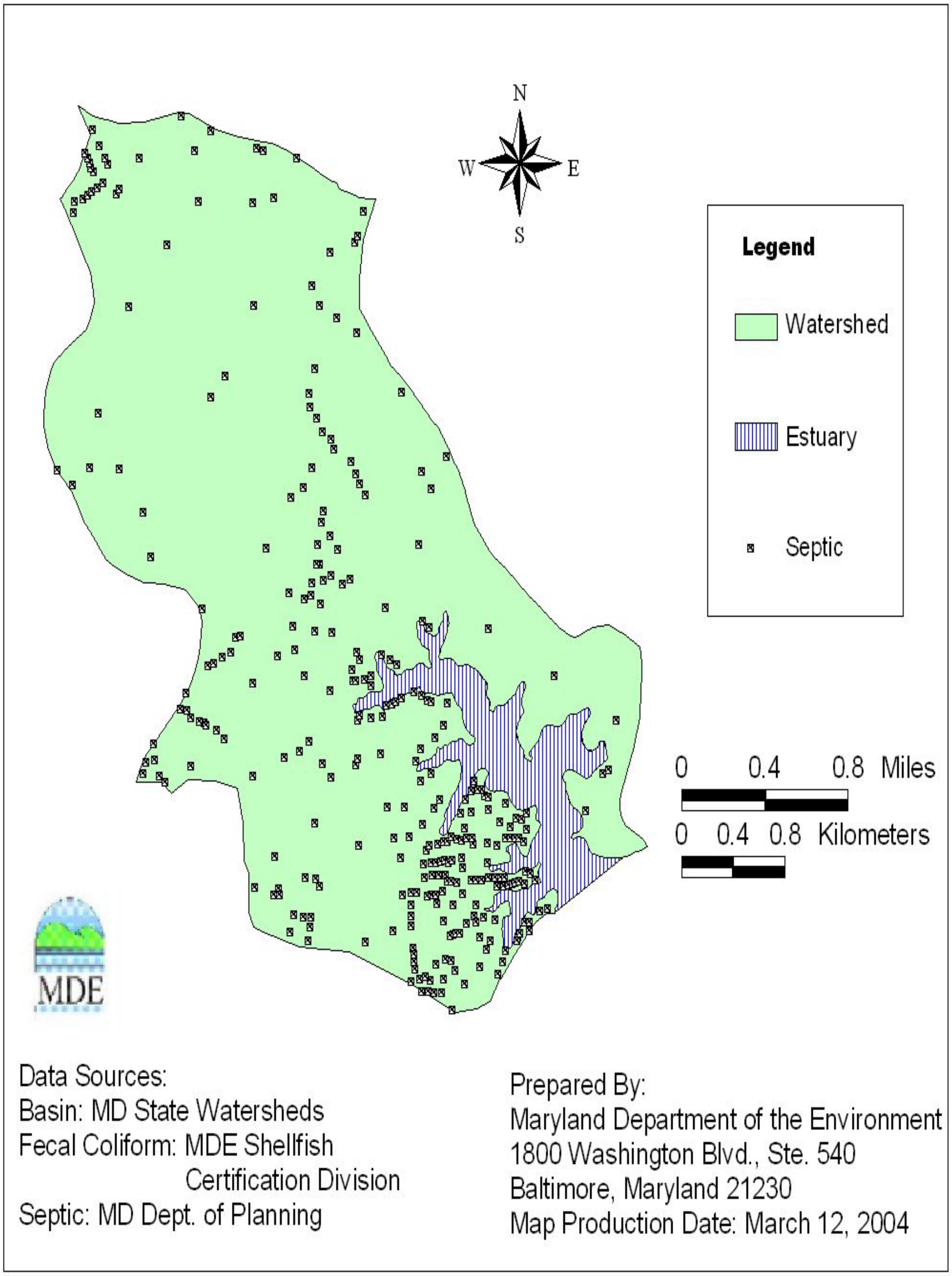


Figure B-2: Distribution of Septic Systems in the Canoe Neck Creek Basin

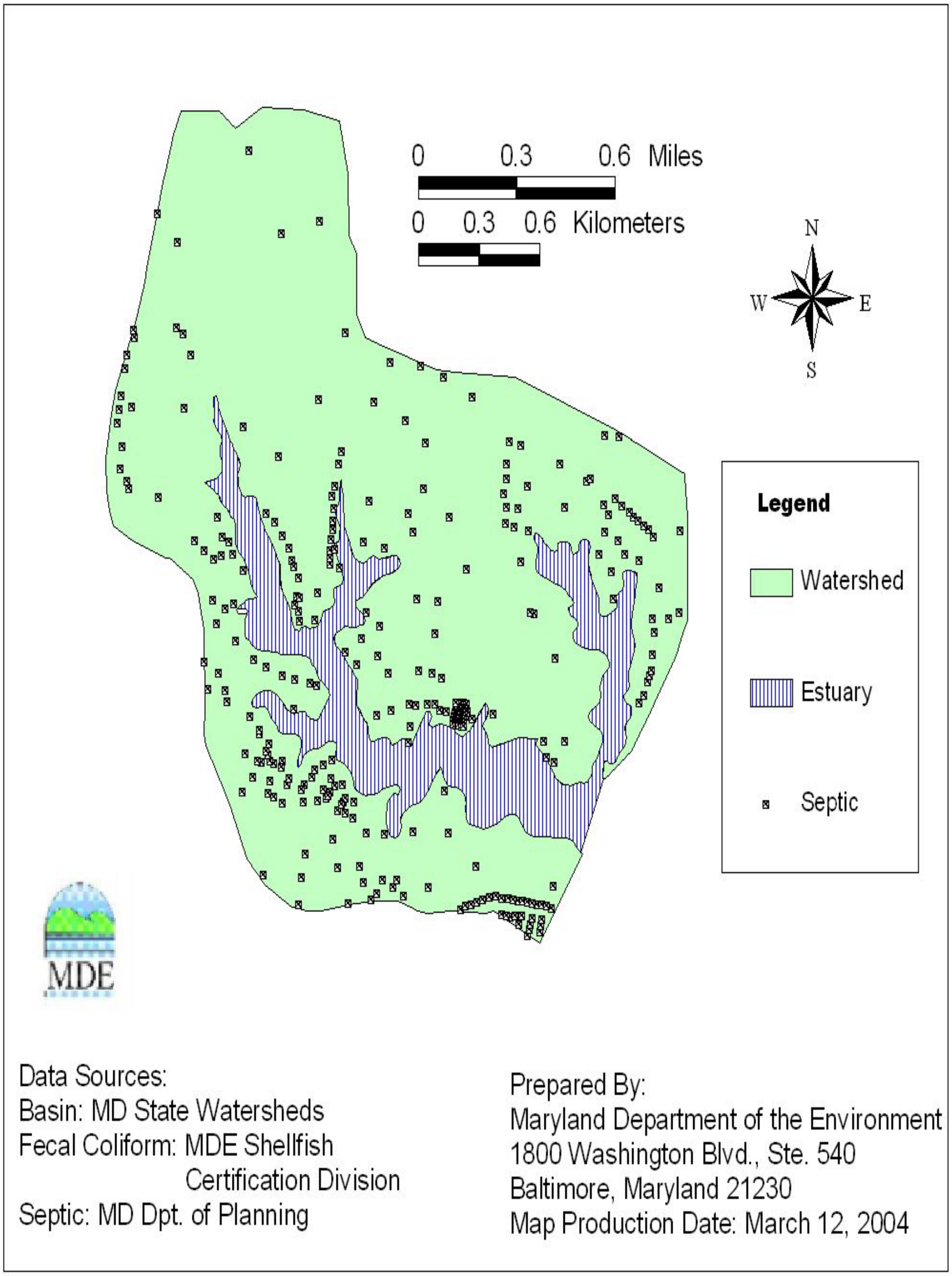


Figure B-3: Distribution of Septic Systems in the St. Patrick Creek Basin

C. Pet Contributions

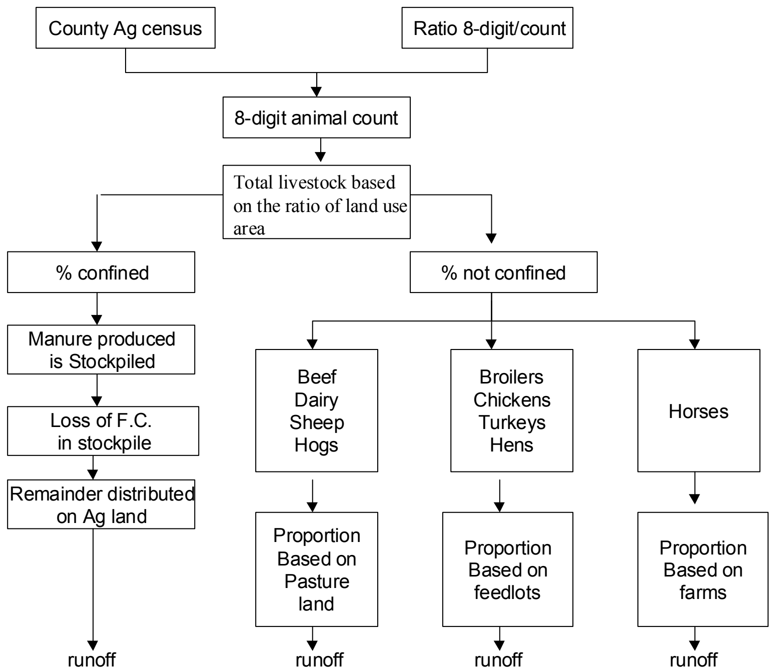
Pet contributions usually occur through runoff from either an urban or a low-density residential area. Dogs are the only domestic pets assumed to contribute fecal coliform. Dog license information can be obtained from the county, however, these data will not include feral or unlicensed pets. This is likely to cause an underestimation of the total population. Therefore, the dog populations for the restricted shellfish areas in St. Clements Bay were estimated based on the number of households (see Table B-4). According to a survey conducted by the Center for Watershed Protection of Chesapeake Bay residents, about 41% of the households own a dog. Of these dog owners, only about 56% walk their dogs, and of that group only 59% clean up most of the time (i.e., 41% do not). The estimated total load available for wash off is 23% (i.e., 56% x 41%). The fecal coliform contribution from the dog population was estimated using a production rate of 5×10^9 counts/dog/day (EPA, 2000). Using information from Table B-4, estimated fecal coliform loading from dogs is calculated as follows:

$$LOADING_{dog} = P\ R_1\ R_2\ R_3\ PR_{dog}$$

where:
P = number of households in specified restricted area
R_1 = ratio of dogs per household in this region
R_2 = percentage of owners that walk their dogs
R_3 = percentage of walked dogs contributing fecal matter
PR_{dog} = average fecal coliform production rate for dogs

D. Livestock Contributions

The fecal coliform contribution from livestock is through the manure spreading processes and direct deposition during grazing. This contribution was estimated based on land use data and the Maryland livestock census data (Brodie and Lawrence, 1996; USDA, 1997; MASS, 2002). Animal ratio estimators for the 8-digit watersheds were developed based on the finest resolution of animal counts available – statewide, region or county. These Maryland 8-digit watershed livestock animal counts were then proportioned to the sub-watersheds using the procedure outlined in Figure B-4. The fecal coliform load was estimated based on the total number of livestock and the fecal coliform production rates.



US EPA (1996); Woods (2004)

Figure B-4: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population

Fecal coliform production rates used to estimate loading are listed in Table B-5. The estimated fecal coliform produced by animals was divided into manure spreading and direct deposition, depending on the percent of time they were confined. The percent of time livestock was confined is listed in Table B-6. The estimated percentage of manure available for wash off is about 40% (VIMS, 2004). For chickens, however, only about 10% is available for wash off (Woods, 2004). Therefore, fecal coliform decay is also considered in the estimation of fecal coliform production. The percent of fecal coliform available for wash off from manure spreading in the field is also listed in Table B-6.

Table B-5: Livestock Fecal Coliform Production Rates

Source	Fecal Coliform Production (counts/animal/day)
Dairy	1.01E+11
Beef	1.20E+10
Horses	4.20E+08
Sheep	1.20E+10
Broilers	1.36E+08
Turkeys	9.30E+07
Chickens	1.36E+08
Layers	1.36E+08
Hogs	1.08E+10

US EPA (2000)

Table B-6: Percent of Time Livestock is Confined

Livestock	Percent of time confined	Percent Manure Available For Wash off
Dairy	80.0%	40.0%
Beef	20.0%	40.0%
Horses	50.0%	40.0%
Sheep	50.0%	40.0%
Broilers	85.0%	10.0%
Turkeys	85.0%	10.0%
Chickens	85.0%	10.0%
Layers	85.0%	10.0%
Hogs	100.0%	40.0%

E. Nonpoint Source Summary

The complete distributions of these source loads are listed in Table B-7 to Table B-9, along with counts/day for each loading. The bacteria source tracking data will be used to further confirm the source distribution when it becomes available.

Table B-7: Distribution of Fecal Coliform Source Loads in the St. Clements Bay Subasin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	2.32E+13	85.0%
Pets	7.12E+11	2.6%
Human	2.89E+10	0.1%
Wildlife	3.34E+12	12.3%
Total	2.73E+13	100.0%

Table B-8: Distribution of Fecal Coliform Source Loads in the Canoe Neck Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	3.40E+12	86.2%
Pets	9.71E+10	2.4%
Human	4.08E+09	0.1%
Wildlife	4.44E+11	11.3%
Total	3.95E+12	100.0%

Table B-9: Distribution of Fecal Coliform Source Loads in the St. Patrick Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	5.21E+12	95.1%
Pets	7.50E+10	1.3%
Human	2.96E+09	0.1%
Wildlife	1.91E+11	3.5%
Total	5.48E+12	100.0%