Total Maximum Daily Loads for Island Creek, Town Creek, Trent Hall Creek, St. Thomas Creek, Harper and Pearson Creeks, Goose Creek and Indian Creek and a Water Quality Analysis for Battle Creek of Fecal Coliform For Restricted Shellfish Harvesting Areas in the Lower Patuxent River Basin in Calvert, Charles and St. Mary's Counties, Maryland

FINAL

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September 2004

EPA Submittal Date: September 29, 2004
EPA Approval Date: May 25, 2005

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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 Statistics 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 Pollution Discharge Elimination System
NSSP	National Shellfish Sanitation Program
RID	MDE Restricted Area Identification
SSO	Sanitary Sewer Overflow
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.

The Lower Patuxent River (basin number 02-13-11-01) was first identified on the 1996 303(d) list submitted to the EPA by MDE as being impaired by nutrients and sediments, with listings of fecal coliform in the tidal portions added in 1998, and listings of toxics in the tidal portion and 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 several restricted shellfish harvesting areas within the Lower Patuxent River Basin: Island Creek (RID 40B), Battle Creek (RID 40F), Harper and Pearson Creeks (RID 40M), and Goose Creek (RID 40N) are located on the northeast shoreline of the Lower Patuxent River. Town Creek (RID 40E), Trent Hall Creek (RID 40H), St. Thomas Creek (RID 40L), and Indian Creek(RID 40O) are located along the Lower Patuxent River southwest shoreline.

This report provides an analysis of recent monitoring data, which shows that the bacteria water quality criteria, determined from the designated use, is being met in Battle Creek within the Lower Patuxent River Basin; therefore, TMDLs of fecal coliform are not necessary to achieve water quality standards in this watershed. Barring the receipt of any contradictory data, this report will be used to support the bacteria listing change for Battle Creek from Category 5 ("waterbodies impaired by one or more pollutants and requiring a TMDL") to Category 6 ("waterbodies that have been de-listed or removed from the list") when MDE proposes the revision of Maryland's 303(d) list for public review in the future.

This document also proposes TMDLs for Island Creek, Town Creek, Trent Hall Creek, St. Thomas Creek; Harper and Pearson Creeks; Goose Creek; and Indian Creek. 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 is an indicator organism 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 at which the designated uses for these restricted shellfish harvesting areas will be met. The nutrient, sediment, toxic, biological, and any remaining bacteria impairments 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. The estimated sources were further verified through field observations. There are no permitted point source facilities in any of the shellfish 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 the Lower Patuxent River Basin. The tidal prism model incorporates both influences of freshwater discharge and tidal flushing for each area, which thereby represents the hydrodynamics of each selected site. 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. These results 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 areas of the Lower Patuxent River Basin for fecal coliform median load and 90th percentile load are as follows:

Island Creek:
The median load of fecal coliform TMDL = 1.08×10^{11} counts per day
The 90th percentile of fecal coliform TMDL = 3.77×10^{11} counts per day

Town Creek:
The median load of fecal coliform TMDL = 3.78×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.32×10^{11} counts per day

Trent Hall Creek:
The median load of fecal coliform TMDL = 4.02×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.41×10^{11} counts per day

St. Thomas Creek:
The median load of fecal coliform TMDL = 4.53×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.59×10^{11} counts per day

Harper and Pearson Creeks:
The median load of fecal coliform TMDL = 8.31×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 2.91×10^{11} counts per day

Goose Creek:
The median load of fecal coliform TMDL = 5.20×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.82×10^{11} counts per day

Indian Creek:
The median load of fecal coliform TMDL = 4.19×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.47×10^{11} counts per day

For the restricted shellfish harvesting areas in the Lower Patuxent River Basin, the 90th percentile criterion requires the greatest 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 source allocation that would meet water quality standards at restricted shellfish harvesting areas in the Lower Patuxent River Basin. 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.

RID	Source	Current Load Distribution (% of Total Load)	Required Reduction	TMDL Load Allocation (% of Total Load)
Island Creek				
40B	Total	100.0%	62.6%	100.0%
	Wildlife	40.1%	14.1%	92.0%
	Human	1.2%	95.0%	0.1%
	Pets	19.3%	95.0%	2.6%
	Livestock	39.4%	95.0%	5.3%
Town Creek				
40E	Total	100.0%	62.0%	100.0%
	Wildlife	34.0%	0.0%	89.6%
	Human	4.0%	94.0%	0.6%
	Pets	62.0%	94.0%	9.8%
	Livestock	0.0%	0.0%	0.0%

Trent Hall Creek				
40H	Total	100.0%	67.3%	100.0%
	Wildlife	24.5%	0.0%	75.0%
	Human	1.2%	89.2%	0.4%
	Pets	12.7%	89.2%	4.2%
	Livestock	61.6%	89.2%	20.4%
St. Thomas Creek				
40L	Total	100.0%	72.5%	100.0%
	Wildlife	48.6%	48.7%	90.6%
	Human	1.5%	95.0%	0.4%
	Pets	25.5%	95.0%	4.6%
	Livestock	24.4%	95.0%	4.4%
Harper and Pearson Creeks				
40M	Total	100.0%	47.2%	100.0%
	Wildlife	98.0%	46.2%	99.8%
	Human	0.0%	0.0%	0.0%
	Pets	2.0%	95.0%	0.2%
	Livestock	0.0%	0.0%	0.0%
Goose Creek				
40N	Total	100.0%	57.1%	100.0%
	Wildlife	98.4%	56.5%	99.8%
	Human	0.0%	0.0%	0.0%
	Pets	1.6%	95.0%	0.2%
	Livestock	0.0%	0.0%	0.0%
Indian Creek				
40O	Total	100.0%	50.3%	100.0%
	Wildlife	21.6%	0.0%	43.4%
	Human	0.8%	64.1%	0.7%
	Pets	12.9%	64.1%	9.3%
	Livestock	64.7%	64.1%	46.6%

Once the U.S. Environmental Protection Agency (EPA) has approved a TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. The Maryland Department of the Environment (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.

A segment identified as a WQLS may not require the development and implementation of a TMDL if current information contradicts the previous finding of an impairment. The most common factual scenarios obviating the need for a TMDL are as follows: 1) more recent data indicating that the impairment no longer exists (i.e., water quality criteria are being met); 2) more recent and updated water quality modeling demonstrates that the segment is now attaining criteria; 3) refinements to water quality criteria, or the interpretation of those standards, which result in standards being met; or 4) correction to errors made in the initial listing.

The Lower Patuxent River (basin number 02-13-11-01) was first identified on the 1996 303(d) list submitted to the EPA by MDE as being impaired by nutrients and sediments, with listings of fecal coliform in the tidal portions added in 1998, and listings of toxics in the tidal portion and biological impacts in non-tidal portions added in 2002. On the draft 2004 303(d) list, additional restricted shellfish harvesting areas were listed. This document proposes to establish Total Maximum Daily Loads (TMDLs) of fecal coliform for identified restricted shellfish harvesting areas in the Lower Patuxent River Basin. Additionally, this report provides an analysis of recent monitoring data, which shows that the fecal coliform water quality criteria, determined from the designated use, is being met in Battle Creek within the Lower Patuxent River Basin. Therefore, a TMDL of fecal coliform is not necessary to achieve water quality standards for this restricted shellfish harvesting area. The nutrient, sediment, toxic, biological, and any remaining bacteria 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 TMDL.

Fecal coliform are found in the intestinal tract 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

Eight restricted shellfish harvesting areas are addressed in this report. Island Creek (RID 40B), Battle Creek (RID 40F), Harper and Pearson Creeks (RID 40M), and Goose Creek (RID 40N) are located on the western shoreline of the Lower Patuxent River. Town Creek (RID 40E), Trent Hall Creek (RID 40H), St. Thomas Creek (RID 40L), and Indian Creek(RID 40O) are located along the Lower Patuxent River southwest shoreline. The Patuxent River, which drains directly to the Chesapeake Bay, is located on Maryland's western shore. Shellfish waters in the Patuxent River extend from Ferry Landing, which is south of Jug Bay, to the mouth of the river where it discharges into the Chesapeake Bay.

The Lower Patuxent River, shown in Figure 2.1.1, is located in the Atlantic Coastal Plain. Soils mainly consist of silt (67.3%), clay (21.5%), and sand (11.2%) (USDA, 1995). The basin has irregular topography, and the majority of the area near the receiving waters consists of low-lying, poorly drained land combined with a high (although variable) water table. 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 Lower Patuxent Restricted Shellfish Harvesting Areas

Restricted Shellfish Harvesting Area (RID)	Mean Water Volume in m^3	Mean Water Depth in m
Island Creek (40B)	1,090,403	1.48
Town Creek (40E)	384,809	1.48
Battle Creek (40F)	1,924,245	1.64
Trent Hall Creek (40H)	378,620	0.62
St. Thomas Creek (40L)	458,794	1.25
Harper and Pearson Creeks (40M)	848,873	1.15
Goose Creek (40N)	531,620	0.79
Indian Creek (40O)	397,473	0.64

The 2000 Maryland Department of Planning (MDP) land use/land cover data was used to estimate areas of urban, forest, agriculture, wetlands and water. The land use percentage

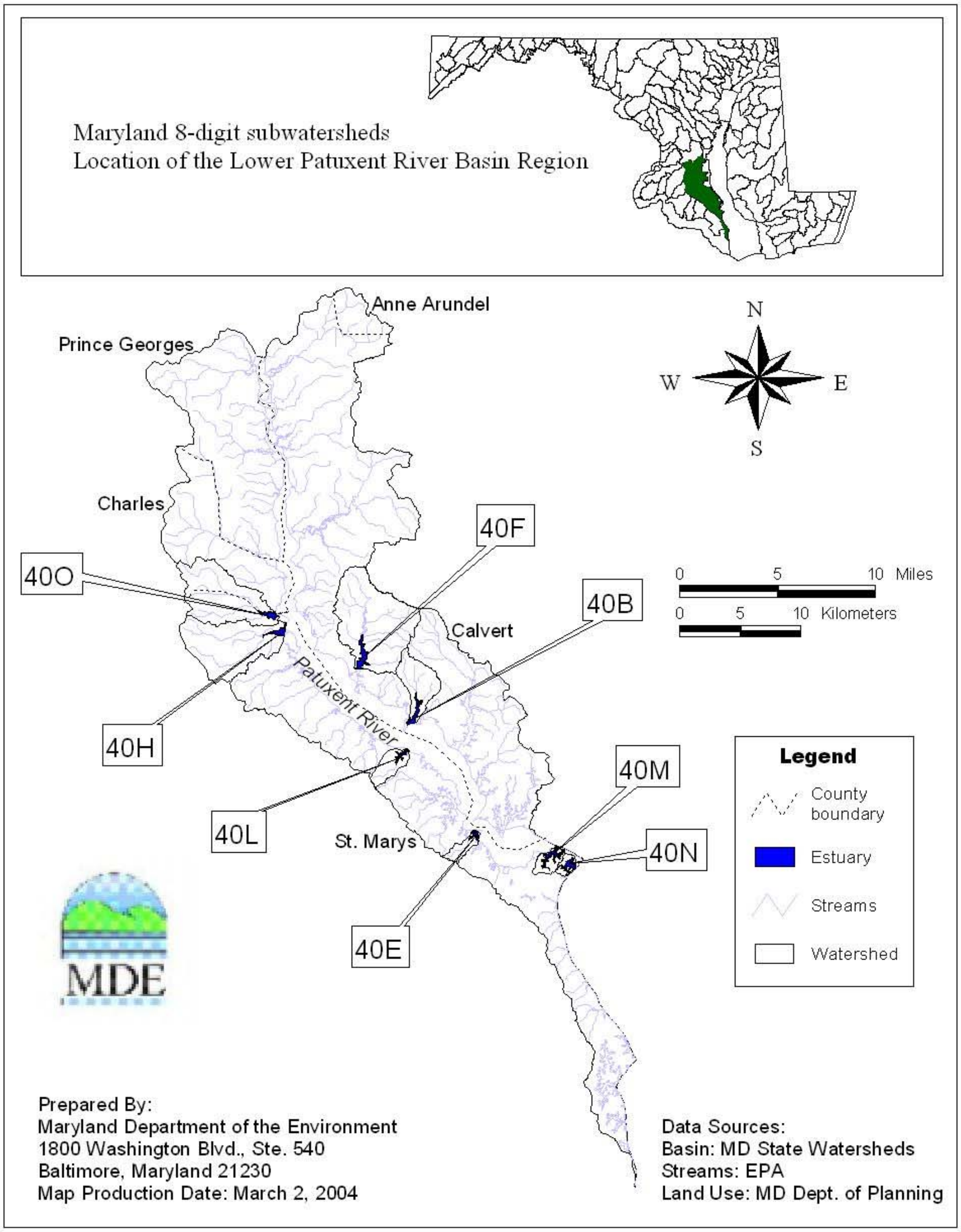

Figure 2.1.1: Location Map of the Lower Patuxent River Basin

distributions for restricted shellfish harvesting areas in the Lower Patuxent River are shown in Tables 2.1.2 to 2.1.9 and Figures 2.1.2 to 2.1.9. Feedlots identified in the figures are MDP land use types, not permitted confined animal feeding operations (CAFOs).

Table 2.1.2: Land Use Percentage Distribution for Island Creek (RID 40B)

Land Type	Acreage	Percentage
Urban	417.3	12.1
Forest	1899.2	54.8
Agriculture	853.1	24.6
Wetlands	43.1	1.2
Water	249.5	7.2
Totals	3462.1	100.0

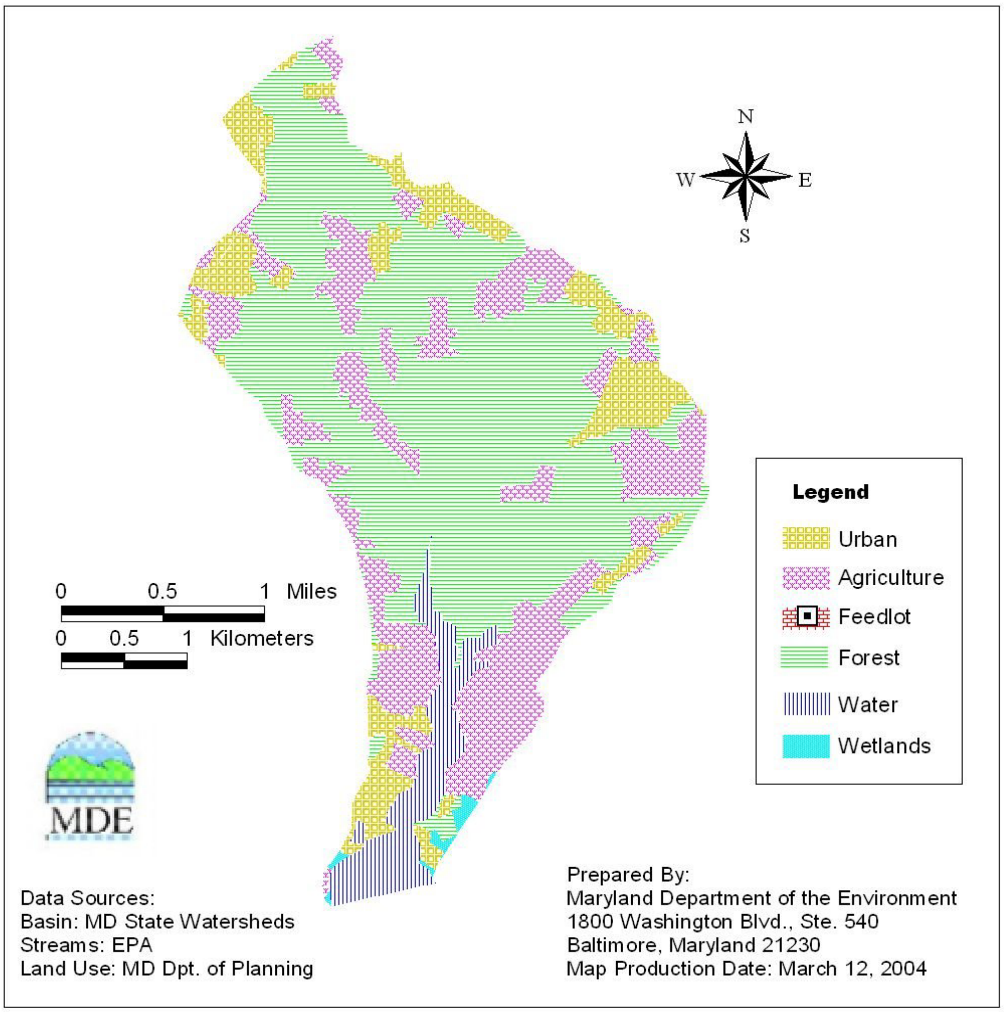

Figure 2.1.2: Land Use in the Island Creek Basin

Table 2.1.3: Land Use Percentage Distribution for Town Creek (RID 40E)

Land Type	Acreage	Percentage
Urban	530.9	59.8
Forest	257.7	29.0
Agriculture	40.8	4.6
Wetlands	0	0.0
Water	57.7	6.6
Totals	887.1	100.0

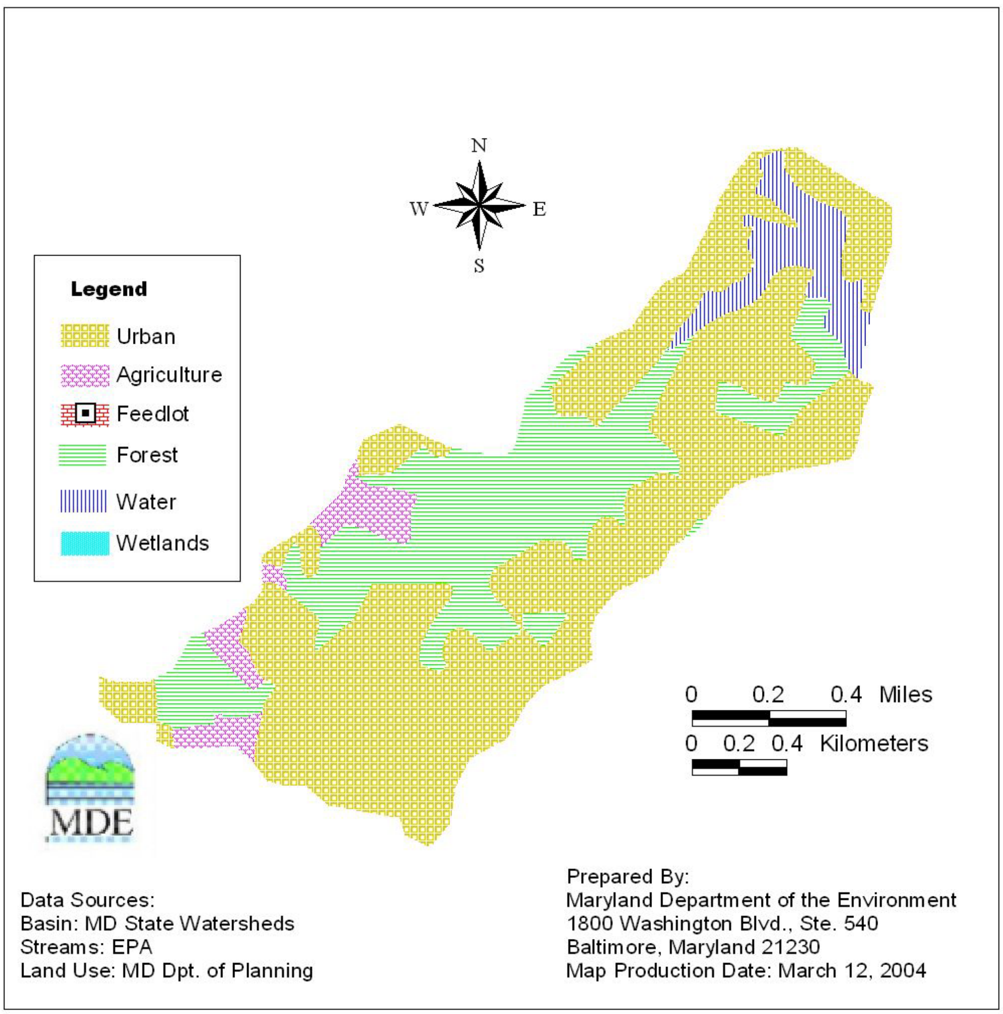

Figure 2.1.3: Land Use in the Town Creek Basin

Table 2.1.4: Land Use Percentage Distribution for Battle Creek (RID 40F)

Land Type	Acreage	Percentage
Urban	1,871.5	16.3
Forest	6,938.4	60.4
Agriculture	2,297.8	20.0
Wetlands	74.1	0.6
Water	308.4	2.7
Totals	11,490.3	100.0

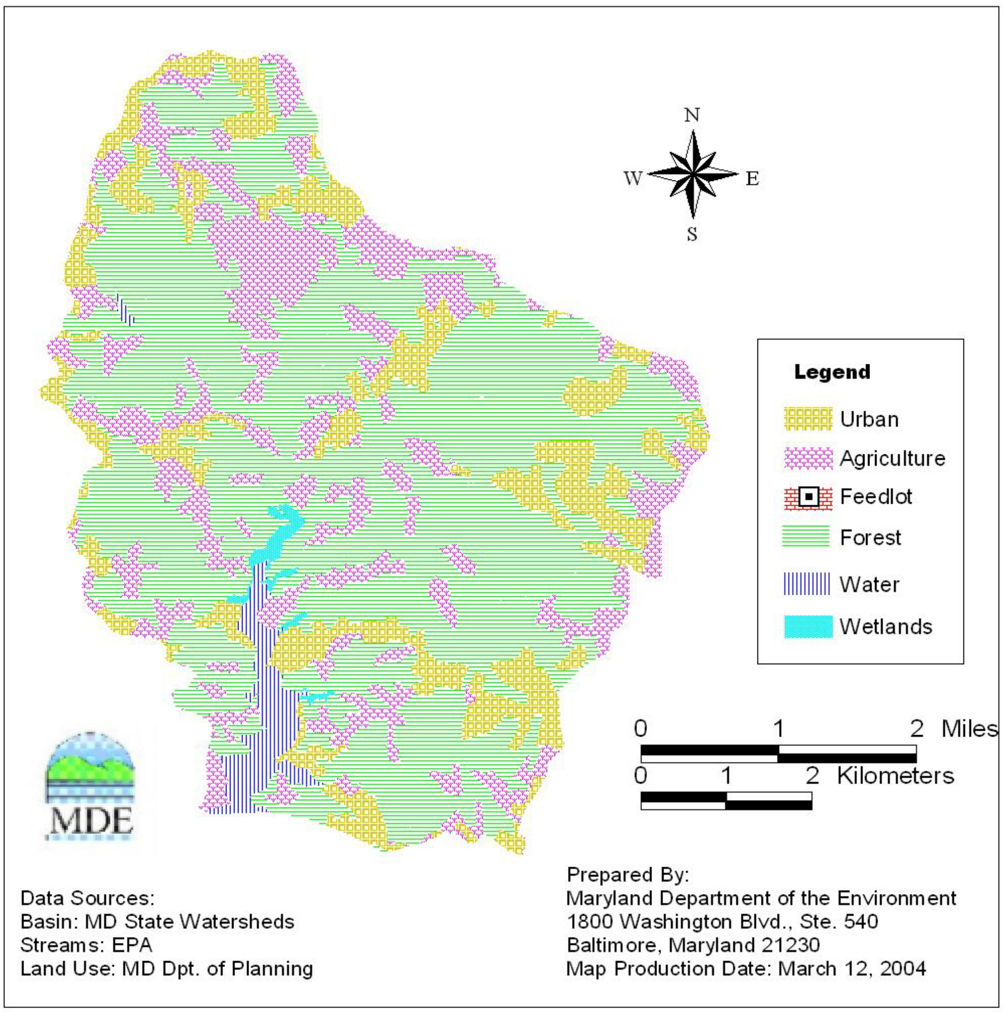

Figure 2.1.4: Land Use in the Battle Creek Basin

Table 2.1.5: Land Use Percentage Distribution for Trent Hall Creek (RID40H)

Land Type	Acreage	Percentage
Urban	1,919.2	22.6
Forest	4,784.8	56.3
Agriculture	1,508.7	17.7
Wetlands	144.3	1.7
Water	143.4	1.7
Totals	8,500.5	100.0

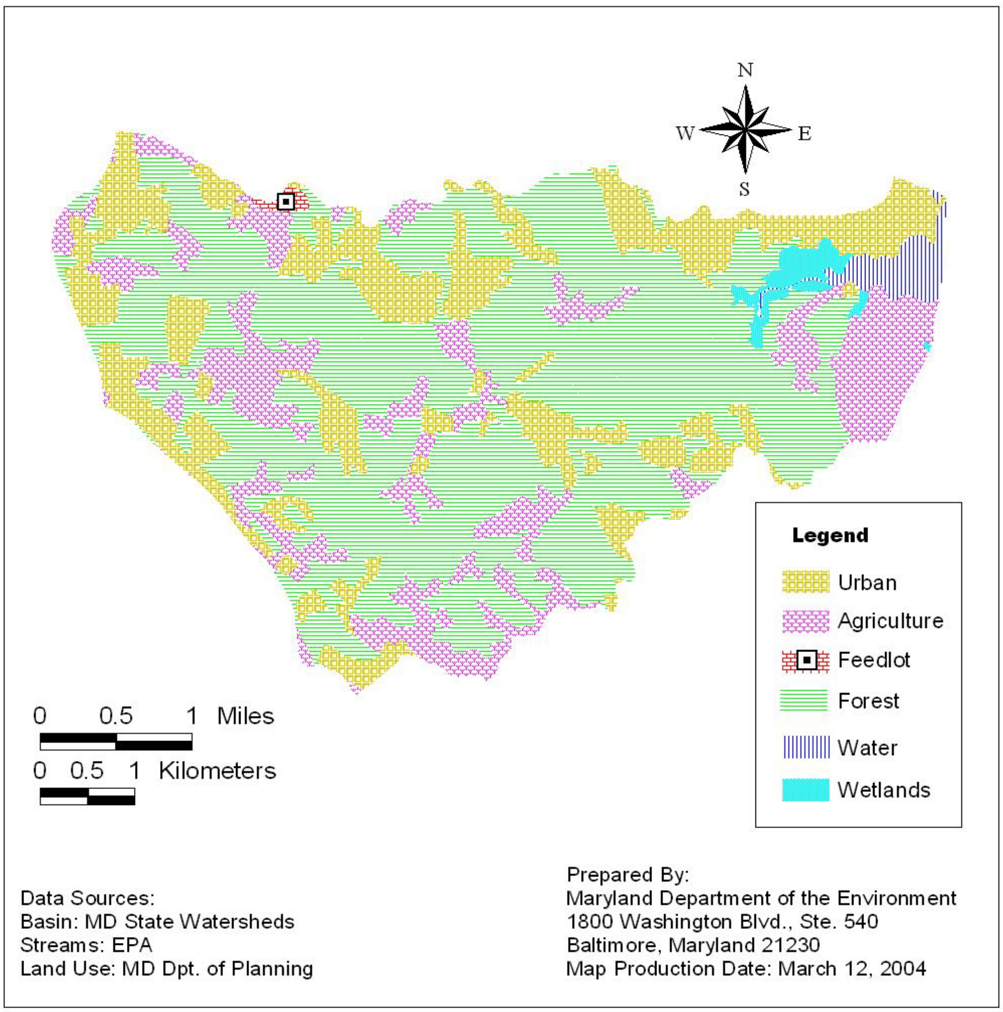

Figure 2.1.5: Land Use in the Trent Hall Creek Basin

Table 2.1.6: Land Use Percentage Distribution for St. Thomas Creek (RID 40L)

Land Type	Acreage	Percentage
Urban	316.2	20.5
Forest	1,048.8	68.1
Agriculture	69.6	4.5
Wetlands	6.3	0.4
Water	99.1	6.4
Totals	1,540.0	100.0

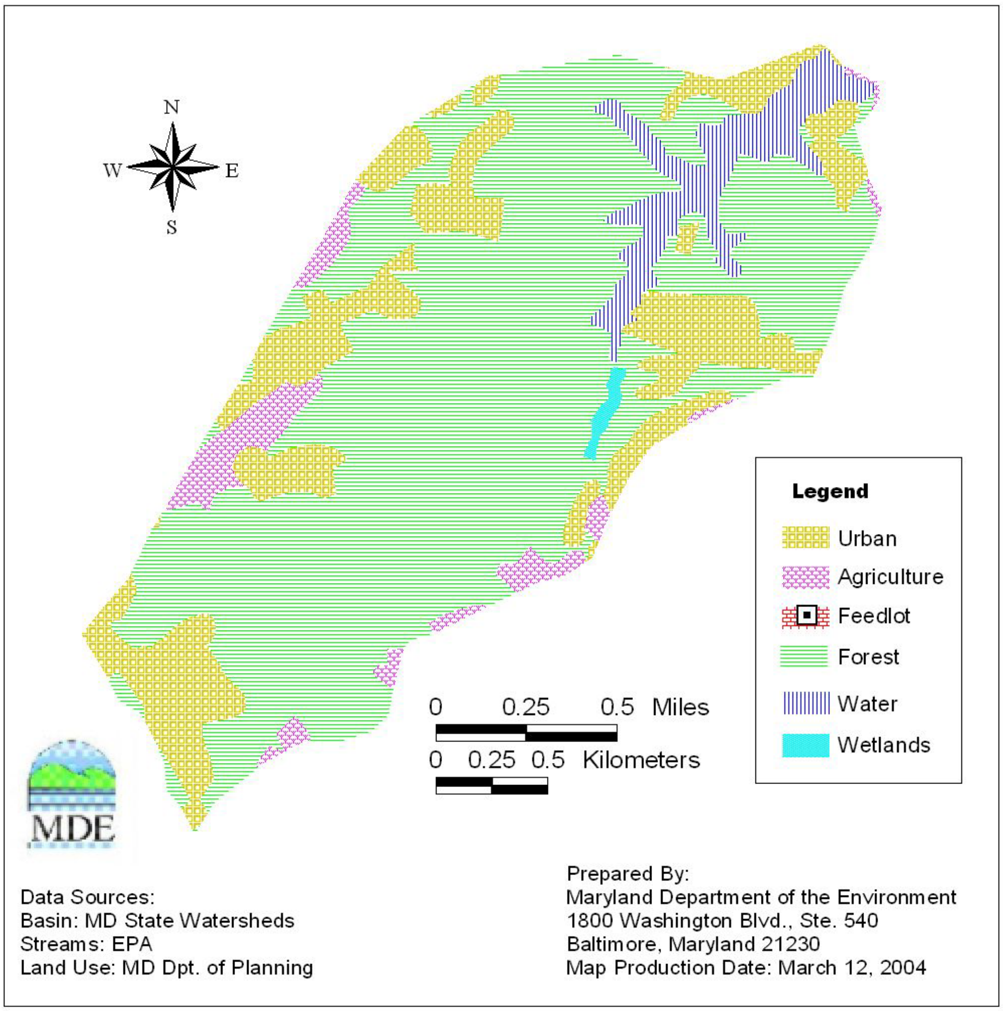

Figure 2.1.6: Land Use in the St. Thomas Creek Basin

Table 2.1.7: Land Use Percentage Distribution for Harper and Pearson Creeks (RID 40M)

Land Type	Acreage	Percentage
Urban	794.1	73.4
Forest	70.5	6.5
Agriculture	0.0	0.0
Wetlands	26.3	2.4
Water	191.4	17.7
Totals	1,082.3	100.0

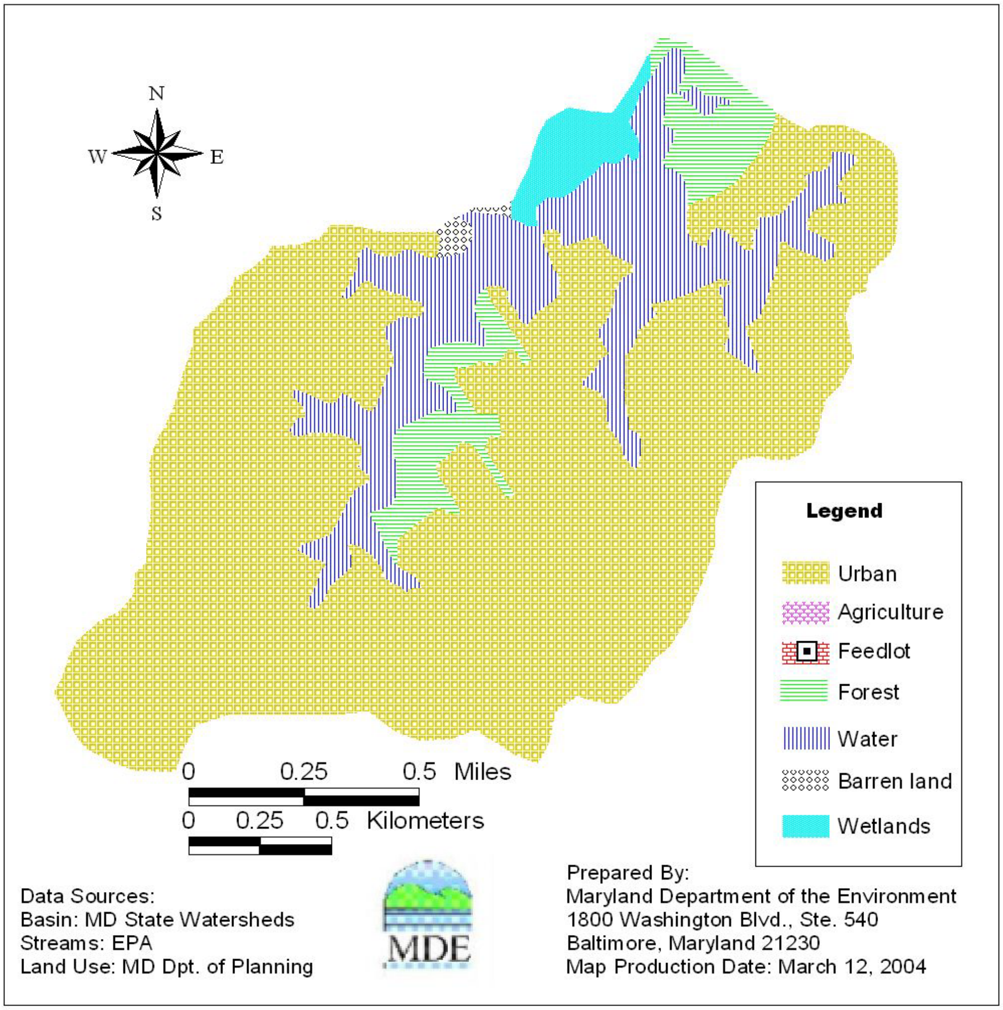

Figure 2.1.7: Land Use in the Harper and Pearson Creeks Basin

Table 2.1.8: Land Use Percentage Distribution for Goose Creek (RID 40N)

Land Type	Acreage	Percentage
Urban	358.5	60.4
Forest	101.1	17.0
Agriculture	0.0	0.0
Wetlands	0.0	0.0
Water	133.5	22.5
Totals	593.0	100.0

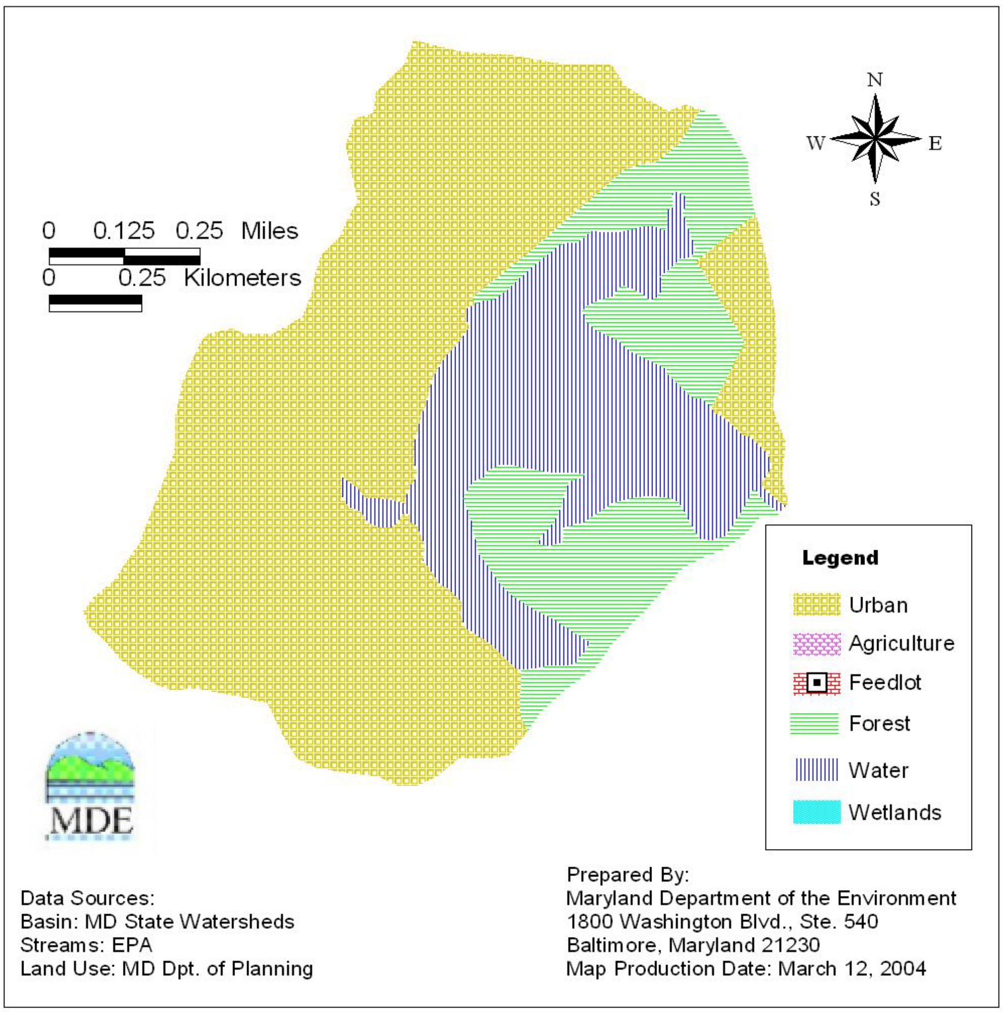

Figure 2.1.8: Land Use in the Goose Creek Basin

Table 2.1.9: Land Use Percentage Distribution for Indian Creek (RID 40O)

Land Type	Acreage	Percentage
Urban	2,142.3	26.8
Forest	4,750.0	59.3
Agriculture	857.6	10.7
Wetlands	105.1	1.3
Water	151.6	1.9
Totals	8,006.6	100.0

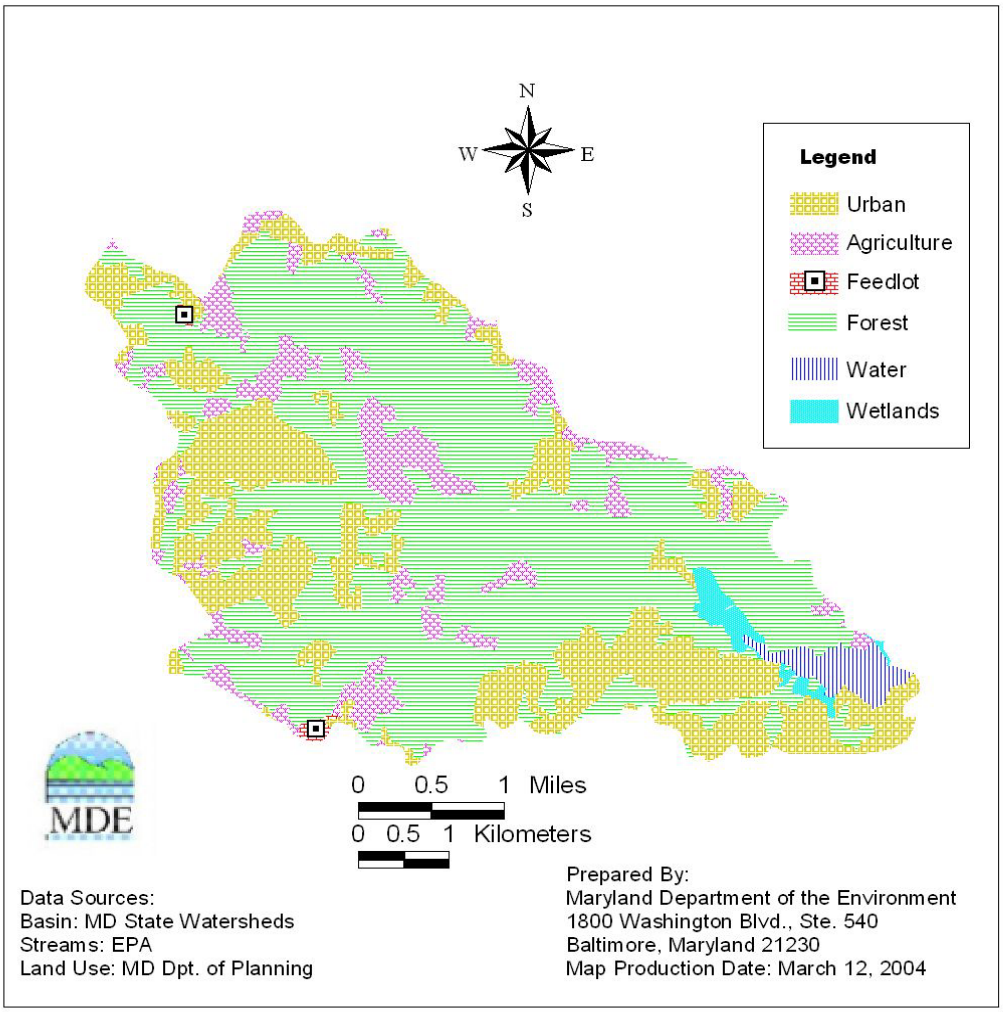

Figure 2.1.9: Land Use in the Indian Creek Basin

The urban landuse listed in the above tables include residential and non-residential urban land use. There is Patuxent Naval Air Station which covers entire watersheds of Goose Creek and Harper and Pearson Creeks. The land use for this Naval Air station is classified as non-residential urban which do not contribute fecal coliform from human sources.

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 standards are being met. If the water quality standards are exceeded, the shellfish areas are closed to harvesting.

MDE's Shellfish Certification Division has monitored shellfish growing regions throughout Maryland for the past several decades. There are 18 shellfish monitoring stations in the restricted shellfish shellfish areas in the Lower Patuxent River. The monitoring stations and observed recordings during the period of 1999 to 2003 are provided in Table 2.2.1 to 2.2.7 and Figure 2.2.1 to 2.2.26. In general, fecal coliform concentrations are higher in the headwaters.

Table 2.2.1: Locations of Shellfish Monitoring Stations for Island Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	Distance from the Mouth of the Patuxent River	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
09-02-109	1999-2003	71	16.6 km	38 24 48.5	76 32 34.8
09-02-020A	1999-2003	71	16.1 km	38 24 29.4	76 32 38.8

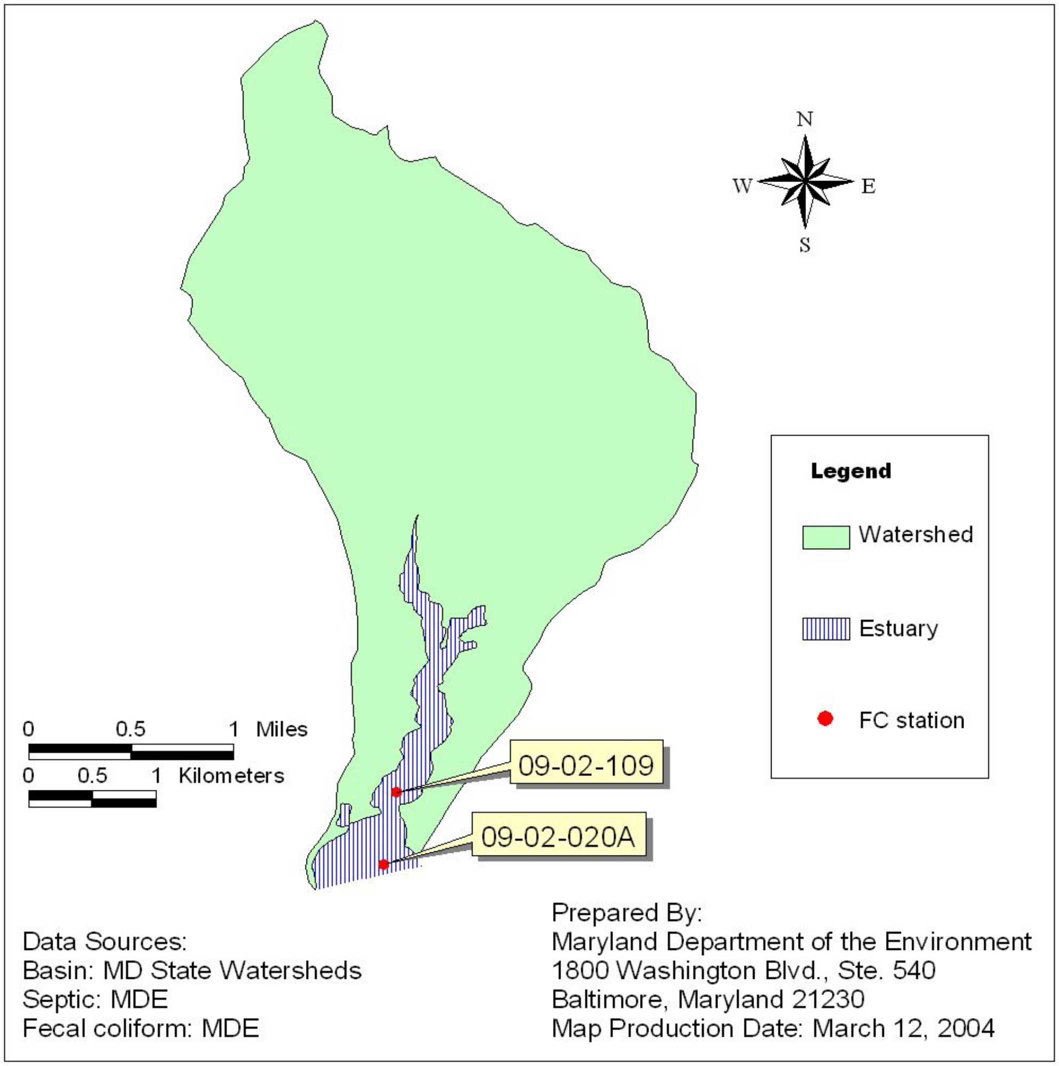

Figure 2.2.1: Shellfish Monitoring Stations in the Island Creek

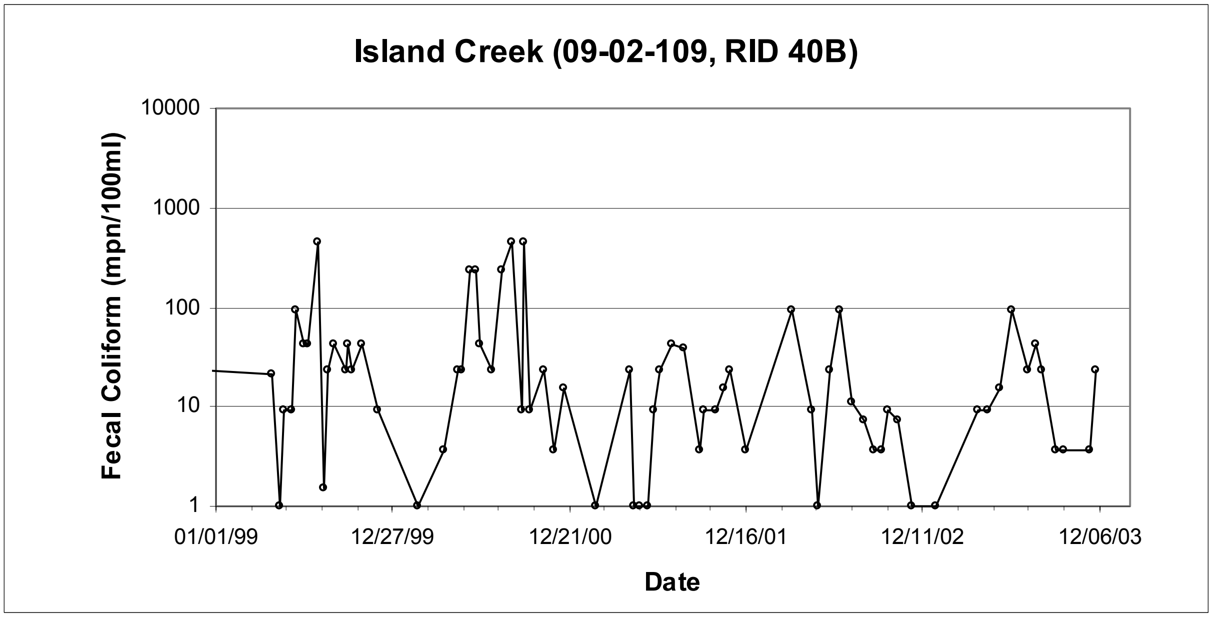

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 09-02-109

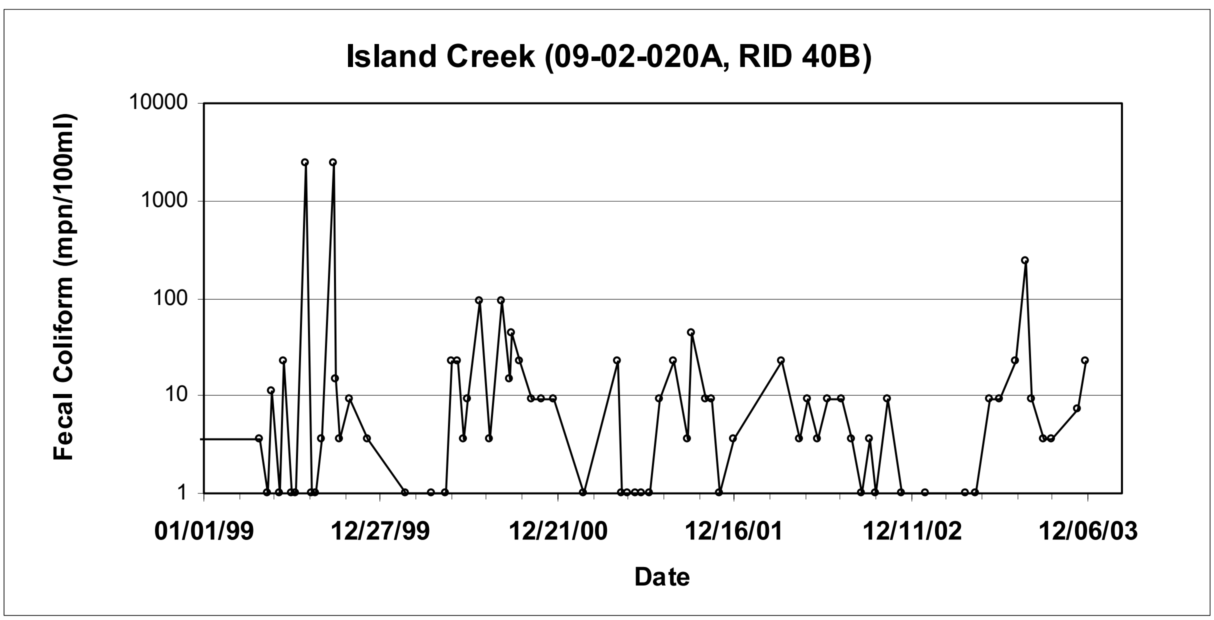

Figure 2.2.3: Observed Fecal Coliform Concentrations at Station 09-02-020A

Table 2.2.2: Locations of Shellfish Monitoring Stations in Town Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	Distance from the Mouth of the Patuxent River	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
09-04-007	1999-2003	55	6.04 km	38 18 54.0	76 28 46.0
09-04-300	1999-2003	55	6.21 km	38 19 8.0	76 28 53.0

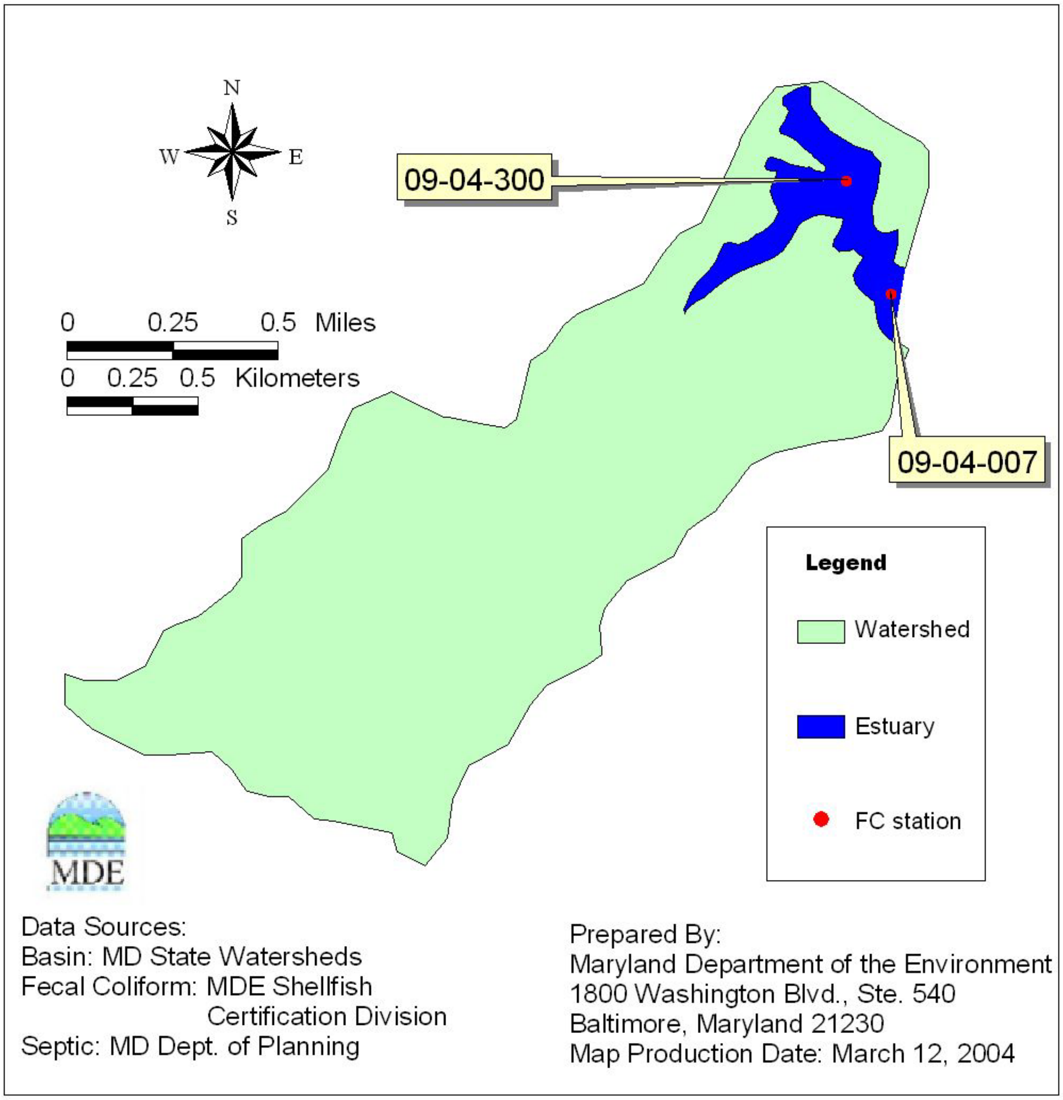

Figure 2.2.4: Shellfish Monitoring Stations in Town Creek

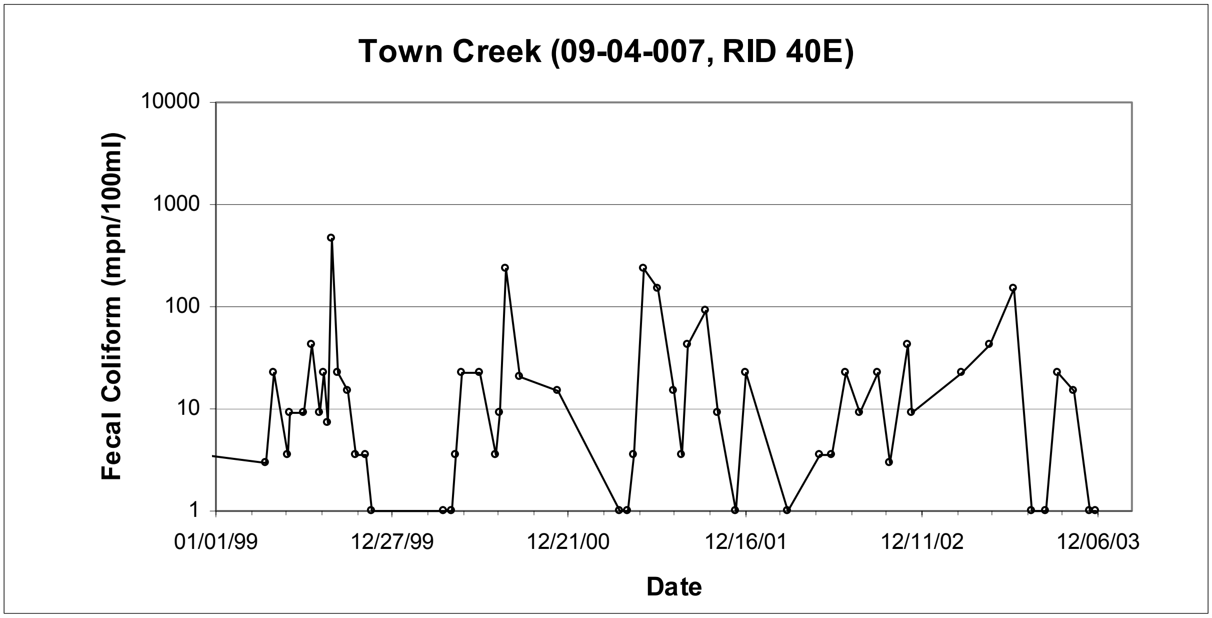

Figure 2.2.5: Observed Fecal Coliform Concentrations at Station 09-04-007

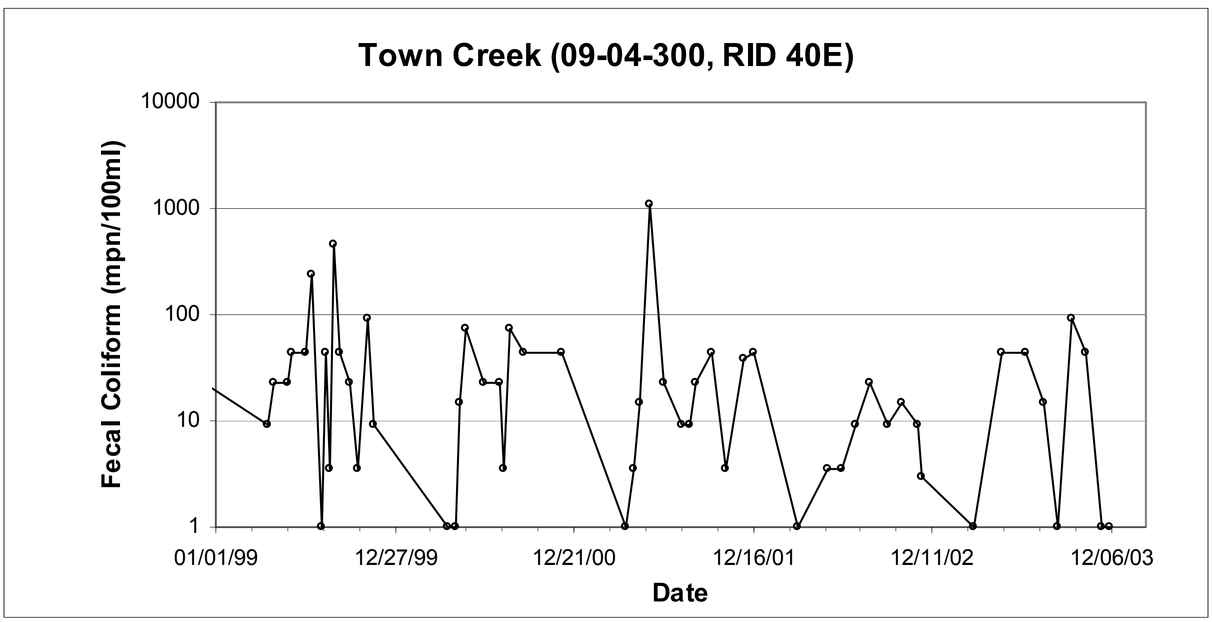

Figure 2.2.6: Observed Fecal Coliform Concentrations at Station 09-04-300

Table 2.2.3: Locations of Shellfish Monitoring Stations in Battle Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	Distance from the Mouth of the Patuxent River	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
09-02-105D	1999-2003	45	22.47 km	38 26 50.0	76 36 13.0
09-02-107A	1999-2003	51	22.52 km	38 27 2.0	76 36 00.0

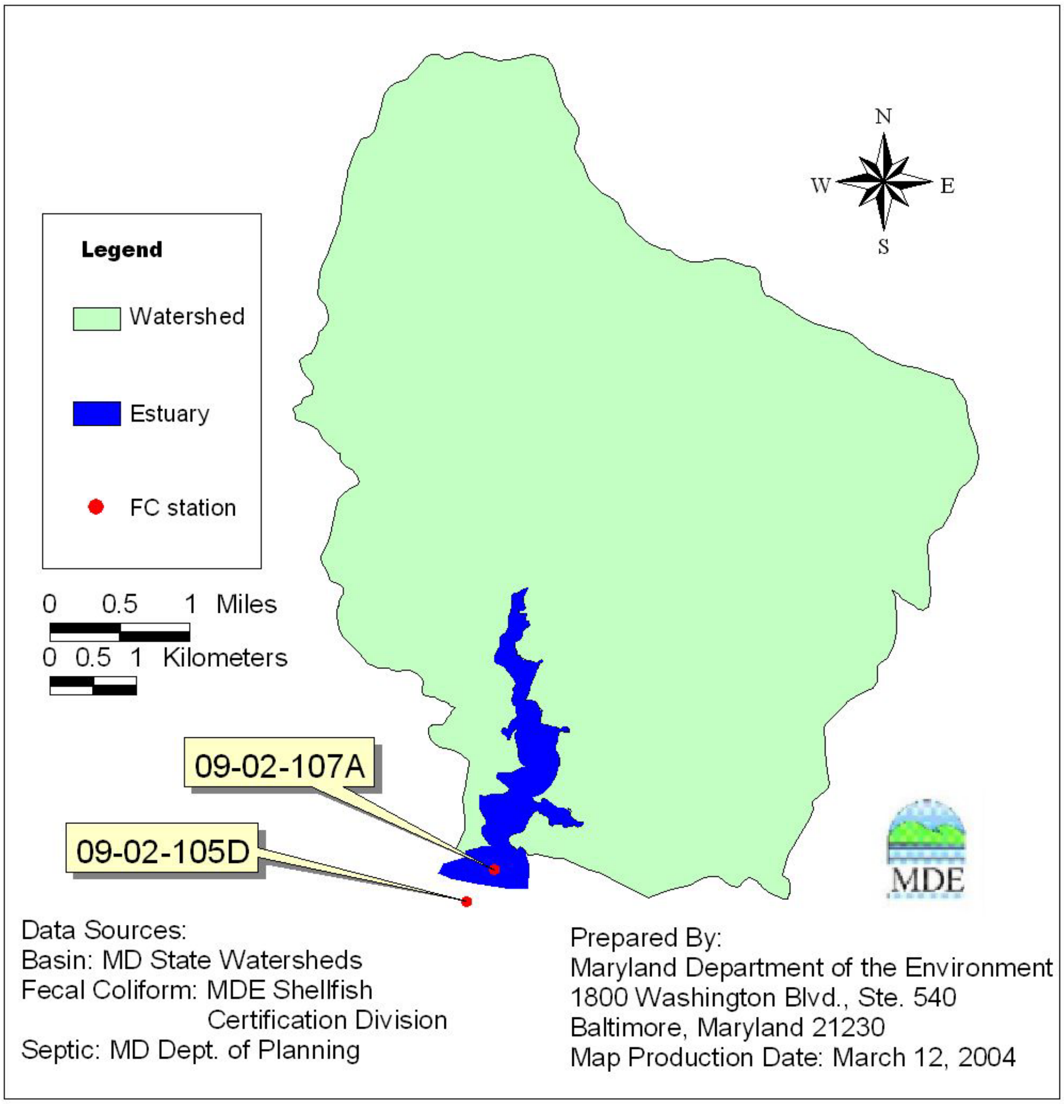

Figure 2.2.7: Shellfish Monitoring Stations in Battle Creek

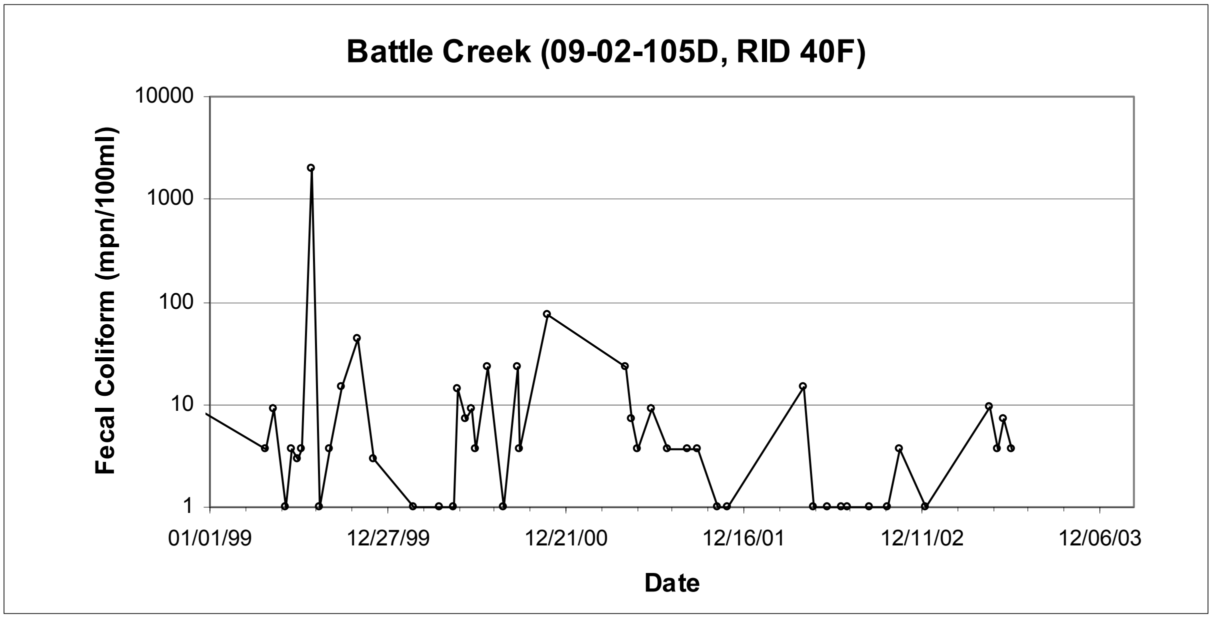

Figure 2.2.8: Observed Fecal Coliform Concentrations at Station 09-02-105D

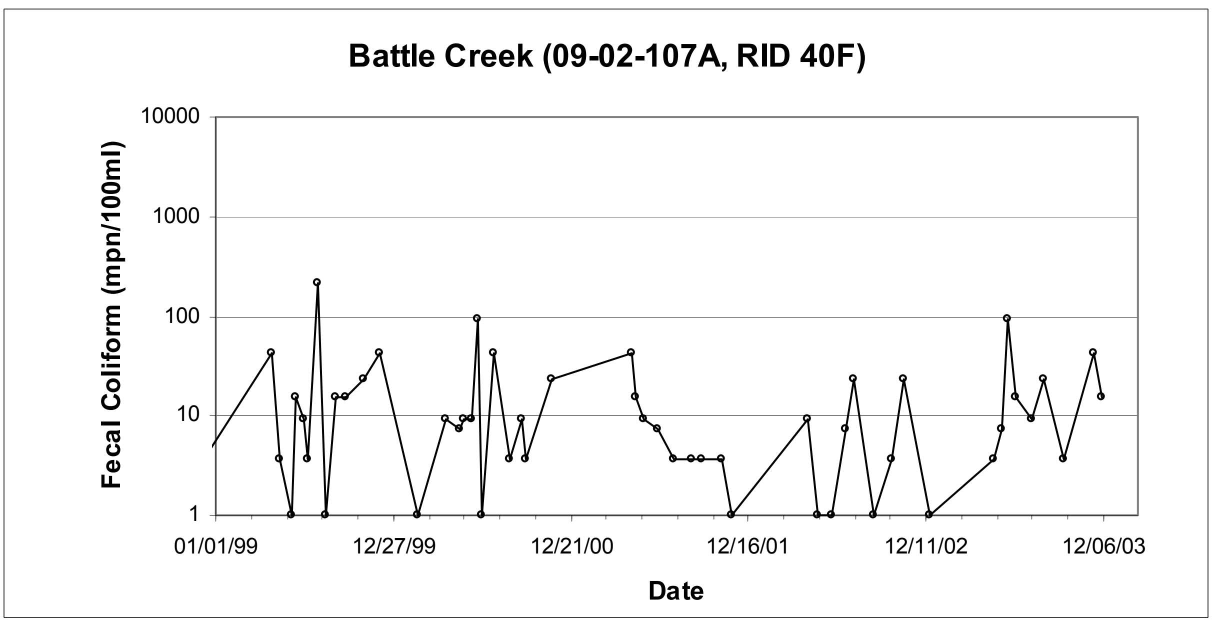

Figure 2.2.9: Observed Fecal Coliform Concentrations at Station 09-02-107A

Table 2.2.4: Location of Shellfish Monitoring Station in Trent Hall Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	Distance from the Mouth of the Patuxent River	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
09-01-101A	1999-2003	47	29.66 km	38 28 57.5	76 40 28.2

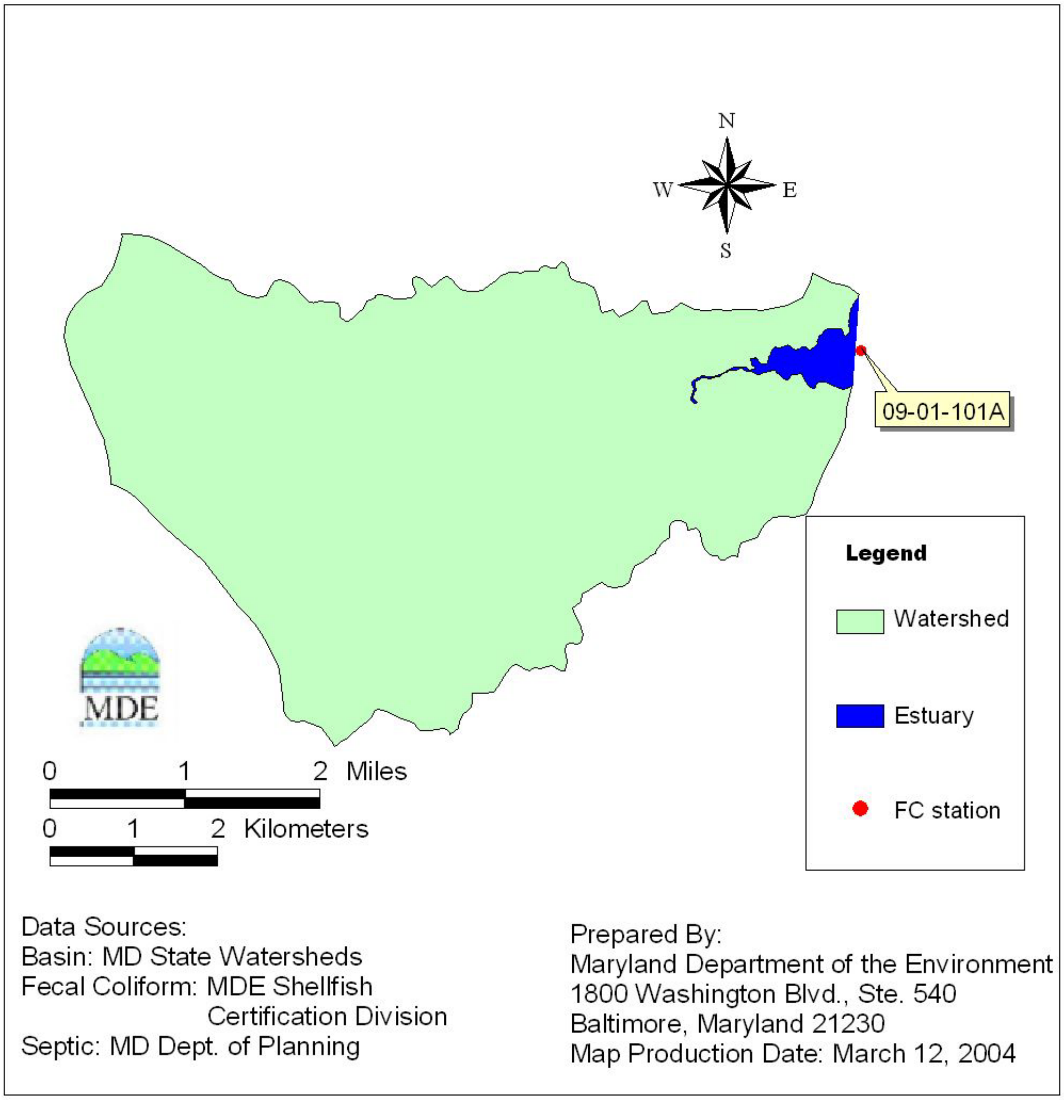

Figure 2.2.10: Shellfish Monitoring Stations in Trent Hall Creek

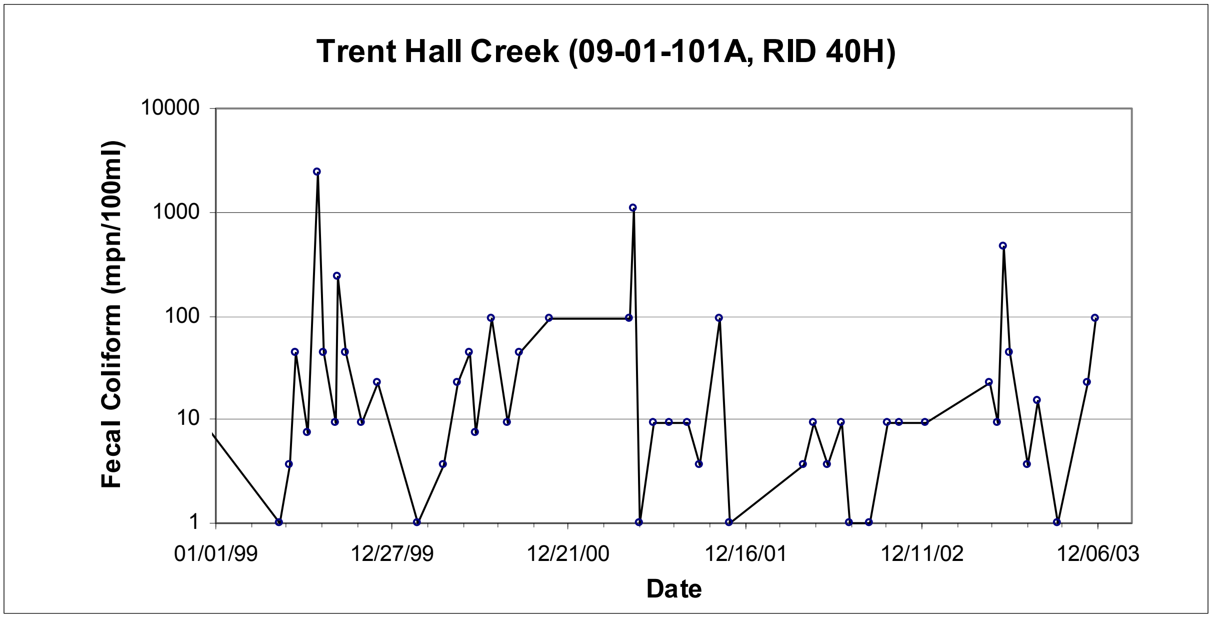

Figure 2.2.11: Observed Fecal Coliform Concentrations at Station 09-02-101A

Table 2.2.5: Locations of Shellfish Monitoring Stations in St. Thomas Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	Distance from the Mouth of the Patuxent River	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
09-02-022	2001-2003	38	14.66 km	38 23 12.0	76 32 59.8
09-02-023	2001-2003	40	14.99 km	38 22 55.9	76 33 26.0
09-02-023F	2002-2003	25	15.13 km	38 22 53.2	76 33 36.8

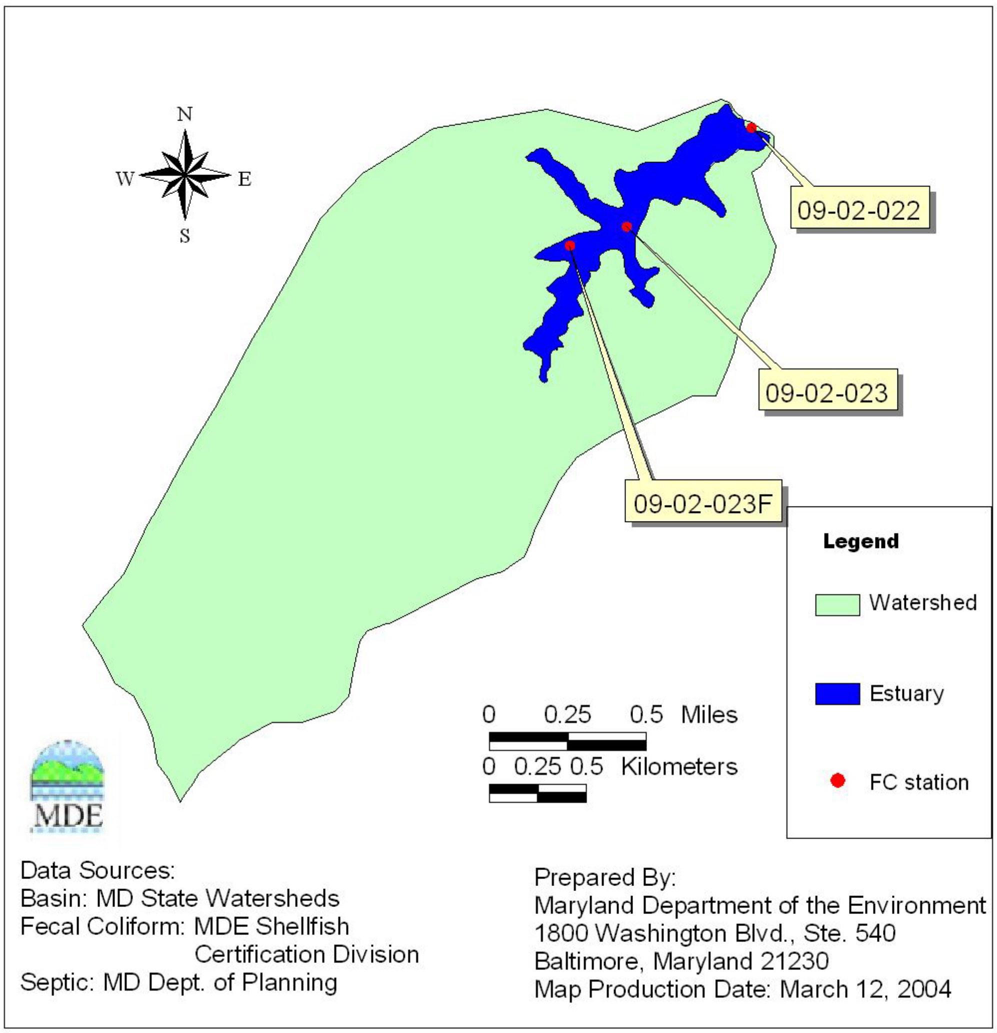

Figure 2.2.12: Shellfish Monitoring Stations in St. Thomas Creek

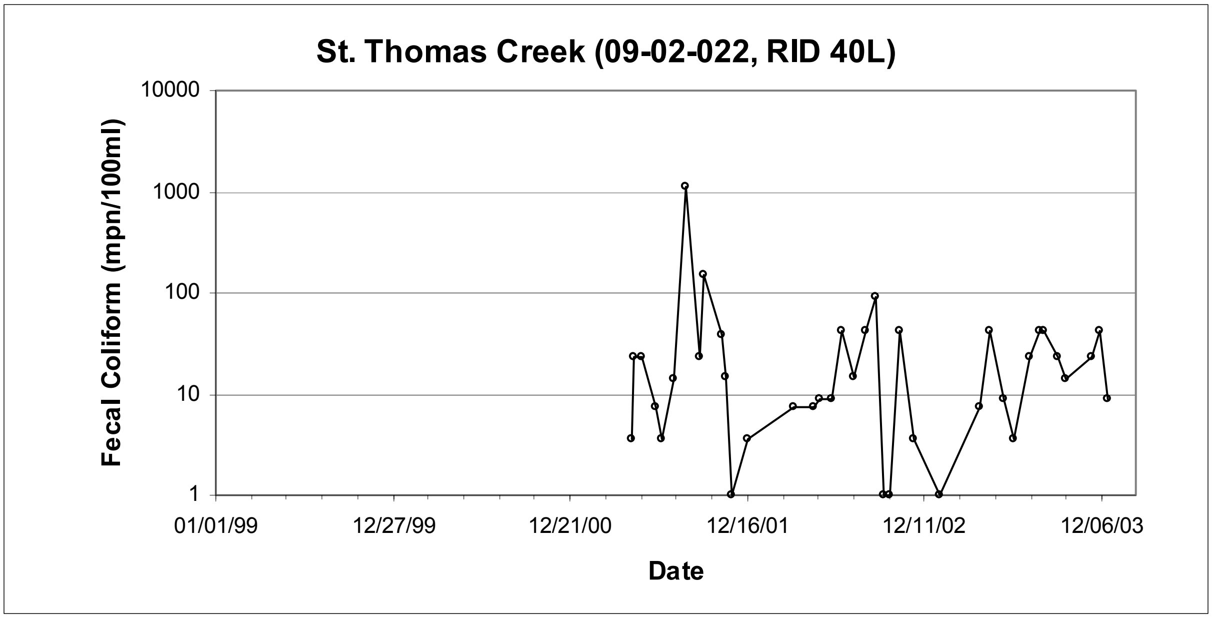

Figure 2.2.13: Observed Fecal Coliform Concentrations at Station 09-02-022

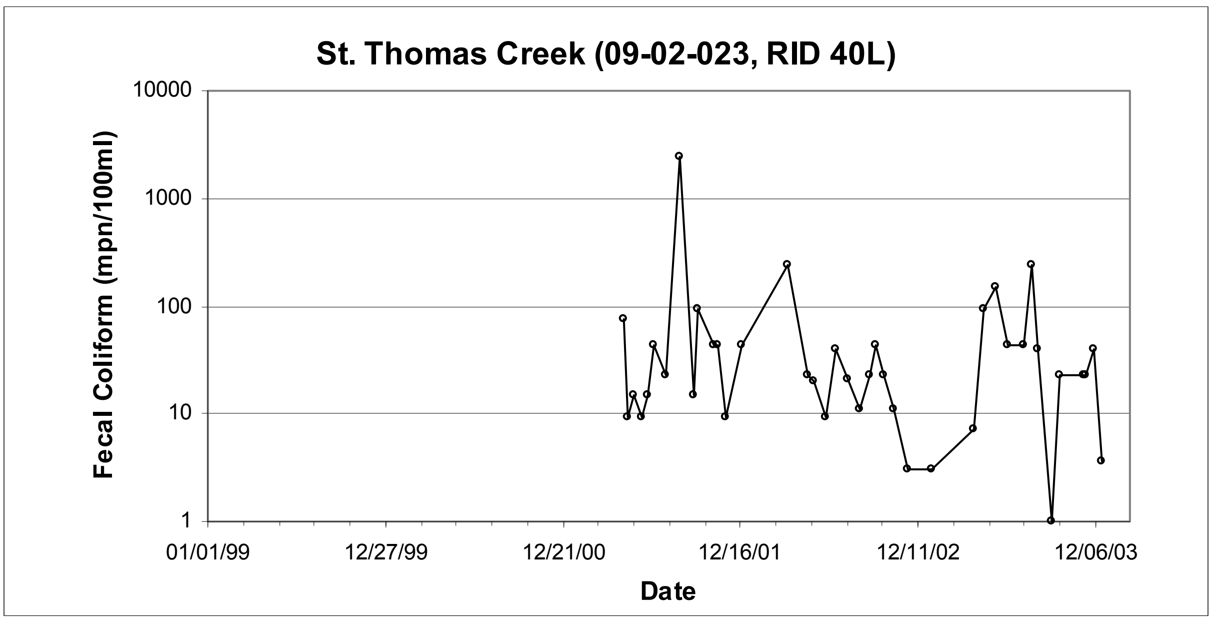

Figure 2.2.14: Observed Fecal Coliform Concentrations at Station 09-02-023

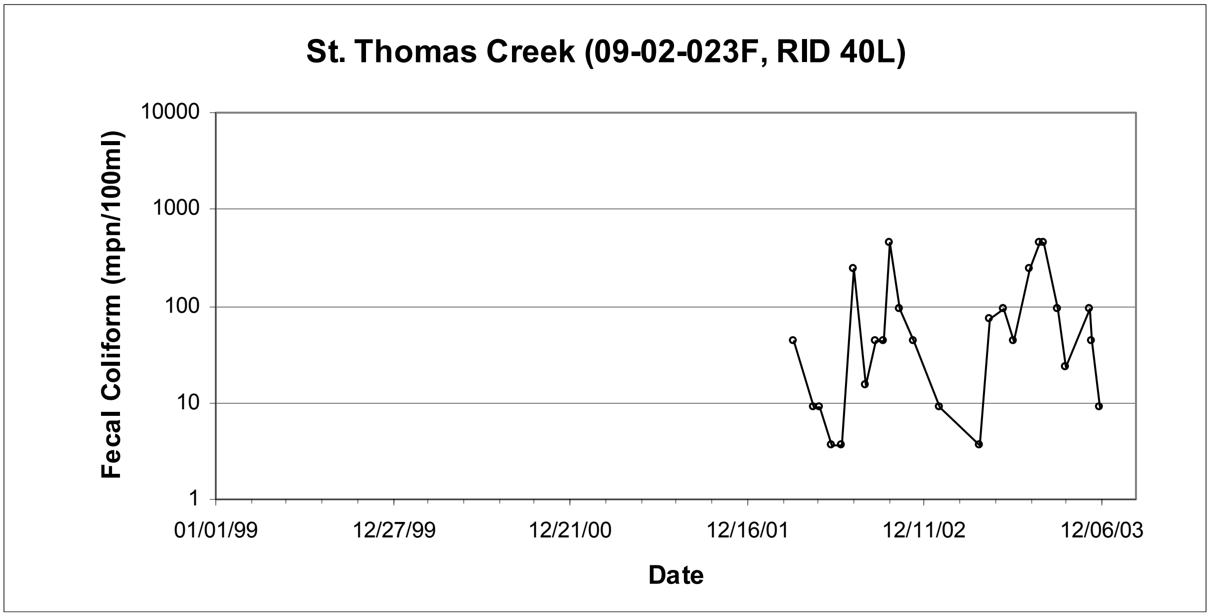

Figure 2.2.15: Observed Fecal Coliform Concentrations at Station 09-02-023F

Table 2.2.6: Locations of Shellfish Monitoring Stations in Harper and Pearson Creeks

Shellfish Monitoring Station	Obs. Period	Total Obs.	Distance from the Mouth of the Patuxent River	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
09-05-101	2001-2003	33	1.28 km	38 18 8.5	76 24 42.0
09-05-102	2001-2003	33	1.21 km	38 18 14.0	76 24 18.7
09-05-103	2001-2003	33	1.06 km	38 18 17.3	76 24 18.7
09-05-104	2001-2003	33	1.15 km	38 18 32.5	76 23 56.8

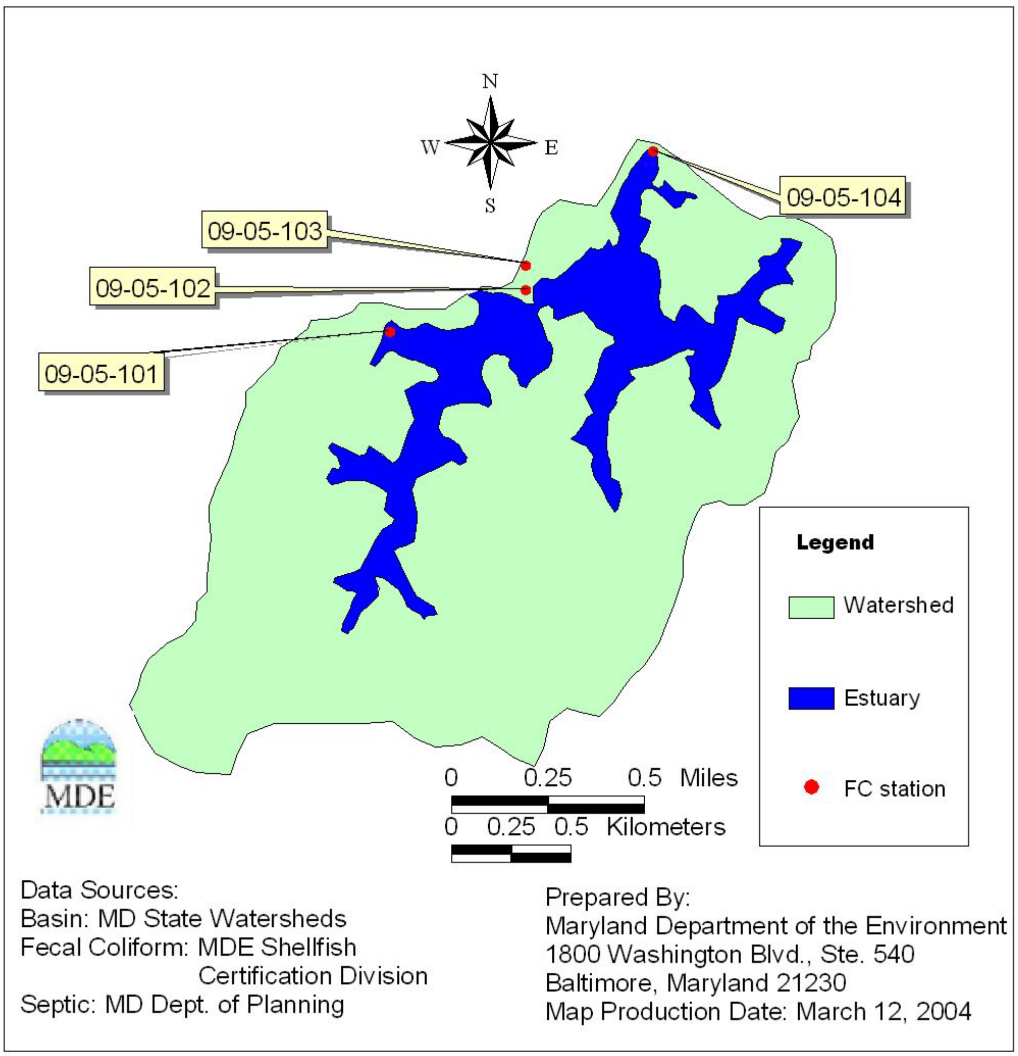

Figure 2.2.16: Shellfish Stations in Harper and Pearson Creeks

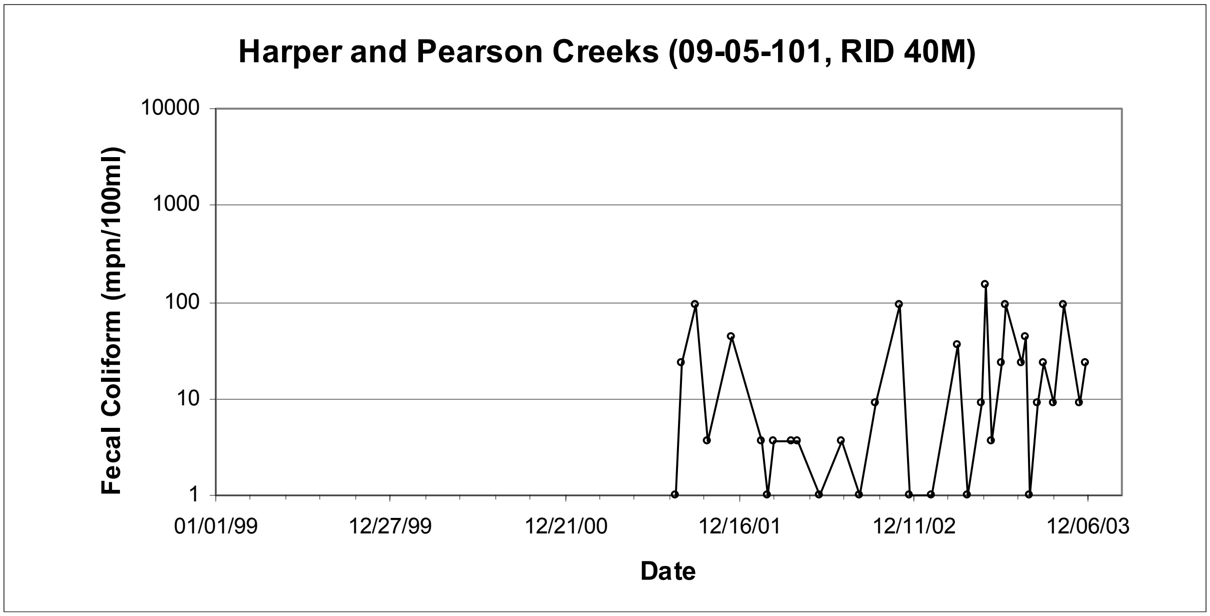

Figure 2.2.17: Observed Fecal Coliform Concentrations at Station 09-05-101

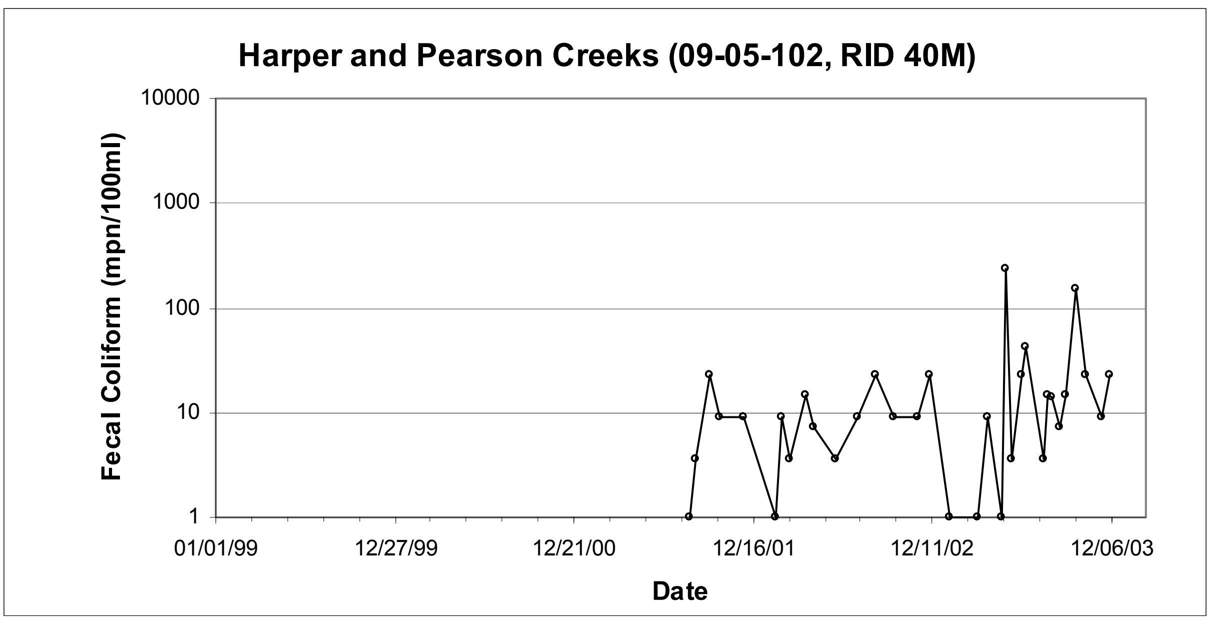

Figure 2.2.18: Observed Fecal Coliform Concentrations at Station 09-05-102

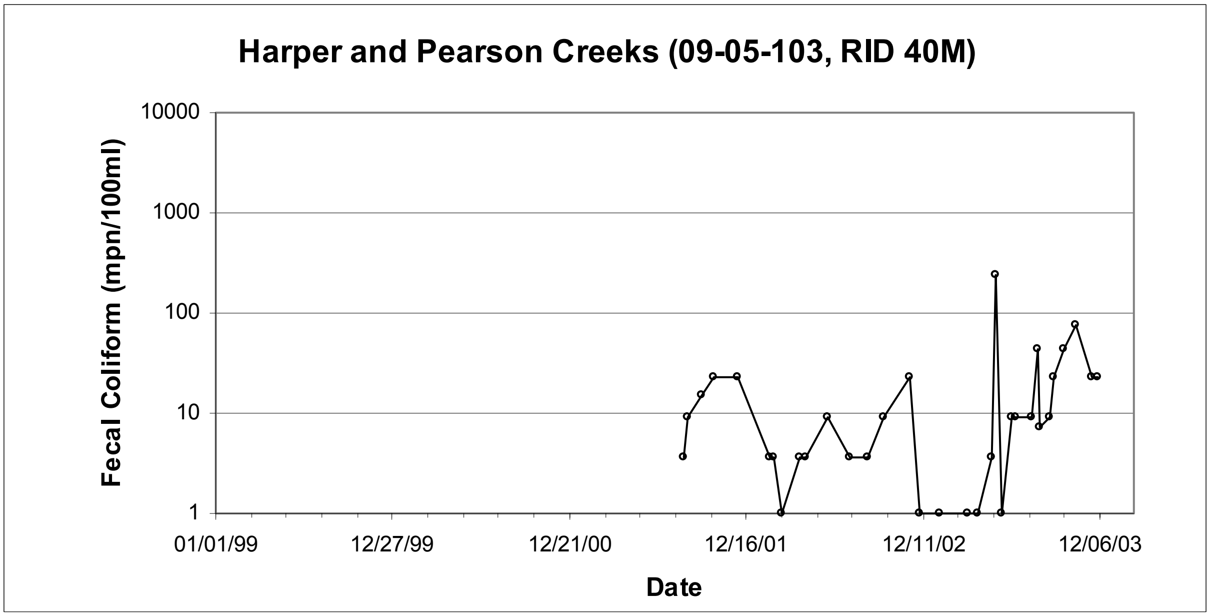

Figure 2.2.19: Observed Fecal Coliform Concentrations at Station 09-05-103

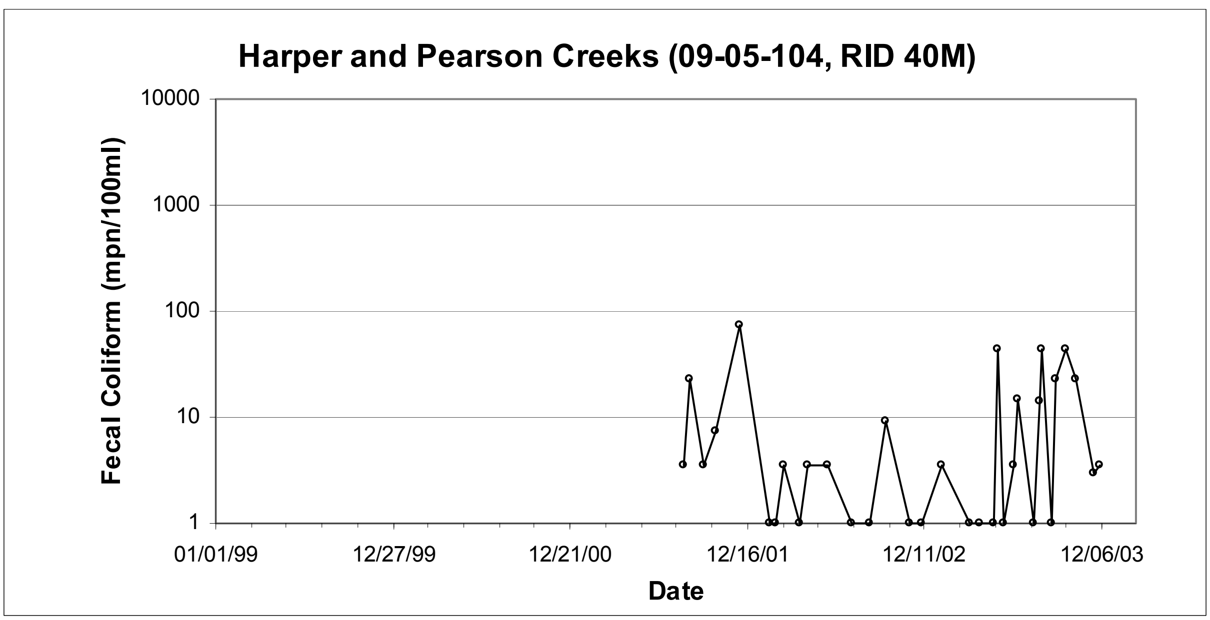

Figure 2.2.20: Observed Fecal Coliform Concentrations at Station 09-05-104

Table 2.2.7: Locations of Shellfish Monitoring Stations in Goose Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	Distance from the Mouth of the Patuxent River	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
11-05-101	2001-2003	33	3.62 km	38 17 30.4	76 22 46.5
11-05-102	2001-2003	33	3.51 km	38 17 34.0	76 22 48.5
11-05-103	2001-2003	33	3.09 km	38 17 32.7	76 23 18.1

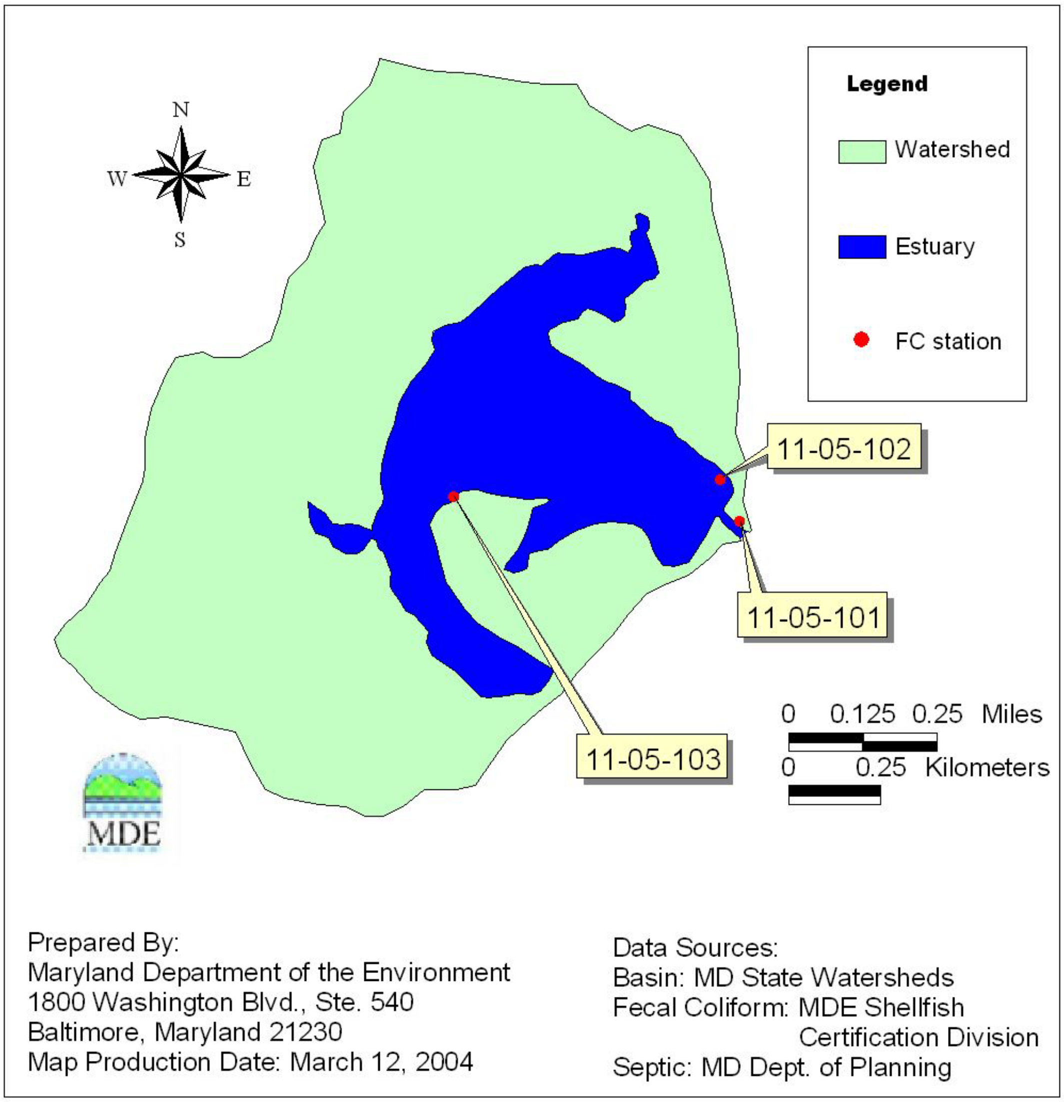

Figure 2.2.21: Shellfish Monitoring Stations in Goose Creek

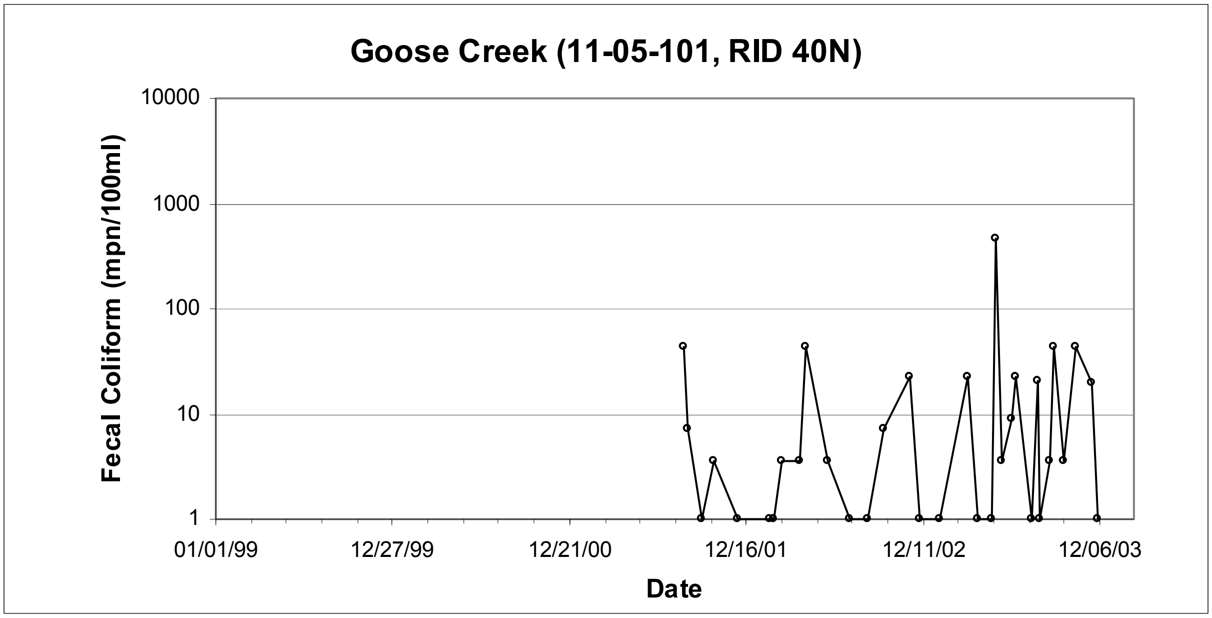

Figure 2.2.22: Observed Fecal Coliform Concentrations at Station 11-05-101

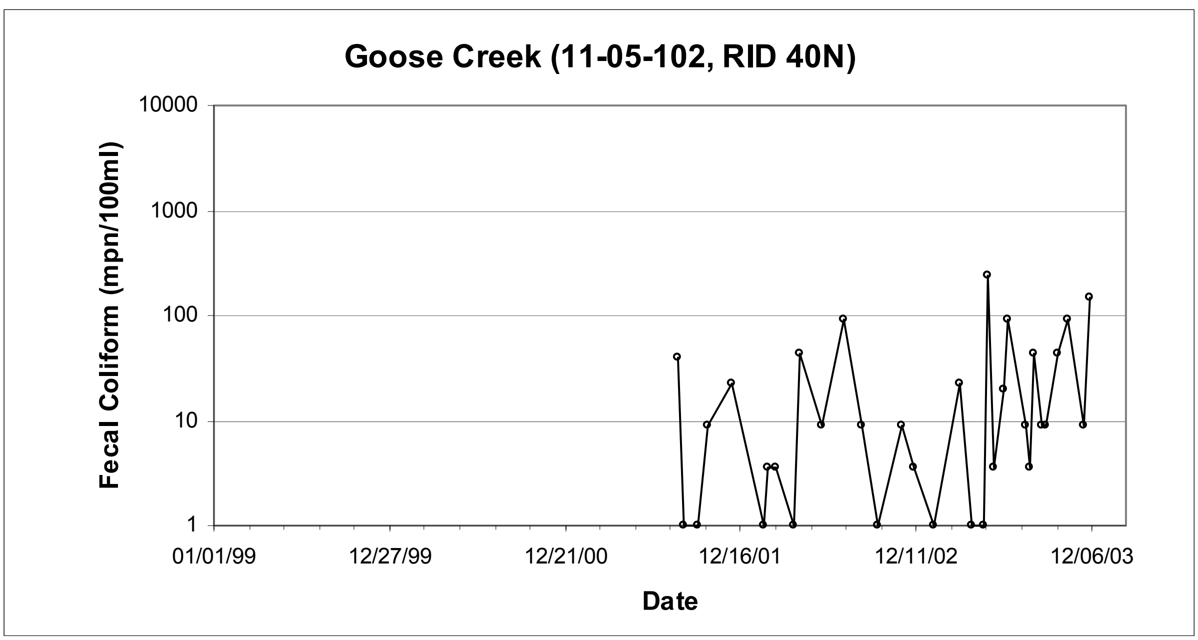

Figure 2.2.23: Observed Fecal Coliform Concentrations at Station 11-05-102

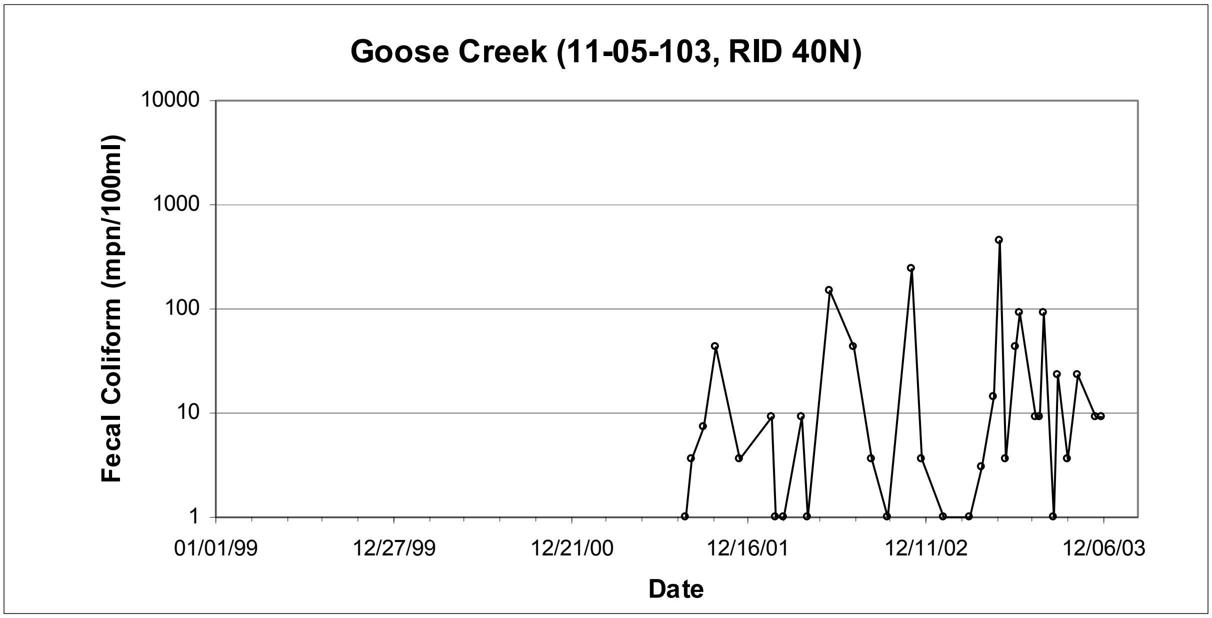

Figure 2.2.24: Observed Fecal Coliform Concentrations at Station 11-05-103

Table 2.2.8: Location of Shellfish Monitoring Station in Indian Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	Distance from the Mouth of the Patuxent River	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
09-01-013	1999-2003	47	31.27 km	38 29 43.0	76 41 2.0

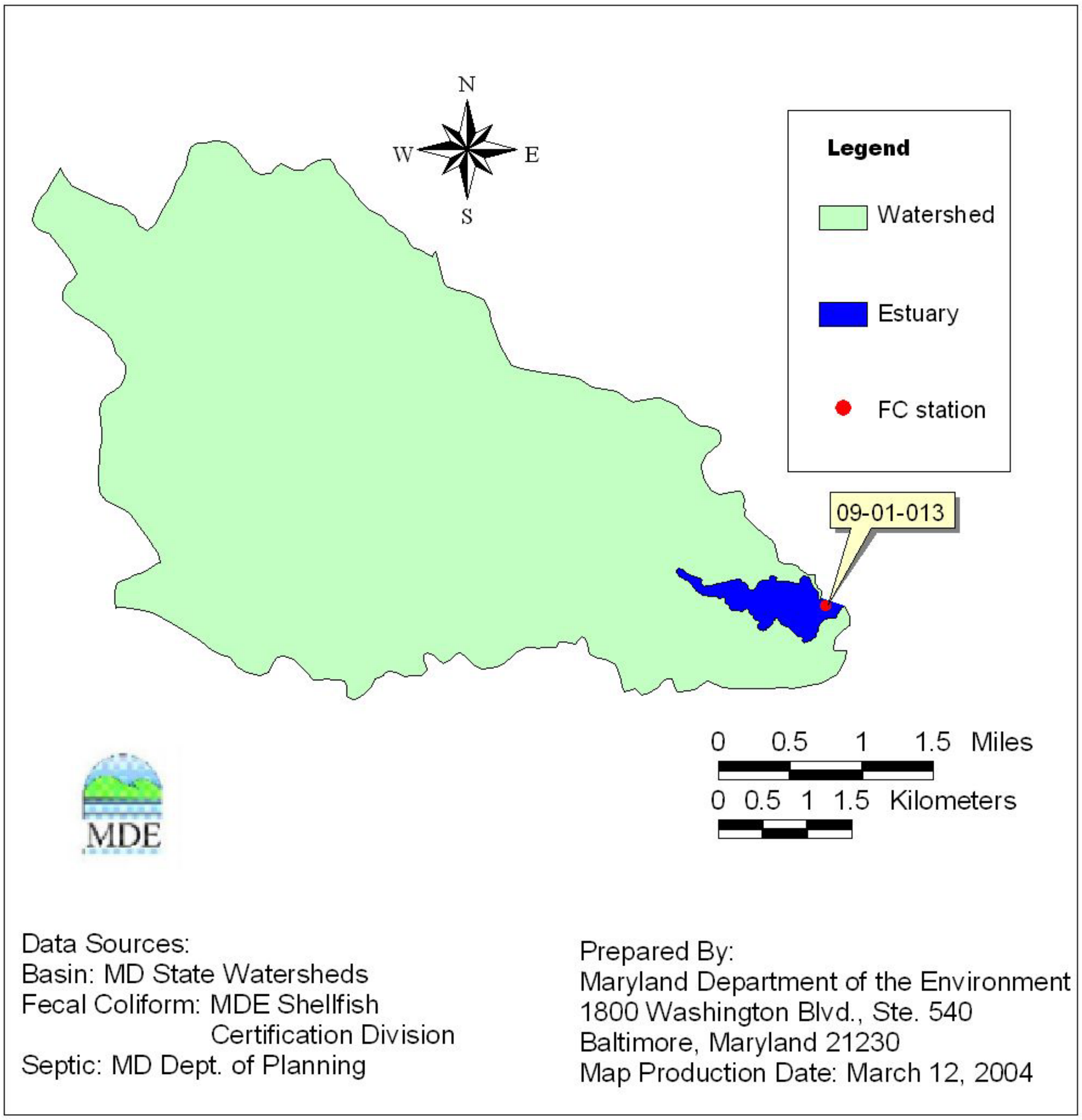

Figure 2.2.25: Shellfish Monitoring Stations in Indian Creek

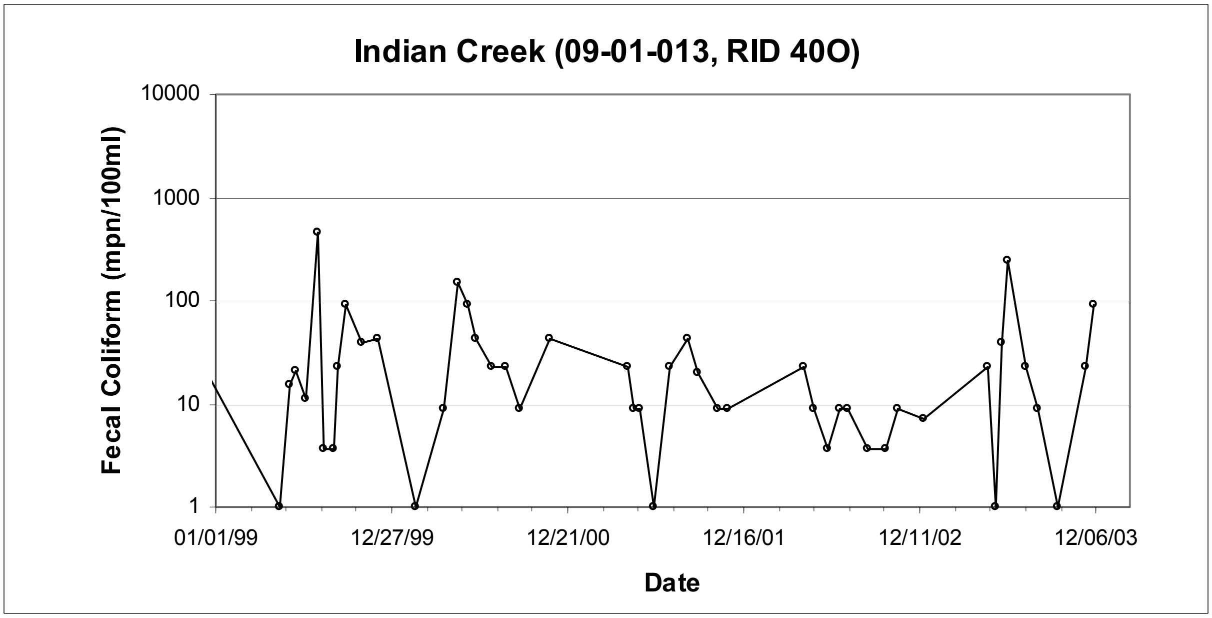

Figure 2.2.26: Observed Fecal Coliform Concentrations at Station 09-01-013

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 26.08.02.08L). The Lower Patuxent River (basin number 02-13-11-01) has been included on the draft 2004 Integrated 303(d) List as impaired for fecal coliform. These restricted shellfish harvesting areas, located along the northeast and southwest shorelines of the Lower Patuxent River, are identified as the areas in this basin that do not meet shellfish water quality standards. Waters within this classification, according to the Code of Maryland Regulation (COMAR) Section 26.08.02.03-3C (criteria for Use II waters - shellfish harvesting) **"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 90th 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 window.

The water quality impairment was assessed based on the most recent five-year median and 90th percentile concentrations. Descriptive statistics of the monitoring data and the water quality criterion are shown in Table 2.3.1.

Table 2.3.1: Lower Patuxent River Shellfish Monitoring Stations (1999-2003) - Median and 90th Percentile Values for Most Recent Five Years

RID	Area Name	Station	Median		90th Percentile	
			Monitoring Data	Criterion	Monitoring Data	Criterion
			MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
40B	Island Creek	09-02-109	15.0	14	106.2	49
		09-02-020A	3.6	14	52.8	49
40E	Town Creek	09-04-007	9.1	14	74.6	49
		09-04-300	15.0	14	111.8	49
40F	Battle Creek	09-02-105D	3.6	14	28.8	49
		09-02-107A	9.1	14	43.9	49
40H	Trent Hall Creek	09-01-101A	9.1	14	150.1	49
40L	St. Thomas Creek	09-02-022	14.5	14	88.5	49
		09-02-023	23.0	14	146.5	49
		09-02-023F	43.0	14	285.2	49
40M	Harper and Pearson Creeks	09-05-101	9.1	14	67.2	49
		09-05-102	9.1	14	47.8	49
		09-05-103	9.1	14	43.6	49
		09-05-104	3.6	14	24.6	49
40N	Goose Creek	11-05-101	3.6	14	38.7	49
		11-05-102	9.1	14	76.5	49
		11-05-103	9.1	14	79.1	49
40O	Indian Creek	09-01-013	15.0	14	87.4	49

Results from this analysis indicate that water quality impairments are demonstrated in all restricted shellfish harvesting areas except Battle Creek. Bacteria water quality criteria, determined from the designated use, is being met in Battle Creek; therefore, TMDLs of fecal coliform are not necessary to achieve water quality standards in this watershed. Barring the receipt of any contradictory data, this report will be used to support the bacteria listing change for Battle Creek from Category 5 ("waterbodies impaired by one or more pollutants and requiring a TMDL") to Category 6 ("waterbodies that have been de-listed or removed from the list") when MDE proposes the revision of Maryland's 303(d) list for public review in the future. The remainder of this document will focus solely on the remaining seven restricted shellfish harvesting areas for which water quality impairments are demonstrated (Island Creek, Town

Creek, Trent Hall Creek, St. Thomas Creek, Harper and Pearson Creeks, Goose Creek and Indian Creek).

2.4 Source Assessment

Nonpoint Source Assessment

Nonpoint sources of fecal coliform 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 area. The possible introductions of fecal coliform 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 harvesting 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 2.4.7, 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 Island Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	4.57E+11	39.4%
Pets	2.24E+11	19.3%
Human	1.34E+10	1.2%
Wildlife	4.65E+11	40.1%
Total	1.16E+12	100.0%

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

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	2.40E+11	62.0%
Human	1.53E+10	4.0%
Wildlife	1.32E+11	34.0%
Total	3.87E+11	100.0%

Table 2.4.3: Distribution of Fecal Coliform Source Loads in the Trent Hall Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	2.70E+12	61.6%
Pets	5.57E+11	12.7%
Human	5.31E+10	1.2%
Wildlife	1.07E+12	24.5%
Total	4.37E+12	100.0%

Table 2.4.4: Distribution of Fecal Coliform Source Loads in the St. Thomas Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	1.17E+11	24.4%
Pets	1.23E+11	25.5%
Human	7.48E+09	1.5%
Wildlife	2.34E+11	48.6%
Total	4.81E+11	100.0%

Table 2.4.5: Distribution of Fecal Coliform Source Loads in the Harper and Pearson Creeks Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	2.83E+09	2.0%
Human	0.00E+00	0.0%
Wildlife	1.40E+11	98.0%
Total	1.43E+11	100.0%

Table 2.4.6: Distribution of Fecal Coliform Source Loads in the Goose Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	1.15E+09	1.6%
Human	0.00E+00	0.0%
Wildlife	7.16E+10	98.4%
Total	7.29E+10	100.0%

Table 2.4.7: Distribution of Fecal Coliform Source Loads in Indian Creek

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	2.99E+12	64.7%
Pets	5.94E+11	12.9%
Human	3.79E+10	0.8%
Wildlife	9.98E+11	21.6%
Total	4.62E+12	100.0%

Point Source Assessment

There are no permitted point source facilities discharging directly into any of the restricted shellfish harvesting 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 Island Creek, Town Creek, Trent Hall Creek, St. Thomas Creek, Harper and Pearson Creeks, Goose Creek and Indian Creek in the Lower Patuxent River. 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 the Lower Patuxent River. 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 CFR 130.2(i)). It is also important to note that the TMDLs presented herein are not literal daily limits. These loads are based on an averaging period that is defined by the water quality criteria (i.e. 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 window of data. 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 embayment 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 embayment. A detailed description of the model is presented in Appendix A.

The most recent five-year median and 90th percentile 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):

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

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) Cf = the unit conversion factor
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 embayments (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 0.3-0.8; 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's basin) to derive estimates of the long-term flows. Freshwater flows are listed in Table 4.2.1.

Table 4.2.1: Drainage Areas and Long Term Flows in the Lower Patuxent River Basin

Restricted Shellfish Harvesting Area (RID)	Drainage Area in Acres	Average Long-Term Flow in cfs
Island Creek (40B)	3,279.8	4.01
Town Creek (40E)	823.5	1.03
Trent Hall Creek (40H)	8,350.5	9.84
St. Thomas Creek (40L)	1,449.6	1.78
Harper and Pearson Creeks (40M)	900.0	1.25
Goose Creek (40N)	427.6	0.69
Indian Creek (40O)	7,853.7	9.27

4.3 Critical Condition and Seasonality

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

The 90th percentile concentration is the concentration exceeded only 10% of the time. Since data collected during the most recent five-year period was used to calculate 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 and the 90th percentile values with the water quality criteria determines which value 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. However, 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 load analyses, the most recent five-year window of monitoring data (at least 30 samples), specifically fecal coliform concentrations(i.e., C) were used to estimate the current loads. This was conducted for median and for 90th percentile conditions. In an area having two or more stations, 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. For those restricted shellfish harvesting areas where only one sampling station was available, its median and 90th percentile value served as both the restricted shellfish harvesting area concentration and boundary condition.

The allowable load is calculated using the water quality criteria of a median of 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 Tables 4-1 and 4-2.

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

Area	Mean Volume (m^3)	Fecal Coliform Conc. Median (MPN/100mL)	Decay Rate Per Tidal Cycle	Estimated Residence Time (day)	Current Load (Counts/day)	Allowable Load (counts/day)	Required Percent Reduction (%)
Island Creek	1,090,403	15.0	0.36	3.0	1.559E+11	1.076E+11	30.99
Town Creek	384,809	15.0	0.36	3.0	4.787E+10	3.783E+10	20.98
Trent Hall Creek	378,620	9.1	0.36	1.2	2.616E+10	4.024E+10	0.00
St. Thomas Creek	458,794	23.0	0.36	2.5	8.944E+10	4.529E+10	49.36
Harper and Pearson Creeks	848,873	9.1	0.36	2.4	7.362E+10	8.31E+10	0.00
Goose Creek	531,620	9.1	0.36	1.6	5.159E+10	5.201E+10	0.00
Indian Creek	397,473	15.0	0.36	1.2	4.488E+10	4.188E+10	6.67

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

Area	Mean Volume (m^3)	Fecal Coliform Conc. Median (MPN/100mL)	Decay Rate Per Tidal Cycle	Estimated Residence Time (day)	Current Load (Counts/day)	Allowable Load (counts/day)	Required Percent Reduction (%)
Island Creek	1,090,403	106.2	0.36	3.0	1.006E+12	3.765E+11	62.58
Town Creek	384,809	111.8	0.36	3.0	3.483E+11	1.324E+11	61.99
Trent Hall Creek	378,620	150.1	0.36	1.2	4.313E+11	1.409E+11	67.34
St. Thomas Creek	458,794	146.5	0.36	2.5	5.767E+11	1.585E+11	72.51
Harper and Pearson Creeks	848,873	67.2	0.36	2.4	5.510E+11	2.909E+11	47.21
Goose Creek	531,620	79.1	0.36	1.6	4.246E+11	1.820E+11	57.12
Indian Creek	397,473	87.4	0.36	1.2	2.615E+11	1.466E+11	43.94

4.5 TMDL Loading Caps

This section presents the TMDL for the median and the 90th percentile conditions. Seasonal variability is addressed implicitly through the interpretation of the water quality standards. The TMDLs for restricted shellfish harvesting areas of the Lower Patuxent River are as follows:

Island Creek:
The median load of fecal coliform TMDL = 1.08×10^{11} counts per day
The 90th percentile of fecal coliform TMDL = 3.77×10^{11} counts per day

Town Creek:
The median load of fecal coliform TMDL = 3.78×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.32×10^{11} counts per day

Trent Hall Creek:
The median load of fecal coliform TMDL = 4.02×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.41×10^{11} counts per day

St. Thomas Creek:
The median load of fecal coliform TMDL = 4.53×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 1.59×10^{11} counts per day

Harper and Pearson Creeks:
The median load of fecal coliform TMDL = 8.31×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 2.91×10^{11} counts per day

Goose Creek:
The median load of fecal coliform TMDL = 5.20×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 1.82×10^{11} counts per day

Indian Creek:
The median load of fecal coliform TMDL = 4.19×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 1.47×10^{11} counts per day

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

4.6 Load Allocation

The allocations below demonstrate how the TMDLs could 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 reduced 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 Load)	Required Reduction[1]	TMDL Load Allocation (% of Total Load)
Island Creek				
40B	Total	100.0%	62.6%	100.0%
	Wildlife	40.1%	14.1%	92.0%
	Human	1.2%	95.0%	0.1%
	Pets	19.3%	95.0%	2.6%
	Livestock	39.4%	95.0%	5.3%
Town Creek				
40E	Total	100.0%	62.0%	100.0%
	Wildlife	34.0%	0.0%	89.6%
	Human	4.0%	94.0%	0.6%
	Pets	62.0%	94.0%	9.8%
	Livestock	0.0%	0.0%	0.0%
Trent Hall Creek				
40H	Total	100.0%	67.3%	100.0%
	Wildlife	24.5%	0.0%	75.0%
	Human	1.2%	89.2%	0.4%
	Pets	12.7%	89.2%	4.2%
	Livestock	61.6%	89.2%	20.4%
St. Thomas Creek				
40L	Total	100.0%	72.5%	100.0%
	Wildlife	48.6%	48.7%	90.6%
	Human	1.5%	95.0%	0.4%
	Pets	25.5%	95.0%	4.6%
	Livestock	24.4%	95.0%	4.4%
Harper and Pearson Creeks				
40M	Total	100.0%	47.2%	100.0%
	Wildlife	98.0%	46.2%	99.8%
	Human	0.0%	0.0%	0.0%
	Pets	2.0%	95.0%	0.2%
	Livestock	0.0%	0.0%	0.0%

Goose Creek				
40N	Total	100.0%	57.1%	100.0%
	Wildlife	98.4%	56.5%	99.8%
	Human	0.0%	0.0%	0.0%
	Pets	1.6%	95.0%	0.2%
	Livestock	0.0%	0.0%	0.0%
Indian Creek				
40O	Total	100.0%	50.3%	100.0%
	Wildlife	21.6%	0.0%	43.4%
	Human	0.8%	64.1%	0.7%
	Pets	12.9%	64.1%	9.3%
	Livestock	64.7%	64.1%	46.6%

[1]Reduction based on critical condition

Stormwater

In November 2002, EPA advised States that NPDES-regulated storm water discharges must be addressed by the wasteload allocation (WLA) component of a TMDL. See 40CFR130.2(h). NPDES-regulated storm water discharges may not be addressed by the load allocation (LA), the nonpoint source component of a TMDL.

Current stormwater Phase I general Municipal Separate Stormwater System (MS4) permits and new stormwater Phase II general MS4 permits will be considered point sources subject to WLA assignment in the TMDL. Currently the MDE issues general MS4 permits at the County scale. Determination of watershed areas that are affected by the permits are based on definitions listed in 40CFR122.26. The MS4 is defined at 40CFR 122.26(b)(8) as "a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains)". The outfall from MS4 is defined in 40CFR 122.26(b)(9) as "a point source at the point where a municipal separate storm sewer discharges to waters of the United States".

As per the definition of the permitted watershed areas, it is assumed that all areas defined with a Maryland Department of Planning urban land use code are to be included in the WLA of the TMDL. Therefore, the stormwater WLA is expressed as a gross allotment, rather than individual allocations for separate pipes, ditches, gutters, etc. Estimating a load contribution to a particular waterbody from the stormwater Phase I and II sources is imprecise, given the variability in sources, runoff volumes, and pollutant loads over time. Therefore, the stormwater WLA portion of a TMDL is based on an estimate.

For bacteria sources, this load estimation is confounded by wildlife distribution because of uncertainty with location of the habitat areas within the watershed. Additionally, pet contribution can be highly variable with implementation solutions more directed toward public education. Considering these issues in source estimation, it was determined that the MS4 bacteria WLA would be estimated based on uniform loads from all land use classifications. Therefore, the WLA for the MS4 area is estimated based on the proportion of urban land within the permitted County in the watershed. To estimate this load, the load from diffuse sources (L_D) is multiplied by the proportion of urban land and the resulting value is assigned to the WLA for the MS4 area.

$WLA_i = L_D*ULU_i$
where
WLA_i = MS4 stormwater load for jurisdiction i
L_D = Load from diffuse sources to retricted shellfish area, including stormwater
ULU_i = Percentage of urban land use within jurisdiction i

The Indian Creek watershed, located in the Lower Patuxent River basin, is in both Charles and St. Mary's County. Charles County is a Phase I - Medium MS4 permitted jurisdiction. The total percentage of urban land within the Charles County portion of the watershed is 10.6% with the majority of the land use classified as low density residential. Since there are no other permitted point sources within the Indian Creek watershed, the load allocated to the Charles County MS4 permitted areas is calculated as 10.6% of the TMDL. Details of the calculations can be found in Appendix C.

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
Island Creek	1.08×10^{11}	=	1.08×10^{11}	+	N/A	+	N/A	+	Implicit
Town Creek	3.78×10^{10}	=	3.78×10^{10}	+	N/A	+	N/A	+	Implicit
Trent Hall Creek	4.02×10^{10}	=	4.02×10^{10}	+	N/A	+	N/A	+	Implicit
St. Thomas Creek	4.53×10^{10}	=	4.53×10^{10}	+	N/A	+	N/A	+	Implicit
Harper and Pearson Creeks	8.31×10^{10}	=	8.31×10^{10}	+	N/A	+	N/A	+	Implicit
Goose Creek	5.20×10^{10}	=	5.20×10^{10}	+	N/A	+	N/A	+	Implicit
Indian Creek	4.19×10^{10}	=	3.75×10^{10}	+	$4.41\text{x}10^{9}$	+	N/A	+	Implicit

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Island Creek	3.77×10^{11}	=	3.77×10^{11}	+	N/A	+	N/A	+	Implicit
Town Creek	1.32×10^{11}	=	1.32×10^{11}	+	N/A	+	N/A	+	Implicit
Trent Hall Creek	1.41×10^{11}	=	1.41×10^{11}	+	N/A	+	N/A	+	Implicit
St. Thomas Creek	1.59×10^{11}	=	1.59×10^{11}	+	N/A	+	N/A	+	Implicit
Harper and Pearson Creeks	2.91×10^{11}	=	2.91×10^{11}	+	N/A	+	N/A	+	Implicit
Goose Creek	1.82×10^{11}	=	1.82×10^{11}	+	N/A	+	N/A	+	Implicit
Indian Creek	1.47×10^{11}	=	1.31×10^{11}	+	$1.56\text{x}10^{10}$	+	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 Pollution Discharge Elimination System (NPDES) permitting activities such as concentrated 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.

In 1983, the EPA Nationwide Urban Runoff Program, found that stormwater runoff from urban areas contains the same general types of pollutants found in wastewater, and that 30% of identified cases of water quality impairment were attributable to stormwater discharges. As a result of this information, EPA began in November 1990 requiring jurisdictions with a population greater than 100,000 to apply for NPDES Permits (MS4) for stormwater discharges. These jurisdiction-wide programs are designed to control stormwater discharges to the maximum extent practicable. Indian Creek watershed is within Charles County, an NPDES MS4 permitted jurisdiction. As part of the NPDES permit Charles County has initiated programs in education and outreach regarding pet waste issues, identification of illicit discharges and septic system management, all of which will be effective is reducing bacteria loads to the estuary.

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 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 an option for state and local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

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 being 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 25, 2004 to September 23, 2004, during which the document was placed in the Calvert County Library, Charles County Library, St. Mary's County Library, MDE's website and notices were published in the St. Mary's Enterprise, the Maryland Independent and the Calvert County Recorder. Following the public comment period, comments will be reviewed and addressed through a comment response document. The documents will then submitted to EPA Region III at which time stakeholders will be notified of this action. Once the document is approved by EPA Region III, stakeholders will be notified of the action and the finalized document will be 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 water body, and that the pollutant is well mixed in the water body 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:

$$Load_T = C_c(Q_b + kV) - Q_0 C_0 \quad (6)$$

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:

$$Load = Load_T \times \frac{24}{12.42} \times 10000 \quad (7)$$

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:

$$Q_0 = \beta Q_T \quad (8)$$

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):

$$\beta = \frac{S_f - S_e}{S_0 - S_e} \quad (9)$$

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:

$$T_L = \frac{V_b}{Q_b} \quad (10)$$

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. It can be shown that 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).

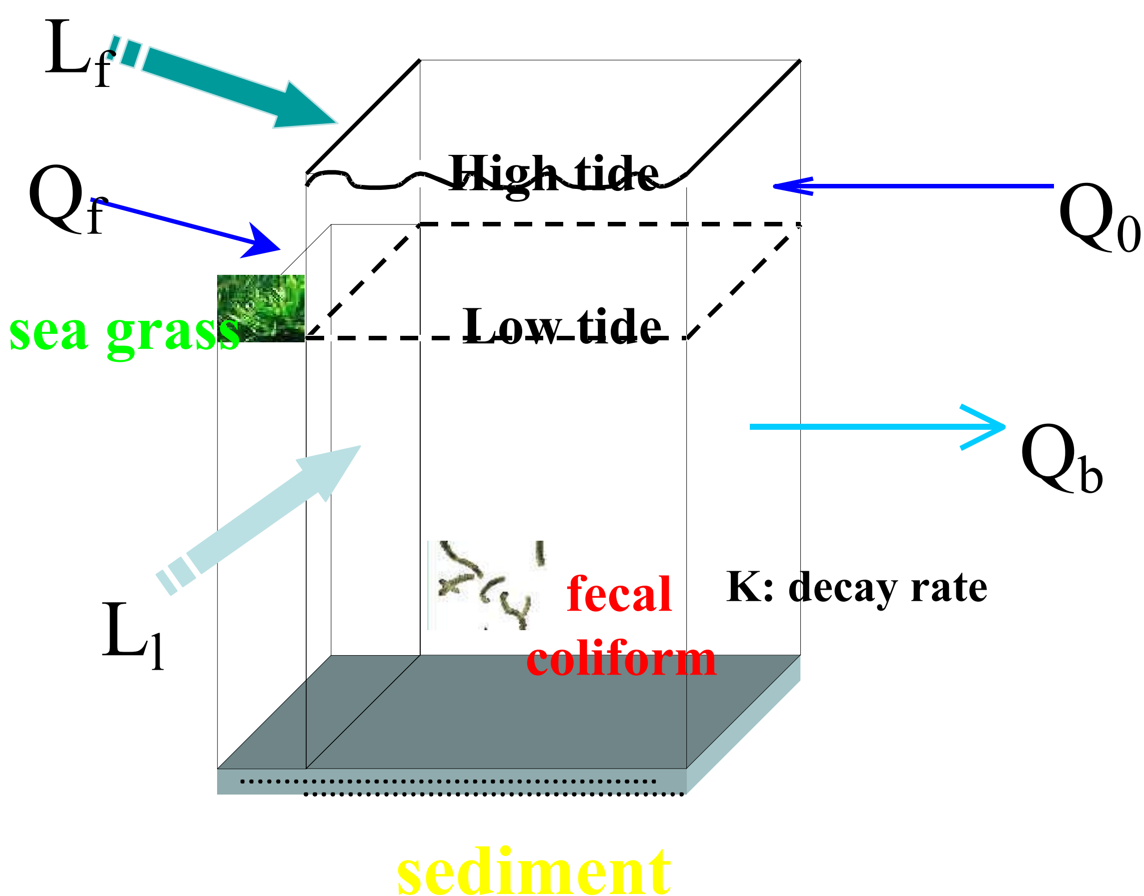

Figure A-1: The schematic diagram for the tidal prism model

A Tidal Prism Model Calculation for Town Creek (RID 40E)

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 = 384809.2(m^3)
k = Fecal coliform decay rate =0.36(T^{-1})
Q_f = Freshwater discharge
= 1.0274 cfs = 1.0274 × 0.0283×86400×12.42÷24 = 1300.0 (m^3T^{-1})
Q_0 = 64409.2 (m^3T^{-1})
Q_b = 65709.2 (m^3 T^{-1})
C_c = water quality criterion = 14 MPN/100ml
C = current fecal coliform 5-year median concentration = 15 (MPN/100ml)
C_0 = fecal coliform 5-year median outside of the embayment = 9.1 (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 as well. The allowable load is calculated as follows:

Allowable Load =

$$Load = [C_c \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$

= [14× (65709.2 +0.36×384809.2) - 64409.2× 14] ×24÷12.42×10000
=3.783×10^{10}

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

Current condition =

$$Load = [C \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$

[(15) × (65709.2 +0.36×384809.2) - 64409.2 × (9.1)] ×24÷12.42×10000
=4.787×10^{10}

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{4.787\times10^{10} - 3.783\times10^{10}}{4.787\times10^{10}} = 20.98\%$$

A Tidal Prism Model Calculation for Town Creek (con't.)

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 = 384809.2(m^3)
k = Fecal coliform decay rate =0.36(T^{-1})
Q_f = Freshwater discharge
= 1.0274 cfs = 1.0274 × 0.0283×86400×12.42÷24 = 1300.0 (m^3T^{-1})
Q_0 = 64409.2 (m^3T^{-1})
Q_b = 65709.2 (m^3 T^{-1})
C_c = water quality criterion = 49 MPN/100ml
C = current fecal coliform 5-year 90th percentile concentration = 111.78 (MPN/100ml)
C_0 = fecal coliform 5-year 90th percentile at the outside of the embayment
= 74.59 (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 uses 49 MPN/100ml as well. The allowable load is calculated as follows:

Allowable Load =
$$Load = [C_c \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$
= [49× (65709.2 +0.36×384809.2) - 64409.2× 49] ×24÷12.42×10000
=1.324×10^{11}

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 =
$$Load = [C \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$
[(111.78) × (65709.2 +0.36×384809.2) - 64409.2 × (74.59)] ×24÷12.42×10000
=3.483×10^{11}

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{3.483\times10^{11} - 1.324\times10^{11}}{3.483\times10^{11}} = 61.99\%$$

Sample calculations load reductions for both the median and 90th percentiles have been presented for the first site in this report (i.e., RID 16A1). The following table lists the parameter values needed for these calculations at all other sites 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 harvesting area

RID	Area Name	V	k	Q_f	Q_0	Q_b	Median		90th Percentile	
							C	C_0	C	C_0
40B	Island Creek	1,090,402.5	0.36	5,086.7	184,402.5	189,489.2	15	3.6	106.18	52.81
40E	Town Creek	384,809.2	0.36	1,300.0	64,409.2	65,709.2	15	9.1	111.78	74.59
40H	Trent Hall Creek	378,620.4	0.36	12,456.7	151,730.4	164,187.0	9.1	9.1	150.05	150.05
40L	St. Thomas Creek	458,793.8	0.36	2,256.8	91,503.8	93,760.6	23	14.5	146.53	88.49
40M	Harper and Pearson Creeks	848,872.5	0.36	1,585.9	184,402.5	185,988.5	9.1	3.6	67.24	24.63
40N	Goose Creek	531,619.6	0.36	869.0	167,299.6	168,168.6	9.1	3.6	79.09	38.65
40O	Indian Creek	397,472.7	0.36	11,732.8	154,652.7	166,385.5	15	15	87.41	87.41

The values attained using the sample calculation are listed below:

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

RID	Area Name	Median			90th Percentile		
		Allowable Load	Current Load	Percent Reduction	Allowable Load	Current Load	Percent Reduction
		counts/day	counts/day		counts/day	counts/day	
40B	Island Creek	1.076E+11	1.559E+11	30.99	3.765E+11	1.006E+12	62.58
40E	Town Creek	3.783E+10	4.787E+10	20.98	1.324E+11	3.483E+11	61.99
40H	Trent Hall Creek	4.024E+10	2.616E+10	0.00	1.409E+11	4.313E+11	67.34
40L	St. Thomas Creek	4.529E+10	8.944E+10	49.36	1.585E+11	5.767E+11	72.51
40M	Harper and Pearson Creeks	8.31E+10	7.362E+10	0.00	2.909E+11	5.510E+11	47.21
40N	Goose Creek	5.201E+10	5.159E+10	0.00	1.820E+11	4.246E+11	57.12
40O	Indian Creek	4.188E+10	4.488E+10	6.67	1.466E+11	2.615E+11	43.94

Appendix B

Nonpoint Source Assessment

Nonpoint sources of fecal coliform 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 area. The possible introductions of fecal coliform 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 harvesting 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 Lower Patuxent River 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 harvesting areas in the Lower Patuxent River 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-4.8.1: 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 listed in Table B-2.

Table B-4.8.2: 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 because 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-4.8.3: 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 harvesting areas. Since the majority of the area near the receiving waters consists of low-lying, poorly drained land, 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 and the number of households were estimated from the GIS 2000 Census Block that includes watersheds of the Lower Patuxent River. Since the subwatersheds throughout the Lower Patuxent River 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-4.8.4: Proportional Population, Households, Septic Systems and Sewer Coverage in the Lower Patuxent

RID	Area Name	Proportional Population	Proportional Septic Systems	Proportional Households	Public Sewer
40B	Island Creek	1,014	488	475	No
40E	Town Creek	1,158	498	509	No
40H	Trent Hall Creek	3,640	1,600	1,181	Partial
40L	St. Thomas Creek	565	261	261	No
40M	Harper and Pearson Creeks	16	0	6	Partial
40N	Goose Creek	9	0	3	Partial
40O	Indian Creek	3,790	1,580	1,259	Partial

The distributions of septic systems in five of the identified restricted shellfish harvesting areas of the Lower Patuxent River are shown in Figures B-1 to B-5. From the GIS property coverage two watersheds, Harper and Pearsons Creeks and Goose Creek, resulted in zero septic systems identified. Based on GIS property coverage, a point is assumed to represent a septic system. The Goose Creek and Harper and Pearson Creeks watersheds are totally within Patuxent Naval Air Station whose land use is classified as non-residential urban which do not contribute fecal coliform from human, and both areas are served by the Marley-Taylor WWTP in St. Mary's county. The discharging point of this point source is located outside the areas addressed in this report. The total number of septic systems in each reported basin is shown in Table B-4. According to GIS coverage, a small portion of the Trent Hall and Indian Creek restricted shellfish harvesting area watersheds have public sewer systems.

It is assumed that the human contribution is attributed to septic systems. The human contribution to the restricted shellfish harvesting 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 Patuxent watershed and other watersheds, an estimated failing rate of 5% 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. If no septic system data are available, the estimated number of households is used as the number of septic systems. The estimated load due to failures of septic systems is less than 2%.

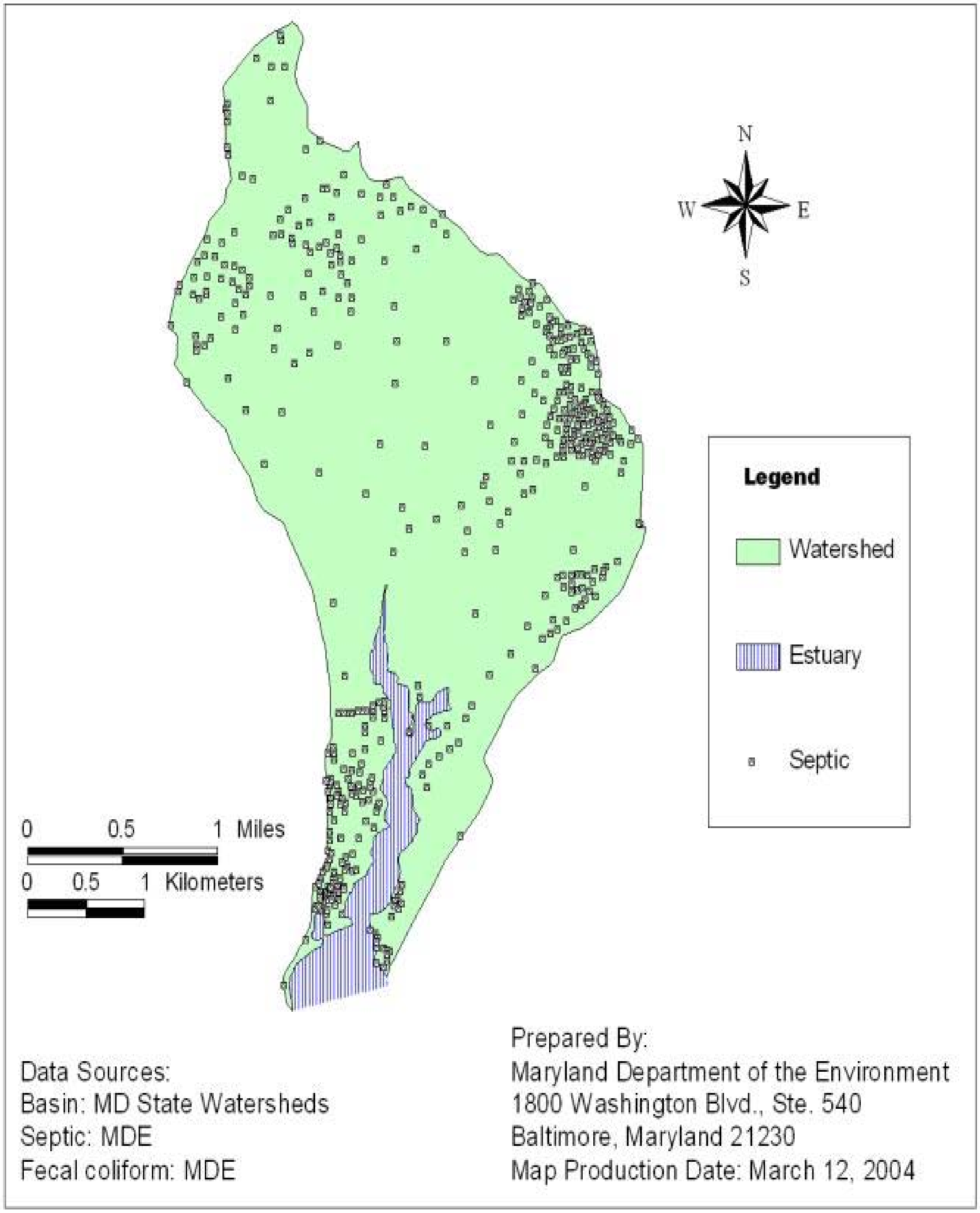

Figure B-4.8.1: Distribution of Septic Systems in the Island Creek Basin

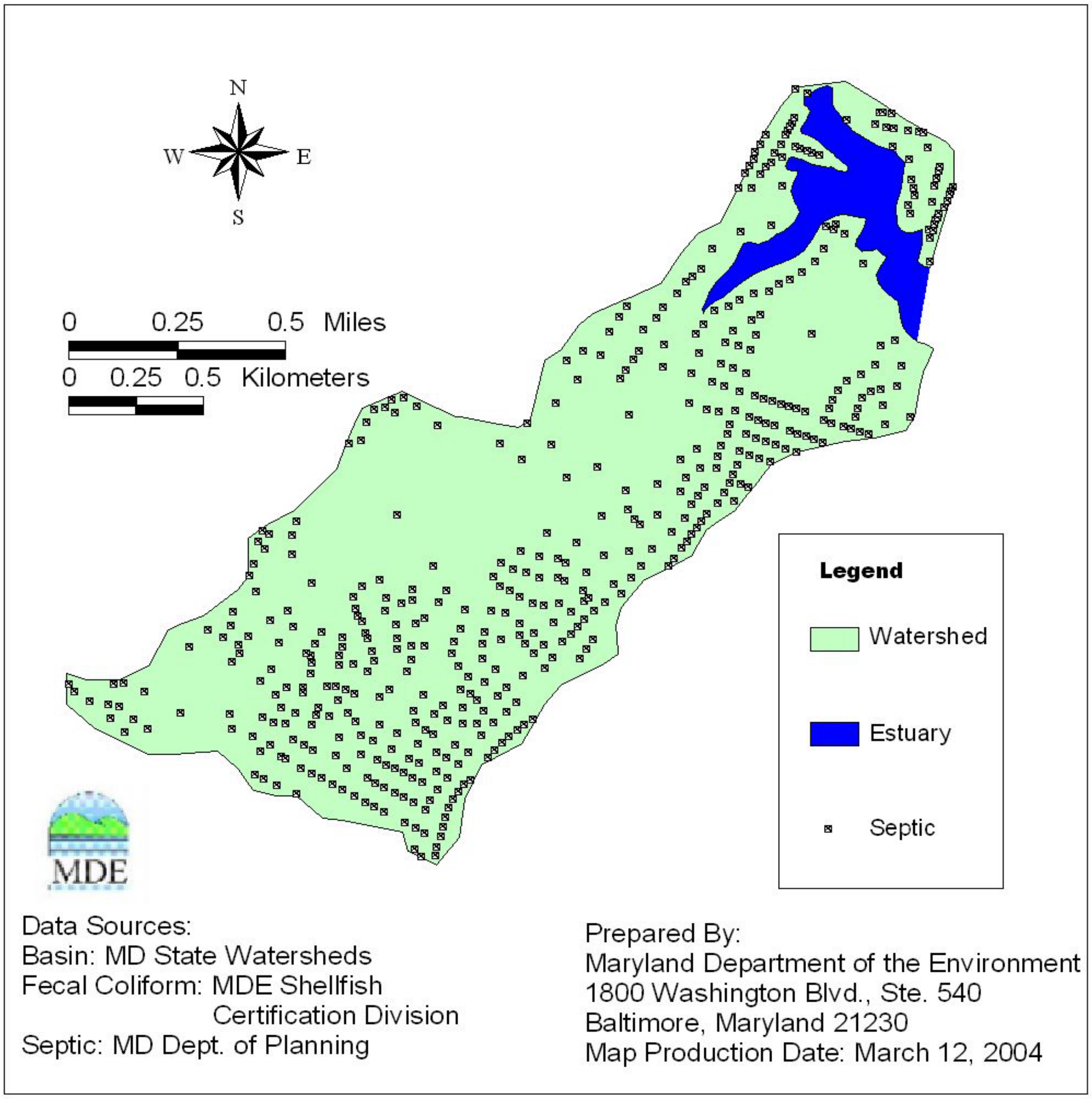

Figure B-4.8.2: Distribution of Septic Systems in the Town Creek Basin

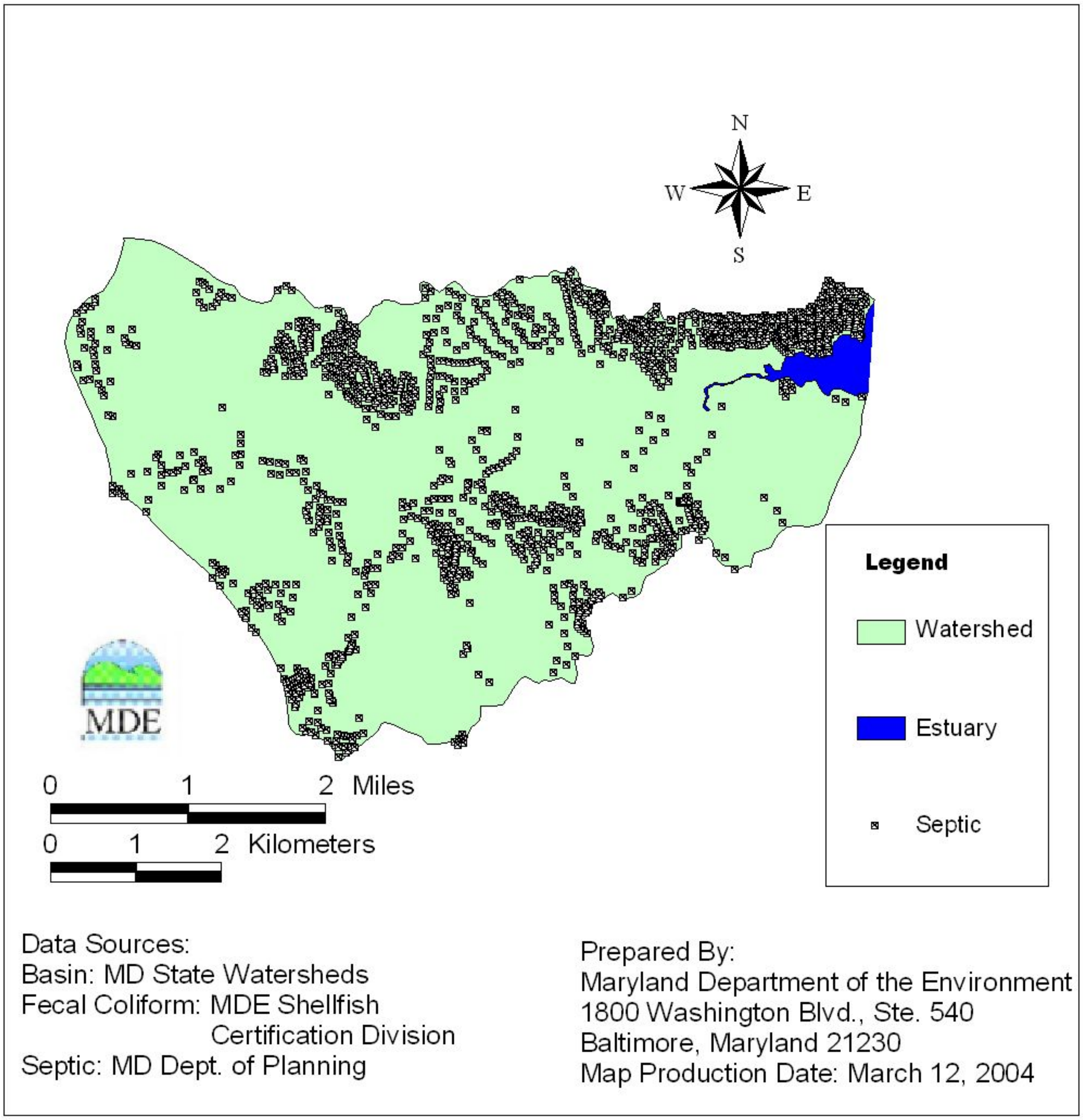

Figure B-4.8.3: Distribution of Septic Systems in the Trent Hall Creek Basin

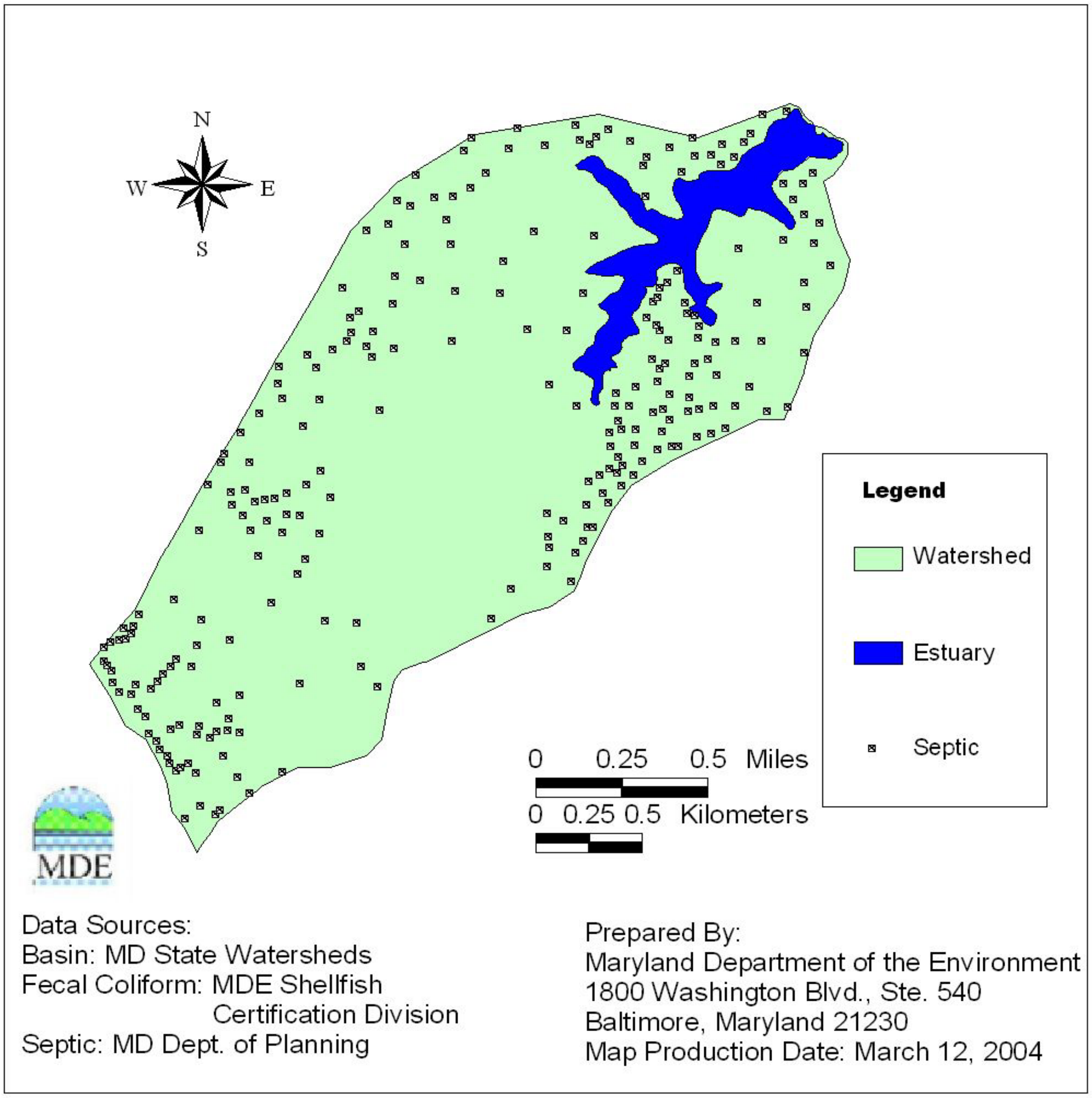

Figure B-4.8.4: Distribution of Septic Systems in the St. Thomas Creek Basin

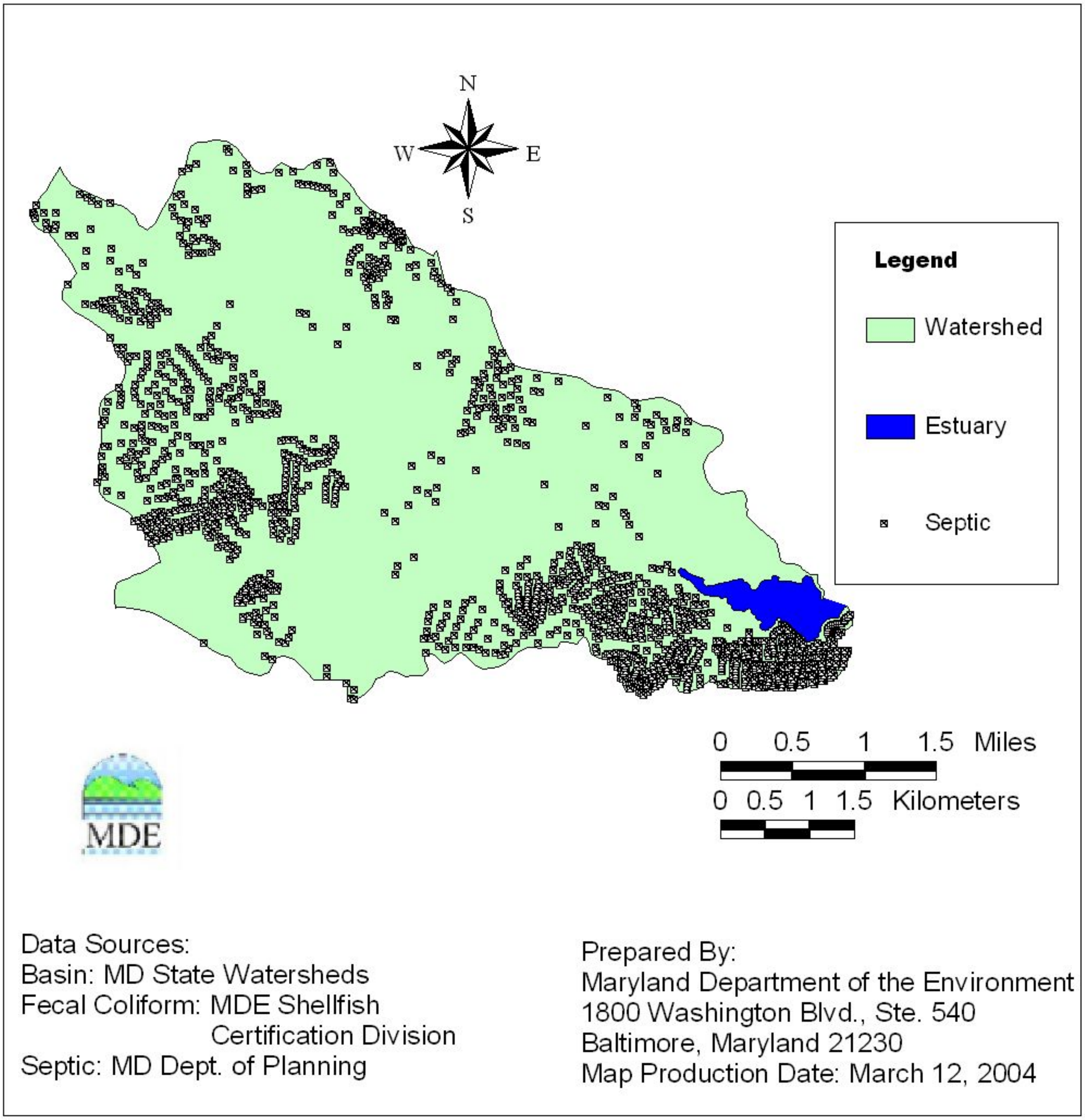

Figure B-4.8.5: Distribution of Septic Systems in the Indian Creek Basin

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 at sites within the Lower Patuxent River 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) (Swann, 1999). 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-6. The fecal coliform load was estimated based on the total number of livestock and the fecal coliform production rates.

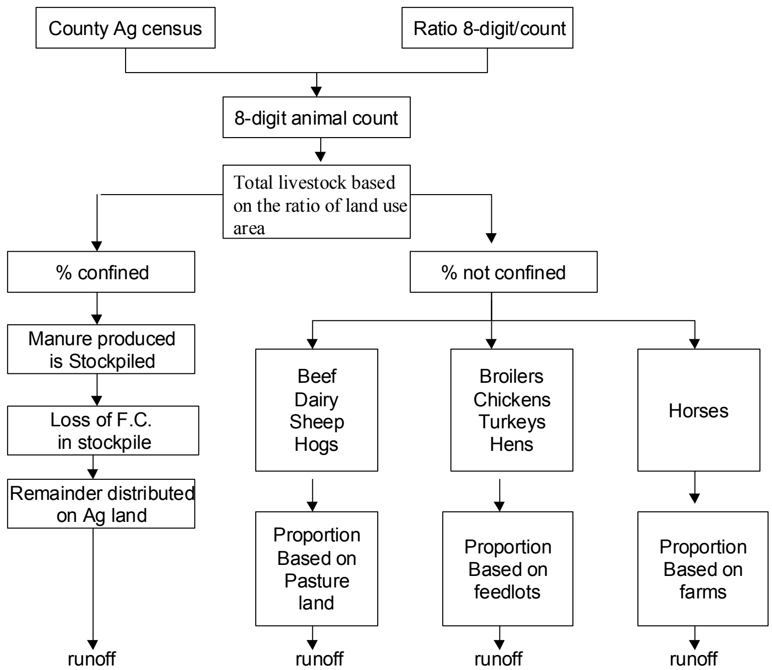

Figure B-4.8.6: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population

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-4.8.5: 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-4.8.6: Percent of Time Livestock is Confined

Livestock	Percent of time confined	Percent Manure Available ForWash 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%

US EPA (1996); Woods (2004)

E. Nonpoint Source Summary

The complete distributions of these source loads are also listed in Tables B-7 to B-13, along with counts/day for each loading. The Bacteria Source Tracking (BST) data will be used to further confirm the source distribution when it becomes available.

Table B-4.8.7: Distribution of Fecal Coliform Source Loads in the Island Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	4.57E+11	39.4%
Pets	2.24E+11	19.3%
Human	1.34E+10	1.2%
Wildlife	4.65E+11	40.1%
Total	1.16E+12	100.0%

Table B-4.8.8: Distribution of Fecal Coliform Source Loads in the Town Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	2.40E+11	62.0%
Human	1.53E+10	4.0%
Wildlife	1.32E+11	34.0%
Total	3.87E+11	100.0%

Table B-4.8.9: Distribution of Fecal Coliform Source Loads in the Trent Hall Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	2.70E+12	61.6%
Pets	5.57E+11	12.7%
Human	5.31E+10	1.2%
Wildlife	1.07E+12	24.5%
Total	4.38E+12	100.0%

Table B-4.8.10: Distribution of Fecal Coliform Source Loads in the St. Thomas Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	1.17E+11	24.4%
Pets	1.23E+11	25.5%
Human	7.48E+09	1.5%
Wildlife	2.34E+11	48.6%
Total	4.81E+11	100.0%

Table B-4.8.11: Distribution of Fecal Coliform Source Loads in the Harper and Pearson Creeks Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	2.83E+09	2.0%
Human	0.00E+00	0.0%
Wildlife	1.40E+11	98.0%
Total	1.43E+11	100.0%

Table B-4.8.12: Distribution of Fecal Coliform Source Loads in the Goose Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	1.15E+09	1.6%
Human	0.00E+00	0.0%
Wildlife	7.16E+10	98.4%
Total	7.29E+10	100.0%

Table B-13: Distribution of Fecal Coliform Source Loads in Indian Creek

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	2.99E+12	64.7%
Pets	5.94E+11	12.9%
Human	3.79E+10	0.8%
Wildlife	9.98E+11	21.6%
Total	4.62E+12	100.0%

Appendix C

Stormwater Allocation Procedure

The WLA for the MS4 area is estimated based on the proportion of urban land within the permitted County in the watershed. To estimate this load, the load from diffuse sources (L_D)is multiplied by the proportion of urban land and the resulting value is assigned to the WLA for the MS4 area.

$WLA_i = L_D * ULU_i$
where
WLA_i = MS4 stormwater load for jurisdiction i
L_D = Load from diffuse sources to restricted shellfish area, including stormwater
ULU_i = Percentage of urban land use within jurisdiction i

MS4 Stormwater Loading Estimates

Indian Creek

Table C-1: MDP Land Use Distribution

Land Use Code	Classification	Total (acres)	Charles County (Acres)	St. Mary's County (Acres)
11	Low Density Residential	1,797.3	735.9	1,061.4
12	Medium Density Residential	207.5	0.4	207.1
14	Commercial	58.7	17.4	41.3
15	Industrial	21.4	21.4	
16	Institutional	44.6	44.6	
18	Open Urban Land	9.3	9.3	
21	Cropland	673.7	473.2	200.6
22	Pasture	160.4	118.2	42.1
41	Deciduous Forest	1,142.6	137.4	1,005.2
42	Evergreen Forest	519.8	387.8	132.0
43	Mixed Forest	2,976.3	1,836.5	1,139.8
44	Brush	110.8	98.2	12.5
50	Water	0.0	0.0	
60	Wetlands	103.1	33.5	69.6
241	Feeding Operations	5.4	5.4	
242	Agricultural Buildings	18.0		18.0
	Total	7,849.0	3,919.4	3,929.6

Table C-2: Urban/Non-urban Land Use Distribution

MS4Class	Total (acres)	Charles County (Acres)	St. Mary's County (Acres)
Non-urban	5,710.1	3,090.2	2,619.8
Urban	2,138.9	829.1	1,309.8
Total	7,849.0	3,919.4	3,929.6

Table C-3: Urban/Non-urban Land Use Distribution (percentage)

MS4Class	Total	Charles County	St. Mary's County
Non-urban	72.7%	39.4%	33.4%
Urban	27.3%	10.6%	16.7%
Total	100.0%	49.9%	50.1%

Table C-4: MS4 Waste Load Allocation

	Lo (MPN/day)	MS4 Allocation (MPN/day) Charles County	MS4 Allocation (MPN/day) St. Mary's County	LA (MPN/day)
median	4.19E+10	4.41E+09	NA	3.75E+10
90 percentile	1.47E+11	1.56E+10	NA	1.31E+11