Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Areas in Whitehall and Meredith Creeks, Mill Creek, and the Severn River Mainstem of the Severn River Basin in Anne Arundel County, Maryland

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FINAL

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List of Abbreviations

BMP	Best Management Practice
BST	Bacteria Source Tracking
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
HEM-3D	Hydrodynamic and Eutrophication Model in 3 Dimensions
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
USGS	United States Geological Survey
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WQS	Water Quality Standard

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2006c).

The Severn River (basin number 02131002) was first identified on the 1996 303(d) List submitted to the U.S. Environmental Protection Agency by the Maryland Department of the Environment (MDE) as impaired by sediments (1996), nutrients (1996), fecal coliform in tidal portions of the basin (1996), and impacts to biological communities (2002). In 2004, the fecal coliform listing was refined by identifying three restricted shellfish harvesting areas within the basin (MDE 2006). This document, upon EPA approval, establishes TMDLs of fecal coliform that will allow for the attainment of the shellfish harvesting designated use in the three restricted shellfish harvesting areas of the Severn River basin: (1) Whitehall and Meredith Creeks, (2) Mill Creek, and (3) the Severn River mainstem. The listings for nutrients, sediments, and impacts to biological communities within the Severn River basin will be addressed at a future date.

An inverse three-dimensional model was used to estimate current fecal coliform loads and to establish allowable loads for the three restricted shellfish harvesting areas in the Severn River watershed. The inverse model incorporates influences of freshwater discharge, tidal and density-induced transport, and fecal coliform decay, thereby representing the fate and transport of fecal coliform in the restricted shellfish harvesting areas. The loadings from potential sources (human, livestock, pets, and wildlife) were quantified based on the specific source density per land use acre multiplied by the fecal coliform production.

The allowable loads for the restricted shellfish harvesting areas 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 areas of the Severn 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**
Whitehall and Meredith Creeks	1.95×10^{10}	4.92×10^{10}
Mill Creek	1.84×10^{11}	2.49×10^{11}
Severn River mainstem	4.08×10^{11}	4.92×10^{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 – here the 90^{th} percent criterion. The TMDLs for Whitehall and Meredith Creeks, Mill Creek, and the Severn River mainstem proposed in this document require reductions of about 90.0%, 86.0%, and 18.9%, respectively.

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

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each State to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and 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 and industry along with academic and federal agencies with oversight by the FDA. The NSSP continues to use fecal coliform as the indicator organism to assess shellfish harvesting waters (FDA 2003). 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, listings that are based on the shellfish water quality monitoring data are limited to the specific restricted shellfish harvesting areas within an 8-digit watershed (MDE 2006).

The Severn River (basin number 02131002) was first identified on the 1996 303(d) List submitted to the EPA by the Maryland Department of the Environment (MDE) as impaired by sediments (1996), nutrients (1996), fecal coliform in tidal portions of the basin (1996), and impacts to biological communities (2002). In 2004, the fecal coliform listing was refined by identifing three restricted shellfish harvesting areas within the basin: (1) Whitehall and Meredith Creeks, (2) Mill Creek, and (3) the Severn River mainstem (MDE 2006). This document, upon EPA approval, establishes TMDLs for fecal coliform for Whitehall and Meredith Creeks, Mill Creek, and the Severn River mainstem. The listings for nutrients, sediments, and impacts to biological communities within the Severn River basin will be addressed at a future date.

The basis of the Severn River shellfish harvesting area listings are the shellfish water quality monitoring program's fecal coliform data, which indicated that water quality criteria has been exceeded, resulting in these areas 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

Three restricted shellfish harvesting areas in the Severn River basin are addressed in this report: Whitehall and Meredith Creeks, Mill Creek, and the Severn River mainstem. Whitehall and Meredith Creeks are located approximately 8 kilometers (km) northeast of the Severn River mouth, along Maryland's Western Shore in Anne Arundel County, as shown in Figure 2.1.1. Whitehall and Meredith Creeks have lengths of approximately 3.5 km and 2.8 km, respectively; widths ranging from 150 meters (m) to 350 m and from 100 m to 150 m, respectively; and a drainage area of 3,282.1 acres (13.28 km^2). Mill Creek, located approximately 6 km to the west of Whitehall and Meredith Creeks, has a length of 3.5 km, a width ranging from 120 m to 300 m, and a drainage area of approximately 3,555.0 acres (14.39 km^2). The Severn River has a length of approximately 20 km, with a width of 2.3 km at its mouth (where it flows into the Chesapeake Bay) tapering to 150 m to 200 m upstream. The Severn River mainstem restricted shellfish harvesting area has a drainage area of 43,997.6 acres (178.05 km^2) and a length of 17.81 km.

Soils in the Severn River watershed are primarily moderate to well drained, silty soils (USDA 2006). The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.25 m in the restricted shellfish harvesting area of the Severn River and 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 these restricted shellfish harvesting areas.

Table 2.1.1: Physical Characteristics of Severn River Restricted Shellfish Harvesting Areas

Restricted Shellfish Harvesting Area	Mean Water Volume (m^3)	Mean Water Depth (m)
Whitehall and Meredith Creeks	1,268,670	0.77
Mill Creek	1,168,316	1.07
Severn River mainstem	98,520,871	3.24

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that the Severn River watershed can be characterized as mixed for all three of its restricted shellfish harvesting area sites. Land use in the Whitehall and Meredith Creeks is composed of nearly 30% residential and non-residential urban and over 60% cropland and forest land uses. Mill Creek land use is over 50% residential and non-residential urban and nearly 40% cropland and forest. The Severn River mainstem is nearly 50% urban and 40% cropland and forest. The land use information for the restricted shellfish harvesting areas in the Severn River is shown in Table 2.1.2 through Table 2.1.4 and Figure 2.1.2 through Figure 2.1.4. Residential urban land use identified in Table 2.1.2 through Table 2.1.4 includes low-density residential, medium-density residential, and high-density residential. Non-residential urban land use in these tables includes commercial, industrial, institutional, extractive, and open urban land.

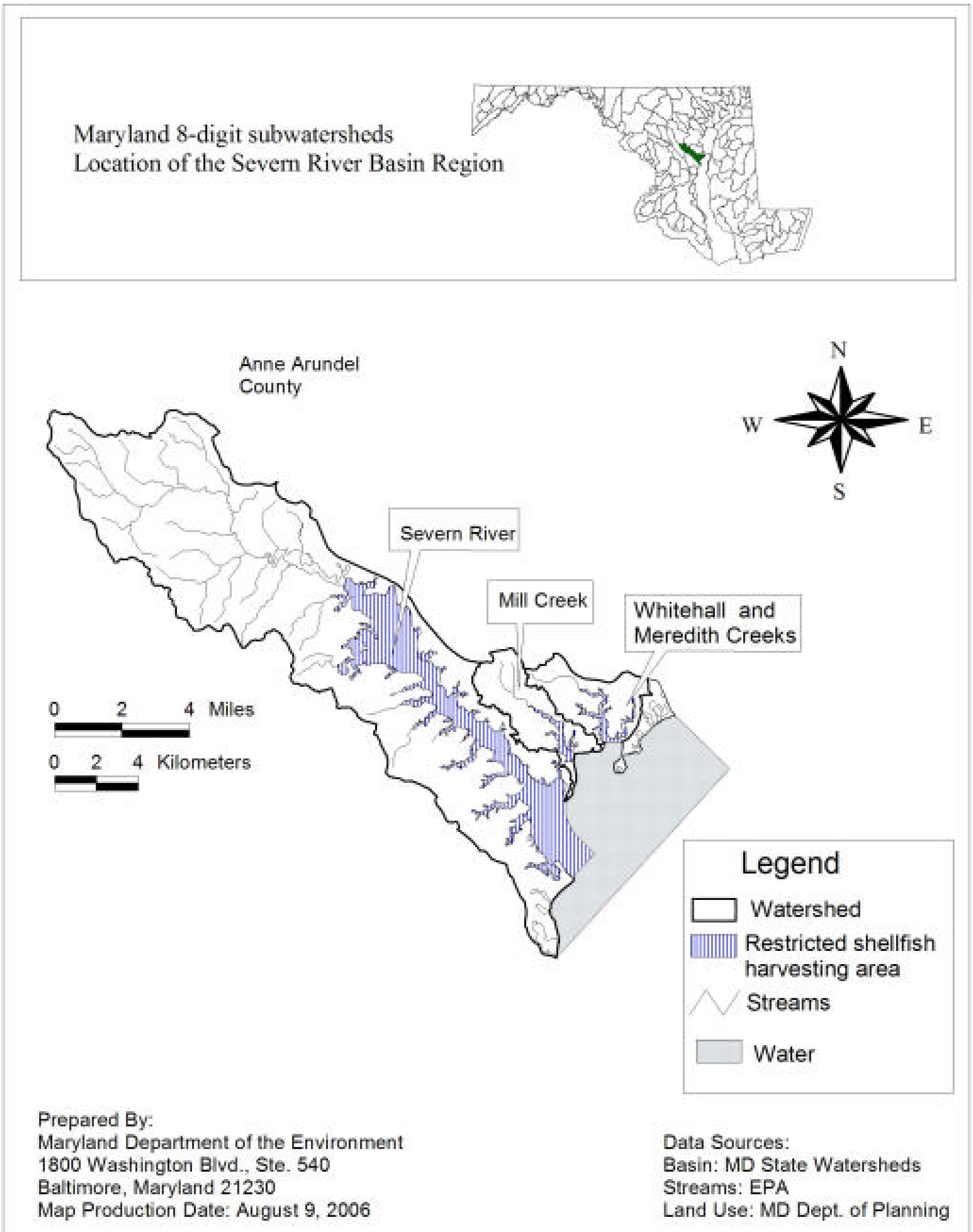

Figure 2.1.1: Location Map of the Severn River Basin

Table 2.1.2: Land Use Percentage Distribution for Whitehall and Meredith Creeks

Land Type	Acreage	Percentage
Residential urban[1]	808.5	24.7
Non-Residential urban[2]	106.0	3.2
Cropland	975.2	29.7
Pasture	0.0	0.0
Feedlot	0.0	0.0
Forest	1,041.1	31.7
Water	351.3	10.7
Wetlands	0.0	0.0
Barren	0.0	0.0
Transportation	0.0	0.0
Totals	**3,282.1**	**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.

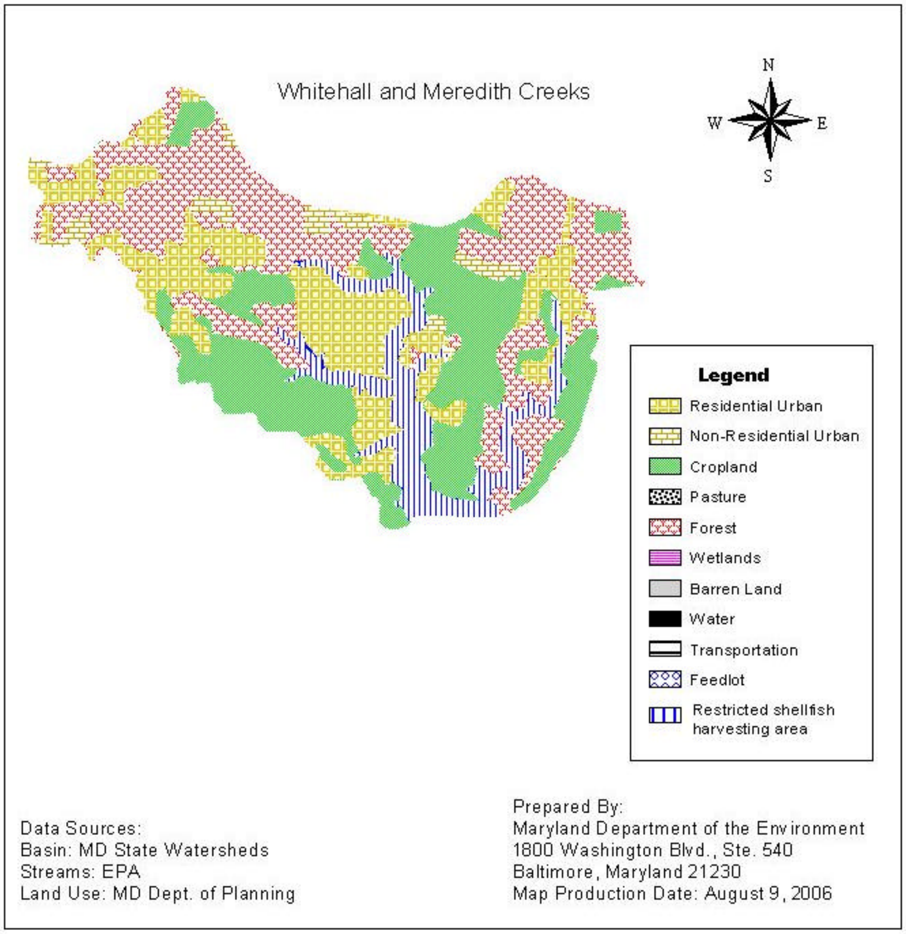

Figure 2.1.2: Land Use in the Whitehall and Meredith Creeks Basin

Table 2.1.3: Land Use Percentage Distribution for Mill Creek

Land Type	Acreage	Percentage
Residential urban[1]	1,535.8	43.2
Non-Residential urban[2]	260.7	7.3
Cropland	287.2	8.1
Pasture	104.3	2.9
Feedlot	0.0	0.0
Forest	1,059.2	29.8
Water	291.9	8.2
Wetlands	5.7	0.2
Barren	0.0	0.0
Transportation	10.2	0.3
Totals	**3,555.0**	**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.

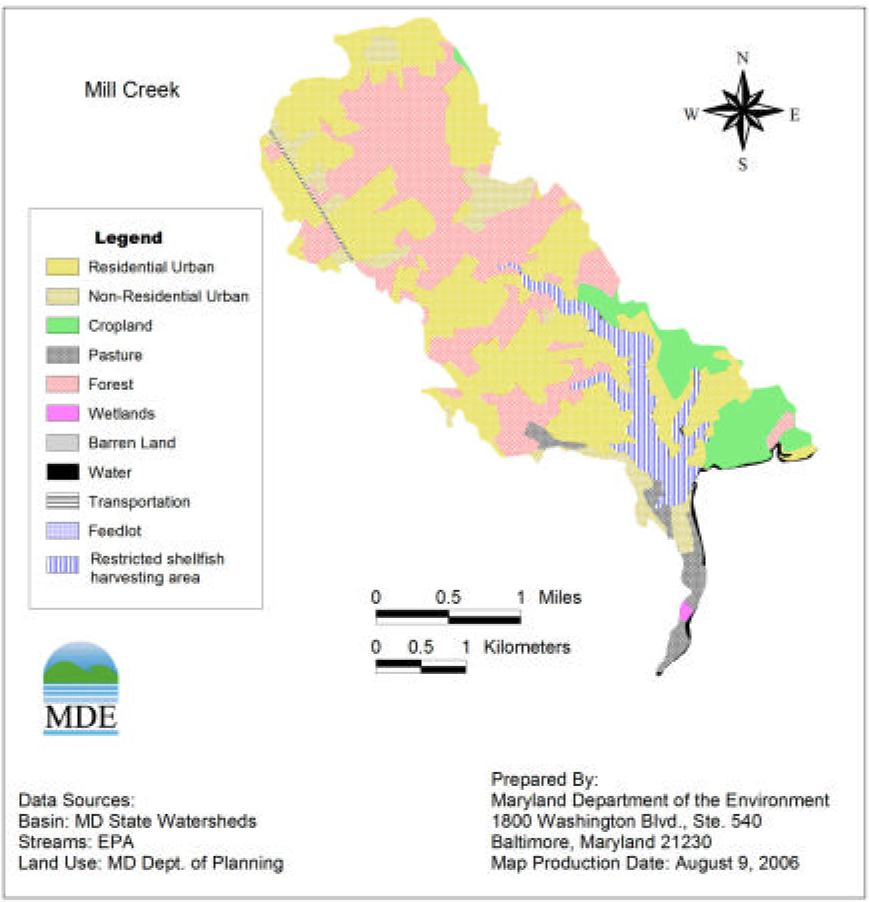

Figure 2.1.3: Land Use in the Mill Creek Basin

Table 2.1.4: Land Use Percentage Distribution for Severn River

Land Type	Acreage	Percentage
Residential urban[1]	16,489.1	37.47
Non-Residential urban[2]	4,448.8	10.11
Cropland	2,140.6	4.87
Pasture	652.2	1.48
Feedlot	38.6	0.09
Forest	13,317.1	30.27
Water	6,740.4	15.32
Wetlands	75.2	0.17
Barren	18.1	0.04
Transportation	77.5	0.18
Totals	**43,997.6**	**100.00**

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

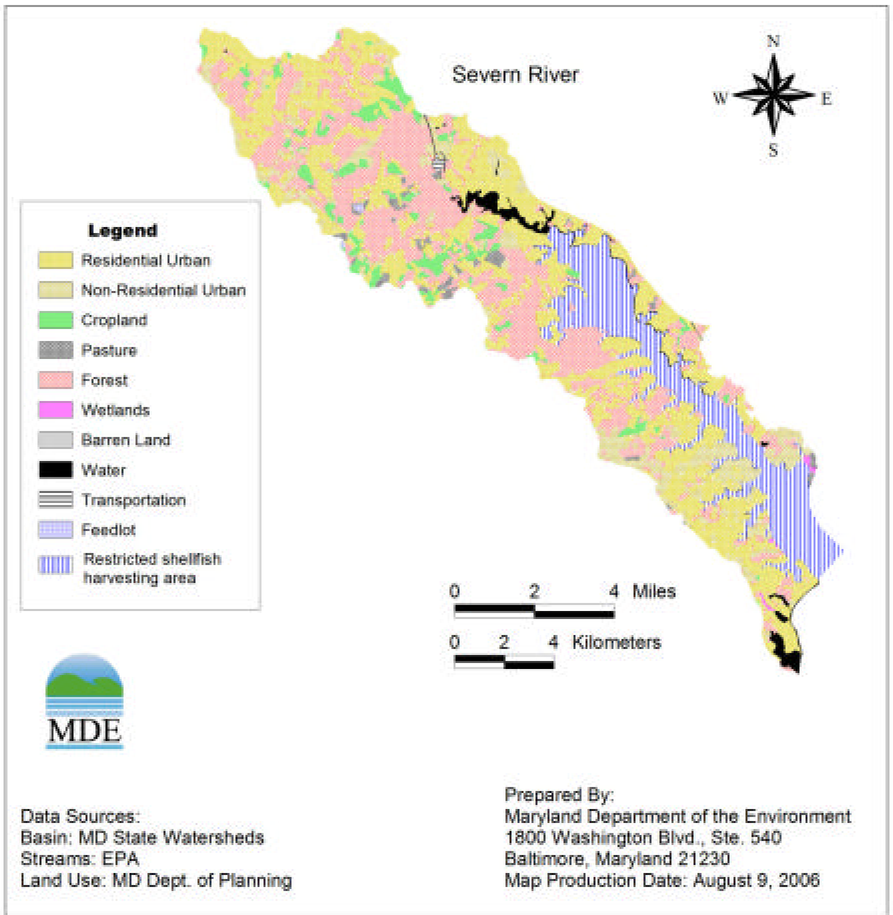

Figure 2.1.4: Land Use in the Severn River Basin

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. 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 being met.

MDE's Shellfish Certification Program has monitored shellfish waters throughout Maryland for the past several decades. There are sixteen shellfish monitoring stations in the restricted shellfish harvesting areas addressed in this report. The station identification and observations recorded during the period of July 2000 – July 2005 are provided in Table 2.2.1 through Table 2.2.3 and Figure 2.2.1 through Figure 2.2.19 for fecal coliform monitoring stations 03-03-005, 03-03-005A, 03-03-006, 03-03-200, 03-03-202, 03-03-204, 03-04-002A, 03-04-005, 03-04-008, 03-04-011, 03-04-013, 03-04-020, 03-04-028, 03-04-029, 03-04-150, and 03-04-152. Tabulations of observed fecal coliform values in Most Probable Number (MPN)/100ml at the monitoring stations included in this report are provided in Appendix E.

Table 2.2.1: Location of the Shellfish Monitoring Stations in Whitehall and Meredith Creeks

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Whitehall Creek	03-03-005	2000-2005	66	39 00 02.0	76 25 54.0
Meredith Creek	03-03-005A	2000-2005	66	39 00 02.0	76 25 31.0

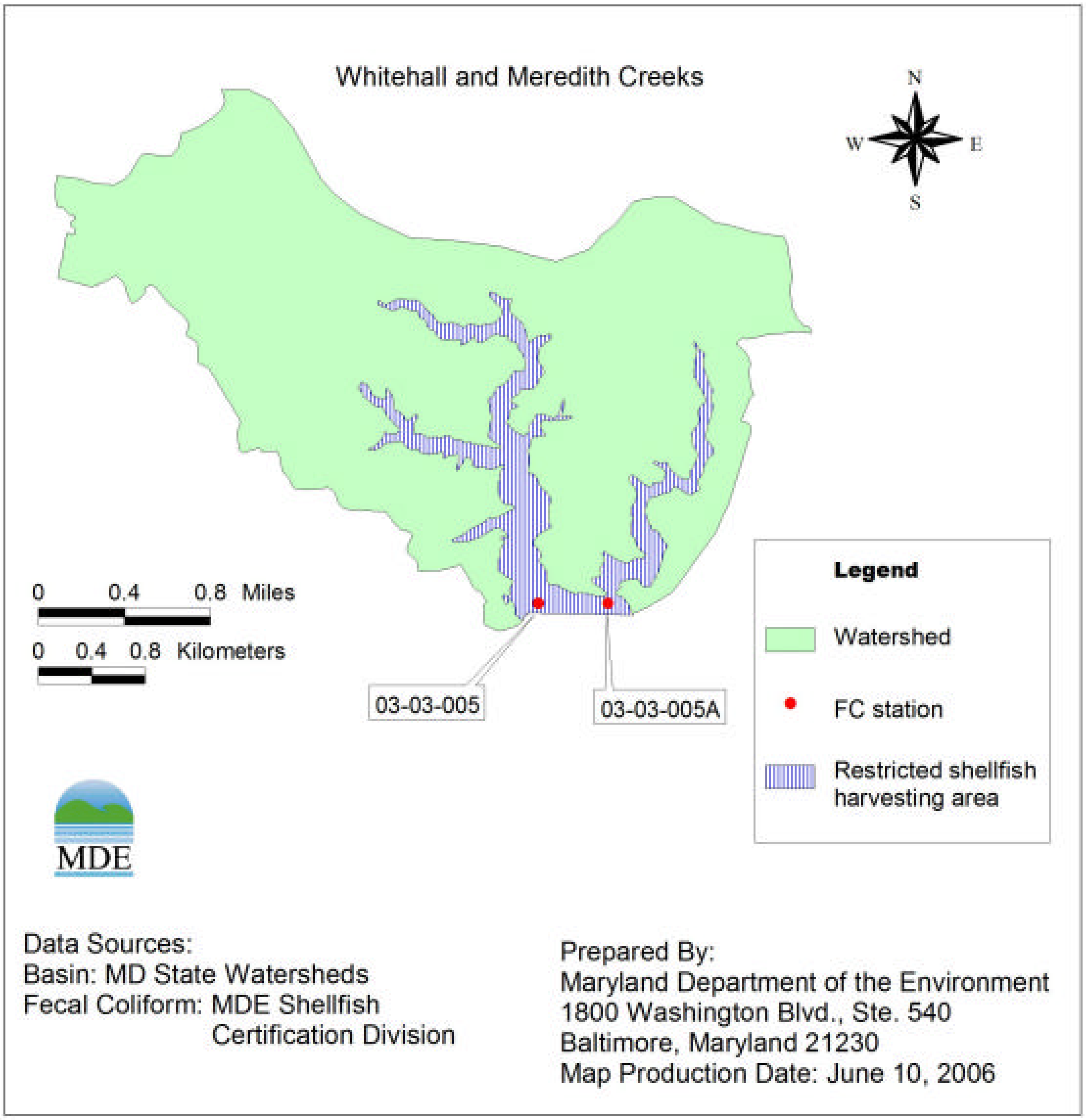

Figure 2.2.1: Shellfish Monitoring Stations in Whitehall and Meredith Creeks

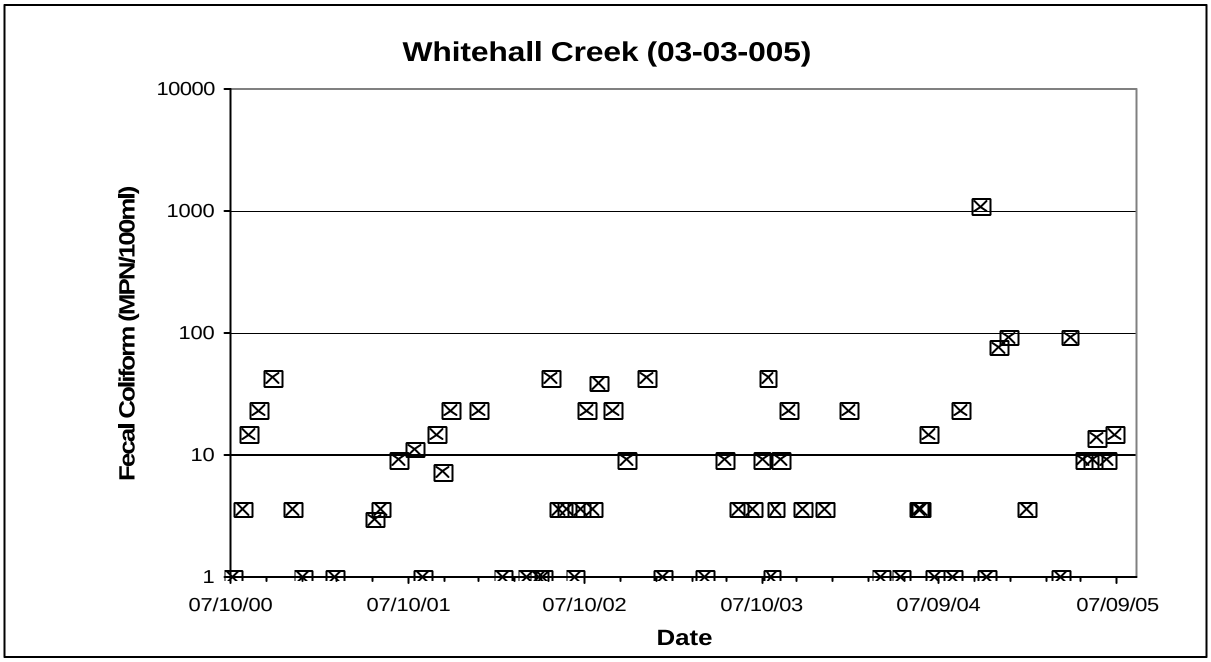

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 03-03-005

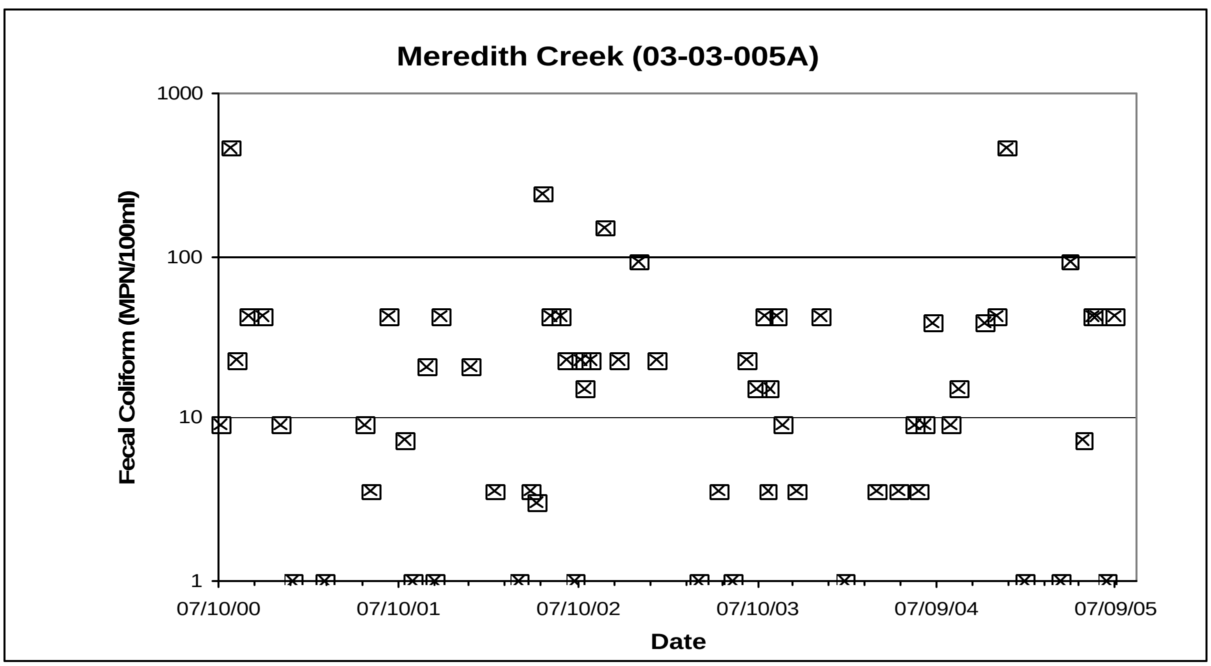

Figure 2.2.3: Observed Fecal Coliform Concentrations at Station 03-03-005A

Table 2.2.2: 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	03-03-006	2000-2005	66	39 59 40.1	76 27 02.8

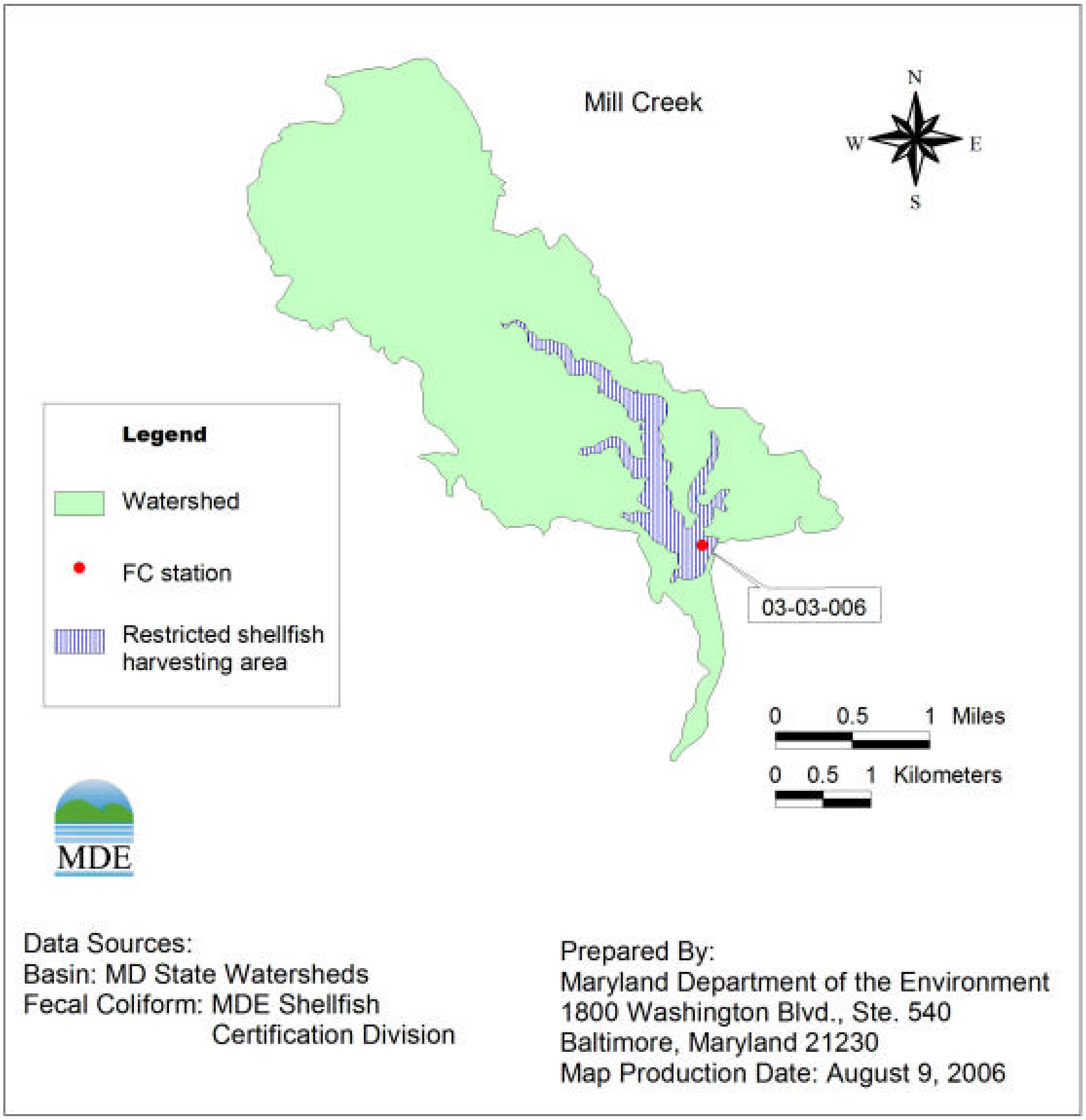

Figure 2.2.4: Shellfish Monitoring Station in Mill Creek

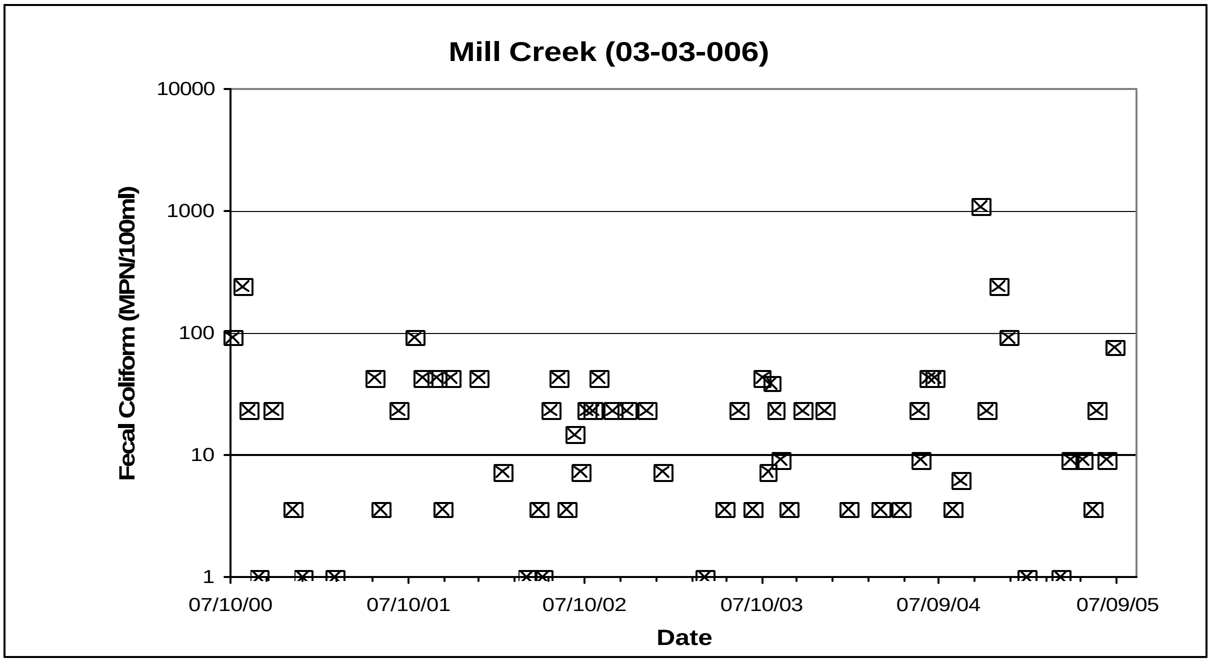

Figure 2.2.5: Observed Fecal Coliform Concentrations at Station 03-03-006

Table 2.2.3: Location of the Shellfish Monitoring Stations in Severn River Mainstem

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Severn River mainstem	03-03-200	2000-2005	67	38 58 05.4	76 27 15.1
Severn River mainstem	03-03-202	2000-2005	67	38 57 09.0	76 26 17.0
Severn River mainstem	03-03-204	2000-2005	66	38 56 37.0	76 26 52.0
Severn River mainstem	03-04-002A	2000-2005	71	39 02 32.0	76 33 36.0
Severn River mainstem	03-04-005	2000-2005	72	39 02 26.0	76 32 21.0
Severn River mainstem	03-04-008	2000-2005	72	39 01 45.0	76 31 34.0
Severn River mainstem	03-04-011	2000-2005	74	39 00 55.0	76 30 50.0
Severn River mainstem	03-04-013	2000-2005	73	39 00 30.0	76 30 46.0
Severn River mainstem	03-04-020	2000-2005	73	38 59 36.0	76 29 00.0
Severn River mainstem	03-04-028	2000-2005	73	38 58 48.0	76 27 33.0
Severn River mainstem	03-04-029	2000-2005	72	38 58 00.0	76 28 05.0
Severn River mainstem	03-04-150	2000-2005	71	39 03 35.9	76 33 52.1
Severn River mainstem	03-04-152	2000-2005	70	39 04 08.0	76 34 31.0

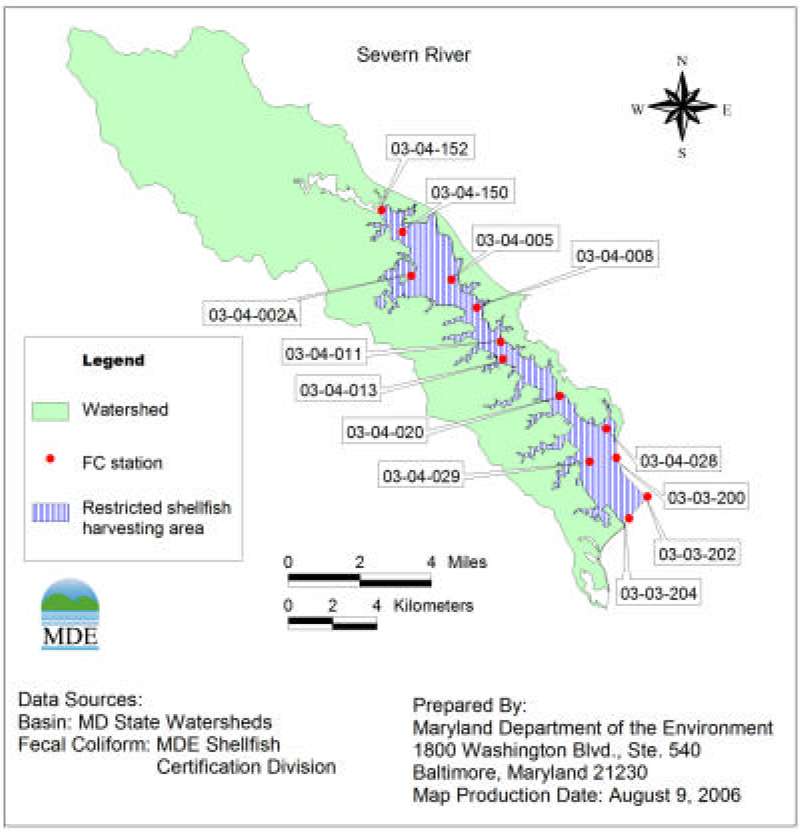

Figure 2.2.6: Shellfish Monitoring Stations in Severn River Mainstem

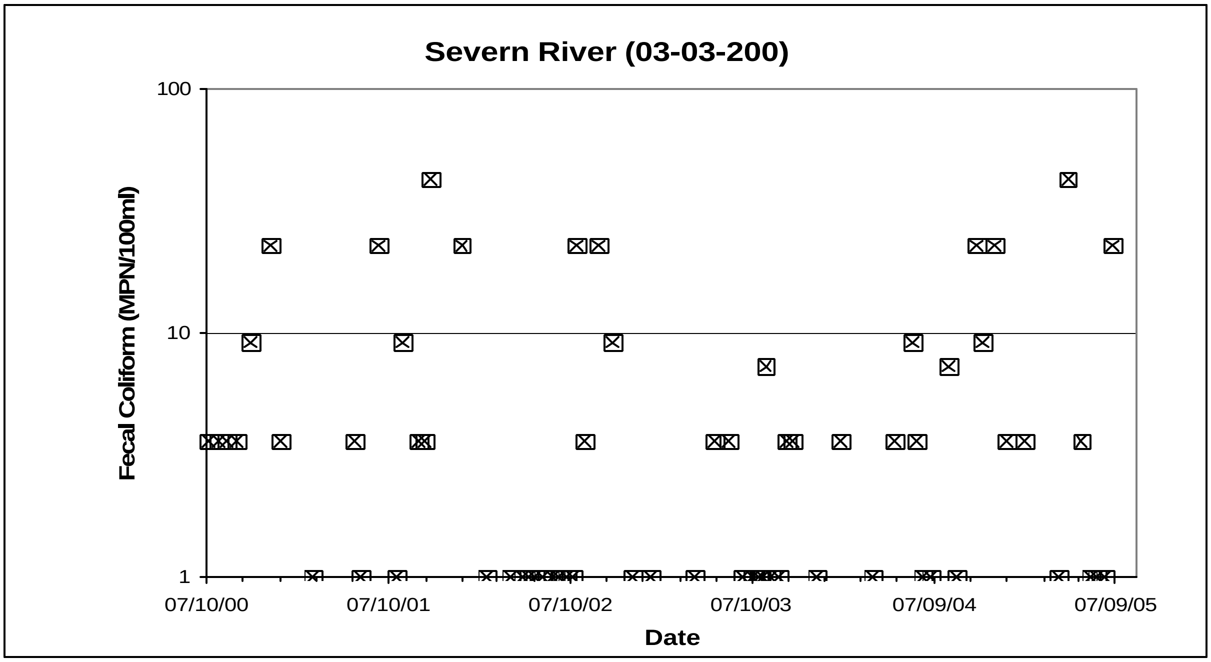

Figure 2.2.7: Observed Fecal Coliform Concentrations at Station 03-03-200

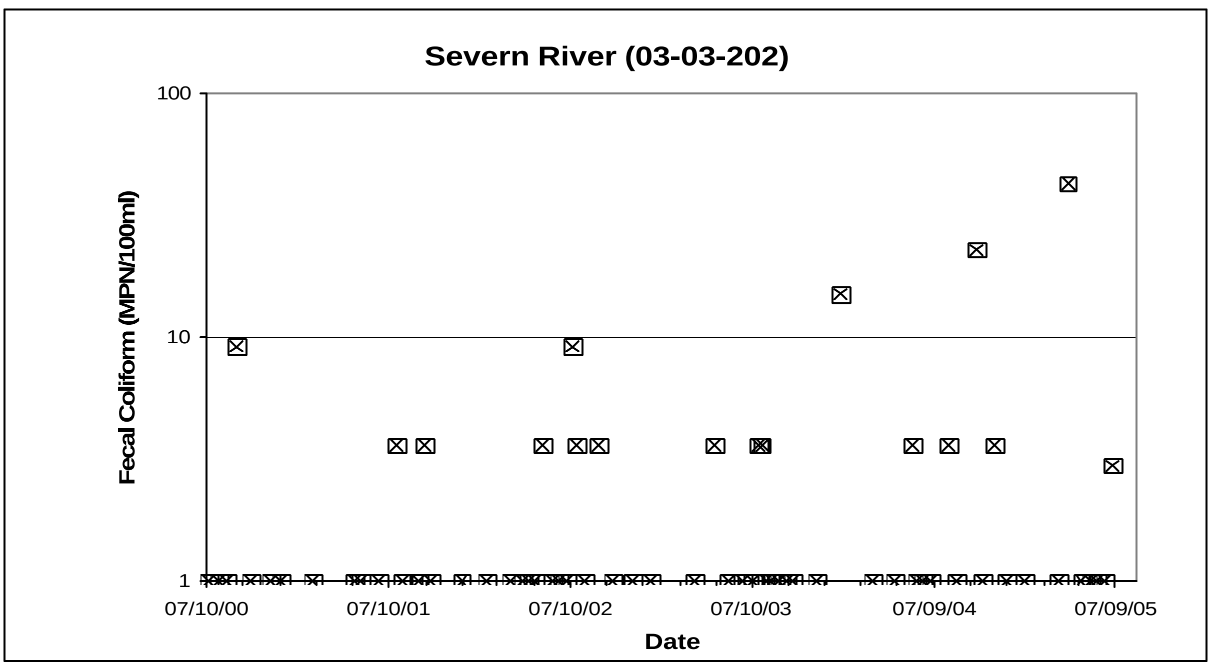

Figure 2.2.8: Observed Fecal Coliform Concentrations at Station 03-03-202

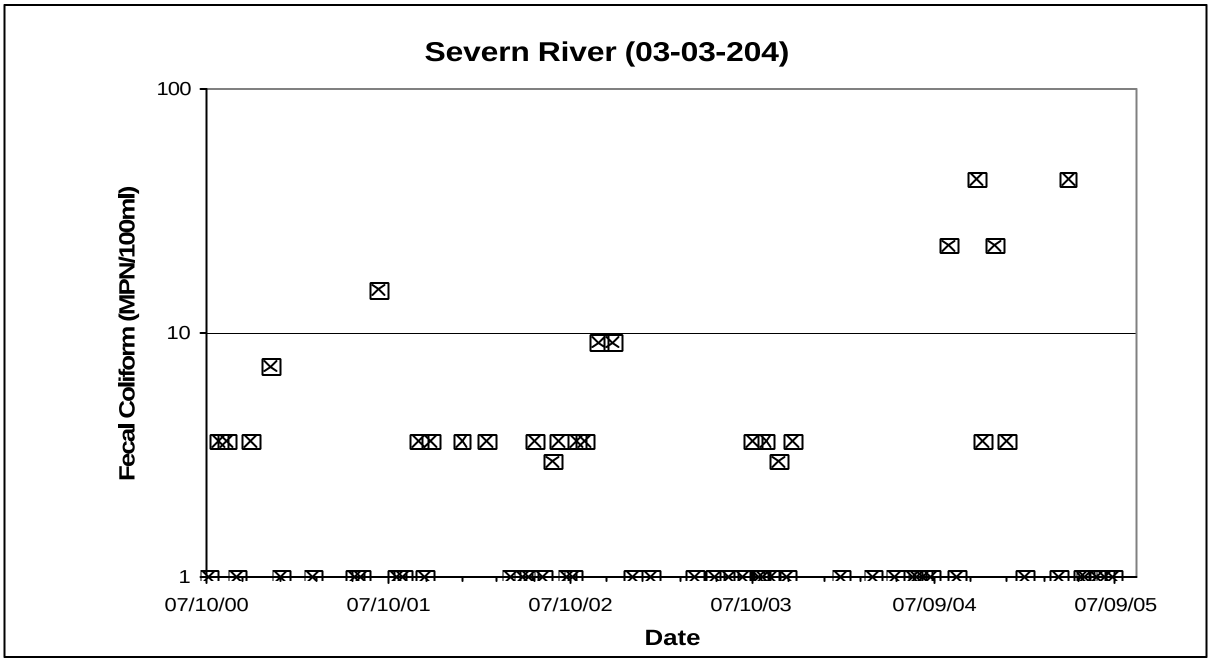

Figure 2.2.9: Observed Fecal Coliform Concentrations at Station 03-03-204

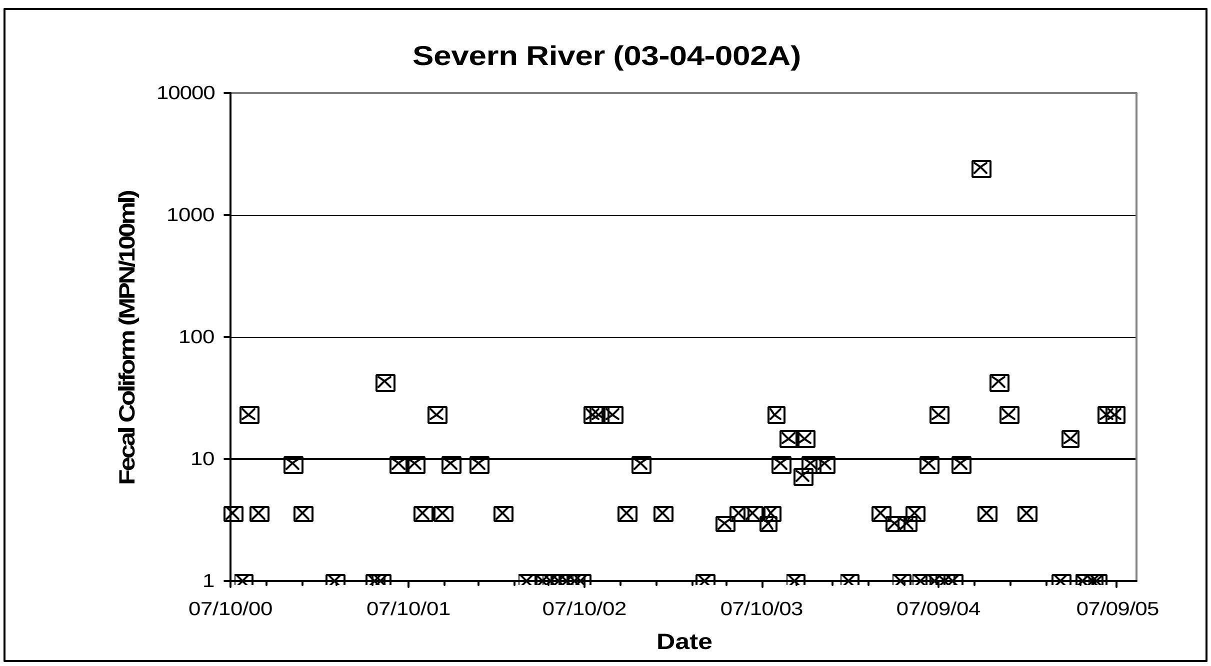

Figure 2.2.10: Observed Fecal Coliform Concentrations at Station 03-04-002A

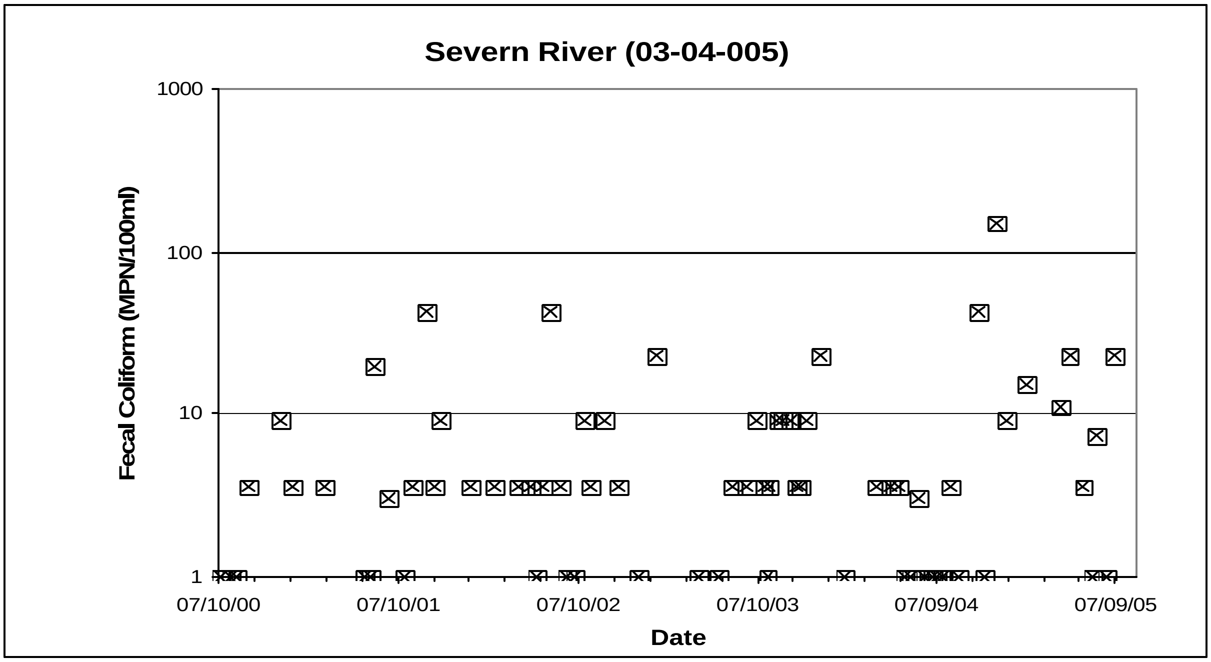

Figure 2.2.11: Observed Fecal Coliform Concentrations at Station 03-04-005

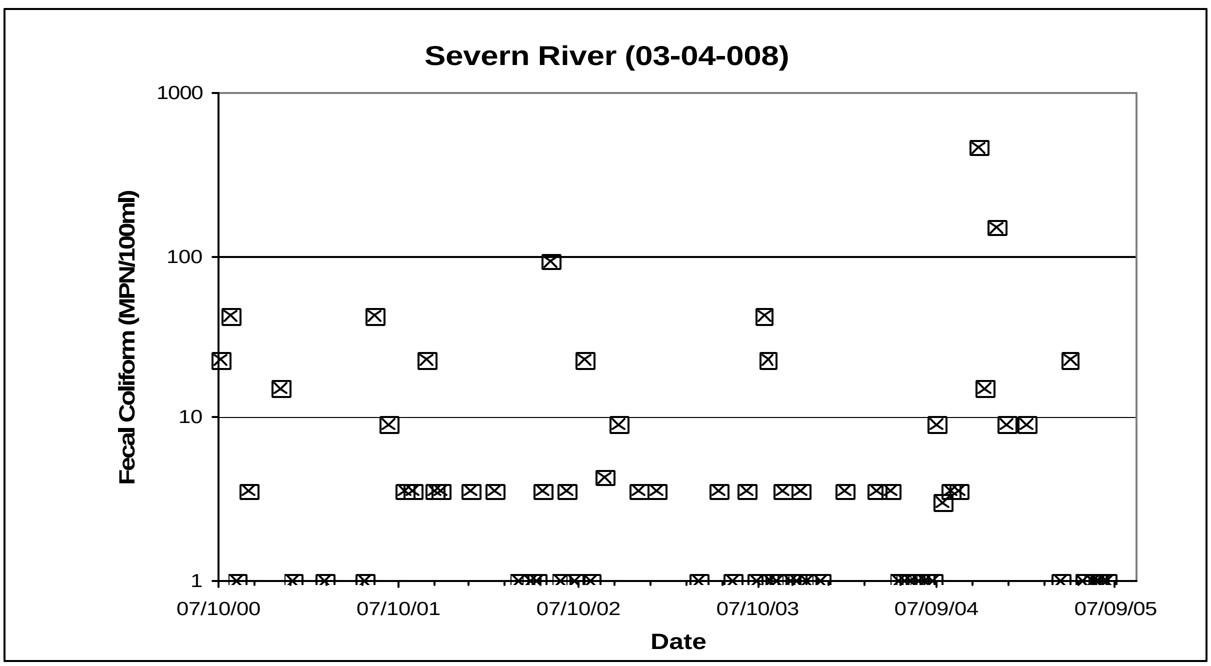

Figure 2.2.12: Observed Fecal Coliform Concentrations at Station 03-04-008

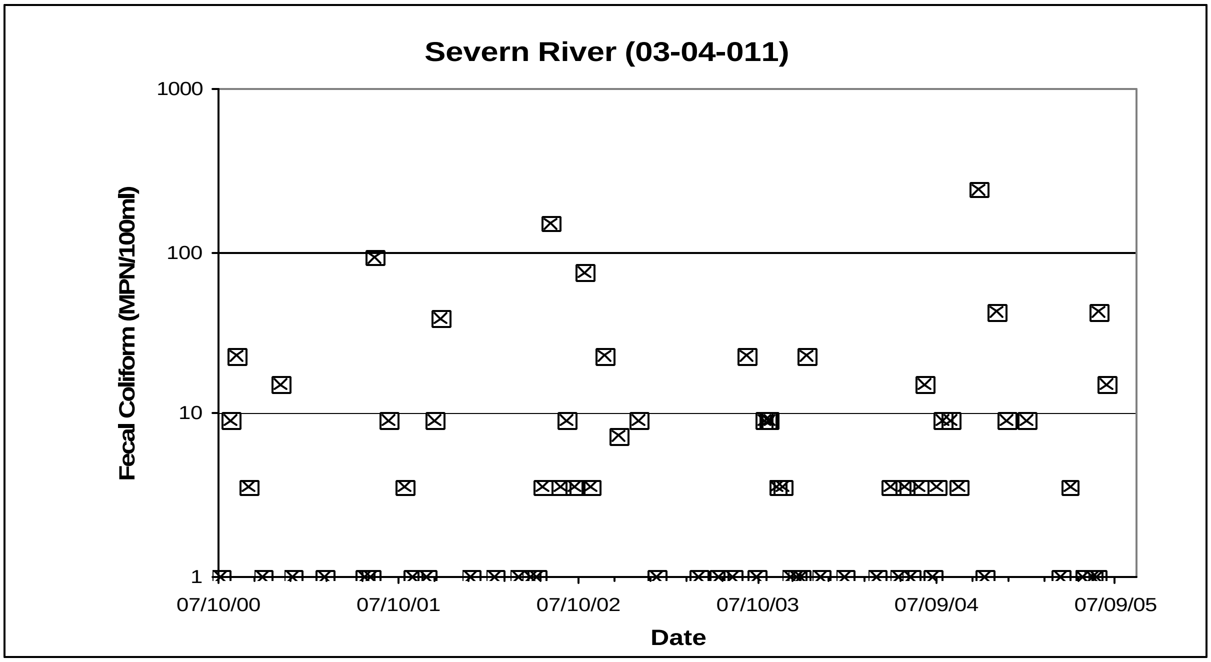

Figure 2.2.13: Observed Fecal Coliform Concentrations at Station 03-04-011

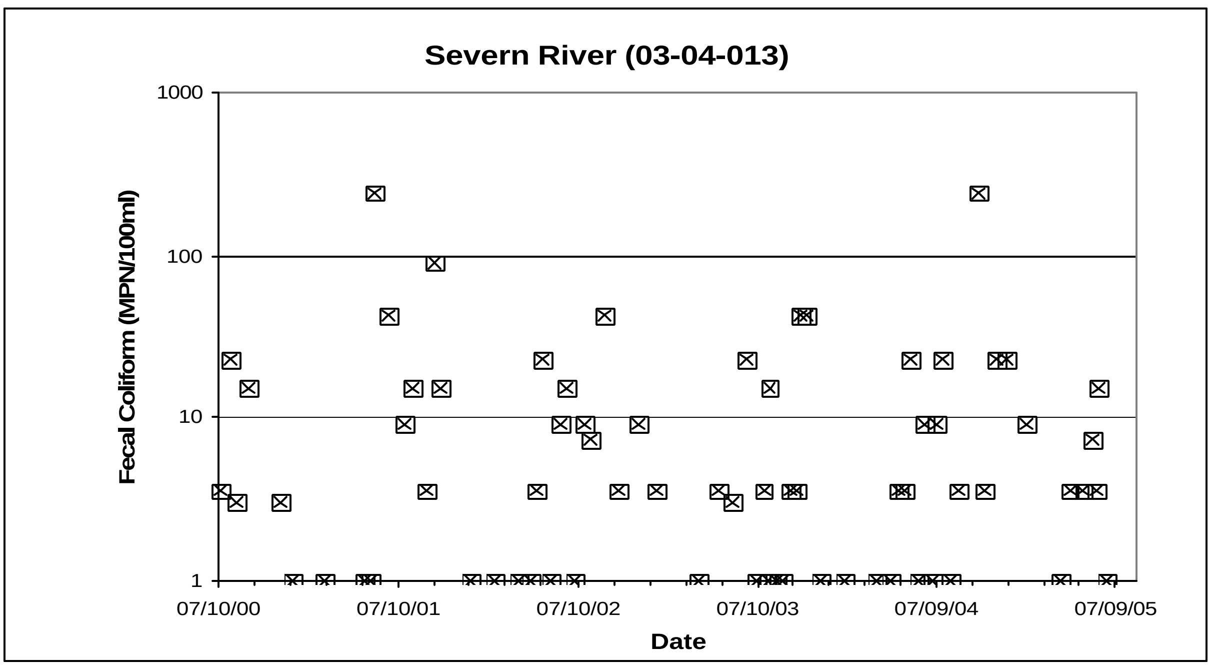

Figure 2.2.14: Observed Fecal Coliform Concentrations at Station 03-04-013

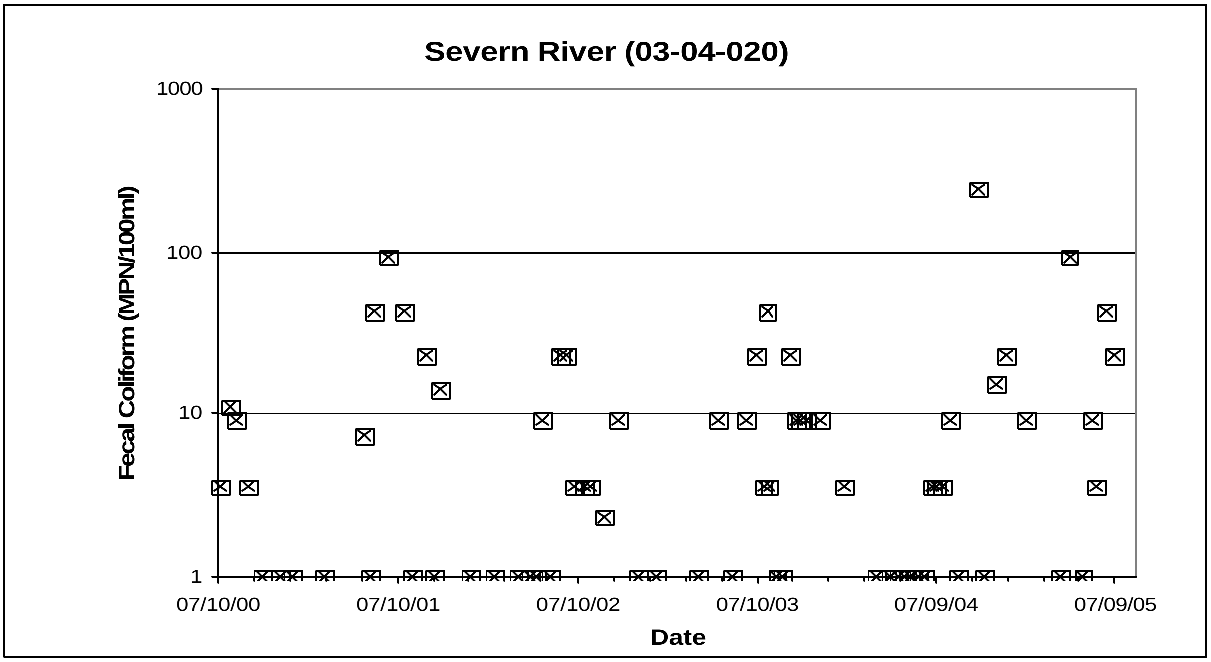

Figure 2.2.15: Observed Fecal Coliform Concentrations at Station 03-04-020

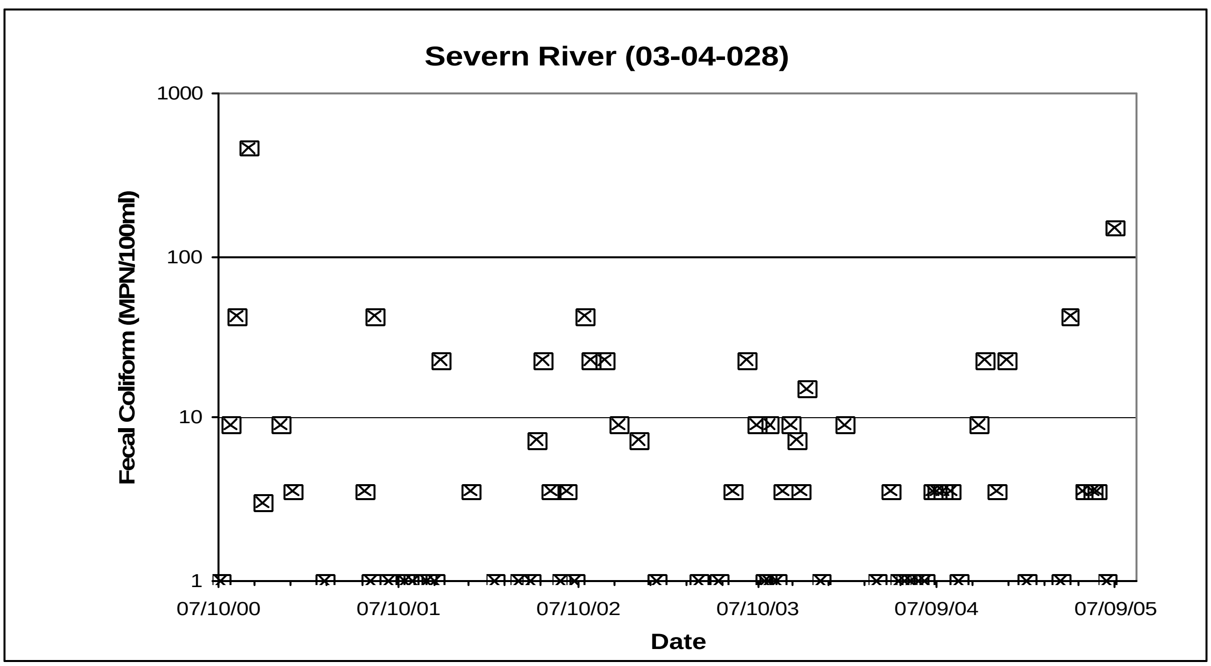

Figure 2.2.16: Observed Fecal Coliform Concentrations at Station 03-04-028

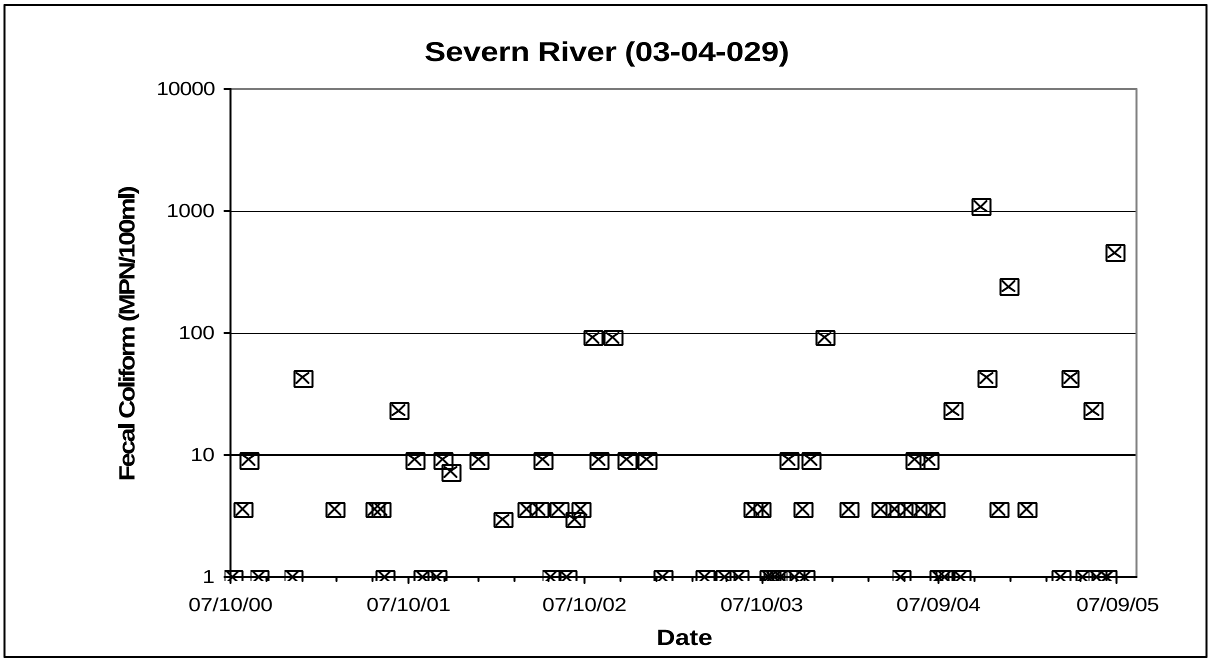

Figure 2.2.17: Observed Fecal Coliform Concentrations at Station 03-04-029

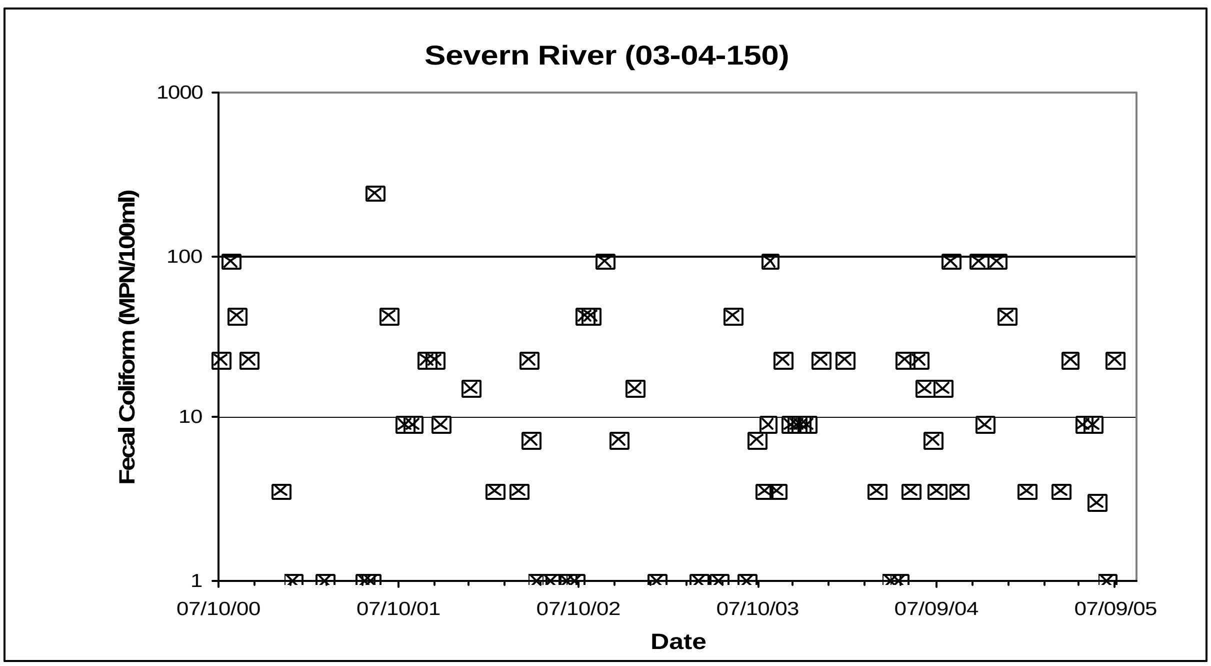

Figure 2.2.18: Observed Fecal Coliform Concentrations at Station 03-04-150

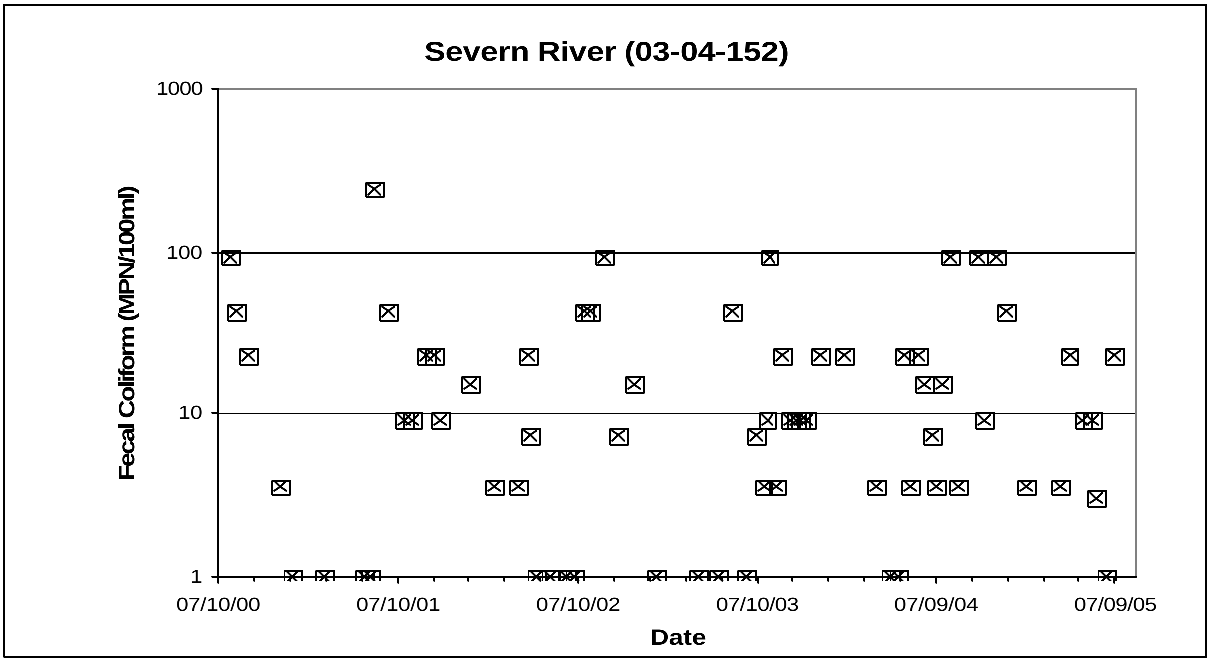

Figure 2.2.19: Observed Fecal Coliform Concentrations at Station 03-04-152

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 (ml); 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 resource 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 five-year period between July 2000 and July 2005. Most shellfish harvesting areas have been monitored routinely since before 1950 and, due to an emerging oyster aquaculture industry, there are a few shellfish harvesting areas that have less than five years worth of data. For the purpose of classifying shellfish harvesting areas, a minimum of 30 samples is required. For TMDL development, if fewer than 30 samples are available, 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.

The Severn River was first listed on the 1996 Integrated 303(d) List as impaired by fecal coliform. This listing was further refined in 2004 and specified the following shellfish harvesting waters as impaired by fecal coliform: (1) Whitehall and Meredith Creeks, (2) Mill Creek, and (3)

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

the Severn River mainstem. The water quality impairment in Whitehall and Meredith Creeks was assessed as not meeting either the median criterion or the 90th percentile criterion at one station (i.e., Station 03-03-005A). The water quality impairment in Mill Creek was assessed as not meeting either the median criterion or the 90th percentile criterion at Station 03-03-006. The water quality impairment in the Severn River mainstem was assessed as not meeting the 90th percentile criterion at Stations 03-04-150 and 03-04-152, and not meeting either the median or the 90th percentile criterion at Station 03-04-152. Descriptive statistics of the monitoring data and the requirements for the approved classification are shown in Table 2.3.1.

Table 2.3.1: Severn River Fecal Coliform Statistics (data from 2000-2005)

Area Name	Station	Median		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Whitehall and Meredith Creeks	03-03-005	3.60	14	43.08	49
	03-03-005A	15.00	14	115.59	49
Mill Creek	03-03-006	23.00	14	87.68	49
Severn River mainstem	03-03-200	3.60	14	13.39	49
	03-03-202	1.00	14	4.59	49
	03-03-204	1.00	14	7.26	49
	03-04-002A	3.60	14	27.02	49
	03-04-005	3.60	14	16.95	49
	03-04-008	3.60	14	22.05	49
	03-04-011	3.60	14	24.92	49
	03-04-013	3.60	14	29.51	49
	03-04-020	3.60	14	26.58	49
	03-04-028	3.60	14	23.42	49
	03-04-029	3.60	14	34.35	49
	03-04-150	9.10	14	55.58	49
	03-04-152	15.00	14	114.31	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 as well as through pollution from recreational vessel discharges. The potential transport of fecal coliform from land surfaces to restricted shellfish harvesting waters is dictated by the hydrology, soil type, land use, and topography of the watershed. The locations of subwatersheds in the Severn River basin are shown in Figure 2.4.1.

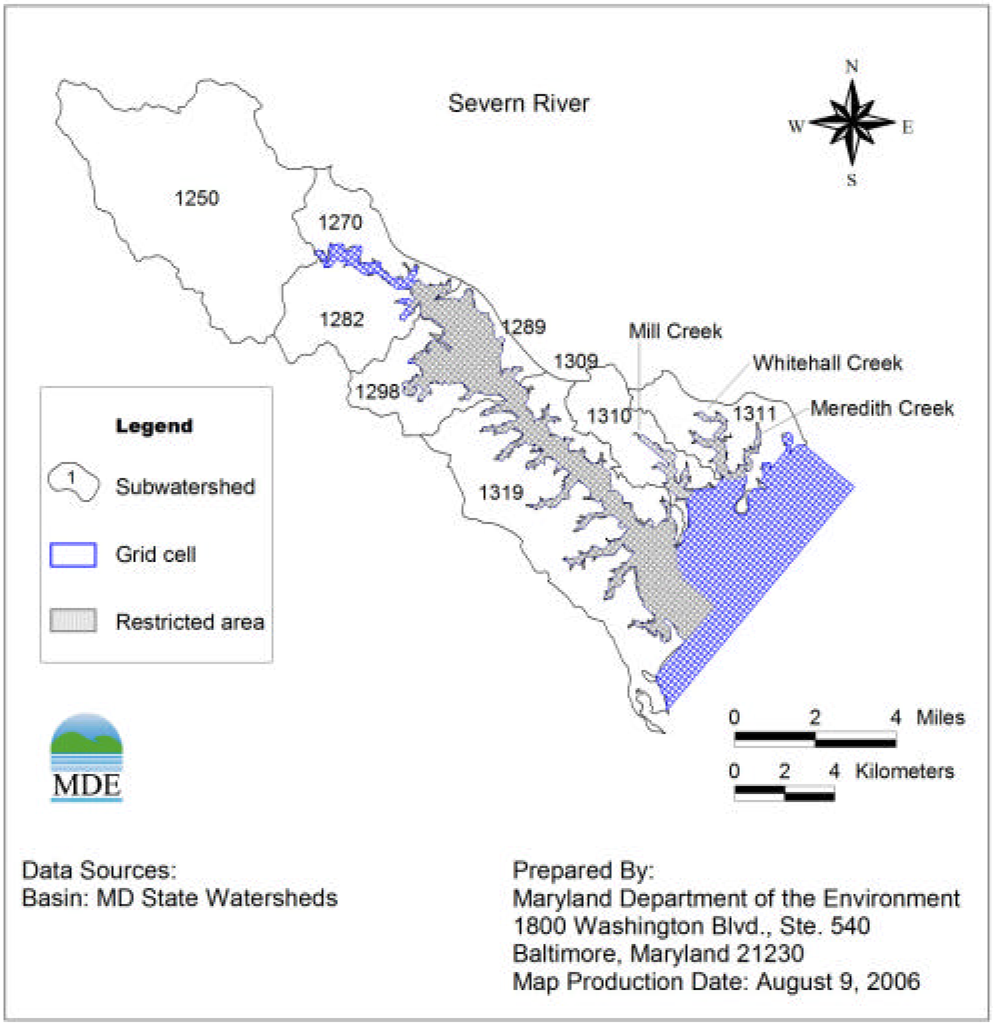

Figure 2.4.1: Subwatersheds in the Severn River Basin

The complete distribution of source loads is listed in Table 2.4.1. The potential nonpoint sources were grouped into four categories: wildlife, human, pets, and livestock. Details of the source estimate procedure can be found in Appendix C. In the future, results of the Bacteria Source Tracking (BST) study will be used to reevaluate the source distribution.

Table 2.4.1: Distribution of Fecal Coliform Source Loads in the Severn River Basin

Subwatershed	Fecal Coliform Source	Loading (Counts/day)	Loading (Percent)
1250	Livestock	1.39E+11	1.99%
	Pets	6.01E+12	85.96%
	Human	6.70E+10	0.96%
	Wildlife	7.75E+11	11.09%
	Total	6.99E+12	100.00%
1270	Livestock	2.46E+10	1.36%
	Pets	1.59E+12	87.99%
	Human	2.57E+10	1.42%
	Wildlife	1.67E+11	9.23%
	Total	1.81E+12	100.00%
1282	Livestock	3.83E+10	3.46%
	Pets	7.66E+11	69.31%
	Human	3.51E+10	3.17%
	Wildlife	2.66E+11	24.06%
	Total	1.11E+12	100.00%
1289	Livestock	7.28E+09	0.42%
	Pets	2.99E+11	17.32%
	Human	6.18E+09	0.36%
	Wildlife	1.41E+12	81.90%
	Total	1.73E+12	100.00%
1298	Livestock	2.52E+10	3.22%
	Pets	4.61E+11	59.03%
	Human	2.44E+10	3.13%
	Wildlife	2.71E+11	34.62%
	Total	7.81E+11	100.00%
1309	Livestock	3.57E+10	1.43%
	Pets	7.60E+11	30.46%
	Human	1.66E+10	0.67%
	Wildlife	1.68E+12	67.45%
	Total	2.49E+12	100.00%
1310	Livestock	1.93E+10	1.03%
	Pets	7.18E+11	38.36%
	Human	3.19E+10	1.70%
	Wildlife	1.10E+12	58.90%
	Total	1.87E+12	100.00%
1311	Livestock	2.68E+10	1.86%
	Pets	3.78E+11	26.26%
	Human	1.73E+10	1.20%
	Wildlife	1.02E+12	70.68%
	Total	1.44E+12	100.00%
1319	Livestock	8.39E+10	0.82%
	Pets	8.62E+12	83.87%
	Human	4.32E+10	0.42%
	Wildlife	1.53E+12	14.89%
	Total	1.03E+13	100.00%

Subwatershed	Fecal Coliform Source	Loading (Counts/day)	Loading (Percent)
Total	Livestock	4.00E+11	1.40%
	Pets	1.96E+13	68.79%
	Human	2.67E+11	0.94%
	Wildlife	8.23E+12	28.87%
	Total	2.85E+13	100.00%

Point Source Assessment

Point sources in the Severn River watershed include loads from municipal point source facilities and National Pollutant Discharge Elimination System (NPDES) regulated stormwater entities. There are no industrial point source facilities discharging fecal coliform that affect any of the three reported shellfish harvesting areas. However, there are three municipal point source facilities with permits to discharge fecal coliform that affect the Severn River mainstem shellfish harvesting area. The permit numbers for these facilities are as follows: MD0021814 (Annapolis Water Reclamation Facility), MD0023523 (U. S. Naval Academy), and MD0052868 (Dreams Landing). Each of these three facilities holds a permit for the discharge of a monthly median fecal coliform concentration of 14 MPN/100 ml, and has design flows of 13.0 million gallons per day (mgd), 1.0 mgd, and 0.02 mgd, respectively (see Table 2.4.2). The allocation of the permitted load from these point source facilities will be addressed in Section 4.7.

The Department applies EPA's requirement that "stormwater discharges that are regulated under Phase I or Phase II of the NPDES storm water program are point sources that must be included in the WLA portion of a TMDL" (USEPA 2002). The stormwater loads are addressed in Section 4.7 and Appendix B.

Table 2.4.2: A Summary of Point Source Facility Discharge

Facility Name	NPDES Permit Number	Design Flow (MGD)	Permitted FC Concentration in MPN/100ml (Monthly Median)	Permitted FC Loads in MPN/Day	
				Median	90th Percentile
Annapolis Water Reclamation Facility	MD0021814	13	14	6.89E+09	2.24E+10
U. S. Naval Academy	MD0023523	1	14	5.30E+08	1.72E+09
Dreams Landing	MD0052868	0.02	14	1.06E+07	3.45E+07

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal coliform TMDLs summarized in this document is to establish the maximum loading needed to ensure attainment of water quality standards in the restricted shellfish harvesting areas in the Severn River basin. 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 Severn River watershed. The required load reduction was determined based on data collected from July 2000 to July 2005. The TMDLs are presented as counts/day. Section 4.2 describes the analysis framework for simulating fecal coliform concentrations in restricted shellfish harvesting waters in the Severn River basin. Section 4.3 addresses critical conditions and seasonality. The TMDL calculations are presented in Section 4.4. A summary of baseline loads is provided in Section 4.5, Section 4.6 discusses TMDL loading caps, and Section 4.7 provides a description of the wasteload allocation (WLA) and load allocation (LA). 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 the 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 the individual wasteload allocations for point sources and the load allocations for nonpoint sources, which incorporate natural background pollutant levels. The TMDL must, either implicitly or explicitly, include a margin of safety that accounts for the uncertainty in both the relationship between pollutant loads and the quality of the receiving waterbody and 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 discharged into the restricted shellfish harvesting area are the dominant forces that influence the transport of fecal coliform. The Severn River mainstem is that portion of the Severn River downstream of Benfield and upstream of Greenbury Point. The Severn River is a tidal river that has a length of 20 km and a width of 2.3 km at its mouth, tapering to widths of 150-200 m upstream. It drains a watershed with dimensions of 33.5 km by 7.6 km (MDP 2004). The current distribution in the system varies as tidal and freshwater discharges change. In order to simulate the transport processes in the Severn River accurately, the 3-dimensional hydrodynamic and eutrophication model (HEM-3D) has been used for this study. The HEM-3D model is a general 3D model for environmental studies. The model simulates density and topographically induced circulation, tidal and wind-driven flows, and spatial and temporal distributions of: salinity, temperature, suspended sediment concentrations, conservative tracers, eutrophication processes, and fecal coliform. For a detailed model description, the reader is referred to Park et al. (1995).

The Severn River, including Whitehall and Meredith Creeks and Mill Creek, is represented by a horizontal model of Cartesian grid cells. There are a total of 1750 grid cells in the modeling domain. To better simulate the stratification effect, three layers are used in the vertical. For this study, the model was calibrated for the tide and long-term mean salinity distribution. In order to address the standards of the median and 90th percentile fecal coliform concentrations, an inverse approach has been adopted here to estimate the loads from the watershed. The watershed is divided into 28 subwatersheds. The loads from each subwatershed are discharged into the river from small creeks connected to the river.

The model was forced by the M_2 constituent of the tide and the mean salinity concentration at the river's mouth. The long-term mean freshwater input estimated based on data from the United States Geological Survey (USGS) gage station 01589795 was used. The discharges from subwatersheds are estimated based on the ratio of subwatershed area to the total drainage basin of the USGS station. The inverse method is used to estimate the existing load discharged from each subwatershed based on median and 90th percentile fecal coliform data obtained from observations. The model is also used to establish the allowable loads for the Severn River restricted shellfish harvesting area sites. Detailed modeling procedures are described 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 counts that are due to the variation of hydrological conditions.

The seasonal fecal coliform distributions for the sixteen applicable monitoring stations are presented in Appendix D. The results show the seasonal variability of fecal coliform concentrations; high concentrations occur in September in the Whitehall and Meredith Creeks and the Mill Creek restricted shellfish harvesting areas and between April and November in the Severn River mainstem restricted shellfish harvesting area, with peaks occurring at several stations in the month of September. The large standard deviations correspond to the high variability in concentration at each station, resulting 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. There are two monitoring stations in the Whitehall and Meredith Creeks' restricted shellfish harvesting areas, one in the Mill Creek restricted shellfish harvesting area, and thirteen in the Severn River mainstem restricted shellfish harvesting area. To accurately estimate the load with consideration of available monitoring data, the 8-digit watershed was segmented into 28 subwatersheds. The load for each subwatershed was discharged into its corresponding receiving water model. The inverse method was used to compute the watershed loads discharged into the river based on the best match of observations and model simulation of fecal coliform concentrations in the river. The total loads are reported in Table 4.4.1 and Table 4.4.2. Detailed description of the inverse method and results by subwatershed are presented in Appendix A.

The allowable load is calculated using the water quality criteria of a median of 14 MPN/100ml and a 90th percentile of 49 MPN/100ml. The 3-D model was used to compute the allowable load for each subwatershed by reducing the existing loads from the watershed so that the fecal coliform concentrations in the receiving water meet the appropriate water quality standards. The total loads discharged into the river are the summation of loads discharged from each subwatershed. For the Whitehall and Meredith Creeks impairment site, neither the median nor 90th percentile criteria are met at Station 03-03-005A. For the Mill Creek impairment site, neither the median nor 90th percentile criteria are met at Station 03-03-006. For the Severn River mainstem, the 90th percentile criterion is not met at Station 03-04-150, and neither the median nor 90th percentile criteria are met at Station 03-04-152. 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 Water Volume M^3	Fecal Coliform Median Criterion MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction percent
Whitehall and Meredith Creeks	1,268,670	14	5.67E+10	1.95E+10	65.53
Mill Creek	1,168,316	14	6.13E+11	1.84E+11	70.00
Severn River mainstem	98,520,871	14	4.79E+11	4.08E+11	14.82

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

Area	Mean Water Volume M^3	Fecal Coliform 90th Percentile Criterion MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction percent
Whitehall and Meredith Creeks	1,268,670	49	4.92E+11	4.92E+10	90
Mill Creek	1,168,316	49	1.78E+12	2.49E+11	86
Severn River mainstem	98,520,871	49	6.07E+12	4.92E+12	19

4.5 Summary of Baseline Loads

For the TMDL analysis period, from July 2000 to July 2005, the calculated baseline (current) loads of fecal coliform from all sources in the watersheds draining to the three restricted shellfish harvesting areas in the Severn 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

Watershed	**Fecal Coliform Baseline Loads (counts per day)**	
	Median Analysis Scenario	**90th Percentile Analysis Scenario**
Whitehall and Meredith Creeks	5.67×10^{10}	4.92×10^{11}
Mill Creek	6.13×10^{11}	1.78×10^{12}
Severn River mainstem	4.79×10^{11}	6.07×10^{12}

4.6 TMDL Loading Caps

This section presents the TMDLs that would meet the median and 90th percentile criteria. Seasonal variability is addressed implicitly through the interpretation of the water quality standards (see Section 4.3). The median and 90th percentile based TMDLs for the restricted shellfish harvesting waters of Whitehall and Meredith Creeks, Mill Creek, and the Severn River mainstem in the Severn River basin are summarized in Table 4.6.1.

Table 4.6.1: Summary of TMDL Loading Caps

Waterbody	**Fecal Coliform TMDL (counts per day)**	
	based on Median Criterion	**based on 90th Percentile Criterion[1]**
Whitehall and Meredith Creeks	1.95×10^{10}	4.92×10^{10}
Mill Creek	1.84×10^{11}	2.49×10^{11}
Severn River mainstem	4.08×10^{11}	4.92×10^{12}

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

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

4.7 TMDL Allocations 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 two categories. When implemented, these allocations are expected to result in attainment of fecal coliform water quality criteria supportive of the shellfish harvesting designated use.

Since the load reductions calculated in this document were based on the 90th percentile water quality criterion, the reductions target those critical events that occur infrequently and reflect the fact that control measures for bacterial loads are needed in order to protect water quality during the more extreme events. Extreme events are often a result of hydrologic variability, land use practices, water recreation uses, or wildlife activities. The percent reductions for each subwatershed are summarized in Table 4.7.1.

Table 4.7.1: Load Reductions

Restricted Shellfish Harvesting Area	Required Reduction
Whitehall and Meredith Creeks	90%
Mill Creek	86%
Severn River mainstem	19%

Wasteload allocations are broken down into two subcategories: allocation assigned to loads from permitted stormwater and allocations assigned to loads from municipal point source facilities. All remaining loads are attributed to the load allocation part of the TMDL. In order to achieve the respective TMDLs, equal reductions were applied to the baseline stormwater and the non-point source loads within each shellfish harvesting area. The allowable loads for the municipal point source facilities were set as equal to their baseline loads, which were based on the information provided in the existing permits (see Section 2.4). No reductions were applied to the municipal point source facilities because at 0.4% of the total Severn River mainsteam load, such controls would produce no discernable water quality benefit.

In the future, when more detailed data and information become available, MDE may revise the WLAs and LAs accordingly. The overall TMDL reductions will not change. Detailed WLAs and LAs for each of the load categories in these three subwatersheds are presented in Table 4.7.2.

Municipal Point Source Facilities

There are three municipal point source facilities (MD0021814 - Annapolis Water Reclamation Facility, MD0023523 - U. S. Naval Academy, and MD0052868 - Dreams Landing) with permits regulating the discharge of fecal coliform directly into waters affecting the Severn River mainstem. The total allowable fecal coliform load from these point sources is set as equal to the baseline load of approximately 2.41×10^{10} counts per day and will be included in the Severn River mainstem WLA.

NPDES Regulated Stormwater

The Department applies EPA's requirement that "stormwater discharges that are regulated under Phase I or Phase II of the NPDES storm water program are point sources that must be included in the WLA portion of a TMDL" (USEPA 2002). Those sources allocated to the Stormwater WLA category of this TMDL include municipal separate storm sewer systems (MS4s) along with any other NPDES Phase I and Phase II stormwater entities in the watershed.

EPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (USEPA 2002). Therefore, in the Severn River watershed, bacteria loads from all regulated NPDES stormwater outfalls will be expressed as a single stormwater wasteload allocation. Upon approval of the TMDL NPDES-regulated "storm water discharge effluent limits should be expressed as best management practices or other similar requirements, rather than as numeric effluent limits" (USEPA 2002).

Given the variability among sources, runoff volumes, and pollutant loads over time, it is difficult to accurately estimate stormwater bacteria load contributions to a particular waterbody. The accuracy of the bacteria source load estimation is largely confounded by the uncertainty related to wildlife contribution; the pet contribution is also highly variable. Consequently, it was determined that both the stormwater baseline load and the stormwater WLA will be best estimated assuming equitable diffuse loads from all land use categories. The fecal coliform stormwater loads will be calculated by multiplying the appropriate diffuse load (L_D) to the specific shellfish area by the proportion of urban land.

$$SL_i = L_D * ULU_i$$

where
SL_i = NPDES regulated stormwater load from jurisdiction i
L_D = Load from diffuse sources to restricted shellfish area, including stormwater
ULU_i = Percentage of urban land use within jurisdiction i

Whitehall and Meredith Creeks, Mill Creek, and the Severn River mainstem are all located in Anne Arundel County, which is a Phase I permitted jurisdiction (permit number: MD0068306). In addition to Anne Arundel County, other entities residing in the watershed are also regulated as part of the NPDES stormwater program. Based on Maryland Department of Planning urban land use classification, the loads allocated to the Whitehall and Meredith Creeks, Mill Creek, and the Severn River mainstem stormwater permitted areas are calculated as 27.86%, 50.53%, and 47.59%, respectively, of the allowable diffuse loads. Details of the calculations can be found in Appendix B.

Table 4.7.2: Summary of Load Allocations and Reductions

Watershed	Baseline Category	Baseline Load (counts per day)	TMDL Category	Allowable Load (counts per day)	Reduction
Whitehall and Meredith Creeks	Non-point Source Load	3.55×10^{11}	LA	3.55×10^{10}	90%
	Stormwater Load	1.37×10^{11}	Stormwater WLA	1.37×10^{10}	90%
Mill Creek	Non-point Source Load	8.81×10^{11}	LA	1.23×10^{11}	86%
	Stormwater Load	8.99×10^{11}	Stormwater WLA	1.26×10^{11}	86%
Severn River Mainstem	Non-point Source Load	3.17×10^{12}	LA	2.57×10^{12}	19%
	Stormwater Load	2.88×10^{12}	Stormwater WLA	2.33×10^{12}	19%
	WWTP Load	2.41×10^{10}	WWTP WLA	2.41×10^{10}	0%

4.8 Margin of Safety

An MOS is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of the pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

For TMDL development, the MOS needs to be incorporated to account for uncertainty due to model parameter selection. The decay rate is one of the most sensitive parameters in the model. For a given system, the higher the decay rate, the higher the assimilative capacity. The value of the decay rate varies from 0.7 to 3.0 per day in salt water (Mancini 1978; Thomann and Mueller 1987). A decay rate of 0.7 per day 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 3 municipal point source facilities (MD0021814 - Annapolis Water Reclamation Facility, MD0023523 - U. S. Naval Academy, and MD0052868 - Dreams Landing) with permits regulating the discharge of fecal coliform directly into waters affecting the Severn River mainstem. The fecal coliform baseline loads from these point sources under 90th percentile scenario are 2.24×10^{10}, 1.72×10^{9}, and 3.45×10^{7} counts per day, respectively (for details see Table 2.4.2). These baseline loads of approximately 2.41×10^{10} counts per day are included in the WLA for the Severn River mainstem without any reductions. In order to meet the most stringent criterion (i.e., the 90th percentile) equal reductions were applied to the baseline stormwater and the non-point source loads within each shellfish harvesting area. The TMDLs are summarized as follows:

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

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Whitehall and Meredith Creeks	**4.92×10^{10}**	**=**	**3.55×10^{10}**	**+**	**1.37×10^{10}**	**+**	**N/A**	**+**	**Implicit**
Mill Creek	**2.49×10^{11}**	**=**	**1.23×10^{11}**	**+**	**1.26×10^{11}**	**+**	**N/A**	**+**	**Implicit**
Severn River mainstem	**4.92×10^{12}**	**=**	**2.57×10^{12}**	**+**	**2.35×10^{12}**	**+**	**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 assurance 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 the watershed analysis (see Table 2.4.1) may be used as a tool to target and prioritize initial implementation efforts. The iterative approach towards 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 Section 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 Section 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 (e.g., Severn Rives shellfish harvesting area between Old Severn River Bridge and the mouth) are expected to remain restricted. Existence of such restrictions does not necessarily mean that the area is not meeting water quality standards.

Additional monitoring will include bacteria source tracking, which will be used to confirm the source estimates presented in this document. Bacteria source tracking will be completed according to the tentative schedule posted on MDE's website, http://www.mde.state.md.us:8001/assets/document/BST_schedule.pdf. Results of these studies may be used as an additional tool to further guide implementation efforts.

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. Model Development

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

Figure A-1 is the model grid that consists of 1750 grid cells. To better distribute flow and loads, the watershed is segmented into 28 subwatersheds. A Cartesian grid was used for the model to represent the River. The model domain extends downstream and includes Whitehall and Meredith Creeks and Mill Creek. In order to better simulate estuarine circulation, 3 different layers are used to represent the vertical dimension of the model. Fecal coliform is simulated using a conservative tracer with first-order decay. The decay rate varies from 0.7 to 3.0 per day in salt water (Mancini 1978; Thomann and Mueller 1987). A decay rate of 0.7 per day was used as a conservative estimate in this TMDL study.

The Severn River is a tidal river. The dominant tidal constituent is the lunar semi-diurnal tide. To simulate the tide correctly, a calibration of the mean tide was conducted. The model was forced by an M_2 tide with a mean tidal range of 0.25 m at the mouth. The model results are compared with National Oceanic and Atmospheric Administration (NOAA) predicted tides at five stations inside the Severn River (NOAA 2006). Station locations are shown in Figure A-2. The results are listed in Table A-1, and they demonstrate that the model simulates the mean tidal range well.

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

Station	Modeled Range (m)	NOAA Predicted Range (m)
Bay Ridge	0.245	0.244
Greenbury Point Shoal Light	0.242	0.243
Annapolis (US Naval Academy)	0.243	0.296
Brewer Point	0.241	0.244
Cedar Point	0.238	0.213

Because there are not enough real-time observation data of stream flow, tide, salinity, and wind available in the Severn River sufficient to conduct real-time model calibration, a comparison of real-time salinity simulation against the observed salinity cannot be performed. Therefore, the model calibration for the mean condition of salinity distribution was performed to reproduce the averaged salinity distribution at 7 stations along the river. The locations of these stations are shown in Figure A-2. For the mean salinity calibration, the dominant M_2 tidal frequency with a mean tidal range was used as a forcing at the model open boundary. Mean salinity measured at the station nearest the mouth was used as the salinity boundary condition. The quantity of freshwater discharged from each subwatershed was estimated according to the average long-term flow from the USGS gage station 01589795 (South Fork Jabez Branch at Millersville, MD). The flow of each subwatershed was estimated based on the ratio of the subwatershed area to the drainage basin area of the USGS gage. The mean flows used for the model calibration are listed in Table A-2 below for the subwatersheds shown in Figure A-1. A comparison of model results of salinity against observations is shown in Figure A-3, which demonstrates that the model simulated salinity distribution well in the estuary.

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

Table A-2: Estimated Mean Flows of Subwatersheds in the Severn River

Subwatershed	Mean Flow (cms)[1]	Subwatershed	Mean Flow (cms)
1	0.3481	15	0.0436
2	0.0232	16	0.0388
3	0.0246	17	0.0171
4	0.0085	18	0.0070
5	0.0051	19	0.0097
6	0.0182	20	0.0169
7	0.0375	21	0.0302
8	0.0185	22	0.0342
9	0.0645	23	0.0160
10	0.0468	24	0.0296
11	0.0196	25	0.0240
12	0.0174	26	0.0278
13	0.0135	27	0.0099
14	0.0385	28	0.0113

[1] **CMS = Cubic meters per second**

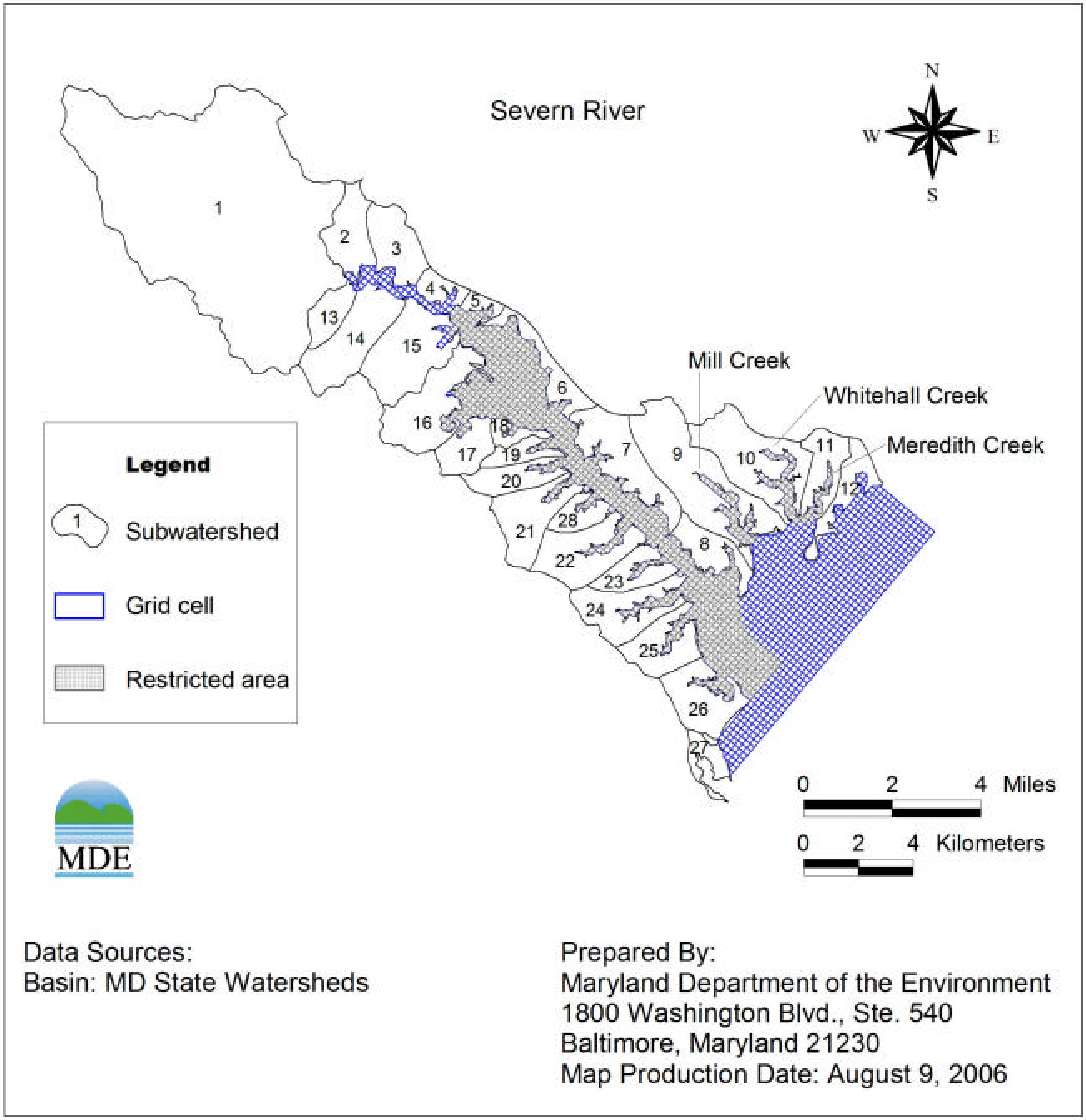

Figure A-1: HEM-3D Grid Cells and Subwatersheds in the Severn River

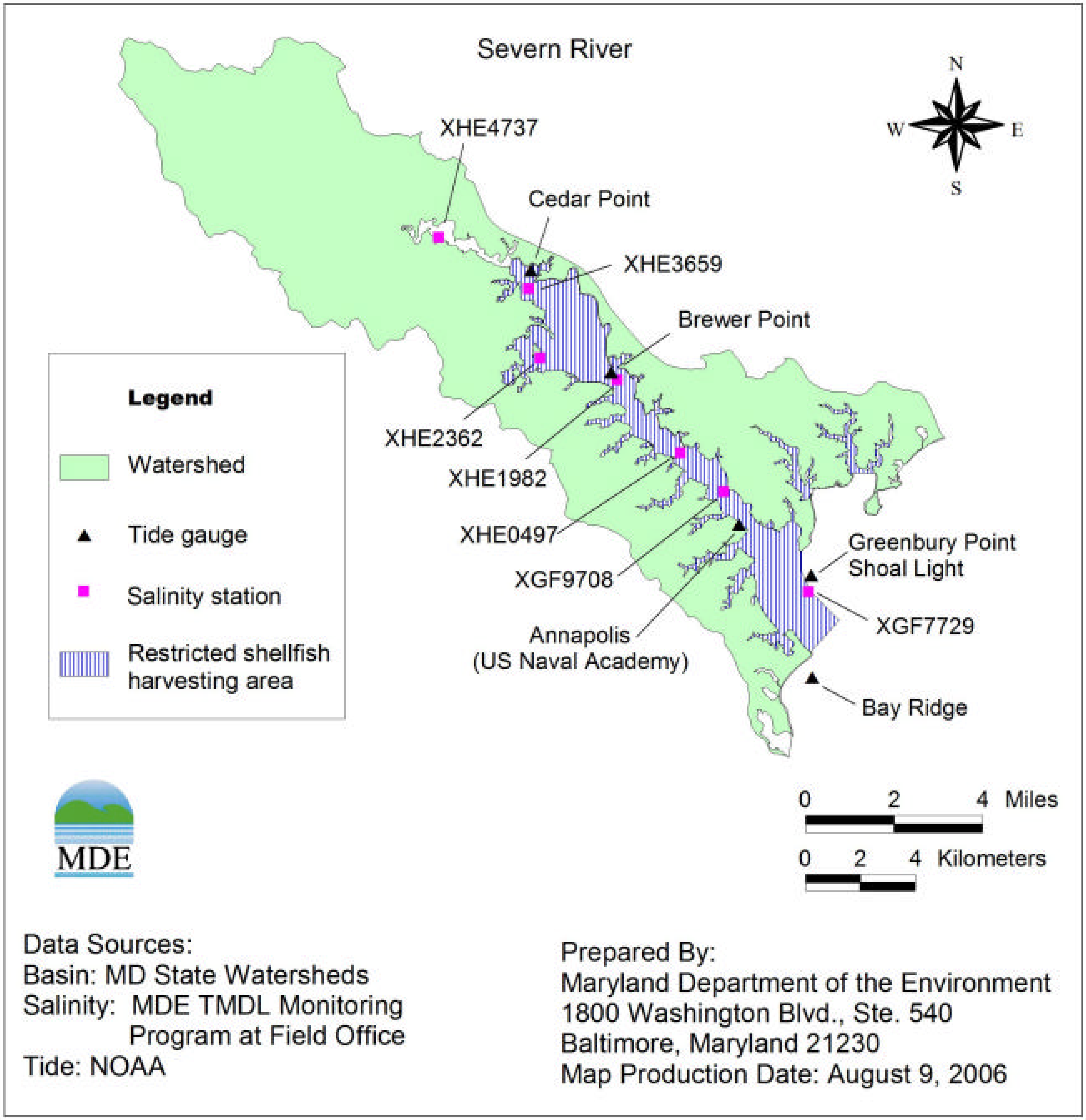

Figure A-2: Tide and Salinity Stations of the Severn River Used in Model Calibration

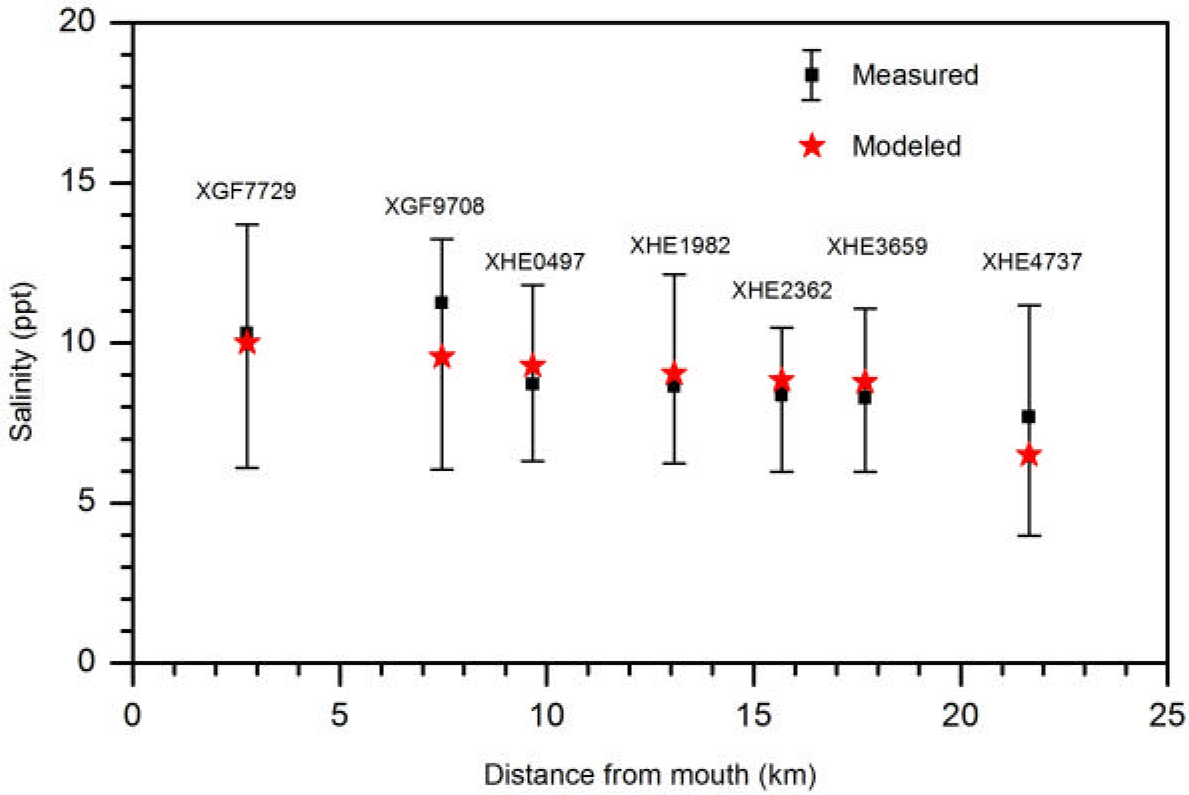

Figure A-3: Comparison of Measured and Calculated Salinities

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

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

subject to

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

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

where $\boldsymbol{J}$ is a goal or cost function; b * $=(\beta_1,\beta_2, ...,\beta_m)$ is the optimal parameter (i.e., loads); b$_{\mathbf{0}}$ is an acceptable set of loads. **F** is transport function. Different methods can be used to characterize the noninferior solutions. Choosing a weighted least-square criterion to measure the data misfit, the scalar cost function is then defined as follows:

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

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

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

Equation (4) can be written as:

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

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

The fecal coliform loads discharged to the river originate from 28 subwatersheds, as shown in Figure A-1. For the estimation of existing median loads, the model was forced by an M_2 tidal frequency with mean tidal range and mean salinity at the mouth. The mean freshwater inflows from the subwatersheds are discharged into the river. A set of initial loads from 28 subwatersheds was estimated in proportion to the area of the subwatersheds and discharged to the river. The inverse model was executed for 10 days to reach equilibrium and the maximum concentration on the last day was used to calculate the cost function against the observed median along the river. The modified Newton method was used to update the loads until the cost function reached its minimum.

Figures A-4 and A-5 show the model results of the simulated median and 90th percentile, respectively. It can be seen that the model results are satisfactory. The existing loads for each subwatershed are listed in Tables A-3-1 through A-3-3.

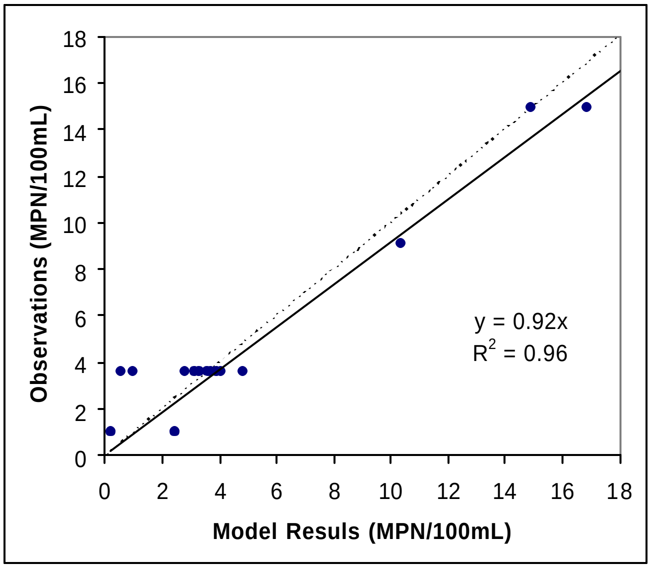

Figure A-4: Comparison of Model Results vs. Observations of Median Concentration

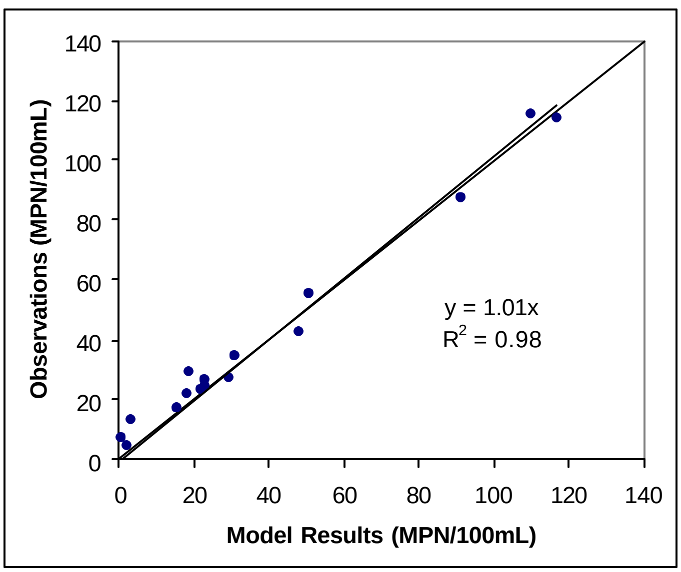

Figure A-5: Comparison of Model Results vs. Observations of 90th Percentile Concentration

Table A-3-1: TMDL Calculation Results for Whitehall and Meredith Creeks

Subwatersheds	Median			90th Percentile		
	Allowable Load* Counts/day	Current Load Counts/day	Percent Reduction	Allowable Load Counts/day	Current Load Counts/day	Percent Reduction
10 and 11	1.95E+10	5.67E+10	65.5%	4.92E+10	4.92E+11	90.0%

Table A-3-2: TMDL Calculation Results for Mill Creek

Subwatersheds	Median			90th Percentile		
	Allowable Load* Counts/day	Current Load Counts/day	Percent Reduction	Allowable Load Counts/day	Current Load Counts/day	Percent Reduction
9	1.84E+11	6.13E+11	70.0%	2.49E+11	1.78E+12	86.0%

Table A-3-3: TMDL Calculation Results for Severn River Mainstem

Subwatersheds	Median			90th Percentile		
	Allowable Load* Counts/day	Current Load Counts/day	Percent Reduction	Allowable Load Counts/day	Current Load Counts/day	Percent Reduction
1,2,3,4,5,13, 14,and 15	3.15E+10	1.02E+11	69.3%	3.63E+11	1.51E+12	76.0%
Other subwatersheds	3.76E+11	3.76E+11	0.0%	4.56E+12	4.56E+12	0.0%
TOTALS	4.08E+11	4.79E+11	14.8%	4.92E+12	6.07E+12	18.9%

For the TMDL calculation, the existing 90th percentile loads and median loads corresponding to the drainage area associated with the locations where violation occurred were reduced until the restricted shellfish harvesting area met water quality standards. Load reductions were not calculated for the small creeks located inside the restricted shellfish harvesting area where no violations have been reported. In those areas, the existing load is the same as the allowable load. The total loads reported are grouped based on the drainage areas associated with different sections of the river. Model results show that the upstream portion of the Severn River watershed required load reductions in subwatersheds 1, 2, 3, 4, 5, 13, 14, and 15 in order to meet the water quality standards. Reductions were not needed in subwatersheds 16 to 26, 6 to 8, and 28, which are associated with the downstream portion of the Severn River, since no water quality violations were reported. For the Whitehall and Meredith Creeks, load reductions from subwatersheds 10 and 11 were needed. The existing and allowable loads are listed in Table A-3. Because the loads from subwatersheds 12, 9, and 27 are either located downstream of the Severn River or discharged directly into the Chesapeake Bay, the loads from these three subwatersheds are not listed in Table A-3.

By comparing the reductions required for the median and 90th percentile, one can see that the 90th percentile requires the largest reduction. Therefore, these reductions will be applied in the subwatersheds. The allowable loads and required reductions for the restricted areas are listed in Table A-4.

Table A-4: Load Allocation and Reduction by Subwatershed

Subwatershed	Load Allocation (Counts/day)	Required Reduction (Percent)
Whitehall and Meredith Creeks	4.92E+10	90.0%
Mill Creek	2.49E+11	86.0%
Severn River mainstem	4.92E+12	18.9%

Appendix B. Stormwater Calculation Procedure

The fecal coliform stormwater load is estimated based on the proportion of urban land within the permitted County in the watershed. To estimate this load, the load from diffuse sources is multiplied by the proportion of urban land, and the resulting value is assigned to the stormwater WLA.

$SL_i = L_D * ULU_i$

where
SL_i = NPDES regulated stormwater load from jurisdiction i
L_D = Load from diffuse sources to restricted shellfish area, including stormwater
ULU_i = Percentage of urban land use within jurisdiction i

Stormwater Loading Estimates

Table B-1 through Table B-12 summarize the following information for each watershed: 1) the MDP land use distribution by land use code, 2) the urban/non-urban land use distribution by acreage, 3) the urban/non-urban land use distribution by percentage, and 4) the stormwater waste load allocation.

Table B-1: MDP Land Use Distribution for Whitehall and Meredith Creeks

Land Use Code	Classification	Total (acres)	Area within Anne Arundel County (acres)
11	Low-density residential	647.0	647.0
12	Medium-density residential	158.0	158.0
13	High-density residential	3.5	3.5
14	Commercial	86.6	86.6
16	Institutional	5.4	5.4
18	Open urban land	14.0	14.0
21	Cropland	961.5	961.5
23	Orchards/vineyards/horticulture	13.7	13.7
41	Deciduous forest	1,022.7	1,022.7
43	Mixed forest	13.9	13.9
44	Brush	4.5	4.5
50	Water	351.3	351.3
	Total	3,282.1	3,282.1

Table B-2: Urban/Non-urban Land Use Distribution at Whitehall and Meredith Creeks

Stormwater Class	Total (acres)	Area within Anne Arundel County (acres)
Non-urban	2,367.6	2,367.6
Urban	914.5	914.5
Total	3,282.1	3,282.1

Table B-3: Urban/Non-urban Land Use Distribution (percentage) at Whitehall and Meredith Creeks

Stormwater Class	Total (percent)	Area within Anne Arundel County (percent)
Non-urban	72.14%	72.14%
Urban	27.86%	27.86%
Total	100.00%	100.00%

Table B-4: Stormwater Waste Load Allocation at Whitehall and Meredith Creeks

Whitehall and Meredith Creeks	L_D (MPN/day)	Stormwater WLA (MPN/day)	LA (MPN/day)
Median	1.95E+10	5.43E+09	1.41E+10
90th percentile	4.92E+10	1.37E+10	3.55E+10

Table B-5: MDP Land Use Distribution for Mill Creek

Land Use Code	Classification	Total (acres)	Area (acres)
11	Low-density residential	1,051.8	1,051.8
12	Medium-density residential	364.9	364.9
13	High-density residential	119.1	119.1
14	Commercial	107.8	107.8
16	Institutional	80.8	80.8
18	Open urban land	72.0	72.0
21	Cropland	287.2	287.2
22	Pasture	104.3	104.3
41	Deciduous forest	991.0	991.0
43	Mixed forest	60.4	60.4
44	Brush	7.8	7.8
50	Water	291.9	291.9
60	Wetlands	5.7	5.7
80	Transportation	10.2	10.2
	Total	3,555.0	3,555.0

Table B-6: Urban/Non-urban Land Use Distribution at Mill Creek

Stormwater Class	Total (acres)	Area within Anne Arundel County (acres)
Non-urban	1,758.5	1,758.5
Urban	1,796.5	1,796.5
Total	3,555.0	3,555.0

Table B-7: Urban/Non-urban Land Use Distribution (percentage) at Mill Creek

Stormwater Class	Total (Percent)	Area within Anne Arundel County (Percent)
Non-urban	49.47%	49.47%
Urban	50.53%	50.53%
Total	100.00%	100.00%

Table B-8: Stormwater Waste Load Allocation at Mill Creek

Mill Creek	L_D (MPN/day)	Stormwater WLA (MPN/day)	LA (MPN/day)
Median	1.84E+11	9.30E+10	9.10E+10
90th percentile	2.49E+11	1.26E+11	1.23E+11

Table B-9: MDP Land Use Distribution for Severn River Mainstem

Land Use Code	Classification	Total (acres)	Area within Anne Arundel County (acres)
11	Low-density residential	8,191.6	8,191.6
12	Medium-density residential	6,807.9	6,807.9
13	High-density residential	1,489.5	1,489.5
14	Commercial	1,702.5	1,702.5
15	Industrial	207.3	207.3
16	Institutional	1,699.3	1,699.3
18	Open urban land	839.7	839.7
21	Cropland	2,126.0	2,126.0
22	Pasture	652.2	652.2
23	Orchards/vineyards/horticulture	4.6	4.6
25	Row and garden crops	10.1	10.1
41	Deciduous forest	3,598.6	3,598.6
42	Evergreen forest	453.8	453.8
43	Mixed forest	9,136.6	9,136.6
44	Brush	128.1	128.1
50	Water	6,740.4	6,740.4
60	Wetlands	75.2	75.2
73	Bare ground	18.1	18.1
80	Transportation	77.5	77.5
241	Feeding operations	9.6	9.6
242	Agricultural buildings	29.0	29.0
	Total	43,997.6	43,997.6

Table B-10: Urban/Non-urban Land Use Distribution in Severn River Mainstem

Stormwater Class	Total (acres)	Area within Anne Arundel County (acres)
Non-urban	23,059.8	23,059.8
Urban	20,937.8	20,937.8
Total	43,997.6	43,997.6

Table B-11: Urban/Non-urban Land Use Distribution (percentage) in Severn River Mainstem

Stormwater Class	Total (percent)	Area within Anne Arundel County (percent)
Non-urban	52.41%	52.41%
Urban	47.59%	47.59%
Total	100.00%	100.00%

Table B-12: Stormwater Waste Load Allocation in Severn River Mainstem

Severn River mainstem	L_D[1] (MPN/day)	Stormwater WLA (MPN/day)	LA (MPN/day)
Median	4.01E+11	1.91E+11	2.10E+11
90th percentile	4.90E+12	2.33E+12	2.57E+12

[1] Value excludes point source loading

Appendix C. Nonpoint Source Assessment

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

In order to determine the sources of fecal coliform, the reductions needed to achieve water quality criteria, and to allocate fecal coliform loads, it is necessary to identify all existing sources. The nonpoint source assessment was conducted using available data collected throughout the watershed. The data used for source assessment are:

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

In the Severn River Basin, wildlife contributions, both mammalian and avian, are natural conditions and may represent a background level of bacterial loadings. Livestock contributions, such as those from mammalian and avian livestock, mainly result from surface runoff. Pet contributions usually occur through runoff from streets and land. There is a lack of information available for the discharge from boats, and it is assumed that the human loading results from failures in septic systems. The major nonpoint source contributions assessed for the restricted shellfish area in the Severn River basin are summarized in Table C-1. The potential nonpoint sources were grouped into four categories: wildlife; human; pets; and livestock. Due to insufficient data sources, the source assessment method does not account for boat discharge, resuspension from bottom sediment, and the potential for regrowth of fecal coliform in the embayment.

Table C-1: Summary of Nonpoint Sources

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

A. Wildlife Contributions

Fecal coliform loadings from wildlife can be from excretion on land that is subject to runoff or direct deposition into the stream. In general, it is assumed that the wildlife species existent in the watershed include beaver, deer, goose, duck, swan, muskrat, raccoon, and wild turkey. In the Severn River watershed, the inclusion of other wildlife species such as squirrels, rabbits, and small birds was considered, but due to a lack of available population density data as well as associated fecal coliform production rates, these species were not included in the fecal coliform load calculations. Wildlife populations within the watershed were estimated based on a combination of information from the Maryland DNR Wildlife and Heritage Service (DNR 2003) and from habitat information listed in the Virginia Dodd Creek watershed fecal coliform TMDL report (VADEQ 2002). Habitat density results were reviewed by the Maryland Department of Natural Resources, and are listed in Table C-2.

Table C-2: Wildlife Habitat and Densities

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

[1] VADEQ (2002) [2] DNR (2003)

The habitat areas for each species were determined using ArcView GIS with the 2000 MDP land use data and EPA reach coverage. The GIS tool was applied to the land use coverage to create a habitat area for each of the wildlife types listed in Table C-2. For the deer population, the total number was estimated based on the deer density in each land use category (DNR 2004). For goose and duck populations, the totals estimated were obtained from GIS data provided by the Maryland DNR (DNR 2005). In other terms, the wildlife populations were obtained by applying animal density factors to estimated habitat areas. The fecal coliform contributions were calculated based on the estimated number of wildlife and their associated fecal coliform production rates, which are listed in Table C-3. To obtain the total wildlife contribution, population density was multiplied by the applicable acreage or stream miles and that product was multiplied by the fecal coliform production rates for each animal.

Table C-3: Wildlife Fecal Coliform Production Rates

Source	Fecal Coliform Production (counts/animal/day)
Beaver[1]	2.50E+08
Deer[1]	5.00E+08
Goose[2]	2.43E+09
Duck[1]	2.43E+09
Swan[5]	2.43E+09
Muskrat[3]	3.40E+07
Raccoon[3]	1.00E+09
Wild turkey[4]	9.30E+07

[1]USEPA 2000 [2]Duck rate used (USEPA 2000)
[3]Kator and Rhodes 1996 [4]ASAE 1998 [5]Duck rate used (USEPA 2000)

B. Human Contributions

Human loadings can result from failures in septic systems as well as possible discharges from recreational vessels in the identified restricted shellfish harvesting area. This study assumes that septic systems represent the only source of human contribution. Although recreational vessels might be an additional human source, correct quantification of this source is difficult. Thus, the estimation of human contribution is based on human population, number of properties, the estimated number of septic systems in the watershed, and an estimated septic system failure rate.

The human population and the number of households were estimated from the GIS 2000 Census Block that includes the Severn River Basin (USDOC 2000). Since the Severn River subwatersheds analyzed in the study are a sub-area of the Census Block, the GIS tool was used to extract this area from the appropriate 2000 Census Block. The percentage of the subwatershed area relative to the total area of the 2000 Census Block was calculated. This percentage was applied to partition the total census block population and total census block number of households in proportion to the population within the area of each of the subwatersheds. The results are shown in Table C-4.

Table C-4: Proportional Population, Households, and Septic Systems in Severn River

Area Name	Sub Area	Proportional Population	Proportional Septic Systems	Proportional Households	Public Sewer
Severn River	1250	37,222	2883	12,736	Partial
	1270	9,886	1105	3,374	Partial
	1282	4,248	1688	1,625	Partial
	1289	1,707	289	634	Partial
	1298	2,537	1185	978	Partial
	1309	4,990	720	1,741	Partial
	1310	3,271	1384	1,142	Partial
	1311	3,020	749	1,054	Partial
	1319	45,484	2182	18,278	Partial

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

The estimated fecal coliform loading from humans was calculated as follows:

$$Load = P\ S\ F_r\ C\ Q\ C_V$$

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

The number of people using each septic system is estimated by the ratio of the population to the number of septic systems. In the absence of shoreline sanitary survey data, the estimated septic system failure rate of 3% for coastal restricted shellfish harvesting areas was used. This rate is in the same range as that in the upper Chesapeake Bay (De Walle 1981; USEPA 2006). It was assumed that wastewater for each person was 70 gallons per day with a fecal coliform concentration of 1×10^5 most probable number (MPN)/100ml. The estimated load from septic system failure is less than 1.5 % of the total load.

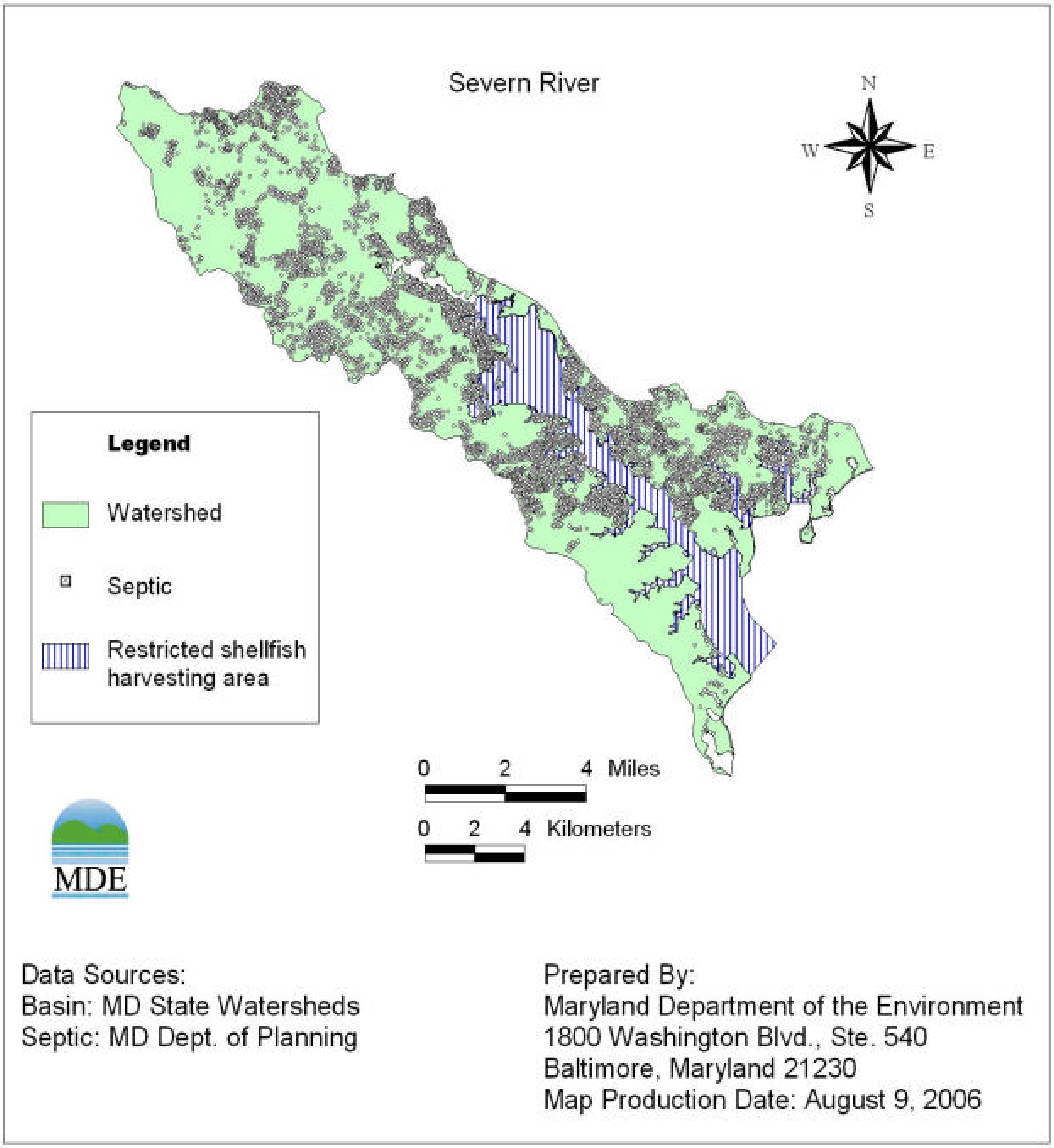

Figure C-1: Distribution of Septic Systems in the Severn River Watershed

C. Pet Contributions

Pet contributions usually occur through runoff from either an urban or a low-density residential area. Dogs are the only domestic pets assumed to contribute fecal coliform. Dog license information can be obtained from the county; however, these data will not include feral or unlicensed pets. This is likely to cause an underestimation of the total population. Therefore, the dog population for the restricted shellfish harvesting area in the Severn River mainstem watershed was estimated based on the number of households (see Table C-4). According to a survey of Chesapeake Bay area residents conducted by the Center for Watershed Protection, about 41% of the households own a dog. Only about 56% of these dog owners walk their dogs, and of that group only 59% clean up most of the time (i.e., 41% do not) (Swann 1999). The estimated total load available for wash off is 23% (i.e., 56% x 41%). The fecal coliform contribution from the dog population was estimated using a production rate of 5×10^9 counts/dog/day (USEPA 2000, 2001). Using information from Table C-4, fecal coliform loading from dogs is calculated as follows:

$$LOADING_{dog} = P\ R_1\ R_2\ R_3\ PR_{dog}$$

where:
P = number of households in specified restricted area
R_1 = ratio of dogs per household in this region
R_2 = percentage of owners that walk their dogs
R_3 = percentage of walked dogs contributing fecal matter
PR_{dog} = average fecal coliform production rate for dogs

D. Livestock Contributions

The fecal coliform contribution from livestock may occur through manure spreading practices and direct deposition during grazing. This contribution was estimated based on land use data and the Maryland livestock census data (Brodie and Lawrence 1996; USDA 1997a,b; MDA 2002a,b). Animal ratio estimators for the 8-digit watersheds were developed based on the finest resolution of animal counts available – statewide, region or county. These Maryland 8-digit watershed livestock animal counts were then proportioned to the sub-watersheds using the procedure outlined in Figure C-2. The fecal coliform load was estimated based on the total number of livestock and their fecal coliform production rates.

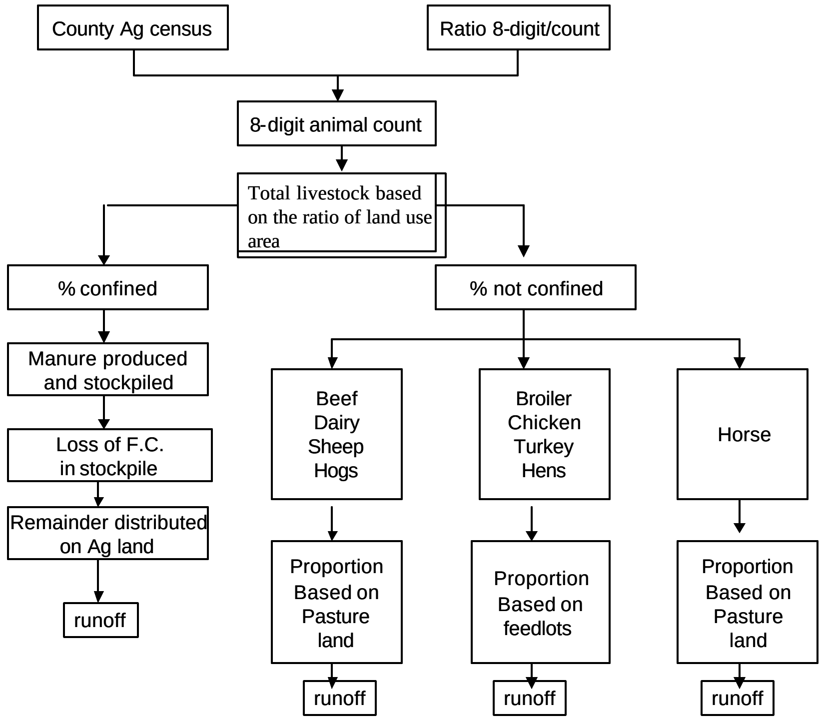

Figure C-2: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population

Fecal coliform production rates used to estimate loadings are listed in Table C-5. The estimated fecal coliform produced by animals was divided into manure spreading and direct deposition, depending on the percent of time they are confined. The percent of time livestock is confined is listed in Table C-6. The estimated percentage of manure available for wash off is about 40% (VIMS 2004). For chickens, however, only about 10% is available for wash off (VIMS 2002-2004). Therefore, fecal coliform decay is also considered in the estimation of fecal coliform production. The percent of fecal coliform available for wash off from manure spreading in the field is also listed in Table C-6.

Table C-5: Livestock Fecal Coliform Production Rates

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

Table C-6: Percent of Time Livestock is Confined

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

E. Nonpoint Source Summary

The complete distributions of these source loads are also listed in Table C-7, along with counts/day for each loading. The Bacteria Source Tracking data, when it becomes available, will be used to further confirm the source distribution.

Table C-7: Distribution of Fecal Coliform Source Loads in the Severn River Basin

Subwatershed	Fecal Coliform Source	Loading (Counts/day)	Loading (Percent)
1250	Livestock	1.39E+11	1.99%
	Pets	6.01E+12	85.96%
	Human	6.70E+10	0.96%
	Wildlife	7.75E+11	11.09%
	Total	6.99E+12	100.00%
1270	Livestock	2.46E+10	1.36%
	Pets	1.59E+12	87.99%
	Human	2.57E+10	1.42%
	Wildlife	1.67E+11	9.23%
	Total	1.81E+12	100.00%
1282	Livestock	3.83E+10	3.46%
	Pets	7.66E+11	69.31%
	Human	3.51E+10	3.17%
	Wildlife	2.66E+11	24.06%
	Total	1.11E+12	100.00%
1289	Livestock	7.28E+09	0.42%
	Pets	2.99E+11	17.32%
	Human	6.18E+09	0.36%
	Wildlife	1.41E+12	81.90%
	Total	1.73E+12	100.00%

Subwatershed	Fecal Coliform Source	Loading (Counts/day)	Loading (Percent)
1298	Livestock	2.52E+10	3.22%
	Pets	4.61E+11	59.03%
	Human	2.44E+10	3.13%
	Wildlife	2.71E+11	34.62%
	Total	7.81E+11	100.00%
1309	Livestock	3.57E+10	1.43%
	Pets	7.60E+11	30.46%
	Human	1.66E+10	0.67%
	Wildlife	1.68E+12	67.45%
	Total	2.49E+12	100.00%
1310	Livestock	1.93E+10	1.03%
	Pets	7.18E+11	38.36%
	Human	3.19E+10	1.70%
	Wildlife	1.10E+12	58.90%
	Total	1.87E+12	100.00%
1311	Livestock	2.68E+10	1.86%
	Pets	3.78E+11	26.26%
	Human	1.73E+10	1.20%
	Wildlife	1.02E+12	70.68%
	Total	1.44E+12	100.00%
1319	Livestock	8.39E+10	0.82%
	Pets	8.62E+12	83.87%
	Human	4.32E+10	0.42%
	Wildlife	1.53E+12	14.89%
	Total	1.03E+13	100.00%
Total	Livestock	4.00E+11	1.40%
	Pets	1.96E+13	68.79%
	Human	2.67E+11	0.94%
	Wildlife	8.23E+12	28.87%
	Total	2.85E+13	100.00%

Appendix D. 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 EPA also requires that these TMDL studies take into account seasonal variations. The consideration of critical condition and seasonal variation is to account for the hydrologic and source variations. The intent of the requirements is to ensure that the water quality of the water body is protected during the most vulnerable times.

In the Chesapeake Bay region, both fecal coliform sources and delivery vary seasonally due to changes in hydrological conditions and land use practices. The most probable fecal coliform sources are runoff from agricultural practices and livestock, wildlife, and developed areas. Precipitation and temperature fluctuate seasonally, producing varied stream flow and surface runoff that serve as a delivery mechanism for fecal coliform, as well as seasonal changes in vegetation. Vegetation, particularly in pastureland and agricultural buffer zones, is very important for trapping and preventing fecal coliform from entering waters by both decreasing surface runoff and absorbing fecal coliform. Warm-blooded animals, the sources of fecal coliform, are directly or indirectly connected with vegetation productivity via food chain relationships. In temperate forests, for example, wildlife are active during summer and fall due to ample food supply, resulting in increased fecal coliform production, and the probability of their direct contact with receiving waters is comparatively high during warm seasons. The seasonal variation of fecal coliform concentrations 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. In croplands, fecal coliform discharge is often related to the timing of crop planting and fertilization. Manure application during crop planting may increase the risk of exceeding fecal coliform standards in the receiving water. Such seasonal changes in both the sources and the delivery mechanisms of fecal coliform may lead to obvious seasonal patterns in fecal coliform concentration in the shellfish growing areas.

The 5-year monthly mean fecal coliform concentration and its standard deviation were calculated for the sixteen monitoring stations used in this report. The results are presented in Figure D-1 through Figure D-16. It is shown that high concentrations occur in September in the Whitehall and Meredith Creeks and Mill Creek restricted shellfish harvesting areas and between April and November in the Severn River mainstem restricted shellfish harvesting area, with peaks occurring at several stations in the month of September. Although seasonal distributions vary from one month to the next, a large standard deviation that corresponds to a high fecal coliform concentration variability at each station suggests that the violations may frequently occur in a few months of the year.

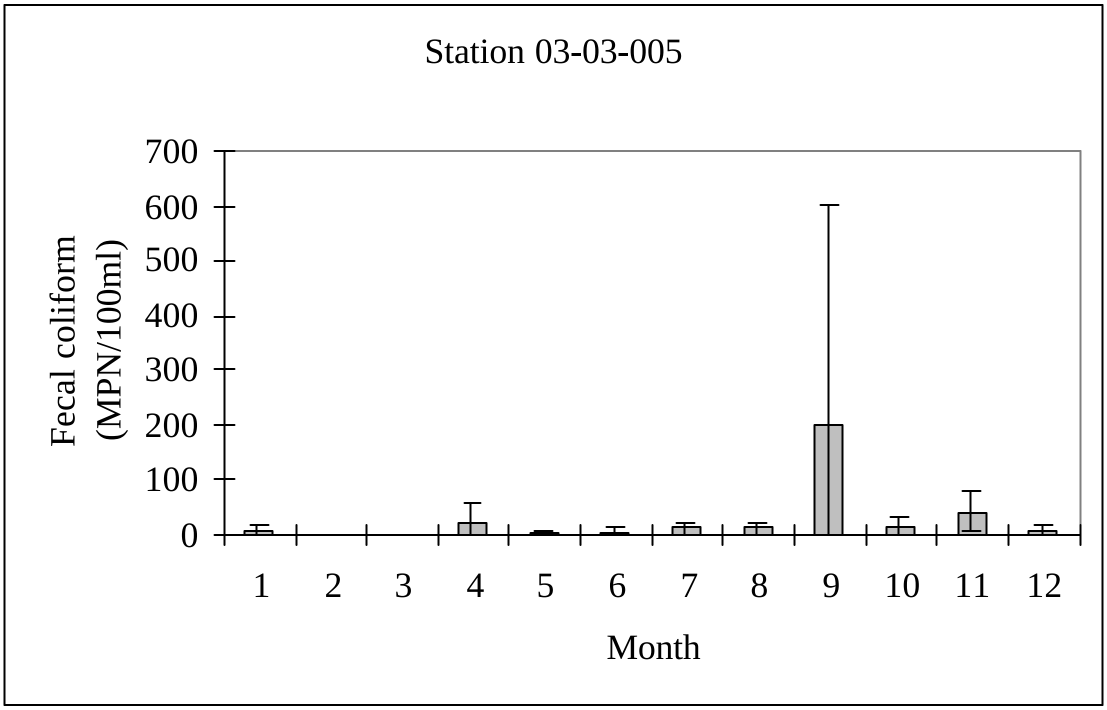

Figure D-1: Seasonality Analysis of Fecal Coliform at Whitehall Creek Station 03-03-005

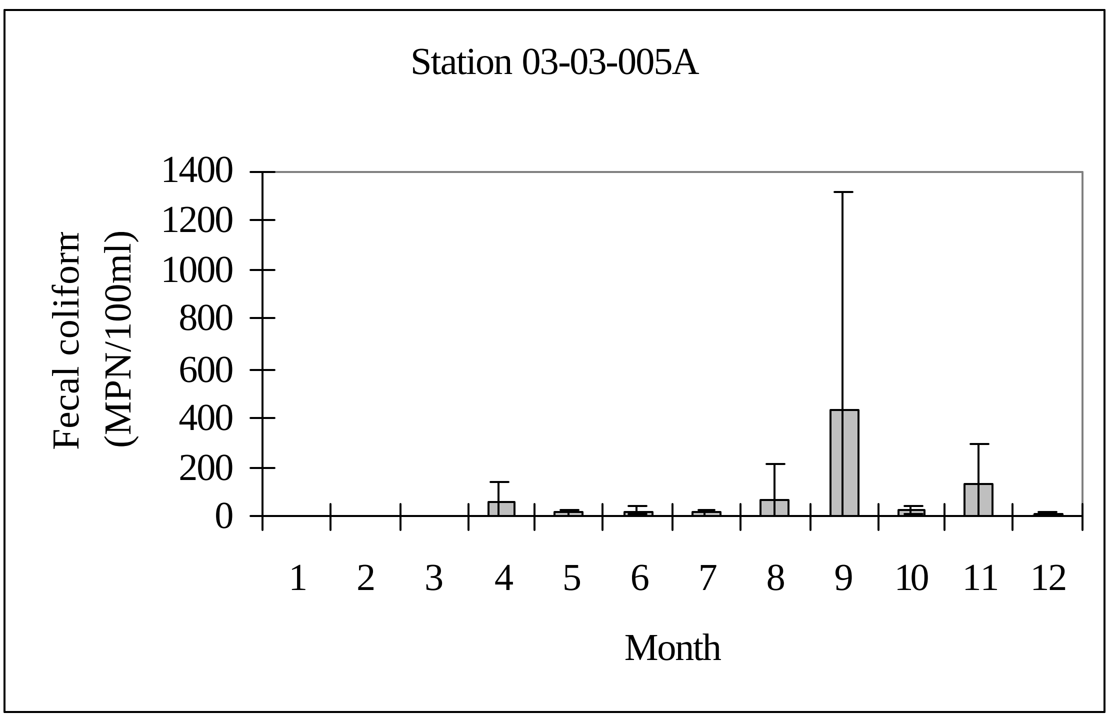

Figure D-2: Seasonality Analysis of Fecal Coliform at Meredith Creek Station 03-03-005A

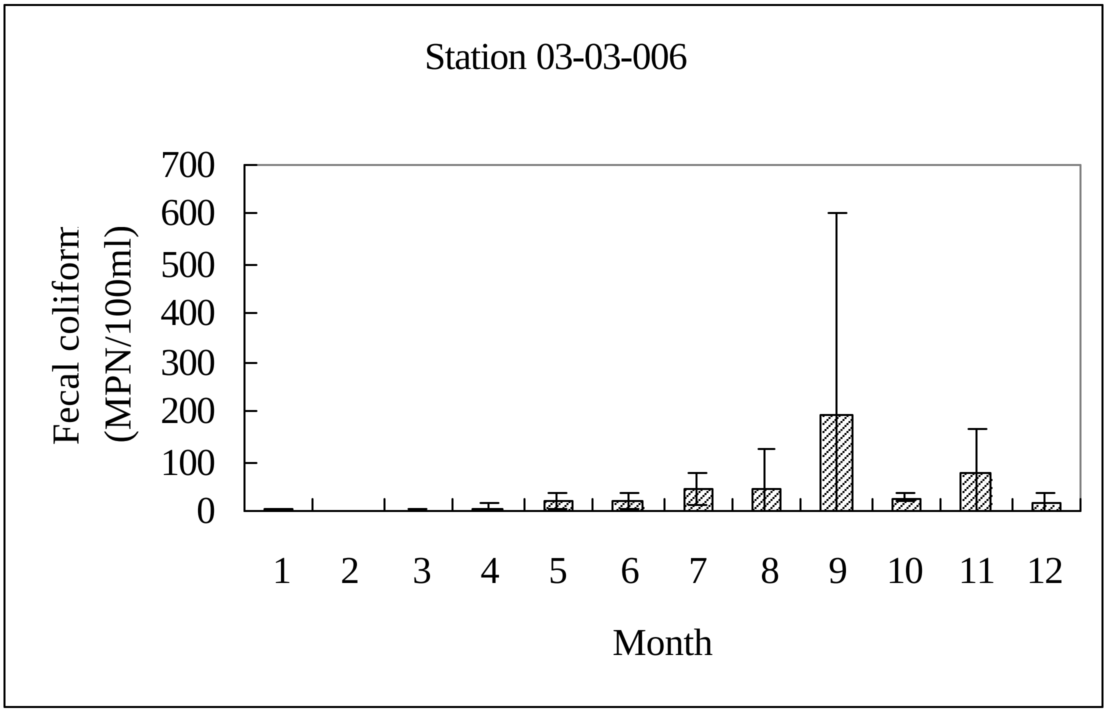

Figure D-3: Seasonality Analysis of Fecal Coliform at Mill Creek Station 03-03-006

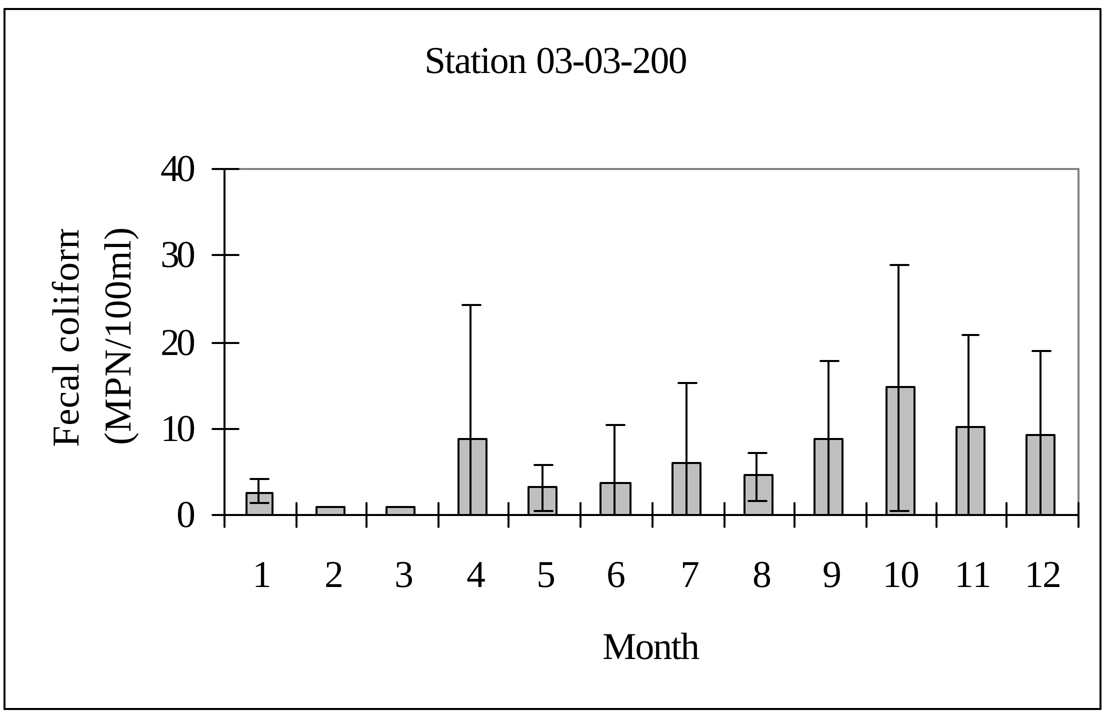

Figure D-4: Seasonality Analysis of Fecal Coliform at Severn River Station 03-03-200

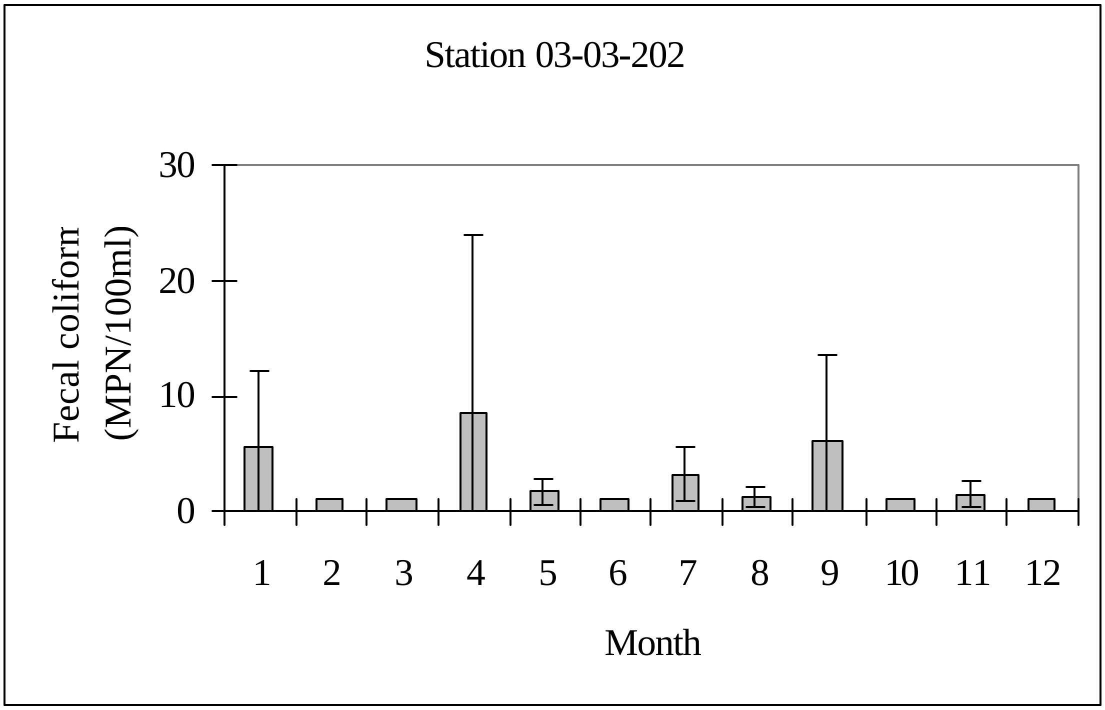

Figure D-5: Seasonality Analysis of Fecal Coliform at Severn River Station 03-03-202

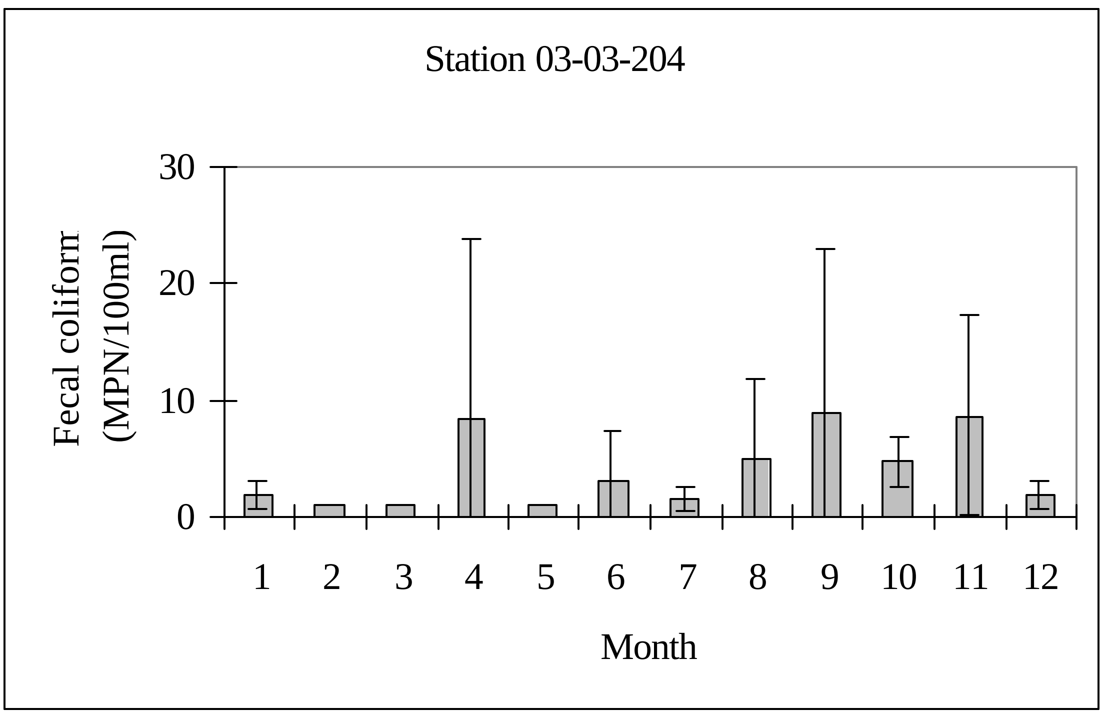

Figure D-6: Seasonality Analysis of Fecal Coliform at Severn River Station 03-03-204

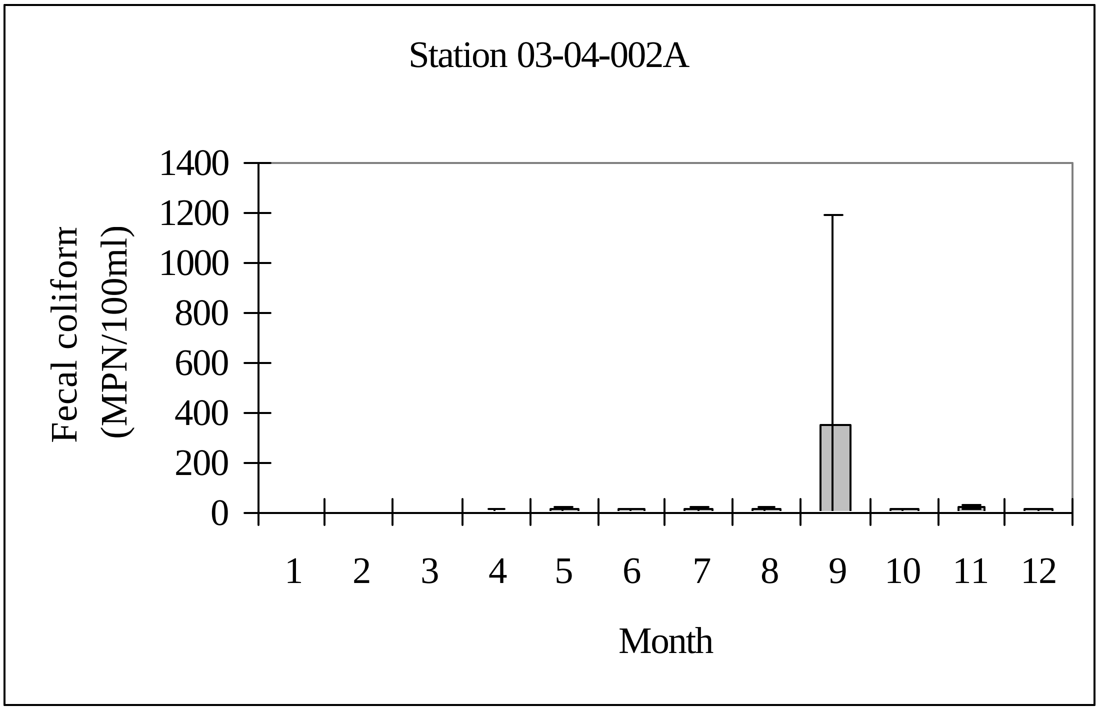

Figure D-7: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-002A

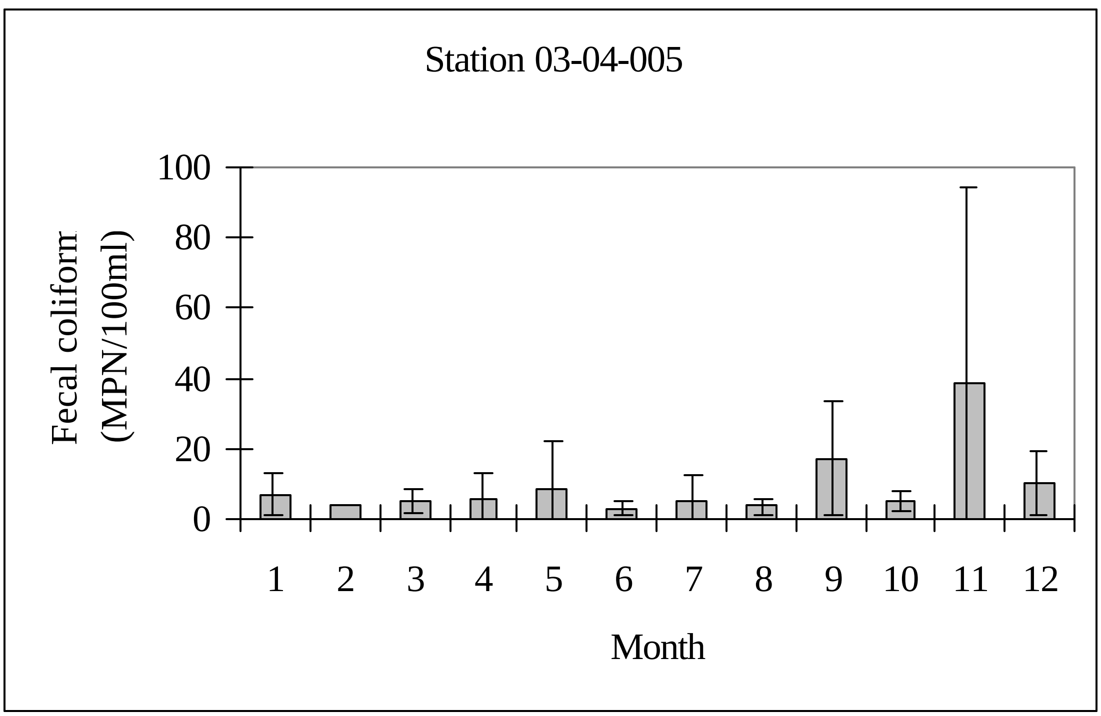

Figure D-8: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-005

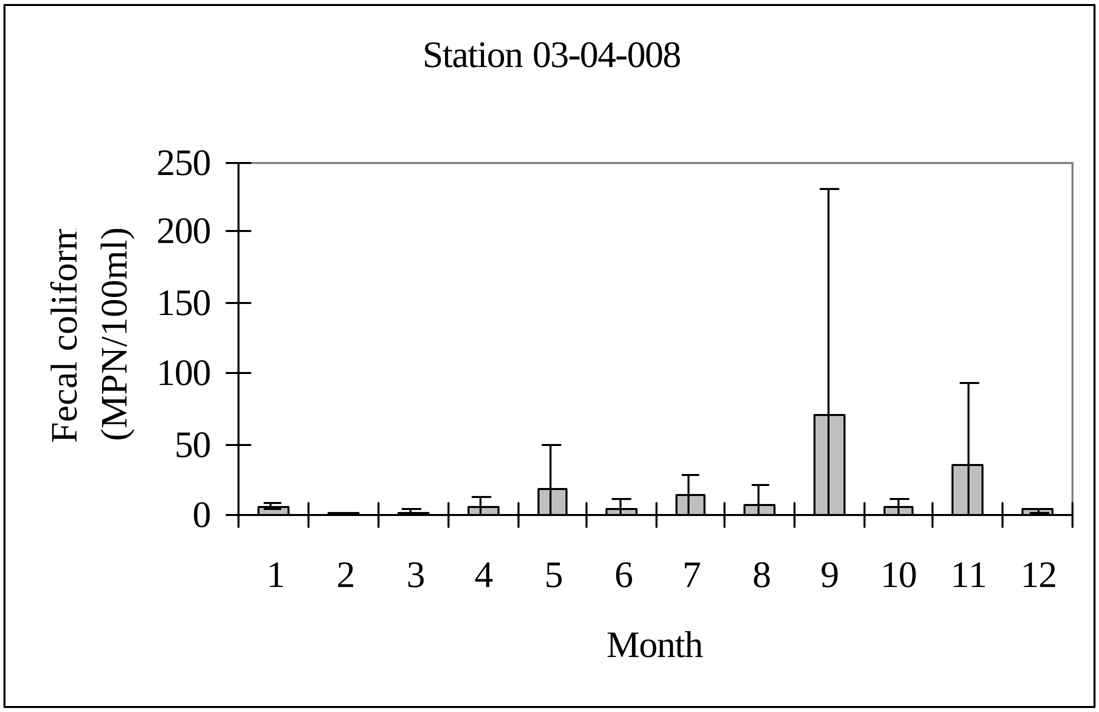

Figure D-9: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-008

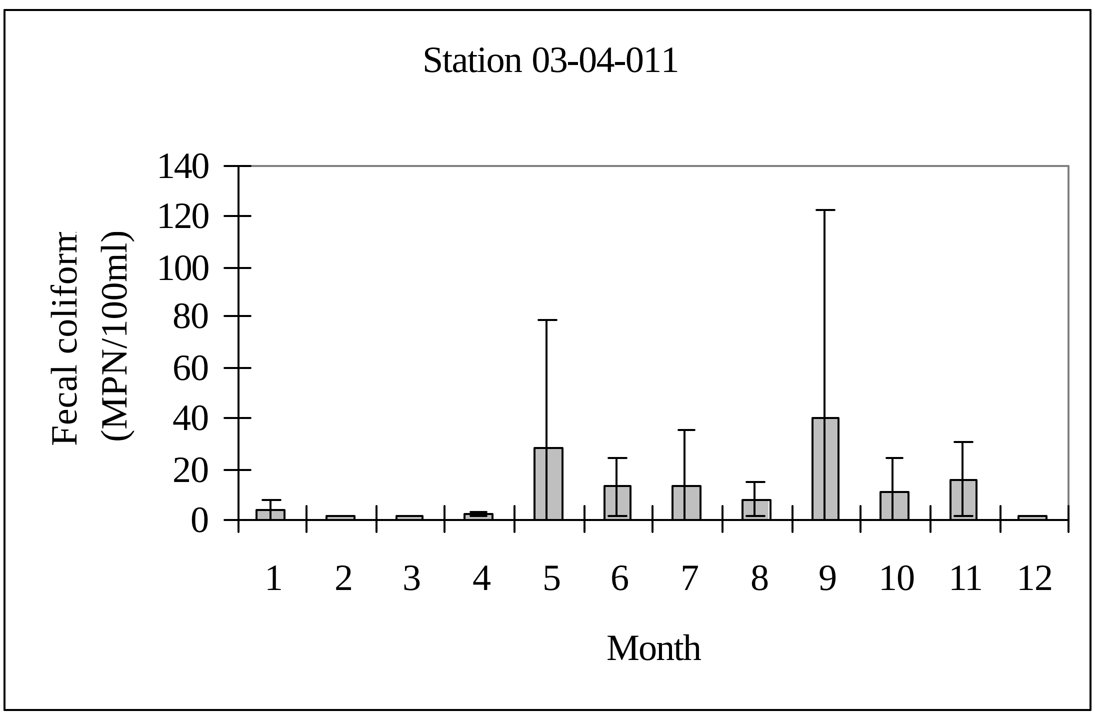

Figure D-10: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-011

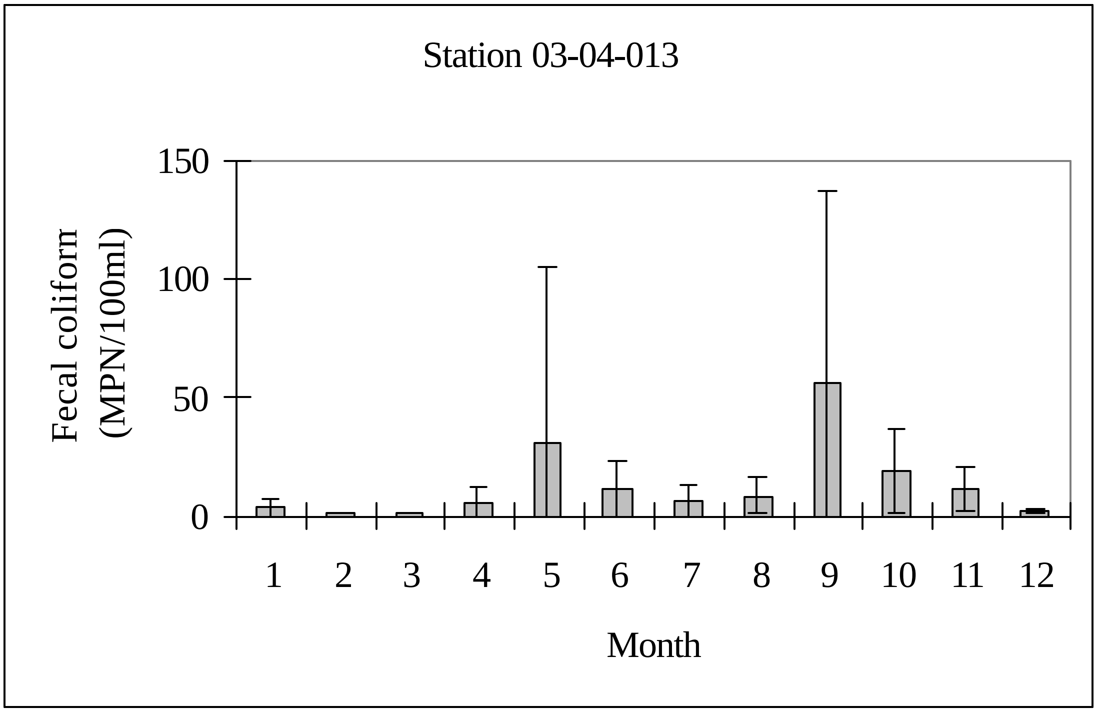

Figure D-11: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-013

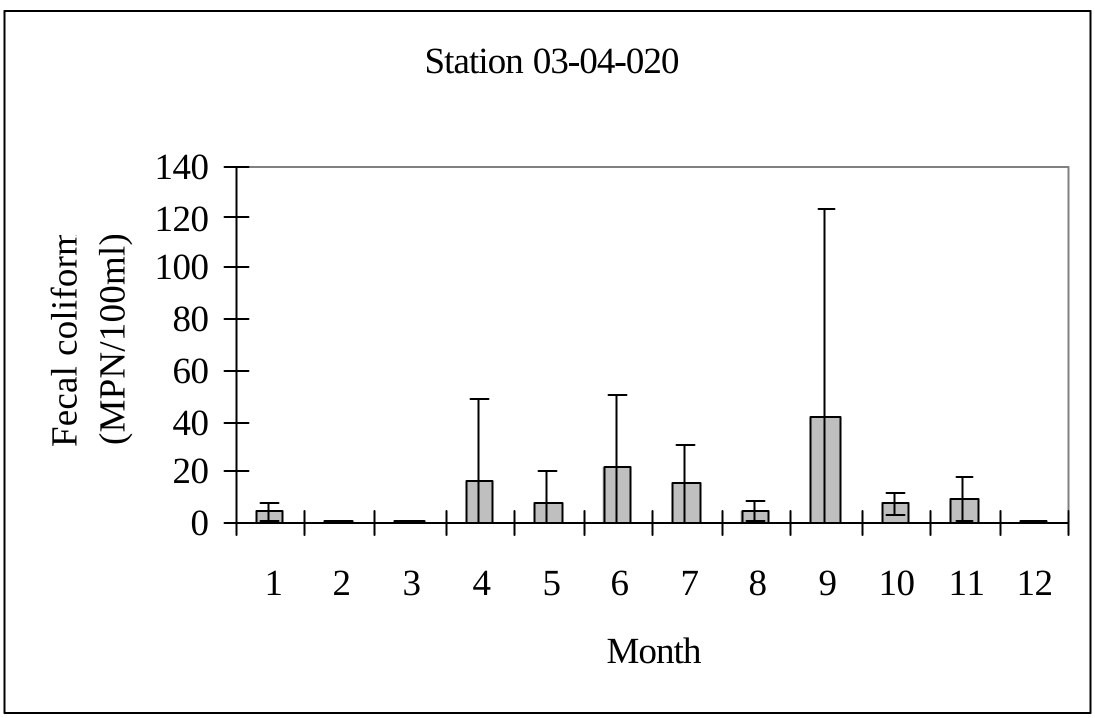

Figure D-12: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-020

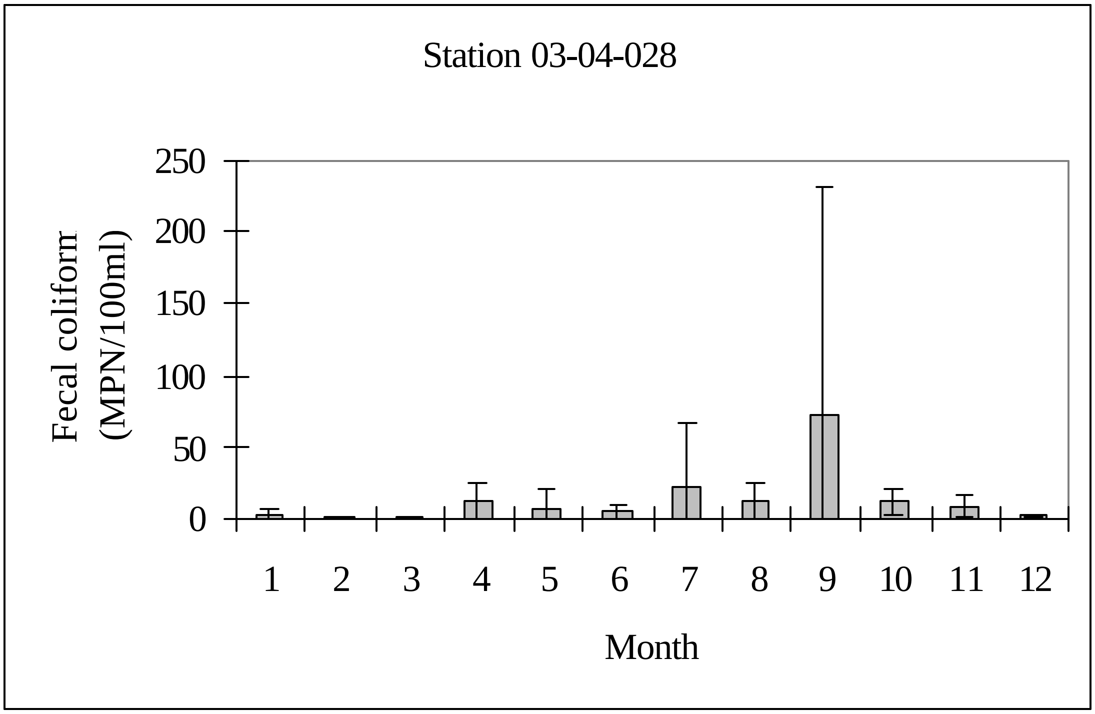

Figure D-13: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-028

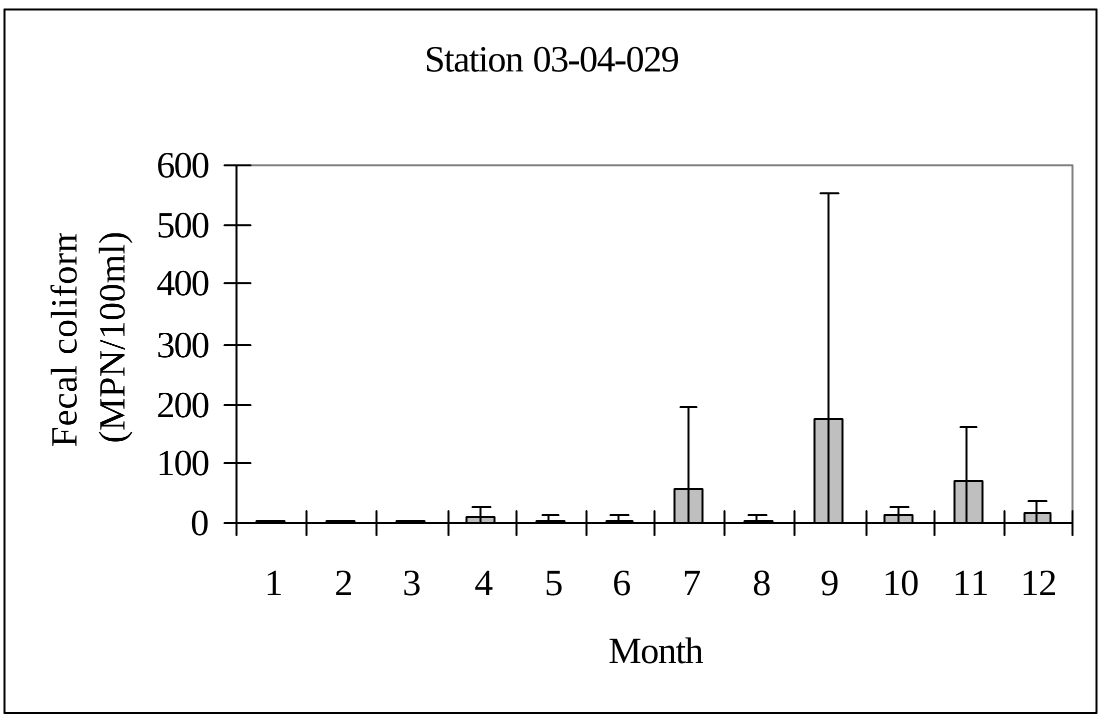

Figure D-14: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-029

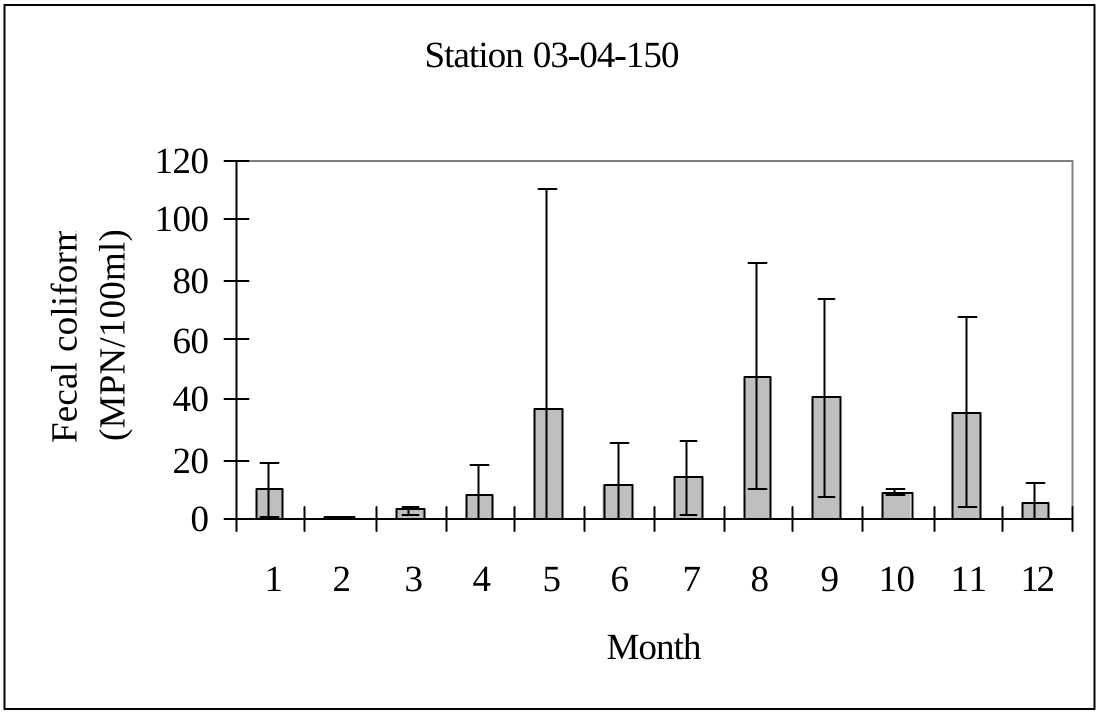

Figure D-15: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-150

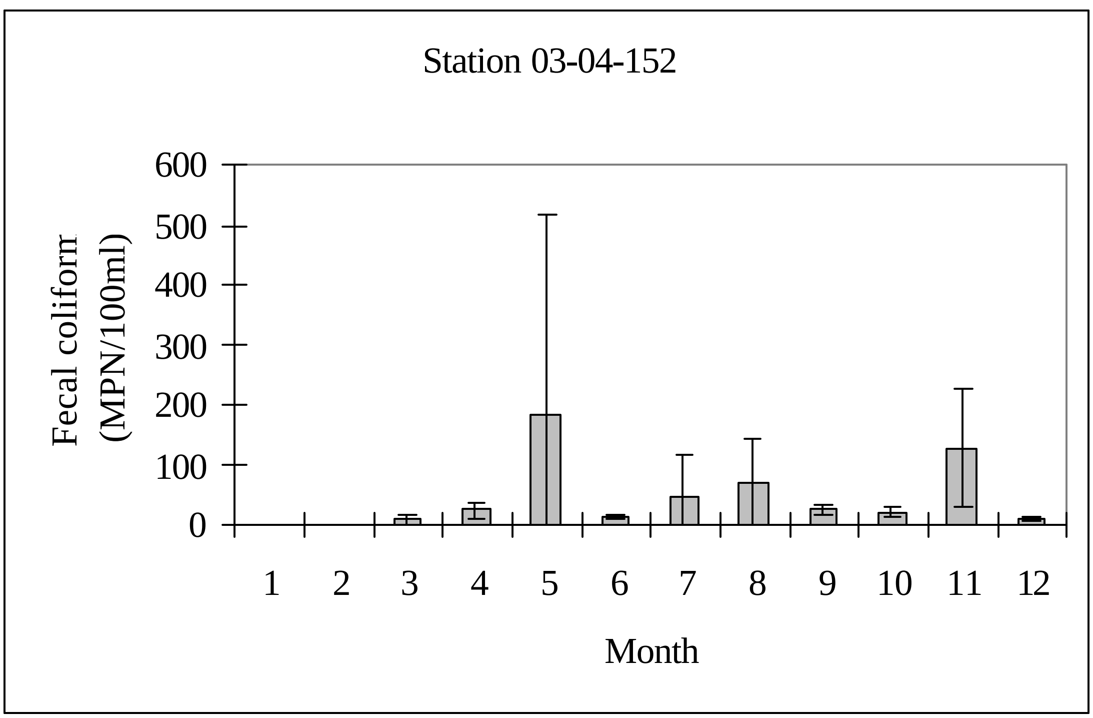

Figure D-16: Seasonality Analysis of Fecal Coliform at Severn River Station 03-04-152

Appendix E. Tabulation of Fecal Coliform Data

This appendix provides tabulations of fecal coliform values for the monitoring stations of the restricted shellfish harvesting areas in (1) Whitehall and Meredith Creeks, (2) Mill Creek, and (3) the Severn River mainstem portion of the Severn River Basin in Tables E-1 through E-16. These data are plotted in report Figures 2.2.2 through 2.2.3, 2.2.5, and 2.2.7 through 2.2.19.

Table E-1: Observed Fecal Coliform Data at Whitehall Creek Station 03-03-005

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	1	3/13/2003	1
8/3/2000	3.6	4/22/2003	9.1
8/17/2000	15	5/20/2003	3.6
9/7/2000	23	6/17/2003	3.6
10/5/2000	43	7/7/2003	9.1
11/13/2000	3.6	7/21/2003	43
12/5/2000	1	7/30/2003	1
2/8/2001	1	8/5/2003	3.6
5/1/2001	3	8/19/2003	9.1
5/15/2001	3.6	9/3/2003	23
6/19/2001	9.1	10/1/2003	3.6
7/23/2001	11	11/18/2003	3.6
8/6/2001	1	1/6/2004	23
9/5/2001	15	3/10/2004	1
9/19/2001	7.3	4/21/2004	1
10/2/2001	23	5/27/2004	3.6
12/4/2001	23	6/2/2004	3.6
1/22/2002	1	6/16/2004	15
3/11/2002	1	6/30/2004	1
4/4/2002	1	8/5/2004	1
4/16/2002	1	8/23/2004	23
4/30/2002	43	9/30/2004	1100
5/15/2002	3.6	10/13/2004	1
6/4/2002	3.6	11/8/2004	75
6/18/2002	1	11/29/2004	93
7/2/2002	3.6	1/4/2005	3.6
7/15/2002	23	3/16/2005	1
7/24/2002	3.6	4/5/2005	93
8/6/2002	39	5/3/2005	9.1
9/4/2002	23	5/23/2005	9.1
10/2/2002	9.1	6/2/2005	14
11/12/2002	43	6/20/2005	9.1
12/17/2002	1	7/6/2005	15

Table E-2: Observed Fecal Coliform Data at Meredith Creek Station 03-03-005A

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	9.1	3/13/2003	1
8/3/2000	460	4/22/2003	3.6
8/17/2000	23	5/20/2003	1
9/7/2000	43	6/17/2003	23
10/5/2000	43	7/7/2003	15
11/13/2000	9.1	7/21/2003	43
12/5/2000	1	7/30/2003	3.6
2/8/2001	1	8/5/2003	15
5/1/2001	9.1	8/19/2003	43
5/15/2001	3.6	9/3/2003	9.1
6/19/2001	43	10/1/2003	3.6
7/23/2001	7.3	11/18/2003	43
8/6/2001	1	1/6/2004	1
9/5/2001	21	3/10/2004	3.6
9/19/2001	1	4/21/2004	3.6
10/2/2001	43	5/27/2004	9.1
12/4/2001	21	6/2/2004	3.6
1/22/2002	3.6	6/16/2004	9.1
3/11/2002	1	6/30/2004	39
4/4/2002	3.6	8/5/2004	9.1
4/16/2002	3	8/23/2004	15
4/30/2002	240	9/30/2004	2400
5/15/2002	43	10/13/2004	39
6/4/2002	43	11/8/2004	43
6/18/2002	23	11/29/2004	460
7/2/2002	1	1/4/2005	1
7/15/2002	23	3/16/2005	1
7/24/2002	15	4/5/2005	93
8/6/2002	23	5/3/2005	7.3
9/4/2002	150	5/23/2005	43
10/2/2002	23	6/2/2005	43
11/12/2002	93	6/20/2005	1
12/17/2002	23	7/6/2005	43

Table E-3: Observed Fecal Coliform Data at Mill Creek Station 03-03-006

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	93	3/13/2003	1
8/3/2000	240	4/22/2003	3.6
8/17/2000	23	5/20/2003	23
9/7/2000	1	6/17/2003	3.6
10/5/2000	23	7/7/2003	43
11/13/2000	3.6	7/21/2003	7.3
12/5/2000	1	7/30/2003	39
2/8/2001	1	8/5/2003	23
5/1/2001	43	8/19/2003	9.1
5/15/2001	3.6	9/3/2003	3.6
6/19/2001	23	10/1/2003	23
7/23/2001	93	11/18/2003	23
8/6/2001	43	1/6/2004	3.6
9/5/2001	43	3/10/2004	3.6
9/19/2001	3.6	4/21/2004	3.6
10/2/2001	43	5/27/2004	23
12/4/2001	43	6/2/2004	9.1
1/22/2002	7.3	6/16/2004	43
3/11/2002	1	6/30/2004	43
4/4/2002	3.6	8/5/2004	3.6
4/16/2002	1	8/23/2004	6.2
4/30/2002	23	9/30/2004	1100
5/15/2002	43	10/13/2004	23
6/4/2002	3.6	11/8/2004	240
6/18/2002	15	11/29/2004	93
7/2/2002	7.3	1/4/2005	1
7/15/2002	23	3/16/2005	1
7/24/2002	23	4/5/2005	9.1
8/6/2002	43	5/3/2005	9.1
9/4/2002	23	5/23/2005	3.6
10/2/2002	23	6/2/2005	23
11/12/2002	23	6/20/2005	9.1
12/17/2002	7.3	7/6/2005	75

Table E-4: Observed Fecal Coliform Data at Severn River Station 03-03-200

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	3.6	4/22/2003	3.6
8/3/2000	3.6	5/20/2003	3.6
8/17/2000	3.6	6/17/2003	1
9/7/2000	3.6	7/7/2003	1
10/5/2000	9.1	7/21/2003	1
11/13/2000	23	7/30/2003	1
12/5/2000	3.6	8/5/2003	7.3
2/8/2001	1	8/19/2003	1
5/1/2001	3.6	9/3/2003	1
5/15/2001	1	9/17/2003	3.6
6/19/2001	23	10/1/2003	3.6
7/23/2001	1	11/18/2003	1
8/6/2001	9.1	1/6/2004	3.6
9/5/2001	3.6	3/10/2004	1
9/19/2001	3.6	4/21/2004	3.6
10/2/2001	43	5/27/2004	9.1
12/4/2001	23	6/2/2004	3.6
1/22/2002	1	6/16/2004	1
3/11/2002	1	6/30/2004	1
4/4/2002	1	8/5/2004	7.3
4/16/2002	1	8/23/2004	1
4/30/2002	1	9/30/2004	23
5/15/2002	1	10/13/2004	9.1
6/4/2002	1	11/8/2004	23
6/18/2002	1	11/29/2004	3.6
7/2/2002	1	1/4/2005	3.6
7/15/2002	1	3/16/2005	1
7/24/2002	23	4/5/2005	43
8/6/2002	3.6	5/3/2005	3.6
9/4/2002	23	5/23/2005	1
10/2/2002	9.1	6/2/2005	1
11/12/2002	1	6/20/2005	1
12/17/2002	1	7/6/2005	23
3/13/2003	1		

Table E-5: Observed Fecal Coliform Data at Severn RiverStation 03-03-202

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	1	4/22/2003	3.6
8/3/2000	1	5/20/2003	1
8/17/2000	1	6/17/2003	1
9/7/2000	9.1	7/7/2003	1
10/5/2000	1	7/21/2003	3.6
11/13/2000	1	7/30/2003	3.6
12/5/2000	1	8/5/2003	1
2/8/2001	1	8/19/2003	1
5/1/2001	1	9/3/2003	1
5/15/2001	1	9/17/2003	1
6/19/2001	1	10/1/2003	1
7/23/2001	3.6	11/18/2003	1
8/6/2001	1	1/6/2004	15
9/5/2001	1	3/10/2004	1
9/19/2001	3.6	4/21/2004	1
10/2/2001	1	5/27/2004	3.6
12/4/2001	1	6/2/2004	1
1/22/2002	1	6/16/2004	1
3/11/2002	1	6/30/2004	1
4/4/2002	1	8/5/2004	3.6
4/16/2002	1	8/23/2004	1
4/30/2002	1	9/30/2004	23
5/15/2002	3.6	10/13/2004	1
6/4/2002	1	11/8/2004	3.6
6/18/2002	1	11/29/2004	1
7/2/2002	1	1/4/2005	1
7/15/2002	9.1	3/16/2005	1
7/24/2002	3.6	4/5/2005	43
8/6/2002	1	5/3/2005	1
9/4/2002	3.6	5/23/2005	1
10/2/2002	1	6/2/2005	1
11/12/2002	1	6/20/2005	1
12/17/2002	1	7/6/2005	3
3/13/2003	1		

Table E-6: Observed Fecal Coliform Data at Severn River Station 03-03-204

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	1	3/13/2003	1
8/3/2000	3.6	4/22/2003	1
8/17/2000	3.6	5/20/2003	1
9/7/2000	1	6/17/2003	1
10/5/2000	3.6	7/7/2003	3.6
11/13/2000	7.3	7/21/2003	1
12/5/2000	1	7/30/2003	1
2/8/2001	1	8/5/2003	3.6
5/1/2001	1	8/19/2003	1
5/15/2001	1	9/3/2003	3
6/19/2001	15	9/17/2003	1
7/23/2001	1	10/1/2003	3.6
8/6/2001	1	1/6/2004	1
9/5/2001	3.6	3/10/2004	1
9/19/2001	1	4/21/2004	1
10/2/2001	3.6	5/27/2004	1
12/4/2001	3.6	6/2/2004	1
1/22/2002	3.6	6/16/2004	1
3/11/2002	1	6/30/2004	1
4/4/2002	1	8/5/2004	23
4/16/2002	1	8/23/2004	1
4/30/2002	3.6	9/30/2004	43
5/15/2002	1	10/13/2004	3.6
6/4/2002	3	11/8/2004	23
6/18/2002	3.6	11/29/2004	3.6
7/2/2002	1	1/4/2005	1
7/15/2002	1	3/16/2005	1
7/24/2002	3.6	4/5/2005	43
8/6/2002	3.6	5/3/2005	1
9/4/2002	9.1	5/10/2005	1
10/2/2002	9.1	6/2/2005	1
11/12/2002	1	6/20/2005	1
12/17/2002	1	7/6/2005	1

Table E-7: Observed Fecal Coliform Data at Severn River Station 03-04-002A

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	3.6	7/21/2003	3
8/3/2000	1	7/30/2003	3.6
8/17/2000	23	8/5/2003	23
9/7/2000	3.6	8/19/2003	9.1
11/13/2000	9.1	9/3/2003	15
12/5/2000	3.6	9/17/2003	1
2/8/2001	1	10/1/2003	7.3
5/1/2001	1	10/8/2003	15
5/15/2001	1	10/20/2003	9.1
5/23/2001	43	11/18/2003	9.1
6/19/2001	9.1	1/6/2004	1
7/23/2001	9.1	3/10/2004	3.6
8/6/2001	3.6	4/8/2004	3
9/5/2001	23	4/21/2004	1
9/19/2001	3.6	5/4/2004	3
10/2/2001	9.1	5/18/2004	3.6
12/4/2001	9.1	6/2/2004	1
1/22/2002	3.6	6/16/2004	9.1
3/11/2002	1	6/30/2004	1
4/16/2002	1	7/7/2004	23
4/30/2002	1	7/19/2004	1
5/15/2002	1	8/5/2004	1
6/4/2002	1	8/23/2004	9.1
6/18/2002	1	9/30/2004	2400
7/2/2002	1	10/13/2004	3.6
7/24/2002	23	11/8/2004	43
8/6/2002	23	11/29/2004	23
9/4/2002	23	1/5/2005	3.6
10/2/2002	3.6	3/16/2005	1
11/2/2002	9.1	4/5/2005	15
12/17/2002	3.6	5/3/2005	1
3/13/2003	1	5/23/2005	1
4/22/2003	3	6/2/2005	1
5/20/2003	3.6	6/20/2005	23
6/17/2003	3.6	7/6/2005	23
7/7/2003	1		

Table E-8: Observed Fecal Coliform Data at Severn RiverStation 03-04-005

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	1	7/7/2003	9.1
8/3/2000	1	7/21/2003	3.6
8/17/2000	1	7/30/2003	1
9/7/2000	3.6	8/5/2003	3.6
11/13/2000	9.1	8/19/2003	9.1
12/5/2000	3.6	9/3/2003	9.1
2/8/2001	3.6	9/17/2003	9.1
5/1/2001	1	10/1/2003	3.6
5/15/2001	1	10/8/2003	3.6
5/23/2001	20	10/20/2003	9.1
6/19/2001	3	11/18/2003	23
7/23/2001	1	1/6/2004	1
8/6/2001	3.6	3/10/2004	3.6
9/5/2001	43	4/8/2004	3.6
9/19/2001	3.6	4/21/2004	3.6
10/2/2001	9.1	5/4/2004	1
12/4/2001	3.6	5/18/2004	1
1/22/2002	3.6	6/2/2004	3
3/11/2002	3.6	6/16/2004	1
4/4/2002	3.6	6/30/2004	1
4/16/2002	1	7/7/2004	1
4/30/2002	3.6	7/19/2004	1
5/15/2002	43	8/5/2004	3.6
6/4/2002	3.6	8/23/2004	1
6/18/2002	1	9/30/2004	43
7/2/2002	1	10/13/2004	1
7/24/2002	9.1	11/8/2004	150
8/6/2002	3.6	11/29/2004	9.1
9/4/2002	9.1	1/5/2005	15
10/2/2002	3.6	3/16/2005	11
11/12/2002	1	4/5/2005	23
12/17/2002	23	5/3/2005	3.6
3/13/2003	1	5/23/2005	1
4/22/2003	1	6/2/2005	7.3
5/20/2003	3.6	6/20/2005	1
6/17/2003	3.6	7/6/2005	23

Table E-9: Observed Fecal Coliform Data at Severn RiverStation 03-04-008

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/20/2000	23	7/7/2003	1
7/13/2000	23	7/21/2003	43
8/3/2000	43	7/30/2003	23
8/17/2000	1	8/5/2003	1
9/7/2000	3.6	8/19/2003	1
11/13/2000	15	9/3/2003	3.6
12/5/2000	1	9/17/2003	1
2/8/2001	1	10/1/2003	1
5/1/2001	1	10/8/2003	3.6
5/23/2001	43	10/20/2003	1
6/19/2001	9.1	11/18/2003	1
7/23/2001	3.6	1/6/2004	3.6
8/6/2001	3.6	3/10/2004	3.6
9/5/2001	23	4/8/2004	3.6
9/19/2001	3.6	4/21/2004	1
10/2/2001	3.6	5/4/2004	1
12/4/2001	3.6	5/18/2004	1
1/22/2002	3.6	6/2/2004	1
3/11/2002	1	6/16/2004	1
4/4/2002	1	6/30/2004	1
4/16/2002	1	7/7/2004	9.1
4/30/2002	3.6	7/19/2004	3
5/15/2002	93	8/5/2004	3.6
6/4/2002	1	8/23/2004	3.6
6/18/2002	3.6	9/30/2004	460
7/2/2002	1	10/13/2004	15
7/24/2002	23	11/8/2004	150
8/6/2002	1	11/29/2004	9.1
9/4/2002	4.3	1/5/2005	9.1
10/2/2002	9.1	3/16/2005	1
11/12/2002	3.6	4/5/2005	23
12/17/2002	3.6	5/3/2005	1
3/13/2003	1	5/23/2005	1
4/22/2003	3.6	6/2/2005	1
5/20/2003	1	6/7/2005	1
6/17/2003	3.6	6/20/2005	1

Table E-10: Observed Fecal Coliform Data at Severn RiverStation 03-04-011

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/20/2000	15	6/17/2003	23
7/13/2000	1	7/7/2003	1
8/3/2000	9.1	7/21/2003	9.1
8/17/2000	23	7/30/2003	9.1
9/7/2000	3.6	8/5/2003	9.1
10/5/2000	1	8/19/2003	3.6
11/13/2000	15	9/3/2003	3.6
12/5/2000	1	9/17/2003	1
2/8/2001	1	10/1/2003	1
5/1/2001	1	10/8/2003	1
5/15/2001	1	10/20/2003	23
5/23/2001	93	11/18/2003	1
6/19/2001	9.1	1/6/2004	1
7/23/2001	3.6	3/10/2004	1
8/6/2001	1	4/8/2004	3.6
9/5/2001	1	4/21/2004	1
9/19/2001	9.1	5/4/2004	3.6
10/2/2001	39	5/18/2004	1
12/4/2001	1	6/2/2004	3.6
1/22/2002	1	6/16/2004	15
3/11/2002	1	6/30/2004	1
4/4/2002	1	7/7/2004	3.6
4/16/2002	1	7/19/2004	9.1
4/30/2002	3.6	8/5/2004	9.1
5/15/2002	150	8/23/2004	3.6
6/4/2002	3.6	9/30/2004	240
6/18/2002	9.1	10/13/2004	1
7/2/2002	3.6	11/8/2004	43
7/24/2002	75	11/29/2004	9.1
8/6/2002	3.6	1/5/2005	9.1
9/4/2002	23	3/16/2005	1
10/2/2002	7.3	4/5/2005	3.6
11/12/2002	9.1	5/3/2005	1
12/17/2002	1	5/23/2005	1
3/13/2003	1	6/2/2005	1
4/22/2003	1	6/7/2005	43
5/20/2003	1	6/20/2005	15

Table E-11: Observed Fecal Coliform Data at Severn RiverStation 03-04-013

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/20/2000	3.6	7/7/2003	1
7/13/2000	3.6	7/21/2003	3.6
8/3/2000	23	7/30/2003	1
8/17/2000	3	8/5/2003	15
9/7/2000	15	8/19/2003	1
11/13/2000	3	9/3/2003	1
12/5/2000	1	9/17/2003	3.6
2/8/2001	1	10/1/2003	3.6
5/1/2001	1	10/8/2003	43
5/15/2001	1	10/20/2003	43
5/23/2001	240	11/18/2003	1
6/19/2001	43	1/6/2004	1
7/23/2001	9.1	3/10/2004	1
8/6/2001	15	4/8/2004	1
9/5/2001	3.6	4/21/2004	3.6
9/19/2001	91	5/4/2004	3.6
10/2/2001	15	5/18/2004	23
12/4/2001	1	6/2/2004	1
1/22/2002	1	6/16/2004	9.1
3/11/2002	1	6/30/2004	1
4/4/2002	1	7/7/2004	9.1
4/16/2002	3.6	7/19/2004	23
4/30/2002	23	8/5/2004	1
5/15/2002	1	8/23/2004	3.6
6/4/2002	9.1	9/30/2004	240
6/18/2002	15	10/13/2004	3.6
7/2/2002	1	11/8/2004	23
7/24/2002	9.1	11/29/2004	23
8/6/2002	7.3	1/5/2005	9.1
9/4/2002	43	3/16/2005	1
10/2/2002	3.6	4/5/2005	3.6
11/12/2002	9.1	5/3/2005	3.6
12/17/2002	3.6	5/23/2005	7.3
3/13/2003	1	6/2/2005	3.6
4/22/2003	3.6	6/7/2005	15
5/20/2003	3	6/20/2005	1
6/17/2003	23		

Table E-12: Observed Fecal Coliform Data at Severn RiverStation 03-04-020

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	3.6	7/7/2003	23
8/3/2000	11	7/21/2003	3.6
8/17/2000	9.1	7/30/2003	43
9/7/2000	3.6	8/5/2003	3.6
10/5/2000	1	8/19/2003	1
11/13/2000	1	9/3/2003	1
12/5/2000	1	9/17/2003	23
2/8/2001	1	10/1/2003	9.1
5/1/2001	7.3	10/8/2003	9.1
5/15/2001	1	10/20/2003	9.1
5/23/2001	43	11/18/2003	9.1
6/19/2001	93	1/6/2004	3.6
7/23/2001	43	3/10/2004	1
8/6/2001	1	4/8/2004	1
9/5/2001	23	4/21/2004	1
9/19/2001	1	5/4/2004	1
10/2/2001	14	5/18/2004	1
12/4/2001	1	6/2/2004	1
1/22/2002	1	6/16/2004	1
3/11/2002	1	6/30/2004	3.6
4/4/2002	1	7/7/2004	3.6
4/16/2002	1	7/19/2004	3.6
4/30/2002	9.1	8/5/2004	9.1
5/15/2002	1	8/23/2004	1
6/4/2002	23	9/30/2004	240
6/18/2002	23	10/13/2004	1
7/2/2002	3.6	11/8/2004	15
7/24/2002	3.6	11/29/2004	23
8/6/2002	3.6	1/5/2005	9.1
9/4/2002	2.3	3/16/2005	1
10/2/2002	9.1	4/5/2005	93
11/12/2002	1	5/3/2005	1
12/17/2002	1	5/23/2005	9.1
3/13/2003	1	6/2/2005	3.6
4/22/2003	9.1	6/20/2005	43
5/20/2003	1	7/6/2005	23
6/17/2003	9.1		

Table E-13: Observed Fecal Coliform Data at Severn RiverStation 03-04-028

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	1	7/7/2003	9.1
8/3/2000	9.1	7/21/2003	1
8/17/2000	43	7/30/2003	1
9/7/2000	460	8/5/2003	9.1
10/5/2000	3	8/19/2003	1
11/13/2000	9.1	9/3/2003	3.6
12/5/2000	3.6	9/17/2003	9.1
2/8/2001	1	10/1/2003	7.3
5/1/2001	3.6	10/8/2003	3.6
5/15/2001	1	10/20/2003	15
5/23/2001	43	11/18/2003	1
6/19/2001	1	1/6/2004	9.1
7/23/2001	1	3/10/2004	1
8/6/2001	1	4/8/2004	3.6
9/5/2001	1	4/21/2004	1
9/19/2001	1	5/4/2004	1
10/2/2001	23	5/18/2004	1
12/4/2001	3.6	6/2/2004	1
1/22/2002	1	6/16/2004	1
3/11/2002	1	6/30/2004	3.6
4/4/2002	1	7/7/2004	3.6
4/16/2002	7.3	7/19/2004	3.6
4/30/2002	23	8/5/2004	3.6
5/15/2002	3.6	8/23/2004	1
6/4/2002	1	9/30/2004	9.1
6/18/2002	3.6	10/13/2004	23
7/2/2002	1	11/8/2004	3.6
7/24/2002	43	11/29/2004	23
8/6/2002	23	1/5/2005	1
9/4/2002	23	3/16/2005	1
10/2/2002	9.1	4/5/2005	43
11/12/2002	7.3	5/3/2005	3.6
12/17/2002	1	5/23/2005	3.6
3/13/2003	1	6/2/2005	3.6
4/22/2003	1	6/20/2005	1
5/20/2003	3.6	7/6/2005	150
6/17/2003	23		

Table E-14: Observed Fecal Coliform Data at Severn RiverStation 03-04-029

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	1	7/7/2003	3.6
8/3/2000	3.6	7/21/2003	1
8/17/2000	9.1	7/30/2003	1
9/7/2000	1	8/5/2003	1
11/13/2000	1	8/19/2003	1
12/5/2000	43	9/3/2003	9.1
2/8/2001	3.6	9/17/2003	1
5/1/2001	3.6	10/1/2003	3.6
5/15/2001	3.6	10/8/2003	1
5/23/2001	1	10/20/2003	9.1
6/19/2001	23	11/18/2003	93
7/23/2001	9.1	1/6/2004	3.6
8/6/2001	1	3/10/2004	3.6
9/5/2001	1	4/8/2004	3.6
9/19/2001	9.1	4/21/2004	1
10/2/2001	7.2	5/4/2004	3.6
12/4/2001	9.1	5/18/2004	9.1
1/22/2002	3	6/2/2004	3.6
3/11/2002	3.6	6/16/2004	9.1
4/4/2002	3.6	6/30/2004	3.6
4/16/2002	9.1	7/7/2004	1
4/30/2002	1	7/19/2004	1
5/15/2002	3.6	8/5/2004	23
6/4/2002	1	8/23/2004	1
6/18/2002	3	9/30/2004	1100
7/2/2002	3.6	10/13/2004	43
7/24/2002	93	11/8/2004	3.6
8/6/2002	9.1	11/29/2004	240
9/4/2002	93	1/5/2005	3.6
10/2/2002	9.1	3/16/2005	1
11/12/2002	9.1	4/5/2005	43
12/17/2002	1	5/3/2005	1
3/13/2003	1	5/23/2005	23
4/22/2003	1	6/2/2005	1
5/20/2003	1	6/20/2005	1
6/17/2003	3.6	7/6/2005	460

Table E-15: Observed Fecal Coliform Data at Severn RiverStation 03-04-150

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/13/2000	23	7/21/2003	3.6
8/3/2000	93	7/30/2003	9.1
8/17/2000	43	8/5/2003	93
9/7/2000	23	8/19/2003	3.6
11/13/2000	3.6	9/3/2003	23
12/5/2000	1	9/17/2003	9.1
2/8/2001	1	10/1/2003	9.1
5/1/2001	1	10/8/2003	9.1
5/15/2001	1	10/20/2003	9.1
5/23/2001	240	11/18/2003	23
6/19/2001	43	1/6/2004	23
7/23/2001	9.1	3/10/2004	3.6
8/6/2001	9.1	4/8/2004	1
9/5/2001	23	4/21/2004	1
9/19/2001	23	5/4/2004	23
10/2/2001	9.1	5/18/2004	3.6
12/4/2001	15	6/2/2004	23
1/22/2002	3.6	6/16/2004	15
3/11/2002	3.6	6/30/2004	7.3
4/3/2002	23	7/7/2004	3.6
4/4/2002	7.3	7/19/2004	15
4/16/2002	1	8/5/2004	93
5/15/2002	1	8/23/2004	3.6
6/18/2002	1	9/30/2004	93
7/2/2002	1	10/13/2004	9.1
7/24/2002	43	11/8/2004	93
8/6/2002	43	11/29/2004	43
9/4/2002	93	1/5/2005	3.6
10/2/2002	7.3	3/16/2005	3.6
11/2/2002	15	4/5/2005	23
12/17/2002	1	5/3/2005	9.1
3/13/2003	1	5/23/2005	9.1
4/22/2003	1	6/2/2005	3
5/20/2003	43	6/20/2005	1
6/17/2003	1	7/6/2005	23
7/7/2003	7.3		

Table E-16: Observed Fecal Coliform Data at Severn RiverStation 03-04-152

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
8/3/2000	93	7/21/2003	3.6
8/17/2000	43	7/30/2003	9.1
9/7/2000	23	8/5/2003	93
11/13/2000	3.6	8/19/2003	3.6
12/5/2000	1	9/3/2003	23
2/8/2001	1	9/17/2003	9.1
5/1/2001	1	10/1/2003	9.1
5/15/2001	1	10/8/2003	9.1
5/23/2001	240	10/20/2003	9.1
6/19/2001	43	11/18/2003	23
7/23/2001	9.1	1/6/2004	23
8/6/2001	9.1	3/10/2004	3.6
9/5/2001	23	4/8/2004	1
9/19/2001	23	4/21/2004	1
10/2/2001	9.1	5/4/2004	23
12/4/2001	15	5/18/2004	3.6
1/22/2002	3.6	6/2/2004	23
3/11/2002	3.6	6/16/2004	15
4/3/2002	23	6/30/2004	7.3
4/4/2002	7.3	7/7/2004	3.6
4/16/2002	1	7/19/2004	15
5/15/2002	1	8/5/2004	93
6/18/2002	1	8/23/2004	3.6
7/2/2002	1	9/30/2004	93
7/24/2002	43	10/13/2004	9.1
8/6/2002	43	11/8/2004	93
9/4/2002	93	11/29/2004	43
10/2/2002	7.3	1/5/2005	3.6
11/2/2002	15	3/16/2005	3.6
12/17/2002	1	4/5/2005	23
3/13/2003	1	5/3/2005	9.1
4/22/2003	1	5/23/2005	9.1
5/20/2003	43	6/2/2005	3
6/17/2003	1	6/20/2005	1
7/7/2003	7.3	7/6/2005	23