West and Rhode Watersheds Assessment

Comprehensive Summary Report








December 2016

Prepared by:
Anne Arundel County
Department of Public Works
Bureau of Engineering
Watershed Protection and
Restoration Program (WPRP)

In association with:
LimnoTech
Versar

This page is blank to facilitate double sided printing.

West and Rhode Watersheds Assessment

Comprehensive Summary Report

December 2016

Prepared by:
Anne Arundel County
Department of Public Works
Bureau of Engineering
Watershed Protection and Restoration Program (WPRP)

In association with:
LimnoTech
Versar

Under:
NPDES Section II. F – Watershed Assessment and Planning

This page is blank to facilitate double sided printing.

ACKNOWLEDGEMENTS

The West and Rhode Watersheds Assessment and resulting Comprehensive Summary Report are collaborative efforts among Anne Arundel County Department of Public Works, LimnoTech, and Versar.

The authors would like to recognize the following people for their invaluable contributions throughout the course of this project:

Jeff Cox, Anne Arundel County
Ginger Ellis, Anne Arundel County
Rick Fisher, Anne Arundel County
Janis Markusic, Anne Arundel County
Dennis McMonigle, Anne Arundel County
Ken Pensyl, Anne Arundel County
Chris Victoria, Anne Arundel County
Doug Bradley, LimnoTech
Ben Crary, LimnoTech
Dan Herrema, P.E., LimnoTech
Ryan O'Banion, LimnoTech
Rachel Moglen, LimnoTech
Brad Udvardy, P.E., LimnoTech
Matthew Zelin, P.E., LimnoTech
Alexi Boado, Versar
Allison Brindley, Versar
Beth Franks, Versar
Tom Jones, Versar
Brenda Morgan, Versar
Nancy Roth, Versar
Mark Southerland, Versar

For questions about the study, please contact:

Raghavenderrao Badami, P.E.
Engineer Manager
Watershed Protection and Restoration Program
Department of Public Works
Anne Arundel County Government, MD
2662 Riva Road
Annapolis, MD 21401
Phone: (410) 222-0529
Email: pwbada78@aacounty.org

This page is blank to facilitate double sided printing.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF OVERSIZED MAPS

This page is blank to facilitate double sided printing.

1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The Anne Arundel County, Maryland, Watershed Protection and Restoration Program (WPRP) initiated a comprehensive assessment of the West and Rhode River watersheds in the fall of 2013 and spring of 2014. See Map 1.1 for the location of these watersheds. This systematic assessment documents current water quality conditions in each watershed to support and prioritize watershed management and planning decisions and develop detailed restoration plans. Assessing current conditions helps the County determine where to focus resources for maintaining those water bodies in good condition and for mitigating problems to improve overall watershed health and quality. The study also fulfills requirements of National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit issued to the County by the Maryland Department of the Environment (MDE). Including this study, watershed studies have been completed for ten of the County's twelve major watersheds.

The scope of the West and Rhode River watersheds study included collection of field and stream assessment data and supporting Geographic Information System (GIS) data, followed by analysis and modeling using the County's customized watershed assessment and modeling tools. The data collected as part of this watershed assessment were compiled and stored in the County's GIS-interfaced Watershed Management Tool (WMT). Assessment data stored in the WMT are available for review via the County's Watershed Mapping Application (http://gis-world2.aacounty.org/silverlightviewer/?Viewer=WERS).

The WMT and other analysis tools were used to synthesize the assessment data for further evaluation with:

- Engineering models to evaluate existing and future hydrologic, hydraulic and water quality conditions;
- Statistical models to explore possible correlations between watershed stressors and select watershed health indicators; and
- Rating and prioritization activities to determine ranked stream reaches and subwatersheds for restoration and preservation.

Assessment and modeling efforts were performed collaboratively by County staff, with assistance from their consultants. A Professional Management Team (PMT) comprised of County staff and LimnoTech and Versar project staff and technical advisors provided peer review and input on the County assessments and modeling efforts. Specific watershed goals and recommendations for implementation from the PMT are provided in this report.

The County's assessment and modeling efforts and findings are detailed in Sections 2, 3, and 4. Recommended watershed management goals and implementation strategies are described in Section 5. The remainder of this section presents the regulatory context for the assessment and describes the physical setting of the West and Rhode River watersheds.

1.2 REGULATORY AND PLANNING CONTEXT

The regulatory and planning context for the watershed assessment includes state regulatory activities, legislative requirements, County actions, and programs aimed at restoration and preservation of water quality in the West and Rhode River watersheds as well as the greater Chesapeake Bay watershed.

1.2.1 Total Maximum Daily Loads

Section 303(d) of the Clean Water Act requires states to establish water quality standards (WQS), identify water bodies for inclusion on the state "303(d) list" that don't meet these standards, and establish the maximum allowable pollutant load (the total maximum daily load [TMDL]) that would allow the listed water body to meet WQS. The Environmental Protection Agency (EPA) has designated MDE as the regulatory authority in Maryland responsible for this process.

In addition to the TMDLs Maryland has developed, EPA has also published the Chesapeake Bay TMDL. This TMDL identifies the necessary pollution reductions of nitrogen, phosphorus and sediment across Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia and the District of Columbia and sets pollution limits necessary to meet applicable water quality standards in the Bay and its tidal rivers and embayments. Discussion associated with the Chesapeake Bay TMDL and "local" TMDLs is presented in the following sub-sections. Map 1.2 identifies each watershed in Anne Arundel County and displays the impairments that have prompted the inclusion of waters on the state 303(d)-listing or an approved TMDL (MDE, 2016).

An online query was conducted using MDE's Searchable Integrated Report Database [Combined 303(d)/305(b) List], current as of the state's approved 2014 Integrated Report on October 16, 2015. The search yielded a list of 20 potential impairments in the West and Rhode watersheds (database accessed June 30, 2016). Of these, 12 impairments are categorized as "4a-Impaired – TMDL completed" and are addressed by the bacteria and Chesapeake Bay TMDLs discussed below. Three others are in the category "5-Impaired, TMDL required", including one listing for PCB, now been addressed by the PCB TMDL approved in January 2016, and listings for sulfate and Total Suspended Solids (TSS), related to impairment of aquatic biota. Two other impairments were listed as "2-Meets water quality criteria for the cause specified" and three were categorized as "3-Insufficient data for assessment".

1.2.1.1 Chesapeake Bay TMDL

On December 29, 2010, EPA finalized the Chesapeake Bay TMDL, establishing pollutant reduction goals for nitrogen, phosphorus, and suspended solids for the 92 segments (52 of which are in Maryland) that make up the Chesapeake Bay watershed. The County was given nutrient and sediment allocations for regulated (MS4) and unregulated stormwater discharges, wastewater discharges, and septic systems. Although multiple Bay segments are located within Anne Arundel County (see Map 1.3), stormwater pollutant allocations for nitrogen and phosphorus were provided at the County scale rather than at the watershed scale. For planning purposes at the watershed level, the County is applying the same percent load reduction required for urban stormwater at the County level to each of its watersheds. For total nitrogen, this amounts to a 21% annual reduction from existing conditions load without credits by the 2017 interim target and a 35% annual load reduction by 2025. For total phosphorus, the interim target load reduction is 38% and the 2025 target load reduction is 63%. For total suspended solids, load allocations have not yet been provided.

To ensure the goals of the TMDL are met, EPA has requested a Watershed Implementation Plan (WIP) be developed along with two-year incremental milestones that allow close tracking and assessment of implementation progress. Anne Arundel County's National Pollutant Discharge Elimination System (NPDES) MS4 permit is the regulatory mechanism to ensure tracking, verifying, and reporting of progress and compliance with the assigned stormwater allocation. Anne Arundel County's WIP was included within the broader State-wide plan and has been approved by the EPA. The County's WIP includes strategies and milestones associated with stream restoration, stormwater best management practice (BMP) retrofits, and other programmatic efforts.

1.2.1.2 Local TMDLs

Bacteria TMDLs

Several portions of the West and Rhode River watersheds have Bacteria TMDLs (Table 1.1). The impairment listings for bacteria in West and Rhode Rivers are related to shellfish waters in the mesohaline tidal area.

Table 1.1 – Bacteria TMDLS in the West and Rhode River Watersheds

Location	Approval Date	% Reduction Required*
Rhode River/Bear Neck Creek	February 20, 2006	43.3
Rhode River/Cadle Creek	February 20, 2006	72.2
West River, Subsegment of 8 Digit Watershed 02131004	February 20, 2006	35.3
West River/Parish Creek	February 20, 2006	53.1

*Based on the MDE published TMDL documents for bacteria impaired watersheds in Anne Arundel County and Anne Arundel County's *Draft Total Maximum Daily Load Restoration Plan for Bacteria, February 2015*.

MDE notes that for Bear Neck Creek, new data show this area as meeting bacteria standards, and has now assigned a conditionally approved classification as “2- Meets water quality criteria for the cause specified” (MDE impaired waters online database, accessed June 30, 2016).

Polychlorinated Biphenyls (PCB) TMDL

There is currently one EPA-approved PCB TMDL for the West and Rhode River watershed in Anne Arundel County (Table 1.2). This is related to the tidal portion of the watershed.

Table 1.2 – PCB TMDL in the West and Rhode River Watershed

Location	Approval Date
West and Rhode Rivers, 8-Digit Watershed 02131004	January 8, 2016

1.2.1.3 Other Impairments

In the West and Rhode River watersheds, aquatic life assessment scores consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) indicate that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions based on Maryland’s biocriteria listing methodology (MDE, 2009a). The biocriteria listing methodology assesses the condition of Maryland’s 8-digit (MD 8-digit) watersheds by measuring the percentage of sites, translated into watershed stream miles, that are assessed as having BIBI and/or FIBI scores significantly lower than 3.0 (on a scale of 1 to 5), and then calculating whether this percentage differs significantly from reference conditions (i.e., unimpaired watershed <10% stream miles differ from reference conditions).

To evaluate whether aquatic life was impacted by elevated sediment loads or other factors, the State’s Biological Stressor Identification (BSID) methodology was applied by MDE. The BSID analysis for the West and Rhode watersheds concluded that biological communities are likely impaired due to sulfates and TSS.

1.2.2 NPDES

The Anne Arundel County NPDES MS4 permit issued in February 2014 by MDE (MD0068306 (11-DP-3316)) covers all stormwater discharges to and from the MS4 owned and operated by the County. Assessments of the West and Rhode River watersheds have been conducted in partial fulfillment of these MS4 permit requirements.

- Section III.C.2 – Source Identification. Collecting and verifying urban BMP facility data including locations and delineated drainage areas.

- Section III.E.3 – Illicit Discharge Detection and Elimination. Reporting illicit discharges and connections to the County during the Physical Habitat Condition Assessment.
- Section III.F – Watershed Assessment and Planning. Developing watershed management plans for all watersheds in Anne Arundel County that:
  - Determine current water quality conditions;
  - Identify and rank water quality problems;
  - Identify all structural and non-structural water quality improvement opportunities;
  - Include the results of visual watershed inspection;
  - Specify how the restoration efforts will be monitored; and
  - Provide an estimated cost and a detailed implementation schedule for the improvement opportunities identified above.
- Section IV.E.2 Watershed Restoration Planning. Implementing restoration efforts to treat 20% of the County's impervious area that is not already treated to the maximum extent practical (MEP) within the five-year permit cycle.
  - Watershed plans developed in conjunction with these requirements will:
    - Include the final date for meeting applicable stormwater wasteload allocations (WLAs) and provide a detailed schedule for implementing structural and nonstructural water quality projects, enhanced stormwater management programs, and alternative stormwater control initiatives necessary for meeting applicable WLAs;
    - Provide detailed cost estimates for individual projects, programs, controls, and plan implementation;
    - Evaluate and track the implementation of restoration plans through monitoring or modeling to document progress toward meeting established benchmarks, deadlines, and stormwater WLAs; and
    - Develop an ongoing, iterative process that continuously implements structural and nonstructural restoration projects, program enhancements, new and additional programs, and alternative BMPs where EPA-approved TMDL stormwater WLAs are not being met according to the benchmarks and deadlines established as part of the County's watershed assessments.

The current generation of MS4 permits in Maryland include greater emphasis on making progress towards meeting both local and Chesapeake Bay wide TMDL WLAs in association with Watershed Assessment and Planning efforts. This is addressed by the requirement to develop Watershed Restoration Plans that include pollutant load reduction benchmarks and deadlines that demonstrate progress toward meeting all applicable stormwater TMDL WLAs.

Anne Arundel County's current NPDES MS4 permit required an impervious area assessment to be submitted to MDE. As reported in the County’s FY2014 MS4 Annual Report to MDE, the County’s process for determining the restoration acreage goal was documented in its May 2015 impervious area assessment (Establishing Baseline - Impervious Area Assessment, Impervious Surfaces Treated to the MEP, submitted to MDE May 26, 2015). In July 2015, MDE approved this impervious surface area assessment and the associated baseline for impervious area restoration. The impervious area assessment identified 30,950 impervious acres under the County’s MS4 jurisdiction. Of these acres, 1,639 were identified as managed to the maximum extent practical (MEP, i.e., the baseline of managed impervious area) and 29,311 acres were identified as either having no stormwater management or only partial management (i.e., the baseline of unmanaged impervious area). This resulted in 20% restoration acreage of 5,862 acres (restoration goal), to be completed by the County on or before February 2019.The Permit requires the County to perform watershed assessments and to develop restoration plans to meet stormwater WLAs in EPA-approved TMDLs. These restoration plans are also required to address restoration of 20% of the County’s impervious area that has little or no stormwater management.

1.3 PHYSICAL SETTING

The West and Rhode River watersheds are two of the twelve major watersheds in Anne Arundel County. Both the West and Rhode Rivers are direct tributaries to the Chesapeake Bay and are located in the southern portion of the County (see Map 1.1).

1.3.1 Physiography

The West and Rhode River watersheds are in the Atlantic Coastal Plain Physiographic Province. The Rhode River watershed is spread in roughly equal proportions across the Crownsville Upland (32%), Prince Frederick Knobby Upland (29%), and Annapolis Estuaries and Lowlands (29%) Districts. The majority of the West River watershed is in the Annapolis Estuaries and Lowlands District (57%); the remainder of the watershed is in the Crownsville Upland (37%) and the Prince Frederick Knobby Upland (5%). The landforms within these districts are described as (Maryland Geological Survey, 2008):

- *Annapolis Estuaries and Lowlands* – featureless lowlands, typically <50 feet in elevation,
- *Crownsville Upland* – undulating uplands with <8% slopes, and

- *Prince Frederick Knobby Upland* – moderately to well-dissected uplands with numerous hillocks.

As seen in Maps 1.4 and 1.5, the majority of steep slopes are in the upstream areas, concentrated in the westernmost half of each watershed.

1.3.2 Soils and Geology

The majority of soils in the West River are classified as hydrologic soil group (HSG) C (NRCS, 2012). These soils have a moderately high runoff potential when thoroughly wet and water transmission through the soil is somewhat restricted.

Table 1.3 - Hydrologic Soil Group

Hydrologic Soil Group	West River	Rhode River
A	0%	0%
B	38%	66%
C	55%	24%
D	7%	10%

HSG B accounts for 66% of the soils in the Rhode River watershed. These soils have a moderately low runoff potential when thoroughly wet and water transfer through the soil is unimpeded. HSG D is found in small amounts (≤10%) in both watersheds; this soil group has a high runoff potential when wet and water movement is very restricted. HSG A was absent from these watersheds; these soils have a low runoff potential when wet and water is transmitted freely through the soil.

Soils classified as not highly erodible are the most common class present in the West River watershed, which can be found in 46% of the watershed; the most common soil class in the Rhode River watershed is highly erodible lands, and includes 55% of the watershed area (NRCS, 2012; see Table 1.4). Map 1.6 illustrates how these soils are interspersed throughout the watersheds.

Table 1.4 -Soil Erodibility

Soil Erodibility	West River	Rhode River
Highly erodible land	34%	55%
Not highly erodible land	46%	17%
Potentially highly erodible land	20%	28%

1.3.3 Surface Water

The West River watershed contains approximately nine miles of perennial stream reaches and three miles of intermittent stream reaches, draining 13 subwatersheds. These 13 subwatersheds range in size from approximately 191 acres to 1,386 acres.

The Rhode River watershed contains approximately 24 miles of perennial stream reaches and five miles of intermittent stream reaches. This watershed is divided into 14 units, including

12 typical subwatersheds and three small islands. The 12 subwatersheds range in size from approximately 229 acres to 1,541 acres.

Table 1.5 lists the subwatersheds for each watershed by name and by acreage. A map of the subwatersheds including the subwatershed three-digit code and name is presented as Map 1.7.

Table 1.5 – Subwatersheds

Subwatershed Code	Subwatershed Name	Area (acres)
WEST RIVER		
WR0	West River Tidal	192
WR1	Johns Creek	683
WR2	Cheston Creek	444
WR3	Gales Creek	701
WR4	Popham Creek	317
WR5	Lerch Creek I	615
WR6	Lerch Creek II	1,386
WR7	Tenthouse Creek	434
WR8	South Creek I	518
WR9	South Creek II	749
WRA	Parish Creek	266
WRB	Smith Creek I	619
WRC	Smith Creek II	372
RHODE RIVER		

Table 1.5 – Subwatersheds

Subwatershed Code	Subwatershed Name	Area (acres)
RR0	Forrest Branch	275
RR1	Bear Neck Creek	879
RR2	Sellman Creek	701
RR3	Many Fork Branch	670
RR4	Big Pond	230
RR5	South Fork Muddy Creek II	1,488
RR6	Cadle Creek	355
RR7	Williamson Branch	660
RR8	North Fork Muddy Creek	1,259
RR9	South Fork Muddy Creek I	1,541
RRB	Beverley Beach	433
RRC	Big Island	12
RRD	High Island	1
RRE	Boathouse Creek	258
RRF	Flat Island	1

1.3.4 Environmental Features

Environmental features in the West and Rhode River watersheds are presented in Map 1.8. As seen in this map, many sensitive environmental features are found throughout the watersheds. Wetlands and greenways are located throughout the watersheds. The entire eastern border of both watersheds falls within the Critical Area.

1.3.5 Land Cover and Land Ownership

The distribution of land cover in the West and Rhode River watersheds is summarized in Table 1.6. Land covered with woods makes up the greatest portion of the West and Rhode River watersheds, approximately 44% and 54% respectively. Apart from woods, the other most significant land use/land cover categories in both watersheds are row crop and 2-acre residential. Map 1.9 represents land cover in the watersheds.

Table 1.6 - Land Cover

Land Cover	West River Watershed		Rhode River Watershed	
	Acres	Percent of Watershed	Acres	Percent of Watershed
Airport	0.0	0.0%	0.0	0.0%
Commercial	138.9	1.9%	111.5	1.3%
Forested Wetland	0.0	0.0%	0.0	0.0%
Industrial	0.0	0.0%	22.2	0.3%
Open Space	314.2	4.3%	564.7	6.4%
Open Wetland	36.5	0.5%	96.0	1.1%
Pasture/Hay	485.9	6.7%	385.6	4.4%
Residential 1/2-acre	284.2	3.9%	205.3	2.3%
Residential 1/4-acre	127.7	1.8%	273.1	3.1%
Residential 1/8-acre	203.6	2.8%	313.3	3.6%
Residential 1-acre	318.8	4.4%	296.7	3.4%
Residential 2-acre	915.6	12.5%	895.1	10.2%
Row Crops	1,019.5	14.0%	544.7	6.2%
Transportation	158.5	2.2%	148.6	1.7%
Utility	43.3	0.6%	61.7	0.7%
Water	41.0	0.6%	93.7	1.1%
Woods	3,208.4	44.0%	4,751.6	54.2%
TOTAL	***7,296.1***	--	***8,763.8***	--

The land use and ownership along with their impervious areas are summarized in Table 1.7. The largest ownership types for the Rhode watershed are Natural Lands, Low-Density Residential, and Agricultural, all within County jurisdiction. Similarly, the largest ownership types for the West watershed are Natural Lands, Agricultural, and Low-Density Residential, all within County jurisdiction. Private low-density residential and County roads and facilities comprise the largest impervious areas. Map 1.10 depicts impervious surfaces and non-private land ownership.

Table 1.7 - Impervious, Land Use, and WIP Sector Ownership

Land Use and WIP Sector Ownership	Area (acres)	Impervious Cover (acres	Impervious % of Land Cover	% of Total Impervious Cover
RHODE RIVER				
County – Private Commercial	101.7	55.6	55%	10%
County – Private Agriculture Lands	921.5	6.4	< 1%	1%
County – Private Natural Lands	5,070.9	41.4	< 1%	8%
County – Private High Density Residential	262.0	66.1	25%	12%
County – Private Medium Density Residential	416.7	83.0	20%	15%
County – Private Low Density Residential	1137.0	132.5	12%	24%
County – Private Utility/Transportation	108.0	12.2	11%	2%
County – Board of Education	0.5	0.1	20%	< 1%
County – Roads and Facilities	652.3	112.8	17%	20%
Maryland State Highway Administration	93.8	40.2	43%	7%
RHODE RIVER TOTAL	**8,764.5**	**550.3**	**6%**	**-**
WEST RIVER				
County – Private Commercial	124.8	68.2	55%	14%
County – Private Agriculture Lands	1,497.4	8.8	< 1%	2%
County – Private Natural Lands	3,470.4	24.1	< 1%	5%
County – Private High Density Residential	165.2	46.8	28%	9%
County – Private Medium Density Residential	364.2	75.3	21%	15%
County – Private Low Density Residential	1191.4	138.4	12%	28%
County – Private Utility/Transportation	91.8	7.6	8%	2%
County – Board of Education	16.4	3.6	22%	1%
County – Roads and Facilities	305.3	96.1	31%	19%
Maryland State Highway Administration	56.8	30.4	54%	6%
Maryland State Institutional Lands	12.2	0.04	< 1%	< 1%
WEST RIVER TOTAL	**7,296.0**	**499.3**	**7%**	**-**

The West and Rhode watersheds were initially developed in the 1650s. Since then, the watershed has developed at varying level of intensities. Table 1.8 is presented as a “heat map” that displays the rate of new impervious surfaces over each time period. Based on this heat map, it is possible to see that the fastest development in the Rhode watershed occurred in the Bear Neck Creek subwatershed (RR1) during the 1940-2015 period. In the West watershed, South Creek I (WR8) had the highest rate of development from 1940-1999, with the Parish Creek subwatershed (WRA) seeing the fastest development in 2000-2015. Land development age and current zoning within the watersheds are shown on Maps 1.11 and 1.12, respectively.

Table 1.8 - Rate of New Development

Subshed	1650 - 1899	1900 - 1919	1920 - 1939	1940 - 1959	1960 - 1979	1980 - 1999	2000 - 2011
RHODE WATERSHED							
RR0	0	0.13431	0.01276	0	0	0	0.00132
RR1	0.00577	0.01807	0.12509	1.06985	1.54928	1.07334	0.98170
RR2	0	0.16557	0.04841	0.00929	0.01389	0.37134	0.01997
RR3	0.00094	0.12200	0.05401	0.07214	0.03086	0.01176	0.17522
RR4	0.00325	0.05988	0.00368	0.15743	0.37330	0.20707	0.24245
RR5	0.00302	0.10233	0.17755	0.06111	0.49634	0.58178	0.30008
RR6	0.00200	0.17420	0.31370	0.52307	0.43965	0.35754	0.89945
RR7	0.00539	0.00496	0.05301	0.14931	0.25256	0.40483	0.16301
RR8	0	0.06603	0.14298	0.04083	0.45624	0.35332	0.30204
RR9	0.01255	0.00465	0.33037	0.14223	0.08193	0.36780	0.05454
RRB	0	0.06361	0.24008	0.43471	0.07930	0.10324	0.32235
RRC	0	0	0	0	0	0	0
RRD	0	0	0	0	0	0	0
RRE	0.00302	0.00147	0.00664	0.01108	0.04914	0.01454	0
RRF	0	0	0	0	0	0	0
WEST WATERSHED							
WR0	0.00355	0.08571	0.12724	0.20570	0.09998	0.17531	0.19995
WR1	0.00786	0.00615	0.04533	0.11217	0.33050	0.04930	0.07929
WR2	0.00608	0.00113	0.01533	0.00688	0.05686	0.03260	0.13258
WR3	0.00841	0.00014	0.19999	0.24523	0.15652	0.61636	0.47163
WR4	0.00779	0	0.04202	0.02033	0.08162	0.01251	0.08113
WR5	0.00379	0.00531	0.21605	0.25040	0.21150	0.41144	0.13052
WR6	0.00143	0.00374	0.04408	0.02925	0.18070	0.89216	0.22651
WR7	0.00263	0.05717	0.19960	0.47520	0.26366	0.20728	0.20177
WR8	0.00326	0.05248	0.32456	0.86825	0.34959	1.15109	0.46813
WR9	0.00105	0.03709	0.18099	0.20137	0.24279	0.96409	0.59169
WRA	0.00217	0.06986	0.28193	0.25793	0.34420	0.15540	0.76675
WRB	0.00384	0.02755	0.05309	0.04051	0.05300	0.12176	0.04267
WRC	0.00431	0	0.01168	0.00492	0.00711	0.02928	0.05183

1. Values represent the number of new impervious acres divided by the number of years in the time period
2. Impervious areas in the right of way were removed from this analysis

2. DATA COLLECTION AND COMPILATION

Field data were collected and compiled to support the County's stream reach and subwatershed condition assessment and rating efforts and to assist in development of the County's Chesapeake Bay TMDL WIP strategy. Field crews verified and classified the West and Rhode tributary stream networks, assessed physical habitat conditions, and collected data on infrastructure, environmental features, road crossing flood potential, and channel geomorphology. This data collection field work was performed in the fall of 2013 and spring of 2014. Additional existing data were also used to support the County's assessment efforts: bioassessment monitoring results, land use cover, impervious areas, BMP characteristics, septic system impacts, soil characteristics, and various other aquatic and landscape indicators. Each of these data components is discussed in more detail in this section. The discussion is organized by pertinent ecosystem zone, including the tributary streams and their associated riparian areas (Section 2.1) and upland areas (Section 2.2).

2.1 STREAM DATA COLLECTION AND COMPILATION

The following subsections present and summarize the collected and compiled data within the West and Rhode tributary streams and the adjacent riparian areas. Stream classifications and verification, physical habitat condition assessment, inventory of infrastructure and environmental features, habitat scores, channel geomorphology, road crossing flood potential, bioassessments, and aquatic resource indicators are all reported in detail. This information is crucial for determining the conditions within the tributary streams and for subsequently identifying, formulating, and prioritizing restoration activities and land management decisions to improve stream conditions.

2.1.1 Stream Classification and Verification

A watershed assessment is predicated on an accurate understanding of stream location and character (e.g., perennial, intermittent, ephemeral, underground, wetland, etc.). The actual position, alignment, and character of all tributary streams in the West and Rhode River watersheds were field-verified. A stream planimetric dataset based on aerial photography, drainage lines derived from a digital elevation model (DEM), and a geodatabase of storm drain outfalls was used as a guide for directing field assessment and verification efforts. Based on field verification activities, a stream reach GIS layer was constructed representing all of the tributary streams that contribute flow to the West and Rhode Rivers.

Field teams confirmed the location of the stream channel and determined the stream character. Additions to and deletions from the existing stream planimetric dataset were recorded as necessary to match observed field conditions. Modifications to the channel alignment in the dataset were made only when significant inconsistencies were noted. Field teams used best professional judgment to evaluate field indicators of perenniality, including hydrologic indicators (e.g., seeps, leaf litter presence, sediment deposition), geomorphic indicators (e.g., riffle-pool sequence, substrate sorting, sinuosity, bankfull bench presence), soil indicators (e.g., redox-morphic features, chroma), and biological indicators (e.g., vegetation, benthic macroinvertebrates).

Collectively, between the two watersheds, approximately 62 miles of streams were verified and characterized. Thirty-five miles of stream (not included in the 62 miles noted above) were not assessed because of limitations relating to private and federally owned access restrictions, physical barriers, and unsafe site conditions. Characterizations in the West River watershed included approximately 8.9 miles of perennial stream, 12.4 miles of ephemeral stream, and 2.7 miles of intermittent stream. The Rhode River watershed characterization covered 24.3 miles of perennial stream, 8.2 miles of ephemeral stream, and 5.4 miles of intermittent stream.

During the field verification efforts, streams were segmented into individual stream reaches to facilitate subsequent assessment and analysis efforts. Stream reaches were identified and segmented in the field as distinct habitat or geomorphic conditions were encountered. Physical features, such as stream confluences, bridges, and culverts, were also used to sub-divide reaches. A total of 307 individual reaches, with an average length of 483 feet, were identified within the West River watershed. The Rhode River watershed included identification of 455 individual reaches, averaging 500 feet in length.

A summary of stream miles and number of reaches by type is presented for both watersheds in Table 2.1. Stream classifications encountered throughout the watersheds are depicted in Map 2.1.

Table 2.1 - Stream Character Types

	West River Watershed			Rhode River Watershed		
Type	**Number of Reaches**	**Stream Miles**	**Percent of Total Stream Miles**	**Number of Reaches**	**Stream Miles**	**Percent of Total Stream Miles**
Ditch	18	1.5	3.4%	0	0.0	0.0%
Ephemeral	120	12.4	27.8%	93	8.2	13.4%
Floodway	0	0.0	0.0%	0	0.0	0.0%
Intermittent	27	2.7	6.0%	56	5.4	8.8%
Main Stem	0	0.0	0.0%	0	0.0	0.0%
Not Assessed	85	16.5	37.0%	106	18.5	30.0%
Perennial	103	8.9	20.0%	237	24.3	39.4%
Pipe	4	0.2	0.4%	10	0.9	1.5%
Pond/Lake	2	0.1	0.2%	12	1.0	1.6%
SWM	0	0.0	0.0%	0	0.0	0.0%
Tidal	7	0.4	0.9%	6	0.5	0.8%

Table 2.1 - Stream Character Types

Type	West River Watershed			Rhode River Watershed		
	Number of Reaches	Stream Miles	Percent of Total Stream Miles	Number of Reaches	Stream Miles	Percent of Total Stream Miles
Underground	0	0.0	0.0%	1	0.0	0.0%
Wetland/Marsh	26	1.9	4.3%	40	2.8	4.5%
TOTAL	***392***	***44.6***	**---**	**561**	**61.6**	

Stream segments were assigned a stream order according to a modified Strahler stream order hierarchy. In this hierarchy, ephemeral and intermittent channels as well as other non-perennial headwater reaches are assigned as zero-order streams. First order streams then generally begin with the first headwater perennial stream encountered. A summary of the stream ordering per subwatershed, including those reaches not assessed, is presented in Table 2.2. A map of the stream ordering is presented in Map 2.2.

Table 2.2 - Strahler Stream Order Per Subwatershed

Subwatershed	Stream Order Miles						
	0	1st	2nd	3rd	4th	5th	Total
WEST RIVER WATERSHED							
WR0	0.2	0.0	0.0	0.0	0.0	0.0	0.2
WR1	3.7	0.6	0.0	0.0	0.0	0.0	4.3
WR2	1.2	0.0	0.0	0.0	0.0	0.0	1.2
WR3	5.1	0.3	0.0	0.0	0.0	0.0	5.4
WR4	0.2	0.5	0.0	0.0	0.0	0.0	0.7
WR5	1.6	0.3	0.6	0.7	0.0	0.0	3.2
WR6	3.6	2.8	4.0	0.4	0.0	0.0	10.8
WR7	0.8	0.3	0.1	0.0	0.0	0.0	1.2
WR8	2.0	0.3	0.0	0.0	0.0	0.0	2.3
WR9	6.5	0.1	0.0	0.0	0.0	0.0	6.6
WRA	0.6	0.0	0.0	0.0	0.0	0.0	0.6
WRB	3.2	0.4	1.1	0.0	0.0	0.0	4.7
WRC	2.1	0.4	0.9	0.0	0.0	0.0	3.4
TOTAL	***30.8***	***6.0***	***6.7***	***1.1***	***0.0***	***0.0***	***44.6***
RHODE RIVER WATERSHED							
RR0	0.6	0.5	0.3	0.0	0.0	0.0	1.4
RR1	3.4	0.9	0.0	0.0	0.0	0.0	4.3
RR2	2.2	2.1	0.5	0.0	0.0	0.0	4.8
RR3	2.2	1.5	0.8	0.1	0.0	0.0	4.6
RR4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RR5	3.2	5.9	2.9	3.1	0.0	0.0	15.1
RR6	0.6	0.1	0.0	0.0	0.0	0.0	0.7
RR7	1.3	1.0	2.4	0.5	0.0	0.0	5.2
RR8	2.1	2.7	1.9	2.0	0.0	0.0	8.7
RR9	10.0	3.1	0.2	0.0	1.4	0.0	14.7
RRB	1.1	0.5	0.0	0.0	0.0	0.0	1.6
RRC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RRD	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RRE	0.5	0.0	0.0	0.0	0.0	0.0	0.5
RRF	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	***27.2***	***18.3***	***9.0***	***5.7***	***1.4***	***0.0***	***61.6***

2.1.2 Physical Habitat Condition Assessment

Physical habitat condition is a widely used measure of the overall health of a stream and its ability to support aquatic life. Healthy physical habitat for aquatic organisms typically includes stable channels and substrates, diverse flow characteristics, and abundant cover and food sources. Natural streams are typically in a state of dynamic equilibrium. However, this equilibrium can be disrupted. Habitat parameters common in healthy streams begin to deteriorate when urban and agricultural stressors are introduced. Examples of assessed stream reaches are depicted in Figure 2-1.

A field assessment of in-stream physical habitat conditions was performed for perennial streams by observing and measuring various physical attributes. This work was completed in accordance with the 2003 *Physical Habitat Index for Wadeable Streams in Maryland* report developed by the Maryland Department of Natural Resources (MDNR; Paul et al., 2003). Collected habitat assessment parameters included qualitative observations of in-stream and riparian conditions (*i.e.*, fish presence, bacteria or algae presence, aquatic vegetation presence, water clarity and odor, and riparian vegetation character) as well as quantified assessment parameters used to calculate a Maryland Physical Habitat Index (MPHI) score. Data used to support the calculation of the scaled MPHI score for each perennial stream reach included individual scores for remoteness, shading, epifaunal substrate, in-stream habitat,

Figure 2-1 - Examples of Assessed Stream Reaches

Stream Reach in the Many Fork Branch Subwatershed (RR3) with Minimally Degraded Habitat Condition

Stream Reach in the Williamson Branch Subwatershed (RR7) with Partially Degraded Habitat Condition

Stream Reach in South Fork Muddy Creek II Subwatershed (RR5) with Degraded Habitat Condition woody debris and rootwads, and bank stability.

Physical habitat condition assessment reaches were created based on observed changes in habitat conditions along a stream. In the West and Rhode River watersheds, approximately 1.1 and 1.3 miles, respectively, of perennial stream were not assessed due to individual reach lengths being less than the minimum assessment length requirement (75 meters). For the West River watershed, approximately 7.9 miles of perennial stream (69 reaches with an average length of 604 feet) were assessed and scored; for the Rhode River watershed, approximately 23.0 miles of perennial stream (197 reaches with an average length of 617 feet) were assessed and scored.

Based on the calculated MPHI score, each stream reach is assigned a condition category of "Severely Degraded", "Degraded," "Partially Degraded," or "Minimally Degraded". Standard MPHI category breakpoints used by MDNR are as follows:

- 0 to 50.9 – Severely Degraded
- 51.0 to 65.9 – Degraded
- 66.0 to 80.9 – Partially Degraded
- 81.0 to 100 – Minimally Degraded

For this and previous watershed studies, the County uses a modified breakpoint of 59.9 to 60.0 between the "Degraded" and "Severely Degraded" categories. The result is an effectively more conservative approach that identifies additional reaches for restoration. This modified scoring is carried through in the calculation of MPHI scores per watershed and the calculation of Final Habitat Scores (FHS) for reaches and subwatersheds described in Section 2.1.4.

The average length-weighted MPHI score for the West River watershed is 62.4 ("Degraded"), while for the Rhode River watershed it is 68.7 ("Partially Degraded"). The majority of stream miles in both subwatersheds were rated in the "Partially Degraded" category. A summary of MPHI condition categories by stream mile and number of reaches is provided in Table 2.3. A map of the MPHI conditions throughout the watersheds is presented as Map 2.3.

Table 2.3 - Physical Habitat Condition Results, MPHI

MPHI Category	West River Watershed			Rhode River Watershed		
	Number of Reaches	Stream Miles	Percent of Total Stream Miles	Number of Reaches	Stream Miles	Percent of Total Stream Miles
Minimally Degraded	4	0.5	6%	65	7.6	33%
Partially Degraded	43	4.8	61%	94	10.8	48%
Degraded	10	1.5	19%	21	2.6	11%
Severely Degraded	12	1.1	14%	17	1.9	8%
TOTAL	***69***	***7.9***	--	***197***	***23.0***	--

2.1.3 Inventory of Infrastructure and Environmental Features

Accurately documenting infrastructure and other environmental features observed along streams is very important for the assessment of current conditions. For this reason, fieldwork included an inventory of infrastructure and significant environmental features that were compiled within each perennial, intermittent, or ephemeral reach and associated riparian area. These features included riparian buffer deficiencies, excessive in-stream erosion, stream obstructions, stream crossings, utilities, dump sites, head cuts, and tributary pipes and drainage ditches. Depending on the inventory feature type, the associated impact was scored in the field as “Minor”, “Moderate”, “Severe”, or “Extreme” based on its potential impact on the integrity or health of the stream reach. These impacts were translated to a 0-10 point scale depending on the feature type according to the County’s protocol. Impact scores increase with the level of impact. A full description of the scores and ratings are found in *Field Data Collection Guide for Watershed Studies, Anne Arundel County Department of Public Works* (Anne Arundel County, 2012a). In addition to the impact scores, other quantitative and qualitative data, such as dimension, relative location, composition, and restoration potential were collected for each feature.

These infrastructure and environmental features can be critical to the health of the tributary streams in the watersheds for different reasons discussed below. Examples of environmental and infrastructure features encountered in the study watersheds are depicted in Figure 2-2.

- Intact wooded/forested **stream buffers** provide important habitat and shading for both terrestrial and aquatic fauna, and also serve to dampen runoff velocities and filter runoff pollutants before they enter a stream. These functions are lost or significantly diminished when stream buffers are removed or compromised by land management decisions.

- Stream **crossings** can vary from a foot bridge with only minor impact on channel stability to a large road crossing that forces a stream into a culvert. Culverted stream crossings tend to be the most problematic because they can become blocked or clogged by accumulated debris, because they can create backwater conditions (from undersized culverts), and because they can act to accelerate stream flow. Stream crossing impacts can include flooding, local bed and bank erosion upstream and downstream of the culvert, excessive deposition, and fish passage impediments.
- **Dump sites** are typically comprised of trash or debris dumped in the stream channel or in the riparian area. Toxic pollutants from dumpsites can impact water quality and bulk trash and debris can alter stream hydrodynamics.
- Although channel bed and bank **erosion** occurs naturally as streams work to maintain a state of dynamic equilibrium, excessive erosion can occur due to increased stream velocities associated with development activities that increase imperviousness within the watershed. Channel erosion can deliver excessive pollutants such as sediment and phosphorus downstream, where water quality can be impacted and important habitat for fish spawning and benthic invertebrates can be smothered. Excessive erosion can also threaten the stability of nearby infrastructure.
- A **head cut** is an abrupt change or drop in stream channel elevation. Head cuts are often indicators of active channel incision or downcutting. The movement of upstream bed material fills in the low points associated with the head cut, and as a result the head cut migrates upstream until a new grade is established for the entire channel.
- Channel **obstructions** can include natural features like fallen trees as well as man-made features like concrete dams or riprap. These obstructions can partially or completely obscure water flow, which can cause flooding and localized erosion and can impede the passage of fish.
- **Pipes and drainage ditches** are typically associated with stormwater conveyance. Depending on their placement and flow characteristics, pipes and drainage ditches can contribute to water quality impairments and erosion in the receiving streams.
- **Utilities** can include sanitary sewers, storm sewers, water lines, gas lines, and electrical transmission lines (buried or overhead). Impacts from utilities are the most severe when they intersect the stream channel where they can alter stream hydraulics and cause localized erosion.

A summary of the impacts for each infrastructure or environmental feature is presented in Table 2.4 and Table 2.5. The distribution of these features throughout the watersheds is presented in Map 2.4. For the both watersheds, riparian buffer impacts and erosion impacts had some of the highest total cumulative impact score of all the inventory features identified. Riparian buffer impacts were most often associated with encroachment from residential lawns. Erosion impacts were attributed mostly to increases in flow associated with development in the watershed. In some cases, erosion impacts may have been due to local hydraulic modifications (e.g., constrictions from a debris dam or fallen tree). The West River watershed had a large number of crossings, though most were rated as having a minor impact. The Rhode River watershed had a large number of obstructions (primarily due to trees and debris), as well as a large number of headcuts. The remaining features (i.e., dump sites, utilities) were encountered less frequently, but certainly contributed locally to areas of stream degradation throughout the watershed.

Table 2.4 - Infrastructure and Environmental Feature Impact Scores

Type	Number of Features with Impact Score:				Total Cumulative Impact Score
	Minor	Moderate	Severe	Extreme	
WEST RIVER WATERSHED					
Buffers	0	67	39	7	678
Crossings	84	14	3	0	259
Dump sites	13	6	1	0	53
Erosion	0	101	40	0	785
Obstructions	44	28	3	0	258
Pipes/Ditches	0	0	0	0	0
Utilities	0	0	1	0	10
Head Cuts	32	21	5	3	177.8*
TOTAL	***174***	***237***	***92***	***10***	***2,220.8***
RHODE RIVER WATERSHED					
Buffers	0	74	20	4	543
Crossings	72	19	4	0	267
Dump sites	22	15	1	0	107
Erosion	0	155	62	2	1,234
Obstructions	120	61	4	0	585
Pipes/Ditches	0	9	3	0	75
Utilities	0	0	0	0	0
Head Cuts	58	52	24	11	513.25*
TOTAL	***272***	***385***	***118***	***17***	***3,324.25***

* Head cut impact score corresponds to cumulative height of head cuts

Figure 2-2 - Examples of Environmental and Infrastructure Features

Crossing in the South Fork Muddy Creek II Subwatershed (RR5) with Moderate Impact Score

Deficient Buffer in the Smith Creek I Subwatershed (WRB) with Moderate Impact Score

Bank Erosion in the South Fork Muddy Creek II Subwatershed (RR5) with Moderate Impact Score

Outfall in the Many Fork Branch Subwatershed (RR3) with Moderate Impact Score

Dumpsite in the Many Fork Branch Subwatershed (RR3) with Moderate Impact Score

Exposed Utility in the Parrish Creek Subwatershed (WRA) with Moderate Impact Score

Table 2.5 - Infrastructure and Environmental Features Per Stream Mile Assessed

Subwatershed	Stream Miles*	Number of Inventory Points**	Number of Inventory Points Per Stream Mile	Total Cumulative Impact Score	Total Cumulative Impact Score Per Stream Mile
WEST RIVER WATERSHED					
WR0	0.0	2	0.0	9	0.0
WR1	1.9	27	14.2	110	57.9
WR2	0.7	11	15.7	6.5	52.1
WR3	1.9	60	31.6	180	94.7
WR4	0.6	7	11.7	27.5	45.8
WR5	0.5	22	44.0	93	186.0
WR6	5.5	217	39.5	1,015.55	184.6
WR7	0.6	23	38.3	66.5	110.8
WR8	2.1	48	22.9	123	58.6
WR9	5.0	104	20.8	274.5	54.9
WRA	0.4	12	30.0	43	107.5
WRB	1.2	13	10.8	33.75	28.1
WRC	3.4	55	16.2	208.5	61.3
TOTAL	***23.8***	***601***	***25.3***	***2,220.8***	***93.3***
RHODE RIVER WATERSHED					
RR0	1.1	21	19.1	84	76.4
RR1	3.2	97	30.3	338	105.6
RR2	3.5	40	11.4	153.5	43.9
RR3	3.7	56	15.1	217.1	58.7
RR4***	0.0	2	0.0	0	0.0
RR5	9.6	249	25.9	1,077.4	112.2
RR6	0.6	11	18.3	46	76.7
RR7	4.0	74	18.5	262.5	65.6
RR8	7.6	178	23.4	737.25	97.0
RR9	3.8	89	23.4	368.5	97.0
RRB	0.4	14	35.0	33	82.5
RRC	0.0	0	0.0	0	0.0
RRD	0.0	0	0.0	0	0.0
RRE	0.4	2	5.0	7	17.5
TOTAL	***37.9***	***833***	***22.0***	***3,324.25***	***87.7***

* Stream miles include perennial, ephemeral and intermittent stream miles

** Number of inventory points includes those in the category of “Other”, as well as those features (not accounted for in Table 2.4) that did not receive an impact score

***The two problems inventory points for this watershed were pipe outfalls near the shoreline; there are no stream miles present in this watershed

2.1.4 Final Habitat Score

A Final Habitat Score for each perennial stream reach was calculated using the MPHI scores generated from the physical habitat condition assessment (Section 2.1.2) and the sum of the impact scores generated from the inventory of infrastructure and environmental features (Section 2.1.3). The Final Habitat Score is calculated as follows (Anne Arundel Co., 2003):

$$\textit{Final Habitat Score} = \textit{MPHI Score} - 0.5\left(\sum \textit{Total impact scores}\right)$$

The Final Habitat Score is utilized in the County's subwatershed prioritization assessments, which are discussed in more detail in Section 4. Final Habitat Scores for individual reaches are combined using a reach length-weighted average to assess the physical habitat conditions of perennial streams at the subwatershed level. Similar to the MPHI scoring, each weighted stream reach and consequently each subwatershed is assigned a condition category of "Minimally Degraded," "Partially Degraded," "Degraded," or "Severely Degraded." A breakdown of Final Habitat Scores for the subwatersheds that contain perennial streams is presented in Table 2.6. The Final Habitat Scores found throughout the watershed are

Table 2.6 - Final Habitat Scores at Subwatershed Level

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Minimally Degraded	0	0.0%	0	0%
Partially Degraded	3	23.1%	8	57%
Degraded	3	23.1%	0	0%
Severely Degraded	4	30.7%	1	7%
N/A	3	23.1%	5	36%
TOTAL	***13***	**---**	***14***	**---**

presented in Map 2.5.

None of the subwatersheds in this study were considered "Minimally Degraded." Eight of the subwatersheds, three in West River and five in Rhode Rivers lack perennial streams and therefore lack Final Habitat Scores.

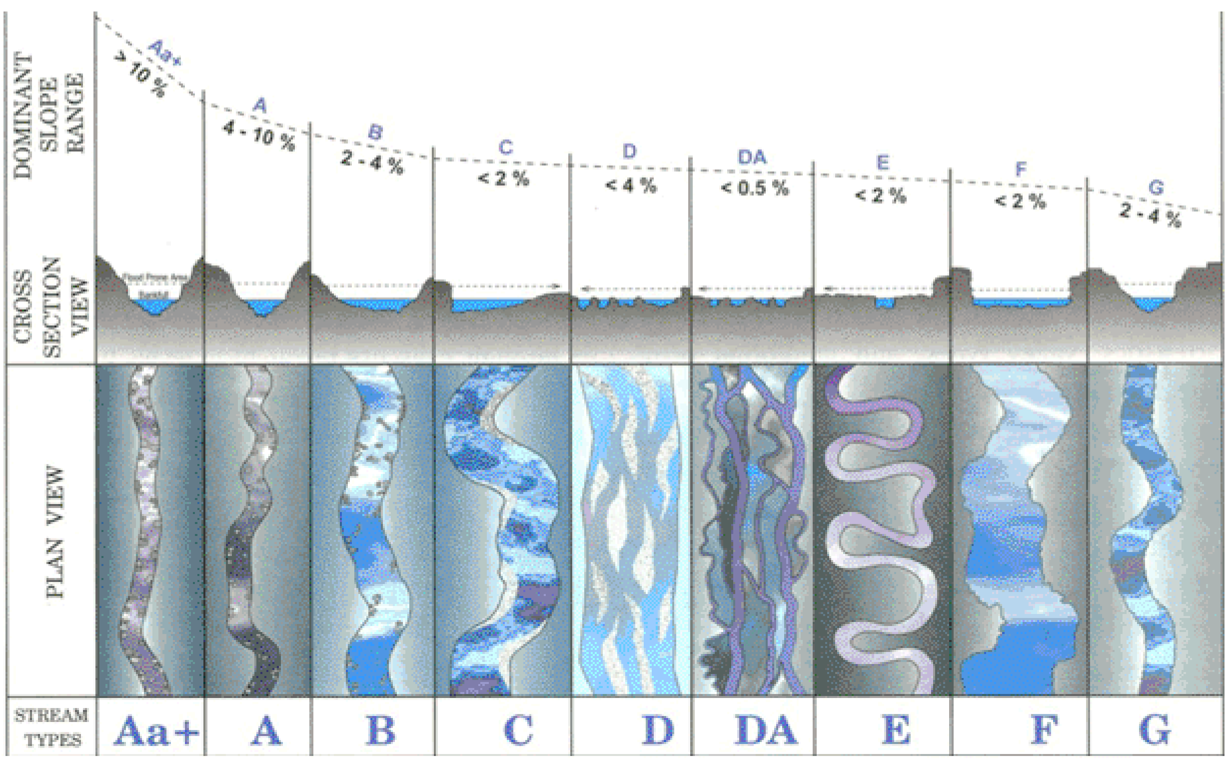
2.1.5 Channel Geomorphology

Over time, a stable natural stream channel will seek and achieve a state of dynamic equilibrium with its contributing watershed. In such a state, the stream will generally maintain its form and function and will undergo lateral adjustments over long periods of time in response to the range of hydrologic conditions to which it is exposed. During periods of normal flow, the stream can safely and efficiently convey the water and sediment that is directed through it. During periods of high flow, the stream can accommodate large volumes of water effectively by allowing it to overtop the stream banks and flow with dissipated energy across the floodplain. Upstream development patterns, however, can alter the volumes and peak flows conveyed through the stream and upset this dynamic equilibrium.

This phenomenon causes the stream flow to actively erode its channel bed and banks and eventually lose access to its existing floodplain. This can lead to loss of aquatic and terrestrial habitat, decreased water quality, and greater risk of flood-related damage (including loss of property), as the stream seeks out a new state of equilibrium.

An assessment of channel geomorphology is useful to better understand the stability of a stream and its associated behaviors. The Rosgen classification system is one such assessment method. It provides measurable benchmarks for determining stream stability and for comparing the stream with similar streams in an undisturbed state regardless of their location. The Rosgen classification system has four levels. The Level I classification is a geomorphic characterization that groups streams as Types A through G based on aspects of channel geometry, including water surface slope, entrenchment, width/depth ratio, and sinuosity. A simplification of the longitudinal, cross-sectional, and plan views of the major stream types under the Rosgen Level I classification scheme is presented in Figure 2-3.

Figure 2-3 - Representation of Rosgen Level I Classifications of Major Stream Types



Rosgen, David L. "A classification of natural rivers." Catena 22 (1994): 179. www.wildlandhydrology.com

The County utilizes Rosgen Level I geomorphic classifications in its watershed modeling and analysis as indicators of stream stability and channel entrenchment. In the West and Rhode River watersheds, field data were collected to support the Rosgen Level I geomorphic classification of each single-threaded reach, regardless of perenniality. This is a change from previous watershed studies where only perennial channels were assessed.

The field data were also used to support calculation of a Manning's roughness number for each eligible reach using the Cowan method (Cowan, 1956). These calculated Manning's roughness values were used with DEM-derived longitudinal profiles, channel cross-sections, and bankfull discharge calculations to perform the actual Rosgen Level I classification. A County-developed spreadsheet tool was used to facilitate the classifications.

Table 2.7 - Rosgen Level I Classifications

Classification	West River Watershed			Rhode River Watershed		
	Number of Reaches	Stream Miles	Percent of Total Stream Miles	Number of Reaches	Stream Miles	Percent of Total Stream Miles
A	8	0.6	3.2%	17	1.1	3.2%
B	66	7.3	38.4%	102	8.5	24.6%
C	64	6.1	32.1%	77	9.1	26.2%
D	0	0.0	0.0%	2	0.2	0.6%
DA	0	0.0	0.0%	0	0.0	0.0%
E	5	0.4	2.1%	16	1.9	5.5%
F	19	1.9	10.0%	55	6.4	18.5%
G	36	2.7	14.2%	76	7.4	21.4%
TOTAL	***198***	***19.0***	---	***345***	***34.6***	---

The distribution of Rosgen Level I classifications across the watershed is summarized in Table 2.7 and depicted in Map 2.6. As shown, the majority of stream miles in both watersheds were classified as Type "B" or "C" channels. Type "B" channels are typically characterized as predominantly stable, moderate gradient channels, with low sinuosity and low erosion rates. Type "C" channels are typically characterized as moderately stable, with a moderate to high width/depth ratio and sinuosity. Approximately 24% of stream miles in the West River watershed and 40% of the stream miles in the Rhode River watershed were classified as Type "F" and "G" channels, which are incised channels with high erosion rates. It is important to note that not all "C" and "B" stream types are stable. Over time, changes in the watershed can transform these relatively stable channels to less stable stream systems such as an "F or a "G" type channels.

2.1.6 Road Crossing Flood Potential

Flooding where streams and roadways cross can be a safety hazard to residents due to high water levels and has the potential to isolate properties from emergency vehicle access. Roadway stream crossings throughout the West and Rhode watersheds were analyzed to assess the potential for flooding and the need for replacement or modification. An initial subset of stream crossings with the potential for overtopping was identified during fieldwork activities. This subset of crossings included those roads owned by the County that were within 20 vertical feet of the stream bed, older than five-years in age, and classified as a "Freeway," "Principal Arterial," "Minor Arterial," "Collector," or "Local." These crossings were analyzed further to determine whether flooding or overtopping of a single crossing or two crossings concurrently could result in a community or business area being cut off from emergency services. Nine crossings were identified that met all of the County's criteria. A technical memorandum with a more detailed description of the road crossing selection process is included in Appendix A. The locations of the analyzed road crossings are presented in Map 2.7.

Field surveys were performed on these nine road crossings to obtain data on stream channel and roadway geometry. The 1-year, 2-year, 10-year, and 100-year discharges from each associated drainage area were calculated using the Natural Resource Conservation Service's (NRCS) TR-20 single event runoff and routing model (NRCS, 1992). The culverts associated with each crossing were modeled using the survey data and the Federal Highway Administration's HY8 model to determine the water level height and associated discharge required to overtop each of the crossings. This overtopping discharge was then compared to the range of return period discharges to determine the expected frequency that the road crossing would flood.

A summary of the discharge and flooding frequency data is presented in Table 2.8. In the West and Rhode watersheds, no crossings were found to have an overtopping return frequency of less than ten years. There were 3 crossings with calculated overtopping return periods of 10 to 100 years (WR9015, WR3029, and RRB006). The remaining 6 crossings had a calculated overtopping return period of greater than 100 years.

Table 2.8 - Flooding Potential of Selected Road Crossings

Crossing ID	Drainage Area (sq mi)	Discharge (cfs)				Overtopping Discharge (cfs)	Overtopping Return Period
		1 year	2 year	10 year	100 year		
Cedarlea Dr (WR9016.C001)	0.065	7	11	26	62	107	More than 100 years
Marx Dr 1 (WR9015.C001)	0.012	2	4	8	19	19	Between 10 and 100 years
Marx Dr 2 (WR9013.C001)	0.164	8	13	29	67	118	More than 100 years

Table 2.8 - Flooding Potential of Selected Road Crossings

Crossing ID	Drainage Area (sq mi)	Discharge (cfs)				Overtopping Discharge (cfs)	Overtopping Return Period
		1 year	2 year	10 year	100 year		
Plantation Blvd 1 (WR3022.C001)	0.064	2	3	8	21	37	More than 100 years
Plantation Blvd 2 (WR3029.C001)	0.084	3	5	12	29	18	Between 10 and 100 years
South Creek Way 1 (WR9031.C001)	0.004	0	0	1	3	4	More than 100 years
South Creek Way 2 (WR9034.C001)	0.017	2	3	8	18	37	More than 100 years
Sweetwater Dr (WR3021.C001)	0.093	3	5	13	34	60	More than 100 years
Triton Beach Rd (RRB006.C001)	0.038	7	11	29	72	39	Between 10 and 100 years

2.1.7 Bioassessment

Anne Arundel County has conducted targeted biological monitoring of streams in the West and Rhode River watersheds in 2012 (KCI, 2012). The full 2012 targeted sampling summary report is included as Appendix B. Additional surveys were conducted in these watersheds as part of the Countywide biological monitoring program.

Benthic monitoring was conducted during the Maryland Biological Stream Survey (MBSS) spring index period (March 1 – April 30) and employed the stream sampling methods specified in the County's Quality Assurance Project Plan (QAPP; Anne Arundel County, 2010), which follows the MBSS protocols (MDNR, 2007). At each 75-meter sampling site, benthic macroinvertebrates were collected using a D- from a combination of habitats that support the most diverse macroinvertebrate community within a sampling segment, as per MBSS protocols. At each site, 20 "jabs" of the net totaling 20 square feet of substrate were distributed among available habitats, including submerged vegetation, overhanging bank vegetation, leaf packs, organic mats, stream bed substrate, submerged woody debris, and rocks. The 20 jabs were composited into a single macroinvertebrate sample, which were preserved in the field for laboratory identification.

In the lab, benthic samples were subsampled and sorted, and oligochaetes and chironomids were slide-mounted to allow identification to genus level (family level for oligochaetes) according to the County's QAPP (Anne Arundel County, 2010) and accompanying Standard Operating Procedures. Benthic macroinvertebrate taxonomic identifications and counts recorded on bench sheets were entered into an Excel spreadsheet. Final data were imported to a MS Access database.

Benthic macroinvertebrate data were analyzed using the Coastal Plain version of the MBSS BIBI (Southerland et al., 2007). Metrics included in the BIBI are detailed in Table 2.9.

Table 2.9 - MBSS Coastal Plain BIBI Metrics and Description

Metric	Description
Total Number of Taxa	Measures the overall variety of the macroinvertebrate assemblage
Number of EPT Taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
Number of Ephemeroptera Taxa	Number of mayfly taxa
Percent Intolerant Urban	Percent of sample considered intolerant to urbanization (tolerance values 0-3)
Percent Ephemeroptera	Percent mayfly nymphs
Number Scraper Taxa	Number of taxa that scrape food from substrate
Percent Climbers	Percent of sample that primarily lives on stem type surfaces

MBSS attributes for each identified taxa, including functional feeding group, habitat preference, and tolerance values, were used to compute BIBI metrics. For each BIBI metric at each site, raw values were assigned a score of 1, 3, or 5 based on ranges of values developed for each metric (Table 2.10).

Table 2.10 - Scoring Criteria for Metrics in the MBSS Coastal Plain BIBI

Metric	Score		
	5	3	1
Total Number of Taxa	≥ 22	14 - 21	< 14
Number of EPT Taxa	≥ 5	2 - 4	< 2
Number of Ephemeroptera Taxa	≥ 2.0	1 - 1	< 1
Percent Intolerant Urban	≥ 28	10 - 27	< 10.0
Percent Ephemeroptera	≥ 11	0.8 – 10.9	< 0.8
Number Scraper Taxa	≥ 2	1 - 1	< 1
Percent Climbers	≥ 8.0	0.9 – 7.9	< 0.9

Scores for each metric were averaged to give a scaled BIBI score ranging from 1.0 to 5.0 and a corresponding narrative rating (Table 2.11).

Table 2.11 - BIBI Scoring and Narrative Rating

BIBI Score	Narrative Rating
4.0 to 5.0	Good
3.0 to 3.9	Fair
2.0 to 2.9	Poor
1.0 to 1.9	Very Poor

In the West River watershed, BIBI scores ranged from a low of 1.29 (“Very Poor”) to a high of 4.14 (“Good”), though only one site received the rating of “Good” (Table 2.12). Approximately 80% of the sites were rated as either “Poor” or “Very Poor”. Within the Rhode River watershed, BIBI scores ranged from 1.57 (“Very Poor”) to 3.29 (“Fair”). Approximately 94% of sites in this watershed were rated as either "Poor" or "Very Poor". Overall, BIBI results indicated that benthic macroinvertebrate communities are seriously impaired across both watersheds. Bioassessment sampling locations and results are presented in Map 2.8.

Table 2.12 - Summary of Bioassessment Data in the West and Rhode River Watersheds

Site	Shed Code	Subwatershed	Survey, Year	BIBI Score	BIBI Narrative Rating
WEST RIVER WATERSHED					
WEST-16-2012	WR1	Johns Creek	Targeted, 2012	2.71	Poor
WEST-17-2012	WR1	Johns Creek	Targeted, 2012	1.86	Very Poor
WEST-19-2012	WR1	Johns Creek	Targeted, 2012	2.14	Poor
WEST-22-2012	WR1	Johns Creek	Targeted, 2012	3.00	Fair
WR1025.G001	WR1	Johns Creek	Countywide Random (Round 1), 2008	2.43	Poor
WEST-53-2012					
WEST-55-2012	WR2	Cheston Creek	Targeted, 2012	1.57	Very Poor
WEST-13-2012	WR3	Gales Creek	Targeted, 2012	2.43	Poor
WEST-15-2012	WR3	Gales Creek	Targeted, 2012	1.29	Very Poor
WEST-50-2012	WR4	Popham Creek	Targeted, 2012	2.43	Poor
WEST-35-2012	WR5	Lerch Creek I	Targeted, 2012	2.71	Poor
WEST-36-2012	WR5	Lerch Creek I	Targeted, 2012	2.43	Poor
WR5006.G002	WR5	Lerch Creek I	Countywide Random (Round 1), 2008	1.86	Very Poor
WEST-39-2012	WR6	Lerch Creek II	Targeted, 2012	3.86	Fair
WEST-42-2012	WR6	Lerch Creek II	Targeted, 2012	2.14	Poor
WEST-43-2012	WR6	Lerch Creek II	Targeted, 2012	3.29	Fair
WR6010.G001	WR6	Lerch Creek II	Countywide Random (Round 1), 2008	1.86	Very Poor
WR6014.G001	WR6	Lerch Creek II	Countywide Random (Round 1), 2008	1.57	Very Poor
WR6015.G001	WR6	Lerch Creek II	Countywide Random (Round 1), 2008	1.57	Very Poor
WR6019.G001	WR6	Lerch Creek II	Countywide Random (Round 1), 2008	1.57	Very Poor
WR6046.G001	WR6	Lerch Creek II	Countywide Random (Round 1), 2008	2.14	Poor
WR6072.G001	WR6	Lerch Creek II	Countywide Random (Round 1), 2008	1.57	Very Poor
WR6085.G001	WR6	Lerch Creek II	Countywide Random (Round 1), 2008	1.86	Very Poor
WEST-46-2012	WR7	Tenthouse Creek	Targeted, 2012	1.57	Very Poor
WEST-48-2012	WR7	Tenthouse Creek	Targeted, 2012	2.43	Poor

Table 2.12 - Summary of Bioassessment Data in the West and Rhode River Watersheds

Site	Shed Code	Subwatershed	Survey, Year	BIBI Score	BIBI Narrative Rating
WEST-49-2012	WR7	Tenthouse Creek	Targeted, 2012	1.86	Very Poor
WEST-23-2012	WRB	Smith Creek I	Targeted, 2012	3.00	Fair
WEST-25-2012	WRB	Smith Creek I	Targeted, 2012	2.43	Poor
WEST-27-2012	WRB	Smith Creek I	Targeted, 2012	2.43	Poor
WEST-28-2012	WRB	Smith Creek I	Targeted, 2012	2.14	Poor
WRB025.G002	WRB	Smith Creek I	Countywide Random (Round 1), 2008	2.14	Poor
WEST-30-2012	WRC	Smith Creek II	Targeted, 2012	4.14	Good
WEST-31-2012	WRC	Smith Creek II	Targeted, 2012	3.29	Fair
WEST-32-2012	WRC	Smith Creek II	Targeted, 2012	2.43	Poor
RHODE RIVER WATERSHED					
RHOD-10-2012	RR0	Forrest Branch	Targeted, 2012	2.14	Poor
RHOD-11-2012	RR2	Sellman Creek	Targeted, 2012	2.71	Poor
RHOD-13-2012	RR2	Sellman Creek	Targeted, 2012	1.86	Very Poor
RHOD-14-2012	RR2	Sellman Creek	Targeted, 2012	2.43	Poor
RHOD-15-2012	RR3	Many Fork Branch	Targeted, 2012	2.14	Poor
RHOD-16-2012	RR3	Many Fork Branch	Targeted, 2012	2.43	Poor
RHOD-30-2012	RR5	South Fork Muddy Creek II	Targeted, 2012	1.86	Very Poor
RHOD-32-2012	RR5	South Fork Muddy Creek II	Targeted, 2012	3.00	Fair
RHOD-33-2012	RR5	South Fork Muddy Creek II	Targeted, 2012	2.43	Poor
RHOD-37-2012	RR5	South Fork Muddy Creek II	Targeted, 2012	2.43	Poor
RHOD-39-2012	RR5	South Fork Muddy Creek II	Targeted, 2012	2.43	Poor
RHOD-40-2012	RR5	South Fork Muddy Creek II	Targeted, 2012	1.57	Very Poor
RHOD-41-2012	RR5	South Fork Muddy Creek II	Targeted, 2012	2.43	Poor
RR5094.G001	RR5	South Fork Muddy Creek II	Countywide Random (Round 1), 2008	2.43	Poor
RHOD-27-2012	RR7	Williamson Branch	Targeted, 2012	1.86	Very Poor
RHOD-28-2012	RR7	Williamson Branch	Targeted, 2012	2.43	Poor
RR7032.G002	RR7	Williamson Branch	Countywide Random (Round 1), 2008	2.14	Poor

Table 2.12 - Summary of Bioassessment Data in the West and Rhode River Watersheds

Site	Shed Code	Subwatershed	Survey, Year	BIBI Score	BIBI Narrative Rating
RR7034.G001	RR7	Williamson Branch	Countywide Random (Round 1), 2008	1.57	Very Poor
RHOD-17-2012	RR8	North Fork Muddy Creek	Targeted, 2012	2.71	Poor
RHOD-18-2012	RR8	North Fork Muddy Creek	Targeted, 2012	2.71	Poor
RHOD-19-2012	RR8	North Fork Muddy Creek	Targeted, 2012	1.86	Very Poor
RHOD-20-2012	RR8	North Fork Muddy Creek	Targeted, 2012	1.57	Very Poor
RHOD-24-2012	RR8	North Fork Muddy Creek	Targeted, 2012	2.14	Poor
RR8002.G001	RR8	North Fork Muddy Creek	Countywide Random (Round 1), 2008	1.86	Very Poor
RR8006.G001	RR8	North Fork Muddy Creek	Countywide Random (Round 1), 2008	2.43	Poor
RR8015.G001	RR8	North Fork Muddy Creek	Countywide Random (Round 1), 2008	1.86	Very Poor
RR8052.G001	RR8	North Fork Muddy Creek	Countywide Random (Round 1), 2008	2.14	Poor
RR8054.G001	RR8	North Fork Muddy Creek	Countywide Random (Round 1), 2008	2.14	Poor
RR8072.G002	RR8	North Fork Muddy Creek	Countywide Random (Round 1), 2008	1.57	Very Poor
RHOD-43-2012	RR9	South Fork Muddy Creek I	Targeted, 2012	3.29	Fair
RHOD-45-2012	RR9	South Fork Muddy Creek I	Targeted, 2012	1.86	Very Poor
RHOD-46-2012	RR9	South Fork Muddy Creek I	Targeted, 2012	2.14	Poor
RHOD-48-2012	RR9	South Fork Muddy Creek I	Targeted, 2012	1.57	Very Poor
RHOD-01-2012	RRB	Beverley Beach	Targeted, 2012	1.86	Very Poor
RHOD-08-2012	RRE	Boathouse Creek	Targeted, 2012	1.57	Very Poor

2.1.8 Aquatic Resource Indicators

Areas that support trout spawning, anadromous fish spawning, and threatened and endangered species are all considered high-quality sensitive habitat that should be preserved. The locations of each of these sensitive habitat types in West and Rhode River subwatersheds were provided by MDNR and supplemented with additional information from the County.

The threatened and endangered species habitat was represented by the Natural Heritage Program's Sensitive Species Project Review Areas (SSPRA). The County overlaid GIS data with locations of these sensitive habitat areas to obtain a single representative GIS layer of all three aquatic resource indicators.

The West and Rhode River watersheds have no subwatersheds with aquatic resource indicators rated as "High" or "Medium High". One subwatershed in West River (8%) and five subwatersheds in Rhode River (33%) were rated as "Medium". The majority of subwatersheds in West and Rhode River were rated as "Low". A summary of aquatic resource ratings is provided in Table 2.13. Subwatershed ratings for aquatic resource indicators are presented in Map 2.9.

Table 2.13 - Aquatic Resource Indicator Ratings

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
High	0	0%	0	0%
Medium High	0	0%	0	0%
Medium	1	8%	5	33%
Low	12	92%	10	66%
TOTAL	***13***	---	***15***	---

2.2 UPLAND DATA COLLECTION AND COMPILATION

The following subsections on impervious cover, urban stormwater BMPs, onsite sewage disposal systems (OSDSs), soil indicators, and landscape indicators summarize the collected and compiled data in the upland areas associated with the West and Rhode River watersheds. This information is crucial for determining the land use conditions that influence the health of the tributary streams in these watersheds. As with the data presented in the previous section, the following upland data are used to identify and formulate restoration activities and land management decisions to improve conditions throughout the watersheds.

2.2.1 Contributory Impervious Cover to Streams

Links have been well-established between the level of impervious cover within a drainage area and the overall health of downgradient water bodies. The Center for Watershed Protection (CWP) suggested that streams with greater than 25% impervious cover are typically considered impaired or non-supporting; streams with 10 to 25% impervious cover are typically considered stressed or impacted, and streams with less than 10% imperviousness can support sensitive habitat and are typically relatively unimpaired

(Schueler, 1992). The County utilized its impervious cover GIS layer based on 2011 aerial photography to calculate the impervious percent cover within the drainage area of all assessed perennial reaches. Based on the guidance discussed above from CWP, each perennial reach was assigned a rating of “Sensitive,” “Impacted,” or “Non-supporting” related to its percent impervious cover. Approximately 91% and 84% of stream reaches, in West and Rhode River watersheds respectively, were rated as “Sensitive”; the only reaches rated as “Non-supporting” were in the Rhode River watershed (2%). A summary of impervious cover ratings is provided in Table 2.14. As described earlier, a map depicting impervious cover throughout the watersheds is presented in Map 1.10.

Table 2.14 - Impervious Cover Ratings

CWP Rating Category (% impervious cover)	West River Watershed		Rhode River Watershed	
	Number of Reaches	Percent of Reaches	Number of Reaches	Percent of Reaches
Sensitive (0-10%)	94	91%	198	84%
Impacted (10-19%)	8	8%	25	11%
Impacted (19-25%)	1	1%	10	4%
Non-supporting (>25%)	0	0%	4	2%
TOTAL	***103***	---	***237***	---

2.2.2 Urban Stormwater Best Management Practices

Urban stormwater BMPs are utilized throughout the County to intercept, detain, retain, and/or treat stormwater runoff before it reaches receiving water bodies. The installation of structural or nonstructural BMPs is required in all new development areas and in certain individual lot developments. The level of requisite stormwater management (e.g., recharge volume, water quality volume, channel protection volume, etc.) is dependent on development size, proximity to Critical Areas, and downstream conditions, among other considerations. Redevelopment sites also have stormwater management requirements, which can be met by actual reductions in impervious cover or effective reductions in impervious cover through BMP implementation, BMP upgrades, or other restoration activities (Anne Arundel County OPZ, 2006). In addition to stormwater management efforts triggered by development or redevelopment requirements, the County also regularly retrofits publicly-owned property with BMPs as part of its capital improvement program and its watershed management planning activities.

A spatially-accurate, GIS inventory dataset was developed for all existing public and private stormwater BMPs to help analyze the level of stormwater management within the study watersheds. This analysis is critical for identifying areas within the watersheds that are under-managed and for guiding future retrofit and BMP implementation efforts. The BMP inventory dataset contained accurate and up-to-date information on the locations, type, drainage area, and ownership of stormwater BMPs. BMPs located on federal land were excluded from the investigation. The effort to develop the dataset entailed compiling existing data from multiple County and State sources, narrowing the dataset to eliminate those BMPs outside of the study watersheds, confirming or updating the spatial locations of the remaining BMPs, removing duplicate records, and performing research to fill any data gaps. In order to properly account for load reductions associated with BMPs in the County's modeling efforts, drainage areas were delineated for all BMPs. Drainage area delineations were handled differently depending on the BMP structure type, the original data source, and the accuracy of the BMP's spatial location. A technical memorandum with a more detailed description of this work is presented in Appendix C.

BMPs in the West and Rhode River watersheds are grouped by the County into six major categories according to their primary mechanism of action. These categories include "Dry Detention," "Dry Extended Detention," "Filtration," "Infiltration," "Wet Structures," and "Other." A list of general BMP types that fall under each of these categories is included in Table 3.4 in Section 3. A total of 251 BMPs were confirmed within the West River watershed as part of the compilation and research process; these BMPs treat a total drainage area of approximately 69 acres. In the Rhode River watershed, a total of 298 BMPs were confirmed and collectively treat a drainage area of approximately 97 acres. A breakdown of BMP types and their drainage areas is presented in Table 2.15. A map of BMPs located throughout the watershed is presented as Map 2.10.

Approximately 3,924 acres or 14% of the area of the West and Rhode Watershed receives water quantity management (storage and attenuation of runoff) or water quality treatment (pollutant removal) through a BMP. Some of this area is receiving treatment by a series of BMPs because there is some overlap of BMP drainage areas. The BMP drainage areas range in size from 0.01 to 685.5 acres, with an average drainage area of 8.1 acres, and a median drainage area of 1 acre. This indicates that many of the BMPs are small in size.

Table 2.15 - Summary of BMPs by Type

Category	Quantity	Percent by Quantity	Total Managed Drainage Area (acres)	Percent by Drainage Area	Average Drainage Area (acres)	Minimum Drainage Area (acres)	Maximum Drainage Area (acres)
WEST RIVER WATERSHED							
Alternative Credits	57	22.7%	4.4	6.3%	0.1	0.0	0.7
Detention Dry	4	1.6%	4.8	6.9%	1.2	0.0	2.6
Environmental Site Design	132	52.6%	13.4	19.4%	0.1	0.0	1.7
Exempt	1	0.4%	0.1	0.1%	0.1	0.1	0.1
Extended Detention Dry	11	4.3%	11.1	16.0%	1.0	0.0	5.2
Filtration	6	2.4%	1.0	1.4%	0.2	0.1	0.4
Infiltration	26	10.4%	5.6	8.2%	0.2	0.0	2.2
Other	1	0.4%	0.1	0.1%	0.1	0.1	0.1
Stream Restoration	0	0.0%	0.0	0.0%	0.0	0.0	0.0
Wet Ponds	8	3.2%	27.0	39.0%	3.4	0.0	8.3
Wetlands	5	2.0%	1.8	2.6%	0.4	0.0	0.9
TOTAL	***251***	---	***69.3***	---	---	---	---
RHODE RIVER WATERSHED							
Alternative Credits	64	21.6%	5.6	5.8%	0.1	0.0	0.7
Detention Dry	1	0.3%	0.3	0.3%	0.3	0.3	0.3
Environmental Site Design	136	45.6%	14.8	15.4%	0.1	0.0	1.2
Exempt	0	0.0%	0.0	0.0%	0.0	0.0	0.0
Extended Detention Dry	9	3.0%	34.1	35.3%	3.8	0.1	22.0
Filtration	17	5.7%	3.9	4.0%	0.2	0.0	2.0
Infiltration	57	19.1%	9.8	10.1%	0.2	0.0	1.0
Other	5	1.7%	0.3	0.3%	0.1	0.0	0.2
Stream Restoration	1	0.3%	0.0	0.0%	0.0	0.0	0.0
Wet Ponds	5	1.7%	25.2	26.1%	5.0	0.0	10.0
Wetlands	3	1.0%	2.6	2.7%	0.9	0.1	2.0
TOTAL	***298***	---	***96.6***	---	---	---	---

The stormwater BMPs in the West and Rhode Watershed are typically owned by private land owners, the County, or other State agencies, such as the Maryland State Highway Administration. A breakdown of BMP types and ownership is presented in Table 2.16. The majority of the BMPs in the watershed (87%) are privately owned. Publicly owned BMPs comprise another 12% of the BMPs. However, when evaluated by the percent of the drainage area that they manage or treat in the watershed, private BMPs cover 55% and public BMPs cover 27% of the managed area. The Maryland State Highway Administration and other state agencies account for the remaining 18% of the managed land. Many of the privately owned BMPs are dry wells, small bioretention cells, and small environmental site design facilities (e.g. rain gardens) that serve to manage runoff from single rooftops or other impervious areas associated with residential properties.

Table 2.16 - Summary of BMPs by Owner

Ownership	Quantity	Percent by Quantity	Total Managed Drainage Area (acres)	Percent by Drainage Area	Average Drainage Area (acres)	Minimum Drainage Area (acres)	Maximum Drainage Area (acres)
Private	424	87%	2,157.8	55%	5.1	0.01	100.0
Public (DPW)	52	10%	1,024.4	26%	19.7	1.0	190.2
Public (non-DPW)	8	2%	20.7	1%	2.6	0.05	18.0
Unknown	2	1%	720.6	18%	360.3	35.2	685.5
TOTAL/ AVERAGE	**486**	**100%**	**3,923.6**	**100%**	**8.1**	**0.01**	**685.5**

2.2.3 Onsite Sewage Disposal Systems

OSDSs (i.e. septic systems) can contribute high levels of nutrients, particularly nitrogen and bacteria to downgradient water bodies via subsurface migration. This is especially true for older or poorly maintained OSDSs. In 2008, the County conducted a study to evaluate service options for properties with OSDSs and to develop a cost-effective approach to reducing pollutant loads from OSDSs (Anne Arundel County, 2008). As part of this study, the locations and basic characteristics of OSDSs throughout the County were identified. This information was used with data on per capita loading to quantify aggregate pollutant loads from OSDSs across the West and Rhode River watersheds.

The 2008 OSDS study noted that the West River watershed has approximately 351 OSDSs, which represents less than 1% of the OSDSs in the County, and contribute approximately 13,630 pounds of total nitrogen annually to streams within the watershed. In the case of the Rhode River watershed, there are 430 OSDSs (<1% of OSDSs in the County) which contribute approximately 12,457 pounds of nitrogen to streams in the watershed per year.

The study also identified the most cost-effective approaches to reducing nitrogen loads from OSDSs. Treatment alternatives examined included sewer extension to an existing water reclamation facility (both in areas of no public service and areas with an existing sewer system), clustering of community sewer service, OSDS upgrades with enhanced nitrogen removal, and no action. In the West River watershed, 27% of OSDSs are recommended for connection to a sewer extension, none are recommended for cluster treatment, and 71% are recommended for enhanced nitrogen removal upgrades at individual OSDS. The implementation of all treatment options would be expected to reduce total nitrogen from OSDSs by approximately 60% or 8,119 pounds per year. In the Rhode River watershed, 3% of OSDSs are recommended for connection to a sewer extension, 0.2% are recommended for cluster treatment, and 93% are recommended for enhanced nitrogen removal upgrades at individual OSDS. The implementation of all treatment options would be expected to reduce total nitrogen from OSDSs by approximately 51% or 6,330 pounds per year. A map of OSDS locations and the areas associated with treatment recommendations is presented in Map 2.11.

Table 2.17 - Total Annual Nitrogen Load Rating from OSDS

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Very Poor	4	31%	3	21%
Poor	2	15%	3	21%
Fair	3	23%	5	37%
Good	4	31%	3	21%
TOTAL	***13***	**---**	***14***	

Since nitrogen is generally the most mobile of the typical pollutants associated with OSDSs, it is used in the County's prioritization assessments as an indicator of septic system impacts to streams within the watershed. Subwatersheds are categorized as "Very Poor," "Poor," "Fair," or "Good" based on the natural breaks (a systematic method for classification) in the cumulative annual total nitrogen loading (in pounds) within the subwatersheds. A breakdown of ratings for total nitrogen loading from OSDSs for the West and Rhode Rive watersheds is presented in Table 2.17 and in Map 2.11.

Milestones for the reduction of total nitrogen from OSDSs in Anne Arundel County have been published in a Watershed Implementation Plan to comply with the Chesapeake Bay TMDL (Anne Arundel County, 2012b).

2.2.4 Soil Indicators

Native soils vary in their susceptibility to erosive forces. Clay soils, for instance, are less susceptible to erosion than are coarse sandy soils. The soil erodibility factor, K, is a measure of the susceptibility of soil to detachment and transport by precipitation and runoff. Soil erodibility factors for Anne Arundel County were obtained from NRCS datasets (NRCS, 2012). The County uses these soil erodibility factors to identify areas susceptible to soil erosion as part of its subwatershed preservation assessment.

Subwatersheds are prioritized "Low," "Medium," "Medium High," or "High" based on natural breaks in soil erodibility factor data across subwatersheds for each study watershed. A summary of subwatershed ratings for soil erodibility is presented in Table 2.18 and depicted in Map 2.12.

Table 2.18 - Subwatershed Ratings for Soil Erodibility

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Low	3	23%	1	7%
Medium	3	23%	3	21%
Medium High	3	23%	6	43%
High	4	31%	4	29%
TOTAL	***13***	**---**	***14***	**---**

2.2.5 Landscape Indicators

The County employs a variety of landscape-based indicators for restoration and preservation assessments. Percent impervious cover, percent forest within the 100-foot stream buffer, ratio of existing wetlands to potential wetlands, and acres of developable land within the Critical Area are used as indicators of the potential need for restoration activities. Percent forest cover, percent wetland cover, density of headwater streams, percent of land within the Greenway Master Plan, the presence of bog wetlands, acres of Resource Conservation Area (RCA) lands within Critical Area, percent of protected lands, and presence of Wellhead Protection Areas are used as indicators of the potential need for preservation.

GIS datasets were used by the County to quantify the extent of the landscape indicators within each subwatershed in the West and Rhode River watersheds. The GIS analyses related to impervious area, forest cover, bog wetland locations, Critical Areas, protected lands, land associated with the Greenway Master Plan, and density of headwater streams were performed using the County's existing geodatabase of land use and land features. The GIS analyses associated with wetland cover were performed using GIS datasets obtained from MDNR.

As with previous indicator categories, subwatersheds are prioritized "Very Poor," "Poor," "Fair," or "Good" for restoration, and "High", "Medium High", "Medium", and "Low" for preservation. These categories are based on natural breaks in the data. Summaries of these ratings for the West and Rhode River watersheds are presented in Table 2.19 and Table 2.20 and depicted on Maps 2.13, 2.14, and 2.15.

In the West River watershed, the majority of subwatersheds rated in the "Good" category for all of the landscape indicators for restoration. The only restoration landscape indicator where any subwatersheds were rated as "Very Poor" was in acres of developable land within the Critical Area. The landscape indicators for protection had varying subwatershed distributions, except for bog wetlands and wellhead protection areas, which were completely lacking in the West River watershed.

In the Rhode River watershed, the majority of subwatersheds rated as "Good" for the restoration landscape indicators of percent impervious cover and acres of developable land in the Critical Area; for percent forest within the 100-foot stream buffer and ratio of exiting to potential wetlands, the majority of subwatersheds rated as "Fair". The landscape indicators for protection had varying subwatershed distributions. One exception was for bog wetlands, of which there were none in the Rhode River watershed. Also a single subwatershed was rated as high for wellhead protection areas.

Table 2.19 - Landscape Indicator Ratings (Subwatershed Restoration)

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Percent Impervious Cover				
Good	9	69%	11	73%
Fair	3	23%	3	20%
Poor	1	8%	1	7%
Very Poor	0	0%	0	0%
Percent Forest within the 100-foot Stream Buffer				
Good	5	38%	5	33%
Fair	3	23%	7	47%
Poor	4	31%	1	7%
Very Poor	1	8%	2	13%
Ratio of Existing to Potential Wetlands				
Good	5	38%	3	20%
Fair	2	15%	7	47%
Poor	4	31%	3	20%
Very Poor	2	15%	2	13%
Acres of Developable Critical Area				
Good	5	38%	11	73%
Fair	4	31%	0	0%
Poor	1	8%	2	13%
Very Poor	3	23%	2	13%

Table 2.20 - Landscape Indicator Ratings (Subwatershed Preservation)

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Percent Forest Cover				
High	1	8%	3	20%
Medium High	5	38%	7	47%
Medium	5	38%	3	20%
Low	2	16%	2	13%
Percent Wetland Cover				
High	1	8%	2	13%
Medium High	5	38%	2	13%
Medium	2	16%	7	47%
Low	5	38%	4	27%
Density of Headwater Streams				
High	2	16%	2	13%
Medium High	3	23%	4	27%
Medium	3	23%	3	20%
Low	5	38%	6	40%
Percent of Land within the Greenway Master Plan				
High	3	23%	2	13%
Medium High	1	8%	3	20%
Medium	5	38%	4	27%
Low	4	31%	6	40%
Presence of Bog Wetlands				
High	0	0%	0	0%
Low	13	100%	15	100%
Acres of RCA lands with the Critical Area				
High	1	8%	3	20%
Medium High	5	38%	4	27%
Medium	4	31%	2	13%
Low	3	23%	6	40%
Percent of Protected Lands				
High	2	15%	3	20%
Medium High	6	46%	3	20%
Medium	1	8%	3	20%
Low	4	31%	6	40%
Presence of Wellhead Protection Areas				
High	0	0%	1	7%
Low	13	100%	14	93%

3. HYDROLOGIC AND POLLUTANT LOAD MODELING

The data collection efforts described in Section 2 provide a solid basis for assessing the current status of the West and Rhode watersheds and identifying potential stressors that may contribute to observed impairments. Modeling, the computer simulation of natural processes, serves to extend the utility of the collected data by allowing extrapolation from existing conditions to alternative future conditions (scenarios) that reflect differing assumptions about the course of land development and the implementation of pollutant controls.

Land development is typically associated with increased imperviousness and decreased capacity for managing precipitation. As watersheds become more developed, runoff volumes and peak flow rates increase and stream base flows decrease. This often results in destabilized streams, increased pollutant loading, and adverse impacts to physical habitat. Nutrients and suspended solids are two of the leading causes of water quality impairment in sensitive water bodies, including the Chesapeake Bay and its tributaries. Nutrients, such as nitrogen and phosphorus, can cause excessive algae growth and eutrophication. Suspended solids can limit growth of aquatic vegetation and destroy physical habitat.

The County's hydrologic and pollutant load modeling provides quantification of watershed processes and allows for the comparison of different scenarios used to prioritize restoration and mitigation projects. The County performed hydrologic and pollutant load modeling to help assess existing conditions as well as future development and pollutant control scenarios within the West River and Rhode River watersheds. The results were used to understand the extent of potential water quality improvements necessary for satisfying MS4 permit and TMDL requirements.

This section presents and discusses the methods and inputs used in the hydrologic and water quality modeling of current and future build-out conditions (Section 3.1) and the results of that modeling (Section 3.2). Discussions of future scenario modeling to support development of the implementation plan for the study watershed are presented in Section 5.

3.1 METHODS

This subsection describes two types of modeling performed in the watershed characterization to help evaluate and prioritize areas and projects for action. Hydrologic modeling, which involves simulation of the runoff and conveyance of rain falling on the watershed, was done to improve understanding of reach and subwatershed sensitivity to erosion and to development. Pollutant load modeling of current conditions, which entails the simulation of the generation, transport, and delivery of solids, nutrients, and pathogens, provides the basis for assessment of current and future condition pollutant loading. Model results enable comparison and prioritization of restoration strategies and projects as discussed in Section 5. The methods and inputs for each model are discussed below.

3.1.1 Hydrologic Modeling

Hydrologic modeling is used to represent rainfall-induced runoff conditions and the conveyance of streamflow in the watershed. The County applies the NRCS TR-20 for hydrologic modeling. This NRCS model is a single event watershed scale runoff and routing model that was used to evaluate runoff volumes and peak flow for various return period storm events. Model inputs include rainfall, curve numbers, and time of concentration. Table 3.1 presents the 24-hour rainfall depths and recurrence intervals for Anne Arundel County. Area-weighted curve numbers, which represent the runoff response to a rain event, are derived from soil types and land cover. Table 3.2 presents the base curve numbers that the County uses to develop the weighted curve numbers.

Time of concentration is the time required for runoff to travel from the hydraulically most distant point in the watershed to the most downstream point or outlet. The County uses a modified version of the NRCS lag equation as a means of calculating the travel time for each subwatershed. The NRCS lag equation relates time of concentration to flow length, average slope, and curve number (NRCS 2010). Since this equation was developed for rural watersheds, the County also applies an urban correction factor (Impervious Area Factor), to account for the more urban nature of the study watersheds (US DOT 1984). The Impervious Area Factor accounts for higher amounts of impervious area that accelerate the rate of overland flow in the watershed.

The TR-20 model results, presented as peak flow rate normalized to area (cfs/acre) and surface runoff yield (inches), are used to evaluate the likely sensitivity of the West and Rhode watersheds to gullying and stream erosion. Areas with higher normalized peak flow rates and/or surface runoff yields are more likely to suffer from erosion in-stream or on the land surface, and therefore could be prioritized higher for restoration versus areas with lower normalized peak flow rates or surface runoff yields. Higher rates and yields are often expected in urbanized areas with more extensive impervious surface area.

Table 3.1 - Rain Frequency

Event Frequency	Rain (in)
1 year	2.7
2 year	3.3
10 year	5.2
100 year	7.4

Table 3.2 - Runoff Curve Numbers for Urban Areas

Land Cover Type and Condition	Hydrologic Soil Group			
	A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%)	Not Used			
Fair condition (grass cover 50% to 75%)	Not Used			
Good condition (grass cover > 75%)	39	61	74	80
Paved parking lots, roofs, driveways, etc.(excluding right-of-way)	98	98	98	98
Streets and roads:				
Paved; curbs and storm drains (excluding right-of-way)	98	98	98	98
Paved; open ditches (including right-of-way)	Not Used			
Gravel (including right-of-way)	Not Used			
Dirt (including right-of-way)	Not Used			
Urban districts:				
Commercial and business	89	92	94	95
Industrial	81	88	91	93
Residential districts by average lot size:				
1/8 acre or less (town houses)	77	85	90	92
1/4 acre	61	75	83	87
1/3 acre	57	72	81	86
1/2 acre	54	70	80	85
1 acre	51	68	79	84
2 acres	46	65	77	82
Newly graded areas (pervious areas only, no vegetation)	77	86	91	94

3.1.2 Water Quality Modeling

Water quality modeling is used to represent the generation of pollutant loads and their potential control by BMPs. The County's water quality model for the West and Rhode watersheds is based on EPA's Simple Method (Schueler, 1987) and PLOAD models (EPA, 2001). The water quality model calculates annual loadings for total nitrogen, total phosphorus, total suspended solids, fecal coliforms, and metals from stormwater under pristine, current, and ultimate build-out or future conditions. Given the focus of the Chesapeake Bay TMDL, only total nitrogen, total phosphorus, and total suspended solids are discussed in this report. The water quality model is also used to tabulate annual load reductions or credits that are achieved with existing BMPs in the ground within the watershed.

The model's basic elements are polygons determined in GIS by the geometric intersection of the County's 2007 land use dataset, land ownership, impervious cover, and subwatershed boundaries. The polygon GIS attribute information is imported into the County's spreadsheet model to perform the loading calculations. The Simple Method calculates annual runoff as a product of annual rainfall (42.9 inches in Anne Arundel County), the fraction of annual rainfall events that produce runoff (assumed to be 90%), and a runoff coefficient based on the impervious fraction in the drainage area. In one modification to the Simple Method, the County's model uses an actual impervious cover delineation to explicitly represent impervious surface runoff instead of the standard impervious rating approach. The pollutant loads are the product of the annual runoff, the drainage area, and the event mean concentrations (EMCs) for each land use category. A delivery ratio is further applied to the loading estimates depending on its proximity to non-tidal and tidal waters. For the study watershed, the delivery ratio is assumed to be equal to one.

A summary of EMC values and associated land use types are presented in Table 3.3 below. These EMC values have been compiled from a number of literature sources or calculated directly from export coefficients used by the Chesapeake Bay Program (CBP). Individually, the County's EMC values are conservatively set to be equal to or greater than the values used by the CBP.

Table 3.3 - Water Quality Modeling Event Mean Concentrations

TMDL Source Sector	Land Use Code	Land Use Name	Average Impervious Percent	TN (mg/L)	TP (mg/L)	TSS (mg/L)
Urban	AIR	Airport	85	2.24	0.30	99
	COM	Commercial	85	2.24	0.30	43
	IND	Industrial	72	2.22	0.19	77
	OPS	Open Space	1	1.15	0.15	34
	R11	Residential - 1 acre lot	13	2.74	0.32	43
	R12	Residential - 1/2 acre lot	18	2.74	0.32	43
	R14	Residential - 1/4 acre lot	20	2.74	0.32	43
	R18	Residential - 1/8 acre lot	34	2.74	0.32	43
	R21	Residential - 2 acre lot	13	2.74	0.32	43
	R20	Residential - 20 acre lot	2	2.20	0.15	51
	RWD	Residential Woods	6	2.00	0.19	51
	TRN	Transportation	75	2.59	0.43	99
	UTL	Utility	75	1.15	0.15	34
Agriculture	PAS	Pasture and Hay	0	7.83	2.09	341
	SRC	Single Row Crop	1	16.06	2.63	1,046

Table 3.3 - Water Quality Modeling Event Mean Concentrations

TMDL Source Sector	Land Use Code	Land Use Name	Average Impervious Percent	TN (mg/L)	TP (mg/L)	TSS (mg/L)
Other	FRW	Forested Wetland	0	1.00	0.11	34
	OPW	Open Wetland	0	1.00	0.11	34
	WAT	Water	0	1.20	0.03	43
	WDS	Woods	0	1.00	0.11	34

To account for pollutant removal associated with existing BMPs or those implemented in the future, the County utilizes pollutant removal efficiencies. These efficiencies are largely derived from MDE's guidance document *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated* (MDE 2014) and conservatively set to be equal to or less than the values used by the CBP. A summary of the BMP pollutant removal efficiencies used by the County are provided in Table 3.4. To facilitate assignment of a pollutant removal efficiency to each BMP type, the County has organized its BMP types into nine BMP category "groups".

Table 3.4 – Water Quality Modeling BMP Pollutant Removal Efficiencies

BMP Category Group	County BMP Code	MDE Code	BMP Name	Percent Removal		
				TN	TP	TSS
Filtration	O-1	ODSW	Dry Swale	33%	52%	66%
	O-2	OWSW	Wet Swale	33%	52%	66%
	ASCD		Attenuation Swale/Check Dam	33%	52%	66%
	F-1	FSND	Surface sand filter	33%	52%	66%
	F-2	FUND	Underground sand filter	33%	52%	66%
	F-3	FPER	Perimeter sand filter	33%	52%	66%
	F-4	FORG	Organic filter	33%	52%	66%
	F-5		Pocket Sand Filter	33%	52%	66%
	F-6	FBIO	Bioretention Facility	33%	52%	66%
	SF	FSND	Sand Filter	33%	52%	66%
	ATTENSWA		Attenuation Swale	33%	52%	66%
	AS		Attenuation Swale	33%	52%	66%
	POSAND		Pocket Sand Filter	33%	52%	66%
	VB		Vegetated Buffer	33%	52%	66%
	BIO	FBIO	Bioretention Facility	33%	52%	66%
	SPSC	SPSC	Regenerative Step Pool Storm Conveyance	33%	52%	66%
	GBMP	FBIO	Bioretention Facility	33%	52%	66%

Table 3.4 – Water Quality Modeling BMP Pollutant Removal Efficiencies

BMP Category Group	County BMP Code	MDE Code	BMP Name	Percent Removal		
				TN	TP	TSS
Infiltration	ATTTRENCH		Attenuation Trench	57%	66%	70%
	DW	MIDW	Dry Well	57%	66%	70%
	DWIT		Dry Well - Infiltration Trench	57%	66%	70%
	DWITCE		Dry Well - Infiltration Trench with Complete Exfiltration	57%	66%	70%
	DWITCE-2		Dry Well - Infiltration Trench with Complete Exfiltration	57%	66%	70%
	C-2/drywells	MIDW	Dry Well	57%	66%	70%
	DWITCW		Dry Well - Infiltration Trench with Complete Exfiltration	57%	66%	70%
	DWITPE		Dry Well - Infiltration Trench with Partial Exfiltration	57%	66%	70%
	DWITWQE		Dry Well - Infiltration Trench with Water Quality Exfiltration	57%	66%	70%
	EDSDITCE		Extended Detention Structure Dry, Infiltration Trench with Complete Exfiltration	57%	66%	70%
	IB	IBAS	Infiltration Basin	57%	66%	70%
	IITCE		Infiltration Trench with Complete Exfiltration	57%	66%	70%
	INPOND		Infiltration Basin No Outfall	57%	66%	70%
	IT	ITRN	Infiltration Trench	57%	66%	70%
	ITVSW		Infiltration Trench, Extended Detention	57%	66%	70%
	ITCE		Infiltration Trench with Complete Exfiltration	57%	66%	70%
	ITCEMB		Infiltration Trench with Complete Exfiltration, Microbasin	57%	66%	70%
	ITPE		Infiltration Trench with Partial Exfiltration	57%	66%	70%
	ITWQE		Infiltration Trench with Water Quality Exfiltration	57%	66%	70%
	OGSITCE		Oil Grit Separator Infiltration Trench with Complete Exfiltration	57%	66%	70%
	PNDTR		Same as infiltration basin	57%	66%	70%
	PP	APRP	Porous Pavement	57%	66%	70%
	SB	IBAS	Infiltration Basin	57%	66%	70%
	WQITPE		Water Quality Infiltration Trench with Partial Exfiltration	57%	66%	70%

Table 3.4 – Water Quality Modeling BMP Pollutant Removal Efficiencies

BMP Category Group	County BMP Code	MDE Code	BMP Name	Percent Removal TN	Percent Removal TP	Percent Removal TSS
	WQP		Water Quality Trench	57%	66%	70%
Wet Ponds	EDSW	PWED	Extended Detention Structure Wet	33%	52%	66%
	MP	PMED	Micro Pool	33%	52%	66%
	P-3	PWED	Extended Detention Structure Wet	33%	52%	66%
	EXPOND	PWET	Wet Pond	33%	52%	66%
	P-2	PWET	Wet Pond	33%	52%	66%
	SW		Wet Structure	33%	52%	66%
	P-1	PMED	Micro Pool	33%	52%	66%
	WP	PWET	Retention Structure (Wet Pond)	33%	52%	66%
	P-4	PMPS	Multiple pond system	33%	52%	66%
	P-5	PPKT	Pocket pond	33%	52%	66%
Wetlands	SM	WSHW	Shallow Marsh	33%	52%	66%
	W-1		Shallow Wetland	33%	52%	66%
	RSC		Regenerative Wetland Seepage	33%	52%	66%
	W-2		ED shallow wetland	33%	52%	66%
	W-3		pond/wetland system	33%	52%	66%
	W-4	WPKT	pocket wetland	33%	52%	66%
Stream Restoration	Stream Conventional		In-stream Riffles/Stabilization	NA	NA	NA
ESD or Stormwater to the MEP	A1	AGRE	Green Roofs	57%	66%	70%
	A2	APRP	Permeable Pavement	57%	66%	70%
	A3	ARTF	Reinforced Turf	57%	66%	70%
	C2	NDRR	ESD rooftop disconnect	57%	66%	70%
	C2/ Raingardens	MRNG	ESD rain gardens	57%	66%	70%
	C3	NDNR	ESD non roof top disconnect	57%	66%	70%
	C4	NSCA	Sheetflow to Conservation Areas	57%	66%	70%
	N1	NDRR	Disconnection of Roof-top	57%	66%	70%
	N2	NDNR	Disconnection of Non Roof-top	57%	66%	70%
	N3	NSCA	Sheetflow to Conservation Areas	57%	66%	70%
	M1	MRWH	Rainwater Harvesting	57%	66%	70%
	M2	MSGW	Submerged Gravel Wetlands	57%	66%	70%
	M3	MILS	Landscape Infiltration	57%	66%	70%
	M4	MIBR	Infiltration Berms	57%	66%	70%
	M5	MIDW	Dry Wells	57%	66%	70%

Table 3.4 – Water Quality Modeling BMP Pollutant Removal Efficiencies

BMP Category Group	County BMP Code	MDE Code	BMP Name	Percent Removal		
				TN	TP	TSS
ESD or Stormwater to the MEP	M6	MMBR	Micro-Bioretention	57%	66%	70%
	M7	MRNG	Rain Gardens	57%	66%	70%
	M8	MSWB	Swales	57%	66%	70%
	M9	MENF	Enhanced Filters	57%	66%	70%
Alternative Credits	Street Sweeping		Regenerative Vacuum Street Sweeping	5%	6%	25%
	Planting pervious		Forestation on pervious urban	66%	77%	57%
	Impervious to Pervious		Impervious Area Elimination and conversion to pervious	13%	72%	84%
	Impervious to Forest		Impervious Area Elimination and conversion to forest	71%	94%	93%

With the exception of stream restoration, pollutant removal efficiencies are reported in Table 3.4 for BMPs as percent of a constituent removed. For stream restoration, pollutant removal is determined on the basis of linear foot of stream restored. These efficiencies, which were recently adopted by the CBP (Schueler and Stack, 2014), are as follows:

- Total nitrogen – 0.2 lb per linear foot
- Total phosphorus – 0.068 lb per linear foot
- Total suspended solids – 310 lb per linear foot

As previously discussed, the County's water quality model is applied to various scenarios that represent real and hypothetical watershed conditions. A summary of the modeled scenarios is presented in Table 3.5.

Table 3.5 - Modeled Water Quality Scenarios

Modeled Scenario	Purpose
A. Pristine Conditions	Baseline, all-forested condition representing pre-development state
B. Existing Conditions with no SWM	Current land use without accounting for any existing BMPs or disconnected impervious surfaces
C. Credits from existing SWM	Credits based on performance of public and private BMPs and disconnected impervious surfaces
D. Existing Conditions with SWM	Current land use accounting for existing BMPs and disconnected impervious surfaces

Table 3.5 - Modeled Water Quality Scenarios

Modeled Scenario	Purpose
E. Future Conditions with Stormwater to the MEP	Expected future land use with development informed by future stormwater regulations and stormwater management retrofits to the MEP

Pristine or pre-development conditions (Scenario A) were modeled for contextual purposes only and assumed that the watershed was entirely forested prior to development. Existing conditions (Scenario B) were based on high resolution 2007 land cover and impervious surface data collected by the County. Existing condition pollutant loads do not account for existing stormwater management (SWM) (i.e., BMPs in the ground or disconnected impervious surfaces).

Existing stormwater management credit modeling (Scenario C) calculates pollutant load reductions for existing stormwater BMPs and disconnection credits. This scenario incorporates into the model all existing publicly and privately owned BMPs, all restoration projects performed as part of the County's Capital Improvement Program (CIP), and all disconnected impervious surfaces (including a subset of rooftops and open section roads with swales). This calculation relies on delineated drainage areas for each BMP or credit and the pollutant removal efficiency. As described in Section 2.2.2, the drainage areas for each BMP were delineated from the County's DEM. Drainage areas for disconnection credits were obtained from the appropriate land cover polygon (i.e., rooftops or road segment). For each polygon representing a BMP or disconnection credit, the resulting baseline pollutant load reduction was calculated using pollutant removal efficiencies summarized in Table 3.4.

In a number of cases, drainage areas from individual BMPs were found to partially or wholly overlap. In reality, it is not unusual for BMPs to treat stormwater pollutants in series (e.g., as part of a treatment train). Nonetheless, in these cases, the County used a conservative accounting approach to avoid double counting of credits. In those areas with overlapping drainage areas, best professional judgment was used to determine which BMP was predominantly managing a particular intersected drainage area. Overlapping drainage area segments were assigned to the closest BMP with the assumption that the closer a segment was to a particular BMP, the more likely the area was to be treated by that facility. The drainage area polygon was then assigned to the predominant BMP. This was performed to ensure that only a single BMP managed a particular area and that the appropriate BMP was receiving the management credit.

Existing conditions with BMP credit accounting (Scenario D) represents actual existing watershed conditions. It combines the results of Scenario B existing conditions modeling and the Scenario C BMP credits for existing BMPs and disconnected impervious surfaces.

The future conditions modeling (Scenario E) relies on realistic estimates of future development. Future watershed conditions were determined in two steps. First, areas in the watershed were identified where future development is legally constrained or not physically possible. These areas, which are shown on Map 3.2, include:

- steep slopes (greater than 25%) derived from the DEM,
- Federal Emergency Management Agency (FEMA) 100-year floodplains,
- jurisdictional wetlands,
- 100-foot regulatory stream buffers,
- schools and parks,
- cemetery lots,
- DNR protected lands, including Maryland Environmental Trust Lands, and
- utility and storm water management easements.

Second, outside of these areas where development is not possible, existing land use was examined to determine where future development or re-development could occur and what form it would likely take. This analysis was informed by a holding capacity or development capacity study conducted by the County's Office of Planning and Zoning. For those areas where future land use is anticipated to change from the existing condition land use, the County estimated a future impervious cover percentage based on the average impervious values presented in Table 3.3. Future development is subject to the Maryland stormwater regulations discussed in Section 1.2.2, where ESD is to be implemented to the maximum extent practicable. As such, for both future development and redevelopment, the calculated pollutant loads were reduced by the pollutant removal efficiency associated with ESD practices (see Table 3.4). MDE refers to stormwater management retrofits using ESD practices as Stormwater to the MEP. For areas where new development is expected to occur, 100% of the new impervious area was assumed to be managed by Stormwater to the MEP. For those areas where redevelopment is expected to occur, 50% of the existing impervious area and 100% of new impervious area is managed with Stormwater to the MEP.

3.2 MODELING RESULTS

This subsection presents and discusses results from application of the hydrological and water quality models to the West and Rhode watersheds.

3.2.1 Hydrologic Modeling

The hydrologic model results are primarily utilized in the subwatershed assessments discussed in Section 4. In these assessments, four hydrologic indicators are evaluated for each subwatershed:

- Area-normalized peak flow (cfs/acre) for a 2.7" (one-year storm)
- Area-normalized peak flow (cfs/acre) for a 3.3" (two-year storm)

- Surface runoff yield (inches) for a 2.7” (one-year storm)
- Surface runoff yield (inches) for a 3.3” (two-year storm)

The one-year and two-year events were selected because bankfull conditions for streamflow, which are generally considered to be the most critical condition for delivery of sediment and associated pollutants, typically occur about once every one to two years in the Chesapeake Bay region. The results of the hydrologic model run for the 1, 2, 10, and 100-year storm events are presented below in Table 3.6.

Table 3.6 - Hydrologic Model Results

Subwatershed		1 year	2 year	10 year	100 year
WEST RIVER WATERSHED					
WR0	Runoff Yield (in)	0.78	1.15	2.49	5.60
	Peak Discharge (cfs)	38	59	134	310
WR1	Runoff Yield (in)	0.61	0.94	2.17	5.08
	Peak Discharge (cfs)	63	103	255	632
WR2	Runoff Yield (in)	0.56	0.87	2.07	5.05
	Peak Discharge (cfs)	65	110	290	735
WR3	Runoff Yield (in)	0.83	1.21	2.56	5.61
	Peak Discharge (cfs)	105	159	354	806
WR4	Runoff Yield (in)	0.57	0.89	2.10	5.10
	Peak Discharge (cfs)	62	105	273	686
WR5	Runoff Yield (in)	0.63	0.96	2.19	5.13
	Peak Discharge (cfs)	61	98	241	593
WR6	Runoff Yield (in)	0.38	0.63	1.64	4.13
	Peak Discharge (cfs)	49	86	240	662
WR7	Runoff Yield (in)	0.81	1.19	2.54	5.73
	Peak Discharge (cfs)	155	239	537	1224
WR8	Runoff Yield (in)	1.07	1.49	2.91	5.98
	Peak Discharge (cfs)	95	136	277	588
WR9	Runoff Yield (in)	0.71	1.04	2.21	4.72
	Peak Discharge (cfs)	52	79	181	423
WRA	Runoff Yield (in)	0.99	1.40	2.84	6.02
	Peak Discharge (cfs)	69	101	294	456
WRB	Runoff Yield (in)	0.42	0.69	1.76	4.41
	Peak Discharge (cfs)	28	48	133	360
WRC	Runoff Yield (in)	0.23	0.44	1.32	3.82
	Peak Discharge (cfs)	10	21	73	233
RHODE RIVER WATERSHED					
RR0	Runoff Yield (in)	0.38	0.64	1.69	4.46
	Peak Discharge (cfs)	27	52	162	460

Table 3.6 - Hydrologic Model Results

Subwatershed		1 year	2 year	10 year	100 year
RR1	Runoff Yield (in)	0.65	0.99	2.25	5.30
	Peak Discharge (cfs)	151	245	604	1470
RR2	Runoff Yield (in)	0.35	0.59	1.60	4.31
	Peak Discharge (cfs)	37	71	222	645
RR3	Runoff Yield (in)	0.37	0.63	1.66	4.34
	Peak Discharge (cfs)	29	53	156	441
RR4	Runoff Yield (in)	0.71	1.07	2.37	5.49
	Peak Discharge (cfs)	58	92	219	518
RR5	Runoff Yield (in)	0.28	0.48	1.31	3.25
	Peak Discharge (cfs)	34	59	168	470
RR6	Runoff Yield (in)	0.93	1.33	2.75	5.98
	Peak Discharge (cfs)	133	197	422	925
RR7	Runoff Yield (in)	0.30	0.53	1.48	3.94
	Peak Discharge (cfs)	20	36	111	323
RR8	Runoff Yield (in)	0.33	0.56	1.52	3.97
	Peak Discharge (cfs)	37	66	195	554
RR9	Runoff Yield (in)	0.32	0.55	1.48	3.74
	Peak Discharge (cfs)	43	75	215	600
RRB	Runoff Yield (in)	0.94	1.34	2.75	5.89
	Peak Discharge (cfs)	93	138	295	649
RRC	Runoff Yield (in)	0.00	0.34	1.14	3.52
	Peak Discharge (cfs)	0	1	6	23
RRD	Runoff Yield (in)	0.00	0.00	2.65	5.89
	Peak Discharge (cfs)	0	0	1	2
RRE	Runoff Yield (in)	0.51	0.81	1.96	4.89
	Peak Discharge (cfs)	35	61	168	439
RRF	Runoff Yield (in)	0	0.83	1.92	4.50
	Peak Discharge (cfs)	0	1	2	6

Subwatersheds were prioritized and rated “High,” “Medium High,” “Medium,” or “Low” based on the natural breaks for each of the four hydrologic indicators. A summary of these ratings for the West and Rhode subwatersheds is presented in Table 3.7. For the majority of the subwatersheds in the Rhode River watershed, the one-year peak flow scores were identical to the two-year peak flow scores, and also the one-year yield scores were similar to the two-year yield scores. The scores for the West River subwatersheds were less consistent. As shown in Map 3.1, most of the subwatersheds have a similar distribution of low, medium high, and medium area-normalized event peak flow values that translate to lower priorities. Approximately 69% of the subwatersheds within the West watershed and 73% of the subwatersheds within the Rhode River watershed are rated "Low" or "Medium" for the two peak flow indicators. The hydrologic indicator ratings for surface runoff yield were more evenly distributed among the rating categories for the Rhode River Watershed. In the Rhode River Watershed, approximately 53% of the subwatersheds were rated "Low" or "Medium" for the runoff indicator for both evaluated storm events. In contrast, 33% of the subwatersheds in West River Watershed are rated "Low" or "Medium" for the surface runoff yield indicators.

Table 3.7 - Hydrologic Indicator Ratings

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Peak Flow (one-year storm)				
High	3	23.1%	3	20.0%
Medium High	2	15.4%	6	40.0%
Medium	5	38.4%	5	33.3%
Low	3	23.1%	1	6.7%
Peak Flow (two-year storm)				
High	4	30.8%	7	46.7%
Medium High	5	38.4%	4	26.7%
Medium	2	15.4%	3	20.0%
Low	2	15.4%	1	6.7%
Surface Runoff Yield (one-year storm)				
High	2	15.4%	3	20.0%
Medium High	4	30.8%	7	46.7%
Medium	4	30.8%	3	20.0%
Low	3	23.1%	2	13.3%
Surface Runoff Yield (two-year storm)				
High	2	15.4%	1	6.7%
Medium High	5	38.4%	8	53.3%
Medium	3	23.1%	4	26.7%
Low	3	23.1%	2	13.3%

3.2.2 Water Quality Modeling Results

Existing condition water quality modeling results are summarized at the watershed scale in Table 3.9. Additional water quality modeling results are summarized at the subwatershed scale in Table 3.10. These tables show the model-predicted annual loadings of total phosphorus, total nitrogen, and total suspended solids for pristine, current, and future scenarios and for the existing conditions credits. Except where noted, these results are presented for all County jurisdictional lands that fall under the urban stormwater (or urban

NPS) sector. Pollutant loading results for existing conditions and future conditions are also depicted in Map 3.3 and Map 3.4, respectively.

Table 3.8 - Annual Loads for Various Scenarios

Scenario	Total Nitrogen (lb/yr)	Total Phosphorus (lb/yr)	Total Suspended Solids (tons/yr)
WEST WATERSHED			
A. Pristine Conditions	3,193	351	54
B. Existing with no SWM Credits	23,087	3,410	434
C. Credits from Existing SWM	184	42	5
D. Existing with SWM Credits	22,904	3,368	430
E. Future with Stormwater to the MEP	20,429	2,881	337
RHODE WATERSHED			
A. Pristine Conditions	3,835	422	65
B. Existing with no SWM Credits	20,723	2,891	328
C. Credits from Existing SWM	181	26	3
D. Existing with SWM Credits	20,541	2,865	325
E. Future with Stormwater to the MEP	19,445	2,643	283

Table 3.9 - Annual Loads at Subwatershed Level for Modeled Scenarios

Shed Code	SCENARIO A			SCENARIO B						SCENARIO C			SCENARIO D			SCENARIO E		
	Pristine Condition Loads			Existing Condition Load without existing SWM credit (All lands)			Existing Condition Load without existing SWM credit (County Urban NPS)			SWM Credits (County Urban NPS)			Existing Condition Load with existing SWM credit (County Urban NPS)			Future Condition Load with Existing SWM Credits (County Urban NPS)		
	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)
WEST RIVER WATERSHED																		
WR0	84	9	1	691	84	7	691	84	7	8	1	0	683	83	6	692	84	6
WR1	301	33	5	2,661	418	69	2,604	409	68	1	0	0	2,603	409	68	1,489	213	28
WR2	194	21	3	996	189	23	996	189	23	1	0	0	995	188	23	996	189	23
WR3	307	34	5	2,654	413	51	2,585	401	49	57	19	2	2,528	382	47	2,259	335	37
WR4	139	15	2	983	148	26	983	148	26	1	0	0	982	148	26	990	149	26
WR5	275	30	5	2,113	323	41	1,917	291	37	12	2	0	1,905	289	37	1,750	253	32
WR6	601	66	10	3,784	614	88	3,649	592	86	10	1	0	3,638	590	86	3,125	460	66
WR7	190	21	3	1,903	272	32	1,853	265	31	11	2	0	1,842	264	31	1849	264	31
WR8	227	25	4	2,644	328	28	2,570	316	27	10	2	0	2,560	341	26	2,504	305	25
WR9	327	36	6	2,229	282	29	2,159	271	28	51	12	1	2,108	358	26	2,031	245	23
WRA	117	13	2	1,249	158	12	1,249	158	12	13	2	0	1,235	156	12	1,231	155	12
WRB	268	30	5	1,373	224	31	1,330	216	30	6	1	0	1,324	216	30	1,191	192	25
WRC	163	18	3	502	71	12	502	71	12	1	0	0	500	71	12	322	39	5
Total	**3,193**	**351**	**54**	**23,784**	**3,523**	**447**	**23,087**	**3,410**	**434**	**184**	**42**	**5**	**22,904**	**3,368**	**430**	**20,429**	**2,881**	**337**
RHODE RIVER WATERSHED																		
RR0	121	13	2	408	70	7	408	70	7	0	0	0	408	70	7	408	70	7
RR1	385	42	7	4,041	496	39	3,843	464	35	95	14	2	3,748	450	34	3,688	438	32
RR2	307	34	5	1,403	232	31	1,392	230	31	0	0	0	1,392	230	31	1,181	194	24
RR3	293	32	5	1,431	216	36	1,341	201	34	0	0	0	1,341	201	34	1,331	200	34
RR4	101	11	2	917	108	8	917	108	8	12	2	0	905	106	8	879	102	7
RR5	651	72	11	3,059	435	61	2948	416	59	3	0	0	2,945	416	59	2,769	382	52
RR6	156	17	3	2,026	244	18	1950	232	16	43	6	1	1,907	226	16	1,890	222	15
RR7	303	33	5	1,205	162	15	1120	147	14	1	0	0	1,119	147	14	1,129	147	13
RR8	537	59	9	2,032	270	30	1856	242	27	16	2	0	1,840	239	27	1,816	232	25
RR9	674	74	11	3,425	571	77	3258	544	74	2	0	0	3,256	543	74	2,669	421	53
RRB	190	21	3	1,182	138	11	1172	137	11	7	1	0	1,165	136	11	1,173	136	11
RRC	5	1	0	6	1	0	6	1	0	0	0	0	6	1	0	6	1	0
RRD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.9 - Annual Loads at Subwatershed Level for Modeled Scenarios

Shed Code	SCENARIO A Pristine Condition Loads			SCENARIO B Existing Condition Load without existing SWM credit (All lands)			Existing Condition Load without existing SWM credit (County Urban NPS)			SCENARIO C SWM Credits (County Urban NPS)			SCENARIO D Existing Condition Load with existing SWM credit (County Urban NPS)			SCENARIO E Future Condition Load with Existing SWM Credits (County Urban NPS)		
	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)	TP (lbs/yr)	TSS (tons/yr)
RRE	**113**	12	2	511	100	11	511	100	11	3	0	0	507	100	11	508	100	11
RRF	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**3,835**	**422**	**65**	**21,646**	**3,040**	**345**	**20,723**	**2,891**	**328**	**181**	**26**	**3**	**20,541**	**2,865**	**325**	**19,445**	**2,643**	**283**

Pollutant loading was considered in the assessments of both subwatershed restoration and subwatershed preservation that are discussed in more detail in Section 4. For the subwatershed restoration assessment, the County evaluated two water quality indicators based on existing conditions: total nitrogen load from runoff (lbs/acre/yr) and total phosphorus load from runoff (lbs/acre/yr). For the subwatershed preservation assessment, the County evaluated water quality indicators based on the percent future departure of loading conditions for total nitrogen and total phosphorus in terms of pounds per acre per year.

Subwatersheds were prioritized and rated “High,” “Medium High,” “Medium,” or “Low” for each of the water quality indicators related to the subwatershed restoration analysis. A summary of these ratings for West and Rhode watersheds is presented in Table 3.11. A visual representation of the existing condition pollutant loads within the study subwatersheds is depicted in Map 3.3. In the West River watershed, subwatersheds were fairly evenly distributed (ranging from 15% to 31%) between all four ratings when evaluating total nitrogen, while approximately 77% of the subwatersheds were rated “High” or “Medium High” in the total phosphorous evaluation. In the Rhode River watershed, nearly 50% of the watersheds were rated “Low” or “Medium” for both total nitrogen and total phosphorus loading.

Table 3.10 - Water Quality Indicator Ratings (Subwatershed Restoration)

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Total Nitrogen Load from Runoff				
High	3	23.1%	3	20.0%
Medium High	4	30.8%	6	40.0%
Medium	4	30.8%	3	20.0%
Low	2	15.4%	3	20.0%
Total Phosphorus Load from Runoff				
High	5	38.5%	2	13.3%
Medium High	5	38.5%	6	40.0%
Medium	1	7.7%	4	26.7%
Low	2	15.4%	3	20.0%

For the subwatershed preservation assessment, subwatersheds are rated and prioritized “High,” “Medium High,” “Medium,” or “Low” based on their relative need for preservation. A summary of these ratings for the West and Rhode watersheds is presented in Table 3.12, and is shown visually on Map 3.5. In both the West and Rhode watersheds, the vast majority of subwatersheds (77% and 93%, respectively) were rated as "High" in both the total nitrogen and total phosphorous indicator categories.

Table 3.11 - Water Quality Indicator Ratings (Subwatershed Preservation)

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Percent Future Departure of Total Nitrogen Load				
High	1	7.7%	1	6.7%
Medium High	1	7.7%	0	0.0%
Medium	1	7.7%	0	0.0%
Low	10	76.9%	14	93.3%
Percent Future Departure of Total Phosphorus Load				
High	1	7.7%	1	6.7%
Medium High	1	7.7%	0	0.0%
Medium	1	7.7%	0	0.0%
Low	10	76.9%	14	93.3%

4. RATING AND PRIORITIZATION

The County performs three detailed prioritization assessments in order to characterize current conditions within each watershed, guide decisions that impact waterways, and assist with land use management planning. The three assessments (stream restoration, subwatershed restoration, and subwatershed preservation) are presented in more detail in the following subsections. Each prioritization assessment relies on indicators derived from the data collected and compiled in Section 2 and the model results generated in Section 3.

4.1 STREAM RESTORATION ASSESSMENT AND RATING

The County's stream restoration assessment is intended to identify and rate the impaired stream reaches in the West and Rhode watersheds to prioritize future stream restoration and capital improvement projects and to guide future land use management and development decisions. Methods and findings for the stream restoration assessment and rating are presented in this subsection.

4.1.1 Methods

The stream restoration assessment uses a suite of indicator scores or ratings that are weighted and then combined to obtain a single stream restoration rating for each perennial reach. The indicators are grouped into one of five categories: stream habitat; stream morphology; land cover; infrastructure; and hydrology and hydraulics. As shown in Table 4.1, each category is comprised of one to six different indicators, and each indicator has a relative weight assigned by the County.

Table 4.1 - Stream Restoration Assessment Indicators

Category	Indicator	Weight
Stream Habitat	MPHI score	31.6%
Stream Morphology	Rosgen Level I classifications	5.3%
Land Cover	Imperviousness (%)	5.3%
Infrastructure	Stream buffer impacts	5.3%
	Channel erosion impacts	10.5%
	Head cut impacts	5.3%
	Dumpsite impacts	5.3%
	Other infrastructure impacts (pipes, ditches, stream crossings, and obstructions)	15.8%
Hydrology and Hydraulics	Crossing flooding likelihood	15.8%

Among the indicators for stream restoration, the MPHI score is utilized to represent the quality of physical stream habitat characteristics. Rosgen Level I classifications are used as an indicator of the degree of stability and entrenchment of each stream reach. The percentage of imperviousness contributes to increased stormwater volumes and thermal and chemical pollutant loading. The presence and impacts associated with stream buffers, channel erosion, head cuts, dumpsites, and other indicators (i.e., pipes, ditches, stream crossings, and obstructions) are a sign of potential channel degradation, excessive pollution and sedimentation, and habitat impairment. Flooding and overtopping of road stream crossings pose an inconvenience and safety hazard to nearby residents.

Although all stream channel types (e.g., perennial, intermittent, ephemeral, etc.) were assessed as part of the physical habitat condition assessment described in Section 2.1.2, several of the metrics used to calculate the MPHI are only applicable for perennial channels. Since the MPHI score is a critical indicator and weighted so heavily in the County's stream restoration prioritization, only perennial streams are considered.

4.1.2 Results

Of the 69 assessed perennial stream reaches in the West River watershed, 8 were rated as "High" priorities for restoration. 17 were rated as "Medium High" priority for restoration. Of the 13 subwatersheds with assessed perennial streams, five had more than one-third of their perennial streams rated as "High" or "Medium High":

- South Creek 1 (WR8) had 100% of its assessed streams rated in the "High" and "Medium High" categories. Only two streams were assessed in WR8;
- Gales Creek (WR3) had one stream assessed, which was rated as "Medium High";
- Lerch Creek 1 (WR5) had four assessed streams; one was rated "High" and two were ranked "Medium High";
- Lerch Creek 2 (WR6) had thirty-nine assessed streams; five were rated as "High" and ten were rated as "Medium High";
- South Creek 2 (WR9) had one stream assessed, which was rated as "High".

The remaining 44 reaches rated in the "Medium" and "Low" categories (19 and 25, respectively). A breakdown of the results by subwatershed is presented in Table 4.2. See Map 4.1 for a map of the stream restoration assessment results. In the Rhode River watershed, 197 perennial stream reaches were assessed. Of these, 22 were rated in the "High" category. Of the 15 subwatersheds with assessed perennial streams, eight had more than one-third of the perennial streams rated as "High" or "Medium High":

- Bear Neck Creek (RR1) had 67% of its assessed streams rated in the "High" and "Medium High" categories. Six streams were assessed in RR1 in total;
- Beverley Beach (RRB) had three assessed stream reaches, two were rated as "Medium High";

- South Fork Muddy Creek 1 (RR9) had 16 assessed stream reaches; two were rated as “High” and six were ranked as “Medium High”;
- Forrest Branch (RR0) had four stream reaches assessed; one was rated as “High”, and one “Medium High”;
- Many Fork Branch (RR3) had nineteen stream reaches assessed; one was rated as “High”, and eight “Medium High”;
- Williamson Branch (RR7) had twenty-seven stream reaches assessed; three were rated as “High”, and eight were rated as “Medium High”;
- South Fork Muddy Creek 2 (RR5) had sixty-three stream reaches assessed; four were rated as “High”, twenty were rated as “Medium High”;
- North Fork Muddy Creek (RR8) had forty-eight stream reaches assessed; seven were rated as “High”, and eleven were rated as “Medium High”.

The other stream reaches in the Rhode Watershed were assessed as “Medium” (44%) and “Low” (16%). A breakdown of the results by subwatershed is presented in Table 4.2. See Map 4.1 for a map of the stream restoration assessment results.

Table 4.2 - Stream Restoration Assessment Results

Subwatershed Code	Subwatershed Name	Number of Reaches with Rating				
		High	Medium High	Medium	Low	Total
WEST RIVER WATERSHED						
WR8	South Creek I	1	1	0	0	2
WR7	Tenthouse Creek	0	0	1	2	3
WR1	Johns Creek	0	0	2	0	2
WR5	Lerch Creek I	1	2	1	0	4
WR3	Gales Creek	0	1	0	0	1
WRA	Parish Creek	0	0	0	0	0
WR6	Lerch Creek II	5	10	13	11	39
WR9	South Creek II	1	0	0	0	1
WR4	Popham Creek	0	0	0	4	4
WRB	Smith Creek I	0	2	0	5	7
WR0	West River Tidal	0	0	0	0	0
WR2	Cheston Creek	0	0	0	0	0
WRC	Smith Creek II	0	1	2	3	6
Total		**8**	**17**	**19**	**25**	**69**
RHODE RIVER WATERSHED						
RR6	Cadle Creek	0	0	0	0	0

Table 4.2 - Stream Restoration Assessment Results

Subwatershed Code	Subwatershed Name	Number of Reaches with Rating				
		High	Medium High	Medium	Low	Total
RR1	Bear Neck Creek	4	0	1	1	6
RRB	Beverley Beach	0	2	1	0	3
RR4	Big Pond	0	0	0	0	0
RR0	Forrest Branch	1	1	1	1	4
RR5	South Fork Muddy Creek II	4	20	26	13	63
RR3	Many Fork Branch	1	8	7	3	19
RR2	Sellman Creek	0	2	7	2	11
RR8	North Fork Muddy Creek	7	11	24	6	48
RR7	Williamson Branch	3	8	12	4	27
RR9	South Fork Muddy Creek I	2	6	7	1	16
RRE	Boathouse Creek	0	0	0	0	0
RRC	Big Island	0	0	0	0	0
RRD	High Island	0	0	0	0	0
RRF	Flat Island	0	0	0	0	0
Total		**22**	**58**	**86**	**31**	**197**

4.2 SUBWATERSHED RESTORATION ASSESSMENT AND RATING

The County’s subwatershed restoration assessment is intended to identify and rate those subwatersheds where conditions warrant priority consideration for restoration activities. Methods and findings for the subwatershed restoration assessment and rating are presented in this subsection.

4.2.1 Methods

Like the stream restoration assessment, the subwatershed restoration assessment uses a suite of indicator ratings that are weighted and combined to obtain a single restoration rating for each subwatershed. The indicators are grouped into one of seven categories: stream ecology; 303(d) list; septics; BMPs; H&H; water quality; and landscape. Each category is comprised of one to four different indicators. A summary of the indicators and their relative weighting assigned by the County are presented in Table 4.3.

Table 4.3 - Subwatershed Restoration Assessment Indicators

Category	Indicator	Weight
Stream Ecology	Final habitat score	8.1%
	Bioassessment score	8.1%

303(d) List	Number of TMDL impairments	8.1%
Septics	Total nitrogen load from septics (lbs)	2.0%
BMPs	Impervious area treated by BMPs (%)	6.4%
H&H (Land and Soils Only)	Peak flow from 1-year storm (cfs/ac)	4.4%
	Peak flow from 2-year storm (cfs/ac)	4.4%
	Runoff volume from 1-year storm (in)	5.6%
	Runoff volume from 2-year storm (in)	5.6%
Water Quality (Land Only)	Total nitrogen load from runoff (lbs/acre/yr)	6.7%
	Total phosphorus load from runoff (lbs/acre/yr)	6.7%
Landscape	% Impervious cover	9.3%
	% Forest within the 100 ft stream buffer	10.1%
	% of existing wetlands to potential wetlands	9.3%
	Acres of developable Critical Area	5.2%

Among the indicators for the subwatershed restoration assessment, the final habitat and bioassessment scores are used as indicators of the quality of the physical and biological characteristics of stream reaches in the subwatershed. The relative magnitude of total nitrogen loading from septics and total nitrogen and total phosphorus loading from runoff are indicative of potential water quality degradation in each subwatershed. Peak flow and runoff volume are indicators of hydrology changes due to increased development and urbanization. BMP and landscape indicators including percent imperviousness, percent BMP treatment, and percent forested buffer influence stormwater volumes, peak flows, and pollutant loading. The presence of potential wetland areas and acres of developable Critical Area serve as indicators of restoration potential.

Table 4.4 - Subwatershed Priority Ranking for Restoration

Subwatershed Code	Subwatershed Name	Priority for Preservation
WEST RIVER WATERSHED		
WR7	Tenthouse Creek	High
WR8	South Creek I	High
WRA	Parish Creek	High
WR3	Gales Creek	High
WR1	Johns Creek	Medium High
WR5	Lerch Creek I	Medium High
WR0	West River Tidal	Medium High
WR4	Popham Creek	Medium
WR2	Cheston Creek	Medium
WR6	Lerch Creek II	Medium
WR9	South Creek II	Medium
WRB	Smith Creek I	Low
WRC	Smith Creek II	Low
RHODE RIVER WATERSHED		
RRB	Beverley Beach	High
RR6	Cadle Creek	High
RR1	Bear Neck Creek	High
RR4	Big Pond	Medium High
RR0	Forrest Branch	Medium High
RRE	Boathouse Creek	Medium High
RR5	South Fork Muddy Creek II	Medium High
RR2	Sellman Creek	Medium High
RR3	Many Fork Branch	Medium High
RR9	South Fork Muddy Creek	Medium
RR8	North Fork Muddy Creek	Medium
RR7	Williamson Branch	Medium
RRC	Big Island	Low
RRF	Flat Island	Low
RRD	High Island	Low

4.2.2 Results

The subwatersheds in the West Watershed were assessed to identify restoration needs. As seen in Table 4.4, of the 13 subwatersheds assessed, four were rated “High”, which makes them priorities for restoration. These four subwatersheds represent 30.8% of the subwatersheds in the West watershed. The remaining watershed area was split between Medium High (23.1%), Medium (30.8%), and Low (15.4%) priority. The breakdown of rating results by subwatershed in presented in Table 4.5. See Map 4.3 for a map of the subwatershed restoration assessment results.

In the Rhode watershed, only three of the 15 subwatersheds (20%) were assessed as a “High” priority for restoration. Six of the 15 subwatersheds (40%) were assessed to be “Medium High” on the prioritization scale for restoration needs, while three subwatersheds each were assessed to be “Medium” and “Low” priority. Summaries of rankings by subwatershed are presented in Tables 4.4 and 4.5. See Map 4.4 for a map of the subwatershed restoration assessment results.

Table 4.5 - Subwatershed Restoration Assessment Results

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
High	4	30.8%	3	20.0%
Medium High	3	23.1%	6	40.0%
Medium	4	30.8%	3	20.0%
Low	2	15.4%	3	20.0%
TOTAL	**13**	---	**15**	---

4.3 SUBWATERSHED PRESERVATION ASSESSMENT AND RATING

The County's subwatershed preservation assessment is intended to identify and rate those subwatersheds where conditions warrant consideration for preservation activities. Methods and findings for the subwatershed preservation assessment and rating are presented below.

4.3.1 Methods

The subwatershed preservation assessment uses a suite of indicator ratings that are weighted and combined to obtain a single preservation rating for each subwatershed. The indicators are grouped into one of five categories: stream ecology, future departure of water quality conditions, soils, landscape, and aquatic living resources. Each category is comprised of one to eight different indicators. A summary of the indicators and the relative weighting assigned by the County are provided in Table 4.6.

Table 4.6 - Subwatershed Preservation Assessment Indicators

Category	Indicator	Weight
Stream Ecology	Final habitat score	7.4%
	Bioassessment score	7.4%
Future Departure of Water Quality Conditions	Percent future departure of total nitrogen	11.1%
	Percent future departure of total phosphorus	11.1%
Soils	NRCS soil erodibility factor	7.4%
Landscape	Percent forest cover	11.1%
	Percent wetland cover	11.1%
	Density of headwater streams (ft/ac)	7.4%
	Percent of land within the Greenway Master Plan	3.7%
	Presence of bog wetlands	3.7%
	Acres of RCA lands within Critical Area	3.7%
	Percent of protected lands	3.7%
	Presence of Wellhead Protection Areas	3.7%
Aquatic Living Resources	Presence of trout spawning, anadromous spawning, and SSPRA	7.4%

4.3.2 Results

A total of six subwatersheds in the West Watershed were assessed to be "High" and "Medium High" priorities on the preservation rating scale. Of these, three were rated as being a "High" priority. "Medium" ratings for preservation make up 23.1% of the subwatersheds. The remaining four subwatersheds were assessed to be a "Low" priority for preservation. The full breakdown for ranking is presented in Tables 4.7 and 4.8. See Map 4.5 for a map of the subwatershed preservation assessment results for the West watershed.

In the Rhode Watershed, the Cradle Creek (RR6) and Flat Island (RRF) subwatersheds were assessed as a "High" priority for preservation. This represents 13.3% of the subwatersheds. Two watersheds were rated "Medium High," an additional 13.3% of the subwatersheds assessed. The remaining 11 subwatersheds were almost evenly split between "Medium" and "Low," with six subwatersheds ranked as "Medium" and five as "Low." Complete breakdown of the subwatershed priority ratings for preservation can be seen in Tables 4.7 and 4.8. See Map 4.6 for a map of the subwatershed preservation assessment results for the Rhode Watershed.

Table 4.7 - Subwatershed Priority Ranking for Preservation

Subwatershed Code	Subwatershed Name	Priority for Preservation
WEST RIVER WATERSHED		
WR4	Popham Creek	High
WR0	West River Tidal	High
WR2	Cheston Creek	High
WRC	Smith Creek II	High
WRB	Smith Creek I	Medium High
WR3	Gales Creek	Medium High
WR9	South Creek II	Medium High
WR5	Lerch Creek I	Medium
WR6	Lerch Creek II	Medium
WR8	South Creek I	Medium
WR1	Johns Creek	Low
WR7	Tenthouse Creek	Low
WRA	Parish Creek	Low
RHODE RIVER WATERSHED		
RRE	Boathouse Creek	High
RR3	Many Fork Branch	High
RR2	Sellman Creek	High

Table 4.7 - Subwatershed Priority Ranking for Preservation

Subwatershed Code	Subwatershed Name	Priority for Preservation
RR7	Williamson Branch	High
RR8	North Fork Muddy Creek	High
RR9	South Fork Muddy Creek	Medium High
RR0	Forrest Branch	Medium High
RRB	Beverley Beach	Medium High
RRC	Big Island	Medium High
RR5	South Fork Muddy Creek II	Medium High
RR1	Bear Neck Creek	Medium High
RR4	Big Pond	Medium
RRD	High Island	Medium
RR6	Cadle Creek	Low
RRF	Flat Island	Low

Table 4.8 - Subwatershed Preservation Assessment Results

Rating	West River Watershed		Rhode River Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
High	4	30.8%	5	33.3%
Medium High	3	23.1%	6	40.0%
Medium	3	23.1%	2	13.3%
Low	3	23.1%	2	13.3%
TOTAL	**13**	---	**15**	---

5. RESTORATION AND PRESERVATION IMPLEMENTATION PLAN

As discussed in detail in the previous sections, the County collected and compiled extensive data on water resource and land use characteristics and conditions (Section 2); conducted hydrologic and water quality modeling for both current and future conditions (Section 3); and prioritized stream reaches and subwatersheds based on the need for restoration and preservation (Section 4). These steps were critical for developing a better understanding of watershed conditions and identifying priorities in the watershed. This section uses the results of these previous steps to identify and describe a specific restoration and preservation implementation plan for the West and Rhode watersheds.

This implementation plan hinges on a gap analysis evaluating load reduction goals, the development of potential restoration activities, and a cost-benefit analysis of restoration scenarios to identify the appropriate mix of restoration activities to meet those load reduction goals. These components are discussed in detail in this section along with a set of specific recommendations for implementation. In addition, efforts are underway to identify and rank land parcels that may be candidates for preservation or naturalization efforts.

5.1 GAP ANALYSIS

A gap analysis in the context of watershed planning is an approach that compares a baseline of existing and/or future conditions with watershed targets or goals. The “gap” then informs the County on what needs to be done to meet its goals. As discussed in Section 1.2, watershed goals in the West and Rhode watersheds are driven primarily by load allocations associated with the Chesapeake Bay TMDL and the Baltimore Harbor TMDL and permit requirements in the County’s NPDES MS4 permit. Because of this, it has been assumed that employing a strategy to satisfy load reduction goals of the Chesapeake Bay TMDL would simultaneously satisfy the Baltimore Harbor TMDL and the NPDES permit impervious treatment requirements.

The focus of this study and this gap analysis is on developing solutions and strategies for addressing urban non-point sources in the watershed. As such, the current pollutant loads, existing credits, and proposed restoration activities are derived from only those associated with urban development. Urban lands, as defined in this plan, include lands coded as industrial, transportation, commercial, residential (all densities), utility, open space, airport, and residential woods. Lands not included as urban are those coded as pasture/hay, row crops, woods, water, and wetland. County urban lands can further be broken down by the contribution from public and private lands.

As discussed in Section 1.2.2.1, the nutrient load allocations assigned from the Chesapeake Bay TMDL are provided for the urban MS4 sector at the County-scale and are not further divided by County watersheds. For planning purposes at the watershed level, the County is applying the same percent load reduction required at the County level to each of its watersheds. For total nitrogen, this amounts to a 21% reduction from an existing conditions annual load without credits by the 2017 interim target, and a 35% annual load reduction by 2025. For total phosphorus, the interim target load reduction is 38% and the 2025 target load reduction is 63%. For total suspended solids, load allocations have not yet been provided by EPA.

Table 5.1 provides a summary of existing and future pollutant loads for the County's urban stormwater sector, the estimated TMDL allocation for urban stormwater for the study watersheds, and the required reduction (gap) to meet the estimated TMDL allocation. The modeling methods to derive the existing and future loads are described in more detail in Section 3.

Table 5.1 - Summary of Loads and Allocations

Scenario	TN (lbs/year)	TP (lbs/year)	TSS (tons/year)
WEST WATERSHED			
2010 Load (No BMPs)	18,130	2,678	341
2011 Progress Load (With BMPs)*	17,918	2,638	337
Future Conditions Load (With Credits)	20,429	2,881	337
Estimated 2025 TMDL Allocation	11,091	918	Not Available
Required Reduction from 2011 Progress Load (With BMPs)	6,827	1,720	Not Available
RHODE WATERSHED			
2010 Load (No BMPs)	18,321	2,556	290
2011 Progress Load (With BMPs)*	18,153	2,530	288
Future Conditions Load (With Credits)	19,445	2,643	283
Estimated 2025 TMDL Allocation	11,208	876	Not Available
Required Reduction from 2011 Progress Load (With BMPs)	6,945	1,654	Not Available

* Note that the 2011 Progress Load includes credits for existing BMPs, but does not include credit for impervious surface disconnections.

5.2 DEVELOPMENT OF POTENTIAL RESTORATION STRATEGIES

A variety of potential restoration activities are available to improve instream and riparian habitat conditions, to improve management and treatment of stormwater runoff, and to meet nutrient load reduction targets. For the County, a key consideration is that restoration activities must be cost effective relative to the quantity of pollutant removed. Other selection criteria include maintenance, life expectancy, and public acceptance of the proposed measure. For these reasons, prioritizing the planning and implementation of these activities is of great importance. The County has selected a range of restoration activities that are summarized in the sections that follow. These activities have been implemented successfully by the County in other watershed restoration efforts and it is expected that they will translate well to the conditions encountered in the West and Rhode watersheds.

These strategies mirror those presented in the County's Phase II WIP that is currently being prepared to satisfy allocations from the Chesapeake Bay TMDL. The WIP strategy is broken down into three primary categories:

- **Core Strategies –** These are generally large capital improvement projects that represent the bulk of the load reductions and capital expenditures in the plan. The goals of the Core Strategies are to restore stream stability, restore connectivity with floodplains and streams, restore biological health of streams, and obtain compliance with water quality standards. The locations of these strategies are presented on Maps 5.1 and 5.2.
- **Core Tier II Strategies –** These are generally smaller scale capital projects or programmatic strategies that are collectively intended to close the gap to achieve the final 2025 required nutrient load reductions. The locations of these strategies are presented on Maps 5.3 and 5.4.
- **Potential Load Reductions Outside of the Core Strategy WIP Areas –** These are credits that may be achieved from installation of stormwater management practices on private property as a result of potential future implementation of a County stormwater utility fee and associated discount program. The locations of these strategies are presented on Maps 5.5 and 5.6.

A description of the individual components of each of these strategies is presented in the sections that follow. The locations of all of the TMDL WIP strategies for the West and Rhode watersheds are presented in Map 5.7.

5.2.1 WIP Core Strategies

The following represent the Core Strategies that will be employed in the West and Rhode watersheds.

- **Outfall Retrofits –** This strategy targets all major outfalls characterized by the Infrastructure Management Division (IMD) as impaired with scores of C and lower, outfalls identified through the Illicit Discharge Detection Elimination (IDDE) survey to be unstable, and other major outfalls located in subwatersheds with the highest priority for restoration (see Section 4.2). Major outfalls are defined as stormwater pipes at the end of the collection system that are larger than 36 inches or larger than 18 inches within commercial areas. Outfalls will be retrofitted with regenerative step pool storm conveyance (SPSC) systems. These retrofits utilize a series of shallow pools, riffle weir grade controls, native vegetation, and underlying sand and compost filters to treat, detain, and safely convey drainage area runoff. These outfall retrofits increase infiltration and dampen flow velocities, which enhances removal of suspended particles and associated nutrients and decreases downstream bed and bank erosion in receiving water bodies.

- **Stormwater Pond Retrofits –** This strategy focuses on retrofitting both public and private wet and dry stormwater ponds built prior to 2002 and with a drainage area greater than 10 acres. Based on MDE's analysis of BMP performance by era (MDE 2009), it is assumed that stormwater ponds built prior to 2002 were not designed to comply with currently accepted criteria for management of water quality. As such, these ponds were deemed to be prime candidates for retrofits to more efficient BMPs that are designed for water quality management, like shallow wetland marshes, regenerative SPSCs, or constructed wetland systems. All dry and wet ponds approved before 2002 were selected for retrofitting regardless of subwatershed or stream condition.
- **Stream Restoration –** This strategy targets degraded and severely degraded ephemeral, intermittent, and perennial stream reaches identified by the County's stream restoration assessment and rating (see Section 4.1) to be in the greatest need for restoration. Lower order, ephemeral and intermittent streams will be restored as SPSC Systems and higher ordered perennial streams will be restored with constructed in-stream riffles or as wetland seepage systems. These measures for perennial streams include installation of low head rock weirs for grade control and floodplain connection, sand seepage berms for additional nutrient filtration, wetland creation, oxbow ponds, bio-engineering, and riparian stream plantings.
- **CIP Projects –** This strategy accounts for all budgeted and programmed environmental restoration projects to be implemented by the County. These projects include outfall retrofits, stream restorations, and BMP retrofits.

5.2.2 WIP Core Tier II Strategies

The following represent the Core Tier II Strategies that will be employed in the West and Rhode watersheds.

- **Street Sweeping –** Starting in Fiscal Year 2015, Anne Arundel County has enhanced their street sweeping program which now includes sweeping curb-miles and parking lots throughout the County. This enhanced program targets impaired watersheds and curbed streets that contribute trash/litter, sediment, and other pollutants. The County's street cleaning frequency is 1 pass per 2 weeks on urban streets. This frequent sweeping of the same street will reduce nitrogen and phosphorus as well as sediment. Under the enhanced street sweeping program, Anne Arundel County is sweeping arterial streets on a bi-weekly basis (26 times a year) and collector and local streets on a monthly basis (12 times a year). In order to quantify sediment load reductions from monthly sweeping efforts, the removal rate of 22% for vacuum-assisted monthly sweeping was applied to total sediment collected from collector and local streets (CWP, 2008).

- **Inlet Cleaning –** Storm drain cleanout ranks among the oldest practices used by communities for a variety of purposes to provide a clean and healthy environment, and more recently to comply with NPDES stormwater permits. Inlet cleaning will occur at a frequency established by the Bureau of Highways at selected inlets.
- **Public Land Reforestation –** This strategy entails reforesting public open space parcels or portions thereof that have been identified by the Anne Arundel County Forestry Program to be potential forestation sites. This direct conversion of open space to forested land
- **Stormwater to the MEP –** This strategy includes retrofitting existing impervious surfaces to the maximum extent practical with stormwater management practices, including but not limited to green roofs, permeable pavement, bioretention, and disconnection. These retrofits will be limited to County-owned properties including Board of Education facilities and Recreation and Park facilities.

5.2.3 Potential Load Reductions Outside of the Core Strategy WIP Areas

The Stormwater Fee is a local government fee established in response to federal stormwater management requirements. The federal requirements are designed to prevent local sources of pollution from reaching local waterways. The stormwater utility was required to include a stormwater remediation fee, to be collected annually from property owners within the County. The County has a stormwater fee credit program to encourage practices that proactively and sustainably manage runoff on private property. It is expected that this program could be a driver for a subset of private property owners to retrofit their properties with stormwater treatment, outside of the normal course of development and redevelopment.

For planning and accounting purposes, the County assumes that these credits are limited to areas outside of existing areas covered by the Core Strategies and Core Tier II Strategies. The following broad categories of restoration activities are considered:

- **Private Commercial/Industrial Stormwater Management –** This credit accounts for stormwater management retrofits to private commercial and industrial properties.
- **Private Residential Stormwater Management –** This credit accounts for retrofitting rooftops in high density residential areas with practices such as rain water harvesting or rain gardens.

In 2015, the State of Maryland made changes to the stormwater utility and remediation fee legislation. The new legislation allows Phase I counties to repeal or reduce stormwater fees before July 1, 2016, but affected counties must still identify dedicated revenues to supply local watershed protection funds to meet stormwater permit requirements. The legislation also requires the submission of Anne Arundel County's Financial Assurance Plan (FAP), as well as the submission of the Watershed Protection and Restoration Program (WPRP) annual report, for compliance with Maryland Environment Article §4-202.1. The FAP is to show that the County has the financial means to achieve the permit requirements.

5.3 COST-BENEFIT ANALYSES OF RESTORATION SCENARIOS

The County performed a cost-benefit analysis of the restoration strategies to determine the level of implementation of each restoration activity and associated costs required to meet the load reductions summarized in Section 5.1. The County applied its hydrologic and water quality modeling (discussed in Section 3) to evaluate the potential for the restoration activities to reduce pollutant loading. The County estimated costs for each strategy based on unit costs developed from previous restoration experiences in the County. This analysis was performed in an iterative manner, where assumptions about specific restoration activities, implementation levels, and performance were adjusted to optimize the overall costs and benefits. The results of this analysis highlight the relative effectiveness of each restoration type and provide a useful tool for setting implementation priorities. In addition, the results indicate, at a planning level, the total magnitude of resources necessary to meet the goals for the watershed. The methods and results of this analysis are discussed below.

5.3.1 Load Reduction Calculations

The benefits (in terms of pollutant load reductions) for the restoration activities associated with each strategy were calculated using the water quality model described in Section 3.1.2. Similar to the baseline modeling, the basic elements of the load reduction model are polygons created in GIS. The County generated polygons for the load reduction modeling primarily from the geospatial Identity of GIS layers representing land use, land ownership, and the drainage area of each restoration activity. Drainage areas for each restoration activity were delineated from the County's DEM or were obtained from the appropriate land use or land cover polygon. See Table 5.2 for a summary of the drainage area delineation assumptions.

For each polygon representing an individual restoration activity, the baseline pollutant load was calculated and reduced in the model using pollutant removal efficiencies summarized in Table 5.2. As described in Section 3.1.2, these efficiencies were largely derived from MDE's guidance document *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated* (MDE 2014). Resultant pollutant loads reductions were calculated for each restoration activity for total nitrogen, total phosphorus, and total suspended solids.

In a number of cases, drainage areas from individual restoration activities were found to overlap either wholly or in part. In reality, it is not unusual for restoration activities to treat stormwater pollutants in series (e.g., as part of a treatment train). Nonetheless, in these cases, the County used a conservative accounting approach to avoid double counting of credits. The exception to this is for the street sweeping Core Tier II Strategy, which has relatively low pollutant removal efficiencies and is widely applied across the watersheds.

The County's water quality model avoided double counting load reduction credits by counting the number of overlapping or nested restoration activities associated with a particular GIS polygon and equally apportioning the existing condition load to each activity. Then the pollutant removal efficiencies for overlapping activities were applied to each distinct portion of the existing condition load assigned to that restoration activity. For example, if a particular polygon was being treated by three distinct restoration activities, then one-third of the existing condition pollutant load would be assigned to each of the three activities. For each activity, this partial load would be reduced based on the pollutant removal efficiency of the practice. The result is effectively a weighted load reduction for situations where overlapping occurs.

Table 5.2 - Summary of Load Reduction Calculation Assumptions

Restoration Type	Drainage Area Delineation	Overlap Allowed?	Removal Efficiency		
			TN	TP	TSS
CORE STRATEGIES					
Outfall Retrofit - SPSC	From DEM, at outfall	No	40%	60%	80%
Stormwater Pond Retrofit	From DEM, at outfall	No	25%	35%	65%
Stream Restoration (Intermittent/ Ephemeral) - SPSC	From DEM, based on reach centroid	No	40%	60%	80%
Stream Restoration (Perennial)	From DEM, based on reach centroid	No	0.2 lb/ft/yr	0.068 lb/ft/yr	310 lb/ft/yr
CORE TIER II STRATEGIES					
Street Sweeping	Road polygons	Yes	4%	4%	10%
Inlet Cleaning	Road polygons	No	5%	6%	25%
Public Land Reforestation	Public open space polygons	No	66%	77%	57%
Stormwater to the MEP	Land use polygons	No	50%	60%	90%

5.3.2 Cost Development

The methods used to derive cost for each treatment type are based on a combination of data and vary by restoration type. The goal is to derive an average unit cost that would apply to most implementation situations. Municipalities across the mid-Atlantic region can have varying design and construction standards in terms of the level of detail, the permits and review agencies required, the type of construction materials allowed for, the type of contracting mechanisms in place, and the type of bidding procedures. All of which can affect a project's cost. With these factors in mind, and because the County has implemented all of these types of projects recently, the use of County-specific recent historical information was determined to be the most effective tool to derive costs[1].

[1] In the past year, actual bid prices for construction have been above estimated costs. This recent inflation of costs may be associated with an increased demand for ecological construction practitioners and materials. If

For the Core Strategies, cost data were compiled for each activity from comparable historical County projects and normalized by the contributory drainage area. A statistical analysis of this data showed a very poor correlation. This is largely due to the fact that these data do not take into account treatment design standards and performance efficiencies of the restoration activities. When this same cost data were normalized by nested impervious drainage areas treated and pounds of TN removed, the statistical analysis showed a much stronger correlation. From this analysis, the County developed average unit costs that can then be applied to the proposed restoration activities to develop a planning level cost estimate. See Table 5.3 below for the unit costs used for estimating the cost of the Core Strategies. It should be noted that these unit costs represent only the upfront capital expenditure (survey, design, permitting, construction, easements), and generally do not include internal County operations and program/project management costs, and do not include system maintenance or monitoring.

Table 5.3 - Annual Cost Basis for Core Strategies

Restoration Type	Cost ($ per lb TN removed)
Outfall Retrofits	$6,496
Stormwater Pond Retrofits	$8,065
Stream Restoration (Intermittent/Ephemeral)	$7,751
Stream Restoration (Perennial)	$3,009

For the Core Tier II Strategies, the cost development methods were more widely varied. The unit costs for each of the Core Tier II Strategy activities are explained below and summarized in Table 5.4:

- **Street Sweeping –** The County's contracted street sweeping program currently relies on regenerative air vacuum street sweepers to accommodate the street sweeping requirements laid out in the Core Tier II Strategy. The County contracted street sweeping services in early FY15 to augment the existing County street sweeping program, utilizing funding appropriated via the Watershed Protection and Restoration Fund (WPRF). On the County-scale, there are 770 miles of closed/curbed section roadways (1,540 lane miles to account for both directions) that will require sweeping. The monthly productivity of a vehicle is 17,280 miles per year (8 hours/day x 20 days/month x 9 miles/hour x 12 months). In order to cover the estimated 1,540 lane miles on a monthly basis, two vehicles, each manned by one driver and one operator,

rates continue to increase, the existing rate model used in this study will need to be adjusted to better reflect true costs in future planning.

would be needed. Weather conditions may not allow sweeping every day, so a 100 day/year operation was assumed. The capital cost of purchasing new street sweeping equipment is $194,500 with an anticipated operational life of 6 years. On an annual basis, the cost for two vehicles is $64,833. The operational cost is approximately $576,000 (4 operators x 8 hours/day x 9 miles/hour x 100 days/year x $20/hour). The sum of equipment cost and operational cost is approximately $640,833 per year. The cost over a thirty year period without accounting for inflation would be $12,475 per lane mile.

- **Inlet Cleaning –** Using historic County information for inlet cleaning, it was determined that $200 per inlet would be a suitable unit cost assumption for inlet clean out.
- **Public Land Reforestation –** For a single acre of reforested land, the Anne Arundel County Forestry Program recommends planting 500 seedlings (at a cost of $2/seedling), 100 1.5-inch caliber trees (at a cost of $85/tree), and 55 2.5-inch caliber trees at a cost of $175/tree. The public land reforestation cost was estimated at $38,250 per acre, which includes a 100% contingency to account for planting costs. When this per acre cost is related to pollutant removal rates, the unit cost becomes $9,430 per pound of TN removed.

Table 5.4 - Annual Cost Basis for Core Tier II Strategies

Restoration Type	Cost	Unit
Street Sweeping	$12,475	per lane mile
Inlet Cleaning	$200	per inlet
Public Land Reforestation	$9,430	per lb TN removed

5.3.3 Specific Recommended Restoration and Preservation Activities

The results of the cost-benefit analysis yielded a comprehensive list of restoration projects and activities in each watershed. These are summarized in Table 5.5 and 5.6 below.

If fully implemented, these restoration projects and activities will meet the Chesapeake Bay TMDL allocations for the West and Rhode watersheds. See Figures 5-1 through 5-4.

Table 5.5 - WIP Phase II Strategy for West Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Impervious Treatment Credit (Acres)	Pollutant Reduction			Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($) /Tons
						TN (lbs/ year)	TP (lbs/ year)	TSS (Tons/ year)				
CORE STRATEGY												
Stream Restoration (Ephemeral and Intermittent) - SPSC/Regenerative Wetland Seepage Systems												
Severely Degraded Streams	0.35	Miles	Retrofit lower order incised channels with regenerative SPSCs or wetland seepage systems	Project designed to filter ESD volume or portion there of	19	140	127	14.0	$1,082,560	$7,751	$8,549	$77,510
Degraded Streams	1.94	Miles			102	769	697	76.9	$5,956,790	$7,751	$8,549	$77,510
Stream Restoration (Perennial) - Instream Constructed Riffles												
Severely Degraded Streams	1.02	Miles	Retrofit higher order incised channels with constructed instream riffles	Length of restoration is based on impacted/ connected upstream length	54	404	367	40.4	$1,217,128	$3,009	$3,319	$30,090
Degraded Streams	1.56	Miles			82	617	560	61.7	$1,857,278	$3,009	$3,319	$30,090
Stormwater Pond Retrofit												
Public Pond Retrofits	1	# of Ponds	Retrofit pre-2002 SWM facilities to meet ESD criteria	Retrofit design for ESD volume or portion thereof. Efficiency based on MDE NPDES approved by era retrofit efficiencies.	0	0	0	0.0	$ -	$ -	$ -	$ -
Private Pond Retrofits	4	# of Ponds			0	0	0	0.0	$ -	$ -	$ -	$ -
Outfall Retrofit - SPSC												
Severely Degraded Outfalls	12	# of Outfalls	Retrofit Outfalls with SPSC system (Ephemeral systems)	Project designed to filter ESD volume or portion thereof	0	0	0	0.0	$ -	$ -	$ -	$ -
Degraded Outfalls	0	# of Outfalls			0	0	0	0.0	$ -	$ -	$ -	$ -

Table 5.5 - WIP Phase II Strategy for West Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Impervious Treatment Credit (Acres)	Pollutant Reduction			Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($) /Tons
CIP Programmed Projects (Various Types of Retrofits)												
Future Budgeted CIP	0	Projects	This scenario quantifies the benefits of implementing future CIP restorations with approved budget	Project is designed to treat water quality volume or portion there of	0	0	0	0.0	$ -	$ -	$ -	$ -
CORE STRATEGY SUBTOTALS					257	1,930	1,750	193	$10,113,756	**N/A**		
CORE TIER II STRATEGY												
Street Sweeping	1	Miles	Monthly Street Sweeping of Curbed County Roads	Reductions are based on contributing acres to vacuum and MDE NPDES approved efficiencies	0	0	0	0.0	$28,591	$ -	$ -	$ -
Inlet Cleaning	4	Inlets	Cleaning of curb opening inlets		0	0	0	0.0	$800	$ -	$ -	$ -
Reforestation	0	Acres	Reforestation of Public Open Space	Based on acres forested per MDE NPDES design criteria and efficiency	0	0	0	0.0	$ -	$ -	$ -	$ -
ESD for County Rec and Parks	0	Acres	Retrofit with ESD devices	Micro practices implemented to MEP to treat contributory ESD volume	0	0	0	0.0	$ -	$ -	$ -	$ -
ESD for County Schools	0	Acres			0	0	0.0	0.0	$ -	$ -	$ -	$ -
ESD for County Facilities	0	Acres			0	0	0	0.0	$ -	$ -	$ -	$ -
CORE TIER II STRATEGY SUBTOTALS					0	0	0	0.0	$29,391	N/A		
POTENTIAL LOAD REDUCTIONS OUTSIDE OF CORE STRATEGY WIP AREAS												

Table 5.5 - WIP Phase II Strategy for West Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Impervious Treatment Credit (Acres)	Pollutant Reduction			Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($) /Tons
ESD for Private Commercial and Industrial Properties	0	Acres	Retrofit with ESD devices	Designed to treat ESD volume or portion thereof	0	0	0	0.0	N/A	N/A	N/A	N/A
POTENTIAL LOAD REDUCTIONS OUTSIDE OF CORE STRATEGY WIP AREAS SUBTOTALS					0	0	0	0.0	**N/A**			
CREDITS CALCULATED FOR CURRENT CONDITIONS WITHOUT CONSIDERATION THAT WIP CORE AND SUPPLEMENTAL STRATEGIES ARE IN PLACE												
Existing CIP	0	Projects	This scenario quantifies the benefit for CIP restorations performed since 2002 and up to 2015	N/A	0	0	0	0.0	N/A	N/A	N/A	N/A
Existing County Public BMPs	0	BMPs	Based on BMP with nested DA delienations		0	0	0	0.0	N/A	N/A	N/A	N/A
Existing County Private BMPs	0	BMPs	Based on BMP with nested DA delineations		0	0	0	0.0	N/A	N/A	N/A	N/A
Rooftop Disconnects	0	Acres	Existing rooftops that are disconnected		0	0	0	0.0	N/A	N/A	N/A	N/A
CREDIT SUBTOTALS					0	0	0	0	**N/A**			
WEST WATERSHED WIP TOTALS					257	1,930	1,750	193	$10,143,147	**N/A**		

Table 5.6 - WIP Phase II Strategy for Rhode Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Impervious Treatment Credit (Acres)	Pollutant Reduction			Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($) /Tons
						TN (lbs/ year)	TP (lbs/ year)	TSS (Tons/ year)				
CORE STRATEGY												
Stream Restoration (Ephemeral and Intermittent) - SPSC/Regenerative Wetland Seepage Systems												
Severely Degraded Streams	0.43	Miles	Retrofit lower order incised channels with regenerative SPSCs or wetland seepage systems	Project designed to filter ESD volume or portion there of	23	169	153	16.9	$1,308,436	$7,751	$8,549	$77,510
Degraded Streams	5.3	Miles			280	2,099	1,903	209.9	$16,266,706	$7,751	$8,549	$77,510
Stream Restoration (Perennial) - Instream Constructed Riffles												
Severely Degraded Streams	1.81	Miles	Retrofit higher order incised channels with constructed instream riffles	Length of restoration is based on impacted/ connected upstream length	96	717	650	71.7	$2,157,803	$3,009	$3,319	$30,090
Degraded Streams	3.84	Miles			203	1,523	1,380	152.3	$4,581,207	$3,009	$3,319	$30,090
Stormwater Pond Retrofit												
Public Pond Retrofits	1	# of Ponds	Retrofit pre-2002 SWM facilities to meet ESD criteria	Retrofit design for ESD volume or portion thereof. Efficiency based on MDE NPDES approved by era retrofit efficiencies.	1	9	2	0.1	$72,357	$8,065	$43,796	$512,218
Private Pond Retrofits	3	# of Ponds			5	33	7	0.7	$264,515	$8,065	$38,874	$358,782
Outfall Retrofit - SPSC												
Severely Degraded Outfalls	7	# of Outfalls	Retrofit Outfalls with SPSC system (Ephemeral systems)	Project designed to filter ESD volume or portion thereof	16	222	30	2.2	$1,443,797	$6,496	$47,833	$653,686
Degraded Outfalls	2	# of Outfalls			1	9	1	0.1	$60,563	$6,496	$48,299	$605,047

Table 5.6 - WIP Phase II Strategy for Rhode Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Impervious Treatment Credit (Acres)	Pollutant Reduction			Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($) /Tons
CIP Programmed Projects (Various Types of Retrofits)												
Future Budgeted CIP	0	Projects	This scenario quantifies the benefits of implementing future CIP restorations with approved budget	Project is designed to treat water quality volume or portion there of	0	0	0	0.0	$ -	$ -	$ -	$ -
CORE STRATEGY SUBTOTALS					623	4,780	4,126	454	$26,155,384	**N/A**		
CORE TIER II STRATEGY												
Street Sweeping	1	Miles	Monthly Street Sweeping of Curbed County Roads	Reductions are based on contributing acres to vacuum and MDE NPDES approved efficiencies	2	1	0	0.03	$17,953	$24,993	$85,257	$522,173
Inlet Cleaning	7	Inlets	Cleaning of curb opening inlets		3	3	1	0.1	$1,400	$501	$1,709	$11,396
Reforestation	0	Acres	Reforestation of Public Open Space	Based on acres forested per MDE NPDES design criteria and efficiency	0	0	0	0.0	$ -	$ -	$ -	$ -
ESD for County Rec and Parks	2	Acres	Retrofit with ESD devices	Micro practices implemented to MEP to treat contributory ESD volume	2	15	2	0.2	$178,149	$12,000	$77,381	$932,397
ESD for County Schools	0	Acres			0	1	0.1	0.01	$6,010	$12,000	$76,150	$959,785
ESD for County Facilities	7	Acres			7	64	8	1.4	$768,590	$12,000	$97,170	$551,654

Table 5.6 - WIP Phase II Strategy for Rhode Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Impervious Treatment Credit (Acres)	Pollutant Reduction			Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($) /Tons
CORE TIER II STRATEGY SUBTOTALS					13	83	11	2	$972,102	$61,494	$337,668	$2,977,415
POTENTIAL LOAD REDUCTIONS OUTSIDE OF CORE STRATEGY WIP AREAS												
ESD for Private Commercial and Industrial Properties	19	Acres	Retrofit with ESD devices	Designed to treat ESD volume or portion thereof	21	193	30	2.4	N/A	N/A	N/A	N/A
POTENTIAL LOAD REDUCTIONS OUTSIDE OF CORE STRATEGY WIP AREAS SUBTOTALS					21	193	30	2.4	**N/A**			
CREDITS CALCULATED FOR CURRENT CONDITIONS WITHOUT CONSIDERATION THAT WIP CORE AND SUPPLEMENTAL STRATEGIES ARE IN PLACE												
Existing CIP	1	Projects	This scenario quantifies the benefit for CIP restorations performed since 2002 and up to 2015	N/A	0	17	3	0.3	Completed / Expended	N/A	N/A	N/A
Existing County Public BMPs	5	BMPs	Based on BMP with nested DA delienations		2	27	5	0.4	N/A	N/A	N/A	N/A
Existing County Private BMPs	113	BMPs	Based on BMP with nested DA delineations		14	167	26	2.2	N/A	N/A	N/A	N/A
Rooftop Disconnects	22	Acres	Existing rooftops that are disconnected		19	230	32	2.6	N/A	N/A	N/A	N/A
CREDIT SUBTOTALS					36	441	67	5.5	**N/A**			
RHODE WATERSHED WIP TOTALS					693	5,497	4,235	463	$27,127,486	**N/A**		

Figure 5-1 - Annual Progress of WIP Strategy towards Meeting Total Nitrogen Load Allocations – Rhode River Watershed

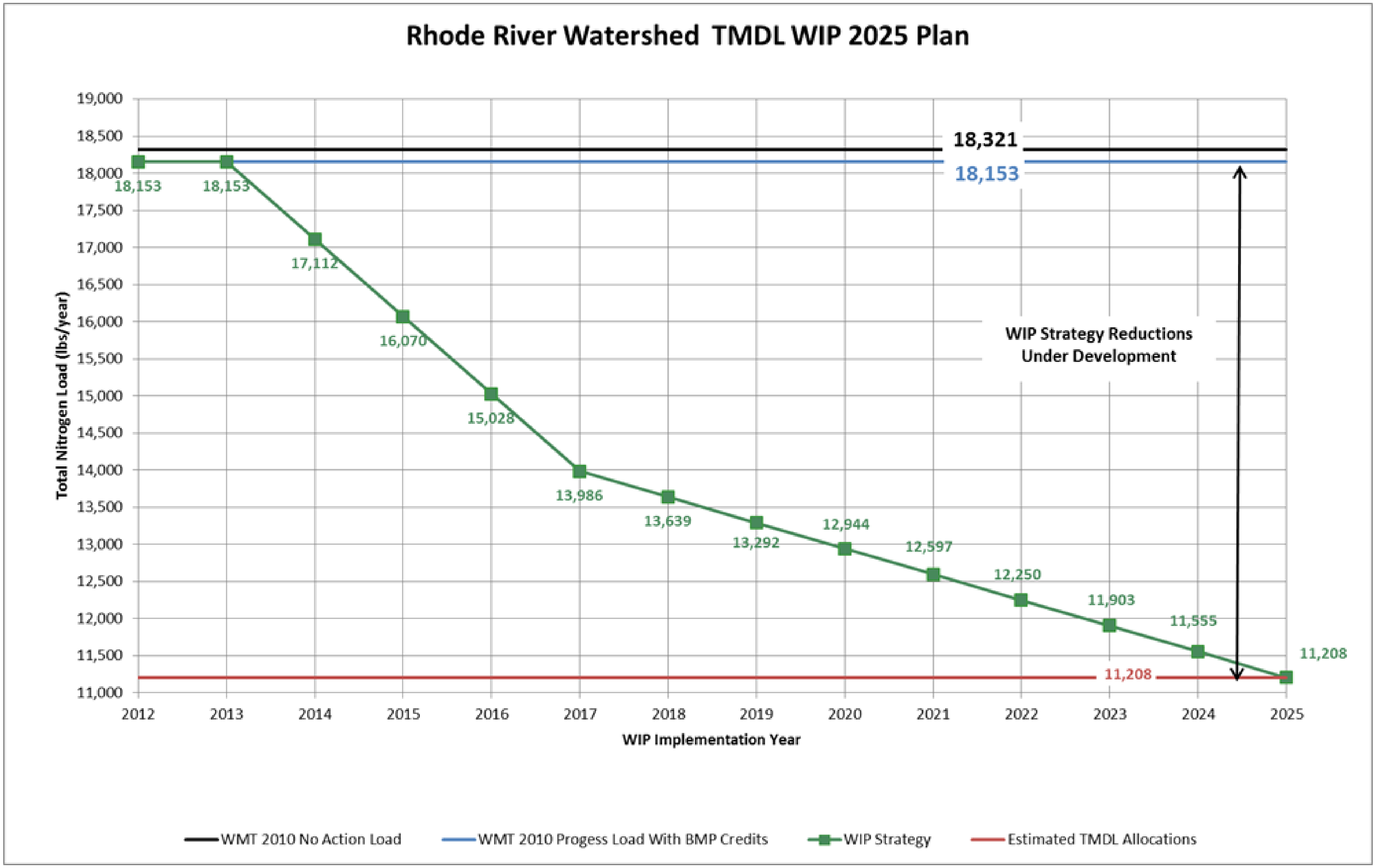


Figure 5-2 - Annual Progress of WIP Strategy towards Meeting Total Phosphorus Load Allocations – Rhode River Watershed

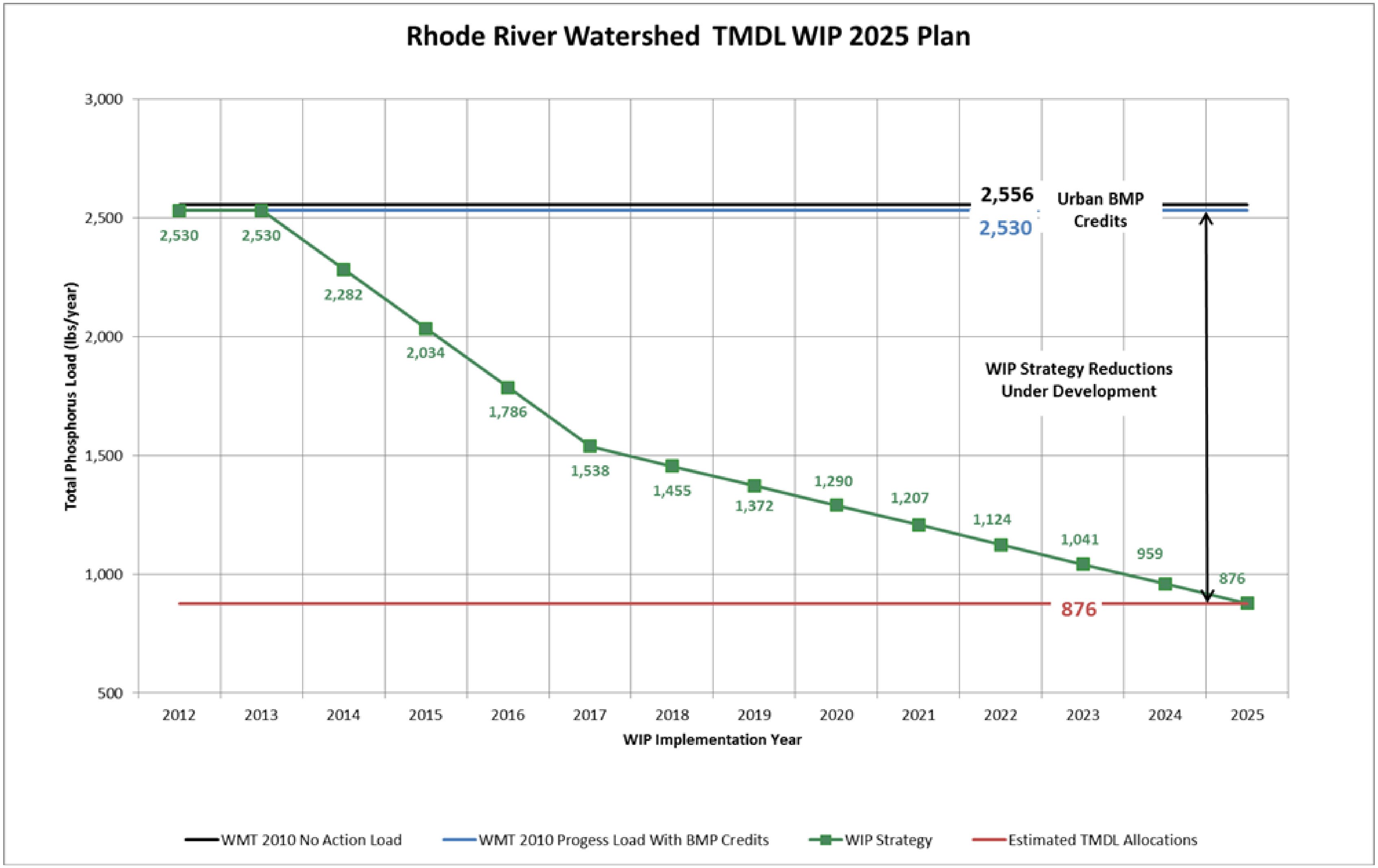


Figure 5-3 - Annual Progress of WIP Strategy towards Meeting Total Nitrogen Load Allocations – West River Watershed

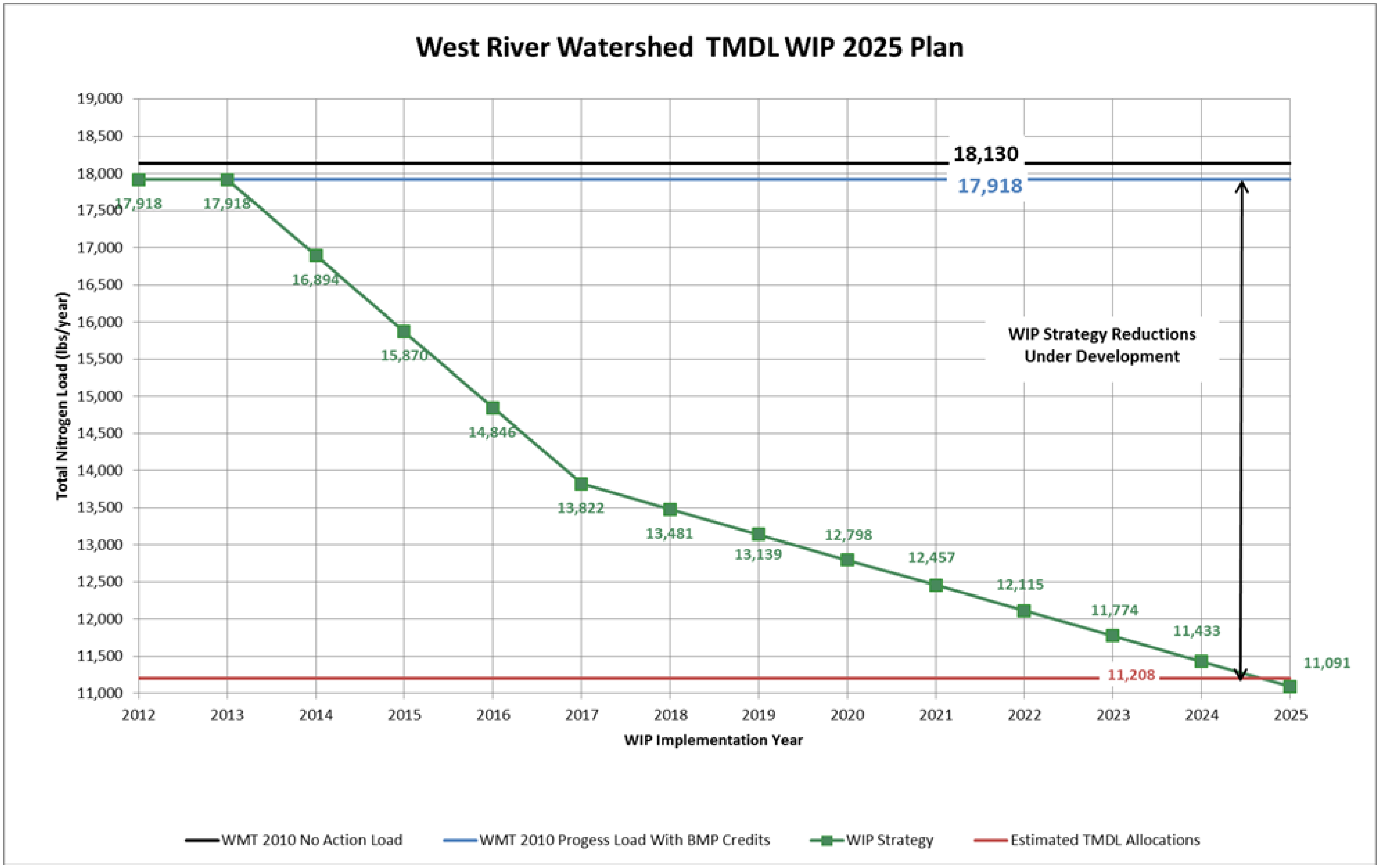
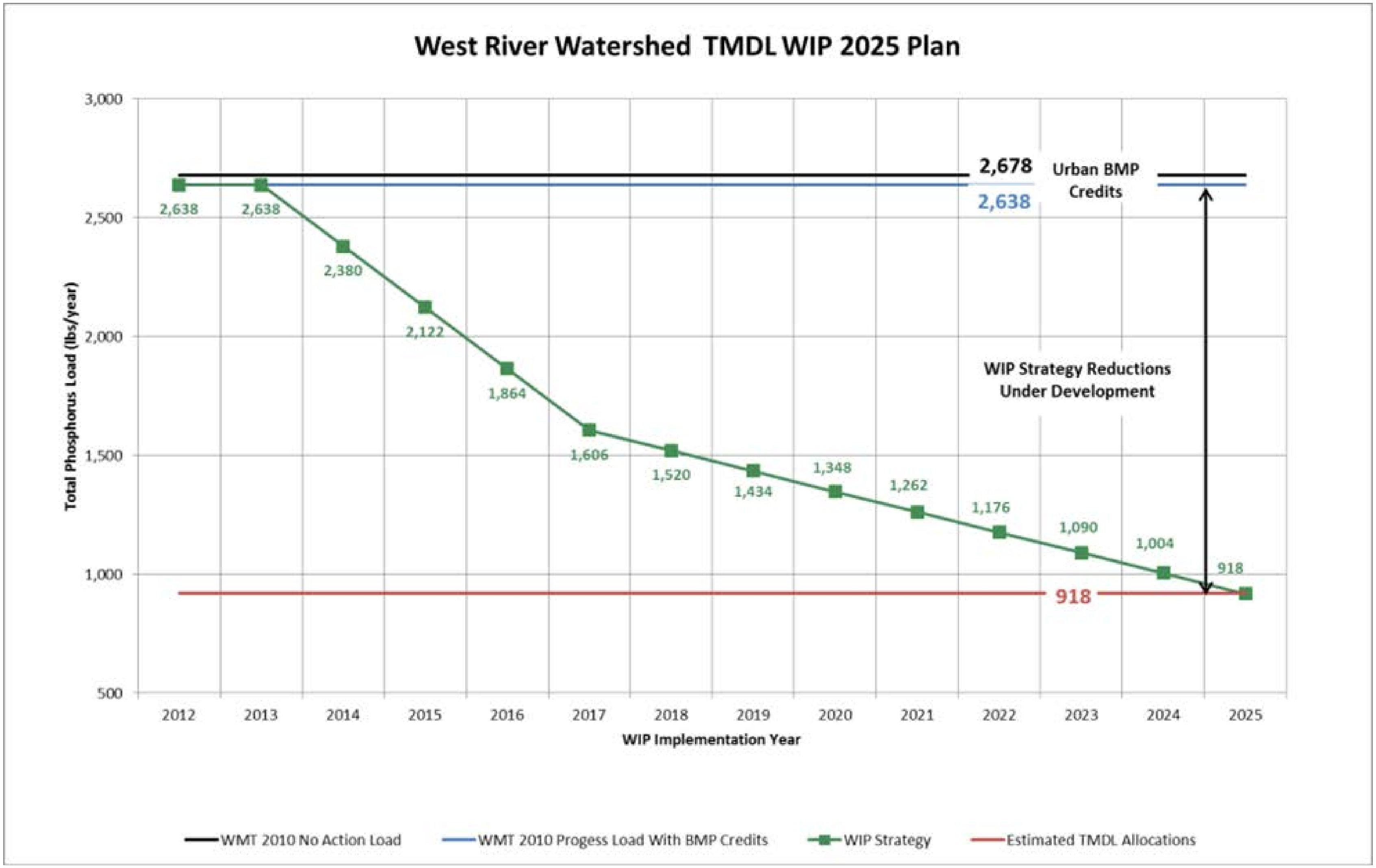


Figure 5-4 - Annual Progress of WIP Strategy towards Meeting Total Phosphorus Load Allocations – West River Watershed



5.4 IMPLEMENTATION PLAN

5.4.1 Tracking and Reporting Protocols

The Chesapeake Bay TMDL allocations for urban stormwater will ultimately be regulated through NPDES permitting. As such, the Anne Arundel County NPDES MS4 permit will serve as the regulatory mechanism to track, verify, and report progress and compliance with the assigned stormwater wasteload allocation. Under the County's current permit, annual progress reports are provided to MDE. These annual reports document watershed restoration activities that include those described in the WIP Strategy discussed above. Projects such as stream restoration, outfall retrofits, pond retrofits, and implementation of stormwater management in those areas currently undermanaged or not managed are captured in a watershed restoration database. Additionally, the County collects and reports projects implemented by entities outside of the County government (e.g., watershed association projects, RiverKeeper projects, Watershed Stewards Academy projects). Pollutant load reductions and impervious surface credits associated with this assemblage of projects are calculated and reported back to MDE. These same tracking and reporting efforts will be used to determine compliance with the Chesapeake Bay TMDL urban stormwater allocation assigned to the County.

5.4.2 Implementation Contingencies

The County has identified a number of contingencies to fall back on should the WIP strategy for urban stormwater not be fully realized. First, other source sectors under the County's control are exceeding their required reduction goals. This provides some cushion for implementation of the urban stormwater WIP strategy. Second, the County has employed a number of conservative accounting assumptions in the water quality modeling used to develop the WIP strategy. These conservative assumptions result in lower load reduction estimates then what may actually be achieved in reality. This is demonstrated by the fact that the Maryland Assessment and Scenario Tool (MAST) used by the State of Maryland for TMDL accounting predicts higher load reductions from the County's WIP strategy than the County's modeling. Foremost amongst these conservative assumptions is the County's approach of using nested drainage areas for determining BMP credits. This approach does not account for the additive load reductions of BMPs in series. Other conservative assumptions include not taking credit for certain landscape components that remove pollutants (e.g., existing tree canopy and functioning wetlands) and for non-structural urban nutrient management BMPs (e.g., neighborhoods that forbid fertilizer application).

5.4.3 Detailed Targets and Schedule

As shown in Figure 5-1 through 5-4, the pace of annual load reductions necessary to meet the 2017 and 2025 targets is significant. The implementation of the full set of proposed projects and activities in the WIP strategy hinges primarily on the availability of funding. Funding is available for the future CIP projects identified through 2016. These future CIP projects are expected to be implemented, but beyond this horizon, funding details for the remaining WIP strategy projects are less clear. The new stormwater utility discussed in Section 1.2.2 will provide a new dedicated funding source, but the specific mechanisms and financial details of this utility have not yet been determined.

5.4.4 Parcel Preservation and Naturalization

The County identified the potential to either purchase land parcels, through the County's annual tax sale process, which could be set aside for preservation or naturalization, or to reforest or preserve existing County-owned land parcels. The County could receive credits from MDE for reforestation of pervious urban land and conversion of impervious urban land to forest, with the caveat that no credit is received for conversion of agricultural land.

The process of identifying parcel candidates is currently underway. The parcels that are ten acres or greater in size, and that are within West and Rhode subwatersheds that are highly ranked for preservation, will serve as the initial candidates. Those parcels will then be analyzed using two criteria:

- Naturalization candidates: Parcels that are highly impervious or have a high percentage of pervious urban land are candidates for naturalization. There will be two subsets of this criterion: one for highly impervious parcels, another for pervious urban (open space) parcels. These subsets are necessary because a component of identification of parcel candidates will be an estimate of naturalization costs. County-owned open space will be given priority in the naturalization rankings.
- Preservation candidates: Parcels that are already forested will be identified as candidates for preservation. County-owned forested parcels will be given priority in the preservation rankings.

6. REFERENCES

Anne Arundel County. 2003. Severn River Watershed Management Master Plan, Current Conditions Report. Prepared by KCI Technologies, Inc. and CH2M HILL for Anne Arundel County Department of Public Works Watershed Management Program. Anne Arundel County, Maryland.

Anne Arundel County, Office of Planning and Zoning (OPZ), 2006. *Stormwater Management Practices and Procedures Manual*, July 2001, Revised July 2006. Prepared by: Office of Planning and Zoning, in conjunction with Department of Public Works, Department of Inspections and Permits, Anne Arundel Soil Conservation District

Anne Arundel County. 2008. Onsite Sewage Disposal Systems: Evaluation Study and Strategic Plan, March 2008. Prepared by CH2M HILL, John E. Harms, Jr. & Associates, and Stearns and Wheeler LLC.

Anne Arundel County. 2010. Quality Assurance Project Plan for Anne Arundel County Biological Monitoring and Assessment Program. Prepared by: Tetra Tech, Inc.

Anne Arundel County, 2012a. Field Data Collection Guide for Watershed Studies, Anne Arundel County Department of Public Works. Prepared by LimnoTech and Versar.

Anne Arundel County, 2012b. Chesapeake Bay TMDL Phase II Watershed Implementation Plan. Available at: http://www.aacounty.org/departments/public-works/wprp/watershed-resources/Anne_Arundel_WIPII_2012.pdf

Cowan, W.L. 1956. Estimating Hydraulic Roughness Coefficients. *Agricultural Engineering*. Vol. 37, no.7. pp. 473–47

EPA, 2001. PLOAD Version 3.0, An ArcView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects. January 2001. Developed by CH2M HILL

KCI. 2012. Targeted Biological Assessment of Streams in the West River and Rhode River Watersheds, Anne Arundel County, Maryland: 2012. Prepared for Anne Arundel County Department of Public Works. Available at: http://dev.aacounty.org/departments/public-works/wprp/forms-and-publications/WestRhodeTargetedBioassessmentReport_FINAL_08.22.12_compressed.pdf

Maryland Department of the Environment. 2009a. State of Maryland's Comprehensive Water Monitoring Strategy. Available at: http://www.mde.state.md.us/assets/document/Maryland_Monitoring_Strategy2009.pdf

Maryland Department of the Environment. 2014. Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated. Available at: http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/Documents/NPDES%20MS4%20Guidance%20August%2018%202014.pdf

Maryland Department of the Environment. 2016. Maryland's TMDL Program: Listing of Approved TMDLs. Available at: http://mde.maryland.gov/programs/water/tmdl/approvedfinaltmdls/pages/programs/waterprograms/tmdl/approvedfinaltmdl/index.aspx

Maryland Department of Natural Resources (MDNR). October 2005. Volume 16, New Biological Indicators to Better Assess The Condition Of Maryland Streams. EA-05-13 (DNR #12-10282005-74)

Maryland Department of Natural Resources. 2007. Maryland Biological Stream Survey Sampling Manual: Field Protocols. CBWP-MANTA-EA-07-01. Published by the Maryland Department of Natural Resources, Annapolis, MD. Publication number 12-2162007-190.

Maryland Geological Survey. 2008. James P. Reger and Emery T Cleaves. "Explanatory Text for the Physiographic Map of Maryland". Open-File Report 08-03-1. Available at: http://www.mgs.md.gov/coastal/maps/physio.html.

NRCS, 1992. TR-20 Computer Program for Project Formulation Hydrology. Revised by The Hydrology Unit and The Technology Development Support Staff, Soil Conservation Service. Washington, DC

NRCS. 2010. "Chapter 15: Time of Concentration." Part 630 Hydrology, National Engineering Handbook. Available at: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=27002.wba. .

NRCS, 2012. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Maryland. Available online at http://sdmdataaccess.nrcs.usda.gov/. Accessed March 15, 2012.

Paul, M.J., J.B. Stribling, R.J. Klauda, P. F. Kayzak, M.T. Southerland, and N. E. Roth. 2003. A Physical Habitat Index for Wadeable Streams Maryland. Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division. Annapolis, MD.
Rosgen, D.L. 1994. A classification of natural rivers. *Catena.* Vol. 22, no. 3. pp. 169-99.

Schueler, T. 1987. Controlling urban runoff: a practical manual for planning and designing urban BMPs. Metropolitan Washington Council of Governments. Washington, DC

Schueler, T.R. 1992. Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government. In Watershed Restoration Sourcebook. Publication #92701 of the Metropolitan Washington Council of Governments. P. Kimble and T. Schueler, editors.

Schueler, T. and B. Stack. 2014. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects.

Southerland, M.T., G.M. Rogers, M.J. Kline, R.P. Morgan, D.M. Boward, P.F. Kazyak, R.J. Klauda, and S.A. Stranko. 2007. Improving Biological Indicators to Better Assess the Condition of Streams. Ecological Indicators 7:751-767.

U.S. Department of Transportation (US DOT), Federal Highway Administration. October 1984. *Hydrology*, Hydraulic Engineering Circular No. 19 (HEC 19).

7. APPENDICES

APPENDIX A – FLOODING POTENTIAL TECHNICAL MEMORANDUM

APPENDIX B – BIOASSESSMENT REPORT

APPENDIX C – URBAN BMP TECHNICAL MEMORANDUM