Total Maximum Daily Loads of Fecal Coliform for the Extended Restricted Shellfish Harvesting Area in Miles River Mainstem of the Miles River Basin in Talbot County, Maryland

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FINAL

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Table of Contents

List of Figures

List of Tables

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).

Miles River (basin number 02-13-05-02) was first identified on the 1996 303(d) List submitted to U.S. EPA by the Maryland Department of the Environment (MDE). The designated uses in Miles River were listed as impaired by nutrients (1996), sediments (1996), fecal coliform (1996, 2006), and impacts to biological communities (2006). On the 2004 303(d) List, the fecal coliform impairment was clarified with the identification of specific restricted shellfish harvesting area within the basin. The fecal coliform TMDL developments for the restricted shellfish harvesting areas in Miles River mainstem, Hunting Creek and Leeds Creek within this basin were completed in 2005, and submitted to US EPA (MDE 2005). In 2006, the existing restricted shellfish harvesting area in Miles River mainstem was extended to include and additional downstream portion due to the fecal coliform impairment. The assessment unit listing code for the area in MD's 2008 303(d) List is MD-EASMH-Miles-River 2. This document, upon EPA approval, establishes TMDLs of fecal coliform for the extended portion of the restricted shellfish harvesting area in the Miles River mainstem. The listings for nutrients, sediments and impacts to biological communities within the Miles River basin will be addressed at a future date.

A steady state multiple segment tidal prism model was used to estimate current fecal coliform load based on volume, tidal prism, and concentration, and establish allowable loads for the extended restricted shellfish harvesting area in the Miles River mainstem. 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 loadings from potential sources (human, livestock, pets, and wildlife) were quantified by analysis of the bacteria source tracking (BST) collected in the Miles River over a one-year period.

The allowable loads for the extended 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 extended restricted shellfish harvesting area of the Miles River watershed for fecal coliform are as follows:

Waterbody	Fecal Coliform TMDL [counts per day]	
	based on Median Criterion	based on 90^{th} Percentile Criterion
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	4.34×10^{11}	1.10×10^{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 90^{th} percentile criterion. The TMDL requires a reduction of approximately 57.7% for the Miles River.

Once EPA has approved this TMDL, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impacts to water quality and creating the greatest risks to human health, with consideration given to ease and cost of implementation. 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 to the specific currently restricted shellfish harvesting areas within an 8-digit watershed (MDE 2006).

Miles River (basin number 02-13-05-02) was first identified on the 1996 303(d) List submitted to U.S. EPA by the Maryland Department of the Environment (MDE). The designated uses in

Miles River were listed as impaired by nutrients (1996), sediments (1996), fecal coliform (1996, 2006), and impacts to biological communities (2006). On the 2004 303(d) List, the fecal coliform impairment was clarified with the identification of specific restricted shellfish harvesting area within the basin. The fecal coliform TMDL developments for the restricted shellfish harvesting areas in Mile River mainstem, Hunting Creek and Leeds Creek within this basin were completed in 2005, and submitted to US EPA (MDE 2005). In 2006, the existing restricted shellfish harvesting area in Miles River mainstem was extended to downstream portion due to the fecal coliform impairment. The assessment unit listing code for the area in MD’s 2008 303(d) List is MD-EASMH-Miles-River 2. This document, upon EPA approval, establishes TMDLs of fecal coliform for the extended portion of the restricted shellfish harvesting area in the Miles River mainstem. The listings for nutrients, sediments and impacts to biological communities within the Miles River basin will be addressed at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

The extended restricted shellfish harvesting area in the Miles River Mainstem is addressed in this report. Miles River is located on Maryland's Eastern Shore in Talbot County, MD, and its restricted shellfish harvesting area is located upstream before the River branches (Figure 2.1.1). The River flows southwest into the unrestricted portion of the Miles River, ending approximately 12.2 km from the mouth of the Miles River, as shown in Figure 2.1.1. Here it flows into Eastern Bay, which in turn flows into Chesapeake Bay. The River and tributaries are relatively narrow with widths of about 100 to 500 m. The Miles River extended restricted shellfish harvesting area has a length of 1.4 km and a drainage area of 15,957 acres (6,457.4 km^2).

The Miles River basin has a thick bed of sand loam and sandy clay loam. The soils mainly consist of sand (61%), clay (23%), and silt (16%) (U. S. Department of Agriculture (USDA), 2006). The area is characterized as hydrology class B, having moderate infiltration and moderately well drained soil. The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.49 m and a tidal period of 12.42 hours in the restricted area portion of Miles River (National Oceanic and Atmospheric Administration (NOAA), 2006). Please refer to Table 2.1.1 for the mean volume and mean water depth of the extended restricted shellfish harvesting area.

Table 2.1.1: Physical Characteristics of the Miles River Mainstem Restricted Shellfish Harvesting Area

Area	Mean Water Volume [m^3]	Mean Water Depth [m]
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	3,424,212	3.24

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that the watershed can be characterized as primarily rural for the Miles River, with 53% of the area being cropland and more than 27% forested. The land use information for the restricted shellfish harvesting area in Miles River watershed is shown in Table 2.1.2 and Figure 2.1.2. Residential urban land use identified in Table 2.1.2 includes low-density residential, medium-density residential, and high-density residential. Non-residential urban land use in this table includes commercial, industrial, institutional, extractive, and open urban land.

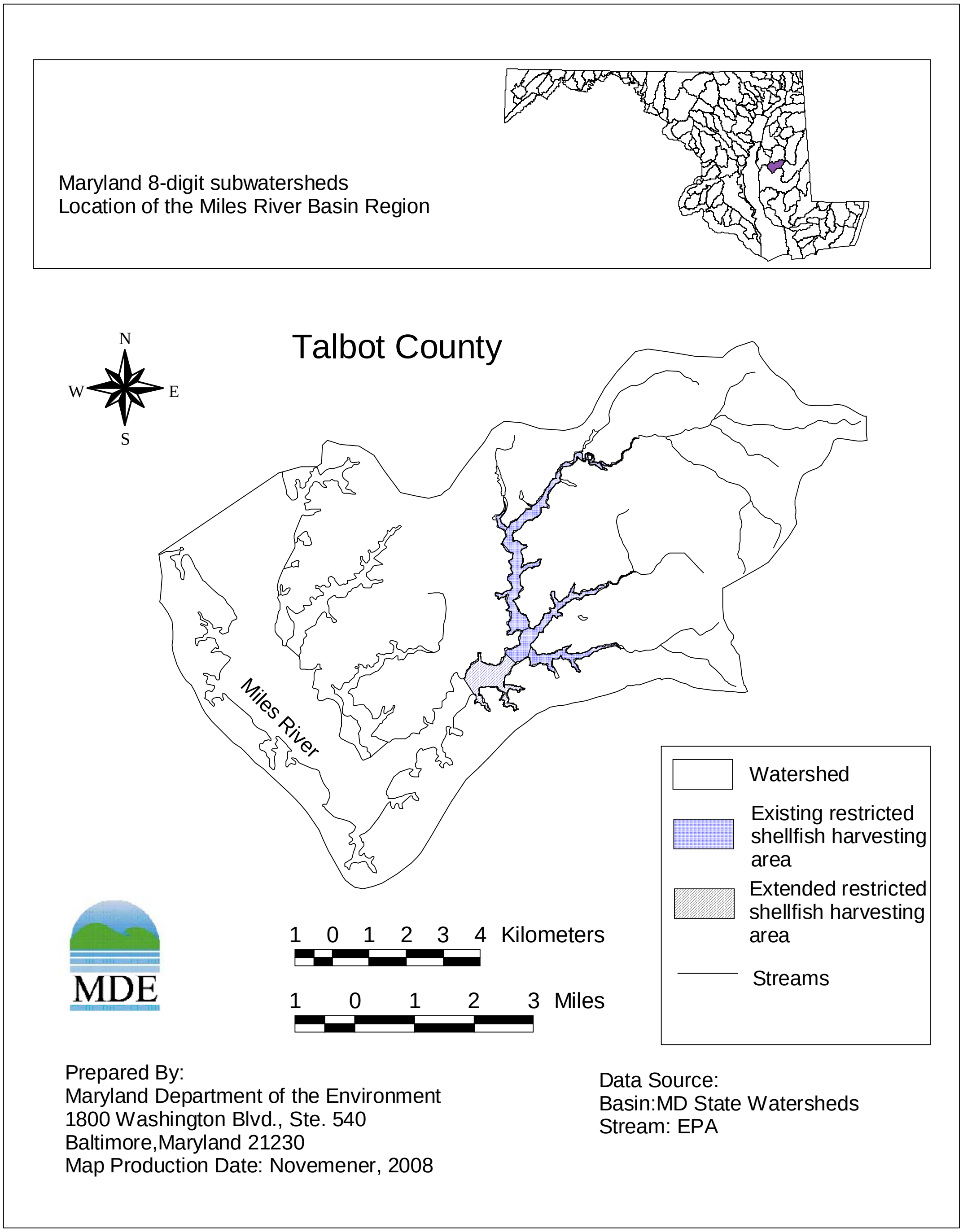

Figure 2.1.1: Location Map of the Miles River Basin

Table 2.1.2: Land Use Percentage Distribution for Miles River Watershed

Land Type	Acreage	Percentage
Residential urban[1]	1,508.6	9.5
Non-Residential urban[2]	1,367.0	8.6
Cropland	8,402.4	52.7
Pasture	117.4	0.7
Feedlot	9.9	0.1
Forest	4,235.0	26.5
Water	150.5	0.9
Wetlands	144.8	0.9
Barren	20.8	0.1
Totals	**15,956.5**	**100.0**

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

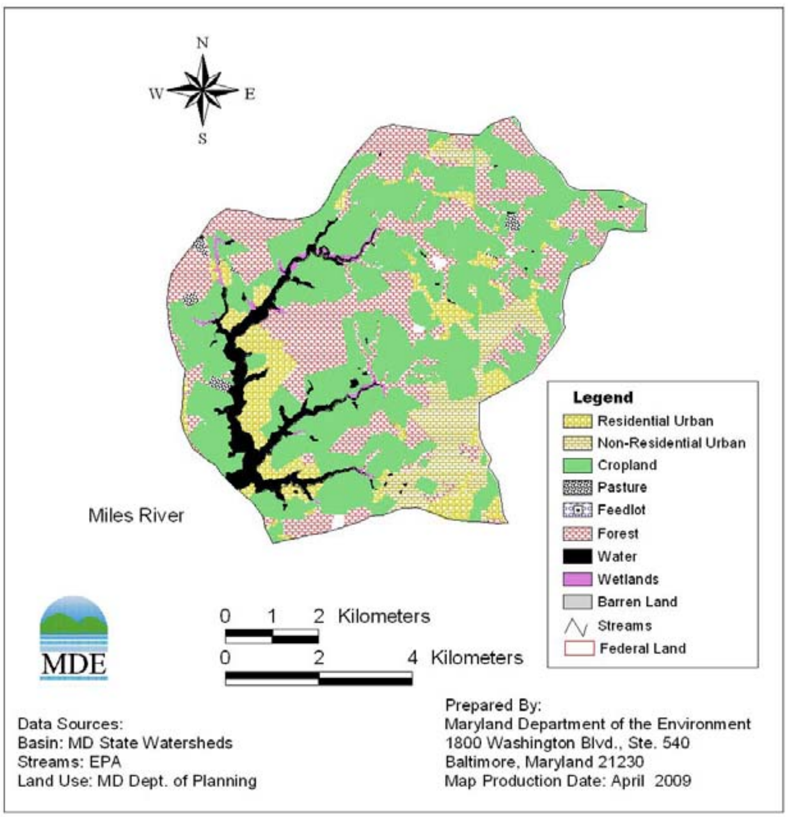

Figure 2.1.2: Land Use in the Miles River Basin

2.2 Water Quality Characterization

MDE's Shellfish Certification Program is responsible for classifying shellfish harvesting waters to ensure oysters and clams are safe for human consumption. As discussed above, MDE adheres to the requirements of the National Shellfish Sanitation Program, 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.

MDE's Shellfish Certification Program monitors shellfish waters throughout Maryland. There is one shellfish monitoring station in the extended restricted shellfish harvesting area in Miles River Mainstem addressed in this report. The station identification and observations recorded during a five-year period of June 2003 – June 2008 are provided in Table 2.2.1 and Figure 2.2.1. A tabulation of observed fecal coliform value at the monitoring station is provided in Appendix D.

Table 2.2.1: Locations of the Shellfish Monitoring Stations in the Extended Shellfish Restricted Harvesting Area in Miles River Mainstem

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Extended Shellfish Harvesting Area in Miles River Mainstem	08-01-033	2003-2008	67	38 47 18.46	76 08 22.35

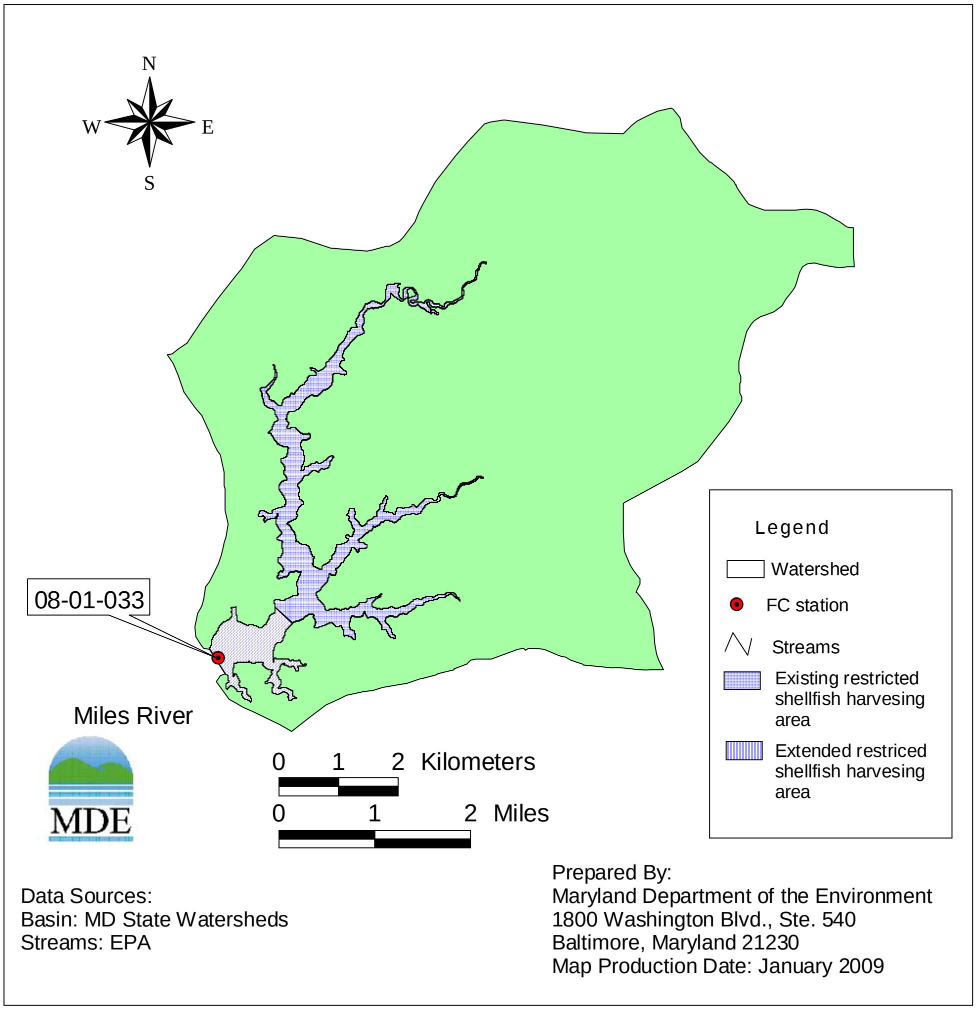

Figure 2.2.1: Shellfish Monitoring Stations in the Extended Shellfish Harvesting Area in Miles River Mainstem

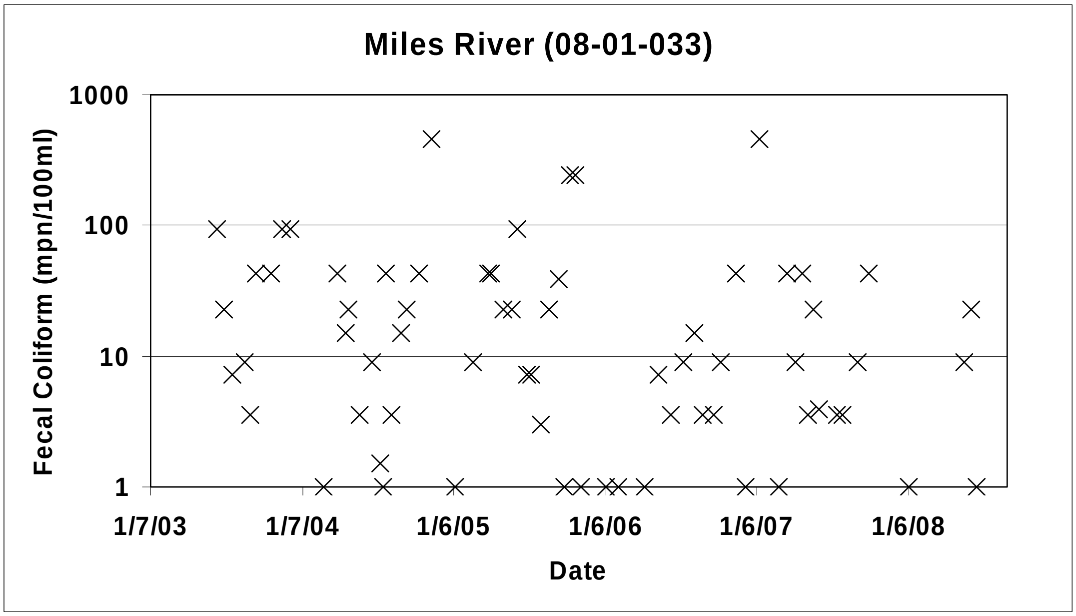

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 08-01-033

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 June 2003 and June 2008. 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.

Miles River was listed on the 1996 Integrated 303(d) List as impaired by fecal coliform. In 2006, the existing restricted shellfish harvesting area in Miles River Mainstem was extended to downstream portion due to the fecal coliform impairment. The assessment unit listing code for the area in MD's 2008 303(d) is MD-EASMH-Miles-River 2. The water quality impairment in the extended restricted area of Miles River Mainstem was assessed as not meeting the 90th

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

percentile criterion at the monitoring 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: Miles River Fecal Coliform Statistics (data from 2003-2008)

Area	**Station**	**Median**		**90th Percentile**	
		Monitoring Data	**Criterion**	**Monitoring Data**	**Criterion**
		MPN/100ml	**MPN/100ml**	**MPN/100ml**	**MPN/100ml**
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	08-01-033	9.1	14	89.5	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 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 conducted sampling over a one-year period (11/2006-10/2007) in the Miles River watershed using bacteria source tracking (BST) to identify sources of fecal coliform. The nonpoint source assessment was conducted by analyzing BST results to quantify source loadings from humans, livestock, pets, and wildlife.

In the Miles River basin, 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 predominately cropland and forest. According to land use information, the livestock and wildlife 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, livestock is the predominant bacteria source followed by human, wildlife, and pet sources. Fifteen percent (15%) of the water isolates were from unknown (unclassified) probable sources. 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	Unknown
19.6%	46.4%	10.5 %	8.5%	15.0%

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. The 15.0% unknown sources for BST analysis are those where no match was identified in the known library. They do not represent unknown sources in the sense that they cannot be identified, rather they represent a portion of the statistical analysis where no matches to the BST library were found (see Appendix B for details on BST used for this report).

Point Source Assessment

There is one municipal point source located in the Miles River Basin: Talbot County Region II WWTP (also known as the St. Michaels WWTP). This facility is located near the mouth of the Miles River and is far downstream from the extended restricted shellfish harvesting area of Miles River Mainstem. The fecal coliform discharge limit for this facility is also set through the Use II (shellfish harvesting water) standard. The discharge from this facility has no effect on the fecal coliform impairment of the restricted harvesting area. There are no permitted industrial point source facilities discharging fecal coliform directly into the restricted shellfish harvesting areas, 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 extended restricted shellfish harvesting waters in the Miles River Mainstem. These standards are described fully in Section 2.3, Water Quality Impairment.

4.0 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

4.1 Overview

This section documents the detailed fecal coliform TMDLs and load allocation development for the extended restricted shellfish harvesting waters in the Miles River watershed. The required load reduction was determined based on data collected from June 2003 to June 2008. 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 Miles River 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 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 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 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 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 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 tidal flushing and amount of freshwater discharge into the restricted 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 multiple segment tidal prism model. Compared to the volumetric method (EPA Shellfish Workshop, 2002), the steady-state tidal prism model provides improvements incorporating the influences of tidal induced transport, freshwater, and decay of fecal coliform in the tidal River. The whole restricted shellfish harvesting area is segmented into three tidal prism segments and the steady-state three-segment tidal prism model was used to estimate the existing loadings and TMDLs. The most recent five-year median and 90th percentile were used to estimate the current loads. 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 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 90th percentile concentration is the concentration that exceeded 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 90th percentile value. Given the length of the monitoring record used and the limited applicability of best management practices (BMPs) to extreme conditions, the 90th percentile concentration is utilized instead of the absolute maximum.

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

The seasonal fecal coliform distribution for the one applicable monitoring station is presented in Appendix C. The results show the seasonal variability of fecal coliform concentrations. High concentrations occur in the months of October, November, and January at the station in the Miles River extended restricted shellfish harvesting area. The large standard deviations occur in October, November, and January. These high concentrations result in high 90th 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. The steady-state multiple segment tidal prism model was used for the analysis (Kuo et al., 1998; Shen et al., 2005). There is one shellfish monitoring station in the extended restricted shellfish harvesting area of the Miles River Mainstem and one shellfish monitoring station located upstream in the existing restricted area. To accurately estimate the load with consideration of available monitoring data, the whole restricted area was segmented into three tidal-prism segments. The load for each subwatershed was discharged into its corresponding receiving water model. The three-segment tidal prism model was used to compute the watershed loads discharged into the River based on tidal flushing, freshwater discharge, and observed fecal coliform concentrations. Because there is no observation station in the middle tidal prism segment, the linear interpolation method is used to obtain the fecal coliform concentration in that segment. Because only one station is located in the upstream segment, the fecal coliform concentration at that station is used to represent the fecal coliform concentration in that segment.

The stream flow used for the estimation of freshwater discharge was based on the flows of the U.S. Geological Survey (USGS) gage # 01492500, located in Sallie Harris Creek near Carmichael, MD. For the restricted shellfish harvesting area, the average long-term flow for this USGS gage (*i.e.*, 7.70 cfs) was adjusted by the ratio of the drainage basin area to that of the gage's basin (*i.e.*, 5,177.6 acres) to derive estimates of long-term flows. The long-term mean flow is 26.33 cfs. The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.49 m (National Oceanic and Atmospheric Administration (NOAA), 2006). This tidal range is used to compute tidal prism of the River.

A detailed computation is presented in Appendix A. The total loads are reported in Table 4.4.1 and Table 4.4.2. Detailed results by subwatershed are also listed in Appendix A.

The allowable load is calculated using the water quality criteria of a median of 14 MPN/100ml and a 90th percentile of 49 MPN/100ml. The three-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:

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

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 (%)
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	3.424×10^6	14	4.340×10^{11}	4.340×10^{11}	0.00

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

Area	Mean Volume M^3	Fecal Coliform 90^{th} Percentile Criterion MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	3.424×10^6	49	2.592×10^{12}	1.095×10^{12}	57.74

4.5 Summary of Baseline Loads

For the TMDL analysis period, from June 2003 to June 2008, the calculated baseline (current) loads of fecal coliform from all sources in the extended restricted shellfish harvesting area in the Miles River basin 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

Waterbody	Fecal Coliform Baseline Loads [counts per day]	
	Median Analysis Scenario	90^{th} Percentile Analysis Scenario
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	4.340×10^{11}	2.592×10^{12}

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 extended restricted shellfish harvesting waters of the Miles River 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 90^{th} Percentile Criterion*
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	4.340×10^{11}	1.095×10^{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 extended restricted shellfish harvesting areas in the Miles River Mainstem. 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 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

The purpose of this section is to allocate the TMDLs between point (WLA) and nonpoint (LA) sources. Because there is no point source discharge having an effect on the fecal coliform impairment of the restricted area, 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 Miles River watershed.

Table 4.7.1: Load Reductions

Area	Required Reduction
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	**57.7 %**

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.

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 point source discharges in the watershed having an effect on the fecal coliform impairment of the restricted shellfish harvesting area in Miles River Mainstem. All the loads are allocated to the load allocation. The TMDL is summarized as follows:

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

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Extended Restricted Shellfish Harvesting Area in Miles River Mainstem	**1.10×10^{12}**	**=**	**1.10×10^{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.

<u>Existing Funding and Regulatory Framework</u>

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. For a single segment tidal prism model, 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:

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

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).

Follows the same procedure, a multiple segment model can be derived. For a three-segment tidal prism model (Figure A-2), the total loading (L) can be estimated as follows;

$$L = (L_1 + L_2 + L_3) \times CF \qquad (10)$$

Where:

L_1, L_2, and L_3 are londings to the segments 1, 2, and 3, respectively

$$L_1 = (Q_1 + Q_b + kV_1)C_1 - Q_{1b}C_2 - Q_0C_b$$

$$L_2 = (Q_2 + Q_{1b} + kV_2)C_2 - Q_{2b}C_3 - Q_1C_1$$

$$L_3 = (Q_{2b} + kV_3)C_3 - Q_2C_2$$

Q_0, Q_1, and Q_2 are inflows to the segments 1, 2, and 3

Q_b, Q_{1b}, and Q_{2b} are outflows from the segments 1, 2, and 3

V_1, V_2, and V_3 are mean volumes of segments 1, 2, and 3

CF is unit conversion factor

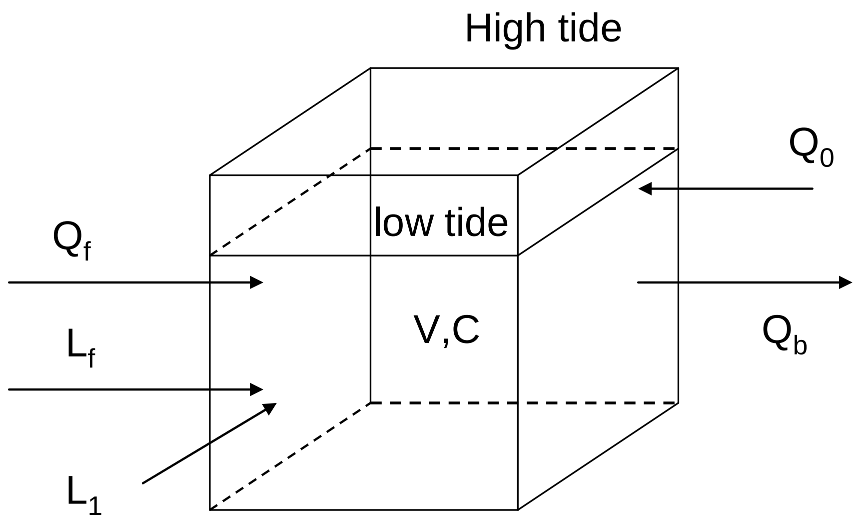

Figure A-1: The schematic diagram for one segment tidal prism model

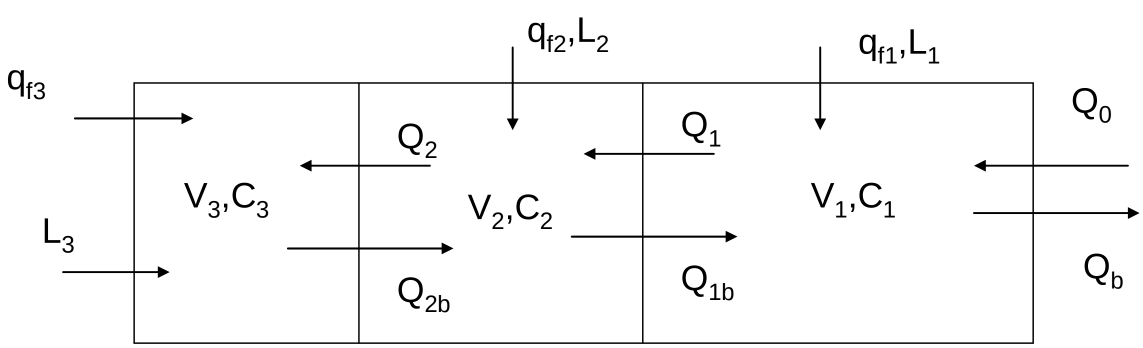

Figure A-2: The schematic diagram for a three-segment tidal prism model

Routine monitoring data were used to estimate the current loads. Both the median and the 90th percentile analyses have been performed. Station 08-01-033 is the only shellfish monitoring station in the extended restricted shellfish harvesting area of the Miles River mainstem. Station 08-01-034 is located upstream, and Station 08-01-033B is located outside of the restricted area which was used as the model open boundary condition. The locations of the monitoring stations are shown in Figure A-3. The median and 90th percentile concentrations are based on 5-year observations (2003-2008) are listed in Table A-1. To accurately estimate the load with consideration of available monitoring data, the whole restricted harvest area was segmented into three tidal-prism segments. The load for each subwatershed was discharged into its corresponding receiving water model. The three-segment tidal prism model was used to compute the watershed loads discharged into the river based on the tidal flushing and observed fecal coliform concentrations. Because there is no observation station in the middle tidal prism segment, the linear interpolation method is used to obtain the fecal coliform concentration in that segment. Because only one station is located in the upstream segment (Segment 3), the fecal coliform concentration at that station is used to represent the fecal coliform concentration in that segment.

The stream flow used for the estimation of freshwater discharge was based on the flows of the U.S. Geological Survey (USGS) gage # 01492500, located in Sallie Harris Creek near Carmichael, MD. For each restricted shellfish harvesting area, the average long-term flow for this USGS gage (*i.e.*, 7.70 cfs) was adjusted by the ratio of the drainage basin area to that of the gage's basin (*i.e.*, 5,177.6 acres) to derive estimates of long-term flows. The long-term mean flow is 26.33 cfs. The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.49 m in the restricted area portion of the Miles River and the dominant tidal period is 12.42 hours (National Oceanic and Atmospheric Administration (NOAA), 2006). This tidal rage is used to compute tidal prism of the River. 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). The loading is computed use Equation (10). Model result corresponding to each tidal prim segment is listed in Table A-2

Table A-1: Miles River Fecal Coliform Statistics (data from 2003-2008)

Area Name	Station	Median		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Shellfish Restricted Harvesting Area in Miles River Mainstem	08-01-034	23.0	14	180.8	49
	08-01-033	9.1	14	89.5	49
	08-01-033B*	9.1	14	53.1	49

* Station located downstream of the extended shellfish restricted area and it was used for model boundary condition

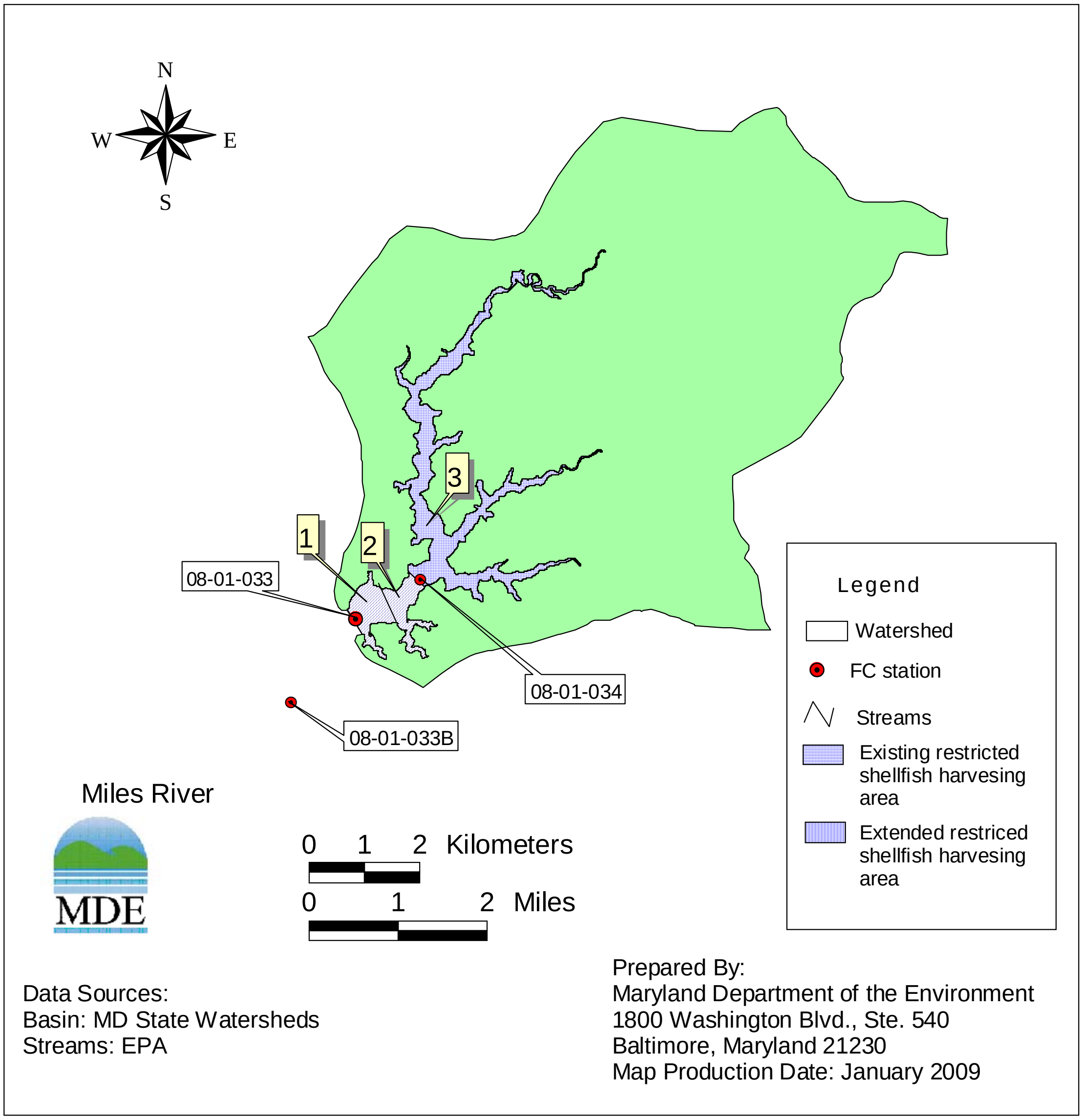

Figure A-3: Locations of Miles River Fecal Coliform Monitoring Stations and Tidal Prism Model Segmentation

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. With the use of existing loads and TMDLs, the percentage reduction can be estimated. Comparing the reduction needed for both median and 90th percentile loads, the maximum reductions required for each watershed are used to establish the TMDLs, so that the model simulated fecal coliform concentrations along the river meet the median and 90th percentile standards, respectively. 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 existing and allowable loads are listed in Table A-2. The downstream segments (Segments 1 and 2) are grouped as one segment.

Table A-2: TMDL Calculation Results for the Restricted Shellfish Harvesting Area in Miles River Mainstem

Tidal Prism Segment	Median			90th Percentile		
	Allowable Load Counts/day	**Current Load Counts/day**	**Percent Reduction**	**Allowable Load Counts/day**	**Current Load Counts/day**	**Percent Reduction**
Existing Restricted Shellfish Harvesting Area* (Segment 3)	3.437×10^{11}	5.646×10^{11}	39.13%	1.203×10^{12}	3.123×10^{12}	61.48%
Extended Restricted Shellfish Harvesting Area (Segments 1 & 2)	4.340×10^{11}	4.340×10^{11}	0.00%	1.095×10^{12}	2.592×10^{12}	57.74%
Totals	7.777×10^{11}	9.986×10^{11}	22.12%	2.298×10^{12}	5.715×10^{12}	59.79%

* TMDL of the upstream restricted harvesting area was completed in 2005 (MDE 2005)

Table A-3: Load Allocation and Reduction by Subwatershed

Subwatershed	Load Allocation	Required Reduction
Existing Restricted Shellfish Harvesting Area	1.203×10^{12}	61.48%
Extended Restricted Shellfish Harvesting Area	1.095×10^{12}	57.74%
TOTALS	$\mathbf{2.298 \times 10^{12}}$	**59.79%**

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 generally arise from failing septic systems or potentially 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 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

In order to assess the potential fecal bacteria sources to the Miles River, one station (08-01-034) in the Miles River was selected for Bacteria Source Tracking (BST) analysis. BST is used to provide evidence regarding contributions from anthropogenic sources (*i.e.*, human or livestock) as well as background sources, such as wildlife. Sampling was conducted over a twelve-month period from November 2006 through October 2007. Antibiotic Resistance Analysis (ARA) was the chosen BST method used to determine the potential sources of fecal coliform in the Miles River. ARA uses enterococci or *Escherichia coli* (*E. coli*) and patterns of antibiotic resistance established by known sources in a library. The premise is that the antibiotic resistance of bacteria isolated from different hosts can be discerned based upon differences in the selective pressure of microbial populations found in the gastrointestinal tract of those hosts (humans, livestock, pets, wildlife) (Wiggins 1996). Bacteria isolated 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. Water samples containing unknown sources are compared to the known source library to identify sources.

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 1999).

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 Miles River basin is located in Frana and Venso (2008).

Results

Water samples were collected monthly from one station in the Miles River. The maximum number of enterococci isolates per water sample was 24, although the number of isolates that actually grew was sometimes fewer than 24. A total of 153 enterococci isolates were analyzed by statistical analysis. Table B-1 below shows The BST results by species category, indicating that 85% of the water isolates were able to be classified to a probable host source when using a 0.50 (50%) probability threshold. The largest category of potential sources in the watershed as a whole was livestock (55% of classified water isolates), followed by human, wildlife, and pet (23%, 12%, and 10%, respectively). The seasonal distribution of water isolates from samples collected at each sampling station is shown below in Table B-2. Table B-3 shows the number and percent of the probable sources for the monitoring station by month.

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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.

Table B-1: Miles River Predicted Host Source Distribution of Water Isolates by Species Category (Using 50% Threshold Probability)

Source	Count	Percent	Percent Without Unknowns
Human	30	19.6%	23.1%
Livestock	71	46.4%	54.6%
Pet	13	8.5%	10.0%
Wildlife	16	10.5%	12.3%
Unknown*	23	15.0%	
Total	153	100.0%	100.0%
% Classified	**85.0%**		
*Unknown means that the library of known sources failed to classify for isolates from water samples collected			

Table B-2: *Enterococcus* Isolates Obtained from Water Collected during the Spring, Summer, Fall, and Winter Seasons)

Season					
Station	**Spring**	**Summer**	**Fall**	**Winter**	**Total**
08-01-034	26	7	48	72	153
Total	26	7	48	72	153

Table B-3: Number of Isolates per Station per Date

			Predicted	Source			
Station	**Date**	**Human**	**Livestock**	**Pet**	**Wildlife**	**Unknown**	**Total**
08-01-034	11/16/06	3	8	6	5	2	24
08-01-034	12/11/06	6	5	0	3	5	19
08-01-034	01/11/07	6	11	2	2	3	24
08-01-034	02/27/07	3	17	0	1	3	24
08-01-034	03/20/07	5	11	3	2	3	24
08-01-034	04/10/07	0	1	0	0	0	1
08-01-034	05/08/07	3	0	0	0	2	5
08-01-034	06/06/07	1	14	2	3	0	20
08-01-034	07/17/07	0	0	0	0	0	0
08-01-034	08/02/07	0	1	0	0	0	1
08-01-034	09/05/07	0	3	0	0	3	6
08-01-034	10/03/07	3	0	0	0	2	5
	Total	**30**	**71**	**13**	**16**	**23**	**153**

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.

A 5-year monthly mean fecal coliform concentration and its standard deviation was calculated for the monitoring station used in this report. The result is presented in Figure C-1. It shows that high concentrations occur in the months of October and November, and January at Station 08-01-033. The large standard deviations occur in October, November, and January, which corresponds to the high fecal coliform variability at the station suggesting that the violation, in regards to the criteria, may occur in a few months of the year.

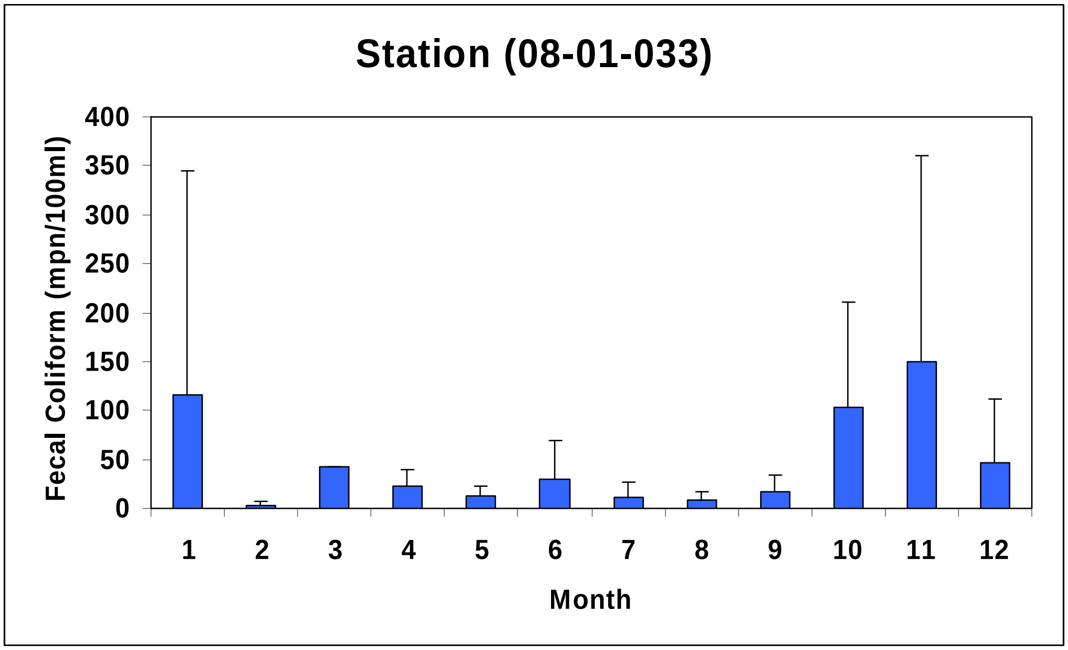

Figure C-1: Seasonality Analysis of Fecal Coliform at Miles River Station 08-01-033

Appendix D. Tabulation of Fecal Coliform Data

This appendix provides a tabulation of fecal coliform values for the monitoring station (08-01-033) of the extended restricted shellfish harvesting area in the Miles River Mainstem in Table D-1. The data are plotted in Figure 2.2.2 of the main report.

Table D-1: Observed Fecal Coliform Data at Miles River Station 08-01-033

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
17-Jun-03	93.0	15-Sep-05	39.0
01-Jul-03	23.0	28-Sep-05	1.0
21-Jul-03	7.3	12-Oct-05	240.0
21-Aug-03	9.1	27-Oct-05	240.0
03-Sep-03	3.6	09-Nov-05	1.0
17-Sep-03	43.0	09-Jan-06	1.0
23-Oct-03	43.0	08-Feb-06	1.0
20-Nov-03	93.0	11-Apr-06	1.0
09-Dec-03	93.0	15-May-06	7.3
26-Feb-04	1.0	14-Jun-06	3.6
31-Mar-04	43.0	13-Jul-06	9.1
22-Apr-04	15.0	09-Aug-06	15.0
29-Apr-04	23.0	29-Aug-06	3.6
24-May-04	3.6	26-Sep-06	3.6
22-Jun-04	9.1	11-Oct-06	9.1
12-Jul-04	1.5	16-Nov-06	43.0
21-Jul-04	1.0	11-Dec-06	1.0
27-Jul-04	43.0	11-Jan-07	460.0
09-Aug-04	3.6	27-Feb-07	1.0
01-Sep-04	15.0	20-Mar-07	43.0
16-Sep-04	23.0	10-Apr-07	9.1
13-Oct-04	43.0	25-Apr-07	43.0
15-Nov-04	460.0	08-May-07	3.6
10-Jan-05	1.0	24-May-07	23.0
23-Feb-05	9.1	06-Jun-07	3.9
30-Mar-05	43.0	17-Jul-07	3.6
07-Apr-05	43.0	02-Aug-07	3.6
05-May-05	23.0	05-Sep-07	9.1
26-May-05	23.0	03-Oct-07	43.0
07-Jun-05	93.0	08-Jan-08	1.0
30-Jun-05	7.3	20-May-08	9.1
11-Jul-05	7.3	04-Jun-08	23.0
04-Aug-05	3.0	19-Jun-08	1.0
23-Aug-05	23.0		