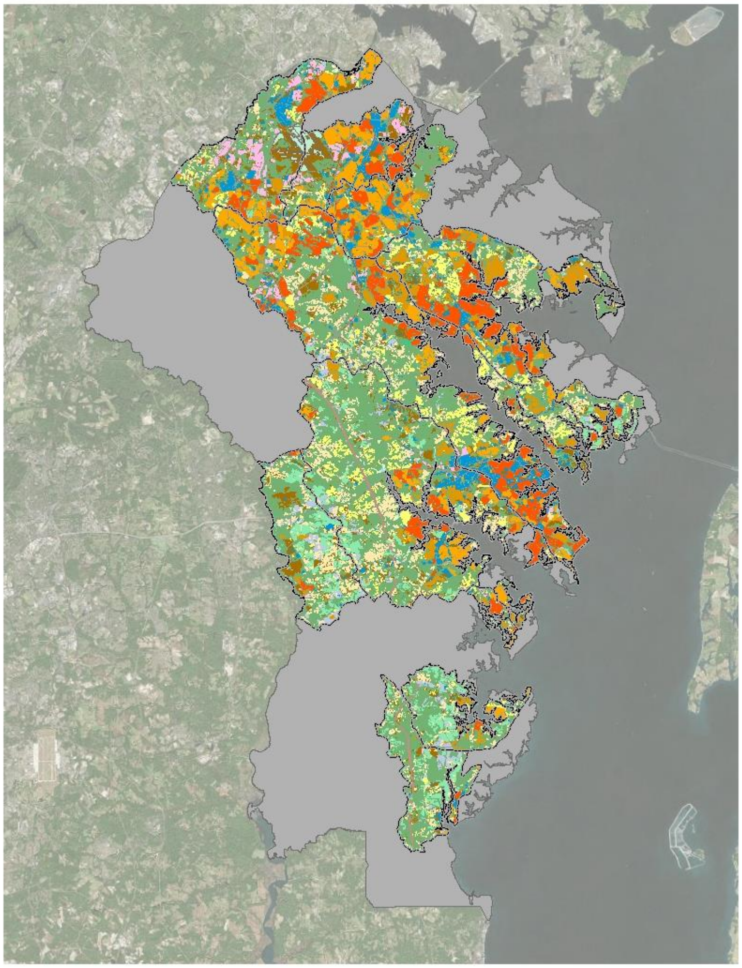
Total Maximum Daily Load Restoration Plan for Bacteria

Draft Report



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URS ESA JOINT VENTURE

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BMP	best management practice
BRF	Bay Restoration Fund
CIP	Capital Improvement Plan
CMOM	Capacity, Management, Operations, and Maintenance
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWP	Center for Watershed Protection
DNR	Department of Natural Resources
DPW	Department of Public Works
EMCs	event mean concentrations
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESD	environmental site design
GIS	Geographic Information System
IDDE	Illicit Discharge Detection and Elimination
LA	Load Allocation
LNB	Lower North Branch
MACS	Maryland Agricultural Water Quality Cost-Share
MDE	Maryland Department of the Environment
ml	milliliters
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NRU	Nitrogen Removal Unit
OSDS	Onsite sewage disposal system (septic system)
PSA	Public Service Announcement
SPS	Sewage Pump Station
SPSC	Step Pool Storm Conveyance
SSO	sanitary sewer overflow
SW	stormwater
SWM	stormwater management

TMDLs	Total Maximum Daily Loads
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
USDA	U.S. Department of Agriculture
WIP	Watershed Implementation Plan
WLA	wasteload allocation
WRF	Water Reclamation Facility
WTM	Watershed Treatment Model

EXECUTIVE SUMMARY

The Anne Arundel County Department of Public Works (DPW) Watershed Protection and Restoration Program is developing restoration plans to address local water quality impairments for watersheds with an approved Total Maximum Daily Load (TMDL) issued by the Maryland Department of the Environment (MDE) and approved by the U.S. Environmental Protection Agency (EPA). As defined by EPA, a TMDL sets a maximum load of a specific pollutant or stressor that a water body can assimilate and still meet water quality standards for its designated use.

There are currently 19 approved bacteria TMDLs associated with Anne Arundel County waterways. Fecal coliform is the impairing pollutant for 15 of the TMDLs, while E. coli and Enterococci are identified as the impairing pollutant for two TMDLs each. These bacteria are indicator organisms that suggest a potential for pathogenic bacteria to be present in the waterways. Anne Arundel County, via the requirements of its National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit (11-DP-3316, MD0068306), has developed this plan to address the Stormwater Waste Load Allocation (SW-WLA) associated with each of the 19 approved bacteria TMDLs.

This report presents a Bacteria TMDL Restoration Plan that identifies potential strategies for reducing bacteria to achieve the TMDL goals in each of the watersheds. MDE developed most of the TMDLs in the early 2000s. Based on the analyses conducted as part of the TMDL development, pet waste was identified as a primary source of bacteria in the watersheds, followed by wildlife, livestock, and human sources.

This restoration plan estimates bacteria load reductions for identified strategies based on modeling and literature review. The strategies were broken down into Tier A strategies (i.e., strategies that treat human sources) and Tier B strategies (i.e., strategies that treat non-human sources). Of the Tier B strategies, pet waste education was found to achieve the greatest load reductions for the least cost.

This Bacteria TMDL Restoration Plan recommends implementing a multi-media-based pet waste education program including increasing educational signage on public lands, adding pet waste stations on public lands, providing grant-funding for pet waste stations in targeted residential communities, and improving management of pet waste at existing dog parks. It is important to prioritize the target areas for the pet waste program because certain watersheds need more intensive outreach than others to reach the required TMDL load reductions.

Other non-structural Tier B strategies such as riparian buffer improvements and possibly localized waterfowl and wildlife management in specific areas (e.g., ponds, public parks, golf courses, campuses) were highly cost-effective, although the load reductions of these strategies may be difficult to measure. Stormwater retrofit projects such as conversion of dry ponds to shallow wetland/marsh filtering systems and step pool storm conveyance (SPSC) retrofits at impaired stream channels and outfalls (as recommended by the County's Chesapeake Bay

TMDL Phase II Watershed Implementation Plan [Phase II WIP]), are also considered Tier B strategies. As the County identifies and confirms dry pond drainage area and retrofit opportunities, this strategy will continue to be implemented.

The County's NPDES MS4 Permit (11-DP-3316, MD0068306) also requires that the County undertake efforts to restore 20 percent of the currently unmanaged impervious cover, within the County's MS4 area, before the end of the 5-year permit term. The County's Phase II WIP suggests this will be accomplished by implementing restoration practices such as SPSCs or other retrofit BMPs with high pollutant removal efficiency. Modeling this implementation strategy resulted in limited load reductions because managing only 20 percent of impervious area is not sufficient to mitigate bacteria loads from such highly urbanized watersheds. Lastly, livestock fencing was identified as a useful cost-effective tool for agricultural pastures that support livestock populations; however, there are only two TMDL watersheds where this strategy would be applicable.

Tier A strategies are a priority, as human bacteria sources pose a greater risk to public health than non-human sources. Implementation of Tier A strategies to treat human sources of bacteria are generally less cost-effective. These strategies primarily involve large projects in the County's Capital Improvement Program (e.g., wastewater capital improvement projects or septic system retirement). Estimated costs for these types of projects can be in the millions and result in relatively small bacteria load reductions.

Overall, it is clear that a suite of strategies should be implemented in combination to achieve bacteria TMDL SW-WLA goals in each watershed. For many of the bacteria TMDL SW-WLAs, all of the strategies are needed, and where load reduction gaps still exist, it is recommended to prioritize pet waste education in high pet-waste areas. There were no meaningful differences in the strategies needed from one watershed to the next, with the slight exception that livestock fencing is applicable in the two watersheds with agricultural areas.

SECTION ONE: INTRODUCTION

All natural water bodies contain bacteria of some kind, but in excessive amounts, bacteria can have ecological impacts and cause potentially serious health problems in humans. Most bacteria are beneficial to the ecosystem because they break down organic matter, help to recycle nutrients and carbon, and serve as part of the food chain. Certain types of bacteria, however, are pathogenic and may cause waterborne illnesses in humans.

Per Maryland State regulations, the Anne Arundel County (County) Health Department monitors more than 80 County beaches for Enterococci bacteria, a type of fecal bacteria that comes from the intestines of warm-blooded mammals, including humans. Enterococci are an indicator organism, meaning it indicates the potential presence of pathogens that cannot be directly measured because they are difficult to isolate and identify in a laboratory (EPA, 2001). While monitoring results establish a general characterization of the water, the data provide no information about the sources of bacteria in the watershed. The sources of bacteria can be difficult to discern, as many factors are involved, (e.g., amount of recent rainfall; presence of waterfowl and wildlife; and location of sewage spills, septic systems, and pet wastes).

The Maryland Department of the Environment (MDE) currently monitors, and has done so for years, various shellfish harvesting waters (Use II waters) in the County for fecal coliform, which is the indicator organism specified in the Code of Maryland Regulations (COMAR) for Use II waters. In the early 2000s, these monitoring data were used to develop the fecal coliform bacteria Total Maximum Daily Loads (TMDLs). Fifteen of the 19 total TMDLs in this TMDL Restoration Plan are for fecal coliform and occur in shellfish harvesting areas. Since the monitoring data at the time of TMDL development indicated that fecal coliform counts periodically exceeded water quality criteria, the 15 fecal coliform TMDL waterways are listed by MDE as restricted for shellfish harvesting. For Use II waters, the median fecal coliform concentration cannot exceed 14 Most Probable Number (MPN) per 100 milliliters (ml), and more than 10 percent of samples taken cannot exceed 43 MPN per 100 ml. For more details, see COMAR 26.08.02.03-3.

In addition to Use II waters, four of the 19 TMDL waterways are in designated Use I waters for public recreational use and are impaired for either E. coli or Enterococci. For Use I waters, the water quality criteria are: for freshwater, the steady state geometric mean cannot exceed 33 counts/100 ml for *Enterococci* and 126 counts/100 ml for *E. coli*; in marine water, the steady state geometric mean cannot exceed 35 counts/100 ml *Enterococci*. Again, for more details, see COMAR 26.08.02.03-3.

To address the concerns about bacteria pollution in the County's waterways, and to meet the requirements of the federal Clean Water Act (CWA), the MDE developed 19 bacteria TMDLs for areas in Anne Arundel County.

A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet State water quality standards and designated uses. TMDLs are typically developed using pollutant load models calibrated with monitoring data. The TMDL is made up of two major components. The first component is the wasteload allocation (WLA), which includes point sources such as municipal wastewater treatment plants (called Water Reclamation Facilities, or WRFs,) and National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4)-regulated urban stormwater (referred to as the SW-WLA). The second component is the Load Allocation (LA), which includes nonpoint sources such as pet waste, wildlife, non-regulated stormwater, and septic systems. Some TMDLs also include a Margin of Safety, which accounts for uncertainty in the TMDL analyses, and a Future Allocation, which accounts for future increases in pollutant loads due to population growth and/or land use changes. However, these are not applicable to the County's bacteria TMDLs because they are built into the TMDL analyses. In summary, a TMDL can be expressed as follows:

TMDL = total allowable load to waterway = point sources + nonpoint sources

= WLA + LA

1.1 ANNE ARUNDEL COUNTY BACTERIA TMDLS

The U.S. Environmental Protection Agency (EPA)-approved bacteria TMDLs are listed in Table 1-1 and shown in Figure 1-1 below. The table lists TMDL watersheds and subwatersheds, along with each waterway's State-designated use. Throughout this plan, the TMDLs are presented in alphabetical order of watershed.

Table 1-1: U.S. Environmental Protection Agency-Approved Bacteria TMDLs in Anne Arundel County

TMDL Watershed	TMDL Subwatershed	Impairment	Designated Use[1]	Jurisdiction
Magothy River	Mainstem	Fecal Coliform	Use II	Anne Arundel County
	Forked Creek	Fecal Coliform	Use II	Anne Arundel County
	Tar Cove	Fecal Coliform	Use II	Anne Arundel County
Patapsco River	Furnace Creek	Enterococci	Use I	Anne Arundel County
	Marley Creek	Enterococci	Use I	Anne Arundel County
Patapsco River Lower North Branch	Patapsco River Lower North Branch	E. Coli[2]	Use I	Anne Arundel, Baltimore, Carroll, and Howard Counties, and Baltimore City
Patuxent River Upper	Patuxent River Upper	E. Coli	Use I	Anne Arundel and Prince George's Counties

TMDL Watershed	TMDL Subwatershed	Impairment	Designated Use[1]	Jurisdiction
Rhode River	Bear Neck Creek	Fecal Coliform	Use II	Anne Arundel County
	Cadle Creek	Fecal Coliform	Use II	Anne Arundel County
Severn River	Mainstem	Fecal Coliform	Use II	Anne Arundel County
	Mill Creek	Fecal Coliform	Use II	Anne Arundel County
	Whitehall and Meredith Creeks	Fecal Coliform	Use II	Anne Arundel County
South River	Mainstem	Fecal Coliform	Use II	Anne Arundel County
	Duvall Creek	Fecal Coliform	Use II	Anne Arundel County
	Ramsey Lake	Fecal Coliform	Use II	Anne Arundel County
	Selby Bay	Fecal Coliform	Use II	Anne Arundel County
West Chesapeake Bay Mainstem	Tracy and Rockhold Creeks	Fecal Coliform	Use II	Anne Arundel County
West River	Mainstem	Fecal Coliform	Use II	Anne Arundel County
	Parish Creek	Fecal Coliform	Use II	Anne Arundel County

1-Use I water = Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life; Use II water = Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting
2-Multiple bacteria indicators were used in the TMDL analyses; however, the TMDL is written for E. coli.

Figure 1-1: Location of Bacteria TMDL Watersheds

MDE requires the County to develop an SW-WLA Restoration Plan and it is enforceable, under the County's NPDES MS4 permit. All but two of the subject TMDLs (i.e., Patapsco River Lower North Branch and Patuxent River Upper) are located entirely within the County.

1.2 DEFINITION AND REQUIREMENTS OF A TMDL RESTORATION PLAN

A TMDL Restoration Plan is a planning-level document that identifies water quality-based strategies that a local jurisdiction may implement to control existing point and nonpoint pollutant sources in a degraded watershed. MDE allows flexibility in how local jurisdictions develop their TMDL Restoration Plans, provided that the approach is reasonable and that the Plan identifies management actions and practices that, when implemented, will restore the State water quality standards and designated uses of the impaired waterway (MDE, 2014).

The County's NPDES MS4 permit (Part IV.E.2.B) requires the development of a TMDL Restoration Plan for each SW-WLA approved by EPA. Once approved by MDE, the Restoration Plan is enforceable under the NPDES MS4 permit.

Pertinent to the development of a TMDL Restoration Plan is acknowledgement that other pollution source sectors such as agriculture or septic systems may contribute to the need for the TMDL. Although the NPDES MS4 permit requires only the SW-WLA to be addressed in the Restoration Plan, if greater load reductions can be achieved for less cost from another sector (i.e., upgrading of septic systems), the County has the option to pursue these strategies to meet the SW-WLA. Per MDE guidance, "if achieving [TMDL] targets is deemed to be technically infeasible via traditional stormwater controls, the jurisdictions are encouraged to offer alternative options to MDE for consideration" (MDE, 2014c). One of the objectives of this TMDL Restoration Plan is to provide the County with a wide array of strategies that can be implemented in all source sectors to maximize the potential for load reductions and achieve TMDL water quality goals.

At the federal level, EPA identifies nine required elements for an approvable watershed Restoration Plan (EPA, 2013b). These elements are commonly called the "a through i criteria." While these elements are specific to CWA Section 319 nonpoint source grants, they are strongly recommended by EPA and others for watershed restoration plans because they provide the basic framework needed for effective watershed planning and implementation (MDE, 2006; EPA, 2013a; EPA, 2013b). This Bacteria TMDL Restoration Plan is prepared in accordance with the EPA's nine elements for watershed planning. The nine elements are listed below along with the corresponding section in this document. For further explanation of the elements, see EPA (2013b).

a. Identification of causes and sources of bacteria (Section 2)

c. Description of management measures needed (Section 4.1)

b. An estimate of the load reductions expected from management measures (Section 4.3)

e. Information and education activities to enhance public understanding of the Restoration Plan and encourage the public's participation (Section 5)

d. Financial and technical assistance needed to implement the above management measures (Section 6)

f. Schedule for implementing the above management measures (Section 7)

f. Description of interim measurable milestones to determine whether the above management measures are being implemented (Section 7)

g. Set of indicators to evaluate progress toward water quality standards (Section 8)

h. Monitoring program to evaluate effectiveness of implementation efforts (Section 8)

1.3 FOUR CATEGORIES OF BACTERIA SOURCES

MDE's TMDL analyses identify four categories of bacteria sources in each of the 19 TMDL watersheds. The four categories are: pet waste, wildlife, humans, and livestock. During the development of the TMDLs, MDE quantified the contribution for each of these categories to the observed impairment in the waterway. Among all 19 TMDL watersheds, the average percent contribution for each category was determined to be:

- pet waste – 46.0 percent
- wildlife – 34.5 percent
- human – 6.9 percent
- livestock – 12.6 percent

Throughout this Restoration Plan, this is referred to as the "bacteria source distribution." The following sections briefly describe and characterize the four primary categories of bacteria.

Pet waste: Pets (mainly domestic dogs) contribute bacteria to a waterway through their waste products that seep into waterways during storms. It is estimated that about 40 percent of households own a dog, and of these, 60 percent pick up their pet's waste (Swann, 1999). Dog waste may contain up to 23 million bacteria per gram, much more than wildlife waste (e.g., deer) and about twice as much as human waste (Van der Wel, 1995; RIDEM, 2014). This is typically due to the diet of many dogs, which contains animal products (unlike herbivores such as deer).

EPA (2012) states that in watersheds up to 20 square miles or 12,800 acres (about the size of the Magothy River Watershed), two to three days of droppings from a population of about 100 dogs may contribute enough bacteria to temporarily close a waterway to swimming and shellfish harvesting. Unlike wildlife waste, pet waste is usually concentrated (e.g., in residential communities where people walk their dogs). Other harmful effects of dog waste include:

- Dog waste may take up to a year to fully decompose; therefore, there is a high likelihood of it being transported to local waterways
- Dog waste may potentially contain parasites and pathogens that remain infectious in contaminated soil and water
- Dog waste is a poor fertilizer and does not enrich the soil (in fact, it can seriously harm soil quality)
- Dog waste attracts rodents and nuisance insects
- Dog waste poses a public health risk, especially to children playing outside

Wildlife: Wildlife contribute bacteria through their waste products that are either directly deposited into streams or on land subject to stormwater runoff. In MDE's TMDL reports, the following are considered to be part of the "wildlife" category: beaver, deer, goose, duck, muskrat, raccoon, and wild turkey. Depending on the analysis method used, some TMDLs also identify foxes, rabbits, swans, squirrels, and herons as potential sources of bacteria. In general, most wildlife is distributed throughout the landscape wherever food and water resources are available. Wildlife diffuse bacteria widely, with the possible exception of Canada geese, which tend to congregate in small open water areas (e.g., a pond). Wildlife may occur in urban or non-urban settings. Some examples of urban wildlife include deer and fox in residential communities, waterfowl in urban ponds, and raccoons feeding on food scraps in poorly managed urban trash receptacles. Non-urban wildlife include beaver, deer, fox, and turkeys in wooded habitats, especially woods with abundant water resources.

Livestock: Livestock in pasture areas are another potential source of bacteria. This category includes farm animals such as horses, chicken, cattle, and sheep. During the grazing season, livestock may deposit their waste products directly into the stream (if the stream is unfenced), or on land near the stream that is subject to runoff. Livestock areas are limited in the County TMDL watersheds, which tend to be urbanized. Although there aren't significant livestock areas in the County TMDL watersheds, according to the Watershed Treatment Model (WTM), dairy cattle are assumed to contribute the highest per-animal loads of bacteria relative to other farm animals. The methodology used for estimating the number of livestock in the County TMDL watershed is included in Appendix A.

Humans: Bacteria from human sources are typically associated with aging urban infrastructure, which is more prone to failure than new infrastructure. Potential sources include sanitary sewer overflows, illicit sewer connections to the MS4, point source discharge from municipal WRFs, and poorly maintained or failing septic systems. Additional sources of human bacteria include homeless encampments, public facilities that lack adequate sanitary services, and marinas without sewage pumpout stations or where boaters do not utilize them. In general, human sources of bacteria pose a much greater public health risk than non-human sources (i.e., pets, wildlife, and livestock) due to the potential for waterborne disease transmission. Therefore, strategies that reduce or mitigate human bacteria sources are considered a top priority in this Restoration Plan and are discussed in Section 4.

SECTION TWO: EXISTING CONDITIONS

This section describes the existing conditions in each of the 19 watersheds in the County with EPA-approved bacteria TMDLs. The description includes current land use (from the County's 2011 land use and impervious cover Geographic Information System [GIS] data), existing best management practices (BMPs), water resource conditions, and the TMDL bacteria source distribution from MDE's TMDL reports.

Existing land use information from the County GIS for the TMDL watersheds is summarized in Table 2-1. County land uses can be grouped into five broad categories: residential urban, non-residential urban, agricultural, forested, and open water. The residential urban category includes low-density, medium-density, and high-density residential land uses. The non-residential urban category includes urban open space, commercial airport, roadways, and industrial land uses. The agricultural category includes pasture/hay and row crops, and the forest category includes forests and forested wetlands type land uses. Land use maps of the TMDL watersheds are provided in their respective sub-sections (i.e., Sections 2.1 through 2.9).

Table 2-1: Existing Land Use in Anne Arundel County's Bacteria TMDL Watersheds

Bacteria TMDL Watershed	Residential Urban	Non-Residential Urban	Agricultural	Forested	Open Water	Total	Total Acres	Total % Impervious
Magothy River Mainstem	56%	15%	0.03%	28%	1%	100%	14,567	20%
Magothy River/Forked Creek	67%	6%	0.00%	26%	1%	100%	849	20%
Magothy River/Tar Cove	50%	14%	0.00%	34%	1%	100%	2,103	15%
Patapsco River Lower North Branch	26%	39%	0.23%	34%	1%	100%	15,022	27%
Patapsco River/Furnace Creek	34%	48%	0.07%	17%	0%	100%	8,579	34%
Patapsco River/Marley Creek	46%	23%	0.84%	30%	0%	100%	8,737	28%
Patuxent River Upper	24%	17%	19.77%	39%	1%	100%	10,449	6%
Rhode River/Bear Neck Creek	50%	16%	0.45%	33%	2%	100%	880	16%
Rhode River/Cadle Creek	70%	9%	0.00%	20%	2%	100%	320	20%
Severn River Mainstem	44%	19%	1.59%	35%	1%	100%	37,011	19%
Severn River/Mill Creek	47%	15%	3.47%	34%	1%	100%	3,256	14%
Severn River/Whitehall and Meredith Creeks	37%	15%	12.63%	35%	1%	100%	2,945	12%
South River Mainstem	32%	15%	6.08%	46%	1%	100%	33,549	12%
South River/Duvall Creek	76%	14%	0.00%	9%	1%	100%	601	23%
South River/Ramsey Lake	65%	17%	0.00%	17%	2%	100%	384	21%
South River/Selby Bay	62%	12%	2.01%	22%	3%	100%	349	20%
W. Chesapeake Bay/Tracy and Rockhold Creeks	18%	15%	14.68%	52%	1%	100%	7,962	5%

Bacteria TMDL Watershed	Residential Urban	Non-Residential Urban	Agricultural	Forested	Open Water	Total	Total Acres	Total % Impervious
West River Mainstem	25%	8%	20.72%	45%	1%	100%	6,304	6%
West River/Parish Creek	41%	25%	0.00%	31%	4%	100%	324	18%
Average:	**46%**	**18%**	**4%**	**31%**	**1%**			**18%**

Residential Urban = low-density, medium-density, and high-density residential land uses
Non-Residential Urban = urban open space, commercial, airport, roadway, and industrial land uses
Agricultural = pasture/hay and row crops
Forested = forests and forested wetlands

The existing BMPs located in the TMDL watersheds were identified using County GIS data and grouped into the following three performance categories based on their bacteria removal efficiency: non-performing (0 percent bacteria removal efficiency), mid-performing (50 percent removal efficiency), and high-performing (75 percent or greater removal efficiency). Drainage areas for the BMPs were obtained using the County GIS data and available BMP inspection database. The County is in the process of compiling the drainage areas for all the BMPs, and as result, drainage areas and impervious areas associated with some of the BMPs were not populated. The Restoration Plan database will be updated when the information becomes available.

The bacteria removal efficiency for each type of practice was obtained from the County's NPDES MS4 Annual Report (Anne Arundel County, 2013). Based on the information provided in the report, infiltration and filtering practices such as infiltration trenches, bioretention systems, step pool conveyance systems, and environmental site design (ESD) practices have high bacteria removal efficiencies. Stormwater management practices that provide limited water quality management, such as extended detention dry pond and underground storage, are mid-performing BMPs in terms of bacteria removal efficiency. Stormwater management facilities that provide runoff quantity control, such as dry ponds, are categorized under non-performing BMPs and have 0 percent bacteria pollutant removal. Bacteria removal efficiencies are provided in Table 2-2, as well as Table A-8 in Appendix A.

Table 2-2: Anne Arundel County BMPs and Pollutant Removal Efficiencies

BMP Type	Bacteria Pollutant Removal Efficiency (%)	Category
Attenuation Trench	0	non-performing
Bioretention	90	high-performing
Check Dam	0	non-performing
Disconnection of Non-Rooftop Runoff	75	high-performing
Disconnection of Rooftop Runoff	75	high-performing
Dry Pond	0	non-performing

BMP Type	Bacteria Pollutant Removal Efficiency (%)	Category
Dry Wells	75-90	high-performing
Environmental Site Design	75	high-performing
Extended Detention	50	mid-performing
Extended Detention Structure, Dry	50	mid-performing
Extended Detention Structure, Wet	75	high-performing
Forestation on Pervious Urban	0	non-performing
Infiltration Trench with Complete Exfiltration Microbasin	90	high-performing
Infiltration Basin	90	high-performing
Infiltration Berms	75	high-performing
Infiltration Trench	90	high-performing
Infiltration Trench with Partial Exfiltration	90	high-performing
Infiltration Trench with Water Quality Exfiltration	90	high-performing
Landscape Infiltration	75	high-performing
Level Spreader	0	non-performing
Micro Pool	75	high-performing
Micro-Bioretention	75	high-performing
Oil-Grit Separator	50	mid-performing
Other	0	non-performing
Permeable Pavement	75	high-performing
Porous Pavement	90	high-performing
Rain Gardens	75-80	high-performing
Rainwater Harvesting	75	high-performing
Regenerative Step Pool Storm Conveyance	90	high-performing
Sand Filter	0	non-performing
Shallow Marsh	75	high-performing
Sheetflow to Conservation Areas	75	high-performing
Submerged Gravel Wetlands	75	high-performing
Swales	75	high-performing
Underground Storage	50	mid-performing
Vegetated Buffer	80	high-performing
Wet Pond	75	high-performing
Wet Structure	75	high-performing

2.1 MAGOTHY RIVER WATERSHED – MAGOTHY RIVER MAINSTEM, FORKED CREEK, AND TAR COVE

The Magothy River Watershed is located in the northeastern portion of the County near Pasadena and Severna Park. The Magothy River flows southeast into the Chesapeake Bay near Gibson Island. Forked Creek is a small tidal creek located along the south shoreline of the river near its mouth and has a mainstem about 2.5 miles long. Tar Cove is on the opposite shoreline (north), adjacent to Sillery Bay. The primary land use category in all three watersheds is residential (Table 2-1 and Figure 2-1).

The Magothy River Watershed has approved bacteria TMDLs for the Magothy River Mainstem, Forked Creek, and Tar Cove. All three of these waterways are designated as Use II waters and are classified as “restricted” shellfish harvesting areas (MDE, 2005c). The Magothy River Mainstem is restricted only in the upper portion; the lower 12.4 miles of the river is unrestricted and is not considered part of the listed bacteria TMDLs.

The bacteria TMDL source distribution provided in MDE’s TMDL report for Magothy River Watershed, as shown in Table 2-3, identifies pet waste as the largest bacteria source in all three watersheds: Magothy River Mainstem, Forked Creek, and Tar Cove (MDE, 2005e).

Table 2-3: Bacteria Source Distribution in the Magothy River Watershed

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
Magothy River Mainstem	65.2%	22.0%	10.8%	2.0%	100%
Magothy River/Forked Creek	85.8%	13.2%	0.4%	0.6%	100%
Magothy River/Tar Cove	54.4%	32.6%	9.9%	3.1%	100%

The Magothy River Mainstem has 1,294 existing BMPs, Tar Cove has 132, and Forked Creek has 86, most of which are high-performing BMPs with 75 percent or greater bacteria removal efficiency (Table 2-4).

Table 2-4: Number of Existing BMPs in the Magothy River Watershed

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
Magothy River Mainstem	62	58	1119	55 (4%)	1,294
Magothy River/Forked Creek	2	0	83	1 (1%)	86
Magothy River/Tar Cove	5	3	122	2 (2%)	132

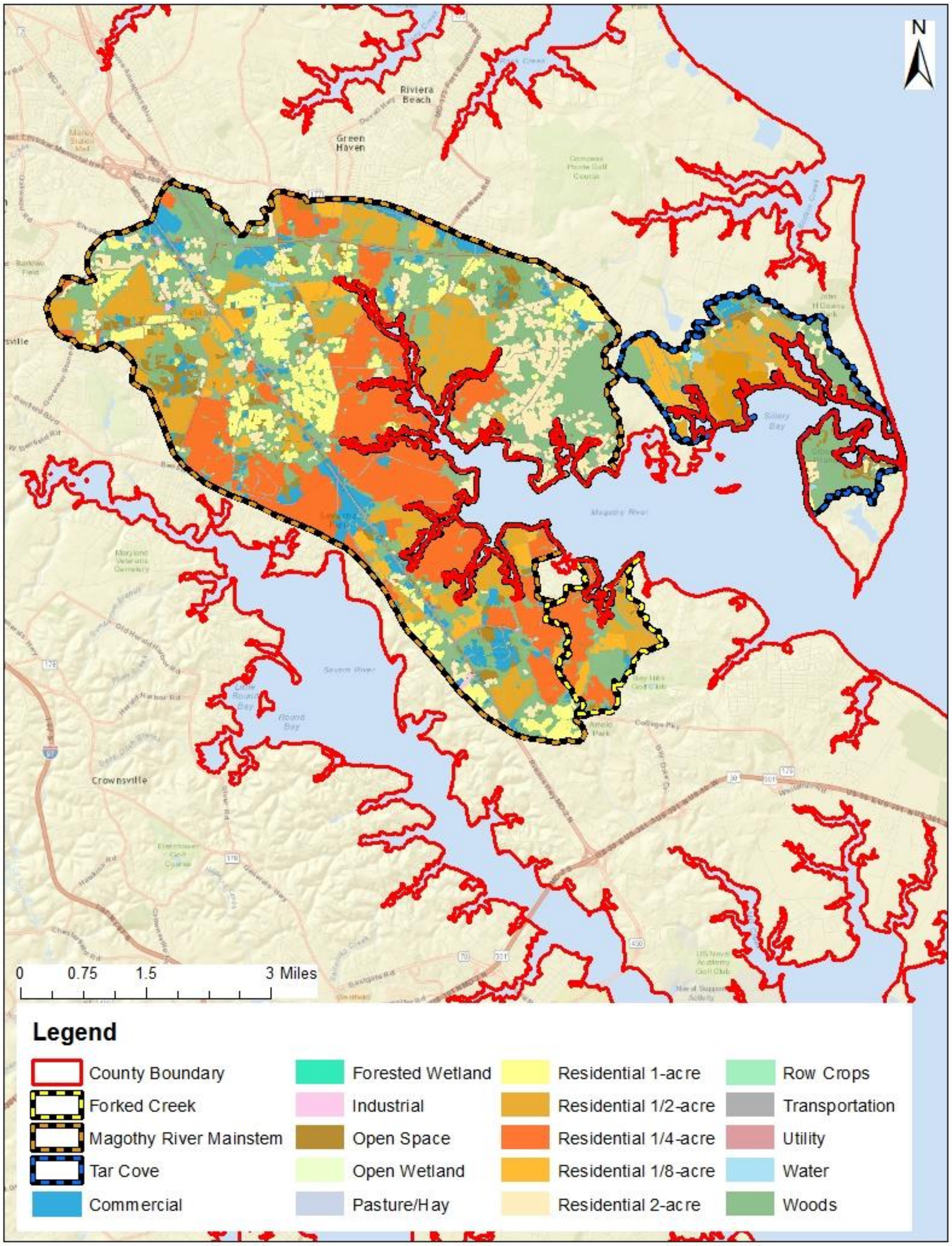


Figure 2-1: Land Use Map of Magothy River Watershed

2.2 PATAPSCO RIVER LOWER NORTH BRANCH

The Patapsco River Lower North Branch (LNB) forms the northwestern boundary of Anne Arundel County. The Patapsco River LNB TMDL covers Baltimore County, Carroll County, Howard County, and Baltimore City in addition to Anne Arundel County. The County's portion of the watershed (15,022 acres) is on the south side of the Patapsco River and includes numerous tributaries that flow north to the mainstem of the LNB, which then flows into the Baltimore Harbor in Baltimore City. The Patapsco River LNB is generally nontidal, which differentiates it from tidal areas of the Patapsco drainage (e.g., Furnace and Marley Creeks; see Section 2.3 below). The County's portion of the watershed is highly developed, and much of it was built in the 1980s and early 1990s, before modern stormwater regulations (Anne Arundel County, 2011). The watershed is 34 percent forested and 26 percent residential (Table 2-1 and Figure 2-2). Total imperviousness is 27 percent. The Patapsco River LNB watershed also includes green spaces such as riverine wetlands, forested floodplains, greenways, and Critical Area lands which help protect water quality.

The Patapsco River LNB has an approved E. coli bacteria TMDL (MDE, 2009b) and is a State-designated Use I water (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life). The bacteria source distribution from MDE's TMDL report for Patapsco River LNB (MDE, 2009b) is shown in Table 2-5. Holiday Mobile Estates is the only Water Reclamation Facility (WRF) in the Patapsco River LNB; it is a privately owned and operated WRF with an average flow (based on their NPDES permit) of 0.108 million gallons per day and reported monthly average bacteria concentrations of 3.0 MPN/100 ml. Given the low daily average flow, this WRF is a relatively minor source of bacteria compared to other sources in the watershed.

Table 2-5: Bacteria Source Distribution in the Patapsco River Lower North Branch Watershed

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
Patapsco River LNB	20.7%	36.7%	9.7%	32.9%	100%

There are 615 existing BMPs in the watershed, and the majority are high-performing BMPs (Table 2-6). Drainage area information is unavailable for three percent of the BMPs at this time.

Table 2-6: Number of Existing BMPs in the Patapsco River Lower North Branch Watershed

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
Patapsco River LNB	107	102	387	19 (3%)	615

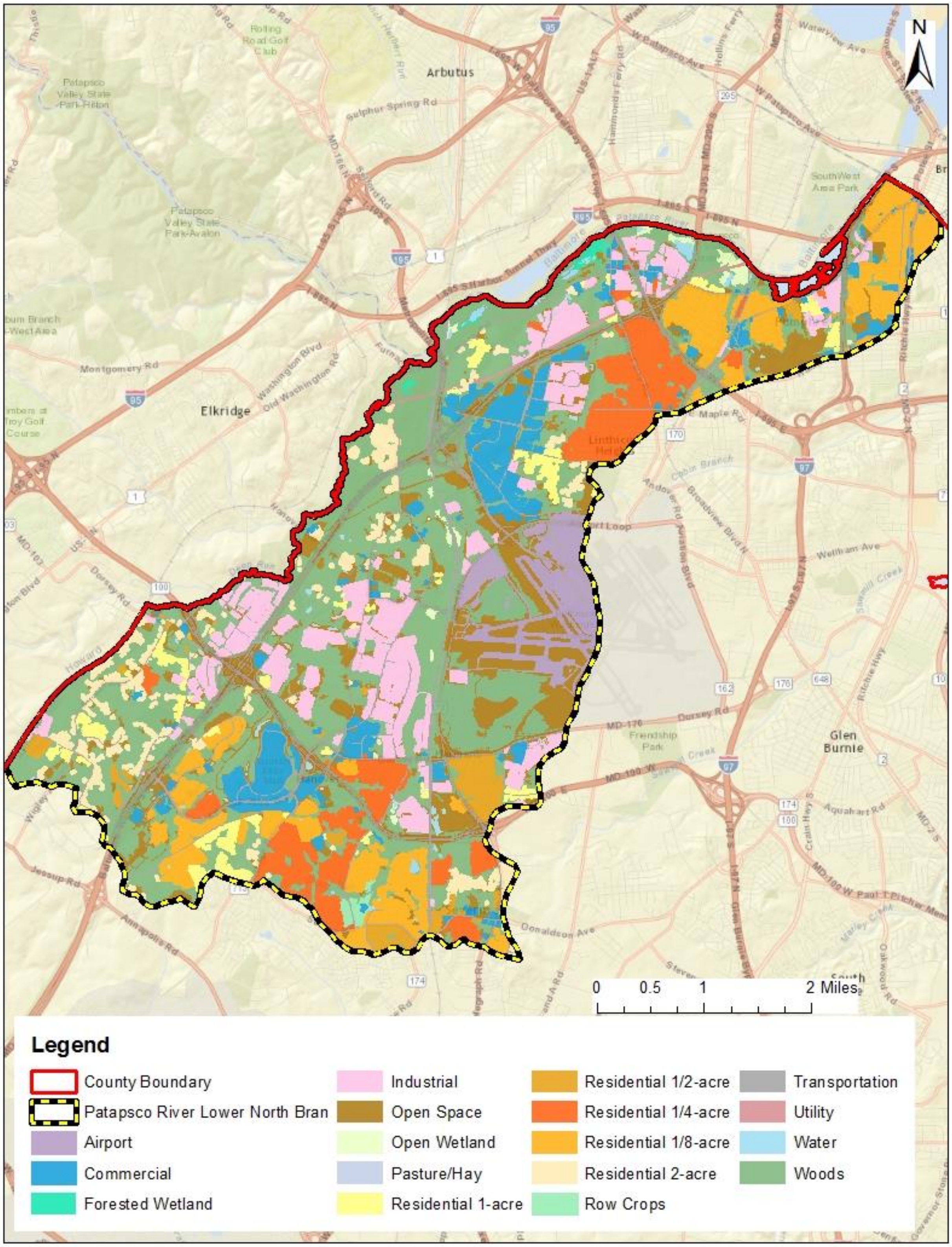


Figure 2-2: Land Use Map of the Patapsco River Lower North Branch Watershed

2.3 PATAPSCO RIVER – FURNACE CREEK AND MARLEY CREEK

Furnace Creek and Marley Creek are tidal creeks in the northern portion of the County, a few miles east of Baltimore-Washington International airport. The Furnace Creek and Marley Creek watersheds are similar in size (8,579 acres for Furnace Creek, 8,737 acres for Marley Creek), are highly urbanized with much residential development (Table 2-1 and Figure 2-3), and are each about 30 percent impervious. Some developments in these watersheds date back to the 1940s (Anne Arundel County, 2012b).

Furnace and Marley Creeks are MDE-designated Use I waters, and the bacteria TMDL impairment is Enterococci (MDE, 2010a). These are the only two watersheds in the County that have TMDLs for Enterococci (see Table 1-1 in Section 1).The Furnace Creek and Marley Creek watersheds have similar bacteria source distributions (Table 2-7 below) as identified by MDE (2010c). There are no livestock loads in either watershed. In each watershed, the contribution from human sources and wildlife is greater than 30 percent of total source loads. Pet waste contributes slightly less than 30 percent of the total loads in Furnace Creek and 34.6 percent of the total loads in Marley Creek. There are no point sources within the watersheds other than permitted MS4 stormwater discharges.

Table 2-7: Bacteria Source Distribution in the Furnace Creek and Marley Creek Watersheds

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
Furnace Creek	29.4%	38.1%	0.0%	32.5%	100%
Marley Creek	34.6%	31.2%	0.0%	34.2%	100%

There are 451 and 570 existing BMPs in the Furnace Creek and Marley Creek watersheds, respectively (Table 2-8). A majority of them are high-performing BMPs for bacteria, which include various types of infiltration BMPs and ESD practices. Thirteen percent of the existing BMPs in the Furnace Creek watershed and 17 percent of the existing BMPs in the Marley Creek watershed do not have drainage area data.

Table 2-8: Number of Existing BMPs in the Furnace Creek and Marley Creek Watersheds

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
Furnace Creek	52	26	314	59 (13%)	451
Marley Creek	114	33	328	95 (17%)	570

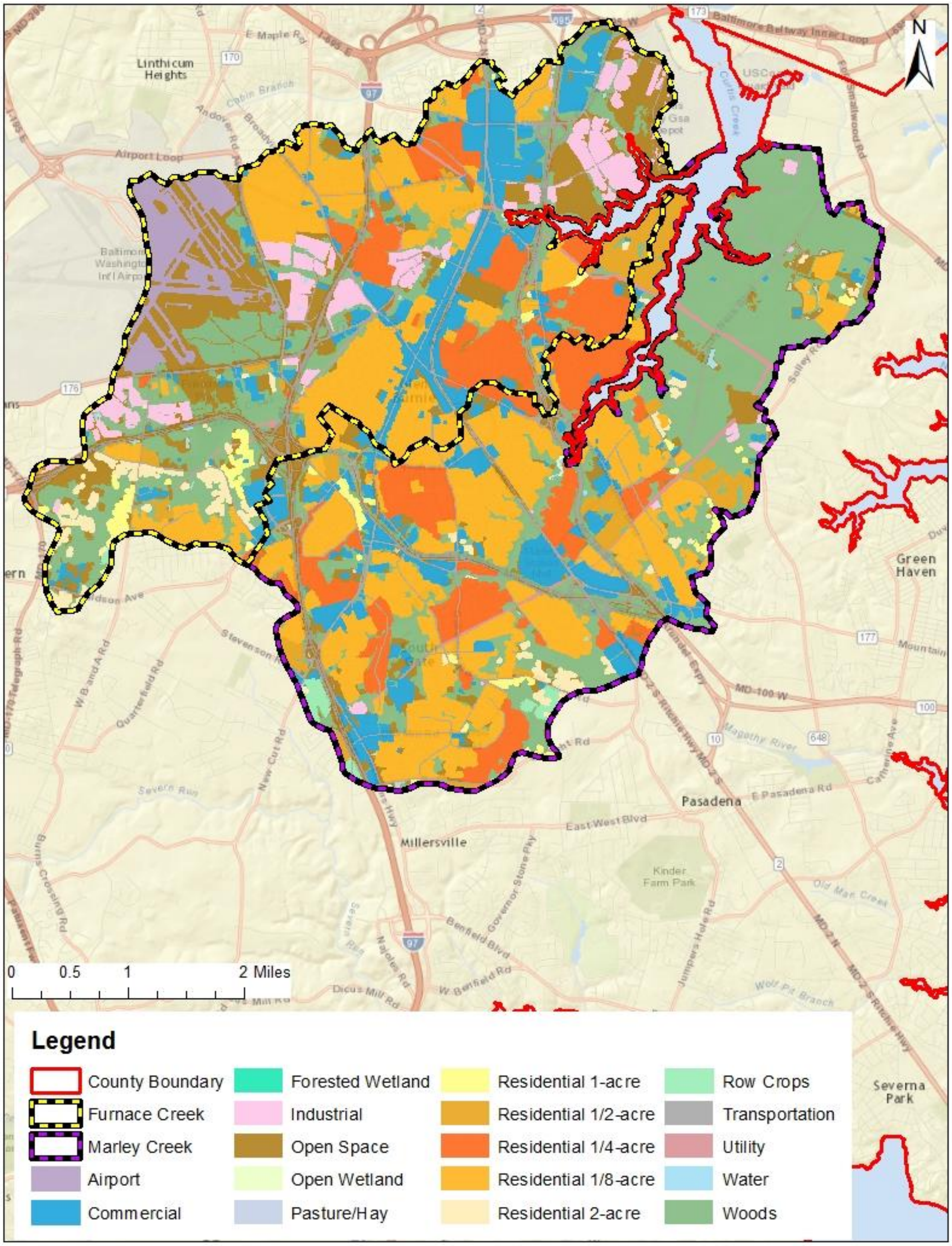


Figure 2-3: Land Use Map of the Furnace Creek and Marley Creek Watersheds

2.4 PATUXENT RIVER UPPER

The Patuxent River is one of the largest watersheds in Maryland. It flows from north to south and forms the boundary between Anne Arundel County to the east and Prince George's County to the west. The river is a designated Use I waterway. The impaired portion for the TMDL consists of a small subwatershed known as the Patuxent River Upper. This subwatershed is in the west central part of Anne Arundel County and extends across the river into Prince George's County. Anne Arundel County's portion is 10,450 acres and extends from the confluence with the Little Patuxent River in the north to the Queen Anne Bridge Road crossing in the south. Over 200,000 additional acres drain from upriver, outside the listed TMDL portion.

The Patuxent River valley is largely forested and includes numerous riparian wetlands. On the Anne Arundel County side of the river (eastern shore), there are several green spaces, including the Globecom Wildlife Management Area, Patuxent River Park, and Davidsonville Park. The upland area is agricultural interspersed with low- to medium-density residential developments (Table 2-1 and Figure 2-4). Major tributaries include Ropers Branch, Kings Branch, and Davidsonville Branch, which all flow from east to west into the Patuxent River Upper Mainstem.

The Patuxent River was placed on the State's 303(d) list in 2008 for fecal coliform impairments, and the bacteria TMDL was approved by EPA in 2011 (EPA, 2011). The TMDL is based on *E. coli*; however, the bacteria source distribution is based on *Enterococci*. This is because the monitoring datasets used to develop the TMDL included multiple pathogen indicators. MDE's TMDL report uses the generic term "fecal bacteria" to refer to all types of bacteria (MDE, 2010b).

MDE's bacteria source distribution in the Patuxent River Upper watershed is shown in Table 2-9 (MDE, 2010d). Wildlife (35.0 percent) and livestock (28.0 percent) are the dominant bacteria sources, but human (19.0 percent) and pet sources (18.0 percent) are also present. Wildlife are the largest source of bacteria in the Patuxent River Upper watershed, probably due to wildlife waste deposited in the river's riparian zone where there is abundant habitat and water resources for animals.

Livestock is the second largest contributor based on MDE's TMDL analyses, which includes not just cattle but also horses, sheep, chickens, and other farm animals. This part of the County has been identified to have a growing equestrian sector. Approximately 20 percent of the land use in the Patuxent River Upper watershed is agricultural. There are no point sources in the listed portion of the Patuxent River Upper watershed other than permitted MS4 stormwater discharges.

Table 2-9: Bacteria Source Distribution in the Patuxent River Upper Watershed

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
Patuxent River Upper	18.0%	35.0%	28.0%	19.0%	100%

There are 125 existing BMPs in the Patuxent River Upper watershed (Table 2-10). Of these, 113 are high-performing BMPs for bacteria. Seven percent of the existing BMPs do not have drainage area data.

Table 2-10: Number of Existing BMPs in the Patuxent River Upper Watershed

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
Patuxent River Upper	1	2	113	9 (7%)	125

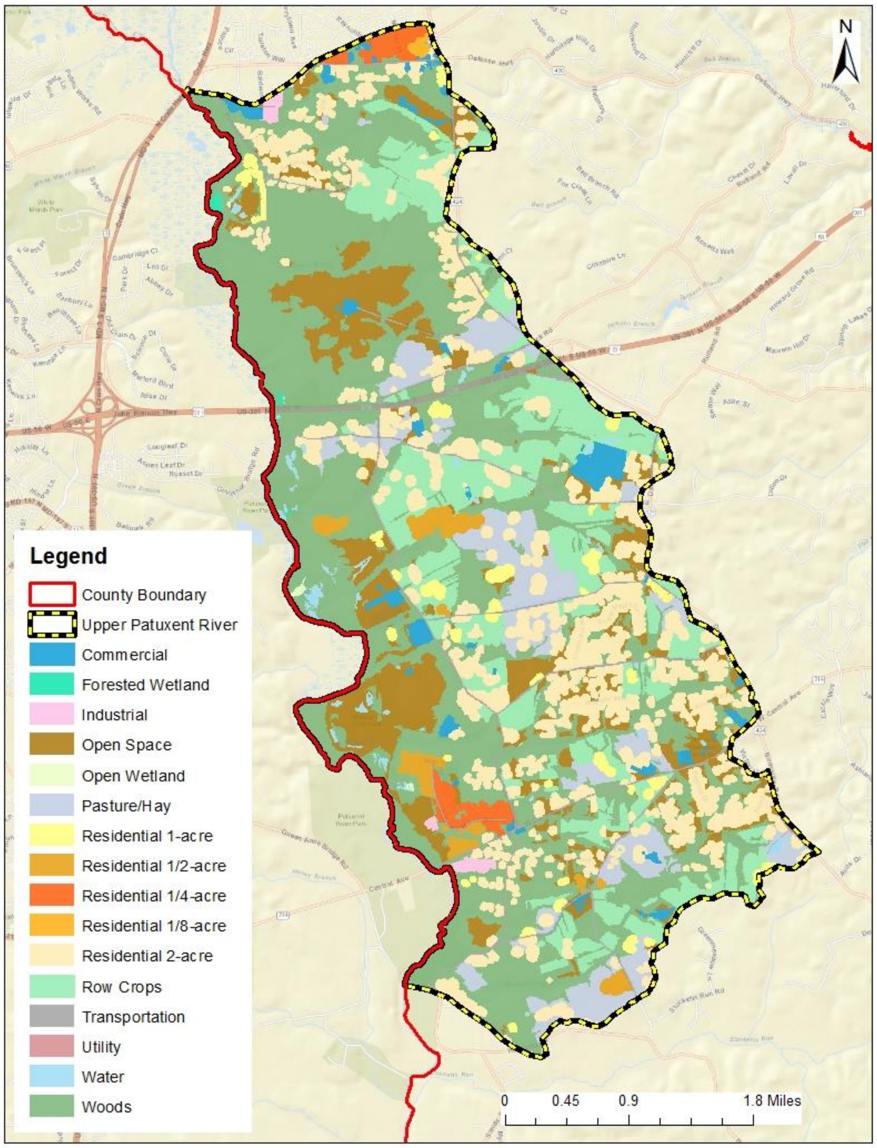


Figure 2-4: Land Use Map of the Patuxent River Upper Watershed

2.5 RHODE RIVER – BEAR NECK CREEK AND CADLE CREEK

Bear Neck Creek and Cadle Creek are located in the Rhode River Watershed. Even though Bear Neck Creek and Cadle Creek are tributaries of Rhode River, their TMDLs are not associated with Rhode River. According to MDE's TMDL report (MDE, 2005g), Bear Neck and Cadle Creeks are fairly large creeks at approximately 1,000 feet wide and about 3 feet deep on average. The Bear Neck Creek watershed is 880 acres with 50 percent of its land use being residential, mainly consisting of the community of Mayo. Most of the developments are on the east side of the creek, while the western shore is mainly forested (Table 2-1 and Figure 2-5). The Bear Neck Creek watershed as a whole is 16 percent impervious, which consists of roofs, driveways, roads, parking lots, and a few marina lots. The Cadle Creek watershed is 320 acres. Approximately 70 percent of the land use is residential and 20 percent is impervious.

Bear Neck Creek and Cadle Creek have approved TMDLs for bacteria. Both of the creeks are Use II waterways and are classified as "conditionally approved" for shellfish harvesting (MDE, 2005b).

The bacteria source distribution for Bear Neck Creek and Cadle Creek from the MDE's TMDL report (MDE, 2005g) are shown in Table 2-11. Livestock is listed as the primary source of bacteria at 46.3 percent in Bear Neck. However, this is not consistent with current land use, which is < 1 percent agricultural according to the County's 2011 GIS land use data. This discrepancy may be due to conversion of farmland in the watershed to urban developments in the last 10 or so years (i.e., since the TMDL was developed). It may be that livestock sources are less of a factor today. Pet waste contributes 33.9 percent of the bacteria load and is likely generated in residential communities. In the Cadle Creek watershed, pet waste contributes 80.2 percent of the total bacteria source loads.

Table 2-11: Bacteria Source Distribution in the Rhode River Watershed

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
Bear Neck Creek	33.9%	19.7%	46.3%	0.1%	100%
Cadle Creek	80.2%	19.5%	0.0%	0.3%	100%

The Bear Neck Creek watershed has 77 existing BMPs and the Cadle Creek watershed has 54 existing BMPs (Table -12). These two are among the watersheds for which the County is currently updating the drainage area database for the BMPs, and as a result, drainage area data are unavailable for many of the BMPs as this report is being written. One restoration project in the Bear Neck Creek watershed is the Ponder Cove storm drain retrofit project in the Holly Hill Harbor community. To date, the County has been able to retrofit about 40 linear feet of storm drain pipe with perforated pipe to facilitate infiltration. The total drainage area treated is approximately 11.9 acres of which 2.6 acres are impervious.

Table 2-12: Number of Existing BMPs in the Rhode River Watershed

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
Bear Neck Creek	1	0	17	59 (77%)	77
Cadle Creek	0	1	6	47 (87%)	54

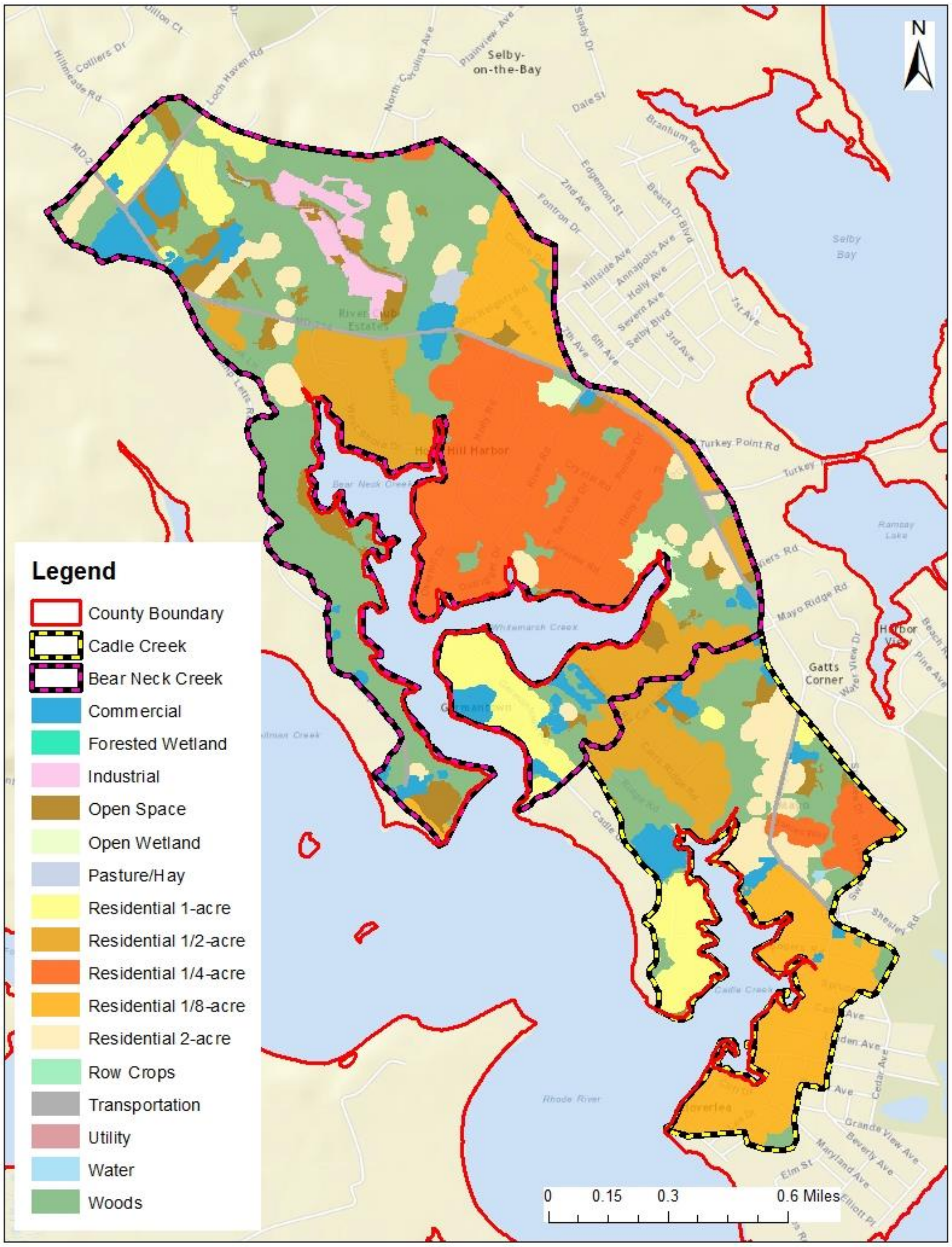


Figure 2-5: Land Use Map of the Bear Neck Creek and Cadle Creek Watersheds

2.6 SEVERN RIVER WATERSHED – SEVERN RIVER MAINSTEM, MILL CREEK, AND WHITEHALL / MEREDITH CREEKS

The Severn River Mainstem flows from northwest to southeast across the center of the County, from the community of Severn at the headwaters to the city of Annapolis near the mouth. According to MDE's TMDL report (MDE, 2008), the river is fairly deep, with an average depth of about 11 feet. The total watershed area is 37,011 acres, and the dominant land uses are residential at 44 percent and forested at 35 percent (Table 2-1 and Figure 2-6). Approximately 20 percent of the watershed is impervious.

Mill Creek, Whitehall Creek, and Meredith Creek are all located a few miles northeast of the Severn River's mouth and discharge into the Chesapeake Bay just west of the Bay Bridge. Mill Creek has a watershed area of 3,256 acres, of which 14 percent is impervious, and consists of residential developments along the shoreline. The Whitehall and Meredith Creeks' combined watershed is 12 percent impervious. These creeks are shallow with an average depth of approximately 3 feet (MDE, 2008).

The Severn River Mainstem, Mill Creek, and Whitehall/Meredith Creeks have approved TMDLs for fecal coliform. Whitehall and Meredith Creeks have one combined TMDL due to their proximity. The Severn River, Mill Creek, and Whitehall/Meredith Creeks are MDE-designated Use II waters and are "restricted" for shellfish harvesting (EPA, 2008). MDE's bacteria source distributions are shown in Table 2-13. The largest bacteria source in the Severn River Mainstem is pet waste (68.8 percent), while the largest source in Mill Creek and Whitehall and Meredith Creeks is wildlife at 59.0 percent and 71 percent, respectively. The Severn River Watershed has two permitted point sources: the Annapolis WRF and the U.S. Naval Academy. Dreams Landing WRF, a privately owned and operated facility, was listed as one of the point sources by MDE at the time of TMDL development; however, the WRF is now defunct. The total combined load from both point sources is 7.41×10^9 fecal coliform counts per day based on the allowable (NPDES-permitted) monthly median concentration of 14 MPN/100 ml. Aside from urban stormwater, which can also contribute substantial fecal coliform loads to the receiving waters, there are no other permitted point sources in the Whitehall/Meredith watershed.

Table 2-13: Bacteria Source Distribution in the Severn River Mainstem, Mill Creek, and Whitehall/Meredith Creek Watersheds

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
Severn River Mainstem	68.8%	28.9%	1.4%	0.9%	100%
Mill Creek	38.0%	59.0%	1.0%	2.0%	100%
Whitehall/Meredith Creeks	26.0%	71.0%	2.0%	1.0%	100%

The Severn River Mainstem watershed has 1,999 existing BMPs, which include 1,294 high-performing BMPs (Table 2-14). The Mill Creek watershed has 216 existing BMPs of which 141 are high-performing. The Whitehall/Meredith Creek watershed has 130 existing BMPs with 74 high-performing BMPs. The number of BMPs without drainage area data is provided in Table 2-14.

Table 2-14: Number of Existing BMPs in the Severn River Mainstem, Mill Creek, and Whitehall/Meredith Creek Watersheds

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
Severn River Mainstem	88	30	1,294	587 (29%)	1,999
Mill Creek	20	2	141	53 (25%)	216
Whitehall/Meredith Creeks	8	1	74	47 (36%)	130

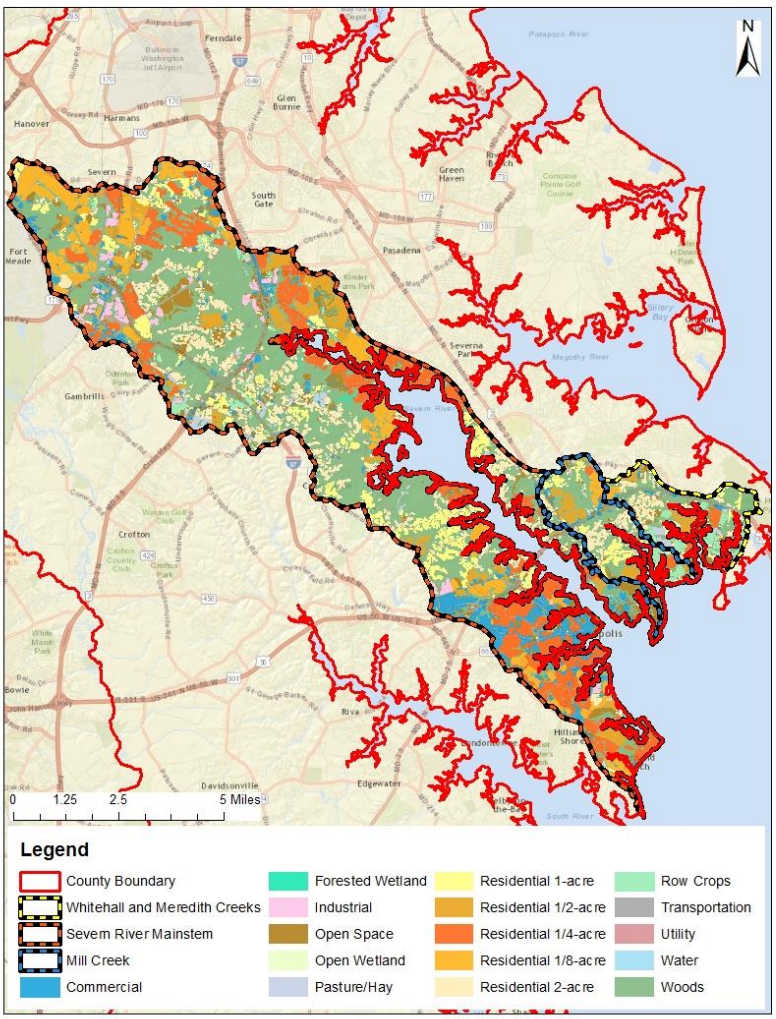


Figure 2-6: Land Use Map of the Severn River Mainstem, Mill Creek, and Whitehall-Meredith Creeks Watersheds

2.7 SOUTH RIVER WATERSHED – SOUTH RIVER MAINSTEM, DUVALL CREEK, RAMSEY LAKE, AND SELBY BAY

The South River Watershed has four impaired waterways with approved bacteria TMDLs: the South River Mainstem, Duvall Creek, Ramsey Lake, and Selby Bay. The South River is located immediately south of the Severn River in the central portion of the County. Like the Severn, it flows from northwest to southeast. The headwaters are near the town of Crownsville. The mouth, where it discharges to the Chesapeake Bay, is near Thomas Point Park. According to MDE's TMDL report (MDE, 2005f), the South River has an average width of 1.2 miles and an average water depth of 8.6 feet. The river drains 33,549 acres and has mixed land use consisting primarily of residential developments (32 percent) and forest (46 percent) (Table 2-1 and Figure 2-7). About 12 percent of the South River watershed is impervious. Duvall Creek, Ramsey Lake, and Selby Bay are small embayments near the mouth of the South River. Duvall Creek is on the north shore of the river and has 76 percent residential land use. Recreational activities in Duvall Creek include boating, canoeing, and windsurfing, and there are many individually moored vessels. Ramsey Lake and Selby Bay are on the south shore of the river. Like Duvall Creek, the majority of the land use in the Ramsey Lake and Selby Bay areas is residential.

The four TMDLs are mostly in restricted shellfish harvesting areas (designated Use II waters) due to fecal coliform impairments; the exception is the lower 3 miles of the South River Mainstem from near the mouth of Almshouse Creek to the mouth, which is not restricted and is currently open to shellfish harvesting according to MDE's shellfish harvesting closure area map (MDE, 2014e).

Based on MDE's TMDL report for South River Watershed (MDE, 2005f), the primary sources of fecal coliform bacteria in the South River Mainstem, Duvall Creek, Ramsey Lake, and Selby Bay are pet waste and wildlife (Table 2-15). Livestock sources also occur in the South River Mainstem and Duvall Creek watersheds. However, the County's GIS data from 2011 shows very little land in agricultural use, suggesting that some of the formerly agricultural land may have been converted to urban developments in the last 10 or so years. Therefore, livestock sources may be less significant today, although this cannot be quantified. Human sources are relatively minor (≤ 2 percent) in all the watersheds. There are no point sources other than permitted MS4 stormwater discharges.

Table 2-15: Bacteria Source Distribution in the South River Mainstem, Ramsey Lake, Selby Bay, and Duvall Creek Watersheds

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
South River Mainstem	43%	34%	22%	1%	100%
Duvall Creek	68%	17%	15%	0.1%	100%
Ramsey Lake	63%	37%	0%	0.3%	100%
Selby Bay	63%	35%	0%	2%	100%

The South River Watershed has 1,320 existing BMPs (Table 2-16), of which 935 are high-performing; these are mainly infiltration type BMPs with 90 percent bacteria removal efficiency. Duvall Creek, Ramsey Lake, and Selby Bay also have high-performing BMPs, which make up 87, 80, and 70 percent of the total BMPs in the respective watersheds.

Table 2-16: Number of Existing BMPs in the South River Mainstem, Ramsey Lake, Selby Bay, and Duvall Creek Watersheds

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
South River Mainstem	145	82	935	158 (12%)	1,320
Duvall Creek	2	0	41	4 (9%)	47
Ramsey Lake	3	2	54	7 (10%)	67
Selby Bay	5	1	57	18 (22%)	81

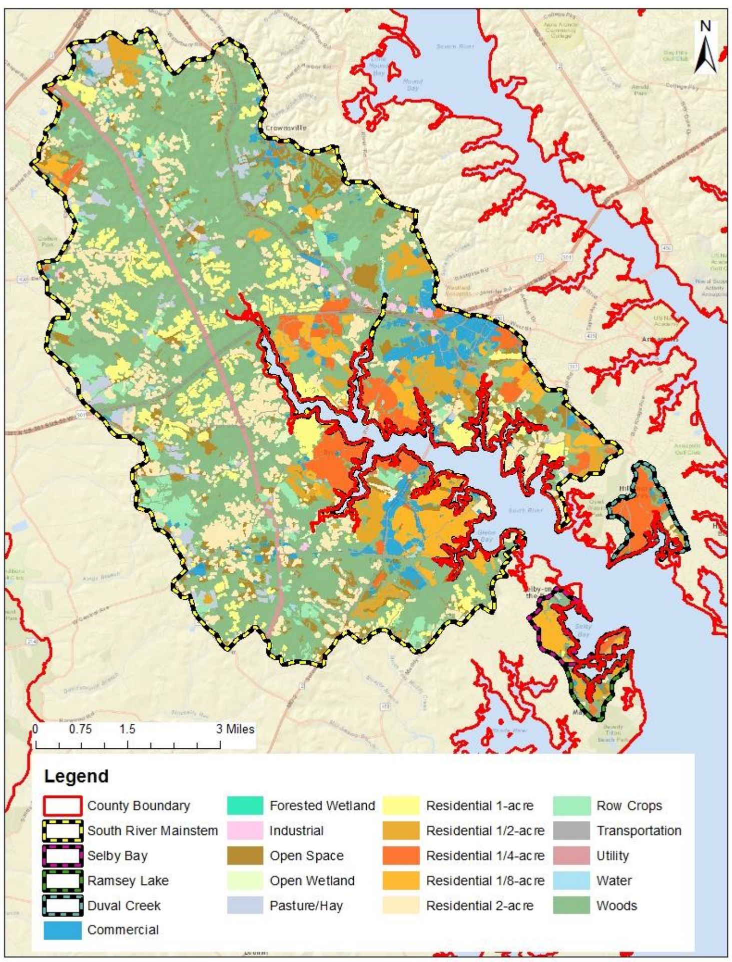


Figure 2-7: Land Use Map of the South River Mainstem, Duvall Creek, Ramsey Lake, and Selby Bay Watersheds

2.8 WEST CHESAPEAKE BAY – TRACY AND ROCKHOLD CREEKS

The West Chesapeake Bay Watershed, also known as the Herring Bay watershed is in the southeast corner of the County. Tracy Creek is lined with mature forests and riparian wetlands. Upland areas consist mainly of agricultural uses including livestock pastures. Rockhold Creek is located immediately east of Tracy Creek. The watershed is slightly more developed and includes the community of Deale along the eastern shoreline.

Tracy and Rockhold Creeks have a combined watershed area of 7,962 acres, about half of which is forest. Residential developments make up 18 percent of the watershed, and agricultural uses make up 15 percent (Table 2-1 and Figure 2-8). Imperviousness is approximately 5 percent.

The West Chesapeake Bay Watershed has an approved bacteria TMDL for Tracy Creek and Rockhold Creek due to fecal coliform impairment. Both are designated as Use II waters and are classified as “restricted” for shellfish harvesting area (MDE, 2005d). In MDE’s TMDL report, Tracy and Rockhold Creeks are represented as one watershed and have one associated TMDL because they are close and both drain to Herring Bay (MDE, 2005h).

The bacteria source distribution for the Tracy and Rockhold Creeks watershed is shown in Table 2-17. Wildlife is the primary bacteria source at 72 percent, and pet waste is the secondary source at 21 percent. There are no point source facility discharges in the watershed other than permitted MS4 stormwater discharges.

Table 2-17: Bacteria Source Distribution in the Tracy and Rockhold Creeks Watershed

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
Tracy and Rockhold Creeks	21%	72%	7%	<1%	100%

There are 67 existing BMPs in the watershed (Table 2-18). Thirteen of them are high-performing BMPs with 75 percent or greater bacteria removal efficiency. Drainage area data are unavailable for 73 percent of the BMPs.

Table 2-18: Number of Existing BMPs in the Tracy and Rockhold Creeks Watershed

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
Tracy and Rockhold Creeks	5	0	13	49 (73%)	67

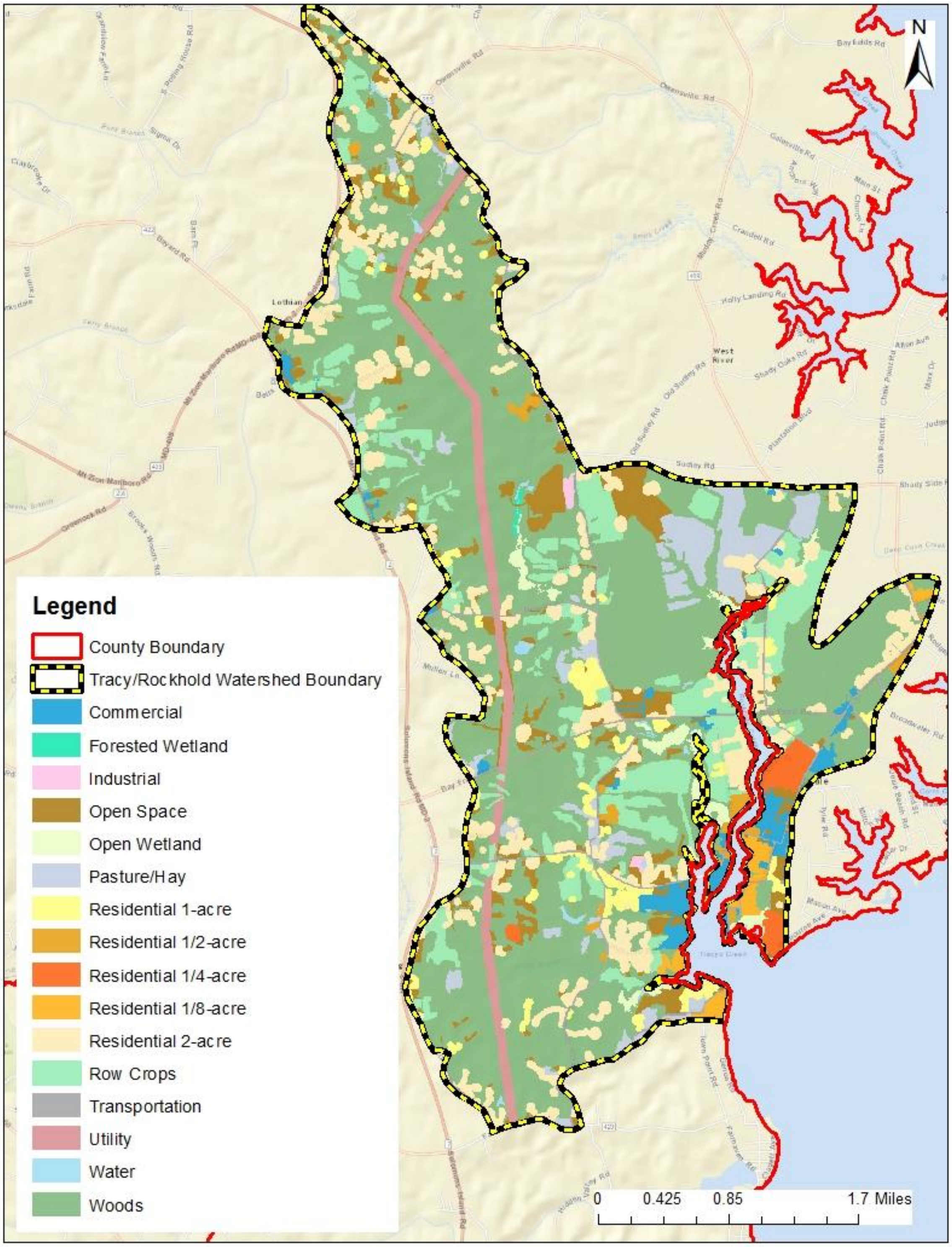


Figure 2-8: Land Use Map of the Tracy and Rockhold Creeks Watershed

2.9 WEST RIVER WATERSHED – WEST RIVER MAINSTEM AND PARISH CREEK

The West River is a tidal estuary and river system in the southeast portion of the County near the town of Galesville. The restricted portion is 0.6 mile wide and 3.2 feet deep on average. It flows northeast into the unrestricted lower river and then into the Chesapeake Bay. The watershed area is 6,304 acres, about 45 percent of which is forest. Residential developments make up 25 percent of the watershed, and agricultural land use (pasture/hay and row crops) makes up 20 percent (Table 2-1 and Figure 2-9). Imperviousness is relatively low compared to the other TMDL watersheds at 6 percent. Parish Creek is a small estuary east of the West River, near the town of Shadyside. Parish Creek drains an area of 324 acres, of which 41 percent is residential and 31 percent is forest.

The West River Watershed has approved bacteria TMDLs for the West River Mainstem and Parish Creek. Both are in restricted shellfish harvesting areas (designated Use II waters) due to fecal coliform impairments. Only the upper portion of the West River Mainstem is restricted; the lower river from Chalk Point to the mouth (a distance of about 1.5 miles) is unrestricted.

The bacteria source distribution in the West River Mainstem is shown in Table 2-19 below. The primary bacteria source is livestock (57.1 percent), which is consistent with the agricultural land use. In Parish Creek, the primary sources are wildlife at 59.0 percent and pets at 40.2 percent (Table 2-19). There are no point sources in either the West River Mainstem or Parish Creek watersheds other than permitted MS4 stormwater discharges.

Table 2-19: Bacteria Source Distribution in the West River Mainstem and Parish Creek Watersheds

Bacteria TMDL Watershed	Percent of Fecal Coliform Source Loads				Total
	Pets	Wildlife	Livestock	Human	
West River Mainstem	15.7%	26.8%	57.1%	0.4%	100%
Parish Creek	40.2%	59.0%	0.0%	0.8%	100%

The West River Mainstem watershed has 125 BMPs, and the Parish Creek watershed has 15. West River Mainstem and Parish Creek are among the watersheds for which the County is currently updating drainage area information for the BMPs, and as a result, drainage area data are unavailable for the majority of the BMPs (Table 2-20).

Table 2-20: Number of Existing BMPs in the West River Mainstem and Parish Creek Watersheds

Bacteria TMDL Watershed	Non-Performing BMPs	Mid-Performing BMPs	High-Performing BMPs	No. (%) of BMPs Without Drainage Area Data	Total
West River Mainstem	1	1	19	104 (83%)	125
Parish Creek	0	0	0	15 (100%)	15

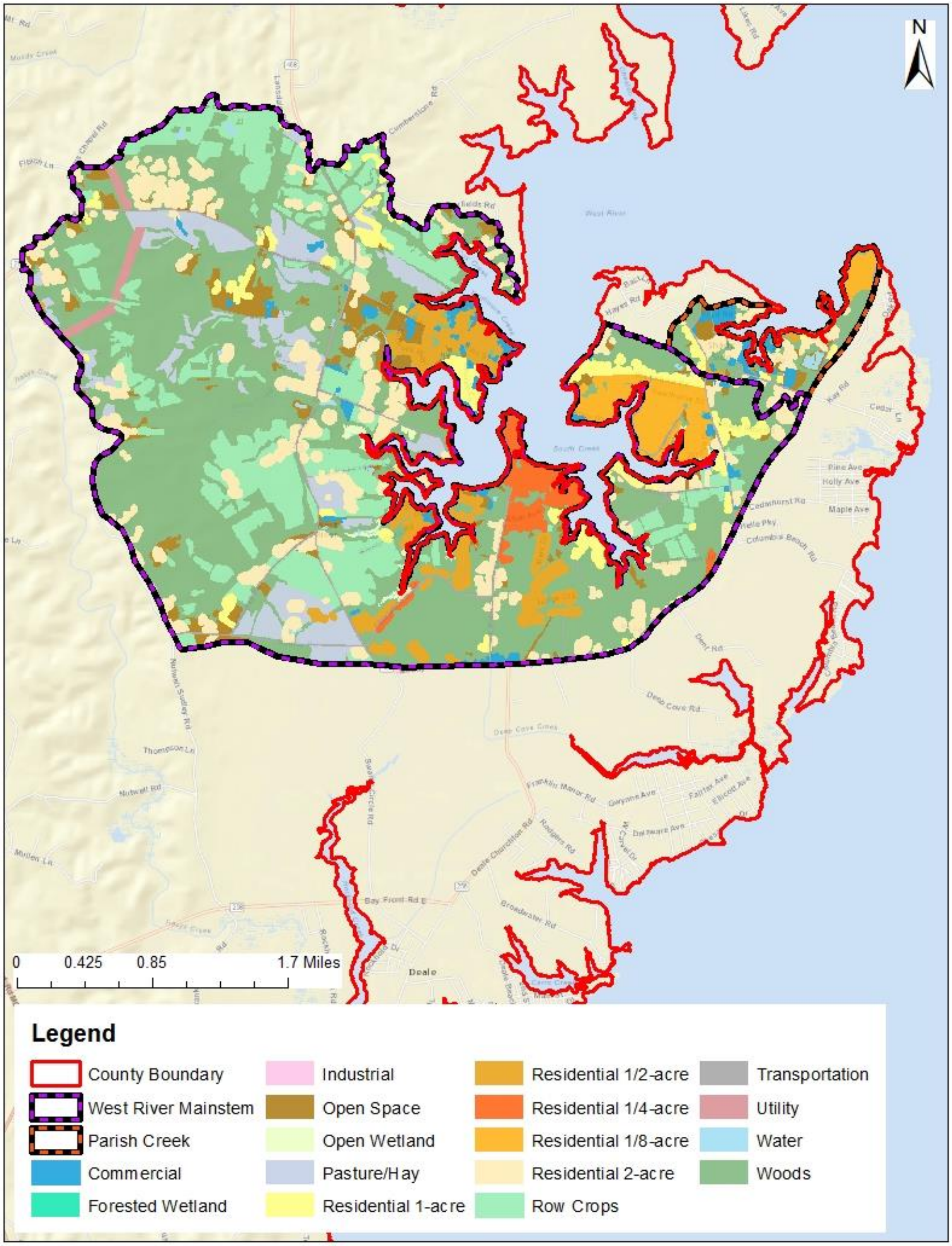


Figure 2-9: Land Use Map of the West River Mainstem and Parish Creek Watersheds

2.10 DEVELOPMENT OF EXISTING CONDITIONS WTM

As a part of development of TMDL Restoration Plan for bacteria impairments, water quality models were developed for all the study watersheds. The Watershed Treatment Model (WTM), a spreadsheet-based model developed by the Center for Watershed Protection (Caraco 2013) was used to characterize and quantify the bacteria loads for existing conditions from primary (land use) and secondary sources of pollutants (e.g. illicit discharges, sanitary sewer overflows) and estimate the potential bacteria load reductions from existing BMPs. The WTM models were developed using the County GIS data and literature review. Appendix A contains the approach adopted to develop the existing conditions model along with the results.

2.11 IMPACT OF TMDL RESTORATION PLAN TO TIER II WATERS

Maryland State water quality standards consist of three components:

- The designated use of the waterway (Use I or Use II in this case);
- Numerical water quality criteria (i.e., bacteria concentrations below certain levels) that are protective of that designated use; and
- An anti-degradation policy specifically for Tier II waters that maintains high quality waters so they do not degrade.

According to COMAR 26.08.02.04-1, high quality waters are where the water quality is better than the minimum requirements specified by the water quality standards. They are listed by MDE as "Tier II" waters. Based on MDE data, Tier II waters occur in two locations in the County:

- Lyons Creek, just west of the Tracy and Rockhold Creeks; it is not part of any TMDL watershed
- Patuxent River, just upstream of the Patuxent River Upper; it is not part of any TMDL watershed

Any watershed restoration or other activities that would affect the above Tier II waters, such as new or major modifications to discharges to the water bodies, are restricted by MDE. However, Lyons Creek flows west, away from Tracy and Rockhold Creeks, and the Tier II portion of the Patuxent River is upstream of the listed Patuxent River Upper TMDL portion. Therefore, the presence of Tier II waters is not expected to impact restoration plans for the 19 TMDL watersheds.

SECTION THREE: RESTORATION PLAN GOALS

The goal of this TMDL Restoration Plan is to reduce or mitigate existing sources of bacteria so that water quality standards and designated uses of the impaired waterways are restored. The approved TMDLs require significant reductions in bacteria loads ranging from 18 percent reduction to 90 percent reduction among the 19 TMDL watersheds (average 50 percent, see Section 3.1); therefore, extensive restoration efforts will be required to meet the TMDL goals.

In addition to meeting the TMDL goals as required by the County's NPDES MS4 permit, this restoration plan will help the County meet overarching goals, which include protecting environmental features such as riparian buffers, forests, and green spaces, as well as restoring water quality and improving habitat conditions. This restoration plan will help prevent further degradation of water resources and help to off-set any future load increases due to population growth and new development.

3.1 TMDL REDUCTION GOALS FOR BACTERIA

To restore the designated uses in each of the impaired waterways and ensure they meet State water quality standards, the MDE requires that loads from bacteria sources be reduced or mitigated by a specific amount. This is expressed in each of the MDE-published TMDLs as a required percent reduction in bacteria loads. The percent reduction is calculated as the difference between the current load (at the time the TMDL was developed) and the allowable load, divided by the current load, as follows:

$$Required\ Load\ Reduction = \frac{Current\ Load - Allowable\ Load}{Current\ Load}\ x\ 100\%$$

The current load is the mass of all bacteria sources in the watershed that drain to the water body and contribute to the observed impairment. It represents the "existing conditions" at the time the TMDLs were developed, typically in the early 2000s. The MDE calculated the current load using a pollutant load model calibrated with monitoring data collected at the base of each watershed.

The allowable load is the amount of pollutant a water body can take in without exceeding its maximum allowable water quality standard for that pollutant.   The allowable load is computed using the same approach as the current load except that the applicable State water quality criteria are used instead of the monitoring data.

The State-approved TMDL water quality goals for all Anne Arundel County watersheds are presented in Table 3-1. The data presented in the table were obtained from the MDE published TMDL reports for each watershed and include the percent reductions required to restore the designated use and water quality of the waterways. These are the ultimate goals for this restoration plan and represent the end point of implementation for the County.

Table 3-1: TMDL Reduction Goals for Bacteria from MDE's TMDL Reports

TMDL Watershed	TMDL Current Load, Counts/Day	TMDL Allowable Load, Counts/Day	Required Percent Reduction
Magothy Mainstem	4.97×10^{12}	4.33×10^{12}	33 to 54 [1]
Magothy River/Forked Creek	1.83×10^{11}	1.35×10^{11}	26
Magothy River/Tar Cove	9.82×10^{11}	2.07×10^{12}	21 to 33[1]
Patapsco River/Furnace Creek	3.66×10^{12}	8.14×10^{11}	78
Patapsco River Lower North Branch	7.78×10^{11}	6.38×10^{11}	18[2]
Patapsco River/Marley Creek	6.19×10^{12}	1.50×10^{12}	76
Patuxent River Upper	7.61×10^{11}	4.02×10^{11}	47[2]
Rhode River/Bear Neck Creek	3.55×10^{11}	2.01×10^{11}	43
Rhode River/Cadle Creek	3.54×10^{11}	9.85×10^{10}	72
Severn River Mainstem	6.07×10^{12}	4.92×10^{12}	19
Severn River/Mill Creek	1.78×10^{12}	2.49×10^{11}	86
Severn River/Whitehall and Meredith Creek	4.92×10^{11}	4.92×10^{10}	90
South River/Duvall Creek	1.52×10^{11}	8.27×10^{10}	46
South River Mainstem	1.32×10^{13}	9.31×10^{12}	46
South River/Ramsey Lake	5.57×10^{11}	2.27×10^{11}	59
South River/Selby Bay	3.27×10^{11}	3.75×10^{11}	28
W. Chesapeake Bay/Tracy and Rockhold Creeks	1.67×10^{12}	3.06×10^{11}	82
West River Mainstem	1.77×10^{12}	1.15×10^{12}	35
West River/Parish Creek	2.56×10^{11}	1.2×10^{11}	53

1- A range of reduction percentages is presented because of the method used by MDE to develop the TMDL.MDE used a segmented tidal prism model; therefore, it was not possible to present a single TMDL for the entire estuary.
2- Applies only to County's portion of drainage.

3.2 TIMELINE FOR MEETING BACTERIA TMDL

The EPA-approved TMDL reports do not include a specific final date for bacteria TMDL compliance. MDE, through the NPDES MS4 Permit, requires that the TMDL Restoration Plan be an iterative process until the TMDL goals are met. It is proposed that the restoration schedule be integrated with the Chesapeake Bay TMDL implementation schedule; therefore, 2025 can be considered the target timeline for meeting the bacteria TMDL. Merging the bacteria restoration activities with the Bay TMDL implementation is proposed because its bacteria reduction strategies are similar to those required by the County's Phase II Watershed Implementation Plan (WIP) (Anne Arundel County, 2012). For example, retrofitting impaired pipe outfalls and degraded stream channels with step pool storm conveyances (SPSCs), a requirement of the WIP, has a removal efficiency per acre of 57 percent for nitrogen, 66 percent for phosphorus, and 70 percent for sediment (MDE, 2014d). For bacteria, the removal efficiency is 90 percent, which makes it a highly desirable BMP to meet goals for bacteria and Bay TMDLs. A detailed implementation schedule for meeting the County's bacteria TMDLs is provided in Section 7.

SECTION FOUR: RESTORATION STRATEGIES

This section outlines restoration strategies proposed to meet the required TMDL load reductions and restore State water quality standards in the County's impaired waterways. The proposed restoration strategies were developed in consultation with several County departments, including the Department of Health, the Department of Public Works' (DPW) Watershed Protection and Restoration Program (WPRP) and Utility Planning divisions, using existing County data and reports. This section also includes planning-level implementation costs for each restoration strategy along with potential load reductions estimated using Center for Watershed Protection's WTM and literature review. The proposed strategies address both point and nonpoint bacteria sources as identified in MDE's bacteria TMDL reports for all 19 TMDL watersheds.

The proposed strategies are broadly grouped into Tier A and Tier B strategies. Tier A strategies are proposed to reduce human bacteria sources and Tier B strategies are proposed to reduce non-human sources (i.e. from wildlife waste, pet waste, and livestock waste). Tier A strategies are considered high priority for the County because human sources of bacteria pose a higher potential public health risk (MDE, 2014b), and these strategies are already part of the County's NPDES MS4 program (e.g., illicit discharge detection and elimination) and the County DPW wastewater program (e.g., sanitary sewer repairs and septic system retirement). However, per the MDE guidance document for developing restoration plans for addressing bacteria TMDL, jurisdictions have considerable flexibility in selecting the order of implementation of the proposed strategies, provided that the required TMDL load reductions are achieved in a reasonable time frame (MDE, 2006; MDE, 2014a; J. White pers. communication, January 8, 2015). Therefore, it is recommended that the County initially implement additional and new strategies that are the most cost-effective while concurrently continuing the existing programs (e.g. illicit discharge detection and elimination and the DPW wastewater program); these new strategies are identified below and more specific recommendations are provided in this section.

Certain strategies are not proposed in this restoration plan because preliminary modeling and information in the TMDL reports indicated that the bacteria load reductions achievable with these strategies is minimal. These strategies include upgrades to County-owned WRFs and management of deer populations. The preliminary modeling results indicated that the County-owned WRFs were a relatively minor bacteria point source in the TMDL watersheds where they occur due to the low effluent concentrations permitted by their WRF NPDES point source discharge permits (14 MPN/100 ml) for fecal coliform bacteria. Further, MDE's TMDL reports assume that deer waste represents a relatively minor source of bacteria relative to other wildlife species such as waterfowl.

4.1 PROPOSED STRATEGIES

4.1.1 Tier A Strategies

Tier A strategies are those that address potential human sources of bacteria such as septic system effluent from poorly maintained septic systems, sanitary sewage overflows, and illicit connections that discharge household human wastewater into the MS4. For all Tier A strategies, bacteria load reductions were estimated using WTM, one of MDE's recommended tools for identifying source loads and estimating pollutant load reductions (MDE, 2014b). County GIS data and related reports were used to develop the existing and proposed conditions WTM to produce a representative estimate of bacteria load reductions. Details on the modeling methodology are included in Appendix A. The Tier A strategies are described below.

Elimination of Household Illicit Connections

Residential household illicit connections are sanitary sewers connected directly to the storm drain instead of to the sanitary sewer, leading to discharge of raw untreated human wastewater into the local waterway. Wash water illicit connections occur when either commercial washwater (from carwashes, fleet washing, commercial laundry wastewater, or floor washing of shop drains) or residential grey water (laundry) is discharged into the MS4 rather than being disposed of properly (CWP, 2004). Commercial washwater and residential grey water primarily contain pollutants such as detergents/surfactants, ammonia, and others, and has an insignificant percentage of bacteria (CWP, 2004).

The County's NPDES MS4 permit (11-DP-3316, MD0068306) requires the County to conduct dry weather field screening and outfall sampling of 150 outfalls annually to detect potential illicit residential household and commercial waste water connections. This Tier A strategy assumes that all illicit connections detected by the County will be enforced and eliminated. From 2005 to 2013, the County-wide illicit detection rate was approximately 2 percent. This was based on 29 illicit connections detected out of 1,350 outfalls surveyed, as documented in the County's Annual NPDES MS4 Reports. It is assumed that the same detection rate of illicit connections would continue through 2020. The County-wide rate of 2 percent was apportioned among the 19 TMDL watersheds based on the amount of impervious cover in each TMDL watershed relative to the total impervious cover in the County (based on 2011 impervious data). It was further assumed that half of the illicit connections detected would be from households that discharge bacteria. The obtained proportioned rate of illicit detection and elimination was modeled in the proposed conditions WTM for each watershed to estimate the potential bacteria load reductions from this Tier A strategy.

Abatement of Sanitary Sewer Overflows

In the County, Sanitary Sewer Overflows (SSOs) generally occur as a result of power and mechanical failures at sewage pump stations (SPSs). According to data provided by the County, 533 SSOs of varying intensity and duration have occurred in the last 14 years (2001 to 2014); of these, approximately 101 have occurred in areas that affected the bacteria TMDL waterways. Table 4-1 below provides a summary of the County data related to SSOs.

Table 4-1: List of Sanitary Sewer Overflows Occurring in Bacteria TMDL Watersheds from 2001 to 2014

TMDL Watershed	TMDL Subwatershed	Number	Frequency (times per year on average)	Volume Range (gallons)
Magothy River	Mainstem	12	1.0	0 – 3,000,000
	Forked Creek	1	n/a (only one occurrence)	4,500
	Tar Cove	n/a	n/a	n/a
Patapsco River	Furnace Creek	8	0.7	100 – 78,000
	Marley Creek	13	1.2	0 – 222,000
Patapsco River Lower North Branch	Patapsco River Lower North Branch	2	0.7	290 – 1,200
Patuxent River Upper	Patuxent River Upper	2	0.6	0 – 50,000
Rhode River	Bear Neck Creek	11	1.0	0 – 79,600
	Cadle Creek	8	1.1	100 - 550
Severn River	Mainstem	14	2.0	0 – 54,000
	Mill Creek	2	0.3	200 - 350
	Whitehall and Meredith Creeks	1	n/a (only one occurrence)	200
South River	Mainstem	7	0.9	0 – 11,000
	Duvall Creek	3	0.6	200 – 2,000
	Ramsey Lake	10	1.3	0 - 500
	Selby Bay	4	0.8	200 – 2,000
West Chesapeake Bay Mainstem	Tracy and Rockhold Creeks	1	n/a (only one occurrence)	800
West River	Mainstem	2	0.5	300 – 8,000
	Parish Creek	n/a	n/a	n/a

This Tier A strategy proposes to reduce the number of SSOs and thereby reduce the discharge of human bacteria to surface waters. Specific wastewater projects that are considered SPS upgrades or otherwise designed to improve the reliability of the sanitary system were identified by the County (G. Heiner, pers. Communication November 6, 2014). A total of 35 wastewater projects in 12 of the 19 TMDL watersheds are currently listed as active in the County's Wastewater Capital Budget and Program annual reports (see Table 4-2 below). The projects were entered into the proposed conditions WTM to estimate the bacteria load reductions from implementing the SPS upgrades. Table 4-2 lists the SPS projects in the TMDL watersheds as identified by the County's Wastewater Capital Budget and Program annual reports along with cost estimates.

Table 4-2: List of Active Sewage Pump Station Upgrade Projects in 12 of the 19 TMDL Watersheds

Project	Project Title	Current Status	Description	TMDL Watershed	Qty. of Pump Stations Being Upgraded	Estimated Annual Cost[1]
S804700	Mill Creek SPS Upgrade	Active	Various upgrades to the Mill Creek sewage pumping station	Magothy River Mainstem	1	$300,000
S806700	Cinder Cove FM Rehab	Active	Construction of 10,000 linear feet of 30" force main to improve operational reliability	Patapsco River/Furnace Creek	1	$1,342,000
S805400	Marley SPS Upgrade	Active	Construction of various upgrades to Marley Sewage Pumping Station to improve operation and reliability	Patapsco River/Marley Creek	1	$900,000
S804900	Parole SPS Upgrade	Active	Construction of miscellaneous improvements to the Parole Sewage Pumping Station to increase operation and reliability	South River Mainstem	1	$100,000
S804000	Sylvan Shores PS Upgrade	Active	Construction of improvements to Sylvan Shore Sewage Pumping Station to improve reliability and efficiency of system	South River Mainstem	1	$407,000
S799200	Mayo Collection Sys Upgrade	Active	Expansion of Mayo Wastewater Collection and Conveyance System to accommodate planned growth within Mayo Sewer service area	Rhode River/Cadle Creek	1	$500,000
S806200	SPS Fac Gen Replacement	Active	Generator replacement	Magothy River Mainstem	3	$782,000
S806200	SPS Fac Gen Replacement	Active	Generator replacement	Magothy River/Forked Creek	1	$260,667
S806200	SPS Fac Gen Replace	Active	Generator replacement	Patapsco River LNB	2	$521,333
S806200	SPS Fac Gen Replace	Active	Generator replacement	Patapsco River/Furnace Creek	1	$260,667
S806200	SPS Fac Gen Replace	Active	Generator replacement	Patapsco River/Marley Creek	1	$260,667

Project	Project Title	Current Status	Description	TMDL Watershed	Qty. of Pump Stations Being Upgraded	Estimated Annual Cost[1]
S806200	SPS Fac Gen Replace	Active	Generator replacement	Severn River/Mill Creek	1	$260,667
S806200	SPS Fac Gen Replace	Active	Generator replacement	South River Mainstem	4	$1,042,667
S806200	SPS Fac Gen Replace	Active	Generator replacement	South River/Duvall Creek	1	$260,667
S791800	Upgr/Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Magothy River Mainstem	1	$397,917
S791800	Upgr/Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Patapsco River LNB	1	$397,917
S791800	Upgr/Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Patapsco River/Furnace Creek	1	$397,917
S791800	Upgr/Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Patapsco River/Marley Creek	1	$397,917
S791800	Upgr/Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Severn River Mainstem	6	$2,387,500
S791800	Upgr/Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	West River/Bear Neck Creek	1	$397,917
S791800	Upgr/Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	West River/Parish Creek	1	$397,917
S805300	Cinder Cove SPS Mods	Active	Pump station reliability improvements necessary to minimize risks of sanitary sewer overflows	Patapsco River/Furnace Creek	1	$64,104[2]
S806300	Big Cypress SPS Retro	Active	Upgrades to Big Cypress sewage pump station	Magothy River Mainstem	1	$231,577[3]
S797800	Furnace Brn Swr Repl	Active	Construct new sewer line and replace existing sewer to relieve capacity problems	Patapsco River/Furnace Creek	1	$123,000[4]
				TOTALS:	**35**	**$12,392,018**

1-Annual costs were estimated from the wastewater CIP budget for FY2015 except where noted.
2-Cost estimate represents funds expended between April 1, 2013 and April 1, 2014. No fiscal year annual budget information was available.
3-Cost estimate represents funds expended between April 1, 2013 and April 1, 2014. No fiscal year annual budget information was available.
4-Cost estimate represents FY2009 annual budget. No fiscal year annual budget information was available.

Retirement of County Septic Systems

Retirement of failing septic systems by connecting them to the public sanitary system reduces human bacteria sources in the watershed. The number of septic systems to be retired was identified in each TMDL watershed based on GIS data provided by the County DPW. A total of 16,007 septic systems were identified in 10 of the 19 TMDL watersheds. These septic systems were previously identified by the County as contributing nitrogen discharges to the Chesapeake Bay and were selected for retirement for the purposes of meeting the Chesapeake Bay TMDL. The number of septic systems to be retired is presented in Table 4-3 below. This information was entered into the proposed conditions WTM to estimate the bacteria load reductions that would be achieved by implementing this strategy.

Table 4-3: Number of Septic Systems Selected for Retirement as Identified by the County Department of Public Works

Bacteria TMDL Watershed	No. of Septic Systems to Be Retired
Magothy Mainstem	4,814
Magothy River/Forked Creek	113
Magothy River/Tar Cove	1,708
Patapsco River/Furnace Creek	252
Patapsco River LNB	174
Patapsco River/Marley Creek	0
Patuxent River Upper	289
Rhode River/Bear Neck Creek	0
Rhode River/Cadle Creek	0
Severn River Mainstem	5,475
Severn River/Mill Creek	1,168
Severn River/Whitehall and Meredith Creek	320
South River/Duvall Creek	0
South River Mainstem	1,694
South River/Ramsey Lake	0
South River/Selby Bay	0
W. Chesapeake Bay/Tracy and Rockhold Creeks	0
West River Mainstem	0
West River/Parish Creek	0

4.1.2 Tier B Strategies

Tier B strategies are those that address non-human sources of bacteria, such as pet waste, wildlife waste, and livestock waste. For the purposes of this TMDL Restoration Plan, urban stormwater runoff is also considered a non-human bacteria source. Many of the Tier B strategies are non-structural measures that are expected to have relatively low implementation costs and are considered a cost-effective means for the County to achieve credit for bacteria load reductions. Non-human sources are considered secondary in importance relative to human sources for public health reasons (MDE, 2014b). Bacteria load reductions for Tier B strategies were estimated using the WTM, as well as literature review. Each of the Tier B strategies and the assumptions and methods used to develop each strategy are described below. The priority of implementing Tier A or Tier B strategies is at the County's discretion.

Tier B strategies that address urban stormwater retrofits were placed into two categories: restoration of 20 percent of currently unmanaged impervious cover and retrofit of pre-2002 ponds to meet current MDE stormwater criteria. This strategy was developed based on the Anne Arundel County's Urban Phase II Watershed Implementation Plan (2012) and requirements of the current NPDES MS4 Permit (11-DP-3316, MD0068306). The current NPDES MS4 Permit requires the County to treat 20% of the impervious area that currently has limited/no stormwater management. Even though the impervious areas draining to pre-2002 ponds can be categorized as impervious area with limited stormwater management and can be counted towards the NPDES MS4 impervious area restoration goals, they are not merged with the "Restoration of 20 Percent of Currently Unmanaged Impervious Cover" strategy in this restoration plan. The purpose of separating these two strategies is to evaluate the relative cost-benefit of each strategy. The objective is to assist the County in 1) identifying the most cost-effective approach to stormwater management, and 2) identifying the optimal combination of retrofits to meet the NPDES permit requirements and Phase II WIP recommendations.

Restoration of 20 Percent of Currently Unmanaged Impervious Cover

The County's NPDES MS4 permit requires the County to undertake efforts to restore 20 percent of currently unmanaged impervious cover. To simulate this requirement, the proposed conditions WTM were configured to treat 20 percent of unmanaged impervious cover in each TMDL watershed. The County's impervious cover data from 2011 which is the latest data available, was used for the development of this restoration plan. However, the County is in the process of deriving a new impervious area baseline assessment as a part of the NPDES MS4 requirements to identify managed and unmanaged areas. Therefore, the impervious information presented in the following sections does not reflect the most recent information. The updated data, when available, will be used to update this Bacteria TMDL Restoration Plan. BMPs with high bacteria removal efficiencies, such as SPSCs and infiltration practices, were selected to manage the 20 percent for consistency with the urban stormwater strategies recommended in the County's Phase II WIP (Anne Arundel County, 2012). As SPSCs are considered a relatively cost-effective BMP for treating larger drainage areas compared to BMPs such as bioretention (see Regenerative Stormwater Conveyance [RSC] factsheet on County's website, Anne Arundel County 2012c), they are considered a high priority for implementation. According to the County's Phase II WIP, SPSC retrofits are proposed for sites in the County that meet the following criteria: streams with physical habitat index rankings of "degraded" or "severely degraded"; and outfalls that are 24 inches or greater in diameter, have a D ranking for impairment, and occur in watersheds that are a high priority for restoration. Table 4-4 below presents the number of unmanaged impervious acres proposed to meet the 20 percent NPDES MS4 restoration goal in each TMDL watershed. This information was entered into the proposed conditions WTM to estimate the expected bacteria load reductions from implementing the 20 percent impervious restoration strategy.

Table 4-4: Number of Currently Unmanaged Impervious Acres[1] in Need of Treatment to Reach 20% Restoration Goal in NPDES Permit

Bacteria TMDL Watershed	Impervious Acres to Be Treated With High Pollutant Removal BMPs such as SPSC[2]
Magothy Mainstem	351.6
Magothy River/Forked Creek	25.5
Magothy River/Tar Cove	51.5
Patapsco River/Furnace Creek	427.1
Patapsco River LNB	491.5
Patapsco River/Marley Creek	368.5
Patuxent River Upper	77.0
Rhode River/Bear Neck Creek	19.2
Rhode River/Cadle Creek	11.6
Severn River Mainstem	877.4
Severn River/Mill Creek	43.1
Severn River/Whitehall and Meredith Creek	44.6
South River/Duvall Creek	25.2
South River Mainstem	349.1
South River/Ramsey Lake	13.6
South River/Selby Bay	13.2
W. Chesapeake Bay/Tracy and Rockhold Creeks	74.2
West River Mainstem	73.2
West River/Parish Creek	11.2

1 Impervious acres listed here are based on 2011 impervious data. The County is in the process of deriving a new impervious area baseline assessment. The updated impervious areas will be included in future evaluation and tracking of this Bacteria TMDL Restoration Plan’s implementation.

2 SPSC=Step Pool Storm Conveyance

Retrofit of Pre-2002 Ponds to Meet Current MDE Stormwater Criteria

According to County’s Phase II WIP, existing pre-2002 dry ponds in the TMDL watersheds are recommended to be retrofitted to meet current Maryland stormwater management criteria. Currently, dry ponds have a bacteria removal efficiency of 0 percent based on information in the County’s 2012 Annual NPDES MS4 report. Converting the dry ponds to shallow wetland/marsh filtering systems or SPSCs, as recommended in the County’s Phase II WIP, would increase the bacteria removal efficiency to 75 percent or 90 percent, which in either case is considered a high-performing BMP for bacteria. Based on the WIP recommendations, only dry ponds with drainage areas of 10 acres or more were proposed for retrofit. The number of ponds proposed for retrofit for each TMDL watershed is shown in Table 4-5 below. This information was entered into the proposed conditions WTM to estimate the expected load reductions from implementing this strategy.

Table 4-5: Number of Pre-2002 Dry Ponds Proposed for Retrofit in Each TMDL Watershed

Bacteria TMDL Watershed	No. of Dry Pond Proposed Retrofits
Magothy Mainstem	8
Magothy River/Forked Creek	0
Magothy River/Tar Cove	0
Patapsco River/Furnace Creek	8
Patapsco River LNB	5
Patapsco River/Marley Creek	11
Patuxent River Upper	0
Rhode River/Bear Neck Creek	0
Rhode River/Cadle Creek	0
Severn River Mainstem	13
Severn River/Mill Creek	3
Severn River/Whitehall and Meredith Creek	0
South River/Duvall Creek	0
South River Mainstem	14
South River/Ramsey Lake	0
South River/Selby Bay	0
W. Chesapeake Bay/Tracy and Rockhold Creeks	0
West River Mainstem	0
West River/Parish Creek	0

Riparian Buffer Education

Riparian buffers help reduce non-human bacteria source loads from the watershed by slowing down and filtering stormwater runoff before it discharges to the waterway. COMAR requires a 100-foot minimum riparian buffer, or larger if steep slopes, hydric soils, highly erodible soils, nontidal wetland, or a Nontidal Wetland of Special State Concern are present (see COMAR 27.02.01.01). Maintaining a minimum buffer size helps preserve the water quality function of the buffer. Development pressure may potentially alter the buffer over time, resulting in a reduced ability of the buffer to filter pollutants (Caraco, 2013a). For this Tier B strategy, the proposed conditions WTM was used to estimate the expected bacteria load reductions from implementing a riparian buffer education program in areas where the buffer is reduced or altered, or where private property abuts the waterway. The education program is recommended to include buffer enhancement components, such as no mow areas, planting trees and shrubs, and promoting the growth of native vegetation.

Expanded Pet Waste Education Program

This strategy involves implementing a multi-media-based pet waste education program to encourage pet owners to pick up after their pets. Other related practices such as dog park improvements, more pet waste stations, and increased enforcement of leash laws may also help to instill behavior change in pet owners and reduce bacteria loads from pet waste. According to MDE's published TMDL reports, pet waste is one of the primary bacteria sources in many of the TMDL watersheds (see Table 2-11); therefore, implementing a strategy to reduce pet waste at its source may potentially have a large impact on improving water quality in the County's impaired waterways.

Some possibilities for an expanded pet waste education program and related practices include:

- Expanding the number of pet waste stations in residential areas and County public parks. Based on a website developed by Winters (2015), there are 11 mapped pet waste stations along the Baltimore and Annapolis Trail, 20 mapped stations in the Annapolis area, and 5 mapped stations in Crofton, although these are only the mapped stations and there are likely many more opportunities throughout the County.
- Increasing signage about leash laws and ranger presence at public parks to enforce leash laws and issue citations
- Developing Public Service Announcements (PSAs) for television and post professionally made videos to the County website. An example of a PSA video, which was developed by the state of Washington and cost $27,000 to develop, is available at http://mynorthwest.com/11/512462/Washington-uses-dog-doogity-music-video-to-encourage-pet-waste-cleanup
- Improving management of pet waste at existing dog parks
- Providing grants to communities to install pet waste stations on community properties.

Bacteria load reductions from implementing a pet waste education program were estimated using the methodology proposed in the Virginia Department of Environmental Quality's (DEQ's) *Bacterial Implementation Plan Development for the James River and Tributaries – City of Richmond Technical Report* (VA DEQ, 2011). The bacteria loads from pet waste were computed by applying the percent of bacteria load contribution from pet waste from the TMDL reports (Table 2-19). To estimate the load reduction, a 25 percent bacteria removal efficiency was used, again based on VA DEQ (2011). The amount of load reduction was subtracted from the total load to get the adjusted load. The percent load reduction was then calculated as the difference between the total load and the adjusted load. This is summarized as follows:

1. $TMDL\ Total\ Load\ x\ \%\ Pet\ Sources\ from\ TMDL\ Bacteria\ Source\ Distribution\ x\ 25\%\ Removal\ Efficency = Amount\ of\ Load\ Reduction$
2. $TMDL\ Total\ Load - Amount\ of\ Load\ Reduction = Adjusted\ Load$
3. $\frac{(TMDL\ Total\ Load - Adjusted\ Load)}{TMDL\ Total\ Load}\ x\ 100 = \%\ Estimated\ Load\ Reduction$

Livestock Fencing (Two TMDL Watersheds Only)

This Tier B strategy proposes to install livestock fencing along streams in pasture areas to prevent grazing livestock from accessing the stream. A study by Zeckoski et al. (2012) in Virginia found that water quality improved once livestock fencing was installed, and the excluded livestock put on 5 to 10 percent additional weight over 9 to 10 months when provided with alternative water sources such as springs and wells. The study also states that livestock fencing may potentially reduce the risk of livestock disease associated with the livestock drinking from the same stream water that is contaminated with their waste.

There are various types of livestock fencing systems available. A simple solution is to provide a trough or alternative water source in the upland area away from the stream; this measure alone may reduce the amount of time the livestock spend in the stream by 80 to 99 percent because livestock prefer drinking from troughs (Zeckoski et al., 2012). More complex systems involve both streamside fencing and cross fencing, i.e., a hardened controlled access point where livestock may cross the stream to reach pasture on the other side without being able to drink from the stream.

The Tier B proposed strategy of livestock fencing is recommended in the Patuxent River Upper and West River mainstream watersheds because these are the only watersheds that have sufficient pastures to support livestock and have a relatively large contribution from livestock waste (see Table 2-19). Load reductions from implementing livestock fencing were estimated by reducing the existing loads from livestock waste by 50 percent.

Canada Goose Management (Site-Specific)

This Tier B strategy involves management of non-migratory Canada goose populations at sites that contain open water, such as ponds, parks, golf courses, campuses, and shorelines. There are many potential management techniques for Canada geese. These include lethal controls (euthanasia, egg addling/oiling, hunting), exclusion methods (fencing, vegetative barriers), habitat alteration (reducing mowing, planting less palatable grass species, steepening banks), public education (signs and handouts at public parks), bird dispersal methods (harassment with trained dogs), and molt capture programs where the captured geese can be processed for food through a program called Farmers and Hunters Feeding the Hungry**.** Multiple techniques are recommended, as geese readily adapt to any single technique. Over the long-term, the more effective methods will be those that reduce the population rather than those that simply disperse the geese to other areas. According to French and Parkhurst (2009), geese often return to the same nesting areas unless transported at least 200 miles away. The U.S. Department of Agriculture's Wildlife Services and Maryland DNR's Wildlife and Heritage Services are potential partners for the County to work with to develop goose management programs.

For the purposes of this TMDL Restoration Plan, the bacteria load reductions were estimated by assuming that 25 percent of existing Canada geese would be removed through various management techniques similar to those described above. The potential bacteria load reductions from this strategy were calculated as follows:

- $TMDL\ bacteria\ load\ from\ geese\ =$ $TMDL\ total\ load\ x\ \%\ wildlife\ x\ \%\ geese\ out\ of\ total\ wildlife$
- $Total\ bacteria\ load\ from\ geese\ x\ 25\%\ = Amount\ of\ load\ reduction$
- $TMDL\ total\ load - amount\ of\ load\ reduction\ = adjusted\ load$
- $\frac{(TMDL\ total\ load - adjusted\ load)}{TMDL\ total\ load}\ x\ 100\% = \%\ estimated\ load\ reduction$

4.2 IMPLEMENTATION COSTS OF PROPOSED RESTORATION STRATEGIES

The costs of the proposed Tier A and Tier B restoration strategies were estimated from local literature sources, the County's CIP annual budget reports, and in some cases best professional judgment based on a range of approximate costs from available literature. The costs of non-structural strategies such as pet waste education and goose management were generally more difficult to estimate due to the lack of available data. The available data unit costs were estimated as follows:

- **Dry pond retrofits**: $171,307 per pond, based on an average of past County expenditures for pond retrofits
- **SPSC retrofits**: $64,500 per impervious acre treated (King and Hagan, 2011)
- **Abatement of SSOs**: varies by SPS upgrade project. Average cost of 35 planned or active projects is $351,463, estimated from CIP wastewater budget reports
- **Retirement of County septic systems**: $51,000 per septic system, estimated from County Phase II WIP; this may be a higher estimate and would be revised in the annual progress report for this restoration plan based on actual implementation costs
- **Livestock fencing**: $12,400 per system, $4.00 per linear foot to install and maintain fencing (Zeckoski et al., 2012)
- **Elimination of household illicit connections**: $121,000 per year, estimated from County 2013 NPDES MS4 Annual Report (Anne Arundel County, 2014)

- **Expanded pet waste education program**: $150,000 per year (includes pet waste video for $27,000 and several television PSAs at $10,000 to $12,000 each)
- **Riparian buffer education program**: $60,000 per year, estimated from other types of education programs cited in the literature
- **Goose management program**: $25,000 to $300,000, depending on intensity of program

4.3 POLLUTANT LOAD REDUCTIONS

As mentioned previously, water quality models were developed using the Center for Watershed Protection's WTM to characterize and quantify the bacteria loads for existing conditions. The model was also used to estimate the pollutant load reductions from restoration measures as described in the following sections. Appendix A contains the WTM modeling approach and results.

4.3.1 Estimation of Load Reductions from Prior Management Measures

MDE (2014b) recommends estimating load reductions from prior management measures to account for progress toward TMDL goals made to date. In the case of the County's bacteria TMDLs, about 10 to 15 years have elapsed since the development of the TMDLs, during which time the County has implemented BMPs and retired septic systems, both of which provide credit for bacteria removal.

To estimate the credit for bacteria removal from the BMPs already implemented, a methodology was developed through correspondence with MDE staff. The methodology involved entering the original TMDL data from the MDE published TMDL reports from 2000 into the WTM and calibrating the WTM baseline loads to the MDE baseline loads. Then, the post-TMDL BMPs and the post-TMDL septic system retirements were entered in the model and the percent reduction relative to the MDE baseline was calculated. "Post-TMDL" refers to the period from 2000 to present. The year 2000 was used as the cut-off because that was the year of the land use data MDE used to develop the TMDLs.

The calculated bacteria load reductions from prior management measures are presented in Table 4-6 below for each of the TMDL watersheds. Some of the load reductions are under-estimated because drainage area data from some BMPs were unavailable, as the County is currently in the process of updating this information. Bacteria load reductions from septic system retirement were typically less than 1 percent (0.88 percent on average) because few have been retired since 2000. In many watersheds, no septic systems have been retired (Table 4-3).

The prior percent load reductions from post-TMDL BMPs and from post-TMDL septic system retirements were added together and subtracted from the overall TMDL-required percent load reduction. The resulting "adjusted" TMDL required percent reduction represents the remaining bacteria load reduction that is required to be achieved to meet the TMDL water quality goals (Table 4-6). On average, the adjusted TMDL reduction was 4.60 percent lower than the original TMDL reduction (Table 4-6).

Table 4-6: Estimates of Load Reductions from Prior Management Measures and Corresponding Adjustments to TMDL Required Percent Reductions

Bacteria TMDL Watershed	Prior Load Reductions Since 2000		TMDL Targets	
	Post-TMDL BMPs	Post-TMDL Septic System Retirement	TMDL Required % Reduction	Adjusted TMDL Required % Reduction
Magothy Mainstem	3.30%	0.61%	54.00%	50.09%
Magothy River/Forked Creek	4.91%	None	26.27%	21.36%
Magothy River/Tar Cove	2.44%	None	32.66%	30.22%
Patapsco River/Furnace Creek	4.47%	0.38%	77.79%	72.94%
Patapsco River LNB	3.70%	2.61%	56.1%	49.79%
Patapsco River/Marley Creek	5.41%	0.26%	75.70%	70.03%
Patuxent River Upper	8.36%	None	47.2%	38.84%
Rhode River/Bear Neck Creek	11.96%	None	43.32%	31.36%
Rhode River/Cadle Creek	3.43%	None	72.16%	68.73%
Severn River Mainstem	1.19%	0.35%	19.00%	17.46%
Severn River/Mill Creek	4.30%	None	86.00%	81.70%
Severn River/Whitehall and Meredith Creek	6.45%	0.43%	90.00%	83.12%
South River/Duvall Creek	3.77%	None	45.56%	41.79%
South River Mainstem	8.09%	0.06%	46.00%	37.85%
South River/Ramsey Lake	6.00%	None	59.30%	53.30%
South River/Selby Bay	1.20%	None	28.4%	27.20%
W. Chesapeake Bay/Tracy and Rockhold Creeks	0.35%	2.70%	82.00%	78.95%
West River Mainstem	0.27%	0.48%	35.41%	34.66%
West River/Parish Creek	None	None	53.04%	53.04%
Average:	4.38%	0.88%	Avg Adjustment = 4.60% lower	

4.3.2 Estimation of Load Reductions for Proposed Strategies

This section provides estimations of potential bacteria load reductions for the proposed Tier A and Tier B strategies described in Sections 4.1.1 and 4.1.2. The load reductions were estimated using modeling techniques, local literature sources, and County data.

The estimated bacteria load reductions are presented in Table 4-7A through Table 4-7I below for all of the TMDL watersheds. Each table includes the estimated load reductions associated with each strategy, the total estimated cost of the strategy, a cost-benefit ratio, and the Tiered Recommendation (either A or B). Also included are the total estimated load reductions for implementing all Tier A strategies, all Tier B strategies, all Tier A and Tier B strategies combined, and the adjusted TMDL required percent reduction, which reflects the remaining reductions needed to meet the TMDL after prior load reductions are accounted for (see Section 4.3.1). The Tier B strategy of livestock fencing is presented as a strategy for only two of the TMDL watersheds (the Patuxent River Upper and the West River Mainstem) since these are the only two where sufficient pasture exists to support livestock.

The load estimation tables show that the greatest bacteria reductions were attributed to the Tier B strategy of pet waste education in seven of the 19 TMDL watersheds (Magothy Mainstem, Forked Creek, Bear Neck Creek, Cadle Creek, Duvall Creek, Ramsey Lake, and Selby Bay), and pet waste education was also one of the most cost-effective strategies. In other watersheds, the highest load reductions were correlated with various Tier A (human sources) and Tier B (non-human sources) strategies, as follows:

- Septic system retirement resulted in the greatest load reductions in Tar Cove, Mill Creek, Whitehall-Meredith Creeks, and South River Mainstem watersheds
- Removal of household illicit connections resulted in the greatest load reductions in the Patapsco River LNB, Marley Creek, and Severn River Mainstem watersheds
- Restoration of 20 percent impervious cover with high pollutant removal efficiency practices such as SPSCs resulted in the greatest load reductions in the Furnace Creek watershed
- Riparian buffer education resulted in the greatest load reductions in the Patuxent River Upper watershed
- SSO abatement resulted in the greatest load reductions in the Parish Creek watershed
- Livestock fencing resulted in the greatest load reductions in the West River Mainstem watershed (of the two pasture watersheds where this strategy was applicable)
- Goose management resulted in the greatest load reductions in the Tracy and Rockhold Creeks watershed

Non-structural Tier B strategies such as pet waste education, riparian buffer education, and goose management were relatively cost-effective compared to structural Tier A strategies such as SPS upgrades and septic system retirement. Livestock fencing was also highly cost-effective in the two pasture watersheds where it was proposed as a strategy (Patuxent River Upper and West River mainstem). Urban stormwater management, including retrofitting pre-2002 dry ponds and restoring of 20 percent of unmanaged impervious cover with SPSCs, was less cost-effective due to the high unit cost assumptions (see Section 4.2) of implementing these types of stormwater projects. Eliminating household illicit connections was also less cost-effective than the other strategies due to the low rate (2 percent, see Section 4.1.1) of detecting and eliminating bacteria sources from household illicit connections.

The magnitude of the load reduction requirements indicates that multiple strategies will need to be implemented in combination in each TMDL watershed to achieve the required TMDL percent reductions. In most of the watersheds, implementing all Tier A and all Tier B strategies is sufficient to meet, or come close to meeting, the TMDL goals. However, this is not the case in seven of the watersheds, where even implementing all the Tier A and Tier B strategies is still not enough to meet the TMDL required reductions. These watersheds include: Furnace Creek (Table 4-7C), Marley Creek (Table 4-7C), Cadle Creek (Table 4-7E), Mill Creek (Table 4-7F), Tracy-Rockhold Creek (Table 4-7H), Whitehall-Meredith Creek (Table 4-7F), and Ramsey Lake (Table 4-7G). In the first five of these watersheds, it is recommended to prioritize pet waste education in high-density residential areas. In the last two watersheds (Whitehall-Meredith Creek and Ramsey Lake), load reductions are limited by other factors, primarily the lack of pond retrofit, SPS upgrade, and septic system retirement opportunities in these watersheds. For example, in the Ramsey Lake watershed, there are no existing dry ponds and no planned SPS upgrade projects. To achieve the TMDL goals in these watersheds, additional restoration opportunities with bacteria removal benefits will need to be identified, and multiple non-structural strategies such as pet waste education and possibly goose management will need to be implemented on a large scale to restore the water quality standards of the impaired waterways.

Table 4-7A: Estimated Load Reductions for Proposed Strategies in the Magothy Mainstem, Forked Creek, and Tar Cove Watersheds

TMDL Watershed: Magothy Mainstem				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	4.27%	$1.37	32.1	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	4.48%	$22.68	506.2	B
Eliminate Household Illicit Connections	8.74%	$0.61	6.9	A
Abatement of SSOs	1.12%	$1.71	152.8	A
Septic Retirement/Connection	13.55%	$245.51	1811.9	A
Riparian Buffer Education	0.91%	$0.06	6.2	B
Expanded Pet Waste Education	16.30%	$0.15	0.9	B
Expanded Goose Management Program	2.88%	$0.03	1.0	B
All Tier A Strategies:	**23.41%**			
All Tier B Strategies:	**28.84%**			
All Strategies:	**52.25%**			
Adjusted TMDL Required % Reduction:	**50.09%**			
TMDL Watershed: Magothy River/Forked Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	7.02%	$1.64	23.4	B
Eliminate Household Illicit Connections	1.13%	$0.61	53.5	A
Abatement of SSOs	12.40%	$0.26	2.1	A
Septic Retirement/Connection	6.14%	$5.76	93.9	A
Riparian Buffer Education	1.93%	$0.06	2.9	B
Expanded Pet Waste Education	21.45%	$0.15	0.7	B
Expanded Goose Management Program	1.73%	$0.03	1.7	B
All Tier A Strategies:	**19.67%**			
All Tier B Strategies:	**32.13%**			
All Strategies:	**51.80%**			
Adjusted TMDL Required % Reduction:	**21.36%**			

Table 4-7A Continued: Estimated Load Reductions for Proposed Strategies in the Magothy Mainstem, Forked Creek, and Tar Cove Watersheds

TMDL Watershed: Magothy River/Tar Cove				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	3.76%	$3.32	88.3	B
Eliminate Household Illicit Connections	0.67%	$0.61	90.3	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	25.25%	$87.11	345.0	A
Riparian Buffer Education	1.02%	$0.06	5.9	B
Expanded Pet Waste Education	13.60%	$0.15	1.1	B
Expanded Goose Management Program	4.27%	$0.03	0.6	B
All Tier A Strategies:	**25.92%**			
All Tier B Strategies:	**22.65%**			
All Strategies:	**48.57%**			
Adjusted TMDL Required % Reduction:	**30.22%**			

Table 4-7B: Estimated Load Reductions for Proposed Strategies in the Patapsco River Lower North Branch Watershed

TMDL Watershed: Patapsco River Lower North Branch				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	1.26%	$0.86	68.0	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	6.59%	$31.70	481.1	B
Eliminate Household Illicit Connections	11.60%	$0.61	5.2	A
Abatement of SSOs	4.90%	$0.92	18.8	A
Septic Retirement/Connection	5.60%	$8.87	158.5	A
Riparian Buffer Education	2.99%	$0.06	2.0	B
Expanded Pet Waste Education	6.50%	$0.15	2.3	B
Expanded Goose Management Program	0.79%	$0.03	3.2	B
All Tier A Strategies:	**22.10%**			
All Tier B Strategies:	**18.13%**			
All Strategies:	**40.23%**			
Adjusted TMDL Required % Reduction:	**49.79%**			

Table 4-7C: Estimated Load Reductions for Proposed Strategies in the Furnace Creek and Marley Creek Watersheds

Proposed Strategy	Expected % Load Reduction	Total Estimated Cost in Millions	Cost-Benefit Ratio	Tiered Recommendation
TMDL Watershed: Patapsco River/Furnace Creek				
Pre-2002 Pond Retrofits	8.16%	$1.37	16.8	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	9.00%	$27.55	306.1	B
Eliminate Household Illicit Connections	7.72%	$0.61	7.8	A
Abatement of SSOs	3.50%	$2.19	62.5	A
Septic Retirement/Connection	3.38%	$12.85	380.2	A
Riparian Buffer Education	1.47%	$0.06	4.1	B
Expanded Pet Waste Education	7.35%	$0.15	2.0	B
Expanded Goose Management Program	4.98%	$0.03	0.5	B
All Tier A Strategies:	**14.60%**			
All Tier B Strategies:	**30.96%**			
All Strategies:	**45.56%**			
Adjusted TMDL Required % Reduction:	**72.94%**			
TMDL Watershed: Patapsco River/Marley Creek				
Pre-2002 Pond Retrofits	4.47%	$1.88	42.2	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	8.42%	$23.77	282.3	B
Eliminate Household Illicit Connections	10.82%	$0.61	5.6	A
Abatement of SSOs	2.04%	$1.56	76.4	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	1.63%	$0.06	3.7	B
Expanded Pet Waste Education	8.65%	$0.15	1.7	B
Expanded Goose Management Program	4.08%	$0.03	0.6	B
All Tier A Strategies:	**12.86%**			
All Tier B Strategies:	**27.25%**			
All Strategies:	**40.11%**			
Adjusted TMDL Required % Reduction:	**70.03%**			

Table 4-7D: Estimated Load Reductions for Proposed Strategies in the Patuxent River Upper Watershed. Note that a Livestock Fencing Strategy is included since this Watershed Contains Some Agricultural Land.

Proposed Strategy	Expected % Load Reduction	Total Estimated Cost in Millions	Cost-Benefit Ratio	Tiered Recommendation
TMDL Watershed: Patuxent River Upper				
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	5.42%	$4.97	91.6	B
Eliminate Household Illicit Connections	0.85%	$0.61	71.2	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	16.45%	$14.74	89.6	A
Riparian Buffer Education	17.20%	$0.06	0.3	B
Expanded Pet Waste Education	4.50%	$0.15	3.3	B
Expanded Goose Management Program	4.58%	$0.03	0.5	B
Livestock Fencing	14.00%	$0.13	0.9	B
All Tier A Strategies:	**17.30%**			
All Tier B Strategies:	**45.70%**			
All Strategies:	**63.00%**			
Adjusted TMDL Required % Reduction:	**38.84%**			

Table 4-7E: Estimated Load Reductions for Proposed Strategies in the Bear Neck and Cadle Creek Watersheds

TMDL Watershed: Rhode River/Bear Neck Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	6.82%	$1.27	18.6	B
Eliminate Household Illicit Connections	0.50%	$0.61	121.0	A
Abatement of SSOs	2.50%	$0.40	15.9	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.11%	$0.06	54.5	B
Expanded Pet Waste Education	8.48%	$0.15	1.8	B
Expanded Goose Management Program	2.58%	$0.03	1.0	B
All Tier A Strategies:	**3.00%**			
All Tier B Strategies:	**17.98%**			
All Strategies:	**20.98%**			
Adjusted TMDL Required % Reduction:	**32.12%**			
TMDL Watershed: Rhode River/Cadle Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	9.40%	$0.75	8.0	B
Eliminate Household Illicit Connections	0.30%	$0.61	201.7	A
Abatement of SSOs	8.40%	$0.50	6.0	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.80%	$0.06	7.5	B
Expanded Pet Waste Education	20.05%	$0.15	0.7	B
Expanded Goose Management Program	2.55%	$0.03	1.0	B
All Tier A Strategies:	**8.70%**			
All Tier B Strategies:	**32.80%**			
All Strategies:	**41.50%**			
Adjusted TMDL Required % Reduction:	**68.73%**			

Table 4-7F: Estimated Load Reductions for Proposed Strategies in the Severn River Mainstem, Mill Creek, and Whitehall-Meredith Creek Watersheds

TMDL Watershed: Severn River Mainstem				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	3.10%	$2.23	71.8	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	3.90%	$56.59	1451.1	B
Eliminate Household Illicit Connections	19.02%	$0.61	3.2	A
Abatement of SSOs	0.36%	$2.39	655.9	A
Septic Retirement/Connection	10.56%	$279.23	2644.2	A
Riparian Buffer Education	1.56%	$0.06	3.8	B
Expanded Pet Waste Education	17.20%	$0.15	0.9	B
Expanded Goose Management Program	3.78%	$0.03	0.7	B
All Tier A Strategies:	**29.94%**			
All Tier B Strategies:	**29.54%**			
All Strategies:	**59.49%**			
Adjusted TMDL Required % Reduction:	**17.46%**			
TMDL Watershed: Severn River/Mill Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	4.34%	$0.51	11.8	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	4.20%	$2.78	66.2	B
Eliminate Household Illicit Connections	1.54%	$0.61	39.3	A
Abatement of SSOs	0.20%	$0.26	130.3	A
Septic Retirement/Connection	34.70%	$59.57	171.7	A
Riparian Buffer Education	2.80%	$0.06	2.1	B
Expanded Pet Waste Education	9.50%	$0.15	1.6	B
Expanded Goose Management Program	7.72%	$0.03	0.3	B
All Tier A Strategies:	**36.44%**			
All Tier B Strategies:	**28.56%**			
All Strategies:	**65.00%**			
Adjusted TMDL Required % Reduction:	**81.70%**			

Table 4-7F Continued: Estimated Load Reductions for Proposed Strategies in the Severn River Mainstem, Mill Creek Southern, and Whitehall-Meredith Creek Watersheds

TMDL Watershed: Severn River/Whitehall and Meredith Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	4.20%	$2.88	68.5	B
Eliminate Household Illicit Connections	0.90%	$0.61	67.2	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	21.10%	$16.32	77.3	A
Riparian Buffer Education	2.24%	$0.06	2.7	B
Expanded Pet Waste Education	6.50%	$0.15	2.3	B
Expanded Goose Management Program	9.29%	$0.03	0.3	B
All Tier A Strategies:	**22.00%**			
All Tier B Strategies:	**22.23%**			
All Strategies:	**44.23%**			
Adjusted TMDL Required % Reduction:	**83.12%**			

Table 4-7G: Estimated Load Reductions for Proposed Strategies in the South River Mainstem, Duvall Creek, Ramsey Lake, and Selby Bay Watersheds

TMDL Watershed: South River Mainstem				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	3.73%	$2.40	64.3	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	3.60%	$22.52	625.5	B
Eliminate Household Illicit Connections	11.30%	$0.61	5.4	A
Abatement of SSOs	0.30%	$1.55	516.6	A
Septic Retirement/Connection	15.60%	$86.39	553.8	A
Riparian Buffer Education	8.00%	$0.06	0.8	B
Expanded Pet Waste Education	10.83%	$0.15	1.4	B
Expanded Goose Management Program	4.44%	$0.03	0.6	B
All Tier A Strategies:	**27.20%**			
All Tier B Strategies:	**30.59%**			
All Strategies:	**57.79%**			
Adjusted TMDL Required % Reduction:	**37.85%**			
TMDL Watershed: South River/Duvall Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	9.13%	$1.63	17.8	B
Eliminate Household Illicit Connections	0.65%	$0.61	93.1	A
Abatement of SSOs	6.40%	$0.26	4.1	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	N/A	N/A	N/A	B
Expanded Pet Waste Education	17.00%	$0.15	0.9	B
Expanded Goose Management Program	2.16%	$0.03	1.2	B
All Tier A Strategies:	**7.05%**			
All Tier B Strategies:	**28.29%**			
All Strategies:	**35.34%**			
Adjusted TMDL Required % Reduction:	**41.79%**			

Table 4-7G Continued: Estimated Load Reductions for Proposed Strategies in the South River Mainstem, Duvall Creek, Ramsey Lake, and Selby Bay Watersheds

TMDL Watershed: South River/Ramsey Lake				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	2.90%	$0.88	30.2	B
Eliminate Household Illicit Connections	0.11%	$0.61	550.0	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.14%	$0.06	42.9	B
Expanded Pet Waste Education	15.73%	$0.15	1.0	B
Expanded Goose Management Program	4.81%	$0.03	0.5	B
All Tier A Strategies:	**0.11%**			
All Tier B Strategies:	**23.58%**			
All Strategies:	**23.69%**			
Adjusted TMDL Required % Reduction:	**53.30%**			

TMDL Watershed: South River/Selby Bay				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	3.20%	$0.85	26.6	B
Eliminate Household Illicit Connections	0.16%	$0.61	378.1	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.06%	$0.06	100.0	B
Expanded Pet Waste Education	15.68%	$0.15	1.0	B
Expanded Goose Management Program	4.58%	$0.03	0.5	B
All Tier A Strategies:	**0.16%**			
All Tier B Strategies:	**23.51%**			
All Strategies:	**23.67%**			
Adjusted TMDL Required % Reduction:	**27.20%**			

Table 4-7H: Estimated Load Reductions for Proposed Strategies in the Tracy and Rockhold Creek Watershed

TMDL Watershed: W. Chesapeake Bay/Tracy and Rockhold Creeks				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with High Pollutant Removal Efficiency BMPs such as SPSC	2.60%	$4.79	184.1	B
Eliminate Household Illicit Connections	0.23%	$0.61	263.0	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	8.20%	$0.06	0.7	B
Expanded Pet Waste Education	5.20%	$0.15	2.9	B
Expanded Goose Management Program	9.38%	$0.03	0.3	B
All Tier A Strategies:	**0.23%**			
All Tier B Strategies:	**25.38%**			
All Strategies:	**25.61%**			
Adjusted TMDL Required % Reduction:	**78.95%**			

Table 4-7I: Estimated Load Reductions for Proposed Strategies in the West River Mainstem and Parish Creek Watersheds. Note that a Livestock Fencing Strategy is included in the West River Mainstem Watershed since this Watershed Contains Some Agricultural Land.

TMDL Watershed: West River Mainstem				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with SPSC	8.30%	$4.72	56.9	B
Eliminate Household Illicit Connections	1.21%	$0.61	50.0	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	11.54%	$0.06	0.5	B
Expanded Pet Waste Education	3.93%	$0.15	3.8	B
Expanded Goose Management Program	3.51%	$0.03	0.7	B
Livestock Fencing	28.55%	$0.13	0.5	B
All Tier A Strategies:	**1.21%**			
All Tier B Strategies:	**55.82%**			
All Strategies:	**57.03%**			
Adjusted TMDL Required % Reduction:	**34.66%**			
TMDL Watershed: West River/Parish Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Pre-2002 Pond Retrofits	N/A	N/A	N/A	B
Restore 20% Impervious Area with SPSC	10.50%	$0.72	6.9	B
Eliminate Household Illicit Connections	0.19%	$0.61	318.4	A
Abatement of SSOs	12.90%	$0.40	3.1	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.46%	$0.06	13.0	B
Expanded Pet Waste Education	10.05%	$0.15	1.5	B
Expanded Goose Management Program	7.72%	$0.03	0.3	B
All Tier A Strategies:	**13.09%**			
All Tier B Strategies:	**28.73%**			
All Strategies:	**41.82%**			
Adjusted TMDL Required % Reduction:	**53.04%**			

4.4 PROPOSED STRATEGIES WITH LARGEST IMPACT AND RECOMMENDED PRIORITIZATION OF STRATEGIES

The proposed Tier A strategies with the largest impacts are reducing the number of SSOs, retiring County septic systems, and eliminating household illicit connections to reduce human bacteria sources. The proposed Tier B strategies with the largest impacts are a pet waste education program and riparian buffer education program to reduce non-human bacteria sources.

In the 12 TMDL watersheds where SSO abatement is proposed, the bacteria load reductions ranged from 0.36 to 12.40 percent. In the 10 TMDL watersheds where County septic systems were identified for retirement based on County data, the bacteria load reductions ranged from 3.38 to 34.70 percent. Implementing a riparian buffer education program resulted in an estimated load reduction of 0.06 to 17.20 percent among 18 of the 19 TMDL watersheds where buffers occur.

Load reductions from implementing an expanded pet waste education program ranged from 4.50 to 21.45 percent in all 19 TMDL watersheds and were highest in the smaller watersheds with a large proportion of residential urban land, e.g., Forked Creek, Cadle Creek, and Duvall Creek, which have dense shoreline communities that could provide excellent case studies for implementing the pet waste education strategy. In addition, removal of pet waste from along or near the shoreline in these watersheds is likely to have an immediate impact on the water quality of the local impaired waterway due to the proximity of the bacteria sources to the receiving water body.

Prioritization of the proposed strategies considers that some are already part of existing County programs, such as eliminating illicit connections, urban stormwater management, and SPS upgrades, and retiring septic systems. The purpose of including these as strategies in this Bacteria TMDL Restoration Plan is to take advantage of the bacteria load reductions being achieved from the County's existing programs and operations, as well as future load reductions that will be achieved by these programs.

The magnitude of the TMDL required load reductions is such that many strategies will need to be implemented to restore TMDL water quality standards in the impaired waterways. In particular, implementation of a multi-media pet waste education program is strongly recommended due to the large bacteria load reductions that are likely to be achieved with this strategy. In addition, riparian buffer education is also recommended because it is also relatively cost-effective and has wide applicability.

Goose management and livestock fencing are generally cost-effective as well, but are not considered a priority since they have limited applicability, i.e., goose management is only relevant in small localized areas where geese are a nuisance and impact water quality, and livestock fencing is only applicable to the two TMDL watersheds where livestock occur (Patuxent River Upper and West River Mainstem).

The proposed strategies are prioritized as listed in Table 4-8 below. The priorities are based on whether the program is in place or not, the estimated magnitude of bacteria load reductions, the relative cost-effectiveness of the strategy, and the applicability of the strategy among the 19 TMDL watersheds.

Table 4-8: Priority of Proposed Strategies

Proposed Strategy	Tier (A or B)	Priority For Implementation	Relative Cost-Effectiveness	Current Status	Recommendation
Expanded Pet Waste Education Program	B - reduces non-human sources	1	High	Limited Implementation	Implement in all TMDL Watersheds
Riparian Buffer Education	B - reduces non-human sources	2	High	Limited Implementation	Implement in all TMDL Watersheds
Goose Management Program	B - reduces non-human sources	3	High	Limited Implementation	Implemented in Site-Specific Areas Only
Livestock Fencing	B - reduces non-human sources	4	High	Limited Implementation	Implemented in Two Pasture Watersheds Only[1]
Abatement of SSOs	A - reduces human bacteria sources	1 - already in place	Low	Being Implemented	Begin Accounting for Bacteria Load Reductions
Retirement of County Septic Systems	A - reduces human bacteria sources	1 - already in place	Low	Being Implemented	Begin Accounting for Bacteria Load Reductions
Eliminate Household Illicit Connections	A - reduces human bacteria sources	1 - already in place	Moderate	Being Implemented	Begin Accounting for Bacteria Load Reductions
Pre-2002 Pond Retrofits	B - reduces non-human sources	1 - already in place	Moderate	Being Implemented	Begin Accounting for Bacteria Load Reductions
Restore 20% Impervious Cover with SPSC	B - reduces non-human sources	1 - already in place	Moderate	Being Implemented	Begin Accounting for Bacteria Load Reductions

1-Patuxent River Upper and West River Mainstem

SECTION FIVE: PUBLIC AND STAKEHOLDER PARTICIPATION

Public participation and stakeholder engagement play an important role in the successful implementation of a TMDL restoration plan. As part of its NPDES MS4 permit, the County is required to engage the public in the TMDL restoration plan development, solicit their input, and incorporate any relevant ideas and program improvements that help achieve the TMDL goals (Part IV.E.3). According to the County's Phase II Watershed Implementation Plan (WIP; Anne Arundel County, 2012), approximately 64 percent of the land in the County is privately owned; therefore, increasing public awareness of TMDL impairment may result in fostering partnerships with private owners which would lead to greater pollutant load reductions. In addition, the participating public can offer useful on-the-ground information, such as confirmation of livestock and wildlife numbers (and locations where they occur), general knowledge of the local community (e.g., landowners' willingness to implement restoration projects), and information about the local impaired waterway (VA DEQ, 2011; EPA, 2013a).

According to the County, one of the major challenges to engaging the public is that "most citizens do not understand the degree that their individual actions affect waterway health and do not understand how they can be part of the solution" (Anne Arundel County, 2012). Specifically, many people are not aware that nonpoint source pollution can contribute to bacteria loads (WGCAC, 2011). Therefore, it is important to inform the public of the impacts of nonpoint source pollution, and to convey a sense of ownership so that individuals can be better stewards of the environment.

5.1 CURRENT OUTREACH PROGRAMS

The County currently directs several outreach programs led by various departments, including the Department of Public Works. These outreach programs are aimed at increasing public awareness on issues related to water quality and include activities such as conducting workshops and providing information through brochures, fliers, volunteer programs etc. The County is also promoting public awareness using social media such as Facebook. A list of current outreach programs is provided in the County's NPDES MS4 Annual Report (Anne Arundel County, 2014). Table 5-1 lists some of the County's current outreach programs that help increase public awareness related to bacteria impairment.

Table 5-1: Available County Outreach Programs/Materials that Promote Awareness Related to Bacteria Impairments

Department	Outreach Program/Outreach Materials	Media Type
Department of Public Works	• Rehabilitation and Maintenance of County Sewer Infrastructure • Information on Recent Wastewater Spills • Preventing Sewer Backups • Homeowner's Guide to Septic Tanks • Homeowner's Guide to Grinder Pumps • Recycling Programs/Waste Management • Watershed Stewards Academy • Stream Cleanups	Brochures, Fliers, Information Sessions, Presentation, Facebook, Workshops, Volunteer Programs
Department of Health	• Water Quality and Swimming or Fishing in Anne Arundel County Rivers and Creeks • On-Site Sewage Disposal Systems and Private Water Wells • Bay Restoration Fund (BRF) Program, for Nitrogen-Reducing Pretreatment Units for Septic Systems to Be Installed within the Chesapeake Bay Critical Area • Collapsed Septic Tanks, Overflowing Septic Systems and Failing Septic Systems Interim Health and Safety Requirements • Application Procedures for Property Improvements Where Well or On-Site Septic Systems are Utilized • Maryland Healthy Beaches Campaign	Factsheets, Brochures, Campaigns

5.2 POTENTIAL CHALLENGES AND SOLUTIONS TO IMPROVE THE COUNTY'S CURRENT OUTREACH PROGRAMS

Several agencies and jurisdictions have published cost-effective methods to engage the public and stakeholders in watershed restoration. Locally, the Watershed Steward Academy has been successful in training watershed stewards and implementing micro-scale stormwater practices, such as rain barrels, rain gardens, plantings, and forested buffers, and promoting pet waste management. However, they have had difficulty reaching the public on bacteria issues such as pet waste (Capital Gazette, 2014). Table 5-2 summarizes some of the challenges faced by the County's outreach programs and potential solutions for overcoming impediments to cooperative watershed restoration. This information was developed based on publications related to outreach from other jurisdictions and agencies. The proposed solutions apply to most types of watershed outreach and are recommended for this bacteria TMDL restoration plan.

Table 5-2: Challenges and Solutions to Public and Stakeholder Participation in the Watershed Restoration Process

Challenge	Solution
Loss of momentum	Setting small, achievable goals throughout the implementation process to show success and keep the project energized; keeping the public and stakeholders actively engaged by periodically checking in with them during slow times (EPA, 2010).
Poor coordination and planning	Conducting organizational planning activities prior to beginning implementation process. Clearly communicating goals and load reduction strategies to achieve those goals. Making sure that the public and stakeholders all agree on the Restoration Plan. Defining roles and responsibilities (EPA, 2010). Identifying the target audience and all stakeholders, and deciding what messages are to be conveyed and the appropriate conveyance method (i.e., type of media). Determining how success will be measured (e.g., website hits, surveys, water quality monitoring).
Lack of communication or infrequent communication	Keeping the public and stakeholders informed at all times. For example the public and stakeholders should be informed if any issues arise during the implementation process, if there are any changes to the original load reduction strategies, and if any lessons were learned along the way. Keeping the public and stakeholders informed of achievements, however small (e.g., website received 500 hits this week) (EPA, 2010). Making sure new information (e.g., technical reports) is conveyed to the technical team, County, public participation team, and stakeholders. When information becomes available, disseminating it quickly to keep participants informed and engaged (EPA, 2013a).
Political controversy	Avoiding heated political debate on controversial implementation projects. Working quietly with individual stakeholder groups to settle disagreements in a satisfactory manner (EPA, 2010).
Fear of the unknown	Accepting that there may be less data available than optimally preferred. Pursuing objectives aggressively despite lack of sufficient information and data (EPA, 2010).
Letting money drive the implementation process	Identifying types of restoration strategies first, and then pursuing funding to support the strategies. Avoiding pursuing funding opportunities for low-priority activities that may distract from the overall goals of the Restoration Plan (EPA, 2010).
Letting the implementation process bog you down	Keeping meetings short such that stakeholders who are usually volunteers can provide complete attention (EPA, 2013a). Avoiding situations where participants are spending more time on meetings than on actual watershed restoration work (EPA, 2010).
Not seeing any results/evaluation of effectiveness not showing anything	Considering different methods of communication. The County of Los Angeles (2002) recommends the following for effective communication: • Give specific, action-oriented messages (e.g., "do's and don'ts"). • Emphasize personal responsibility and empowerment. Inspire and motivate people and convey that individuals can make a difference. • Emphasize aesthetic and health benefits of improving water quality (e.g., in the case of bacteria, removal of pet waste and other bacteria sources leads to cleaner neighborhoods and reduces health risk to children, swimmers, boaters). • Make information easily accessible on the Web so the public can follow up on initial interest. Alternatively, Bruce and Tiger (2009) suggest that the effectiveness of public outreach efforts may not be apparent immediately afterwards if the evaluation

Challenge	Solution
	method does not capture the full long-term effects. In general, outreach campaigns may result in only small, incremental behavior changes that are difficult to measure. Outreach programs should focus on changing behaviors rather than just raising awareness. Better knowledge about water quality issues is not well-correlated with better behavior (CWEP, 2009).

5.3 POTENTIAL NEW OUTREACH PROGRAMS

As described above, the County currently conducts numerous outreach/education programs. Additional outreach programs that can be considered to reduce bacteria loads include boater education with respect to marina pump out stations and reducing waste due to homelessness, via reduction in homeless populations or in providing routine cleanup of encampment areas. Estimating the bacteria load reductions due to these two programs is not possible at this time due to the limited amount of quantitative information available. However, based on other education and outreach programs, in general, these programs are likely to be relatively cost effective in terms of reducing bacteria loads.

A potential outreach program is education of boat owners to raise awareness about the importance of always using pump-out stations at marinas for proper sewage disposal. This would help reduce the amount of human bacteria discharged directly into waterways. In general, boat waste discharges can have a significant impact upon the aquatic environment, especially in small, poorly flushed waterways where pollutant concentrations may reach unusually high levels (Klein, 2007). It is estimated that a single weekend boater flushing untreated sewage into waterways produces the same amount of bacterial pollution as 10,000 people whose sewage passes through a treatment plant (CA DBW, 2014). Based on a survey of 227 Maryland boaters, Strand and Gibson (1990) determined that only 24.8% of boaters at marinas with pump-out facilities actually used the facility.

One of the best methods for conveying information about proper use of pump-out stations is posting signs, which are considered a more effective method of conveying information than distributing literature or conducting boater education workshops (EPA, 2014). Signs would be most beneficial at highly visible locations in marinas such as boat ramps, anchorages/moorings, fuel docks, and liveaboard docks. The cost of posting a sign is estimated to be $105 (RI Sea Grant, 1992). MD DNR currently conducts workshops and outreach for marina operators as a part of "Clean Marina Program" to promote environmentally friendly boating practices such as use of pump-outs for waste disposal, proper disposal of trash etc. County agencies can partner with MDDNR to promote environmentally friendly boating activities in watersheds with large number of community marinas such as Severn and South River watersheds. Additional boater outreach may also be conducted through the County's social media and the County website. In addition to signage, installing additional pump-out facilities at marinas would help to reduce human bacteria discharges from vessels. Strand and Gibson (1990) found that the availability of a pump-out facility at a marina increased the likelihood of pumping by twofold.

Another potential outreach program is related to homeless populations in the County. Reducing homelessness helps to reduce human bacteria in runoff from homeless encampments. Based on a 2012 assessment of the County's homeless population, it was determined that 1,300 homeless individuals utilized existing emergency shelters, transitional housing, and permanent supportive housing during the 2012 Federal Fiscal Year (Anne Arundel County, 2012d). The MDE states that addressing homeless populations can take the form of surveys of other units of local government including social services, police, schools, the health department, and nongovernmental organizations, which also serve the purpose of educational outreach on the health concerns of bacteria (MDE, 2014b).

In other jurisdictions with similar bacteria TMDLs, homeless encampments are addressed by frequent river and green area clean-ups, enforcement by police and park rangers, and annual funding of social service programs that directly serve the local homeless population (CA Central Coast Regional Board, 2011). One local organization involved in ensuring the needs of persons who are homeless is the "Anne Arundel and Annapolis Coalition to End Homelessness," a community based planning and advocacy organization.

SECTION SIX: FUNDING SOURCES AND TECHNICAL ASSISTANCE

6.1 FUNDING SOURCES

Achieving proposed improvements to meet bacteria TMDLs requires adequate funding to cover the cost of project implementation, operating expenditures, administrative costs, and other programmatic costs. This section presents potential federal, state, and non-profit grants and loans that may be suitable for use for proposed restoration strategies. Many of the grant programs focus on reducing nonpoint source nutrients and sediment to improve general water quality, and a few of the programs include specific provisions for practices that address bacteria pollution. For example, the Maryland Department of Natural Resources has a grant program to fund installation of sewage pumpout stations at marinas, which reduce bacteria discharges from boats. Table 6-1 provides an overview of potential funding sources.

Table 6-1: Potential Funding Sources for Bacteria TMDL Implementation

Funding Type	Funding Agency	Restoration Activity	Purpose of Program	Available Funding
State	State Water Quality Revolving Loan Fund	Varies; implementation of NPS projects requiring capital investment, or replacement of failing septic tanks	To provide low interest loans to projects that improve water quality and public health	State allotments vary; in 2011, Maryland received $35.7 M
State	The Maryland Stormwater Pollution Control Cost-Share Program	Implementation of any urban stormwater BMPs	To fund the implementation of stormwater management retrofit projects to control pollutants from older developed areas	$20,000 - $500,000
Non-profit	Chesapeake Bay Trust	Varies: must contribute to the restoration of the Chesapeake Bay	To promote public awareness and participation in restoration and protection of the Chesapeake Bay	$2,000 - $50,000
State	Bay Restoration Fund - OSDS Grant Program	Sewer upgrades and connection of septic systems to public sewer	To upgrade septic systems with Nitrogen Reducing Units. Program has expanded to include connection of septic tanks to sewer system. Funding priority is given to Chesapeake Bay Critical Areas.	$5,000 - $15,000
Federal	EPA 319 Funds	Implementation of agricultural and residential BMPs	To restore impaired waters by implementing watershed-based plans	Varies
Federal	EPA Urban Waters Small Grants	Implementation of pet waste public education program	To help restore urban water quality and revitalize neighborhoods by engaging communities in activities that increase their connection to,	$40,000 - $60,000

Funding Type	Funding Agency	Restoration Activity	Purpose of Program	Available Funding
			understanding of, and stewardship of local urban waterways	
State	MACS Program	Installation of stream protection systems to limit livestock access to streams	To help farmers protect natural resources on their farms, maintain farm productivity, and comply with state and federal regulations	Provides farmers with grants to cover up to 87.5% of the cost to install conservation BMPs on their farms. More than 30 BMPs are currently eligible for MACS grants, including livestock exclusion fencing.
Federal	USDA EQIP (Cost-Share)	Installation of stream protection systems to limit livestock access to streams and reduce sediment into streams	To implement conservation BMPs on land used for livestock and crop production	Total payments not to exceed $10,000/year or $50,000 for length of contract; average payment is $15,000
Private Funds	National Fish and Wildlife Foundation/Wells Fargo Environmental Solutions for Communities	Implementation of local water quality improvement projects that encourage broad-based citizen participation in project implementation	To support projects linking economic development and community well-being to the stewardship and health of the environment	$25,000 - $100,000 (median: $40,000)
State	The Supplemental Assistance Program	OSDS upgrades, including connection of older OSDS to public sewers, correction of system deficiencies such as SSOs, excessive inflow and infiltration, or outdated pump stations	To fund local governments for planning, design, and construction of wastewater projects needed to address public health or water quality issues considered to be high priority to MDE	Varies
State	Linked Deposit Loan Program	OSDS upgrades or other NPS capital improvements on private lands	To provide a source of low-interest financing to encourage private landowners and water system owners to implement capital improvements that will reduce the delivery of nutrients to the Chesapeake Bay and its tributaries	Varies
State	Maryland DNR Boating Services Unit	Installation of marina pumpout stations	To reduce bacteria loads from marinas by providing boaters with a proper method of disposing of their sewage and thus prevent it from entering local waters	Up to $15,000

Funding Type	Funding Agency	Restoration Activity	Purpose of Program	Available Funding
State	Chesapeake and Coastal Bays 2010 Trust Fund Grants	Various restoration projects	To accelerate Chesapeake Bay restoration via innovative new technologies, by engaging the community, and accountability	$5,001 - $70,000 for Watershed Assistance Program grants; minimum $500,000 for Cost-Effective Non-Point Source Pollution Reduction grants (no maximum); up to $75,000 annually for *CoastSmart* Communities grants

BMP = Best management practice
CIP = Capital Improvement Program
DNR= Department of Natural Resources
EQIP = Environmental Quality Incentives Program
MACS = Maryland Agricultural Water Quality Cost-Share
MDE = Maryland Department of the Environment
NPS = Nonpoint source
OSDS = Onsite sewage disposal system (septic system)

Relatively recent changes to the legislative requirements for the Bay Restoration Fund allow the collected monies to be used to connect septic systems to public sewers. However, it is expected that use of this funding source will be limited because it is likely to cover only a portion of the cost (Anne Arundel County Phase II WIP, 2012). Therefore, additional funding sources will need to be identified to implement proposed restoration strategies for septic systems. An additional source of funding is the Maryland Supplemental Assistance Program administered by MDE, which finances repair and upgrade of existing septic systems.

For livestock source reduction practices, Maryland's Agricultural Water Quality Cost-Share, or MACS program, provides funding for various eligible agricultural BMPs, one of which is streamside livestock exclusion fencing (see MDA, 2013 and MDA, 2014). Funding source for improvements related to livestock are likely to have limited applicability in Anne Arundel County because livestock areas are limited in the TMDL watersheds and, further, agricultural land is increasingly being converted to residential uses.

Other grant programs are focused on community-based initiatives to improve water quality and are potentially applicable to pet waste outreach activities and associated installation of pet waste stations, doggy loos, etc. Two examples of community-based grant programs are EPA's Urban Waters Small Grants Program and the National Fish and Wildlife Foundation's Environmental Solutions for Communities. In addition, Chesapeake Bay Trust, a non-profit grant-making organization also awards funding for eligible restoration and outreach programs.

Implementing stormwater retrofits such as converting dry ponds to shallow marshes, or restoring degraded outfalls and stream channels with Step Pool Storm Conveyance (SPSC) systems are currently funded through the County CIP program. Funds are secured through revenue from the stormwater remediation fee that resulted from passage of County Bill 2-13. This provides a predictable source of dedicated funding for stormwater management purposes. Funding sources such as the Chesapeake Bay Trust funds, may be used to supplement County funds for specific projects

Wastewater CIP projects implemented through the County DPW are currently funded through wastewater bonds and wastewater PayGo (i.e., pay-as-you-go funds from wastewater utility operations, as provided in the annual budget). Improvements to the sewer infrastructure that would abate SSOs are expected to continue to be funded through the County's wastewater CIP projects.

6.2 TECHNICAL ASSISTANCE

Technical assistance refers to staffing and resources needed to oversee and implement the TMDL restoration plan. Since the passage of the Chesapeake Bay TMDL in 2010, the County passed County Bill 2-13, which established the Watershed Protection and Restoration Fund to support Chesapeake Bay Restoration activities. As a result, the County has been aligning resources needed to meet the requirements of the Chesapeake Bay TMDL and individual TMDLs as required by the NPDES MS4 permit. The alignment consists of departmental reorganization, hiring additional County staff, and engaging consulting resources. This framework enables the County to move forward with design and installation of urban stormwater BMPs based on the Phase II WIP strategy proposed by the County. This includes pre-2002 dry pond retrofits, and especially SPSC retrofits that are likely to figure prominently in the County's restoration activities over the next decade, primarily in areas where degraded stream channels are observed.

The changes in the County's program will also support the implementation of restoration strategies to meet the bacteria TMDL. For example, County programs can be expanded to install and deploy the pet waste stations, doggy loos, etc. in the County park system; to ramp up outreach activities and notify owners of existing pet waste pick-up laws; and to engage specialized outreach personnel to develop videos, County website content, public service announcements for television, social media, etc. Expansion of the County's program can also include developing buffer education programs to instruct residential owners on acceptable and unacceptable practices in buffer areas, and developing educational materials and signage for posting in buffer zones.

SECTION SEVEN: IMPLEMENTATION SCHEDULE AND MILESTONES

Based on MDE's recommendations and published guidance document for developing restoration plans for bacteria impairment, TMDL restoration plans should begin by addressing controllable sources of bacteria in the watershed (e.g., from humans, livestock, and pets) (MDE, 2014b). Further, as mentioned previously, reductions in human sources are given a priority because they pose a greater public health risk than non-human sources. Even though wildlife is one of the contributing factors of bacteria impairment, elimination of wildlife is considered "undesirable and impracticable" by MDE and EPA and is not listed as an intended goal of the TMDL.

Load reduction strategies that address urban stormwater (Tier B) are structural in nature and are in line with the strategies proposed to meet the Chesapeake Bay TMDL. The County is required to meet the Chesapeake Bay TMDL requirements by 2025, therefore integrating bacteria Restoration Plan schedules with the Bay TMDL schedule has a beneficial impact on both programs. Adhering to the Bay TMDL schedule would result in 60 percent of the implementation efforts to reduce bacteria loads being implemented by 2017. Under this scenario, milestone review would occur every 2 years to determine whether the proposed strategies are being implemented, and to what extent.

A generalized implementation schedule is provided in Table 7-1. This schedule is based on implementing strategies incrementally to reduce bacteria loads with achievement of all of the TMDL required percent load reductions by 2025. Since all of the TMDLs require the same combination of load reduction strategies (i.e., highly cost-effective Tier B non-structural controls to reduce non-human bacteria sources, followed by less cost-effective Tier A structural controls to reduce human sources of bacteria), the schedule applies to all the bacteria TMDLs. The only watersheds where TMDLs need a slight adjustment to the strategies is Patuxent River Upper and West River mainstem, both of which have agricultural pastures that support livestock populations. In these cases, livestock fencing is recommended as a part of Tier B strategies. This is noted in the table below. In addition, there is considerable flexibility for conducting pet waste education. It is recommended that the County identify and prioritize specific high-density residential areas, especially those where the expected load reductions otherwise fall short of the TMDL (see Section 4.4).

Table 7-1: Bacteria TMDL Implementation Schedule by Milestone Year

Milestone Year	Programmatic Criteria
2015	• Begin securing any funding sources needed • Make programmatic adjustments and identify any additional staffing needs • Identify drainage areas for existing BMPs, as required • Begin planning and developing pet waste education program, prioritize watersheds, and identify funds needed • Conduct survey to determine pet waste education needs • Begin site identification and design process for new dry pond or SPSC retrofits (already underway)

Milestone Year	Programmatic Criteria
2017	• 25% of all planned SPS upgrades completed • 10% of impervious area managed with SPSC or other high-performing BMP • Continued triennial inspection and maintenance of constructed BMPs • 25% of planned septic systems connected to sewers, if funding allows • Pet waste education program fully planned and coordinated, begin media campaign via television PSAs, videos on County website, and social media • Implement livestock fencing in two agricultural watersheds*
2019 (end of NPDES permit cycle)	• 50% of all planned SPS upgrades completed • 20% of impervious area managed with SPSC or other high-performing BMP (meet NPDES/WIP goal) • Continued triennial inspection and maintenance of constructed BMPs • 50% of planned septic systems connected to sewers, if funding allows • Pet waste education program continues; implement additional television PSAs, videos, social media, etc. as funds allow • Streamside livestock fencing completed
2021	• 75% of all planned SPS upgrades completed • 30% of impervious area managed with SPSC or other high-performing BMP • Continued triennial inspection and maintenance of constructed BMPs • 75% of planned septic systems connected to sewers, if funding allows • Pet waste education program continues; implement additional television PSAs, videos, social media, etc. as funds allow • Maintain livestock fencing and inspect triennially
2023	• 100% of all planned SPS upgrades completed (wastewater CIP goals met) • 40% of impervious area managed (permit/WIP goal achieved) • 100% of planned septic systems connected to sewers, if funding allows (goal achieved) • Pet waste education program continues; implement additional television PSAs, videos, social media, etc. as funds allow
2025 (bacteria TMDLs achieved)	• 50% of impervious area managed (on track to meet 60% goal in 2027) • Conduct survey to evaluate effectiveness of pet waste education program • Continued triennial inspection of constructed BMPs/retrofits

*Patuxent River Upper and West River mainstem.

BMPs = best management practices
CIP = Capital Improvement Program
NPDES = National Pollutant Discharge Elimination System
PSAs = Public Service Announcements
SPS = Sewage Pump Station
SPSC= Step Pool Storm Conveyance
WIP = Watershed Implementation Plan

SECTION EIGHT: METHODS FOR EVALUATING PROGRESS

Establishing methods for tracking and evaluating progress toward TMDL water quality goals is important to determine whether the proposed restoration strategies are being implemented according to the stated schedule or if adjustments are required. The methods for evaluating progress vary depending on the restoration strategy. For strategies related to the NPDES MS4 permit program such as urban stormwater retrofits and Illicit Discharge Detection and Elimination (IDDE), it is recommended to use a water quality model that can estimate bacteria load reductions from proposed restoration strategies. Water quality models can also be used to estimate potential pollutant load reductions from SSO abatements and on-site disposal system (OSDS) retirements/connections. Potential options for water quality models include the WTM that was used to develop this restoration plan (see Section 4) or other water quality models that include bacteria loading. The County's Watershed Management Tool does not include a bacteria specific model module, so it is not proposed for use.

Data compiled for the NPDES MS4 annual report could be used to model the load reductions achieved over the previous year. Modeling the SSO abatement and septic system retirement would entail coordination with the County Department of Health to obtain the required information. Information on SSOs is compiled for Wastewater Capacity, Management, Operations, and Maintenance (CMOM) Program reports submitted to MDE.

Table 8-1 lists potential methods for tracking the progress of bacteria load reduction for each of the proposed strategies.

Table 8-1: Potential Methods to Evaluate Progress

Proposed Strategy	Potential Method to Evaluate Progress	Frequency	Data Source
Pre-2002 Pond Retrofits	Water Quality Modeling*	Annually	NPDES reporting
Restore 20% Impervious Area with SPSC	Water Quality Modeling*	Annually	NPDES reporting
Eliminate Illicit Connections (IDDE)	Water Quality Modeling*	Annually	NPDES reporting
Abatement of SSOs	Water Quality Modeling*	Annually	CMOM reporting
Septic Retirement/Connection	Water Quality Modeling*	Annually	Dept. of Health
Stricter Buffer Ordinance/Education	Walk-through of buffer area with adjacent homeowners	Annually	n/a
Expanded Pet Waste Education	Pre- and post-implementation surveys of residential pet owners	Would depend on implementation time frame, pre-implementation survey could occur in 2015	n/a
Expanded Goose Management Program	Annual survey of goose population by USFWS and Maryland DNR	Annually as part of waterfowl survey	USFWS/ Maryland DNR

Proposed Strategy	Potential Method to Evaluate Progress	Frequency	Data Source
Livestock Stream Exclusion Fencing	Pre- and post-implementation surveys of farmers	Annually	Soil Conservation District Office

*Watershed Treatment Model or other applicable water quality models
CMOM = Capacity, Management, Operations, and Maintenance
DNR = Department of Natural Resources
IDDE = Illicit Discharge Detection and Elimination
n/a = Not Applicable
NPDES = National Pollutant Discharge Elimination System
SSOs = Sanitary Sewer Overflows
USFWS = U.S. Fish and Wildlife Service

Because the proposed water quality models do not effectively capture restoration strategies related to non-human sources, alternative methods for evaluating progress of these strategies need to be developed.

The Tier B controls, including pet waste education, livestock fencing, buffer education, and goose management, are difficult to quantify in terms of load reductions. Some potential methods for tracking progress of each of these strategies include:

- Conduct pre- and post-implementation surveys of pet owners to determine how many people are picking up after their pets;
- Conduct pre- and post-implementation survey of farmers to determine if they have been successfully keeping livestock out of the stream and an annual walk-through of buffer areas to see if any improvements have occurred; and
- Review the annual waterfowl survey conducted by USFWS and Maryland DNR (Maryland DNR, 2014) to estimate the size of the local goose population.

Water Quality Monitoring

The above methods for evaluating TMDL Restoration Plan progress will provide a general measurement of the implementation progress and the resulting bacteria load reductions from the proposed strategies. However, to confirm whether on-the-ground actions in the watershed are leading to measurable water quality improvements in the impaired TMDL waterways, MDE recommends water quality monitoring.

The County's current NPDES MS4 permit-required monitoring at the Parole Plaza outfall and Church Creek in-stream station is designed to assess the cumulative effects of watershed restoration activities in this commercial and residential watershed. This could be a suitable starting point for the monitoring program, and monitoring could be expanded to capture the effects of the strategies in the other TMDL watersheds. Adding monitoring locations would require submitting the proposed monitoring program details to MDE for approval.

In general, water quality improvements related to watershed restoration can be difficult to detect due to such factors as potential time lags, wet and dry years, and uncertainty in the success of implementation (e.g., whether there is actual behavior change in dog owners leading to more pet waste pickup). Therefore, EPA recommends at least 2 or more years of monitoring to acquire statistically significant results.

The proposed monitoring program would combine monitoring data from a number of existing sources/programs as a cost savings measure and to reduce duplication of effort among multiple organizations/agencies. It is recommended that the County conduct bacteriological monitoring of non-tidal waters in impaired TMDL watersheds. Monitoring can be conducted at representative stream locations to adequately characterize the bacteria loadings. Not all streams/watersheds would need to be monitored, only those with distinct differences in geographic setting and land use (see Section Two). Five years of monitoring is proposed during various conditions, including wet weather, dry weather, and different seasons to account for variations in flow and inter-annual changes related to wet years and dry years.

For tidal monitoring, it is proposed that the County utilize bacteriological monitoring data from the MDE's ongoing shellfish harvesting area monitoring program. Other sources of data include the County Health Department's monitoring of recreational beaches, and Operation Clearwater, another beach bacteria monitoring program. By integrating all of these programs, the County can leverage multiple monitoring efforts to save on costs while still gathering sufficient data to determine to what extent the implemented TMDL strategies are leading to actual water quality improvements in the impaired waterways.

Trend analysis is not required annually, as implementation of proposed restoration strategies is not likely to have an immediate impact on water quality. As an alternative, trend analysis should be conducted every 5 years, with 2015 as a baseline, 2020 as a mid-implementation assessment, and 2025 as a post-implementation assessment.

SECTION NINE: REFERENCES

Anne Arundel County. 2011. Patapsco Non-Tidal Watershed Assessment, Comprehensive Summary Report. Prepared by: Anne Arundel County Watershed Assessment & Planning Program, KCI Technologies, Inc., CH2M HILL. August 2011 Final.

Anne Arundel County. 2012. Chesapeake Bay TMDL Phase II Water Implementation Plan – FINAL. July 2, 2012.

Anne Arundel County. 2012b. Patapsco Tidal and Bodkin Creek Watershed Assessment – Comprehensive Summary Report. August.

Anne Arundel County. 2012c. RSC Fact Sheet. May. Available online at: http://www.aacounty.org/DPW/Watershed/StepPoolStormConveyance.cfm

Anne Arundel County. 2012d. Annual Homeless Assessment Report (2012). Available online at: http://www.aacounty.org/Homeless/Resources/Anne%20Arundel%20and%20Annapolis%20Annual%20Homeless%20Assessment%20Report%202012.pdf

Anne Arundel County. 2013. National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System Discharge Permit 2012 Annual Report: Anne Arundel County, Maryland. Available online at: http://www.aacounty.org/DPW/Watershed/2012%20NPDES%20Documents/2012%20Anne%20Arundel%20Annual%20Report_No%20Appendices.pdf

Anne Arundel County. 2014. National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System Discharge Permit 2013 Annual Report: Anne Arundel County, Maryland. Available online at: http://www.aacounty.org/DPW/Watershed/2012%20NPDES%20Documents/2012%20Anne%20Arundel%20Annual%20Report_No%20Appendices.pdf

Bruce, S. and M. Tiger. 2009. A Review of Research Relevant to Evaluating Social Marketing Mass Media Campaigns. Available online at: http://www.piedmontnutrientsourcebook.org/Assetts/outreach/evaluating-social-marketing-mass-media-campaigns.pdf

CA DBW (California Division of Boating and Waterways). 2014. Shipshape Sanitation, MSDS and Pumpouts. Available online at: http://www.dbw.ca.gov/pubs/sanitation/index.htm

CA (California) Central Coast Regional Board. 2011. Draft Comment Summary and Responses: Total Maximum Daily Loads (TMDLs) for Pathogens in the San Lorenzo River Watershed. February 1, 2011. Available online at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/sanlorenzo/comments010611/cmmnt_rpns010611.pdf

Capital Gazette. September 2, 2014 article by Brandi Bottalico. Watershed stewards find few takers for dog poop campaign. Available online at: http://www.capitalgazette.com/maryland_gazette/news/ph-ac-gn-poop-patrol-0903-20140902,0,6062570.story

Caraco, D. 2013. Watershed Treatment Model (WTM) 2013 "Custom" version. Center for Watershed Protection, Ellicott City, MD.

Caraco, D. 2013a. Watershed Treatment Model (WTM) 2013 Documentation. Center for Watershed Protection, Ellicott City, MD. Pages 1-114

Code of Maryland Regulations (COMAR). Critical Area Commission for the Chesapeake and Atlantic Coastal Bays. Available online at: http://www.dsd.state.md.us/comar/SubtitleSearch.aspx?search=27.02.01.*

County of Los Angeles. 2002. Department of Public Works, Storm Water/Urban Runoff, Public Education Model Program. Available online at: http://ladpw.org/wmd/npdes/Pipp/PIPP.pdf

CWEP (Clean Water Education Partnership). 2009. Pre- and Post-TV Campaign Surveys of Stormwater Awareness & Behavior in the Clean Water Education Partnership Service Area: Comparisons and Findings. Available online at: http://www.nccleanwater.org/pdf/cwep-final-survey-comparison-report.pdf

CWP (Center for Watershed Protection). 2004. Illicit Discharge Detection and Elimination – A Guidance Manual for Program Development and Technical Assessments. October. Available online at: http://www.cwp.org/online-watershed-library/cat_view/64-manuals-and-plans/79-illicit-discharge-detection-and-elimination

EPA (Environmental Protection Agency). 2001. National Menu of Best Management Practices for Storm Water Phase II, Public Education and Outreach on Storm Water Impacts. Available online at: http://www.georgiaplanning.com/watertoolkit/Documents/WaterProtectionIssues/PublicEdandOutreach.pdf

EPA. 2008. Decision Rationale: Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Areas in Whitehall and Meredith Creeks, Mill Creek, and the Severn River Mainstem of the Severn River Basin in Anne Arundel County, Maryland. April 2008.

EPA. 2010. Getting in Step: A Guide to Conducting Watershed Outreach Campaigns, 3rd edition. Office of Water Nonpoint Source Control Branch (4503T), Washington, DC. November. Available online at: http://water.epa.gov/polwaste/npdes/stormwater/upload/getnstep.pdf

EPA. 2011. Decision Rationale: Total Maximum Daily Loads of Fecal Bacteria for the Patuxent River Upper Basin Anne Arundel and Prince George's Counties Maryland. August 9, 2011.

EPA. 2012. A: Pollution Prevention Management Measure. Available online at: http://water.epa.gov/polwaste/nps/czara/ch4-6.cfm

EPA. 2013a. Getting in Step: Engaging Stakeholders in your Watershed. 2nd edition. EPA 841-B-11-001. Office of Water, Nonpoint Source Control Branch (4503T) , Washington, DC 20460. May. Available online at: http://cfpub.epa.gov/npstbx/files/stakeholderguide.pdf

EPA. 2013b. Nonpoint Source Program and Grants Guidelines for States and Territories. US EPA Office of Water, Nonpoint Source Control Branch. April. Available online at: http://water.epa.gov/polwaste/nps/upload/319-guidelines-fy14.pdf

EPA. 2014. Search the NPS Outreach Toolbox. Available online at: http://cfpub.epa.gov/npstbx/index.cfm

French, L. and J. Parkhurst. 2009. Managing Wildlife Damage: Canada Goose (*Branta canadensis*). Virginia Cooperative Extension, publication 420-203.

King, D., and P. Hagan. 2011. Costs of Stormwater Management Practices In Maryland Counties – Draft Final Report. October 10.

Klein, R. 2007. The Effects of Marinas & Boating Activity Upon Tidal Waterways. July. Available online at: http://www.ceds.org/pdfdocs/Marinas.pdf

Maryland DNR (Department of Natural Resources). 2014. Maryland's Midwinter Waterfowl Survey Results Announced. March 7, 2014. Available online at: http://news.maryland.gov/dnr/2014/03/07/dnr-announces-midwinter-waterfowl-survey-results/

MDA (Maryland Department of Agriculture). 2013. MACS Manual 382 Fencing. October. Available online at: http://mda.maryland.gov/resource_conservation/Documents/macs_manual/2/382_fencing.pdf

MDA. 2014. Maryland Agricultural Water Quality Cost-Share Program. Available online at: http://mda.maryland.gov/resource_conservation/Pages/macs.aspx

MDE. 2005b. Comment Response Document (CRD) Regarding the Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in Bear Neck Creek, Cadle Creek, West River, and Parish Creek for the West River Basin in Anne Arundel County, Maryland. July 25, 2005.

MDE. 2005c. Comment Response Document Regarding the Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in Magothy River, Tar Cove, and Forked Creek and a Water Quality Analysis of Fecal Coliform for Deep Creek for Restricted Shellfish Harvesting Areas in the Magothy River Basin in Anne Arundel County, Maryland. July 25, 2005.

MDE. 2005d. Comment Response Document Regarding the Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Areas in Tracy and Rockhold Creeks of the Other West Chesapeake Bay Drainages Basin in Anne Arundel County, Maryland. August 24, 2005.

MDE. 2005e. Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in Magothy River, Tar Cove, and Forked Creek and a Water Quality Analysis of Fecal Coliform for Deep Creek of the Magothy River Basin in Anne Arundel County, Maryland. August.

MDE. 2005f. Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in the South River, Duvall Creek, Selby Bay, and Ramsey Lake of the South River Basin in Anne Arundel County, Maryland. June.

MDE. 2005g. Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in Bear Neck Creek, Cadle Creek, West River, and Parish Creek for the West River Basin in Anne Arundel County, Maryland. August.

MDE. 2005h. Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in Tracy and Rockhold Creeks of the Other West Chesapeake Bay Drainages Basin In Anne Arundel County, Maryland. August.

MDE. 2006. Maryland's 2006 TMDL Implementation Guidance for Local Governments. May 24.

MDE. 2008. Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Areas in Whitehall and Meredith Creeks, Mill Creek, and the Severn River Mainstem of the Severn River Basin in Anne Arundel County, Maryland. April.

MDE. 2009b. 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. August.

MDE. 2010a. Comment Response Document Regarding the Total Maximum Daily Loads of Bacteria for the Impaired Recreational Areas in Marley Creek and Furnace Creek of Baltimore Harbor Basin in Anne Arundel County, Maryland. July 27, 2010.

MDE. 2010b. Comment Response Document Regarding the Total Maximum Daily Load of Fecal Bacteria for the Patuxent River Upper Basin in Anne Arundel and Prince George's Counties, Maryland. September 16, 2010.

MDE. 2010c. Total Maximum Daily Loads of Bacteria for Impaired Recreational Areas in Marley Creek and Furnace Creek of Baltimore Harbor Basin in Anne Arundel County, Maryland. July.

MDE. 2010d. Total Maximum Daily Loads of Fecal Bacteria for the Patuxent River Upper Basin in Anne Arundel and Prince George's Counties, Maryland. September.

MDE. 2014a. General Guidance for Developing a Stormwater Wasteload Allocation (SW-WLA) Implementation Plan - Final. May.

MDE. 2014b. Guidance for Developing a Stormwater Wasteload Allocation Implementation Plan for Bacteria Total Maximum Loads –Final. May.

MDE. 2014c. Guidance for Developing Stormwater Wasteload Allocation Implementation Plans for Nutrient and Sediment Total Maximum Daily Loads – Final. November.

MDE. 2014d. Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated. August.

MDE. 2014e. Maryland Shellfish Harvesting and Closure Area Map. Available online at: http://www.mde.state.md.us/programs/Marylander/CitizensInfoCenterHome/Pages/citizensinfocenter/fishandshellfish/pop_up/shellfishmaps.aspx

RIDEM (Rhode Island Department of Environmental Management). 2014. Pollution Prevention: Animal Waste Collection. Available online at: http://www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/t4guide/fact1.htm

RI (Rhode Island) Sea Grant. 1992. Environmental Guide for Marinas: Fact Sheets. University of Rhode Island Bay Campus, Narragansett, RI. Available on-line at: http://seagrant.gso.uri.edu

Strand, I.E and G.R. Gibson. 1990. The Use of Pump-Out Facilities by Recreational Boaters in Maryland. *Estuaries*, Vol. 13, No. 3 (Sep., 1990), pp. 282 – 286. Available online at: http://www.beamreach.org/data/101/Science/processing/Kathryn/BEAM%20REACH/Sustainability%20Project/pump%20outs.pdf

Swann, C. 1999. A Survey of Residential Nutrient Behaviors in the Chesapeake Bay. Widener Burrows, Inc. Chesapeake Research Consortium. Center for Watershed Protection. Ellicott City, MD. 112 pp.

VA DEQ (Virginia Department of Environmental Quality). 2011. Bacterial Implementation Plan Development for the James River and Tributaries – City of Richmond Technical Report. Final Submitted: December.

Van der Wel, B. 1995. Dog Pollution. The Magazine of the Hydrological Society of South Australia. 2(1)1.

WGCAC (Wildcat Glades Conservation & Audubon Center). 2011. Connections. Summer 2011, Volume 5, Number 2. Available online at: http://www.wildcatglades.audubon.org/connections_v5no2.pdf

Winters, J. 2015. Annapolis and Anne Arundel County Pet Walks. Available online at: http://www.imrivers.org/annapolispetwalk/

Zeckoski, R., B. Benham, C. Lunsford. 2012. Streamside Livestock Exclusion: a tool for increasing farm income and improving water quality. December.

Appendix A: Watershed Treatment Model Methodology

A.1 INTRODUCTION

As a part of the development of the Total Maximum Daily Load (TMDL) Restoration Plan for bacteria impairments for the nineteen approved TMDLs in Anne Arundel County (County), the URS/ESA team developed water quality models for each of the 19 TMDL watersheds. The Watershed Treatment Model (WTM), a spreadsheet-based model developed by the Center for Watershed Protection (Caraco, 2013) was used to characterize and quantify the bacteria loads for existing conditions and estimate the pollutant load reductions from future Best Management Practices (BMPs) to meet the TMDL requirements.

The WTM is a planning level model that quantifies bacteria loads based on both point and non-point sources of pollution. The model calculates the fate and transport of bacteria from pollutant sources to the receiving water bodies. In addition to the bacteria loads, the model also has the capability to estimate annual loads for total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS). The model has several tabs where pollutant sources and treatment options can be input. The Pollutant Sources tabs estimate the pollutant loads from primary sources such as land use and secondary sources such as channel erosion, illicit connections etc. The Treatment Options tabs of the model estimate the pollutant load reductions from structural and non-structural treatment options for existing and future conditions.

The URS/ESA team used the Maryland Department of Environment (MDE)-provided watershed boundaries, County geographic information system (GIS) data, and additional information on County operations to develop the baseline models for the study watersheds. The sections below provide a detailed description of the inputs and the methodology adopted in developing the WTM models for the study watersheds.

A.2 EXISTING CONDITIONS MODELING

An existing conditions model was developed to estimate the pollutant loads from primary sources such as existing land use and secondary sources such as illicit discharges, on-site sanitary disposal systems, and sanitary sewer overflows and the current pollutant reductions from existing BMPs. The data that were used in the model to estimate the current pollutant loads were based on the following:

Primary Sources

The Primary Sources tab of the WTM estimates pollutant loads in the stormwater runoff from land uses such as residential, commercial, industrial, rural, forest, and water. It also has an option to include acreage of land under active construction as one of the land uses. The model uses Simple Method (Schueler, 1987) to estimate the annual pollutant loads from different type of land uses based on their event mean concentrations (EMCs) and impervious cover, annual rainfall, and runoff coefficients. A description of the input information for primary sources is provided below.

- **Land use:** GIS data for existing land cover and impervious cover developed by the County in 2011 was used to identify the acreage of each land use type in the study watersheds. The default impervious cover percentage per land use type was adjusted in the WTM model to reflect existing watershed conditions by intersecting the land use and impervious cover GIS data. The default EMCs for TN, TP, TSS, and bacteria for each land use category were modified in the WTM model based on literature review of the watershed management plans developed by the County. Land cover categories with similar runoff characteristics and EMC values were grouped for the model input. Table A-1 below provides information on the land use and the EMCs used in the model.

Table A-1: Land Use Classification and EMCs

County Land Cover Classification	WTM Land Use Category	Event Mean Concentration (EMC)			
		TN (mg/l)	TP (mg/l)	TSS (mg/l)	Bacteria (MPN/100 ml)
Airport	Airport	2.24	0.30	99	4500
Commercial	Commercial	2.24	0.30	43	4500
Forested Wetland	Forest	1.00	0.11	34	500
Industrial	Industrial	2.22	0.19	77	2614
Open Space	Open Space	1.15	0.15	34	3100
Open Wetland	Forest	1.00	0.11	34	500
Pasture/Hay	Pasture/Hay	7.83	2.09	341	500
Residential 1- acre	Medium Density Residential (1-4 DU)	2.74	0.32	43	7750
Residential 1/2-acre	Medium Density Residential (1-4 DU)	2.74	0.32	43	7750
Residential 1/4-acre	Medium Density Residential (1-4 DU)	2.74	0.32	43	7750
Residential 2-acre	Low Density Residential (<1DU)	2.74	0.32	43	7750
Residential 1/8-acre	High Density Residential (>4 DU)	2.74	0.32	43	7750
Row Crops	Row Crops	16.06	2.63	1,046	500
Transportation	Transportation	2.59	0.43	99	1400
Utility	Open Space	1.15	0.15	34	3100
Water	Water	1.20	0.03	43	500
Woods	Forest	1.00	0.11	34	500

DU-Dwelling Units
mg/l-milligrams per liter
MPN/100 ml = most probably number per 100 milliliters

- **Annual rainfall:** The average annual rainfall recorded the by National Oceanic and Atmospheric Administration at the Baltimore-Washington International Thurgood

Marshall Airport (BWI) was used as the input. An average annual rainfall of 42 inches was observed at BWI based on 143 years of recorded precipitation data.

- **Streams:** The stream GIS data obtained from the County website was used as the source to input stream length in miles in the study watersheds. The GIS data were analyzed, and features such as shoreline and pipes were not included in estimating the total stream length per watershed.
- **Soils:** The soils data downloaded from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service were used to estimate the percentage of each hydrologic soil groups in the study watersheds. The downloaded soils data was also used to determine hydric soils in the watershed to classify average depth to groundwater.

Secondary Sources

The input information for secondary sources was obtained from County GIS data, operations information, and research. The secondary sources are as follows:

- **Onsite sewage disposal system (OSDSs):** The model estimates the loads from OSDSs to surface water and groundwater based on the volume and concentration of pollutants in wastewater (Table A-2). The obtained pollutant loads are further adjusted based on several factors such as efficiency of the OSDSs, percent of OSDSs that are less than 100 feet away from any water bodies, general soil types, level of maintenance, and their density in the watershed. Based on the County-provided information, the following data were used as input for wastewater characteristics:

Table A-2: WTM Pollutant Concentration in Wastewater

Water Use (gallons/capita/day)	Wastewater Characteristics			
	TN (mg/l)	TP (mg/l)	TSS (mg/l)	Bacteria (MPN/100 ml)
75	60	10	400	10,000,000

mg/l-milligrams per liter
MPN-most probable number

- The Anne Arundel County Department of Health developed GIS coverage of all the properties in the County that have an OSDS, and this information was used to identify properties in the study watersheds with no sewer connection. The GIS data also categorized the OSDSs as Best Available Technology (BAT) and Engineering (ENG) Nitrogen Removal Units (NRUs). The performance efficiency of both the type of NRUs (Table A-3) was obtained based on research and WTM literature. Properties that were not categorized as an NRU type were assumed to have a conventional system. Based on the spatial analysis of the GIS stream layer with the OSDS properties, 10 percent of the properties were assumed to have an OSDS less than 100 feet from a waterway. A 5-foot separation from groundwater was assumed for all the systems. Based on research on the

Anne Arundel County website, a medium level of septic system management that includes inspection at installation and education to encourage ongoing maintenance were factored in to adjust the obtained pollutant loads through OSDSs.

Table A-3: Bacteria Pollutant Removal Efficiency of OSDSs

Nitrogen Removal Unit (NRU) Type	Bacteria Log Reduction
Conventional System	3.5
ENG	2.9
BAT	3.0

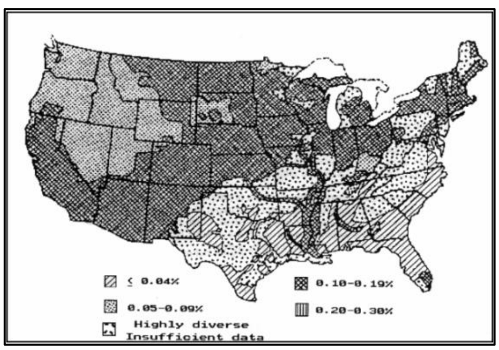
- **Sanitary sewer overflows (SSOs):** Pollutant loads due to SSOs are estimated based on total SSO volume and effluent concentration (Table A-2). Based on County-provided information, a volume of 55,650 gallons per SSO, which is the County-wide average, was used to estimate the loads, and approximately 30 SSOs were assumed to occur for every 1,000 miles of sewer line. The sanitary sewer GIS data obtained from the County website was used to estimate the total length in miles of the sewer system in each study watershed.
- **Combined sewer overflows:** None of the study watersheds have any combined sewer outfalls.
- **Illicit connections:** Pollutant loads due to illicit connections of residences and businesses were estimated based on the County's National Pollutant Discharge Elimination System (NPDES) MS4Annual Reports. According to the NPDES MS4 reports and illicit discharge detection and elimination annual report (IDDE, 2013), the County-wide detection rate of illicit connections is approximately 2 percent (29 cases out of 1,350 outfalls surveyed from 2005 to 2013). This detection rate was proportioned to each TMDL watershed based on the amount of impervious cover in the watershed relative to the total impervious area in the County. This obtained percent of illicit connections for each watershed was distributed equally among residential and commercial illicit connections. Among the percent of businesses illicitly connected, the majority (90 percent) was assumed to be illicit wash water connections, and 10 percent of the businesses were assumed to be illicit waste water connections. The concentrations of pollutants for business illicit connections used in the model are provided in Table A-4 below. The pollutant concentration of residential illicit connections is the same as that of wastewater (Table A-3).

Table A-4: Pollutant Concentrations for Illicit Business Connections

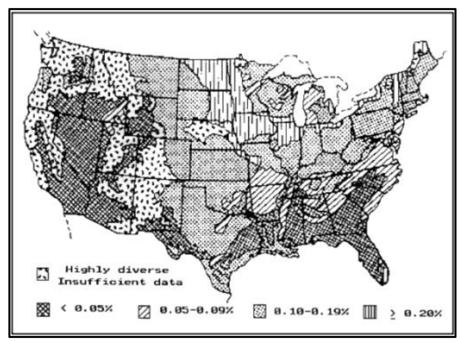
Pollutant	Pollutant Concentration	
	Wash Water	Wash Water and Wastewater
TN (mg/l)	15	30
TP (mg/l)	10	10
TSS (mg/l)	150	225
Bacteria (MPN/100ml)	0	3,300,000

mg/l-milligrams per liter
MPN-maximum probable number

- **Urban channel erosion:** Urban channel erosion is a required input parameter in the model, however it only affects nutrients and sediment, not bacteria. The sediment loads due to urban channel erosion in each study watersheds were assumed to be a fraction of total sediment loads from other urban sources in the watershed. Moderate rates of erosion (50 percent of total watershed sediment loads) in the channel were assumed to estimate the sediment loads for all the study watersheds. Phosphorus and nitrogen concentrations of 0.064 percent and 0.07 percent, respectively, were used to estimate the nutrient loads due to channel erosion. These are default percentages for the State of Maryland and were obtained using Figures 4.1 and 4.2 of the Watershed Treatment Model (Caraco, 2013a) documentation.



Distribution of phosphorus (P2O5) in the top 12 inch of soil (Source: Figure 4.1, CWP 2013)



Distribution of nitrogen in the top 12 inch of soil (Source: Figure 4.2, CWP 2013)

- **Livestock:** USDA's 2012 farm censuses were used to get the count of livestock such as horses, cattle (dairy and beef), broilers, turkeys, hogs, and pigs. The livestock numbers were associated with the County's rural land use (crops and pastures/hay). Based on the acreage of rural land use in the study watersheds, the livestock numbers were estimated proportionally. Table A-5 lists the census data obtained from USDA. The estimated bacteria loads per animal type were obtained from TMDL plans developed by MDE for various impaired watersheds.

Table A-5: Livestock Census Data for Anne Arundel County (USDA, 2012) and Associated Bacteria Loads (MDE)

Animal	Census Data for County	Fecal Coliform Production (count/animal/day)	Percent Manure Available for Washoff (%)
Dairy	586	1.01+10	40
Beef	584	1.20+10	40
Horse	1,791	4.20+08	40
Sheep	316	1.20+08	40
Broilers	300[1]	1.36+08	10
Turkeys	34	9.30+07	10
Chicken and Layers	1,133	1.36+08	10
Hogs and Pigs	42	1.08+10	40

1- 2007 data used as 2012 data was unavailable in the USDA Report

- **Marinas:** Pollutant loads from marinas were estimated based on the number of boats, flow rates, and number of boating days per year. The County-published document *Marinas of Anne Arundel County* (2010) was used to obtain information on type of marina and number of slips in each marina. For the model, 50 percent of the slips were assumed to be occupied during a 5-month boating season. The Maryland Department of Natural Resources' (DNR's) website was used to obtain information on the number of pumpouts in each TMDL watershed. Note that the model does not have a parameter for estimating bacteria load reductions due to educational outreach to the boating community about proper disposal of onboard sewage. Therefore, marinas are included as a source in the model, but not as a load reduction. Educational outreach is discussed in Section 5.3 of the main report.
- **Road sanding:** Based on County provided information; road sanding is not performed by the County.
- **Non-stormwater point sources:** Based on research and County-provided information, one of the seven County-owned water reclamation facilities (WRFs), Annapolis WRF, discharges to the TMDL watershed. The remaining WRFs do not discharge to any of the TMDL watersheds. In addition to the County-owned WRF, two other point sources listed in the MDE-published TMDL documents with permitted discharges for bacteria were included in the models. Table A-6 below lists all the point sources in the study watersheds with permitted discharges for bacteria that were included in the models.

Table A-6: Permitted Discharges of Non-stormwater Point Sources in the Study Watersheds

TMDL Watershed	Facility	Design Flow (MGD)	Permitted Bacteria Loads (MPN/100 ml)
Severn (Mainstem, Mill, Meredith and Whitehall Creeks)	Annapolis Water Reclamation Facility	13	14
Severn (Mainstem, Mill Southern, Meredith-Whitehall Creeks)	U.S. Naval Academy	1	14
Patapsco River Lower North Branch	Holiday Mobile Estates Wastewater Treatment plan	0.108	3.0

MGD = million gallons per day
MPN-maximum probable number

Existing Management Practices

Input data for existing management practices were developed based on County-provided information, research and GIS data, and other management practices data related to County operations.

- **Turf condition and management practices in residential and other land uses:** As field reconnaissance was not included as a part of this study, it was assumed that approximately 10 percent of the lawns in the watershed are bare or compacted and 10 percent were assumed to be highly managed as a result of excess fertilization to estimate the annual TN and TP loads. The turf management for other land uses such as commercial, transportation, and industrial was also assumed to be managed at the same level as residential areas.
- **Erosion and sediment control:** Active construction sites were not included as a part of the model input; therefore, sediment load reduction due to the County's existing erosion and sediment control program was not estimated in the model.
- **Pet waste education:** Based on the WTM documentation, bacteria loads from pet waste are calculated based on the assumption that 40 percent of the homeowners in a study area have dogs, and approximately 50 percent of the dog owners walk their dogs. Approximately 60 percent of the dog owners who walk their dogs are assumed to clean up after their pets. The pollutant load reductions achieved by a pet waste education program in the model are calculated based on its effectiveness in educating the pet owners. Table A-7 lists various media outlets used for educating the pet owners and their effectiveness in reducing the bacteria loads from pets.

Table A-7: Effectiveness of Media for Pet Waste Education Program

Media Outlet	Effectiveness (%)
Television	40
Radio	25
Newspaper	30
Billboard	13
Brochure	8
Workshop	7

- Based on research of current County outreach programs, it was observed that the County currently provides information on pet waste management through its website and that it includes some educational brochures. A corresponding effectiveness of 8 percent was used in the model to estimate the reduction in bacteria loads through pet waste education.
- **Street sweeping:** The model estimates the load reductions in TSS, TN, and TP that would be achieved by street sweeping based on acreage of streets swept and the type of street sweeping technique used. The pollutant load reductions are further adjusted by factoring in efficiency of the street sweeping program. According to the County, arterial, collector, and roads in business districts are swept four times a year. The County GIS data were used to input the acres of roads swept in each study watershed. A program efficiency of 75 percent was used in the model based on the assumption that operators are not effectively trained and that parking restrictions are in place during the street sweeping period.
- **Structural stormwater management (SWM) practices:** Information on existing structural SWM practices was obtained from County stormwater management GIS data and the BMP database and input in the model. The County is in the process of compiling the drainage areas for all the BMPs, and as result, drainage areas and impervious areas associated for some of the BMPs were not populated. The pollutant removal efficiencies of the practices were modified in the model to match the bacteria removal efficiencies listed in the County's NPDES MS4 Annual Report (2012) (Anne Arundel County, 2013). The pollutant load reductions achieved by structural SWM practices were further adjusted based on the assumptions that 90 percent of annual rainfall is captured by the structures (0.9), the County has design criteria that will result in high pollutant removal efficiencies for practices (1.2), and that regular maintenance of the practices is enforced and conducted by the County (0.9). Table A-8 shows the bacteria pollutant removal efficiencies of BMPs input into the model. Most of the TMDLs in the study watersheds were developed in the early 2000s. Therefore, the baseline WTM included BMPs that were implemented only until the year 2000 to account for load reductions that would be achieved from BMPs at the time of TMDL development.

Table A-8: Anne Arundel County BMPs and Pollutant Removal Efficiencies

BMP Type	Bacteria Pollutant Removal Efficiency (%)
Attenuation Trench	0
Bioretention	90
Check Dam	0
Disconnection of Non Roof-top runoff	75
Disconnection of Roof-top Runoff	75
Dry Pond	0
Dry Wells	75-90
Environmental Site Design	75
Extended Detention	50
Extended Detention Structure-Dry	50
Extended Detention Structure-Wet	75
Forestation on Pervious Urban	0
Infiltration Trench with Complete Exfiltration Microbasin	90
Infiltration Basin	90
Infiltration Berms	75
Infiltration Trench	90
Infiltration Trench with Partial exfiltration	90
Infiltration Trench with Water Quality Exfiltration	90
Landscape Infiltration	75
Level Spreader	0
Micro Pool	75
Micro-Bioretention	75
Oil-Grit Separator	50
Other	0
Permeable Pavement	75
Porous Pavement	90
Rain Gardens	75-80
Rainwater Harvesting	75
Regenerative Step Pool Storm Conveyance	90
Sand Filter	0
Shallow Marsh	75
Sheetflow to conservation areas	75
Submerged Gravel Wetlands	75
Swales	75
Underground Storage	50
Vegetated Buffer	80
Wet Pond	75

BMP Type	Bacteria Pollutant Removal Efficiency (%)
Wet Structure	75

- **Riparian buffers:** The effectiveness of riparian buffers in reducing pollutant loads is estimated based on stream length and buffer width. The County 2011 land cover data downloaded from the County website was used to identify all the forested areas in the study watersheds. A GIS analysis was conducted to identify stream length in study watersheds that had 100 feet and 50 feet of riparian buffers on either side. The default pollutant removal efficiencies in the model were modified to match the County-approved pollutant removal efficiencies for vegetated buffers (Table A-8). The estimated pollutant load reductions were further adjusted (to 60 percent) based on the assumption that the County does not have effective signage at all places that specify acceptable and unacceptable activities.
- **Catch basin cleanouts:** The model estimates the pollutant load reductions achieved by catch basin cleanouts based on the number of impervious acreage captured by the inlets. Based on the Phase II WIP developed by the County for the Chesapeake Bay TMDL, approximately 5,281 acres of impervious area was captured by cleaning 12,625 of the 34,095 inlets in the County. This data was used to find the proportion of inlets cleaned in each study watershed and to obtain the approximate impervious area captured by them. The County GIS data was used to identify the number of inlets in each study watershed.

The bacteria pollutant loads contributing to surface water from primary and secondary sources and subsequent load reductions from existing management practices for all the study watersheds is provided in Table A-9.

Table A-9: Baseline Bacteria Loads Contributing to Surface Water for Study Watersheds

Bacteria TMDL Watershed	Local Waterway	Bacteria Loads (billion/year)	Bacteria Loads (billion/day)
Chesapeake Bay Mainstem	Tracy and Rockhold Creeks	563,451	1,544
Magothy River	Forked Creek	78,605	215
Magothy River	Magothy River Mainstem	1,793,426	4,913
Magothy River	Tar Cove	262,717	720
Patapsco River Lower North Branch	Patapsco River Lower North Branch	1,207,758	3,309
Patapsco River	Furnace Creek	1,162,324	3,184
Patapsco River	Marley Creek	1,028,407	2,818
Severn River	Mill Creek	235,329	645
Severn River	Severn River Mainstem	5,034,108	13,792
Severn River	Whitehall and Meredith Creeks	182,911	501
South River	Duvall Creek	68,159	187
South River	Ramsey Lake	109,113	299
South River	Selby Bay	104,777	287
South River	South River Mainstem	2,105,817	5,769
Upper Patuxent River	Upper Patuxent River	1,688,688	4,627
West River and Rhode River	Bear Neck Creek	68,501	188
West River and Rhode River	Cadle Creek	32,488	89
West River and Rhode River	Parish Creek	22,862	63
West River and Rhode River	West River Mainstem	201,795	553

A.3 ESTIMATION OF LOAD REDUCTIONS FROM PRIOR MANAGEMENT MEASURES

Based on the MDE's TMDL guidance document, *Guidance for Developing a Stormwater Wasteload Allocation Implementation Plan for Bacteria Total Maximum Daily Loads* (May 2014), load reductions from prior management measures should be estimated to account for progress towards TMDL goals at the time the TMDL Restoration Plan is developed. Most of the TMDLs for bacteria in Anne Arundel County were developed in the early 2000s. The County has since implemented several BMPs. Additionally, based on the County-provided GIS data, several OSDS have also been retired in the TMDL watersheds since development of the TMDLs by MDE 15 years ago. Potential credits from both these management measures were estimated by developing a WTM using the TMDL data. This method was developed based on correspondence with MDE.

For the prior-load reductions WTM model, the 2000 land use data used by MDE to develop the TMDLs was input as the primary source. The secondary sources in the model remained unchanged. The annual bacteria loads in the model were calibrated such that the baseline loads from the WTM matched the MDE-published TMDL baseline loads.

Credits from Post-TMDL BMPs

The potential credits that would be achieved from the "Post-TMDL" BMPs were calculated by including all the BMPs that were implemented after the TMDL was published by MDE. Since the majority of the TMDLs were developed in the early 2000s, 2000 was used as the cut-off year to estimate the number of post-TMDL BMPs for each watershed. The drainage area and impervious cover for all the post-TMDL BMPs were obtained from the County-provided GIS data and IMP database. All the Post-TMDL BMPs were not accounted in the WTM as drainage area and impervious area information was not available for some of the BMPs. This is because the County is in the process of updating this information for the County wide BMPs. Impervious area treated was not available for some BMPs in the County IMP database. In such cases, it was assumed that 50 percent of the treated drainage area was impervious. The bacteria removal efficiencies provided in Table A-8 were used for the post-TMDL BMPs as well.

Credits from Retired Septic Systems

The County provided a GIS coverage of all the OSDS that were retired or connected to a public sewer from 2008 to 2013. The County-provided GIS data were clipped to the TMDL watersheds to obtain the number of retired OSDS in each watershed. The obtained numbers were input into the calibrated WTM to estimate the credits that would be achieved towards meeting the TMDL goals for all the study watersheds.

Table A-10 shows the TMDL credits that would be achieved for all the study watersheds from post-TMDL BMPs and retired septic systems.

Table A-10: Septic Systems Identified by the County to Be Connected to a Public Sewer System

Bacteria TMDL Watershed	Prior Load Reductions Since 2000		TMDL Targets	
	Post-TMDL BMPs	Post-TMDL Septic System Retirement	TMDL Required % Reduction	Adjusted TMDL Required % Reduction
Magothy Mainstem	3.30%	0.61%	54.00%	50.09%
Magothy River/Forked Creek	4.91%	None	26.27%	21.36%
Magothy River/Tar Cove	2.44%	None	32.66%	30.22%
Patapsco River/Furnace Creek	4.47%	0.38%	77.79%	72.94%
Patapsco River LNB	3.70%	2.61%	56.1%	49.79%
Patapsco River/Marley Creek	5.41%	0.26%	75.70%	70.03%
Patuxent River Upper	8.36%	None	47.2%	38.84%
Rhode River/Bear Neck Creek	11.96%	None	43.32%	31.36%
Rhode River/Cadle Creek	3.43%	None	72.16%	68.73%
Severn River Mainstem	1.19%	0.35%	19.00%	17.46%
Severn River/Mill Creek	4.30%	None	86.00%	81.70%
Severn River/Whitehall and Meredith Creek	6.45%	0.43%	90.00%	83.12%
South River/Duvall Creek	3.77%	None	45.56%	41.79%
South River Mainstem	8.09%	0.06%	46.00%	37.85%
South River/Ramsey Lake	6.00%	None	59.30%	53.30%
South River/Selby Bay	1.20%	None	28.4%	27.20%
W. Chesapeake Bay/Tracy and Rockhold Creeks	0.35%	2.70%	82.00%	78.95%
West River Mainstem	0.27%	0.48%	35.41%	34.66%
West River/Parish Creek	None	None	53.04%	53.04%

A.4 PROPOSED CONDITIONS MODELING

A proposed conditions model was developed to estimate the potential reductions in baseline loads that could be achieved from implementation of certain future management practices in the TMDL watersheds. The goal of this modeling was to identify and prioritize the most effective strategies. These strategies were categorized into Tier A and Tier B strategies.

Tier A included strategies such as elimination of illicit discharges, abatement of sanitary sewer overflows, and retirement of septic systems which addressed human sources of bacteria. Pollutant load reductions that would be achieved by implementing Tier A strategies were quantified using the WTM.

Tier B strategies were recommended to address non-human sources of bacteria and included strategies such as urban stormwater retrofits, improvement of the riparian buffer ordinance/education program, expanded pet waste education program, livestock stream exclusion fencing, and Canada goose management. Load reductions that would be achieved by implementing Tier B strategies were quantified using WTM and available literature. Load reductions from urban stormwater retrofits and a riparian buffer ordinance/education program were calculated using WTM, as it effectively captures loads from urban sources. As WTM does not effectively capture load reductions from an expanded pet waste education program, livestock stream exclusion fencing, and Canada goose management were quantified using available literature. Based on MDE's recommendations, Tier A strategies were given higher priority than Tier B strategies because they address human sources of bacteria.

Tier A Strategies

- **Retirement of County septic systems:** This Tier A strategy proposes retirement of existing septic systems in the TMDL watersheds and connecting them to public sanitary systems to reduce the bacteria loads from OSDSs. The County provided County-wide GIS coverage of all the OSDSs that would be retired to be connected to a WRF or to a cluster treatment system. This GIS coverage was based on the County's OSDS Evaluation Study (2008). The County-provided GIS layer was clipped to the TMDL watersheds to obtain the number of septic systems that are proposed to be retired in each watershed. Thus obtained data was entered into the future management practices of WTM under "Septic System Retirement (Convert to WWTP)" option to calculate the load reductions that would be achieved from this strategy. The table below (Table A-11) provides information on the number of septic systems proposed to be retired in each watershed.

Table A-11: Septic Systems Identified by the County to Be Connected to a Public Sewer System

TMDL Watershed ID	No. of Septic Systems Identified to Be Connected to Sewer	Portion in Each Watershed (%)
Magothy Mainstem	4,814	71
Magothy River/Forked	113	88
Magothy River/Tar Cove	1,708	94
Patapsco River Lower North Branch	174	15
Patapsco River/Furnace Creek	252	37
Patapsco River/Marley Creek	0	0
Patuxent River Upper	289	24
Rhode River/Bear Neck Creek	0	0
Rhode River/Cadle Creek	0	0
Severn River Mainstem	5,475	55
Severn River/Mill Creek	1,168	76
Severn River/Whitehall and Meredith Creek	320	45
South River Mainstem	1,694	20
South River/Duvall Creek	0	0
South River/Ramsey Lake	0	0
South River/Selby Bay	0	0
W. Chesapeake Bay/Tracy and Rockhold Creeks	0	0
West River Mainstem	0	0
West River/Parish Creek	0	0

- **Abatement of sanitary sewer overflows:** This strategy involved minimizing the volume of SSOs discharging to the waterways after a storm event. The County provided historic SSO data that included approximately 500 SSOs documented since 2001. Based on the County-provided information, the majority of the SSOs were primarily caused by sewage pump station (SPS) failure. The proposed strategy to reduce the SSOs included SPS "upgrades," which involves projects such as improving SPS operations and relieving capacity problems, and replacing SPS generators. Based on the County-provided capital improvement projects (CIP) for wastewater, approximately 35 projects related to SPS upgrades were identified in 12 of the 19 TMDL watersheds. The obtained information was entered in the future management practices under the "SSO Repair/Abatement" options to estimate the load reductions that would be achieved from the County CIP projects. The number of SPS upgrades in each TMDL watershed based on the County CIP data is provided in the table below (Table A-12).

Table A-12: List of SPS Upgrades in the TMDL Watersheds

Bacteria TMDL Watershed	No. of SPS Upgrades	SSO Goal Reduction (%)
Magothy Mainstem	6	27
Magothy River/Forked	1	100
Magothy River/Tar Cove	N/A	N/A
Patapsco Lower North Branch	3	75
Patapsco River/Furnace Creek	5	63
Patapsco River/Marley Creek	3	25
Patuxent River Upper	N/A	N/A
Rhode River/Bear Neck Creek	1	17
Rhode River/Cadle Creek	1	50
Severn River Mainstem	8	14
Severn River/Mill Creek	1	10
Severn River/Whitehall and Meredith Creek	0	0
South River Mainstem	6	9
South River/Duvall Creek	1	50
South River/Ramsey Lake	0	0
South River/Selby Bay	0	0
W. Chesapeake Bay/Tracy and Rockhold Creeks	0	0
West River Mainstem	0	0
West River/Parish Creek	1	100

- **Elimination of illicit connections:** The County currently conducts field screening of outfalls to identify illicit connections from residences and businesses. This is required to meet the County's NPDES MS4 permit requirement. As a part of this program, approximately 150 outfalls are sampled every year, and all identified illicit connections are enforced/eliminated immediately. Based on the County-provided data from 2005 to 2013, the rate of illicit connections detection/elimination is approximately 2 percent (29 cases out of 1,350 outfalls surveyed). Assuming the County will continue the illicit detection/elimination program at the same rate in the future, an average of 41 percent of outfalls would be surveyed by 2020 in all the TMDL watersheds, and all identified illicit connections are assumed to be eliminated. This proposed rate was input into the "Illicit Connection Removal" option under the future management practices of the WTM to quantify the load reductions from this strategy.

Tier B Strategies

Urban stormwater retrofits in Tier B strategies were categorized into: Restoration of 20 Percent of Currently Unmanaged impervious Cover and Retrofit of Pre-2002 Ponds to Meet Current MDE Stormwater Criteria. This strategy was developed based on the Anne Arundel County's Urban Phase II Watershed Implementation Plan (2012) and requirements of the current NPDES MS4 Permit. The current NPDES MS4 Permit requires the County to treat 20% of the impervious area that currently has limited/no stormwater management. Even though the impervious areas draining to pre-2002 ponds can be categorized under impervious area with limited stormwater management and can be counted towards the NPDES MS4 impervious area restoration goals, they are not merged with the "Restoration of 20 Percent of Currently Unmanaged Impervious Cover" strategy in this restoration plan. This was done so that cost-benefits of retrofitting ponds and implementing new practices in untreated areas can be compared and a combination of options can be selected by the County to meet the TMDL goals.

- **Restoration of 20 Percent of Currently Unmanaged Impervious Cover:** This Tier B strategy included implementing stormwater management practices to restore 20% of the impervious area that currently does not have adequate stormwater controls. Stormwater management practices with high bacteria removal efficiency such SPSCs and infiltration practices are proposed to be implemented. This proposed restoration measure is based on the County's NPDES MS4 permit requirements that require restoration of 20% of untreated impervious area by the end of the permit term i.e. 2019. Table A-13 provides information on the 20% of the untreated impervious cover that is proposed to be treated by this strategy.
- **Retrofit of Pre-2002 Ponds to Meet Current MDE Stormwater Criteria:** This strategy involved retrofitting all the pre-2002 dry ponds with more than 10 acres of drainage area to meet the current Maryland Stormwater Design criteria, thereby improving their bacteria removal efficiency to 75%-90%. This strategy is concurrent with the County's Phase II WIP (2012). The dry ponds are proposed to be upgraded to practices such as wetlands or step pool conveyance systems (SPCS). The drainage area for the dry ponds was obtained from the County GIS and IMP database. Based on County's direction, an impervious cover of 50% was assumed for all the drainage areas that were missing impervious cover information. The IMP database included several dry ponds in the TMDL watersheds where the drainage area was not populated. These ponds were not included in the restoration strategy. Table A-13 provides information on the number of dry pond retrofits proposed in each watershed and the area that would be treated.

The two proposed urban stormwater retrofit strategies were input in the "Retrofit Worksheet" of the WTM to estimate the load reductions that would be achieved from this strategy. The load reductions were further adjusted based on the assumptions that the proposed practices would capture 90 percent of annual rainfall, the County has design criteria that will result in high pollutant removal efficiencies for practices (1.2), and that regular maintenance of the practices will be enforced and conducted by the County (0.9).

Table A-13: Proposed Urban Stormwater Retrofits in the TMDL Watersheds

Bacteria TMDL Watershed	No. of Dry Ponds	Impervious Area Treated by Dry Pond Retrofits (acres)	Impervious Area Treated by NPDES Requirement (acres)
Magothy Mainstem	8	255.4	351.6
Magothy River/Forked	0	0	25.5
Magothy River/Tar Cove	0	0	51.5
Patapsco Lower North Branch	5	51.9	491.5
Patapsco River/Furnace Creek	8	301.4	427.1
Patapsco River/Marley Creek	11	128.6	368.5
Patuxent River Upper	0	0	77.0
Rhode River/Bear Neck Creek	0	0	19.7
Rhode River/Cadle Creek	0	0	11.6
Severn River Mainstem	13	559.1	877.4
Severn River/Mill Creek	3	35.5	43.1
Severn River/Whitehall and Meredith Creek	0	0	44.6
South River Mainstem	14	293.4	349.1
South River/Duvall Creek	0	0	25.2
South River/Ramsey Lake	0	0	13.6
South River/Selby Bay	0	0	13.2
W. Chesapeake Bay/Tracy and Rockhold Creeks	0	0	74.2
West River Mainstem	0	0	73.2
West River/Parish Creek	0	0	11.2

- **Riparian Buffer Education:** This Tier B strategy aims at improving the buffer areas along the stream by implementing a riparian buffer education program for private property owners adjacent to buffer areas. The education programs will include buffer enhancement components such as no mow areas, planting trees and shrubs and promoting growth of native vegetation. The pollutant load reductions from this strategy were obtained by adjusting the buffer maintenance factor to 0.9 in future management practices of WTM indicating the County would have implemented a buffer education program.

The expected pollutant load reductions from Tier A and Tier B strategies that were quantified using WTM are provided in Table A-14 below.

Table A-14: Bacteria Load Reductions from Proposed Tier A and Tier B Strategies that Were Quantified Using WTM

Bacteria TMDL Watershed	Expected % Load Reduction					
	Septic Retirement/ Connection	Abatement of SSOs	Urban Stormwater Retrofits (Pre 2002-Pond Retrofits)	Urban Stormwater Retrofits (Restore 20% Untreated Impervious Area)	Eliminate Illicit Connections	Buffer Ordinance/Education
Magothy Mainstem	13.55	1.12	4.7	4.48	8.74	0.91
Magothy River/Forked	6.14	12.40	-	7.02	1.13	1.93
Magothy River/Tar Cove	25.25	-	-	3.76	0.67	1.02
Patapsco Lower North Branch	5.60	4.90	1.26	6.59	11.60	2.99
Patapsco River/Furnace Creek	3.38	3.5	8.16	9.00	7.72	1.47
Patapsco River/Marley Creek	-	2.04	4.47	8.42	10.82	1.63
Patuxent River Upper	16.45	-	-	5.42	0.85	17.20
Rhode River/Bear Neck Creek	-	2.50	-	6.82	0.50	0.11
Rhode River/Cadle Creek	-	8.40	-	9.40	0.30	0.80
Severn River Mainstem	10.56	0.36	3.10	3.90	19.02	1.56
Severn River/Mill Creek	34.70	0.20	4.34	4.20	1.54	2.80
Severn River/Whitehall and Meredith Creek	21.10	-	-	4.20	0.9	2.24
South River Mainstem	15.60	0.30	3.73	3.60	11.30	8.00
South River/Duvall Creek	-	6.40	-	9.13	0.65	-
South River/Ramsey Lake	-	-	-	2.90	0.11	0.14
South River/Selby Bay	-	-	-	3.20	0.16	0.06
W. Chesapeake Bay/Tracy and Rockhold Creeks	-	-	-	2.60	0.23	8.20
West River Mainstem	-	-	-	8.30	1.21	11.54
West River/Parish Creek	-	12.90	-	10.50	0.19	0.46

A.5 REFERENCES

Anne Arundel County. 2010. Marinas of Anne Arundel County.

Anne Arundel County. 2013. National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System Discharge Permit 2012 Annual Report: Anne Arundel County, Maryland. Available online at: http://www.aacounty.org/DPW/Watershed/2012%20NPDES%20Documents/2012%20Anne%20Arundel%20Annual%20Report_No%20Appendices.pdf

Anne Arundel County. 2014. National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System Discharge Permit 2013 Annual Report: Anne Arundel County, Maryland. Available online at: http://www.aacounty.org/DPW/Watershed/2012%20NPDES%20Documents/2012%20Anne%20Arundel%20Annual%20Report_No%20Appendices.pdfMaryland Department of the Environment. 2014. *MDE Guidance for Developing a Stormwater Wasteload Allocation Implementation Plan for Bacteria Total Maximum Daily Loads*.

Caraco, D. 2013. Watershed Treatment Model (WTM) 2013 "Custom" version. Center for Watershed Protection, Ellicott City, MD.

Caraco, D. 2013a. Watershed Treatment Model (WTM) 2013 Documentation. Center for Watershed Protection, Ellicott City, MD. Pages 1-114

Maryland Department of Natural Resources (MD DNR), Pumpout Locations in Maryland http://www.dnr.state.md.us/boating/pumpout/locations.asp (visited November 2014)

Natural Resources Conservation Services (NRCS), US Department of Agriculture, (USDA) *Soil Survey Geographic (SSURGO)* database. 2014.

Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.