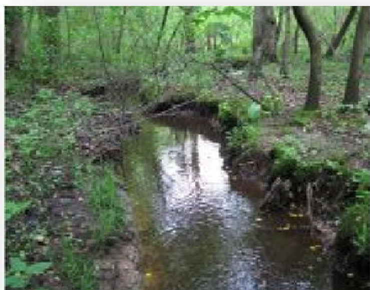
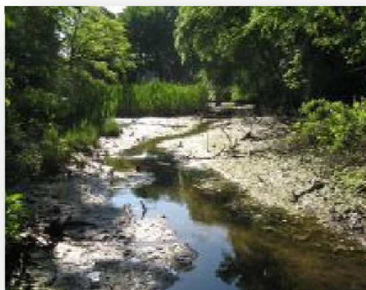
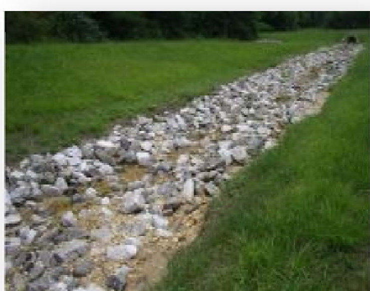
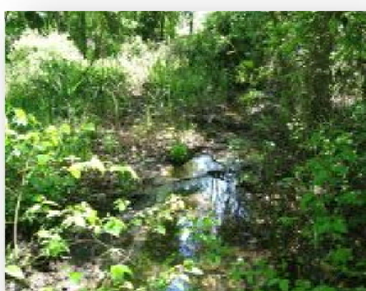
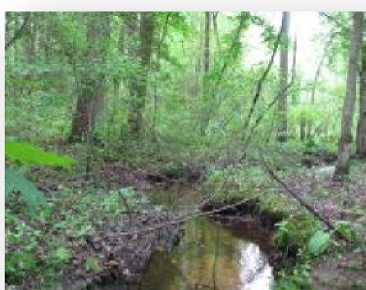
Patapsco Tidal and Bodkin Creek Watershed Assessment

Comprehensive Summary Report



August 2012

Prepared by:
Anne Arundel County
Department of Public Works
Bureau of Engineering
Watershed Ecosystem and
Restoration Services Division
Watershed Assessment and
Planning Program

In association with:
LimnoTech
Versar

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NPDES Section II. F – Watershed Assessment and Planning

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ACKNOWLEDGEMENTS

The Patapsco Tidal and Bodkin Creek Watershed 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:

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The Anne Arundel County, Maryland, Watershed Assessment and Planning Program initiated a comprehensive assessment of the Patapsco Tidal and Bodkin Creek Watersheds in the spring of 2010. See Map 1.1 for the location of these watersheds. The main purpose of the assessment was to characterize current stream and upland conditions in the watershed to support and prioritize watershed management and planning activities. 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 the 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). Similar watershed studies have been completed previously for five of the County's twelve major watersheds.

The scope of the Patapsco Tidal and Bodkin Creek 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-world.aacounty.org/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.
- 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 derived from the PMT meetings 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 Patapsco Tidal and Bodkin Creek 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 Patapsco Tidal and Bodkin Creek Watersheds as well as the greater Chesapeake Bay system.

1.2.1 Total Maximum Daily Load

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 [TMDLs]) that would allow the listed water body to meet WQS. EPA has designated MDE is 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.

1.2.2.1 Chesapeake Bay

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 23% annual reduction from existing conditions load without credits by the 2017 interim target and a 38% annual load reduction by 2025. For total phosphorus, the interim target load reduction is 39% and the 2025 target load reduction is 65%. 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. NPDES permits, such as the Anne Arundel County NPDES MS4 permit, become the regulatory mechanism to ensure tracking, verifying, and reporting of progress and compliance with the assigned stormwater or wastewater allocations. Anne Arundel County submitted its WIP for inclusion within the larger State-wide plan for EPA response and comment on November 17, 2011. The County's WIP includes strategies and milestones associated with stream restoration, stormwater BMP retrofits, and other programmatic efforts.

As implementation begins on projects and programs to meet pollutant allocations, programmatic goals, and milestones, the Bay TMDL continues to generate discussions regarding future regulatory requirements (such as EPA's anticipated post-construction stormwater regulatory requirements) and suggested "consequences" for the failure to implement requirements (ranging from reductions in state revolving fund [SRF] funding to bans on the issuance of new permits). Specific legislation has been offered in the U.S. Congress to implement President Obama's Executive Order on the Chesapeake Bay, including the Chesapeake Bay Ecosystem Restoration Act of 2009 introduced by Senator Benjamin Cardin of Maryland. Several key revisions were made to the bill prior to its approval by the Senate Environmental and Public Works Committee (June 30, 2010). However, no action has yet been taken on the House version of the bill. Overall, the bill would codify certain TMDL requirements, such as deadlines associated with Chesapeake Bay TMDL development and the content of the associated watershed implementation plans. The bill would not, however, require their submittal to EPA nor allow EPA to add additional requirements when reviewing state implementation plans for approval.

1.2.2.2 Baltimore Harbor

The Baltimore Harbor estuary (basin number 02130903), otherwise known as the Patapsco Tidal area, is the 15- mile tidal region of the lower Patapsco River. It is the end of the Patapsco River where it joins the Chesapeake Bay. The Patapsco Tidal area and Bodkin Creek watersheds, along with the tidal segments of the Colgate Creek, Bear Creek, Curtis Creek, Stony Creek, and Rock Creek, are included in the Patapsco River Mesohaline (PATMH) Chesapeake Bay segment.

The Baltimore Harbor was first identified on the 303(d) list in 1996. It was listed as impaired by nutrients due to signs of eutrophication, expressed as high levels of chlorophyll *a* and low concentrations of dissolved oxygen. The Baltimore Harbor has also been identified on the 303(d) list as impaired by bacteria (enterococcus) (1998), toxics (*e.g.*, chlordane, polychlorinated biphenyls (1998), metals (chromium, zinc, and lead) (1998), suspended sediments (1996), impacts to biological communities (2004), and floatables and trash (2008). Bodkin Creek (02130902) has been listed for a number of impairments, but no TMDLs have been developed as of yet for this watershed.

MDE has established a TMDL for toxics (chlordane). The TMDL was approved by EPA in March, 2001 and can be found on the MDE TMDL website[1]. In-situ Harbor sediment, however, is identified as the sole remaining source of chlordane to the estuary, so this TMDL is not applicable to Anne Arundel County stormwater discharges. MDE developed a TMDL

[1] http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Pages/Programs/WaterPrograms/TMDL/approvedfinaltmdl/tmdl_baltoharbor.aspx

for bacteria for impaired recreational areas in Marley Creek and Furnace Creek (Patapsco Tidal Tributaries) of the Baltimore Harbor Basin. The TMDL was approved by EPA in March, 2011, and can be found on the MDE website[2]. Regulated stormwater is considered a point source in this TMDL. Bacteria loads attributable to MS4 Phase I and Phase II NPDES-regulated stormwater entities in the watershed, including Anne Arundel County MS4 discharges, are combined in aggregated stormwater WLA. The TMDL states, however, that these permittees "are regulated based on BMPs and [the TMDL does] not include bacteria limits" for these discharges.

MDE has also established a TMDL for nitrogen and phosphorous in the PATMH Segment (not including Bodkin Creek). The TMDL was approved by EPA in December 2007 and can be found on the MDE website[3]. This TMDL calls for a 15% reduction in total nitrogen and total phosphorus load from urban stormwater. MDE's Draft 2012 Integrated Report (March, 2012) includes the background and rationale for reevaluation of previously approved nutrient TMDLs for tidal tributaries to the Chesapeake Bay. MDE has proposed that a number of nutrient TMDLs be "superseded" by the individual Bay TMDLs for the corresponding Bay Water Quality Segments. This decision is based on improved modeling tools and modeling data used in developing the Bay TMDL and the fact that water quality standards have been revised since the time the local TMDLs were developed. The Baltimore Harbor (02130903) TMDLs for Nitrogen and Phosphorus (2007) are included in those proposed to be superseded by the Maryland portion of the PATMH Bay segment.

1.2.2 NPDES

Anne Arundel County holds an NPDES MS4 permit issued by the Maryland Department of the Environment (MDE). This permit (99-DP-3316, MD0068306) covers all stormwater discharges to and from the MS4 owned and operated by the County. Assessments of the Patapsco Tidal and Bodkin Creek Watersheds have been conducted in partial fulfillment of these MS4 permit requirements.

- Section III.C.2 – Source Identification. Collecting and verifying urban best management practice 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

[2] http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Pages/TMDL_final_Marley.aspx
[3] http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Pages/Programs/WaterPrograms/TMDL/approvedfinaltmdl/tmdl_final_baltimoreharbor_nutrient.aspx

  - Provide an estimated cost and a detailed implementation schedule for the improvement opportunities identified above.
- Section III.G – Watershed Restoration. Implementing restoration efforts in one or more watersheds to restore ten percent of the County's impervious surface area within the five-year permit cycle.

The fourth generation of this five year MS4 permit is currently in the renewal phase. It is anticipated several changes will be made to the County's permit requirements including increasing watershed restoration to 20% of the County's impervious area that is not already restored to the maximum extent practical (MEP).

It is also anticipated that the new permit will include greater emphasis on tracking progress towards meeting both local and Chesapeake Bay wide TMDL waste load allocations in association with Watershed Assessment and Planning efforts. This would be 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.

1.2.3 Maryland Stormwater Regulations

Maryland's Stormwater Management Act became effective on October 1, 2007. The Act requires that environmental site design (ESD) be implemented to the maximum extent practicable through the use of nonstructural best management practices and other better site design techniques. As part of its implementation of the Act, MDE published the 2009 Model Standard Stormwater Management Plan (October 2009) and the 2009 Model Stormwater Management Ordinance (June 2009). Changes to Maryland's stormwater management regulations (COMAR 26.17.02) to address the Act became effective in May of 2009. Anne Arundel County's amended County Code Article 16 (Floodplain Management, Sediment Control, and Stormwater Management) in August and September 2010 to incorporate requirements for ESD as required by the Act. The update of County Code section 16.4.202.a.1 states that "[t]he planning techniques, nonstructural practices, and design methods specified in the Design Manual shall be used to implement ESD to the MEP. The use of ESD planning techniques and treatment practices must be exhausted before any structural best management practice (BMP) is implemented."

The Governor of Maryland signed the *Stormwater Management – Watershed Protection and Restoration Program Act* into law on May 2, 2012. This Act requires counties and municipalities with Phase I MS4 permits to establish local watershed protection and restoration programs. These "stormwater utility" programs are to be funded by new stormwater remediation fees for property owners to be assessed by counties and municipalities. The stormwater remediation fees will be used to improve storm water systems, restore streams and wetlands, fund stormwater management planning activities, and support nonprofit organizations on local restoration projects.

1.3 PHYSICAL SETTING

The Patapsco Tidal and Bodkin Creek watersheds are two of the twelve major watersheds in Anne Arundel County, Maryland. The two watersheds are located next to each other in the north portion of the County (see Map 1.1).

1.3.1 Physiography

Both the Patapsco Tidal and Bodkin Creek watersheds are in the Atlantic Coastal Plain Physiographic Province. A majority of the Patapsco Tidal watershed is in the Glen Burnie Rolling Upland District. This landform is an undulating upland with slopes typically less than eight degrees (Maryland Geological Survey, 2008). The Bodkin Creek watershed also contains portions of the Glen Burnie Rolling Upland District as well as the Annapolis Estuaries and Lowlands and the Crownsville Upland districts. The Crownsville Upland District is similar to the Glen Burnie Rolling Upland District but is somewhat more dissected (Maryland Geological Survey, 2008). Only a small portion of the Bodkin Creek watershed is in the Annapolis Estuaries and Lowlands District. This physiographic district is relatively featureless and is mostly less than 50 feet in elevation (Maryland Geological Survey, 2008).

As seen in Maps 1.4 and 1.5, the majority of steep slopes in the Patapsco Tidal watershed are in the upstream portion of the watershed. The low lying Bodkin Creek Watershed is small and the terrain is rather flat.

1.3.2 Soils and Geology

Table 1.1 – Hydrologic Soil Group

Hydrologic Soil Group	Patapsco Tidal	Bodkin Creek
A	18%	31%
B	42%	48%
C	27%	19%
D	13%	3%

A mix of soils from the four hydrologic groups is present in the Patapsco Tidal and Bodkin Creek watersheds (see Map 1.6 and Table 1.1) (NRCS, 2012). The majority of the soils (42%) in the Patapsco Tidal Watershed are classified as hydrologic soil group B. These soils have a moderately low runoff potential when thoroughly wet and water transfer through the soil is unimpeded. Hydrologic soil group C, accounts for 27% of the soils in the Patapsco Tidal Watershed. These soils have a moderately high runoff potential when thoroughly wet and water transmission through the soil is somewhat restricted. Hydrologic soil groups A (18%) and D (13%) are also found in the Patapsco Tidal Watershed. Hydrologic soil group A soils have a low runoff potential when wet and water is transmitted freely through the soil. Hydrologic soil group D soils have a high runoff potential when wet and water movement is very restricted. Soils in the Bodkin Creek Watershed are similar. The majority of soils are also classified as hydrologic soil group B. Hydrologic soil group A accounts for 31% of the Bodkin Creek soils. Class C and D soils make up 19% and 3% of the Bodkin Creek Watershed.

Table 1.2 – Soil Erodibility

Soil Erodibility	Patapsco Tidal	Bodkin Creek
Highly erodible land	20%	21%
Not highly erodible land	22%	11%
Potentially highly erodible land	58%	67%

Table 1.3 – Subwatersheds

Subwatershed Code	Subwatershed Name	Area (acres)
PATAPSCO TIDAL		
PT0	Stony Creek	3,367
PT1	Unnamed Tributary	312
PT2	Cabin Branch 2	370
PT3	Cabin Branch	2,667
PT4	Swan Creek	652
PT5	Furnace Creek	1,856
PT6	Curtis Creek	1,179
PT7	Sawmill Creek 1	2,914
PT8	Marley Creek 1	2,767
PT9	Cox Creek	544
PTA	Patapsco Tidal	181
PTB	Rock Creek	2,574
PTC	Back Creek	1,045
PTD	Sawmill Creek 2	2,684
PTE	Marley Creek 2	492
PTF	Marley Creek 3	2,517
PTG	Marley Creek 4	2,517
PTH	Nabbs Creek	688
PTI	Patapsco Tidal	242
PTJ	Patapsco Tidal	215
PTK	Patapsco Tidal	85
PTL	Patapsco Tidal	207
PTM	Hines Bog Pond	199
PTN	Hines Bog	154
PTO	Leath Pond	179
PTP	Boyd Pond	227
PTQ	Patapsco Tidal	12
BODKIN CREEK		
BK2	Back Creek	912
BK3	Main Creek	2,995
BK4	Chesapeake Bay	66
BK5	Bodkin Creek	190
BK6	Main Creek	> 0
BK7	Wharf Creek	245
BK8	Locust Cove	310
BK9	Chesapeake Bay	316

A majority of the soils in the Patapsco Tidal and Bodkin Creek Watersheds can be classified as potentially highly erodible land (58% and 67% respectively) (NRCS, 2012). See Table 1.2. Map 1.6 illustrates how these soils are interspersed throughout the watersheds. Soils classified as highly erodible lands are also found throughout the watersheds. These soils represent 20% of the soil in the Patapsco Tidal Watershed and 21% in the Bodkin Creek Watershed. Not highly erodible land soils are found to a lesser extent in the Bodkin Creek Watershed (11%) when compared to the Patapsco Tidal Watershed (22%).

1.3.3 Surface Water

The Patapsco Tidal watershed contains approximately 50 miles of perennial stream reaches, draining 27 subwatersheds. The 27 subwatersheds range in size from approximately 12 acres to 3,367 acres. See Table 1.3.The Bodkin Creek Watershed contains approximately eight miles of perennial stream draining eight subwatersheds. The subwatersheds in the Bodkin Creek watershed range in size from less than one acre to approximately 2,995 acres. A map of the subwatersheds including the subwatershed three-digit code and name is presented as Map 1.7.

1.3.4 Environmental Features

Environmental features in the Patapsco Tidal and Bodkin Creek watersheds are presented in Map 1.8. As seen in this map, many sensitive environmental features are found throughout the two watersheds. In both watersheds, the majority of wetlands are located along the Patapsco River. Critical areas are found in the coastal areas of both watersheds. In the Patapsco Tidal watershed, greenways are concentrated in the PT4, PT6, PT8, and PTH subwatersheds. Greenways are located throughout the Bodkin Creek Watershed.

1.3.5 Land Cover and Land Ownership

The distribution of land cover in the Patapsco Tidal and Bodkin Creek watersheds is summarized in Table 1.4. Residential land uses (approximately 40 %) make up the greatest portion of the Patapsco Tidal Watershed. Just over half of this consists of small properties of 1/8th acre. Apart from residential land use, the other large land use/land cover category is woods at 27% of the watershed.

Table 1.4 – Land Cover

Land Cover	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Acres	Percent of Watershed	Acres	Percent of Watershed
Airport	473.1	1.5%	8.4	0.2%
Commercial	2,225.9	7.2%	152.3	3.0%
Industrial	1,803.0	5.8%	0	0.0%
Open Space	3,110.6	10.1%	374.2	7.4%
Open Wetland	45.9	0.1%	15.5	0.3%
Pasture/Hay	3	< 0.1%	10.3	0.2%
Residential 1/2-acre	1,288.7	4.2%	415.4	8.3%
Residential 1/4-acre	3,229.1	10.5%	346.7	6.9%
Residential 1/8-acre	6,478.0	21.0%	279	5.5%
Residential 1-acre	656.1	2.1%	645.5	12.8%
Residential 2-acre	791.2	2.6%	591.9	11.8%
Residential Woods	47	0.2%	0	0.0%
Row Crops	58.1	0.2%	0	0.0%
Transportation	1,635.1	5.3%	123.3	2.4%
Utility	249.2	0.8%	0	0.0%
Water	296.2	1.0%	40.4	0.8%
Woods	8,459.1	27.4%	2,031.7	40.4%
TOTAL	*30,849.3*	---	*5,034.6*	---

Land cover in the Bodkin Creek Watershed is similar with approximately 45% classified as residential. But unlike the Patapsco Tidal Watershed, residential properties of 1 to 2 acres and larger are dominant. Woods are the single largest land cover category and make up 40.4% of total area in the Bodkin Creek watershed. Map 1.9 represents land cover in the two watersheds.

Impervious surfaces in the Patapsco Tidal Watershed cover 30 % of the area, with imperviousness in individual subwatersheds ranging from 6% to 48%. The Bodkin Creek Watershed is less impervious at 13%, with imperviousness in individual subwatersheds ranging from 5% to 19%. Impervious cover broken down by owner is shown in Map 1.10. Impervious cover by WIP sector ownership is summarized in Table 1.5.

The Patapsco Tidal and Bodkin Creek watersheds were initially developed in the 1780s. Since then, the two watersheds have experienced varying rates of development. Table 1.6 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 Bodkin Creek Watershed has occurred in the Main Creek Subwatershed (BK3). The Back Creek Subwatershed (BK2) has experienced increasing impervious surface creation over time, but not at the same pace as Main Creek. The table also shows how the Patapsco Tidal Watershed has experienced faster rates of new impervious surface development over time than the Bodkin Creek watershed. The Patapsco Tidal development rates in individual subwatersheds have peaked at varying times. In the Furnace Creek (PT5) and Sawmill Creek 1 (PT7) subwatersheds, the rates of development reached their maximum in the 1940s and 1950s. Stony Creek (PT0) has seen an increasing rate of development over time that peaked in the 1980s and 1990s. Stony Creek and Sawmill Creek (PT0 and PT7) had the greatest rates of development in the 2000s. Land development age and current zoning within the watersheds are shown on Maps 1.11 and 1.12, respectively.

Table 1.5 – 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
PATAPSCO TIDAL				
County - Commercial	1,605.2	964.2	60%	10%
County - Industrial	3,023.6	960.1	32%	10%
County - Maritime	50.7	24.3	48%	<1%
County - Mixed Use Transit	62.8	48.6	77%	1%
County - Natural Features	862.1	39.7	5%	<1%
County - Residential High Density	1,044.3	461.1	44%	5%
County - Residential Low - Medium Density	3,720.2	907.9	24%	10%
County - Residential Low Density	2,893.5	372.3	13%	4%
County - Residential Medium Density	5,553.7	1,474.1	27%	16%
County - Rural Agricultural	910.0	40.1	4%	0%
County - Small Business	9.1	2.6	29%	<1%
County - Town Center	39.6	35.1	89%	<1%
County - Utility/Transportation	227.8	61.8	27%	1%
County Board of Education	691.0	191.4	28%	2%
County Roads and Facilities	4,853.8	2,007.4	41%	22%
GOV - Government/Institution	323.4	64.9	20%	1%
Maryland Aviation Administration	1,553.4	499.2	32%	5%
Maryland Department of Transportation	443.8	78.6	18%	1%
Maryland DNR Lands	0.6	0	8%	<1%
Maryland State Highway Administration	2,279.4	945.8	41%	10%
Maryland State Institutional Lands	15.4	5.5	36%	<1%
Other DOD Facilities	479.6	69.8	15%	1%
US Coast Guard	107.1	65.7	61%	1%
US Postal Service	0.5	0.5	99%	<1%
TOTAL	*30,750.3*	*9,320.9*	*30%*	-
BODKIN CREEK				
County - Commercial	27.0	7.4	27%	1%
County - Maritime	14.3	9.5	66%	1%
County - Natural Features	114.8	0.8	1%	<1%
County - Residential Low - Medium Density	42.5	6.2	15%	1%
County - Residential Low Density	2576.3	312.8	12%	47%
County - Rural Agricultural	771.8	63.9	8%	10%
County - Utility/Transportation	8.8	2	22%	<1%
County Board of Education	196.2	41	21%	6%
County Roads and Facilities	1215.5	192.8	16%	29%
GOV - Government/Institution	19.8	4.7	24%	1%
Maryland State Highway Administration	34.7	17.7	51%	3%
TOTAL	*5,021.7*	*658.6*	*13%*	-

Table 1.6 – Rate of New Development

Subshed	1780 - 1899	1900 - 1919	1920 - 1939	1940 - 1959	1960 - 1979	1980 - 1999	2000 - 2011
PATAPSCO TIDAL							
PT0	0.003	0.177	1.015	5.314	6.46	9.296	5.104
PT1	0	0.088	0.62	2.293	0.965	0.577	0.43
PT2	0	0.074	0.278	2.392	0.673	0.117	0.463
PT3	0.046	0.087	0.704	5.633	6.622	3.904	0.834
PT4	0	0.026	0.001	0.096	0.051	1.447	2.299
PT5	0.008	0.06	0.514	8.912	5.913	3.488	2.829
PT6	0.046	0.093	0.411	1.571	4.135	2.088	2.368
PT7	0.032	0.143	1.243	9.375	8.348	6.687	4.902
PT8	0	0.348	0.104	2.58	2.201	1.844	1.228
PT9	0	0.019	0.024	0.286	0.215	7.061	0.744
PTA	0	0.007	0.28	1.024	0.656	0.117	0.067
PTB	0.017	0.313	0.371	4.086	3.88	7.092	2.977
PTC	0	0	0.002	0.882	1.575	9.445	4.703
PTD	0.077	0.086	0.42	1.779	1.731	5.042	3.225
PTE	0.014	0.006	0.232	2.56	0.824	0.685	0.313
PTF	0	0.045	0.147	10.593	6.055	6.927	3.304
PTG	0	0.063	0.1	1.029	12.244	5.98	2.171
PTH	0	0.2	0.253	0.55	0.284	1.108	1.416
PTI	0	0	0	0	0	0	0
PTJ	0	0	0	0	0	3.781	0
PTK	0	0	0	0	0	1.807	0
PTL	0	0.218	0.082	0.26	0.116	0.209	0.053
PTM	0	0.021	0.037	0.081	0.156	0.369	0.156
PTN	0	0.027	0.019	0.1	0.032	0.435	0.091
PTO	0	0.004	0.009	0.062	0.047	0.564	0.149
PTP	0.001	0.005	0.029	0.059	0.1	0.172	0.105
PTQ	0	0	0	0	0	0.056	0.02
BODKIN CREEK							
BK2	0.013	0.043	0.069	0.851	1.326	1.112	1.133
BK3	0.02	0.064	0.204	2.569	3.38	3.431	4.18
BK4	0	0.002	0.035	0.066	0.029	0.114	0.084
BK5	0	0	0.011	0.051	0.137	0.221	0.333
BK6	0	0	0	0	0.001	0	0
BK7	0.004	0	0.046	0.08	0.293	0.158	0.014
BK8	0	0.001	0.05	0.119	0.063	0.204	0.212
BK9	0	0.008	0.153	0.079	0.105	0.683	0.108

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 Patapsco Tidal and Bodkin Creek tributary stream network, 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 from April to July 2010. Additional existing data were also used to support the County's assessment efforts. This includes bioassessment monitoring results, land use cover, impervious areas, best management practices (BMPs) 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 Patapsco Tidal and Bodkin Creek 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 and formulating 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 Patapsco Tidal and Bodkin Creek 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 tidal portion of the Patapsco River and Bodkin Creek.

Field teams confirmed the location of the stream channel and made a determination of the stream character. Additions to and deletions from the existing stream planimetric dataset were recorded and updated 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 a number of 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 in the two watersheds, approximately 153 miles of streams were verified and characterized. The Patapsco Tidal Watershed contained approximately 135 miles of characterized streams, while the Bodkin Creek Watershed contained approximately 18 miles. In both watersheds, perennial streams were the most commonly encountered type of stream. Ephemeral streams were also widespread, particularly in the Patapsco Tidal Watershed 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 1,211 individual reaches were identified within the Patapsco Tidal Watershed. The average reach length was approximately 590 feet. Within the Bodkin Creek Watershed, 188 individual reaches were identified with an average length of 515 feet.

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

Table 2.1 – Stream Character Types

	Patapsco Tidal Watershed			Bodkin Creek Watershed		
Type	Number of Reaches	Stream Miles	Percent of Total Stream Miles	Number of Reaches	Stream Miles	Percent of Total Stream Miles
Ephemeral	454	47.8	35.3%	46	3.5	19.8%
Intermittent	102	10.5	7.7%	26	2.7	15.3%
Perennial	389	50.2	37.1%	59	7.5	42.4%
Pipe	56	8.0	5.9%	3	0.1	0.6%
Pond/Lake	36	5.2	3.8%	11	1.2	6.8%
SWM	29	3.1	2.3%	2	0.1	0.6%
Tidal	32	1.7	1.3%	7	0.2	1.1%
Unknown/No Access	---	---	---	2	0.1	0.6%
Wetland/Marsh	113	8.8	6.5%	32	2.3	13.1%
TOTAL	**1,211**	**135.3**	**---**	**188**	**17.7**	**---**

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 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
PATAPSCO TIDAL							
PT0	104	24	11	10	5	0	154
PT1	1	0	0	0	0	0	1
PT2	13	2	0	12	0	0	27
PT3	128	12	10	7	0	0	157
PT4	19	2	0	0	0	0	21
PT5	51	9	0	17	0	0	77
PT6	23	9	0	0	0	0	32
PT7	63	13	11	13	9	0	109
PT8	45	18	0	0	0	0	63
PT9	17	7	0	0	0	0	24
PTA	8	0	0	0	0	0	8
PTB	49	24	9	8	0	0	90
PTC	38	6	1	0	0	0	45
PTD	37	23	22	1	0	0	83
PTE	6	0	0	1	0	0	7
PTF	42	7	3	11	8	2	73
PTG	67	33	30	14	9	0	153
PTH	47	3	0	0	0	0	50
PTI	4	0	0	0	0	0	4
PTJ	3	0	0	0	0	0	3
PTM	11	5	0	0	0	0	16
PTN	4	0	0	0	0	0	4
PTO	5	0	0	0	0	0	5
PTP	4	1	0	0	0	0	5
TOTAL	**789**	**198**	**97**	**94**	**31**	**2**	**1211**
BODKIN CREEK							
BK2	14	8	2	0	0	0	24
BK3	60	29	12	5	0	0	106
BK5	4	0	0	0	0	0	4
BK7	10	0	0	6	0	0	16
BK8	18	2	0	0	0	0	20
BK9	14	4	0	0	0	0	18
TOTAL	**43**	**43**	**14**	**11**	**0**	**0**	**188**

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 is typically comprised of 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 increased urban and agricultural stressors are introduced. Examples of assessed stream reaches are depicted in Figure 2.1.

Figure 2.1 – Examples of Assessed Stream Reaches

Stream Reach in the Hines Bog Pond Subwatershed (PTM) with Minimally Degraded Habitat Condition

Stream Reach in the Main Creek Subwatershed (BK3) with Minimally Degraded Habitat Condition

Concrete-lined Stream Reach in the Cabin Branch 2 Subwatershed (PT2)

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 Freshwater Wadeable Streams in Maryland* report developed by 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, 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 both watersheds, approximately 2.3 miles of perennial stream reaches were not assessed due to access issues or due to individual reach lengths being less than the minimum assessment size requirement (75 meters). For the Patapsco Tidal Watershed, approximately 48 of the 50 miles of perennial streams were assessed and scored. The aggregate assessed perennial stream length is comprised of 342 individual reaches with an average assessed stream reach length of approximately 743 feet. For the Bodkin Creek Watershed, approximately 7.3 of the 7.5 perennial stream miles were assessed and scored. In this watershed, there were 54 individual assessed perennial stream reaches with an average length of 713 feet.

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 stream-weighted MPHI score for the Patapsco Tidal Watershed is 71.2, which corresponds to a "Partially Degraded" condition. Approximately 55% of perennial stream miles in the watershed were rated as "Partially Degraded." "Minimally Degraded" and "Severely Degraded" streams both comprised roughly 16% of the perennial streams, followed by "Degraded" streams at 12%. The Cabin Branch 2, Marley Creek 1, and Cabin Branch subwatersheds had the highest percentages of stream reaches that are either "Degraded" or "Severely Degraded" at 44%, 34%, and 29%, respectively. The Stony Creek and Curtis Creek subwatersheds had the highest percentage of reaches that were considered "Minimally Degraded" with 57% and 48%, respectively.

For the Bodkin Creek Watershed, the average stream-weighted MPHI score is 78.2, which corresponds to a "Partially Degraded" condition. Approximately 54% of perennial stream miles in the watershed were rated as "Partially Degraded" and 43% were rated as "Minimally Degraded." "Degraded" streams comprised only 2% of the stream miles in the watershed. No streams were rated "Severely Degraded." The Main Creek subwatershed had the highest percentage of perennial stream reaches that were considered "Minimally Degraded" with 66%, but also had the only reaches considered "Degraded" in the whole watershed.

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 watershed is presented as Map 2.3.

Table 2.3 – Physical Habitat Condition Results, MPHI

MPHI Category[1]	Patapsco Tidal Watershed			Bodkin Creek Watershed		
	Number of Reaches	Stream Miles	Percent of Total Stream Miles	Number of Reaches	Stream Miles	Percent of Total Stream Miles
Minimally Degraded	61	7.9	16.4%	24	3.2	43.2%
Partially Degraded	187	26.7	55.4%	28	4.0	54.4%
Degraded	41	5.7	11.8%	2	0.2	2.4%
Severely Degraded	53	7.9	16.4%	0	0	0%
TOTAL	342	48.1	---	54	7.3	---

[1] Using modified MPHI categories as described above.

2.1.3 Inventory of Infrastructure and Environmental Features

Being aware of and knowledgeable about infrastructure and other environmental features observed along streams is very important for assessment of current conditions. For this reason, fieldwork included an inventory of infrastructure and significant environmental features that was compiled within each perennial reach and associated riparian area. These features included riparian buffer deficiencies, excessive in-stream erosion, stream obstructions, stream crossings, utilities, dumpsites, 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, 2010). 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 natural vegetated **stream buffers** provide important terrestrial habitat and shading 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, 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, and fish passage impediments.

- **Dumpsites** 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 other nearby built 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 Tables 2.4 and 2.5. The distribution of these features throughout the watershed is presented in Map 2.4. For both watersheds, riparian buffer impacts and erosion impacts had 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). Pipes and drainage ditches that contribute flow and erosive forces to the watersheds' streams were the most numerous of all the features, but had relatively lower cumulative impact scores. The relative abundance of these infrastructure features (*i.e.*, erosion, crossings, deficient buffers, and pipes and ditches) is consistent with more urbanized watersheds like the Patapsco Tidal and Bodkin Creek. The remaining features (*i.e.*, dumpsites, obstructions, utilities, and head cuts) 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: Minor	Moderate	Severe	Extreme	Total Cumulative Impact Score
PATAPSCO TIDAL WATERSHED					
Buffers	---	321	102	5	2,369
Crossings	297	47	7	1	888
Dumpsites	63	32	3	---	253
Erosion	---	256	99	7	2,043
Obstructions	133	48	10	---	606
Pipes/Ditches	754	89	29	---	735
Utilities	35	14	0	8	220
Head Cuts	---	---	---	---	349.9
TOTAL	**1,282**	**807**	**250**	**21**	**7,463.9**
BODKIN CREEK WATERSHED					
Buffers	---	37	6	0	227
Crossings	47	3	0	1	119
Dumpsites	5	1	0	---	10
Erosion	---	21	4	0	133
Obstructions	5	1	1	---	25
Pipes/Ditches	60	2	1	---	20
Utilities	1	0	0	0	2
Head Cuts	---	---	---	---	27.5
TOTAL	**118**	**65**	**12**	**1**	**563.5**

* Head cut impact score corresponds to cumulative height of head cuts
--- Not considered as an impact score for associated feature

Figure 2.2 – Examples of Environmental and Infrastructure Features

Crossing in the Cabin Brach Subwatershed (PT3) with Moderate Impact Score

Deficient Buffer in the Sawmill Creek 1 Subwatershed (PT7) with Moderate Impact Score

Bank Erosion in the Furnace Creek Subwatershed (PT5) with Moderate Impact Score

Outfall in the Marley Creek 4 Subwatershed (PTG) with Moderate Impact Score

Washdown from Dumpsite in the Furnace Creek Subwatershed (PT5)

Exposed Utility in the Rock Creek Subwatershed (PTB) with Moderate Impact Score

Table 2.5 – Infrastructure and Environmental Features Per Stream Mile

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
PATAPSCO TIDAL WATERSHED					
PT0	14.6	337	23.0	983	67.1
PT2	2.0	88	43.1	304	148.6
PT3	16.7	350	21.0	1114	66.8
PT4	3.3	17	5.2	45	13.8
PT5	7.0	122	17.5	313	44.9
PT6	3.2	52	16.2	204	63.6
PT7	13.9	242	17.5	692	49.9
PT8	8.2	139	17.0	474	57.9
PT9	2.1	27	12.9	66	31.6
PTA	0.6	13	20.9	0	0.0
PTB	7.5	169	22.4	541	71.7
PTC	4.8	75	15.7	172	36.0
PTD	13.3	107	8.0	292	21.8
PTE	0.6	14	23.2	38	63.0
PTF	11.4	217	19.0	619	54.2
PTG	16.5	451	27.3	1358	82.2
PTH	4.1	59	14.4	208	50.5
PTI	0.5	1	2.0	0	0.0
PTJ	0.8	0	0.0	0	0.0
PTM	1.6	9	5.5	25	15.3
PTN	0.4	2	4.8	0	0.0
PTO	0.7	4	5.4	10	13.5
PTP	1.1	2	1.8	2	1.8
TOTAL	135.3	2500.0	18.5	7464	55.2
BODKIN CREEK WATERSHED					
BK2	2.7	36	13.3	113	41.5
BK3	10.9	110	10.1	267	24.5
BK5	0.2	2	9.0	3	13.5
BK7	0.9	20	21.5	60	64.4
BK8	1.7	18	10.3	43	24.7
BK9	1.2	23	18.7	79	63.8
TOTAL	17.7	209.0	11.8	564	31.9

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., 2006):

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

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 presented in Map 2.5. All of the subwatersheds in the Bodkin Creek Watershed and 75% of the subwatersheds in the Patapsco Tidal Watershed are considered "Partially Degraded." Two subwatersheds, Cabin Branch (PT2) and Cabin Branch 2 (PT3) in the Patapsco Tidal Watershed, were rated as "Severely Degraded."

Table 2.6 – Final Habitat Scores at Subwatershed Level

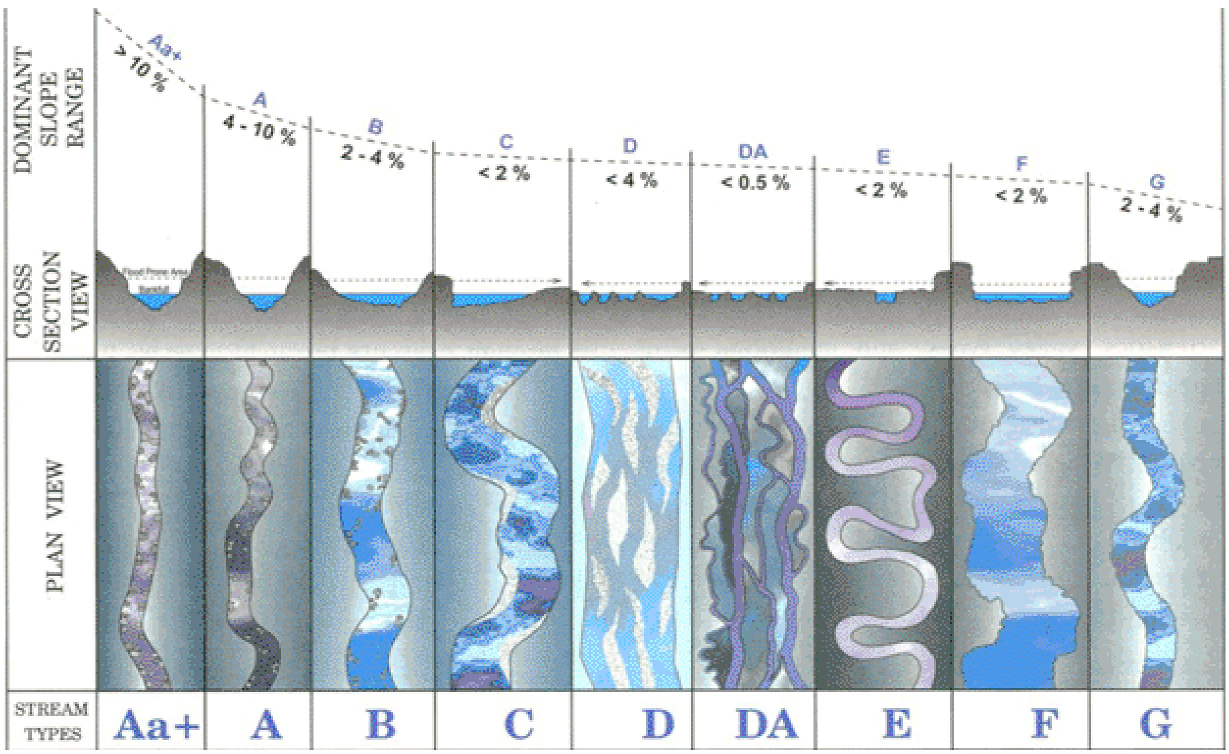
Rating	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Minimally Degraded	0	0%	0	0%
Partially Degraded	12	75.0%	5	100%
Degraded	2	12.5%	0	0%
Severely Degraded	2	12.5%	0	0%
TOTAL	**16**	**---**	**5**	**---**

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 through 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 to actively erode down 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 Patapsco Tidal and Bodkin Creek 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.

The distribution of Rosgen Level I classifications across the watershed is summarized in Table 2.7 and depicted in Map 2.6. As shown, approximately 33% and 38% of single-threaded stream miles were classified as Type "B" channels for the Patapsco Tidal Watershed and the Bodkin Creek Watershed, respectively. Type "B" channels are typically characterized as predominantly stable, moderate gradient channels, with low sinuosity and low erosion rates. Approximately 32% of stream miles in the Patapsco Tidal Watershed and 16% in the Bodkin Creek Watershed were classified as Type "F" and "G" channels, which are incised channels with high erosion rates.

Table 2.7 – Rosgen Level I Classifications

Classification	Patapsco Tidal Watershed			Bodkin Creek Watershed		
	Number of Reaches	Stream Miles	Percent of Total Stream Miles	Number of Reaches	Stream Miles	Percent of Total Stream Miles
A	15	1.4	1.9%	3	0.3	3.4%
B	220	24.7	33.2%	32	3.2	37.9%
C	146	20.2	27.1%	21	2.5	29.6%
D	21	2.9	3.9%	3	0.3	3.3%
DA	7	1.3	1.7%	1	0.3	3.7%
E	4	0.2	0.3%	3	0.5	6.4%
F	97	12.1	16.3%	7	0.6	6.8%
G	126	11.6	15.6%	8	0.8	8.9%
TOTAL	636	74.4	---	78	8.5	---

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 the potential to isolate properties from emergency vehicle access. Roadway stream crossings throughout both the Patapsco Tidal and Bodkin Creek 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. Twelve 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 twelve 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 NRCS's 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 Patapsco Tidal Watershed, crossing PT8030.C001 was found to have an overtopping return frequency of less than two years. Overtopping return periods between two and ten years were calculated for four of the Patapsco Tidal crossings (PT8045.C001, PTG067.C001, PTG070.C001, and PTG096.C001). Of less concern in the Patapsco Tidal Watershed are the crossings with calculated overtopping return periods of ten years (PTG068.C001) and greater than 100 years (PTG071.C001, PTG102.C001, and PTG083.C001). In the Bodkin Creek Watershed, crossing BK2006.C001 was determined to have an overtopping return period of more than 100 years. BK2013.C001 poses a much greater risk of overtopping with a return period of between two and ten 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		
Bayside Beach Rd (BK2013.C001)	0.080	0	2	21	64	6	Between 2 and 10 years
Bayside Beach Rd (BK2006.C001)	0.074	0	0	1	7	16	More than 100 years
Marley Neck Rd (PT8045.C001)	0.428	23	43	133	263	119	Between 2 and 10 years
Marley Neck Rd (PT8030.C001)	0.571	42	70	186	342	51	Less than 2 years
Phirne Rd E (PTG067.C001)	1.127	292	436	944	1572	663	Between 2 and 10 years
Phirne Rd E (PTG071.C001)	0.044	6	13	41	81	130	More than 100 years
Nolcrest Rd (PTG070.C001)	0.147	66	104	246	425	130	Between 2 and 10 years
Phirne Rd E (PTG068.C001)	0.166	67	105	247	425	288	Between 10 and 100 years
Kramer Ct (PTG096.C001)	0.514	178	262	553	909	275	Between 2 and 10 years
Green Branch Ln (PTG102.C001)	0.214	64	98	220	372	455	More than 100 years
Phirne Rd E (PTG083.C001)	0.163	74	108	229	376	803	More than 100 years

2.1.7 Bioassessment

Anne Arundel County has conducted both random and targeted biological monitoring of streams in the Patapsco Tidal and Bodkin Creek Watersheds. Random samples were collected in 2006 in Bodkin Creek Watershed and in 2006 and 2008 in Patapsco Tidal Watershed (Stribling et al., 2008, Victoria et al., 2010). Targeted sampling was also conducted in 2009 in Patapsco Tidal and Bodkin Creek watersheds to supplement the random sampling program. The full 2009 targeted sampling summary report (Roth et al., 2009) is included as Appendix B.

Benthic monitoring was conducted during the MBSS spring index period (March 1 – April 30) and employed the stream sampling methods specified in the County's SAP (Tetra Tech, 2007), which closely follows the MBSS protocols (DNR, 2007). At each 75-m sample site, benthic macroinvertebrates were collected using a D-net to collect organisms from a combination of habitats that support the most diverse macroinvertebrate community within a sample segment as per MBSS protocols. At each site, 20 "jabs" of the net 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 per site, which were preserved in the field for laboratory identification.

In the lab, benthic samples were subsampled and sorted, and oligochaetes and chironomids were permanent slide-mounted to allow identification to genus level (family level for oligochaetes) according to the County's SAP (Tetra Tech, 2007) 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 Benthic Index of Biotic Integrity (BIBI) (Southerland et al., 2007). Metrics included in this IBI 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 in a SAS program 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 Patapsco Tidal Watershed, BIBI scores ranged from a low of 1.29 (Very Poor) to a high of 4.14 (Good) (Table 2.12). Combining the BIBI results from the targeted and random sampling events, the greatest number of sites (29 out of 65, or 45%) rated "Poor." An additional 20 sites (31%) rated "Very Poor," while 15 sites (23%) rated "Fair." Only one site, a targeted site on Sawmill Creek, rated "Good." In Bodkin Creek, BIBI scores ranged from a low of 1.57 (narrative rating of Very Poor) to a high of 3.57 (Fair) (Table 2.13). Combining the BIBI results from the targeted and random sampling events, half of the 20 sites (50%) rated "Poor," 5 sites rated "Very Poor," and the remaining 5 sites rated "Fair." See Map 2.8 for bioassessment sample locations and results.

Table 2.12 – Summary of Bioassessment Data in the Patapsco Tidal Watershed

Site	Shed Code	Subwatershed	Survey, Year	BIBI Score	BIBI Narrative Rating
AA_2006_05-02	PT5	Furnace Creek	Random, 2006	1.57	Very Poor
AA_2006_05-04	PTG	Marley Creek 4	Random, 2006	2.71	Poor
AA_2006_05-06	PT8	Marley Creek 1	Random, 2006	3.29	Fair
AA_2006_05-07	PT5	Furnace Creek	Random, 2006	2.14	Poor
AA_2006_05-08	PT0	Stony Creek	Random, 2006	2.71	Poor
AA_2006_05-09	PTG	Marley Creek 4	Random, 2006	2.14	Poor
AA_2006_05-10	PTF	Marley Creek 3	Random, 2006	3	Fair
AA_2006_05-11A	PT8	Marley Creek 1	Random, 2006	2.43	Poor

Table 2.12 – Summary of Bioassessment Data in the Patapsco Tidal Watershed

Site	Shed Code	Subwatershed	Survey, Year	BIBI Score	BIBI Narrative Rating
AA_2006_05-13A	PTG	Marley Creek 4	Random, 2006	2.43	Poor
AA_2006_05-15A	PT0	Stony Creek	Random, 2006	3.29	Fair
AA_2008_04-01	PTD	Sawmill Creek 2	Random, 2008	2.43	Poor
AA_2008_04-06	PT3	Cabin Branch	Random, 2008	1.29	Very Poor
AA_2008_04-07	PT3	Cabin Branch	Random, 2008	1.29	Very Poor
AA_2008_04-08	PT7	Sawmill Creek	Random, 2008	1.86	Very Poor
AA_2008_04-09	PT7	Sawmill Creek	Random, 2008	2.14	Poor
AA_2008_04-10	PT7	Sawmill Creek	Random, 2008	2.14	Poor
AA_2008_04-12A	PTD	Sawmill Creek 2	Random, 2008	2.14	Poor
AA_2008_04-13A	PTD	Sawmill Creek 2	Random, 2008	1.86	Very Poor
AA_2008_04-15A	PTD	Sawmill Creek 2	Random, 2008	2.14	Poor
AA_2008_04-20A	PT7	Sawmill Creek	Random, 2008	1.86	Very Poor
PT0-911-T-2009	PT0	Stony Creek	Targeted, 2009	2.43	Poor
PT0-916-T-2009	PT0	Stony Creek	Targeted, 2009	3.57	Fair
PT0-917-T-2009	PT0	Stony Creek	Targeted, 2009	3	Fair
PT0-925-T-2009	PT0	Stony Creek	Targeted, 2009	1.86	Very Poor
PT0-940-T-2009	PT0	Stony Creek	Targeted, 2009	2.14	Poor
PT2-949-T-2009	PT2	Cabin Branch 2	Targeted, 2009	1.57	Very Poor
PT2-950-T-2009	PT2	Cabin Branch 2	Targeted, 2009	2.71	Poor
PT3-944-T-2009	PT3	Cabin Branch	Targeted, 2009	1.86	Very Poor
PT3-947-T-2009	PT3	Cabin Branch	Targeted, 2009	2.14	Poor
PT3-948-T-2009	PT3	Cabin Branch	Targeted, 2009	2.43	Poor
PT5-929-T-2009	PT5	Furnace Creek	Targeted, 2009	1.57	Very Poor
PT5-931-T-2009	PT5	Furnace Creek	Targeted, 2009	1.29	Very Poor
PT6-943-T-2009	PT6	Curtis Creek	Targeted, 2009	2.14	Poor
PT6-945-T-2009	PT6	Curtis Creek	Targeted, 2009	2.71	Poor
PT7-932-T-2009	PT7	Sawmill Creek	Targeted, 2009	1.29	Very Poor
PT7-934-T-2009	PT7	Sawmill Creek	Targeted, 2009	3	Fair
PT7-936-T-2009	PT7	Sawmill Creek	Targeted, 2009	1.86	Very Poor
PT7-938-T-2009	PT7	Sawmill Creek	Targeted, 2009	2.43	Poor
PT8-923-T-2009	PT8	Marley Creek 1	Targeted, 2009	1.57	Very Poor
PT8-927-T-2009	PT8	Marley Creek 1	Targeted, 2009	1.86	Very Poor
PT8-937-T-2009	PT8	Marley Creek 1	Targeted, 2009	3.57	Fair
PT9-933-T-2009	PT9	Cox Creek	Targeted, 2009	2.71	Poor
PT9-935-T-2009	PT9	Cox Creek	Targeted, 2009	2.71	Poor
PTB-909-T-2009	PTB	Rock Creek	Targeted, 2009	2.14	Poor
PTB-910-T-2009	PTB	Rock Creek	Targeted, 2009	2.43	Poor
PTB-918-T-2009	PTB	Rock Creek	Targeted, 2009	2.14	Poor
PTC-941-T-2009	PTC	Back Creek	Targeted, 2009	1.57	Very Poor

Table 2.12 – Summary of Bioassessment Data in the Patapsco Tidal Watershed

Site	Shed Code	Subwatershed	Survey, Year	BIBI Score	BIBI Narrative Rating
PTC-942-T-2009	PTC	Back Creek	Targeted, 2009	1.86	Very Poor
PTD-922-T-2009	PTD	Sawmill Creek 2	Targeted, 2009	4.14	Good
PTD-924-T-2009	PTD	Sawmill Creek 2	Targeted, 2009	3.57	Fair
PTD-928-T-2009	PTD	Sawmill Creek 2	Targeted, 2009	2.43	Poor
PTF-915-T-2009	PTF	Marley Creek 3	Targeted, 2009	2.14	Poor
PTG-903-T-2009	PTG	Marley Creek 4	Targeted, 2009	3.86	Fair
PTG-905-T-2009	PTG	Marley Creek 4	Targeted, 2009	1.57	Very Poor
PTG-908-T-2009	PTG	Marley Creek 4	Targeted, 2009	3.57	Fair
PTG-939-T-2009	PTG	Marley Creek 4	Targeted, 2009	3	Fair
PTH-926-T-2009	PTH	Nabbs Creek	Targeted, 2009	2.14	Poor
PTH-930-T-2009	PTH	Nabbs Creek	Targeted, 2009	1.57	Very Poor
PTM-920-T-2009	PTM	Hines Bog Pond	Targeted, 2009	1.57	Very Poor
PTM-921-T-2009	PTM	Hines Bog Pond	Targeted, 2009	2.71	Poor
PTN-919-T-2009	PTN	Hines Bog	Targeted, 2009	3	Fair
Duplicate Sites for QC					
PT0-D17-T-2009	PT0	Stony Creek	Targeted, 2009	3.57	Fair
PT3-D47-T-2009	PT3	Cabin Branch	Targeted, 2009	2.43	Poor
PTF-D15-T-2009	PTF	Marley Creek 3	Targeted, 2009	3	Fair
PTG-D39-T-2009	PTG	Marley Creek 4	Targeted, 2009	3.29	Fair

Table 2.13 – Summary of Bioassessment Data in the Bodkin Creek Watershed

Site	Shed Code	Subwatershed	Survey, Year	BIBI Score	BIBI Narrative Rating
AA_2006_06-02	BK3	Main Creek	Random, 2006	2.71	Poor
AA_2006_06-03	BK3	Main Creek	Random, 2006	1.57	Very Poor
AA_2006_06-04	BK3	Main Creek	Random, 2006	2.71	Poor
AA_2006_06-05	BK3	Main Creek	Random, 2006	3.29	Fair
AA_2006_06-08	BK3	Main Creek	Random, 2006	3.00	Fair
AA_2006_06-09	BK3	Main Creek	Random, 2006	1.86	Very Poor
AA_2006_06-10	BK3	Main Creek	Random, 2006	2.71	Poor
AA_2006_06-11A	BK3	Main Creek	Random, 2006	1.57	Very Poor
AA_2006_06-12A	BK3	Main Creek	Random, 2006	2.71	Poor
AA_2006_06-13A	BK3	Main Creek	Random, 2006	2.14	Poor
BK2-912-T-2009	BK2	Back Creek	Targeted, 2009	3.29	Fair
BK2-913-T-2009	BK2	Back Creek	Targeted, 2009	2.43	Poor
BK2-914-T-2009	BK2	Back Creek	Targeted, 2009	2.43	Poor
BK3-904-T-2009	BK3	Main Creek	Targeted, 2009	3.57	Fair
BK3-906-T-2009	BK3	Main Creek	Targeted, 2009	3.29	Fair

Table 2.13 – Summary of Bioassessment Data in the Bodkin Creek Watershed

Site	Shed Code	Subwatershed	Survey, Year	BIBI Score	BIBI Narrative Rating
BK3-907-T-2009	BK3	Main Creek	Targeted, 2009	2.71	Poor
BK3-946-T-2009	BK3	Main Creek	Targeted, 2009	2.43	Poor
BK7-902-T-2009	BK7	Wharf Creek	Targeted, 2009	1.86	Very Poor
BK8-901-T-2009	BK8	Locust Cove	Targeted, 2009	1.86	Very Poor
Duplicate Sites for QC					
BK3-D07-T-2009	BK3	Main Creek	Targeted, 2009	2.71	Poor

Overall, BIBI results indicated that benthic macroinvertebrate communities have been degraded to a great degree in many areas across the Patapsco Tidal and Bodkin Creek watersheds. The overwhelming majority of sites sampled in both watersheds were rated either “Poor” or “Very Poor” (Figures 2.4 and 2.5). There is a good deal of consistency over time in the proportion of sites in each of the categories. The percentages described above for the entire datasets follow fairly closely the patterns displayed by each year in each watershed. Poor to Very Poor scores were not restricted to a certain portion of the watersheds, but were observed in many subwatersheds throughout Patapsco Tidal and Bodkin Creek. Many of the targeted sites sampled in 2009 were characterized by low Percent Ephemeroptera, Number of Ephemeroptera Taxa, Number of EPT Taxa, and Percent Intolerant Urban (Roth et al., 2009). Other data examined in the 2009 report suggested that water quality degradation, in addition to habitat condition, was likely affecting stream biological integrity. The results of the targeted sampling in 2009 are consistent with the prior random assessments performed in both the Bodkin Creek (Stribling et al., 2008) and Patapsco Tidal (Victoria et al., 2010) watersheds.

Figure 2.4 – Bioassessment Ratings in the Patapsco Tidal Watershed by Year and Study

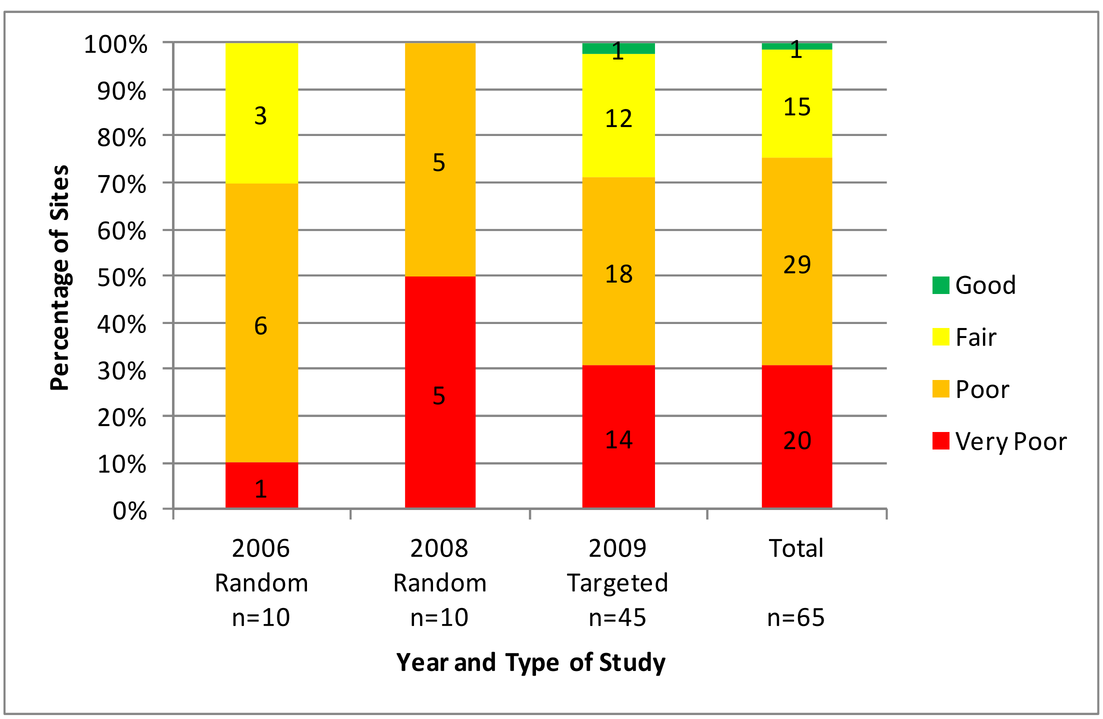
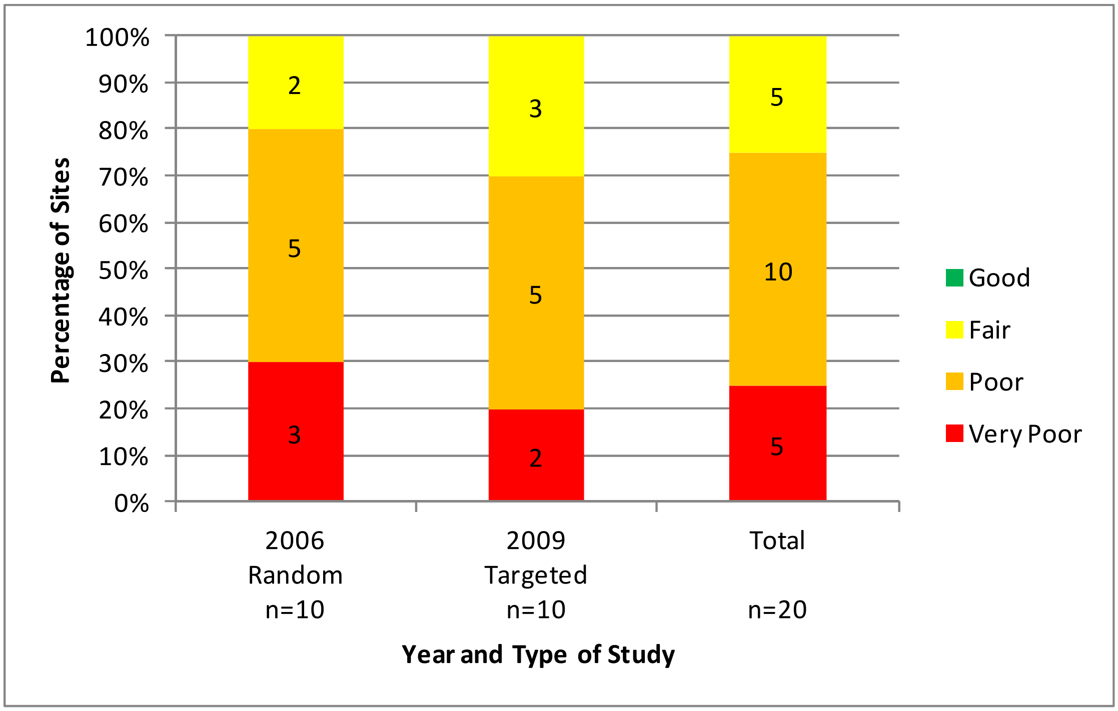


Figure 2.5 – Bioassessment Ratings in the Bodkin Creek Watershed by Year and Study



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 the Patapsco Tidal and Bodkin Creek Watersheds 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 Patapsco Tidal Watershed has no subwatersheds with aquatic resource indicators rated as "High" or "Medium High." A total of 63%, or 17 of the subwatersheds, are rated in the "Low" category of aquatic resource indicators. A minority of subwatersheds (10) have been rated as "Medium" for aquatic resource Indicators. A similar situation is seen in the Bodkin Creek Watershed where five subwatersheds are rated in the "Low" category (71%). The remaining two subwatersheds are rated in the "Medium" category. See Map 2.9 for the aquatic resource ratings across all the study subwatersheds. A summary of aquatic resource ratings is provided in Table 2.14.

Table 2.14 – Aquatic Resource Indicator Ratings

Rating	Patapsco Tidal Watershed		Bodkin Creek 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	10	37%	2	29%
Low	17	63%	5	71%
TOTAL	27	---	7	---

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 Patapsco Tidal and Bodkin Creek tributary streams. This information is crucial for determining the land use conditions that influence the health of the tributary streams and the tidal portion of the Patapsco River and Bodkin Creek. 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 watershed.

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% tributary 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 2007 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 69% of the stream reaches in the Patapsco Tidal Watershed were rated “Non-supporting.” Similarly, only 7% of the Bodkin Creek Watershed stream reaches were “Non-supporting.” This disparity is consistent with the relative degrees of urbanization within both watersheds. A summary of impervious cover ratings is provided in Table 2.15. As described earlier, a map depicting impervious cover throughout the watershed is presented in Map 1.10.

Table 2.15 – Impervious Cover Ratings

CWP Rating Category (% impervious cover)	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Number of Reaches	Percent of Reaches	Number of Reaches	Percent of Reaches
Sensitive (0-10%)	19	6%	12	22%
Impacted (10-19%)	44	13%	32	59%
Impacted (19-25%)	42	12%	6	11%
Non-supporting (>25%)	237	69%	4	7%
TOTAL	342	---	54	---

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 these BMPs triggered by development or redevelopment, the County also regularly implements BMP retrofits of publicly owned property as part of its capital improvement program and its watershed management planning activities.

To facilitate understanding of the level of stormwater management provided by BMPs in both study watersheds, a spatially-accurate GIS inventory dataset was developed for all existing public and private stormwater BMPs. This analysis is critical for identifying areas within the watershed 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. 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. 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 Patapsco Tidal and Bodkin Creek 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 1,578 BMPs were confirmed to be located within the Patapsco Tidal and Bodkin Creek watersheds as part of the compilation and research process. The sum of the drainage areas for these BMPs is 6,096 acres. A breakdown of BMP types and their drainage areas is presented in Table 2.16. A map of BMPs located throughout the watershed is presented as Map 2.10.

Table 2.16 – 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)
Detention Dry	105	7%	1,684.8	28%	16.0	0.042	386.3
Extended Detention Dry	98	6%	839.2	14%	8.6	0.019	166.9
Filtration	94	6%	505.1	8%	5.4	0.005	340.9
Infiltration	1,153	73%	837.0	14%	0.7	0.001	39.1
Wet Ponds	116	7%	2,167.9	35%	18.7	0.023	272.5
Wetlands	12	1%	75.8	1%	6.3	0.101	31.7
TOTAL	**1,578**	**100%**	**6,109.8**	**100%**	**3.9**	**0.001**	**386.3**

Approximately 6,110 acres or 17% of the area of the Patapsco Tidal and Bodkin Creek watersheds 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 0.001 to 386 acres, with an average drainage area of 3.9 acres, and a median drainage area of 0.09 acres. This indicates that many of the BMPs are small in size.

The stormwater BMPs in the Patapsco Tidal and Bodkin Creek watersheds 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 2.17. The majority of the BMPs in the watershed (78%) are privately owned. Publicly owned BMPs comprise another 16% of the BMPs. However, when evaluated by the percent of the drainage area that they manage or treat in the watershed, private BMPs cover 38% and public BMPs cover 39% of the managed area. Many of the privately-owned BMPs are dry wells that serve to manage runoff from single rooftops or other impervious areas associated with residential properties.

Table 2.17 – 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	1,232	78%	2,292.8	38%	1.9	0.001	386.3
Public (DPW)	258	16%	2,369.7	39%	9.2	0.004	141.8
Public (non-DPW)	22	1%	578.7	9%	26.3	0.084	140.1
Unknown	66	4%	868.6	14%	13.2	0.002	272.5
TOTAL	**1,578**	**100%**	**6,109.8**	**100%**	**3.9**	**0.001**	**386.3**

2.2.3 Onsite Sewage Disposal Systems

OSDSs or 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 Patapsco Tidal and Bodkin Creek watersheds.

The 2008 OSDS study noted that the Patapsco Tidal Watershed has approximately 2,163 OSDSs, which represents approximately 5% of the OSDS County-wide. The Bodkin Creek watershed has approximately 3,093 OSDSs, representing approximately 8% of the OSDS County wide. These systems contribute approximately 50,000 and 67,800 lbs of total nitrogen annually to streams within the Patapsco Tidal and Bodkin Creek watersheds respectively. 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 (WRF) (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 Patapsco Tidal Watershed, approximately 61% of OSDSs are recommended for connection to a sewer extension, 22% are recommended for cluster treatment, and 6% 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 76% or 38,000 pounds per year. In the Bodkin Creek Watershed, less than 1% of OSDSs are recommended for connection to a sewer extension, 77% are recommended for cluster treatment, and 23% are recommended for enhanced nitrogen removal upgrades at individual OSDS. The implementation of all treatment options in the Bodkin Creek Watershed would be expected to reduce total nitrogen from OSDSs by approximately 76% or 51,600 pounds per year. A map of OSDS locations and the areas associated with treatment recommendations is presented in Map 2.11.

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 prioritized 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 subwatershed. A breakdown of ratings for total nitrogen loading from OSDSs for the Patapsco Tidal and Bodkin Creek subwatersheds is presented in Table 2.18 and in Map 2.11. Approximately 18% of subwatersheds within the Patapsco Tidal Watershed are rated "Very Poor" or "Poor." Collectively, the estimated annual total nitrogen contribution from these subwatersheds is 42,756 lbs/year. This is approximately 67% of the watershed-wide total nitrogen contribution from OSDSs. In the Bodkin Creek Watershed, approximately 25% of the subwatersheds are rated as "Very Poor". These subwatersheds have an estimated annual total nitrogen contribution of 44,434 lbs/year. This represents 82% of the total nitrogen contribution from OSDSs in the entire watershed.

It should be noted that a Watershed Implementation Plan is being developed under a separate study that addresses OSDSs and their loadings related to the Chesapeake Bay TMDL.

Table 2.18 – Total Annual Nitrogen Load Rating from OSDS

Rating	Patapsco Tidal		Bodkin Creek	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Very Poor	3	11%	2	25%
Poor	2	7%	0	0%
Fair	11	41%	4	50%
Good	11	41%	2	25%
TOTAL	**27**	**-**	**8**	**-**

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. The County uses these soil erodibility factors to identify areas susceptible to soil erosion as part of its subwatershed preservation assessment.

Subwatersheds are prioritized "Good," "Fair," "Poor," or "Very Poor" based on natural breaks in soil erodibility factor data across subwatersheds. A summary of subwatershed ratings for soil erodibility is presented in Table 2.19 and depicted in Map 2.12.

For the Patapsco Tidal Watershed, 37% of the subwatersheds are rated as "Poor" for soil erodibility. Subwatersheds with "Fair" ratings are the second most prevalent in the watershed. 19% of the subwatersheds are rated as "Good" and only 15% of the subwatersheds fall into the “Very Poor” category for soil erodibility. In the Bodkin Creek Watershed, the majority of soils are rated at “Fair” (57%). One subwatershed is rated in each of the remaining three categories.

Table 2.19 – Subwatershed Ratings for Soil Erodibility

Rating	Patapsco Tidal		Bodkin Creek	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Very Poor	4	15%	1	14%
Poor	10	37%	1	14%
Fair	8	30%	4	57%
Good	5	19%	1	14%
TOTAL	**27**	**---**	**7**	**---**

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 Patapsco Tidal and Bodkin Creek 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” based on natural breaks in the data. Summaries of these ratings for the Patapsco Tidal and Bodkin Creek subwatersheds are presented in Tables 2.20 and 2.21 and depicted on Maps 2.13, 2.14, and 2.15.

In the Patapsco Tidal watershed, the impervious cover indicator had a majority of subwatersheds rated as very poor. 96% of the subwatersheds fit into the good category for the percent of forest within the 100-foot stream buffer. The ratio of existing wetlands to potential wetlands was fairly evenly distributed except for 44% of the subwatersheds which were classified as “Fair.” The majority (70%) of the subwatersheds had acres of developable lands within the Critical Area that rated them as “Good” or “Fair”.

Table 2.20 – Landscape Indicator Ratings (Subwatershed Restoration)

Rating	Patapsco Tidal		Bodkin Creek	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Percent Impervious Cover				
Good	1	4%	4	50%
Fair	9	33%	4	50%
Poor	2	7%	0	0%
Very Poor	15	56%	0	0%
Percent Forest within the 100-foot Stream Buffer				
Good	24	96%	0	0%
Fair	0	0%	3	50%
Poor	0	0%	3	50%
Very Poor	1	4%	0	0%
Ratio of Existing to Potential Wetlands				
Good	5	19%	1	13%
Fair	12	44%	2	25%
Poor	6	22%	3	38%
Very Poor	4	15%	2	25%
Acres of Developable Critical Area				
Good	9	33%	5	63%
Fair	10	37%	1	13%
Poor	4	15%	2	25%
Very Poor	4	15%	0	0%

For the Bodkin Creek Watershed, subwatersheds were either “Fair” or “Good” in terms of the impervious cover indicator. Based on the percent of forest within the 100-foot stream buffer, Bodkin Creek subwatersheds were either “Fair” or “Poor”. The existing wetlands to potential wetlands indicator has most of the subwatersheds classified a “Poor”. The rest of subwatersheds are distributed between the other categories. A majority of the subwatersheds were rated as “Good” in terms of the acres of developable lands within the Critical Area.

Subwatersheds ratings for preservation in the Patapsco Tidal Watershed vary across the landscape indicators. Percent wetland cover, percent of land within the Greenway Master Plan, presence of bog wetlands, acres of RCA lands within the Critical Area, and presence of wellhead protection are primarily rated as “Low”. The density of headwater streams and percent of forest cover are more evenly distributed between the rating categories. Only one indicator, percentage of protected lands, has the majority of subwatersheds rated in the “High” category. In the Bodkin Creek Watershed, subwatershed preservation landscape indicator ratings are also varied. All subwatersheds are rated as “Low” for the presence of wellhead protection areas. The percent of protected lands is the exact opposite with 100% of the subwatersheds rated as “High”. Six of the seven subwatersheds have a rating of “Low” for the presence of bog watersheds. The other landscape indicators for subwatershed preservation are more evenly distributed across the rating categories.

Table 2.21 – Landscape Indicator Ratings (Subwatershed Preservation)

Rating	Patapsco Tidal		Bodkin Creek	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Percent Forest Cover				
High	3	11%	1	14%
Medium High	10	37%	1	14%
Medium	7	26%	3	43%
Low	7	26%	2	29%
Percent Wetland Cover				
High	5	19%	1	14%
Medium High	4	15%	3	43%
Medium	3	11%	2	29%
Low	15	56%	1	14%
Density of Headwater Streams				
High	4	15%	2	29%
Medium High	8	30%	1	14%
Medium	5	19%	0	0%
Low	10	37%	4	57%
Percent of Land within the Greenway Master Plan				
High	5	19%	3	43%
Medium High	4	15%	0	0%
Medium	4	15%	2	29%
Low	14	52%	2	29%
Presence of Bog Wetlands				
High	3	11%	1	14%
Low	24	89%	6	86%
Acres of RCA lands with the Critical Area				
High	3	11%	2	29%
Medium High	5	19%	3	43%
Medium	5	19%	0	0%
Low	14	52%	2	29%
Percent of Protected Lands				
High	20	74%	7	100%
Medium High	2	7%	0	0%
Medium	2	7%	0	0%
Low	3	11%	0	0%
Presence of Wellhead Protection Areas				
High	6	22%	0	0%
Low	21	78%	7	100%

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 Patapsco Tidal and Bodkin Creek 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 Patapsco Tidal and Bodkin Creek 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 watersheds 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.

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

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 Patapsco Tidal and Bodkin Creek watershed areas 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.

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 Patapsco Tidal and Bodkin Creek 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 watersheds.

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 watersheds, 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
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 2011) 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
Detention Dry	DP	DP	Detention Structure (Dry Pond)	5	10	10
	UGVAULT	UGS	Underground Storage	5	10	10
	BS	BS	Bay Saver	5	10	10
	OGS	OGS	Oil Grit Separator	5	10	10
	WQINLET	OGS	Water Quality Inlet	5	10	10
	STMCEPTOR	SC	Stormceptor	5	10	10
	Pretreatment	SC	Pretreatment	5	10	10
	UGS	UGS	Underground Storage	5	10	10
Extended Detention Dry	ED	ED	Extended Detention	20	20	60
	EDSD	EDSD	Extended Detention Structure Dry	20	20	60
	MB	EDSD	Microbasin - Extended Detention Structure Dry	20	20	60
Filtration	O-1	SW	Dry Swale	40	60	80
	O-2	SW	Wet Swale	40	60	80
	ASCD	CD	Attenuation Swale/Check Dam	40	60	80
	F-1	SF	Surface sand filter	40	60	80
	F-2	SF	Underground sand filter	40	60	80
	F-3	SF	Perimeter sand filter	40	60	80
	F-4	BIO	Organic filter	40	60	80
	F-5	SF	Pocket Sand Filter	40	60	80
	F-6	BIO	Bioretention Facility	40	60	80
	SF	SF	Sand Filter	40	60	80
	ATTENSWA	SW	Attenuation Swale	40	60	80
	AS	SW	Attenuation Swale	40	60	80
	POSAND	SF	Pocket Sand Filter	40	60	80
	VB	VB	Vegetated Buffer	40	60	80
	BIO	BIO	Bioretention Facility	40	60	80
	SPSC	SPSC	Regenerative Step Pool Storm Conveyance	40	60	80
	GBMP	BIO	Bioretention Facility	40	60	80
Infiltration	ATTTRENCH	DW	Attenuation Trench	80	85	95
	DW	DW	Dry Well	80	85	95
	DWIT	DW	Dry Well - Infiltration Trench	80	85	95
	DWITCE	DW	Dry Well - Infiltration Trench with Complete Exfiltration	80	85	95
	DWITCE-2	DW	Dry Well - Infiltration Trench with Complete Exfiltration	80	85	95
	C-2/drywells	DW	Dry Well	80	85	95
	DWITCW	DW	Dry Well - Infiltration Trench with Complete Exfiltration	80	85	95

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	DWITPE	DW	Dry Well - Infiltration Trench with Partial Exfiltration	80	85	95
	DWITWQE	ITCE	Dry Well - Infiltration Trench with Water Quality Exfiltration	80	85	95
	EDSDITCE	ITCE	Extended Detention Structure Dry, Infiltration Trench with Complete Exfiltration	80	85	95
	IB	IB	Infiltration Basin	80	85	95
	IITCE	ITCE	Infiltration Trench with Complete Exfiltration	80	85	95
	INPOND	IB	Infiltration Basin No Outfall	80	85	95
	IT	IT	Infiltration Trench	80	85	95
	ITVSW	IT	Infiltration Trench, Extended Detention	80	85	95
	ITCE	ITCE	Infiltration Trench with Complete Exfiltration	80	85	95
	ITCEMB	ITCE	Infiltration Trench with Complete Exfiltration, Microbasin	80	85	95
	ITPE	ITPE	Infiltration Trench with Partial Exfiltration	80	85	95
	ITWQE	ITWQE	Infiltration Trench with Water Quality Exfiltration	80	85	95
	OGSITCE	ITCE	Oil Grit Separator Infiltration Trench with Complete Exfiltration	80	85	95
	PNDTR	IB	Same as infiltration basin	80	85	95
	PP	PP	Porous Pavement	80	85	95
	SB	IB	Infiltration Basin	80	85	95
	WQITPE	ITWQE	Water Quality Infiltration Trench with Partial Exfiltration	80	85	95
	WQP	ITWQE	Water Quality Trench	80	85	95
Wet Ponds	EDSW	EDSW	Extended Detention Structure Wet	20	45	60
	MP	MP	Micro Pool	20	45	60
	P-3	EDSW	Extended Detention Structure Wet	20	45	60
	EXPOND	WP	Wet Pond	20	45	60
	P-2	WP	Wet Pond	20	45	60
	SW	WP	Wet Structure	20	45	60
	P-1	MP	Micro Pool	20	45	60
	WP	WP	Retention Structure (Wet Pond)	20	45	60
	P-4	WP	Multiple pond system	20	45	60
	P-5	WP	Pocket pond	20	45	60

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
Wetlands	SM	SM	Shallow Marsh	20	45	60
	W-1	SM	Shallow Wetland	20	45	60
	RSC	SM	Regenerative Wetland Seepage	50	60	90
	W-2	SM	ED shallow wetland	20	45	60
	W-3	SM	pond/wetland system	20	45	60
	W-4	SM	pocket wetland	20	45	60
Stream Restoration	Stream Conventional	STRE	In-stream Riffles/Stabilization	NA	NA	NA
ESD	A1	ESDGR	Green Roofs	50	60	90
	A2	ESDPERMP	Permeable Pavement	50	60	90
	A3	ESDRTRF	Reinforced Turf	50	60	90
	C2	ESDRTD	ESD rooftop disconnect	50	60	90
	C2/ Raingardens	ESDRG	ESD rain gardens	50	60	90
	C3	ESDNRTD	ESD non roof top disconnect	50	60	90
	C4	ESDSFNAC	Sheetflow to Conservation Areas	50	60	90
	N1	ESDRTD	Disconnection of Roof-top	50	60	90
	N2	ESDNRTD	Disconnection of Non Roof-top	50	60	90
	N3	ESDSFNAC	Sheetflow to Conservation Areas	50	60	90
	M1	ESDRH	Rainwater Harvesting	50	60	90
	M2	ESDSGW	Submerged Gravel Wetlands	50	60	90
	M3	ESDIL	Landscape Infiltration	50	60	90
	M4	ESDIB	Infiltration Berms	50	60	90
	M5	ESDDW	Dry Wells	50	60	90
	M6	ESDMB	Micro-Bioretention	50	60	90
	M7	ESDRG	Rain Gardens	50	60	90
	M8	ESDSW	Swales	50	60	90
	M9	ESDEF	Enhanced Filters	50	60	90
Alternative Credits	Street Sweeping	VSS	Regenerative Vacuum Street Sweeping	5	6	25
	Inlet Cleaning	CBC	Stormdrain Vacuuming	5	6	25
	Planting pervious	FPU	Forestation on pervious urban	66	77	57
	Impervious to Pervious	IMPP	Impervious Area Elimination and conversion to pervious	13	72	84
	Impervious to Forest	IMPF	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, 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
E. Future Conditions with ESD to the MEP	Expected future land use with development informed by future stormwater regulations and ESD 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 watersheds 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 1.2.3, 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). For areas where new development is expected to occur, 100% of the new impervious area was assumed to be managed by ESD 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 ESD to the MEP.

3.2 MODELING RESULTS

This subsection presents and discusses results from application of the hydrological and water quality models to the Patapsco Tidal and Bodkin Creek 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
PATAPSCO TIDAL WATERSHED					
PT0	Runoff Yield (in)	0.69	1.06	2.46	4.3
	Peak Discharge (cfs)	555	908	2,263	4,046
PT1	Runoff Yield (in)	1.54	2.07	3.82	5.85
	Peak Discharge (cfs)	334	451	826	1,257
PT2	Runoff Yield (in)	1.16	1.63	3.28	5.26
	Peak Discharge (cfs)	161	231	471	761
PT3	Runoff Yield (in)	0.93	1.34	2.79	4.52
	Peak Discharge (cfs)	317	475	1,045	1,765
PT4	Runoff Yield (in)	0.58	0.92	2.23	3.98
	Peak Discharge (cfs)	61	103	274	506
PT5	Runoff Yield (in)	0.99	1.43	2.98	4.89
	Peak Discharge (cfs)	424	633	1,372	2,292
PT6	Runoff Yield (in)	0.77	1.16	2.61	4.48
	Peak Discharge (cfs)	217	346	826	1,446
PT7	Runoff Yield (in)	1.02	1.47	3.03	4.92
	Peak Discharge (cfs)	606	896	1,916	3,181
PT8	Runoff Yield (in)	0.33	0.59	1.68	3.23
	Peak Discharge (cfs)	105	201	641	1,307

Table 3.6 – Hydrologic Model Results

Subwatershed		1 year	2 year	10 year	100 year
PT9	Runoff Yield (in)	1.01	1.46	3.04	5.02
	Peak Discharge (cfs)	297	440	942	1,557
PTA	Runoff Yield (in)	1.47	2.00	3.74	5.77
	Peak Discharge (cfs)	205	280	519	799
PTB	Runoff Yield (in)	0.38	0.65	1.79	3.42
	Peak Discharge (cfs)	271	548	1,812	3,653
PTC	Runoff Yield (in)	1.27	1.76	3.41	5.35
	Peak Discharge (cfs)	343	483	956	1,521
PTD	Runoff Yield (in)	0.2	0.40	1.30	2.62
	Peak Discharge (cfs)	46	95	336	721
PTE	Runoff Yield (in)	0.85	1.26	2.76	4.69
	Peak Discharge (cfs)	259	401	913	1,559
PTF	Runoff Yield (in)	0.99	1.43	2.99	4.9
	Peak Discharge (cfs)	584	870	1,887	3,150
PTG	Runoff Yield (in)	0.86	1.28	2.78	4.66
	Peak Discharge (cfs)	495	763	1,741	2,983
PTH	Runoff Yield (in)	0.63	0.99	2.35	4.16
	Peak Discharge (cfs)	126	213	551	1,002
PTI	Runoff Yield (in)	1.61	2.14	3.86	5.87
	Peak Discharge (cfs)	171	229	416	632
PTJ	Runoff Yield (in)	0.87	1.29	2.79	4.69
	Peak Discharge (cfs)	45	68	156	266
PTK	Runoff Yield (in)	1.02	1.47	3.05	5.05
	Peak Discharge (cfs)	48	70	150	247
PTL	Runoff Yield (in)	0.64	1.00	2.36	4.18
	Peak Discharge (cfs)	39	65	167	302
PTM	Runoff Yield (in)	0.16	0.34	1.22	2.59
	Peak Discharge (cfs)	5	16	83	198
PTN	Runoff Yield (in)	0.12	0.28	1.08	2.38
	Peak Discharge (cfs)	2	7	38	95
PTO	Runoff Yield (in)	0.06	0.18	0.86	2.03
	Peak Discharge (cfs)	1	4	26	72
PTP	Runoff Yield (in)	0.32	0.58	1.66	3.23
	Peak Discharge (cfs)	11	23	77	160
PTQ	Runoff Yield (in)	0.74	1.12	2.55	4.42
	Peak Discharge (cfs)	8	13	30	53
BODKIN CREEK WATERSHED					
BK2	Runoff Yield (in)	0.17	0.35	1.24	2.62
	Peak Discharge (cfs)	19	50	228	533
BK3	Runoff Yield (in)	0.27	0.50	1.52	3.03
	Peak Discharge (cfs)	110	234	848	1,814

Table 3.6 – Hydrologic Model Results

Subwatershed		1 year	2 year	10 year	100 year
BK4	Runoff Yield (in)	0.64	1.00	2.37	4.19
	Peak Discharge (cfs)	31	53	134	240
BK5	Runoff Yield (in)	0.44	0.74	1.95	3.63
	Peak Discharge (cfs)	35	67	206	401
BK7	Runoff Yield (in)	0.44	0.73	1.93	3.62
	Peak Discharge (cfs)	38	73	224	437
BK8	Runoff Yield (in)	0.39	0.67	1.82	3.45
	Peak Discharge (cfs)	25	49	157	314
BK9	Runoff Yield (in)	0.17	0.35	1.23	2.61
	Peak Discharge (cfs)	7	19	85	200

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 Patapsco Tidal and Bodkin Creek subwatersheds is presented in Table 3.7. For the majority of the subwatersheds in both the Patapsco Tidal and Bodkin Creek watersheds, the one-year peak flow scores were identical to the two-year peak flow scores, and the one-year yield scores were identical to the two-year yield scores. As shown in Map 3.1, most of the subwatersheds have low area-normalized event peak flow values that translate to lower priorities. Approximately 70% of subwatersheds within the Patapsco Tidal Watershed and 88% of the subwatersheds in Bodkin Creek 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 Patapsco Tidal Watershed. Approximately 48% of the subwatersheds were rated “Low” or “Medium” for the runoff indicator for both evaluated storm events. In contrast, 88% of the subwatersheds in Bodkin Creek are rated “Low” or “Medium” for the surface runoff yield indicators.

Table 3.7 – Hydrologic Indicator Ratings

Rating	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Peak Flow (one-year storm)				
High	2	7.4%	0	0%
Medium High	6	22.2%	1	12.5%
Medium	10	37.0%	2	25.0%
Low	9	33.3%	5	62.5%
Peak Flow (two-year storm)				
High	2	7.4%	0	0%
Medium High	6	37.0%	1	12.5%
Medium	11	40.1%	2	25.0%
Low	8	29.6%	5	62.5%

Table 3.7 – Hydrologic Indicator Ratings

Rating	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Surface Runoff Yield (one-year storm)				
High	4	14.8%	0	0%
Medium High	10	37.0%	1	12.5%
Medium	6	22.2%	3	37.5%
Low	7	25.9%	4	50.0%
Surface Runoff Yield (two-year storm)				
High	4	14.8%	0	0%
Medium High	10	37.0%	1	12.5%
Medium	6	22.2%	4	50.0%
Low	7	25.9%	3	37.5%

3.2.2 Water Quality Modeling Results

Existing condition water quality modeling results are summarized at the watershed scale in Table 3.8. Additional water quality modeling results are summarized at the subwatershed scale in Table 3.9. These tables shows the model-predicted annual loadings for both watersheds 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)
PATAPSCO TIDAL WATERSHED			
A. Pristine Conditions	18,317	2,388	396
B. Existing with no SWM Credits	170,100	20,312	1,695
C. Credits from Existing SWM	13,737	2,474	305
D. Existing with SWM Credits	156,362	17,838	1,391
E. Future with ESD to the MEP	165,612	18,300	1,323
BODKIN CREEK WATERSHED			
A. Pristine Conditions	2,989	391	65
B. Existing with no SWM Credits	15,867	1,946	147
C. Credits from Existing SWM	1,867	316	36
D. Existing with SWM Credits	13,999	1,630	111
E. Future with ESD to the MEP	14,854	1,664	105

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)
PATAPSCO TIDAL WATERSHED																		
PT0	1,999	261	43	20,978	2,555	193	20,016	2,429	176	998	160	17	19,018	2,269	159	20,121	2336.3	157.13
PT1	185	24	4	3,393	417	30	3,257	395	28	639	172	17	2,618	223	11	2,473	200.5	9.42
PT2	219	29	5	2,694	328	25	2,517	301	22	35	5	0	2,483	296	21	2,592	295.9	20.44
PT3	1,585	206	34	20,179	2,530	236	14,224	1,687	139	704	130	13	13,520	1,557	126	14,116	1586.3	116.17
PT4	387	51	8	2,253	234	37	1,378	138	22	197	21	7	1,181	117	14	2,398	194.1	14.17
PT5	1,102	144	24	16,235	1,992	177	14,294	1,694	142	946	122	17	13,348	1,572	125	13,523	1570.7	121.55
PT6	700	91	15	7,205	747	124	4,384	441	74	406	51	15	3,977	390	59	3,999	372.0	49.09
PT7	1,730	226	38	27,520	3,426	302	19,086	2,248	196	1,147	217	29	17,939	2,031	166	18,101	2034.5	162.34
PT8	1,643	214	36	8,604	1,075	97	7,240	906	73	547	87	10	6,694	819	63	10,222	1068.5	55.46
PT9	323	42	7	4,219	445	65	3,935	403	60	504	91	17	3,430	312	43	3,483	310.1	41.49
PTA	108	14	2	1,566	187	13	1,561	186	13	4	0	0	1,557	186	13	1,558	185.9	13.24
PTB	1528	199	33	15,029	1,853	144	14,042	1,714	127	1,266	193	20	12,776	1,521	107	13,021	1531.5	104.77
PTC	621	81	13	9,569	1,224	113	7,625	948	79	1,551	265	28	6,074	683	52	6,057	676.1	50.28
PTD	1,594	208	35	12,523	1,593	163	7,293	842	83	1,063	153	22	6,230	689	61	7,248	735.5	53.16
PTE	292	38	6	4,277	529	41	3,726	442	30	83	11	1	3,644	430	29	3,669	430.2	28.83
PTF	1,495	195	32	23,507	3,021	240	19,942	2,458	175	1,906	480	51	18,036	1,977	125	18,353	1999.5	122.66
PTG	1,495	195	32	20,947	2,676	224	18,510	2,305	172	1,232	251	30	17,277	2,054	142	17,428	2020.6	129.06
PTH	409	53	9	2,479	290	28	2,244	261	24	198	26	5	2,046	235	18	2,586	268.6	17.65
PTI	144	19	3	665	58	12	29	4	0	0	0	0	29	4	0	29	3.7	0.48
PTJ	128	17	3	1,467	131	26	1,431	128	25	103	9	2	1,327	118	23	1,448	126.2	22.75
PTK	51	7	1	690	60	12	677	59	12	0	0	0	677	59	12	677	58.7	11.72
PTL	123	16	3	638	77	6	593	72	6	8	1	0	586	71	6	587	70.8	5.59
PTM	118	15	3	693	80	6	646	76	5	60	8	1	587	67	4	590	67.5	4.44
PTN	91	12	2	562	66	5	534	63	4	64	9	1	470	53	3	473	53.4	3.35
PTO	106	14	2	534	64	5	493	60	4	55	7	1	439	52	4	446	52.6	3.66
PTP	135	18	3	456	54	5	381	48	4	19	3	0	362	45	4	379	46.4	3.52
PTQ	7	1	0	44	5	0	43	5	0	6	1	0	37	4	0	37	4.3	0.29
Total	**18,317**	**2,388**	**396**	**208,925**	**25,718**	**2,328**	**170,100**	**20,312**	**1,695**	**13,737**	**2,474**	**305**	**156,362**	**17,838**	**1,391**	**165,612**	**18,300**	**1,323**

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)
BODKIN CREEK WATERSHED																		
BK2	542	71	12	3,414	416	33	3,169	386	29	337	56	7	2,832	330	22	3,049	344.4	21.04
BK3	1,778	232	39	10,694	1,309	106	9,887	1,208	92	1,329	230	26	8,558	978	66	8,932	978.2	61.29
BK4	39	5	1	239	29	2	232	28	2	0	0	0	232	28	2	238	28.3	2.05
BK5	113	15	2	515	62	5	473	58	4	20	3	0	454	55	4	468	56.1	3.99
BK6	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0.1	0.01
BK7	145	19	3	1,075	137	10	1,037	133	10	139	21	2	898	112	8	915	113.3	7.67
BK8	184	24	4	730	92	9	513	64	5	15	2	0	498	62	5	561	65.7	4.52
BK9	188	25	4	713	90	8	555	70	5	27	4	0	527	66	5	691	78.3	4.75
Total	**2,989**	**391**	**65**	**17,381**	**2,135**	**174**	**15,867**	**1,946**	**147**	**1,867**	**316**	**36**	**13,999**	**1,630**	**111**	**14,854**	**1,664**	**105**

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 Patapsco Tidal and Bodkin Creek subwatersheds is presented in Table 3.10. A visual representation of the existing condition pollutant loads within the study subwatersheds is depicted in Map 3.5. In the Patapsco Tidal watershed, the largest percentage (37%) of subwatersheds were rated "Low" when evaluating total nitrogen or total phosphorus loading. Between 26 and 30% of the subwatersheds were rated "High" for the two indicator categories. In the generally more rural Bodkin Creek watershed, nearly 88% 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	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Total Nitrogen Load from Runoff				
High	8	29.6%	0	0%
Medium High	5	18.5%	1	12.5%
Medium	4	14.8%	4	50.0%
Low	10	37.0%	3	37.5%
Total Phosphorus Load from Runoff				
High	7	25.9%	0	0%
Medium High	4	14.8%	1	12.5%
Medium	6	22.2%	3	37.5%
Low	10	37.0%	4	50.0%

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 Patapsco Tidal and Bodkin Creek subwatersheds is presented in Table 3.11 and is shown visually on Map 3.5. In the Patapsco Tidal watershed, for the percent future departure of total nitrogen loading, over 59% of the subwatersheds were rated as "Low" priorities. For the percent future departure of total phosphorus loads, "Low" priorities comprise 48% of the total. In the Bodkin Creek watershed, 67% of the subwatersheds were rated as "Low" or "Medium" priorities for both indicators.

Table 3.11 – Water Quality Indicator Ratings (Subwatershed Preservation)

Rating	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Percent Future Departure of Total Nitrogen Load				
High	2	7.4%	1	16.7%
Medium High	4	14.8%	1	16.7%
Medium	5	18.5%	2	33.3%
Low	16	59.3%	2	33.3%
Percent Future Departure of Total Phosphorus Load				
High	2	7.4%	1	16.7%
Medium High	5	18.5%	1	16.7%
Medium	7	25.9%	2	33.3%
Low	13	48.1%	2	33.3%

4. RATING AND PRIORITIZATION

The County performs three detailed prioritization assessments in order to characterize current conditions within the 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 Patapsco Tidal and Bodkin Creek 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 342 assessed perennial stream reaches in the Patapsco Tidal Watershed, 28 were rated as "High" priorities for restoration. Of the 16 subwatersheds with assessed perennial streams, five had more than one-third of their perennial streams rated as "High" or "Medium High":

- Cabin Branch (PT3) had 24 assessed streams; nine were ranked "High" and seven were ranked as "Medium High"
- Cabin Branch 2 (PT2) had the greatest percentage (66%) of assessed streams ranked in the "High" and "Medium High" categories
- Marley Creek 1 (PT8) had 15 assessed stream reaches; two were ranked as "High"
- Marley Creek 3 (PTF) had 26 assessed stream reaches; four were "High" and 11 were "Medium High"
- Sawmill Creek 1 (PT7) had 41 assessed stream reaches, 11 were ranked as "Medium High" and four were "High"

The remaining 255 reaches were assessed in the "Medium" and "Low" categories (136 and 119 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 Bodkin Creek Watershed, 54 perennial stream reaches were assessed. Of these, seven were ranked in the "High" category. Of the five subwatersheds with assessed perennial streams, three had more than one-third of the perennial streams rated as "High" or "Medium High":

- Back Creek (BK2) had nine assessed stream reaches; three were "High" and another three were "Medium High"
- Locust Cove (BK8) had two assessed stream reaches; one was ranked as "Medium High"
- Wharf Creek (BK7) had three assessed stream reaches; one was ranked as "High" and one was ranked as "Medium High".

The other stream reaches in the Bodkin Creek Watershed were assessed as “Medium” (30%) and “Low” (33%). A breakdown of the results by subwatershed is presented in Table 4.2. See Map 4.2 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
PATAPSCO TIDAL WATERSHED						
PT0	Stony Creek	0	3	11	31	45
PT2	Cabin Branch 2	2	4	2	1	9
PT3	Cabin Branch	9	7	4	4	24
PT4	Swan Creek	0	0	1	1	2
PT5	Furnace Creek	0	4	5	9	18
PT6	Curtis Creek	0	1	1	1	3
PT7	Sawmill Creek 1	2	11	17	11	41
PT8	Marley Creek 1	2	3	7	3	15
PT9	Cox Creek	0	1	4	0	5
PTB	Rock Creek	4	3	20	10	37
PTC	Back Creek	0	0	6	1	7
PTD	Sawmill Creek 2	0	3	13	22	38
PTE	Marley Creek 2	0	0	1	0	1
PTF	Marley Creek 3	4	11	7	4	26
PTG	Marley Creek 4	5	8	35	19	67
PTM	Hines Bog Pond	0	0	2	2	4
Total		**28**	**59**	**136**	**119**	**342**
BODKIN CREEK WATERSHED						
BK2	Back Creek	3	3	1	2	9
BK3	Main Creek	2	8	11	16	37
BK7	Wharf Creek	1	1	1	0	3
BK8	Locust Cove	0	1	1	0	2
BK9	Chesapeake Bay	1	0	2	0	3
Total		**7**	**13**	**16**	**18**	**54**

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.

4.2.2 Results

The subwatersheds in the Patapsco Tidal Watershed were assessed to identify restoration needs. Of the 27 subwatersheds assessed, six were rated "High", which makes them priorities for restoration. As seen in Table 4.4, six subwatersheds are rated "High" priorities for restoration. These six subwatersheds represent 22.2% of the subwatersheds in the Patapsco Tidal. The majority of subwatersheds were assessed to be "Medium High"(29.6%) and "Medium" (33.3%) priorities. Only four subwatersheds (24.8%) were assessed to show a "Low" need for restoration. 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 Bodkin Creek Watershed, only one of the eight subwatersheds (Wharf Creek BK7) was assessed as a "High" priority for restoration. Four of the eight subwatersheds (50%) were assessed to be "Medium High" on the prioritization scale for restoration needs. 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 4.4 – Subwatershed Priority Ranking for Restoration

Subwatershed Code	Subwatershed Name	Priority for Restoration
PATAPSCO TIDAL WATERSHED		
PTF	Marley Creek 3	High
PT5	Furnace Creek	High
PT3	Cabin Branch	High
PT7	Sawmill Creek 1	High
PTC	Back Creek	High
PTE	Marley Creek 2	High
PTG	Marley Creek 4	Medium High
PT2	Cabin Branch 2	Medium High
PT1	Unnamed Tributary	Medium High
PTA	Patapsco Tidal	Medium High
PT9	Cox Creek	Medium High
PT0	Stony Creek	Medium High
PT6	Curtis Creek	Medium High
PTI	Patapsco Tidal	Medium High
PTK	Patapsco Tidal	Medium
PTJ	Patapsco Tidal	Medium
PTB	Rock Creek	Medium
PTD	Sawmill Creek 2	Medium
PT8	Marley Creek 1	Medium
PTQ	Patapsco Tidal	Medium
PTH	Nabbs Creek	Medium
PTM	Hines Bog Pond	Medium
PTL	Patapsco Tidal	Medium
PT4	Swan Creek	Low
PTO	Leath Pond	Low
PTN	Hines Bog	Low
PTP	Boyd Pond	Low
BODKIN CREEK WATERSHED		
BK7	Wharf Creek	High
BK4	Chesapeake Bay	Medium High
BK8	Locust Cove	Medium High
BK2	Back Creek	Medium High
BK3	Main Creek	Medium High
BK5	Bodkin Creek	Medium
BK9	Chesapeake Bay	Medium
BK6	Main Creek	Low

Table 4.5 – Subwatershed Restoration Assessment Results

Rating	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Red	6	22.2%	1	12.5%
Orange	8	29.6%	4	50%
Yellow	9	33.3%	2	25%
Green	4	14.8%	1	12.5%
TOTAL	**27**	---	**8**	---

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 16 subwatersheds in the Patapsco Tidal Watershed were assessed to be "High" and "Medium High" priorities on the preservation rating scale. Of these, six were rated as being a "High" priority. "Medium" ratings for preservation make up 25.9% 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 Patapsco Tidal Watershed.

Table 4.7 – Subwatershed Priority Rating for Preservation

Subwatershed Code	Subwatershed Name	Priority for Preservation
PATASPCO TIDAL WATERSHED		
PT8	Marley Creek 1	High
PT6	Curtis Creek	High
PT4	Swan Creek	High
PT0	Stony Creek	High
PTH	Nabbs Creek	High
PTD	Sawmill Creek 2	High
PTJ	Patapsco Tidal	Medium High
PTM	Hines Bog Pond	Medium High
PTP	Boyd Pond	Medium High
PT3	Cabin Branch	Medium High
PTG	Marley Creek 4	Medium High
PTL	Patapsco Tidal	Medium High
PTB	Rock Creek	Medium High
PT9	Cox Creek	Medium High
PTN	Hines Bog	Medium High
PT2	Cabin Branch 2	Medium High
PTE	Marley Creek 2	Medium
PTF	Marley Creek 3	Medium
PTO	Leath Pond	Medium
PTC	Back Creek	Medium
PTI	Patapsco Tidal	Medium
PT7	Sawmill Creek 1	Medium
PT5	Furnace Creek	Medium
PTA	Patapsco Tidal	Low
PTK	Patapsco Tidal	Low
PTQ	Patapsco Tidal	Low
PT1	Unnamed Tributary	Low
BODKIN CREEK WATERSHED		
BK9	Chesapeake Bay	High
BK8	Locust Cove	High
BK5	Bodkin Creek	Medium High
BK3	Main Creek	Medium High
BK4	Chesapeake Bay	Medium
BK2	Bodkin Creek	Medium
BK7	Wharf Creek	Low

In the Bodkin Creek Watershed, the Chesapeake Bay (BK9) and Locust Cove (BK8) subwatersheds were assessed as a "High" priority for preservation. This represents 28.5% of the subwatersheds. The remaining five subwatersheds were split between "Medium High" and "Medium" and one subwatershed, Wharf Creek (BK7), was assessed as a "Low" priority for preservation. It should be noted that subwatershed BK6 (Main Creek) was not included in this analysis since it is a small island with no perennial streams. A 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 Bodkin Creek Watershed.

Table 4.8 – Subwatershed Preservation Assessment Results

Rating	Patapsco Tidal Watershed		Bodkin Creek Watershed	
	Number of Subwatersheds	Percent of Subwatersheds	Number of Subwatersheds	Percent of Subwatersheds
Red	6	22.2%	2	28.5%
Orange	10	37.0%	2	28.5%
Yellow	7	25.9%	2	28.5%
Green	4	14.8%	1	14.3%
TOTAL	**27**	---	**7**	---

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 Patapsco Tidal and Bodkin Creek 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, concept design plans for a subset of prioritized restoration activities within the Patapsco Tidal and Bodkin Creek Watersheds are also presented.

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 Patapsco Tidal and Bodkin Creek 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 watersheds. 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. In the Patapsco Tidal Watershed, private lands make up 13,925 acres or 78 percent of the total 17,848 urban acres, while public lands account for 3,923 acres or 22 percent. In the Bodkin Creek Watershed there is a comparable distribution of area where private lands make up 2,756 acres or 78 percent of the urban total and public lands account for 775 acres or 22 percent.

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)
PATASPCO TIDAL WATERSHED			
2010 Load (No BMPs)	170,100	20,312	1,695
2011 Progress Load (With BMPs)*	164,917	19,383	1,579
Future Conditions Load (With Credits)	165,612	18,300	1,323
Estimated 2025 TMDL Allocation	111,247	7,584	NA
Required Reduction from 2011 Progress Load (With BMPs)	58,853	12,728	NA
BODKIN CREEK WATERSHED			
2010 Load (No BMPs)	15,867	1,946	147
2011 Progress Load (With BMPs)*	15,391	1,848	137
Future Conditions Load (With Credits)	14,854	1,664	105
Estimated 2025 TMDL Allocation	10,377	724	NA
Required Reduction from 2011 Progress Load (With BMPs)	5,490	1,222	NA

* 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 both the Patapsco Tidal and Bodkin Creek 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 ESD 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 Patapsco Tidal and Bodkin Creek Watersheds are presented in Maps 5.7 and 5.8, respectively.

5.2.1 WIP Core Strategies

The following represent the Core Strategies that will be employed in the Patapsco Tidal and Bodkin Creek 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 2011-2014 Programmed Projects –** This strategy accounts for all budgeted and programmed environmental restoration projects to be implemented by 2014. 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 Patapsco Tidal and Bodkin Creek Watersheds.

- **Street Sweeping –** This strategy prescribes sweeping all closed curbed County roads using vacuum assisted technologies on a monthly basis. Street sweeping captures roadway pollutants before they are conveyed to the stormwater system and receiving waters. The County's current program sweeps closed curbed roads with mechanical sweepers two times per year.
- **Inlet Cleaning –** This strategy includes vacuum cleaning stormwater curb inlets and catch basins located the same curbed roads identified for street sweeping described above. Like street sweeping, inlet cleaning helps prevent flooding and captures pollutants before they are conveyed to receiving waters. Inlet cleaning will occur once per year at the 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
- **ESD Retrofit to the MEP –** This strategy includes retrofitting existing impervious surfaces to the maximum extent practical with ESD micro-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, Recreation and Park facilities, and other County facilities.

5.2.3 Potential Load Reductions Outside of the Core Strategy WIP Areas

As discussed in Section 1.2.3, the State of Maryland recently passed legislation that calls for Phase I counties and municipalities to establish a stormwater utility, among other requirements. The stormwater utility must include a stormwater remediation fee to be collected annually from property owners within the County. Under this act, the County may also consider a concomitant fee discount program. It is expected that a stormwater fee and potential discount program could be a driver for a subset of private property owners to retrofit their properties with ESD to the MEP outside of the normal course of development and redevelopment.

Although the specific elements of such a program have not yet been worked out, the County assumes that a limited number of private retrofits could be counted as credits. 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 ESD –** This credit accounts for ESD retrofits to private commercial and industrial properties.
- **Private Residential ESD –** This credit accounts for retrofitting rooftops in high density residential areas with rain barrels or rain gardens.

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 2011). 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) – Instream Constructed Riffle	From DEM, based on reach centroid	No	0.2 lb/ft/yr	0.068 lb/ft/yr	310 lb/ft/yr
CIP Projects (2012-2013)	From DEM	No	Varies, see Table 3.4		
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%
ESD 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.

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 existing bi-annual street sweeping program currently relies on one mechanical street sweeper. To accommodate the street sweeping requirements laid out in the Core Tier II Strategy, the County will need to purchase new vehicles and employ additional crews. 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 vacuuming. 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 1,541 lane miles on a monthly basis, two vehicles, each manned by one driver and one operator, 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.
- **ESD Retrofit to the MEP –** Unit costs for ESD retrofits were taken from a pilot concept plan in the Patapsco Non-Tidal Watershed Master Plan to restore the neighborhood of Brooklyn Park. This plan proposed the use of green alleyways, porous pavement, and rain gardens within the established community of Brooklyn Park along the County's northern border with Baltimore City. Cost estimates from the Brooklyn Park concept were used to estimate the anticipated cost for installing similar types of stormwater management on Board of Education and Department of Recreation and Park lands. The average cost for ESD retrofits from this concept is estimated at $90,876/acre. A 30% contingency was added to accommodate varying site conditions, right of way needs, etc. This results in approximately $120,000 per impervious acre treated. When this per acre cost is related to pollutant removal rates, the unit cost becomes $12,000 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
ESD to the MEP	$12,000	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 Tables 5.5 and 5.6 below.
If fully implemented, these restoration projects and activities will meet the Chesapeake Bay TMDL allocations for the Patapsco Tidal Watershed and come close to meeting the allocations for the Bodkin Creek Watershed. See Figures 5.1 through 5.4.

Table 5.5 – WIP Phase II Strategy for Patapsco Tidal Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Nested Treatment Drainage Acres	Nested Treatment Impervious Acres	Pollutant Reduction TN (lbs/ year)	Pollutant Reduction TP (lbs/ year)	Pollutant Reduction TSS (Tons/ year)	Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($)/Tons
CORE STRATEGY													
Stream Restoration (Ephemeral and Intermittent) - SPSC/Regenerative Wetland Seepage Systems													
Severely Degraded Streams	1.31	Miles	Retrofit lower order incised channels with regenerative SPSCs or wetland seepage systems	Project designed to filter ESD volume or portion there of	1,902	635	5,465	1,036	94.7	$42,358,553	$7,751	$40,891	$447,326
Degraded Streams	3.89	Miles			1,692	300	3,124	571	59.4	$24,216,946	$7,751	$42,429	$407,936
Stream Restoration (Perennial) - Instream Constructed Riffles													
Severely Degraded Streams	3.82	Miles	Retrofit higher order incised channels with constructed instream riffles	Length of restoration is based on impacted/ connected upstream length	739	181	4,029	1,370	3,122.4	$12,123,150	$3,009	$8,850	$3,883
Degraded Streams	7.42	Miles			5,378	861	7,840	2,665	6,075.7	$23,589,347	$3,009	$8,850	$3,883
Stormwater Pond Retrofit													
Public Pond Retrofits	62	# 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.	671	223	1,204	202	31.0	$9,707,294	$8,065	$47,971	$313,070
Private Pond Retrofits	36	# of Ponds			636	320	1,579	280	52.2	$12,737,661	$8,065	$45,545	$244,020
Outfall Retrofit - SPSC													
Severely Degraded Outfalls	308	# of Outfalls	Retrofit Outfalls with SPSC system (Ephemeral systems)	Project designed to filter ESD volume or portion there of	3,527	1,464	12,453	2,306	260.8	$80,893,577	$6,496	$35,083	$310,170
Degraded Outfalls	193	# of Outfalls			2,170	787	6,887	1,265	134.8	$44,737,250	$6,496	$35,361	$331,916

Table 5.5 – WIP Phase II Strategy for Patapsco Tidal Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Nested Treatment Drainage Acres	Nested Treatment Impervious Acres	Pollutant Reduction TN (lbs/ year)	Pollutant Reduction TP (lbs/ year)	Pollutant Reduction TSS (Tons/ year)	Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($)/Tons
CIP Programmed Projects (Various Types of Retrofits)													
Future Budgeted CIP	6	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	535	172	1,361	260	28.1	$2,729,928	$2,006	$10,480	$97,153
CORE STRATEGY SUBTOTALS					**17,250**	**4,944**	**43,941**	**9,955**	**9,859**	**$253,093,706**			**N/A**
CORE TIER II STRATEGY													
Street Sweeping	220	Miles	Monthly Street Sweeping of Curbed County Roads	Reductions are based on contributing acres to vacuum and MDE NPDES approved efficiencies	444	369	852	108	21.7	$5,484,511	$6,440	$50,987	$252,353
Inlet Cleaning	3,990	Inlets	Cleaning of curb opening inlets		6,816	2,278	2,430	363	126.3	$798,000	$328	$2,201	$6,319
Reforestation	220	Acres	Reforestation of Public Open Space	Based on acres forested per MDE NPDES design criteria and efficiency	140	4	70	11	0.9	$663,693	$9,430	$62,588	$764,185
ESD to MEP for County Rec and Parks	91	Acres	Retrofit with ESD devices	Micro practices implemented to MEP to treat contributory ESD volume	46	46	351	53	8.1	$4,212,809	$12,000	$80,058	$521,333
ESD to MEP for County Schools	191	Acres			73	73	630	102	11.3	$7,563,294	$12,000	$74,263	$666,536
ESD to MEP for County Facilities	157	Acres			72	72	644	96	12.7	$7,722,141	$12,000	$80,731	$606,093
CORE TIER II STRATEGY SUBTOTALS					**7,591**	**2,842**	**4,977**	**731**	**181**	**$26,444,448**	**$52,199**	**$350,827**	**$2,816,819**

Table 5.5 – WIP Phase II Strategy for Patapsco Tidal Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Nested Treatment Drainage Acres	Nested Treatment Impervious Acres	Pollutant Reduction TN (lbs/ year)	Pollutant Reduction TP (lbs/ year)	Pollutant Reduction TSS (Tons/ year)	Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($)/Tons
POTENTIAL LOAD REDUCTIONS OUTSIDE OF CORE STRATEGY WIP AREAS													
ESD to MEP for Private Commercial and Industrial Properties	0	Acres	Retrofit with ESD devices	Designed to treat ESD volume or portion there of	222	222	1,924	232	53.1	N/A	N/A	N/A	N/A
Rain Barrels/ Rain Gardens for Residential Rooftops in High Density Areas	0	Acres	Retrofit downspouts/driveways for high density residential areas with rain barrels		107	97	1,030	144	14.6	N/A	N/A	N/A	N/A
POTENTIAL LOAD REDUCTIONS OUTSIDE OF CORE STRATEGY WIP AREAS SUBTOTALS					**329**	**319**	**2,954**	**377**	**68**				**N/A**
PATAPSCO TIDAL WATERSHED WIP TOTALS					**25,169**	**8,105**	**51,872**	**11,063**	**10,108**	**$279,538,154**			**N/A**

Table 5.6 – WIP Phase II Strategy for Bodkin Creek Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Nested Treatment Drainage Acres	Nested Treatment Impervious Acres	Pollutant Reduction TN (lbs/ year)	Pollutant Reduction TP (lbs/ year)	Pollutant Reduction TSS (Tons/ year)	Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($)/tons
CORE STRATEGY													
Stream Restoration (Ephemeral and Intermittent) - SPSC/Regenerative Wetland Seepage Systems													
Severely Degraded Streams	0.32	Miles	Retrofit lower order incised channels with regenerative SPSCs or wetland seepage systems	Project designed to filter ESD volume or portion there of	72	3	37	7	0.6	$283,435	$7,751	$42,608	$469,098
Degraded Streams	1.46	Miles			533	80	677	125	9.8	$5,249,903	$7,751	$41,972	$535,772
Stream Restoration (Perennial) - Instream Constructed Riffles													
Severely Degraded Streams	0.20	Miles	Retrofit higher order incised channels with constructed instream riffles	Length of restoration is based on impacted/ connected upstream length	86	27	207	71	160.8	$624,150	$3,009	$8,850	$3,883
Degraded Streams	0.28	Miles			62	10	297	101	230.5	$895,023	$3,009	$8,850	$3,883
Stormwater Pond Retrofit													
Public Pond Retrofits	17	# 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.	404	52	328	55	7.6	$2,641,820	$8,065	$48,223	$345,340
Private Pond Retrofits	1	# of Ponds			9	1	5	1	0.1	$41,523	$8,065	$48,508	$318,965
Outfall Retrofit - SPSC													
Severely Degraded Outfalls	10	# of Outfalls	Retrofit Outfalls with SPSC system (Ephemeral systems)	Project designed to filter ESD volume or portion there of	146	21	196	37	3.7	$1,273,514	$6,496	$34,584	$341,786
Degraded Outfalls	44	# of Outfalls			607	103	977	180	18.8	$6,349,562	$6,496	$35,255	$338,322

Table 5.6 – WIP Phase II Strategy for Bodkin Creek Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Nested Treatment Drainage Acres	Nested Treatment Impervious Acres	Pollutant Reduction TN (lbs/ year)	Pollutant Reduction TP (lbs/ year)	Pollutant Reduction TSS (Tons/ year)	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	0.0	$ -	$ -	$ -	$ -
CORE STRATEGY SUBTOTALS					**1,920**	**295**	**2,725**	**576**	**432**	**$17,358,929**			**N/A**
CORE TIER II STRATEGY													
Street Sweeping	9	Miles	Monthly Street Sweeping of Curbed County Roads	Reductions are based on contributing acres to vacuum and MDE NPDES approved efficiencies	27	19	31	4	0.9	$226,349	$7,224	$55,304	$262,256
Inlet Cleaning	141	Inlets	Cleaning of curb opening inlets		261	52	62	9	2.7	$28,200	$457	$3,146	$10,286
Public Land Reforestation	4	Acres	Reforestation of Public Open Space	Based on acres forested per MDE NPDES design criteria and efficiency	4	0	2	0	0.0	$15,293	$9,430	$61,969	$738,635
ESD to MEP for County Rec and Parks	2	Acres	Retrofit with ESD devices	Micro practices implemented to MEP to treat contributory ESD volume	2	2	9	1	0.2	$104,146	$12,000	$79,631	$517,524
ESD to MEP for County Schools	41	Acres			19	19	168	27	3.0	$2,013,868	$12,000	$74,204	$664,506
ESD to MEP for County Facilities	17	Acres			9	9	51	8	1.1	$607,649	$12,000	$78,236	$549,774
CORE TIER II STRATEGY SUBTOTALS					**322**	**100**	**322**	**50**	**8.0**	**$2,995,504**	**$53,111**	**$352,490**	**$2,742,980**

Table 5.6 – WIP Phase II Strategy for Bodkin Creek Watershed

Retrofit Type	Quantity	Units	Description	Design Efficiency Basis	Nested Treatment Drainage Acres	Nested Treatment Impervious Acres	Pollutant Reduction TN (lbs/ year)	Pollutant Reduction TP (lbs/ year)	Pollutant Reduction TSS (Tons/ year)	Preliminary Cost ($)	TN Cost($)/lb	TP Cost($)/lb	TSS Cost($)/tons
POTENTIAL LOAD REDUCTIONS OUTSIDE OF CORE STRATEGY WIP AREAS													
ESD to MEP for Private Commercial and Industrial Properties	11	Acres	Retrofit with ESD devices	Designed to treat ESD volume or portion there of	10	10	86	14	1.5	N/A	N/A	N/A	N/A
Rain Barrels/ Rain Gardens for Residential Rooftops in High Density Areas	32	Acres	Retrofit downspouts/driveways in high density residential areas with rain barrels/rain gardens		31	27	290	41	4.1	N/A	N/A	N/A	N/A
POTENTIAL LOAD REDUCTIONS OUTSIDE OF CORE STRATEGY WIP AREAS SUBTOTALS					**41**	**37**	**376**	**54**	**5.6**				**N/A**
BODKIN CREEK WATERSHED WIP TOTALS					**2,282**	**432**	**3,423**	**680**	**445.9**	**$20,354,433**			**N/A**

Figure 5.1 – Annual Progress of WIP Strategy towards Meeting Total Nitrogen Load Allocations – Patapsco Tidal Watershed

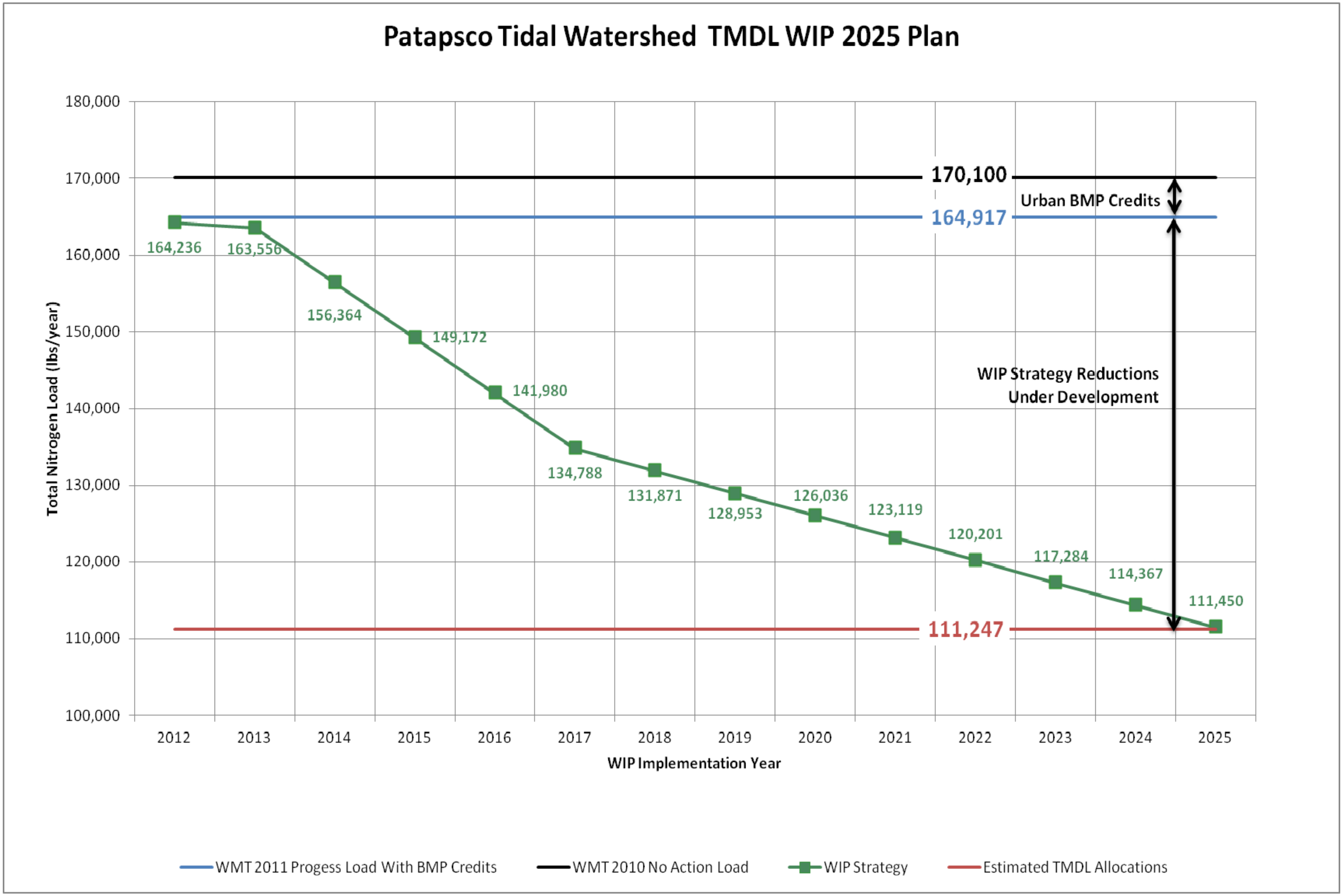


Figure 5.2 – Annual Progress of WIP Strategy towards Meeting Total Phosphorus Load Allocations – Patapsco Tidal Watershed

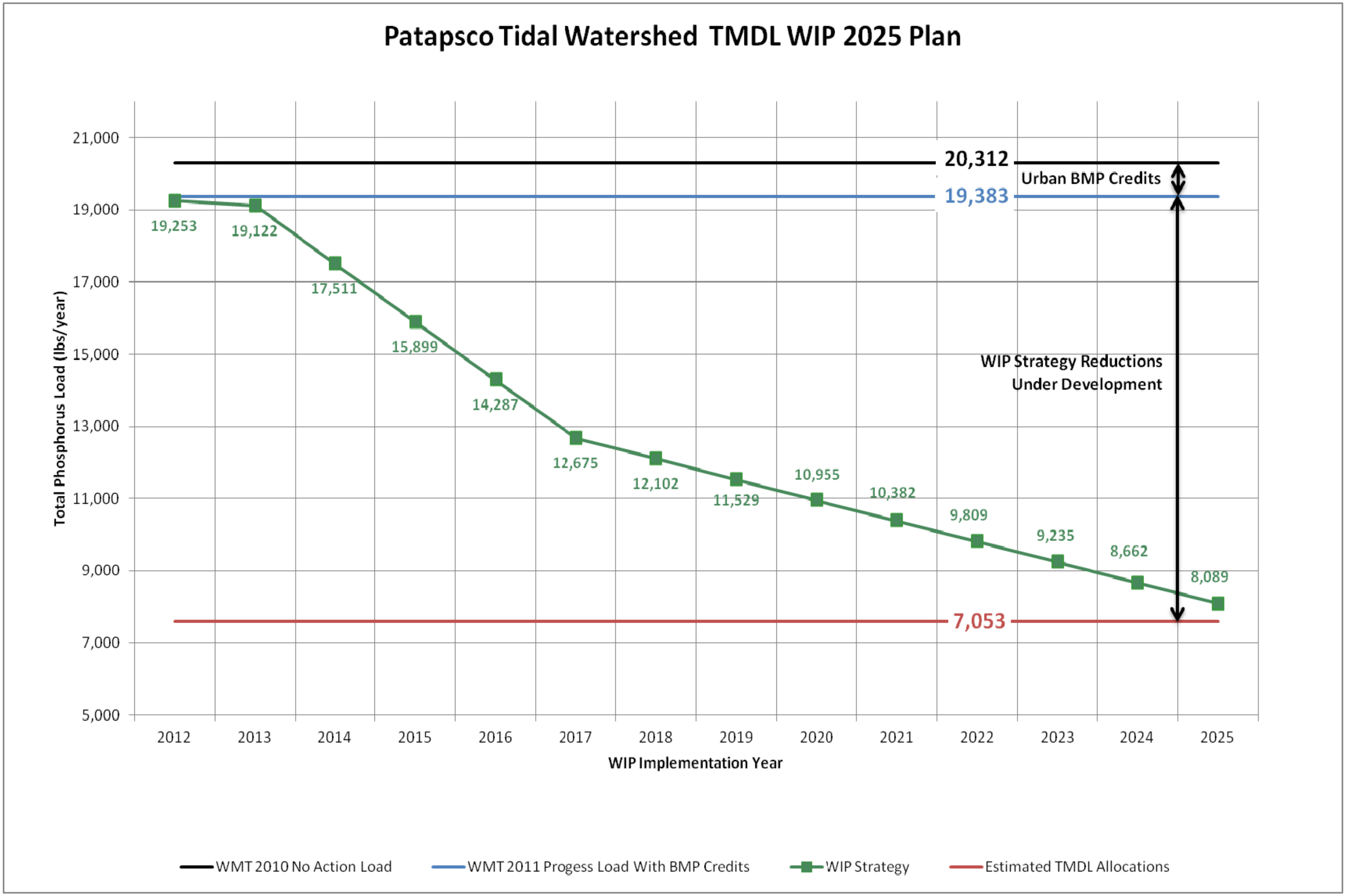


Figure 5.3 – Annual Progress of WIP Strategy towards Meeting Total Nitrogen Load Allocations – Bodkin Creek Watershed

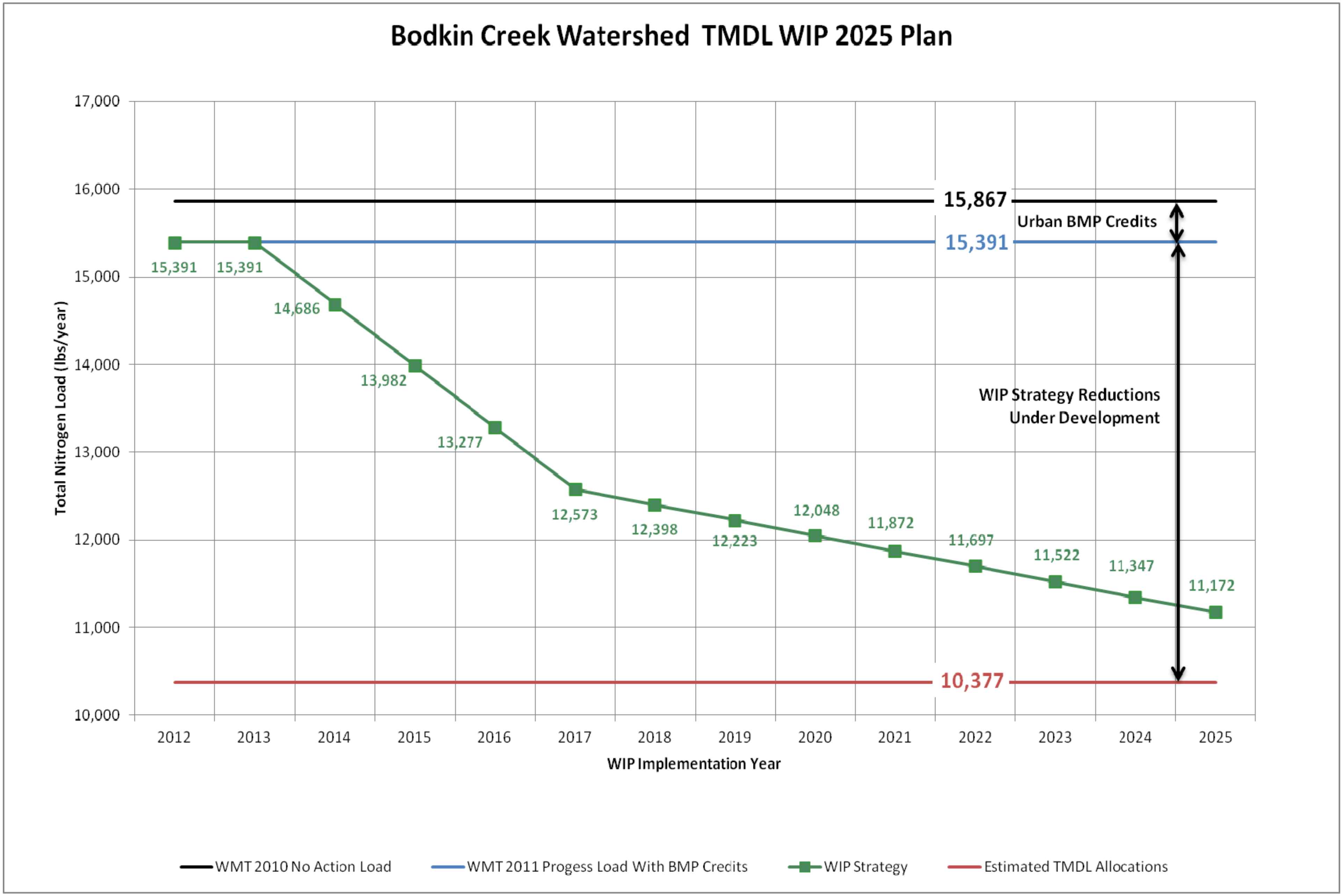
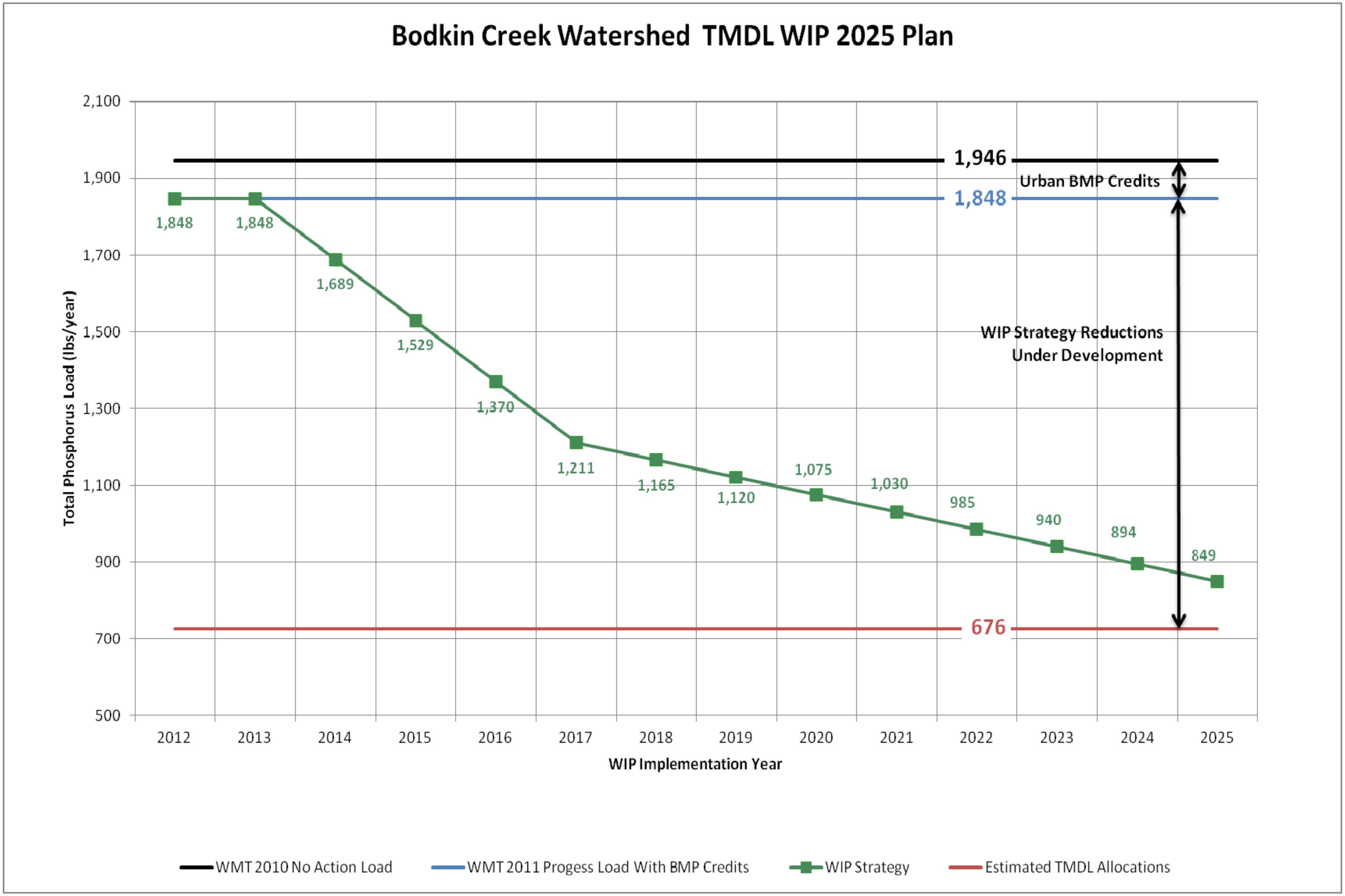


Figure 5.4 – Annual Progress of WIP Strategy towards Meeting Total Phosphorus Load Allocations – Bodkin Creek Watershed



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 Figures 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 2013. 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 1.2.3 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 Development of Concept Plans

As a first step toward implementation, the County developed concept design plans for five of the proposed restoration projects discussed in Section 5.3.3. Each concept plan contained a narrative description of the issue to be addressed, the purpose of the restoration activity, a site location map, hydrologic and hydraulic volumes, a plan view of the conceptual design, existing condition photos, design and construction cost estimates, and a feasibility assessment.

The concept plans were developed following a rigorous analysis of existing site conditions. For each of the key projects, field crews conducted site visits to assess the full suitability and feasibility of the selected restoration activity and to collect any necessary field measurements and photos. GIS and modeling data were used to identify project area characteristics, determine project drainage areas, and calculate hydraulic and pollutant load benefits. County-approved design specifications were used to site and size each of the project elements. Standard construction cost guides were used in tandem with County-specific unit costs to develop preliminary design and construction cost estimates. An assessment was also undertaken to identify and address conceptually important constructability issues such as land ownership, construction access, erosion and sediment controls, and potential utility conflicts.

The five projects and a brief description of each are provided below. The full concept design plans are included in Appendix D.

- 209th Street Step Pool Storm Conveyance Retrofit – This project is located in the Stony Creek subwatershed (PT0) at the northeast end of 209th Street in Pasadena, MD. This project was chosen because the existing stormwater BMP draining a small subdivision is undersized and failing. Neighborhood residents are unhappy with the condition of the current BMP and it is causing erosion at the BMP outfall. A regenerative SPSC system was chosen for conceptual design to improve water quality and reduce water quantity. The regenerative SPSC system chosen will replace the current BMP and provide a better connection with the nearby perennial stream. To account for possible easement issues, two possible flow paths were conceptually designed. Both SPSC routes utilize a series of shallow pools, riffle grade controls, native vegetation and underlying sand and woodchip media to filter, treat, and safely convey stormwater runoff.
- Granite Baptist Church Stream Restoration – This two-phased stream restoration project is in the Marley Creek subwatershed (PTF) near the Granite Baptist Church. The project is intended to restore and stabilize two branches of an unstable stream and reconnect them with the floodplain. The first phase is located on the north branch of the unnamed tributary to Marley Creek. This portion of stream is heavily incised is threatening a walking bridge that is used by the church. The second phase of construction is on the southern branch of stream that receives high wet-weather velocities and is actively downcutting. Both phases of construction entail creating a Rosgen B characteristic stream channel that has access to floodprone areas, but that fits within the topography and infrastructure constraints of the site.

- Century Towne Road ESD to the MEP Retrofit – This project is located along Century Towne Road (a County road) in the Marley Creek subwatershed (PTG). The conceptual design describes the retrofitting of stormwater controls to the maximum extent practicable. Conditions downstream of the stormwater outfall associated with this road are severely degraded. This project utilizes bioretention cells at catch basins and pervious pavement in parallel parking lanes to capture stormwater runoff before it reaches the stormwater collection system. A total of 24 bioretention cells and 17 pervious pavement strips have been initially proposed to address stormwater associated with water quantity from a one inch storm. All practices are placed in publically owned right-of-ways within the drainage area.

- Old Mill Stream Restoration - This project in the Marley Creek subwatershed (PTG), is designed to work in conjunction with the previously described Century Town Road ESD to the MEP Retrofit project. Two stream reaches in the vicinity of the Old Mill Middle School and Senior High School are highly incised and unstable making them an ideal candidate for restoration. This project is designed to stabilize and reconnect the reaches to the floodplain. Reach 1 starts at a previously restored upstream segment and runs 1,100 feet to the crossing of Shetlands Lane. The restoration conceptual design relies on stone boulder toe protection and soft bank stabilization to move the reach from a Rosgen Type G stream to a Type C. Reach 2 is a highly impaired 440 foot reach downstream of the crossing. The conceptual stream restoration for this reach uses a series of four rock weirs to raise the bed slope of the highly incised stream.

- Old Mill Community Association Bioretention Facility - This project was completed in coordination with the Old Mill Community Association, in the PTG subwatershed. This site was chosen based on input from the Community Association and the Watershed Stewards Academy. A bioretention facility concept plan has been developed to manage stormwater from the large community pool parking lot. With a grassed filter strip directing stormwater flows to the facility, the bioretention will treat the water quality volume for a one-inch storm event.

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