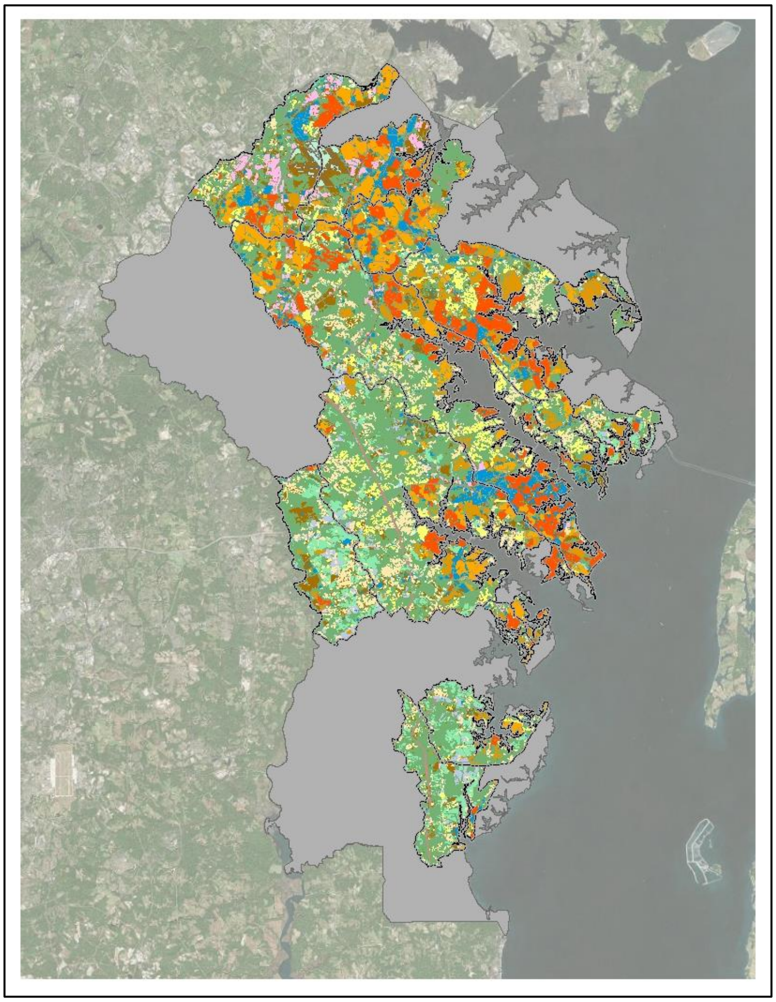
Draft Total Maximum Daily Load Restoration Plan for Bacteria

For Public Comment



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URS ESA JOINT VENTURE

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AACC	Anne Arundel Community College
AACCMP	Anne Arundel County Citizen Monitoring Program
AASCD	Anne Arundel County Soil Conservation District
BMP	best management practice
CIP	Capital Improvement Program
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
MDA	Maryland Department of Agriculture
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
USFWS	U.S. Fish and Wildlife Service
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 (WPRP) developed this restoration plan to address local water quality impairments for watersheds with an approved bacteria 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 watersheds. MDE developed most of the TMDLs in the early 2000s. 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 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 recommended that the target areas for the pet waste program be prioritized 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. 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.

An additional Tier B strategy is the County's effort to comply with the County's NPDES MS4 Permit (11-DP-3316, MD0068306) that requires the County to 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 Chesapeake Bay TMDL Phase II Watershed

Implementation Plan [Phase II WIP]) suggests this will be accomplished by implementing new and retrofit stormwater projects such as conversion of pre-2002 dry ponds and other stormwater management facilities to shallow wetland/marsh filtering systems and step pool storm conveyance (SPSC) retrofits at impaired stream channels and outfalls. Currently 132 CIP projects are identified in the TMDL watersheds that would include implementation of outfall and pre-2002 stormwater management retrofits. As the County continues to implement additional CIP projects, additional bacteria load reductions would be achieved.

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 CIP (e.g., wastewater capital improvement projects or septic system retirement).

Overall, it is clear that a suite of strategies in combination are necessary 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 only 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 deleterious ecological impacts and potentially cause 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 they indicate 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 waste).

> After rainfall, all Anne Arundel County beaches are under a no swimming/no direct water contact advisory for at least 48 hours due to predicted high bacterial levels.
>
> (Source: http://www.aahealth.org/programs/env-hlth/rec-water)

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. According to COMAR 26.08.02.03-3, 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.

In the early 2000s, these monitoring data were used to develop the fecal coliform bacteria Total Maximum Daily Loads (TMDLs) for 19 bacteria-impaired waters in the County. 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. 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 (Figure 1-1). 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*. 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.

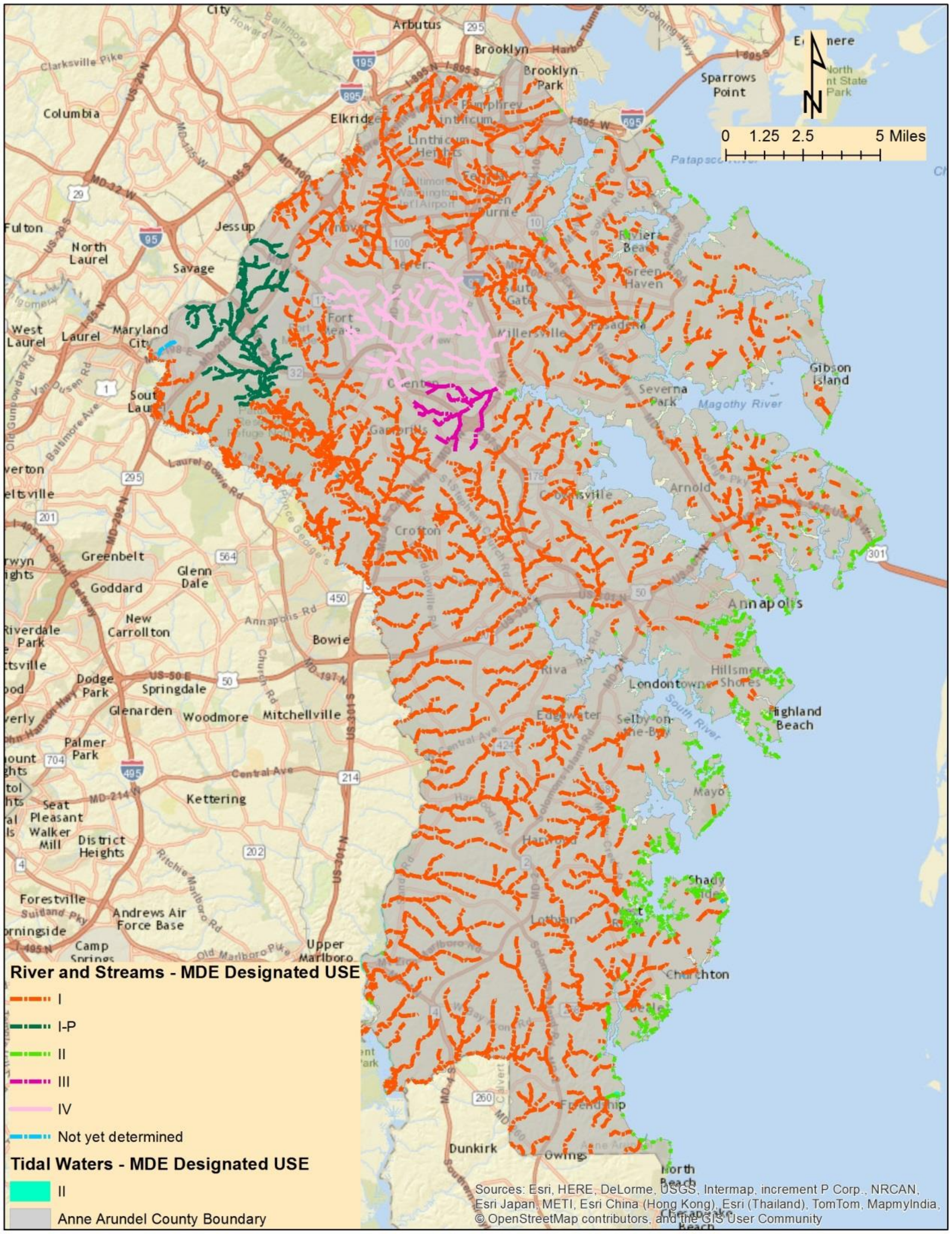

Figure 1-1: MDE Designated Uses for Surface Waters in Anne Arundel County

1.1 DEFINITION OF A TMDL

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

1.2 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 1-2. 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.

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 TMDL watersheds (i.e., Patapsco River Lower North Branch and Patuxent River Upper) are located entirely within the County.

1.3 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 to address SW-WLA allocated by MDE and approved by EPA. Once approved by MDE, the Restoration Plan is enforceable under the NPDES MS4 permit.

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
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 1-2: Location of Bacteria TMDL Watersheds

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)
b. An estimate of the load reductions expected from management measures (Section 4.3)
c. Description of management measures needed (Section 4.1)
d. Financial and technical assistance needed to implement the above management measures (Section 6)
e. Information and education activities to enhance public understanding of the Restoration Plan and encourage the public's participation (Section 5)
f. Schedule for implementing the above management measures (Section 7)
g. Description of interim measurable milestones to determine whether the above management measures are being implemented (Section 7)
h. Set of indicators to evaluate progress toward water quality standards (Section 8)
i. Monitoring program to evaluate effectiveness of implementation efforts (Section 8)

1.4 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, yards where dog waste is not routinely cleaned up). According to a fact sheet published by Clear Choices Clean Water, 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) and the MDE published TMDL documents, 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 pump-out 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 (up to 50 percent removal efficiency), and high-performing (70 percent or greater removal efficiency). Drainage areas for the BMPs were obtained using the County GIS data. 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 new information becomes available.

The bacteria removal efficiency for each type of practice was compiled from various literature sources (provided at the end of Table 2-2). Based on review of various literature sources, infiltration and filtering practices such as infiltration trenches, bioretention systems, step pool storm conveyance systems (SPSC), and environmental site design (ESD) practices have high bacteria removal efficiencies. Stormwater management practices that provide limited water quality management, such as permeable pavements and sand filters, are mid-performing BMPs in terms of bacteria removal efficiency. Hydrodynamic structures and grass swales 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
Bioretention	70[2]	high-performing
Detention Structure Dry (Dry Pond)	88[1]	high-performing
Disconnection of Non-Rooftop Runoff	0[10]	non-performing
Disconnection of Rooftop Runoff	0[10]	non-performing
Dry Swale	0[6]	non-performing
Dry Wells	96[3]	high-performing
Extended Detention Structure, Dry	88[1]	high-performing
Extended Detention Structure, Wet	70[1]	high-performing

BMP Type	Bacteria Pollutant Removal Efficiency (%)	Category
Forestation on Pervious Areas	42[5]	mid-performing
Grass Swale	0[6]	non-performing
Green Roof	0[11]	non-performing
Impervious Surface Elimination	0[10]	non-performing
Infiltration Basin	96[3]	high-performing
Infiltration Berms	96[3]	high-performing
Infiltration Trench	96[3]	high-performing
Landscape Infiltration	96[3]	high-performing
Level Spreader	0[9]	non-performing
Micropool Extended Detention Pond	70[1]	high-performing
Oil-Grit Separator	0[7]	non-performing
Other	0[7]	non-performing
Permeable Pavements	37[1]	mid-performing
Rain Gardens	70[2]	high-performing
Rain Water Harvesting	0[10]	non-performing
Retention Pond	70[1]	high-performing
Sand Filter	37[1]	mid-performing
Shallow Marsh	78[1]	high-performing
Sheetflow to Conservation Areas	42[5]	mid-performing
Step Pool Conveyance System	70[4]	high-performing
Stream Restoration	0[10]	non-performing
Submerged Gravel Wetland	78[1]	high-performing

[1] Fraley-McNeal, L., Schueler, T., Winer, R. 2007. National Pollutant Removal Performance Database - Version 3. Center for Watershed Protection, Ellicott City, MD.
[2] Hunt, W. F., Smith, J.T., Jadlocki, S.J., Hathaway, J.M., Eubanks, P.R., 2008. Pollutant Removal and Peak Flow Mitigation by a Bioretention Cell in Urban North Carolina. Biological and Agriculture Engineering, North Carolina State University, Raleigh, NC.
[3] Birch, G. F., Fazeli,M.S., Matthai, C., 2006. Efficiency of an Infiltration Basin in Removing Contaminants from Urban Stormwater. Environmental Geology Group School of Geo Sciences, University of Sydney, Sydney, Australia.
[4] According to Accounting for Wasteload Allocations and Impervious Acres Treated (MDE, 2014d) , Step Pool Storm Conveyance (SPSC) function similar to bioretention and efficiencies of bioretention basins can be used (Page 48). Therefore, efficiency will be the same as that of bioretention, which is 70%.
[5] Parajuli P.B., K.R.Mankin, P.L. Batnes, 2008. Applicability of targeting vegetative filter strips to abate fecal bacteria and sediment yield using Soil and Water Assessment Tool SWAT.
[6] http://water.epa.gov/polwaste/npdes/swbmp/Grassed-Swales.cfm.
[7] Hathaway, J.M., W.F. Hunt, and S.J. Jadlocki. 2009. "Indicator Bacteria Removal in Stormwater Best Management Practices in Charlotte, North Carolina." *Journal of Environmental Engineering*, 135(12), 1275-1285.
[8] Green roofs filter runoff in a similar way to bioretention systems, so a removal efficient of 70% assumed.
[9] http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-02-020.pdf.
[10] Substantial data not available; therefore, 0 was used.
[11] Stormwater captured by green roofs has negligible bacteria concentrations; therefore, 0 was used.

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 2-1and 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%

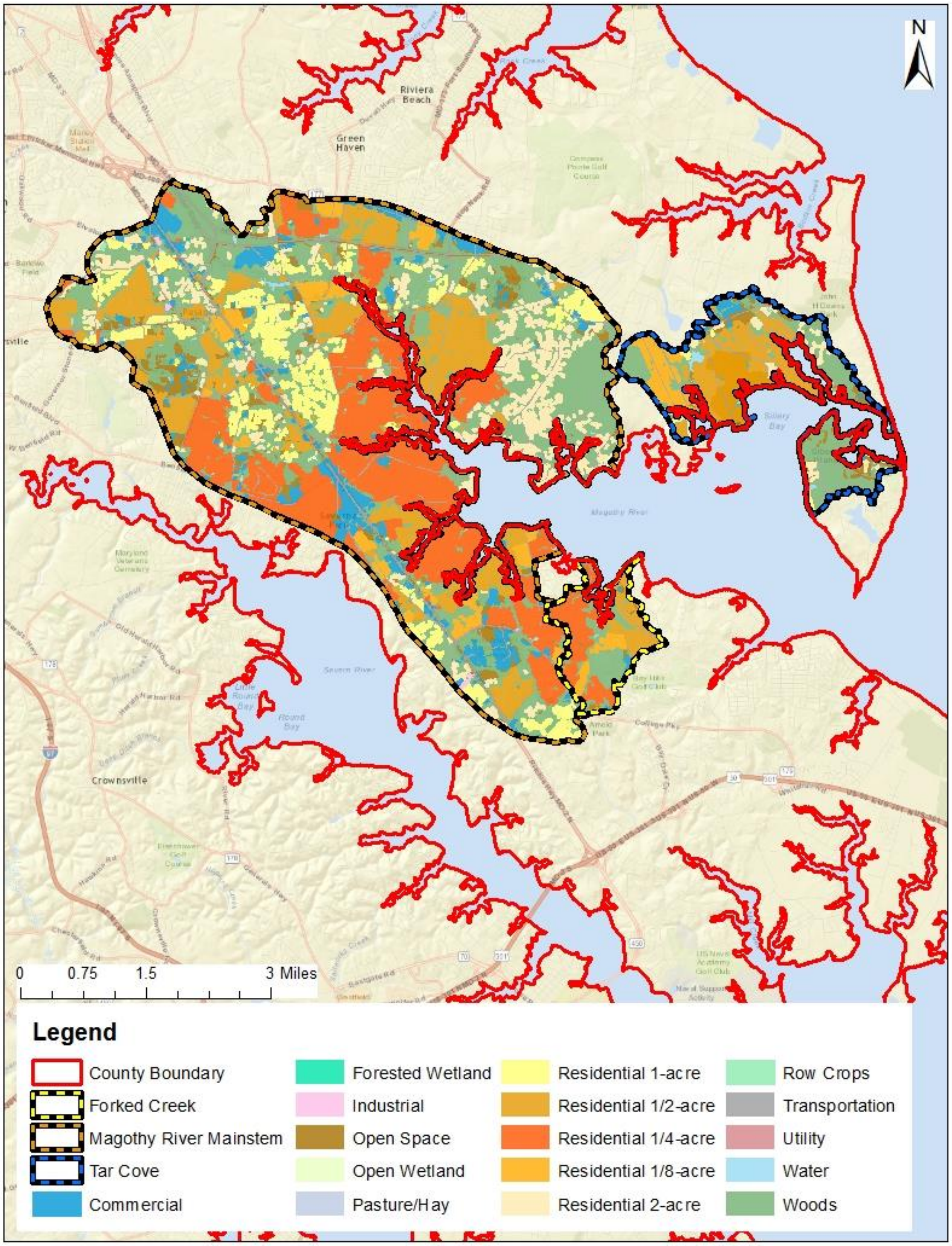

Figure 2-1: Land Use Map of Magothy River Watershed

The Magothy River Mainstem has 1,288 existing BMPs, Tar Cove has 132, and Forked Creek has 87, most of which are high-performing BMPs with 70 percent or greater bacteria removal efficiency (Table 2-4). In 2015, County completed approximately eight projects in the Magothy River Watershed and one project in the Forked Creek Watershed as a part of its Capital Improvement Program (CIP). The projects in the Magothy River Watershed involved converting old stormwater management facilities to wet ponds to comply with current MDE stormwater management standards, and the project in Forked Creek included retrofitting an existing outfall to a SPSC.

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	96	80	1,112	37 (3%)	1,288
Magothy River/Forked Creek	1	4	82	1 (1%)	87
Magothy River/Tar Cove	9	31	92	0 (0%)	132

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). 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 2-1and 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 State-owned Baltimore-Washington International Airport occupies a large portion of this watershed.

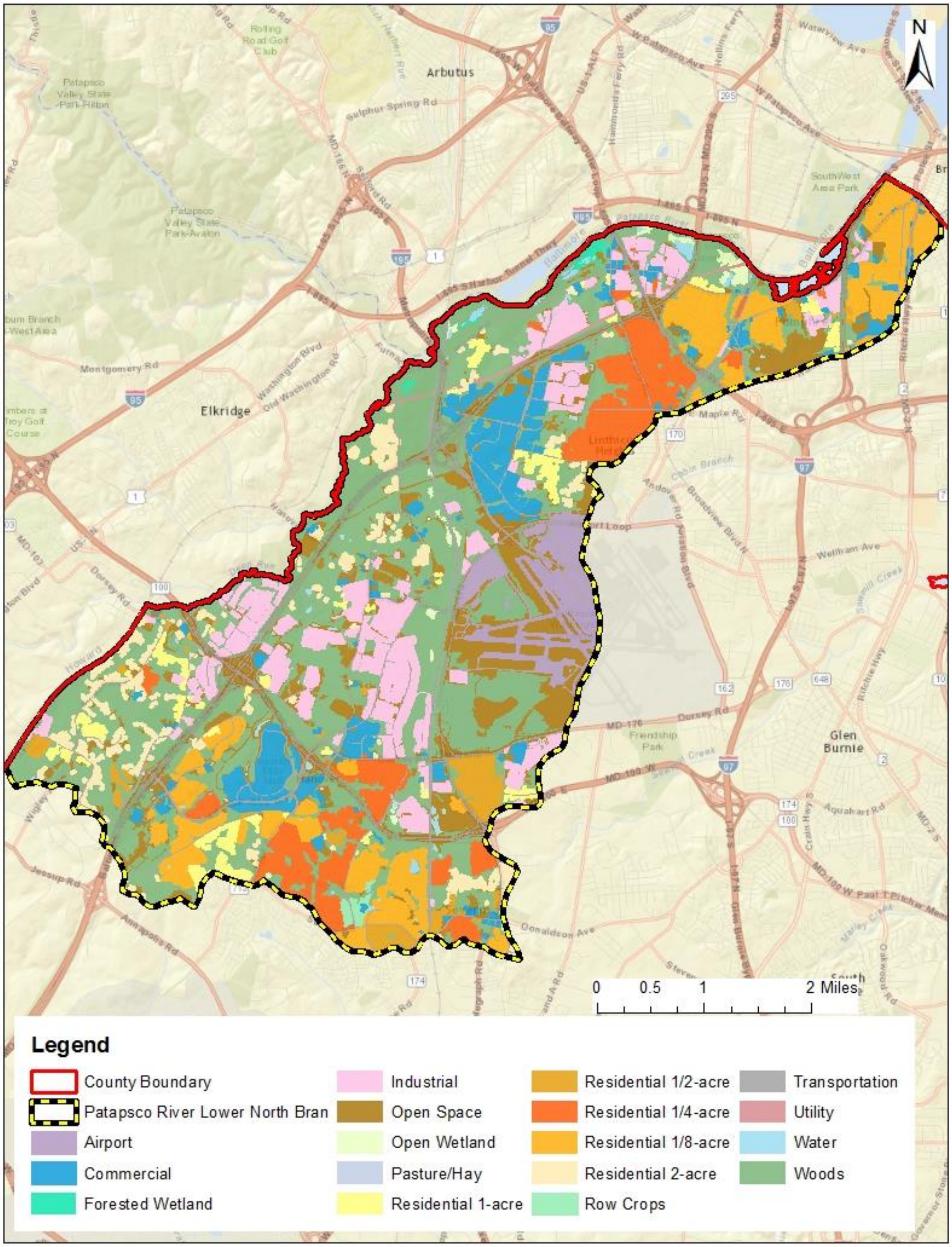

Figure 2-2: Land Use Map of the Patapsco River Lower North Branch Watershed

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

As a part of its 2015 CIP projects, the County has restored approximately 200 linear feet of stream at Leeds Road; however, the project will not reduce bacteria loads.

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	35	77	489	10 (2%)	601

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 2-1and Figure 2-3), and are each about 30 percent impervious. Some developments in these watersheds date back to the 1940s (Anne Arundel County, 2012b).

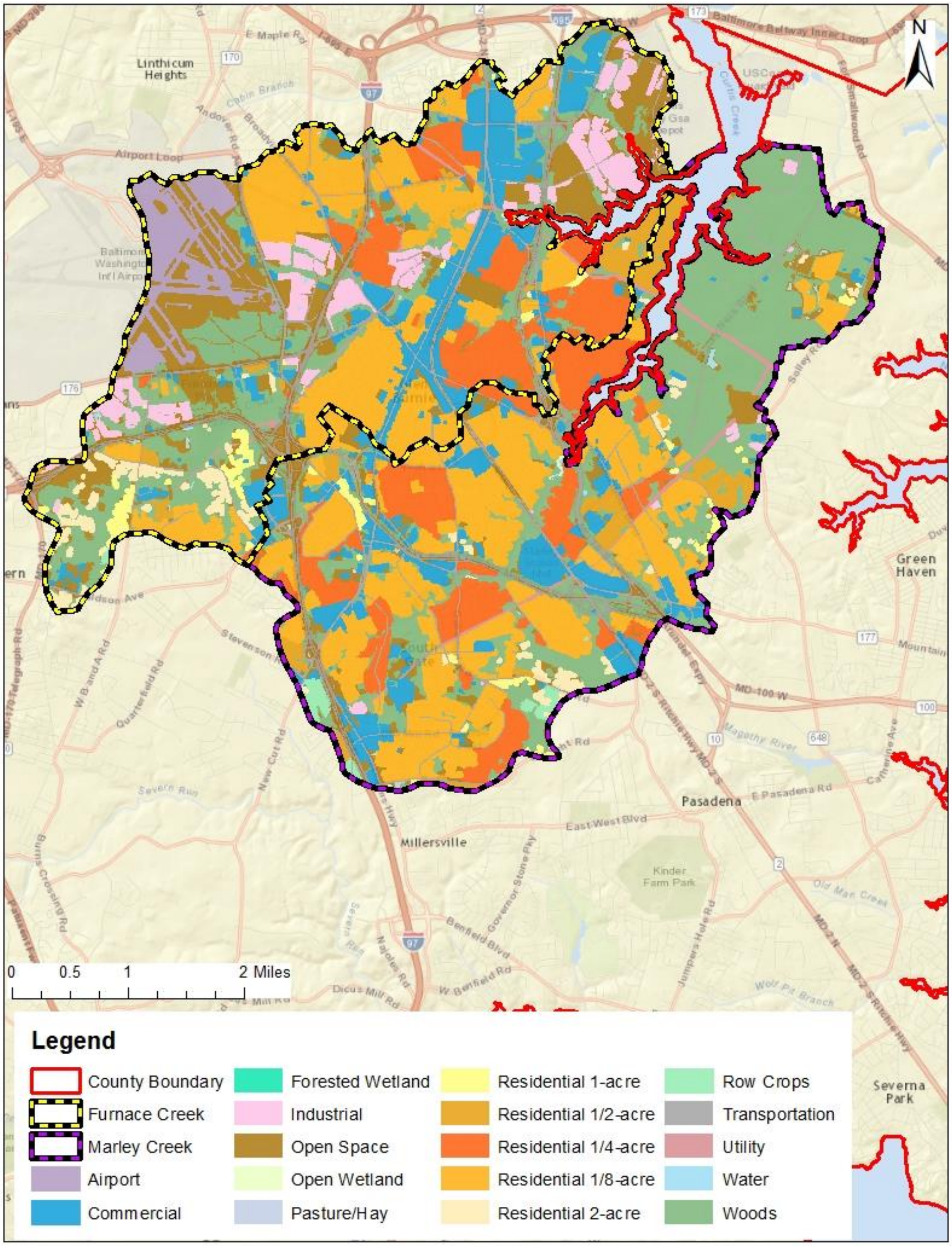

Figure 2-3: Land Use Map of the Furnace Creek and Marley Creek Watersheds

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 identified 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 430 and 556 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. Four percent of the existing BMPs in the Furnace Creek Watershed and 3 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	45	26	359	19 (4%)	430
Marley Creek	49	40	467	15 (3%)	556

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 2-1and 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 122 existing BMPs in the Patuxent River Upper Watershed (Table 2-10). Of these, 99 are high-performing BMPs for bacteria. Three 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	16	7	99	4 (3%)	122

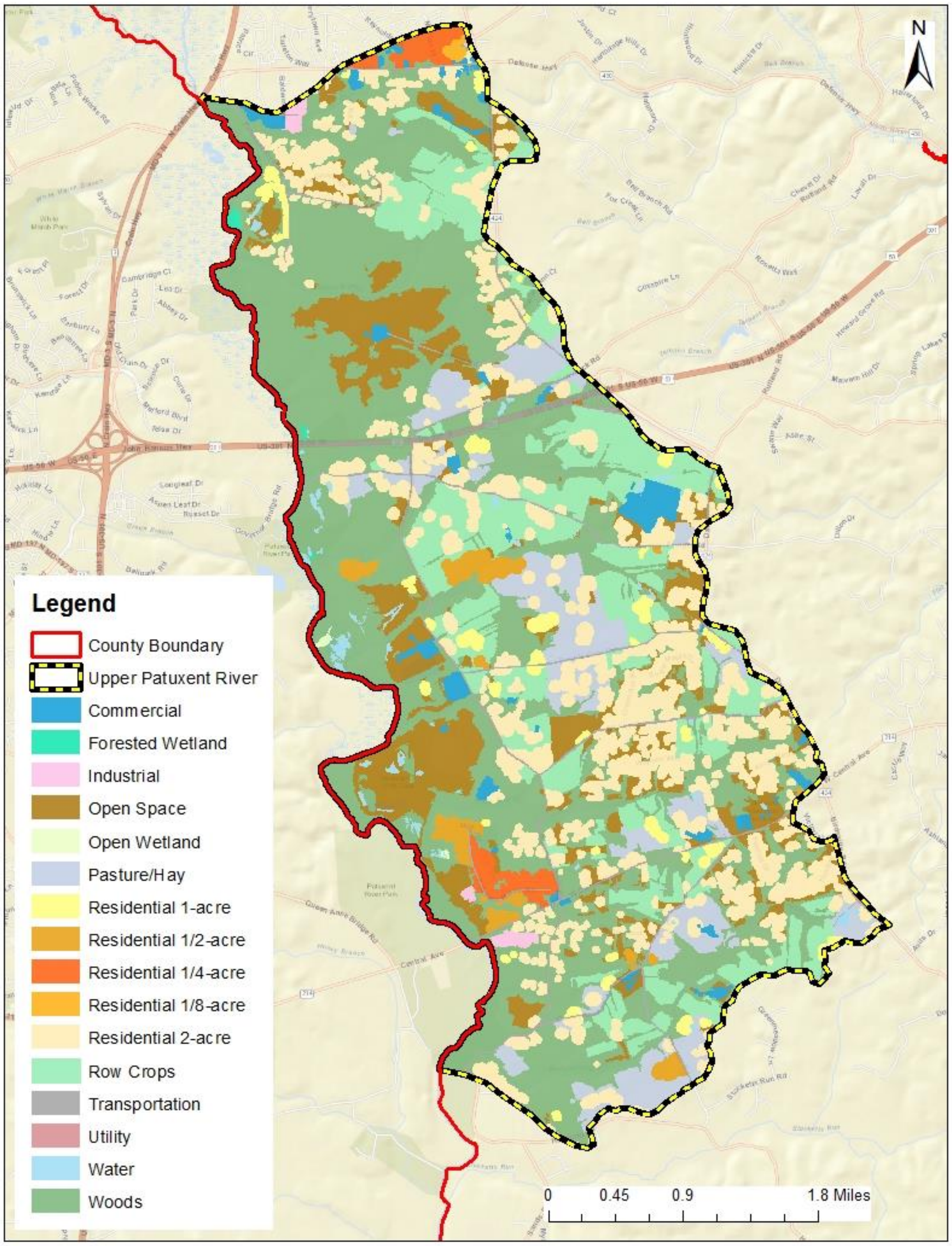

Figure 2-4: Land Use Map of the Patuxent River Upper Watershed

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 2-1and 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 and Cadle Creeks from the MDE’s TMDL report (MDE, 2005g) is 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 should also be noted that a sizeable co-educational summer residence camp and conference center is located within both the Bear Neck Creek watershed and the adjacent Sellman Creek watershed. Equestrian facilities associated with this camp, however, are primarily within the Sellman Creek drainage area. Therefore, it may be that livestock sources are somewhat less of a factor now than when the TMDL data were collected. 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 75 existing BMPs and the Cadle Creek Watershed has 55 existing BMPs (Table 2-12). These two are among the watersheds for which the County is currently updating the drainage area database for the BMPs. One restoration project in the Bear Neck Creek Watershed is the Ponder Cove storm drain retrofit project in the Holly Hill Harbor community. The County was able to retrofit about 40 linear feet of storm drain pipe with perforated pipe to facilitate infiltration. The total drainage area treated by this retrofit 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	4	16	55	2 (3%)	75
Cadle Creek	4	18	33	2 (4%)	55

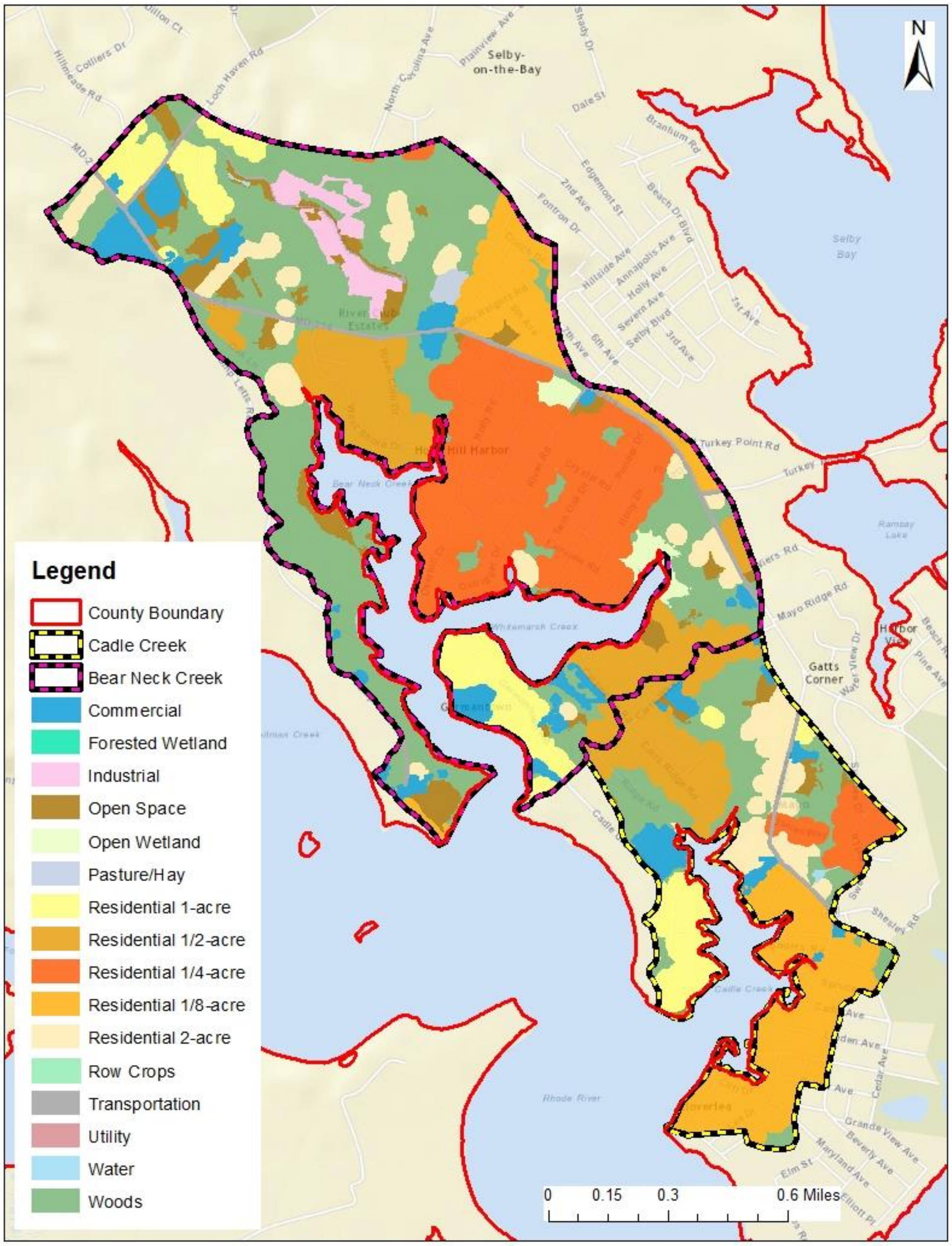

Figure 2-5: Land Use Map of the Bear Neck Creek and Cadle Creek Watersheds

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 2-1and Figure 2-6). Approximately 20 percent of the watershed is impervious.

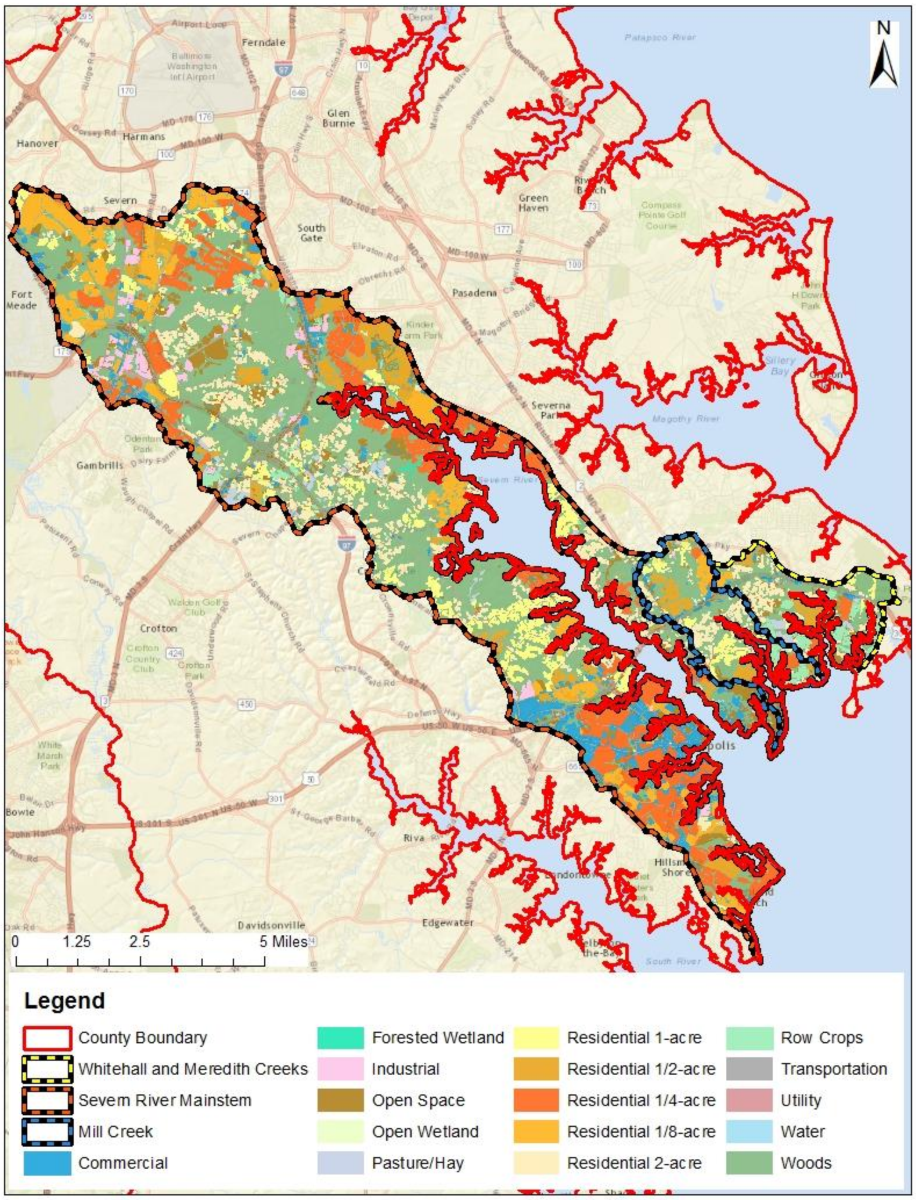

Figure 2-6: Land Use Map of the Severn River Mainstem, Mill Creek, and Whitehall-Meredith Creeks Watersheds

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 1,995 existing BMPs, which include 1,675 high-performing BMPs (Table 2-14). The Mill Creek Watershed has 225 existing BMPs of which 200 are high-performing. The Whitehall/Meredith Creek Watershed has 136 existing BMPs with 113 high-performing BMPs. The number of BMPs without drainage area data is provided in Table 2-14.

The County implemented six projects in 2015 in the Severn River Watershed as a part of its CIP projects. Two of the CIP projects included converting extended detention dry ponds to wet ponds and the remaining four involved installing SPSCs.

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	123	197	1,675	113 (6%)	1,995
Mill Creek	16	9	200	19 (8%)	225
Whitehall/Meredith Creeks	6	17	113	9 (7%)	136

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).

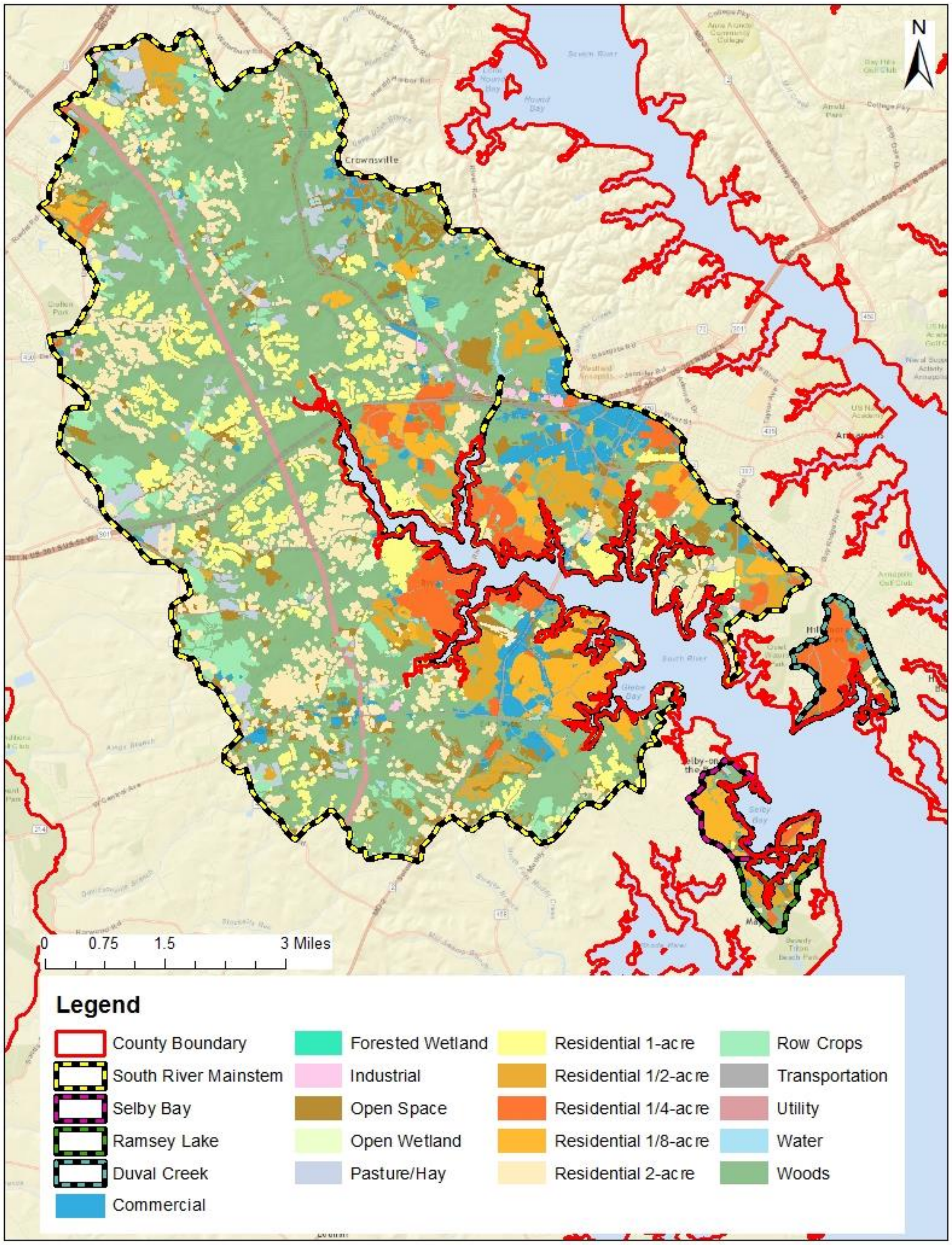

Figure 2-7: Land Use Map of the South River Mainstem, Duvall Creek, Ramsey Lake, and Selby Bay Watersheds

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 1,329 existing BMPs (Table 2-16), of which 1,066 are high-performing; these are mainly infiltration type BMPs with 96 percent bacteria removal efficiency. Duvall Creek and Ramsey Lake also have high-performing BMPs, which make up 71 percent and 70 percent of the total BMPs in the respective watersheds. In Selby Bay, 41 percent of BMPs are high-performing and 47 percent are mid-performing.

As a part of its 2015 CIP, the County implemented two projects in the South River Watershed involving converting an existing extended detention dry pond to a wet pond and installing an SPSC. One project was implemented in Duvall Creek that converted an existing extended detention dry pond to a wet pond.

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	79	184	1,066	46 (3%)	1,329
Duvall Creek	4	10	34	1 (2%)	48
Ramsey Lake	4	15	44	0 (0%)	63
Selby Bay	10	38	33	0 (0%)	81

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.

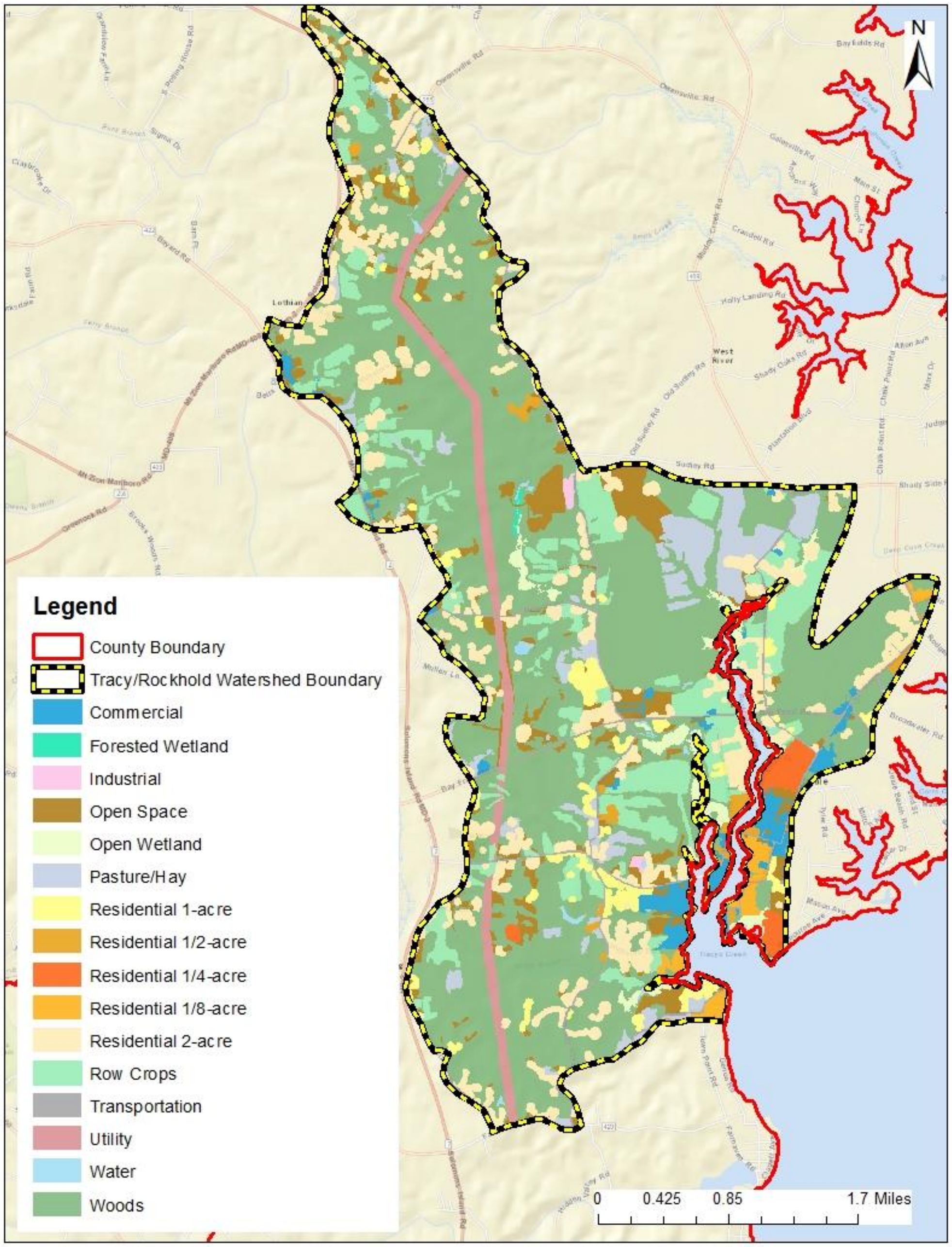

Figure 2-8: Land Use Map of the Tracy and Rockhold Creeks Watershed

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 70 existing BMPs in the watershed (Table 2-18). Thirty-five of them are high-performing BMPs with 70 percent or greater bacteria removal efficiency. Drainage area data are unavailable for 9 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	15	20	35	6 (9%)	70

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 2-1and Figure 2-9). Imperviousness is relatively low compared to the other watersheds in the County with bacteria impairment 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.

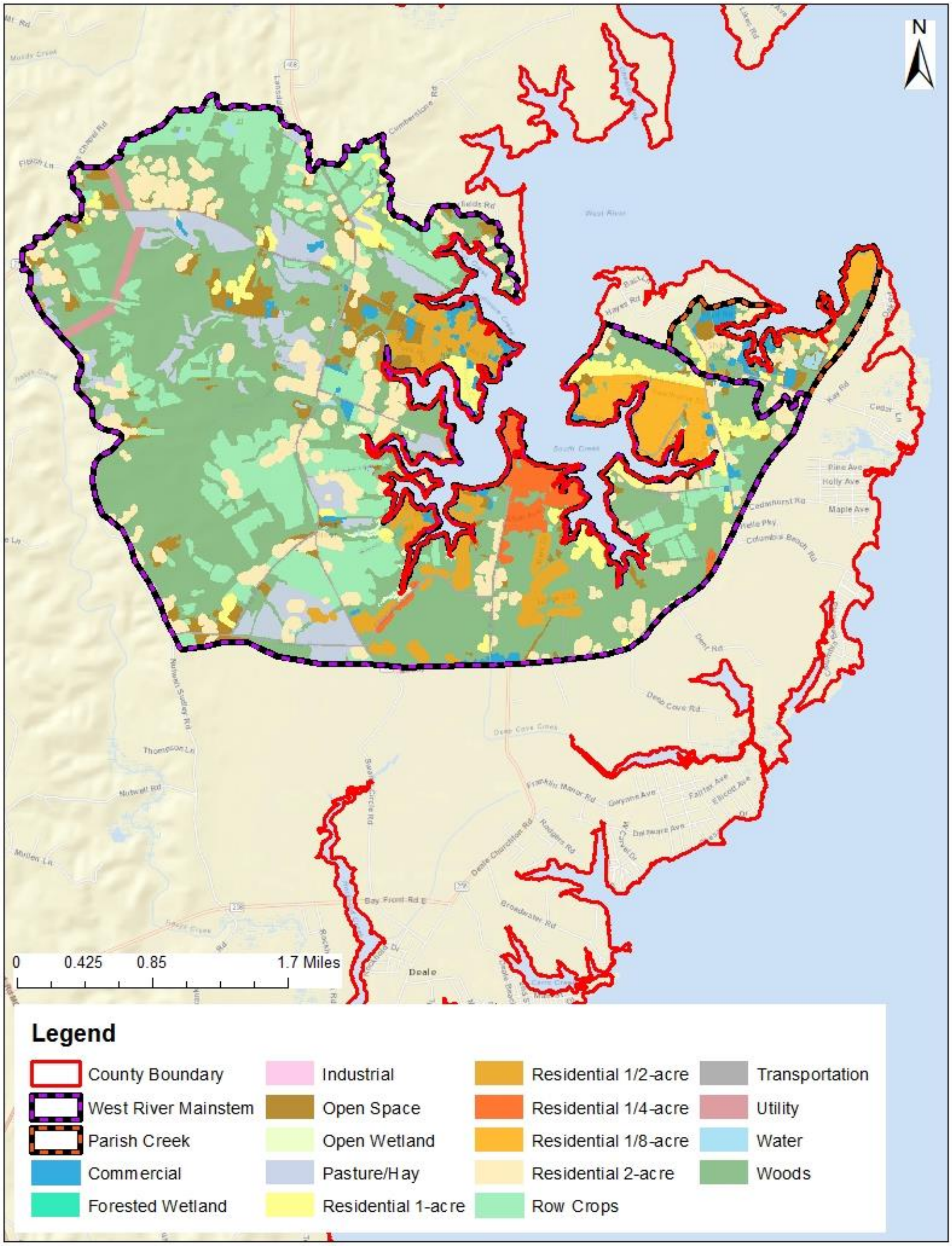

Figure 2-9: Land Use Map of the West River Mainstem and Parish Creek Watersheds

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 Watershed 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 134 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 (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	13	53	68	9 (7%)	134
Parish Creek	4	6	5	1 (7%)	15

2.10 DEVELOPMENT OF EXISTING CONDITIONS WATERSHED TREATMENT MODEL

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 2013a and b) 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
- 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 watersheds in this restoration plan
- Patuxent River, just upstream of the Patuxent River Upper; it is not part of any watersheds in this restoration plan

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 12.8 percent reduction to 90 percent reduction among the 19 TMDL watersheds (average 51 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 MDE published TMDL documents for each watershed set a reduction goal, which is allocated to point and nonpoint sources. As a part of the NPDES MS4 requirements, MDE has set goals for SW-WLAs for all watersheds in Anne Arundel County with bacteria TMDLs. These SW-WLAs are provided in the MDE's WLA search portal.

Seventeen of the 19 TMDL watersheds are located entirely in the Anne Arundel County, therefore the overall watershed level reduction goals published in the MDE TMDL documents for the 17 watersheds with the exception of South River TMDL watersheds is the same as the SW-WLAs provided in the MDE's WLA search portal. For South River TMDL watersheds, including South River Mainstem, Duvall Creek, Selby Bay and Ramsey Lake, the required load reductions presented in the MDE published TMDL document do not match the SW-WLAs goals provided in the MDE's WLA search portal. For all the South River TMDL watersheds, except for Duvall Creek, the reduction requirements published in MDE's SW-WLAs portal are higher compared to the reductions published in the TMDL document. This discrepancy is noted in Table 3-1. For these watersheds, the reduction requirement provided in the TMDL documents is used as the ultimate reduction requirements.

The TMDL reduction requirements for Tar Cove and Selby Bay watersheds are higher than the loads at the time of TMDL development, resulting in no reduction requirements for these watersheds as noted in the last two columns of Table 3-1. However, restoration strategies have been proposed for both the watersheds to prevent future bacteria impairment of these watersheds.

As Patapsco Lower North Branch Watershed and Patuxent River Upper Watersheds are located in multiple counties, the reduction requirement for Anne Arundel County was scaled based on the loads contributed from the Anne Arundel County portion of these watersheds. The load reduction requirement for Anne Arundel County portion of these watersheds is shown below.

SWA-WLA Reduction Requirements for the Anne Arundel County Portion of the Patapsco Lower North Branch Watershed:

- Stormwater baseline loads for Anne Arundel County: 60,361 billion MPN/year[a]
- Stormwater allocations for Anne Arundel County: 47,814 billion MPN/year[b]
- SW-WLA goals for Anne Arundel County: (60,361-47,814)/60,361=**20.7%**

Source:

[a] – From table 4.9.2 of the MDE document "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 2009
[b] – From table 4.9.3 of the MDE document "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 2009

SWA-WLA Reduction Requirements for the Anne Arundel County Portion of the Patuxent River Upper Watershed:

- Stormwater baseline loads for Anne Arundel County: 50,616 billion MPN/year[c]
- Stormwater allocations for Anne Arundel County: 39,283 billion MPN/year[d]
- SW-WLA goals for Anne Arundel County: (50,616-39,283)/50,616=**22.3%**

Source:

[a] – From table 4.9.2 of the MDE document "Total Maximum Daily Loads of Fecal Bacteria for the Patuxent River Upper Basin in Anne Arundel and Prince George's County, Maryland", September 2010
[b] – From table 4.9.2 of the MDE document "Total Maximum Daily Loads of Fecal Bacteria for the Patuxent River Upper Basin in Anne Arundel and Prince George's County, Maryland", September 2010

The data presented in the Table 3-1 were obtained from the MDE-published TMDL reports for each watershed and the MDE's WLA search portal; and include the percent reductions required to restore the designated use and water quality of the waterways. The ultimate goals used for this restoration plan are provided in farthest right column and represent the end point of implementation for the County.

Table 3-1: TMDL Reduction Goals for Bacteria

TMDL Watershed	Impairment	TMDL Baseline Year[a]	TMDL Baseline Year Load[b]	Unit	TMDL Allowable Load[c]	Unit	SW-WLAs for the County[d] (percent)	Overall Watershed Reduction Requirement[e] (percent)	Target Reduction Requirement Used for this Plan (percent)
Magothy Mainstem	Fecal Coliform	2001	4.97×10^{12}	counts/day	4.33×10^{12}	counts/day	12.8	12.8	12.8
Magothy River/Forked Creek	Fecal Coliform	2001	1.83×10^{11}	counts/day	1.35×10^{11}	counts/day	26.3	26.3	26.3
Magothy River/Tar Cove	Fecal Coliform	2001	9.82×10^{11}	counts/day	2.07×10^{12}	counts/day	0.0	0.0	0.0
Patapsco River/Furnace Creek	Enterococci	2006	3.66×10^{12}	counts/day	8.14×10^{11}	counts/day	77.7	77.7	77.7
Patapsco River Lower North Branch	E. Coli	2003	2.37×10^{15}	MPN/year	1.99×10^{15}	MPN/year	20.7	16[f]	20.7
Patapsco River/Marley Creek	Enterococci	2006	6.19×10^{12}	counts/day	1.50×10^{12}	counts/day	75.7	75.7	75.7
Patuxent River Upper	E. Coli	2009	1.20×10^{16}	MPN/year	6.01×10^{15}	MPN/year	22.3	49.9[g]	22.3
Rhode River/Bear Neck Creek	Fecal Coliform	2001	3.55×10^{11}	counts/day	2.01×10^{11}	counts/day	43.3	43.3	43.3
Rhode River/Cadle Creek	Fecal Coliform	2001	3.54×10^{11}	counts/day	9.85×10^{10}	counts/day	72.2	72.2	72.2
Severn River Mainstem	Fecal Coliform	2002	6.07×10^{12}	counts/day	4.92×10^{12}	counts/day	19.0	19.0	19.0
Severn River/Mill Creek	Fecal Coliform	2002	1.78×10^{12}	counts/day	2.49×10^{11}	counts/day	86.0	86.0	86.0
Severn River/Whitehall and Meredith Creek	Fecal Coliform	2002	4.92×10^{11}	counts/day	4.92×10^{10}	counts/day	90.0	90.0	90.0
South River/Duvall Creek	Fecal Coliform	2001	1.52×10^{11}	counts/day	8.27×10^{10}	counts/day	17.4[h]	45.6[i]	45.6
South River Mainstem	Fecal Coliform	2001	1.32×10^{13}	counts/day	9.31×10^{12}	counts/day	68.0[h]	29.5[i]	29.5
South River/Ramsey Lake	Fecal Coliform	2001	5.57×10^{11}	counts/day	2.27×10^{11}	counts/day	65.0[h]	59.3[i]	59.3
South River/Selby Bay	Fecal Coliform	2001	3.27×10^{11}	counts/day	3.75×10^{11}	counts/day	45.1[h]	0.0[i]	0.0
W. Chesapeake Bay/Tracy and Rockhold Creeks	Fecal Coliform	2001	1.67×10^{12}	counts/day	3.06×10^{11}	counts/day	81.6	81.6	81.6
West River Mainstem	Fecal Coliform	2001	1.77×10^{12}	counts/day	1.15×10^{12}	counts/day	35.3	35.3	35.3
West River/Parish Creek	Fecal Coliform	2001	2.56×10^{11}	counts/day	1.20×10^{11}	counts/day	53.1	53.1	53.1

[a, b ,c, e-] Based on the MDE published TMDL document for bacteria impaired watersheds in Anne Arundel County.
[d-] Based on the MDE published SW-WLAs for Anne Arundel County Storm Sewer System (from MDE TMDL Data Center: http://wlat.mde.state.md.us/ByMS4.aspx).
[f-] Overall watershed level reduction requirement and includes Anne Arundel, Baltimore, Carroll and Howard Counties and Baltimore City
[g-] Overall watershed level reduction requirement and includes Anne Arundel and Prince George's Counties
[h,i-] There is a discrepancy in bacteria load reduction requirements for South River TMDL watersheds from SW-WLAs provided in the MDE's WLA portal and from the MDE published TMDL documents.

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, 2012a). For example, retrofitting impaired pipe outfalls and degraded stream channels with SPSCs, a requirement of the WIP, has 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 70 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's) 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 and the MDE-published TMDL documents 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. Upgrades to all the County-owned WRFs have been implemented and are nearing completion. 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 have a low 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 approximately 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 2014, 32 illicit connections were detected out of 1,500 outfalls surveyed, as documented in the County's Annual NPDES MS4 Reports; this makes the County-wide illicit detection rate approximately 2 percent. 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 water. 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 34 wastewater projects in 12 of the 19 TMDL watersheds were identified as of 2015. Some of the identified projects, such as the upgrades to the existing sewage pump stations, are recurring, and some of the projects are finite in nature. Table 4-2 and Table 4-3 list the discrete and recurring SPS projects in the TMDL watersheds as identified by the County's Wastewater Capital Budget and Program annual reports along with cost estimates. The Marley SPS Upgrade (S805400), Parole SPS (S804900), Mill Creek SPS Upgrade (S804700), and Sylvan Shores PS Upgrade (S80400) are completed by DPW's Utility Planning Division, therefore they are listed as complete in Table 4-2. All projects were entered into the proposed conditions WTM to estimate the bacteria load reductions from implementing the SPS upgrades. All the SPS projects can be categorized under two categories: (i) short term projects such as generator replacement and (ii) projects that are recurring such as upgrades to existing pump stations. Table 4-2 and Table 4-3 list the discrete (i.e., short term) and the recurring 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 Discrete Sewage Pump Station Upgrade Projects in the TMDL Watersheds

Project	Project Title	Current Status	Description	TMDL Watershed	Qty. of Pump Stations Being Upgraded	Total Budgeted Costs[1]	Expended and/or Encumbered as of 12/23/2015
S804700	Mill Creek SPS Upgrade	Complete	Various upgrades to the Mill Creek sewage pumping station	Magothy River Mainstem	1	$11,377,000	$10,970,909
S805400	Marley SPS Upgrade	Complete	Construction of various upgrades to Marley Sewage Pumping Station to improve operation and reliability	Patapsco River/Marley Creek	1	$4,229,000	$4,127,181
S804900	Parole SPS Upgrade	Complete	Construction of miscellaneous improvements to the Parole Sewage Pumping Station to increase operation and reliability	South River Mainstem	1	$4,737,000	$4,630,427
S804000	Sylvan Shores PS Upgrade	Complete	Construction of improvements to Sylvan Shore Sewage Pumping Station to improve reliability and efficiency of system	South River Mainstem	1	$3,899,000	$3,717,286

Project	Project Title	Current Status	Description	TMDL Watershed	Qty. of Pump Stations Being Upgraded	Total Budgeted Costs[1]	Expended and/or Encumbered as of 12/23/2015
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	12	$10,740,393	$5,290,266
S806200[2]	SPS Fac Gen Replacement	Active	Generator replacement (Phase 5 contract)	Magothy River Mainstem, Patapsco River LNB, South River/Duvall Creek	6	$44,809,000	$1,081,508
S806200	SPS Fac Gen Replacement	Active	Generator replacement (Design 1 and Phase 6 contracts)	Patapsco River LNB, Baltimore Harbor, Stony Creek, Rock Creek	8	See above	$5,826,661
S806200	SPS Fac Gen Replace	Active	Generator replacement (Design 2 and Phase 7 contracts)	Unknown	multiple	See above	$3,325,716
S806200	SPS Fac Gen Replace	Active	Generator replacement/CMI services at all sites	Multiple	multiple	See above	$ 455,214
S805300	Cinder Cove SPS Mods	Active	Pump station reliability improvements necessary to minimize risks of sanitary sewer overflows	Patapsco River/ Furnace Creek	1	$10,765,000	$$6,823,132
S806300	Big Cypress SPS Retro	Active	Upgrades to Big Cypress sewage pump station	Magothy River Mainstem	1	$3,756,000	$2,742,248
S804200	Riva Woods SPS Upgrades	Complete	Design/construct improvements to Riva Woods SPS	South River Mainstem	1	$1,180,500	$1,177,722

Project	Project Title	Current Status	Description	TMDL Watershed	Qty. of Pump Stations Being Upgraded	Total Budgeted Costs[1]	Expended and/or Encumbered as of 12/23/2015
S804300	Jennifer Road SPS Upgrade	Active	Upgrades to Jennifer Rd sewage pump station; pump station force main replacement	Severn River Mainstem	1	$10,140,000	$8,006,761
				Total	**34**	$105,632,893	$51,351,899

[1] - Total Budgeted Cost derived from FY2016 Anne Arundel County Approved Capital Budget and Program and includes current and prior appropriation as well as projected appropriation requests for FY2017 through FY2021.

[2] - Total Budgeted Cost for this project includes completed and active SPS upgrades Countywide; however, the total budget is not broken down at the level of bacteria TMDL watersheds, therefore total project costs are listed

Table 4-3: List of Recurring Sewage Pump Station Upgrade Projects in the TMDL Watersheds

Project	Project Title	Current Status	Description	TMDL Watershed	Qty. of Pump Stations Being Upgraded	Annual Budget Allocation for Parent Project[1]	Expended and/or Encumbered as of 12/23/2015
S791800	Upgr/ Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Magothy River Mainstem	5	$4,775,000	$2,745,830
S791800	Upgr/ Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Patapsco River LNB	1	See above	$87,617
S791800	Upgr/ Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Patapsco River/Furnace Creek	1	See above	$200,733
S791800	Upgr/ Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Patapsco River/Marley Creek	5	See above	$749,653
S791800	Upgr/ Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	Severn River Mainstem	6	See above	$2,852,641
S791800	Upgr/ Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	South River Mainstem	10	See above	$7,354,907
S791800	Upgr/ Retrofit SPS	Multi-Year	Upgraded existing sewage pump stations	West River/Parish Creek	3	See above	$1,095,576
				Totals	31	$4,775,000	$15,086,957

[1] - Annual Budgeted Allocation derived from FY2016 Anne Arundel County Approved Capital Budget and Program and includes current as well as projected appropriation requests for FY2017 through FY2021. The Annual Budget Allocation for this project applies to SPS upgrades Countywide and is not broken down at the level of bacteria TMDL watersheds.

Retirement of County Septic Systems

Retirement of septic systems by connecting them to the public sanitary system can reduce human bacteria sources in the watershed. Based on GIS data provided by the County DPW, a total of 21,793 septic systems were identified for the entire County of which 16,007 septic systems were located in 10 of the 19 TMDL watersheds. These septic systems were previously identified by the County (as part of the Chesapeake Bay TMDL Phase II WIP) as contributing nitrogen to the Chesapeake Bay and are considered eligible to be retired for the purpose of meeting the Chesapeake Bay TMDL. The Anne Arundel County Department of Health has indicated that the current rate of retirement of septic systems in the County is 20 to 40 per year. The retirement of septic systems is dependent on several factors, such as availability of funding and willingness of the homeowner to connect to a sanitary sewer system. The current rate of retirement was proportioned to each watershed to identify the septic systems that could be retired by 2025. This information was entered into the proposed conditions WTM to estimate the bacteria load reductions that would be achieved by implementing this strategy. Table 4-4 below, presents the total number of septic systems that are identified to be retired in the TMDL watersheds and the anticipated number of septic systems that could be retired by 2025 based on current County rate.

Table 4-4: Anticipated Number of Septic Systems That Could Be Retired as Identified by the County Department of Public Works and Department of Health

Bacteria TMDL Watershed	No. of Septic Systems Identified by DPW as Eligible to be Retired	No. of Septic Systems That Could be Retired by 2025 Based on Current Rate of Retirement
Magothy River Mainstem	4,814	88
Magothy River/Forked Creek	113	2
Magothy River/Tar Cove	1,708	31
Patapsco River/Furnace Creek	252	5
Patapsco River LNB	174	3
Patapsco River/Marley Creek	0	0
Patuxent River Upper	289	5
Rhode River/Bear Neck Creek	0	0
Rhode River/Cadle Creek	0	0
Severn River Mainstem	5,475	100
Severn River/Mill Creek	1,168	21
Severn River/Whitehall and Meredith Creek	320	6
South River/Duvall Creek	0	0
South River Mainstem	1,694	31
South River/Ramsey Lake	0	0
South River/Selby Bay	0	0
W. Chesapeake Bay/Tracy and Rockhold Creeks	0	0

Bacteria TMDL Watershed	No. of Septic Systems Identified by DPW as Eligible to be Retired	No. of Septic Systems That Could be Retired by 2025 Based on Current Rate of Retirement
West River Mainstem	0	0
West River/Parish Creek	0	0
Total	**16,007**	**292**

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. 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). As implementation of new and retrofit stormwater management facilities to treat 20 percent of the currently unmanaged impervious area is required by County's NPDES MS4 Permit, anticipated bacteria reductions from managing urban stormwater runoff is also included as a part of Tier B strategies. 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. Per MDE's guidance, (MDE, 2014b), the priority of implementing Tier A or Tier B strategies is at the County's discretion.

Implementing New Stormwater Management Projects and Retrofitting Pre-2002 Stormwater Management Facilities to Meet Current MDE Criteria

Tier B strategies that address urban stormwater retrofits include restoring 20 percent of currently unmanaged impervious cover through: (i) implementing new stormwater management projects and (ii) retrofitting pre-2002 ponds and other stormwater management facilities to meet current MDE stormwater criteria. This strategy was developed based on the Anne Arundel County's Urban Phase II Watershed Implementation Plan (2012a) and requirements of the current NPDES MS4 Permit (11-DP-3316, MD0068306). The current NPDES MS4 Permit requires the County to treat 20 percent of the impervious area that currently has limited or no stormwater management. Based on the County's Impervious Area Baseline Assessment (Anne Arundel County, 2015c), 1,639 acres of impervious area throughout the County is managed through various stormwater management practices, and 29,311 acres of impervious area is currently unmanaged. This results in 5,862 acres of impervious area required to be treated by the County by the end of the current permit term.

As one of the strategies to meet the 20 percent restoration requirements, the County is evaluating retrofitting existing outfalls by implementing BMPs having high pollutant-removal efficiency, such as SPSCs. Because SPSCs are a relatively cost-effective BMP for treating larger drainage areas compared to BMPs such as bioretention (see the Regenerative Stormwater Conveyance factsheet on the 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. In 2014–2015, the County implemented six SPSCs, all of which were located in the TMDL watersheds. As new projects are identified through the County CIP, the proposed conditions WTM will be modified to quantify the benefits of the proposed new projects.

According to the County's Phase II WIP, existing pre-2002 dry ponds and other stormwater management facilities in the TMDL watersheds are recommended to be retrofitted to meet current Maryland stormwater management criteria. The goal for retrofitting these facilities is to increase nutrient and sediment removal capacity by converting the facilities to either wet ponds or SPSCs. Dry ponds are usually ideal candidates for retrofits because they have larger areas draining to them. Currently, dry ponds have a bacteria removal efficiency of 88 percent and are considered high-performing BMPs for bacteria removal. Converting the dry ponds to shallow wetland/marsh filtering systems, wet ponds, or SPSCs, as recommended in the County's Phase II WIP, would still maintain a bacteria removal efficiency of 70 or 78 percent, which in either case is considered a high-performing BMP for bacteria. The County retrofitted approximately 12 pre-2002 stormwater management facilities in 2014–2015 by converting them to wet ponds, and all of them are located in the bacteria TMDL watersheds. 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 load reductions obtained from implementing this strategy.

The County plans to retrofit 141 pre-2002 stormwater management facilities and 69 outfalls to convert them to SPSCs, wet ponds, infiltration basins, and other high-pollutant-removal BMPs. Of these, 34 outfall retrofits and 98 pre-2002 stormwater management facility retrofits are planned in the TMDL watersheds targeted for bacteria reduction.

To simulate the impact of the proposed stormwater management projects, the proposed conditions WTM for these watersheds were configured to include the drainage area and impervious area that will be managed by these proposed projects. Table 4-5 below presents the impervious area proposed to be managed by the planned projects to meet the 20 percent NPDES MS4 restoration goal in the respective TMDL watersheds.

Table 4-5: County CIP Urban Stormwater Retrofit Projects Proposed in the Bacteria TMDL Watersheds

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
Pinewood & Sycamore Roads	SPSC	SPSC	Magothy River Mainstem	29.66	7.79	70
College Parkway	Riser Modifications for Water Quality	Retention Pond	Magothy River Mainstem	19.00	0.83	70
Tarks Lane	Infiltration Basin	Infiltration Basin	Magothy River Mainstem	7.35	0.14	96
Copperwood Drive	Wet Pond & SPSC	SPSC	Magothy River Mainstem	8.06	0.79	70
Lahinch Drive	Infiltration Basin	Infiltration Basin	Magothy River Mainstem	33.74	0.62	96
Collington Court	Wet Pond	Retention Pond	Magothy River Mainstem	29.66	4.11	70
Mayfield Road at Gladnor Road	Wet Pond	Retention Pond	Magothy River Mainstem	5.15	1.23	70
Amesbury Court	Wet Pond	Retention Pond	Magothy River Mainstem	32.42	0.80	70
Longfellow Drive	Infiltration Basin	Infiltration Basin	Magothy River Mainstem	16.77	0.89	96
Jumpers Hole Road at Sylvan Avenue	Wet Pond	Retention Pond	Magothy River Mainstem	9.00	4.10	70
262 Finnegan Drive	Wet Pond & SPSC	SPSC	Magothy River Mainstem	5.15	1.23	70
103 Evon Court	Wet Pond	Retention Pond	Magothy River Mainstem	7.88	0.12	70
240 Waycross Way	Wet Pond	Retention Pond	Magothy River Mainstem	46.51	5.22	70
Colleen Garden Lane - Pond 2	Wet Pond	Retention Pond	Magothy River Mainstem	1.30	0.60	70
Earleigh Heights B&A Trail Facility	Wet Pond	Retention Pond	Magothy River Mainstem	12.50	3.10	70
790 Richie Highway	Wet Pond	Retention Pond	Magothy River Mainstem	150.32	3.47	70
249 Armstrong Lane	Wet Pond	Retention Pond	Magothy River Mainstem	TBD	TBD	70
109 Chelsea Grove Court	Wet Pond with Micro-Pool	Micropool Extended Detention Pond	Magothy River Mainstem	9.2	2.0	70

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
8013 Tickneck Road	Wet Pond	Retention Pond	Magothy River Mainstem	9.1	0.9	70
603 Deering Road	Wet Pond with Micro-Pool	Micropool Extended Detention Pond	Magothy River Mainstem	52.6	TBD	70
725 Bridge Drive	Wet Pond	Retention Pond	Magothy River Mainstem	No Data	No Data	70
244 Kennedy Drive	Wet Pond with Micro-Pool	Micropool Extended Detention Pond	Magothy River Mainstem	2.0	0.7	70
Anne Arundel Community College (AACC)	Wet Pond	Retention Pond	Magothy River Mainstem	20.9	2.8	70
AACC	Pond	Retention Pond	Magothy River Mainstem	No Data	No Data	70
AACC	Bioretention	Bioretention	Magothy River Mainstem	2.7	No Data	70
Buena Vista neighborhood in Glen Burnie	SPSC	SPSC	Magothy River Mainstem	45.9	10.9	70
Barrensdale Neighborhood Outfall from Pond	SPSC	SPSC	Magothy River Mainstem	18.5	7.9	70
Will-O-Brooke Dive	SPSC	SPSC	Magothy River Mainstem	4.7	1.3	70
College Parkway	SPSC	SPSC	Magothy River Mainstem	9.3	0.1	70
College Parkway	SPSC	SPSC	Magothy River Mainstem	12.0	0.1	70
College Parkway	SPSC	SPSC	Magothy River Mainstem	19.4	0.9	70
College Parkway	SPSC	SPSC	Magothy River Mainstem	No Data	No Data	70
College Parkway	SPSC	SPSC	Magothy River Mainstem	13.0	1.2	70
College Parkway	SPSC	SPSC	Magothy River Mainstem	9.8	0.4	70
College Parkway	SPSC	SPSC	Magothy River Mainstem	74.0	46.1	70

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
Riverside Park	Stormwater Wetland and Grass Filter Strip	Micropool Extended Detention Pond	Patapsco River LNB	124.0	55.8	78
Located on 10th Avenue. between Valley Road and Chatham Road, Brooklyn	Infiltration Trench and SPSC	SPSC	Patapsco River LNB	3.3	1.1	70
Brooklyn Park - located on 10th Avenue between Valley Road, and Chatham Road, Brooklyn	Micro-Bioretentions and Permeable Pavements	Bioretention	Patapsco River LNB	3.6	1.6	70
Bingo World - Bounded by Belle Grove Road, 10th Avenue and Harbor Valley Drive.	Grass Filters and Bioretention Basins	Bioretention	Patapsco River LNB	9.3	8.2	70
Brooklyn Middle School - off Hammonds Lane, Brooklyn, MD	Grass Swale; Stormwater Wetland	Shallow Marsh	Patapsco River LNB	195.0	66.9	78
Flows parallel to I-895 then underneath Belle Grove Road	Stream Restoration (SPSC)	SPSC	Patapsco River LNB	199.0	73.2	70
Bound by I-895 on east & private commercial property on St Thomas Ave on the west	Stream Restoration (SPSC)	SPSC	Patapsco River LNB	33.0	6.3	70
East of I-895 and north of Hammonds Lane	Stream Restoration (SPSC)	SPSC	Patapsco River LNB	25.0	4.1	70
Off of Belle Grove Road & owned by American Legion	Stream Restoration (SPSC)	SPSC	Patapsco River LNB	5.0	4.2	70
Located along Belle Grove Road & owned by State of Maryland	Stream Restoration (SPSC)	SPSC	Patapsco River LNB	48.0	10.8	70
Bordered on the north by Baltimore Washington Parkway on the east by Hammonds Ferry, & on the west by West Nursery Road	Stream Restoration (SPSC)	SPSC	Patapsco River LNB	6.6	1.7	70

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
Bordered on the north by Baltimore Washington Parkway on the east by Hammonds Ferry and on the west by West Nursery Road	Stream Restoration (SPSC)	SPSC	Patapsco River LNB	55.7	23.9	70
Bordered on the north by Baltimore Washington Parkway on the east by Hammonds Ferry and on the west by West Nursery Rd	Constructed Wetland	Shallow Marsh	Patapsco River LNB	57.8	3.7	78
Bordered on the north by Baltimore Washington Parkway on the east by Hammonds Ferry and on the west by West Nursery Rd	Constructed Wetland	Shallow Marsh	Patapsco River LNB	2.9	0.9	78
601-611 North Hammonds Ferris, Linthicum, MD	Wet Pond	Retention Pond	Patapsco River LNB	48.0	10.0	70
806 Central Avenue, Linthicum	Wet Pond	Retention Pond	Patapsco River LNB	10.2	3.1	70
Behind 419 Jerome Avenue, Linthicum Heights	Infiltration Basin	Infiltration Basin	Patapsco River LNB	3.7	0.4	96
Behind 1467 Fairbanks Drive, Hanover, MD	Wet Pond	Retention Pond	Patapsco River LNB	58.0	5.5	70
7306 Musical Way, Severn	Infiltration Basin	Infiltration Basin	Patapsco River LNB	13.9	2.7	96
7900 Severn Hills Way, Severn	Wet Pond	Retention Pond	Patapsco River LNB	10.1	1.4	70
Gesna Drive (off Pinyon Road), Hanover	Wetland	Shallow Marsh	Patapsco River LNB	36.1	4.4	78
Gesna Drive (South of Siden) Hanover, MD	Wet Pond	Retention Pond	Patapsco River LNB	13.1	1.8	70
East of 7924 Green Moss Glen, Severn, MD	Wet Pond	Retention Pond	Patapsco River LNB	21.5	3.0	70
Behind 7508 Terrain Court, Hanover	Wet Pond	Retention Pond	Patapsco River LNB	10.1	0.8	70
Harmons Woods; south of Strider Court	SPSC	SPSC	Patapsco River LNB	20.9	2.5	70
Harmons Woods; south of Strider Court	SPSC	SPSC	Patapsco River LNB	75.5	8.3	70

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
Behind 6202 Grovel Road, Linthicum Heights MD	SPSC	SPSC	Patapsco River LNB	16.1	4.4	70
Sheckells Road	Infiltration Basin	Infiltration Basin	Patapsco River/Furnace Creek	1.3	0.2	96
East end of Chalmers Avenue	Infiltration Basin	Infiltration Basin	Patapsco River/Furnace Creek	21.8	4.1	96
711 Towering Oaks Court, Glen Burnie	Infiltration	Infiltration Basin	Patapsco River/Furnace Creek	7.8	1.1	96
Baby Bear Court	Infiltration	Infiltration Basin	Patapsco River/Furnace Creek	11.5	1.2	96
1506 Lochaber Court	Wet Pool	Micropool Extended Detention Pond	Patapsco River/Furnace Creek	16.9	1.6	70
17 McNeil Ct, Glen Burnie, MD[1]	Wet Pond	Retention Pond	Patapsco River/Furnace Creek	11.9	1.1	70
Intersection of Foxwell Bend Road and Hospital Drive	Wet pond with high and low marsh	Shallow Marsh	Patapsco River/Marley Creek	29.0	2.9	78
Fox Cub Court	Wet pond with high and low marsh	Shallow Marsh	Patapsco River/Marley Creek	14.5	1.8	78
Fox Cub Court	Wet pond with high and low marsh	Shallow Marsh	Patapsco River/Marley Creek	14.5	1.8	78
Hospital Drive [2]	SPSC	SPSC	Patapsco River/Marley Creek	6.8	0.9	70
Hospital Drive[2]	SPSC	SPSC	Patapsco River/Marley Creek	13.0	5.8	70
Intersection of Veterans Highway & Harpers Mill Road Millersville[3]	Constructed Wetland	Shallow Marsh	Patapsco River/Marley Creek	48.6	5.2	78

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
600 Rolling Hill Walk Odenton	Constructed Wetland	Shallow Marsh	Severn River Mainstem	8.2	3.6	78
2016 Governor Thomas Bladen Way Annapolis	SPSC	SPSC	Severn River Mainstem	24.8	3.6	70
550 Francis Nicholson Way Annapolis	SPSC	SPSC	Severn River Mainstem	13.0	5.8	70
412 Headquarters Drive Millersville	SPSC	SPSC	Severn River Mainstem	22.3	5.4	70
South of Watch House Circle South, Severn	Constructed Wetland	Shallow Marsh	Severn River Mainstem	29.6	4.5	78
North of Watch House Circle North, Severn	Constructed Wetland	Shallow Marsh	Severn River Mainstem	31.3	3.6	78
2059 Generals Hwy, Annapolis	Wet Pond	Retention Pond	Severn River Mainstem	6.5	0.5	70
Council Oaks Dr, Severn, MD[4]	Wetland Pond	Shallow Marsh	Severn River Mainstem	15.2	4.5	78
Western District Police Station	Wet Pond	Retention Pond	Severn River Mainstem	6.6	1.3	70
East of Ft. Meade, West of Railroad	Wet Pond	Retention Pond	Severn River Mainstem	654.9	60.2	70
On Pasture Brook Road between Silo Road & Loft Court	Constructed Wetland	Shallow Marsh	Severn River Mainstem	30.2	3.0	78
Myers Drive, between Hyde Park Drive & Radnor Court Severn	SPSC	SPSC	Severn River Mainstem	51.6	6.5	70
West of Rustling Oaks Drive, off of Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	78.5	7.9	70
East of FT. Meade, West of Railroad	TBD	Other	Severn River Mainstem	No Data	No Data	70
Mill Race Community Pond, southeast of Veterans Highway & Harpers Mill Road	Constructed Wetland	Shallow Marsh	Severn River Mainstem	48.0	No Data	78
Isabella Court, Millersville	Wetland	Shallow Marsh	Severn River Mainstem	140.2	7.7	78
Old Herald Harbor Road	Constructed Wetland	Shallow Marsh	Severn River Mainstem	35.0	No Data	78

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
Old County Road	SPSC	SPSC	Severn River Mainstem	22.0	No Data	70
West Benefield Road & Pixie Drive	Box Culvert	Other	Severn River Mainstem	338.0	30.7	0
Annapolis Mall	Pond	Retention Pond	Severn River Mainstem	No Data	No Data	70
Various locations around US 50 & Medical Parkway	SPSC	SPSC	Severn River Mainstem	6.4	3.4	70
Brietwert Avenue and Oakton Road	SPSC	SPSC	Severn River Mainstem	13.8	1.7	70
Buttonwood Trail	SPSC	SPSC	Severn River Mainstem	No Data	No Data	70
Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	72.9	7.9	70
Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	TBD	TBD	70
Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	TBD	TBD	70
Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	TBD	TBD	70
Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	TBD	TBD	70
Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	0.5	0.2	70
Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	42.1	6.3	70
Benfield Boulevard	SPSC	SPSC	Severn River Mainstem	No Data	No Data	70
Olde Severna Park Neighborhood	SPSC	SPSC	Severn River Mainstem	37.8	15.9	70
Lakeview Road	SPSC	SPSC	Severn River Mainstem	1.3	0.6	70
LakeView Road	SPSC	SPSC	Severn River Mainstem	7.3	2.5	70
LakeView Road	SPSC	SPSC	Severn River Mainstem	0.6	0.2	70
South of the First United Pentecostal Church, 1535 Richie Highway, Arnold	Constructed Wetland	Shallow Marsh	Severn River/Mill Creek	22.0	1.5	78

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
1550 Comanche Road	Dry Pond	Detention Structure Dry (Dry Pond)	Severn River/Mill Creek	11.8	1.5	88
48 Old Sturbridge Road	Dry Pond	Detention Structure Dry (Dry Pond)	Severn River/Mill Creek	No Data	No Data	88
1681 Nickerson Way	Dry Pond	Detention Structure Dry (Dry Pond)	Severn River/Mill Creek	No Data	No Data	88
Off Broadneck Creek Road at the end of Pennington Lane South	SPSC	SPSC	Severn River/Whitehall and Meredith Creek	24.7	2.3	70
Loch Haven Road & Havenhill Road	Wet Pond	Retention Pond	South River Mainstem	7.5	0.8	70
Wordsworth & Breckenridge Way	Updated Wet Pond	Retention Pond	South River Mainstem	70.3	10.6	70
Howards Point Road & Stepney Lane, Edgewater	Updated Pond	Retention Pond	South River Mainstem	52.2	9.2	70
619 Dillon Court	Wet Pond	Retention Pond	South River Mainstem	12.2	1.5	70
Southdown Road	SPSC	SPSC	South River Mainstem	84.6	24.8	70
2930 Spring Lakes Drive[5]	Wet Pond	Retention Pond	South River Mainstem	80.3	No Data	70
Riva Road. North Broad Creek	SPSC	SPSC	South River Mainstem	10.4	4.2	70
Truman Parkway	SPSC	SPSC	South River Mainstem	10.7	3.4	70
Truman Parkway/Golf Ridge Road	SPSC	SPSC	South River Mainstem	25.9	10.7	70
Across from 3233 Homewood Road	SPSC	SPSC	South River Mainstem	27.5	4.0	70
On Breckenridge Way south of Wordsworth	SPSC	SPSC	South River Mainstem	104.3	31.2	70
Admiral Cochrane & Route 2	SPSC	SPSC	South River Mainstem	5.4	4.1	70
Riva Road at Camp Woodlands	SPSC	SPSC	South River Mainstem	8.4	2.4	70

Proposed Urban Retrofit Project	Proposed Project Type	BMP Classification Based on Table 2-2	Bacteria TMDL Watershed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)	Potential Bacteria Removal Efficiency (percent)
Admiral Cochrane & Route 2	SPSC	SPSC	South River Mainstem	27.3	6.8	70
Admiral Cochrane & Route 2	SPSC	SPSC	South River Mainstem	18.8	15.3	70
Admiral Cochrane & Route 2	SPSC	SPSC	South River Mainstem	17.7	4.6	70
Admiral Cochrane & Route 2	SPSC	SPSC	South River Mainstem	41.5	13.3	70
Old Annapolis Neck	Wet Pond	Retention Pond	South River/Duvall Creek	13.1	2.0	70

[1]-This project even though listed under the Patapsco Non-Tidal Watershed, it is included in Furnace Watershed in this Plan. This is due to discrepancy in the watershed boundaries between the County and the MDE GIS data.
[2]-This project even though listed under the Patapsco Non-Tidal Watershed, it is included in Marley Watershed in this Plan. This is due to discrepancy in the watershed boundaries between the County and the MDE GIS data.
[3]-This project even though listed under the Severn River Mainstem Watershed, it is included in Marley Watershed in this Plan. This is due to discrepancy in the watershed boundaries between the County and the MDE GIS data.
[4]-This project even though listed under the Patuxent River Watershed, it is included in Severn River Mainstem Watershed in this Plan. This is due to discrepancy in the watershed boundaries between the County and the MDE GIS data.
[5]-This project even though listed under the South River Watershed, it is included in Severn River Mainstem Watershed in this Plan. This is due to discrepancy in the watershed boundaries between the County and the MDE GIS data.

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, 2013b). 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, 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. $TMDL\ Total\ Load\ x\ \%\ Pet\ Sources\ from\ TMDL\ Bacteria\ Source\ Distribution\ x\ 25\%\ Removal\ Efficiency = Amount\ of\ Load\ Reduction$
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 and Lunsford (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 and Lunsford 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 mainstem 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 2-9 and 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 Department of Natural Resources' (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:

- **Urban Stormwater Management Retrofits**: County CIP and budget reports. Cost per project is currently unavailable at this time and a budgeted cost for all the projects planned at watershed level is included in this plan.

- **Abatement of SSOs**: varies by SPS upgrade project. Average cost of 34 planned or active projects is $9,950,171, 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 high 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 and Lunsford 2012)
- **Identification and 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 (i.e. end of year 2014). 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. The BMP data provided by the County as a part of the 2015 NPDES MS4 Annual Report (Anne Arundel County, 2015a) was used to estimate the potential load reductions from the BMPs implemented after 2000. 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.

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 4.19 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 Target Reduction Requirements (%)	Adjusted TMDL Required Reduction (%)
Magothy Mainstem	3.04	0.61	12.80	9.15
Magothy River/Forked Creek	6.25	None	26.30	20.05
Magothy River/Tar Cove	2.23	None	0.00	0.00
Patapsco River/Furnace Creek	3.65	0.38	77.70	73.67
Patapsco River LNB	3.96	2.61	20.70	14.13
Patapsco River/Marley Creek	5.83	0.26	75.70	69.61
Patuxent River Upper	4.54	None	22.30	17.82
Rhode River/Bear Neck Creek	2.23	None	43.30	41.07
Rhode River/Cadle Creek	6.25	None	72.20	65.95
Severn River Mainstem	1.18	0.35	19.00	17.47
Severn River/Mill Creek	6.82	None	86.00	79.18
Severn River/Whitehall and Meredith Creek	4.42	0.43	90.00	85.15
South River/Duvall Creek	3.13	None	45.60	42.47
South River Mainstem	9.06	0.06	29.50	20.38
South River/Ramsey Lake	5.72	None	59.30	53.58
South River/Selby Bay	1.30	None	0.00	0.00
W. Chesapeake Bay/Tracy and Rockhold Creeks	0.35	2.70	81.60	78.55
West River Mainstem	1.38	0.48	35.30	33.44
West River/Parish Creek	0.45	None	53.10	52.65
Average:	3.78	0.88	Average Adjustment = 4.19% 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, Patuxent River Upper and South River Mainstem watersheds
- Removal of household illicit connections resulted in the greatest load reductions in the Patapsco River LNB, Marley Creek, Severn River Mainstem and South 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 Patapsco River LNB, South River Mainstem and Severn River Mainstem watersheds
- 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 Patapsco River LNB, Cadle Creek and 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, Whitehall-Meredith Creek, Mill Creek and Parish Creek watersheds.

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). Even though urban stormwater management, including implementing new stormwater management facilities and retrofitting pre-2002 stormwater management facilities have high implementation costs, they are required to be implemented by the County to restore 20 percent of unmanaged impervious cover, and therefore these measures would be effective in reducing the bacteria loads.

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 many 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 ten of the watersheds, where implementing all the Tier A and Tier B strategies is still not enough to meet the TMDL required reductions. These watersheds are: Furnace Creek (Table 4-7C), Marley Creek (Table 4-7C), Bear Neck Creek (Table 4-7E), Cadle Creek (Table 4-7E), Mill Creek (Table 4-7F), Whitehall-Meredith Creek (Table 4-7F), Duvall Creek (Table 4-7G), Ramsey Lake (Table 4-7G),Tracy-Rockhold Creek (Table 4-7H), and Parish Creek (Table 4-7I). Load reductions in these watersheds are limited by factors such as lack of stormwater management retrofit projects, SPS upgrade, and septic system retirement opportunities. For example, in the Ramsey Lake watershed, there are no currently planned existing stormwater management projects or SPS upgrade projects.

Load reductions in Cadle Creek, Duvall Creek, and Ramsey Lake watersheds can be achieved by prioritizing the pet waste education in high-density residential areas. Additional reductions can be achieved in all the identified ten watersheds with the implementation of additional stormwater management practices by the County as a part of the CIP program. 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.

The costs provided for the urban stormwater management retrofits in Tables 4-7A through 4-7I are the costs for stormwater management CIP projects budgeted by the County at the watershed level and may include implementation costs for projects that are located in the portions of the watershed that do not have the bacteria TMDL.

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	1.95%	$54.29	2784.1	B
Eliminate Household Illicit Connections	9.05%	$0.61	6.7	A
Abatement of SSOs	1.12%	$82.26	7344.6	A
Septic Retirement/Connection	0.26%	$4.49	1726.2	A
Riparian Buffer Education	0.85%	$0.06	7.1	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:	**10.43%**			
All Tier B Strategies:	**21.98%**			
All Strategies:	**32.41%**			
Adjusted TMDL Required % Reduction:	**9.15%**			
TMDL Watershed: Magothy River/Forked Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	1.14%	$0.61	53.5	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	0.11%	$0.10	92.7	A
Riparian Buffer Education	1.74%	$0.06	3.4	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:	**1.25%**			
All Tier B Strategies:	**24.92%**			
All Strategies:	**26.17%**			
Adjusted TMDL Required % Reduction:	**20.05%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	0.67%	$0.61	91.0	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	0.46%	$1.58	343.7	A
Riparian Buffer Education	0.92%	$0.06	6.5	B
Expanded Pet Waste Education	13.60%	$0.15	1.1	B
Expanded Goose Management Program	4.27%	$0.03	0.7	B
All Tier A Strategies:	**1.13%**			
All Tier B Strategies:	**18.79%**			
All Strategies:	**19.92%**			
Adjusted TMDL Required % Reduction:	**0.0%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	4.80%	$45.31	944.0	B
Eliminate Household Illicit Connections	11.76%	$0.61	5.2	A
Abatement of SSOs	4.96%	$101.39	2044.2	A
Septic Retirement/Connection	0.10%	$0.15	153.0	A
Riparian Buffer Education	2.73%	$0.06	2.2	B
Expanded Pet Waste Education	6.50%	$0.15	2.3	B
Expanded Goose Management Program	0.79%	$0.03	3.8	B
All Tier A Strategies:	**16.82%**			
All Tier B Strategies:	**14.82%**			
All Strategies:	**31.64%**			
Adjusted TMDL Required % Reduction:	**14.13%**			

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				
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	0.10%	$104.81	104810	B
Eliminate Household Illicit Connections	8.27%	$0.61	7.4	A
Abatement of SSOs	3.75%	$15.74	419.7	A
Septic Retirement/Connection	0.07%	$0.26	364	A
Riparian Buffer Education	1.41%	$0.06	4.3	B
Expanded Pet Waste Education	7.35%	$0.15	2.0	B
Expanded Goose Management Program	4.98%	$0.03	0.6	B
All Tier A Strategies:	**12.09%**			
All Tier B Strategies:	**13.84%**			
All Strategies:	**25.93%**			
Adjusted TMDL Required % Reduction:	**73.67%**			
TMDL Watershed: Patapsco River/Marley Creek				
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	0.53%	$93.30	17604	B
Eliminate Household Illicit Connections	11.21%	$0.61	5.4	A
Abatement of SSOs	2.12%	$13.88	654.7	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	1.52%	$0.06	3.9	B
Expanded Pet Waste Education	8.65%	$0.15	1.7	B
Expanded Goose Management Program	4.08%	$0.03	0.7	B
All Tier A Strategies:	**13.33%**			
All Tier B Strategies:	**14.78%**			
All Strategies:	**28.11%**			
Adjusted TMDL Required % Reduction:	**69.61%**			

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				
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	1.14%	$0.61	53.6	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	0.38%	$0.26	67.1	A
Riparian Buffer Education	20.57%	$0.06	0.3	B
Expanded Pet Waste Education	4.50%	$0.15	3.3	B
Expanded Goose Management Program	4.58%	$0.03	0.7	B
Livestock Fencing	14.00%	$0.13	0.9	B
All Tier A Strategies:	**1.52%**			
All Tier B Strategies:	**43.65%**			
All Strategies:	**45.17%**			
Adjusted TMDL Required % Reduction:	**17.82%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	0.50%	$0.61	122.0	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.11%	$0.06	54.5	B
Expanded Pet Waste Education	8.48%	$0.15	1.8	B
Expanded Goose Management Program	2.58%	$0.03	1.2	B
All Tier A Strategies:	**0.50%**			
All Tier B Strategies:	**11.17%**			
All Strategies:	**11.67%**			
Adjusted TMDL Required % Reduction:	**41.07%**			

TMDL Watershed: Rhode River/Cadle Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	0.30%	$0.61	203.3	A
Abatement of SSOs	8.50%	$16.03	188.6	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.70%	$0.06	8.6	B
Expanded Pet Waste Education	20.05%	$0.15	0.7	B
Expanded Goose Management Program	2.55%	$0.03	1.2	B
All Tier A Strategies:	**8.80%**			
All Tier B Strategies:	**23.30%**			
All Strategies:	**32.10%**			
Adjusted TMDL Required % Reduction:	**65.95%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	0.80%	$71.40	8925.0	B
Eliminate Household Illicit Connections	19.40%	$0.61	3.1	A
Abatement of SSOs	0.37%	$25.77	6946.1	A
Septic Retirement/Connection	0.20%	$5.10	2550.0	A
Riparian Buffer Education	1.43%	$0.06	4.2	B
Expanded Pet Waste Education	17.20%	$0.15	0.9	B
Expanded Goose Management Program	3.78%	$0.03	0.8	B
All Tier A Strategies:	**19.97%**			
All Tier B Strategies:	**23.21%**			
All Strategies:	**43.18%**			
Adjusted TMDL Required % Reduction:	**17.47%**			
TMDL Watershed: Severn River/Mill Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	0.65%	$20.14	3098.5	B
Eliminate Household Illicit Connections	1.54%	$0.61	39.6	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	0.63%	$1.07	170.0	A
Riparian Buffer Education	2.50%	$0.06	2.4	B
Expanded Pet Waste Education	9.50%	$0.15	1.6	B
Expanded Goose Management Program	7.72%	$0.03	0.4	B
All Tier A Strategies:	**2.17%**			
All Tier B Strategies:	**20.37%**			
All Strategies:	**22.54%**			
Adjusted TMDL Required % Reduction:	**79.18%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	0.63%	$16.71	2652.4	B
Eliminate Household Illicit Connections	0.96%	$0.61	63.5	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	0.42%	$0.31	72.9	A
Riparian Buffer Education	2.13%	$0.06	2.8	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:	**1.38%**			
All Tier B Strategies:	**18.55%**			
All Strategies:	**19.93%**			
Adjusted TMDL Required % Reduction:	**85.15%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	2.00%	$72.22	3611	B
Eliminate Household Illicit Connections	11.40%	$0.61	5.4	A
Abatement of SSOs	0.31%	$31.47	10152	A
Septic Retirement/Connection	0.29%	$1.58	545.2	A
Riparian Buffer Education	7.30%	$0.06	0.8	B
Expanded Pet Waste Education	10.83%	$0.15	1.4	B
Expanded Goose Management Program	4.44%	$0.03	0.7	B
All Tier A Strategies:	**12.00%**			
All Tier B Strategies:	**24.57%**			
All Strategies:	**36.57%**			
Adjusted TMDL Required % Reduction:	**20.38%**			
TMDL Watershed: South River/Duvall Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	0.83%	$7.89	950.6	B
Eliminate Household Illicit Connections	0.65%	$0.61	93.8	A
Abatement of SSOs	6.40%	$45.89	717.0	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	1.4	B
All Tier A Strategies:	**7.05%**			
All Tier B Strategies:	**19.99%**			
All Strategies:	**27.04%**			
Adjusted TMDL Required % Reduction:	**42.47%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	0.11%	$0.61	554.5	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.12%	$0.06	50.0	B
Expanded Pet Waste Education	15.73%	$0.15	1.0	B
Expanded Goose Management Program	4.81%	$0.03	0.6	B
All Tier A Strategies:	**0.11%**			
All Tier B Strategies:	**20.66%**			
All Strategies:	**20.77%**			
Adjusted TMDL Required % Reduction:	**53.58%**			
TMDL Watershed: South River/Selby Bay				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	0.16%	$0.61	381.3	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	0.7	B
All Tier A Strategies:	**0.16%**			
All Tier B Strategies:	**20.32%**			
All Strategies:	**20.48%**			
Adjusted TMDL Required % Reduction:	**0.0%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	0.23%	$0.61	265.2	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	7.70%	$0.06	0.8	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:	**22.28%**			
All Strategies:	**22.51%**			
Adjusted TMDL Required % Reduction:	**78.55%**			

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**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	1.39%	$0.61	43.9	A
Abatement of SSOs	N/A	N/A	N/A	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	11.90%	$0.06	0.5	B
Expanded Pet Waste Education	3.93%	$0.15	3.8	B
Expanded Goose Management Program	3.51%	$0.03	0.9	B
Livestock Fencing	28.55%	$0.13	0.5	B
All Tier A Strategies:	**1.39%**			
All Tier B Strategies:	**47.89%**			
All Strategies:	**49.28%**			
Adjusted TMDL Required % Reduction:	**33.44%**			

TMDL Watershed: West River/Parish Creek				
Proposed Strategy	**Expected % Load Reduction**	**Total Estimated Cost in Millions**	**Cost-Benefit Ratio**	**Tiered Recommendation**
Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	N/A	N/A	N/A	B
Eliminate Household Illicit Connections	0.19%	$0.61	321.1	A
Abatement of SSOs	12.90%	$5.87	45.5	A
Septic Retirement/Connection	N/A	N/A	N/A	A
Riparian Buffer Education	0.42%	$0.06	14.3	B
Expanded Pet Waste Education	10.05%	$0.15	1.5	B
Expanded Goose Management Program	7.72%	$0.03	0.4	B
All Tier A Strategies:	**13.09%**			
All Tier B Strategies:	**18.19%**			
All Strategies:	**31.28%**			
Adjusted TMDL Required % Reduction:	**52.65%**			

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 9 TMDL watersheds where SSO abatement is proposed, the bacteria load reductions ranged from 0.3 to 12.90 percent. In the 10 TMDL watersheds where County septic systems were identified for retirement based on County data, the bacteria load reductions ranged from 0.07 to 0.63 percent. Implementing a riparian buffer education program resulted in an estimated load reduction of 0.06 to 20.57 percent among 18 of the 19 TMDL watersheds where buffers occur.

Load reductions from implementing an expanded pet waste education program ranged from 3.93 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 are noted in the TMDL document as a potential source (i.e., 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: General 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
Restore 20% Impervious Cover with Urban Stormwater Management Retrofits	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, 2012a), 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

Education and Outreach Programs Led by Anne Arundel County Departments

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 and Twitter. A description 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: 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, Twitter, 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 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

Education and Outreach Programs for Livestock and Equine Operations

In addition to the outreach programs above, the Anne Arundel County Soil Conservation District (AASCD) and Maryland Department of Agriculture (MDA) work with farmers and livestock owners to educate them about conservation practices that would help protect natural resources while succeeding in their business operations. As a part of nutrient management, the MDA now requires waters of the State of Maryland to be fenced to prevent animals from accessing them. Based on information provided by AASCD and the U.S. Department of Agriculture (USDA) Animal Census Data (2012), chicken and dairy operations are uncommon in Anne Arundel County, and the majority of the animal population in the County consists of horses.

According to AASCD, the largest animal population in the County is of horses and the owners are not traditional farmers. To educate horse owners on pasture and manure management, MDA has assembled a "Horse Outreach Workgroup" and published a "Horse Owner's Guide" that describes the impact of equine management practices on water resources.

In addition, the AASCD has a "Horse Survey" to collect information from both experienced equine handlers and non-traditional farmers so additional County level education and outreach programs can be developed for them.

A list of MDA and AASCD conservation practices that reduce pathogens from agriculture and livestock operations in surface water is provided below (Table 5-2). Some of these practices are included as a part of MDA's Water Quality Cost-Share Program (MACS) where MDA provides grants to farmers to cover up to 87.5 percent of the implementation costs of these practices.

Table 5-2: List of MDA and AASCD Practices that Address Pathogen Control from Agriculture and Livestock Operations in Surface Waters (MDA, 2014)

Practice Type	Included in MACS	Practice Type	Included in MACS
Access Control	Yes	Riparian Herbaceous Cover	Yes
Alley Cropping	No	Roofs and Covers	No
Animal Mortality Facility	No	Waste Gasification Facility	No
Composting Facility	No	Waste Recycling	No
Conservation Cover	Yes	Waste Separation Facility	No
Constructed Wetland		Waste Storage Facility	No
Filter Strip	Yes	Waste Transfer	No
Karst Sinkhole Treatment	No	Waste Treatment	No
Pumping Plant	No	Waste Treatment Lagoon	Yes
Riparian Forest Buffer	Yes		

Marina Outreach Programs

Raw and poorly managed sewage from boats contain pathogens that cause detrimental effects through either direct contact (e.g., swimming) or other sources (e.g., consumption of shellfish contaminated with sewage). In general, boat waste discharges can have a significant impact on 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 percent of boaters at marinas with pump-out facilities actually used the facility. According to federal and State law, it is illegal to discharge raw sewage, so enforcing this regulation may discourage illegal discharges. Seventeen of the 19 TMDL watersheds have shoreline and include marinas.

The "Clean Marina Program" is a Maryland DNR voluntary program that promotes environmentally friendly boating practices by certifying those marinas that exceed the State's minimum requirements to prevent polluted runoff. Marinas are designated as Clean Marinas if they comply with all pertinent environmental regulations and permits while providing training and outreach to staff and customers on preventing polluted runoff (e.g., sewage handling, petroleum control, proper vessel cleaning, waste containment, and waste disposal). There are currently 129 certified Maryland Clean Marinas in the State of Maryland, and approximately 32 in Anne Arundel County bacteria TMDL watersheds (Maryland DNR, 2015).

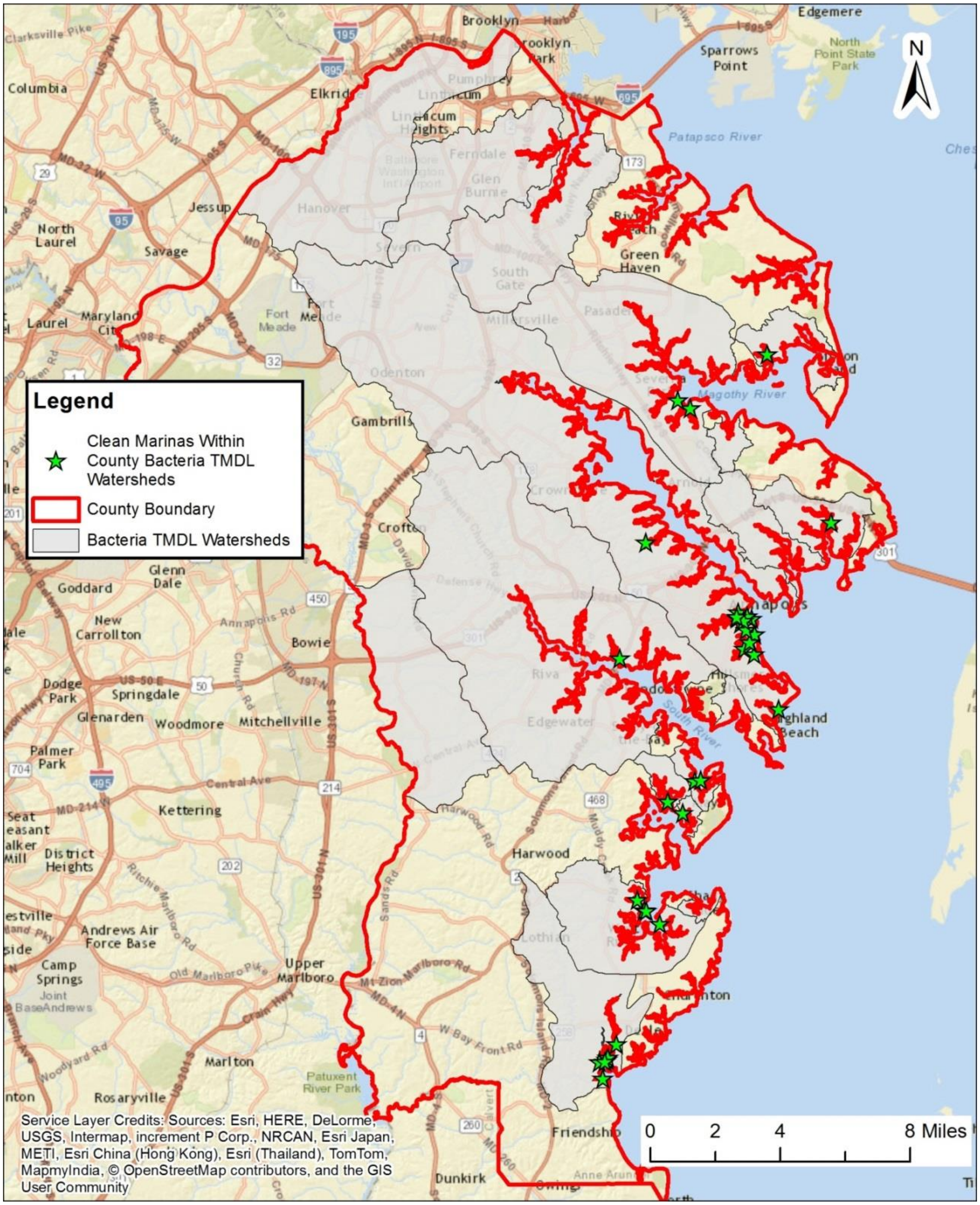

Figure 5-1: Location of Certified Clean Marinas in Bacteria TMDL Watersheds

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 Anne Arundel County 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 5-3 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 5-3: Challenges and Solutions to Public and Stakeholder Participation in the Watershed Restoration Process

Challenge	Potential 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).

Challenge	Potential Solution
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 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 ADDITIONAL OUTREACH OPPORTUNITIES

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

Outreach Programs for Homeless Populations

The County is considering an outreach program for homeless populations. Reducing homelessness would 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 used emergency shelters, transitional housing, and permanent supportive housing during the 2012 Federal Fiscal Year (Anne Arundel County, 2012d). The MDE states that reaching homeless populations can take the form of surveying units of local government that serve the homeless, including social services, police, schools, the health department, and nongovernmental organizations, and also educate the public 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 meeting the needs of persons who are homeless is the Anne Arundel and Annapolis Coalition to End Homelessness, a community-based planning and advocacy organization.

Expanded Outreach Programs for Stray Animals

Another potential outreach program is related to stray animals in the County. The Anne Arundel County Animal Control Division patrols the County for stray animals and gives them shelter and care and provides an "Adoption Program" to place them in suitable homes. In addition, the Division is also considering expanding their Animal Control Foster Program to encourage more volunteers to temporarily support the rescued animals. The County could advertise this beneficial program by issuing flyers, magnets, or newspaper advertisements to increase awareness.

Expanded Outreach Programs for Marinas

County agencies can promote MD DNR's Clean Marinas by providing maps with the locations of all Clean Marinas in the County, posting them online, and posting signage identifying Clean Marinas. By promoting the Clean Marinas Program, the County would encourage other marinas to join and could educate the public on the existence and benefits of the program. County agencies could also partner with the Maryland DNR to encourage environmentally friendly boating activities in watersheds with a large number of community marinas such as the Severn and South River Watersheds.

In addition to MD DNR's outreach program, the County could expand the outreach program to educate boat owners to raise awareness about the importance of always using pump-out stations at marinas for proper sewage disposal. This would reduce the amount of human bacteria discharged directly into waterways. The County could also promote pump-out boats that would be more convenient to boaters.

One of the best methods for conveying information about proper use of pump-out stations is posting signs, which are a more effective method of conveying information than distributing literature or conducting boater education workshops (EPA, 2014). Signage is required to enter the Clean Marinas program and is most beneficial at highly visible locations in marinas such as boat ramps, anchorages/moorings, fuel docks, and live-aboard docks. The cost of posting a sign is estimated to be $105 (RI Sea Grant, 1992).

In addition to signage, installing additional pump-out facilities at marinas would 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 twofold. Additional boater outreach may also be conducted through the County's social media and website, as well as through cooperative efforts with local watershed organizations and RiverKeepers.

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 DNR has a grant program to fund installation of sewage pump-out 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	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, understanding of, and stewardship of local urban waterways	$40,000 - $60,000

Funding Type	Funding Agency	Restoration Activity	Purpose of Program	Available Funding
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 Sewerage Facilities 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 pump-out 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, 2012a). Therefore, additional funding sources will need to be identified to implement proposed restoration strategies for septic systems. An additional source of funding may be 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). Use of this funding source for improvements related to livestock may 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.

Projects to implement new and retrofit stormwater management facilities, 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. This resulting 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 and other stormwater management facility retrofits, and especially degraded stream and outfall restoration projects 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
2015-2016	• Begin securing any funding sources needed • Make programmatic adjustments and identify any additional staffing needs • Identify drainage areas for existing BMPs, as required (data compiled for majority of the BMPs) • 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 and retrofit stormwater management

Milestone Year	Programmatic Criteria
	facilities (already underway)
2017	• 25% of all planned new and retrofit stormwater management facilities complete • 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 MS4 permit cycle)	• 20% of impervious area managed with SPSC or other high-performing BMP (meet NPDES MS4 Permit/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)	• Maintain the achieved WIP/permit goal for impervious area treatment through inspections and maintenance of stormwater management facilities. • 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
MS4=Municipal Separate Storm Sewer System
PSAs = Public Service Announcements
SPS = Sewage Pump Station
SPSC= Step Pool Storm Conveyance
WIP = Watershed Implementation Plan

SECTION EIGHT: METHODS FOR EVALUATING PROGRESS

8.1.1 Evaluating Progress of Proposed Restoration Strategies

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
Restore 20% Impervious Area with Urban Stormwater Projects	Water Quality Modeling*	Annually	NPDES MS4 reporting
Eliminate Illicit Connections (IDDE)	Water Quality Modeling*	Annually	NPDES MS4 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 2016	n/a

Proposed Strategy	Potential Method to Evaluate Progress	Frequency	Data Source
Expanded Goose Management Program	Annual survey of goose population by USFWS and Maryland DNR	Annually as part of waterfowl survey	USFWS/ Maryland DNR
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

Evaluation of Pet Waste Education and Outreach Programs

As expanded pet waste outreach program has been identified as one of the most cost-effective strategies, with modeled results showing the greatest bacteria reduction in seven out of 19 TMDL watersheds, the County could develop ways to evaluate the effectiveness of an expanded pet waste program. There are several ways to evaluate effectiveness of the pet waste outreach program. Methods include:

- Measuring pet owner behavior changes
- Measuring pet waste at target sites
- Measuring bacteria loads at target sites

Each method of determining program effectiveness would involve different assumptions.

Measuring pet owner behavior changes: To measure pet owner behavior changes as a result of the program, surveys can be sent during the baseline year and again after the program is implemented. This survey should ask whether the citizen has a pet, how and where the pet's waste is disposed of, and what locations the pet has access to within the County (i.e., local dog park, hiking trails, or backyards of houses). The survey should ask whether the owner picks up pet waste if disposed of outside and where they dispose of it. It should also ask why the owner does or does not pick up waste outside and if they have seen any of the County's outreach materials (perhaps include a dropdown list of materials published). The surveys could be taken once each year to show progress in pet owner behavior in the "Public Education and Outreach" section of the County's annual NPDES MS4 report.

Assumptions made for this assessment are that the only item influencing behavior change in citizens is the County's efforts, that survey responders are honest, and that the data collected can be generalized to the whole pet owner community (because not all pet owners will respond). This method does not directly tie actual conditions to contributed bacteria loads since bacteria loads are not measured. A sample survey developed by the Watershed Stewards Academy is provided in Appendix B.

Measuring pet waste at target sites: Another method to measure effectiveness of the expanded pet waste outreach program is to compare the amount of pet waste collected in the pet waste stations over the period of the outreach education program to the baseline year. The County would need to know the total number pet owners in the County, which could be collected from pet registration documentation.

The assumptions for this method is that an increase in pet waste collection at the stations indicates a decrease of pet waste in the field, that all pets are registered, and that number of pet owners corresponds to the number of pets.

Measuring bacteria loads at target sites: To determine the actual bacteria load reduction effectiveness of the expanded pet waste program, runoff could be sampled in targeted areas like trails and dog parks without existing pet waste stations, and then sampled again after pet waste stations and/or increased signage is added through the expanded program. Bacteria load transport varies in different seasons of the year, so runoff sampling should be done seasonally for a year to determine actual conditions. Additional seasonal sampling should be done after the program is implemented, either at defined increments or annually since the NPDES MS4 permit requires annual updates on restoration plan goal progress.

This method more directly ties the actual bacteria loading from pet waste to that transported to surface water and reduces assumptions based on community response. The assumption for this method would be that contributions of bacteria from wildlife would be relatively similar in each sampling event.

A similar pet waste education and outreach program was implemented by Anne Arundel County Watershed Steward Academy in which they canvassed and sent mailings to influence the Southgate Community in Glen Burnie in the Marley Creek Watershed. The impact of the outreach program was assessed by analyzing samples of the tributaries of Marley Creek for bacteria. The Academy is currently expanding its outreach program and plans to analyze stream samples again in spring 2016 to evaluate its effectiveness. If this program proves successful, the County can implement a similar method to evaluate the expanded pet waste education and outreach program in all County watersheds.

Conclusion: Ideally, all three of these methods could be implemented to measure behavior change, waste reduced from the land, and actual runoff. An analysis of the results could give a full indication of how effective the outreach program is in reducing bacteria loads.

8.1.2 Water Quality Monitoring and Evaluation

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. 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.

Existing Bacteria Monitoring Programs

It is important to leverage existing monitoring programs as much as possible to save cost and effort, and minimize the need to initiate new monitoring programs, which would require significant start-up and administrative time. Currently, several County and other monitoring programs are in place that measure bacteria concentrations in various County waterways. These programs include the County's ongoing NPDES MS4 monitoring of the Parole Plaza outfall and Church Creek; MDE's shellfish harvesting area monitoring; the County Health Department's bacteria monitoring of public bathing beaches; and the community-sponsored Operation Clearwater, which is (as of summer 2015) monitoring water quality at select locations along the Severn River, South River, West River, Rhode River, and Rock Creek. All of these programs measure bacteria concentrations in local waterways according to information on their websites and available monitoring reports. The County's NPDES MS4 IDDE program does not measure bacteria.

Note that many of these programs are not focused on meeting bacteria TMDL objectives. They are driven by permitting needs (NPDES MS4), public health (beach monitoring), and general characterization of water quality in a limited number of watersheds (Operation Clearwater). A summary of the existing monitoring programs is provided in Table 8-2.

Table 8-2: Description of County and Other Monitoring Programs in Maryland

Monitoring Program	Number of Location of Monitoring Stations	Bacteriological Parameter Measured	Type/Frequency of Bacteria Sampling
County's NPDES MS4 chemical monitoring	2 (Church Creek and Parole Plaza outfall, part of South River watershed)	E. coli	12 storm events per year at each monitoring location
MDE's shellfish harvesting area monitoring	Dozens throughout the County in estuaries and along shoreline[a]	Fecal coliform	Samples collected monthly, weather permitting
County Health Department's beach monitoring	>80 public bathing beaches throughout County	Enterococci	Samples collected as needed after rainfall events
County's NPDES MS4 IDDE program	150 outfalls/year throughout County	None	n/a; bacteria currently not being monitored
Operation Clearwater	Currently monitoring at 4 sites along Rock Creek and 33 sites along Severn River[b]	Enterococci	Several times a month during both dry and wet weather
County's Stream Restoration Project Monitoring	Cowhide Branch/Weems Creek Furnace Branch	E. coli	Monthly baseflow, Storm flows (minimum of twice per quarter)

[a]-see map of monitoring stations at: http://www.mde.state.md.us/programs/Marylander/CitizensInfoCenterHome/Pages/citizensinfocenter/fishandshellfish/pop_up/shellfishmaps.aspx

[b]-see map of monitoring stations at: https://www.google.com/maps/d/viewer?mid=zfiDnsNAg-ak.knZ5RgPdZmWw&msa=0&ll=39.104489%2C-76.522179&spn=0.158785%2C0.338173

Trends in Bacteria Concentration in Impaired Watersheds

MDE collects monitoring data from MDE's shellfish harvesting monitoring stations throughout the year. The collected monitoring data is used by MDE to prepare the Integrated Report for Surface Water Quality which includes a surface water quality assessment of the State waters. This report is published by MDE every two tears and it is recommended that Anne Arundel County continue to review this report to determine if any of the bacteria TMDL waterbodies are removed from the TMDL list through achievement of water quality standards for bacteria.

Monitoring data from MDE's shellfish harvesting area monitoring stations was reviewed for all the watersheds with fecal coliform impairment. A comparison of bacteria trends to the water quality criterion was conducted using the MDE's bacteria monitoring data and the data collected by the various agencies. For consistency, the monitoring stations that were used in the TMDL development were used. For most stations, monitoring was available since 2012. Anne Arundel County Department of Health has three monitoring stations on Patapsco River; however the stations are not located in Marley and Furnace Creek Watersheds, therefore latest enterococci monitoring data was not available for these watersheds. Similarly, latest e-coli monitoring data was not available for Patapsco River LNB and Patuxent River Upper Watersheds. Table 8-3 provides a comparison of the latest monitoring data with the MDE criterion for median and 90th percentile fecal coliform concentration. Except for Tar Cove and Selby Bay, all the watersheds had at least one monitoring station which equaled or exceeded the MDE's 90th percentile fecal coliform concentration criteria. This is consistent with the monitoring data published in the MDE's TMDL document as both Tar Cove and Selby Bay Watersheds have a TMDL reduction requirement of "0". Monitoring data from all the stations along with plots is included in Appendix C.

Table 8-3: Comparison of Latest Monitoring Data to Water Quality Criterion

Bacteria TMDL Watershed	Monitoring Data Source	Monitoring Station	Period of Data Collected	Median (MPN/100ml)	MDE Criteria for Median Sample (MPN/100ml)	90^{th} Percentile (MPN/100ml)	MDE Criteria for 90^{th} Percentile Sample (MPN/100ml)
Magothy Mainstem	MDE	0301001	July 2012 – June 2015	12.1	14	46.2	43
Magothy Mainstem	MDE	0301001A	June 2012 – June 2015	23.0	14	82.5	43
Magothy Mainstem	MDE	0101001A	July 2012 – June 2015	3.6	14	25	43
Magothy Mainstem	MDE	0301800	July 2012 – June 2015	3.6	14	23	43
Magothy River/Forked Creek	MDE	0301011	July 2012 – June 2015	9.1	14	262	43
Magothy River/Tar Cove	MDE	0301005C	July 2012 – June 2015	3.6	14	23	43
Magothy River/Tar Cove	MDE	0301006B	July 2012 – June 2015	9.1	14	39.4	43
Magothy River/Tar Cove	MDE	0301801	July 2012 – June 2015	1	14	7.5	43
Magothy River/Tar Cove	MDE	0301802	July 2012 – June 2015	2.3	14	9.7	43
Rhode River/Bear Neck Creek	MDE	0307120A	June 2012 – June 2015	12.1	14	62.7	43
Rhode River/Cadle Creek	MDE	0307019	July 2012 – June 2015	8.2	14	84.7	43
Severn River Mainstem	MDE	0304152	March 2013 – June 2015	9.1	14	262	43
Severn River Mainstem	MDE	0304150	March 2013 – June 2015	3.6	14	48	43
Severn River Mainstem	MDE	0304002A	March 2013 – June 2015	3.6	14	43	43
Severn River Mainstem	MDE	0304005	March 2013 – June 2015	2.3	14	43	43
Severn River Mainstem	MDE	0304008	March 2013 – June 2015	3.6	14	23	43
Severn River Mainstem	MDE	0304011	March 2013 – June 2015	3.6	14	43	43
Severn River Mainstem	MDE	0304016	March 2013 – June 2015	3.6	14	43	43
Severn River Mainstem	MDE	0304020	March 2013 – June 2015	3.6	14	10.5	43
Severn River Mainstem	MDE	0304028	March 2013 – June 2015	1	14	9.1	
Severn River Mainstem	MDE	0304029	March 2013 – June 2015	1	14	15.8	43

Bacteria TMDL Watershed	Monitoring Data Source	Monitoring Station	Period of Data Collected	Median (MPN/100ml)	MDE Criteria for Median Sample (MPN/100ml)	90th Percentile (MPN/100ml)	MDE Criteria for 90th Percentile Sample (MPN/100ml)
Severn River Mainstem	MDE	0303200	March 2013 – June 2015	1	14	7.5	43
Severn River Mainstem	MDE	0303202	March 2013 – June 2015	1	14	1	43
Severn River Mainstem	MDE	0303204	March 2013 – June 2015	3.6	14	9.1	43
Severn River/Mill Creek	MDE	0306006	March 2013 – June 2015	6.4	14	48.0	43
Severn River/Whitehall and Meredith Creek	MDE	0303005	March 2013 – June 2015	7.3	14	23.0	43
Severn River/Whitehall and Meredith Creek	MDE	0303005A	March 2013 – June 2015	9.1	14	43.0	43
South River/Duvall Creek	MDE	0306104	September 2012 – June 2015	7.3	14	23.0	43
South River/Duvall Creek	MDE	0306013A	September 2012 – June 2015	8.2	14	75.0	43
South River Mainstem	MDE	0306110	September 2012 – June 2015	19	14	75.0	43
South River Mainstem	MDE	0306211	September 2012 – June 2015	3.6	14	43.0	43
South River Mainstem	MDE	0306002	September 2012 – June 2015	9.1	14	23.0	43
South River Mainstem	MDE	0306205	September 2012 – June 2015	3.6	14	23.0	43
South River Mainstem	MDE	0306111	September 2012 – June 2015	9.1	14	43.0	43
South River Mainstem	MDE	0306208A	September 2012 – June 2015	9.1	14	53.0	43
South River/Ramsey Lake	MDE	0306115A	September 2012 – June 2015	5.5	14	43	43
South River/Selby Bay	MDE	0306801	September 2012 – June 2015	3.6	14	25.0	43
South River/Selby Bay	MDE	0306115	September 2012 – June 2015	1	14	12.5	43
W. Chesapeake Bay/Tracy and Rockhold Creeks	MDE	0501004	August 2011 – June 2015	23	14	93.0	43
W. Chesapeake Bay/Tracy and Rockhold Creeks	MDE	0501004A	August 2011 – June 2015	9.1	14	150.0	43
West River Mainstem	MDE	0307205	June 2012 – June 2015	9.1	14	43	43
West River/Parish Creek	MDE	0307011	June 2012 – June 2015	8.2	14	84.7	43

Expansion of Bacteria Monitoring

To verify that water quality is improving as a result of implementing restoration strategies in the 19 TMDL watersheds, a comprehensive monitoring effort could be undertaken. There are cost-saving measures and ways to conserve on effort that would facilitate this type of monitoring. First, only certain TMDL watersheds or subwatersheds should be sampled. Priority would be given to those watersheds with distinct differences in size, geographic setting, and land use rather than duplicating efforts in watersheds that are very similar (e.g., Furnace and Marley Creeks).

Water quality improvements related to watershed restoration projects can be difficult to detect because of such factors as time lag between project implementation and detectable results, 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.   A minimum of 5 years of monitoring data would be collected under various climatic conditions and seasons to account for variations in flow and inter-annual changes related to wet years and dry years. A minimum of 5 years of monitoring is desired, because there will be a delay from the time restoration strategies are implemented to when a water quality improvement may be detected. More years of data will provide a much better basis for evaluating the success of the TMDL Restoration Plan so that required load reductions can be met in a timely fashion. Targeted monitoring downstream of restoration projects to evaluate their effectiveness should be implemented depending on the availability of the County's resources.

One way to expand bacteria monitoring is to continue incorporation of bacteria as a measured constituent in the County's project-specific monitoring programs. County field personnel are trained in proper sample collection methods and already collect samples for bacteria analyses at project specific restoration sites and as part of the NPDES MS4 Permit required stormwater monitoring program in the Church Creek subwatershed of the South River. As additional project specific restoration projects are brought on-line (e.g., Furnace Branch stream restoration), pre and post-construction monitoring plans will include bacteria as a water quality analytes. Should consultants be utilized in assessing the bacteria composition of non-tidal waterways in the County, the County will utilize Standard Operating Procedures to ensure that consultants' methods are standardized. All bacteria samples collected by County staff or their consultants are analyzed by a certified laboratory.

Volunteer bacteria monitoring programs in targeted watersheds could also be developed by collaborating with watershed groups. As with the use of consultants for bacteria monitoring, the County would require adherence to a Standard Operating Procedure to ensure consistency in methodology among all parties involved.

Monitoring equipment and test kits are commercially available for purchase and use by volunteer personnel to directly quantify bacteria concentrations in the impaired TMDL waterways. Typically, once the samples are collected, there is a 16- or 24-hour incubation period before bacteria levels can be measured using the test kits. A list of potential test kits and equipment is provided in Table 8-4 . Alternatively, rather than having volunteers test for bacteria on their own, water samples can be sent to a certified laboratory for testing. While this is the most accurate way to measure bacteria concentrations, the costs involved could be significant; furthermore, bacteria samples have a very short hold time (typically 6 hours), which can make logistics of sample delivery to the lab difficult.

Table 8-4: Potential Testing Equipment and Methods to Measure Bacteria Concentrations

Equipment	Type of Bacteria Measured	Description of Method	For More Information
Coliscan CSK 10	E. Coli / Total Coliforms	Petri dish, 24-hour incubation (count)	See link 1 below
Quantitube	E. Coli / Total Coliforms	16-hour recovery, no petri dish; snap shut tube (count)	See link 2 below
Lovibond E.Coli Test Kit	E. Coli / Total Coliforms	Collect sample, allow to incubate for 24 hours. The color change indicates the presence of total coliforms. E. Coli must be viewed under UV light.	See link 3 below
Colilert	E. Coli / Total Coliforms	EPA approved method for measuring E. Coli and Total Coliforms. May potentially require additional equipment. Allow for a 24-hour incubation period, but takes less than 1 minute of hands-on time	See link 4 below

1- http://www.lamotte.com/en/microbiological/coliform
2- http://coliform.com/Ecoli_test.html
3- http://www.lovibondwater.com/product/coliformecoli-test-kit.aspx
4- https://www.idexx.com/water/products/colilert.html

The monitoring approach for evaluating progress will incorporate existing monitoring programs, as possible, and make small adjustments to County programs as needed to obtain a more comprehensive picture of the effectiveness of the TMDL Restoration Plan in the County.

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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, 2013a) 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 nonpoint 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	4,500
Commercial	Commercial	2.24	0.30	43	4,500
Forested Wetland	Forest	1.00	0.11	34	500
Industrial	Industrial	2.22	0.19	77	2,614
Open Space	Open Space	1.15	0.15	34	3,100
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	7,750
Residential 1/2 acre	Medium Density Residential (1-4 DU)	2.74	0.32	43	7,750
Residential ¼ acre	Medium Density Residential (1-4 DU)	2.74	0.32	43	7,750
Residential 2 acre	Low Density Residential (<1 DU)	2.74	0.32	43	7,750
Residential 1/8 acre	High Density Residential (>4 DU)	2.74	0.32	43	7,750
Row Crops	Row Crops	16.06	2.63	1,046	500
Transportation	Transportation	2.59	0.43	99	1,400
Utility	Open Space	1.15	0.15	34	3,100
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 systems (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

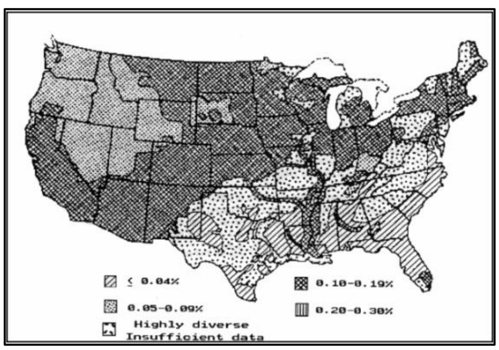
- **Sanitary sewer overflows (SSOs):** Pollutant loads due to SSOs are estimated based on total SSO volume and effluent concentration (Table A-2). Based on County-provided information, a volume of 55,650 gallons per SSO, which is the County-wide median value, was used to estimate the loads, and approximately 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) Municipal Separate Storm Sewer System (MS4) Annual 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 (32 cases out of 1,500 outfalls surveyed from 2005 to 2014). 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

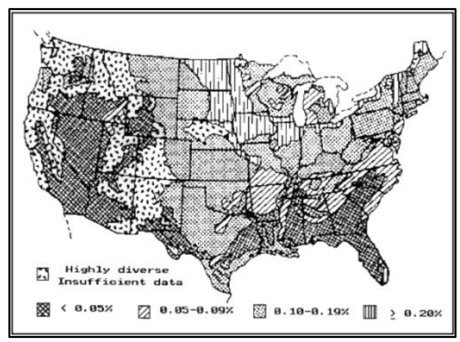
Pollutant	Pollutant Concentration	
	Wash Water	Wash Water and Wastewater
TN (mg/l)	15	30
TP (mg/l)	10	10
TSS (mg/l)	150	225
Bacteria (MPN/100 ml)	0	3,300,000

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, 2013b) 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). An aerial imagery survey of the rural land use was conducted to further narrow down the livestock area in all watersheds where crops and pastures/hay was determined to be 10 percent or more of the total land use. 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)[2]	Percent Manure Available for Washoff (%)[2]
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
2- From MDE published TMDL reports

- **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 pump-outs 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 the stormwater management GIS BMP database developed by the County as a part of 2014 NPDES MS4 Annual Report (Anne Arundel County, 2015) and input into 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 to match the bacteria BMP removal efficiencies compiled by the County and learned through various literature sources. All BMPs input into the model are inspected at least once every 3 years as required by the County's NPDES MS4 permit. 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 (%)	BMP Type	Bacteria Pollutant Removal Efficiency (%)
Bioretention	70[2]	Landscape Infiltration	96[3]
Detention Structure Dry (Dry Pond)	88[1]	Level Spreader	0[9]
Disconnection of Non-Rooftop Runoff	0[10]	Micropool Extended Detention Pond	70[1]
Disconnection of Rooftop Runoff	0[10]	Oil-Grit Separator	0[7]
Dry Swale	0[6]	Other	0[7]
Dry Wells	96[3]	Permeable Pavements	37[1]
Extended Detention Structure, Dry	88[1]	Rain Gardens	70[2]
Extended Detention Structure, Wet	70[1]	Rain Water Harvesting	0[10]
Forestation on Pervious Areas	42[5]	Retention Pond	70[1]
Grass Swale	0[6]	Sand Filter	37[1]
Green Roof	0[11]	Shallow Marsh	78[1]
Impervious Surface Elimination	0[10]	Sheetflow to Conservation Areas	42[5]
Infiltration Basin	96[3]	Step Pool Conveyance System	70[4]
Infiltration Berms	96[3]	Stream Restoration	0[10]
Infiltration Trench	96[3]	Submerged Gravel Wetland	78[1]

[1] Fraley-McNeal, L., Schueler, T., Winer, R. 2007. National Pollutant Removal Performance Database - Version 3. Center for Watershed Protection, Ellicott City, MD.
[2] Hunt, W. F., Smith, J.T., Jadlocki, S.J., Hathaway, J.M., Eubanks, P.R., 2008. Pollutant Removal and Peak Flow Mitigation by a Bioretention Cell in Urban North Carolina. Biological and Agriculture Engineering, North Carolina State University, Raleigh, NC.
[3] Birch, G. F., Fazeli,M.S., Matthai, C., 2006. Efficiency of an Infiltration Basin in Removing Contaminants from Urban Stormwater. Environmental Geology Group School of Geo Sciences, University of Sydney, Sydney, Australia.
[4] According to Accounting for Wasteload Allocations, Step Pool Storm Conveyance function similar to bioretention and efficiencies of bioretention basins can be used (Page 48). Therefore, efficiency will be the same as that of bioretention, which is 70%.
[5] Parajuli P.B., K.R.Mankin, P.L. Batnes, 2008. Applicability of targeting vegetative filter strips to abate fecal bacteria and sediment yield using Soil and Water Assessment Tool (SWAT).
[6] http://water.epa.gov/polwaste/npdes/swbmp/Grassed-Swales.cfm.
[7] Hathaway, J.M., W.F. Hunt, and S.J. Jadlocki. 2009. “Indicator Bacteria Removal in Stormwater Best Management Practices in Charlotte, North Carolina.” *Journal of Environmental Engineering*, 135(12), 1275-1285.
[8] Green roofs filter runoff in a similar way to bioretention systems, so a removal efficient of 70% assumed.
[9] http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-02-020.pdf.
[10] Substantial data not available; therefore, 0 was used.
[11] Stormwater captured by green roofs has negligible bacteria concentrations; therefore, 0 was used.

- **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	542,407	1,486
Magothy River	Forked Creek	78,350	215
Magothy River	Magothy River Mainstem	1,731,125	4,743
Magothy River	Tar Cove	262,855	720
Patapsco River Lower North Branch	Patapsco Lower North Branch	1,190,776	3,262
Patapsco River	Furnace Creek	1,084,267	2,971
Patapsco River	Marley Creek	992,234	2,718
Severn River	Mill Creek	234,320	642
Severn River	Severn River Mainstem	4,935,668	13,522
Severn River	Whitehall/Meredith Creeks	173,222	475
South River	Duvall Creek	67,854	186
South River	Ramsey Lake	109,101	299
South River	Selby Bay	105,511	289
South River	South River Mainstem	2,074,463	5,683
Upper Patuxent River	Patuxent River Upper	210,791	578
West River and Rhode River	Bear Neck Creek	63,684	174
West River and Rhode River	Cadle Creek	32,192	88
West River and Rhode River	Parish Creek	22,860	63
West River and Rhode River	West River Mainstem	176,084	482

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. 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 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 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: Prior Load Reductions from Implemented Strategies Since 2000

Bacteria TMDL Watershed	Prior Load Reductions Since 2000		TMDL Targets	
	Post-TMDL BMPs (%)	Post-TMDL Septic System Retirement (%)	TMDL Target Reduction Requirements (%)	Adjusted TMDL Required Reduction (%)
Magothy Mainstem	3.04	0.61	12.80	9.15
Magothy River/Forked Creek	6.25	None	26.30	20.05
Magothy River/Tar Cove	2.23	None	0.00	0.00
Patapsco River/Furnace Creek	3.65	0.38	77.70	73.67
Patapsco River LNB	3.96	2.61	20.70	14.13
Patapsco River/Marley Creek	5.83	0.26	75.70	69.61
Patuxent River Upper	4.54	None	22.30	17.82
Rhode River/Bear Neck Creek	2.23	None	43.30	41.07
Rhode River/Cadle Creek	6.25	None	72.20	65.95
Severn River Mainstem	1.18	0.35	19.00	17.47
Severn River/Mill Creek	6.82	None	86.00	79.18
Severn River/Whitehall and Meredith Creek	4.42	0.43	90.00	85.15
South River/Duvall Creek	3.13	None	45.60	42.47
South River Mainstem	9.06	0.06	29.50	20.38
South River/Ramsey Lake	5.72	None	59.30	53.58
South River/Selby Bay	1.30	None	0.00	0.00
W. Chesapeake Bay/Tracy and Rockhold Creeks	0.35	2.70	81.60	78.55
West River Mainstem	1.38	0.48	35.30	33.44
West River/Parish Creek	0.45	None	53.10	52.65

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. An implementation rate of 40 septic disconnections was used based on the information provided by Anne Arundel County Health Department. The number of septic systems that would be retired in all the watersheds by the year 2025 was calculated by proportioning the current County implementation rate. 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 by the year 2025.

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	Number of Septic Systems that would be Retired by 2025 (%)
Magothy Mainstem	4,814	88
Magothy River/Forked	113	2
Magothy River/Tar Cove	1,708	31
Patapsco River Lower North Branch	174	3
Patapsco River/Furnace Creek	252	5
Patapsco River/Marley Creek	0	0
Patuxent River Upper	289	5
Rhode River/Bear Neck Creek	0	0
Rhode River/Cadle Creek	0	0
Severn River Mainstem	5,475	100

TMDL Watershed ID	No. of Septic Systems Identified to Be Connected to Sewer	Number of Septic Systems that would be Retired by 2025 (%)
Severn River/Mill Creek	1,168	21
Severn River/Whitehall and Meredith Creek	320	6
South River Mainstem	1,694	31
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 Program (CIP) projects for wastewater, approximately 34 discrete projects and 31 recurring projects related to SPS upgrades were identified in 9 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

TMDL Watershed	No. of Discrete SPS Upgrade Projects	No. of Recurring SPS Upgrade Projects
Magothy River Mainstem	2	5
Magothy River Mainstem, Patapsco River LNB, South River/Duvall Creek	6	N/A
Patapsco River Lower North Branch	N/A	1
Patapsco River/Furnace Creek	1	1
Patapsco River/Marley Creek	1	5

TMDL Watershed	No. of Discrete SPS Upgrade Projects	No. of Recurring SPS Upgrade Projects
Patapsco River LNB, Baltimore Harbor, Stony Creek, Rock Creek	8	N/A
Rhode River/Cadle Creek	12	N/A
Severn River Mainstem	1	6
South River Mainstem	3	10
West River/Parish Creek	N/A	3

- **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 2014, the rate of illicit connections detection/elimination is approximately 2 percent (32 cases out of 1,500 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 include restoring 20 percent of currently unmanaged impervious cover through constructing new stormwater management facilities and retrofitting pre-2002 ponds and other stormwater management facilities 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 percent of the impervious area that currently has limited or no stormwater management practice in place. The restoration projects planned as a part of the County's CIP include retrofitting existing outfalls to step pool storm conveyance systems (SPSCs) or retrofitting pre-2002 ponds to wet ponds, wetlands, and SPSCs. Table A-13 lists the number of CIP projects planned by the County in the TMDL watersheds along with the proposed impervious area that they would treat.

The 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	Number of Urban Retrofit Projects Proposed	Drainage Area Proposed to Be Treated (acres)	Impervious Area Proposed to Be Treated (acres)
Magothy Mainstem	35	717.6	110.3
Magothy River/Forked	N/A	N/A	N/A
Magothy River/Tar Cove	N/A	N/A	N/A
Patapsco Lower North Branch	27	1105.3	310.7
Patapsco River/Furnace Creek	6	71.0	9.4
Patapsco River/Marley Creek	6	126.3	18.3
Patuxent River Upper	N/A	N/A	N/A
Rhode River/Bear Neck Creek	N/A	N/A	N/A
Rhode River/Cadle Creek	N/A	N/A	N/A
Severn River Mainstem	35	1738.6	187.3
Severn River/Mill Creek	4	33.8	3.0
Severn River/Whitehall and Meredith Creek	1	24.7	2.3
South River Mainstem	17	605.0	146.8
South River/Duvall Creek	1	13.1	2.0
South River/Ramsey Lake	N/A	N/A	N/A
South River/Selby Bay	N/A	N/A	N/A

- **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	Septic Retirement/Connection	Abatement of SSOs	Restoration of 20% Untreated Impervious Area through Urban Stormwater Management Retrofits	Eliminate Household Illicit Connections	Riparian Buffer Education
Magothy Mainstem	0.26%	1.12%	1.95%	9.05%	0.85%
Magothy River/Forked Creek	0.11%	N/A	N/A	1.14%	1.74%
Magothy River/Tar Cove	0.46%	N/A	N/A	0.67%	0.92%
Patapsco River/Furnace Creek	0.07%	3.75%	0.10%	8.27%	1.41%
Patapsco River LNB	0.10%	4.96%	4.80%	11.76%	2.73%
Patapsco River/Marley Creek	N/A	2.12%	0.53%	11.21%	1.52%
Patuxent River Upper	0.38%	N/A	N/A	1.14%	20.57%
Rhode River/Bear Neck Creek	N/A	N/A	N/A	0.50%	0.11%
Rhode River/Cadle Creek	N/A	8.50%	N/A	0.30%	0.70%
Severn River Mainstem	0.20%	0.37%	0.80%	19.40%	1.43%
Severn River/Mill Creek	0.63%	N/A	0.65%	1.54%	2.50%
Severn River/Whitehall and Meredith Creek	0.42%	N/A	0.63%	0.96%	2.13%
South River/Duvall Creek	N/A	6.40%	0.83%	0.65%	N/A
South River Mainstem	0.29%	0.31%	2.00%	11.40%	7.30%
South River/Ramsey Lake	N/A	N/A	N/A	0.11%	0.12%
South River/Selby Bay	N/A	N/A	N/A	0.16%	0.06%
W. Chesapeake Bay/Tracy and Rockhold Creeks	N/A	N/A	N/A	0.23%	7.70%
West River Mainstem	N/A	N/A	N/A	1.39%	11.90%
West River/Parish Creek	N/A	12.90%	N/A	0.19%	0.42%

A.5 REFERENCES

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Appendix B: Sample Pet Waste Survey from Anne Arundel County Watershed Stewards Academy

BASELINE: Pet Waste Behavior Survey

Check Box after responses are entered into Survey Monkey: ☐

Date____________________ Time____________________ Surveyor____

Responder's Name____Phone____

Address____Email____

Introduce yourself and your purpose (separate text).

1. Do you have a dog?
   - ☐ **Yes** `☐ **No/Not sure/Refused** *(Skip to **Classification (question 9.)***)

If YES, ask the following questions.

2. Not everyone picks up their dog's [waste/poop], especially in their own yard. What about you? Typically, do you pick up the dog waste from your back yard … *(Read categories, ALTERNATING high to low and low to high for each survey you take.)*
   - ☐ **Every day**
   - ☐ **Once or twice a week**
   - ☐ **Once or twice a month**
   - ☐ **Less than once a month**
   - ☐ **Never**
   - ☐ *(DO NOT READ):* Dog never poops in own yard
   - ☐ *(DO NOT READ):* Refused to say
   - ☐ *(DO NOT READ):* Not sure

3. When you do pick up your dog waste, where do you put it?
   - ☐ **In the trash can**
   - ☐ **Flush down the toilet**
   - ☐ **In the woods or other natural area**
   - ☐ **In a pile in the yard**
   - ☐ **Other: ________________**
   - ☐ *(DO NOT READ):* Refused to say
   - ☐ *(DO NOT READ):* Not sure

4. How about outside of your own yard? Do you pick up your dog's waste… *(Read categories, ALTERNATING high to low and low to high for each survey you take.)*
   - ☐ **Always**
   - ☐ **Usually**
   - ☐ **Sometimes**
   - ☐ **Seldom**
   - ☐ **Never**
   - ☐ *(DO NOT READ):* Dog is never outside its own yard

- ☐ *(DO NOT READ):* Refused to say
- ☐ *(DO NOT READ):* Not sure

5. When you do pick up your dog waste outside of your yard, where do you put it?
- ☐ **In the trash can**
- ☐ **Flush down the toilet**
- ☐ **In the woods or other natural area**
- ☐ **In a pile in the yard**
- ☐ **Other: _______________**
- ☐ *(DO NOT READ):* Refused to say
- ☐ *(DO NOT READ):* Not sure

If they do not responded "always" in previous question, ask:

6. *What is the main reason you don't always pick up after your dog?*
   - ☐ *(Specify. Record VERBATIM, and clarify.)*

____

____

7. Are you or someone else always with your dog when he or she is outside your yard, or does your dog sometimes roam on its own?
   - ☐ **Always with the dog**
   - ☐ **Sometimes roams on its own**
   - ☐ *(DO NOT READ):* Sometimes escapes/roams by accident
   - ☐ *(DO NOT READ):* Refused to say
   - ☐ *(DO NOT READ):* Not sure

8. Do you think disposing of your pet's waste in the trash can would make a big difference, a little difference, or no difference in cleaning up our local waters?
   - ☐ **Big difference**
   - ☐ **Little difference**
   - ☐ **No difference**
   - ☐ *(DO NOT READ):* **Not sure**

Tell me a little bit about why you say it would make a (big, little, no) difference?

CLASSIFICATION

9. We have almost completed the survey. Which of these do you tend to rely on fairly regularly for local news and events?

(Record all that apply.)

- ☐ **The Capital newspaper**
- ☐ **The Patch**
- ☐ **A neighborhood email group**
- ☐ **A printed neighborhood newsletter**
- ☐ **Emails from other local organizations** (Which ones?)

____

- ☐ **Posters or signs you see in the neighborhood** (Where?)

____

- ☐ **Any other sources of local information?** (Record what.)

____

- ☐ **None of those**

10. Just to classify the survey, what is your age?

- ☐ **Less than 24**
- ☐ **25 – 34**
- ☐ **35 – 44**
- ☐ **45 – 54**
- ☐ **55 – 64**
- ☐ **65 and over**
- ☐ *(DO NOT READ):* Not sure/Refused

11. Do you own or rent your home?
   - ☐ **Own** ☐ **Rent** ☐ Not sure/Refused

12. How many years have you lived in this neighborhood?
   (Record years.)

   ____

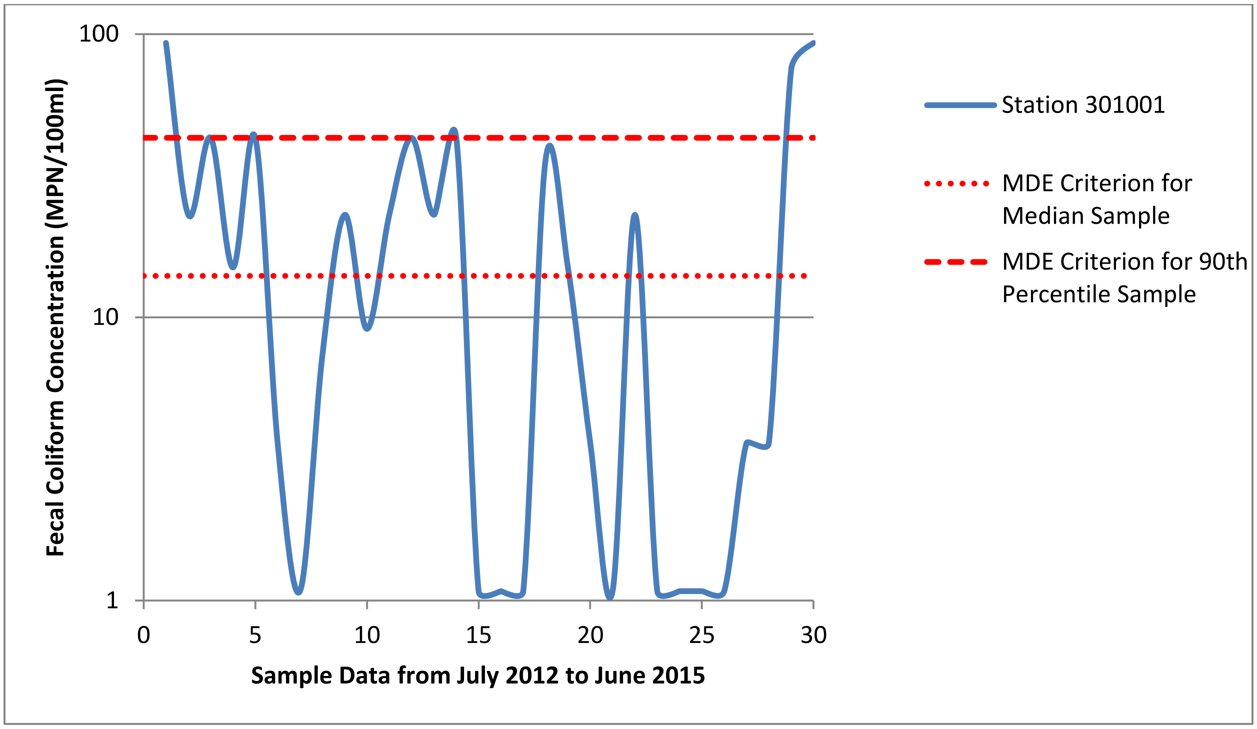
13. Which of these comes closest to describing your own race or ethnic background?
   (RANDOMIZE [read list in a different order each time]):
   - ☐ **White**
   - ☐ **African-American**
   - ☐ **Hispanic**
   - ☐ **Asian**
   - ☐ **Mixed race**
   - ☐ **Other**
   - ☐ Not sure/Refused to say

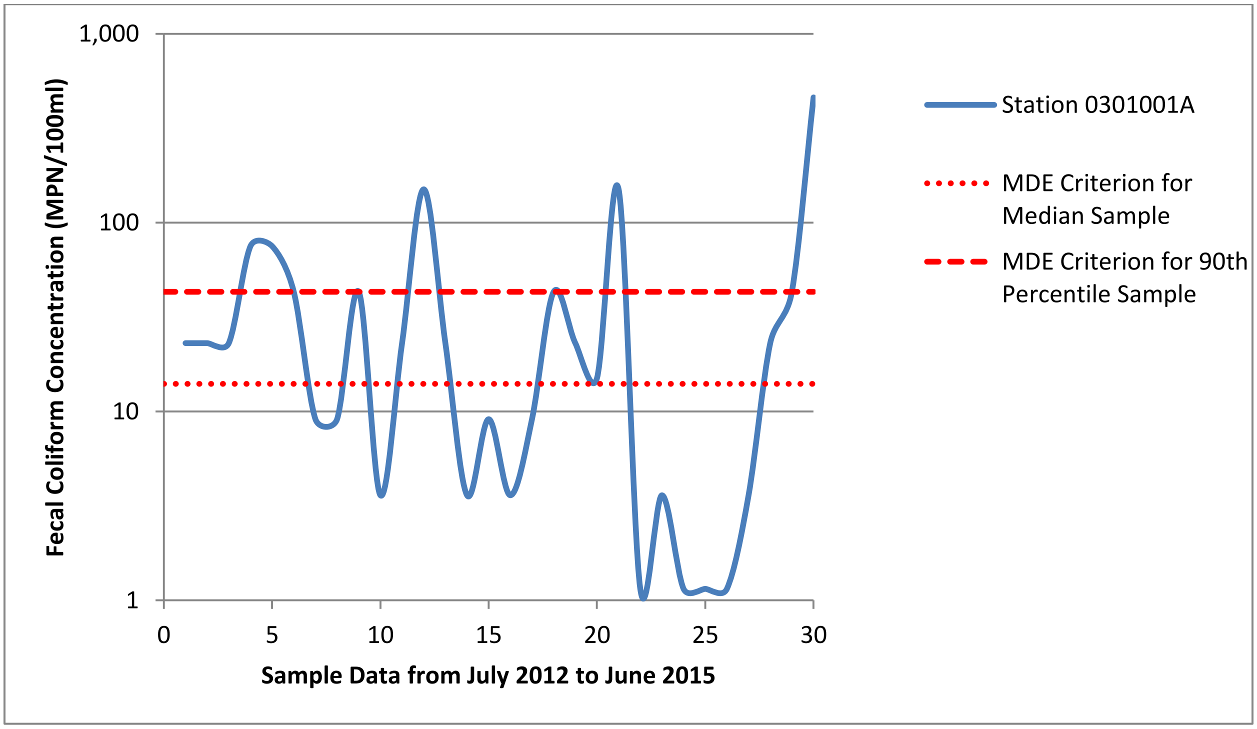
14. Gender *(By observation)*
   - ☐ **Female** ☐ **Male**

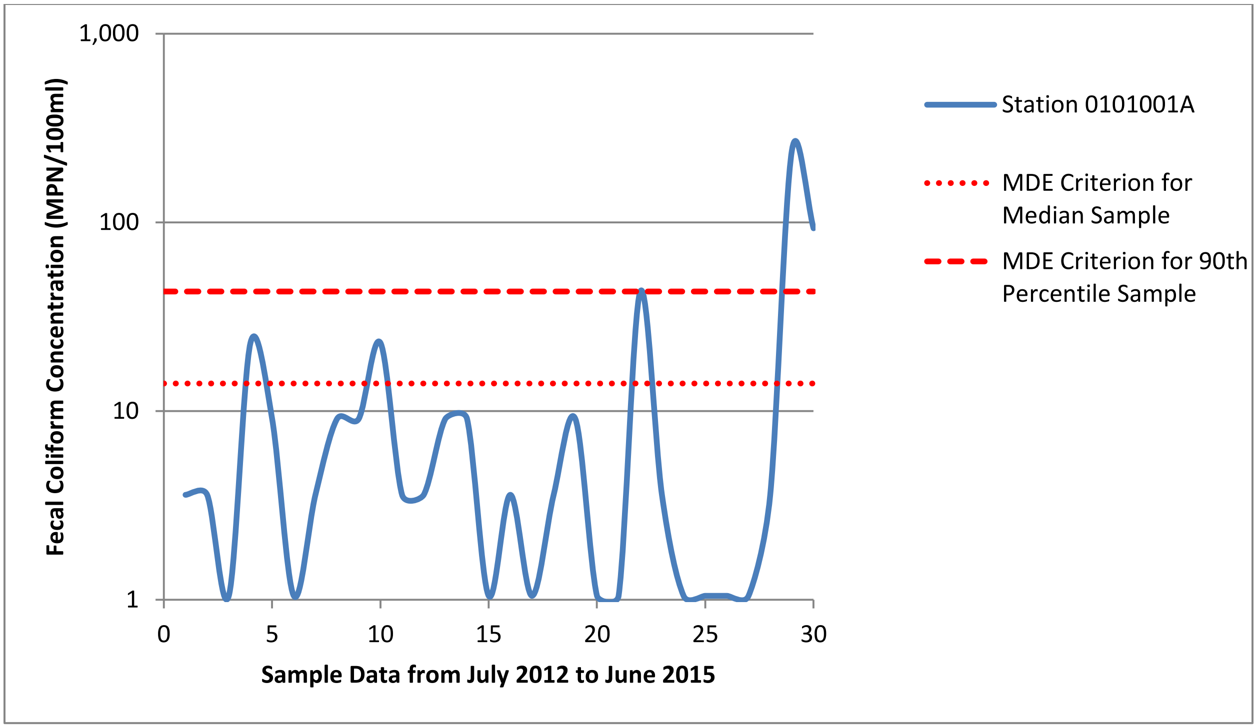
That completes the survey. Thanks very much for your time.

Appendix C: Monitoring Data

C.1 Magothy River Mainstem



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15
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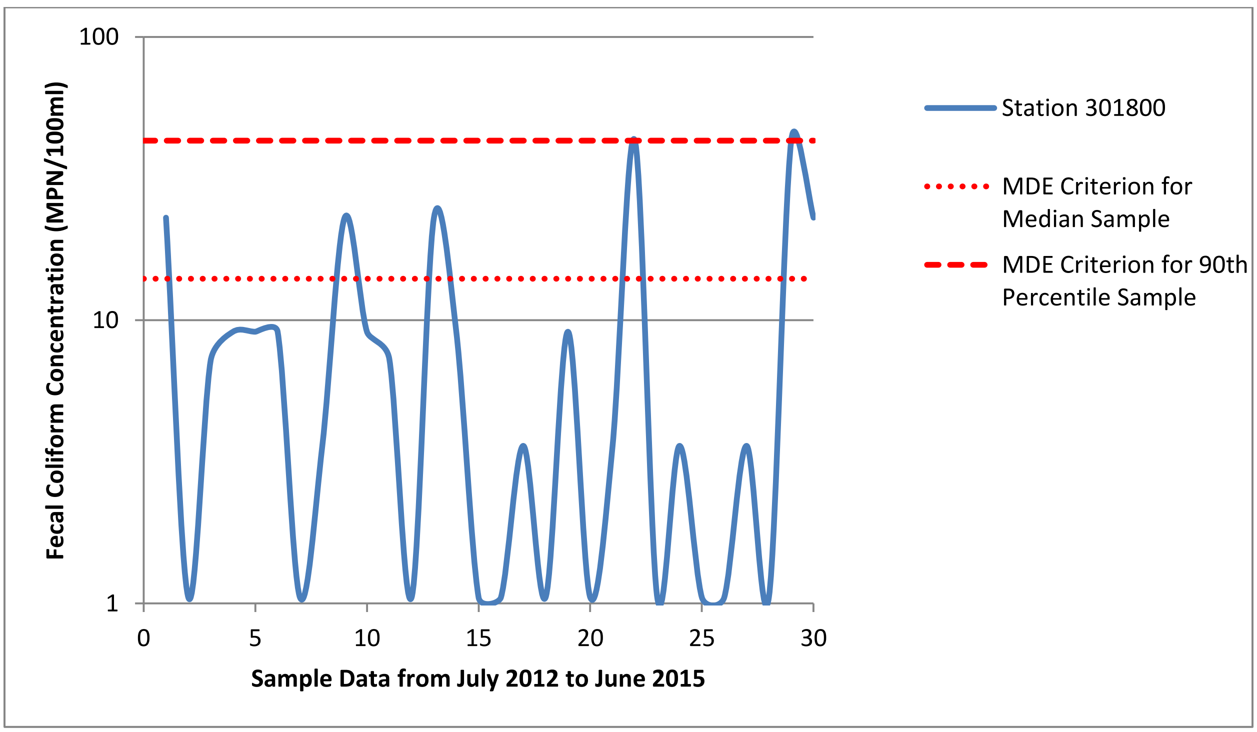
Sample Data from July 2012 to June 2015
Station 0101001A
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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25
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Fecal Coliform Concentration (MPN/100ml)
Sample Data from July 2012 to June 2015
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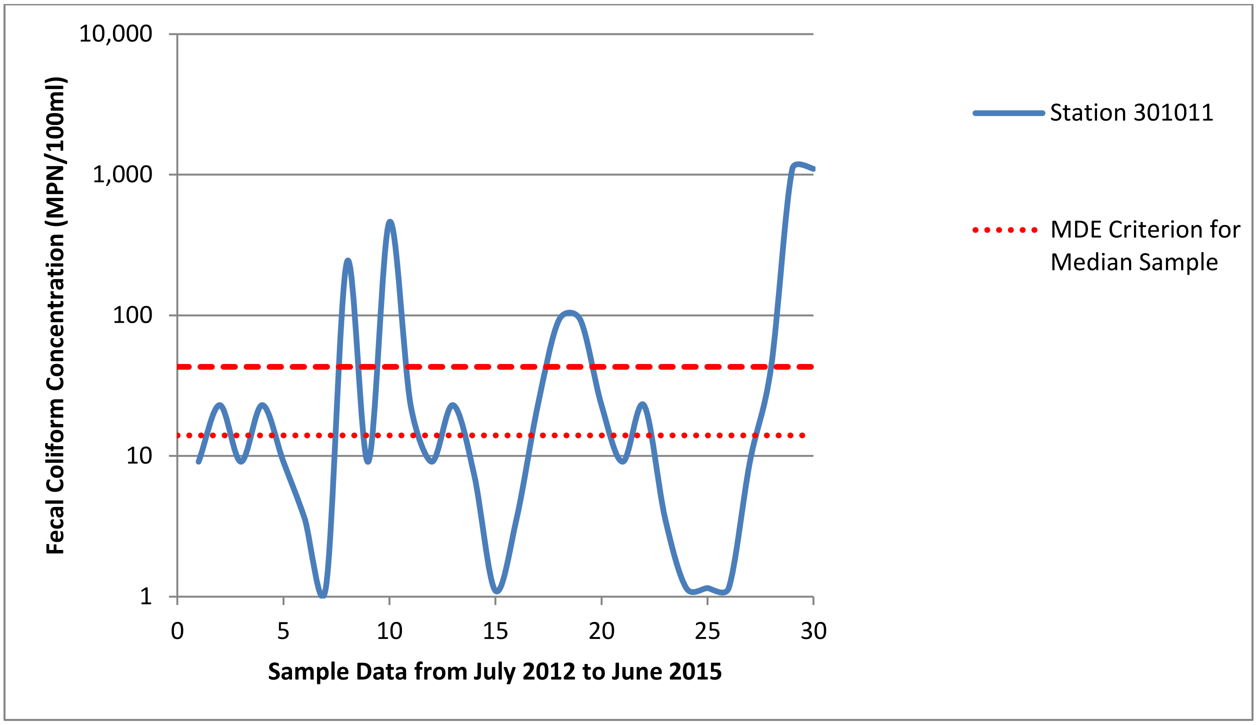
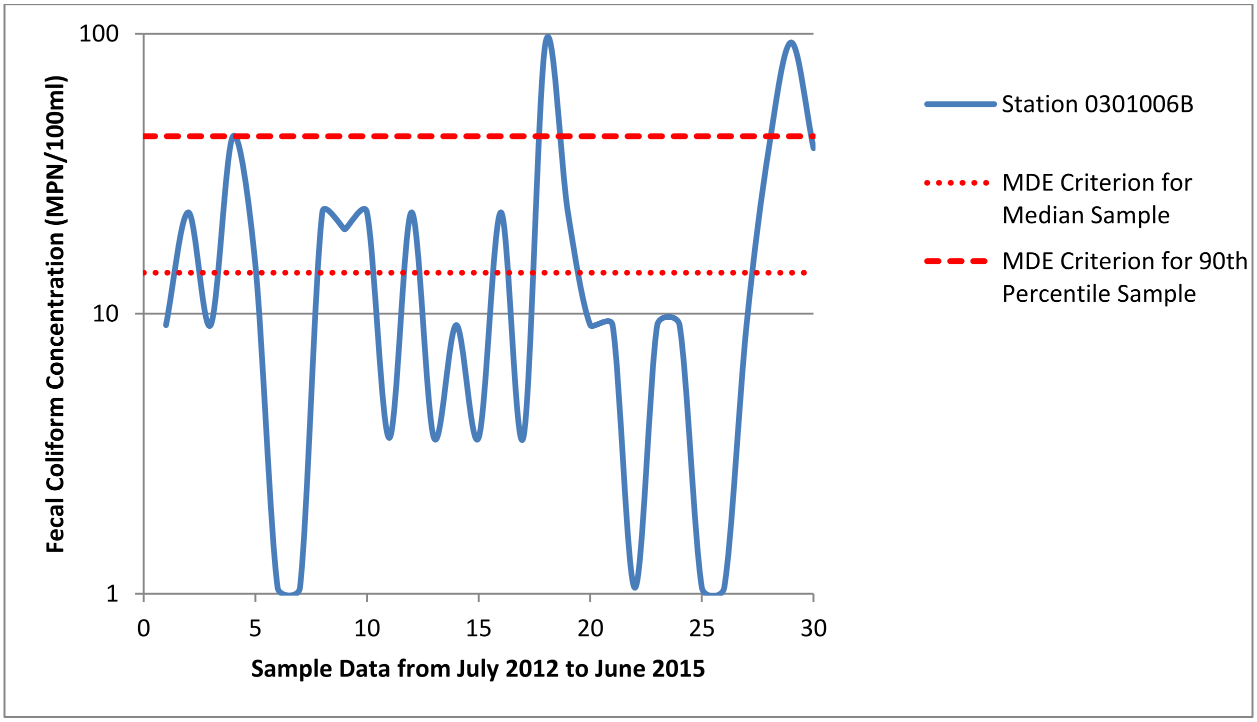
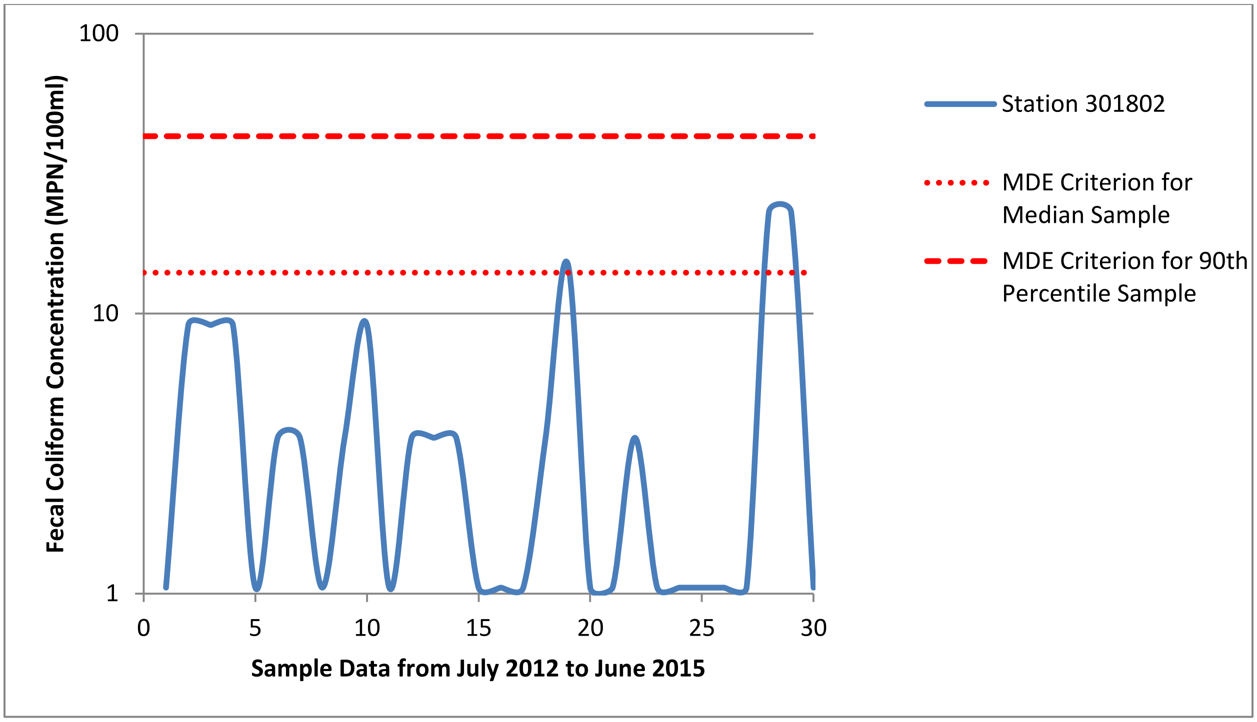
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample

C.2 Magothy River Mainstem/Forked Creek



C.3 Magothy River Mainstem/Tar Cove

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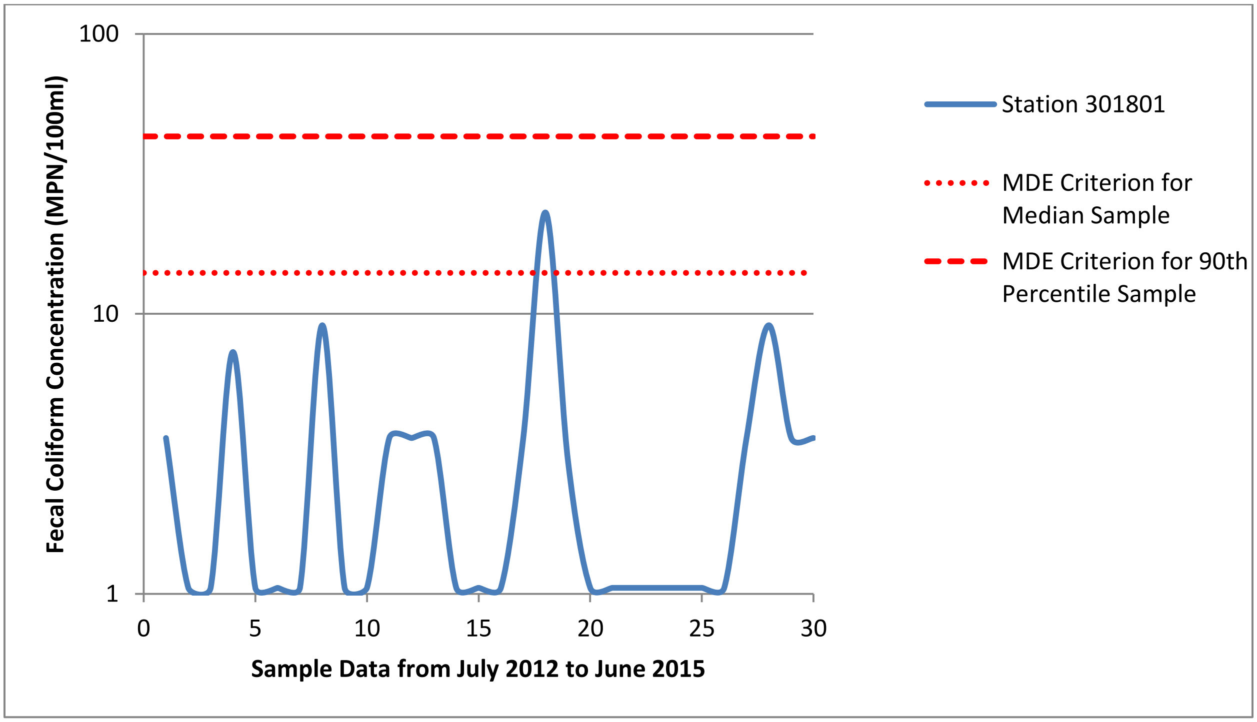
MDE Criterion for 90th Percentile Sample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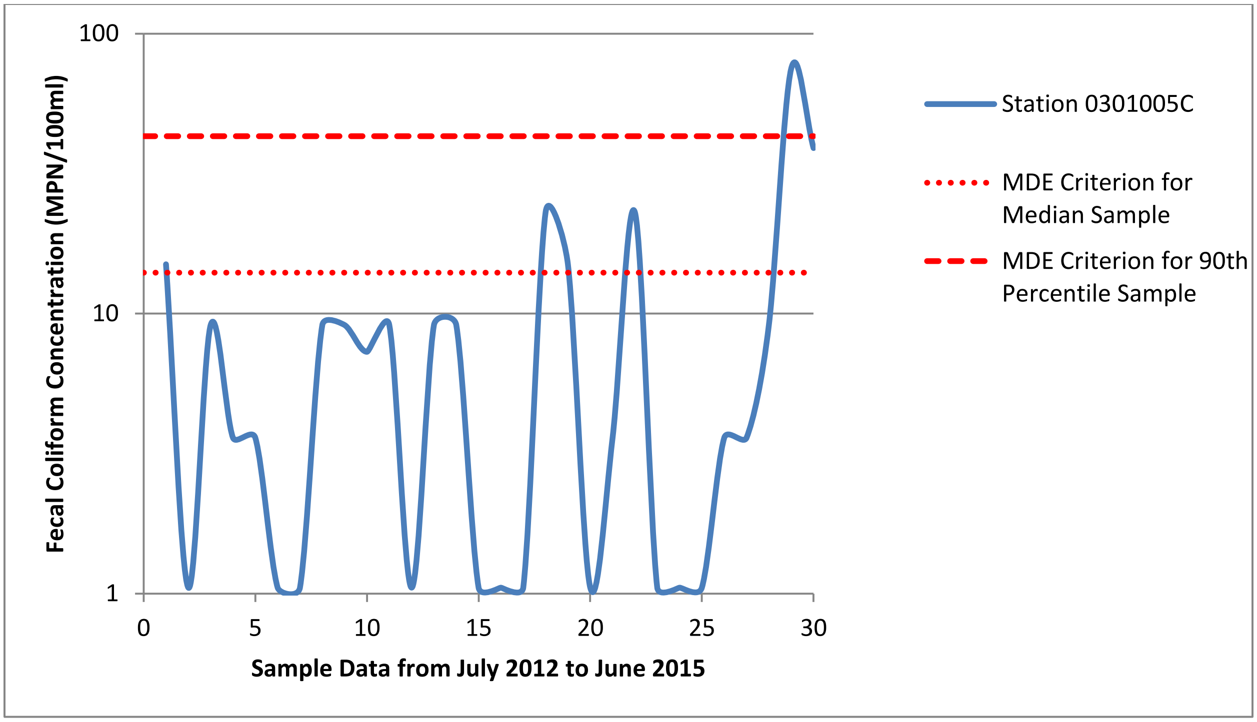
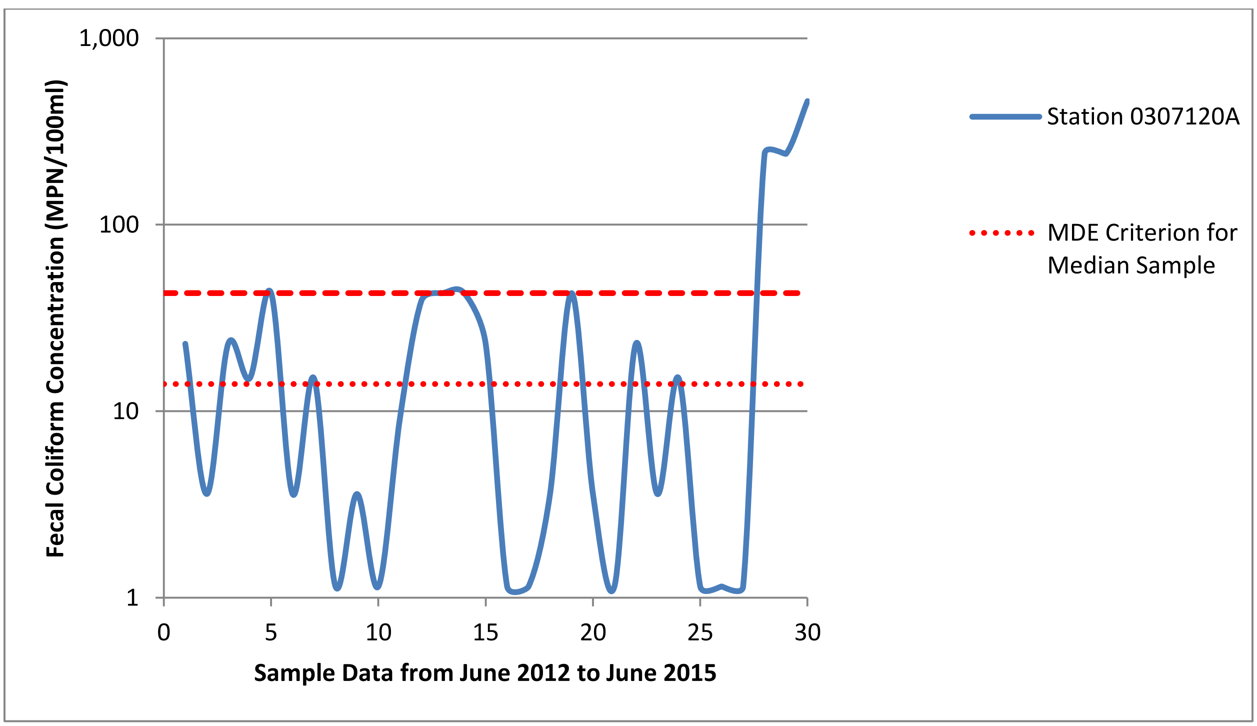
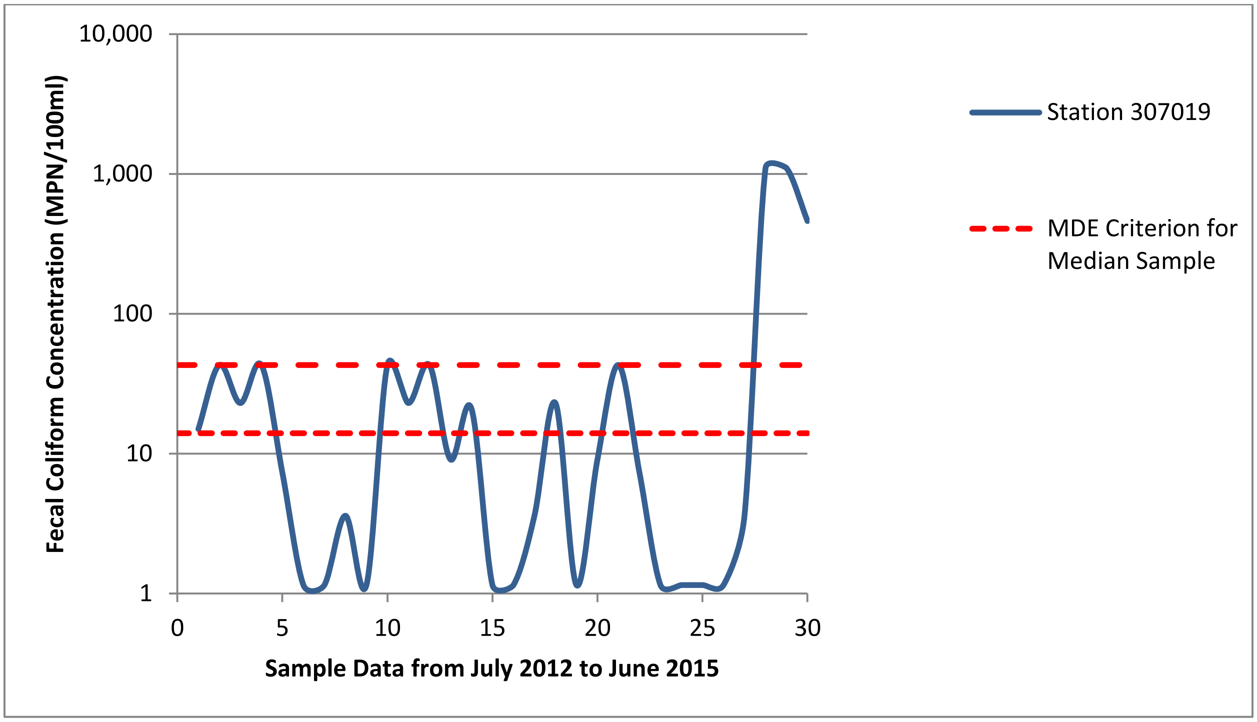
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample



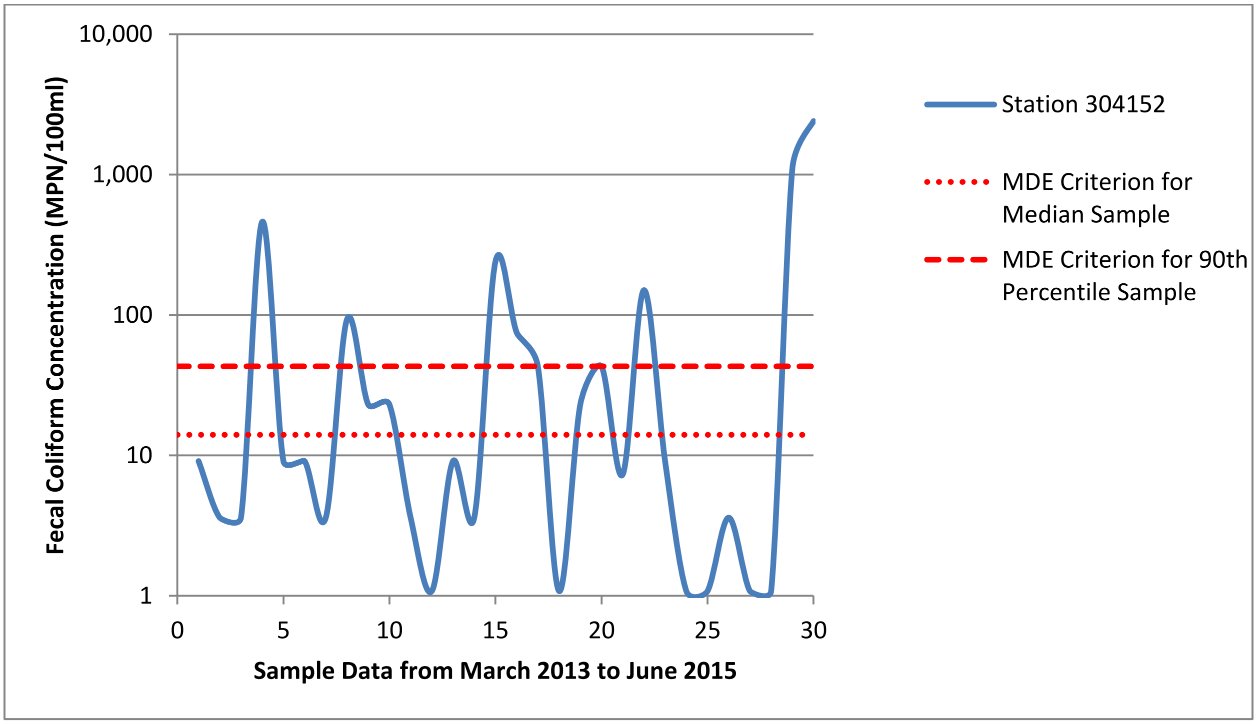
C.4 Rhode River/Bear Neck Creek

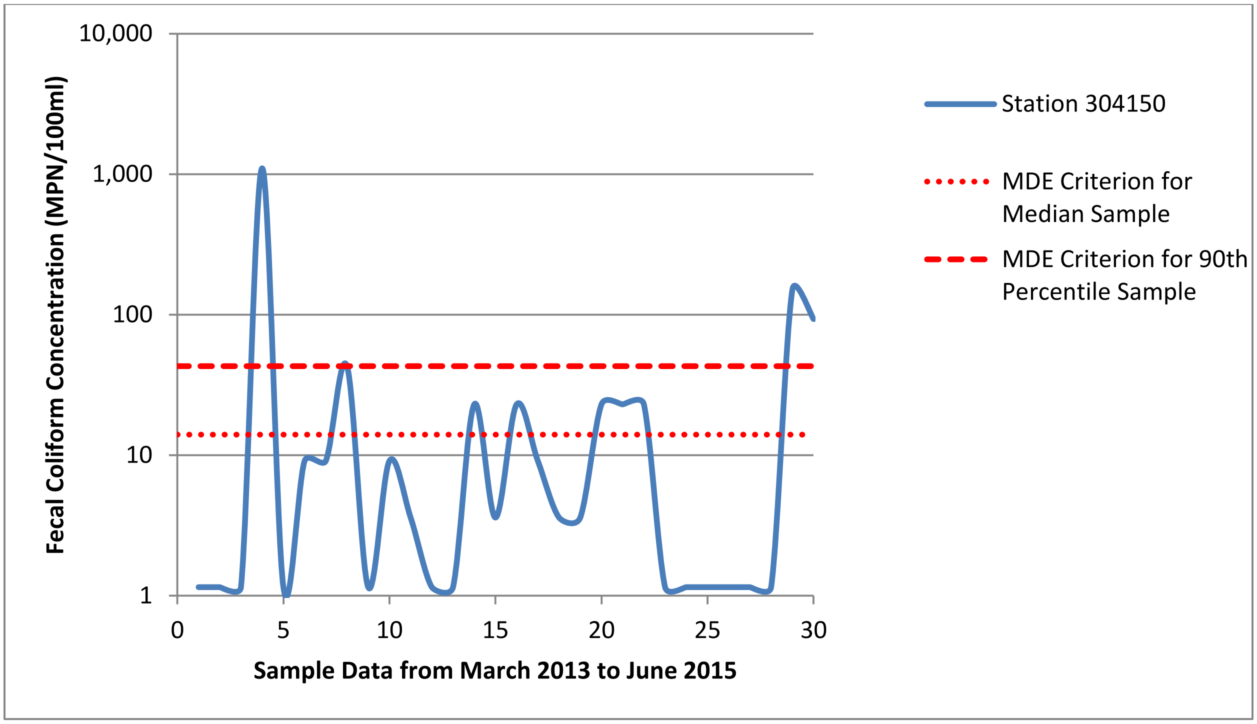


C.5 Rhode River/Cadle Creek



C.6 Severn River Mainstem

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Fecal Coliform Concentration (MPN/100ml)
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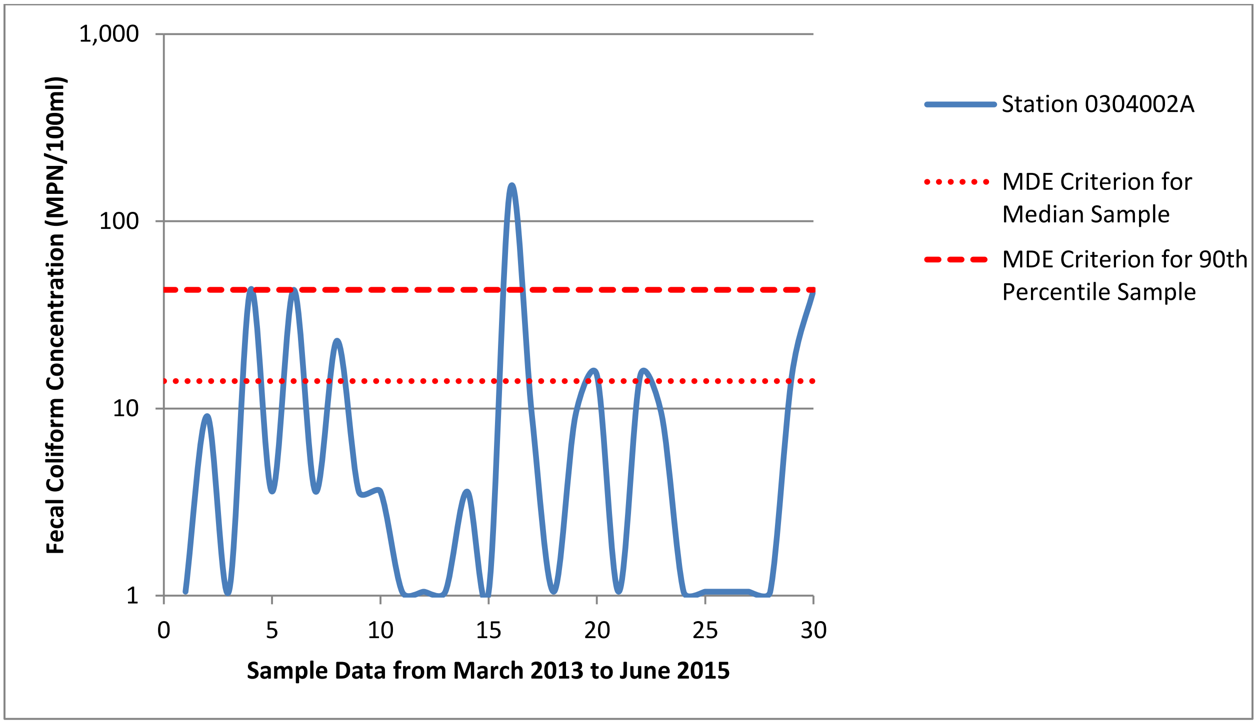
Station 304150
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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20
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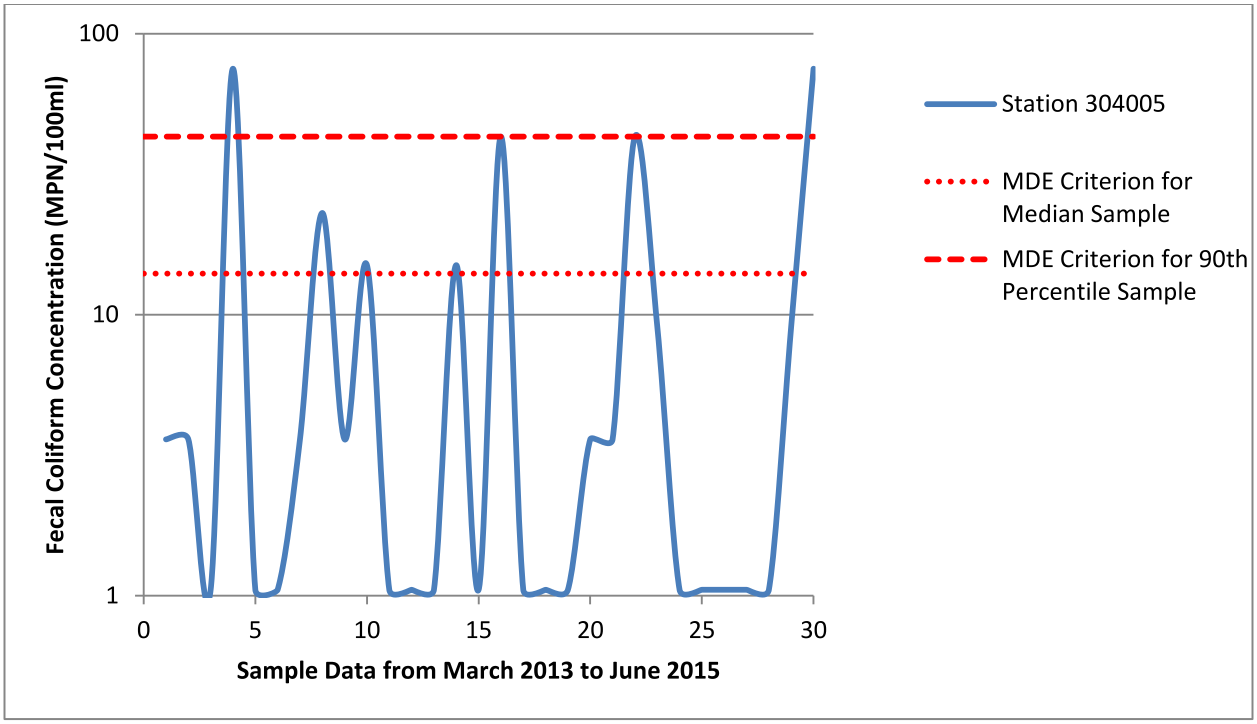
30
Fecal Coliform Concentration (MPN/100ml)
Sample Data from March 2013 to June 2015
Station 0304002A
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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15
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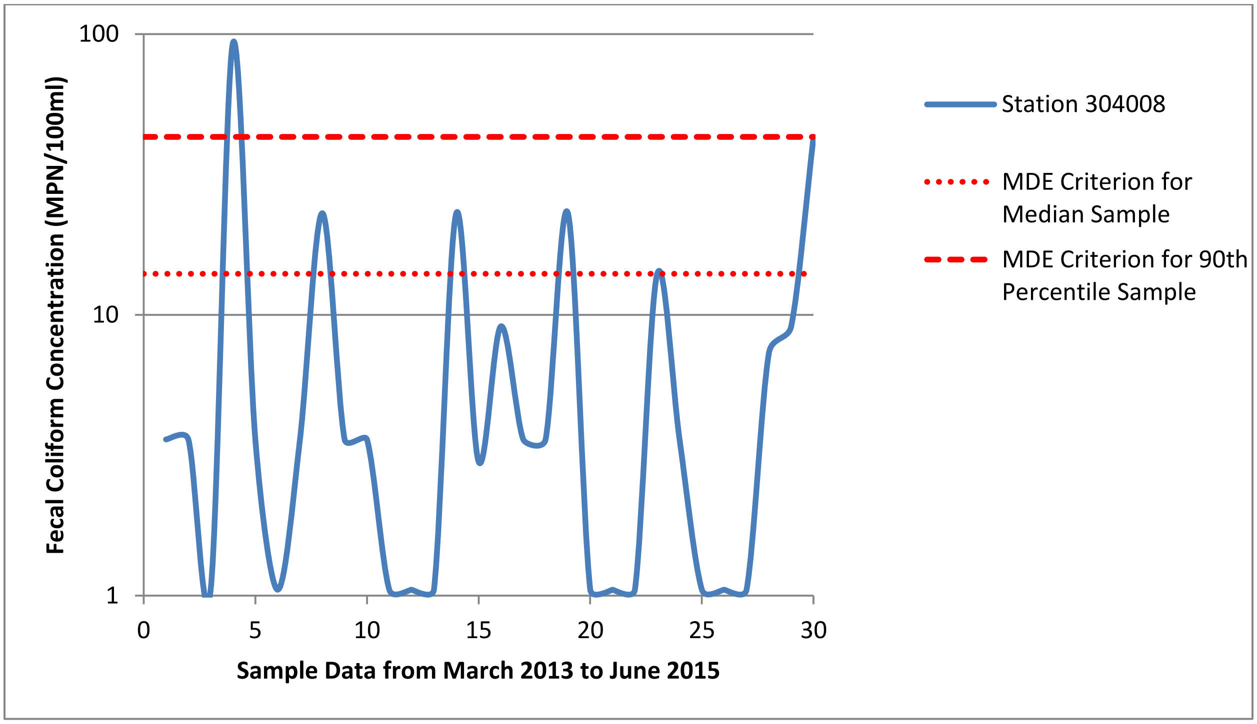
30
Fecal Coliform Concentration (MPN/100ml)
Sample Data from March 2013 to June 2015
Station 304005
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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0
5
10
15
20
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30
Fecal Coliform Concentration (MPN/100ml)
Sample Data from March 2013 to June 2015
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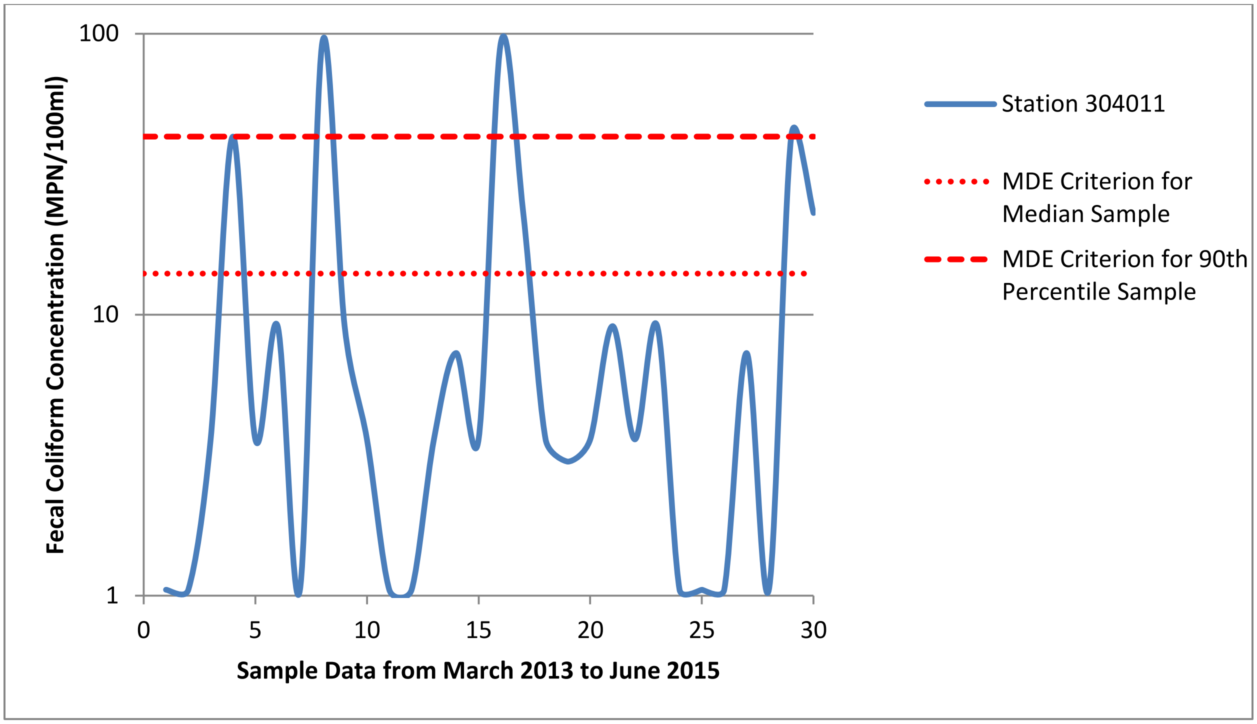
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample


Fecal Coliform Concentration (MPN/100ml)
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1
0
5
10
15
20
25
30
Sample Data from March 2013 to June 2015
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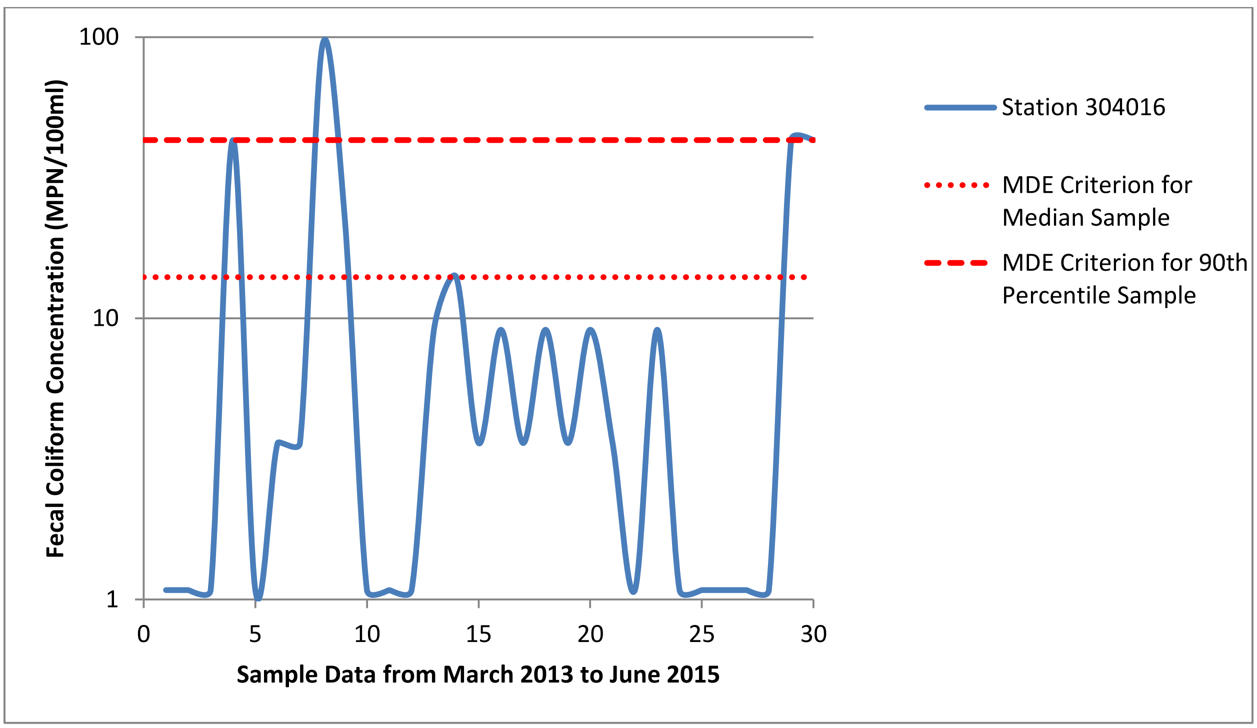
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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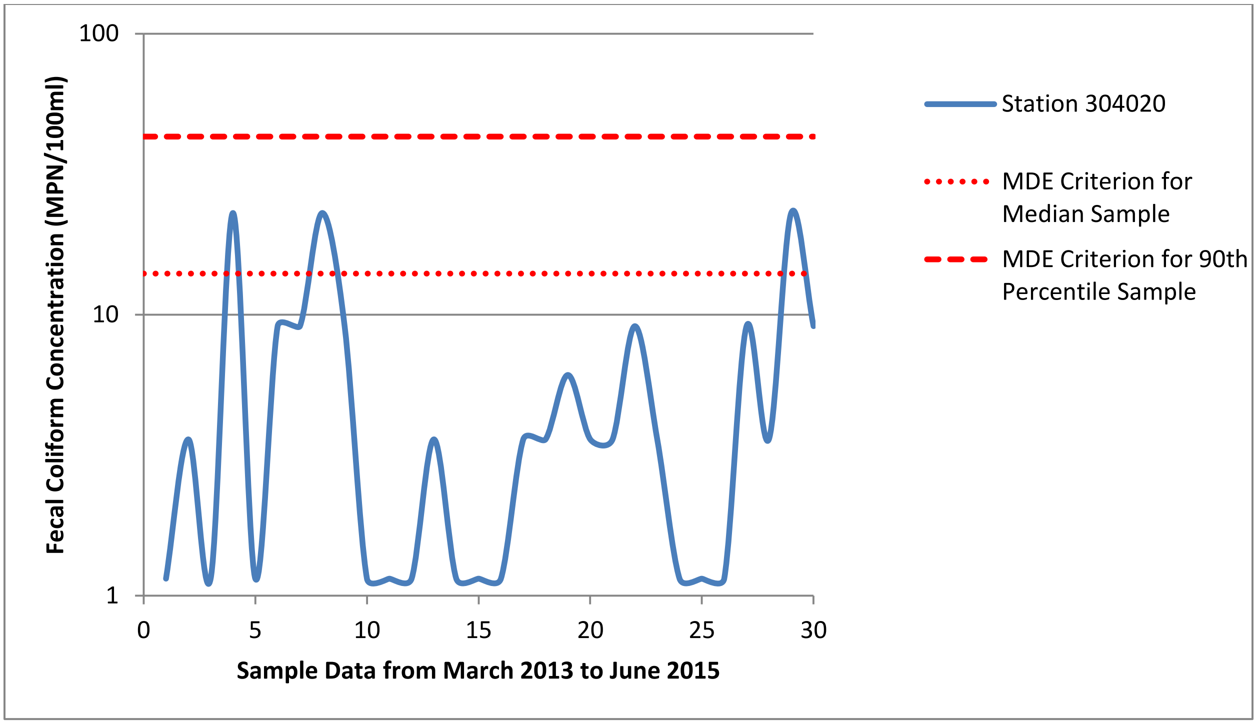
5
10
15
20
25
30
Sample Data from March 2013 to June 2015
Station 304016
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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5
10
15
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25
30
Sample Data from March 2013 to June 2015
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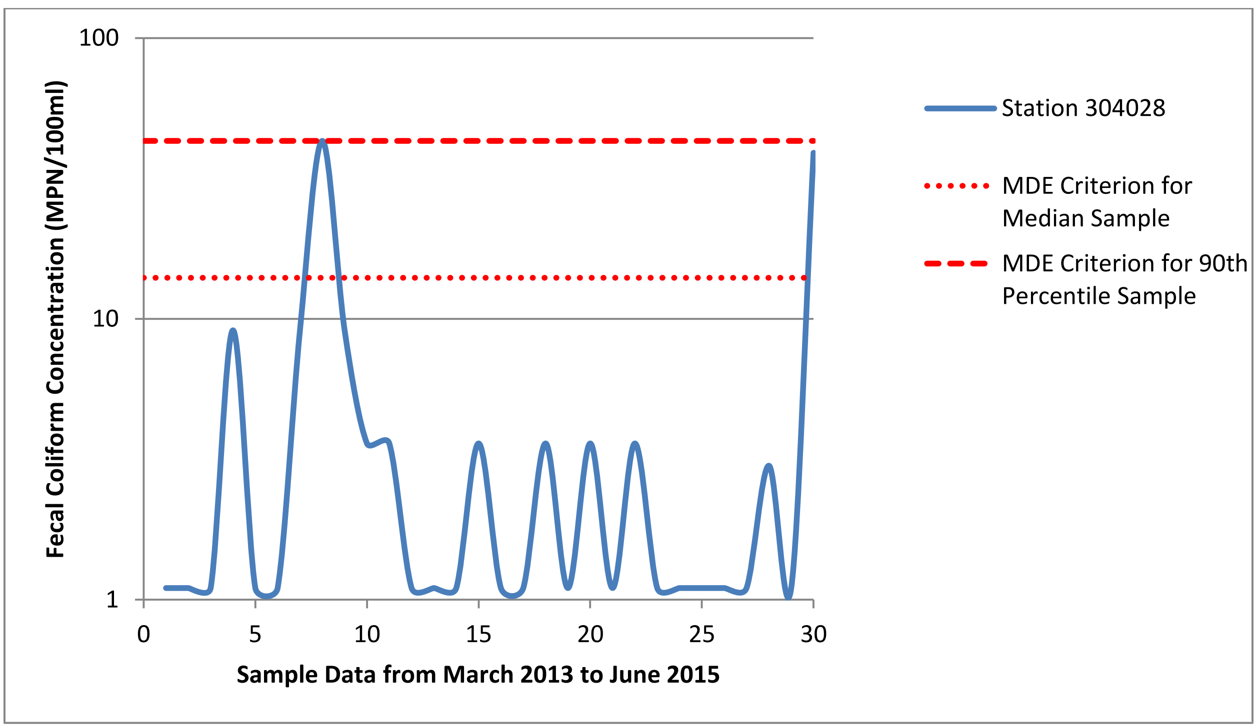
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample


Fecal Coliform Concentration (MPN/100ml)
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1
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15
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25
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Sample Data from March 2013 to June 2015
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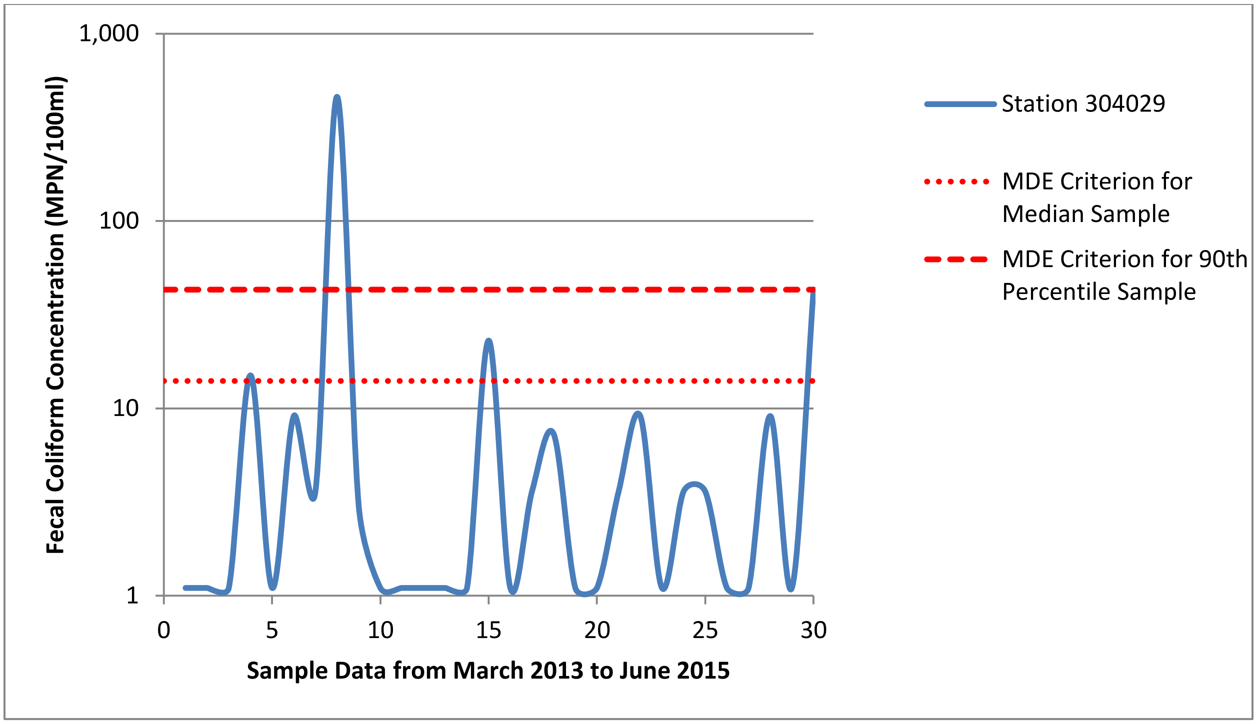
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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Fecal Coliform Concentration (MPN/100ml)
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25
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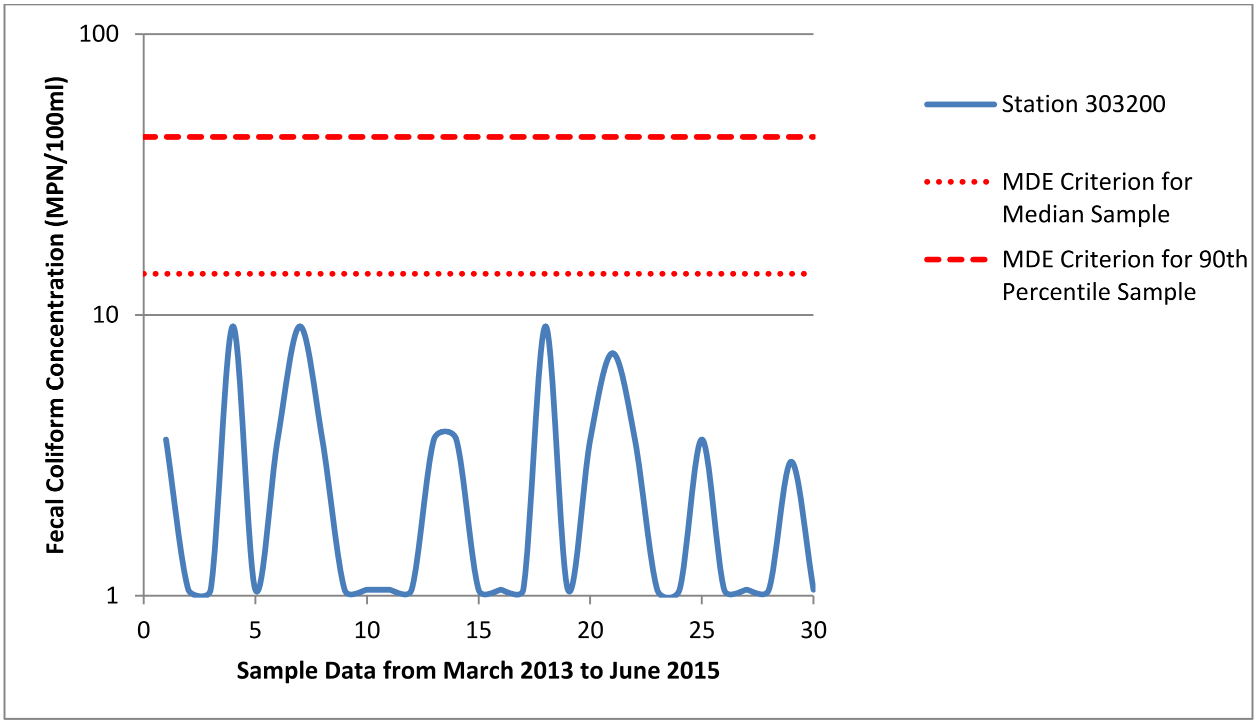
Sample Data from March 2013 to June 2015
Station 304029
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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1
Fecal Coliform Concentration (MPN/100ml)
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15
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Sample Data from March 2013 to June 2015
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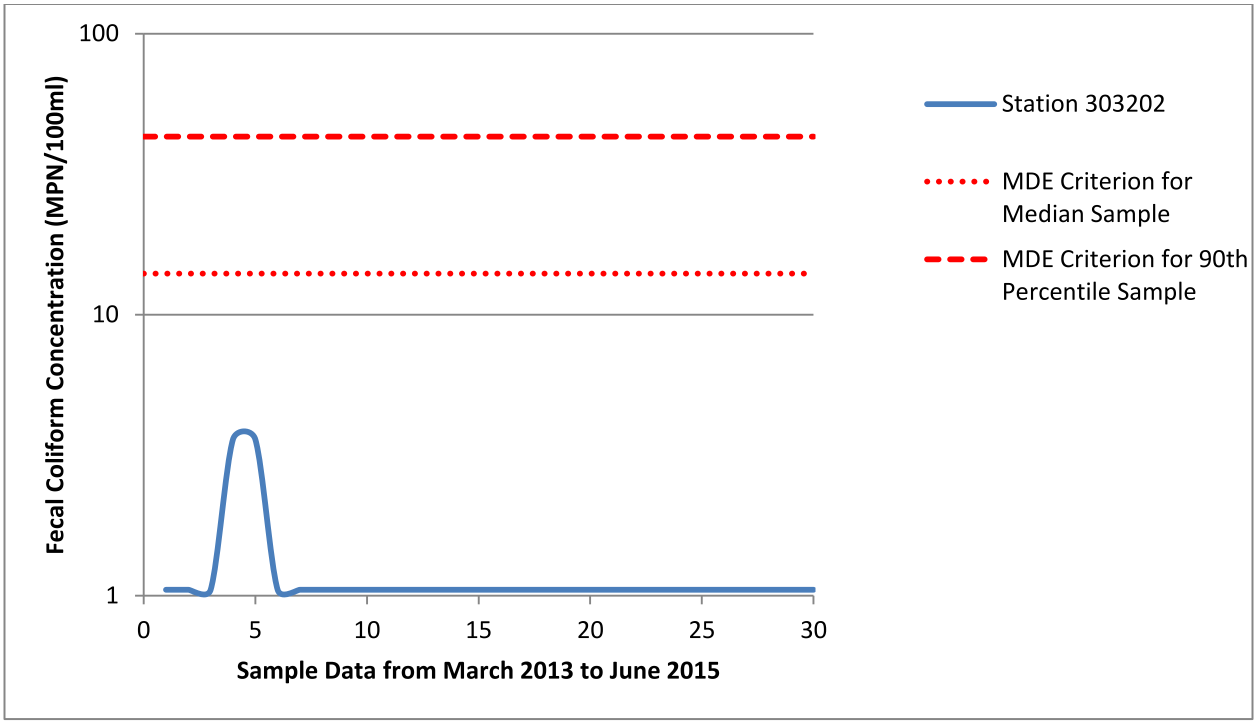
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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30
Sample Data from March 2013 to June 2015
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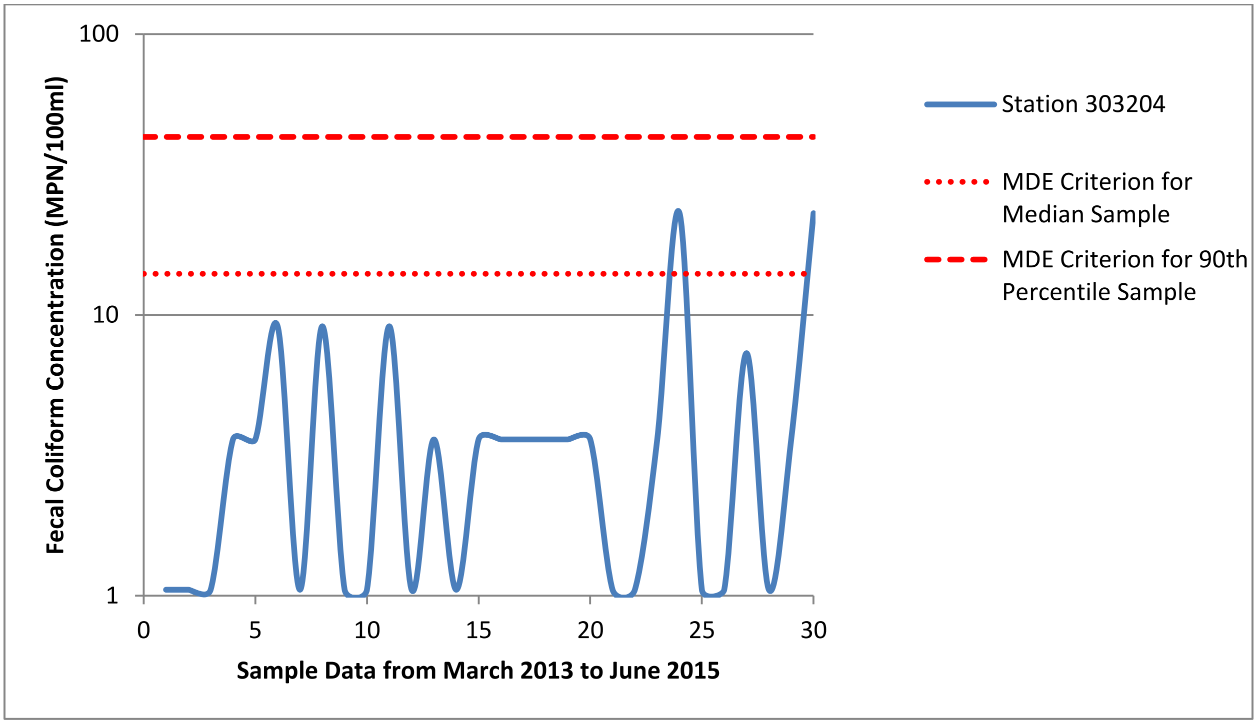
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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10
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Sample Data from March 2013 to June 2015
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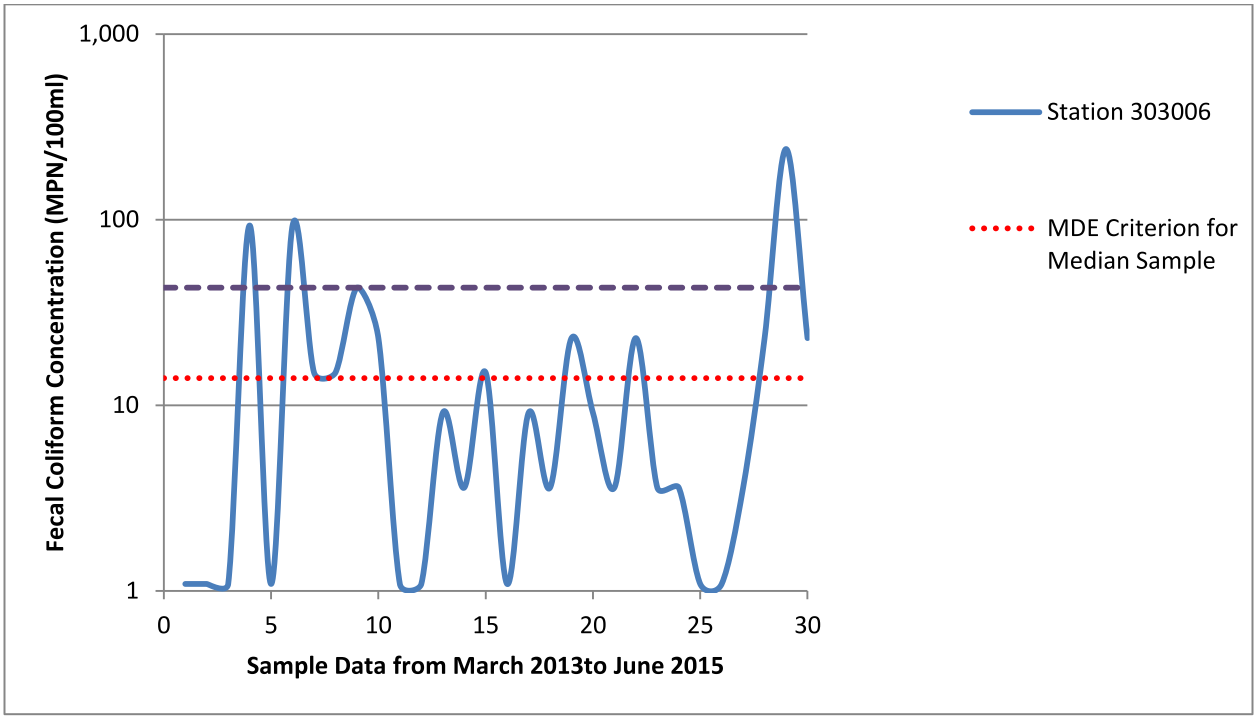
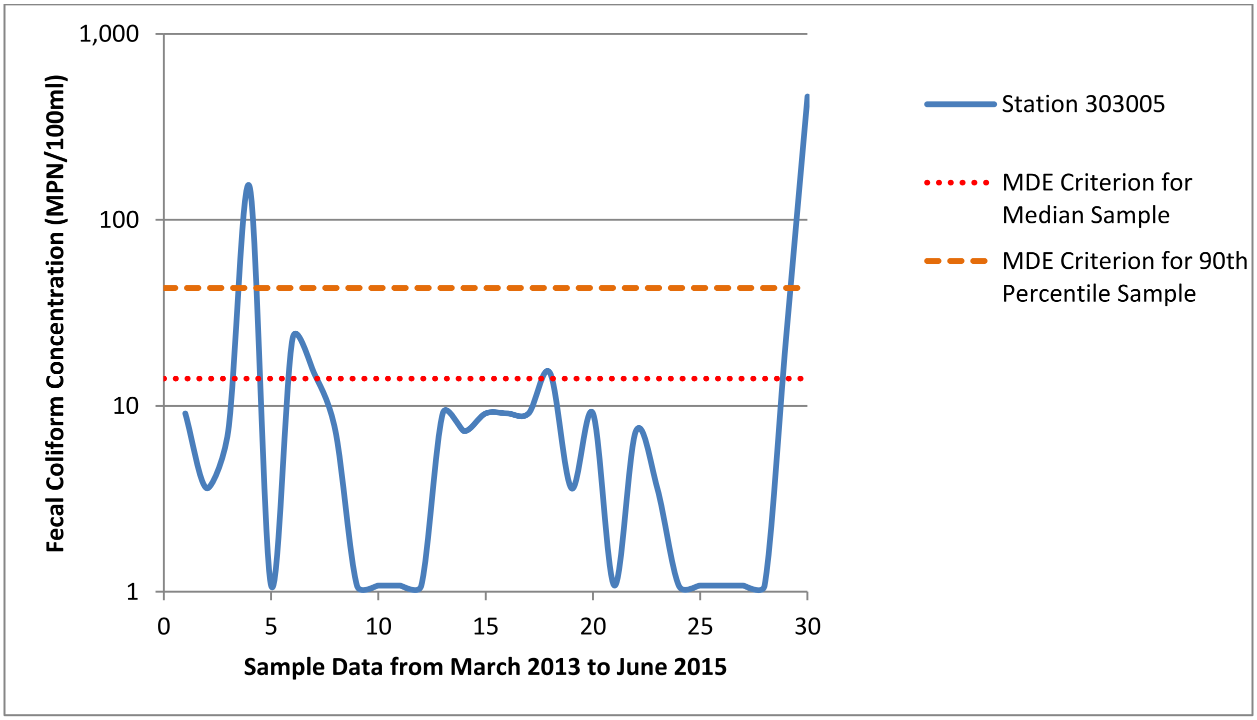
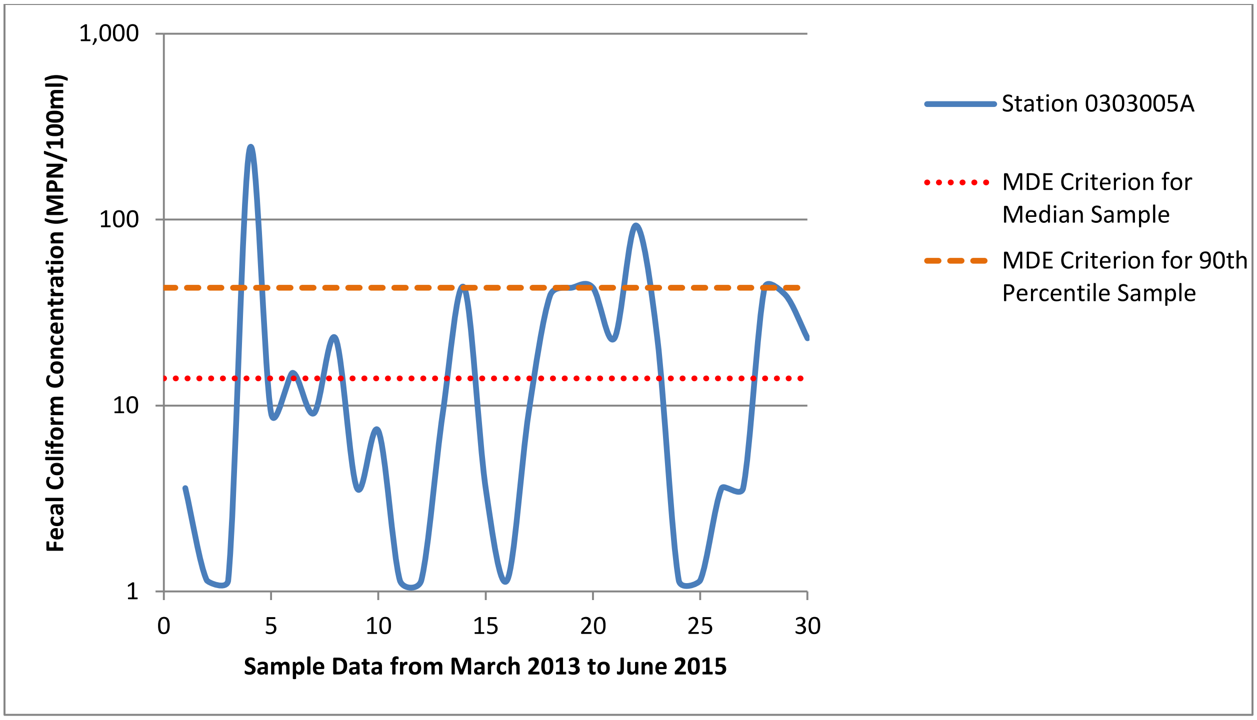
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample

C.7 Severn River Mainstem/Mill Creek

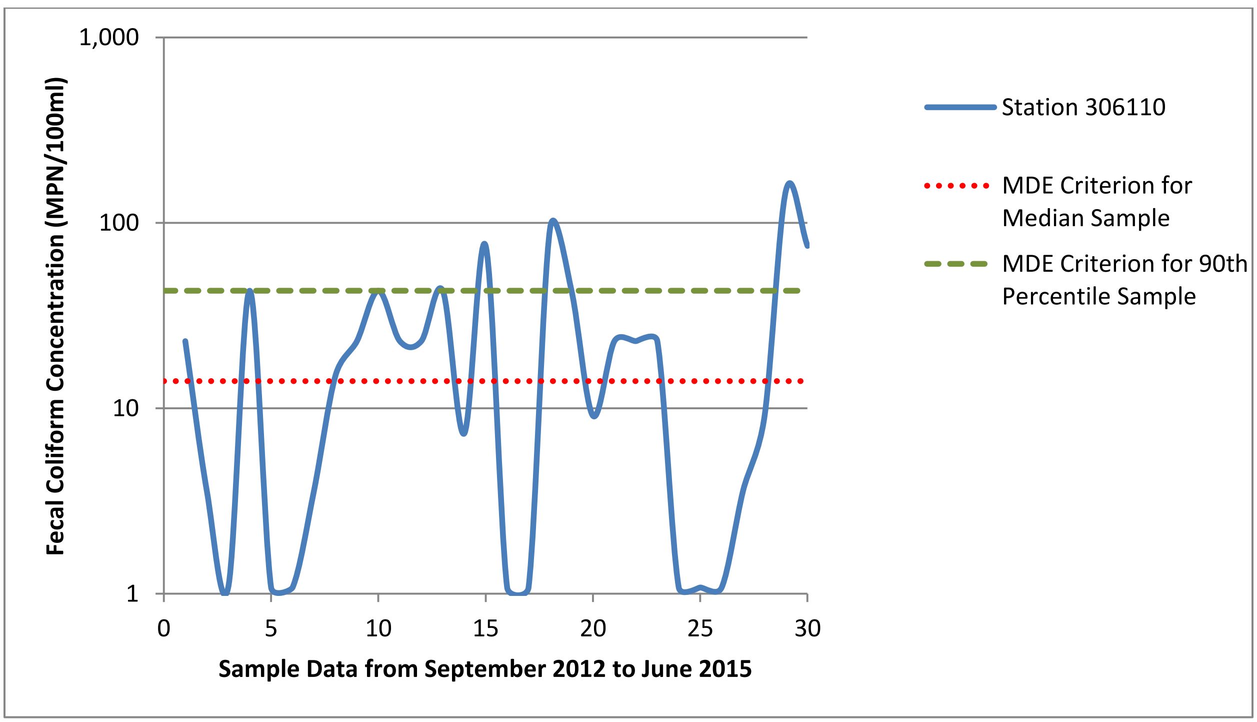


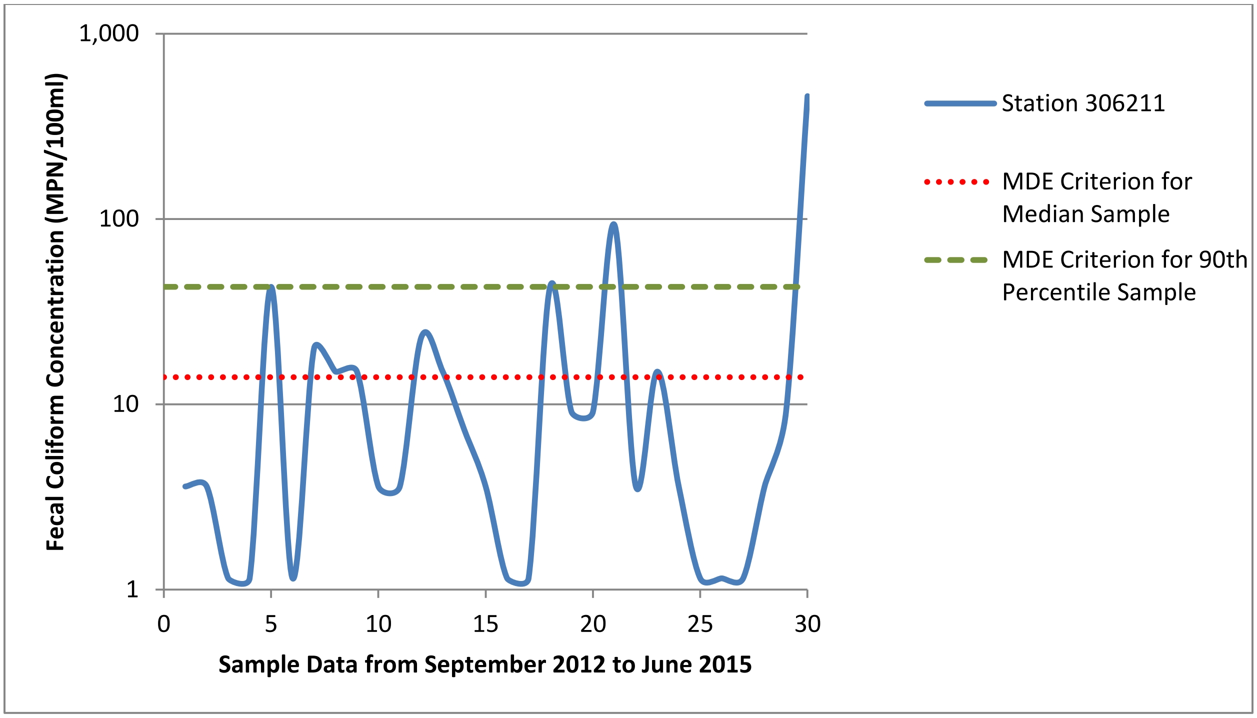
C.8 Severn River Mainstem/Whitehall and Meredith Creeks





C.9 South River Mainstem

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Sample Data from September 2012 to June 2015
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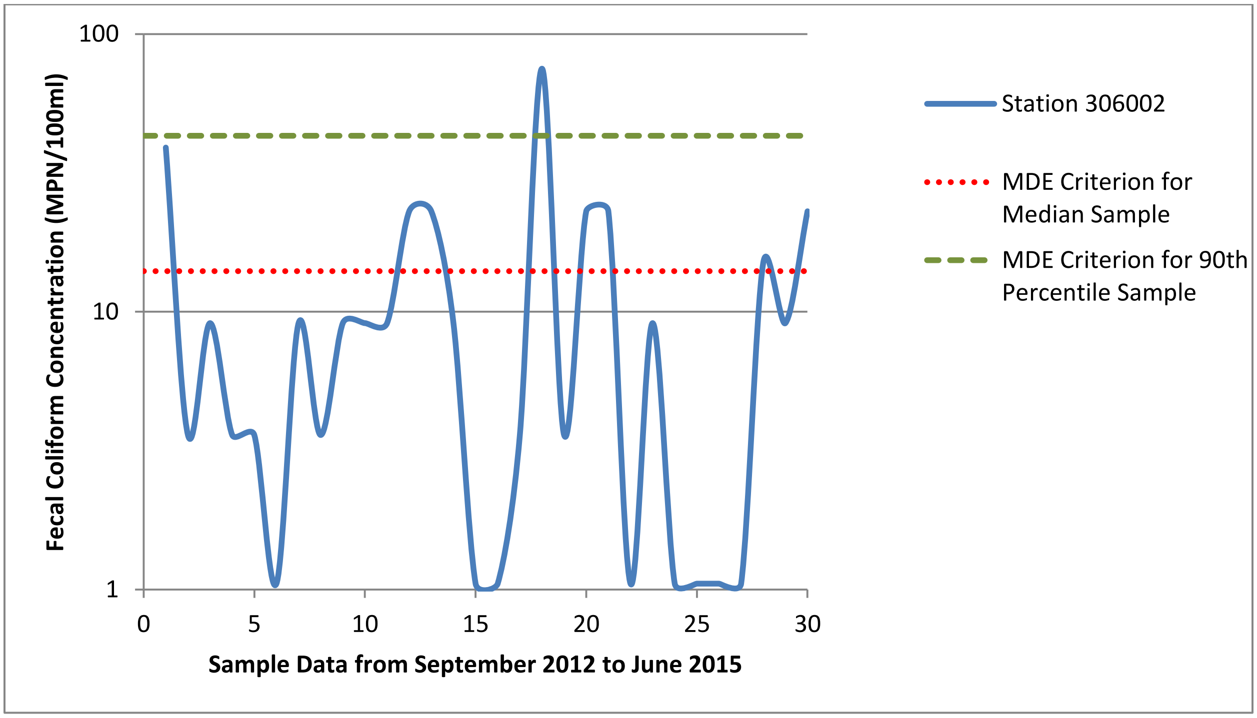
MDE Criterion for Median Sample
MDE Criterion for 90th Percentile Sample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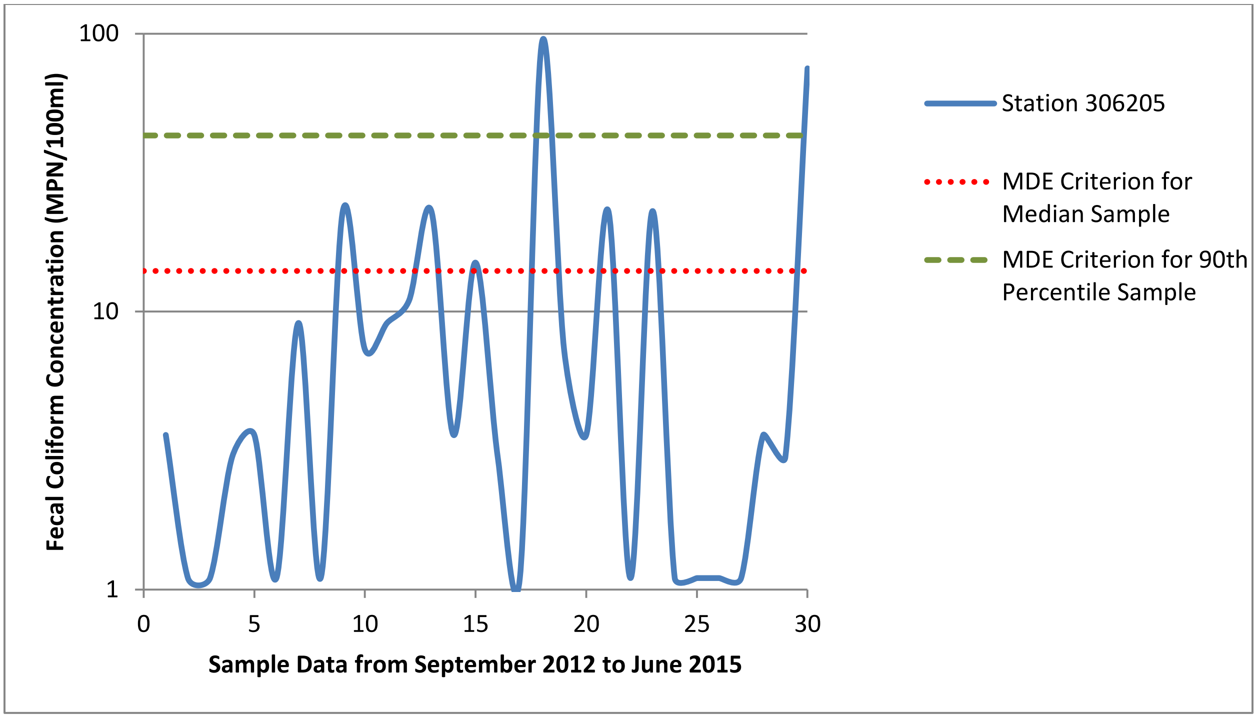
MDE Criterion for 90th Percentile Sample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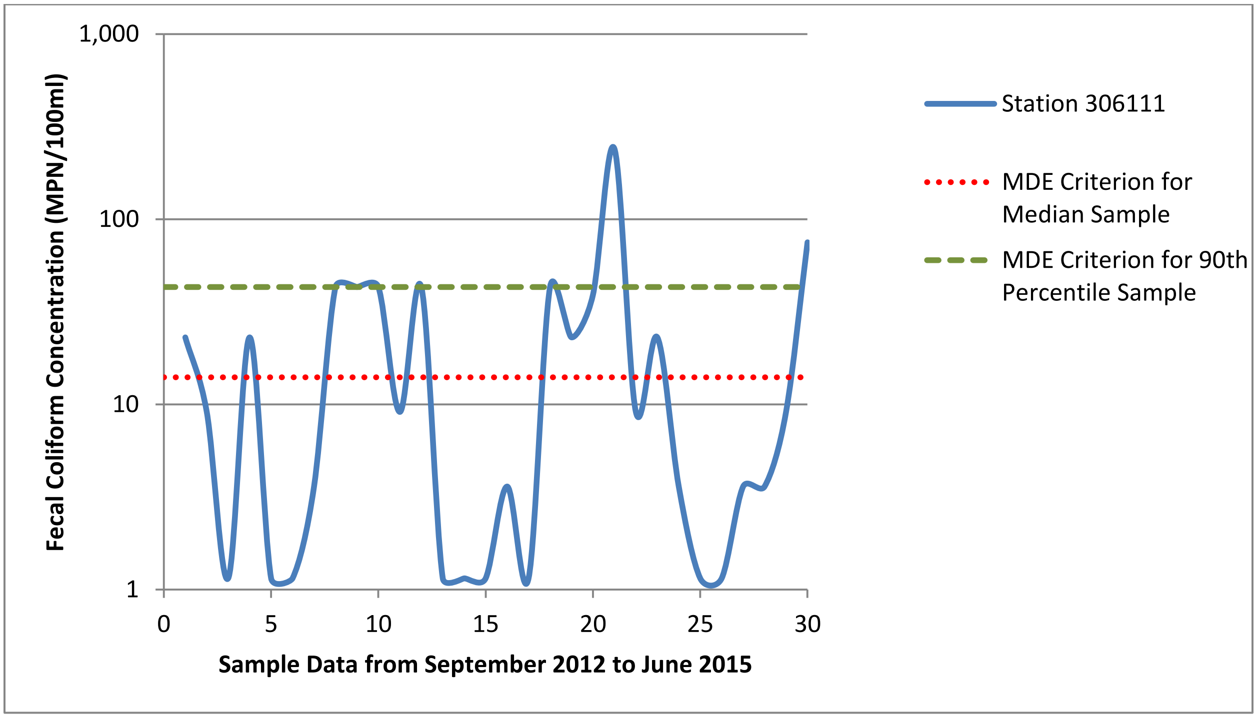
MDE Criterion for 90th Percentile Sample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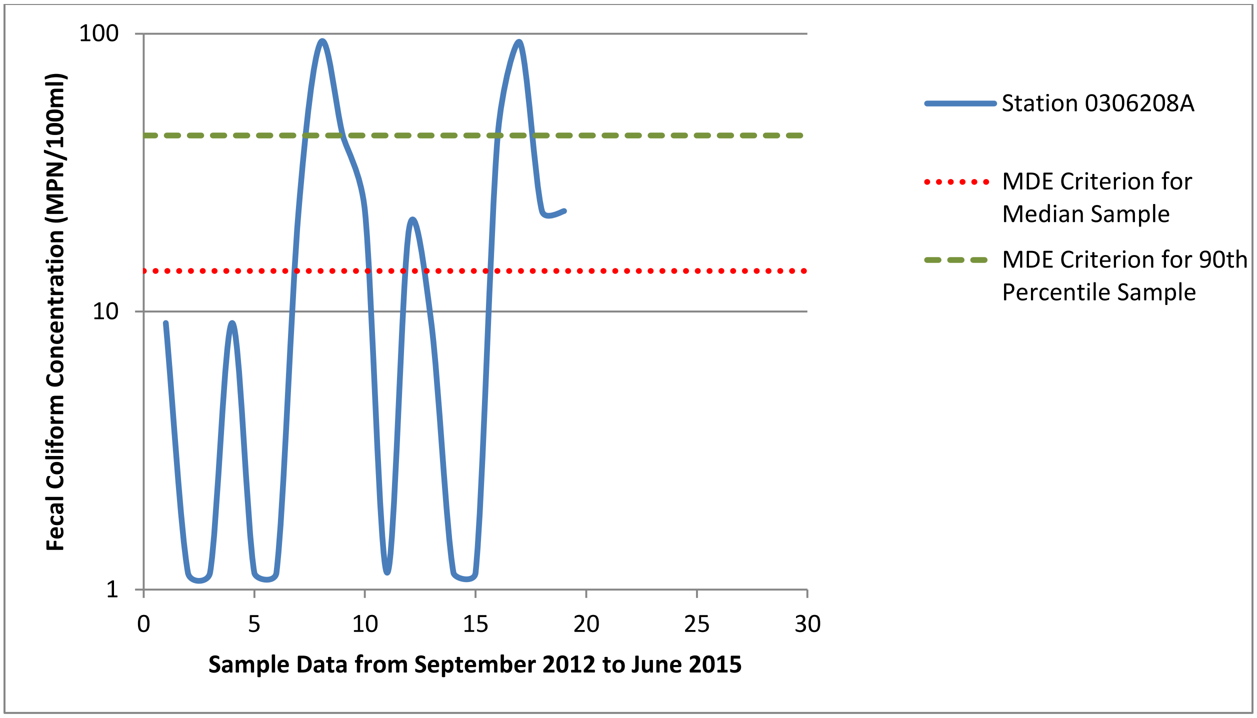
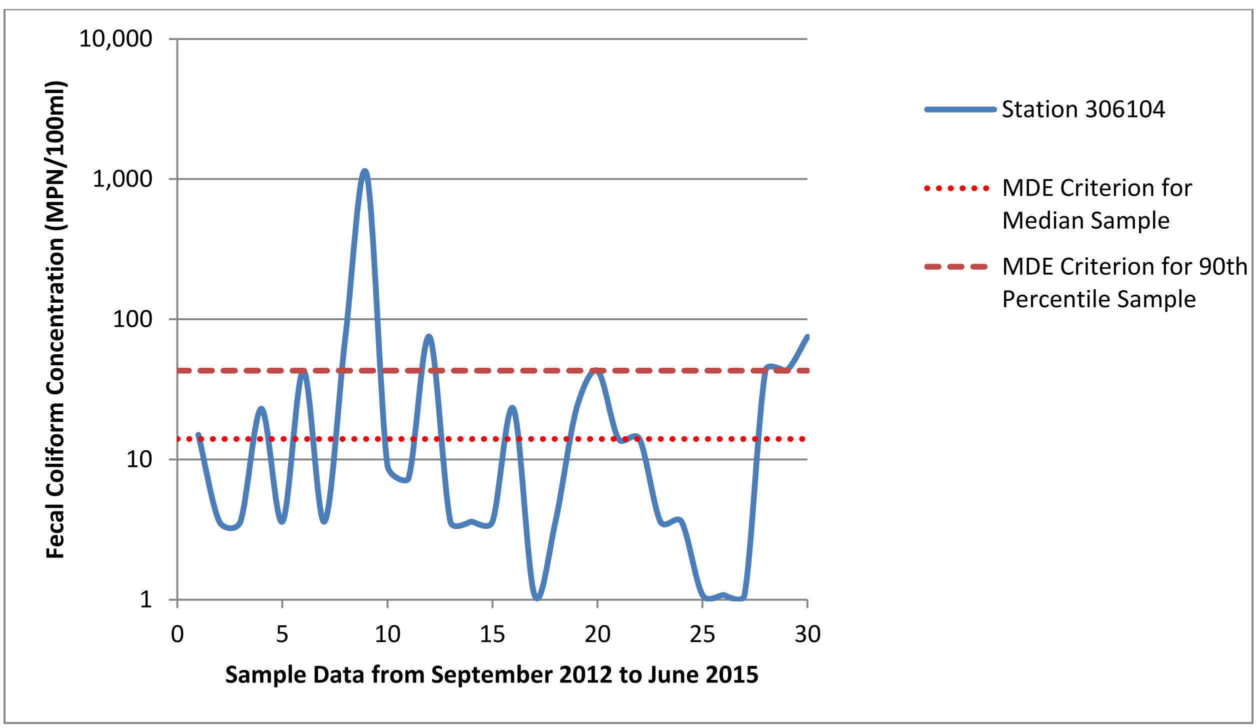
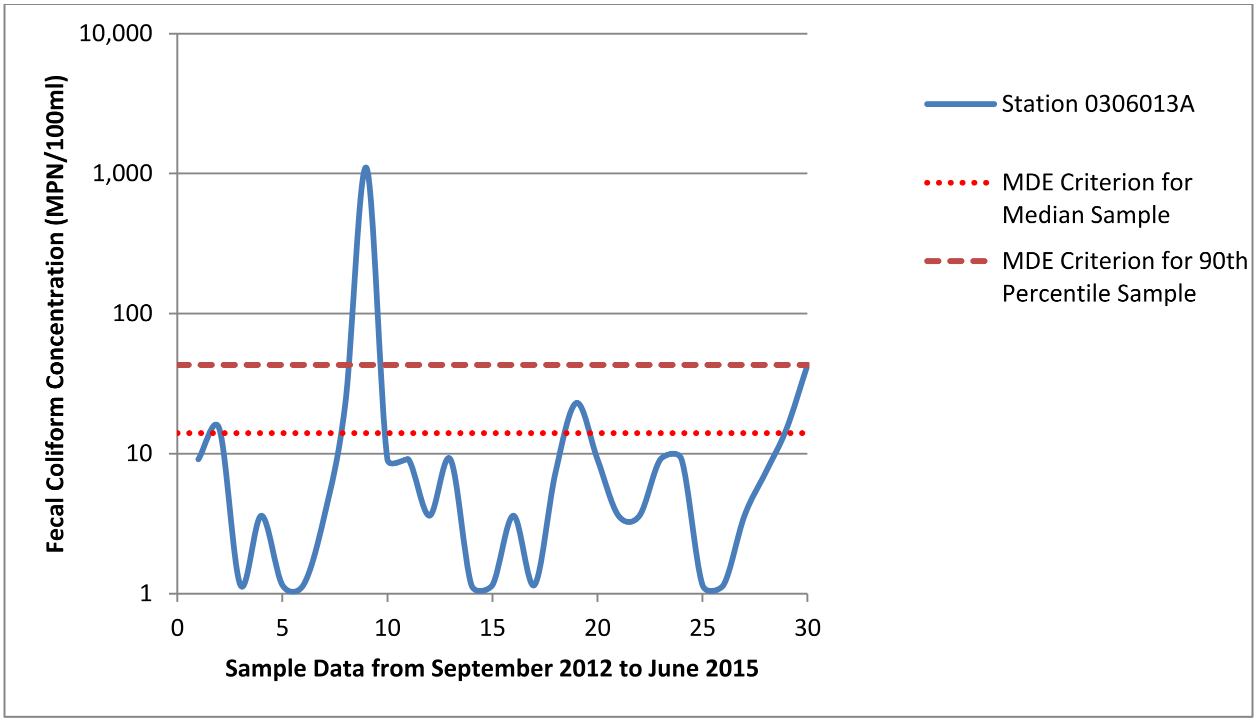
MDE Criterion for 90th Percentile Sample

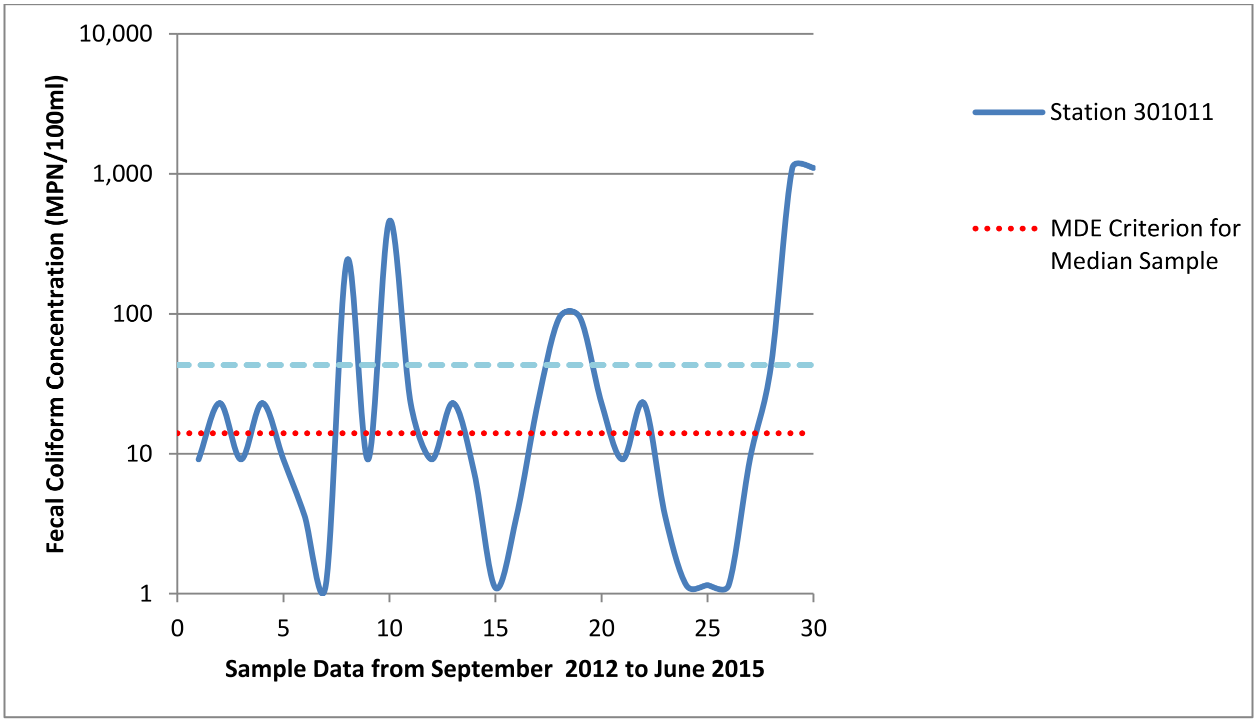


C.10 South River Mainstem/Duvall Creek

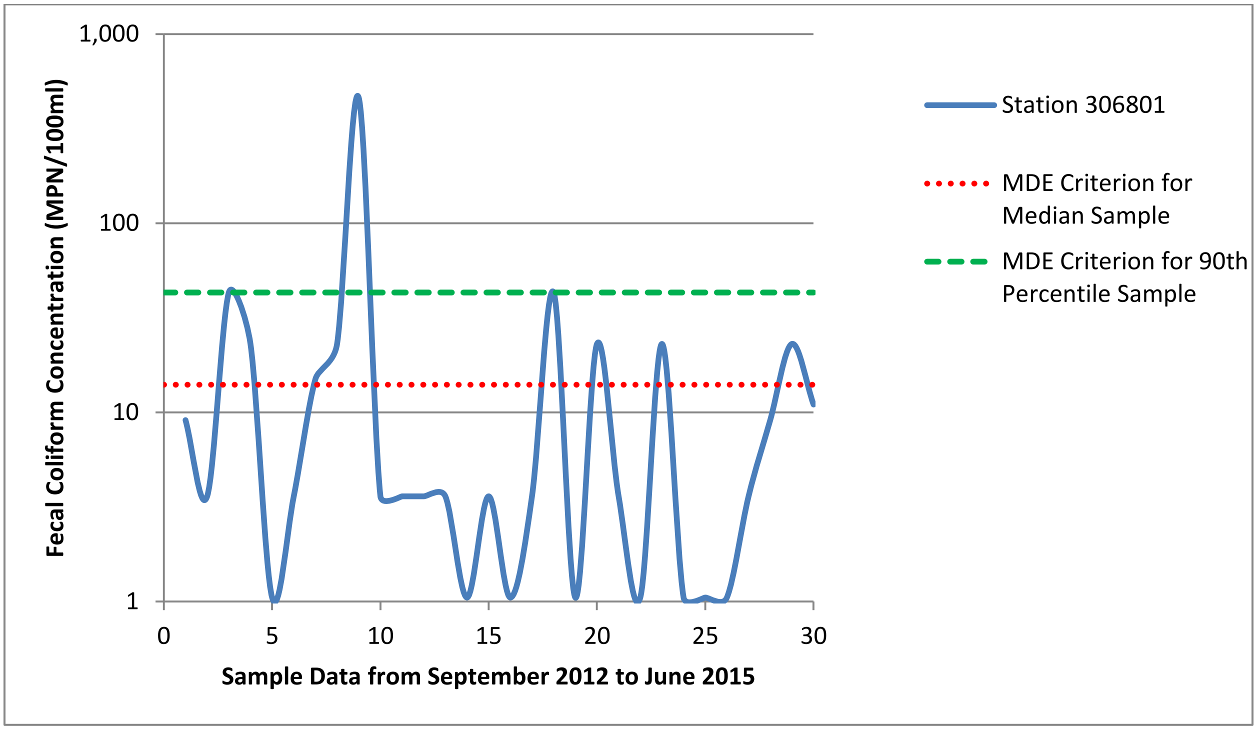


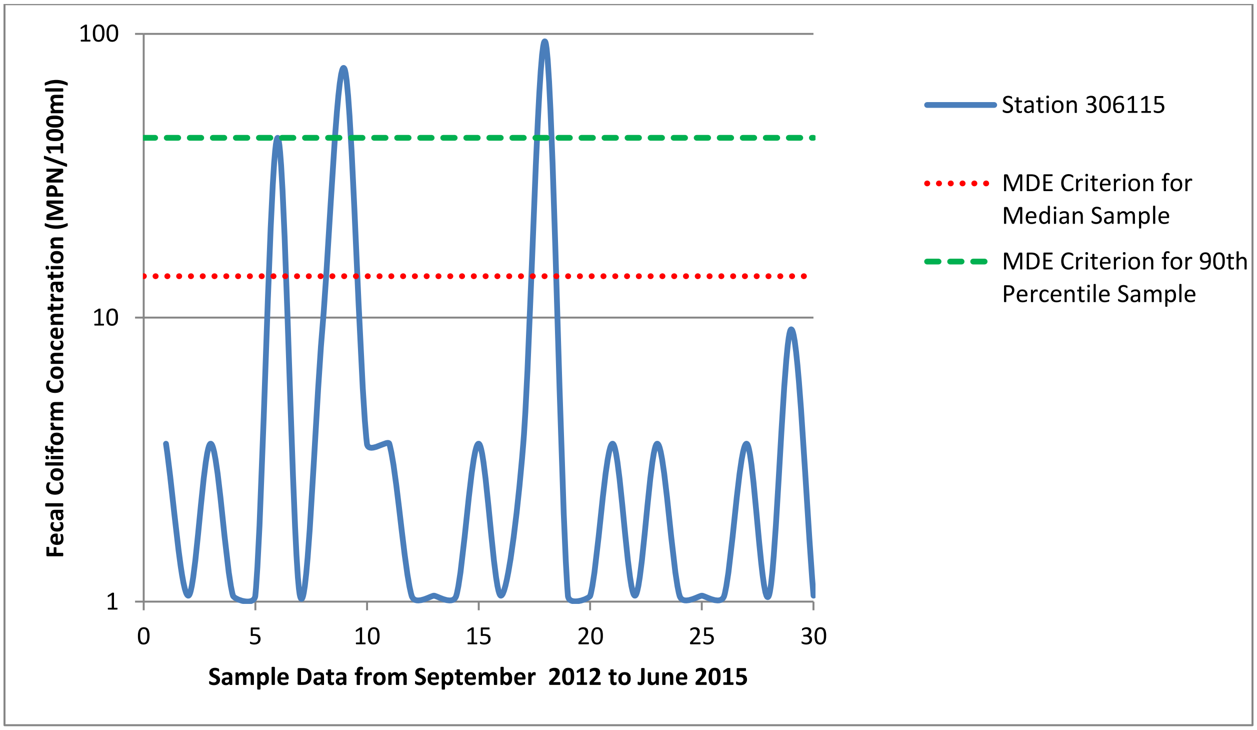


C.11 South River Mainstem/Ramsey Lake

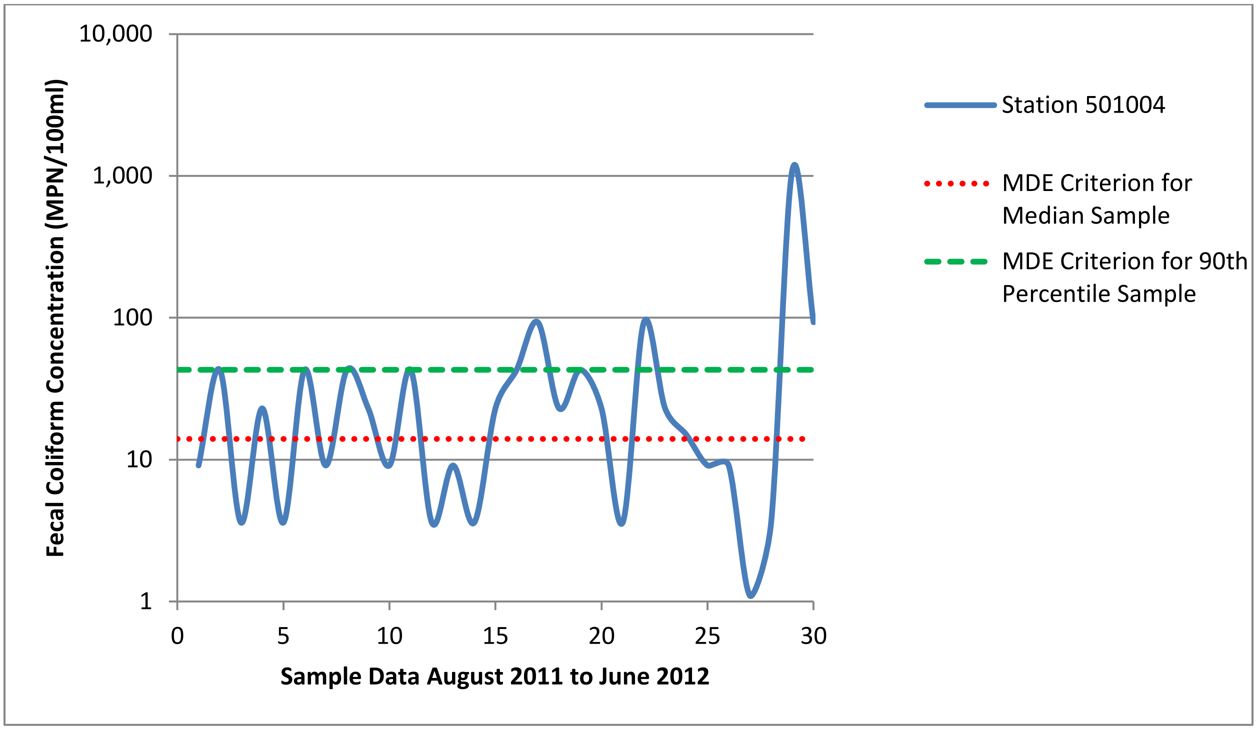


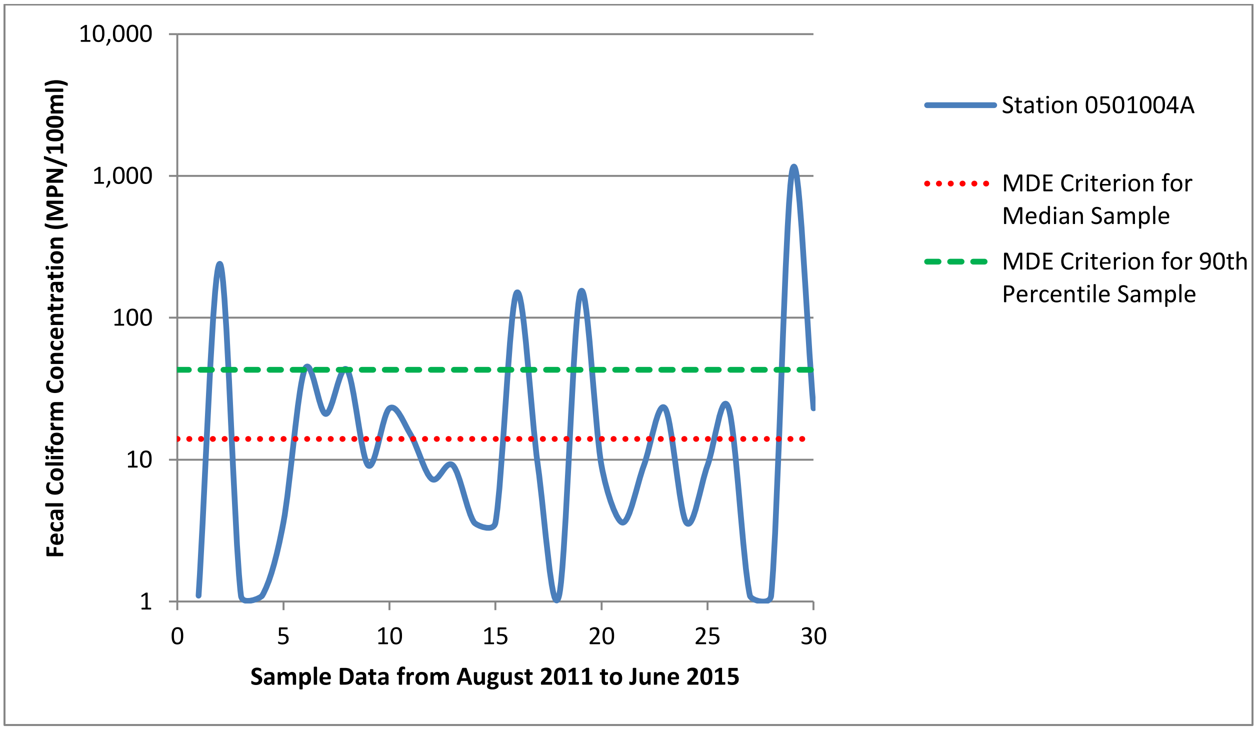
C.12 South River Mainstem/Selby Bay



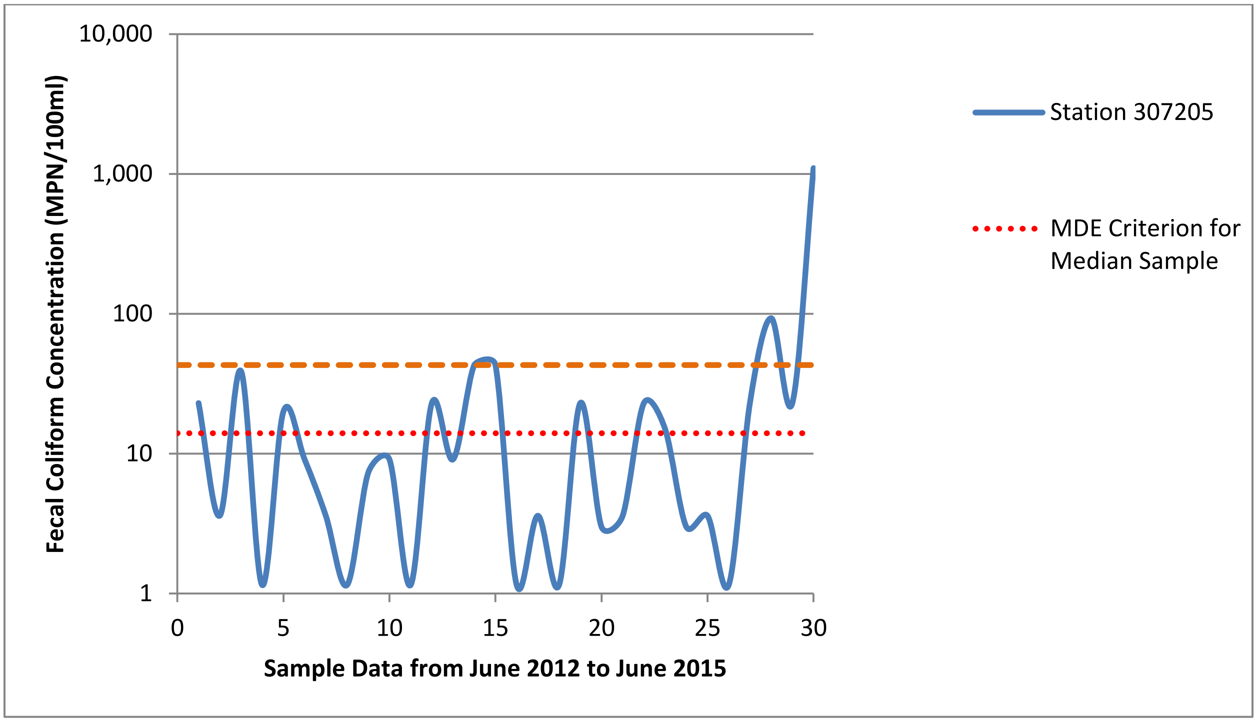


C.13 Chesapeake Mainstem/Tracey and Rockhold Watersheds





C.14 West River Mainstem



C.15 West River Mainstem/Parish Creek