Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Area in Mill Creek of the Lower Patuxent River Basin in Charles County, Maryland

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FINAL

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List of Abbreviations

ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BST	Bacteria Source Tracking
CFR	Code of Federal Regulations
cms	Cubic Meters per Second
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
EPA	Environmental Protection Agency
FA	Future Allocation
FDA	U.S. Food and Drug Administration
GIS	Geographic Information System
km	Kilometer
LA	Load Allocation
L_D	Load From Diffuse Sources
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
mgd	Million Gallons per Day
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer Systems
MSSCC	Maryland State's Soil Conservation Committee
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
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 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 2006c).

Mill Creek of Lower Patuxent River Basin (basin number 02131101) was first identified on the 1998 303(d) List submitted to U.S. Environmental Protection Agency (EPA) by the Maryland Department of the Environment (MDE). The designated uses in Mill Creek were listed as impaired by fecal coliform in a restricted shellfish harvesting area within the basin (MDE 2006). This document, upon EPA approval, establishes a TMDL of fecal coliform for the restricted shellfish harvesting area in the Mill Creek.

A tidal prism model was used to estimate current fecal coliform loads and to establish allowable loads for the restricted shellfish harvesting area in the Mill Creek watershed. The tidal prism model incorporates influences of freshwater discharge, tidal flushing, and fecal coliform decay, thereby representing the fate and transport of fecal coliform in the Mill Creek restricted shellfish harvesting area. The loadings from potential sources (human, livestock, pets, and wildlife) were quantified by analysis of the bacteria source tracking (BST) collected in the Patuxent River over a one-year period.

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 the Mill Creek watershed for fecal coliform are as follows:

Waterbody	**Fecal Coliform TMDL [counts per day]**	
	based on Median Criterion	**based on 90th Percentile Criterion**
Mill Creek	8.88×10^{09}	3.11×10^{10}

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 reduction - here the 90th percentile criterion. The TMDL for Mill Creek proposed in this document requires a reduction of approximately 47.71%.

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 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 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 (CFR 2006c). 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 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 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.

In 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 further refined in the 2004 303(d) List. Since 2004, the listings that are based on the shellfish water quality monitoring data are limited specifically to currently restricted shellfish harvesting areas within an 8-digit watershed (MDE 2006).

Mill Creek in the Lower Patuxent River Basin (basin number 02131101) was first identified on the 1998 303(d) List submitted to the EPA by the Maryland Department of the Environment

(MDE). The designated use in Mill Creek was listed as impaired by fecal coliform in the restricted shellfish harvesting area within the basin. This document, upon EPA approval, establishes a TMDL for fecal coliform for Mill Creek.

The basis of the Mill Creek shellfish harvesting area listing is the shellfish water quality monitoring program's fecal coliform data, which indicated that water quality criteria has been exceeded, resulting in this area being classified as "restricted" or closed to direct harvest. The fecal coliform criteria include both median and 90th percentile concentration requirements (COMAR 2006).

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

The restricted shellfish harvesting area in Mill Creek is addressed in this report. Mill Creek is a small coastal embayment located on the upstream western side of the Lower Patuxent River, approximately 35.2 km from the mouth, Charles County, MD, as shown in Figure 2.1.1. Mill Creek has a length of approximately 620 m and its width ranges from 90 to 122 m. The embayment flows into the Patuxent River, just north of Indian Creek. Mill Creek has a drainage area of 359 acres (1.45 km^2). Most of the Mill Creek watershed is contained within the Patuxent Vista Natural Resource Management Area.

Soils surrounding Mill Creek are mixed, with approximately 47% sandy loam and 35% plastic clays. The Mill Creek watershed has a moderate to high runoff (USDA 2006). The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.49 m with a tidal period of 12.42 hours (NOAA 2006). 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 Mill Creek Restricted Shellfish Harvesting Area

Restricted Shellfish Harvesting Area	Mean Water Volume [m^3]	Mean Water Depth [m]
Mill Creek	97,643	0.67

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that the watershed can be characterized as primarily rural, with 56% of the area being cropland and more than 28% forested or wetland. The land use information in the Mill Creek Watershed is shown in Table 2.1.2 and Figure 2.1.2. The 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.

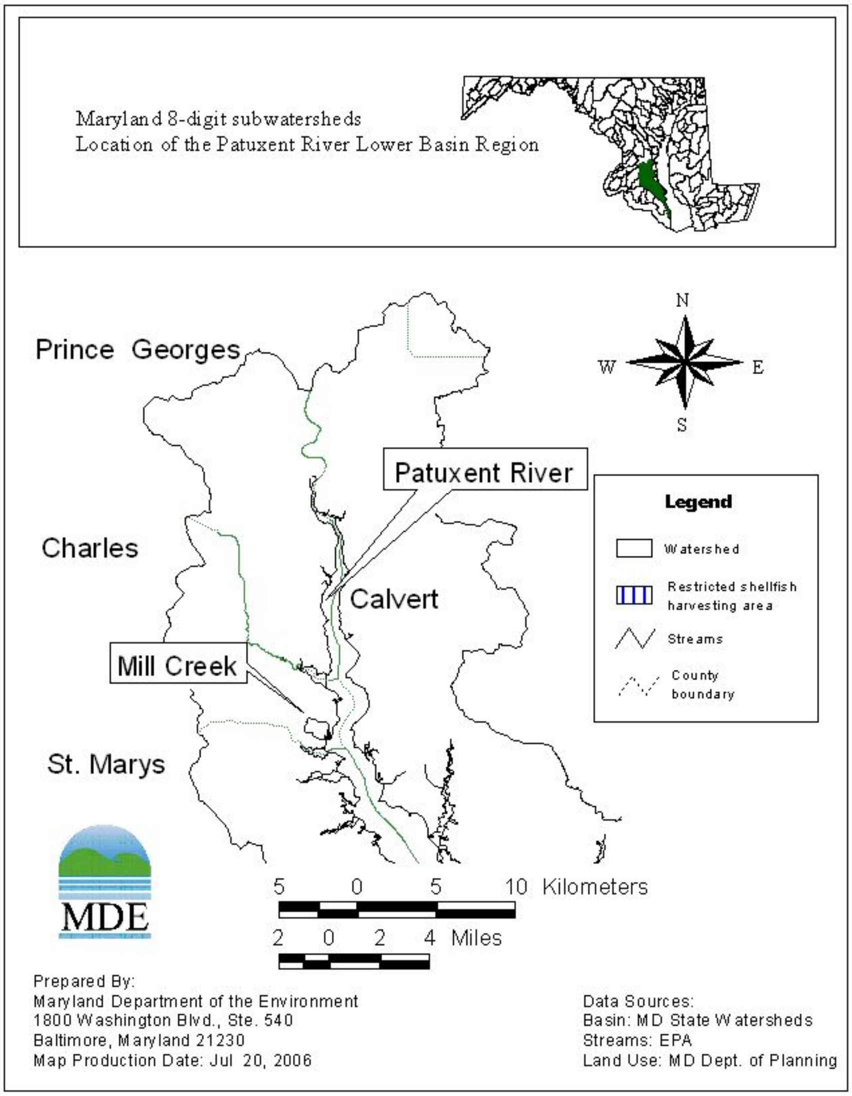

Figure 2.1.1: Location Map of the Mill Creek Watershed

Table 2.1.2: Land Use Percentage Distribution for Mill Creek Watershed

Land Type	Acreage	Percentage
Residential urban[1]	26.0	7.2%
Non-Residential urban[2]	1.7	0.5%
Open urban land	24.4	6.8%
Cropland	199.7	55.6%
Forest	43.4	12.1%
Wetlands	64.2	17.9%
Totals	**359.4**	**100%**

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

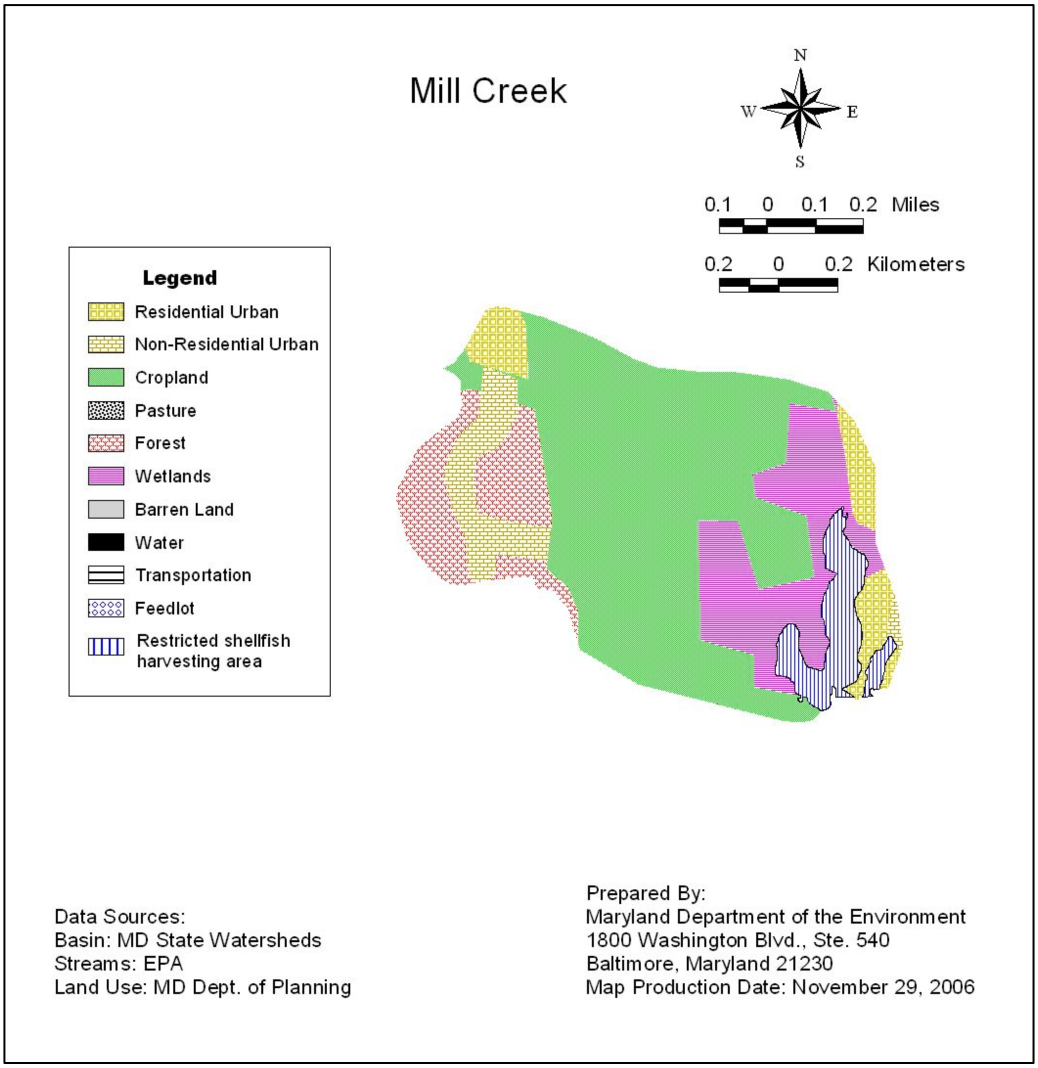

Figure 2.1.2: Land Use in the Mill Creek Watershed

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 National Shellfish Sanitation Program, 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 appropriate and if water quality standards are being met.

MDE's Shellfish Certification Program monitors shellfish waters throughout Maryland. There is one shellfish monitoring station in Mill Creek addressed in this report. The station identification and observations recorded during the period from May 2004 to September 2007 are provided in Table 2.2.1 and Figure 2.2.1. A tabulation of observed fecal coliform values in Most Probable Number (MPN)/100 ml at the one monitoring station included in this report is provided in Appendix D.

Table 2.2.1: Location of the Shellfish Monitoring Station in Mill Creek

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Mill Creek	09-01-012	2004-2007	44	38 30 10.30	76 40 54.40

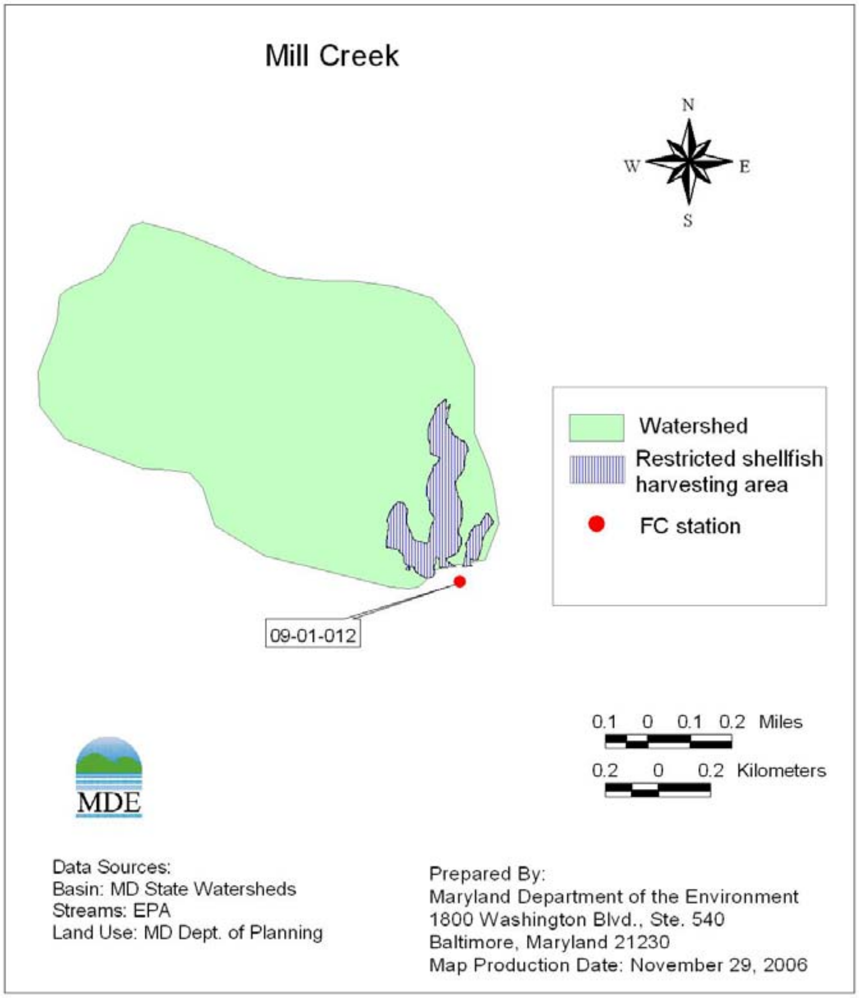

Figure 2.2.1: Shellfish Monitoring Station in Mill Creek

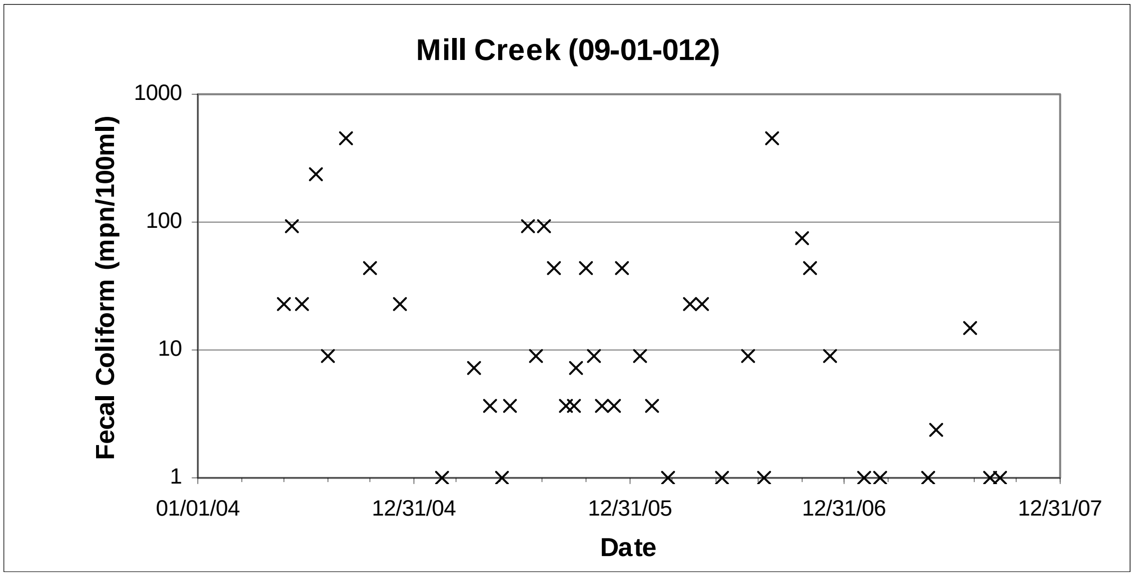

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 09-01-002

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 NSSP classification requirements that previously were 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.

Maryland water quality standards explicitly state the fecal coliform criteria as a median and 90th percentile of at least 30 water sample results taken over a 3-year period. Therefore, a requirement of a daily TMDL value is not appropriate. Rather, the TMDL refers to an average daily value that will ensure that the more stringent of the two criteria is met.

For this analysis, MDE is using routine monitoring data collected over a four-year period between May 2004 and September 2007. 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 concentration of 14 MPN/100 ml and a 90th percentile concentration of less than 49 MPN/100 ml.

Mill Creek was first listed on the 1998 Integrated 303(d) List as impaired by fecal coliform in the shellfish harvesting waters. The water quality impairment in Mill Creek was assessed as not

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

meeting the 90^{th} percentile criterion at one station. Descriptive statistics of the monitoring data and the requirements for the approved classification are shown in Table 2.3.1.

Table 2.3.1: Mill Creek Fecal Coliform Statistics (data from 2004-2007)

Area Name	Station	Median		90^{th} Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Mill Creek	09-01-012	9.1	14	93.7	49

2.4 Source Assessment

<u>Nonpoint Source Assessment</u>

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 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.

In order to determine the sources of fecal coliform contribution and reduction needed to achieve water quality criteria and to allocate fecal coliform loads among these sources, it is necessary to identify all existing sources. MDE used Bacteria Source Tracking (BST) analysis throughout the Patuxent River to determine fecal coliform sources. Since there is no BST station in Mill Creek, the BST data used to evaluate the source characterization in Mill Creek were the data at a nearby Patuxent River sampling station (approximately 650 m from Station 09-01-012) collected over a one-year period for a total 87 isolates from November 2003 to October 2004. BST analysis result is used to provide evidence regarding contributions from anthropogenic sources (*i.e.*, human or livestock) as well as background sources, such as wildlife. Antibiotic Resistance Analysis (ARA) was the chosen BST method used to determine the potential sources of fecal coliform in the Patuxent River. ARA compares patterns of antibiotic resistance from known sources collected in the watershed to patterns of unknown sources found in water samples to identify sources.

In the Mill Creek watershed, wildlife contributions, both mammalian and avian, are considered 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. The watershed is predominantly cropland, wetland, and forest. According to land use information, the wildlife and livestock could be the dominant sources. Pet contributions usually occur through runoff from streets and land. Human sources mainly result from failure of septic systems. Figure 2.1.2 shows the land use categories. Based on the analysis of BST data using the Full Library (Frano and Venso 2006), wildlife is the predominant bacteria source (33%), followed by livestock (28%), human (20%), and pets (19%). Table 2.4.1 summarizes the source distribution based on BST data analysis. Detailed results of BST analysis are presented in Appendix B.

Table 2.4.1: Source Distribution Based on BST Data Analysis

Human	Livestock	Wildlife	Pets
20%	28%	33%	19%

Point Source Assessment

There are no industrial or wastewater treatment facilities discharging fecal coliform that affect the Mill Creek restricted shellfish harvesting area. In Charles County, where the Mill Creek watershed is located, the National Pollutant Discharge Elimination System (NPDES) regulated municipal separate storm sewer systems (MS4s) Phase I permit is applied only to Charles County's Development District. The Mill Creek watershed is not in the development District and is not under subject to the MS4 Phase I permit. Therefore, for Mill Creek, there are no loads from the point source category.

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 the Mill Creek. 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 Mill Creek watershed. The required load reduction was determined based on data collected from May 2004 to September 2007. The TMDLs are presented as counts/day. Section 4.2 describes the analysis framework for simulating fecal coliform concentration in the restricted shellfish harvesting waters in Mill Creek. 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 margin of safety 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 standards, which in the case of this document would be Maryland's water quality criteria of fecal coliform for shellfish harvesting waters. A TMDL may be expressed as a “mass per unit time, toxicity, or other appropriate measure” (CFR 2006b). 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 taken over a 3-year period 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 margin of safety 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:

$$TMDL = WLAs + LAs + MOS + (FA, \text{ where applicable})$$

4.2 Analysis Framework

In general, tidal waters are exchanged through their connecting boundaries. The tide and amount of freshwater discharge into the restricted shellfish harvesting area are the dominant influences on the transport of fecal coliform. The methodology used assumes that freshwater input, tidal range, and the first-order decay of fecal coliform are all constant. The TMDL is calculated based on the steady-state tidal prism model. Compared to the volumetric method (VADEQ 2007), the steady-state tidal prism model provides improvements incorporating the influences of tidalinduced transport, freshwater, and decay of fecal coliform in the embayment. A detailed description of the model is presented in Appendix A.

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

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

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

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

$$Q_b = Q_0 + Q_f$$

where Q_f is the mean freshwater discharge during the tidal cycle

$$Q_0 = \beta Q_T$$

where β is an exchange ratio and Q_T is the total ocean water entering the embayment on the flood tide, which is calculated based on tidal range. The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal period of 12.42 hours; therefore, the M_2 tide is used for the representative tidal cycle. In general, the exchange ratio varies from 0.3 to 0.7 (Kuo *et al.* 1998; Shen *et al.* 2002). Therefore, a value of 0.5 is used for the exchange ratio. The stream flow used for the estimation of Q_f was based on the flows of U.S. Geological Survey (USGS) gage # 02060006, located in the Calvert County, Maryland, which was used to estimate average long-term flows for Mill Creek. For the restricted shellfish harvesting areas, the average long-term flow for this USGS gage (*i.e.*, 7 cfs) was adjusted by the ratio of the drainage basin area to that of the gage's basin (*i.e.*, 4307.18 acres) to derive estimates of long-term flows (Table 4.2.1 below).

Table 4.2.1: Restricted Shellfish Harvesting Area Drainage Acreage and Average Long-Term Flow

Restricted Shellfish Harvesting Area	Drainage Area in Acres	Average Long-Term Flow in cfs
Mill Creek	359.4	0.58

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 2006c). 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 exceeds the water quality criterion only 10% of the time. Since the data used were collected over a four-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 values and the 90^{th} 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 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 one applicable monitoring station is presented in Appendix C. The results show strong seasonal variability of fecal coliform concentrations. High concentrations occur in the months from July through October. The large standard deviations occur from July through September. 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 90th percentile scenarios.

Routine monitoring data were used to estimate the current loads. Both the median and the 90th percentile analyses have been performed. There is one shellfish monitoring station in the restricted shellfish harvesting area of Mill Creek. Because this station is located near the mouth, it was also used as the boundary condition. The total loads are reported in Table 4.4.1 and Table 4.4.2. Detailed results are 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 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 Loads and Estimated Load Reduction

Area	Mean Volume M^3	Fecal Coliform Median Criterion MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Mill Creek	89,161.9	14	5.77×10^{09}	8.88×10^{09}	0.0

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

Area	Mean Volume M^3	Fecal Coliform 90th Percentile Criterion MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Mill Creek	89,161.9	49	5.95×10^{10}	3.11×10^{10}	47.71

4.5 Summary of Baseline Loads

For the TMDL analysis period, from May 2004 to September 2007, the calculated baseline (current) loads of fecal coliform from all sources in the restricted shellfish harvesting area in the Mill Creek watershed are summarized in Table 4.5.1 (see also Table 4.4.1 and Table 4.4.2 above).

Table 4.5.1: Summary of Baseline Loads

Watershed	Fecal Coliform Baseline Loads [counts per day]	
	Median Analysis Scenario	90^{th} Percentile Analysis Scenario
Mill Creek	5.77×10^{09}	5.95×10^{10}

4.6 TMDL Loading Caps

This section presents the TMDLs that would meet the median and 90^{th} percentile criteria. Seasonal variability is addressed implicitly through the interpretation of the water quality standards (see Section 4.3). The median and 90^{th} percentile based TMDLs for the restricted shellfish harvesting waters of Mill Creek 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 90^{th} Percentile Criterion*
Mill Creek	8.88×10^{09}	3.11×10^{10}

* 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 four-year averaging period was used to develop the fecal coliform TMDLs for the shellfish harvesting areas in Mill Creek. This specific averaging period was chosen based on the water quality criteria, which requires at least 30 samples over a three-year period (COMAR 2006). When allocating loads among sources, the scenario that requires the greatest overall reductions (here the 90^{th} percentile scenario) was applied. Table 4.7.1 below summarizes the necessary load reductions for this area.

4.7 Load Allocation and Percent Reductions

All TMDLs need to be presented as a sum of waste load allocations (i.e., permitted point sources) and load allocations (i.e., nonpoint sources). The purpose of this section is to present how TMDLs are allocated between these categories. When implemented, these allocations are expected to result in attainment of fecal coliform water quality criteria for the shellfish harvesting waters. 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 Mill Creek watershed.

Table 4.7.1: Load Reductions

Restricted Shellfish Harvesting Area	Required Reduction
Mill Creek	**47.7 %**

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.

As stated in Section 2.4, there are no loads from point sources in the Mill Creek watershed. Therefore, all the loads are allocated to the load allocation part of the TMDL (see Section 4.9).

4.8 Margin of Safety

A margin of safety 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 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 loads from point sources in the Mill Creek watershed. All load will be allocated to the LA part of the TMDL. The TMDLs are summarized as follows:

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

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Mill Creek	**3.11×10^{10}**	=	**3.11×10^{10}**	+	**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 monitoring.

Existing Funding and Regulatory Framework

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 utilized for livestock and agricultural production. 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. 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 NPDES permitting activities. Also, although 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'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 flushing model is presented in this section. It is assumed that a single volume can represent a waterbody, and that the pollutant is well mixed in the waterbody system, as shown in Figure A-1.

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

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

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:

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

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:

$$Q_b = Q_0 + Q_f \tag{3}$$

$$Q_bC + kVC = Q_0C_0 + L_f + L_l \tag{4}$$

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

$$C = \frac{Q_0C_0 + L_f + L_l}{Q_b + kV} \tag{5}$$

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

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

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).

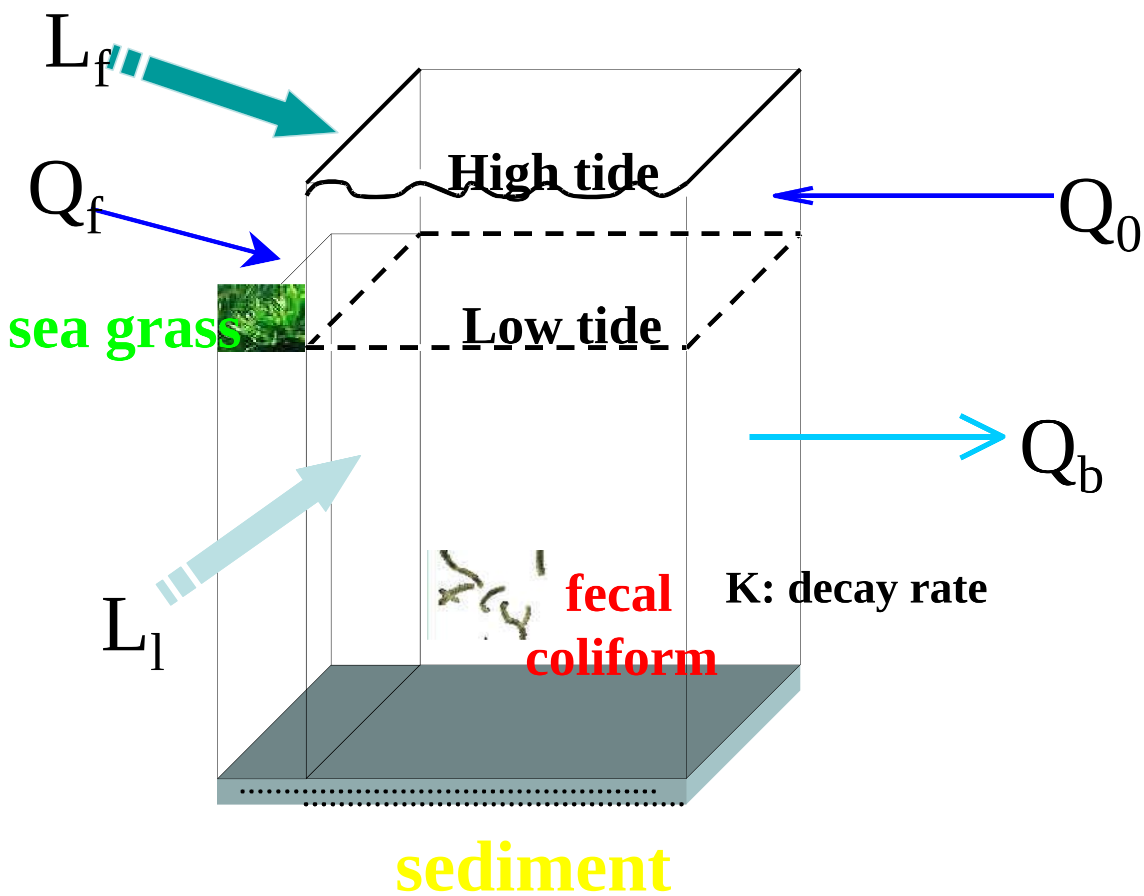

Figure A-1: The schematic diagram for the tidal prism model

A Tidal Prism Model Calculation for Mill Creek

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

The median load calculation is illustrated as follows:

V = Mean volume of the embayment = 89161.9 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 0.58 cfs = 0.58 × 0.0283×86400×12.42÷24 = 733.9 (m^3T^{-1})
Q_0 = 23922.6 (m^3T^{-1})
Q_b = 24656.5 (m^3 T^{-1})
C_c = water quality criterion = 14 MPN/100ml
C = current fecal coliform 4-year median concentration = 9.10 (MPN/100ml)
C_0 = fecal coliform 4-year median outside of the embayment = 9.10 (MPN/100ml)
T = tidal cycle =12.42 hours
Cf = the unit conversion factor

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

Allowable Load
$= [C_c(Q_b + kV) - Q_0 C_c] \times Cf$
= [14× (24656.5 +0.36×89161.9) – 23922.6 ×14] ×24÷12.42×10000
= 8.882×10^{09}

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

Current Load
$= [(C)(Q_b + kV) - Q_0(C_0)] \times Cf$
= [(9.1) × (128136.2 +0.36×297457) – 125820.6 × (9.1)] ×24÷12.42×10000
= 5.773×10^{09}

The current load is less than the allowable load. Therefore, no load reduction is applied to the watershed for the median scenario.

A Tidal Prism Model Calculation for Mill Creek

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

The 90th percentile load calculation is illustrated as follows:

V = Mean volume of the embayment = 89161.9 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 0.58 cfs = 0.58 × 0.0283×86400×12.42÷24 = 733.9 (m^3T^{-1})
Q_0 = 23922.6 (m^3T^{-1})
Q_b = 24656.5 (m^3 T^{-1})
C_c = water quality criterion = 49 MPN/100ml
C = current fecal coliform 4-year median concentration = 93.7 (MPN/100ml)
C_0 = fecal coliform 4-year median outside of the embayment = 93.7 (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
$= [C_c(Q_b + kV) - Q_0 C_c] \times Cf$
= [49× (24656.5 +0.36×89161.9) – 23922.6 ×49] ×24÷12.42×10000
= 3.109×10^{10}

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

Current Load
$= [(C)(Q_b + kV) - Q_0(C_0)] \times Cf$
= [(93.7) × (128136.2 +0.36×297457) – 125820.6 × (93.7)] ×24÷12.42×10000
= 5.945×10^{10}

The load reduction is estimated as follows:

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

$$Load\_Reduction = \frac{5.945\times10^{10} - 3.109\times10^{10}}{5.945\times10^{10}} \times 100\% = 47.71\%$$

The load calculation and load reductions for both the median and 90th percentile scenarios for Mill Creek have been presented in the following table.

Table A-1: TMDL calculation results for Mill Creek

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	
Mill Creek	8.882×10^{09}	5.773×10^{09}	0.00	3.109×10^{10}	5.945×10^{10}	47.71

Appendix B. Bacteria Source Tracking

Nonpoint sources of fecal coliform do not have one discharge point and may occur over the entire length of a stream or waterbody. 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 to surface waters. Nonpoint source contributions to the bacteria levels from human activities may arise from failing septic systems as well as through pollution from recreation vessel discharges. The transport of fecal coliform from land surface to shellfish harvesting areas is dictated by the hydrology, soil type, land use, and topography of the watershed.

In order to determine the significant sources of fecal coliform and reduction needed to achieve water quality criteria and to allocate fecal coliform loads among these sources, it is necessary to identify all existing sources. The nonpoint source assessment was conducted using the fecal coliform monitoring data (provided by MDE Shellfish Certification Programs) and bacteria source tracking analysis to quantify source loadings from humans, livestock, pets, and wildlife.

Bacteria Source Tracking

There is no BST station in the Mill Creek. In order to assess the potential fecal bacteria sources that contribute to Mill Creek, the BST data of the station located in the Patuxent River about 650 m from Mill Creek Shellfish Monitoring Station 09-01-012 was used to evaluate the source characterization. BST is used to provide evidence regarding contributions from anthropogenic sources (*i.e.*, human, pets or livestock) as well as background sources, such as wildlife. Sampling was conducted over a twelve-month period from November 2003 through October 2004. Antibiotic Resistance Analysis (ARA) was the chosen BST method used to determine the potential sources of fecal coliform. ARA uses enterococci or *Escherichia coli* (*E. coli*) and patterns of antibiotic resistance to identify sources. Antibiotic resistance patterns of bacteria isolated from different hosts are compared to antibiotic resistance patterns from water samples. Bacteria isolates from the fecal material of wildlife would be expected to have a much lower level of resistance to antibiotics than bacteria isolates collected from the fecal material of humans, livestock and pets. In addition, depending upon the specific antibiotics used in the analysis, isolates from humans, livestock and pets could be differentiated from each other.

In ARA, isolates from known sources are tested for resistance or sensitivity against a panel of antibiotics and antibiotic concentrations. This information is then used to construct a library of antibiotic resistance patterns from known-source bacterial isolates. Bacterial isolates collected from water samples are then tested and their resistance results are recorded. Based upon a comparison of resistance patterns of water and known library isolates, a statistical analysis can predict the likely host source of the water isolates. (Hagedorn 1999; Wiggins 1996).

A tree classification method, [1]CART, was applied to build a model that classifies isolates into source categories based on ARA data. CART builds a classification tree by recursively splitting the library of isolates into two nodes. Each split is determined by the antibiotic variables (antibiotic resistance measured for a collection of antibiotics at varying concentrations). The first step in the tree-building process splits the library into two nodes by considering every binary split associated with every variable. The split is chosen in order to maximize a specified index of homogeneity for isolate sources within each of the nodes. In subsequent steps, the same process is applied to each resulting node until a *stopping* criterion is satisfied. Nodes where an additional split would lead to only an insignificant increase in the *homogeneity index* relative to the *stopping* criterion are referred to as *terminal* nodes.[2] The collection of *terminal* nodes defines the classification model. Each *terminal* node is associated with one source, the source that is most populous among the library isolates in the node. Each water sample isolate (*i.e*., an isolate with an unknown source), based on its antibiotic resistance pattern, is identified with one specific *terminal* node and is assigned the source of the majority of library isolates in that *terminal* node.[3] The full BST report for the Patuxent River basin is located in Frana and Venso (2006).

Results

Water samples were collected monthly from the Patuxent River BST stations. If weather conditions prevented sampling at a station, a second collection(s) in a later month was performed. The station, whose BST data was chosen to be used for Mill Creek watershed source assessment in this report, located approximately 650m from Mill Creek Shellfish monitoring Station 09-01-012, had a total of 87 enterococci isolates used for the source assessment. Table B-1 below shows the ARA results by category using a 0.60 (60%) cutoff probability. Because of the size of the Patuxent River harvesting area, the basin was divided into several project areas. The goal was to determine whether potential bacterial contamination sources were better described for the drainage basin as a whole or for water obtained from monitoring stations within smaller areas of the river. In addition, the library of known sources was divided into several project area libraries according to field observations and scat collection. The water sample isolates for the areas were then analyzed for BST using both the corresponding area library and the full library containing all known-source isolates from the Patuxent River watershed. After examining the data, it was determined that the use of the full library most often produced results consistent with field observations (Frana and Venso 2006). According to the ARA analysis

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1 The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Hastie T, Tibshirani R, and Friedman J. Springer 2001.

2 An ideal split, i.e., a split that achieves the theoretical maximum for homogeneity, would produce two nodes each containing library isolates from only one source.

3 The CART tree-classification method we employed includes various features to ensure the development of an optimal classification model. For brevity in exposition, we have chosen not to present details of those features, but suggest the following sources: Breiman L, et al. *Classification and Regression Trees*. Pacific Grove: Wadsworth, 1984; and Steinberg D and Colla P. *CART—Classification and Regression Trees.* San Diego, CA: Salford Systems, 1997.

using the full library, wildlife is the predominant bacteria source followed by livestock, human, and pets for the Mill Creek watershed.

Table B-1: Probable Host Sources of Water Isolates by Category

Potential Sources	Full library (%)	Area library (%)
Human	20	25
Livestock	28	38
Pet	19	27
Wildlife	33	10

Appendix C. 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.

In the Chesapeake Bay region, both fecal coliform sources and delivery vary seasonally due to wildlife activity, changes in hydrological conditions, and land use practices. The most probable fecal coliform sources result from runoff from wildlife, agricultural practices and livestock, 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 agricultural buffer zones, is very important for trapping and preventing fecal coliform from entering waters by decreasing surface runoff. Wildlife is active during summer and fall due to an ample food supply, and could result in increased fecal coliform production. The probability of direct contact by wildlife may be higher during warm seasons. The seasonal variation of fecal coliform concentration in water not only results from activities of wildlife on forestland and wetland, but it is also related to agricultural activities. Fecal coliform deposition on a field by livestock can be transported into streams and rivers through surface runoff, and thus there tends to be an increase in fecal coliform concentrations during wet seasons. For croplands, fecal coliform transport to surface water may be related to the timing of crop planting and fertilization. Improper 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 of fecal coliform may lead to obvious seasonal patterns in fecal coliform concentration in the shellfish growing areas.

A 4-year monthly mean fecal coliform concentration distribution and its standard deviations were calculated for the monitoring station used in this report. The result is presented in Figure C-1 and shows that high concentrations occur in the months from July to October. Large standard deviations occur from July to September, corresponding to the high fecal coliform variability at this station during this period. This suggests that the violation, in regards to the criteria, may occur in a few months of the year.

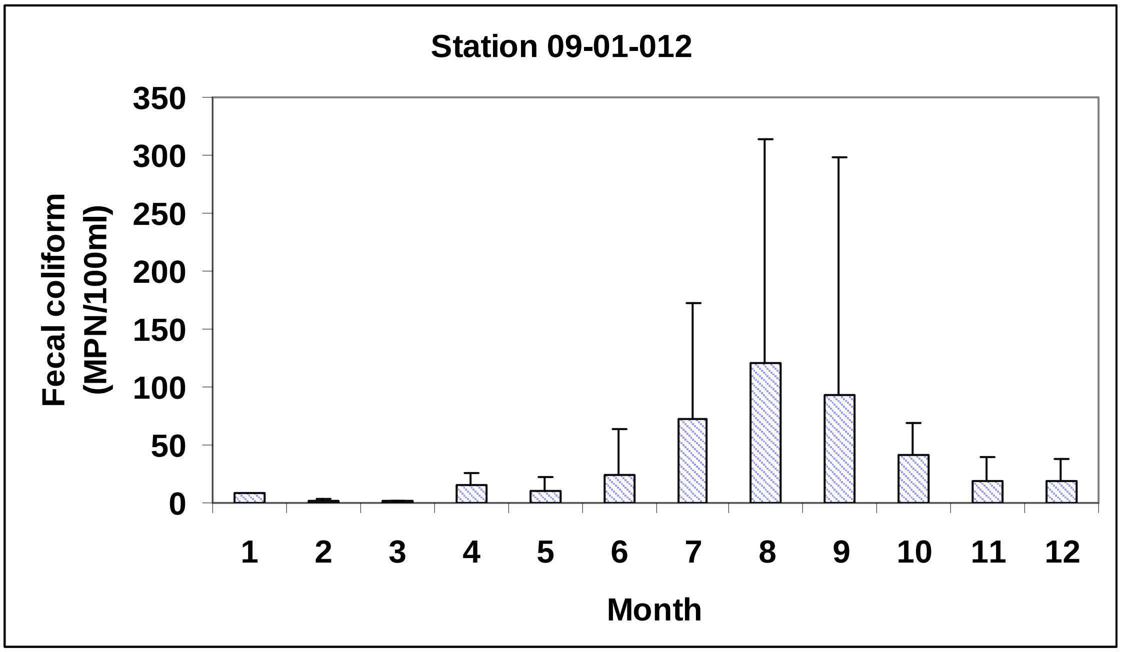

Figure C-1: Seasonality Analysis of Fecal Coliform at Mill Creek Station 09-01-012

Appendix D. Tabulation of Fecal Coliform Data

This appendix provides a tabulation of fecal coliform values for the Mill Creek monitoring station (Table D-1). The data are plotted in Figure 2.2.2 of the main report.

Table D-1: Observed Fecal Coliform Data at Mill Creek Station 09-01-012

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
5/25/04	23	11/15/05	3.6
6/7/04	93	12/7/05	3.6
6/24/04	23	12/19/05	43
7/20/04	240	1/17/06	9.1
8/9/04	9.1	2/7/06	3.6
9/7/04	460	3/7/06	1
10/18/04	43	4/13/06	23
12/8/04	23	5/2/06	23
2/16/05	1	6/5/06	1
4/13/05	7.3	7/20/06	9.1
5/11/05	3.6	8/16/06	1
5/31/05	1	8/31/06	460
6/14/05	3.6	10/19/06	75
7/13/05	93	11/1/06	43
7/27/05	9.1	12/5/06	9.1
8/10/05	93	2/1/07	1
8/25/05	43	3/1/07	1
9/14/05	3.6	5/21/07	1
9/28/05	3.6	6/4/07	2.4
10/3/05	7.2	7/31/07	15
10/19/05	43	9/4/07	1
11/1/05	9.1	9/20/07	1