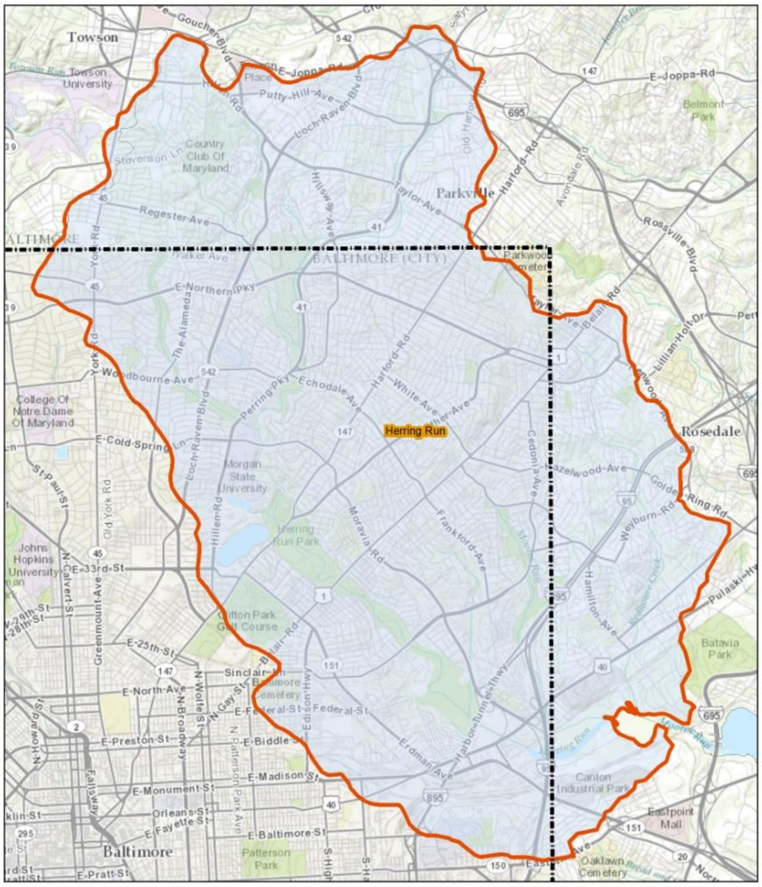
BALTIMORE COUNTY
TMDL IMPLEMENTATION PLAN

Bacteria in Herring Run



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LIST OF ABBREVIATIONS

ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BOD	Biological Oxygen Demand
BST	Bacteria Source Tracking
BSID	Biological Stressor Identification
CBP	Chesapeake Bay Program
Chl *a*	Chlorophyll *a*
COMAR	Code of Maryland Regulations
CFR	Code of Federal Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
DPW	Department of Public Works
ED	Extended Detention
EOF	Edge of Field
EOS	Edge of Stream
EPA	U.S. Environmental Protection Agency
HUC	Hydrologic Unit Code
IP	Implementation Plan
FSA	Farm Service Administration
HSG	Hydrologic Soil Groups
LA	Load Allocation
lbs/yr	Pounds per Year
MAST	Maryland Assessment Scenario Tool
MD	Maryland
MDA	Maryland Department of Agriculture
MDE	Maryland Department of Environment
MDP	Maryland Department of Planning
MGD	Million Gallons per Day
MGS	Maryland Geological Survey
MPR	Maximum Practicable Reduction
mg/l	Milligrams per Liter

MPN	Most Probable Number
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NLCD	National Land Cover Dataset
NMP	Nutrient Management Plan
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NQBEL	Water Quality Based Effluent Limitations
POM	Particulate Organic Matter
PS	Point Source
RTG	Reservoir Technical Group
SCWQP	Soil Conservation and Water Quality Plan
SSA	Science Services Administration
SSO	Sanitary Sewer Overflow
SWAP	Small Watershed Action Plan
SWM	Stormwater Management
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
URDL	Urban Rural Demarcation Line
USLE	Urban Soil Loss Equation
WAG	Watershed Advisory Group
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WQMP	Water Quality Management Plan
WIP	Watershed Implementation Plan
WRAS	Watershed Restoration Action Strategy
WWTP	Waste Water Treatment Plant
µg/l	Micrograms per Liter

This Implementation Plan (IP) has been prepared to address the presence of Bacteria in the Herring Run watershed that has been found to be posing a human health risk. The amount of reduction needed in Bacteria input has been determined by a Total Maximum Daily Load (TMDL) developed by the Maryland Department of the Environment (MDE) in the document titled *Total Maximum Daily Loads of Fecal Bacteria for the Herring Run Basin in Baltimore City and Baltimore County, Maryland* and after a public comment period, submitted to the US Environmental Protection Agency (EPA) Region 3 for review and approval. EPA approved the TMDL December 04, 2007.

1.1 What is a TMDL?

A TMDL has two different meanings. It is the document that is produced by MDE when any Maryland water body is listed on the state's 303(d) list of impaired and threatened waters. MDE must then submit the TMDL to EPA for approval. Any time a TMDL document is developed, extensive scientific study is done on the pollutant of concern in the listed water body. This study is done with the goal of finding the maximum load of the pollutant that the water body can receive and still meet Maryland's water quality standards. It is often thought of as a "pollution diet" for the watershed. All of the studying and monitoring that is done in preparing the TMDL document boils down to a single maximum load number that will be the target for pollution reduction in the water body. This number is also called a TMDL. In other words, the goal of the TMDL document is to justify the TMDL number, which can be found within the TMDL document.

The TMDL number is expressed as a sum of all the different sources of the pollutant plus a margin of safety (MOS) that accounts for any lack of knowledge or understanding concerning the relationship between loads and water quality and also for any rounding errors in the TMDL calculation. Expressing the TMDL in terms of this simple equation makes it easier to see where pollution reduction efforts need to be focused. In other words, which sources can be reduced to reach the final TMDL number, by how much do they need to be reduced, and which sources are not practical for reduction. The sources that make up the final TMDL number are categorized as either Load Allocation (LA) or Waste Load Allocation (WLA). LAs are all non-point source loads, meaning that they do not come from a single source or pipe. LAs include agricultural runoff, forest runoff, and upstream loads. WLAs are all point source loads, meaning that they do come from a single traceable source. WLAs are further categorized as process water or stormwater. Process water WLA comes from sources that have permits allowing them to release a specific amount of a pollutant into the water. They include individual industrial facilities, individual municipal facilities, and mineral mining facilities. Stormwater WLA is any stormwater that is regulated by a municipal separate storm sewer systems (MS4) permit, water from industrial facilities permitted to release stormwater, and all runoff from construction sites.

All Baltimore County urban stormwater is regulated under Baltimore County's MS4 permit. That means that stormwater WLA includes all of the water that runs to any storm drain within the watershed area. The MOS is the final part of the equation. The MOS can be implicit, meaning that the final TMDL was calculated in such a way that it accounted for any errors without needing to tack an explicit MOS to the end of the sum of load sources equation. When an explicit MOS is necessary, it is assumed that a 5% reduction of the final TMDL number will be sufficient.

TMDL Sum of Load Sources Equation:

$$\textbf{TMDL} = \textbf{LA} + \textbf{WLA Stormwater} + \textbf{WLA Process Water} + \textbf{MOS}$$

1.1.1 How is the Final TMDL Determined?

The process of determining the TMDL number can be very complex. Pollution data is regularly collected throughout Maryland by many different federal, state, and local government agencies as well as universities and watershed organizations. The agency or organization may send individuals out to the stream to collect and measure information about the watershed as part of a study or regular monitoring program. Data is also collected from the many different monitoring stations that are located throughout Maryland's watersheds. Some of these monitoring stations have been collecting water data for decades. The U.S. Geological Survey and the Maryland Department of Natural Resources monitoring stations are often used as the data source for Maryland TMDLs. To find out who is keeping an eye on your watershed see MDE's Water Quality Monitoring Web Page.

Complex scientific models are often used to help find a practical number for the total reduction. Models often use existing monitoring data and observations about the watershed area in a calculation that determines the TMDL number. The type of model used and the complexity of the model vary by pollutant, water body type, and complexity of flow conditions. The specific model used for this TMDL is explained in Section 3.

In all cases, scientists first find a baseline load for the pollutant. The baseline load is how much of the pollutant is in the water body at the time of the study, before restoration actions specifically developed to reach the TMDL number are implemented. The calculated target number, that is the TMDL, is the final goal. It could be thought of as the finish line in the TMDL process. That is not to say that other restoration efforts will not continue once that target is reached, but that the water body will be able to meet state water quality standards and can be removed from the list of impaired and threatened waters for that particular pollutant.

When calculating the TMDL number, a percent reduction and load reduction are usually calculated as well. The load reduction is the difference between the baseline load and the TMDL target. Think of it as the amount that needs to be removed from the system in order to reach the target. The percent reduction is the percentage of the baseline load that needs to be removed in order to reach the TMDL target.

1.2 Geographic Area

Pollution reduction goals are determined by watershed. A watershed is all the land area where all of the water that runs off that land and all the water running under that land drain into the same place. Everything within a watershed is linked by a common water destination. Watersheds exist at many levels: some very large, and some quite small. Identifying your watershed is similar to identifying your current location on a map. You could say you are in the United States, or that you are in Maryland, or that you are in your kitchen at your specific street address. Similarly, you could say that you are in the Mid-Atlantic Region Watershed, which drains to the Atlantic Ocean, Long Island Sound and Riviere Richelieu, a tributary of the St. Lawrence River. You could also say that you are in the Upper Chesapeake Bay Watershed, which includes the area of drainage to the Chesapeake Bay that is north of the Maryland-Virginia line. Both would describe a watershed that you are located in. However, watersheds can become much more specific.

A system was established by the U.S. Geological Survey for dividing the U.S. into successively smaller hydrologic units. Each hydrologic unit is identified by a hydrologic unit code (HUC), which range from two to twelve digits. The smaller the scale of the watershed, the more digits it has in its code. For example, the Mid-Atlantic Region is a 2-digit watershed and the Upper Chesapeake Bay is a 4-digit watershed. The 6-digit unit, also known as the "basins" unit, is to serve as the common scale for watershed assessments at the national level, but the condition of these basins can be determined based on an aggregation of assessments of even smaller watershed units. Maryland has chosen to go the route of assessing smaller watershed units. As a result, TMDLs are determined at the 8-digit watershed scale. For a further explanation of HUCs or to see maps of watersheds at different HUC levels, go to: USGS Hydrologic Unit Maps. If you would like to know which Maryland 8-digit watershed you are located in, go to MDE's Find My Watershed Map.

It is important to note that 8-digit watersheds can overlap multiple counties and may, therefore, have several regulating authorities.

1.2.1 Herring Run Geographic Area

Herring Run is a watershed that covers a total land area of 19,198.80 acres, 7,569 acres of which are located within Baltimore County. The Herring Run watershed begins in the East-central portion of Baltimore County, with portions of the watershed contained within the City of Baltimore, before discharging into the Back River to the East of the Baltimore City line. This TMDL Implementation plan will specifically address the land area of the watershed and watershed tributaries that are located in Baltimore County.

Within Baltimore County's portion of the Herring Run watershed, there are many land uses. Table 1.1 shows the land use of Baltimore County's ~7,569 acres of the Back River watershed as of 2011.

Table 1.1: Land Uses of Baltimore County's Portion of the Herring Run Watershed

Land Use	Acres	Portion of Watershed (%)
Urban Pervious	4,570.43	60.40
Urban Impervious	2,300.22	30.40
Forest	691.9	9.10
Water	6.9	0.10
Total	**7,569.45**	**100.00**

The acreage amounts reported in this document may vary slightly when compared to other sources as a result of minor Geographic Information Systems overlay errors. Figure 1.1 below shows the above data in a pie chart to give visualization to proportions of land uses. With both the above and below data representations, it is immediately apparent that urban land uses are the dominant forms of land cover.

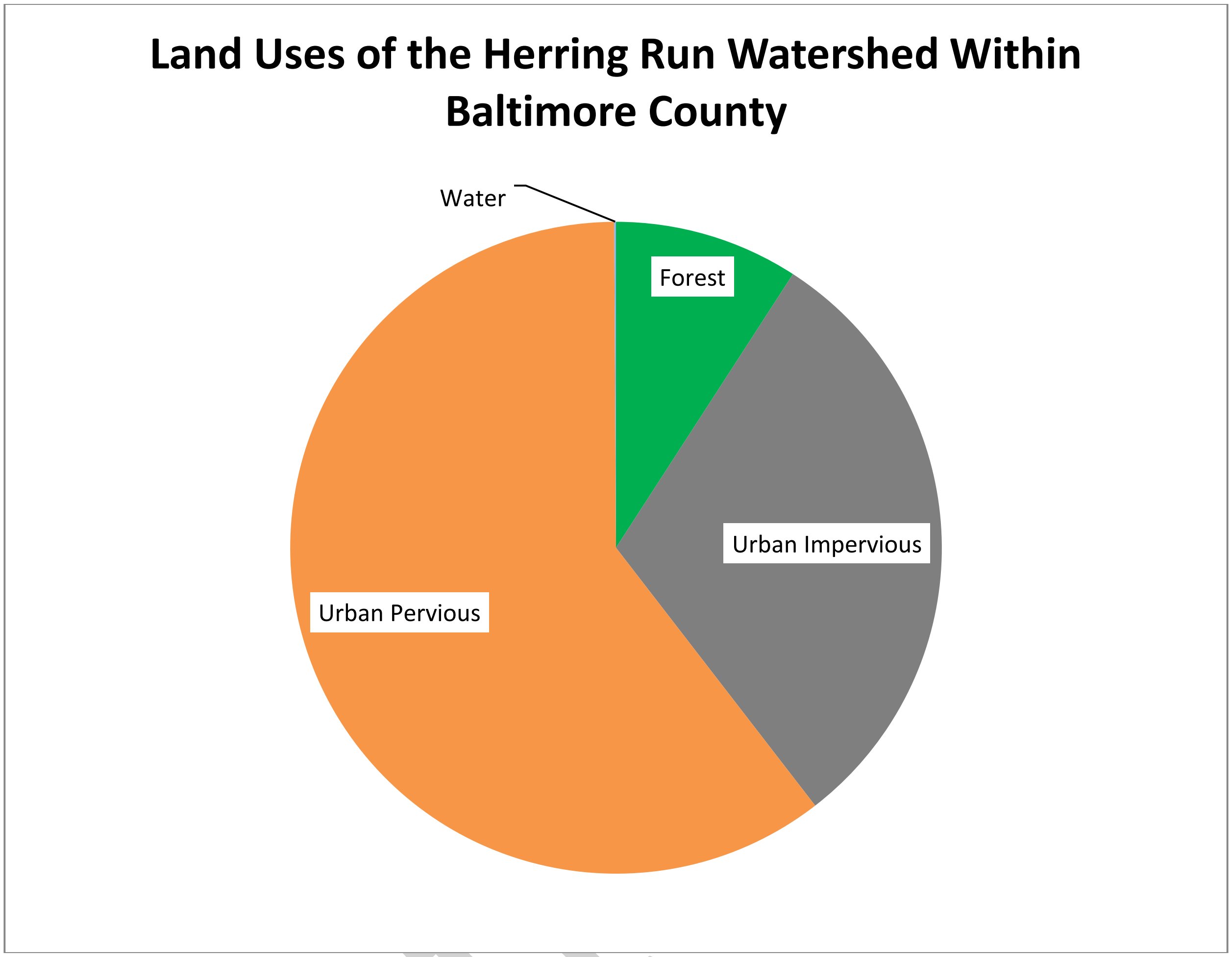

Figure 1.1: Land uses of Baltimore County's portion of the Herring Run Watershed

As visible in Figure 1.2, the areas of Herring Run watershed that are within Baltimore County are non contiguous, creating two distinct planning and implementation areas.

> **<u>Implementation Area A</u>** refers to the portion of the Harford Road monitoring station subwatershed which is located in the County and includes Chinquapin Run, West Branch Herring Run, and East Branch Herring Run. Implementation Area A covers 3,993.3 acres.
>
> **<u>Implementation Area B</u>** refers to the portions of the Pulaski Highway and the Biddle & 62nd Street monitoring stations subwatersheds located in the County and includes Moores Run and Redhouse Run. Implementation Area B covers 3,575.4 acres.

The further disposition of the watershed will be addressed during Section 5 of this IP which presents the watershed characterization.

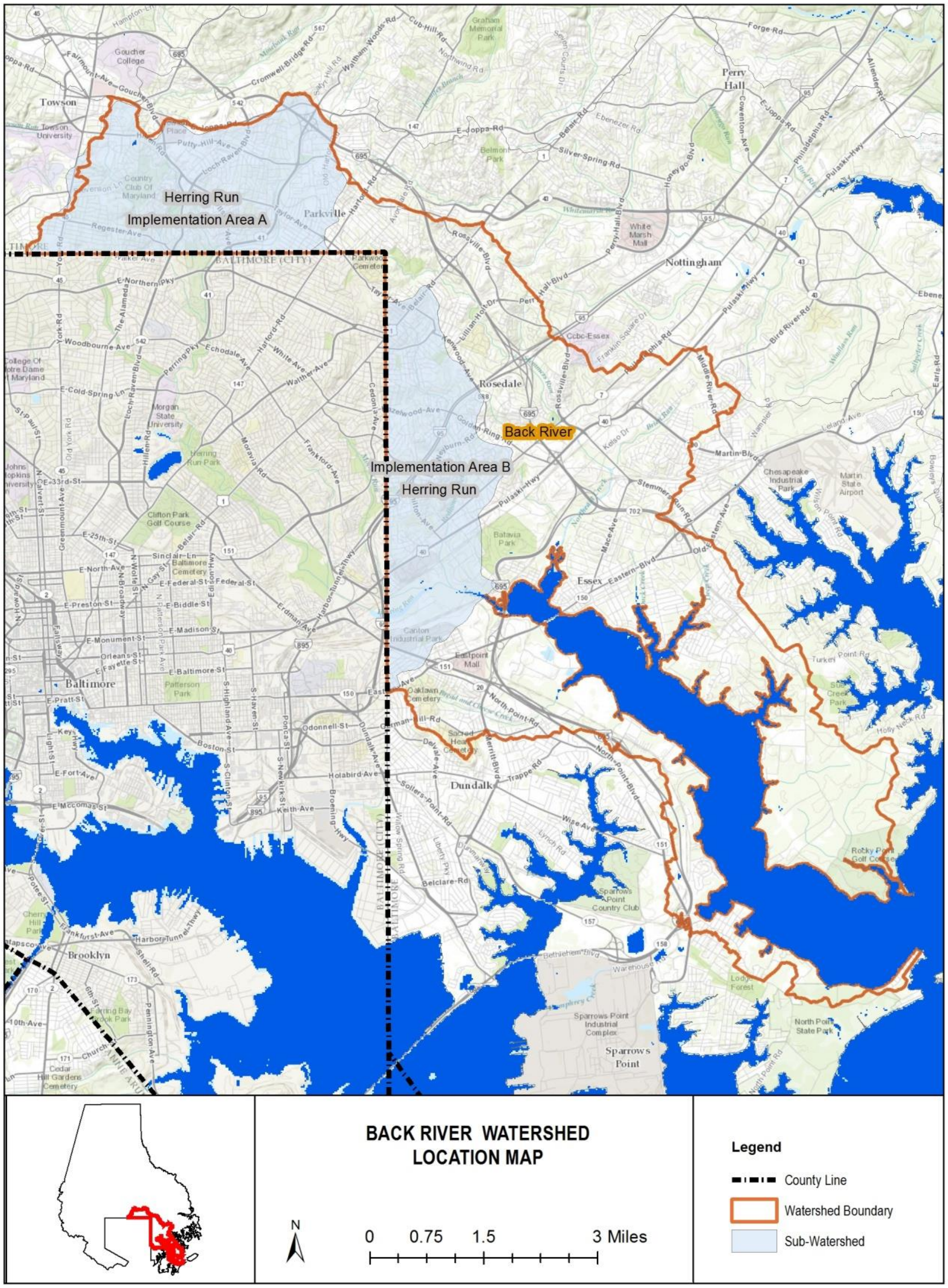

Figure 1.2: A Map Highlighting the Two Non-Contiguous Implementation Areas of the Herring Run Watershed within the Back River Watershed within Baltimore County.

1.3 Goal of the TMDL Implementation Actions

TMDL Implementation Plan Objective:

Through a cooperative effort of Baltimore County Department of Environmental Protection and Sustainability, other county agencies, local watershed associations, and the general public, to provide a comprehensive plan of action for achieving TMDL targets and ultimately restoring the health of Baltimore County waters to acceptable water quality standards.

Baltimore County is required to reduce pollution in its waterways; the plans to meet these reductions need to be in place by December 23, 2014. More on the legal requirements for these implementation plans will be discussed in depth during Section 2 of this document. The goal of this IP is to set the "road map" for the county to reach the goal of reducing pollutant loads in the water to meet water quality standards.

1.4 Document Organization

The Baltimore County TMDL implementation plans provide the following information to explain the necessity of the TMDL Implementation Plan and to develop a management strategy that will be followed in order to meet county TMDL reduction targets. The County will take an adaptive management approach that will include periodic assessments to determine progress and identify changes needed in the management strategy to meet the reduction targets in a timely, cost effective manner.

Section 1: Introduction

This Introduction states the pollutant that is being addressed by the TMDL IP, and the watershed for which the IP was developed. It provides a background on what a TMDL is and how the TMDL is determined. A general description of the geographic area for the specific IP is provided. The Introduction also states the overall goal of the TMDL IP and summarizes the actions that have been identified to bring Baltimore County to that goal. It also includes a brief summary of the contents of the thirteen sections of the TMDL Implementation Plan.

Section 2: Regulatory Policy and Planning

This part of the document describes the administration and legal authority that mandates the development of Baltimore County's TMDL implementation plan and oversees its fulfillment. It will provide a background of how various regulating authorities and policies are related to the requirement to develop a TMDL Implementation Plan. It will also summarize the various planning guidance documents that have been produced to assist in the development of TMDL Implementation Plans and how TMDL Implementation Plans fit in the overall Baltimore County planning context.

Section 3: TMDL Summary

The section summarizes the original TMDL document that was submitted by MDE and approved by the EPA. The summary includes: when the TMDL was developed, what is impaired, why the TMDL was developed, a description of the analysis process that was used to determine the total maximum daily load targets, the baseline year of data collection and analysis, the results from that analysis, and a further break down of the target loads by source sector.

Section 4: Literature Summary

Each TMDL IP will address a specific pollutant. This part of the document provides an overview of the pollutant that is summarized from published literature. The literature summary includes known sources of the pollutant, the impacts associated with the pollutant, the pathways and transformations of the pollutant, and other relevant ecological processes that affect how the pollutant can be controlled and regulated.

Section 5: Watershed Characterization

Characterization of the watershed will include geographical and technical information for the portion of the watershed that is specific to each TMDL IP. Each characterization will describe the watershed acreage, population size, geology and soils, topography, land use, streams, infrastructure related to watershed pollution sources, implemented restoration projects since the baseline year, and changes in pollutant load since the baseline year.

Section 6: Existing Data Summary

This section will include a summary of Baltimore County's existing monitoring data that will be pertinent to the pollutant in question. It may also include some data received from sources other than Baltimore County, such as data from the Maryland Department of the Environment, or other relevant sources.

Section 7: Summary of Existing Restoration Plans

Previous planning efforts will be summarized in this section. Water Quality Management Plans (WQMP) and Small Watershed Action Plans (SWAP) applicable to the IP area are identified. The process and goals for SWAP development are explained.

Section 8: Best Management Practice Efficiencies

This section is an explanation of the best management practices that will be used for removing the particular pollutant and the known efficiency of those best management practices. A table will be found in this section of BMPs and the known reduction efficiency for the pollutants that can be reduced by each BMP. BMP efficiencies will also include a discussion of the uncertainty and research needs for BMPs.

Section 9: Implementation

The implementation section will provide a description of programmatic, management, and restoration actions; and pollutant load reduction calculations to meet the pollutant reduction target for the specific pollutant. For each of the programmatic, management, and restoration actions there will be a list of responsible parties, actions, timeframe of actions, and performance standards.

Section 10: Assessment of Implementation Progress

Assessment of implementation progress will give Baltimore County a formal method of reporting on the development of implementation and of describing the progressive success of implementation actions. The section will include a description of tracking and reporting mechanisms, and a monitoring plan that includes progress monitoring as well as BMP effectiveness monitoring.

Section 11: Continuing Public Outreach Plan

This part of the document will be a continuing public outreach plan. It will encourage public involvement in the implementation process, extending beyond the finalization of this document.

Section 12: References

A list of references used in the creation of this document.

Section 2 – Legal Authority, Policy, and Planning Framework

The Legal Authority, Policy, and Planning Framework section will present, in brief, the background on the legal requirements that pertain to the development of Total Maximum Daily Loads (TMDLs), and the preparation of TMDL Implementation Plans. This section will also cover the planning framework for the development of the TMDL Implementation Plans (IP). Furthermore, this section is intended to provide the context for the development of this TMDL Implementation Plan and understanding of the linkage between water quality and the TMDL.

Whether at the federal or state level there are a number of processes at work that result in the regulations that must be followed to remain within the law. First, legislation is passed by an elected governing body (e.g. Congress, state legislature), and once passed and signed by the executive branch, they become Acts (laws), such as the Clean Water Act. In order to provide guidelines in maintaining compliance with these laws, it is often necessary that regulations be issued to specify the law's requirements. A regulation is a rule issued by a government agency that provides details on how legislation will be implemented, and may set specific minimum requirements for the public to meet if they are to be considered in compliance with the law. These regulations may come in various forms, such as the Code of Federal Regulations (CFR), or Code of Maryland Regulations (COMAR). The information that follows is generally taken from CFR and COMAR.

Under the Code of Federal Regulations (CFR), Title 40 encompasses the regulations enforced by the U.S. Environmental Protection Agency (EPA). These regulations include not only those related to water quality, but also air quality, noise, and a variety of land based regulations (oil operations, etc.)

2.1 Regulatory and Policy Framework

The ultimate regulatory authority for protecting and restoring water quality rests with the federal government through legislative passage of the Clean Water Act in 1972 and subsequent amendments. Prior to the Clean Water Act (1972), the Federal Water Pollution Control Act (1948) served as the basis for controlling water pollution. The Clean Water Act significantly amended the Federal Water Pollution Control Act and established the basic structure for regulating discharges of pollutants into the waters of the United States. Major amendments were enacted in 1977 and 1987 that further strengthened and expanded the Clean Water Act of 1972. The 1987 amendments incorporated the requirement that stormwater discharges from urban (municipal) areas be required to obtain a permit for discharge and that stormwater discharges from industrial sources also be permitted. There have been a number of minor amendments and reauthorizations over the years that have resulted in the law as it now stands.

There are several significant provisions of the Clean Water Act that pertain to TMDLs. These provisions include the requirement that states adopt Water Quality Standards by designating water body uses and set criteria that protect those uses. The Clean Water Act also requires states to assess their waters and provide a list (known as the 303(d) list) of waters that are impaired. The list specifies the impairing substance and requires that a TMDL be developed to address the impairment.

Through policy (memos dated November 22, 2002 and November 12, 2010) the US EPA has indicated that the pollutant loads attributable to regulated stormwater discharges are to be included in the Waste Load Allocation as a point source discharge and not as part of the non-point load. The initial memo also affirmed that the Water Quality-Based Effluent Limitations (WQBELs) in Municipal Separate Storm Sewer System (MS4) permits may be expressed in the form of Best Management Practices (BMPs) and not as numeric limits for stormwater discharges. The second memo clarified that when the MS4 permits are expressed in the form of BMPs, the permit should contain objectives and measurable elements (e.g., schedule for BMP installation or level of BMP performance). By providing both an expected level of BMP performance and a schedule of implementation of the various practices, Baltimore County will have addressed this requirement. This plan once approved by Maryland Department of the Environment (MDE) will be enforceable under the terms of the permit.

2.2 Maryland Use Designations and Water Quality Standards

In conformance with the Clean Water Act, the State of Maryland has developed use designations for all of the waters in the state of Maryland, along with water quality standards to maintain the use designations.

Designated uses define an intended human and aquatic life goal for a water body. It takes into account what is considered the attainable use for the water body, for protection of aquatic communities and wildlife, use as a public water supply, and human uses, such as recreation, agriculture, industry, and navigation. Water quality standards include both the Use Designation and Water Quality Criteria (numeric standards).   Water Quality Criteria are developed to protect the uses of a water body.

2.2.1 Use Class Designations

Every stream, lake, reservoir, and tidal water body in Maryland has been assigned a Use Designation. The Use Designation is linked to specific water quality standards that will enable the Designated Use of the water body to be met. A listing of the Use Designations follows:

- Use I: Water contact recreation, and protection of nontidal warm water aquatic life.
- Use II: Support of estuarine and marine aquatic life and shellfish harvesting (not all subcategories apply to each tidal water segment)
    - Shellfish harvesting subcategory
    - Seasonal migratory fish spawning and nursery subcategory (Chesapeake Bay only)
    - Seasonal shallow-water submerged aquatic vegetation subcategory (Chesapeake Bay only)
    - Open-water fish and shellfish subcategory (Chesapeake Bay only)
    - Seasonal deep-water fish and shellfish subcategory (Chesapeake Bay only)
    - Seasonal deep-channel refuge use (Chesapeake Bay only)
- Use III: Nontidal cold water – usually considered natural trout waters
- Use IV: Recreational trout waters – waters are stocked with trout

The letter "P" may follow any of the Use Designations, if the surface waters are used for public water supply. There may be a mix of Use Classes within a single 8-digit watershed; for example, Gwynns Falls has Use I, Use III, and Use IV Designations depending on the subwatershed.

Table 2.1: Designated Uses and Applicable Use Classes

Designated Uses	Use Classes							
	I	I-P	II	II-P	III	III-P	IV	IV-P
Growth and Propagation of fish (not trout), other aquatic life and wildlife	✓	✓	✓	✓	✓	✓	✓	✓
Water Contact Sports	✓	✓	✓	✓	✓	✓	✓	✓
Leisure activities involving direct contact with surface water	✓	✓	✓	✓	✓	✓	✓	✓
Fishing	✓	✓	✓	✓	✓	✓	✓	✓
Agricultural Water Supply	✓	✓	✓	✓	✓	✓	✓	✓
Industrial Water Supply	✓	✓	✓	✓	✓	✓	✓	✓
Propagation and Harvesting of Shellfish			✓	✓				
Seasonal Migratory Fish Spawning and Nursery Use			✓	✓				
Seasonal Shallow-Water Submerged Aquatic Vegetation Use			✓	✓				
Seasonal Deep-Water Fish and Shellfish Use			✓	✓				
Seasonal Deep-Channel Refuge Use			✓	✓				
Growth and Propagation of Trout					✓	✓		
Capable of Supporting Adult Trout for a Put and Take Fishery							✓	✓
Public Water Supply		✓		✓		✓		✓

2.2.2 Water Quality Criteria

Water quality criteria are developed to protect the uses designated for each water body. Certain standards apply over all uses, while some standards are specific to a particular use. The criteria are based on scientific data that indicate threats to aquatic life or human health. For the protection of aquatic communities the criteria have been developed for fresh water, estuarine water, and salt water. The criteria have been further based on acute levels (have an immediate negative effect) and chronic levels (have longer term effects). The human health criteria are based on drinking water levels, organism consumption levels, or a combination of drinking water and organism consumption levels, or recreational contact bacteria levels.

Dissolved oxygen criteria for all Use Designations is 5 mg/L, except for Use II Designations and special criteria for drinking water reservoir hypolimnion waters (bottom waters of the reservoir).

Bacteria criteria are based on human health concerns, and apply to all Uses, with additional bacteria criteria applicable in shellfish waters. Since none of the local TMDLs are related to the shellfish criteria, they are not discussed here. The human health criteria are based on either the geometric mean of 5 samples or single sample criteria based on the frequency of full body contact, these criteria are displayed in Table 2.2. For the freshwater bacteria TMDLs the indicator bacteria *E. coli* has been used in the development of the TMDL, therefore serves as the water quality end point. The human health recreational contact bacteria criteria are displayed in Table 2.2. The table displays both the geometric mean for bacteria and single sample maximum allow bacteria concentrations based on the frequency of full body contact.

Table 2.2: Bacteria Criteria for Human Health (MPN/100 ml)

Indicator	Steady State Geometric Mean Density	Single Sample Maximum Allowable Density			
		Frequent Full Body Contact Recreation	Moderately Frequent Full Body Contact Recreation	Occasional Full Body Contact Recreation	Infrequent Full Body Contact Recreation
Freshwater (Either Apply)					
Enterococci	33	61	78	107	151
E. coli	126	235	298	410	576
Marine					
Enterococci	35	104	158	275	500

2.3 Planning Guidance

In March of 2008 the EPA released a guidance document on the development of watershed plans entitled *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*. The handbook laid out nine minimum elements to be included in watershed plans, commonly called the "a through i" criteria. The criteria include:

a. An identification of the causes and sources or groups of sources that will need to be controlled to achieve the load reductions estimated in the watershed plan.

b. Estimates of pollutant load reductions expected through implementation of proposed Non-point Source (NPS) management measures.

c. A description of the NPS management measures that will need to be implemented.

d. An estimate of the amounts of technical and financial assistance needed to implement the plan.

e. An information/education component that will be used to enhance public understanding and encourage participation.

f. A schedule for implementing the NPS management measures.

g. A description of interim, measurable milestones for the NPS management measures.

h. A set of criteria to determine load reductions and track substantial progress towards attaining water quality standards.

i. A monitoring component to evaluate effectiveness of the implementation efforts over time.

EPA now evaluates watershed plans on the basis of the above criteria in consideration of its grant funding. The State of Maryland is also increasingly using the above criteria for funding consideration. Baltimore County has used these criteria since the publication of the handbook in the development of its Small Watershed Action Plans; and will use the criteria in the development of this TMDL Implementation Plan.

Maryland Department of the Environment (MDE) developed a guidance document in conjunction with local government representatives entitled *Maryland's 2006 TMDL Implementation Guidance for Local Governments*, which provides a framework for the development of TMDL Implementation Plans. MDE has also provided guidance on the development of TMDL Implementation Plans related to specific pollutants. Guidance for specific pollutants includes:

- PCBs
- Bacteria
- Mercury
- Trash

These guidance documents have been taken into consideration in the development of the Baltimore County TMDL Implementation Plans.

2.4 Water Quality Standards Related to This Implementation Plan

The tidal portion of the Back River (02-13-09-01) watershed has been designated as Use Class II, while a Use Class IV designation is held by the non-tidal portion (which includes Herring Run). Protections retained by Class IV designations include water contact recreation, protection of aquatic life, and recreational trout waters (stocked). Only Herring Run and tributary stream to Herring Run have been found impaired by bacteria, these waters fall into the following 12-digit subwatersheds: 102-13-09-01-1040, 102-13-09-01-1041, 102-13-09-01-1042. The water quality criteria applicable to the bacteria TMDL are those related to bacteria, specifically, the *E. coli* criteria above in Table 2.2. The bacteria criteria are designed to protect humans from health issues that may arise from water contact recreation.

The ultimate water quality endpoint is the attainment of an *E. coli* geometric mean concentration of 126 MPN for all weather conditions and during all seasons. Since the majority of human recreation water contact occurs during dry weather and in the warm seasons, the 126 MPN criteria target will be applied to those conditions. In addition, Baltimore County will use the frequency of full body contact criteria for single samples as measures of progress. Streams, unlike swimming beaches, will not have frequent full body contact, but much more limited contact. The targets for interim periods are displayed in Table 2.3.

Table 2.3: Five Year Interim Targets for Single Sample and Geometric Mean Bacteria Densities

Single Sample Target				
Weather Condition	**2020**	**2025**	**2030**	**2035**
Dry	576	410	298	235
Wet	NA	NA	NA	NA
Geometric Mean Target				
Dry	477	360	243	126
Wet	6,880	4,630	2,380	126

This section provides a brief summary of the information contained in the Maryland Department of the Environment (MDE) document titled *Total Maximum Daily Loads of Fecal Bacteria for the Herring Run Basin in Baltimore City and Baltimore County, Maryland*, approved by the U.S. Environmental Protection Agency (EPA) December 4, 2007.

3.1 TMDL Background

MDE first listed Herring Run as being impaired by Bacteria in 2002 due to high levels of *Escherichia coli (E. coli)*, the fecal bacteria indicator used by the State of Maryland. Fecal bacteria are microscopic single-celled organisms found in the wastes of warm-blooded animals (including humans). Their presence in water is used to assess the sanitary quality of water for body-contact recreation, consumption of molluscan bivalves and other shellfish, and drinking water. Excessive amounts of fecal bacteria in surface water used for recreation are known to indicate an increased risk of illness to humans. Infections due to contaminated recreation waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases (EPA, 1986).

The Code of Maryland Regulations (COMAR) section 26.08.02.03-3 indicates a freshwater impairment threshold of 126 Most Probable Number (MPN) of *E. coli* per 100 ml of water. More about the MPN, or “Most Probable Number” technique of counting bacteria Colony Forming Units may be found here. Through regular monitoring of *E. coli*, MDE was able to determine a baseline of conditions at the time of measurement (2007), and a proposed set of targeted conditions suitable for a healthier watershed. Concentrations of *E. coli* in freshwater that are greater than the geometric mean of 126 MPN/100 ml would cause a water body to be listed as impaired. At all sampling locations, the geometric mean of *E. coli* MPN/100 ml were above 126. While this concentration of 126 MPN/100 ml is the regulatory limit for *E. coli*, it is required to account for general uncertainty by factoring in a Margin of Safety (MOS).

Based on EPA guidance, the MOS can be achieved through two approaches. One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = LA + WLA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis. For this TMDL, the second approach was used by estimating the loading capacity of the stream based on a more stringent water quality criterion concentration. Thus, the *E. coli* water quality criterion concentration was reduced by 5%, from 126 *E. coli* MPN/100ml to 119.7 *E. coli* MPN/100ml.

3.2 TMDL Development

To determine the TMDL for Bacteria, MDE utilized laboratory analysis of in-stream water samples for bacteria indicators (e.g., *E. coli*), whose concentrations were expressed using the Most Probable Number (MPN) of colonies. Because they reproduce and die off in a non-linear fashion as a function of many environmental factors, and can occur in concentrations that vary widely, direct sampling was used rather than computer models to determine the TMDL and baseline of current conditions.

The sources of fecal bacteria were estimated over four years at one monitoring station maintained by MDE, and three representative stations in the Herring Run watershed where Baltimore City’s Department of Public Works collected fecal coliform samples for four years. These fecal coliform samples were translated to *E. coli*, the fecal bacteria indicator used by the

State of Maryland. Translation of fecal coliform data to *E. coli* data was achieved by using a translator equation developed from a regression analysis developed by the State of Virginia Department of Environmental Quality (VA DEQ). The MDE monitoring station was used to identify that there was an impairment that would require the development of a TMDL, while the other monitoring stations were used to develop the TMDL once it was determined it was necessary. These data was categorized by low flow and high flow conditions, as measured by the USGS stream gauge. As shown in Figure 3.1, the USGS gauge is located on the West Branch of Herring Run, the MDE monitoring station is located in the mainstem of Herring Run below the confluence with Chinquapin Run, and there are two other Baltimore City Department of Public Works (DPW) monitoring stations throughout the watershed area.

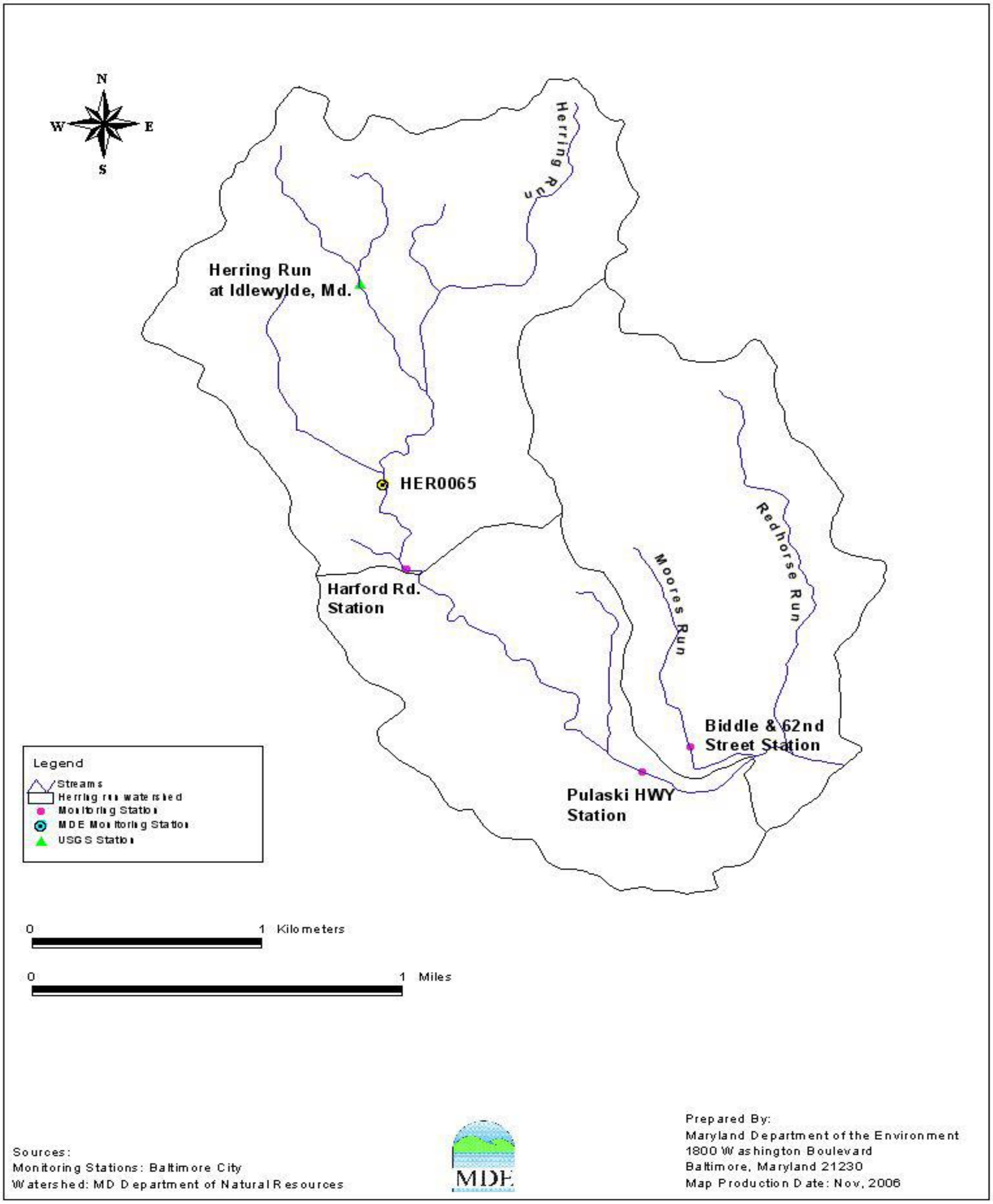

Figure 3.1: Map showing locations of DPW monitoring stations throughout the Herring Run watershed. The stations indicated by pink markers are the locations where measurements were taken for baseline load and TMDL development.

Due to the nature of bacteria transport within streams and rivers, bacteria counts can vary widely throughout the watershed. Herring run is no exception, having highly variable counts of bacteria measured between each monitoring station, shown in Table 3.1.

Table 3.1: The Annual Overall Geometric Mean of *E. coli* at each Baltimore City DPW monitoring station.

Monitoring Station	Annual Overall Geometric Mean (*E. coli* MPN/100 ml)
Harford Road	**1,063**
Pulaski Highway	**644**
Biddle Street	**1,462**

An analysis process called Multiple Antibiotic Resistance Analysis (ARA) source tracking was used to determine the relative proportion of domestic (pets and human associated animals), human (human waste), livestock (agricultural related animals), and wildlife (mammals and waterfowl) source categories. This process helps to determine the amount of bacteria coming from each source, and how to address reduction requirements. For the Herring Run Bacteria TMDL the percent contribution from each source was only determined at one station (HER0065) Table 3.2 shows the breakdown of bacteria by source. This information was extrapolated to the entire watershed.

Table 3.2: Average Annual Percentage Contribution *E. coli* of by Source Type

Domestic Pet	Human	Livestock	Wildlife
18.9%	**70.7%**	**0.0%**	**10.4%**

Human sources of *E. coli* were the most pronounced sources in the Herring Run watershed, likely in part due to the aging infrastructure which is responsible for carrying wastewater to treatment facilities. These conduits had historically been prone to Sanitary Sewer Overflows (SSOs) and failures in the system in both Baltimore City and County. SSOs occur when the capacity of a sanitary sewer is exceeded and the contents of the sewer overflows. These occurrences can be impacted by pipe capacity shortfalls, effectiveness of maintenance operations, geology, blockages, loss of power at pumping stations, inflow and infiltration of stormwater, vandalism, or other influences. In a great majority of cases these overflows carry raw, untreated sewage into the environment, posing considerable health and environmental risks. Baltimore City and Baltimore County have entered into Consent Decrees, with the State of Maryland and the Federal Government, to eliminate all SSOs within their jurisdictional boundaries. Baltimore City is required to complete its evaluation and SSO eliminations by January 2016, while Baltimore County is required to fulfill its commitment by March 2020.

Because of the nature of bacteria movements and persistence within freshwater streams, monitoring data was analyzed for two separate times of year, and for two separate streamflow amounts. This measuring during varying conditions allows for analysis of the human health threat from bacteria which people are more likely to encounter during warmer months and lower flow rates (high flows are generally associated with storm events, during which there is less chance of exposure).

The low and high stream flow breakdowns are listed in table 3.3 showing the annual steady-state geometric mean and overall annual geometric mean for each sampling location. The table that follows immediately (Table 3.4) is showing the same information, but instead of for the annual geometric mean, it shows the seasonal geometric mean (which is measured from May 1 – September 30).

Table 3.3: Annual Overall Geometric Mean of Bacteria Concentrations at Each Monitoring Station Dependant on Flow Rate

Monitoring Station	Flow	Annual Steady-State Geometric Mean (MPN/100ml)	Annual Overall Geometric Mean (MPN/100ml)
Harford Road	High	6,471	1,063
	Low	582	
Pulaski Highway	High	3,500	644
	Low	366	
Biddle Street	High	2,016	1,462
	Low	1,313	

Table 3.4: Seasonal (May1 – September 30) Overall Geometric Mean of Bacteria Concentrations at Each Monitoring Station Dependant on Flow Rate

Monitoring Station	Flow	Seasonal Steady-State Geometric Mean (MPN/100ml)	Seasonal Overall Geometric Mean (MPN/100ml)
Harford Road	High	9,129	1,176
	Low	594	
Pulaski Highway	High	4,326	1,003
	Low	616	
Biddle Street	High	3,840	2,283
	Low	1,920	

It can be seen that high levels of bacteria in the water coincide with high flow rates. This is likely the result of bacteria being washed into the waterways during storm events and many sanitary sewer overflows resulting from flow of stormwater into the sanitary sewer system, thereby exceeding their capacity. High concentrations of bacteria also coincide with warmer times of year. While we do not expect high flow times (during or immediately following storm events) to be common times for human contact recreation in the water, we do expect greater occurrences of recreation and contact during the warmer period of the year. More on this will be discussed in Section 9 of this Implementation Plan.

3.3 TMDL Results

Through the use of direct sampling and analysis, the baseline established an estimated average annual load of *E. coli* as 9,850,940 billion MPN. The water quality goal for bacteria in Herring Run, based on the MOS discussed above, is 119.7 *E. coli* MPN/100 ml.

3.4 TMDL Reduction Targets by Source Sector

E. coli enter the water mainly through feces, which is traceable to its sources through a source identification test as discussed previously. There are both point sources and non-point sources of fecal bacteria. Point sources of fecal waste enter the stream or river through a pipe from sources such as Municipal Separate Sewer Systems (MS4) including Sanitary Sewer Overflows (SSOs).

The target for the average annual load of Bacteria in Herring Run is 652,459 billion MPN per year. The total load allocation is made up of two types of sources: nonpoint sources (73,872 billion MPN per year) and point sources (578,588 billion MPN per year).

Nonpoint sources of fecal bacteria do not have one discharge point but occur over the entire length of a stream or water body, such as pet and wildlife deposition, grazing livestock, leaking or failing septic and sewer systems and their associated infrastructure, other urban and agricultural runoff. Point sources of fecal bacteria can include industrial and municipal points such as Sanitary Sewer Overflow events. While it is good to mention septic systems as potential sources of bacteria, the Herring Run watershed does not include any septic systems. Waste Water Treatment Plants (WWTPs) can also be considered point sources of bacteria input, however there are none within Herring Run watershed.

In this study, a Margin of Safety (MOS) was included in the calculations of the target bacteria loads. As a result, the loading capacity of the stream was based on a 5% more stringent water quality criterion in order to account for uncertainties.

In Section 1 of this Implementation Plan, we discussed a different way to visualize the TMDL allocations by showing the equation that relates the TMDL to the load allocation, waste load allocation and the margin of safety. In section 3.1 we discussed the use of a Margin of Safety (MOS), and that for this TMDL the MOS is determined by having 5% more stringent water quality standards. Because of this implicit MOS, there will not be a separate numerical addition to the TMDL allocations.

Using this equation we can show the TMDL goal as the sum of the Bacteria colonies that would be present in the Herring Run if required reductions were met (in billion MPN).

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
652,459	**=**	**73,872**	**+**	**578,588**	**+**	**Implicit (included)**

Table 3.5 shows the target average annual loads for bacteria in the Herring Run watershed. (Because the Back River Waste Water Treatment Plant (WWTP) is in the tidal region of the watershed (which is not impaired by fecal bacteria) it is not factored into this TMDL which is specific to the non-tidal (Herring Run) portions of Back River.)

Table 3.5: Target Average Annual Loads of Bacteria colonies in the Herring Run Watershed

Source	Bacteria Colonies (billion MPN/year)
Nonpoint Sources[1] (Load Allocation)	**73,872**
Point Sources[2] (Waste Load Allocation)	**578,588**
Margin of Safety[3] (MOS)	**Implicit (Included)**
Total	**652,459**

1. Excluding urban-stormwater.
2. Including urban-stormwater.
3. Representing 5% more stringent water quality standards.
4. The calculations in the TMDL document show that at each station the Load Allocation accounts for roughly 11% of the total.

With each monitoring station reporting different loads for *E. coli*, it is needed to set target goals for each station individually. Table 3.6 displays a comparison of the baseline load measurements with the target loads associated with the TMDL and the percentage reduction that would be required for each monitoring station.

Table 3.6: Baseline and Target Loads for *E. coli* in the Herring Run Watershed

Monitoring Site	Baseline Load for *E. coli* (Billion MPN/year)	TMDL Target for *E. coli* (Billion MPN/year)	Reduction Required (%)
Harford Road	**6,288,811**	**408,147**	**93.5**
Pulaski Highway	**1,992,522**	**173,532**	**91.3**
Biddle Street	**1,569,606**	**70,781**	**95.5**
Total	**9,850,939**	**652,459**	**93.4**

A reduction of 93.4% is necessary for the entire Herring Run to meet the water quality endpoint of 119.7 MPN/100 ml (5% lower than 126 MPN/ 100 ml to account for margin of safety). The TMDL document lists required reductions by each bacteria source: Human, Domestic (pets), Livestock, and Wildlife. The maximum required source reductions are 98% for human, 98% for domestic animals, 0% for livestock (as there are none in this watershed), and 73.8% for wildlife. MDE examined potential source reductions for bacteria in all watersheds and determined, through best professional judgment and a review of the available literature, that the Maximum Practicable Reductions (MPR) in any subwatershed would be 95% for human, 75% for domestic animals, 75% for livestock, and 0% for wildlife. Table 3.7 shows the percentage of bacteria loads that would be required to meet the average annual goal shown above.

Table 3.7 Required Reductions and Maximum Practicable Reductions of Bacteria in the Herring Run Watershed

Source	Required Reduction to Meet Goal (%)	Maximum Practicable Reduction (%)
Domestic	**98.0**	**75.0**
Human	**98.0**	**95.0**
Livestock	**0.0**	**75.0**
Wildlife	**73.8**	**0.0**

As shown in table 3.6 and referenced in the TMDL document the Maximum Practicable Reductions for bacteria inputs were below the levels required to achieve Water Quality Standards. This acknowledges the possibility that the goal for bacteria reductions may not be met.

Because these goals are beyond the accepted Maximum Practicable Reductions, MDE has proposed an adaptive management program or “staged approach” to implementation beginning with attainment of the MPR scenario for anthropogenic sources (domestic and human inputs), with regularly scheduled follow-up monitoring to assess the effectiveness of implementation (which will be covered in section 9 of this Implementation Plan).

This section of the Implementation Plan provides an overview of the pollutant in question summarized from published literature. This is not intended to be an exhaustive review of primary literature, but rather a summary of the sources, pathways and biological effects of bacteria in non-tidal watersheds from literature available to Baltimore County Department of Environmental Protection and Sustainability. The literature summary includes known sources of the pollutant, the impacts associated with the pollutant, the pathways and transformations of the pollutant, and other relevant ecological processes that affect how the pollutant can be controlled and regulated.

This review pertains to the impairment of Baltimore County waters caused by the presence of bacteria, specifically fecal bacteria. Fecal bacteria are a type of microorganism that lives in and on the feces of animals, humans and livestock. Bacterial contamination in water sources is an issue of public health and safety. There is a wide variety of microorganisms that can be found in fecal matter. Most microorganisms are non pathogenic and do not cause disease to humans and wildlife, but some can be hazardous (U.S. Geological Survey 2007) (World Health Organization 2003). These disease causing microorganisms are known as pathogens. There is no specified number of pathogen cells that will make an individual sick (U.S. Geological Survey 2007). Every person has a different state of health and immune system, which determines how susceptible his or her body is to disease. For this reason, water quality standards for bacteria are based on approximate risk of illness per 1,000 swimmers. The water quality standard is discussed in detail in the TMDL summary section. There is no way to say exactly how much bacteria will make someone sick, but it is possible to approximate the risk from a large sample of people (Maryland Department of The Environment 2009). For more information on the risk of pathogens in recreational water use, see the Centers for Disease Control and Prevention website on recreational water: Oceans Lakes and Rivers.

Pathogenic microorganisms can cause gastrointestinal infection from accidental ingestion of polluted water. Certain pathogenic organisms from fecal sources can also cause infections of the upper respiratory tract, ears, eyes, nasal passages, and skin (World Health Organization 2003). Infections due to recreational water contact are generally mild; however, this makes them hard to detect and attribute to water exposure (World Health Organization 2003). In many situations these pathogens can spread from person to person. Spreading of disease between humans can happen in a number of ways, and one of those pathways is through water contamination. As an example for how this could happen, the USGS provides a possible scenario: “Several human gastrointestinal pathogens produce toxins which act on the small intestine, causing secretion of fluid which results in diarrhea. In severe cases, as with cholera (caused by the Vibrio-cholerae bacteria), the afflicted person may die from loss of body fluids and severe dehydration. Cells of the pathogen are shed in the feces, and if these cells contaminate food or water which is then consumed by another person, the disease spreads” (U.S. Geological Survey 2007). In this situation the fecal matter acts as a transport for the pathogens, and it is the pathogen, not the fecal matter, which causes the disease. This demonstrates the importance of monitoring for fecal matter, as it may be used as an indicator of disease causing pathogens.

When we talk about bacteria in the watershed, we are specifically referring to fecal bacteria, which are bacteria that indicate the presence of fecal matter from humans, pets, livestock, and wild animals. Tests are costly and time consuming and, therefore, testing for individual pathogens is not practical for routine monitoring. Because there are so many different types of pathogens that cause many different symptoms of illness, indicator organisms are used to estimate the overall risk of illness, instead of testing the water for each individual pathogen. Index organisms are also measured instead of testing for pathogens because each variety of possible pathogens requires a unique test (U.S. Geological Survey 2007). There are four different characteristics that make a good indicator organism for fecal contamination in both surface and ground water. The organism should be easily spotted with laboratory testing, it should not be present in unpolluted waters, the concentrations in which it is present should be correlated with the level of contamination, and the die-off rate should not be faster than the rate for the pathogens of concern (Environmental Protection Agency 2001). In the State of Maryland, *Escherichia coli (E. coli)* are used as the fecal bacteria indicator species to determine the potential for disease causing organisms in fresh water.

Escherichia coli (E. coli) are index organisms used to approximate the presence of illness causing organisms in fresh water. *E. coli* are bacteria that normally inhabit the gut of animals. Most *E. coli* are harmless and are actually healthy for the human intestinal tract (Centers for Disease Control and Prevention 2012). However, some are pathogenic and cause illness, in most cases diarrhea. These diarrhea causing *E. coli* are the bacteria that are associated with contaminated water (Centers for Disease Control and Prevention 2012) (World Health Organization 2003). In the late 1970s and early 1980s, the USEPA conducted a study determining that *E. coli* has the strongest relationships to gastrointestinal illness in freshwater swimmers when compared to other possible fecal bacteria indicators (U.S. Geological Survey 2007). For more information on bacteria monitoring and source tracking, see MDE's Bacterial Water Quality Monitoring page.

Regional and local factors such as the nature and seriousness of local illness, population behavior, exposure patterns, economic, socio-cultural, environmental, technical and health risk should all be considered when assessing recreational water quality and determining how to treat the problem. For example, areas with high populations of elderly or infants would be more vulnerable to pathogens because they tend to have weaker immune systems (World Health Organization 2003).

4.1 Sources

Bacteria enter the water mainly through feces, which is traceable to its sources through a source identification test as discussed in the TMDL summary section. There are both point sources and non-point sources of fecal bacteria. Point sources of fecal waste will typically enter the waterway through a pipe from sources such as Municipal Separate Storm Sewer Systems (MS4) including Sanitary Sewer Overflows (SSOs). Non-point sources of pollution are those sources that do not have one discharge point but occur as runoff flows into streams such as pet and wildlife deposition, grazing livestock, leaking or failing septic systems and other agricultural and urban runoff.

4.1.1 Point Sources

MS4 storm drain outfalls may be considered point sources of stormwater discharge. Fecal bacteria enter the watershed through the storm drain system when domestic pet and wildlife wastes are washed into the local water during rain events (Clary, et al. 2008). Pet waste should always be disposed of properly, as it can wash into storm drains even when not directly dumped in or left near drains. Pet waste left in yards or on sidewalks will eventually contaminate the nearest storm drain.

Human wastes can enter waterways as a point source through illicit connections of sanitary sewers to stormwater sewers, and sanitary sewer overflows (Clary, et al. 2008). Illicit connections occur when individuals, intentionally or unintentionally, connect their sanitary sewer pipes to the storm sewer pipe. The sanitary sewer is meant to transport fecal waste to a sewage treatment plant where the water can be treated before returning it to a river or stream. The storm sewer system is not filtered. It runs directly under roadways and land to rivers and streams. Illicit connections allow the fecal waste to flow, generally untreated, into streams and rivers and introducing pathogens directly into the water body. The Baltimore County Department of Environmental Protection and Sustainability Watershed Management and Monitoring Program is responsible for testing for the presence of illicit connections in the county.

Sanitary Sewer Overflows (SSO) are another point source of human fecal bacteria pollution. SSOs occur when the capacity of a sanitary sewer is exceeded and the contents of the sewer overflows. In a great majority of cases these overflows carry raw, untreated sewage into the environment, posing considerable health and environmental risks, as these systems can flow into and contaminate local waters (Clary, et al. 2008). These occurrences can be impacted by pipe capacity shortfalls, effectiveness of maintenance operations, geology, blockages, vandalism, or other influences. Baltimore City and Baltimore County have entered into Consent Decrees, with the State of Maryland and the Federal Government, to eliminate all SSOs within their jurisdictional boundaries. Baltimore City is required to complete its evaluation and SSO eliminations by January 2016, while Baltimore County is required to fulfill its commitment by March 2020. Waste Water Treatment Plants (WWTPs) can also be considered point sources of bacteria input.

4.1.2 Non-point Sources

In agricultural areas, inputs from runoff of animal manure from infected cattle pose one of the biggest threats due to the large amounts of fecal bacteria it contains. Grazing cows contribute 47 L of manure daily to pastures (Walker, et al. 1990). The presence and amount of fecal contamination from manure can be linked to temporal and spatial variables, such as rain and run off after a storm. Fecal contamination can also be directly deposited if cattle have access to streams (Environmental Protection Agency 2002) (Radcliffe, et al. 2006 as cited in (Haynes 2006)). Certain best management practices can reduce the amount of runoff from these sites, such as runoff control practices and long term storage of waste, which allows some bacteria to die off and allows manure to be applied during appropriate weather conditions to reduce runoff (Walker, et al. 1990). For more information on agricultural BMPs, see the Maryland Department of Agriculture's Watershed Implementation Plan strategies.

Pet waste is a non-point source of pollution which can be carried by runoff into streams and storm drains. Pets, particularly dogs, are significant contributors to source water contamination (Environmental Protection Agency 2001). The presence of the bacteria *E. coli* is an indicator for the presence of fecal matter and the other unwanted pathogens that come with it. It should be noted that pet waste does not only introduce bacteria into the water, but also protozoan organisms, such as cryptosporidium, which is highly resistant to chlorine disinfection and may be fatal to people with weak immune systems. Pet waste also contains frequent occurrences of roundworms and other parasitic nematodes (Environmental Protection Agency 2001).

Wildlife are almost always going to be categorized as a non-point source of bacteria, as they can be difficult to actively manage. Not only can their wastes be flushed into waterways during runoff events, but many wild animals, especially birdlife, will deposit wastes directly in the water. In many areas, it is difficult to restrict or even track the movements of groups and individuals leading to widely dispersed depositions.

The resuspension of pathogens and bacteria indicators in sediment is also a non-point source of pollution. As an example, in Buttermilk Bay, Massachusetts, the density of fecal bacteria increased in the water column after artificial disturbances of 2 cm of underlying sediment. This increase can indicate the presence of pathogens in a water body and have been most prominent in sites which lay on fine-grained, high-organic-carbon mud. The resuspension occurs during a storm event when the discharge and velocity of runoff increases and the sediment from the bottom of the water body is disturbed. As a result there is an increased level of bacteria concentration in the water column and a decrease in sediments. This can be a health hazard for recreational waters because of the potential for accidental ingestion of resuspended pathogens (Environmental Protection Agency 2001).

Human waste can also enter the water body as a non-point source through failed septic systems and damaged sanitary sewer pipes. The drainage from these systems amy make its way through the drainage field and eventually into local waters (Clary, et al. 2008). To reduce the risk associated with leaking or failing septic systems the location, installation and maintenance of septic systems are important factors to consider (Radcliffe et al. 2006 & USEPA 1997; 2002b as cited in (Haynes 2006)).

4.2 Environmental Fate

This section of the literature review was developed from the United States Environmental Protection Agency's Protocol for Developing Pathogen TMDLs document which provides a summary of factors influencing pathogen survival. Some of these factors are temperature, moisture, salinity, and soil conditions. Temperature has an inverse relationship with microorganisms that originate from fecal waste, as temperature increases the survival rate of microorganisms decrease. The estimated die-off rate doubles with each 10 degrees Celsius rise in temperature. Since fecal bacteria associated with warm blooded organisms live in a warm environment, colder water temperatures will result in die-off, as well as, temperature higher than their normal environment. Soil moisture also affects the survival time for bacteria, as the moisture retained increases so does the survival time. For example, soils with high clay content retain more moisture and as a result have an increased bacteria survival. Salinity of a water body can also decrease the survival rate of bacteria. Soil conditions such as pH can influence the survival of bacteria as well. Acidic soils from pH ranges 3 to 5 have had shorter survival times compared to neutral soils and in general bacteria survival decreases with low pH. Also, bacteria have been noted to have longer survival rates when large amounts of organic matter are present. Based on these factors a water body can be either support or deter bacteria growth. For more information see the EPA Protocol for Developing Pathogen TMDLs document.

Other literature on factors associated with fecal bacteria in streams has been reviewed in a literature review developed for the Minnesota Pollution Control Agency. For this literature review, see Literature Summary of Bacteria- Environmental Associations Developed for the Minnesota Pollution Control Agency, 2009

This section summarizes the natural and human related characteristics of the Herring Run watershed. The Herring Run watershed is a section of the Back River watershed, which is the only portion of the Back River watershed that has been listed as impaired by fecal bacteria. The other streams and the tidal waters of Back River are not listed as impaired by fecal coliform.

5.1 The Natural Landscape

5.1.1 Location

The Herring Run watershed is located in the south east portion of Baltimore County. The mainstem of Herring Run originates in the region known as Loch Raven, near Taylor Avenue and Perring Parkway. It continues southeast through the City of Baltimore, and then returns to Baltimore County, where it is joined by Redhouse Run and Moores Run, eventually becoming Back River. The major stream systems that constitute the watershed within Baltimore County include: Chinquapin Run, West Branch Herring Run, East Branch Herring Run, Redhouse Run, and a small portion of Moores Run. The Herring Run watershed comprises approximately 7,569 acres within Baltimore County.

MDE divided Herring Run into three subwatersheds based on sampling locations: Harford Road Station, Pulaski Highway Station, and the Biddle and 62nd Street Station. This Implementation Plan breaks Herring Run into two Implementation Areas: Implementation Area A and Implementation Area B, see Figure 5.1.

> **Implementation Area A** refers to the portion of the Harford Road monitoring station subwatershed which is located in the County and includes Chinquapin Run, West Branch Herring Run, and East Branch Herring Run.
>
> **Implementation Area B** refers to the portions of the Pulaski Highway and the Biddle & 62nd Street monitoring stations subwatersheds located in the County and includes Moores Run and Redhouse Run.

This IP only discusses the characteristics of the portions of the watershed located within Baltimore County.

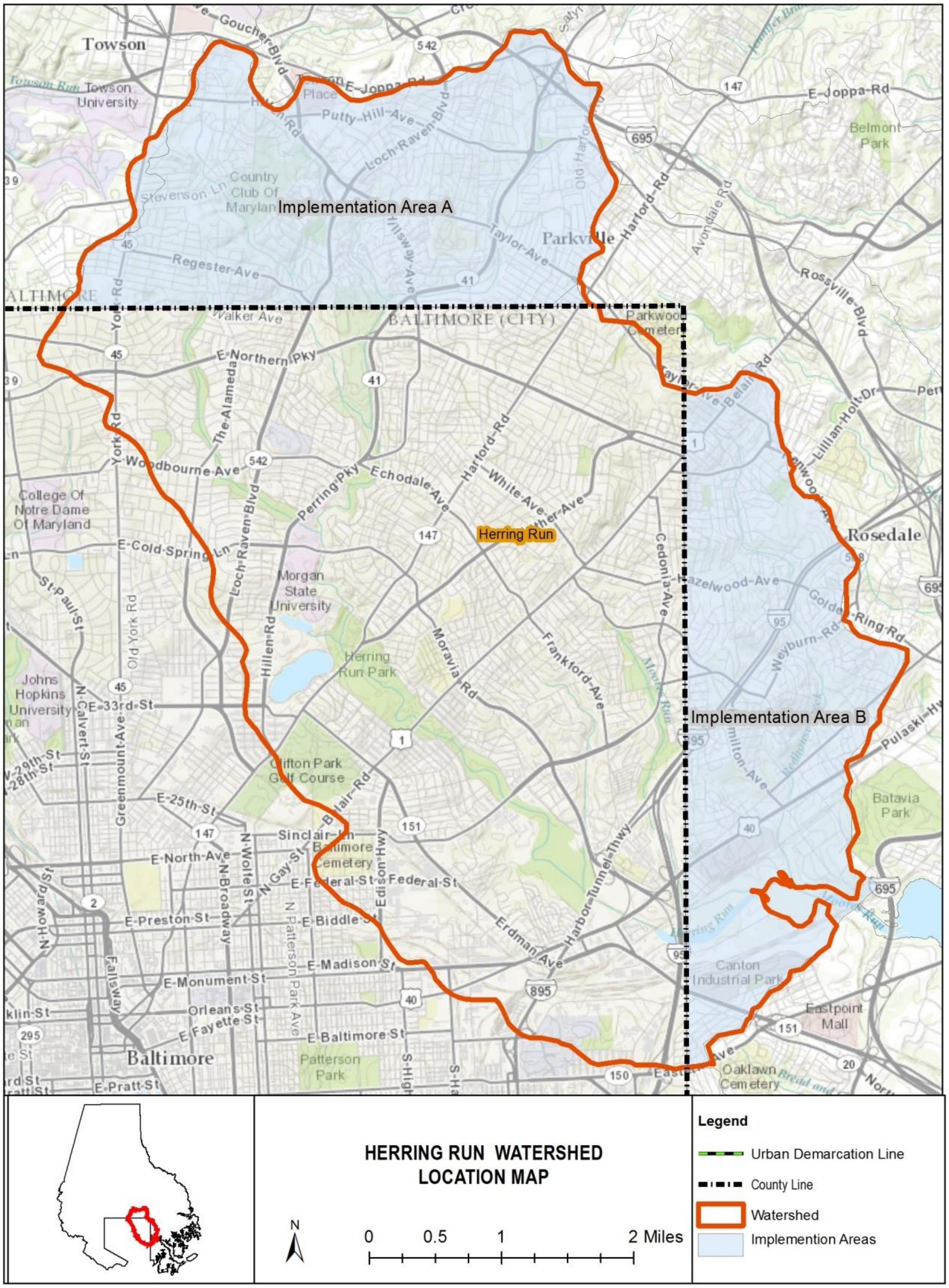

Figure 5.1: General Location Map Highlighting the Two Distinct Implentation Areas within Baltimore County

5.1.2 Geology/Soils

Geology

The Baltimore County portion of the Herring Run watershed is located within the Coastal Plain physiographic province (64%) and the Piedmont physiographic province (36%). The natural Piedmont landscape is characterized by rolling hills, extensive forests, thick soils on deeply weathered crystalline bedrock, and abundant forest litter that minimizes overland flow. The natural Coastal Plain is relatively flatter with soils formed from sedimentary deposits. (MGS 2014).

Soils

Soil type and moisture conditions greatly affect how land may be used and the potential for vegetation and habitat on the land. Soil conditions are also one determining factor for water quality and quantity in streams and rivers. Soils are an important factor to incorporate in targeting projects aimed at improving water quality or habitat.

The Natural Resources Conservation Service classifies soils into four Hydrologic Soil Groups (HSGs) based on the soil's runoff potential. Runoff potential is the opposite of infiltration capacity; soils with high infiltration capacity will have low runoff potential, and vice versa. The four Hydrologic Soils Groups are A, B, C and D, where A's generally have the lowest runoff potential and D's have the greatest runoff potential. Dual hydrologic soil groups can be assigned as well. This happens when certain wet soils are placed in group D based solely on the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, then they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained.

Soils with low runoff potential will be less prone to erosion, and their higher infiltration rates result in faster throughflow of precipitation to groundwater. As shown in Table 5.1, the Herring Run watershed is comprised of approximately 56% of C and D soils which means the soils in this watershed are prone to erosion. The more erosion that occurs, the more likely nutrients, pollutants and pathogens are likely to enter waterways.

Table 5.1: Acreage of Herring Run Watershed in Baltimore County

Hydrologic Soil Group	Description	Acres	Percent within watershed in BC
A	Soils which have a low runoff potential and high infiltration rates when thoroughly wet. The depth to a permanent water table is deeper than 6 feet.	1,277.89	16.91
B	Soils which have moderate infiltration rates when thoroughly wet. Water movement is moderately rapid and depth to a permanent water table is deeper than 2 feet.	2,046.25	27.09
C	Soils which have a slow rate of infiltration when thoroughly wet and moderately high runoff potential since water movement through these soils is moderate or moderately slow and they generally consist of a layer that impedes downward movement of water.	3,071.76	40.66
D	Soils which have the highest runoff potential and very low infiltration rates when thoroughly wet. Water movement through the soil is slow or very slow. Generally consists of a restrictive layer of nearly impervious material within 20 inches of the soil surface and the depth to a permanent water table is shallower than 2 feet.	898.07	11.89
B/D	Dual hydrologic soil group: Group B has moderate infiltration rate when thoroughly wet; Group D assignment is based solely on the presence of a water table within 24 inches of the surface.	29.35	0.39
C/D	Dual hydrologic soil group: Group C has slow infiltration rate when thoroughly wet and moderately high runoff potential; Group D assignment is based solely on the presence of a water table within 24 inches of the surface.	30.86	0.41
No group	These areas consist of water, soils under highways, or quarries.	200.49	2.65

Source: USDA-NRCS 2009

5.1.3 Stream Systems

Stream systems are a watershed's circulatory system, and the most visible attribute of the hydrological cycle. The stream system is an intrinsic part of the landscape, and closely reflects conditions on the land. The streams are a fundamental natural resource, with myriad benefits for plants, animals, and humans. Maintaining a healthy stream system is a priority for many individuals and organizations, and requires insuring that stream flows and water quality closely mimic the conditions found in un-impacted watersheds. Streams are the flowing surface waters, and are distinct from both groundwater and standing surface water (such as lakes), though they are connected with both of them.

The Herring Run watershed contains approximately 28.5 miles of streams, all of which drain to tidal Back River, which empties into the Chesapeake Bay. Table 5.2 shows the length of streams in each Implementation area in Herring Run in Baltimore County only. The major stream systems that constitute the watershed within Baltimore County include: Chinquapin Run, West Branch Herring Run, East Branch Herring Run, Redhouse Run, and a small portion of Moores Run.

Table 5.2: Linear feet and miles of streams within Herring Run within Baltimore County

Implementation Area	Linear Feet of Streams	Miles of Streams
Implementation Area A	69,267	13.12
Implementation Area B	47,045	15.38
Total in Herring Run (Baltimore County only)	**150,499**	**28.50**

5.2 The Human Modified Landscape

The natural landscape has been modified for human use over time. The intensity of this modification has increased, starting with the colonization of Maryland in the 1600s. This modification has resulted in environmental impacts to both the terrestrial and aquatic ecosystems. This section will provide a characterization of the human modified landscape and how that modification is associated with impacts to the natural ecosystem. The characterization will progress from the general characteristics of land use and land cover to specific issues including population, drinking water and wastewater, storm water systems, and sanitary sewer overflows, all of which contribute to bacteria in the watershed.

5.2.1 Land Use: Baseline and Current

The land use of an area has an influence on the water quality of the watershed. Forested land absorbs nutrients and slows the flow of water into streams. Roads, parking areas, roofs and other human constructions are collectively called impervious surface. Impervious surfaces block the natural seepage of rain into the ground. Unlike many natural surfaces, impervious surfaces typically concentrate stormwater runoff, accelerate flow rates and direct stormwater to the nearest stream. This can cause bank erosion and destruction of in-stream and riparian habitat. Watersheds with small amounts of impervious surface tend to have better water quality in local streams than watersheds with greater amounts of impervious surface.

The Herring Run watershed is comprised of 7,569 acres or 11.8 square miles of land within Baltimore County. Land Use data from the USGS National Land Cover Database (Jin, 2013) from 2001, 2006, and 2011 was combined with Baltimore County impervious surface data from 1995, 1996, 1997, 2001, 2005, and 2011. This combined land use land cover data was used to interpolate the baseline (2004) land use for Herring Run. The land use percentage distribution for Herring Run for 2004 and current (using 2011 data) are shown in Table 5.3. This watershed is already mostly developed therefore land use has not changed considerably over time.

Table 5.3: Land use in Herring Run Watershed in Baltimore County in 2004 and present

Land Type	2004 (Baseline year) Acres	2004 (Baseline year) Percent	Current (2011 data) Acres	Current (2011 data) Percent	Change since Baseline Acres	Change since Baseline Percent
Forest	715.89	9.5%	691.90	9.1%	-23.99	-3.4%
Urban Impervious	2,201.07	29.1%	2,300.22	30.4%	99.15	+4.5%
Urban Pervious	4,645.76	61.4%	4,570.43	60.4%	-75.33	-1.6%
Water	6.19	0.1%	6.90	0.1%	0.02	0.3%

Urban impervious is developed land, including any structure (houses, shopping centers, etc.), roads, parking areas, and pavement. Urban pervious is any developed land cover that is not impervious including turf, gardens, bare soil, mulch, hedges, shrubs, and trees. Land classified as forest includes forests, natural meadows/grassland, and wetlands. Water includes any ponds, reservoirs, or other open water bodies in the watershed.

5.2.2 Population

Census block data from the 2000 US Census and 2010 US Census was used to determine the population in the watershed. Data from the 2000 US Census was interpolated in order to estimate the population for 2004, which is the baseline year for the TMDL and therefore important to understand the conditions at the time the TMDL was developed. The 2010 Census is the most recent census therefore there is not more recent data. Population for 2004 and 2010 and the percent change over time in the Herring Run watershed and its implementation areas are shown in Table 5.4.

Table 5.4: Population of Herring Run Watershed within Baltimore County

Implementation Area	2004 (Baseline year)	Current (2010 data)	Percent change
Implementation Area A	41,671	41,576	-0.23%
Implementation Area B	22,746	22,670	-0.33%
Total Herring Run (Baltimore County portion only)	64,418	64,247	-0.27%

Sources: U.S. Census Bureau 2000 and U.S. Census Bureau 2010

5.2.3 Infrastructure

Drinking Water

Drinking water is a fundamental need for human development. Drinking water can be supplied by either public distribution systems or by wells associated with individual developed properties. Having an adequate supply of drinking water is essential to maintaining the human population in a region. The entire Herring Run watershed is served by public water.

Wastewater

Wastewater created through human use must be treated and properly disposed of. This may be accomplished in two ways, either through individual wastewater treatment systems (septic systems) or through public conveyance to a treatment facility. Residential wastewater consists of all of the water that is typically used by residents, including wash water, bathing water, human waste deposal water, and any other rinse water (paint brush, floor washing, etc). Industrial operations must also dispose of any water used as part of their operation. Depending on the operation the water could contain any number of contaminants, including pathogens, metals, organic compounds, detergents, or synthetic compounds. All of these wastes have the potential to harm the natural environment.

Septic Systems

Properly functioning septic systems provide treatment for virtually all of the phosphorus, but leak nitrogen in the form of nitrates. Depending on the location of the system the nitrates may either be reduced or eliminated through denitrification as the water passes through riparian buffers, particularly forested riparian buffers. Failing systems can result in increased contamination of the aquatic environment through increased releases of nitrogen, phosphorus, and other chemicals. They can also result in increased bacterial contamination of the waterways and potential for human health concerns.

There are no on-site disposal (septic) systems located in the Herring Run watershed.

Public Sewer System

A public sewer system conveys wastewater from individual residences or businesses to a facility that treats the wastewater prior to discharge. The Herring Run watershed is serviced entirely by a public sewer system. The part of the system that is in the public right-of-way is owned and maintained by the County government. The public system consists of the gravity piping system, access manholes, pumping stations, and force mains. Private property owners are responsible for the maintenance of the pipes and cleanouts located on their property.

Wastewater, like water, naturally flows downhill through pipes. When this occurs, it is referred to as gravity pipes. However, sometimes it is necessary to be able to force the water in another direction, therefore creating a pressurized pipe or a force main. This scenario occurs in low lying areas. In order for the water to go against gravity, a pump is needed which is kept in a pump station. Table 5.5 shows length of gravity pipe, pressurized pipe, and number of pumps stations in the Herring Run watershed and its Implementation Areas.

Table 5.5: Infrastructure in Herring Run Watershed in Baltimore County

Implementation Area	Length of Gravity Pipe (miles)	Length of Pressurized Pipe (miles)	Number of Pump Stations
Implementation Area A	104.2	0.88	1
Implementation Area B	77.2	4.78	7
Total Herring Run (Baltimore County portion only)	181.4	5.66	8

Waste Water Treatment Facilities

There are no wastewater treatment facilities in the Herring Run watershed. The Back River waste water treatment plant is located on the tidal waters of the Back River and is just south of the Herring Run watershed.

Sanitary Sewer Overflows (SSOs)

Environmental impacts associated with the public sewer system are usually the result of sewage overflows. These Sanitary Sewer Overflows (SSOs) usually result from blockages within the sewage system, pumping station failure, or rainwater inflows exceeding the capacity of the pipe. There are several factors that may contribute to SSOs from a sewer system, including pipe capacity, operations and maintenance effectiveness, sewer design, age of system, pipe materials, geology and building codes. The U.S. EPA reports there are at least 40,000 of these incidents per year in the United States of America (U.S. EPA 2012). The environmental and human health consequences of these overflows can be serious. *E. coli* bacteria and other pathogens can be present, posing health risks to individuals who may come in contact with contaminated water. Sewer overflows can also contain high levels of nitrogen and phosphorus that are toxic to aquatic life and feed organisms that deplete oxygen in waterways. High levels of sediment are also present in these overflows, which can clog streams and block sunlight from reaching essential aquatic plants.

Between 2000 and 2013, there were 171 SSOs totaling 11,958,554 gallons in Herring Run; there were 129 SSOs totaling 5,383,326 gallons in Implementation Area A and 42 SSOs totaling 6,575,228 gallons in Impelementation Area B. See Figure 5.2 for the distribution of SSO in the Herring Run watershed in Baltimore County from 2000-2013. Figure 5.3 shows the volume of

SSOs per year in Implementation Area A and Figure 5.4 shows the volume of SSOs per year in Implementation Area B. Figure 5.5 shows the cause of the SSOs in the Baltimore County portion of the Herring Run.

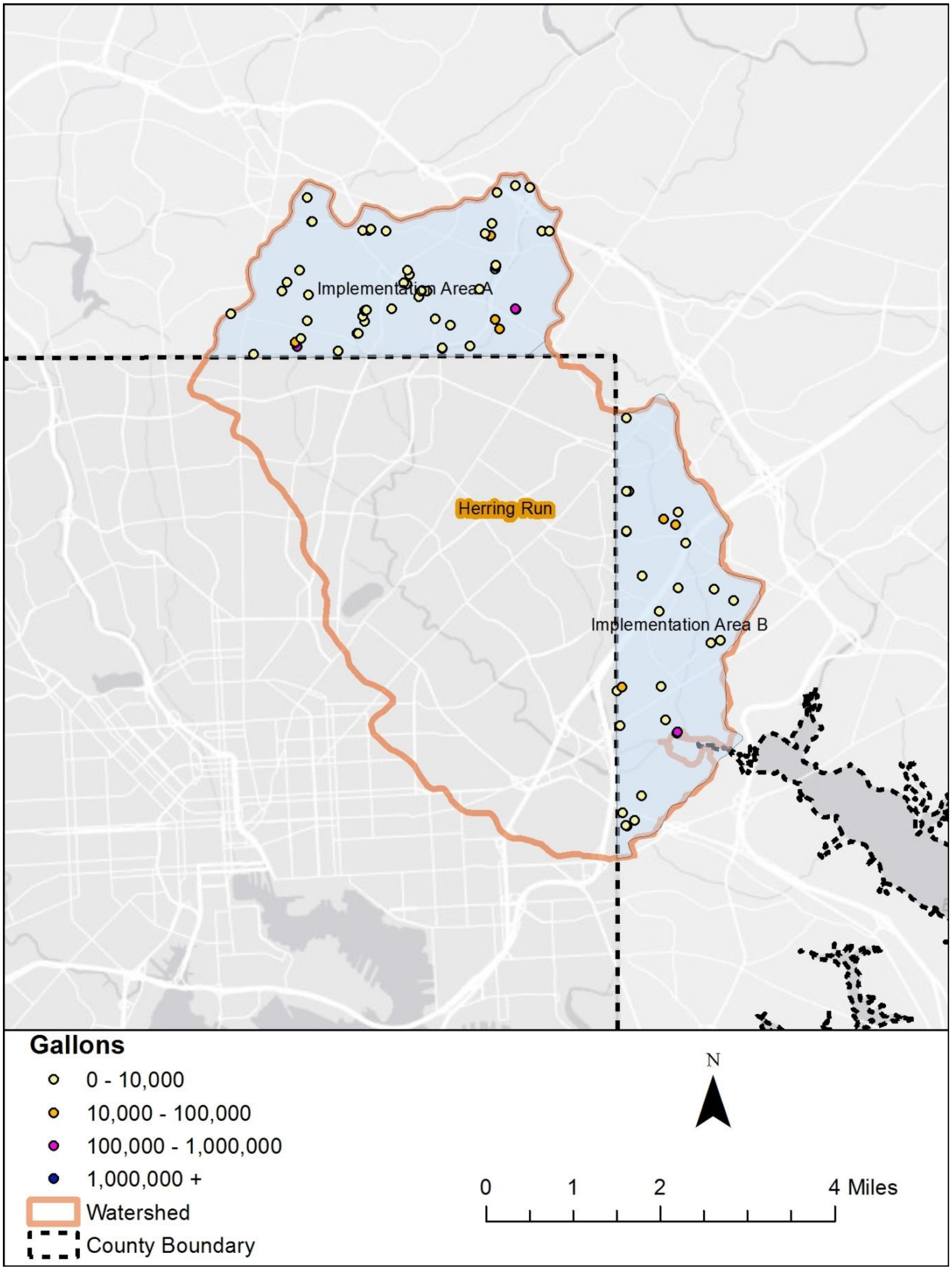

Figure 5.2: Location of SSOs in Herring Run Watershed from 2000-2013

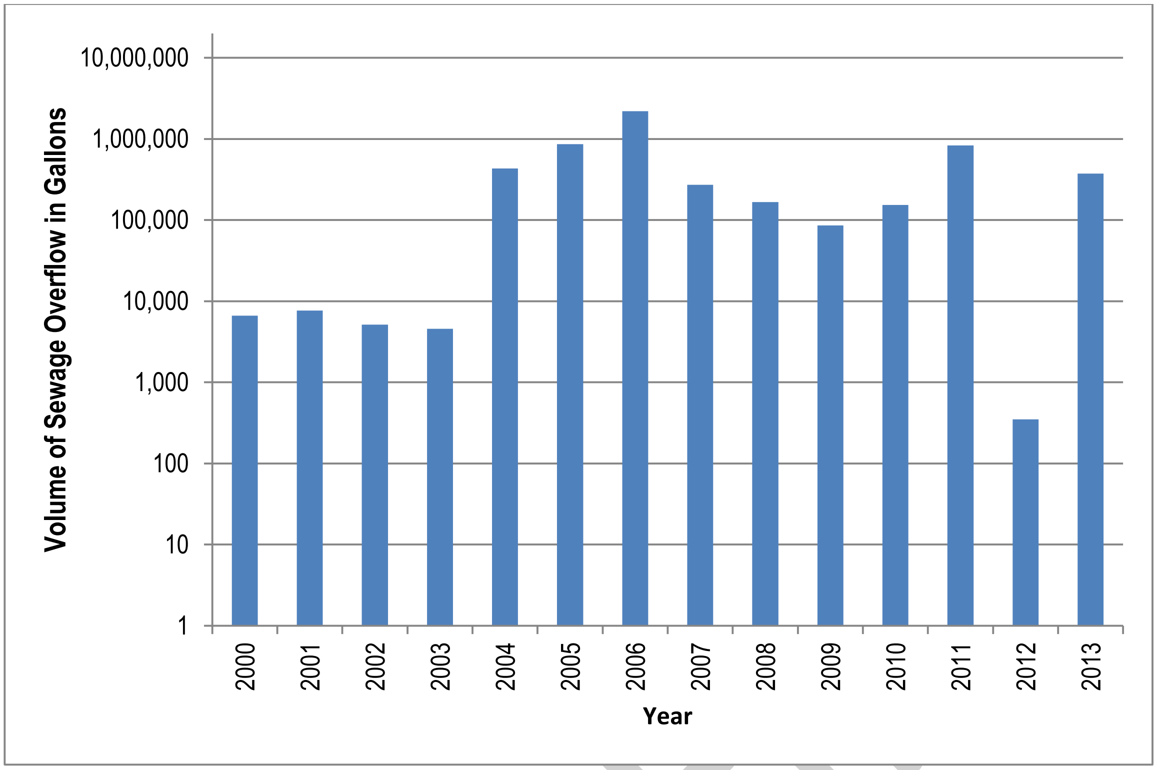

Figure 5.3: Volume of SSOs in Implementation Area A per Year from 2000-2013

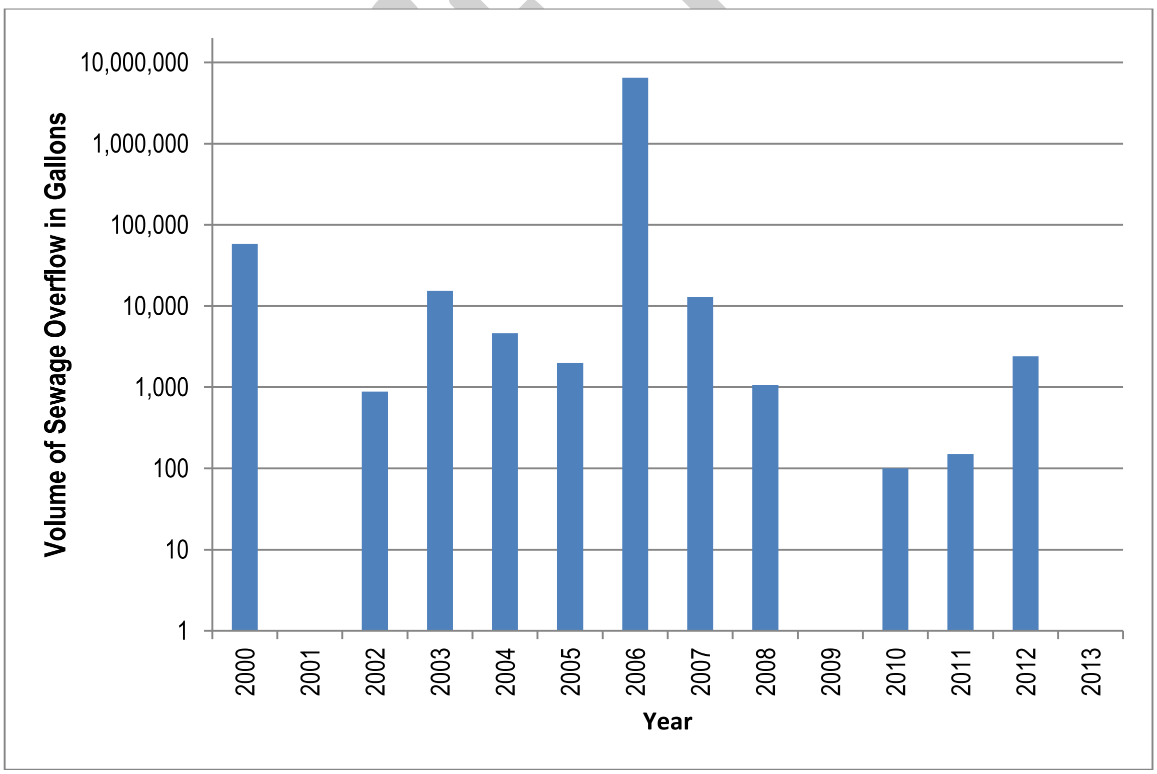

Figure 5.4: Volume of SSOs in Implementation Area B per Year from 2000-2013

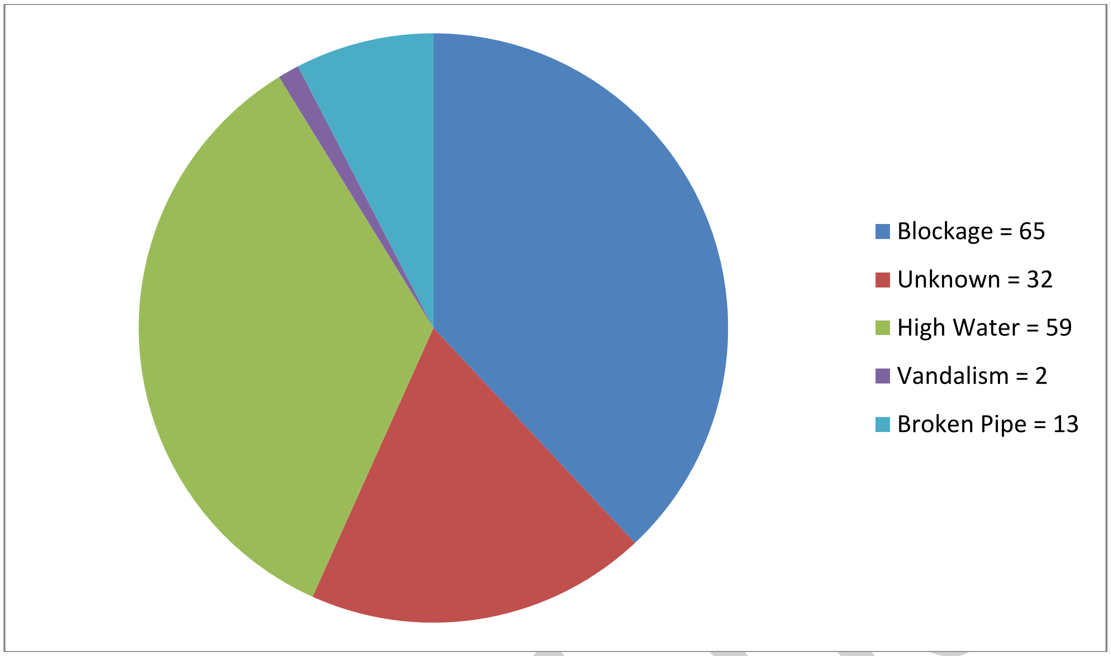

Figure 5.5: SSOs by Cause in Herring Run watershed in Baltimore County from 2000-2013

Baltimore County conducts bacteria water quality sampling for *Escherichia coli* (*E. coli*) in the Herring Run subwatershed of Back River. This section outlines the major ongoing bacteria monitoring programs in Herring Run, which include a monthly trend monitoring program and a seasonal source tracking program. Major sources of *E. coli*, as described in the TMDL are domestic animals, humans, livestock, and wildlife. Through trend and tracking monitoring, Baltimore County is attempting to locate and eliminate *E. coli* hotspots to reduce bacteria levels and meet bacteria water quality standards.

6.1 Baltimore County Bacteria Trend Monitoring Program

Baltimore County EPS has coordinated with Baltimore City Surface Water Management Division to monitor bacteria trend levels over time at 3 monitoring locations within Back River, beginning in June 2010. This is part of the Bacteria Trend Monitoring Program that includes Baltimore County, Baltimore City, and Carroll County to monitor bacteria trends over time at 32 monitoring locations within 1 subwatershed and 6 major watersheds. The bacteria trend monitoring program was developed in response to the development of bacteria TMDLs in Herring Run, Gwynns Falls, Loch Raven, Prettyboy, Jones Falls, Liberty Reservoir, and Lower North Branch of the Patapsco watersheds. Bacteria monitoring began in June 2010, with 16 sites in Baltimore County, and 11 sites in Baltimore City. Bacteria monitoring in Carroll County began in 2012 and includes 5 sites in Carroll County. Herring Run trend monitoring samples are collected on the first Thursday of every month by Baltimore City, and are brought to the Baltimore County EPS lab for *E. coli* analysis using IDEXX methodology. Table 6.1 shows the latitude/longitude locations of the current bacteria monitoring stations within Back River. Figure 6.1 shows the locations of the monitoring sites for the entire trend monitoring program.

Table 6.1 Baltimore County Bacteria Monitoring Station Locations

Station Code	County Code	Stream	Watershed	Latitude	Longitude	County
HER0065	HER-1	Herring Run	Back River	39 20.730	-76 34.870	Balt. City
Pulaski	Pulaski	Herring Run	Back River	39 30.512	-76 53.732	Balt. City
Biddle/62	Biddle	Moore's Run	Back River	39 30.595	-76 52.946	Balt. City

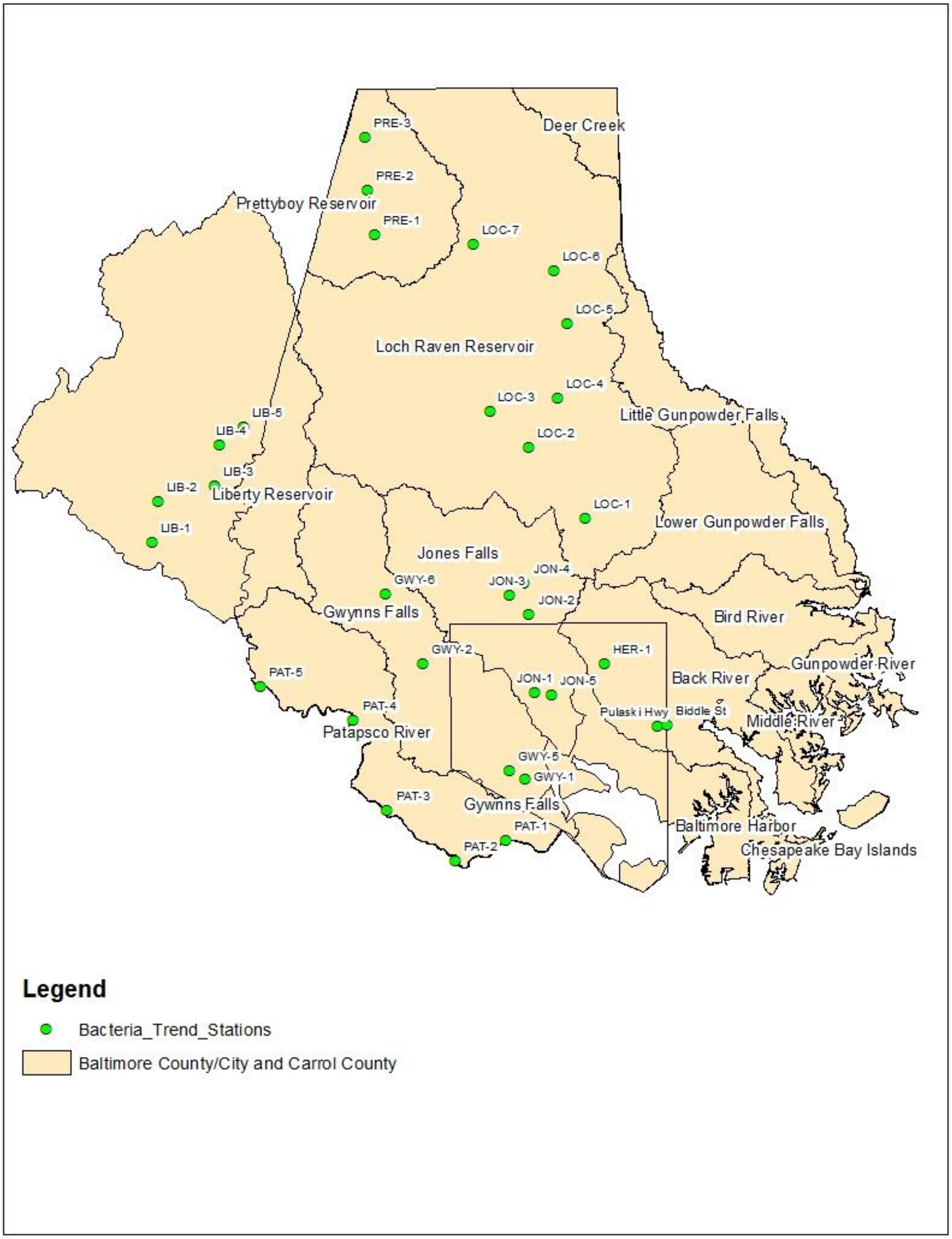

Figure 6.1: Map of Baltimore County/City, and Carrol County Bacteria Monitoring Sites

6.1.1 Summary of Data Results

Raw Data can be found in Appendix 6.1. Samples are collected on the first Thursday of every month, except in circumstances of severe weather. Table 6.2 presents the number of samples and the geometric mean for high (wet) flow and low (dry) flow by year. It also presents the geometric mean of all samples by year regardless of condition. The table is stratified by annual data (includes all data collected for the year) and seasonal data (includes only those samples collected between May 1st and September 30th each year. Geometric means that meet the water quality standard (126 MPN) are highlighted in green. Sampling at the Biddle Street and Pulaski Highway sites did not commence until 2011. These data are displayed graphically in Figures 6.2 through 6.4.

Table 6.2 Herring Run Annual Geometric Mean by Weather

Annul Data (number of samples and geometric mean MPN)									
Site	**Flow Type**	**2010**		**2011**		**2012**		**2013**	
		N	**MPN**	**N**	**MPN**	**N**	**MPN**	**N**	**MPN**
HER-1	High	2	2420	4	1267	2	448	2	1253
	Low	5	616	6	842	7	136	9	85
	All	7	910	10	991	9	177	11	139
Biddle	High			2	863	3	388	2	618
	Low			4	667	8	196	8	103
	All			6	727	11	236	10	147
Pulaski Hwy	High			2	1218	3	763	2	1849
	Low			4	512	8	123	4	402
	All			6	684	11	202	10	146
Seasonal Data (May 1st to September 30th)									
Site	**Flow Type**	**2010**		**2011**		**2012**		**2013**	
		N	**MPN**	**N**	**MPN**	**N**	**MPN**	**N**	**MPN**
HER-1	High	0		2	1455	0		1	649
	Low	4	921	3	989	4	74	3	106
	All	4	790	5	1154	4	74	4	166
Biddle	High	0		1	2420	1	167	1	158
	Low	0		3	1383	4	356	3	192
	All	0		4	1591	5	306	4	183
Pulaski Hwy	High	0		1	2420	1	333	1	2420
	Low	0		3	695	4	189	3	649
	All	0		4	950	5	211	4	170

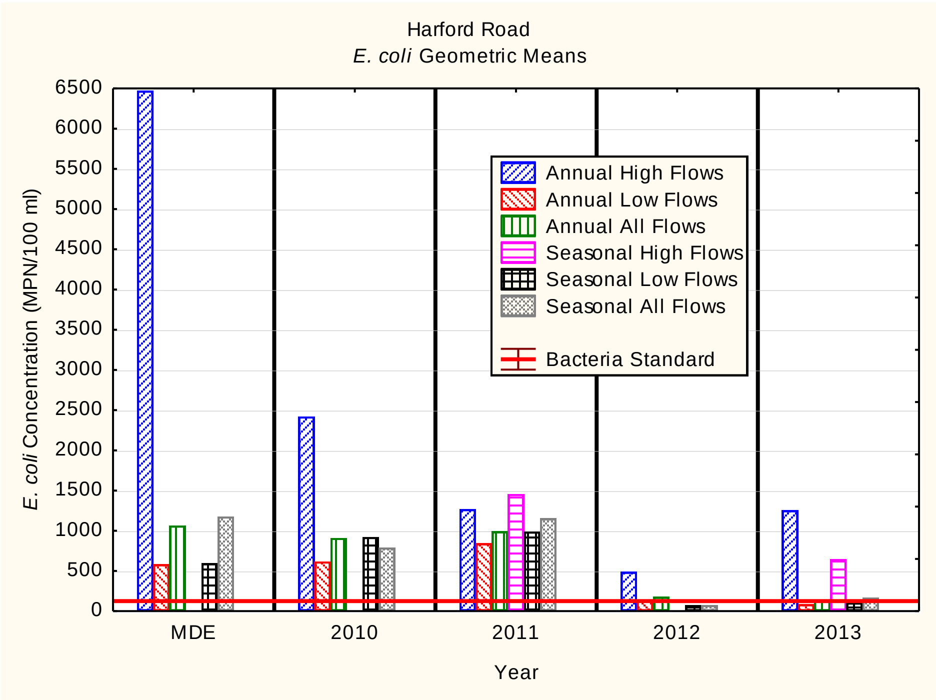

Figure 6.2: *E. coli* Geometric Mean Concentrations at the Harford Road Site (HER-1) for both Annual and Seasonal Flow Periods Stratified by Flow Condition, MDE Results Added for Comparison

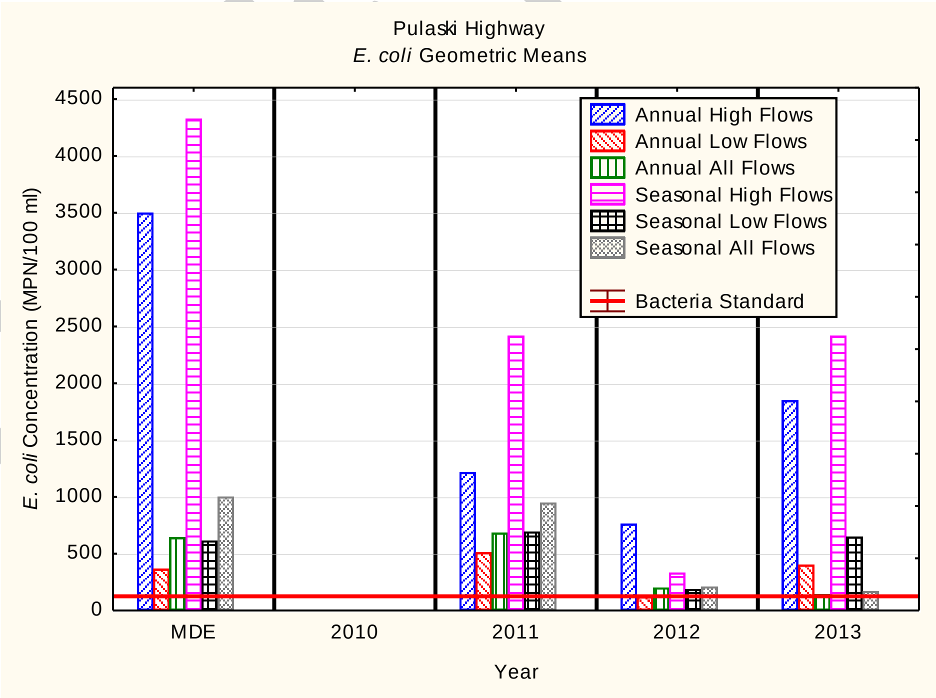

Figure 6.3: *E. coli* Geometric Mean Concentrations at the Pulaski Highway Site for both Annual and Seasonal Flow Periods Stratified by Flow Condition, MDE Results Added for Comparison. No Samples Collected in 2010

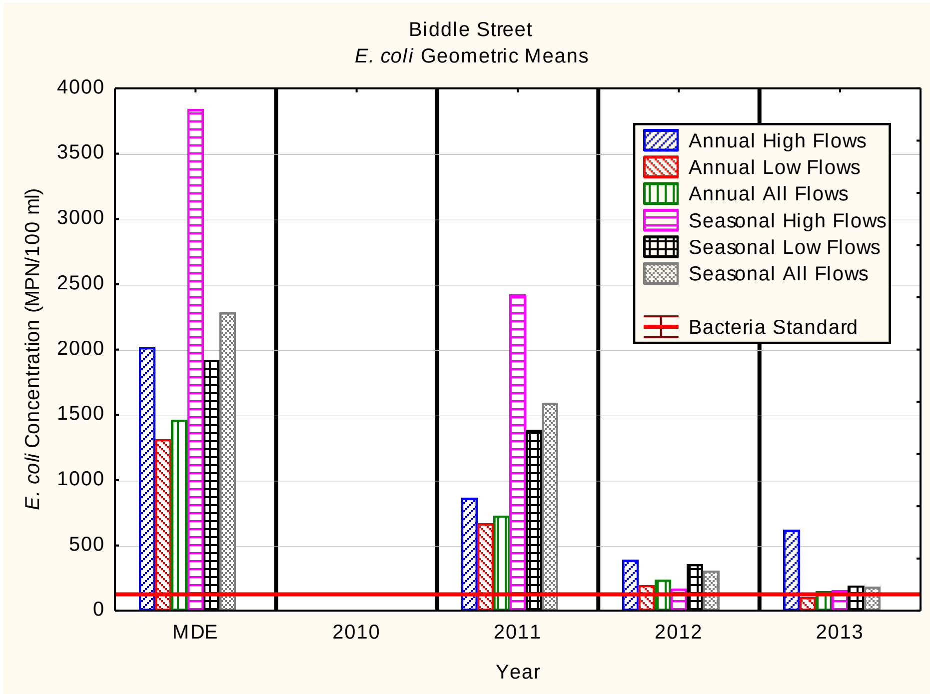

Figure 6.4: *E. coli* Geometric Mean Concentrations at the Biddle Street Site for both Annual and Seasonal Flow Periods Stratified by Flow Condition, MDE Results Added for Comparison. No Samples Collected in 2010

There appears to be an improving trend in the *E. coli* MPN concentrations, as indicated by the annual and seasonal geometric means for all samples. The bacteria water quality standard has been achieved on a sporadic basis in recent (2012, 2013) years, primarily on an annual basis, but at HER-1 on a seasonal basis as well. While it remains to be seen if the apparent improvement trend will continue, the data are an encouraging indication that actions resulting from the sanitary sewer consent decrees for Baltimore City and Baltimore County are resulting in water quality improvement.

In addition to analyzing the data for the geometric means, the data were analyzed based on the single sample exceedance for seasonal data (May 1st to September 30th). Single sample exceedance standards are based on frequency of full body contact, ranging from infrequent (576 MPN) to frequent (235). The objective in the control of bacteria is to not only meet the geometric mean water quality standards, but to also meet the single sample water quality standards. This is particularly important for the low flow (dry weather) component of the flow regime, as this is when human recreational use of water is most likely to occur. Table 6.3 presents the results of the analysis by station, by year and by flow regime. The zero percent exceedances are high-lighted in green.

Table 6.3: Frequency of Exceedance of Single Sample Water Quality Standards

Site	Year	N		Percent Single Sample Exceedance (MPN)							
		Flow Type		576		410		298		235	
		High	Low	High	Low	High	Low	High	Low	High	Low
HER-1	2010	0	4		75%		75%		75%		75%
	2011	2	3	100%	67%	100%	67%	100%	100%	100%	100%
	2012	0	4		0%		0%		0%		0%
	2013	1	3	100%	0%	100%	0%	100%	0%	100%	33%
Biddle	2010	0	0								
	2011	1	3	100%	100%	100%	100%	100%	100%	100%	100%
	2012	1	4	0%	50%	0%	50%	0%	75%	75%	0%
	2013	1	3	0%	33%	0%	33%	0%	33%	0%	67%
Pulaski	2010	0	0								
	2011	1	2	100%	75%	100%	75%	100%	100%	100%	100%
	2012	1	4	0%	0%	0%	25%	0%	50%	0%	50%
	2013	1	3	0%	0%	0%	0%	0%	0%	0%	25%

These data also indicate an improving trend over time in the bacteria concentrations, particularly during low flow (dry weather) conditions. The high flows also indicate improving trends, but given the limited number of samples, it is not possible to ascertain the accuracy of this trend.

The bacteria trend monitoring program will continue until such time as all bacteria water quality standards are met in the Herring Run subwatershed.

6.2 Baltimore County Bacteria Tracking Program

In 2010, Baltimore County performed a synoptic bacteria survey in Herring Run, Implementation Area A, to initiate a pilot study on developing techniques to identify sources of bacteria in streams. The initial 11 sites were surveyed three times to gain an understanding of the baseline bacteria levels. Following this survey, Baltimore County began seasonal dry-weather tracking of bacteria throughout the Herring Run watershed, based on bacteria hotspots. The number of samples taken increased in 2012, and again in 2013, as the program developed and Baltimore County identified stream reaches which required extensive analysis. The most significant finding from this survey has been a sewage leak from an MS4 outfall, which was traced to a residential property and eliminated with the help of Baltimore County Department of Public Works (DPW). This was a small leak which was impacting the bacteria levels of the stream, and required extensive tracking through the storm drain system.

This program is different than the BST performed by MDE in that the contribution specific sources are not being analyzed. Instead, Baltimore County is attempting to locate point and nonpoint sources of bacteria by means of tracking high in-stream levels of bacteria through targeted *E. coli* sample testing, as well as using ammonia as an indicator.

Figure 6.5 shows the 11 sites used for the initial survey, from which further sampling took place. The two main branches of Herring Run have been defined as “East Branch” and “West Branch” for the purposes of analyzing data for this study. Results from the study are shown in Table 6.4.

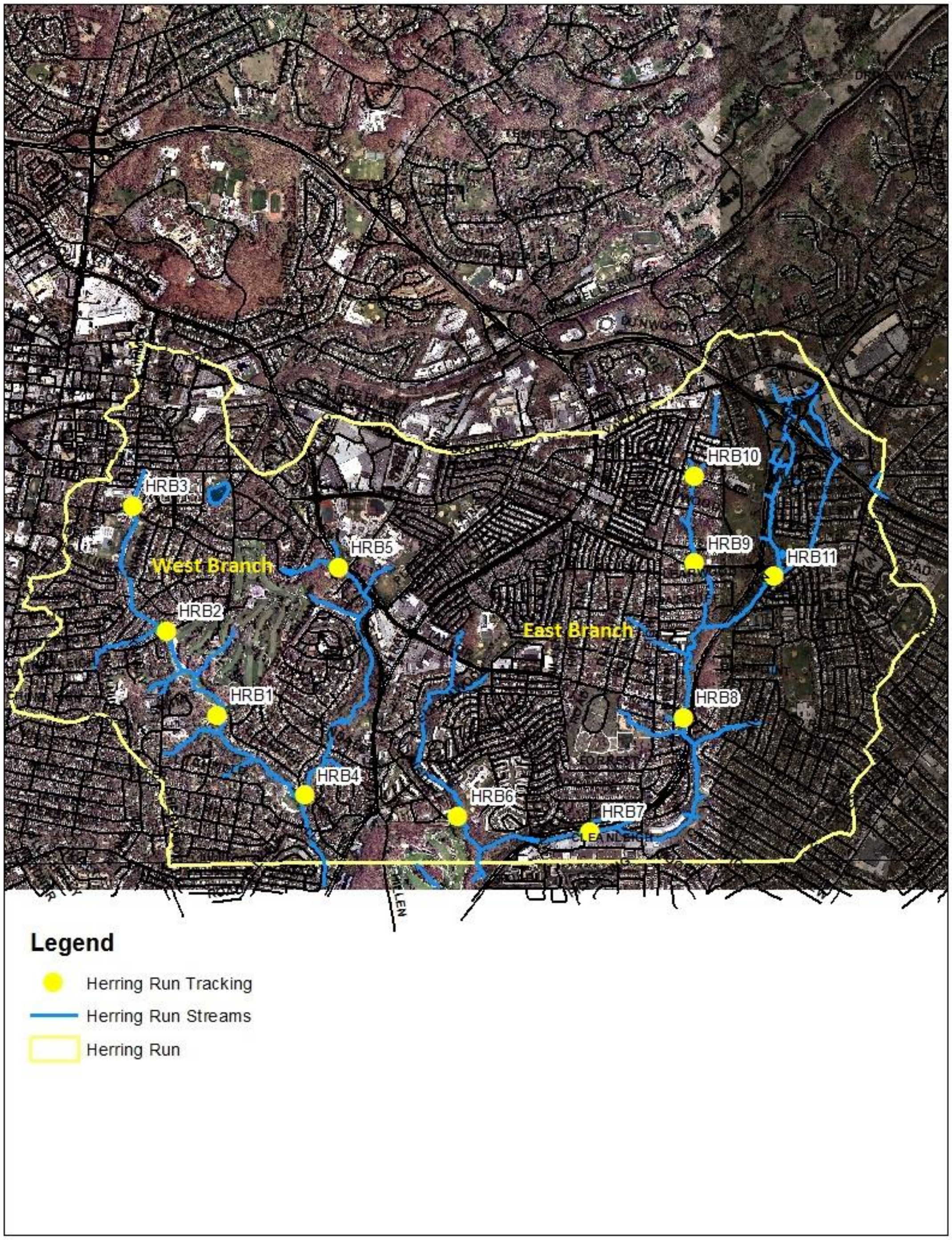

Figure 6.5 Map of Herring Run Bacteria Trend Monitoring Sites

6.2.1 Summary of Data Results

The results in Table 6.4 below represent the two main branches of Herring Run in Implementation Area A of Baltimore County, as shown in the map above. The number of samples, minimum and maximum MPN, and annual geometric mean have been calculated per year for each branch.

Table 6.4: Herring Run Bacteria Tracking Annual Geometric Mean

Year	# Samples	MPN/100ml		
		E. coli Minimum	*E. coli* Maximum	Annual Geometric Mean
West Branch Herring Run				
2010	5	272.3	2419.7	605.5
2011	5	410.6	2419.7	1035.7
2012	15	5.2	2419.7	117.2
2013	50	11.6	2613	916.2
East Branch Herring				
2010	6	57.6	2419.7	442.0
2011	6	686.7	2419.7	1689.4
2012	23	21.1	2419.7	598.6
2013	6	261.3	2419.7	672.0

In 2010 and 2011, only the initial synoptic samples were monitored. The tracking component of the program began in 2012, with a slightly larger focus on the east branch of Herring Run. In 2013, bacteria tracking was primarily focused on the west branch, with extensive monitoring to locate sources such as the sewage leak previously mentioned.

6.2.2 Comparison of Data to TMDL Targets

In all of the years sampled, the annual geometric mean for the targeted tracking has exceeded the steady-state geometric mean indicator limit of 126 MPN/100ML. There does not appear to be a trend as to which branch consistently shows the highest annual geometric mean. This is probably due, in part, to the inconsistent nature of illicit discharges and other sources of bacteria in the watershed.

6.3 Summary of Current Conditions

Based on the results of the current monitoring programs, sampling indicates that Herring Run is exceeding the steady-state geometric mean limits for bacteria. However, all of the sampling locations in the Baltimore County Bacteria Trend monitoring program have shown a downward trend since 2010. The results of the Baltimore County Bacteria Tracking Program are more widely variable, due to the nature of bacteria, the sampling season, and the types of samples being collected. Since Baltimore County is tracking known bacteria hotspots, results from this program will likely continue to show higher bacteria levels.

The Back River watershed within Baltimore County has been previously assessed in documents that detail three separate studies; the Back River Water Quality Management Plan (WQMP) completed January 1997, the Upper Back River Small Watershed Action Plan (SWAP) completed November 2008, and the Tidal Back River SWAP completed February 2010. All completed SWAP documents and their appendices are available online.

The WQMP for Back River is a document that details potential Capital Improvement Projects (CIPs) that the County could consider to improve water quality. These Management Plans focused on County-specific actions, and not citizen-based initiatives. The plans outlined in the WQMP may be useful for determining CIPs that the County may still implement through this plan and in the future, however the WQMP does not have a water quality end point target. The SWAPs include some additional CIPs along with various citizen-based plans that can reinforce the efforts of the County. In addition, the SWAPs were developed in relation to specific goals and objectives, including Total Maximum Daily Loads (TMDLs).

The Back River watershed, for purposes of SWAP development, was divided into two distinct assessment and planning areas (Upper Back River and Tidal Back River) because of the very different ecosystems and geography encountered in both areas. These documents present strategies and provide guidance for restoration of their respective portions of the watershed, and identify priority projects for implementation. SWAPs delineate multiple subwatersheds within the main subject of restoration to allow for more focused review of each area, which permits customized plans for restoration in each area. The Upper Back River SWAP is broken into 14 subwatersheds, and the Tidal Back River SWAP is broken into 10 subwatersheds. Neighborhoods, institutional facilities, and potential pollution hot-spots are then identified within the subwatersheds and individually assessed by multiple field crews to develop strategies for pollution reduction in each area.

Section 9 of this Implementation Plan will detail specific actions that may be taken by the County to reduce bacteria counts within the Herring Run watershed.

Bacteria can be removed from or inactivated in surface waters and stormwater through several treatment mechanisms by implementing best management practices (BMPs). Treatment mechanisms include ultraviolet light (from sunlight), sedimentation, settling, plant uptake, drying, temperature, and filtration. Bacteria require specific environmental conditions to thrive and survive (Clary, Leisenring, & Jeray, 2010); Hathaway and Hunt 2008). BMPs commonly have moist soils and readily available nutrients, conditions that may be conducive to pathogen persistence. In some instances, BMPs can be sources of pathogens. This occurs in BMPs which attract wildlife including deer, waterfowl, rodents, and domestic animals which defecate in and around the BMP resulting in direct pathogen inputs to the system (Hathaway and Hunt 2008).

Removal efficiencies are typically calculated by comparing contaminant concentrations or loads entering and exiting a structural control (US DOI 2002). Removal efficiencies of structural controls depend on many factors including the type and design; site characteristics such as soil type, catchment size, land use, percent impervious area, storm size and intensity, bypass issues, maintenance and upkeep of the systems, and retention time (US DOI 2002). BMP systems rather than individual BMP installation tends to work better (Haynes 2006).

Several sources were consulted including the International BMP Database, research studies, and other existing TMDL implementation plans. Below is a description of several BMPs that have been studied for removal of bacteria and Table 8.1 summarizes the efficiencies of each BMP.

8.1 Types of Best Management Practices for Addressing Bacteria

This section provides an overview of pollutant reduction measures and their predicted effectiveness. This overview is meant to serve as a guide to aid in selecting the most efficient possible BMPs that may be implemented to meet the pollutant reduction goals required by the TMDL. This review utilizes conservative estimates of BMP efficiency for planning purposes, as exact types of BMPs (e.g. structural BMPs) will not be chosen until appropriate on-site analysis is complete. It is possible that only some of the listed actions in this section will be selected for inclusion in Section 9 of this Implementation Plan.

8.1.1 Sanitary Sewer Repairs

Sanitary Sewer Overflows (SSOs) occur when the capacity of a sanitary sewer is exceeded. There are several factors that may contribute to SSOs from a sewer system, including pipe capacity, operations and maintenance effectiveness, sewer design, age of system, pipe materials, geology and building codes. As of September 2005, Baltimore County is under a consent decree with the U.S. Environmental Protection Agency (EPA) to repair, replace or rehabilitate the system with the goal of eliminating all overflow structures to be completed by March 2020 (US EPA et al. 2006). It is assumed that there will be a 95% bacteria efficiency removal.

8.1.2 Grass Swales/Bioswale

Grass swales are vegetated open channels designed to treat stormwater runoff by slowing the water to allow sedimentation and filtering as the water flows along these channels. Grass swales are typically located along roads because they are linear. They should be sited on relatively flat sites as steep slopes encourage erosion. Grass swales typically do not have a high efficiency of bacteria removal, in fact several studies have shown a negative bacteria removal efficiency (-50%) which indicates more bacteria left the system than entered (US EPA 2012a). This may be because swales are attractive to animals and are not necessarily intended to completely dry between storms, potentially providing an environment where pathogens can persist (Hathaway and Hunt 2008).

8.1.3 Riparian Buffer Zones

Riparian buffer zones are vegetated areas used along streams to reduce erosion, sedimentation, and pollution of water (US EPA 2012a). Densely vegetative cover removes pollutants through detention of runoff, filtration by the vegetation, and infiltration into soil (Boyer Year Unknown). The effectiveness of buffers for reducing bacteria pollution, however, is dependent on the type of vegetation and the width of the buffer. Typically, the wider the buffer, the more pollution reduced. The VA DEQ Guide reports a bacteria removal efficiency of 43-57% (VA DECR and VA DEQ 2003).

8.1.4 Dry Detention Ponds

Dry detention ponds are basins whose outlets have been designed to detain stormwater runoff for some minimum time (e.g., 24 hours) to allow particles and associated pollutants to settle. They do not have a large permanent pool of water but are often designed with small pools at the inlet and outlet of the basin or can be completely dry between precipitation events (Hathaway et al. 2009; US EPA 2012a). The primary pollutant removal mechanisms are sedimentation, drying, and sun exposure (Hathaway et al. 2009). Studies show detention ponds have a bacteria removal efficiency of 25% (VA DECR and VA DEQ 2003).

8.1.5 Retention Ponds/Wet Ponds

Retention ponds/wet ponds are basins where influent runoff enters the pond and theoretically replaces captured runoff from prior events (the principle of plug flow) (Hathaway et al. 2009). The wet pond retains the runoff for 1-2 days and then slowly drains (Hathaway and Hunt 2008). Bacteria removal is facilitated through settling (sedimentation), plant uptake and sun exposure (Hathaway et al. 2009; Hathaway and Hunt 2008). According to Emmons and Olivier Resources, Inc. and the EPA, literature review studies cite average bacteria removal rates of 65-70% (Tilman et al. 2011; US EPA 2012a).

8.1.6 Bioretention/Biofiltration Ponds

Bioretention areas function as filtration and infiltration BMPs. Storm water enters the system and passes through a permeable soil media where pollutants are filtered, similar to sand filter systems, and are also vegetated. The system may pond water; however, it is drained within 12–24 hours. Tree box filters are smaller versions of bioretention systems which are installed along sidewalks as vegetated catch basins. The actual collection or entry point is typically a concrete structure with a catch basin or gutter opening integrated with the street curbing. Treated runoff is filtered into the groundwater or transported to the storm sewer system. The bioretention system is intended to dry out between storm events. (Hathaway et al. 2009) Literature review studies cite average bacteria removal rates of 70% (Tilman et al. 2011).

8.1.7 Wetland Treatment Systems

Wetland treatment systems consist of a wetland constructed with the purpose of treating wastewater or stormwater inputs. The wetlands may be vegetated, open water, or a combination (Tilman et al. 2011). These BMPs promote sedimentation like wet ponds, but provide more exposure of captured stormwater to wetland soils and plants in a shallow system (Hathaway et al.

2009). Sun exposure in the open areas and natural die-off are thought to reduce the bacteria population (Tilman et al. 2011). Research studies found average measured bacteria removal efficiencies for wetland systems of 79% (Tilman et al. 2011). The level of bacteria reduction has been shown to increase as the treatment time (e.g., longer than 1-2 days) increases (Khatiwada and Polprasert 1999).

8.1.8 Sand Filters

Sand filters are a storm water treatment practice designed to remove sediment and pollutants from the first flush of runoff from pavement and impervious areas after a rain or storm event (Boyer Year Unknown). Runoff first enters a sedimentation chamber before flowing through a column of soil. Sand chamber is dry between events. Treatment mechanisms relevant to pathogen removal include drying, sedimentation and filtration (Hathaway and Hunt 2008). Stormwater Best Management practices database (2010) indicated that sand filters are effective in removing from 36 to 83% of the bacteria in urban runoff.

8.1.9 Infiltration Basin

An infiltration basin is a shallow vegetated open impoundment where incoming stormwater runoff is stored until it gradually infiltrates into the soil. Runoff enters the basin and bacteria are removed through detention and filtration. Limitations include the need for permeable soils to reduce the potential for clogging and the need for regular maintenance. The VA DEQ Guidance Manual cites infiltration basins can provide 50% bacteria removal efficiency (VA DECR and VA DEQ 2003).

8.1.10 Infiltration Trench

An infiltration trench is an excavated trench that has been lined with filter fabric and backfilled with stone to form an underground basin or reservoir (Boyer Year Unknown; VA DECR and VA DEQ 2003). Stormwater runoff is directed into the trench through the use of grass areas or pretreatment devices. Trenches tend to be more suitable for ultra-urban situations, where the soil has low permeability (Boyer Year Unknown). The VA DEQ Guidance Manual cites infiltration trenches can provide 50% bacteria removal efficiency (VA DECR and VA DEQ 2003).

8.1.11 Porous Pavement

Porous or pervious pavement allows rainfall to percolate through it to the subbase, providing storage and enhancing soil infiltration that can be used to reduce runoff and combined sewer overflows. The water stored in the subbase then gradually infiltrates the subsoil (VA DECR and VA DEQ 2003). According to the VA DEQ Guidance Manual (2003), porous pavement can provide 50% bacteria removal efficiency.

8.1.12 Stream Bank Protection and Stabilization

Waterways that are being eroded can be stabilized by constructing bulkheads, using riprap, gabion systems or establishing vegetation which can reduce the amount of bacteria, nutrients, and sediment from entering the waterway (VA DECR and VA DEQ 2003). Stream bank protection and stabilization can provide for 40-75% bacteria removal efficiency (40% without fencing and 75% with fencing) (VA DECR and VA DEQ 2003).

8.1.13 Public Education – Pet Waste

Public education and outreach are important tools for reducing bacterial pollution due to pet waste. A pet waste education program would educate pet owners to better understand the importance of appropriate pet waste management practices. This program will include the development and distribution of educational materials and the promotion of pet waste BMPs. Public education for pet waste can provide for 25% bacteria removal efficiency (VADEQ 2013).

8.1.14 Street Sweeping

There are three types of street sweepers commonly used: mechanical, vacuum-assisted, and regenerative air (US DOI 2002). The most common type of sweeper, the mechanical sweeper, lifts dirt off the street by a rotating broom and feeds it to a hopper by a conveyor system. A water spray is often used to control dust. Vacuum-assisted sweepers combine a mechanical sweeper with a high-power vacuum. Some use a water spray to control dust. Regenerative-air sweepers combine a mechanical sweeper to loosen dirt with forced air to dislodge the remaining dirt. Street sweeping frequency is an important variable in the effectiveness of removing contaminants (US DOI 2002). For example, sweeping the street at least once between storms is important to remove contaminants before they are washed away by storms. Removal efficiencies are highest for suspended solids, intermediate for removal of lead, and lowest for fecal coliform bacteria and total phosphorus (US DOI 2002). Multiple passes with the street sweeper and the speed of the street sweeper also can affect the removal capabilities. Simulation models developed by USGS show a fecal coliform removal efficiency of 1.3-5.3%, depending on sweeping frequency and land use (US DOI 2002).

Table 8.1, below, summarizes the bacteria reduction efficiencies for BMPs that treat bacteria. Please note, while some BMPs provide ranges of effectiveness, the lowest reported efficiencies will be used in calculations to determine the acres treated by each BMP.

Table 8.1: Reduction Efficiencies for BMPs Treating Bacteria

Best Management Practice	Efficiency
Sanitary Sewer Overflow repairs	100%
Grass swale	-50%
Riparian buffer zone	43-57%
Dry Detention Ponds	25%
Retention Ponds	65-70%
Bioretention/Biofiltration Ponds	70%
Wetland Treatment Systems	79%
Sand Filters	30%
Infiltration basin	50%
Infiltration trench	50%
Porous pavement	50%
Stream bank protection and stabilization (no fencing)	40%
Stream bank protection and stabilization (with fencing)	75%
Public Education – Pet Waste	25%
Street sweeping	1.3-5.3%

8.2 Discussion of Uncertainty

Literature reviews have shown that pathogen removal appears to vary not only by BMP type, but also among similar BMP types at various locations (Clary et al. 2010; Hathaway and Hunt 2008). For example, there is considerable variability in the effectiveness of wet ponds, and it is believed that properly designing and maintaining ponds may help to improve their performance (Clary et al. 2010; US EPA 2012). Based on the performance data available to date in the BMP Database for fecal indicator bacteria, only general inferences regarding BMP selection are appropriate at this time. General recommendations as a result of the analysis include:

- In general, bioretention and sand filters appear to have ability to remove pathogens; these systems have little input from animals due to their lack of standing water, eliminating a common attraction for waterfowl (Clary et al. 2010; Hathaway and Hunt 2008).
- Conversely detention ponds and grass swales have not been shown to be very effective. Swales are attractive to animals and are not necessarily intended to completely dry between storms, potentially providing an environment where pathogens can persist (Clary et al. 2010; Hathaway and Hunt 2008).
- Seasonal distribution of samples may affect conclusions drawn related to BMP performance (Clary et al. 2010). For example, winter concentrations of fecal indicator bacteria may be lower than summer concentrations (Clary et al. 2010).

The majority of conventional stormwater BMPs in the BMP Database do not appear to be effective at reducing fecal indicator bacteria concentrations to primary contact stream standards, which is the ultimate target of TMDLs. Because the data are limited, both in the number of data points and the representativeness of the data, rigorous statistical conclusions cannot be drawn based on available data. Significantly more studies are needed for all BMP types to increase the confidence of performance estimates with regard to bacteria (Clary et al. 2010).

8.3 Alternative BMPs

8.3.1 Sanitary Sewer Lateral Line Program

The consent decree addresses sanitary sewer pipes which are located on public property. The connection between private owners and the county portion are referred to as lateral lines. These lateral lines are also prone to leaking which can result in bacteria entering waterways. If water quality standards are not achieved through the consent decree and other BMPs to address bacteria, the County will assess the feasibility of developing a program to monitor bacteria that may be the result of leaking lateral lines.

8.3.2 Stormtech Isolator Row

Stormtech Isolator Row is a manufactured treatment device that uses a series of subsurface chambers over geotextile fabric and crushed stone for filtration of pollutants beneath parking lots or other infrastructure. Over time, an organic filter cake forms between the chamber and geotextile fabric for enhanced chemical sorption. More research is needed to determine the bacteria removal efficiency.

In this section you will find a list of actions that together become one scenario as to how the county could reach the pollutant load target. While EPS has developed this scenario, progress will be assessed on an annual basis through results of implementation actions and monitoring data. It is intended that the Implementation Plan (IP) will be reviewed on a five-year cycle for potential revisions. The County takes an adaptive management approach to all watershed planning efforts.

Adaptive management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood (U.S. Department of the Interior 2009). The tools that Baltimore County will use in adaptive management are the tracking of implementation progress, identification of barriers that prevent targeted actions from occurring, and an enhanced monitoring program to measure progress in both reductions and meeting water quality standards. While this will be an on-going process, there will be a formal review of the strategy at five year intervals to determine if changes are needed or if the strategies are on track.

For this section, we will bring together information from earlier sections of this Implementation Plan to determine actions that will reduce pollutant inputs to acceptable regulatory levels. We will consider the existing data on pollution input levels (Section 6), existing restoration plans (Section 7), and the efficiencies of known Best Management Practices (BMPs) for pollution reductions (Section 8). By examining our existing data on pollution loads we can know how much of a reduction is needed to reach water quality goals, and what needs to be done to reach those goals.

The actions discussed in this section are to be implemented in addition to currently in-progress or completed programs and restoration actions. Some actions in some parts of Baltimore County have already been completed, such as certain stream restorations, or riparian area reforestations, but there are still many projects in need of completion before water quality goals are met. The Herring Run watershed is unique in that some waterways begin in Baltimore County, flow through the City of Baltimore, and discharge again in Baltimore County. While the 93.4% reduction goal outlined in the MDE document (Total Maximum Daily Loads of Fecal Bacteria for the Herring Run Basin in Baltimore City and Baltimore County, Maryland) applies to the entire Herring Run watershed, the actions described in this implementation section will be limited to what Baltimore County may oversee, as we cannot direct reduction efforts in the City of Baltimore.

Of the 19,198 acre Herring Run watershed, only 7,569 acres are included within Baltimore County's jurisdiction which is equal to roughly 39.4% of the watershed. Baltimore County assumes that it is responsible for reducing its *E. coli* load by 3,626,041 billion MPN/year, which is 39.4% of the 9,198,480 billion MPN/year that needs reducing for the watershed as a whole. A reduction of 93.4% is necessary for the entire Herring Run to meet the water quality endpoint of 119.7 MPN/100 ml (5% lower than 126 MPN/ 100 ml to account for margin of safety). The reductions needed by station are displayed in Table 9.1. This section includes many actions that were planned in the SWAP and also discussed in Section 7 of this document. Many of these plans were written with the entire Herring Run Watershed in mind, so some actions may include parts that are not specific to Baltimore County.

Table 9.1: Baseline and Target Loads for *E. coli* in the Herring Run Watershed

Monitoring Site	Baseline Load *E. coli* (Billion MPN/year)	TMDL Target *E. coli* (Billion MPN/year)	Recduction Required *E. coli* (Billion MPN/year	Reduction Required (%)
Harford Road	**6,288,811**	**408,147**	**5,880,664**	**93.5**
Pulaski Highway	**1,992,522**	**173,532**	**1,818,990**	**91.3**
Biddle Street	**1,569,606**	**70,781**	**1,498,825**	**95.5**
Total	**9,850,939**	**652,459**	**9,198,480**	**93.4**

As discussed in Section 3, and shown in Tables 3-3 and 3-4, it can be seen that high levels of bacteria in the water coincide with high flow rates. This is likely the result of bacteria being washed into the waterways during storm events. High concentrations of bacteria also coincide with warmer times of year. It is expected that human contact will occur most frequently during times of low flow, as storm events (high flow) are not as conducive to water contact recreation. The actions outlined in this section will target reducing bacteria counts during all conditions to acceptable levels.

The final target will be to achieve water quality standards for all flow conditions and for annual and seasonal periods by the end of 20 years of implementation. This 20 year plan will be assessed at five-year interim goals that will help track progress to the end goal. Table 9.2 shows the interim targets for *E. coli* concentrations when measured both by single samples and by the calculated geometric mean from longer term monitoring.

Table 9.2: Five Year Interim Targets for Single Sample and Geometric Mean *E. coli* Densities

Single Sample Target (MPN/100 ml)				
Weather Condition	**2020**	**2025**	**2030**	**2035**
Dry	576	410	298	235
Wet	NA	NA	NA	NA
Geometric Mean Target (MPN/100 ml)				
Dry	477	360	243	126
Wet	6,880	4,630	2,380	126

9.1 Action Types

For this IP we will categorize the actions to be taken with respect to addressing source reduction. While there are still three different categories of actions (programmatic, management, and restoration), the sources of bacteria are identifiable, and have very specific pollutant reduction strategies for each. Therefore, the actions below will be divided between Human, Domestic (Pets), Livestock, and Wildlife source reductions. There are many actions that may be taken that would have an explicitly indirect impact on bacteria, however with no ability to prove the cause/effect relationship of these actions, they will be omitted (e.g. stream restorations).

Within each source table we will identify which involve programmatic, management, or restoration actions. Programmatic actions are actions that do not directly result in load reductions, but create the necessary conditions for load reduction. Management actions are those where there is regular management of county property, such as, street sweeping, and sanitary sewer maintenance. Restoration actions include the development of new control measures aimed to reduce pollutant loads as well as retrofits of existing stormwater management facilities.

Programmatic Actions

Programmatic actions are actions that do not directly result in load reductions, but create the necessary conditions for load reduction. Actions within this category might include public education and outreach activities, monitoring, or supporting specific legislation. These actions will move Baltimore County closer to achieving TMDL targets; however, there is currently no way to attribute a predictable pollutant load reduction to programmatic actions. Some programmatic actions, such as investigation and monitoring, are necessary to implement management and restoration actions or make those actions more efficient. Other programmatic actions, such as education and outreach actions, are predicted to increase the load reduction over time through behavioral change and/or BMP implementation by individual citizens. The exact load reduction is not predictable because the participation rate for individual home owners installing BMPs, as a result of public education, is not yet known. Educated citizens may support load reductions in other ways such as educating other citizens about watershed management actions, supporting legislation that improves watershed management, and other actions that do not have associated load reductions but support the necessary condition for pollutant reduction.

Management Actions

Management actions are those where there is regular management of county property, such as, street sweeping. It does not include the development of new control measures, such as, retrofitting highway yards. Management actions have predictable load reductions, which can be used to calculate the contribution of each action toward meeting the overall load reduction required by the TMDL.

Restoration Actions

Restoration actions include the development of new control measures aimed to reduce pollutant loads as well as retrofits of existing stormwater management facilities. It may include reforestation actions as well as any stormwater control measures that do not require regular management on county property. Restoration actions will have predictable load reductions, which will be used to calculate the contribution of each action toward meeting the overall load reduction required by the TMDL.

Monitoring and Reporting Action

The monitoring and reporting actions will provide the means for determining progress made in meeting the load reductions. Some of the monitoring actions will be used to better target programs for remediation.

9.2 Reductions by Source

Many actions that Baltimore County will be implementing for other pollutants (i.e. Nutrients) have the potential for bacteria reductions, but without knowing specific land-use loading rates for bacteria contributions to the watershed, the amount of reduction will be unknown. Because of this uncertainty, those actions (e.g. stream restorations, etc.) will be omitted from this plan, as they will be done with the main purpose of reducing nutrients and will be detailed in that plan.

Reductions to Human Sources

Human sources may be some of the more important bacteria sources to focus on reducing, as human fecal matter is the most probable transporter of human pathogens. According to the TMDL document, MDE estimates that of all the bacteria inputs into Herring Run, 70.7% are from humans. A major source of human bacteria in this watershed is the existence of Sanitary Sewer Overflows (SSOs), which allow raw sewage to spill from the sewer system into the waterway. A majority of the reduction of human bacteria sources is expected to result from Baltimore County's continuing compliance with the consent decree to eliminate all SSOs within the County by March 2020.

Reductions to Domestic Pet Sources

According to the TMDL document, domestic pets account for about 18.9% of total bacteria inputs to Herring Run. A large contributor of the domestic bacteria in Herring Run comes from pet owners failing to pick up dog waste, and from runoff carrying that dog waste into streams and tributaries. MDE states the maximum possible reduction for this type of bacteria input as 75%. The majority of reductions to domestic bacteria inputs are expected to come from a focus on educational programs to promote behavioral change in pet owners.

Reductions to Livestock Sources

There were no recorded sources of livestock bacteria in the Herring Run watershed at the time of TMDL development. Because of this, there are no required reductions for livestock sources.

Reductions to Wildlife Sources

Wildlife sources are widespread throughout the watershed, accounting for about 10.4% of the total bacteria loads in Herring Run. They are not subject to laws or property boundaries, and are not suited to educational programs. This makes managing wildlife bacteria inputs quite difficult, and MDE acknowledges that the maximum possible reduction for wildlife bacteria inputs is actually 0.0% meaning MDE does not require reductions to wildlife bacteria loads. While it is unknown which individual species are most significantly contributing to bacteria loads, there are source tracking technologies that may be useful for determining specific wildlife sources. Using this information, it may be possible to make educated decisions about future BMPs.

Actions listed in the Upper Back River SWAP, the action plan that included Herring Run, did not differentiate between actions with respect to jurisdictional location. With the uncertainty surrounding the intended locations of many potential actions, it was decided to include the actions in our implementation plan, but to omit the quantity and specific locations of these actions. To see the list of actions in the SWAP, please see the Upper Back River SWAP.

9.3 Implementation Actions

Table 9.3 below outlines the specific actions intended to be taken to reduce bacteria inputs to Herring Run. These actions are organized by action type, as discussed above, and they indicate which source will be addressed by implementing each action. The table also includes a time frame to indicate a predicted time period by which the action should be fully implemented, and a performance standard to measure success. The column of responsible parties will indicate who will likely be tasked with implementing that specific action.

The actions listed in this table were selected with assistance from Section 8 of this document which details potential pollutant reductions associated with certain actions. Some of these actions, such as with Stormwater Management (SWM) Conversions and Retrofits, have a range of reduction efficiencies based on numerous variables. Because of this uncertainty, Baltimore County has elected to represent these actions with conservative estimates of efficiency, based on the Maryland Assessment Scenario Tool (MAST).

Table 9.3: Actions to Reduce Bacteria Inputs with Performance Standards and Schedule

Action	Time Frame	Performance Standard	Responsible Parties	Source Addressed[1]		
				H	D	W
Programmatic Actions						
Develop and implement a public education program on pet waste and create materials	3-20 years	Educational Materials developed	EPS		X	
Measure behavioral change in pet waste management as a result of educational/ outreach efforts. Check behavior against state/ national averages if data is available	5-10 years	Report on behavioral change that has resulted from educational/ outreach efforts	EPS		X	
Investigate the effect of Environmental Site Design on bacteria	20 years	Investigation report completed	EPS		X	X
Promote PAI's "Rat Attack" program to mitigate rat infestations	20 years	Measurable reduction in number of rat complaints; measurable reduction in rat sourced bacteria if species tracking is available	PAI			X
Support State and County efforts to reduce and eliminate homelessness	10 years	Actions taken	EPS	X		
Assess alternate implementation practices over time as they become known to Baltimore County	On-going	Take advantage of future advancements in technology and accepted practices that we may not be aware of at the time of producing this document	All	X	X	X
Management Actions						
Provide for on-going maintenance through periodic inspection of implemented BMPs	On-going	Number of BMPs inspected	EPS, DPW		X	X
Continue street sweeping. Investigate streets that appeared to need enhanced street sweeping for potential increase in frequency	On-going	Pounds collected; miles of streets identified	DPW-Highways		X	X
Continue Storm Drain Cleaning Program	On-going	Pounds of Material Removed	DPW-BU		X	X
Continue supporting USGS gauges to enhance the ability to measure flow and calculate pollutant loads	On-going	USGS gauges supported in an on-going effort	EPS	X	X	X
Restoration Actions						
Implement Consent Decree and Eliminate Sewer Overflows	6 years (Consent decree is until 2020)	SSOs addressed each year	DPW	X		
Convert existing dry detention stormwater ponds to an enhanced treatment method where feasible	20 years	Number of dry detention ponds identified and enhanced per year	EPS		X	X
Install SWM retrofits and conversions at feasible sites	20 years	Number of feasible sites identified and retrofits installed per year	EPS		X	X

Action	Time Frame	Performance Standard	Responsible Parties	Source Addressed[1]		
				H	D	W
Monitoring Actions						
Continue the Bacteria Trend Monitoring Program. Add sites at the City/County line and on Redhouse Run	On-going	Annual monitoring at all sites	EPS	X	X	X
Continue and expand, as needed, the bacteria source tracking monitoring program	On-going	Annual monitoring at all designated sites	EPS	X	X	X
Work with MDE to repeat the bacteria source contribution monitoring, in association with the MS4 Permit renewal for all sites that are not meeting bacteria water quality standards	5 year intervals	Results at 5-year intervals	EPS, MDE	X	X	X
Work with MDE to investigate feasibility of a method of source tracking that will provide more specific allocations among wildlife species (e.g. DNA testing or other)	2 years	Ability to track wildlife bacteria sources by species.	EPS, MDE			X
Reporting Actions						
Develop a unified restoration tracking system to track progress toward meeting TMDL reduction requirements	2 years	Tracking system implemented after 2 years.	EPS	X	X	X
Upper Back River SWAP Implementation Committee to meet on a semi-annual basis to discuss implementation progress and assess any changes needed to meet the goals	20 years	2 meetings per year	EPS and Implementation Committee partners	X	X	X
Continue to update status of restoration projects and BMPs in the Annual MS4 Report	Annually	MS4 Report submitted to MDE and posted on county website	EPS	X	X	X
Implement the Continuing Public Outreach Plan	On-going	Number of actions per year	EPS	X	X	X
Hold Biennial State of Our Watersheds Conference in even years	Biennially	Conference Held	EPS	X	X	X
Adaptive Management assessment of the Implementation Plan	5 year intervals	Assessment complete	EPS	X	X	X

1. Sources H (Human); D (Domestic Pet); W (Wildlife); There are no reported Livestock/Agricultural sources of bacteria in Herring Run.

9.4 Timeframe and Responsible Parties

Baltimore County Department of Environmental Protection and Sustainability (EPS) will partner with other County agencies and with local citizen-based organizations to implement this plan. Dependant on the specific action, different parties may be responsible for implementation. Some actions involve implementing a program, such as tree planting or impervious surface removal, at an institutional site, and that institution will be one of the multiple groups responsible for implementation.

This TMDL Implementation Plan is built using an adaptive management approach. This approach requires periodic assessment of progress and an assessment of changes needed in the Implementation Plan. This periodic assessment will be coordinated with the MS4 Permit cycle and will take plan prior to the re-application process, and will be included as part of the re-application assessment of the success of the management programs.

9.5 Anticipated Pollutant Load Reductions

The available literature supports that the actions above will have a positive effect on bacteria load reduction, however, the exact reductions from implementing those actions is not yet known. There is no known loading rate of bacteria by land use for Baltimore County and therefore it is not possible to predict reductions from BMPs by drainage acre treated. For this reason, specific acreages and linear feet are not provided in the table above. Baltimore County acknowledges that the priority is to address human sources of bacteria due to greater health risk. The TMDL states that the reduction of human sources has a Maximum Extent Practicable of 95%; however, the County feels that a goal of 100% efficiency from SSO elimination will be achievable. While Baltimore County expects a 100% reduction in SSO elimination, we cannot account for failures due to mechanical failure, natural disaster, or vandalism, which are issues that may be addressed by an adaptive management solution in the future. Additionally, through data received regarding a point in time survey for homeless people from Baltimore County Department of Planning, the County can determine outdoor public areas where there are no sanitary facilities and can conduct public outreach on the health concerns of bacteria which could prevent bacteria from entering waterways.

9.6 Reductions Discussed

The timeline to implement all of the future actions with measurable reduction extends over the next 20 years. That means that all actions will be implemented by December 2034. Many of the actions cited in this implementation plan have 20 year timelines associated with them, however the bulk of the bacteria reductions will be achieved from actions that may be completed much sooner. Long term actions are mainly programmatic and management actions, as many of them will be responsible for indirect reductions in bacteria, working to create the proper conditions for reductions to occur, such as public education regarding dog waste. The elimination of SSOs is more short term, expected to be completed by 2020, removing the bulk of bacteria inputs to all Baltimore County waterways.

Given the difficulty of applying bacteria load reductions to specific actions, the County will rely on the bacteria monitoring programs to assess progress in meeting the bacteria water quality standards.

Section 10 – Assessment of Implementation Progress

The assessment of implementation progress is based on two aspects; progress in meeting programmatic, management, and restoration actions; and progress in meeting water quality standards and any interim water quality benchmarks. The assessment of progress in meeting the restoration actions includes; setting up methods of data tracking, validation of projects, and pollutant load reductions associated with the actions (10.1) and will be consistent across all TMDL Implementation Plans. The assessment of progress in meeting water quality standards and interim milestones (10.2) is the data analysis associated with the monitoring plan specific to each TMDL Implementation Plan.

10.1 Implementation Progress: Data Tracking, Validation, Load Reduction Calculation, and Reporting

The Baltimore County Department of Environmental Protection and Sustainability – Watershed Management and Monitoring Section is currently preparing a document entitled *Baltimore County Method for Pollutant Load Calculations, Pollutant Load Reduction Calculations, and Impervious Area Treated*. This document will detail the data sources, data analysis (including pollutant load calculations, and pollutant load reductions calculations), validation of the practices, and reporting of progress made. It was determined that a document was needed to document how Baltimore County calculated pollutant loads and pollutant load reductions from the implementation of various best management practices, as guidance from the State continues to evolve. The document also needs modification based on the published literature and to include any additional findings that result from our monitoring programs. The document will be updated annually to account for any changes that may have occurred during the previous year. Due to the fact that implementation is being achieved through the actions of many county agencies, it was also determined that the means of data acquisition, any data manipulation, and the means of data analysis needs to be documented on an annual basis to provide consistency in the data acquisition and analysis and to document any changes in the process over time. The overall result is intended to provide transparency for the general public and users of reports on progress generated as a result of the analysis.

The Maryland Department of the Environment (MDE) has provided a guidance document for NPDES – MS4 permits entitled: *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated*. The draft document was released in June 2011, followed by a final release in August 2014. The document is intended to provide consistency among the MS4 jurisdictions in calculating baselines and reporting implementation progress. This document however, does not provide guidance on bacteria, chlordane, mercury, or PCB reduction efficiencies. MDE also provides guidance through its web site, with a webpage entitled *Maryland TMDL Data Center*. This site provides guidance on the development of the TMDL Implementation Plans and is updated on a regular basis.

The document *Baltimore County Method for Pollutant Load Calculations, Pollutant Load Reduction Calculations, and Impervious Area Treated* will be posted for review and comment in the spring of 2015. It will be modified on an annual basis to take into account any modifications to any guidance documents, monitoring results, and/or new literature; and future calculations will reference the edition on which the calculations were based.

10.1.1 Reporting

Baltimore County will prepare two-year milestones for each local TMDL in conformance with the Chesapeake Bay TMDL two-year milestone process. Programmatic actions and monitoring data analysis will be based on the calendar year, while restoration actions will be based on the fiscal year (July 1 – June 30). The current two-year milestone period was developed in January 2014; for Programmatic actions covers January 2014 through December 2015, and for restoration actions cover July 1, 2013 through June 30, 2015. When the next two-year milestones are developed in 2016, they will be presented by watershed and will include each of the local TMDLs.

Reporting will be done through the annual NPDES – MS4 Permit Report. This is technically due on the anniversary date of the permit renewal, but will be completed for submittal to MDE in October each year. The report will detail progress made in meeting each of the local TMDLs and the Chesapeake Bay TMDL. The analysis will include progress in meeting the two-year milestone programmatic and restoration actions, along with the calculated load reduction. It will also present the results of the monitoring conducted the previous year. See below for TDML specific monitoring.

In January of each year, a progress report (mostly extracted from the MS4 report) will be prepared and posted on the web.

10.2 Implementation Progress: Water Quality Monitoring

The Herring Run bacteria monitoring will focus on two of the three bacteria monitoring programs, trend monitoring and bacteria source monitoring; subwatershed prioritization monitoring is not required for this bacteria TMDL. Table 10.1 presents the bacteria monitoring locations, by subwatershed and monitoring type and Figure 10.1 displays the locations.

Table 10.1: Existing and Future Herring Run Bacteria Monitoring Site Locations and Type

Station Code	Subwatershed	Monitoring Type	Latitude	Longitude
HER-1	Herring Run	Trend	39.346	-76.581
Biddle Street	Moore’s Run	Trend	39.306	-76.529
Pulaski Hwy.	Herring Run	Trend	39.305	-76.537
HR-B-1	West Branch – Herring Run	Bacteria Source Tracking	39.380	-76.591
HR-B-2	West Branch – Herring Run	Bacteria Source Tracking	39.385	-76.595
HR-B-3	West Branch – Herring Run	Bacteria Source Tracking	39.393	-76.597
HR-B-4	West Branch – Herring Run	Bacteria Source Tracking	39.376	-76.585
HR-B-5	West Branch – Herring Run	Bacteria Source Tracking	39.389	-76.582
HR-B-6	East Branch – Herring Run	Bacteria Source Tracking	39.375	-76.573
HR-B-7	East Branch – Herring Run	Bacteria Source Tracking	39.374	-76.564
HR-B-8	East Branch – Herring Run	Bacteria Source Tracking	39.380	-76.557
HR-B-9	East Branch – Herring Run	Bacteria Source Tracking	39.389	-76.556
HR-B-10	East Branch – Herring Run	Bacteria Source Tracking	39.394	-76.556
HR-B-11	East Branch – Herring Run	Bacteria Source Tracking	39.388	-76.550
HR-B-12	East Branch – Herring Run	New Trend	39.369	-76.574
HR-B-13	West Branch – Herring Run	New Trend	39.371	-76.583
HR-B-14	Unnamed Trib to Redhouse Run	New Trend	39.316	-76.518
HR-B-15	Redhouse Run	New Trend	39.317	-76.518

10.2.1 Bacteria Trend Monitoring

The Bacteria Trend Monitoring has been implemented in conjunction with Baltimore City since June 2010 and consists of three monitoring sites within Herring Run, which MDE used in developing the Herring Run Bacteria TMDL. The program is designed to determine bacteria concentration trends over time and whether the sites are improving, degrading or meeting water quality standards. Monitoring at these three sites will continue, with the addition of four new trend sites. The two of the four new trend sites will measure *E. coli* concentrations at the city/county line where the east and west branches of Herring Run enter the city. These sites will be used to distinguish bacteria water quality trends related to county actions over time. The other two new trend monitoring sites are located on Redhouse Run. Redhouse Run was included in the TMDL, even though no monitoring had occurred on the tributary and all mainstem monitoring is upstream of where the tributary enters Herring Run. These sites, one on the mainstem of Redhouse Run and the other on an unnamed tributary will establish if bacteria concentrations are exceeding water quality standards in the subwatershed.

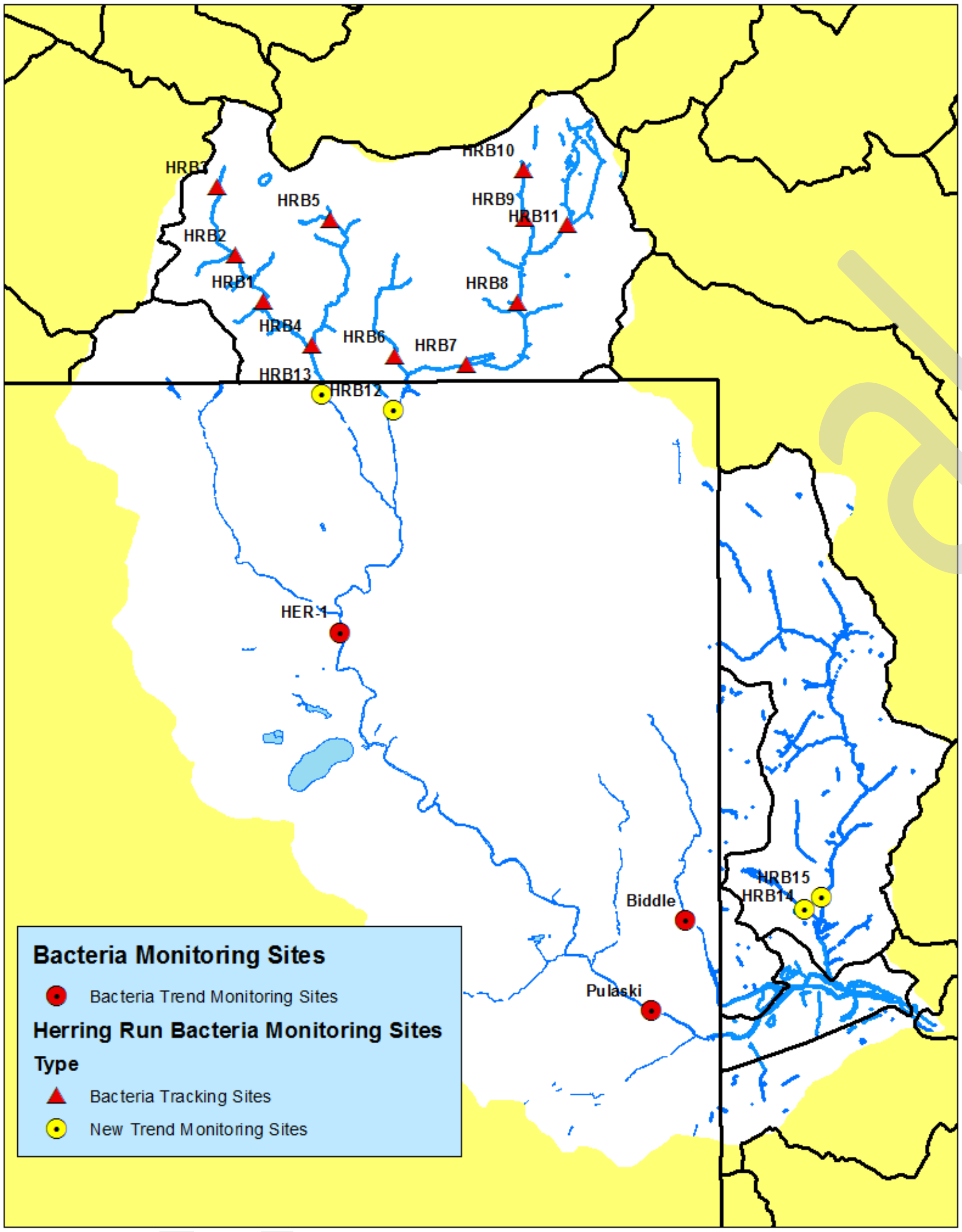

Figure 10.1: Herring Run Bacteria Monitoring Locations by Monitoring Type.

10.2.2 Bacteria Source Tracking

The bacteria source tracking program is designed to locate sources of bacterial contamination by monitoring stream reaches in tributaries identified as having high bacteria concentrations. Herring Run has served as a pilot study for the development of the monitoring program. There are 11 sites along the Baltimore County portion of Herring Run (5 on the West Branch and 6 on the East Branch). This program has already located one sanitary sewer leak that has subsequently been corrected. This program will continue and will be expanded to Redhouse Run if high bacteria concentrations are detected at the two new bacteria trend monitoring sites located on tributary.

10.2.3 Bacteria Source Relative Contribution Monitoring

In the development of the Herring Run Bacteria TMDL, MDE uses a methodology to identify bacteria sources in four categories, human, pet waste, livestock, and wildlife; and the relative contribution of each to the bacteria load. As progress is made in reducing the bacteria concentration, it is expected that the relative contribution from the various source categories will change. Since it is important to know the relative contribution from the various sources in order to target remediation actions correctly, Baltimore County will work with MDE to develop a program whereby at the beginning of each 5-year MS4 Permit cycle, the Bacteria Source Monitoring will be repeated for those Bacteria Trend Monitoring sites that are not meeting bacteria water quality standards.

For those sites that require a wildlife bacteria reduction to meet the bacteria water quality standards, Baltimore County will work with MDE to determine how to refine the wildlife source to species if possible. The results will determine if an existing program can be enhanced (rat control and deer control programs), if another program needs to be developed, or whether the wildlife sources are such that we will need a greater period of time to meet the bacteria standard or whether it is possible to meet the standard.

Section 11 – Continuing Public Outreach Plan

In order to engage the public in the TMDL implementation process this continuing public outreach plan will be implemented upon approval of this TMDL Implementation Plan. The continuing public outreach plan is applicable to all TMDL Implementation Plans that are currently being developed and those developed in the future, as well as the Trash and Litter Reduction Strategy. This continuing public outreach plan is meant to engage county agencies, environmental groups, the business community, and the general public.

11.1 County Agencies

County agencies will be engaged through two regularly scheduled NPDES Management Committee meetings per year and other agencies meetings as necessary to move implementation forward.

11.1.1 NPDES Management Committee

The NPDES Management Committee is composed of representative agencies that are involved in meeting the NPDES – MS4 Permit requirements. This committee has met irregularly in the past, generally to review information on permit requirements and other upcoming regulatory requirements, such as, the General Industrial Stormwater Discharge Permit. In the future this committee will meet twice per year and will discuss not only the NPDES – MS4 Permit requirements, but also the TMDL Implementation Plans and progress being made in meeting the implementation strategy. In order to address all components of the TMDL Implementation Plans the committee membership will be expanded to include any county agency that has some responsibility for TMDL implementation. Examples being, the County Police Department and the Department of Environmental Protection and Sustainability – Groundwater Management Section. Prior to the development of the TMDL Implementation Plans and the Trash and Litter Reduction Strategy, these agencies were not specifically engaged in NPDES – MS4 Permit activities.

The first yearly meeting will be held in January of each year. The focus of this meeting will be to review the implementation plan 2-year milestones for each plan; provide a forum for discussion of the ability to meet the implementation actions; and determine any revisions necessary to meet the interim implementation milestones set in the plan. This meeting is also the forum for discussion of data tracking and reporting to ensure that the implementation actions are properly credited.

The second yearly meeting will be held in July of each year and will provide the forum for determining data submittal for the yearly progress report on the implementation actions and the resulting load reductions. The monitoring data from the previous calendar year will be presented and contrasted with the interim water quality milestones that are detailed in each implementation plan.

11.1.2 Other Agency Meetings

In order to move forward with implementation, agency meetings regarding specific implementation actions are anticipated. These will be scheduled as needed, and tracked by meeting date, attendance, TMDL Implementation Plans discussed, and topic. Meeting minutes will be reported in the Annual NPDES – MS4 Report submitted to Maryland Department of the Environment. This report is also posted on the County website for public access.

11.2 Environmental Groups

Baltimore County is currently engaged with local watershed associations through its funding of *Watershed Association Restoration Planning and Implementation Grants*, and through inclusion of watershed association members on the Steering Committees of the Small Watershed Action Plans. Formerly, this engagement and support was coordinated through the *Baltimore Watershed Agreement*. As part of that engagement, periodic Watershed Advisory Group (WAG) meetings were held. As part of this continuing public outreach plan, WAG participation will be formalized with two meetings per year.

The first meeting will be held in March of each year and focus on the local and Chesapeake Bay TMDL implementation actions and implementation progress, including an analysis of the pollutant load reduction calculations from the previous fiscal year. The watershed associations are currently engaged in citizen-based restoration activities and report their implementation progress to the county for inclusion in the Annual NPDES – MS4 Report. This meeting will provide a forum for discussion of the progress being made, coordination between the watershed associations, and any changes to the *Watershed Association Restoration Planning and Implementation Grant* being considered for the next grant period.

The second meeting will be held in November of each year and will focus on the water quality monitoring results from the previous calendar year. The results presented will compare trends and measures against the TMDL Implementation Plans water quality benchmarks and water quality standards.

11.3 Business Community

The business community will be engaged through various business forums, targeted outreach and education efforts on specific topics, and hosting workshops on specific topics as necessary.

11.3.1 Business Forums

Business forums, such as the Hunt Valley Business Forum with greater than 200 business members, provide opportunities to present the TMDL Implementation Plans and the Trash and Litter Reduction Strategy, and discuss the role of business in helping improve water quality. These forums will be convened as the opportunities arise. Summaries of these meetings will be reported in the annual NPDES – MS4 Report and will include the name of the forum (or other business organization), approximate number in attendance, the topic presented, and audience responses.

11.3.2 Targeted Business Outreach and Education

The Small Watershed Action Plan (SWAP) process includes an upland assessment of potential pollution hotspots. Often, these potential hotspots are commercial or industrial sites. The information derived from this assessment will be used to target outreach and education to businesses specific to the issue(s) at the location identified in each SWAP. These actions will be tracked and reported in the annual NPDES – MS4 Report.

11.3.3 Business Workshops

There are certain issues that may be pervasive through a segment of the business community that can most effectively be addressed through hosting workshop education on the specific topic. These issues will be identified as SWAP implementation moves forward, but one potential topic for a business workshop is related to the recently renewed *General Discharge Permit for*

Stormwater Associated with Industrial Activities. A workshop designed in conjunction with Maryland Department of the Environment would not only result in improved water quality, but it would also benefit the business community through increased understanding of the requirements of the permit.

11.4 General Public

The general public will be engaged through a number of mechanisms, including:

- WIP Team meetings
- Targeted outreach and education efforts on specific topics
- Steering Committee meetings and stakeholder meetings in the development of Small Watershed Action Plans
- Meetings of the Implementation Committee for completed Small Watershed Action Plans
- Displays at various events
- Annual progress reports posted on the county website and placed in our libraries
- A biennial *State of Our Watersheds* conference.

11.4.1 Watershed Implementation Plan (WIP) Team Meetings

Baltimore County has assembled a Watershed Implementation Plan (WIP) team to serve as a sounding board for the development of the WIP to address the Chesapeake Bay TMDL. Members of the team include representatives from various county agencies, business community representatives (particularly the environmental engineering community), watershed associations, representatives from the agricultural community, and Baltimore County citizens.

The county will schedule at least one meeting annually to present implementation progress and to address specific topics related to the TMDL Implementation Plans and the Trash and Litter Reduction Strategy. Meetings will be scheduled as issues arise. It is anticipated that the WIP team will provide initial review of newly developed outreach and education materials, in order to provide feedback from a variety of perspectives.

11.4.2 Targeted Outreach and Education

The Small Watershed Action Plan development process includes upland assessments of neighborhoods to identify pollution sources and restoration opportunities. This information will be used to prioritize and target outreach and education efforts specific to the issue(s) in neighborhoods with the intent to affect behavioral change and/or increase citizen based restoration actions. These actions will be tracked and reported in the annual NPDES – MS4 Report.

11.4.3 Small Watershed Action Plans (SWAPs)

Baltimore County has been developing Small Watershed Action Plans since 2008. There are 22 planning areas in the county, with 13 completed plans, 5 plans in development, and 4 areas pending. These planning areas cover the entire county. The planning process includes the development of a steering committee, the composition of which is determined by the issues, and land ownership within the planning area. At a minimum, membership consists of agency representatives, watershed associations, and citizen representatives. The process also includes a number of stakeholder meetings, open to all planning area residents and businesses, which provide information on the plan and solicit input. Once the SWAP is complete, the steering committee becomes the implementation committee. As designed the implementation committee is to meet twice per year, however, most implementation committees have not met this goal.

The plans have addressed to varying degrees the TMDLs that are applicable within the planning area. Some of the TMDLs have been developed subsequent to the specific SWAP development or did not address the full range of TMDLs that were applicable to the planning area. The TMDL Implementation Plans are built on incorporation of the actions from each SWAP within the applicable TMDL area. In some cases, additional actions have been identified in order to meet water quality standards.

11.4.3.1 Small Watershed Action Plans in Development and Future Plans

For SWAPs currently under development, and for plans developed in the future, the steering committee and stakeholder meetings will be used for outreach regarding the TMDL Implementation Plans and the progress being made in achieving water quality standards. The meeting participants will be informed on where they can access the TMDL Implementation Plans, the Trash and Litter Reduction Strategy and any Progress Reports that have been developed.

Applicable TMDL Implementation Plan actions will be incorporated into the SWAP based on the assessment of applicable restoration actions within the SWAP planning area. Since the SWAPs incorporate field assessments of streams and uplands, they provide more detailed information on applicable restoration actions, both on quantity and location. The accelerated schedule for developing TMDL Implementation Plans precluded conducting field work to build the plans.

11.4.3.2 Small Watershed Action Plans Already Developed

For those SWAPs already developed, the implementation committee meetings will be scheduled twice per year. The first meeting will be held in winter and will present the implementation progress not only of the SWAP, but also any applicable TMDL Implementation Plan progress. The progress analysis will be based on fiscal year. This meeting will also provide the opportunity to discuss any changes in the SWAP or the TMDL Implementation Plan based on an analysis of what actions have been successful and what actions have been more difficult to implement.

The second implementation committee meeting will be held in fall of each year and will present the monitoring data in relation to progress being made in relation to interim milestones and water quality standards.

11.4.4 Educational Displays at Events

Educational displays and handouts will continue to be used at applicable events as they occur. The particular display and handout materials will be determined by the location and focus of the event. The location and focus of the event, number of citizens engaging staff at the display, and the number of handouts taken by citizens will be tracked for annual reporting in the NPDES – MS4 Report.

11.4.5 TMDL Implementation Plan, Trash and Litter Reduction Strategy, and Progress Report Availability

The TMDL Implementation Plans and the Trash and Litter Reduction Strategy will be posted on the Baltimore County website with hard copies placed in county libraries. The hard copies in the libraries will be specific to the watershed in which the library is located. Progress reports will be posted on the County website and placed in libraries. A set of hard copy plans will be kept at the Baltimore County Department of Environmental Protection and Sustainability

11.4.6 Biennial State of Our Watersheds Conference

Baltimore County, in conjunction with Baltimore City, has held *State of Our Watershed* conferences in the past to present information to county and city citizens on water quality issues applicable to the watersheds in these jurisdictions. Future conferences will be held in early March of even numbered years. Information on implementation progress for local TMDLs and the Bay TMDL will be presented, along with other topics of interest. These conferences will be organized with the assistance of the Watershed Advisory Group (WAG), and the surrounding local jurisdictions (Baltimore City, Howard County, Carroll County, Harford County, and York County, PA) will be invited to participate in the organization and presentation of the conference.

The timing of even years is related to the 2-year milestone process set up by the Maryland Chesapeake Bay TMDL Watershed Implementation Plan (WIP) whereby in January of even calendar years, progress in meeting the previous 2-year milestone programmatic and restoration implementation is reported and the next 2-year programmatic and restoration implementation milestones are proposed by the local jurisdictions. The timing of the conference not only permits reporting on the progress made in meeting the previous 2-year milestones but also what is planned for the next two years.

11.5 Summary of Continuing Public Outreach Plan

A summary of the continuing public outreach plan, by component, element and frequency is presented in Table 11.1.

Table 11.1: Continuing Public Outreach Plan Summary

Plan Component	Plan Element	Frequency
Agencies	NPDES Management Committee	2x per year
	Other Agency meetings	As needed
Environmental Groups	Watershed Advisory Group (WAG) meetings	2x per year
Business Community	Business Forums	As identified
	Targeted Business Outreach and Education	As identified
	Topical Workshop	As identified
General Public	WIP Team meetings	1x per year
	Targeted Outreach and Education	As identified
	SWAP – Steering Committee meetings	6x per year, each
	SWAP – Stakeholder meetings	2x per year, each
	SWAP – Implementation Committee meetings	2x per year, each
	Educational Displays at Events	As identified
	Document availability (various)	As needed
	Biennial Conference	Even # Years

Baltimore County Department of Environmental Protection & Sustainability. 2008. Upper Back River Small Watershed Action Plan.

Baltimore County Office of Information Technology (OIT). 2014a. FACILITIES.BUILDING_POLY1995 [computer file]. Towson, MD

Baltimore County Office of Information Technology (OIT). 2014c. FACILITIES.BUILDING_POLY2001 [computer file]. Towson, MD

Baltimore County Office of Information Technology (OIT). 2014e. FACILITIES.BUILDING_POLY2005 [computer file]. Towson, MD

Baltimore County Office of Information Technology (OIT). 2014b. TRANSPORTATION.ROAD_POLY1995 [computer file]. Towson, MD.

Baltimore County Office of Information Technology (OIT). 2014d. TRANSPORTATION.ROAD_POLY2001 [computer file]. Towson, MD.

Baltimore County Office of Information Technology (OIT). 2014f. TRANSPORTATION.ROAD_POLY2005 [computer file]. Towson, MD.

Baltimore County. Office of Information Technology (OIT). 2014g. ImperviousData [computer file]. Towson, MD

Boyer, A. Year Unknown. Reducing Bacteria with Best Management Practices. Delaware Department of Natural Resources and Environmental Control.

Centers for Disease Control and Prevention. (2012, August 3). *Escherichia coli E. coli*. Retrieved from CDC: http://www.cdc.gov/ecoli/general/index.html

Chesapeake Bay Program. (2012). *Incorporating Lag Times in the Chesaeake Bay Program.* Annapolis : Chesapeake Bay Program .

Clary, J., Leisenring, M., & Jeray, J. (2010). *International Stormwater Best Management Practices (BMP) Database; Pollutant Category Summary: Fecal Indicator Bacteria.* www.bmpdatabase.org. Retrieved 2014, from http://www.bmpdatabase.org/Docs/BMP%20Database%20Bacteria%20Paper%20Dec%202010.pdf

Clary, J., Jones, J. E., Urbonas, B. R., Quigley, M. M., stecker, E., & Wagner, T. (2008, May). Can Stormwater BMPs Remove Bacteria? New findings from the International Stormwater BMP Database. *Stormwater Magazine*. Retrieved from http://www.stormh2o.com/SW/Articles/Can_Stormwater_BMPs_Remove_Bacteria_203.aspx

Connecticut Department of Energy and Environmental Protection (CT DEEP). 2012. A Statewide Total Maximum Daily Load Analysis for Bacteria Impaired Waters. Hartford, Connecticut.

Edberg, S., Rice, E., Karlin, R., & Allen, M. (2000). Escherichia coli: the best biological drinking water indicator for public health protection. *Journal of Applied Microbiology*, 106S-116S. Retrieved April 28, 2014, from http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2672.2000.tb05338.x/pdf

Environmental Protection Agency. (2001). *Protocol for Developing Pathogen TMDLs.* Office of Water, Washington, D.C. Retrieved June 23, 2014, from http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/2003_07_03_tmdl_pathogen_all.pdf

Environmental Protection Agency. (2001). *Source Water Protection Practices Bulletin; Managing Pet and Wildlife Waste to Prevent Contamination of Drinking Water.* Environmental Protection Agency, Office of Water. Retrieved June 03, 2014, from http://www.epa.gov/safewater/sourcewater/pubs/fs_swpp_petwaste.pdf

Environmental Protection Agency. (2002). *Wastewater Technology Fact Sheet.* Washington, D.C. Retrieved from http://water.epa.gov/scitech/wastetech/upload/2002_10_15_mtb_bacsortk.pdf

Environmental Protection Agency. (2012, March 6). *Water: Monitoring & Assessment; 5.11 Fecal Bacteria*. Retrieved April 28, 2014, from U.S. Environmental Protection Agency: http://water.epa.gov/type/rsl/monitoring/vms511.cfm

EPA. (1986). *Ambient Water Quality Criteria for Bacteria.* Washington, D.C. Retrieved from http://water.epa.gov/action/advisories/drinking/upload/2009_04_13_beaches_1986crit.pdf

Fecal Bacteria for the Herring Run Basin in Baltimore City and Baltimore County, Maryland. Submitted to Water Protection Division, U.S. Environmental Protection Agency, Region III. Baltimore, MD. http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Documents/www.mde.state.md.us/assets/document/Herring_Run_TMDL_final.pdf

Feng, P., Weagant, S. D., Grant, M. A., & Burkhardt, W. (2002, September). *Food; Bacteriological Analytical Manual, Chapter 4: Enumeration of Escherichia coli and the Coliform Bacteria.* Retrieved April 28, 2014, from U.S. Food and Drug Administration: http://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm064948.htm

Hathaway, J.M., W.F. Hunt, S. Jadlocki. 2009. “Indicator Bacteria Removal in Storm-Water Best Management Practices in Charlotte, North Carolina.” Journal of Environmental Engineering, 135(12): 1275-1285.

Hathaway, J.M., W.F. Hunt. 2008. “Urban Waterways Removal of Pathogens in Stormwater”. North Carolina Cooperative Extension Service. E09-51807. 1-10.

Haynes, R. L. (2006). *Bacteria TMDL Implementaion Control Strategies of the Southeast: Recommendations for Georgia; A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree Master of Science.* Masters Thesis, University of Georgia. Retrieved June 23, 2014, from http://rivercenter.uga.edu/research/bacteria_tmdl/documents/2006_12_bacteria_tmdl_haynes_complete.pdf

Haynes, R.L. 2006. Bacteria TMDL Implementation Control Strategies of the Southeast: Recommendations for Georgia. A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree Master of Science. Athens, Georgia.

http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., and Xian, G. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. *Remote Sensing of Environment*, 132: 159 - 175. " http://www.mrlc.gov/nlcd2011.php

Khatiwada, N. R. and C. Polprasert. 1999. Kinetics of fecal coliform removal in constructed wetlands. Water Science Technology 40: 109-116.

Maryland Department of the Environment (MDE). 2007. Total Maximum Daily Loads of

Maryland Department of The Environment. (2009). *Total Maximum Daily Loads of Fecal Bacteria for the Patapsco River Lower North Branch Basin in Anne Arundel, Baltimore, Carroll, and Howard Counties, and Baltimore City, Maryland.* Baltimore: Maryland Department of The Environment.

Maryland Geological Survey (MGS). 2014. MGS Online –Maryland Geology. Baltimore, MD. http://www.mgs.md.gov/indexgeo.html

Meals, D. W., Dressing, S. A., & Davenport, T. E. (2010). Lag Time in Water Quality Response to Best Management Practices: A Review. *J. Environ. Qual.*, 39:85–96.

Oram, B. (n.d.). *Water Research Center e Coli in Water*. Retrieved from http://www.water-research.net/Watershed/ecoli.htm

Tilman, L., A. Plevan, P. Conrad. 2011. Effectiveness of Best Management Practices for Bacteria Removal. Developed for the Upper Mississippi River Bacteria TMDL.

U.S. Census Bureau. 2000. United States Census Block Group Data for 2000. Washington, D.C.

U.S. Census Bureau. 2010. United States Census Block Group Data for 2010. Washington, D.C.

U.S. Department of the Interior. (2009). *Adaptive Management: The U.S. Department of the Interior Technical Guide.* Washington. Retrieved 2014, from U.S. Department of the Interior: http://www.doi.gov/ppa/upload/TechGuide-WebOptimized-2.pdf

U.S. Department of the Interior, U.S. Geological Survey. 2002. Potential Effects of Structural Controls and Street Sweeping on Stormwater Loads to the Lower Charles River, Massachusetts. Water-Resources Investigations Report 02-4220. Northborough, Massachusetts.

U.S. Environmental Protection Agency (EPA) and Maryland Department of the Environment v Baltimore County. Entered September 20, 2006. Baltimore County Consent Decree, Consolidated Case Number: AMD-05-2028.

U.S. Environmental Protection Agency (EPA). 2012a. Best Management Practices.

U.S. Environmental Protection Agency (EPA). 2012b. Municipal Storm Water: Combined Sewer Overflows, Sanitary Sewer Overflows Compliance Monitoring. http://www.epa.gov/compliance/monitoring/programs/cwa/csos.html

U.S. Geological Survey. (2007, December 21). *Feacal Indicator Bacteria and Sanitary Water Quality*. Retrieved April 28, 2014, from USGS: http://mi.water.usgs.gov/h2oqual/BactHOWeb.html

University of Rhode Island. (n.d.). *Policy and Management*. Retrieved April 25, 2014, from University of Rhode Island; Office of Marine Programs: http://omp.gso.uri.edu/ompweb/doee/policy/orga1.htm

US Geological Survey. (2007, December 21). *Feacal Indicator Bacteria and Sanitary Water Quality*. Retrieved from USGS: http://mi.water.usgs.gov/h2oqual/BactHOWeb.html

USDA-Natural Resources Conservation Service (NRCS). 2009. National Engineering Handbook; Part 360: Chapter 7: Hydrologic Soil Groups. ftp://ftp.wcc.nrcs.usda.gov/wntsc/H&H/NEHhydrology/ch7.pdf

USDA-Natural Resources Conservation Service (NRCS). Unknown. Hydrology Training Series: Module 103: Runoff Concepts. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1082991.pdf

Virginia Department of Conservation and Recreation and Virginia Department of Environmental Quality. 2003. Guidance Manual for Total Maximum Daily Load Implementation Plans. Richmond, Virginia.

Virginia Department of Environmental Quality. 2013. A Water Quality Improvement Plan: A Plan to reduce Bacteria in Darden Mill Run, Mill Swamp, and Three Creek.

Walker, S., Mostaghimi, S., Dillaha, T. A., & Woeste, R. E. (1990). MODELING ANIMAL WASTE MANAGEMENT PRACTICES: IMPACTS ON BACTERIA LEVELS IN RUNOFF FROM AGRICULTURAL LANDS. *American Society of Agricultural Engineers VOL. 33(3): MAY-JUNE 1990*, http://www.pcwp.tamu.edu/docs/lshs/end-notes/modelinganimalwastemgmt-1077313798/modelinganimalwastemgmt.pdf.

World Health Organization . (2003). *Guidelines for Safe Recreational Water Environments Volume 1*. Geneva: World Health Organization .