FINAL

Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Area in Monie Bay in Somerset County, Maryland

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List of Abbreviations

ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BST	Bacteria Source Tracking
CFR	Code of Federal Regulations
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
EPA	Environmental Protection Agency
FA	Future Allocation
FDA	U.S. Food and Drug Administration
km	Kilometer
LA	Load Allocation
m	Meter
M_2	Lunar semi-diurnal tidal constituent
MACS	Maryland Agricultural Cost Share Program
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WICMH	Wicomico River Mesohaline
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment

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 currently 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 (CFR 2006b).

Wicomico River Mesohaline (WICMH) is the Chesapeake Bay segment within which Monie Bay (8-digit basin number 02130302) lies. In the *2008 Integrated Report of Surface Water Quality* (Integrated Report), submitted to the U.S.EPA by the Maryland Department of the Environment (MDE), WICHMH was identified as impaired by nutrients (1996), sediments (1996) and fecal coliform (2006). For the fecal coliform listing, the restricted shellfish harvesting area in Monie Bay is specified. Monie Creek within the basin was also listed in 1996. Monie Creek is a conditionally approved shellfish harvesting water and these waters are not identified in the Integrated Report, therefore this listing was removed from the impaired waters list in 2004. This document, upon EPA approval, establishes TMDLs of fecal coliform for the restricted shellfish harvesting area in Monie Bay of the WICMH basin. All other impairment listings for WICMH will be addressed at a future date.

A steady-state single-segment tidal prism model was used to estimate current fecal coliform load based on volume, tidal prism, and concentration, and to establish allowable loads for the restricted shellfish harvesting area in Monie Bay. The tidal prism model incorporates both influences of freshwater discharge and tidal flushing for the river, which thereby represents the hydrodynamics of 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 90th percentile criterion concentration of 49 MPN/100ml for a three-tube decimal dilution. 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 Monie Bay watershed for fecal coliform are as follows:

Waterbody	**Fecal Coliform TMDL [counts per day]**	
	based on Median Criterion	**based on 90th Percentile Criterion**
Restricted Shellfish Harvesting Area in Monie Bay	2.196×10^{12}	7.547×10^{12}

The goal of TMDL allocation is to determine the maximum allowable loads for each known source in the watershed that will ensure the attainment of the water quality standard. The TMDL allocations proposed in this document were developed based on the criterion requiring the largest percent reductions, in this case, the 90th percentile criterion. The TMDL requires a reduction of approximately 57.0% for Monie Bay.

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 Bacteria Source Tracking (BST) results may be used as a tool to target and prioritize initial implementation efforts. Continued monitoring will be undertaken by MDE's Shellfish Certification Program, 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 (CFR 2006b). 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 are indicator organisms used in water quality monitoring in shellfish waters to indicate fresh sources of fecal contamination 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 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 that meet the criteria associated with the shellfish harvesting designated use.

On both the 1996 and 1998 Maryland 303(d) Lists of Impaired Waterbodies, many shellfish listings were identified on a broad 8-digit watershed scale. These listings were refined on the 2004 *Integrated Report of Surface Water Quality* (Integrated Report) (MDE 2004). Since 2004, the listings that are based on the shellfish water quality monitoring data are limited to specific, currently restricted shellfish harvesting areas within an 8-digit watershed (MDE 2006).

Wicomico River Mesohaline (WICMH) is the Chesapeake Bay segment within which Monie Bay (8-digit basin number 02130302) lies. In the *2008 Integrated Report*, submitted to the U.S.EPA by the Maryland Department of the Environment (MDE), WICHMH was identified as impaired by nutrients (1996), sediments (1996) and fecal coliform (2006). For the fecal coliform listing, the restricted shellfish harvesting area in Monie Bay is specified. Monie Creek within the basin was also listed in 1996. Monie Creek is a conditionally approved shellfish harvesting water and these waters are not identified in the *Integrated Report*, therefore this listing was removed from the impaired waters list in 2004. This document, upon EPA approval, establishes TMDLs of fecal coliform for the restricted shellfish harvesting area in Monie Bay of the WICMH basin. All other impairment listings for WICMH will be addressed at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Monie Bay is located on Maryland's Eastern Shore in Somerset County, MD. The restricted shellfish harvesting area extends from the mouth of the Monie River to the confluence of Monie Bay and Tangier Sound, which is a part of the Chesapeake Bay. The restricted shellfish harvesting area has an area of 3,165 acres (12.8 km^2) and a drainage area of 19,858 acres (80.4 km^2) (Figure 2.1.1).

The dominant tide in Monie Bay region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.701 m and a tidal period of 12.42 hours (National Oceanic and Atmospheric Administration (NOAA 2009). Please refer to Table 2.1.1 for the mean volume and mean water depth of the restricted shellfish harvesting area.

Table 2.1.1: Physical Characteristics of Monie Bay Restricted Shellfish Harvesting Area

Area	Mean Water Volume [m^3]	Mean Water Depth [m]
Restricted Shellfish Harvesting Area in Monie Bay	21,705,348	1.69

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that Monie Bay watershed is primarily rural, with 40.1% of the area being forest, 27% wetland and 15% cropland. The land use information for the restricted shellfish harvesting area in Monie Bay watershed is shown in Figure 2.1.2 and Table 2.1.2.

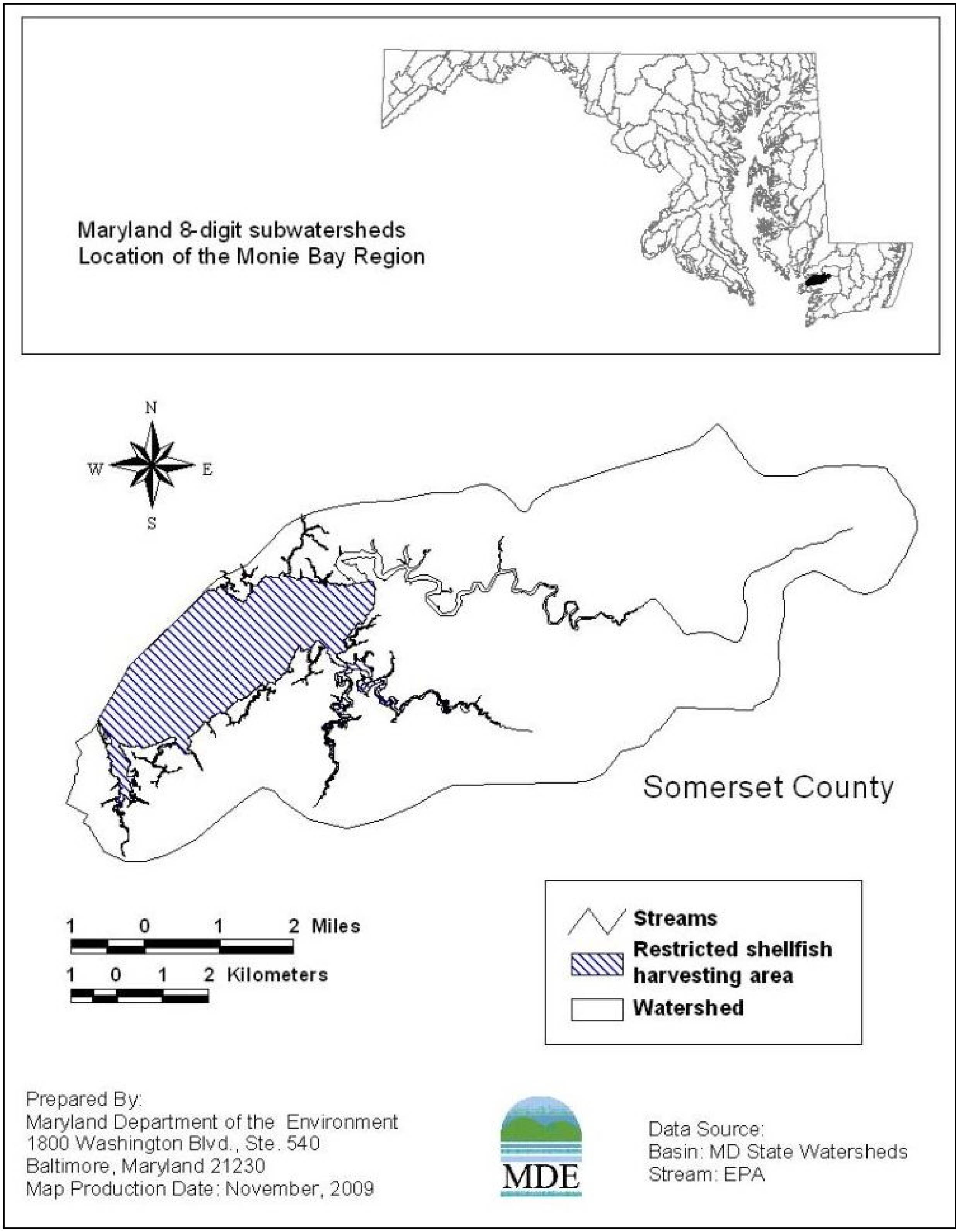

Figure 2.1.1: Location Map of the Monie Bay Basin

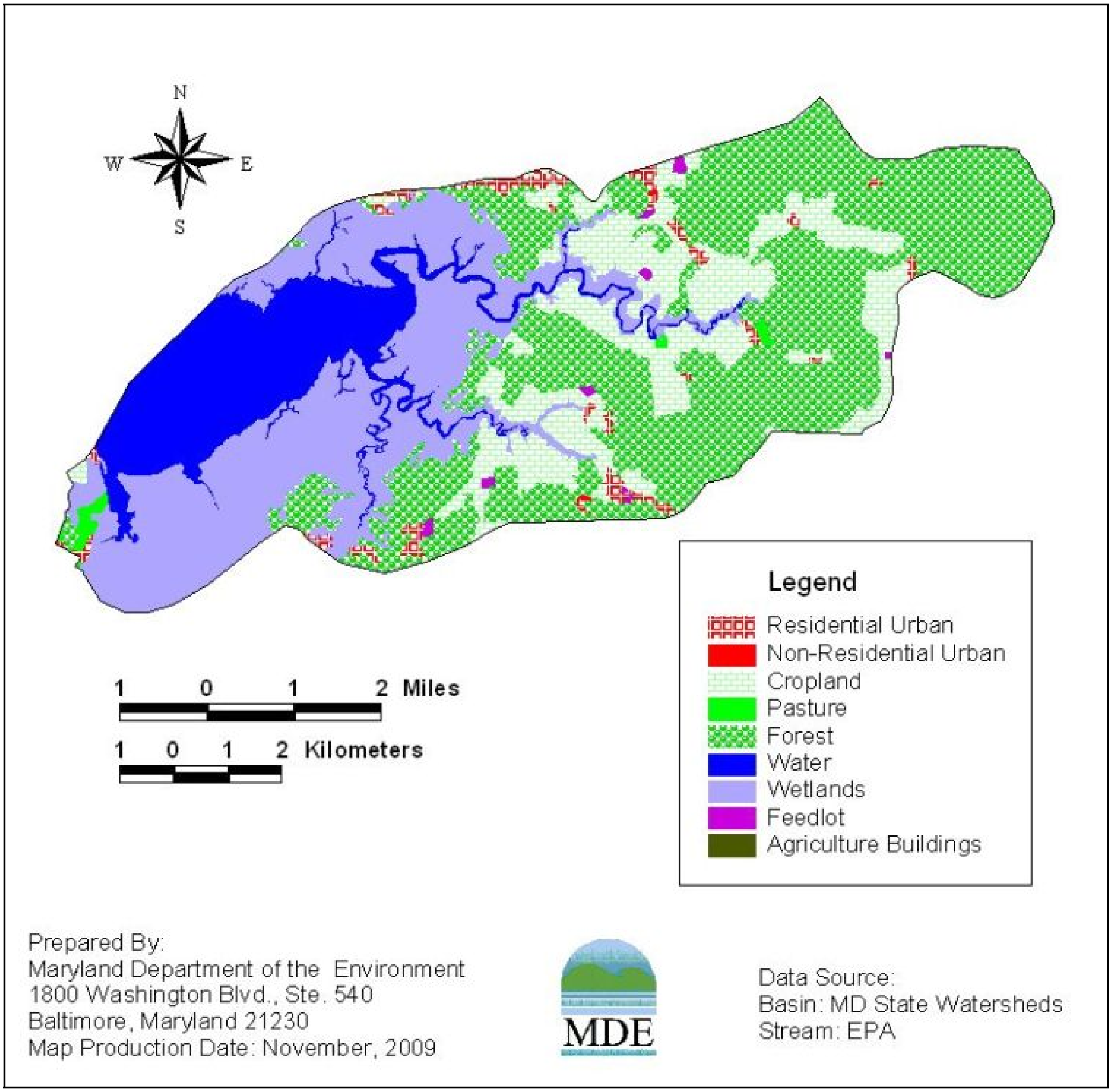

Figure 2.1.2: Land Use in the Monie Bay Basin

Table 2.1.2: Land Use Percentage Distribution for Monie Bay Watershed

Land Type	Acreage	Percentage
Residential urban[1]	510.9	2.20
Non-Residential urban[2]	10.6	0.05
Cropland	3,568.3	15.39
Pasture	120.5	0.52
Feedlot	75.4	0.33
Forest	9303.1	40.12
Water	3341.2	13.41
Wetlands	6259.3	26.99
Agriculture Buildings	1.2	0.00
Totals	**23,190.4**	**100**

Notes: [1] Includes low-density residential, medium-density residential, and high-density residential.
[2] Includes commercial, industrial, institutional, extractive, and open urban land.

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. As discussed above, MDE adheres to the requirements of the NSSP, with oversight by the FDA. MDE conducts shoreline surveys and collects routine bacteria water quality samples in the shellfish waters of Maryland to assure that Maryland's shellfish waters are properly classified.

There are four shellfish monitoring stations in the restricted shellfish harvesting area in Monie Bay. The station identification and observations recorded during a five-year period of July 2004 – June 2009 are provided in Table 2.2.1 and Figures 2.2.1-2.2.5. A tabulation of observed fecal coliform values at the monitoring stations is provided in Appendix C.

Table 2.2.1: Locations of the Shellfish Monitoring Stations in the Restricted Shellfish Harvesting Area in Monie Bay

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE	LONGITUDE
Restricted Shellfish Harvesting Area in Monie Bay	18-01-010	2004-2009	48	38.23007	-75.82208
	18-01-013	2004-2009	46	38.20352	-75.87949
	18-01-019	2004-2009	46	38.22359	-75.86102
	18-01-108A	2004-2009	45	38.22338	-75.84269

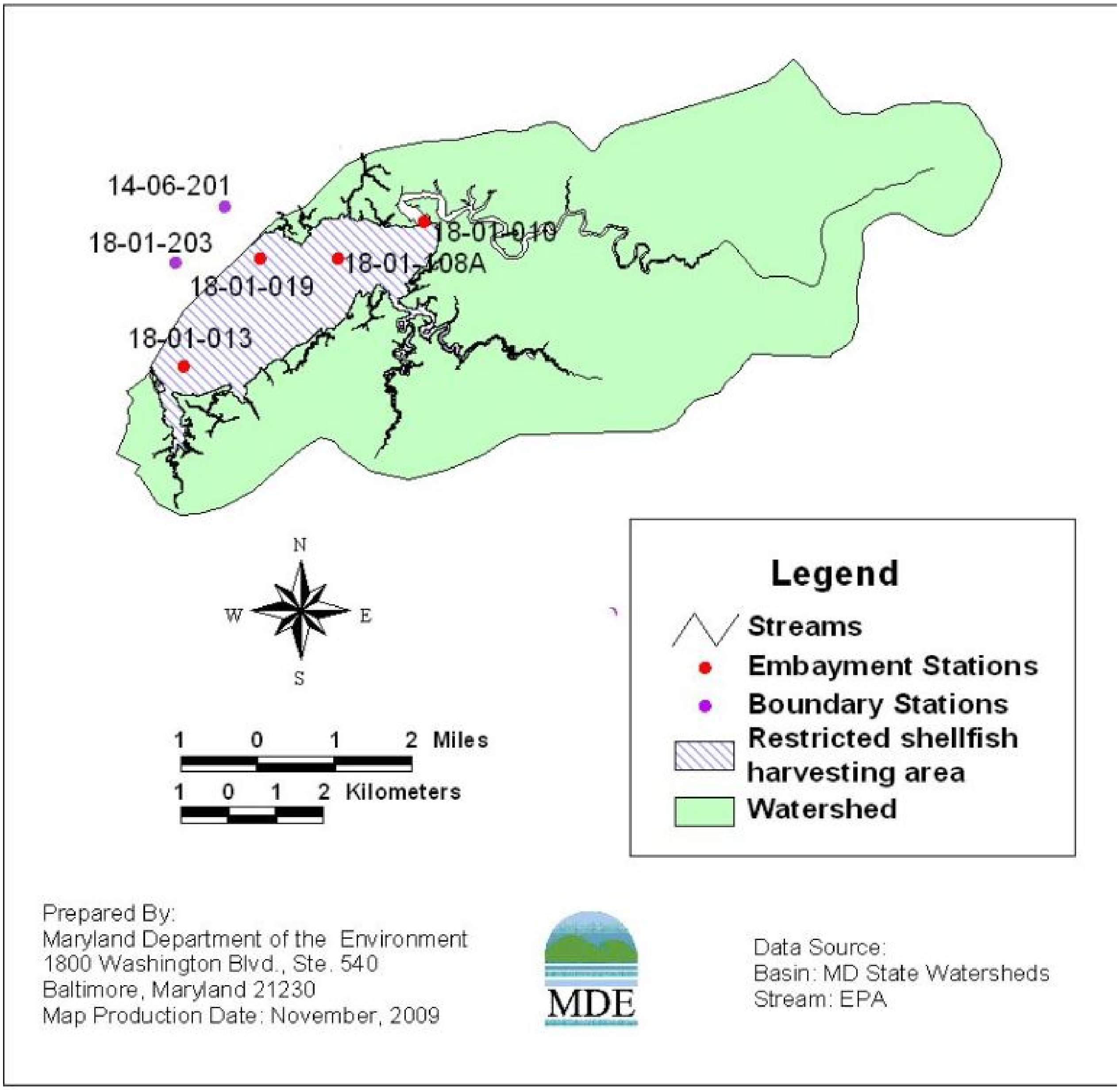

Figure 2.2.1: Shellfish Monitoring Stations in the Restricted Shellfish Harvesting Area in Monie Bay

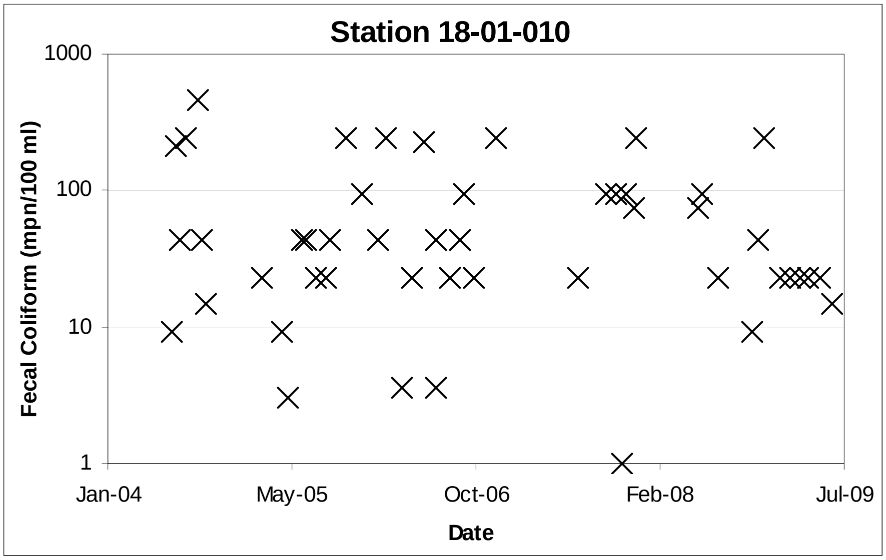

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 18-01-010

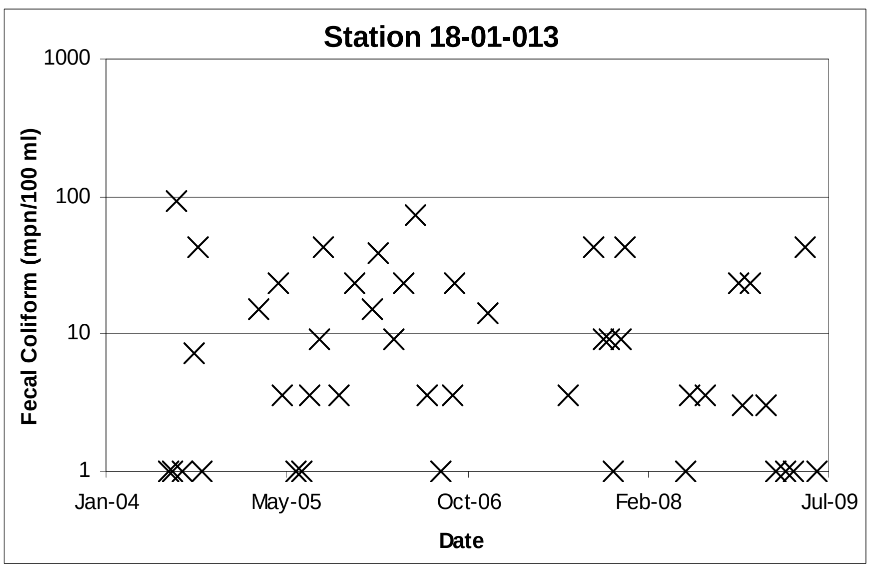

Figure 2.2.3: Observed Fecal Coliform Concentrations at Station 18-01-013

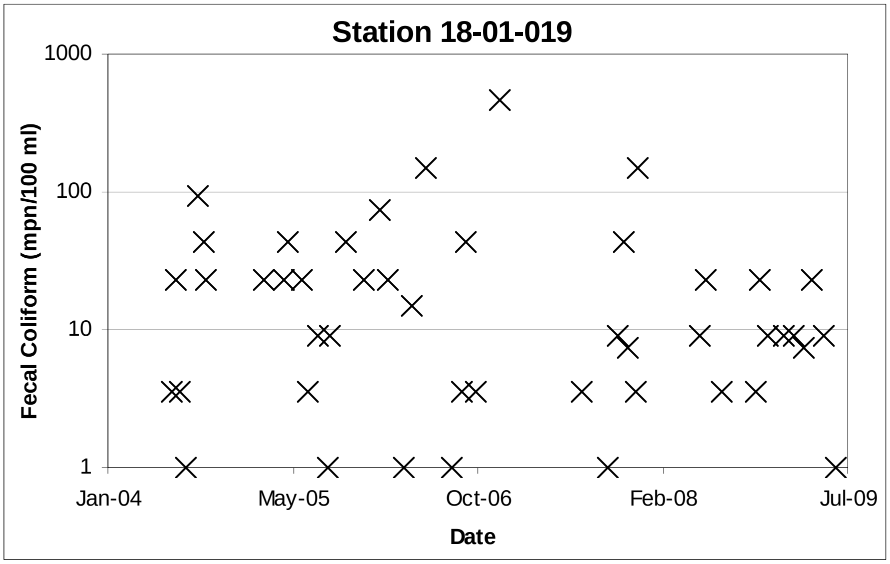

Figure 2.2.4: Observed Fecal Coliform Concentrations at Station 18-01-019

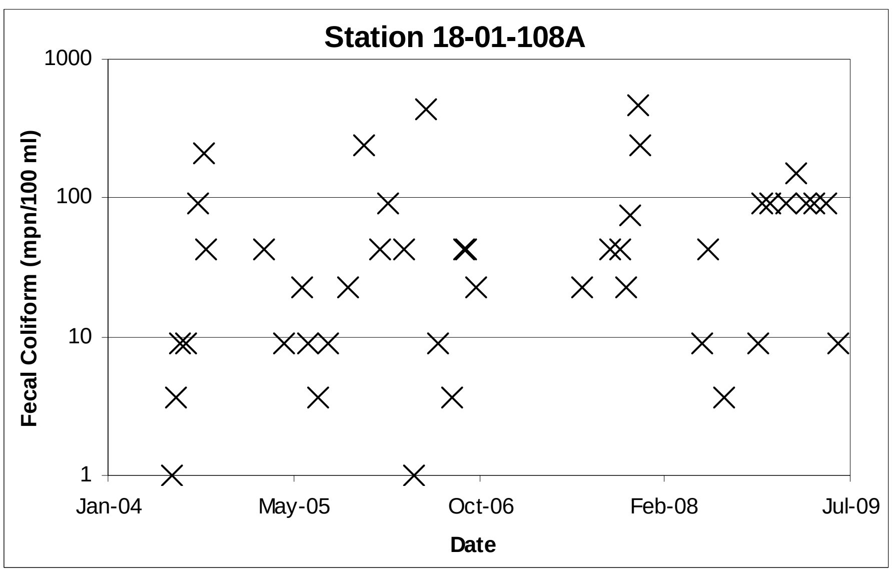

Figure 2.2.5: Observed Fecal Coliform Concentrations at Station 18-01-108A

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 the Code of Maryland Regulations (COMAR), Surface Water Quality Criteria 26.08.02.03-3.C(2), 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 (COMAR 2006).[1]

MDE updated and promulgated water quality criteria for shellfish waters in June 2004. Although bacteriological criteria for shellfish harvesting waters were unchanged, the update included the classification criteria required under the NSSP that previously was not 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 2004 and June 2009. 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, current loads are estimated based on all of the most recent data. The assimilative capacity will be based on the approved classification requirements of a median fecal coliform concentration of 14 MPN/100 ml and a 90th percentile concentration of less than 49 MPN/100 ml.

The water quality impairment in the restricted area of Monie Bay was assessed as not meeting the median and 90th percentile criteria at the monitoring stations. Two of the stations exceeded both the median criterion and 90th percentile criterion. One of the stations exceeded only the 90th percentile criterion. Descriptive statistics of the monitoring data and the requirements for the approved classification are shown in Table 2.3.1.

[1] Note that Maryland uses the three-tube decimal dilution test for fecal coliform bacteria monitoring purposes.

Table 2.3.1: Monie Bay Fecal Coliform Statistics (Data from 2004-2009)

Area	Station	Median		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Restricted Shellfish Harvesting Area in Monie Bay	18-01-010	43	14	240	49
	18-01-013	5	14	43	49
	18-01-019	9	14	59	49
	18-01-108A	43	14	228	49

2.4 Source Assessment

Nonpoint Source Assessment

Nonpoint sources of fecal coliform do not have a single discharge point, but rather they 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 and may come 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.

In order to better identify potential sources of bacterial contamination that may be impacting the water quality of Monie Bay, MDE conducted Bacterial Source Tracking (BST) in the area from November 2008 to October 2009. BST technology was used to distinguish the origins of bacteria found in environmental waters. Under the premise that bacteria isolated from different hosts can be discriminated based on differences in the selective pressure of microbial populations found in the gastrointestinal tract of the hosts, i.e., humans, livestock, pets, and wildlife (Wiggins 1996), a biochemical method called Antibiotic Resistance Analysis (ARA) was used. In ARA, microbial isolates from water samples are tested and their resistance to several antibiotics are recorded and compared with a library of known-source isolates and resistance patterns. Finally, a statistical analysis can predict the likely host source of the water isolates (Hagedorn 1999, Price *et al.* 2006, Wiggins 1999, Frana and Venso, 2010).

Based on the ARA results, the largest category of potential sources in Monie Bay were human (28.69%) and wildlife ((28.55%), followed by livestock (25.5%) and pets (17.26%). Table 2.4.1

summarizes the source distribution based on BST results. Detailed results of BST analysis are presented in Appendix D.

Table 2.4.1: Source Distribution Based on BST Results

Human	Livestock	Pets	Wildlife
28.69%	25.50%	17.26%	28.55%

BST data analysis includes a statistical comparison of known sources collected in the watershed and compared with unknown source samples collected over the study period. The fecal coliform sources in water samples are unknown until matched with the library of known sources. Four source distribution categories were used to estimate bacterial sources.

Point Source Assessment

There are no permitted municipal or industrial point source facilities with permits regulating the discharge of bacteria in the Monie Bay watershed, based on MDE point source permitting information.

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal coliform TMDLs summarized in this document is to establish the maximum loading allowed to ensure attainment of water quality standards in the restricted shellfish harvesting waters in Monie Bay. 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 Monie Bay watershed. The required load reduction was determined based on data collected from July 2004 to June 2009. The TMDLs are presented as counts/day. Section 4.2 describes the analysis framework for simulating fecal coliform concentration in the restricted shellfish harvesting water in the Monie Bay watershed. Section 4.3 addresses critical conditions and seasonality. The TMDL calculations are presented in Section 4.4. Section 4.5 provides a summary of baseline loads and Section 4.6 discusses TMDL loading caps. Section 4.7 provides the description of the waste load and load allocations. The MOS is discussed in Section 4.8. Finally, the TMDL equation is summarized in Section 4.9.

A TMDL is the total amount of a pollutant that a waterbody can receive and still meet water quality criteria, which in the case of this document would be 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” (CFR 2006a). These loads are based on an averaging period that is defined by the specific water quality criteria for shellfish harvesting waters. 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 the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, incorporating natural background levels. The TMDL must, either implicitly or explicitly, include a MOS 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, when applicable, the TMDL may include a future allocation (FA) when necessary. This definition is denoted by the following equation:

TMDL = WLAs + LAs + MOS + (FA, where applicable)

4.2 Analysis Framework

In general, tidal waters are exchanged through their connecting boundaries. The tidal flushing and amount of freshwater discharge into shellfish harvesting area are the dominant influences on the transport of fecal coliform (Kuo *et al*. 1998; Shen *et al*. 2005). 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 single-segment tidal prism model. Compared to the volumetric method (USEPA 2002), the steady-state tidal prism model provides improvements incorporating the influences of tidal induced transport, freshwater, and decay of fecal coliform in the tidal Bay. The whole restricted shellfish harvesting area is considered as a single well-mixed waterbody and the steady-state one-segment tidal prism model was used to estimate the existing loadings and TMDLs. As there are four monitoring stations in the restricted area, their volumetric averages from the same observational days were used. The whole restricted area was divided into 4 segments, so that each station locates approximately in the middle of the segment. The volume of each segment was calculated by multiplying its mean depth, which was obtained through GIS data, and surface area. The concentration at the station in each segment was multiplied by segment volume, and the 4 products were summed up and divided by the total volume of the embayment to get the volumetric average concentration. The most recent five-year median and 90th percentile of these averaged values, i.e., 24 and 108 MPN/100ml, were used to estimate the current loads. Used as the boundary conditions, the fecal colifrom concentrations from the same observational days of Stations 18-01-203 and 14-06-201, which are located outside of the Monie Bay restricted shellfish harvesting area, were averaged. The most recent five-year median and 90th percentiles of the averages for these two stations are 10 and 43 MPN/100ml. The locations of these two stations are shown on Figure 2.2.1. A detailed description of the model and computation is presented in Appendix A.

4.3 Critical Condition and Seasonality

EPA's regulations require TMDLs to be "established at levels necessary to attain and maintain the applicable narrative and numerical WQS [water quality standards] with *seasonal variations* and a *margin of safety* . . . Determinations of TMDLs shall take into account *critical conditions* for stream flow, loading, and water quality parameters" (CFR 2006b). 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.

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

A comparison of the median value and the 90^{th} percentile value 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 high with limited variation around the mean. If the 90^{th} 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 distribution for the monitoring stations is presented in Appendix B. High concentrations occur in the months of December in Monie Bay restricted shellfish harvesting area. The large standard deviations occur in December. These high concentrations result in high 90^{th} percentile concentrations, which 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 standards for fecal coliform in shellfish waters, computation of a TMDL requires analyses of both the median and 90^{th} percentile scenarios. A detailed computation is presented in Appendix A.

Routine monitoring data were used to estimate the current loads. Both the median and the 90^{th} percentile analyses have been performed. The steady-state single-segment tidal prism model was used for the analysis (Kuo *et al*. 1998; Shen *et al*. 2005). There are four shellfish monitoring stations in the restricted shellfish harvesting area of Monie Bay. The entire restricted area was considered as a well mixed single tidal-prism segment. The tidal prism model was used to compute the watershed loads discharged into Monie Bay based on tidal flushing, freshwater discharge, and observed fecal coliform concentrations.

The stream flow used for the estimation of freshwater discharge was based on the flows of the U.S. Geological Survey (USGS) gage # 02060009, located in the Somerset County, Maryland. For the restricted shellfish harvesting area, the average long-term flow for this USGS gage (5.74 cfs) was adjusted by the ratio of the drainage basin area to that of the gage's basin (4.8 square miles) to derive estimates of long-term flows. The estimated long-term mean flow is 37.12 cfs. The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.701 m (National Oceanic and Atmospheric Administration (NOAA) 2009). This tidal range is used to compute tidal prism of the Bay.

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 single-segment tidal prism model was used to compute the allowable load for the restricted shellfish harvesting area. The load reduction needed for the attainment of the criteria is determined as follows:

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

4.5 Summary of Baseline Loads

For the TMDL analysis period, from July 2004 to June 2009, the calculated baseline (current) loads of fecal coliform from all sources in the restricted shellfish harvesting area in the Monie Bay basin are summarized in Table 4.5.1.

Table 4.5.1: Summary of Baseline Loads

Waterbody	Fecal Coliform Baseline Loads [Counts/day]	
	Median Analysis Scenario	90th Percentile Analysis Scenario
Restricted Shellfish Harvesting Area in Monie Bay	3.889×10^{12}	1.753×10^{13}

4.6 TMDL Loading Caps

This section presents the TMDLs that would meet the median and 90th percentile criteria. Seasonal variability is addressed implicitly through the interpretation of the water quality standards (see Section 4.3). The median and 90th percentile based TMDLs for the restricted shellfish harvesting waters of the Monie Bay watershed are summarized in Table 4.6.1.

Table 4.6.1: Summary of TMDL Loading Caps

Waterbody	Fecal Coliform TMDL [counts per day]	
	based on Median Criterion	based on 90th Percentile Criterion*
Restricted Shellfish Harvesting Area in Monie Bay	2.196×10^{12}	7.547×10^{12}

* The comparison of the reductions required based on the median and 90th percentile criteria indicated that the 90th percentile scenario requires the largest percent reductions. Therefore, reductions required to meet the 90th percentile criterion were the bases for the TMDL allocations.

A five-year averaging period was used to develop the fecal coliform TMDLs for the restricted shellfish harvesting area in Monie Bay. This specific averaging period was chosen based on the water quality criteria, which requires at least 30 samples (COMAR 2006). When allocating loads among sources, the scenario that requires the greatest overall reductions (here, the 90th percentile scenario) was applied. Table 4.7.1 below summarizes the necessary load reductions for this area.

4.7 Load Allocation and Percent Reductions

The purpose of this section is to allocate the TMDLs between point (WLA) and nonpoint (LA) sources. Because there are no permitted municipal or industrial point source facilities with permits regulating the discharge of bacteria in the Monie Bay watershed, the 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. The load reduction calculated in this document was based on the 90th percentile water quality criterion, which is shown in Table 4.7.1 for the restricted shellfish harvesting area of the Monie Bay watershed.

Table 4.7.1: Load Reductions

Area	Required Reduction
Restricted Shellfish Harvesting Area in Monie Bay	57.0 %

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.

4.8 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 the 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 (0.36 per tidal circle) 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.

4.9 Summary of Total Maximum Daily Loads

There are no permitted municipal or industrial point source facilities with permits regulating the discharge of bacteria in the Monie Bay watershed. All the loads are allocated to the LA. The TMDL is summarized as follows:

Fecal Coliform TMDL (counts per day) Based on 90th percentile Criterion:

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Restricted Shellfish Harvesting Area in Monie Bay	**7.547×10^{12}**	**=**	**7.547×10^{12}**	**+**	**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 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. 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 greatest impact on water quality, with consideration given to ease of implementation and cost. The source contributions estimated from BST analysis (see Table 2.4.1) may be used as a tool to target and prioritize initial implementation efforts. The iterative approach towards best management practice (BMP) implementation throughout the watershed will help to ensure that the most cost-effective practices are implemented first. The success of BMP implementation will be evaluated and tracked through follow-up stream monitoring.

Existing Funding and Regulatory Framework

Funding sources for implementation include low interest loans are available to property owners with failing septic systems through MDE's Linked Deposit Program. It is also anticipated that the Bay Restoration Fund will provide funding to upgrade onsite sewage disposal systems with priority given to failing systems and holding tanks in the Chesapeake and Atlantic Coastal Bays Critical Areas. Local governments can utilize funding from the State Water Quality Revolving Loan Fund and the Stormwater Pollution Cost Share Program. Other potential funding sources 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 utilized for livestock and agricultural production. Details of these programs and additional funding sources can be found at http://www.dnr.state.md.us/bay/services/summaries.html.

Maryland law requires the following types of facilities to have pumpout 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 (Maryland 1996). Any public or private marina in Maryland is eligible to apply for up to $15,000 in grant funds to install a pumpout station through the Maryland Department of Natural Resources.

Regulatory enforcement of potential bacteria sources would be covered by MDE's routine sanitary surveys of shellfish growing areas and National Pollutant Discharge Elimination System (NPDES) permitting activities. Also, although not directly linked, it is assumed that the nutrient management plans from the Water Quality Improvement Act (WQIA) of 1998 will result in some reduction of bacteria from manure application practices.

As part of Maryland's commitment to the NSSP, MDE's Shellfish Certification Program continues to monitor shellfish waters and classify shellfish harvesting areas as restricted, approved, or conditionally approved. A major component of MDE's responsibilities under the Shellfish Certification Program is to identify potential pollution sources and correct or eliminate them. Waters meeting shellfish water quality standards are reclassified as approved or conditionally approved harvesting areas. The removal of shellfish harvesting restrictions may serve as a tracking tool measuring water quality improvements. However, when performing such analyses, it is important to understand that, per FDA/NSSP requirements, areas located near point sources are expected to remain restricted. Existence of such restrictions does not necessarily mean that the area is not meeting water quality standards.

Implementation and Wildlife Sources

It is expected that, due to significant wildlife bacteria contribution, some waterbodies will not be able to meet water quality standards even after all anthropogenic sources are controlled. 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 the changing of a natural background condition is not the intended goal of a TMDL.

MDE envisions an iterative approach to TMDL implementation, which first addresses the controllable sources (i.e., human, livestock, and pets), especially those that have the largest impacts on water quality and create the greatest risks to human health, with consideration given to ease the cost of implementation. It is expected that the best management practices applied to controllable sources may also result in reduction of some wildlife sources. Following the initial implementation stage, MDE expects to re-assess the water quality to determine if the designated use is being attained. If the water quality standards are not attained, other sources may need to be controlled. However, if the required controls go beyond maximum practical reductions, MDE might 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. Tidal Prism Model

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

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

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

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

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

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

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

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

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

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

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

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

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

$$Load_T = C_c(Q_b + kV) - Q_0C_0 \qquad (6)$$

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:

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

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:

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

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):

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

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:

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

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 entering 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).

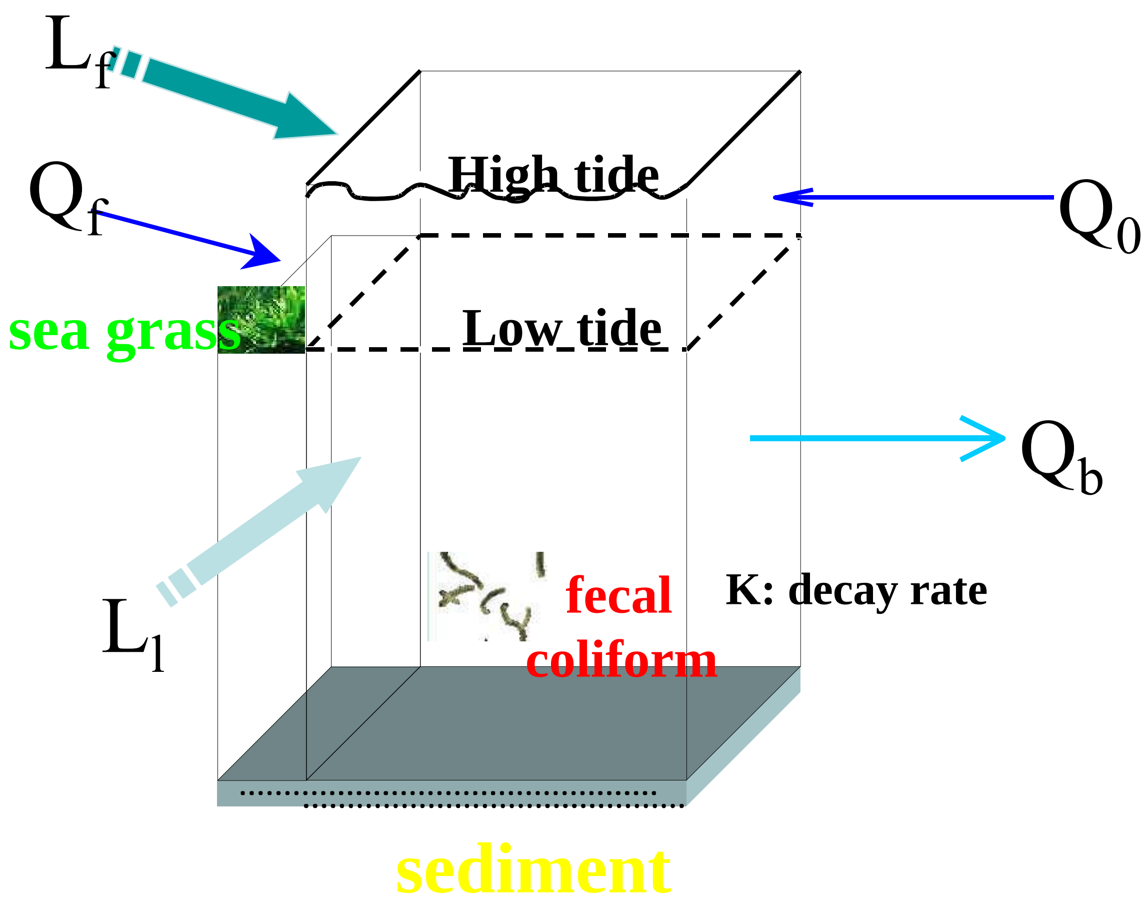

Figure A-1: The Schematic Diagram for One Segment Tidal Prism Model

A Tidal Prism Model Calculation for Monie Bay

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 restricted area = 21705348.3 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 37.116 cfs = 37.116 × 0.0283 × 86400 × 12.42 ÷ 24 = 46964.3 (m^3T^{-1})
Q_0 = 897915.6 (m^3T^{-1})
β = 0.1
Q_b = 944879.9 ($m^3\ T^{-1}$)
C_c = water quality criterion = 14 MPN/100ml
C = current fecal coliform 5-year median concentration = 24 (MPN/100ml)
C_0 = fecal coliform 5-year median outside of the embayment = 10 (MPN/100ml)
T = tidal cycle =12.42 hours
Cf = the unit conversion factor

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

Allowable Load

$$= \left[C_c(Q_b + kV) - Q_0C_0\right] \times C_f$$

$$= [14\times (944879.9 + 0.36\times 21705348.3) - 897915.6 \times 10] \times 24 \div 12.42 \times 10000$$

$$= 2.196\times 10^{12}$$

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

$$= \left[C(Q_b + kV) - Q_0C_0\right] \times C_f$$

$$= [24 \times (944879.9 + 0.36\times 21705348.3) - 897915.6 \times 10] \times 24 \div 12.42 \times 10000$$

$$= 3.889\times 10^{12}$$

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{3.889 \times 10^{12} - 2.196 \times 10^{12}}{3.889 \times 10^{12}} \times 100\% = 43.5\%$$

A Tidal Prism Model Calculation for Monie Bay

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 restricted area = 21705348.3 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 37.116 cfs = $37.116 \times 0.0283 \times 86400 \times 12.42 \div 24 = 46964.3$ (m^3T^{-1})
Q_0 = 897915.6 (m^3T^{-1})
β = 0.1
Q_b = 944879.9 ($m^3\ T^{-1}$)
C_c = water quality criterion = 49 MPN/100ml
C = current fecal coliform 5-year 90th percentile concentration = 108 (MPN/100ml)
C_0 = fecal coliform 5-year 90th percentile outside of the embayment = 43 (MPN/100ml)
T = tidal cycle =12.42 hours
Cf = the unit conversion factor

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

Allowable Load

$$= \left[C_c(Q_b + kV) - Q_0C_0\right] \times C_f$$

$$= [49\times (944879.9 + 0.36\times 21705348.3) - 897915.6 \times 43] \times 24 \div 12.42 \times 10000$$

$$= 7.547\times 10^{12}$$

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

Current condition

$$= \left[C(Q_b + kV) - Q_0C_0\right] \times C_f$$

$$= [108 \times (944879.9 + 0.36\times 21705348.3) - 897915.6 \times 43] \times 24 \div 12.42 \times 10000$$

$$= 1.753\times 10^{13}$$

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{1.753 \times 10^{13} - 7.547 \times 10^{12}}{1.753 \times 10^{13}} \times 100\% = 56.95\%$$

Sample calculations of load reductions for both the median and 90th percentiles have been presented for Monie Bay. The following table lists the parameter values needed for this calculation. 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

Area Name	V	k	Q_f	Q_0	Q_b	Median		90th Percentile	
						C	C_0	C	C_0
Restricted Shellfish Harvesting Area in Monie Bay	21705348.3	0.36	46964.3	897915.6	944879.9	24	10	108	43

The values attained using the sample calculation are listed below:

Table A-2: TMDL Calculation Results

Area Name	Median			90th Percentile		
	Allowable Load	Current Load	Percent Reduction	Allowable Load	Current Load	Percent Reduction
	Counts/Day	Counts/Day		Counts/Day	Counts/Day	
Restricted Shellfish Harvesting Area in Monie Bay	2.198×10^{12}	3.889×10^{12}	43.5	7.547×10^{12}	1.753×10^{13}	57.0

Appendix B. Seasonality Analysis

The Code of Federal Regulations requires that TMDL studies take into account critical conditions for stream flow, loading, and water quality parameters (CFR 2006c). The Environmental Protection Agency (EPA) also requires that these Total Maximum Daily Load (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.

A 5-year station-averaged monthly fecal coliform concentrations and their standard deviations were calculated. The result is presented in Figure B-1. It shows that high concentrations occur in the months of February, April, May, September, and December. The largest standard deviation occurs in December, which corresponds to the high fecal coliform variability. This suggests that the violation, in regards to the criteria, may occur in a few months of the year.

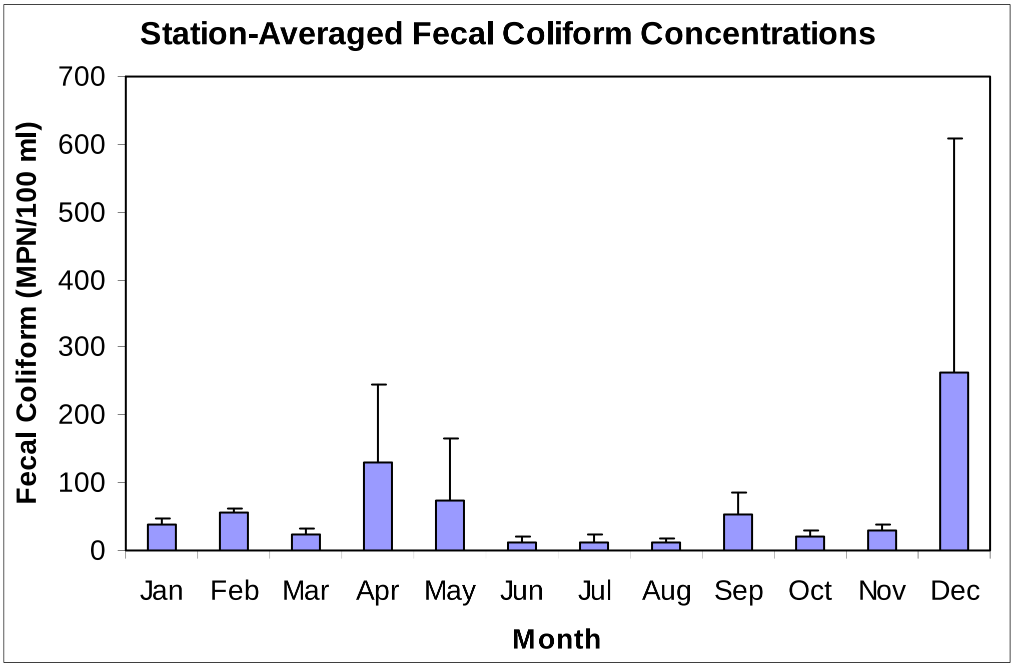

Figure B-1: Seasonality Analysis of Fecal Coliform at Monie Bay Monitoring Stations

Appendix C. Tabulation of Fecal Coliform Data

This appendix provides a tabulation of fecal coliform values for the monitoring stations of the restricted shellfish harvesting area in Monie Bay (Table C-1 to Table C-4). The data are plotted in Figure 2.2.2 of the main report.

Table C-1: Observed Fecal Coliform Data at Monie Bay Station 1801010

Station	DATE	Fecal Coliform MPN/100 ml
1801010	07-Jul-04	9.1
1801010	15-Jul-04	210
1801010	27-Jul-04	43
1801010	11-Aug-04	240
1801010	14-Sep-04	460
1801010	27-Sep-04	43
1801010	06-Oct-04	15
1801010	10-Mar-05	23
1801010	03-May-05	9.1
1801010	16-May-05	3
1801010	22-Jun-05	43
1801010	07-Jul-05	43
1801010	01-Aug-05	23
1801010	29-Aug-05	23
1801010	06-Sep-05	43
1801010	20-Oct-05	240
1801010	05-Dec-05	93
1801010	18-Jan-06	43
1801010	08-Feb-06	240
1801010	22-Mar-06	3.6
1801010	17-Apr-06	23
1801010	22-May-06	230
1801010	22-Jun-06	3.6
1801010	22-Jun-06	43
1801010	31-Jul-06	23
1801010	28-Aug-06	43
1801010	07-Sep-06	93
1801010	04-Oct-06	23
1801010	06-Dec-06	240
1801010	16-Jul-07	23
1801010	26-Sep-07	93
1801010	24-Oct-07	93
1801010	09-Nov-07	1
1801010	20-Nov-07	93
1801010	11-Dec-07	75
1801010	18-Dec-07	240

1801010	03-Jun-08	75
1801010	17-Jun-08	93
1801010	30-Jul-08	23
1801010	30-Oct-08	9.1
1801010	12-Nov-08	43
1801010	02-Dec-08	240
1801010	12-Jan-09	23
1801010	09-Feb-09	23
1801010	10-Mar-09	23
1801010	01-Apr-09	23
1801010	04-May-09	23
1801010	01-Jun-09	15

Table C-2: Observed Fecal Coliform Data at Monie Bay Station 1801013

Station	DATE	Fecal Coliform MPN/100 ml
1801013	07-Jul-04	1
1801013	15-Jul-04	1
1801013	27-Jul-04	93
1801013	11-Aug-04	1
1801013	14-Sep-04	7.3
1801013	27-Sep-04	43
1801013	06-Oct-04	1
1801013	10-Mar-05	15
1801013	03-May-05	23
1801013	16-May-05	3.6
1801013	22-Jun-05	1
1801013	07-Jul-05	1
1801013	01-Aug-05	3.6
1801013	29-Aug-05	9.1
1801013	06-Sep-05	43
1801013	20-Oct-05	3.6
1801013	05-Dec-05	23
1801013	18-Jan-06	15
1801013	08-Feb-06	39
1801013	22-Mar-06	9.1
1801013	17-Apr-06	23
1801013	22-May-06	73
1801013	22-Jun-06	3.6
1801013	31-Jul-06	1
1801013	28-Aug-06	3.6
1801013	07-Sep-06	23
1801013	06-Dec-06	14
1801013	16-Jul-07	3.6
1801013	26-Sep-07	43

1801013	24-Oct-07	9.1
1801013	09-Nov-07	9.1
1801013	20-Nov-07	1
1801013	11-Dec-07	9.1
1801013	18-Dec-07	43
1801013	03-Jun-08	1
1801013	17-Jun-08	3.6
1801013	30-Jul-08	3.6
1801013	30-Oct-08	23
1801013	12-Nov-08	3
1801013	02-Dec-08	23
1801013	12-Jan-09	3
1801013	09-Feb-09	1
1801013	10-Mar-09	1
1801013	01-Apr-09	1
1801013	04-May-09	43
1801013	01-Jun-09	1

Table C-3: Observed Fecal Coliform Data at Monie Bay Station 1801019

Station	DATE	Fecal Coliform MPN/100 ml
1801019	07-Jul-04	3.6
1801019	15-Jul-04	23
1801019	27-Jul-04	3.6
1801019	11-Aug-04	1
1801019	14-Sep-04	93
1801019	27-Sep-04	43
1801019	06-Oct-04	23
1801019	10-Mar-05	23
1801019	03-May-05	23
1801019	16-May-05	43
1801019	22-Jun-05	23
1801019	07-Jul-05	3.6
1801019	01-Aug-05	9.1
1801019	29-Aug-05	1
1801019	06-Sep-05	9.1
1801019	20-Oct-05	43
1801019	05-Dec-05	23
1801019	18-Jan-06	75
1801019	08-Feb-06	23
1801019	22-Mar-06	1
1801019	17-Apr-06	15
1801019	22-May-06	150
1801019	31-Jul-06	1
1801019	28-Aug-06	3.6

1801019	07-Sep-06	43
1801019	03-Oct-06	3.6
1801019	06-Dec-06	460
1801019	16-Jul-07	3.6
1801019	26-Sep-07	1
1801019	24-Oct-07	9.1
1801019	09-Nov-07	43
1801019	20-Nov-07	7.3
1801019	11-Dec-07	3.6
1801019	18-Dec-07	150
1801019	03-Jun-08	9.1
1801019	17-Jun-08	23
1801019	30-Jul-08	3.6
1801019	30-Oct-08	3.6
1801019	12-Nov-08	23
1801019	02-Dec-08	9.1
1801019	12-Jan-09	9.1
1801019	09-Feb-09	9.1
1801019	10-Mar-09	7.3
1801019	01-Apr-09	23
1801019	04-May-09	9.1
1801019	01-Jun-09	1

Table C-4: Observed Fecal Coliform Data at Monie Bay Station 1801108A

Station	DATE	Fecal Coliform MPN/100 ml
1801108A	07-Jul-04	1
1801108A	15-Jul-04	3.6
1801108A	27-Jul-04	9.1
1801108A	11-Aug-04	9.1
1801108A	14-Sep-04	93
1801108A	27-Sep-04	210
1801108A	06-Oct-04	43
1801108A	10-Mar-05	43
1801108A	03-May-05	9.1
1801108A	22-Jun-05	23
1801108A	07-Jul-05	9.1
1801108A	01-Aug-05	3.6
1801108A	29-Aug-05	9.1
1801108A	20-Oct-05	23
1801108A	05-Dec-05	240
1801108A	18-Jan-06	43
1801108A	08-Feb-06	93
1801108A	22-Mar-06	43
1801108A	17-Apr-06	1

1801108A	22-May-06	430
1801108A	22-Jun-06	9.1
1801108A	31-Jul-06	3.6
1801108A	28-Aug-06	43
1801108A	07-Sep-06	43
1801108A	03-Oct-06	23
1801108A	06-Dec-06	2400
1801108A	16-Jul-07	23
1801108A	26-Sep-07	43
1801108A	24-Oct-07	43
1801108A	09-Nov-07	23
1801108A	20-Nov-07	75
1801108A	11-Dec-07	460
1801108A	18-Dec-07	240
1801108A	03-Jun-08	9.1
1801108A	17-Jun-08	43
1801108A	30-Jul-08	3.6
1801108A	30-Oct-08	9.1
1801108A	12-Nov-08	93
1801108A	02-Dec-08	93
1801108A	12-Jan-09	93
1801108A	09-Feb-09	150
1801108A	10-Mar-09	93
1801108A	01-Apr-09	93
1801108A	04-May-09	93
1801108A	01-Jun-09	9.1

Appendix D. Identifying Sources of Fecal Pollution in Monie Bay

Introduction

In order to better identify potential sources of bacterial contamination that may be impacting the water quality of Monie Bay restricted shellfish harvesting area, MDE conducted bacteria source tracking (BST) in the area from November 2008 to October 2009. BST (bacterial source tracking) technology was used to distinguish the origins of bacteria found in environmental waters. One of the biochemical BST methods, Antibiotic Resistance Analysis (ARA), was used with Enterococcus as the indicator organism. The premise of this method is that bacteria isolated from different hosts can be discriminated based on differences in the selective pressure of microbial populations found in the gastrointestinal tract of the hosts, i.e., humans, livestock, pets, and wildlife (Wiggins 1996). In ARA, microbial isolates collected from water samples are tested and their resistance results are recorded and compared with library isolates from known sources. A statistical analysis can predict the likely host source of the water isolates (Hagedorn 1999, Price *et al.* 2006, Wiggins 1999).

<u>Monie Bay Watershed BST Results</u>

A 1,091 known-source isolate library was constructed from sources in Monie Bay. The number of unique antibiotic resistance patterns was calculated, and the known sources in the library were grouped into four categories: human, livestock (chicken, cow, horse), pet (cat, dog), and wildlife (blue heron, deer, fox, goose, rabbit, raccoon, seagull). Water samples were obtained from Stations 18-01-010, 18-01-013, 18-01-019, and 18-01-108A in Monie Bay. All Enterococcus isolates were analyzed by statistical analysis. The BST results are shown in Table D-1. The largest category of potential sources in Monie Bay watershed was human (28.69%), %) and wildlife (28.55%), followed by livestock (25.50%) and pet (17.26%) (Frana and Venso, 2010).
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Table D-1: Predicted Host Source Distribution in Monie Bay*

Source	Distribution
Human	28.69%
Livestock	25.50%
Pet	17.26%
Wildlife	28.55%
Total	**100%**

*Frana, M.F. and E. A. Venso. 2010. Final Report: Identifying source of fecal pollution in shellfish and nontidal waters in Maryland watersheds (November 2008 – June 2010)