Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Area in the Lower Choptank River Mainstem in Dorchester and Talbot Counties, Maryland

REVISED FINAL

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List of Abbreviations

BMP	Best Management Practice
BST	Bacteria Source Tracking
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	U.S. Environmental Protection Agency
FA	Future Allocation
FDA	U.S. Food and Drug Administration
GIS	Geographic Information System
HEM-3D	Hydrodynamic and Eutrophication Model in 3 Dimensions
km	Kilometer
LA	Load Allocation
m	Meter
M_2	Lunar semi-diurnal tidal constituent
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
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
T^{-1}	Per Tidal Cycle
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
VIMS	Virginia Institute of Marine Science
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 Choptank River (basin number 02130403) was first identified on the 1996 303(d) List submitted to U.S. Environmental Protection Agency (EPA) by the Maryland Department of the Environment (MDE). The designated uses in the Lower Choptank River were listed as impaired by sediments, nutrients, and fecal coliform in tidal portions, with listings of impacts to biological communities in the non-tidal portions added in 2002. On the 2004 303(d) List, the fecal coliform listing was clarified by the identification of the Lower Choptank River mainstem as the specific area of impairment. Eleven restricted shellfish harvesting areas in the lower Choptank River were listed on the 303(d) List: 1) Jenkins Creek, 2) Tred Avon River, 3) Tar Creek, 4) Cummings Creek, 5) Northeast Branch, 6) Whitehall Creek, 7) Indian Creek, 8) Goose Creek, 9) Warwick River, 10) San Domingo Creek, and 11) the Choptank River mainstem downstream of Hunting Creek and upstream of Warwick River (hereinafter referred to as Lower Choptank River mainstem). Fecal Coliform TMDLs for the first ten of these restricted areas have been addressed in separate reports in 2004 and 2006. This document, upon EPA approval, establishes a TMDL of fecal coliform for the Lower Choptank River mainstem. The impairments due to nutrients, sediments and impacts to biological communities within the Lower Choptank River basin will be addressed at a future date.

It should be noted that the TMDL assessment for the Lower Choptank River mainstem required a different methodology than did all previously reported restricted shellfish harvesting areas of the Lower Choptank River. Therefore, the Lower Choptank River mainstem is being reported on separately to document this enhanced methodology.

An inverse three-dimensional model was used to estimate current fecal coliform loads based on the model simulations of median and 90th percentile of fecal coliform concentrations in the Lower Choptank River, and to establish allowable loads for the restricted shellfish harvesting area in the Choptank River watershed in the Lower Choptank River Basin. The inverse model incorporates influences of freshwater discharge, tidal and density-induced transport, and fecal coliform decay; thereby representing the fate and transport of fecal coliform in the Lower Choptank River and its corresponding restricted shellfish harvesting area. The potential sources (human, livestock, pets and wildlife) are identified by determining the proportional contribution of each source based on animal/source density per land use acre multiplied by the fecal coliform production.

The length of the Lower Choptank River is approximately 45 km and the restricted shellfish harvesting area portion of the Lower Choptank River mainstem is approximately 7.5 km.

Numerical model simulation results show that it requires 72 days for fecal coliform discharged into the river at the headwaters to be transported to the downstream near the mouth of Hunting Creek under the mean flow condition. Because of the decay of fecal coliform, large amounts of bacteria will be lost during the transport. Model sensitivity tests further confirm that the fecal coliform concentration in the restricted area does not depend on the load in the watershed upstream of Kings Creek. Therefore, this TMDL was developed for those watersheds downstream of Kings Creek that have significant influence on the restricted shellfish harvesting area.

The allowable loads for the restricted shellfish harvesting area were computed using both the median concentration water quality criterion for shellfish harvesting use of 14 Most Probable Number (MPN)/100ml, and the 90^{th} percentile criterion concentration of 49 MPN/100ml. An implicit Margin of Safety (MOS) was incorporated into the analysis to account for uncertainty. The TMDLs developed for the restricted shellfish harvesting area of the Lower Choptank River watershed in the Lower Choptank River Basin for fecal coliform median load and 90^{th} percentile load are as follows:

Lower Choptank River mainstem:
The median load fecal coliform TMDL = 1.225×10^{11} counts per day
The 90^{th} percentile fecal coliform TMDL = 3.070×10^{11} counts per day

The goal of load allocation is to determine the estimated loads that may be allocated for each source in the watershed while ensuring that the water quality standard can be attained. For the Lower Choptank River mainstem restricted harvesting area in the Lower Choptank River Basin, the 90^{th} percentile criterion requires the greatest reduction – about 66% within the watershed. Therefore, the load reduction scenario is developed based on the 90^{th} percentile TMDL, and will result in the load reductions that allow attainment of the water quality standard. Reductions from current baseline conditions are estimated and presented in this report.

Once EPA has approved this TMDL, MDE will begin an iterative process of implementation, focusing first on those sources that have the greatest impact on water quality while giving consideration to the relative ease of implementation and cost. The source contributions estimated from the watershed analysis may be used as a tool to target and prioritize initial implementation efforts. To confirm the bacteria source allocations, MDE is conducting a one-year bacteria source tracking (BST) study for the restricted shellfish harvesting area identified in this report. Continued monitoring will be undertaken by MDE's Shellfish Certification Division and the data will be used to assess the effectiveness of the Department's implementation efforts on an ongoing basis.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and including a protective margin of safety (MOS) to account for scientific uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and/or numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

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

Fecal coliform is an indicator organism used in water quality monitoring in shellfish waters to indicate fresh sources of pollution from human and other animal wastes. 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 U.S. Food and Drug Administration (FDA), rather than EPA, is responsible for food safety. Water quality criteria for shellfish waters are established under the National Shellfish Sanitation Program (NSSP), a cooperative program that involves States, industry, academic and federal agencies with oversight by FDA. The NSSP continues to use fecal coliform as the indicator organism to assess shellfish harvesting waters. The water quality goal of this TMDL is to reduce high fecal coliform concentrations to levels whereby the designated uses for this restricted shellfish harvesting area will be met.

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. Shellfish waters are continuously monitored, and openings and closings occur routinely. The 2004 303(d) List indicates currently restricted shellfish harvesting areas that require TMDLs within an 8-digit watershed.

The Lower Choptank River (basin number 02130403) was first identified on the 1996 303(d) List submitted to EPA by the Maryland Department of the Environment (MDE). The designated uses in Lower Choptank River were listed as impaired by sediments, nutrients, and fecal coliform in tidal portions, with listings of impacts to biological communities in the non-tidal portions added in 2002 and 2004. On the 2004 303(d) List, the fecal coliform listing was clarified by the identification of specific areas of impairments. Eleven restricted shellfish harvesting areas in the Lower Choptank River were listed on the 303(d) List: 1) Jenkins Creek, 2) Tred Avon River, 3) Tar Creek, 4) Cummings Creek, 5) Northeast Branch, 6) Whitehall Creek, 7) Indian Creek, 8) Goose Creek, 9) Warwick River, 10) San Domingo Creek, and 11) the Choptank River mainstem downstream of Hunting Creek and upstream of Warwick River (hereinafter referred to as Lower Choptank River mainstem). Fecal coliform TMDLs for the first ten of these restricted areas were addressed in separate reports in 2004 and 2006. This document, upon EPA approval, establishes TMDLs for fecal coliform for the Lower Choptank River mainstem.

It should be noted that the TMDL assessment for the Lower Choptank River mainstem required a different methodology than did all previously reported restricted shellfish harvesting areas of the Lower Choptank River. Therefore, the Lower Choptank River mainstem is being reported on separately to document this enhanced methodology.

The basis of the shellfish harvesting area closure is fecal coliform data from the shellfish water quality monitoring program, which indicate that the shellfish harvesting area waters exceeded water quality criteria. As a result, the shellfish areas were classified as “restricted” or closed to direct harvest. Shellfish waters are closed or restricted to harvesting when the fecal coliform criteria for shellfish harvesting waters are exceeded. The criteria include both a median and a 90^{th} percentile. The impairments due to nutrients, sediments and impacts to biological communities within the Lower Choptank River basin will be addressed at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

The restricted shellfish harvesting area in the Lower Choptank River addressed in this report is the Lower Choptank River mainstem. The Lower Choptank River mainstem is located on Maryland's Eastern Shore in Dorchester and Talbot Counties, as shown in Figure 2.1.1a. The Lower Choptank River has a length of approximately 45 km. Its width ranges from 700 m upstream to approximately 7 km at its mouth, where it flows to the southwest into Chesapeake Bay. The Lower Choptank River mainstem restricted shellfish harvesting area is the section downstream of Hunting Creek and upstream of Warwick River, and has a drainage area of 387,496.9 acres (1,568.14 km^2). A portion of this drainage area, approximately 16.2%, is in Kent County, Delaware. The Lower Choptank River mainstem has a length of 7.52 km and is shown in more detail in Figure 2.1.1b.

Soils in the Lower Choptank River mainstem watershed are primarily moderately well drained, silty soils (U.S. Department of the Agriculture (USDA), 1995). The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.49 m in the restricted shellfish harvesting area of the Lower Choptank River and a tidal period of 12.42 hours (National Oceanic and Atmospheric Administration (NOAA), 2004). Please refer to Table 2.1.1 for the mean volume and mean water depth of this restricted shellfish harvesting area.

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

Restricted Shellfish Harvesting Area	Mean Water Volume in m^3	Mean Water Depth in m
Lower Choptank River Mainstem	29,455,620	3.03

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that the watershed can be characterized as rural for the Lower Choptank River mainstem with 56% of the area being cropland and another 23% being forest. The land use information for the restricted shellfish harvesting area in the Lower Choptank River mainstem is shown in Table 2.1.2 and Figure 2.1.2. Residential urban land use identified in Table 2.1.2 includes low-density residential, medium-density residential, and high-density residential. Non-residential urban land use in this table includes commercial, industrial, institutional, extractive, and open urban land.

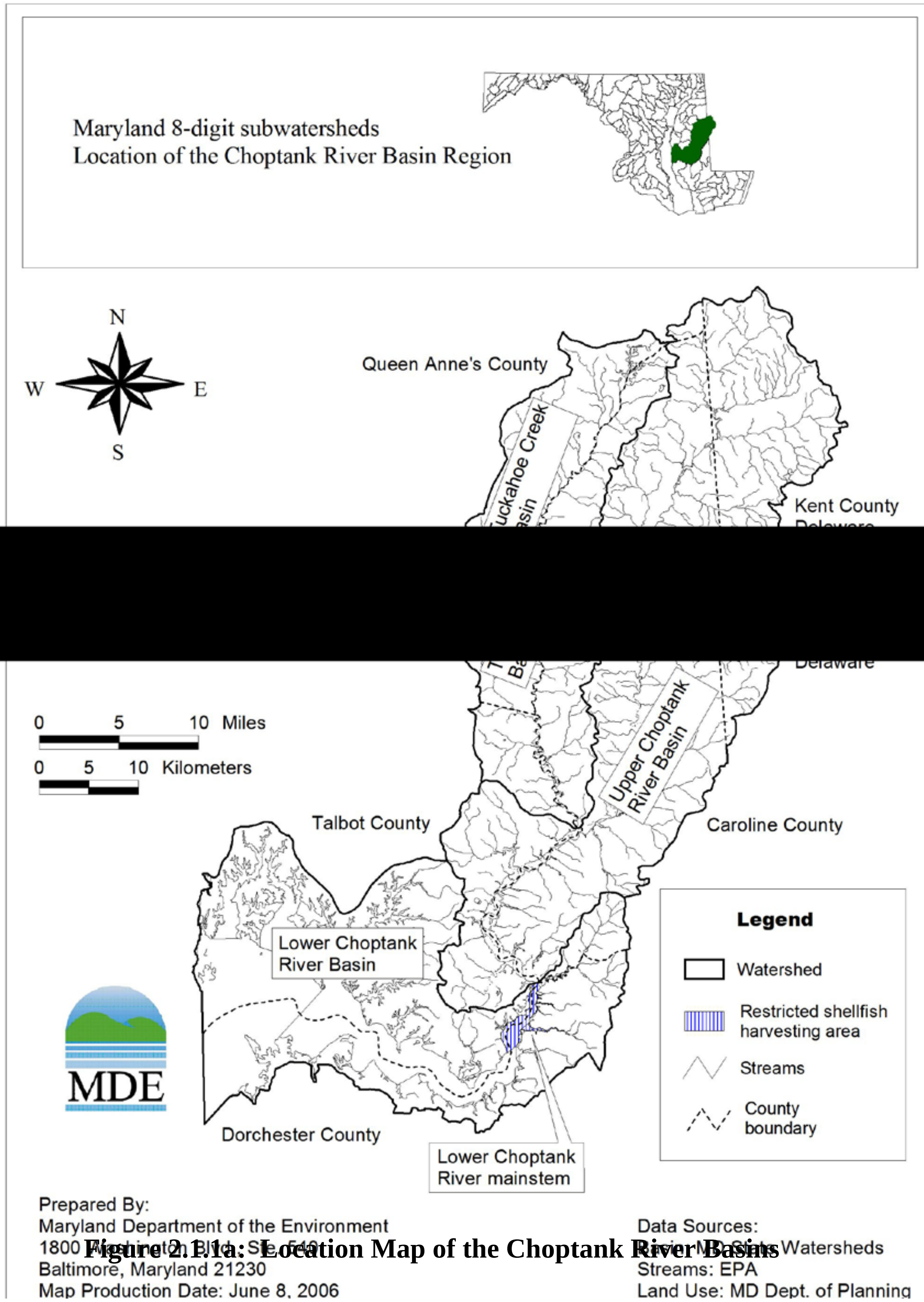

Figure 2.1.1a: Location Map of the Choptank River Basins

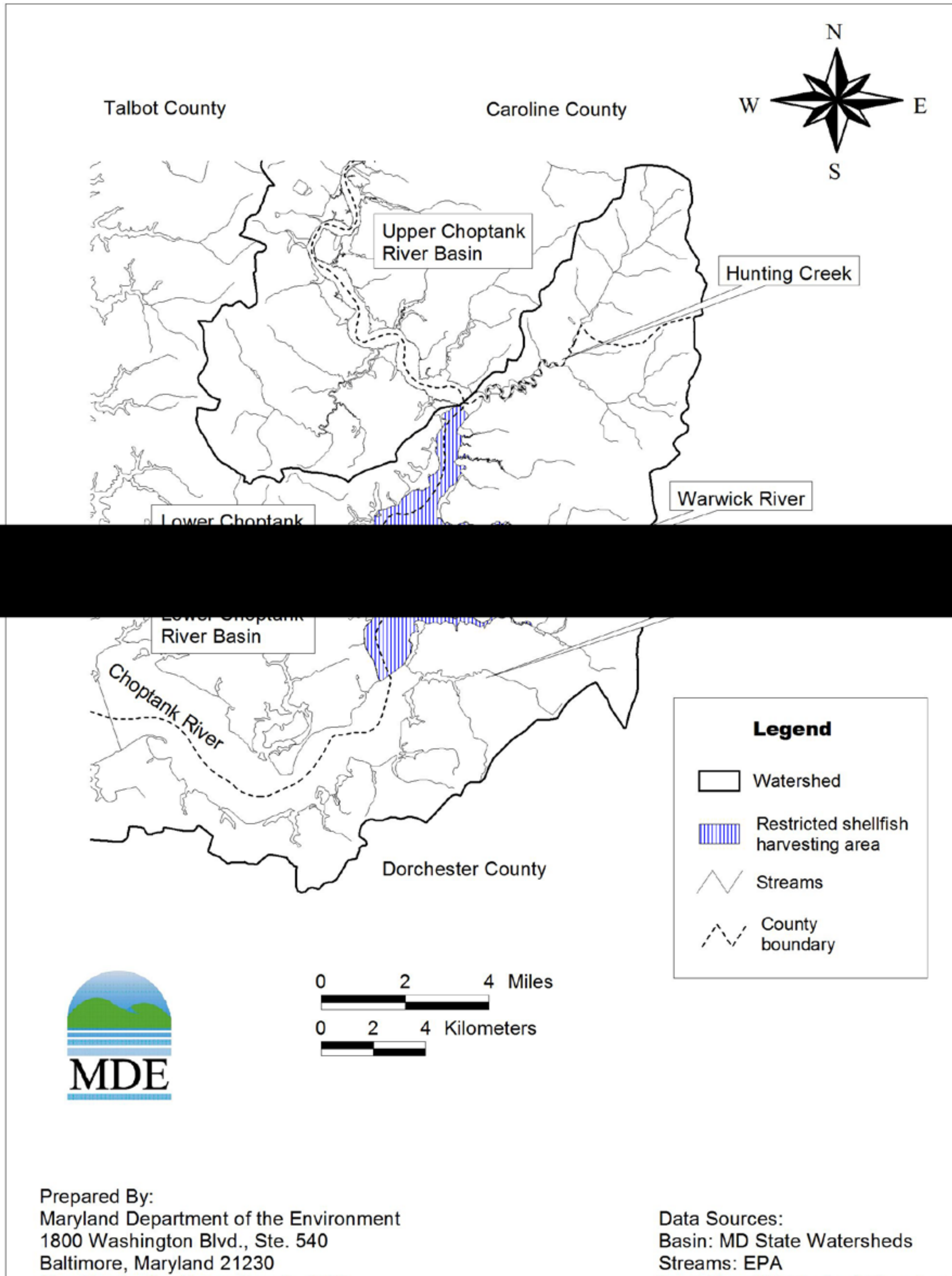

Figure 2.1.1b: Location Map surrounding Lower Choptank River Mainstem site

Table 2.1.2: Land Use Percentage Distribution for Choptank River

Land Type	Acreage	Percentage
Residential urban	23,761.8	6.13
Non-Residential urban	5,138.8	1.33
Cropland	218,796.8	56.46
Pasture	1,902.3	0.49
Feedlot	3,914.6	1.01
Forest	90,798.2	23.43
Water	18,701.3	4.83
Wetlands	24,297.1	6.27
Barren	185.9	0.05
Totals	**387,496.8**	**100.00**

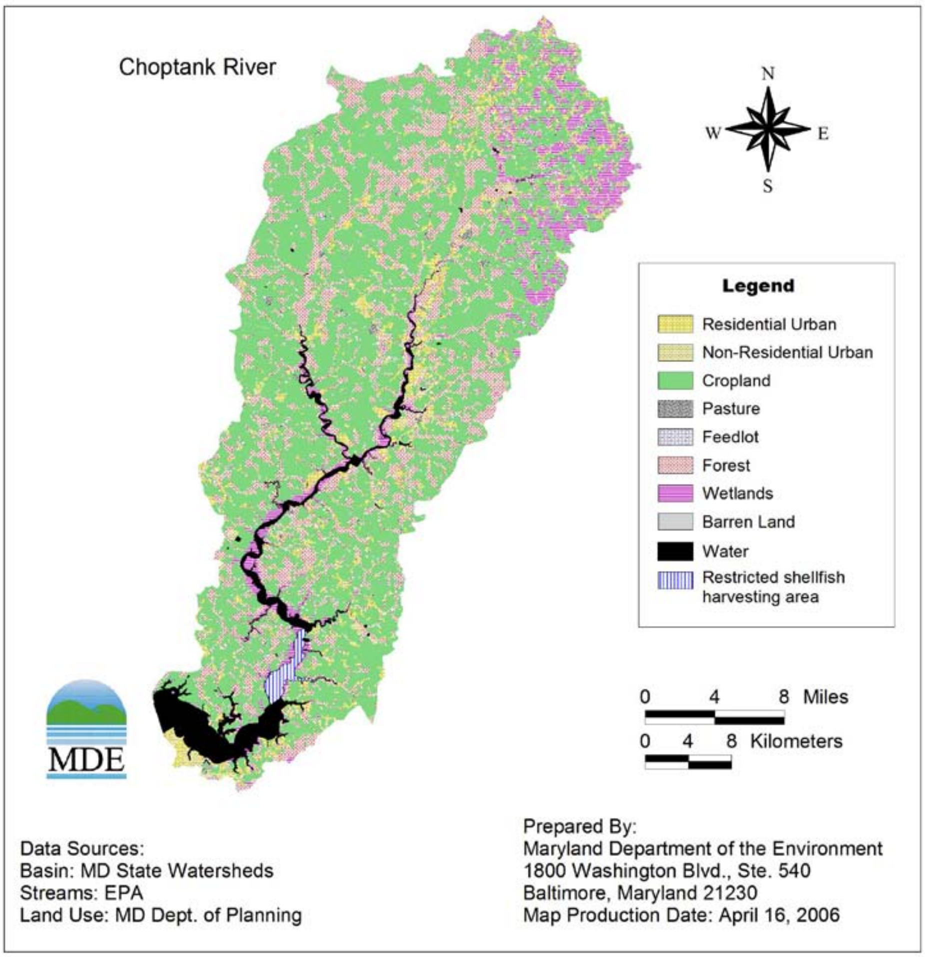

Figure 2.1.2: Land Use in the Choptank River Basins

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 waters of Maryland. These data are used to determine if the shellfish water classification is being met.

MDE's Shellfish Certification Program has monitored shellfish waters throughout Maryland for the past several decades. There are three shellfish monitoring stations in the restricted shellfish harvesting area addressed in this report. The station identification and observations recorded during the period of July 2000 – July 2005 are provided in Table 2.2.1 and Figure 2.2.1 through Figure 2.2.4 for fecal coliform monitoring stations 10-01-010, 10-01-701, and 10-01-800. Tabulations of observed fecal coliform values in Most Probable Number (MPN)/100ml at the monitoring stations included in this report are provided in Appendix D.

Table 2.2.1: Location of the Shellfish Monitoring Stations in Lower Choptank River Mainstem

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Lower Choptank R. mainstem	10-01-010	2000-2005	60	38 36 59.5	75 58 55.8
Lower Choptank R. mainstem	10-01-701	2000-2005	60	38 38 36.0	75 58 02.0
Lower Choptank R. mainstem	10-01-800	2000-2005	60	38 38 01.1	75 57 49.0

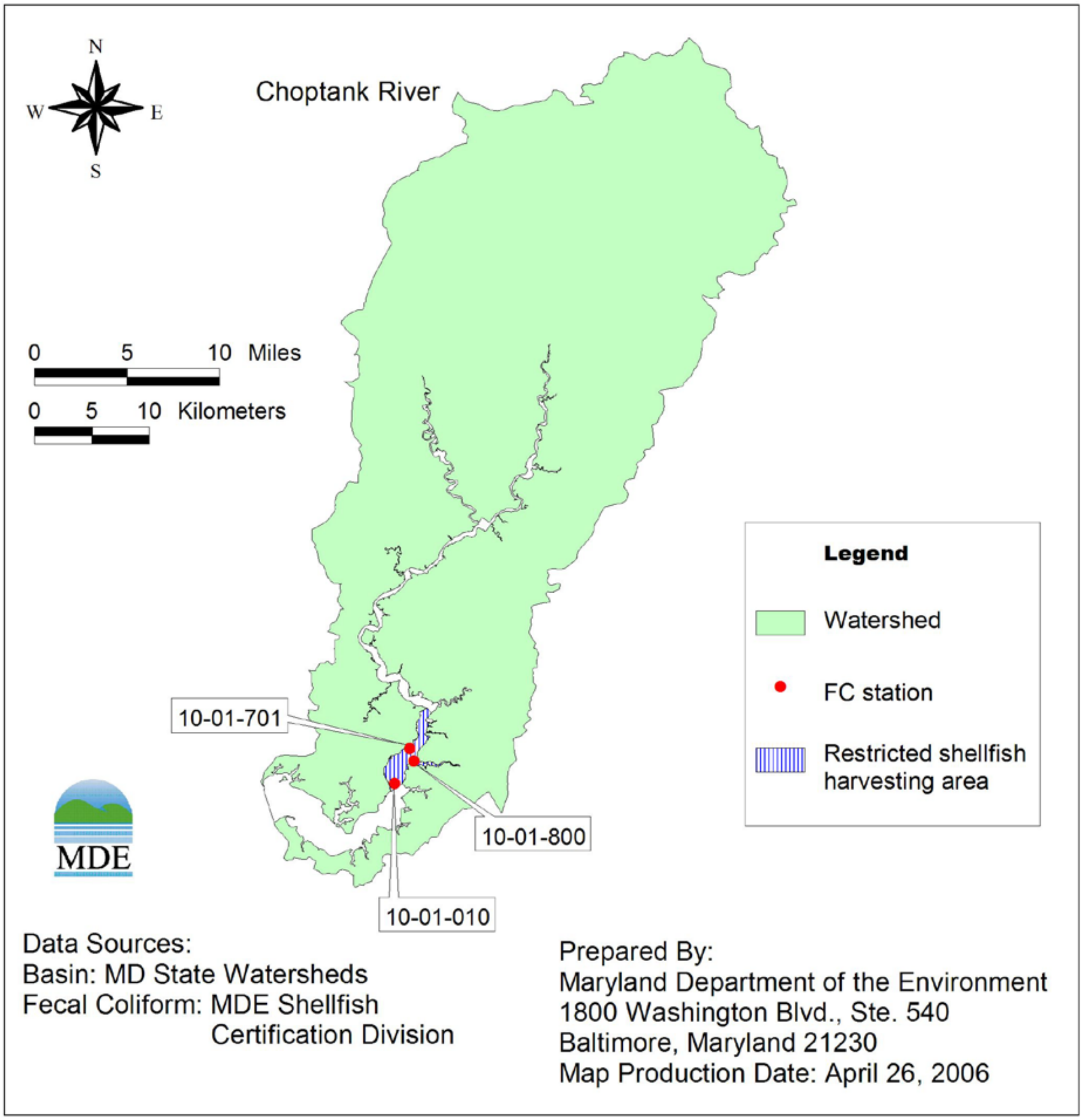

Figure 2.2.1: Shellfish Monitoring Stations in Lower Choptank River Mainstem

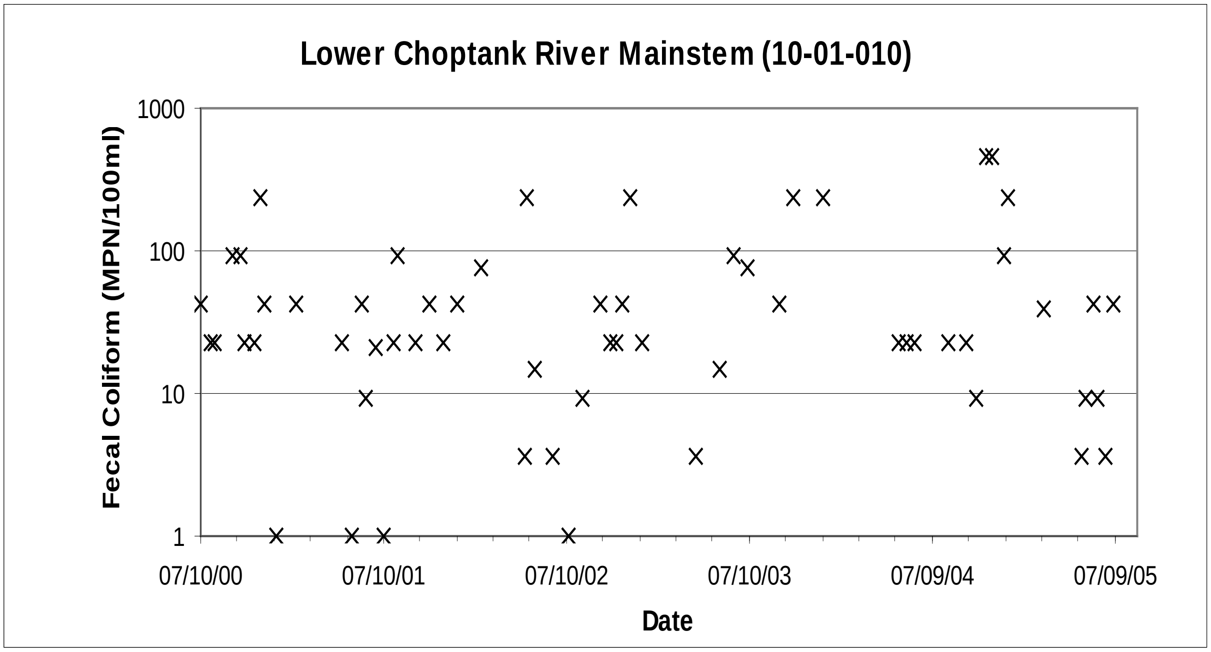

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 10-01-010

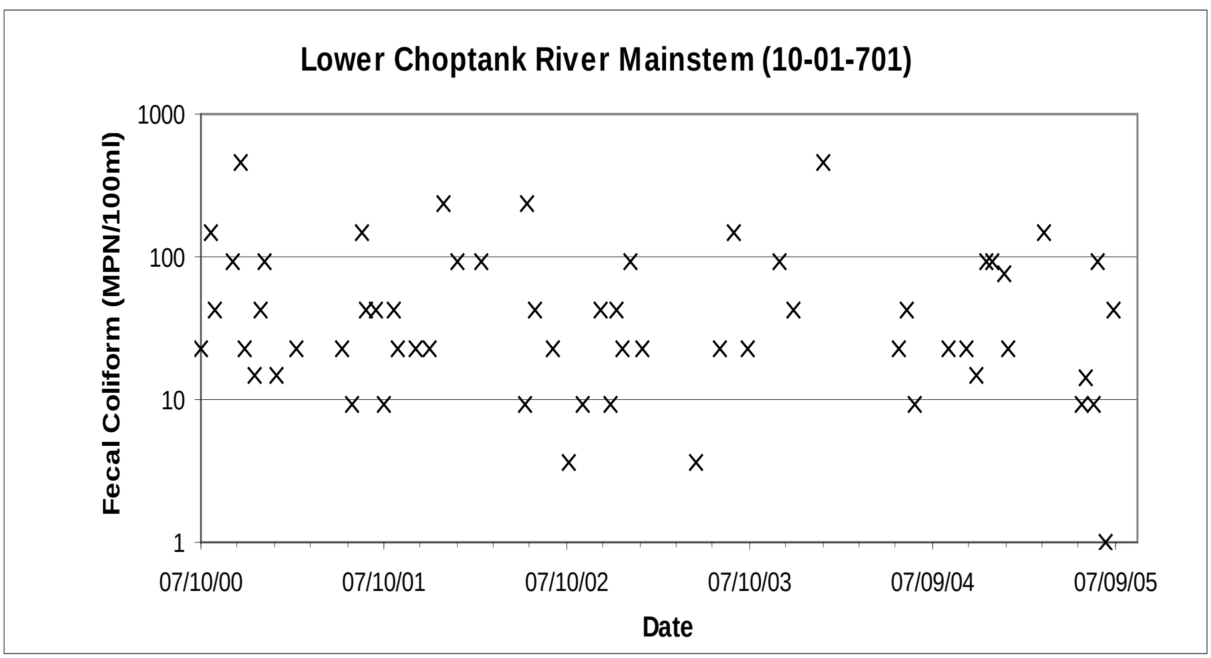

Figure 2.2.3: Observed Fecal Coliform Concentrations at Station 10-01-701

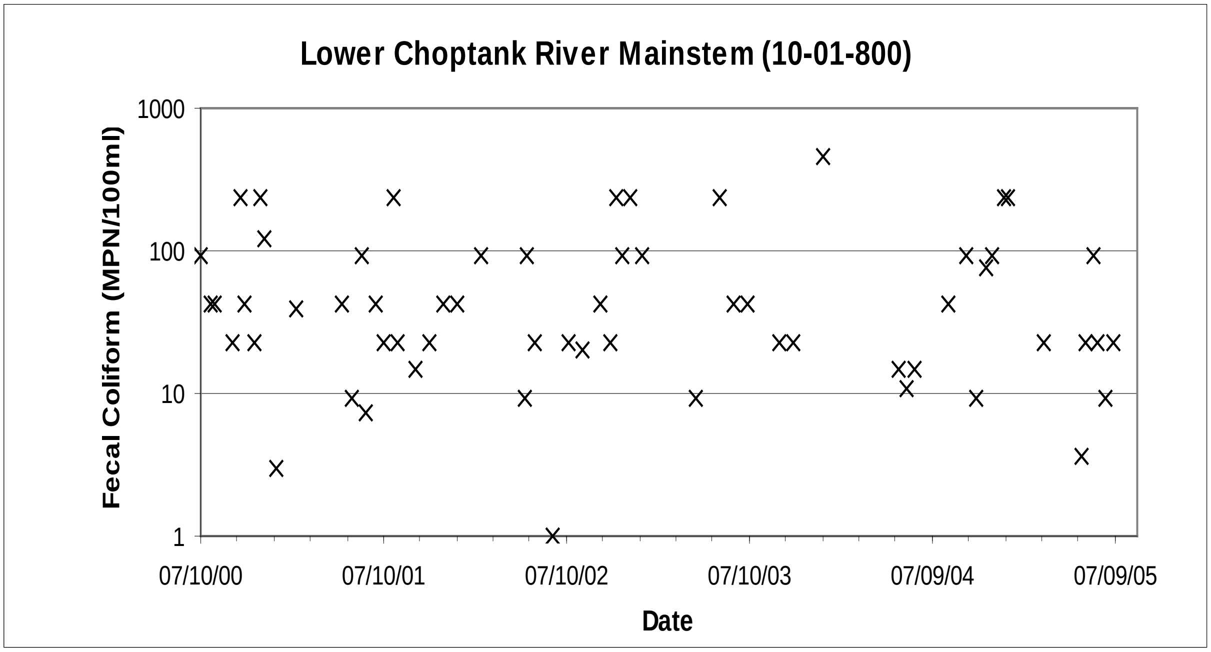

Figure 2.2.4: Observed Fecal Coliform Concentrations at Station 10-01-800

2.3 Water Quality Impairment

The fecal coliform impairment addressed in this analysis was determined with reference to Maryland's Classification of Use II Waters- Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting in Code of Maryland Regulations (COMAR), Surface Water Quality Criteria 26.08.02.03-3.C2, which states:

> 2) Classification of Use II Waters for Harvesting.
>
> (a) Approved classification means that the median fecal coliform MPN of at least 30 water sample results taken over a 3-year period to incorporate inter-annual variability does not exceed 14 per 100 milliliters; and:
>
> (i) In areas affected by point source discharges, not more than 10 percent of the samples exceed an MPN of 43 per 100 milliliters for a five tube decimal dilution test or 49 MPN per 100 milliliters for a three tube decimal dilution test; or
>
> (ii) In other areas, the 90th percentile of water sample results does not exceed an MPN of 43 per 100 milliliters for a five tube decimal dilution test or 49 MPN per 100 milliliters for a three tube decimal dilution test.

MDE updated and promulgated shellfish water quality criteria for shellfish waters in June 2004. Although bacteriological criteria for shellfish harvesting waters were unchanged, the intent of the update was to include classification criteria required under the NSSP that were not previously included in COMAR. In 2005, MDE revised the use designations in COMAR as part of the Chesapeake Bay Program revision to reflect living resources-based habitat needs, but did not change the fecal coliform criteria for shellfish harvesting waters or shellfish harvesting use designations.

For this analysis, MDE is using routine monitoring data collected over a five-year period between July 2000 and July 2005. Most shellfish harvesting areas have been monitored routinely since before 1950 and, due to an emerging oyster aquaculture industry, there are a few shellfish harvesting areas that have less than five years worth of data. For the purpose of classifying shellfish harvesting areas, a minimum of 30 samples is required. For TMDL development, if fewer than 30 samples are available, all of the most recent data will be used to estimate current loads, and the assimilative capacity will be based on the approved classification requirements of a median of 14 MPN/100 ml and a 90th percentile of less than 49 MPN/100 ml.

Lower Choptank River, specifically the Lower Choptank River mainstem, was listed in the 2004 Integrated 303(d) List as impaired by fecal coliform. The water quality impairment in the Lower Choptank River mainstem was assessed as not meeting either the median or the 90th percentile criterion at three monitoring stations (note that Maryland uses the 3-tube decimal dilution test for fecal coliform bacteria). Descriptive statistics of the monitoring data and the requirements for the approved classification are shown in Table 2.3.1.

Table 2.3.1: Lower Choptank River Mainstem Fecal Coliform Statistics (2000-2005 data)

Area Name	Station	Median		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Lower Choptank River Mainstem	10-01-010	23.00	14	177.05	49
Lower Choptank River Mainstem	10-01-701	23.00	14	152.07	49
Lower Choptank River Mainstem	10-01-800	43.00	14	181.12	49

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 is introduced into surface waters. The deposition of non-human fecal coliform directly to the restricted shellfish harvesting areas may occur when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreational vessel discharges. The potential transport of fecal coliform from land surfaces to restricted shellfish harvesting waters is dictated by the hydrology, soil type, land use, and topography of the watershed. The locations of subwatersheds in the Lower Choptank River mainstem basin are shown in Figure 2.4.1.

The complete distribution of source loads is listed in Table 2.4.1, along with counts/day for each source. Details of the source estimate procedure can be found in Appendix B. Bacteria Source Tracking (BST) data, when they become available, will be used to further confirm the source distribution.

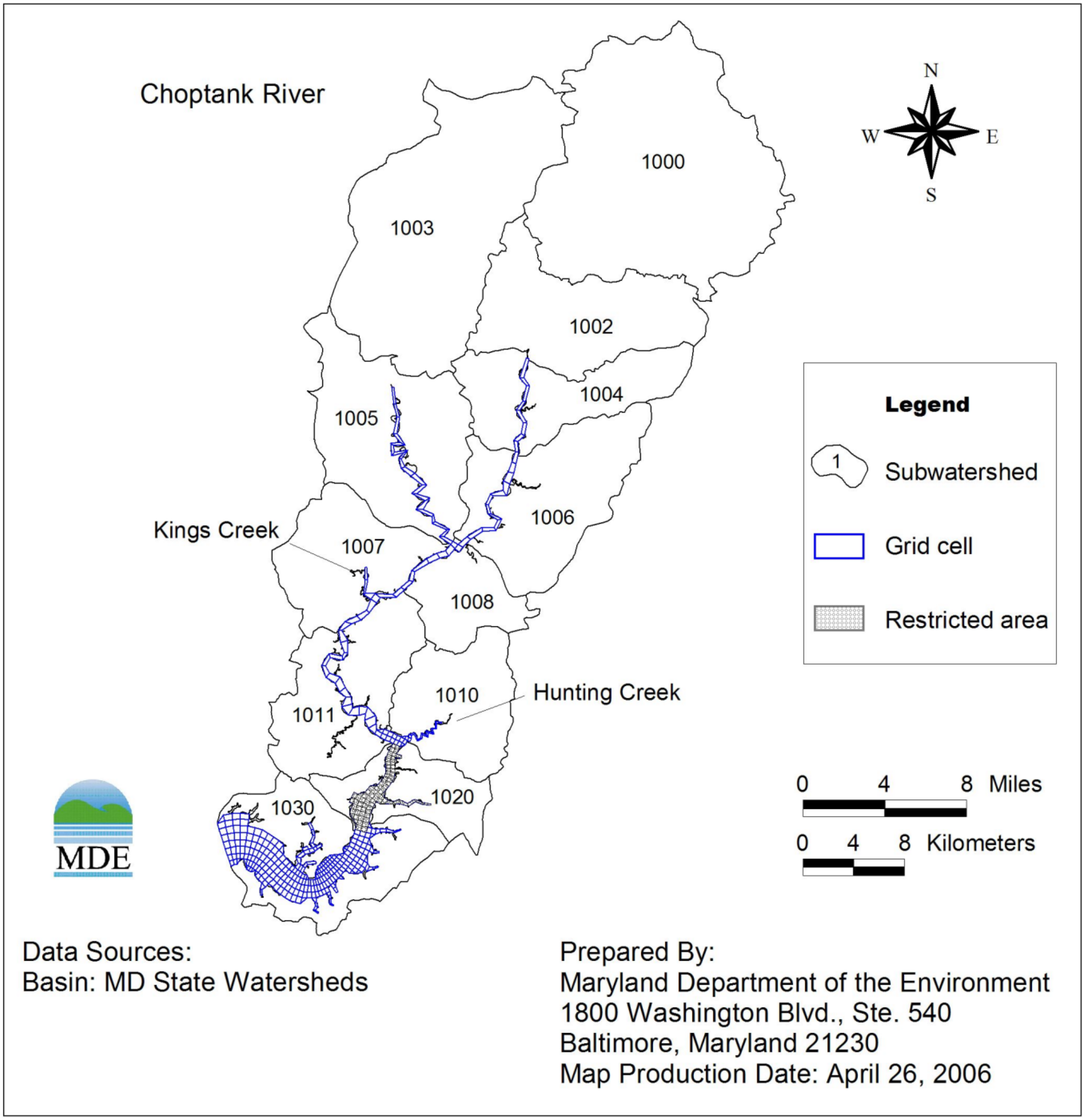

Figure 2.4.1: Subwatersheds in the Lower Choptank River Basin

Table 2.4.1: Distribution of Fecal Coliform Source Loads in Lower Choptank River Basin

Subwatershed	Fecal Coliform Source	Loading Counts/day	Loading Percent
1000	Livestock	1.657E+14	96.50%
	Pets	2.492E+12	1.46%
	Human	5.219E+10	0.03%
	Wildlife	3.459E+12	2.01%
	Total	1.717E+14	100.00%
1002	Livestock	1.657E+14	98.42%
	Pets	1.054E+12	0.63%
	Human	1.918E+10	0.01%
	Wildlife	1.588E+12	0.94%
	Total	1.684E+14	100.00%
1003	Livestock	2.107E+14	98.10%
	Pets	8.803E+11	0.41%
	Human	1.171E+10	0.01%
	Wildlife	3.177E+12	1.48%
	Total	2.147E+14	100.00%
1004	Livestock	1.325E+14	98.13%
	Pets	1.436E+12	1.07%
	Human	2.568E+10	0.02%
	Wildlife	1.057E+12	0.78%
	Total	1.350E+14	100.00%
1005	Livestock	1.190E+14	98.02%
	Pets	7.134E+11	0.59%
	Human	1.360E+10	0.01%
	Wildlife	1.676E+12	1.38%
	Total	1.214E+14	100.00%
1006	Livestock	2.212E+14	98.98%
	Pets	8.581E+11	0.38%
	Human	1.330E+10	0.01%
	Wildlife	1.405E+12	0.63%
	Total	2.235E+14	100.00%
1007	Livestock	1.565E+14	98.81%
	Pets	7.784E+11	0.49%
	Human	7.842E+09	0.01%
	Wildlife	1.086E+12	0.69%
	Total	1.584E+14	100.00%
1008	Livestock	8.992E+13	98.92%
	Pets	3.442E+11	0.38%
	Human	5.981E+09	0.01%
	Wildlife	6.280E+11	0.69%
	Total	9.090E+13	100.00%

Subwatershed	Fecal Coliform Source	Loading Counts/day	Loading Percent
1010	Livestock	5.812E+13	90.29%
	Pets	7.054E+11	1.10%
	Human	1.112E+10	0.02%
	Wildlife	5.530E+12	8.59%
	Total	6.437E+13	100.00%
1011	Livestock	1.859E+14	86.22%
	Pets	7.859E+11	0.36%
	Human	1.477E+10	0.02%
	Wildlife	2.890E+13	13.40%
	Total	2.156E+14	100.00%
1020	Livestock	1.904E+13	43.73%
	Pets	4.790E+11	1.10%
	Human	7.210E+09	0.02%
	Wildlife	2.400E+13	55.15%
	Total	4.353E+13	100.00%
1030	Livestock	1.878E+13	25.32%
	Pets	3.598E+12	4.85%
	Human	5.874E+10	0.08%
	Wildlife	5.174E+13	69.75%
	Total	7.418E+13	100.00%
Total	Livestock	1.543E+15	91.76%
	Pets	1.412E+13	0.84%
	Human	2.413E+11	0.01%
	Wildlife	1.242E+14	7.39%
	Total	1.682E+15	100.00%

Point Source Assessment

There are no industrial point sources with permits regulating the discharge of fecal coliform in the watershed affecting the restricted shellfish harvesting area of Lower Choptank River mainstem. There are six municipal wastewater treatment plants (WWTP) in the watershed with permits regulating the discharge of fecal coliform: Cambridge WWTP (NPDES number MD0021636), Preston WWTP (MD0020621), Easton WWTP (MD0020273), Twin Cities WWTP (MD0055352), Trappe WWTP (MD0020486) and Oxford WWTP (MD0022543). Twin Cities WWTP has been included in the fecal coliform TMDL of Warwick River, a tributary of Lower Choptank River. Because the results of the Warwick River TMDL were used as an input to this TMDL model, it is not necessary to assign an allocation to Twin Cities WWTP under this TMDL. Cambridge WWTP, Trappe WWTP and Oxford WWTP are located downstream from the restricted shellfish harvesting area of Lower Choptank River mainstem. The bacteria discharges from these facilities do not have an effect on the water quality of the restricted shellfish harvesting area of Lower Choptank River mainstem. Therefore, the only WWTP facilities considered in this TMDL are the Easton and Preston WWTPs, which are located upstream of the restricted area. The Easton WWTP has a fecal coliform permit limit of 14 MPN/100ml (monthly median) and a design flow of 4 million gallons per day (MGD). The permitted loads from this facility are 2.12E+09 counts per day for median scenario and 6.88E+09 counts per day for 90th percentile scenario. The Preston WWTP has a fecal coliform permit of 200 MPN/100ml (monthly median) and design flow of 0.115 MGD. The permitted loads from this facility are 8.71E+08 counts per day for median scenario and 2.83E+09 counts per day for 90th percentile scenario.

The allocation of the permitted load from this point source facility will be addressed in Section 4.8.

3.0 TARGETED WATER QUALITY GOAL

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

4.0 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

4.1 Overview

This section documents the detailed fecal coliform TMDLs and load allocation development for the restricted shellfish harvesting waters in the Lower Choptank River mainstem watershed. The required load reduction was determined based on the data from July 2000 to July 2005. The TMDLs are presented as counts/day. The second section describes the analysis framework for simulating fecal coliform concentration in restricted shellfish harvesting waters in the Lower Choptank River mainstem. The third section addresses critical conditions and seasonality. The fourth section presents the TMDL calculations. The fifth section discusses TMDL loading caps. The sixth section presents the load allocations. The margin of safety is discussed in Section 4.7. Finally, the TMDL equation is summarized in Section 4.8.

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 harvesting waters. A TMDL may be expressed as a “mass per unit time, toxicity, or other appropriate measure” (40 Code of Federal Regulations (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 specific water quality criteria for shellfish harvesting waters (*i.e.*, at least 30 samples). The averaging period used for development of these TMDLs requires at least 30 samples and uses a five-year window of data to identify current baseline conditions.

A TMDL is comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, incorporating 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, where applicable)

4.2 Analysis Framework

In general, tidal waters are exchanged through their connecting boundaries. The tide and amount of freshwater discharged into the restricted shellfish harvesting area are the dominant forces that influence the transport of fecal coliform. The Lower Choptank River mainstem is that portion of the Choptank River downstream of Hunting Creek and upstream of Warwick River. Choptank River is a tidal river that has a length of 85 km and a width of 7 km at its mouth, tapering to widths of 200-300 m upstream. All exterior boundaries of the Choptank River are located within the State of Maryland. It drains a watershed with dimensions of 72 km by 44 km. The current distribution in the system varies as tidal and freshwater discharges change. In order to simulate the transport processes in the Choptank River accurately, the 3-dimensional hydrodynamic and eutrophication model (HEM-3D) has been used for this study. The HEM-3D model is a general 3D model for environmental studies. The model simulates density and topographically induced circulation as well as tidal and wind-driven flows, and spatial and temporal distributions of salinity, temperature, and suspended sediment concentration, conservative tracers, eutrophication processes, and fecal coliform. For a detailed model description, the reader is referred to Park et al. (1995). It should be noted that, although the reported site, Lower Choptank River mainstem, is confined to the Lower Choptank River, the model domain spans the entire Choptank River.

The Choptank River is represented by a horizontal network of the model grid cells. There are a total of 461 model grids in the modeling domain. To better simulate the stratification effect, three layers are used in the vertical dimension. For this study, the model was calibrated for the tide and long-term mean salinity distribution. In order to address the standards of median and 90^{th} percentile, an inverse approach has been adopted here to estimate the loads from the watershed. The watershed is divided into 40 subwatersheds. The loads from each subwatershed are discharged into the river from small creeks connected to the river.

The model was forced by the M_2 constituent of tide and the mean salinity concentration at the river mouth. The long-term mean freshwater input estimated based on data from the United States Geological Survey (USGS) gage stations 01487000, 01491000, 01492500, 01493500, and 01483700 were used. The discharges from subwatersheds are estimated based on the ratio of subwatershed area to the total drainage basin of the USGS station. The inverse method is used to estimate the existing load discharged from each subwatershed based on median and 90th percentile data obtained from observations. The model is also used to establish the allowable loads for the Lower Choptank River mainstem. Detailed modeling procedures are described in Appendix A.

4.3 Critical Condition and Seasonality

EPA's regulations require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters (40 CFR 130.7 (c)(1)). 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 time during which a waterbody is most likely to violate the water quality standard(s).

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

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

The seasonal fecal coliform distributions for the three applicable monitoring stations are presented in Appendix C. The results show the seasonal variability of fecal coliform concentrations. High concentrations occur in February and April and between September and December in the Lower Choptank River mainstem restricted shellfish harvesting area. The largest standard deviations correspond to the highest variability in concentration for each station. These high concentrations result in a high 90th percentile concentration. The results indicate that exceedances may occur only during a few months of the year.

Similar to the critical condition, seasonality is also implicitly included in the analysis due to the averaging required in the water quality standards. The MDE shellfish-monitoring program uses a systematic random sampling design that was developed to cover inter-annual variability. The monitoring design and the statistical analysis used to evaluate water quality attainment therefore implicitly include the effect of seasonality. By examining the seasonal variability of fecal coliform, the highest fecal coliform concentration often occurs during the few months of the year that correspond to the critical condition. If loads under the critical condition can be controlled, water quality attainment can be achieved.

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.

Routine monitoring data were used to estimate the current loads. These data were analyzed for the median and for the 90th percentile conditions. The Lower Choptank River mainstem restricted shellfish harvesting area has three monitoring stations. To estimate accurately the load with consideration of available monitoring data, the watershed was segmented into 40 subwatersheds. The load for each subwatershed was discharged into its corresponding receiving water model. The inverse method was used to compute the watershed loads discharged into the river based on the best match of observations and model simulation of fecal coliform concentrations in the river. The total loads are reported in Table 4.4.1 and Table 4.4.2. Detailed results by subwatershed are also listed in Appendix A.

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 3-D model was used to compute the allowable load for each subwatershed by reducing the existing loads from the watershed so that the fecal coliform concentration in the receiving water meets the standards. The total loads discharged into the river are the summation of loads discharged from each subwatershed. For the Lower Choptank River mainstem, neither the median nor the 90th percentile standard is met at any of the three stations. The load reduction needed for the attainment of the criteria is determined as follows:

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

The TMDL calculations are presented in Appendix A. The calculated results are listed in Table 4.4.1 and Table 4.4.2.

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

Area	Mean Water Volume M^3	Fecal Coliform Median Standard MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Lower Choptank River mainstem	29,455,620	14	1.920E+11	1.225E+11	36.21

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

Area	Mean Water Volume M^3	Fecal Coliform 90th Percentile Standard MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Lower Choptank River mainstem	29,455,620	49	8.907E+11	3.070E+11	65.53

4.5 TMDL Loading Caps

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

Lower Choptank River mainstem:
The median load fecal coliform TMDL = 1.225×10^{11} counts per day
The 90th percentile fecal coliform TMDL = 3.070×10^{11} counts per day

The greater reduction required when comparing the median and the 90th percentile results (see Table 4.4.1 and Table 4.4.2) was used for the source allocation. In this case, the 90th percentile requires the greater reduction for the area. It is 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 purpose of this section is to allocate the TMDLs between point (WLA) and nonpoint (LA) sources. There are two point source facilities, Easton WWTP00DP0579A and Preston WWTP (MD0020621)) that hve permits regulating the discharge of fecal coliform into the Lower Choptank River mainstem watershed. The permitted fecal coliform load from these point sources is approximately 2.99×10^{9} counts per day and will be included in the WLA. The remaining assimilative capacity will be allocated to the load allocation.

The load reduction scenario results in a load allocation by which the TMDL can be implemented to achieve water quality standards. The State reserves the right to revise these allocations, provided the allocations are consistent with the achievement of water quality standards. This load allocation results in load reductions shown in Table 4.6.1 for the restricted shellfish harvesting areas of the Lower Choptank River mainstem watershed.

Table 4.6.1: Load Reductions

Restricted Shellfish Harvesting Area	Required Reduction
Lower Choptank River Mainstem	**65.53%**

Since the load reduction applied to this watershed was based on the 90th percentile water quality standard, it targets only those critical events that occur less frequently. Therefore, the load reduction established is not a literal daily reduction, but rather an indicator that the control of measures for bacterial loads is needed for these more extreme events. Extreme events are often a result of hydrologic variability, land use practices, water recreation uses, or wildlife activities.

4.7 Margin of Safety

A 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 waterbodies. 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. The decay rate is one of the most sensitive parameters in the model. For a given system, the higher the decay rate, the higher the assimilative capacity. 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

There are two municipal point source facilities (Easton and Preston WWTP) with permits regulating the discharge of fecal coliform directly into a region affecting the restricted area of the Lower Choptank River mainstem. The permitted fecal coliform loads from these point sources are 2.99E+09 counts per day for median scenario and 9.71E+09 counts per day for 90th percentile scenario and will be included in the WLA. The remaining assimilative capacity will be allocated to the load allocation. The TMDLs are summarized as follows:

The median TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Lower Choptank River Mainstem	**1.22×10^{11}**	=	**1.19×10^{11}**	+	**2.99×10^{9}**	+	**N/A**	+	**Implicit**

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Lower Choptank River Mainstem	**3.07×10^{11}**	=	**2.97×10^{11}**	+	**9.71×10^{9}**	+	**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 TMDLs 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).

In general, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the greatest impact on water quality, with consideration given to ease of implementation and cost. The source contributions estimated from the watershed analysis (see Table 2.4.1) may be used as a tool to target and prioritize initial implementation efforts. 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 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 includes 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. Property owners can apply for a low interest loan, through MDE, that can be used to improve a failing septic system. It is anticipated that in 2006, there may be funding available to provide improvement to a portion of septic systems in Maryland's designated Critical Areas. Maryland law, Environment Article § 9-333, requires the following types of facilities to have pump-out stations: Existing marinas wishing to expand to a total of 11 or more slips that are capable of berthing vessels that are 22 feet or larger; new marinas with more than 10 slips capable of berthing vessels that are 22 feet or larger; and marinas with 50 or more slips and that berth any vessel over 22 feet in length. Any public or private marina in Maryland is eligible to apply for up to $15,000 in grant funds to install a pump-out station through the Maryland Department of Natural Resources.

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

As part of Maryland's commitment to the NSSP, MDE continues to monitor shellfish waters and classify harvesting areas. Those waters meeting shellfish water quality standards are reclassified as open to harvesting and may serve to track the effectiveness of TMDL implementation and water quality improvements.

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 will 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.

Implementation may begin by first managing controllable resources (human, livestock, and pets) and then determining if the TMDL can be achieved. If the total required reduction is still not met, then a reduction may need to be applied to the wildlife source. Given the nonpoint source characteristics of the wildlife contribution, it may be assumed that best management practices applied to controllable sources may also reduce some wildlife sources contributing to the restricted shellfish harvesting area.

Following this first implementation stage, MDE would re-assess the water quality to determine if the designated use is being achieved. If the water quality standards are not attained, then MDE may 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 (natural) sources.

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Appendix A. Model Development

The 3-dimensional hydrodynamic and eutrophication model (HEM-3D) has been used for this study. The HEM-3D model is a general 3D model for environmental studies. The model simulates density and topographically induced circulation as well as tidal and wind-driven flows, and spatial and temporal distributions of salinity, temperature, and suspended sediment concentration, conservative tracers, eutrophication processes, and fecal coliform. The model has been applied for a variety of environmental problems in estuaries (Hamrick, 1992a; Shen *et al*., 1999). For a detailed discussion of the model theory, readers are referred to Hamrick (1992b).

Figure A-1 is the model grid that consists of 461 grid cells. To better distribute flow and loads, the watershed is segmented into 40 subwatersheds. A curvilinear grid was used for the model to better represent the shoreline of the river. The model domain extends to the upstream and includes both the Choptank River and Tuckahoe Creek. Because the river is narrow upstream, a horizontal network approach is used to represent these portions upstream. To better simulate estuarine circulation, a total of three layers are used in the vertical dimension. The fecal coliform is simulated using a conservative tracer with first-order decay. 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 this TMDL study.

The Choptank River is a tidal river. The dominant tidal constituent is M_2 (lunar semi-diurnal tide). To simulate tide correctly, a calibration of mean tide was conducted. The model was forced by an M_2 tide with the mean tidal range of 0.49 m at the mouth. The model results are compared with NOAA predicted tide (http://tidesonline.nos.noaa.gov/) at five stations inside the Choptank River and Tuckahoe Creek. Station locations are shown in Figure A-2. The results are listed in Table A-1. It can be seen that the model simulates the mean tidal range well.

Table A-1: Comparison of modeled and NOAA predicted mean tidal range

Station	Modeled Range (m)	NOAA Predicted Range (m)
Cambridge	0.502	0.494
Choptank	0.510	0.488
Dover Bridge	0.538	0.518
Denton	0.666	0.670
Wayman Wharf, Tuckahoe Creek	0.676	0.730

Because there are insufficient real-time observation data of stream flow, tide, and wind available in the Lower Choptank River to conduct a real-time model calibration, comparison of real-time salinity simulation against the observed salinity cannot be performed. Therefore, the model calibration for the mean condition of salinity distribution was performed to reproduce the averaged salinity distribution at eleven stations along the river. The locations of these stations are shown in Figure A-2. For the mean salinity calibration, the dominant M_2 tidal frequency with a mean tidal range was used as a forcing at the model open boundary. Mean salinity measured at the station nearest the mouth was used as the salinity boundary condition. The quantity of freshwater discharged from each subwatershed was estimated according to the average long-term flow from the USGS gage stations 0487000 (Nanticoke River near Bridgeville, DE), 01491000 (Choptank River near Greensboro, MD), 01492500 (Sallie Harris Creek near Carmichael, MD), 01493500 (Morgan Creek near Kennedyville, MD), and 01483700 (St. Jones River at Dover, DE). The flow of each subwatershed was estimated based on the ratio of the subwatershed area to the drainage basin area of the USGS gage. The mean flows used for the model calibration are listed in Table A-2 below for the subwatersheds shown in Figure A-1. A comparison of model results of salinity against observations is shown in Figure A-4. It can be seen that the model simulated salinity distribution well in the estuary.

Since the water quality standards for fecal coliform are median and 90th percentile, the modeling tasks are to estimate fecal coliform mean daily loads from the watershed corresponding to the median and 90th percentile, respectively. For a relatively small waterbody, the tidal prism model has been used to estimate the loads based on the observations and water quality standards using the inverse method (or back calculation) (MDE, 2005). For this study, an inverse modeling approach method built on the HEM-3D has been used to estimate fecal coliform loading from the watershed. The purpose of the inverse modeling is to estimate the long-term average daily loads corresponding to the median and 90th percentile concentrations in the waterbody. Therefore, the fecal coliform daily loads from each subwatershed can be considered as constant model parameters. The inverse methods have been used for many environmental problems to estimate point source loads and model parameters (Shen and Kuo, 1996; Sun and Yeh, 1990; Shen, 2006).

Table A-2: Estimated mean flows of subwatersheds in the Choptank River

Subwatershed	Flow (cms)	Subwatershed	Flow (cms)
1	0.031	21	0.750
2	0.065	22	0.210
3	0.019	23	0.520
4	0.070	24	0.200
5	0.345	25	0.200
6	0.046	26	0.115
7	0.056	27	0.122
8	0.052	28	0.295
9	0.035	29	0.133
10	0.097	30	0.250
11	0.231	31	0.350
12	0.110	32	0.200
13	2.900	33	0.370
14	0.370	34	0.245
15	0.370	35	0.810
16	0.350	36	0.900
17	0.045	37	0.275
18	0.210	38	4.850
19	0.150	39	0.750
20	0.225	40	0.034

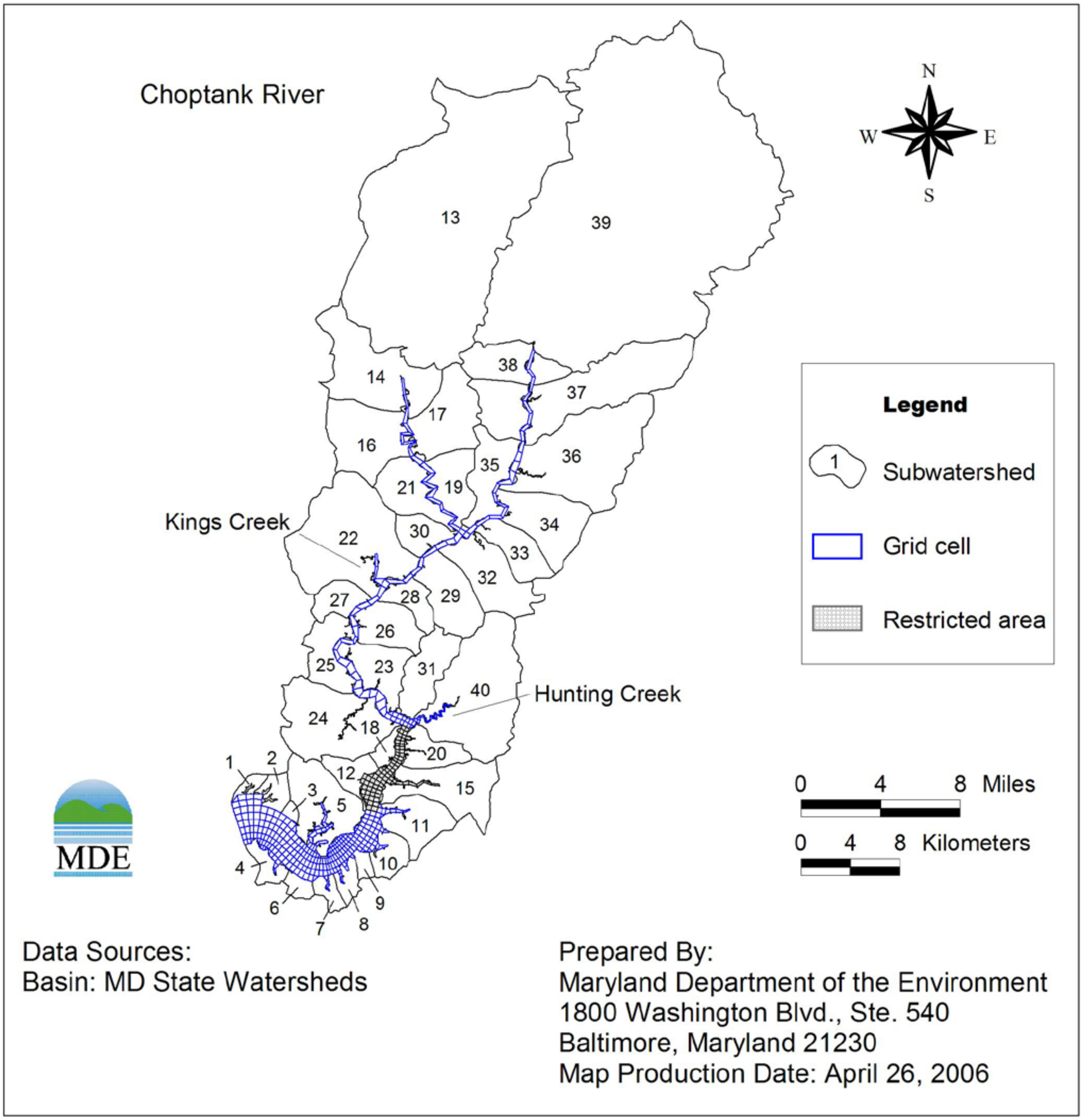

Figure A-1: HEM-3D grid cells and subwatersheds in the Choptank River

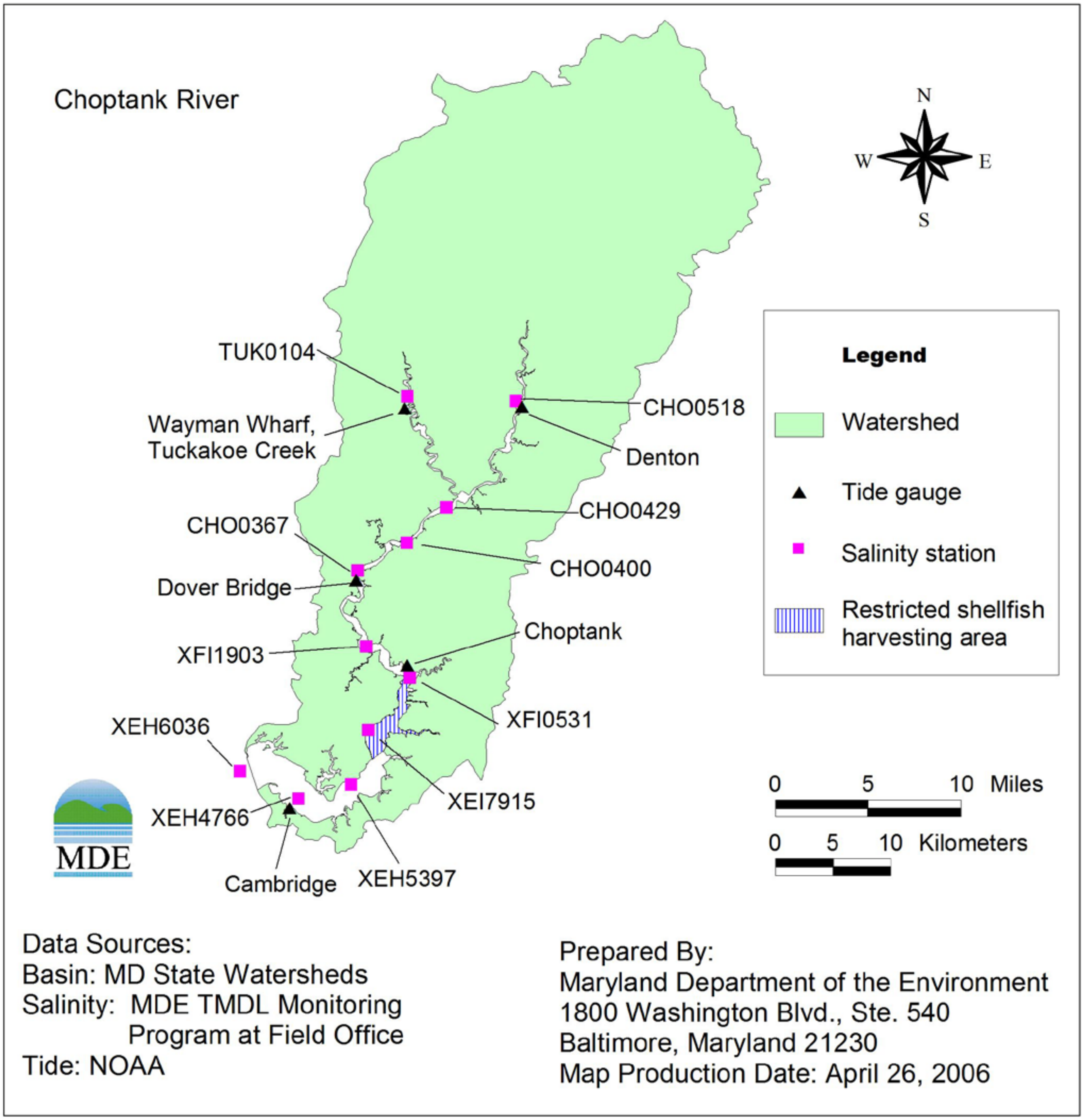

Figure A-2: Tide and salinity stations of the Choptank River used in model calibration

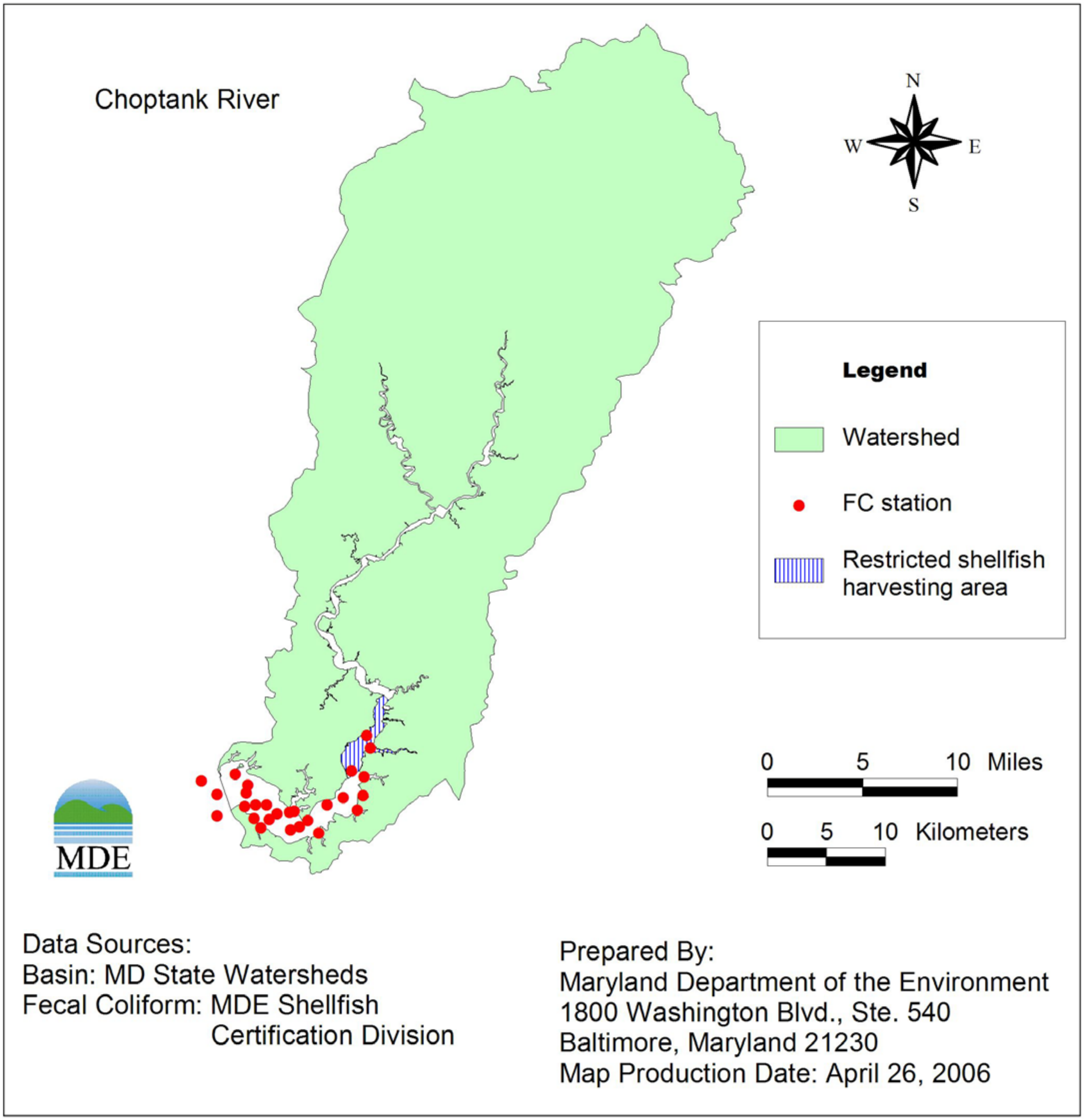

Figure A-3: Locations of fecal coliform observation stations

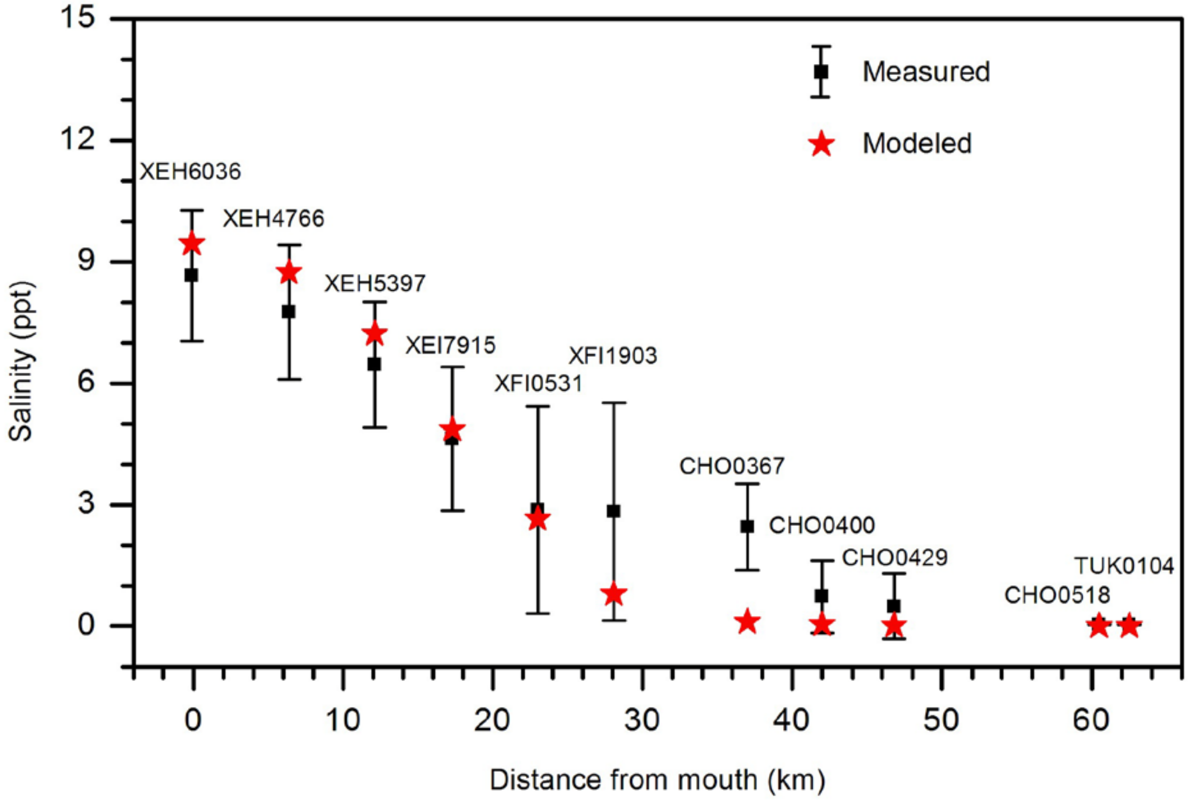

Figure A-4: Comparison of measured and calculated salinities

The problem of loads estimation can be treated as an inverse problem: to find a set of loads such that a defined goal function (or cost function), which measures the data misfit between the model predictions and the observations, becomes minimal. It can be presented as follows:

$$J(\mathbf{C};\boldsymbol{\beta}^*) = \min J(\mathbf{C};\boldsymbol{\beta}) \qquad (1)$$

subject to

$$\boldsymbol{\beta}^* \in \boldsymbol{\beta}_0 \qquad (2)$$

$$\mathbf{F} = 0 \qquad (3)$$

where $\boldsymbol{J}$ is a goal or cost function; $\boldsymbol{\beta}^* = (\beta_1, \beta_2, ..., \beta_m)$ is the optimal parameter (*i.e.*, loads); $\boldsymbol{\beta}_0$ is an acceptable set of loads. **F** is transport function. Different methods can be used to characterize the noninferior solutions. Choosing a weighted least-square criterion to measure the data misfit, the scalar cost function is then defined as follows:

$$J(\mathbf{C};\boldsymbol{\beta}) = \int_{T_N} \iint_{\Omega} \frac{w}{2}(C(x,z,t) - C^0(x,z,t))^2 \, d\Omega dt \qquad (4)$$

where C and C^0 are modeled and measured fecal coliform in the river, w is weights, Ω is the spatial domain in the x- and z- directions, T_N is time since the last date when the prototype observations became available, and w is the weight. In our case, let $C_m^0(x)$ be the median or 90th percentile obtained from the observations at location (x). If we choose

$$C_m(x) = \max(C(x,z,t)) \qquad for \quad T_0 < t < T_N \tag{5}$$

Equation (1) can be written as:

$$J(\mathbf{C};\boldsymbol{\beta}) = \int_X \frac{w}{2}(C_m(x,t) - C_m^0(x))^2 dx \tag{6}$$

The algorithm can be constructed as a sequence of the unconstrained minimization problem. Many authors have studied the solution of the optimization problem extensively. Several different methods can be used to solve the problem including the Gradient method, Conjugate direction method, and the Variational method (Bertsekas, 1995). For this study, the modified Newton method was used to solve the optimization problem (Shen, 2006).

The fecal coliform loads discharged to the river originate from 40 subwatersheds, as shown in Figure A-1. For the estimation of existing median loads, the model was forced by an M_2 tidal frequency with mean tidal range and mean salinity at the mouth. The mean freshwater inflows from the subwatersheds are discharged into the river. A set of initial loads from 40 subwatersheds was estimated and discharged to the river. Because the observation data are only available in the downstream portion of the river, it is not feasible to use data collected in this downstream region and in turn use the inverse model to estimate loads from 40 subwatersheds. A monthly survey was conducted in the upstream region from September to November in 2005. The data analysis shows that the variation of the mean concentration of fecal coliform is not significant along the river, which indicates that sources of fecal coliform are discharged into the river from subwatersheds along the river. The mean concentration of fecal coliform along the upstream portion of the Choptank River is in the same range as the 90th percentile concentration in the restricted area. Note that the distances from the headwaters of the Choptank River to the mouth of Hunting Creek and to the mouth of the model boundary are approximately 48 km and 65 km, respectively. Based on the model results, the estimated transport time from upstream to the boundary of the modeling domain is approximately 90 days under the mean flow condition as shown in Figure A-5. It can be expected that fecal coliform discharged from the upstream region will be lost due to decay before it reaches the downstream. Figure A-6 shows the results of the sensitivity tests of the change of downstream fecal coliform concentrations with respect to the change of upstream loading. For the sensitivity tests, very high fecal coliform loading was discharged into the headwater of the Choptank River. It can be seen that the concentration near Hunting Creek, just upstream of the restricted area, is less than 0.01 MPN/100ml. While increasing loading by 40% at the headwater, the fecal coliform concentration does not increase downstream. Another sensitivity test was conduced by discharging fecal coliform loads into the river from subwatersheds upstream of SWS22, *i.e.*, upstream of Kings Creek. The concentration at the junction of Kings Creek is approximately 160 MPN/100ml, which is in the same range as observations. However, the concentration inside the river just upstream of the restricted area is less than 0.6 MPN/100ml. These results suggest that the downstream fecal coliform concentration depends less on the loads from the upstream watershed. Therefore, the load allocation will only be established for downstream watersheds that influence the restricted areas significantly.

Based on the sensitivity test, the loads discharged from the subwatersheds upstream of Kings Creek can be estimated independently from the loads discharged into the river from downstream watersheds. Therefore, the loads from subwatersheds upstream of Kings Creek were estimated based initially on the mean fecal coliform concentration for the three-month survey. For the downstream loads, the existing loads were estimated based on the observed data inside the restricted area and in the Lower Choptank River using the inverse model. Station locations for these observed data are shown in Figure A-3.

Utilizing results of the TMDL studies of four restricted areas, namely Whitehall Creek, Indian Creek, Goose Creek, and Warwick River of the Lower Choptank River that were compiled in a previous report using the tidal prism model, the median and 90th percentile loads computed in the previous studies were discharged into the Choptank River. The median fecal coliform concentration is approximately 20% of the 90th percentile concentration. Therefore, the existing loads upstream of Kings Creek were reduced by a factor of five when estimating median loads for the downstream watershed. Although the estimation of upstream median loads may seem subjective and the load can be over- or under-estimated, the estimated loads will not affect the downstream, due to decay that occurs when fecal coliform is transported downstream as shown in the sensitivity tests.

The inverse model was run for 30 days to reach equilibrium and the maximum concentration on the last day was used to calculate the cost function against the observed median along the river. The modified Newton method was used to update the loads until the cost function reached its minimum.

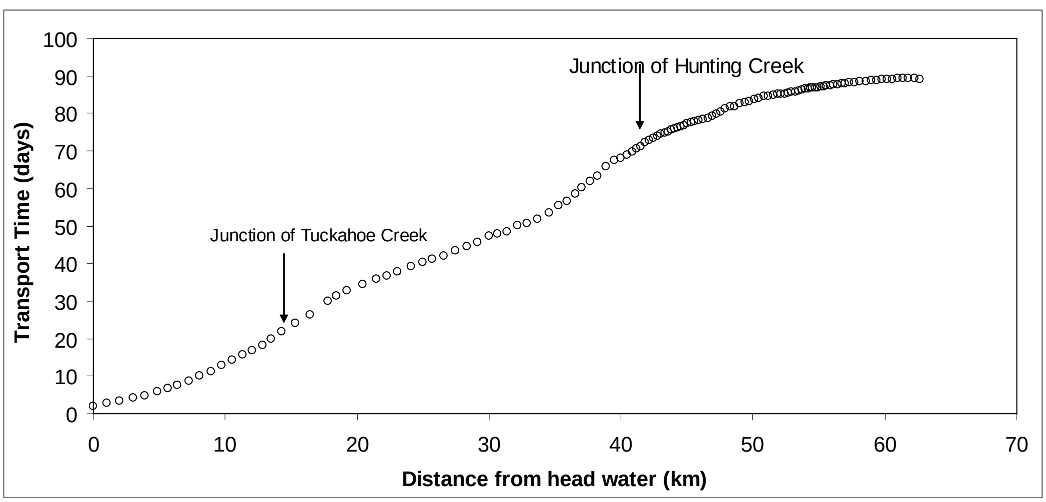

Figure A-5: Transport time along the River

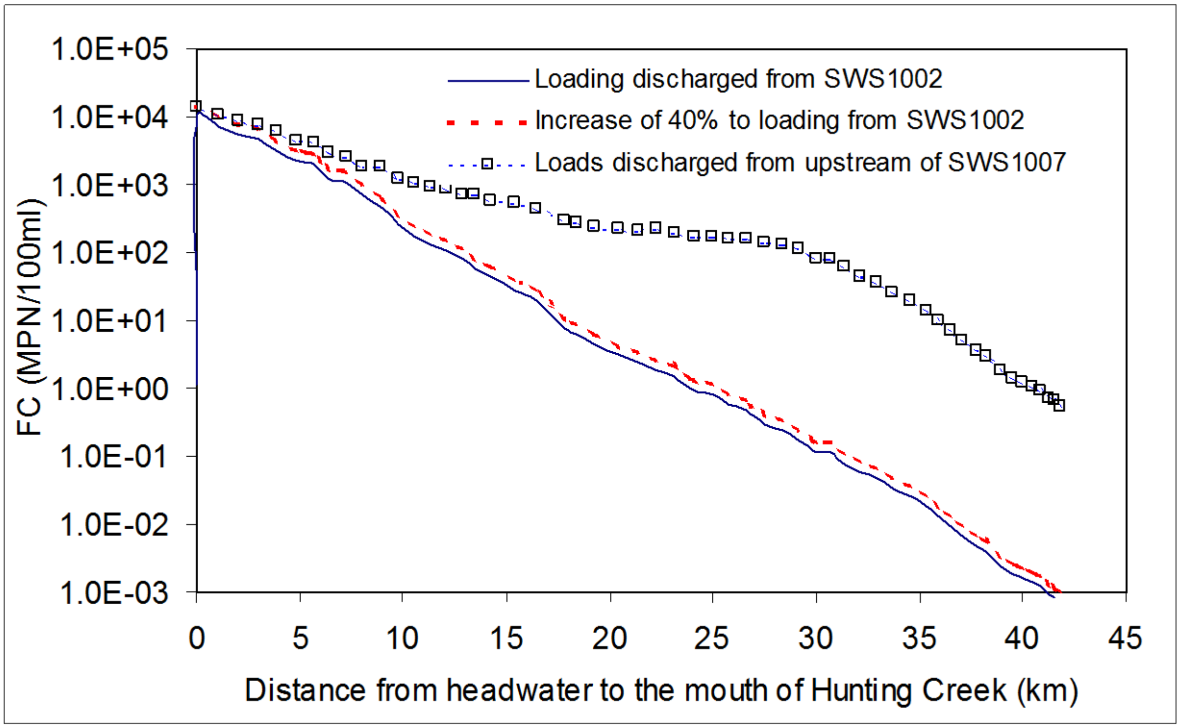

Figure A-6: Model results of sensitivity tests

Figures A-7 and A-8 show the model results of simulated median and 90th percentile, respectively. It can be seen that the model results are satisfactory. The existing loads for each subwatershed are listed in Table A-3.

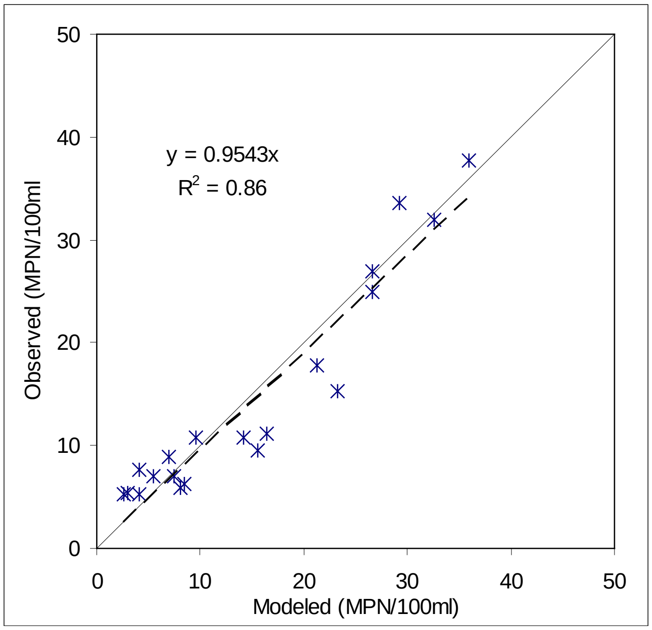

Figure A-7: Comparison of model results vs. observations of median concentration

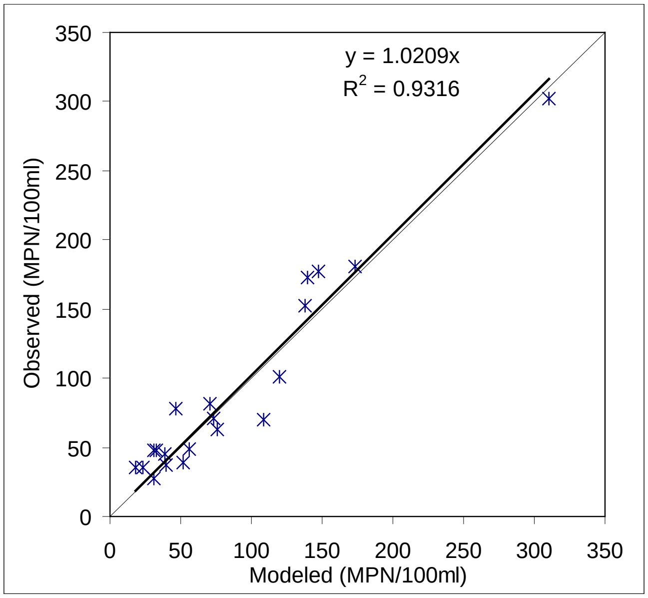

Figure A-8: Comparison of model results vs. observations of 90th percentile concentration

Table A-3: TMDL calculation results for each subwatershed

Subwatersheds	Median			90th Percentile		
	Allowable Load*	Current Load	Percent Reduction	Allowable Load	Current Load	Percent Reduction
	Counts/day	Counts/day		Counts/day	Counts/day	
12,15,18,20	8.30E+10	1.47E+11	43.60%	2.25E+11	7.38E+11	69.59%
31,40	3.67E+09	9.18E+09	60.00%	8.19E+09	6.66E+10	87.70%
23,24,25,26,27	3.58E+10	3.58E+10	0.00%	7.38E+10	8.61E+10	14.33%
TOTALS	**1.23E+11**	**1.92E+11**	**36.20%**	**3.07E+11**	**8.91E+11**	**65.53%**

For the TMDL calculation, the previously estimated allowable loads from four creeks were used as allowable loads for the current TMDL calculation. The existing 90th percentile loads from subwatersheds 12,15,18,20, 23-27, 31, and 40 were reduced so that the model simulated the fecal coliform concentration inside the restricted area meeting the water quality standards. The resultant loads are the allowable loads for the River. With the use of existing loads and TMDLs, the percentage reduction can be estimated. For the TMDL calculation, there is no indication of a need to reduce loads either from the watersheds upstream of Kings Creek or from the watershed downstream of the restricted area other than the four restricted shellfish harvesting areas where the TMDLs have previously been established. Therefore, these upstream watersheds are excluded from the current TMDL calculation. Comparing the reduction needed for both median and 90th percentile loads, the maximum reductions required for each watershed are used to establish the TMDLs. The existing and allowable loads are listed in Table A-3.

By comparing the reductions required for median and 90th percentile, one can see that the 90th percentile requires the largest reduction. Therefore, the reductions required to meet the 90th percentile at each subwatershed are for the overall reductions required for the subwatersheds. The allowable loads and required reductions for the watershed are listed in Table A-4.

Table A-4: Load allocation and reduction by subwatershed

Subwatershed	Load Allocation	Required Reduction
12,15,18,20	2.25E+11	69.59%
31,40	8.19E+09	87.70%
23,24,25,26,27	7.38E+10	14.33%
TOTALS	**3.07E+11**	**65.53%**

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

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

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

In the 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. There is a lack of information available for the discharge from boats and it is assumed that human loading results from failures in septic systems. The major nonpoint source contributions assessed for the restricted shellfish area in the Lower Choptank River basin are summarized in Table B-1. The potential nonpoint sources were grouped into four categories: wildlife; human; pets; and livestock. Due to insufficient data sources, the source assessment method does not account for boat discharge, resuspension from bottom sediment, and the potential for regrowth of fecal coliform in the embayment.

Table B-1: Summary of Nonpoint Sources

Category	Source
Wildlife	Beaver, deer, goose, duck, swan, 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, swan, 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 population, the total number was estimated based on the deer density in each land use category (Horton, 2004). For goose, duck, and swan populations, the totals estimated were obtained from GIS data provide by the Maryland DNR (Hindman, 2005). Wildlife populations were obtained by applying assumed wildlife densities to these extracted areas. The populations of the wildlife were obtained by applying density factors to estimated habitat areas. The fecal coliform contributions were estimated based on the estimated number of wildlife and fecal coliform production rates, which are listed in Table B-3. To obtain the total wildlife contribution, population density is multiplied by the applicable acreage or stream mile and that product is multiplied by fecal coliform production rates for each animal.

Table B-3: Wildlife Fecal Coliform Production Rates

Source	**Fecal Coliform Production (counts/animal/day)**
Beaver[1]	2.50E+08
Deer[1]	5.00E+08
Goose[2]	2.43E+09
Duck[1]	2.43E+09
Swan[5]	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); [5]use duck rate

B. Human Contributions

Human loading can result from failures in septic systems or through pollution from recreational vessel discharges in the identified restricted shellfish harvesting area. It is assumed that a failing septic system is a direct load contribution from humans. The estimation of human contribution is based on human population, number of properties, the estimated 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 Basin. Since the subwatershed of the Lower Choptank River basin is a sub-area of the Census Block, the GIS tool was used to extract this area 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 total census block number of households in proportion to the population within the area of the subwatershed. The results are shown in Table B-4.

Table B-4: Proportional Population, Households, and Septic Systems in Lower Choptank River, Upper Choptank River and Tuckahoe Creek

Area Name	Sub Area	Proportional Population	Proportional Septic Systems	Proportional Households	Public Sewer
Choptank River	1000	14077	1398	5285	Partial
	1002	5630	1911	2234	Partial
	1003	5014	1804	1867	Partial
	1004	7343	2991	3045	Partial
	1005	3909	1688	1513	Partial
	1006	4500	1810	1820	Partial
	1007	4206	1522	1651	Partial
	1008	1764	640	730	Partial
	1010	3652	1780	1496	Partial
	1011	4048	1375	1667	Partial
	1020	2418	957	1016	Partial
	1030	18109	1453	7631	Partial

The distribution of septic systems for the Choptank River watershed is shown in Figure B-1. Based on GIS property coverage, a point is assumed to represent a septic system. The total number of septic systems as estimated using GIS is shown in Table B-4. According to GIS coverage, most of the Choptank River restricted shellfish harvesting area is served partially by a public sewer system.

It is assumed that any human contribution is attributed to septic systems (although recreational vessels might be a source, we have not found a means to quantify that source). The human contribution to the restricted shellfish harvesting area was estimated using the number of septic systems, the average number of people per septic system, and an estimated failure rate for 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. In the absence of shoreline sanitary survey data, the estimated septic system failure rate of 3% for coastal restricted shellfish harvesting areas was used. 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 from septic system failure is less than 1%.

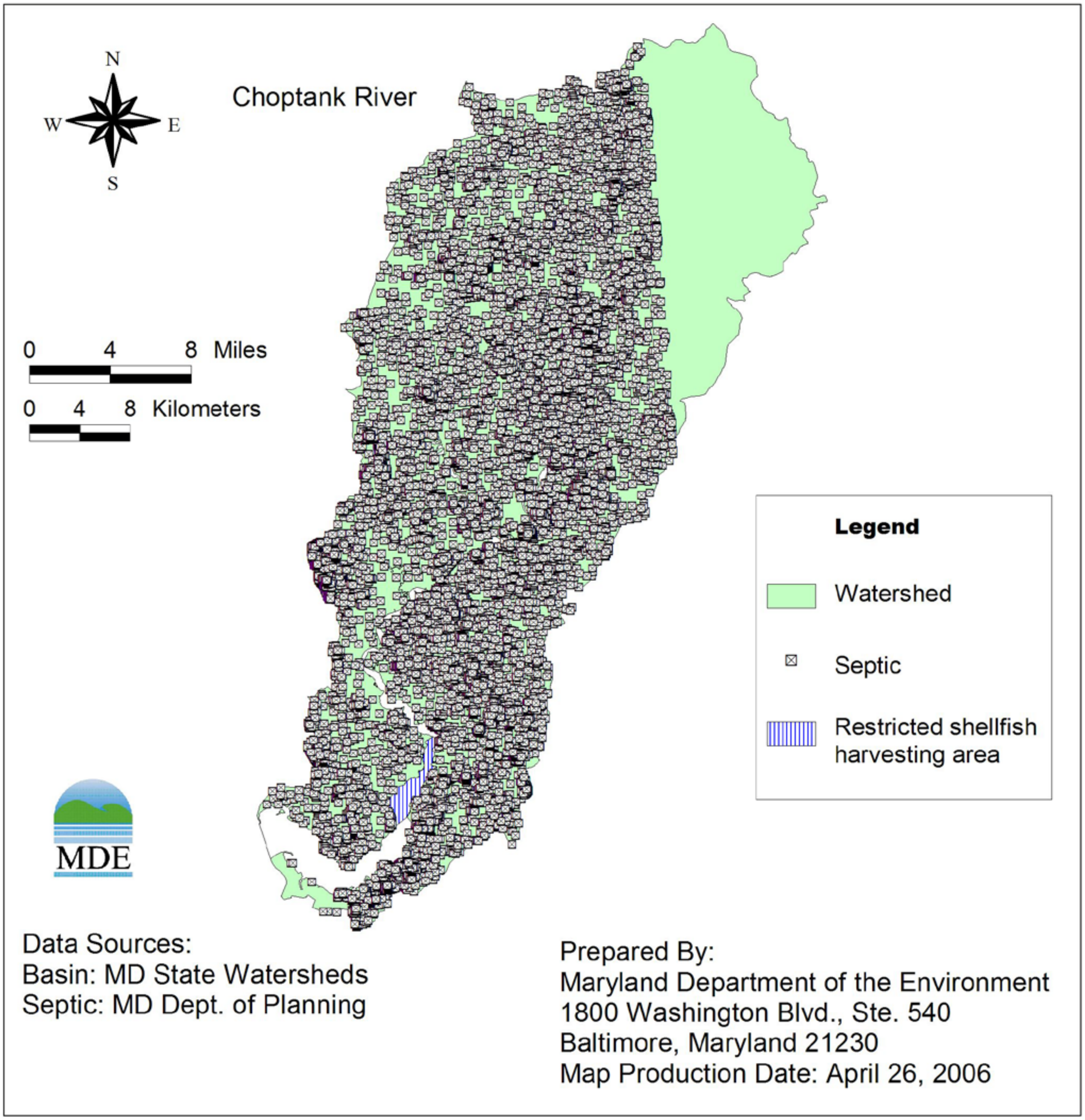

Figure B-1: Distribution of Septic Systems in the Choptank River Watershed

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 for the restricted shellfish harvesting area in the Lower Choptank River mainstem watershed was estimated based on the number of households (see Table B-4). According to a survey of Chesapeake Bay area residents conducted by the Center for Watershed Protection, 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 may be through manure spreading 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-2. The fecal coliform load was estimated based on the total number of livestock and their fecal coliform production rates.

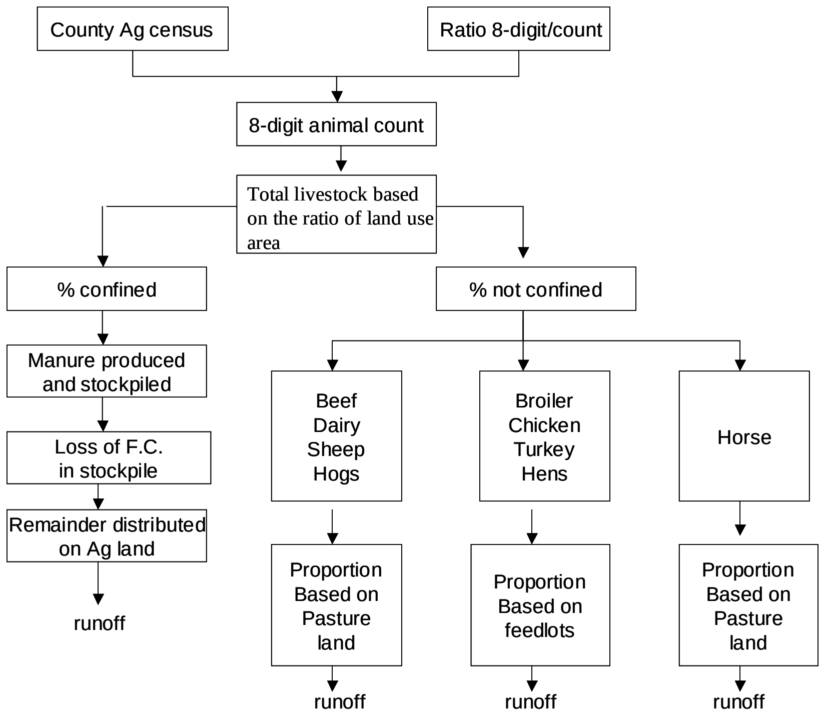

Figure B-2: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population

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, 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 Choptank River Basin

Subwatershed	Fecal Coliform Source	Loading Counts/day	Loading Percent
1000	Livestock	1.657E+14	96.50%
	Pets	2.492E+12	1.46%
	Human	5.219E+10	0.03%
	Wildlife	3.459E+12	2.01%
	Total	1.717E+14	100.00%

1002	Livestock	1.657E+14	98.42%
	Pets	1.054E+12	0.63%
	Human	1.918E+10	0.01%
	Wildlife	1.588E+12	0.94%
	Total	1.684E+14	100.00%
1003	Livestock	2.107E+14	98.10%
	Pets	8.803E+11	0.41%
	Human	1.171E+10	0.01%
	Wildlife	3.177E+12	1.48%
	Total	2.147E+14	100.00%
1004	Livestock	1.325E+14	98.13%
	Pets	1.436E+12	1.07%
	Human	2.568E+10	0.02%
	Wildlife	1.057E+12	0.78%
	Total	1.350E+14	100.00%
1005	Livestock	1.190E+14	98.02%
	Pets	7.134E+11	0.59%
	Human	1.360E+10	0.01%
	Wildlife	1.676E+12	1.38%
	Total	1.214E+14	100.00%
1006	Livestock	2.212E+14	98.98%
	Pets	8.581E+11	0.38%
	Human	1.330E+10	0.01%
	Wildlife	1.405E+12	0.63%
	Total	2.235E+14	100.00%
1007	Livestock	1.565E+14	98.81%
	Pets	7.784E+11	0.49%
	Human	7.842E+09	0.01%
	Wildlife	1.086E+12	0.69%
	Total	1.584E+14	100.00%
1008	Livestock	8.992E+13	98.92%
	Pets	3.442E+11	0.38%
	Human	5.981E+09	0.01%
	Wildlife	6.280E+11	0.69%
	Total	9.090E+13	100.00%
1010	Livestock	5.812E+13	90.29%
	Pets	7.054E+11	1.10%
	Human	1.112E+10	0.02%
	Wildlife	5.530E+12	8.59%
	Total	6.437E+13	100.00%
1011	Livestock	1.859E+14	86.22%
	Pets	7.859E+11	0.36%
	Human	1.477E+10	0.02%
	Wildlife	2.890E+13	13.40%
	Total	2.156E+14	100.00%

1020	Livestock	1.904E+13	43.73%
	Pets	4.790E+11	1.10%
	Human	7.210E+09	0.02%
	Wildlife	2.400E+13	55.15%
	Total	4.353E+13	100.00%
1030	Livestock	1.878E+13	25.32%
	Pets	3.598E+12	4.85%
	Human	5.874E+10	0.08%
	Wildlife	5.174E+13	69.75%
	Total	7.418E+13	100.00%
Total	Livestock	1.543E+15	91.76%
	Pets	1.412E+13	0.84%
	Human	2.413E+11	0.01%
	Wildlife	1.242E+14	7.39%
	Total	1.682E+15	100.00%

Appendix C. Seasonality Analysis

The Code of Federal Regulations (40 CFR 130.7 (c)(1)) requires that TMDL studies take into account critical conditions for stream flow, loading, and water quality parameters. The EPA also requires that these TMDL studies take into account seasonal variations. The consideration of critical condition and seasonal variation is to account for the hydrologic and source variations. The intent of the requirements is to ensure that the water quality of the water body is protected during the most vulnerable times.

In the Chesapeake Bay region, both fecal coliform sources and delivery vary seasonally due to changes of hydrological conditions and land use practices. The most probable fecal coliform sources result from runoff from agricultural practices and livestock, wildlife, and developed areas. Precipitation and temperature fluctuate seasonally, producing varied stream flow and surface runoff that serve as a delivery mechanism for fecal coliform, as well as seasonal change in vegetation. Vegetation, particularly in pastureland and agriculture buffer zones, is very important for trapping and preventing fecal coliform from entering waters by both decreasing surface runoff and absorbing fecal coliform. Warm-blooded animals, the sources of fecal coliform, are directly or indirectly connected with vegetation productivity via food chain relationships. In temperate forests, for example, wildlife are active during summer and fall due to ample food supply, resulting in large sources of fecal coliform, and the probability of their direct contact with receiving waters is comparatively high during warm seasons. The seasonal variation of fecal coliform concentration in water not only results from activities of wildlife on forestland and wetland, but also is related to agricultural activities. Fecal coliform deposition on the field by livestock can be transported into streams and rivers through surface runoff, and thus tends to increase fecal coliform concentrations during wet seasons. In croplands, fecal coliform discharge is often related to the timing of crop planting and fertilization. Manure application during crop planting may increase the risk of exceeding fecal coliform standards in the receiving water. Such seasonal changes in both the sources and the delivery mechanisms perhaps lead to obvious seasonal patterns for receiving water fecal coliform concentration in the shellfish growing area.

The 5-year monthly mean fecal coliform concentration and its standard deviation were calculated for the three monitoring stations used in this report. The results are presented in Figure C-1 through Figure C-3. It is shown that high fecal coliform concentrations occur in the months of February and April and between September and December in the Lower Choptank River mainstem. Although seasonal distributions vary from one month to the next, a large standard deviation that corresponds to the high fecal coliform concentration variability at each station suggests that the violation frequently may occur in a few months of the year.

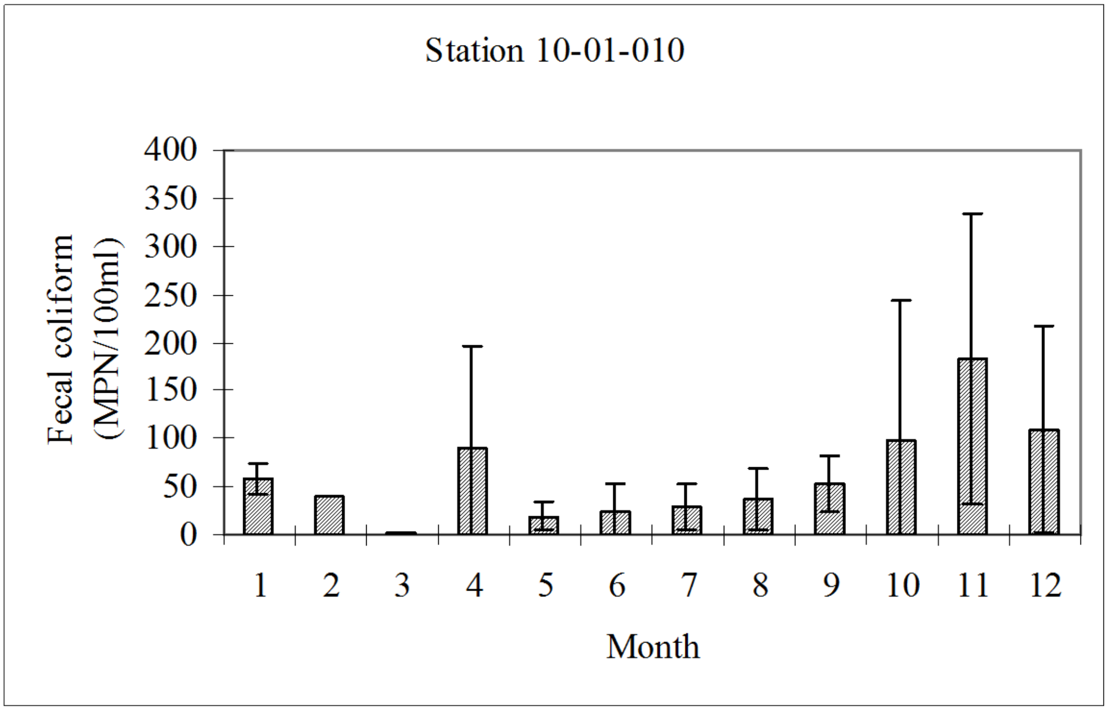

Figure C-1: Seasonality analysis of fecal coliform at Lower Choptank River mainstem Station 10-01-010

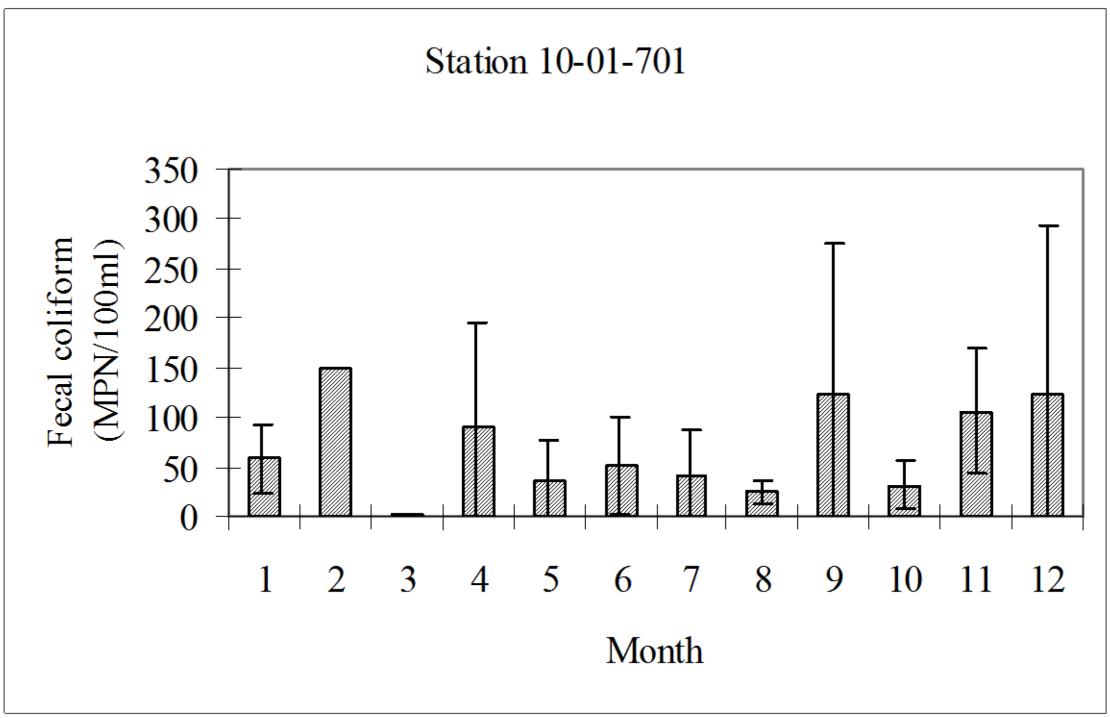

Figure C-2: Seasonality analysis of fecal coliform at Lower Choptank River mainstem Station 10-01-701

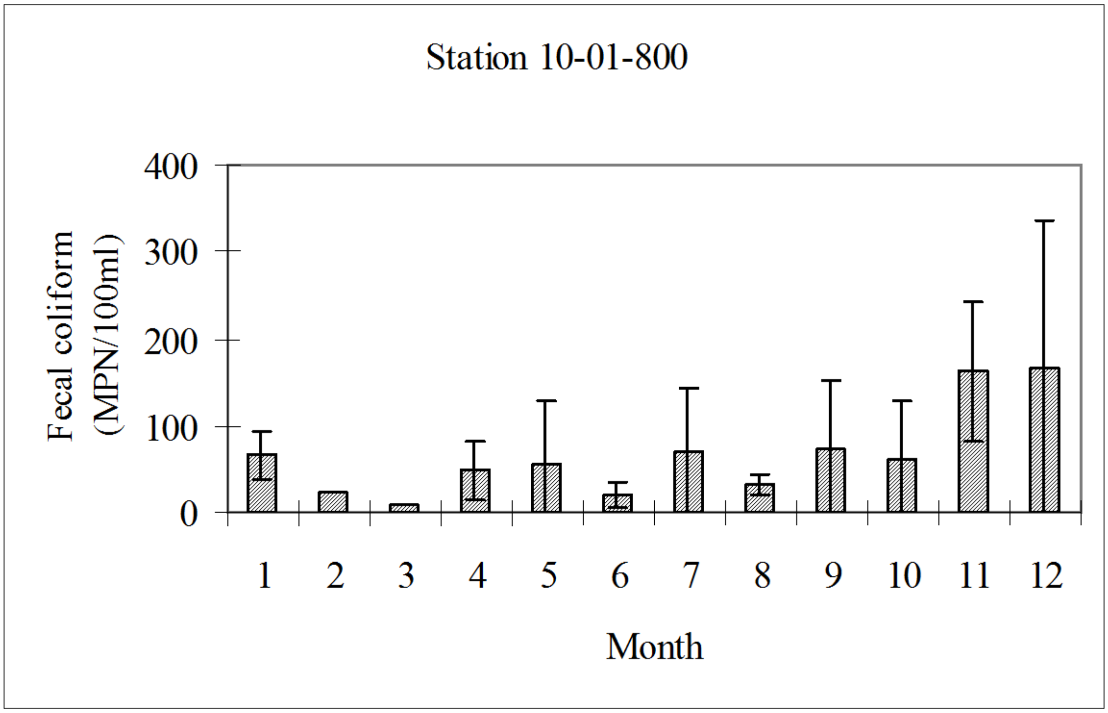

Figure C-3: Seasonality analysis of fecal coliform at Lower Choptank River mainstem Station 10-01-800

Appendix D. Tabulation of Fecal Coliform Data

This appendix provides a tabulation of fecal coliform values for the monitoring stations of the Lower Choptank River mainstem portion of the Lower Choptank River Basin in Tables D-1 through D-3. These data are plotted in report Figures 2.2.2 through 2.2.4.

Table D-1: Observed Fecal Coliform data at Lower Choptank River Mainstem Station 10-01-010

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	43	9/18/2002	43
7/31/2000	23	10/7/2002	23
8/7/2000	23	10/17/2002	23
9/11/2000	93	10/28/2002	43
9/28/2000	93	11/13/2002	240
10/5/2000	23	12/10/2002	23
10/25/2000	23	3/25/2003	3.6
11/6/2000	240	5/12/2003	15
11/13/2000	43	6/9/2003	93
12/6/2000	1	7/8/2003	75
1/17/2001	43	9/8/2003	43
4/18/2001	23	10/7/2003	240
5/7/2001	1	12/4/2003	240
5/29/2001	43	5/5/2004	23
6/6/2001	9.1	5/19/2004	23
6/26/2001	21	6/3/2004	23
7/11/2001	1	8/12/2004	23
7/30/2001	23	9/14/2004	23
8/7/2001	93	10/7/2004	9.1
9/12/2001	23	10/27/2004	460
10/10/2001	43	11/8/2004	460
11/7/2001	23	11/30/2004	93
12/5/2001	43	12/6/2004	240
1/22/2002	75	2/17/2005	39
4/17/2002	3.6	5/2/2005	3.6
4/22/2002	240	5/12/2005	9.1
5/9/2002	15	5/26/2005	43
6/13/2002	3.6	6/6/2005	9.1
7/15/2002	1	6/20/2005	3.6
8/12/2002	9.1	7/7/2005	43

Table D-2: Observed Fecal Coliform data at Lower Choptank River Mainstem Station 10-01-701

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	23	9/18/2002	43
7/31/2000	150	10/7/2002	9.1
8/7/2000	43	10/17/2002	43
9/11/2000	93	10/28/2002	23
9/28/2000	460	11/13/2002	93
10/5/2000	23	12/10/2002	23
10/25/2000	15	3/25/2003	3.6
11/6/2000	43	5/12/2003	23
11/13/2000	93	6/9/2003	150
12/6/2000	15	7/8/2003	23
1/17/2001	23	9/8/2003	93
4/18/2001	23	10/7/2003	43
5/7/2001	9.1	12/4/2003	460
5/29/2001	150	5/5/2004	23
6/6/2001	43	5/19/2004	43
6/26/2001	43	6/3/2004	9.1
7/11/2001	9.1	8/12/2004	23
7/30/2001	43	9/14/2004	23
8/7/2001	23	10/7/2004	15
9/12/2001	23	10/27/2004	93
10/10/2001	23	11/8/2004	93
11/7/2001	240	11/30/2004	75
12/5/2001	93	12/6/2004	23
1/22/2002	93	2/17/2005	150
4/17/2002	9.1	5/2/2005	9.1
4/22/2002	240	5/12/2005	14
5/9/2002	43	5/26/2005	9.1
6/13/2002	23	6/6/2005	93
7/15/2002	3.6	6/20/2005	1
8/12/2002	9.1	7/7/2005	43

Table D-3: Observed Fecal Coliform data at Lower Choptank River mainstem Station 10-01-800

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	93	9/18/2002	43
7/31/2000	43	10/7/2002	23
8/7/2000	43	10/17/2002	240
9/11/2000	23	10/28/2002	93
9/28/2000	240	11/13/2002	240
10/5/2000	43	12/10/2002	93
10/25/2000	23	3/25/2003	9.1
11/6/2000	240	5/12/2003	240
11/13/2000	120	6/9/2003	43
12/6/2000	3	7/8/2003	43
1/17/2001	39	9/8/2003	23
4/18/2001	43	10/7/2003	23
5/7/2001	9.1	12/4/2003	460
5/29/2001	93	5/5/2004	15
6/6/2001	7.3	5/19/2004	11
6/26/2001	43	6/3/2004	15
7/11/2001	23	8/12/2004	43
7/30/2001	240	9/14/2004	93
8/7/2001	23	10/7/2004	9.1
9/12/2001	15	10/27/2004	75
10/10/2001	23	11/8/2004	93
11/7/2001	43	11/30/2004	240
12/5/2001	43	12/6/2004	240
1/22/2002	93	2/17/2005	23
4/17/2002	9.1	5/2/2005	3.6
4/22/2002	93	5/12/2005	23
5/9/2002	23	5/26/2005	93
6/13/2002	1	6/6/2005	23
7/15/2002	23	6/20/2005	9.1
8/12/2002	20	7/7/2005	23