Total Maximum Daily Loads and Water Quality Analyses of Fecal Coliform for Restricted Shellfish Harvesting Areas in the Lower Choptank River Basin in Talbot and Dorchester Counties, Maryland

FINAL

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List of Abbreviations

BMP	Best Management Practice
CAFO	Confined Animal Feeding Operations
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
COMAR	Code of Maryland Regulations
CSO	Combined Sewer Overflow
CWA	Clean Water Act
CWP	Center for Watershed Protection
EPA	Environmental Protection Agency
FA	Future Allocation
GIS	Geographic Information System
HUC	Hydrologic Unit Code
LA	Load Allocation
LMM	Long-term Moving Median
MACS	Maryland Agricultural Cost Share Program
MASS	Maryland Agriculture 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 Pollutant 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
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	Wasteload Allocation
WQA	Water Quality Analysis
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 Choptank River (basin number 02-13-04-03) was first identified on the 1996 303(d) list submitted to the U.S. Environmental Protection Agency (EPA) by Maryland Department of the Environment (MDE) as being impaired by nutrients, suspended sediments and fecal coliform, with listings of biological impacts in non-tidal and tidal portions added in 2002 and 2004, respectively. On the draft 2004 303(d) list, additional restricted shellfish harvesting areas were listed. This document addresses the fecal coliform impairment listings of several restricted shellfish harvesting areas within the Lower Choptank River Basin: Jenkins Creek (RID 8H); San Domingo Creek (RID16A1); Tred Avon River (RID17C); Tar Creek (RID17D); Cummings Creek (RID 57A); and Northeast Branch (RID 57B). Jenkins Creek is located in Dorchester County on the southern shoreline of the Lower Choptank River that directly drains to the Chesapeake Bay; San Domingo Creek, Tred Avon River Tar Creek, Cummings Creek, and Northeast Branch are located in Talbot County along the Lower Choptank River northeast shoreline. The nutrient, suspended sediment, biological, and any remaining bacteria impairments within the Lower Choptank River Basin will be addressed at a future date.

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 Jenkins Creek and Cummings Creek within the Lower Choptank 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 Jenkins Creek and Cummings 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 of fecal coliform for San Domingo Creek, Tred Avon River, Tar Creek, and Northeast Branch. 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.

A variety of data at the watershed scale, including shoreline sanitary survey data, was the primary data sources to identify potential fecal coliform contributions. The potential fecal coliform contributions were estimated using Geographical Information System (GIS) data coverage including land use, septic, distribution, property, and stream data, concurrently with local agriculture census data. There are no permitted point source facilities in any of the restricted shellfish harvesting areas addressed in this report. From these estimates, the major contributions of fecal coliform load are nonpoint sources, including livestock, wildlife, pets, and failing septic systems. Estimated sources will be revisited once laboratory analysis, using bacteria source tracking, is completed.

A steady state tidal prism model was used to estimate current fecal coliform load based on volume and concentration, and to establish allowable loads for each restricted shellfish harvesting area in the Lower Choptank 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 then used to estimate the current load condition. The allowable loads for each restricted shellfish harvesting area were then computed using both the 30-sample median water quality standard for shellfish harvesting of 14 Most Probable Number (MPN)/100ml and the 30-sample 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 Choptank River Basin for fecal coliform median load and 90th percentile load are as follows:

San Domingo Creek (RID 16A1):
The median load of fecal coliform TMDL = 5.36×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.88×10^{11} counts per day

Tred Avon River (RID 17C):
The median load of fecal coliform TMDL = 3.41×10^{11} counts per day
The 90th percentile of fecal coliform TMDL = 1.20×10^{12} counts per day

Tar Creek (RID 17D):
The median load of fecal coliform TMDL = 2.88×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.01×10^{11} counts per day

Northeast Branch (RID 57B):
The median load of fecal coliform TMDL = 5.96×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 2.09×10^{11} counts per day

The goal of load allocation is to determine the estimated loads for each source while ensuring that the water quality standard can be attained.

For the restricted shellfish harvesting areas in the Lower Choptank River Basin, the 90^{th} percentile criterion requires the greatest reduction. Therefore, the source reduction scenario is developed based on the 90^{th} 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 Choptank 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)	Required Reduction	TMDL Load Allocation (% of Total)
San Domingo Creek				
16A1	Total	100.0%	37.7%	100.0%
	Wildlife	26.3%	0.0%	42.2%
	Human	0.2%	51.1%	0.2%
	Pets	33.3%	51.1%	26.1%
	Livestock	40.2%	51.1%	31.5%
Tred Avon River				
17C	Total	100.0%	73.9%	100.0%
	Wildlife	5.5%	0.0%	21.4%
	Human	0.1%	78.3%	0.0%
	Pets	11.5%	78.3%	9.6%
	Livestock	82.9%	78.3%	69.0%
Tar Creek				
17D	Total	100.0%	35.2%	100.0%
	Wildlife	0.8%	0.0%	1.2%
	Human	0.0%	35.5%	0.0%
	Pets	0.1%	35.5%	0.1%
	Livestock	99.1%	35.5%	98.7%
Northeast Branch				
57B	Total	100.0%	82.9%	100.0%
	Wildlife	62.9%	75.7%	89.2%
	Human	0.5%	95.0%	0.1%
	Pets	12.0%	95.0%	3.5%
	Livestock	24.6%	95.0%	7.2%

Once the EPA has approved a TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of Best Management Practices (BMPs) is expected to take place. 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 Choptank River (basin number 02-13-04-03) was first identified on the 1996 303(d) list submitted to the U.S. Environmental Protection Agency (EPA) by Maryland Department of the Environment (MDE) as being impaired by nutrients, suspended sediments and fecal coliform, with listings of biological impacts in non-tidal and tidal portions added in 2002 and 2004, respectively. On the draft 2004 303(d) list, additional restricted shellfish harvesting areas were listed. 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 Jenkins Creek and Cummings Creek within the Lower Choptank River Basin; therefore, TMDLs of fecal coliform are not necessary to achieve water quality standards in these two watersheds. This document also proposes to establish TMDLs of fecal coliform for four restricted shellfish harvesting areas in the Lower Choptank River Basin: San Domingo Creek; Tred Avon River; Tar Creek; and Northeast Branch. The nutrient, suspended sediment, biological, an any remaining fecal coliform impairments within the Lower Choptank River 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 TMDLs.

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 indicates recent sources of pollution. Some common human water borne 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

Six restricted shellfish harvesting areas are addressed in this report. Jenkins Creek (8H) is located in Dorchester County, near the City of Cambridge, on the southern shoreline of the Lower Choptank River that directly drains to the Chesapeake Bay. San Domingo Creek (RID 16A1), Tred Avon River (RID 17C), Tar Creek (RID 17D), Cummings Creek (RID 57A), and Northeast Branch (RID 57B) are located in Talbot County along the Lower Choptank River northeast shoreline. Tred Avon River is located downstream from the City of Easton. Shellfish waters in the Lower Choptank River Basin extend from Cambridge, Maryland to the mouth of the river where it discharges into the Chesapeake Bay. The Lower Choptank River watershed spans about 22 km of coastline bounded upstream by Cambridge and downstream by the mouth of the Lower Choptank River.

Jenkins Creek drains south to the Lower Choptank River, while other site basins drain north to this river, as shown in Figure 2.1.1. The watershed in the lower portion of the Choptank River consists of fine textured to medium textured soils. The thick beds of clay, silt, or silt-clay loam are characteristic of this area. Soils mainly consist of silt (72%), sand (14%), and clay (14%) (U.S. Department of Agriculture (USDA), 1995). The topography of the watershed is generally level to gently rolling. The majority of the area near the receiving waters are poorly drained, which is characterized as a typical hydrologic D group (USDA, 1995). The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal range of 0.5 m and tidal period of 12.42 hours. Please refer to Table 2.1.1 for the mean volume and mean water depth of each restricted shellfish harvesting area.

Table 2.1.1: Physical Characteristics of Lower Choptank River Restricted Shellfish Harvesting Areas

Restricted Shellfish Area (RID)	Mean Water Volume in m^3	Mean Water Depth in m
Jenkins Creek (8H)	282,250	0.53
San Domingo Creek (16A1)	546,625	1.15
Tred Avon River (17C)	3,473,500	1.46
Tar Creek (17D)	294,177	0.96
Cummings Creek (57A)	1,267,293	1.08
Northeast Branch (57B)	606,645	0.89

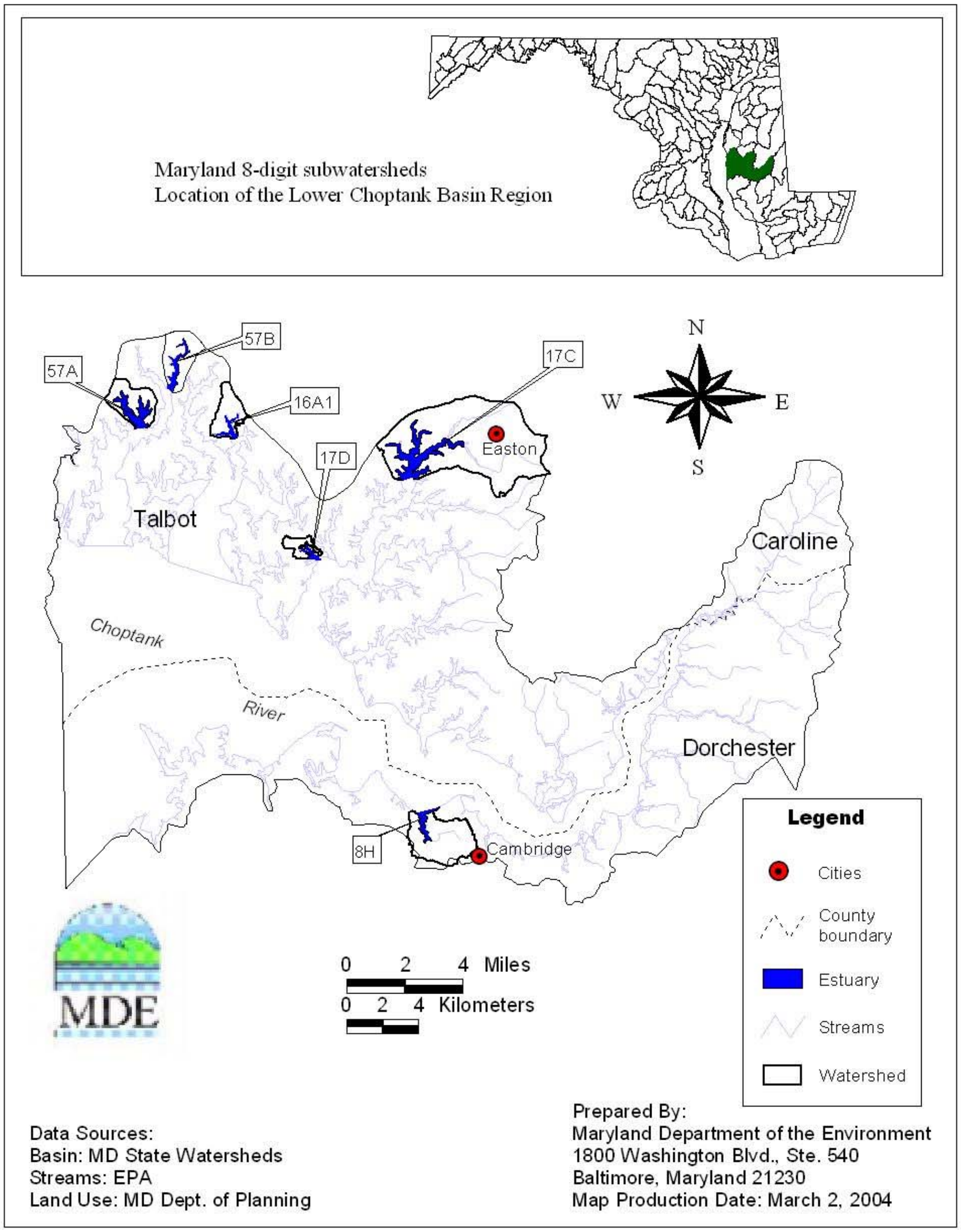

Figure 2.1.1: Location Map of the Lower Choptank River Basin

The 2000 Maryland Department of Planning (MDP) land use/land cover data shows that the watershed can be characterized as rural. The land use information for these six restricted shellfish harvesting areas in the Lower Choptank River are shown in Table 2.1.2 to Table 2.1.7 and Figure 2.1.2 to Figure 2.1.7. 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 Jenkins Creek (RID 8H)

Land Type	Acreage	Percentage
Urban	654.1	31.8
Forest	399.0	19.4
Agriculture	842.3	41.0
Wetlands	7.1	0.3
Water	153.6	7.5
Totals	**2056.1**	**100.0**

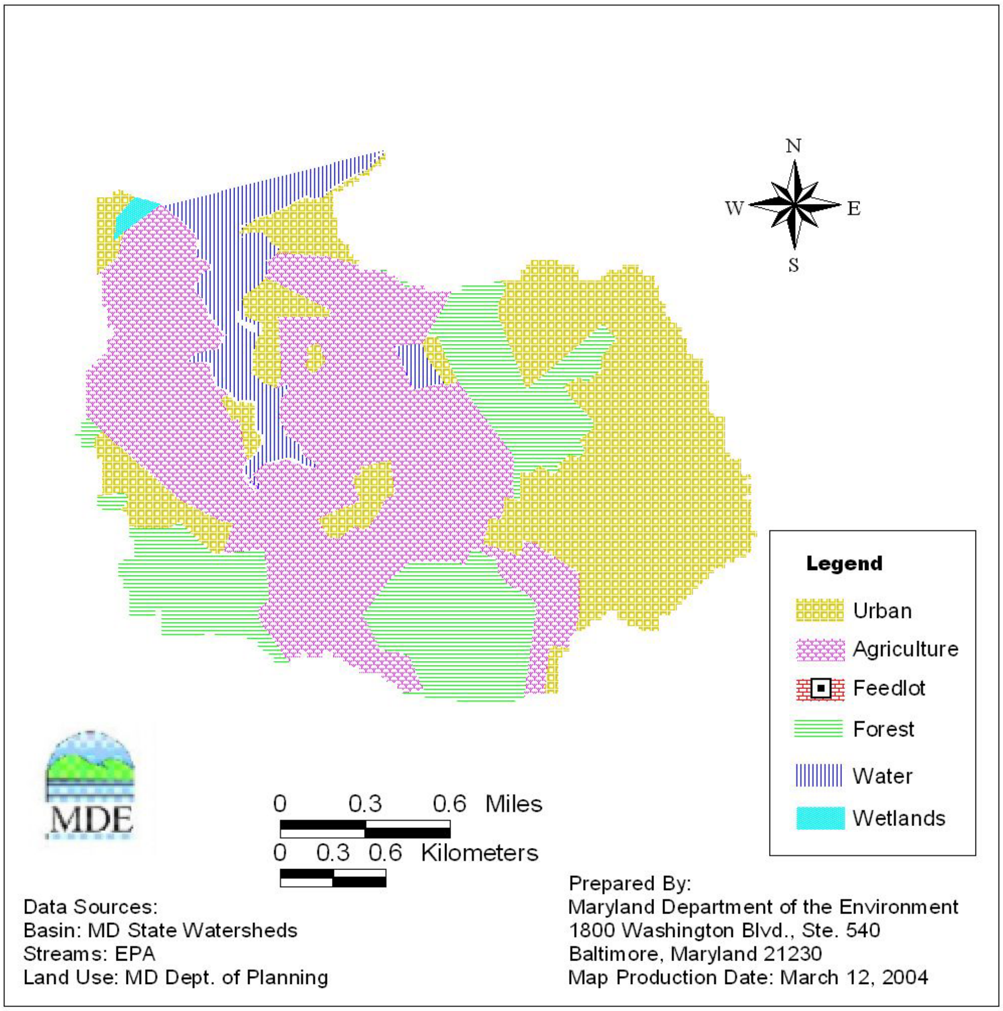

Figure 2.1.2: Land Use in the Jenkins Creek Basin

Table 2.1.3: Land Use Percentage Distribution for San Domingo Creek (RID 16A1)

Land Type	Acreage	Percentage
Urban	224.1	25.4
Forest	208.7	23.7
Agriculture	331.3	37.6
Wetlands	0.0	0.0
Water	117.9	13.4
Totals	**882.1**	**100.0**

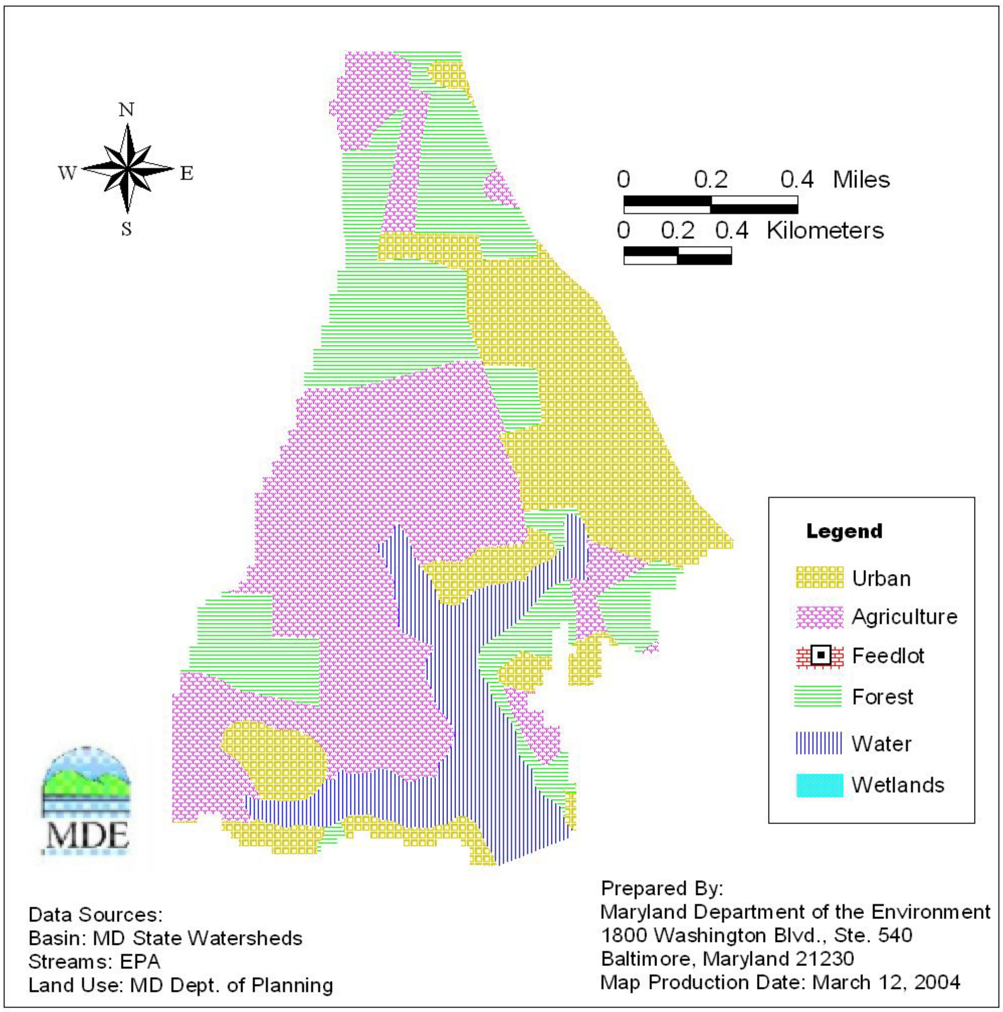

Figure 2.1.3: Land Use in the San Domingo Creek Basin

Table 2.1.4: Land Use Percentage Distribution for Tred Avon River (RID 17C)

Land Type	Acreage	Percentage
Urban	3242.1	40.9
Forest	1233.3	15.5
Agriculture	2756.3	34.7
Wetlands	99.8	1.2
Water	600.7	7.6
Totals	**7932.1**	**100.0**

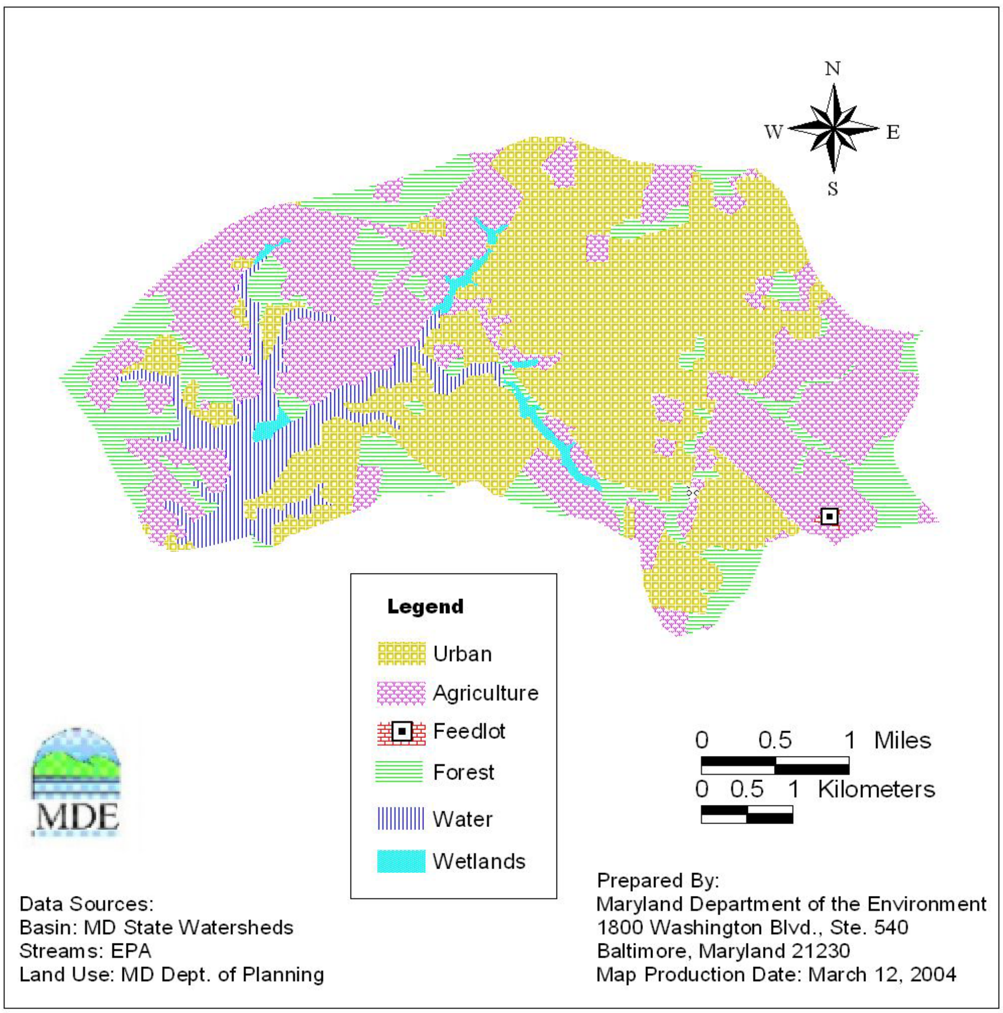

Figure 2.1.4: Land Use in the Tred Avon River Basin

Table 2.1.5: Land Use Percentage Distribution for Tar Creek (RID 17D)

Land Type	Acreage	Percentage
Urban	38.2	9.3
Forest	119.2	28.9
Agriculture	179.9	43.2
Wetlands	0.0	0.0
Water	77.0	18.7
Totals	**412.2**	**100.0**

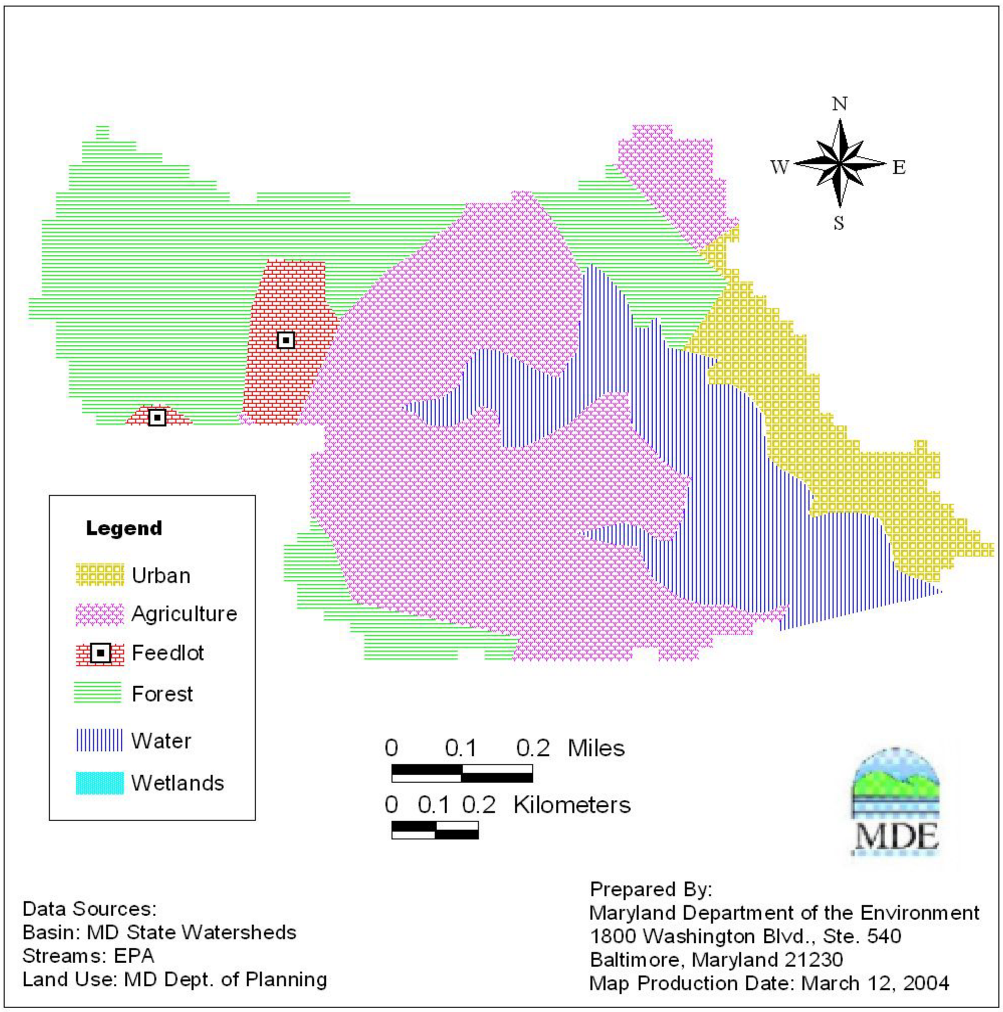

Figure 2.1.5: Land Use in the Tar Creek Basin

Table 2.1.6: Land Use Percentage Distribution for Cummings Creek (RID 57A)

Land Type	Acreage	Percentage
Urban	189.0	15.8
Forest	171.5	14.4
Agriculture	543.2	45.5
Wetlands	0.0	0.0
Water	291.3	24.3
Totals	**1195.0**	**100.0**

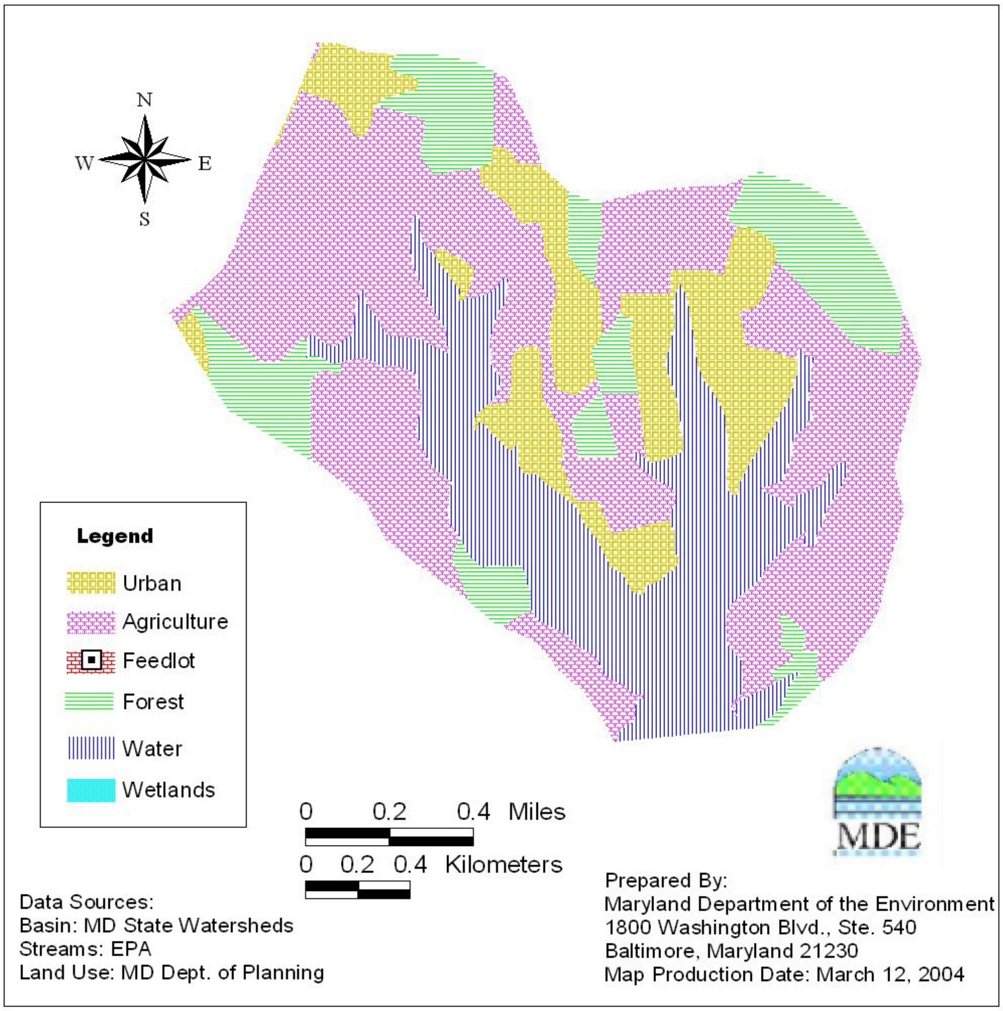

Figure 2.1.6: Land Use in the Cummings Creek Basin

Table 2.1.7: Land Use Percentage Distribution for Northeast Branch (RID 57B)

Land Type	Acreage	Percentage
Urban	146.9	12.2
Forest	268.7	22.3
Agriculture	620.0	51.5
Wetlands	0.0	0.0
Water	168.8	14.0
Totals	**1204.3**	**100.0**

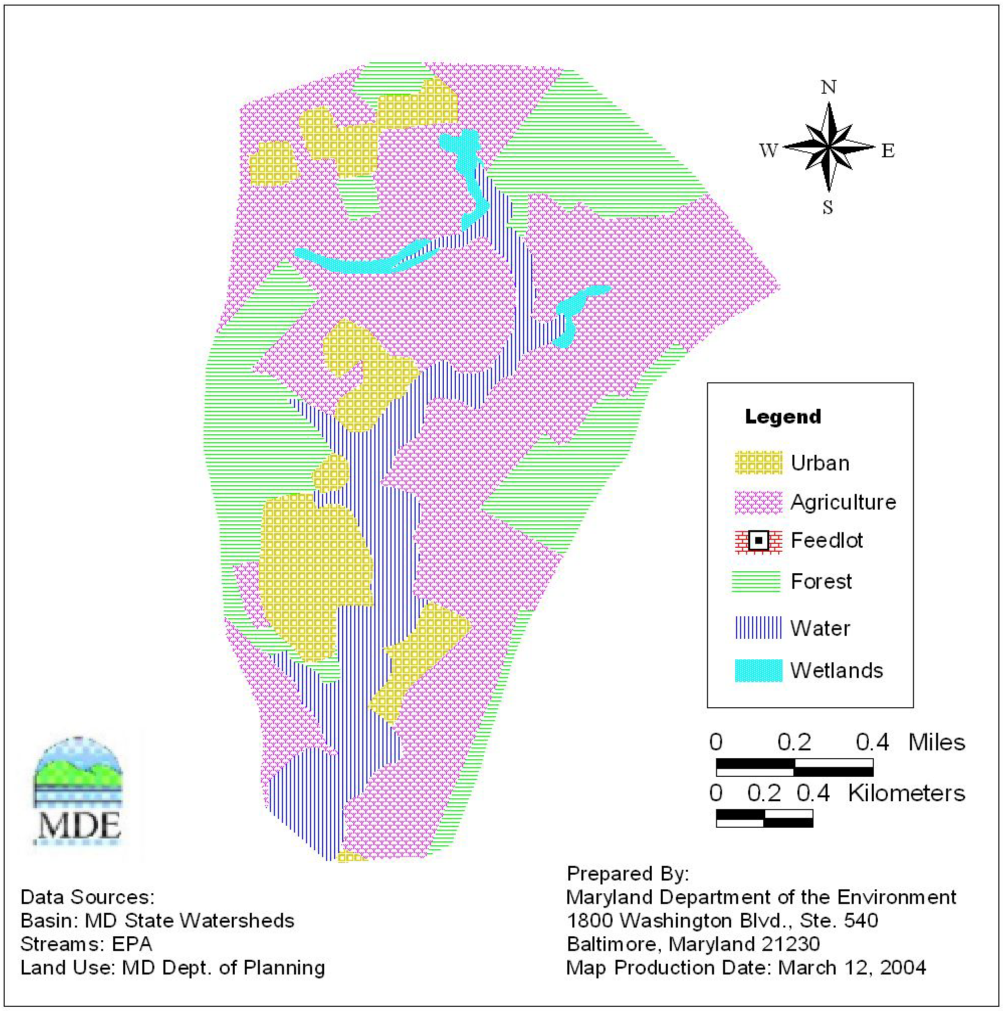

Figure 2.1.7: Land Use in the Northeast Branch Basin

2.2 Water Quality Characterization

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

MDE's Shellfish Certification Division has monitored shellfish growing regions throughout Maryland for the past several decades. There are eight shellfish monitoring stations in the restricted shellfish harvesting areas in the Lower Choptank River Basin. The monitoring stations and observations recorded during the period of 1999 – 2003 are provided in Table 2.2.1 to Table 2.2.6 and Figure 2.2.1 to Figure 2.2.14. In general, based on Statewide shellfish monitoring data, fecal coliform concentrations are higher in the headwaters.

Table 2.2.1: Location of Shellfish Monitoring Station in Jenkins Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
10-03-005	1999-2003	55	38 34 59.2	76 06 47.0

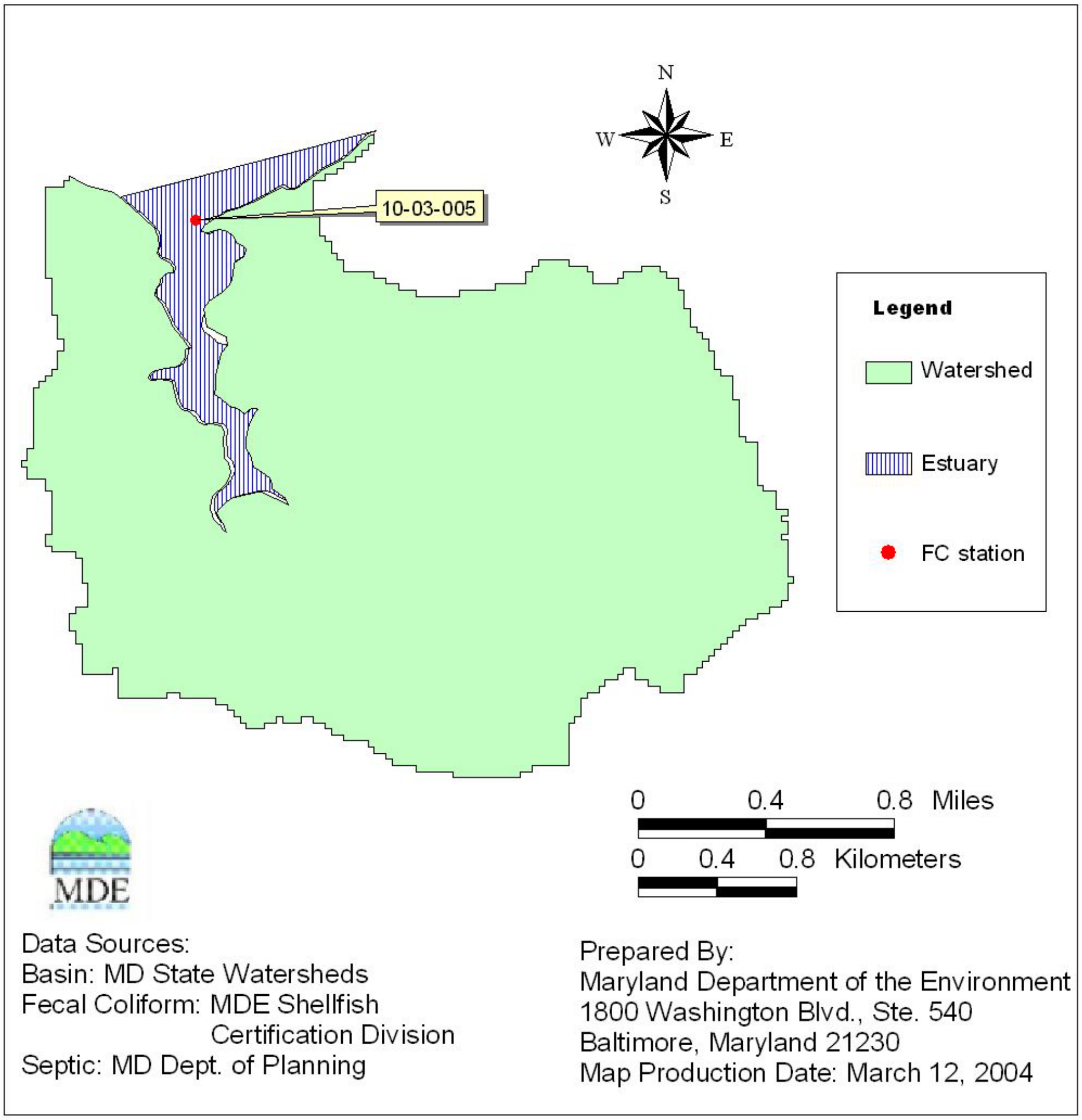

Figure 2.2.1: Shellfish Monitoring Station in Jenkins Creek

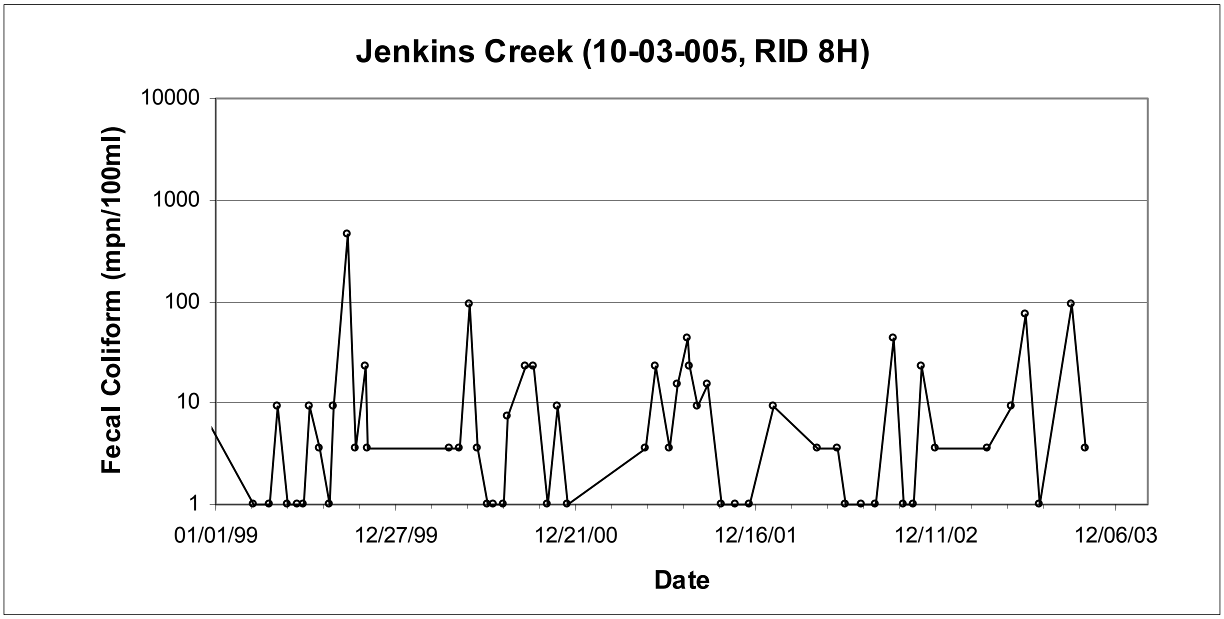

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 10-03-005

Table 2.2.2: Location of Shellfish Monitoring Station in San Domingo Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
08-07-006C	1999-2003	47	38 46 17.0	76 13 52.0

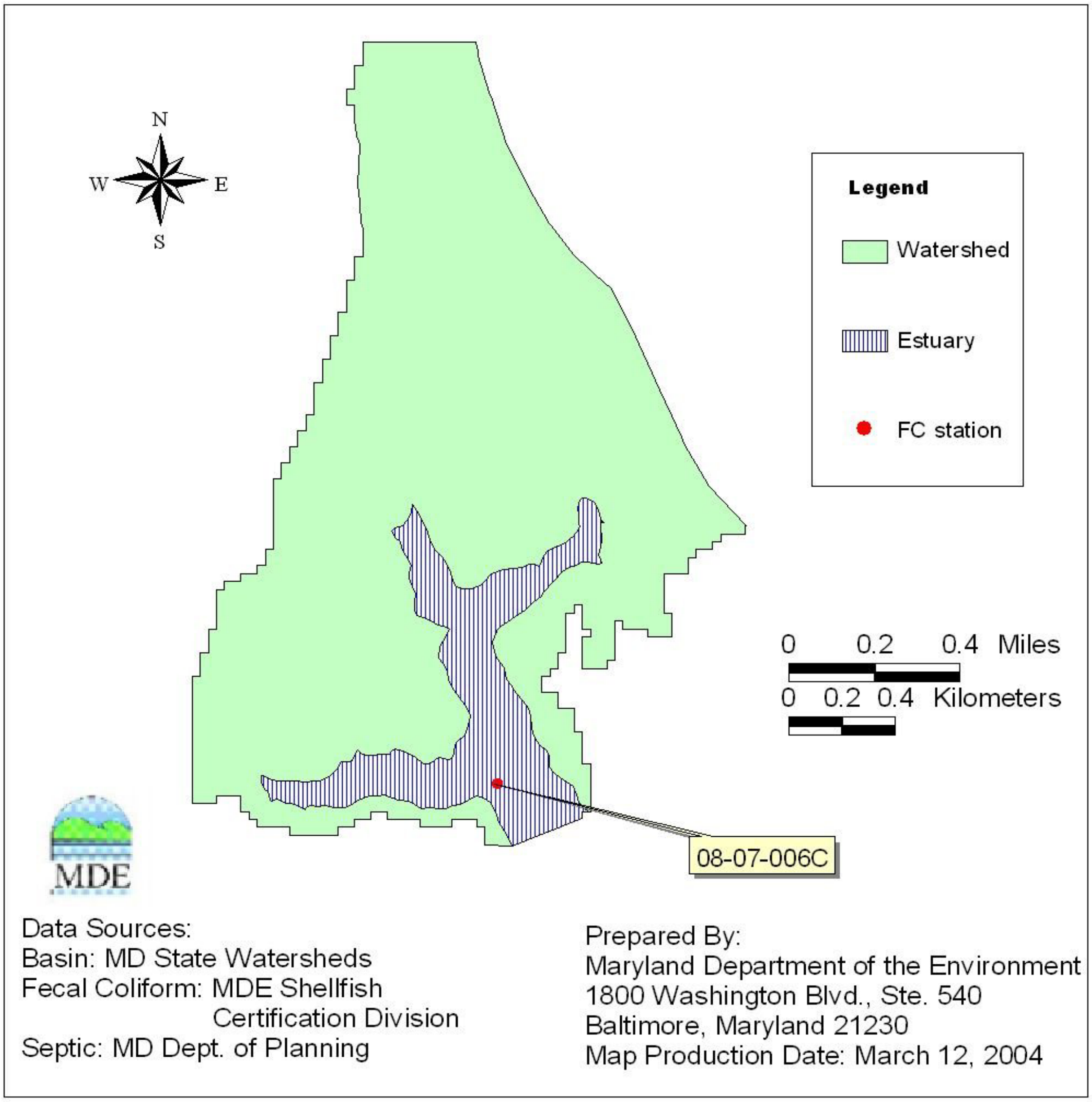

Figure 2.2.3: Shellfish Monitoring Stations in San Domingo Creek

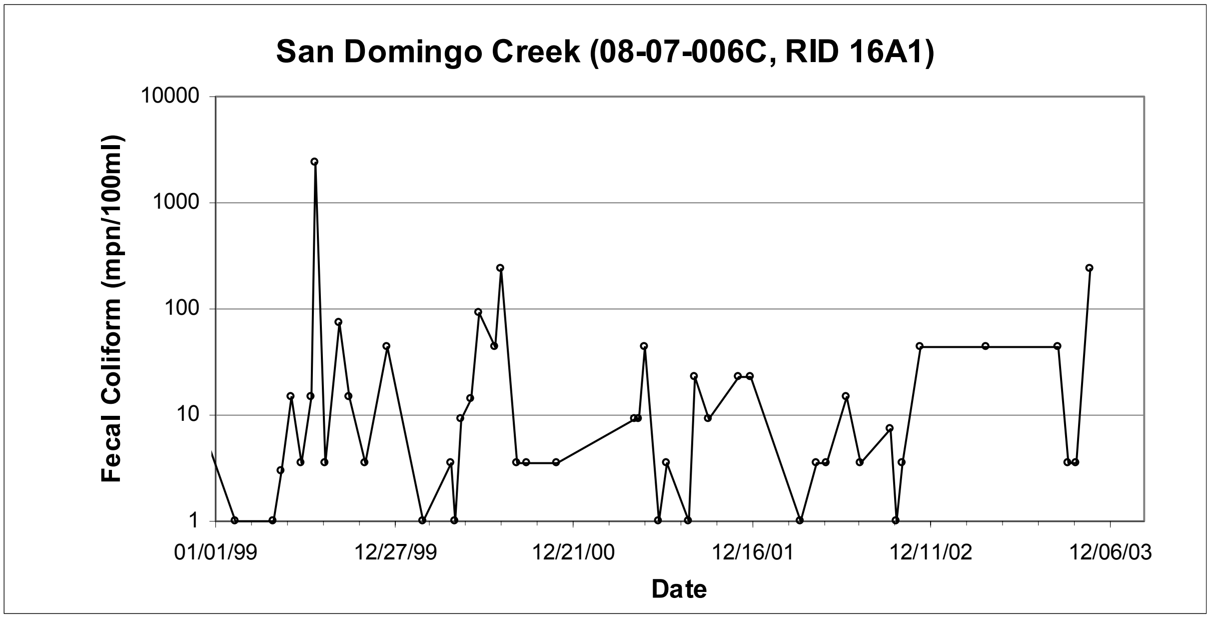

Figure 2.2.4: Observed Fecal Coliform Concentrations at Station 08-07-006C

Table 2.2.3: Locations of Shellfish Monitoring Stations in Tred Avon River

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
08-06-004	1999-2003	79	38 45 11.0	76 10 38.0
08-06-300	1999-2003	79	38 45 34.4	76 07 03.0

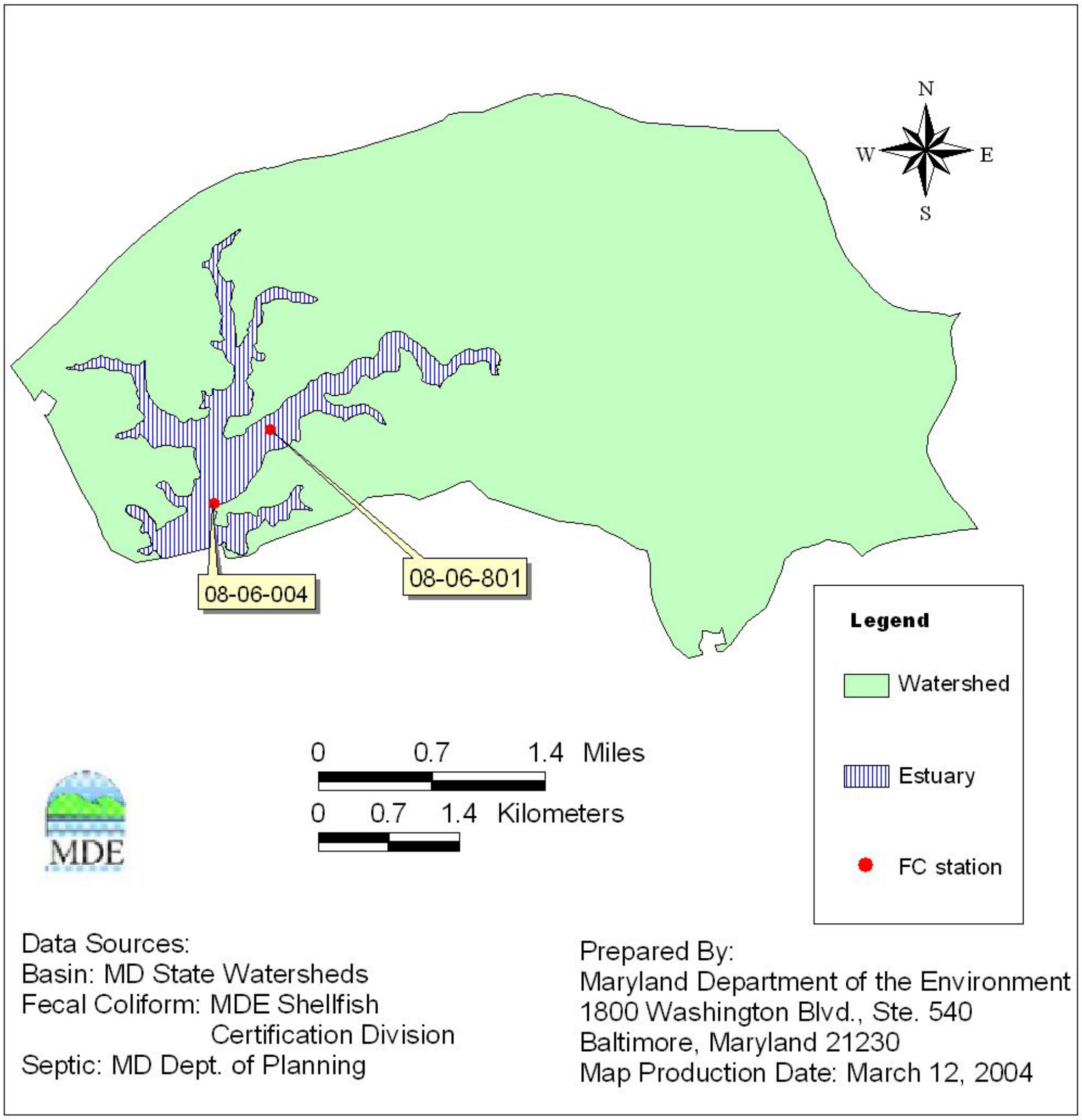

Figure 2.2.5: Shellfish Monitoring Stations in the Tred Avon River

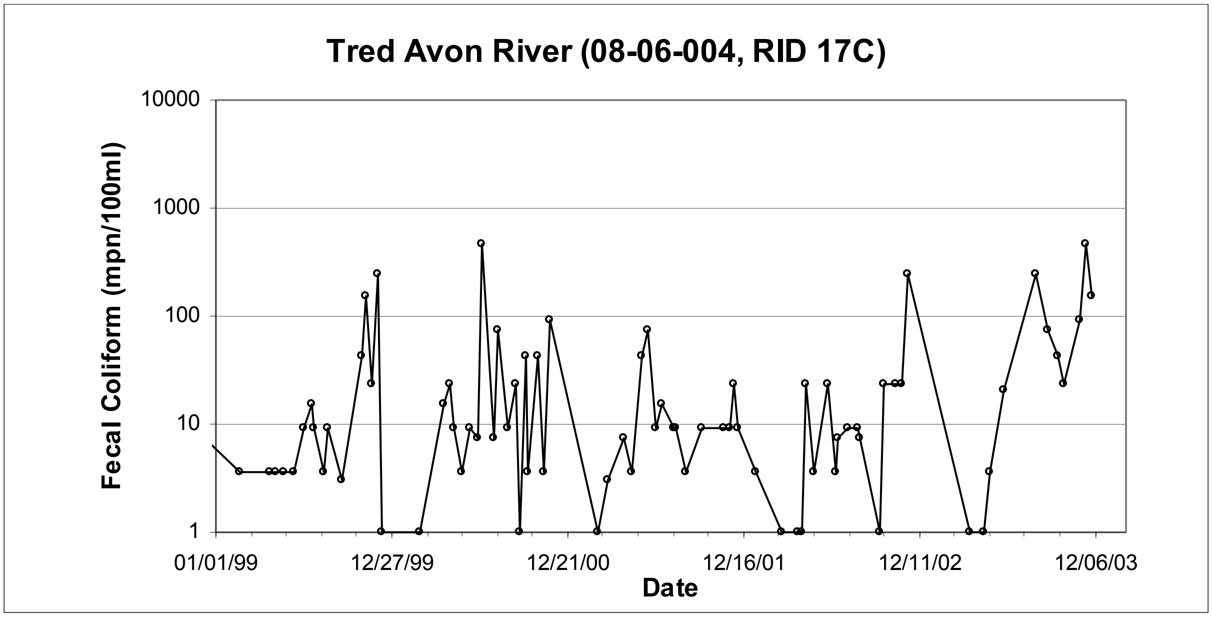

Figure 2.2.6: Observed Fecal Coliform Concentrations at Station 08-06-004

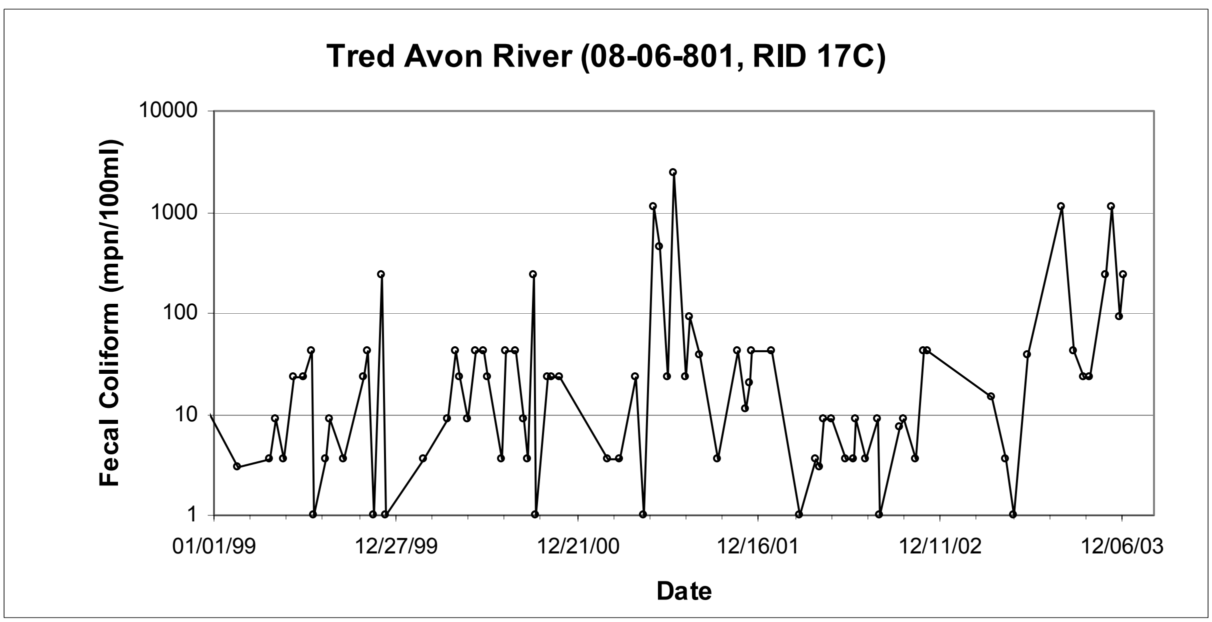

Figure 2.2.7: Observed Fecal Coliform Concentrations at Station 08-06-801

Table 2.2.4: Location of Shellfish Monitoring Station in Tar Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
08-06-120	1999-2003	79	38 42 33.0	76 10 38.0

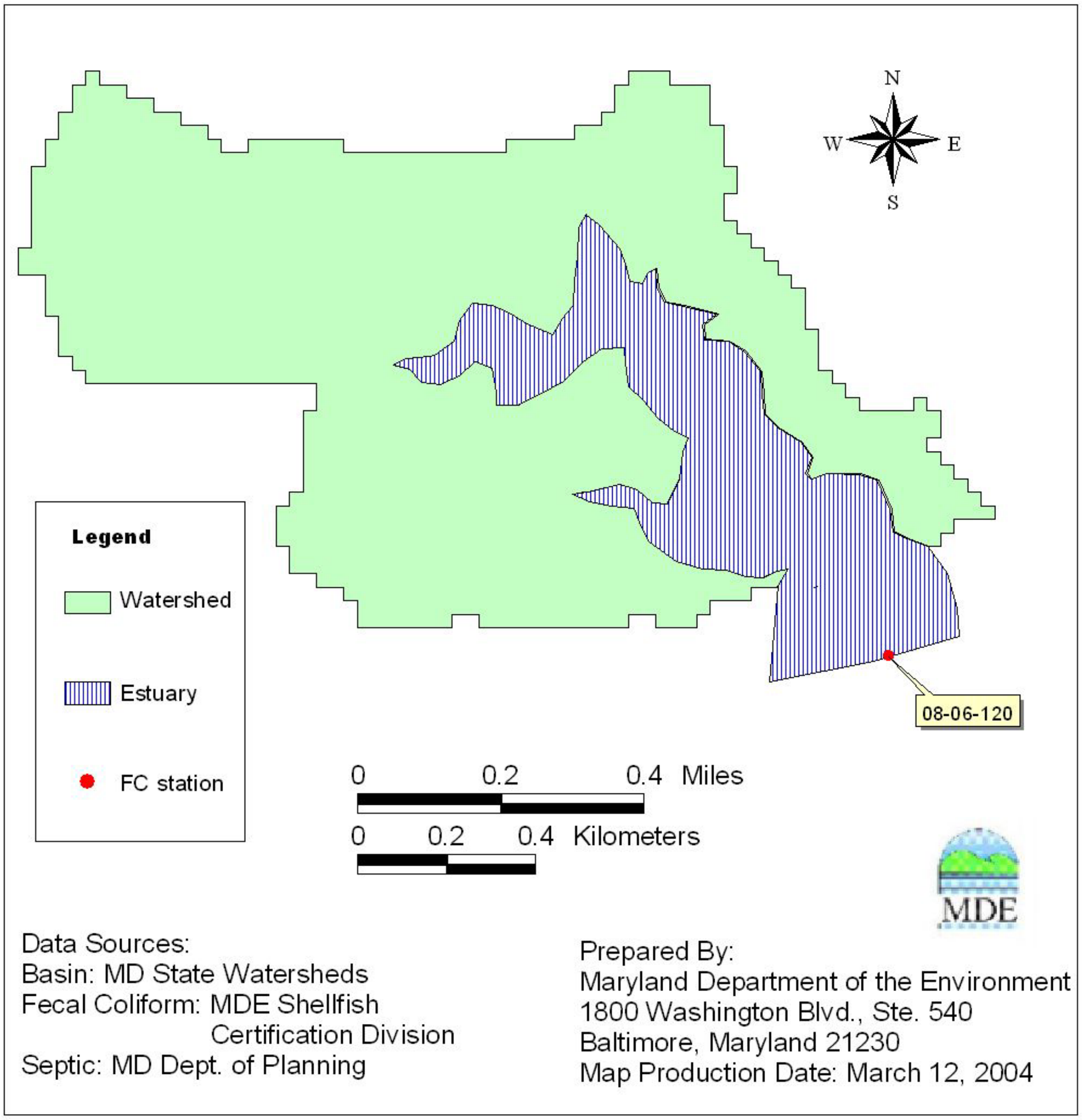

Figure 2.2.8: Shellfish Monitoring Stations in Tar Creek

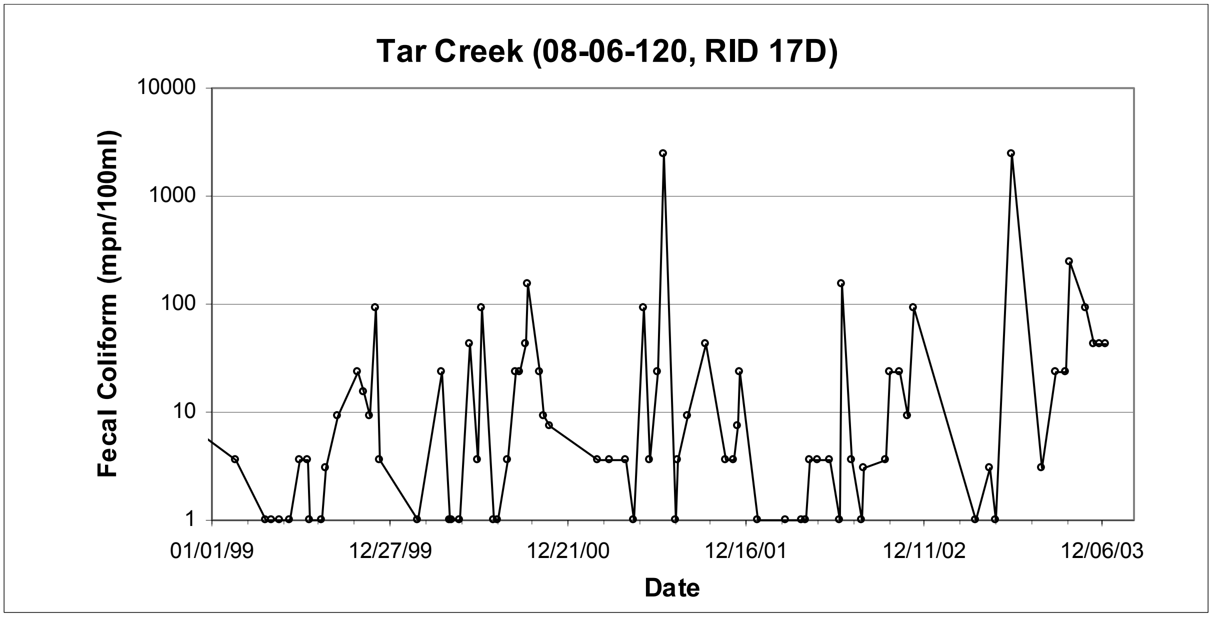

Figure 2.2.9: Observed Fecal Coliform Concentrations at Station 08-06-120

Table 2.2.5: Location of Shellfish Monitoring Station in Cummings Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
08-08-048B	1999-2003	38	38 46 42.0	76 17 23.0

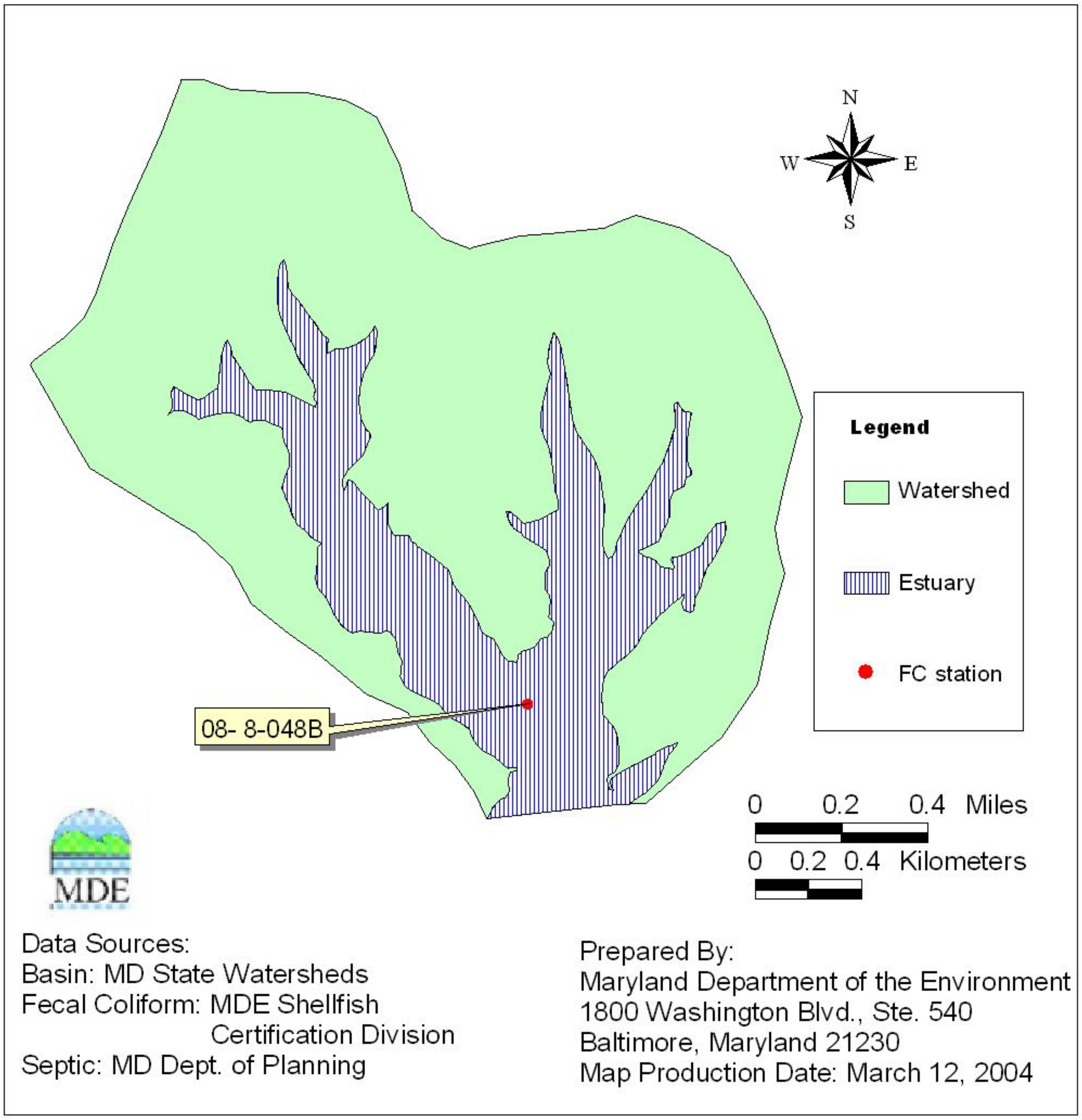

Figure 2.2.10: Shellfish Monitoring Station in Cummings Creek

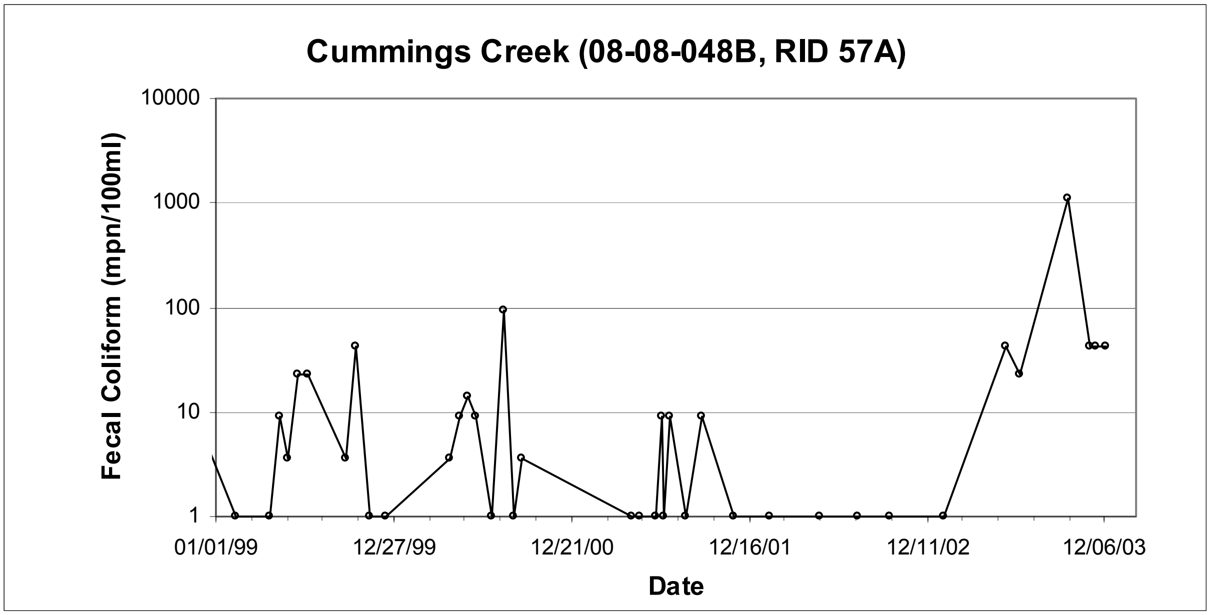

Figure 2.2.11: Observed Fecal Coliform Concentrations at Station 08-08-048B

Table 2.2.6: Locations of Shellfish Monitoring Stations in Northeast Branch

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
08-08-109	1999-2003	39	38 47 38.0	76 16 12.0
08-08-110	1999-2003	38	38 48 24.6	76 15 59.3

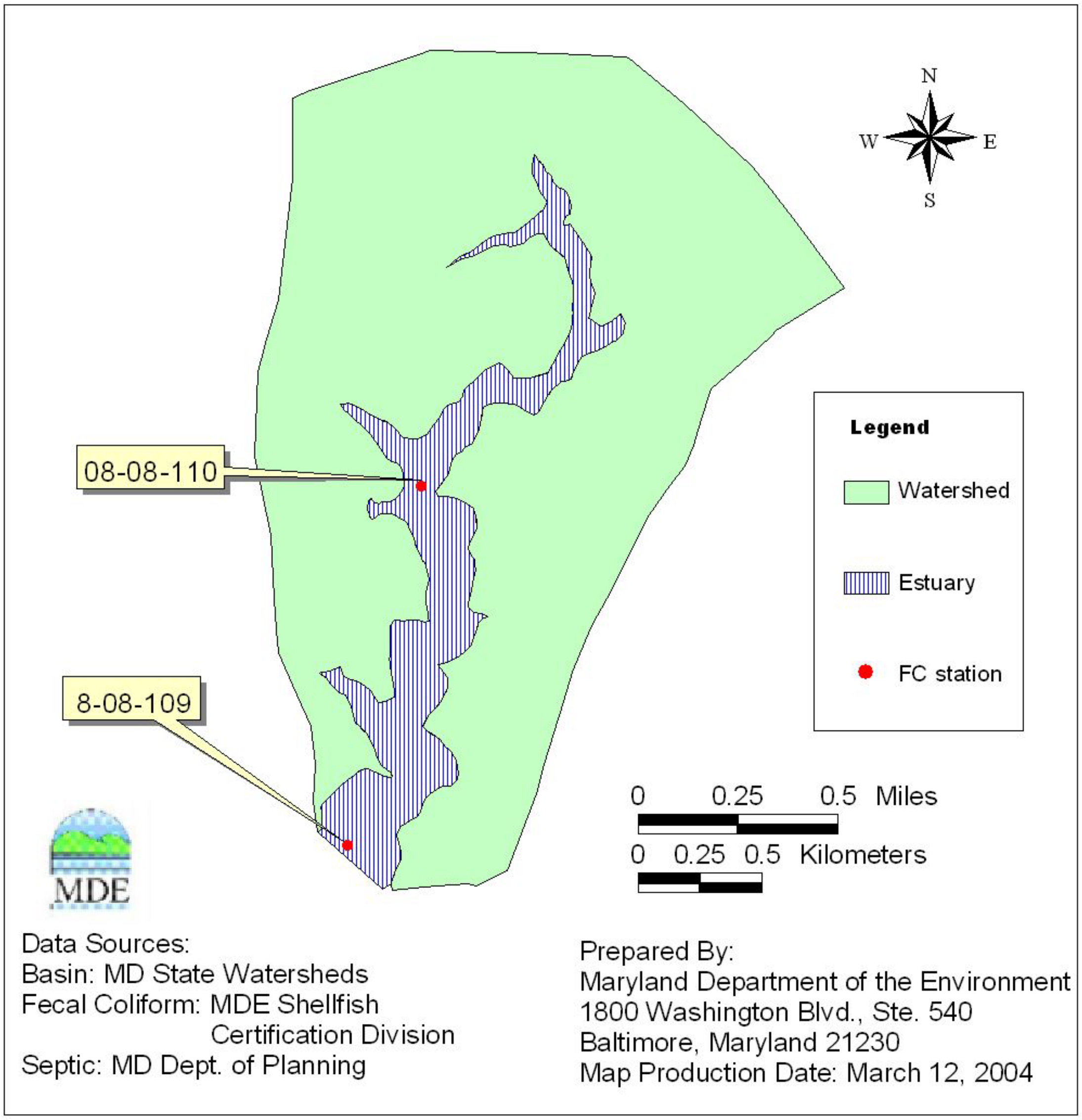

Figure 2.2.12: Shellfish Monitoring Stations in Northeast Branch

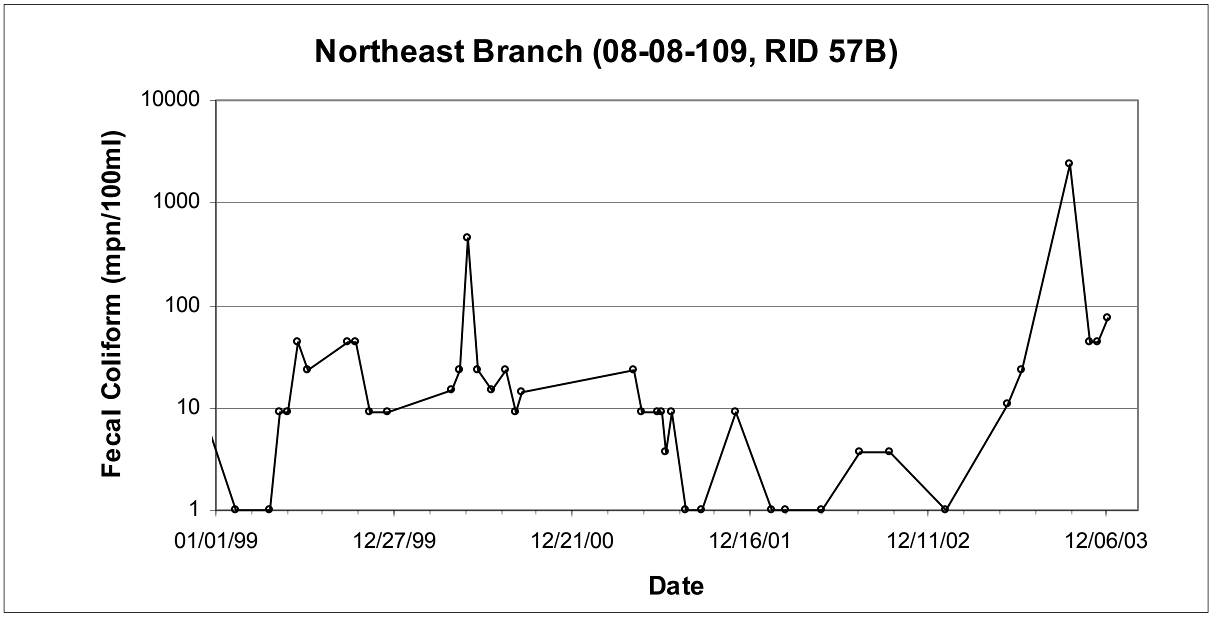

Figure 2.2.13: Observed Fecal Coliform Concentrations at Station 08-08-109

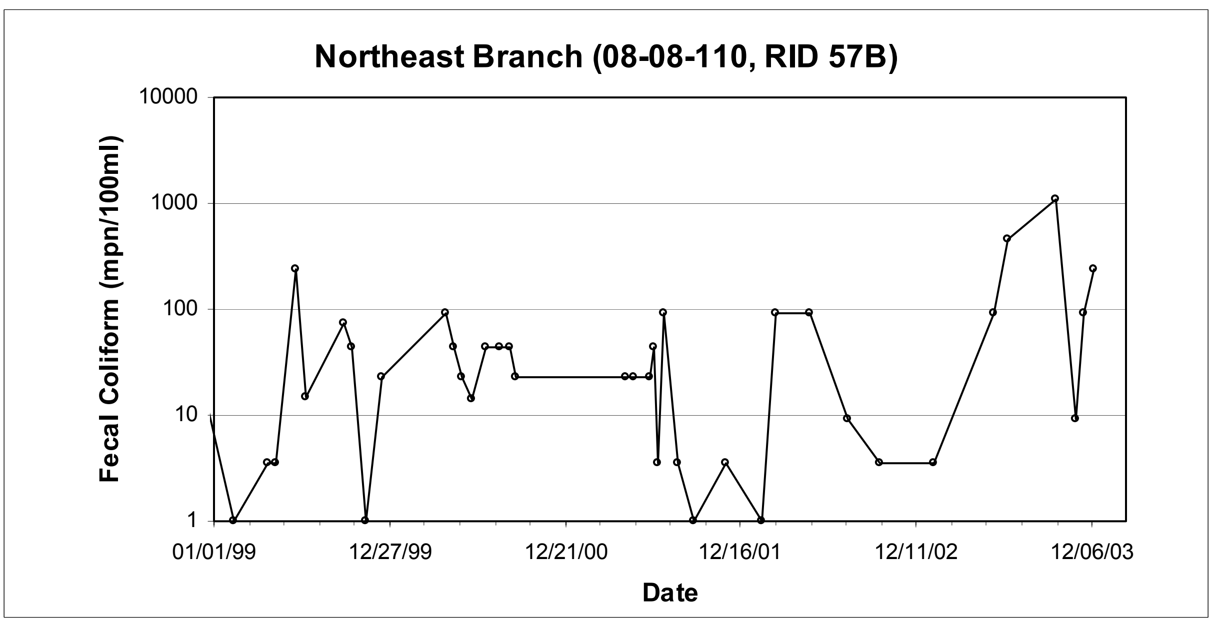

Figure 2.2.14: Observed Fecal Coliform Concentrations at Station 08-08-110

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) 26.08.02.08E). The Lower Choptank River (basin number 02-13-04-03) 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 south shoreline of the Lower Choptank River are identified as 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 period.

The water quality impairment was assessed using the 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 Choptank River Shellfish Monitoring Stations (1999-2003) - Median and 90th Percentile

RID	Area Name	Station	Median		90th Percentile	
			Monitoring Data	Criterion	Monitoring Data	Criterion
			MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
8H	Jenkins Creek	10-03-005	3.6	14	33.4	49
16A1	San Domingo Creek	08-07-006C	7.3	14	78.6	49
17C	Tred Avon River	08-06-004	9.1	14	83.3	49
		08-06-801	20.0	14	154.5	49
17D	Tar Creek	08-06-120	3.6	14	75.6	49
57A	Cummings Creek	08-08-048B	3.6	14	47.5	49
57B	Northeast Branch	08-08-109	9.1	14	93.5	49
		08-08-110	23.0	14	202.0	49

Results from this analysis indicate that water quality impairments are demonstrated in all restricted shellfish harvesting areas except Jenkins Creek and Cummings Creek. Bacteria water quality criteria, determined from the designated use, is being met in Jenkins Creek and Cummings Creek; therefore, TMDLs of fecal coliform are not necessary to achieve water quality standards in these watersheds. Barring the receipt of any contradictory data, this report will be used to support the bacteria listing change for Jenkins Creek and Cummings 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 four restricted shellfish harvesting areas for which water quality impairments are demonstrated (San Domingo Creek, Tred Avon River, Tar Creek, and Northeast Branch).

2.4 Source Assessment

Nonpoint Source Assessment

Nonpoint sources of fecal coliform bacteria do not have one discharge point but occur over the entire length of a stream or waterbody. There are many types of nonpoint sources in watersheds discharging to the restricted shellfish harvesting area. The possible introductions of fecal coliform bacteria to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and discharges to the restricted shellfish harvesting area. The deposition of non-human fecal coliform directly to the restricted shellfish area occurs when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions to the bacterial levels from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreation vessel discharges. The transport of fecal coliform from land surface to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

The complete distributions of these source loads are also listed in Tables 2.4.1 to 2.4.2, 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 San Domingo Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	2.00E+11	40.2%
Pets	1.65E+11	33.3%
Human	8.95E+08	0.2%
Wildlife	1.31E+11	26.3%
Total	4.97E+11	100.0%

Table 2.4.2: Distribution of Fecal Coliform Source Loads in the Tred Avon River Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	1.51E+13	82.9%
Pets	2.09E+12	11.5%
Human	1.04E+10	0.1%
Wildlife	1.01E+12	5.5%
Total	1.82E+13	100.0%

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

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	1.15E+13	99.1%
Pets	1.04E+10	0.1%
Human	3.74E+08	0.0%
Wildlife	8.98E+10	0.8%
Total	1.16E+13	100%

Table 2.4.4: Distribution of Fecal Coliform Source Loads in the Northeast Branch Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	6.48E+10	24.6%
Pets	3.16E+10	12.0%
Human	1.26E+09	0.5%
Wildlife	1.66E+11	62.9%
Total	2.64E+11	100%

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 TMDLs and source allocation developments for San Domingo Creek, Tred Avon River, Tar Creek, and Northeast Branch in the Lower Choptank River Basin. The required load reductions were determined based on the most recent five-year data spanning the years 1999 to 2003. The TMDLs are presented as counts/day. The second section describes the analysis framework for simulating fecal coliform concentration in areas of the Lower Choptank River Basin. The third section addresses the critical period. The fourth section presents the TMDL calculations. 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 TMDLs.

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 5 year period 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:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS} + \text{FA}$$

4.2 Analysis Framework

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

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

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

where:
L = fecal coliform load (counts per day)
C = fecal coliform concentration (MPN /100ml) of embayment
Q_b = the quantity of mixed water that leaves the embayment on the ebb tide that did not enter the embayment on the previous flood tide (m^3 per tidal cycle)

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

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

$$Q_b = Q_0 + Q_f$$

where Q_f is mean freshwater discharge during the tidal cycle

$$Q_0 = \beta Q_T$$

where β is an exchange ratio and Q_T is the total ocean water entering the bay on the flood tide, which is calculated based on tidal range. The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal period of 12.42 hours; therefore, the M_2 tide is used for the representative tidal cycle. In general, the exchange ratio varies from 0.3 to 0.7, based on the previous model tests in Virginia coastal embayment areas (Kuo et al., 1998; Shen et al., 2002). The observed salinity data were also used to estimate the exchange ratio. The estimated values range from 0.3-0.8; 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 reported site, 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 (i.e., 4307.5 acres) to derive estimates of long-term flows (see Table 4.2.1 below).

Table 4.2.1. Drainage Areas and Long-Term Flows in the Lower Choptank River Basin

Restricted Shellfish Harvesting Area (RID)	Drainage Area in Acres	Average Long-Term Flow in cfs
Jenkins Creek (8H)	1925.29	2.38
San Domingo Creek (16A1)	764.18	1.02
Tred Avon River (17C)	7344.05	9.19
Tar Creek (17D)	336.13	0.48
Cummings Creek (57A)	903.96	1.38
Northeast Branch (57B)	1035.71	1.39

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 90^{th} 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 90^{th} percentile, the critical condition is implicitly included in the value of the 90^{th} percentile. Given the length of the monitoring record used and the limited applicability of best management practices to extreme conditions, the 90^{th} percentile is utilized instead of the absolute maximum.

A comparison of the median and the 90^{th} 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 90^{th} percentile criterion requires a higher reduction, this suggests an occurrence of the high fecal coliform due to the variation of hydrological conditions.

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

4.4 TMDL Computation

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

For the load analyses, the most recent five-year period of monitoring data (at least 30 sample), specifically fecal coliform concentration was used to estimate the current loads. This was conducted for median and for 90^{th} 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 down stream station(s) were used to represent boundary conditions. For those restricted shellfish harvesting areas where only one sampling station was available, its median and 90^{th} 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 90^{th} percentile of 49 MPN/100 ml. The load reductions needed for the attainment of the criteria is determined by subtracting the allowable loads from the current loads. The TMDL calculations are presented in Appendix A. The calculated results are listed in Table 4.4.1and Table 4.4.2.

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

Area	Mean Volume m^3	Fecal Coliform Concentration Median MPN/100mL	Decay Rate per tidal cycle	Estimated Residence Time Days	Current Load Counts/day	Allowable Load Counts/day	Required Percent Reduction (%)
San Domingo Creek	546625	7.3	0.36	2.3	2.794E+10	5.359E+10	0.00
Tred Avon River	3473499	20.0	0.36	3.0	6.131E+11	3.414E+11	44.31
Tar Creek	294177	3.6	0.36	2.0	7.409E+09	2.881E+10	0.00
Northeast Branch	606645	23.0	0.36	1.8	1.437E+11	5.956E+10	58.54

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

Area	Mean Volume m^3	Fecal Coliform Concentration 90th percentile MPN/100mL	Decay Rate per tidal cycle	Estimated Residence Time days	Current Load Counts/day	Allowable Load counts/day	Required Percent Reduction (%)
San Domingo Creek	546625	78.6	0.36	2.3	3.010E+11	1.876E+11	37.69
Tred Avon River	3473499	154.5	0.36	3.0	4.587E+12	1.195E+12	73.94
Tar Creek	294177	75.6	0.36	2.0	1.556E+11	1.008E+11	35.19
Northeast Branch	606645	202.0	0.36	1.8	1.217E+12	2.085E+11	82.87

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 in the Lower Choptank River Basin are as follows:

San Domingo Creek (RID 16A1):
The median load of fecal coliform TMDL = 5.36×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.88×10^{11} counts per day

Tred Avon River (RID 17C):
The median load of fecal coliform TMDL = 3.41×10^{11} counts per day
The 90th percentile of fecal coliform TMDL = 1.20×10^{12} counts per day

Tar Creek (RID 17D):
The median load of fecal coliform TMDL = 2.88×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.01×10^{11} counts per day

Northeast Branch (RID 57B):
The median load of fecal coliform TMDL = 5.96×10^{10} counts per day

The 90th percentile of fecal coliform TMDL = 2.09×10^{11} counts per day

The greater reduction required when comparing the median and the 90th 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 described in this section demonstrate how the TMDL can be implemented to achieve water quality standards. However, the State reserves the right to revise these allocations provided the allocations are consistent with the achievement of water quality standards.

Source reductions were assigned by first managing controllable sources (human, livestock and pets) and then determining if the TMDL could be achieved. If the total required reduction was not achieved then the wildlife source was then reduced. Given the non-point source characteristics of the wildlife contribution, it was assumed that best management practices applied to controllable sources may also 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.

Tred Avon River watershed includes the City of Easton which does not meet the CWA's population threshold and criteria for NPDES Phase II stormwater permit coverage. Therefore, all stormwater runoff and associated pollutant loads from the City of Easton are considered non-point sources and are part of the LA for the Tred Avon River watershed.

Table 4.6.1: Load Allocations and Reductions

RID	Source	Current Load Distribution (% of Total)	Required Reduction	TMDL Load Allocation (% of Total)
San Domingo Creek				
16A1	Total	100.0%	37.7%	100.0%
	Wildlife	26.3%	0.0%	42.2%
	Human	0.2%	51.1%	0.2%
	Pets	33.3%	51.1%	26.1%
	Livestock	40.2%	51.1%	31.5%
Tred Avon River				
17C	Total	100.0%	73.9%	100.0%
	Wildlife	5.5%	0.0%	21.4%
	Human	0.1%	78.3%	0.0%
	Pets	11.5%	78.3%	9.6%
	Livestock	82.9%	78.3%	69.0%
Tar Creek				
17D	Total	100.0%	35.2%	100.0%
	Wildlife	0.8%	0.0%	1.2%
	Human	0.0%	35.5%	0.0%
	Pets	0.1%	35.5%	0.1%
	Livestock	99.1%	35.5%	98.7%
Northeast Branch				
57B	Total	100.0%	82.9%	100.0%
	Wildlife	62.9%	75.7%	89.2%
	Human	0.5%	95.0%	0.1%
	Pets	12.0%	95.0%	3.5%
	Livestock	24.6%	95.0%	7.2%

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
San Domingo Creek	**5.36×10^{10}**	=	**5.36×10^{10}**	+	**N/A**	+	**N/A**	+	**Implicit**
Tred Avon River	**3.41×10^{11}**	=	**3.41×10^{11}**	+	**N/A**	+	**N/A**	+	**Implicit**
Tar Creek	**2.88×10^{10}**	=	**2.88×10^{10}**	+	**N/A**	+	**N/A**	+	**Implicit**
Northeast Branch	**5.96×10^{10}**	=	**5.98×10^{10}**	+	**N/A**	+	**N/A**	+	**Implicit**

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
San Domingo Creek	**1.88×10^{11}**	=	**1.88×10^{11}**	+	**N/A**	+	**N/A**	+	**Implicit**
Tred Avon River	**1.20×10^{12}**	=	**1.20×10^{12}**	+	**N/A**	+	**N/A**	+	**Implicit**
Tar Creek	**1.01×10^{11}**	=	**1.01×10^{11}**	+	**N/A**	+	**N/A**	+	**Implicit**
Northeast Branch	**2.09×10^{11}**	=	**2.09×10^{11}**	+	**N/A**	+	**N/A**	+	**Implicit**

Where:

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

5.0 ASSURANCE OF IMPLEMENTATION

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

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

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

Regulatory enforcement of potential bacteria sources may include MDE's routine sanitary surveys of shellfish growing areas and through National Pollutant Discharge Elimination System (NPDES) permitting activities such as 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.

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 19, 2004 to September 17, 2004, during which the document was placed in the Talbot County Library, Dorchester County Library, MDE's website and notices were published in the Daily Banner and the Star Democrat. Following the public comment period, comments were reviewed and addressed through a comment response document. The documents were then submitted to EPA Region III at which time stakeholders were notified of this action. Once the document was approved by EPA Region III, stakeholders were notified of the action and the finalized document was posted on MDE's website.

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Appendix A

Tidal Prism Model

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

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

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

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:

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

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:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

where V_b is mean volume of the embayment. From the definition, the denominator can either be Q_T or Q_b. However, using Q_T assumes that the ocean water enters into the embayment during the flood tide is 100% new, whereas using Q_b takes into consideration that a portion of water is not entirely new. 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).

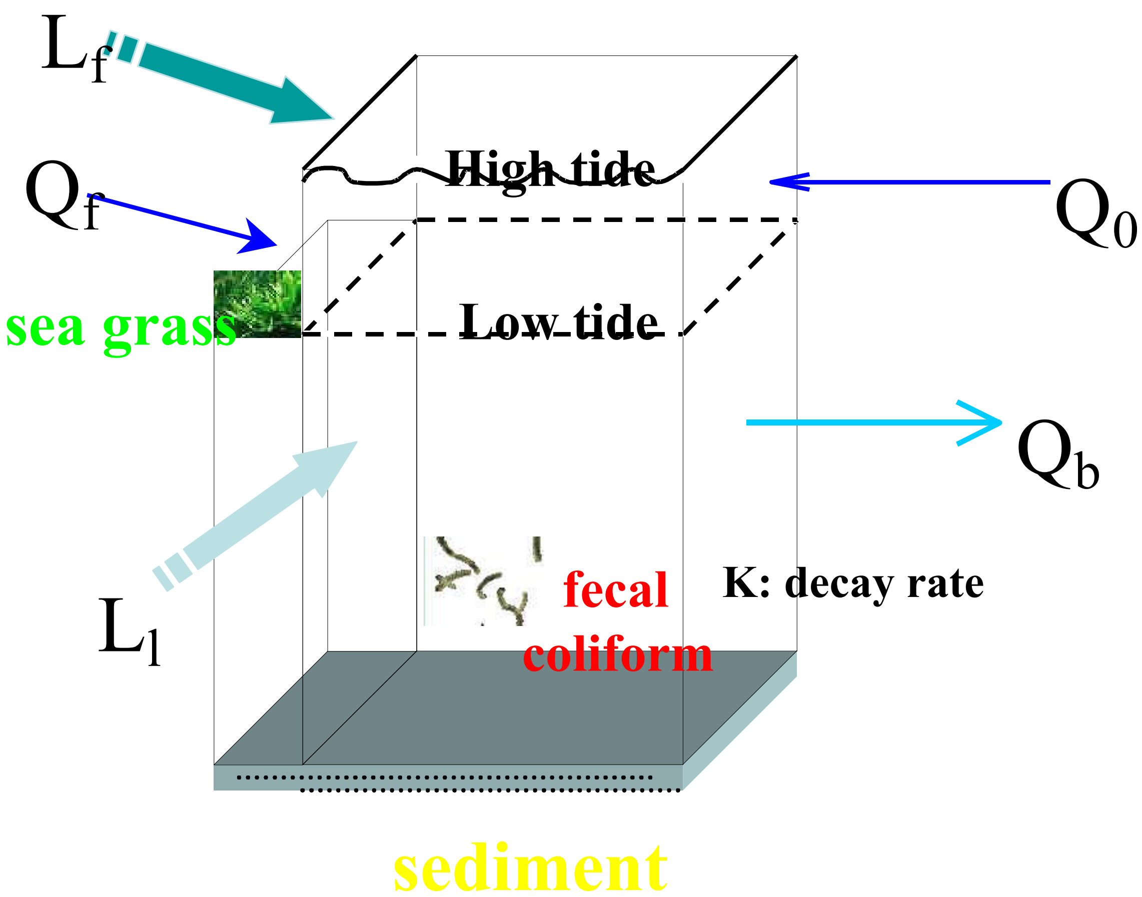

Figure A-1: The schematic diagram for the tidal prism model

A Tidal Prism Model Calculation for San Domingo Creek (RID 16A1)

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 = 546624.9(m^3)
k = Fecal coliform decay rate 0.36 (T^{-1})
Q_f = Freshwater discharge
= 1.0215 cfs = 1.0215 × 0.0283×86400×12.42÷24 = 1292.6 (m^3T^{-1})
Q_0 = 119304.9 (m^3T^{-1})
Q_b = 120597.6 (m^3 T^{-1})
C_c = water quality criterion = 14 MPN/100ml
C = current fecal coliform 5-year median concentration = 7.3 (MPN/100ml)
C_0 = fecal coliform 5-year median outside of the embayment = 7.3 (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× (120597.6 +0.36×546624.9) - 119304.9× 14] ×24÷12.42×10000
= 5.359×10^{10}

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

Current condition =

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

[(7.3) × (120597.6 +0.36×546624.9) - 119304.9 × (7.3)] ×24÷12.42×10000
=2.794×10^{10}

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{2.794 \times 10^{10} - 5.359 \times 10^{10}}{2.794 \times 10^{10}} = 0\%$$

A Tidal Prism Model Calculation for San Domingo Creek (RID 16A1)

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 = 546624.9(m^3)
k = Fecal coliform decay rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 1.0215 cfs = 1.0215 × 0.0283×86400×12.42÷24 = 1292.6 (m^3T^{-1})
Q_0 = 119304.9 (m^3T^{-1})
Q_b = 120597.6 (m^3 T^{-1})
C_c = water quality criterion = 49 MPN/100ml
C = current fecal coliform 5-year 90th percentile concentration = 78.64 (MPN/100ml)
C_0 = fecal coliform 5-year 90th percentile at the outside of the embayment
= 78.64 (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× (120597.6 +0.36×546624.9) - 119304.9× 49] ×24÷12.42×10000
= 1.876×10^{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 =
$$Load = [C \times (Q_b + kV) - Q_0 \times C_0] \times Cf$$
[(78.64) × (120597.6 +0.36×546624.9) - 119304.9 × (78.64)] ×24÷12.42×10000
=3.010×10^{11}

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{3.010\times10^{11} - 1.876\times10^{11}}{3.010\times10^{11}} = 37.69\%$$

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
16A1	San Domingo Creek	546624.9	0.36	1292.6	119304.9	120597.6	7.3	7.3	78.6	78.6
17C	Tred Avon River	3473499.1	0.36	11623.7	594939.1	606562.9	20	9.1	154.5	83.3
17D	Tar Creek	294176.5	0.36	604.0	76916.5	77520.5	3.6	3.6	75.6	75.6
57B	Northeast Branch	606645.0	0.36	1764.8	170595.0	172359.9	23	9.1	202.0	93.5

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 counts/day	Current Load counts/day	Percent Reduction	Allowable Load counts/day	Current Load Counts/day	Percent Reduction
16A1	San Domingo Creek	5.359E+10	2.794E+10	0.00	1.876E+11	3.010E+11	37.69
17C	Tred Avon River	3.414E+11	6.131E+11	44.31	1.195E+12	4.587E+12	73.94
17D	Tar Creek	2.881E+10	7.409E+09	0.00	1.008E+11	1.556E+11	35.19
57B	Northeast Branch	5.956E+10	1.437E+11	58.54	2.085E+11	1.217E+12	82.87

Appendix B

Nonpoint Source Assessment

Nonpoint sources of fecal coliform bacteria do not have one discharge point but occur over the entire length of a stream or waterbody. There are many types of nonpoint sources in watersheds discharging to the restricted shellfish harvesting area. The possible introductions of fecal coliform bacteria to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and discharges to the restricted shellfish harvesting area. The deposition of non-human fecal coliform directly to the restricted shellfish area occurs when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions to the bacterial levels from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreation vessel discharges. The transport of fecal coliform from land surface to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

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

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

In the Lower Choptank 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 areas in the Lower Choptank 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 restricted shellfish harvesting area.

Table B-1: Summary of Nonpoint Sources

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

A. Wildlife Contributions

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

Table B-2: Wildlife Habitat and Densities

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

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

The habitat areas for each species were determined using ArcView GIS with the 2000 MDP land use data and EPA reach coverage in the watershed. The GIS tool was applied to the land use coverage to create a habitat area according to Table B-2. For the deer, goose and duck estimates the entire watershed was used 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 is listed in Table B-3. To obtain the total wildlife contribution, population density is multiplied by the applicable acreage or stream mile and that product is multiplied by fecal coliform production rates for each animal.

Table B-3: Wildlife Fecal Coliform Production Rates

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

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

B. Human Contributions

Human loading can result from failures in septic waste treatment systems or through pollution from recreation vessel discharges in the identified restricted shellfish 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 the Lower Choptank River watershed. Since the restricted shellfish harvesting areas throughout the Lower Choptank 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: Proportional Population, Households, Septic Systems and Sewer Coverage in the Lower Choptank

RID	Area Name	Proportional Population	Proportional Septic Systems	Proportional Households	Public Sewer
16A1	San Domingo Creek	793	77	351	Partial
17C	Tred Avon River	10,229	648	4,428	Partial
17D	Tar Creek	47	22	22	No
57B	Northeast Branch	159	85	67	No

The distributions of septic systems in the restricted shellfish harvesting areas of the Lower Choptank River Basin are shown in Figure B-1 to Figure B-4. Based on GIS property coverage, a point is assumed to represent a septic system. The total number of septic systems in each restricted shellfish harvesting area is shown in Table B-4. According to GIS coverage, some areas are partially covered by public sewer systems in the restricted shellfish harvesting area watersheds.

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:

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

Where
P = number of people per septic system
S = number of septic systems in the restricted area
F_r = failure rate of septic systems
C = fecal coliform concentration of wastewater
Q = daily discharge of wastewater per person
C_V = unit conversion factor (37.854)

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

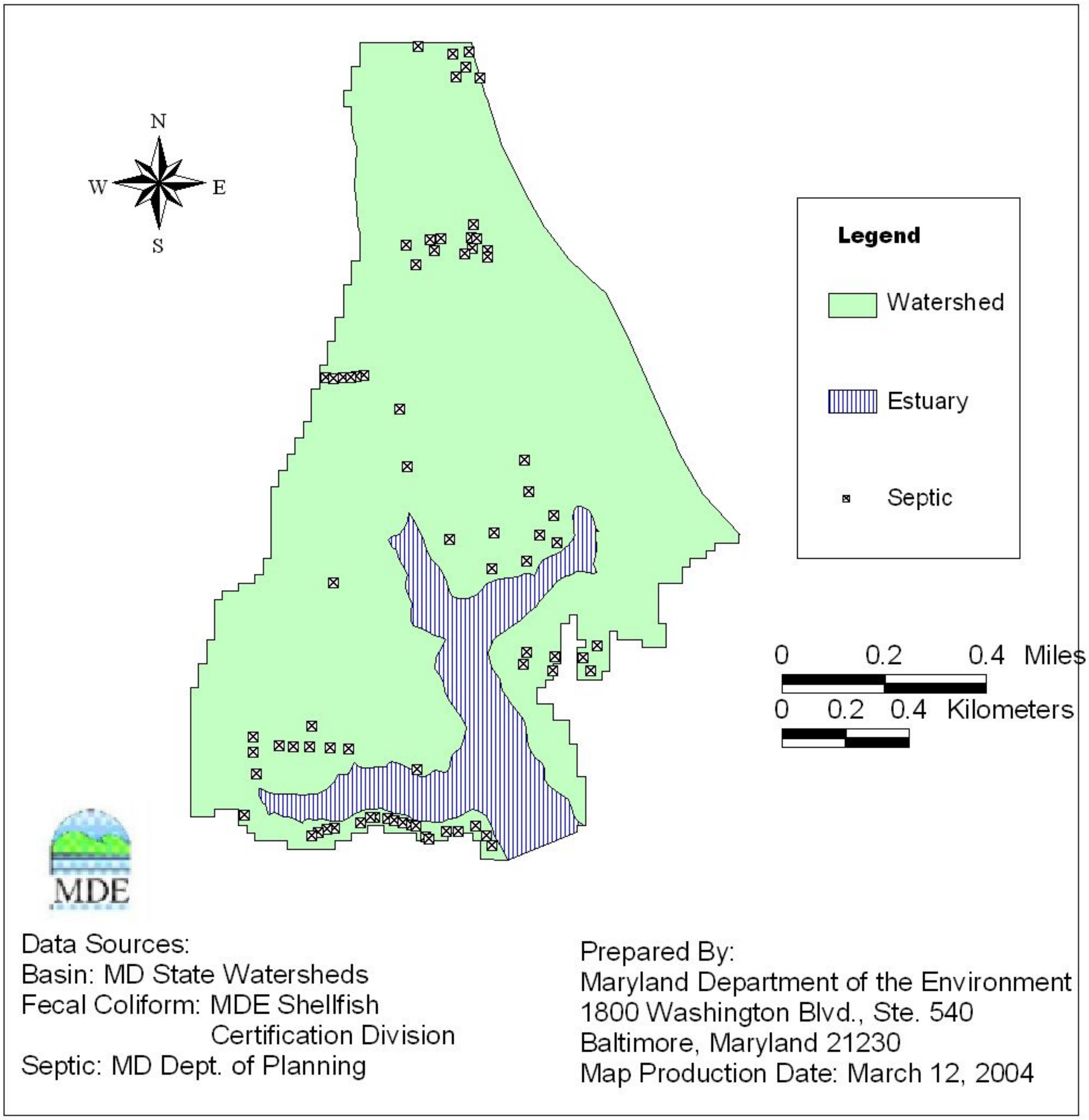

Figure B-1: Distribution of Septic Systems in the San Domingo Basin

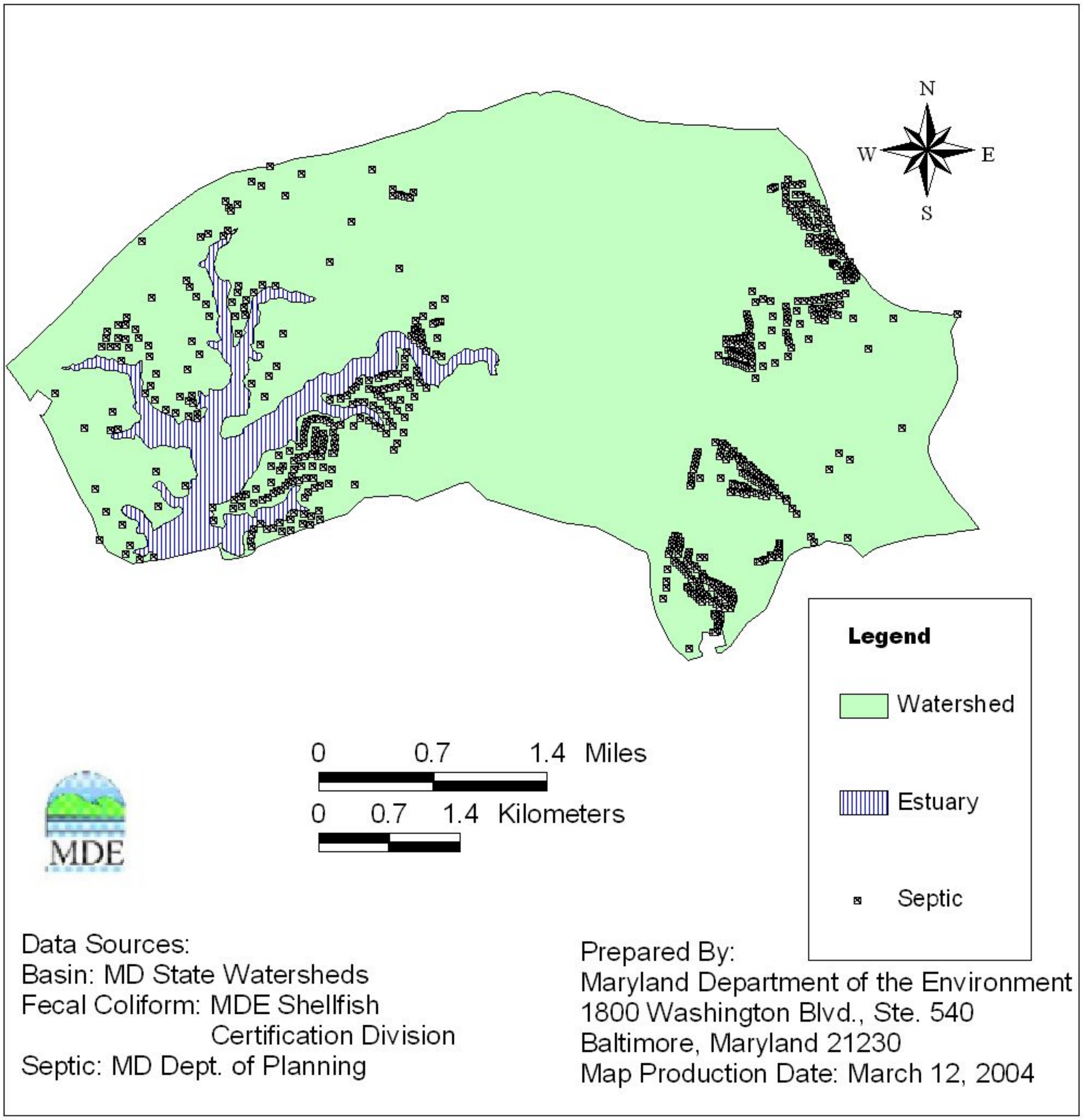

Figure B-2: Distribution of Septic Systems in the Tred Avon River Basin

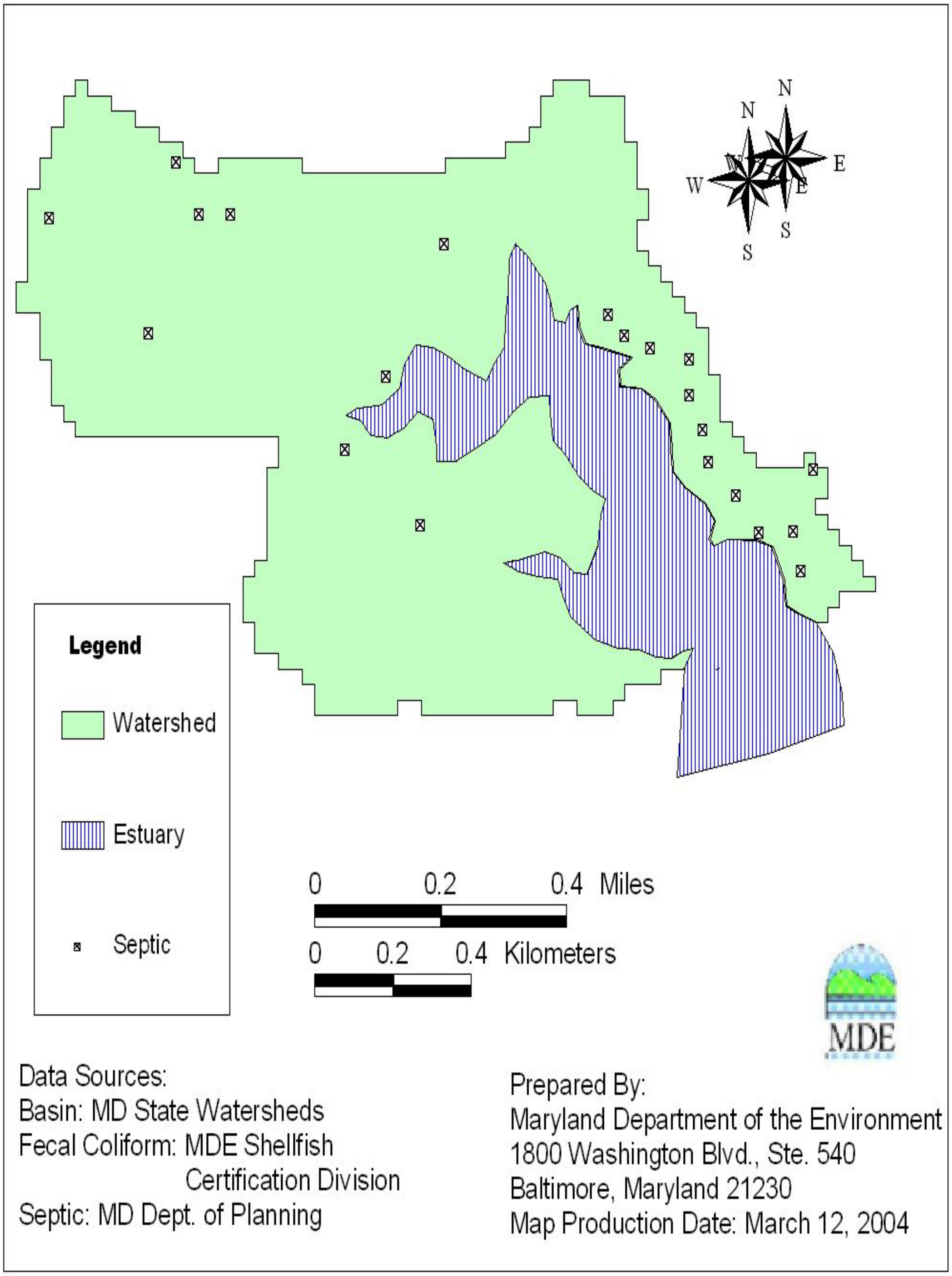

Figure B-3: Distribution of Septic Systems in the Tar Creek Basin

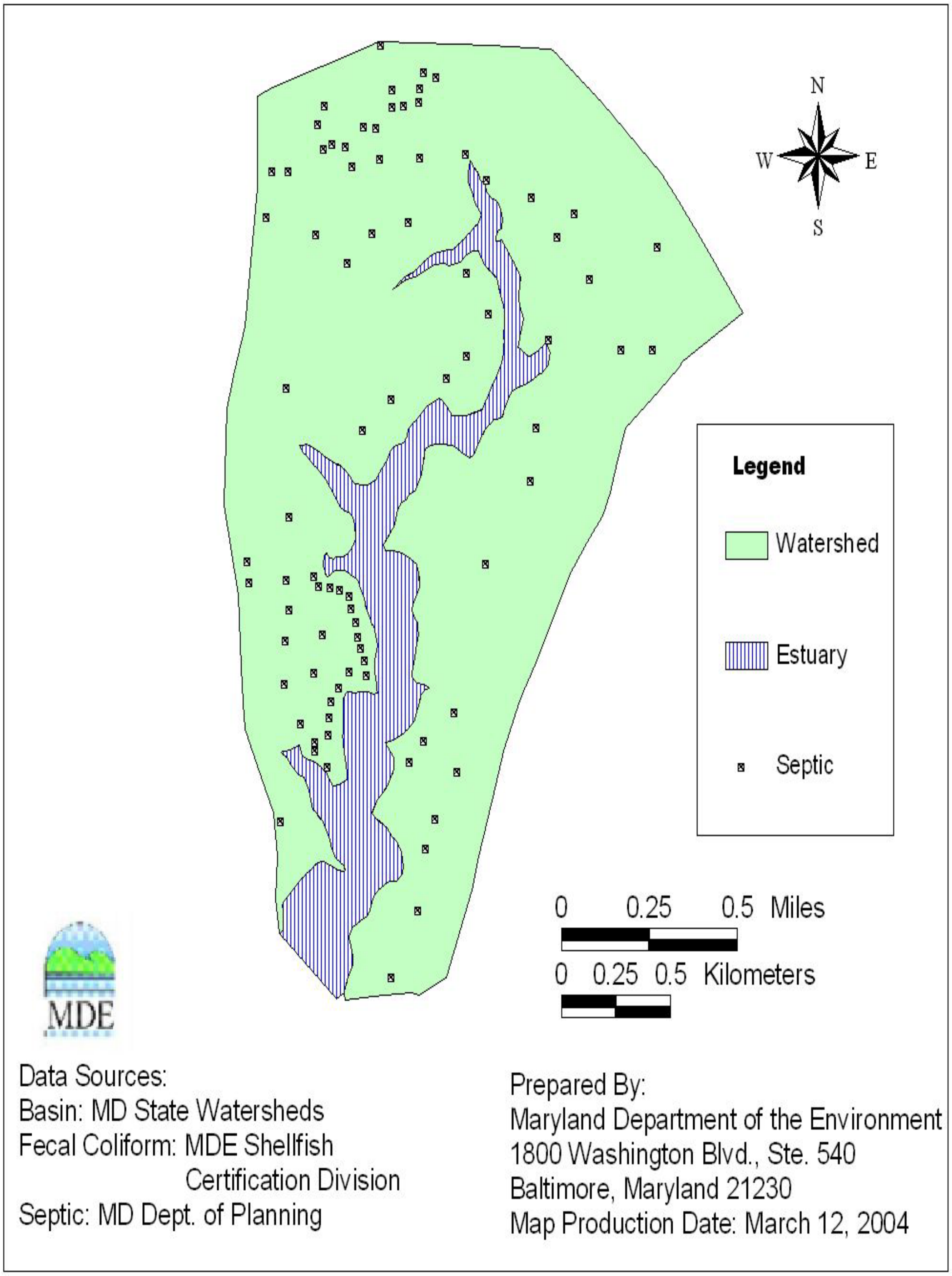

Figure B-4: Distribution of Septic Systems in the Northeast Branch Basin

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 population around the Lower Choptank River Basin was estimated based on the number of households (see Table B-4). According to a survey conducted by the Center for Watershed Protection of Chesapeake Bay residents, about 41% of the households own a dog. Of these dog owners, only about 56% walk their dogs, and of that group only 59% clean up most of the time (i.e., 41% do not). The estimated total load available for wash off is 23% (i.e., 56%x41%). 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-5. The fecal coliform load was estimated based on the total number of livestock and the fecal coliform production rates.

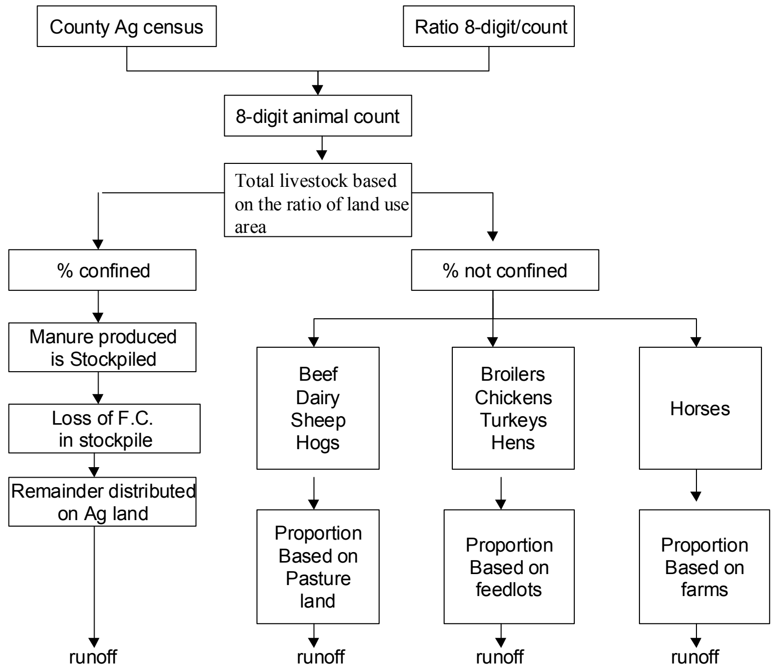

Figure B-5: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population

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

Table B-5: Livestock Fecal Coliform Production Rates

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

Table B-6: Percent of Time Livestock is Confined

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

E. Nonpoint Source Summary

The complete distributions of these source loads are also listed in Table B-7 to Table B-10, 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-7: Distribution of Fecal Coliform Source Loads in the San Domingo Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	2.00E+11	40.2%
Pets	1.65E+11	33.3%
Human	8.95E+08	0.2%
Wildlife	1.31E+11	26.3%
Total	4.97E+11	100.0%

Table B-8: Distribution of Fecal Coliform Source Loads in the Tred Avon River Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	1.51E+13	82.9%
Pets	2.09E+12	11.5%
Human	1.04E+10	0.1%
Wildlife	1.01E+12	5.5%
Total	1.82E+13	100.0%

Table B-9: Distribution of Fecal Coliform Source Loads in the Tar Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	1.15E+13	99.1%
Pets	1.04E+10	0.1%
Human	3.74E+08	0.0%
Wildlife	8.98E+10	0.8%
Total	1.16E+13	100.0%

Table B-10: Distribution of Fecal Coliform Source Loads in the Northeast Branch Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	6.48E+10	24.6%
Pets	3.16E+10	12.0%
Human	1.26E+09	0.5%
Wildlife	1.66E+11	62.9%
Total	2.64E+11	100.0%