November 30, 2024

Prince George's County
DEPARTMENT OF THE
ENVIRONMENT

2024 Phosphorus and Sediment Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plan (WIP) for the **Patuxent River Watershed** in Prince George's County, Maryland

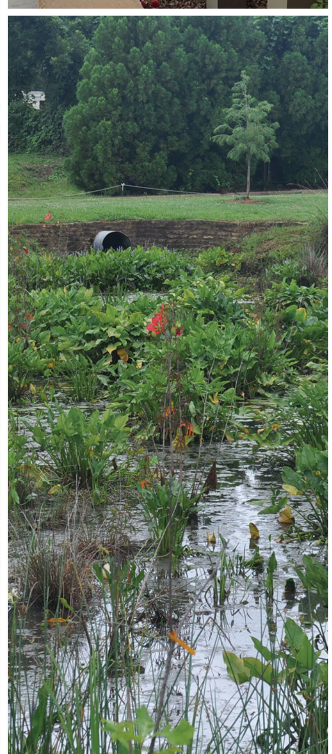
Prepared for: Prince George's County Department of the Environment, 1801 McCormick Drive, Suite 500, Largo, Maryland 20774
Prepared by: Tetra Tech, 10306 Eaton Place, Suite 340, Fairfax, VA 22030









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Abbreviations and Acronyms

ALT	alternative BMP practice
A-StoRM	Advancing Stormwater Resiliency in Maryland
BIBI	Benthic Index of Biotic Integrity
BMP	best management practice
BSID	Biological Stressor Identification
CFR	Code of Federal Regulations
CIP	Capital Improvement Program
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWP	Clean Water Partnership
DO	dissolved oxygen
DoE	[Prince George's County, MD] Department of the Environment
DPIE	[Prince George's County, MD] Department of Permitting, Inspection, and Enforcement
DPW&T	[Prince George's County, MD] Department of Public Works and Transportation
EPA	U.S. Environmental Protection Agency
ESD	environmental site design
°F	degrees Fahrenheit
FAP	Financial Assurance Plan
FIBI	Fish Index Biotic Integrity
FY	fiscal year
GRTS	Generalized Random Tessellation Stratified
HOA	homeowner association
HSG	hydrologic soil group
IBI	Index of Biotic Integrity
IDDE	illicit discharge detection and elimination
IDF	intensity-duration-frequency
LA	load allocation
lb	pound
MARISA	Mid-Atlantic Regional Integrated Sciences and Assessments
MBSS	Maryland Biological Stream Survey
MD DNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MEP	maximum extent practicable
mg/L	milligrams per liter
MGS	Maryland Geological Survey
M-NCPPC	Maryland-National Capital Park and Planning Commission
MOS	margin of safety

MS4	municipal separate storm sewer system
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
O&M	operation and maintenance
PCB	polychlorinated biphenyl
PR-L	Patuxent River Lower
PR-M	Patuxent River Middle
PR-U	Patuxent River Upper
ROW	right-of-way
RR	runoff reduction
SCA	stream corridor assessment
ST	stormwater treatment
SW-WLA	stormwater wasteload allocation
SWM	stormwater management
SWMM	Stormwater Management Model
TIPP	TMDL Implementation Progress and Planning
TMDL	total maximum daily load
TP40	Technical Paper Number 40
TP	total phosphorus
TSS	total suspended solids
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WIP	Watershed Implementation Plan
WLA	wasteload allocation
WSSC	Washington Suburban Sanitary Commission
XSa	cross sectional area
XS	cross-section

Executive Summary

On December 2, 2022, the Maryland Department of the Environment (MDE) issued Prince George's County (the County) its fifth-generation permit (Permit Number: 20-DP-3314 MD0068284) for its National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4), which is a series of stormwater sewers owned by a municipal entity (e.g., the County) that discharges the conveyed stormwater runoff into a water body (e.g., Patuxent River). The permit covers the period of December 2, 2022, through December 1, 2027. The MS4 permits are generally issued in 5-year cycles enabling regulators and permit holders to adjust permit objectives and expectations.

The 2022 MS4 permit requires that the County develop local restoration plans to address each U.S. Environmental Protection Agency (EPA)-approved total maximum daily load (TMDL) with a stormwater wasteload allocation (SW-WLA). A TMDL can be seen as a *pollution diet* in that it is the maximum amount of a pollutant that a water body can assimilate and still meet water quality standards and designated uses.

This SW-WLA Watershed Implementation Plan (WIP) covers the SW-WLA assigned to the County's MS4 for phosphorus and sediment impairments in the Patuxent River watershed (Figure ES-1). A WIP is a strategy for managing the natural resources within a geographically defined watershed. For the County's Department of the Environment (DoE), this means managing urban stormwater (i.e., runoff originating from rainstorms) to restore and protect the County's water bodies. Stormwater management is most effective when viewed in the watershed context—watersheds are land areas and their network of streams that convey stormwater runoff downstream to a single point.

Along with the 2022 MS4 permit, MDE released multiple guidance documents on addressing TMDLs. This WIP contains updates based on the latest MDE guidance and is an update to a previous restoration plan that included total phosphorus (TP), bacteria, and sediment submitted to MDE in 2015 (Tetra Tech 2015). It uses new information, including loading rates derived from the Bay Model 6, provided by MDE to counties in the TMDL Implementation Progress and Planning (TIPP) tool. This WIP follows the following MDE guidance documents:

- *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for National Pollutant Discharge Elimination System Stormwater Permits* (November 2021)
- *General Guidance for Local TMDL (Total Maximum Daily Load) Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plans (WIPs)* (February 2022)
- *Guidance for Developing Local Nutrient and Sediment TMDL (Total Maximum Daily Load) Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plans (WIPs)* (March 2022)
- *TMDL Implementation Progress and Planning (TIPP) Tool* (Original version: June 2021, Most recent version: April 2022

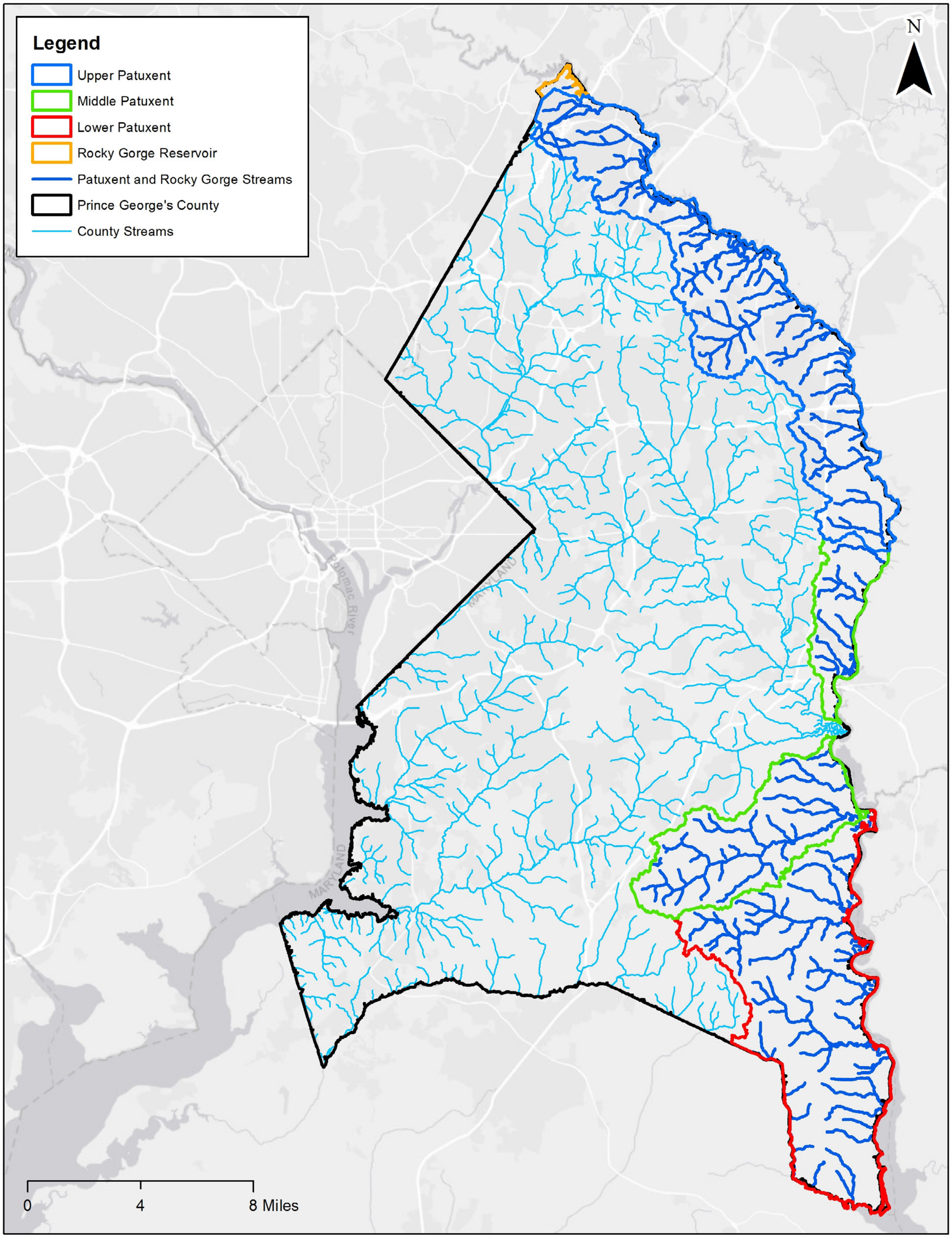
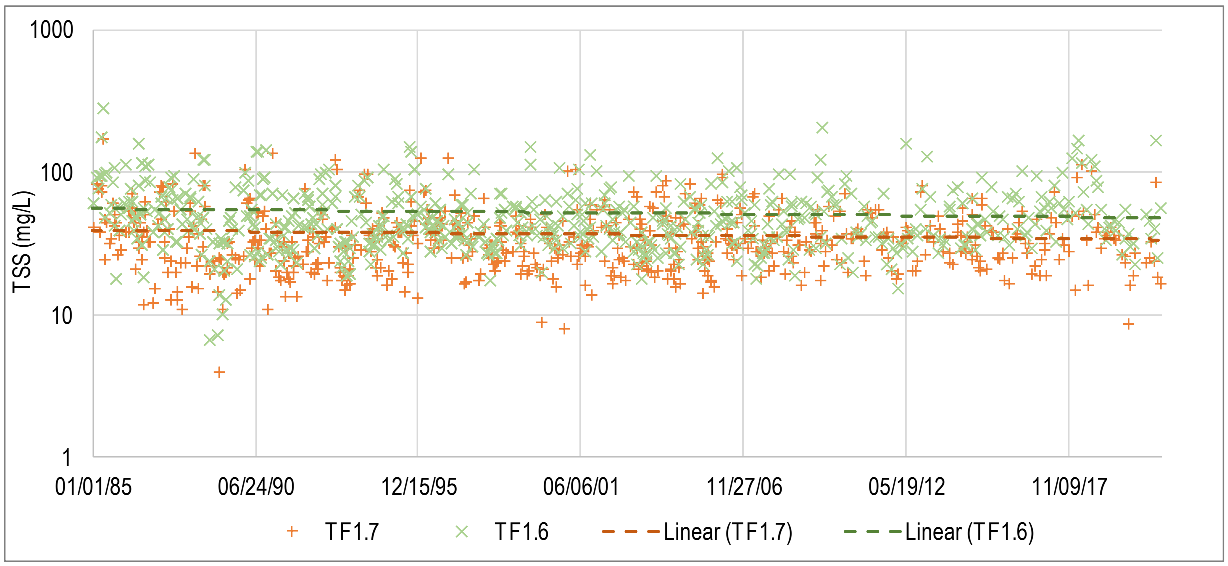


Figure ES-1. Patuxent River Watershed.

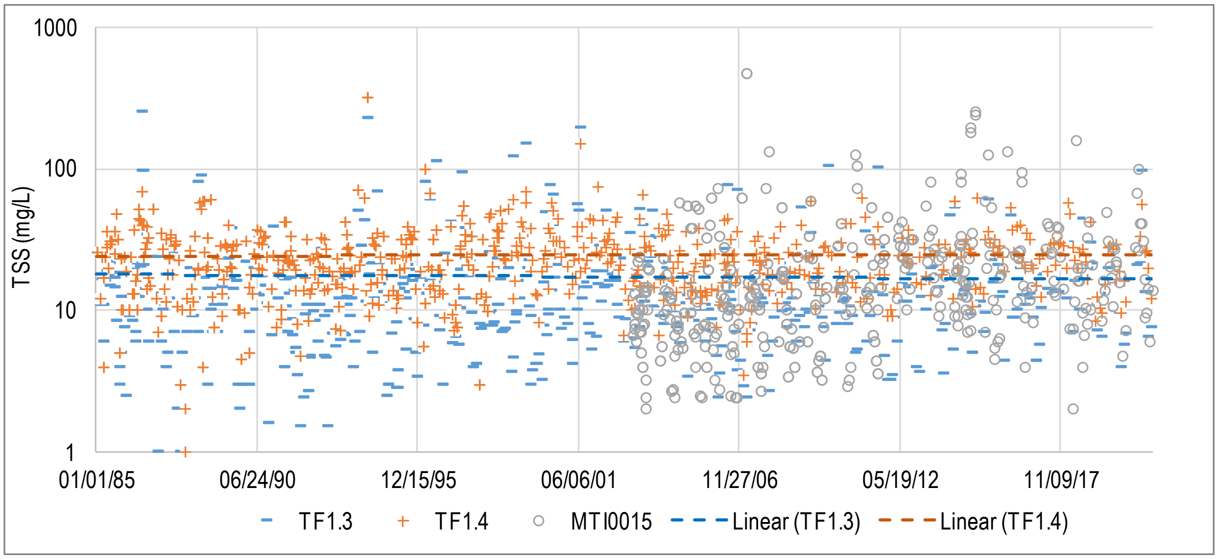
Long-term Water Quality Data

There are multiple locations in the Patuxent watershed with long-term monitoring data (1985–2020). Figure ES-2 through Figure ES-5 present an overview of sediment and TP trends from the locations with the most data. (Refer to Section 3.1 for a location map, summary tables, and additional information on these and other locations.) Sediment TMDLs were established in 2011 for Patuxent River Upper and in 2018 for the Patuxent River Middle and Lower and the Rocky Gorge Reservoir TP TMDL was established in 2008. Stations in the Patuxent River Lower (PR-L) show slight decreases in sediment (total suspended solids [TSS]), while other locations are inconclusive. There are other water quality stations in the watershed, but without a long period of record. Stations in the Patuxent River Middle (PR-M) and Patuxent River Lower (PR-L) indicate stable TSS trends to slightly decreasing trends. The Patuxent River Upper (PR-U) station exhibits an increasing trend for TSS. It is difficult to determine a trendline for TP due to limited samples and intermittent data collection. Trends might be attributed to various watershed factors (see Section 2 for the watershed characterization). Data from these stations are further summarized in Section 3.1 of this document.



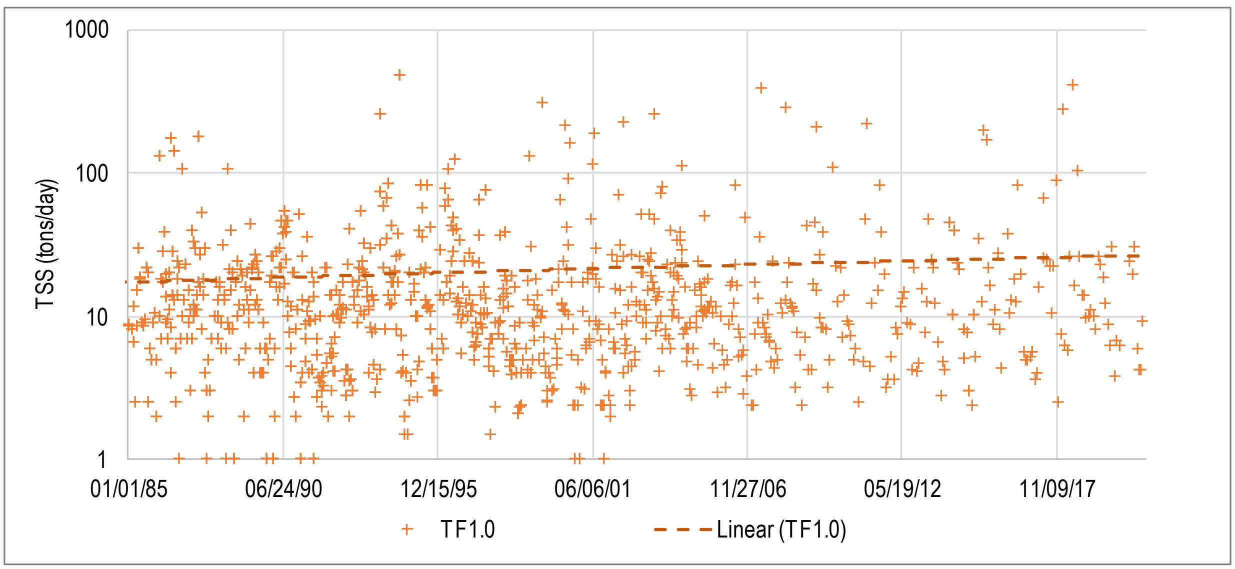
Source: NWQMC 2023.

Figure ES-2. Plot of TSS concentration over time at monitoring stations TF1.6 and TF1.7 in the Patuxent River Lower watershed.



Source: NWQMC 2023.

Figure ES-3. Plot of TSS concentration over time at monitoring stations MTI0015, TF1.3, and TF1.4 in the Patuxent River Middle watershed.



Source: NWQMC 2023.

Figure ES-4. Plot of TSS concentration over time at monitoring station TF1.0 in the Patuxent River Upper watershed.

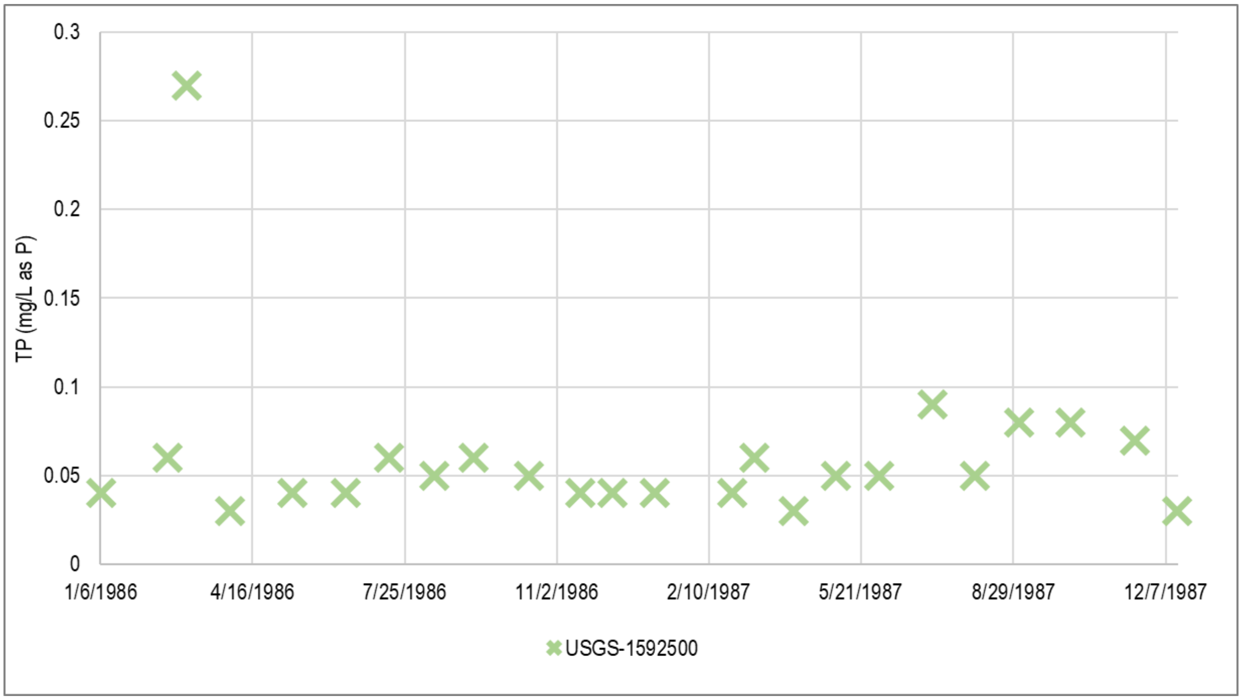


Figure ES-5. Plot of TP concentration over time at monitoring station USGS-1592500 in the Rocky Gorge Reservoir watershed.

TMDL Load Reduction Goals

Table ES-1 summarizes the load reductions for the Prince George's County portion of the Patuxent River watershed.

The table presents the baseline load at the time of the TMDL, progress loads as of July 2023, and projected future loads. (For full descriptions of load reduction terminology, please see Section 5.1 of this document.) Figure ES-6 through Figure ES-8 presents the cumulative reductions by restoration activity for each river segment since the TMDL was developed, which are represented in Table ES-1 as the difference between the baseline load and the progress load. The sediment reductions for Patuxent River Lower, Patuxent River Middle, and Patuxent River Upper, along with the total phosphorus reductions for Rocky Gorge Reservoir, are expected to be met with best management practices (BMPs) that are in the planning or design phase.

MDE has not mandated an end date for the local TMDL WIPs; however, the County understands the public prefers an expedited restoration process and shares that sense of urgency. The County and its watershed partners are committed to finding site opportunities and expediting the planning, design, and construction phases for management activities to the maximum extent practicable (MEP). Implementation milestones in these tables follow a proposed 2 percent restoration rate of untreated impervious surfaces having a 36-year time span to accomplish the reductions needed for the PR-M TMDL. With BMPs in the planning, design, or construction phases, the RR-L, PR-U, and Rocky Gorge TMDLs are expected to meet load reductions.

The PR-M sediment TMDL requires 56 percent reductions. For local TMDL compliance, load reduction estimates are based on MDE's 2021 *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for National Pollutant Discharge Elimination System*

Stormwater Permits (MDE 2021a). The guidance lists available best management practices (BMPs) and practices and the associated load reduction efficiencies for WIP load reduction calculations. Assuming a runoff reduction BMP treats a rainfall depth of 1 inch, the maximum sediment reduction is 74.9 percent. The current load reduction targets could take $118 million over 36 years to meet the target.

The County identifies specific BMPs opportunities over a 6-year planning horizon, which become part of the approved annual county stormwater capital improvement program (CIP) budget. The milestones in Table ES-1 were developed through the CIP and represent future CIP and programmatic restoration initiatives. These opportunities are included in the County's biannual Financial Assurance Plan (FAP) and summarized in the County's annual MS4 progress report. Planning, design, and construction activities follow a rigorous internal evaluation, including budget, CIP progress tracking, and necessary adjustments to implementation schedules due to unforeseen conditions. The result of this process is adjusted annually. Any BMPs installed by the County to address local TMDLs will also help meet Chesapeake Bay load reduction goals.

Table ES-1 presents the required reductions, current restoration progress (from restoration BMPs installed from the date of the TMDL to June 30, 2023), planned BMP reductions for BMPs in the County's BMP database of upcoming projects, and BMPs identified in this WIP to meet the restoration gap (load reductions from current and planned BMPs from the required reduction).

Table ES-1. Summary of WIP sediment and TP load reductions in the Patuxent River watershed.

Measure or Practice	Patuxent – Lower TSS (lbs/yr)	% of Baseline Load	Patuxent – Middle TSS (lbs/yr)	% of Baseline Load	Patuxent – Upper TSS (lbs/yr)	% of Baseline Load	Rocky Gorge TP (lbs/yr)	% of Baseline Load
Information from Table 5-5								
Required Reductions	3,593,205	61%	3,616,655	56%	1,894,824	11.4%	13	15%
Current Restoration BMP Reductions (through June 30, 2023)	3,681,774	63%	9,336	0%	4,129,502	25%	0	0%
Planned Restoration BMP Reductions (Identified in County BMP database)	937,338	16%	0	0%	1,108,534	7%	155	100%
Remaining Restoration Gap to meet TMDL	0	0%	3,607,320	56%	0	0%	0	0%
BMPs identified in this WIP to Meet Restoration Gap								
Stream Restoration / Outfall Stabilization	0	0%	599,311	9%	0	0%	0	0%
Tree Planting	0	0%	80,595	1%	0	0%	0	0%
Wet Ponds	0	0%	2,502,491	39%	0	0%	0	0%
RR Practices	0	0%	424,942	7%	0	0%	0	0%
Impervious to Turf	0	0%	0	0%	0	0%	0	0%
Total WIP	**0**	**0%**	**3,607,339**	**56%**	**0**	**0%**	**0**	**0%**
Total Restoration Activities								
Current BMPs, Planned BMPs, and WIP BMPs	4,619,112	78%	3,616,675	56%	5,238,036	32%	155	100%

Notes:
lbs/yr = pounds per year.
See Section 5.1 for a discussion of the terminology in this table.

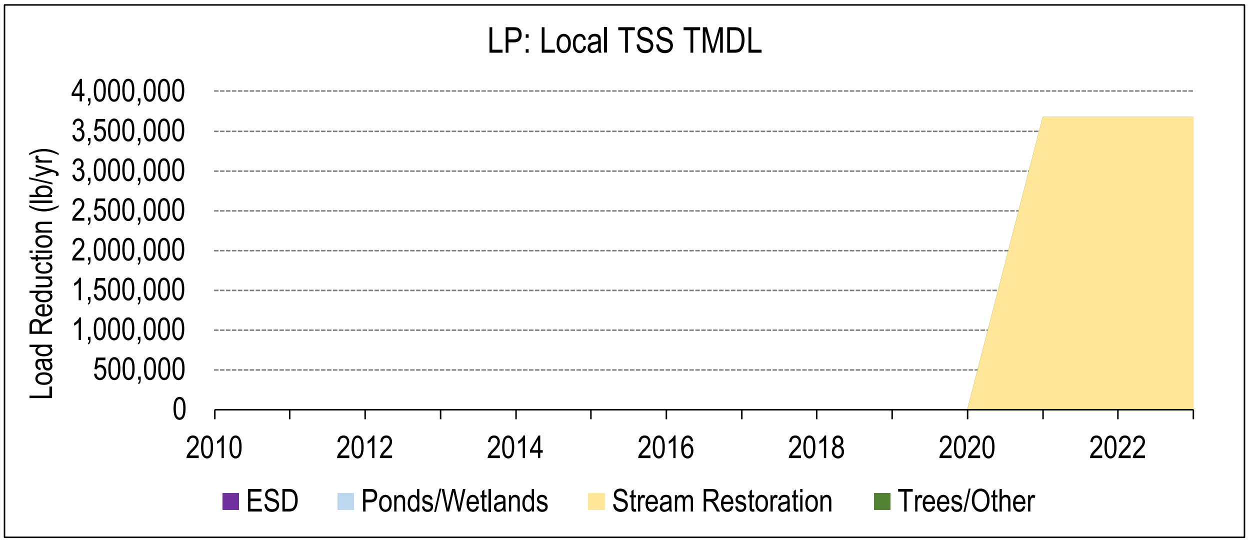


Figure ES-6. Cumulative Reductions for Lower Patuxent Local TMDL.

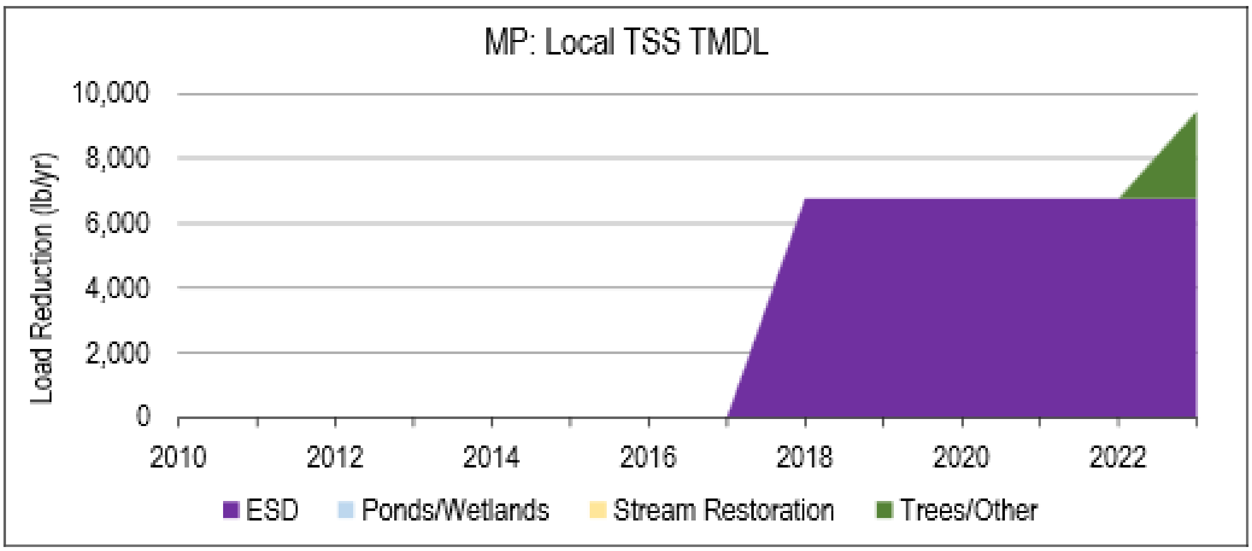


Figure ES-7. Cumulative Reductions for Middle Patuxent Local TMDL.

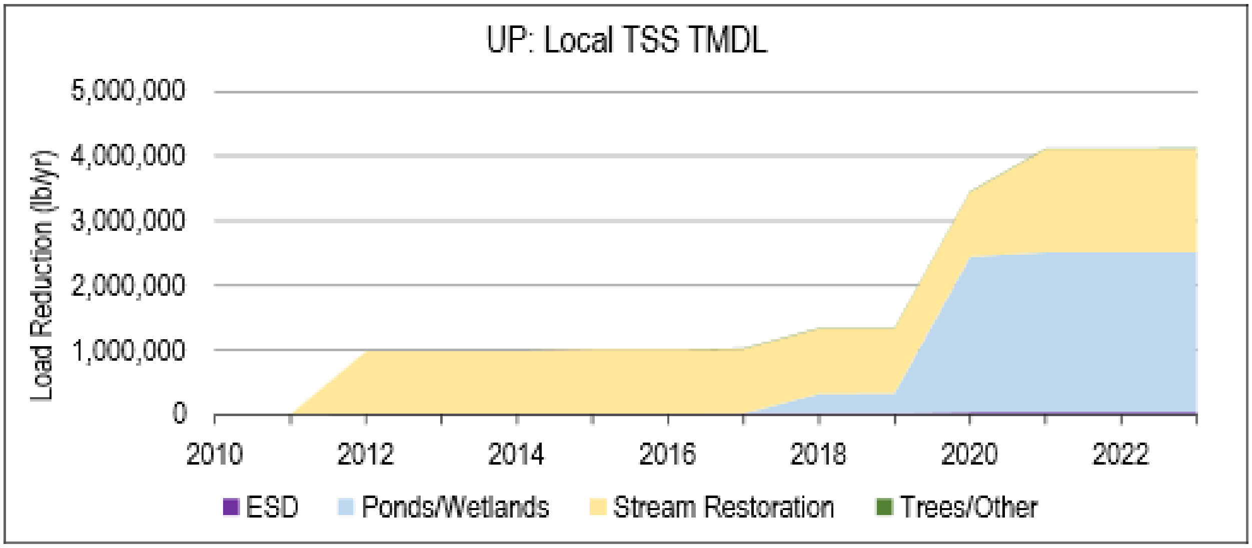


Figure ES-8. Cumulative Reductions for Upper Patuxent Local TMDL.

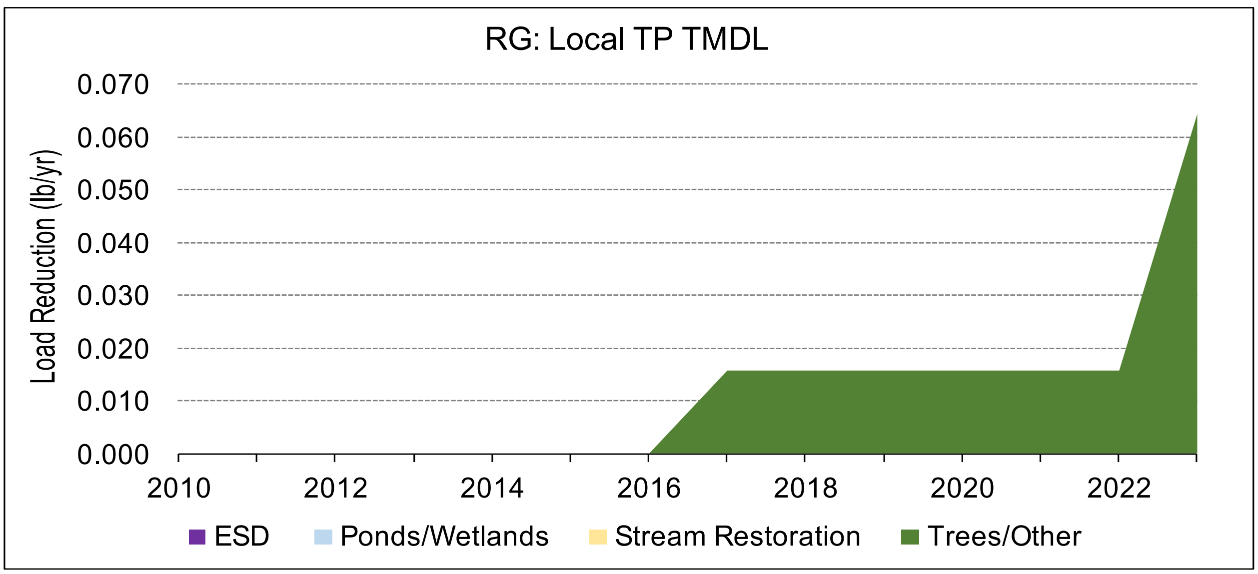


Figure ES-9. Cumulative Reductions for Rocky Gorge Local TMDL.

WATERSHED IMPLEMENTATION PLAN DOCUMENT ORGANIZATION

This document is organized into the following sections, which help the reader understand the TMDL, the watershed, and existing or planned restoration activities. Sections 4 through 7 build on information from the prior sections:

- **Section 1 – Introduction:** Contains information for readers new to TMDLs and WIPs and includes information on previous studies, water quality standards, designated uses, and impaired waters.
- **Section 2 – Watershed Characterization:** Contains information on watershed hydrology, climate/precipitation, topography soil, land use, land cover including impervious area, and land ownership. Focuses on watershed information to aid in planning and designing restoration projects.
- **Section 3 – Watershed and Water Quality Conditions:** Contains information on past water quality data, along with biological data, geomorphic data, stream erosion estimates, and potential pollutant sources. Provides Capital Improvement Project (CIP) designers with background to plan restoration projects.
- **Section 4 – Current Stormwater Management Activities:** Provides non-technical readers insight and information on current BMPs in the watershed. Provides the foundation for the discussion of the load reduction targets and current progress in Section 5. Written in a general form for an audience of readers who do not have a background in stormwater management.
- **Section 5 – Load Reduction Targets and Current Progress:** Provides the WIP's overall load calculation methodology and terminology, so that the non-technical readers understand the discussions in Section 6 and Section 7. Contains baseline, progress, and target loads.
- **Section 6 – Load Reduction Strategy:** Provides the overall WIP methodology and restoration scenarios for achieving load reductions. Includes information on BMP identification and selection along with implementation budgeting.
- **Section 7 – WIP Restoration Activities**: Analyzes the future BMPs necessary to meet the TMDL reductions. Includes budget and timeline.
- **Section 8 –Tracking Progress, Monitoring Stream Health, and Conducting Adaptive Management:** Contains information on County restoration progress tracking and reporting, along with information on County monitoring programs. Discusses the County's adaptive management approach to the WIP.
- **Appendix A – Current Stormwater Management Programs:** Overview of existing County stormwater management programs for readers unfamiliar with the programs.
- **Appendix B – BMP Removal Efficiencies:** Contains the BMP efficiencies used in load reduction calculations.
- **Appendix C – BMP Identification and Selection:** Overview of the methodology for identifying and siting BMPs for readers unfamiliar with County protocols.
- **Appendix D – Funding:** Overview of County funding mechanisms for readers unfamiliar with them.

- **Appendix E – Public Outreach and Involvement:** Provides residents and businesses ways that they can stay informed about and aid in the watershed restoration process.
- **Appendix F – Geomorphic Cross Section Assessment:** Provides result summary tables and plots of 2020 cross section analysis in the watershed.

WIP Compliance Checklist

MDE's *General Guidance for Local TMDL (Total Maximum Daily Load) Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plans (WIPs)* (MDE 2022a) listed seven items that must be included in SW-WLA WIPs. This table lists these seven primary elements and suggested sub-elements. Each item has a link to the relevant section in this WIP.

Elements and Sub-elements from MDE Guidance		Section/Page
1. What is being adaptively managed, e.g., a resource, a pollutant, a program, and/or individual implementation projects?		1.2.1 / 1-11
2. Why is adaptive management being used?		8.3 / 8-4
	2.1. Is there an aspect of the water resource management process that is specialized?	8.3 / 8-4
	2.2. Does the jurisdiction expect to have to modify the project or program as a result of an issue?	8.3 / 8-4
3a. What are the stepwise goals and objectives that consider both jurisdictional resources and the goals and objectives of the SW-WLA and TMDL?		1.1.2 / 1-3 7 / 7-1
3b. What are the costs associated with proposed management strategies?		6.3/ 6-8 7.3 / 7-5
	3.1. What is the budget?	D-1 / D-1
	3.2. Who has responsibility?	8.1 / 8-2
	3.3. Who is legally liable?	1 / ix
4. Who is the primary audience of the plan, and why?		1.1.3 / 1-4
5. What information is available and how is that information used to inform WIP development?		2 / 2-1 3 / 3-1 4.2 / 4-2
	5.1. Is information from permit required watershed assessments being addressed in detail by section in the TMDL implementation plan?	0 / 2-1 3 / 3-1
	5.2. Have other documents/studies been published that contribute to understanding the watershed as a multi-faceted system and the natural resources it supports?	1.1.4 / 1-5
	5.3. Do other watershed plans exist in the watershed; either generated by a government, utility, or nongovernmental entity? Provide this information and details about other monitoring programs, so data can be shared on a regularly scheduled basis.	1.1.4 / 1-5 3 / 3-1
	5.4. Has the jurisdiction modeled pollutant sources and expected load reductions from potential, planned actions, where applicable?	5 / 5-1 7.2.2 / 7-3
	5.5. Is monitoring data being used to inform actions?	8.2 / 8-2 C.2.3 / C-5
6. How does the watershed function for the public in terms of its beneficial uses?		1.2.1 / 1-11
	6.1. How are stakeholders considered in the planning document	1.1.3 / 1-4 E / E-1
7. What are the proposed planning horizons and how will they be justified?		7.4 / 7-6
	7.1. Identify indicators and determine if they are currently meeting goals.	8 / 8-1
	7.2. Is the proposed planning horizon the point at which improvement is expected? 7.3. Or is the planning horizon simply based on model accounting?	7.4 / 7-6
	7.5. Who does what if milestones for horizons are not met on time?	8.1 / 8-2 8.3 / 8-4

1 INTRODUCTION

On December 2, 2022, the Maryland Department of the Environment (MDE) issued Prince George's County (the County) its fifth-generation permit (Permit Number: 20-DP-3314 MD0068284) for its National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4), which is a series of stormwater sewers owned by a municipal entity (e.g., the County) that discharges the conveyed stormwater runoff into a water body (e.g., Patuxent River). The permit covers the period of December 2, 2022, through December 1, 2027. The MS4 permits are generally issued in 5-year cycles enabling regulators and permit holders to adjust permit objectives and expectations that could require adjustments to this plan.

The County's 2022 MS4 permit requires that the County develop local restoration plans to address each U.S. Environmental Protection Agency (EPA)-approved total maximum daily load (TMDL) with a stormwater wasteload allocation (SW-WLA). A TMDL can be seen as a *pollution diet* in that it is the maximum amount of a pollutant that a water body can assimilate and still meet water quality standards and designated uses.

This SW-WLA Watershed Implementation Plan (WIP) is the portion of the TMDL that is allocated to permitted dischargers such as wastewater treatment plants or MS4s. This SW-WLA WIP covers the SW-WLA that was assigned to the County's MS4 for nutrient and sediment impairments in the Patuxent River watershed, which consists of the Patuxent River Upper (PR-U), Patuxent River Middle (PR-M), Patuxent River Lower (PR-L), and Rocky Gorge Reservoir watersheds. These watersheds cover portions of Montgomery, Anne Arundel, and Howard Counties. All maps and data in this document only reflect the Prince George's County portion of the watershed, unless specifically stated otherwise.

The 2014 and 2022 MS4 permits stipulate that the County must develop additional restoration plans within one (1) year of the EPA approval of a new TMDL. This WIP covers nutrient (phosphorus) and sediment TMDLs, which were approved by EPA in 2008, 2011, and 2018. This WIP contains updates to a previous restoration plan for nutrients, bacteria, and sediment that were submitted to MDE in 2015 as part of the 2014 MS4 permit compliance for the PR-U and Rocky Goerge TMDLs and in 2019 for the PR-M and PR-L sediment TMDLs (Tetra Tech 2015, 2019). This WIP uses new information, including loading rates derived from the Bay Model 6, provided by MDE to counties in the TMDL Implementation Progress and Planning (TIPP) tool. This plan was developed in a similar way as previous plans, following guidance provided by MDE's *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for National Pollutant Discharge Elimination System Stormwater Permits* (MDE 2021a).

1.1 Purpose of Report and Watershed Restoration

1.1.1 What is a TMDL?

Section 303(d) of the Clean Water Act (CWA) and EPA's Water Quality Planning and Management Regulations (codified in Title 40 of the *Code of Federal Regulations* Part 130) require states to develop TMDLs for impaired water bodies. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA 1991).

A TMDL is a *pollution diet* that establishes the amount of a pollutant a water body can assimilate without exceeding its water quality standard for that pollutant and is represented as a mass per unit of time (e.g., pounds per day). The mass per unit of time is called the *load*. For instance, a TMDL could stipulate that a maximum load of 1,000 pounds of sediment per day could be discharged into an entire stream before the stream experiences any detrimental effects. The pollution diet for a given pollutant and water body is composed of the sum of individual waste load allocations (WLAs) for point sources and LAs for nonpoint sources and natural background levels. The WLA is the portion of the TMDL that is allocated to permitted dischargers such as wastewater treatment plants or MS4s. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. The following equation illustrates TMDL components:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The County's MS4 permit requires the County to develop local WIPs to address each EPA-approved TMDL with stormwater WLAs.

Figure 1-1 shows a generalized TMDL schematic. A TMDL identifies the maximum amount of pollutant load that the water body can receive and still meet applicable water quality criteria. The bar on the left represents the *baseline* pollutant load that exists in a water body before a TMDL is developed. The elevated load causes the water body to exceed water quality criteria associated with the water body's officially designated uses. The bar on the right represents the amount the pollutant load will need to be reduced for the water body to meet water quality criteria. Another way to convey the required load reduction is by identifying the percent reduction needed.

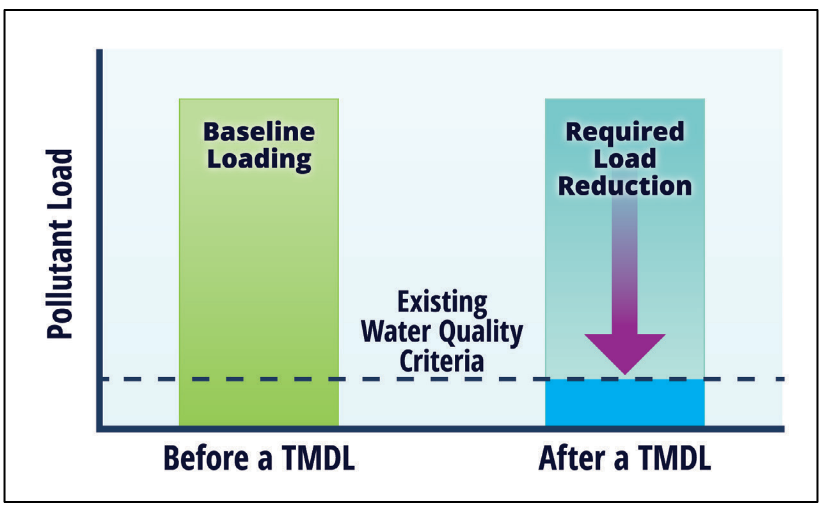


Figure 1-1. Conceptual schematic of a typical pollution diet, or TMDL.

1.1.2 What is a SW-WLA Watershed Implementation Plan?

A WIP is a strategy for managing natural resources in a geographically defined watershed. For the County's Department of the Environment (DoE), this means managing urban stormwater (i.e., runoff originating from rainstorms) to restore and protect the County's water bodies. Stormwater management is most effective when viewed in the watershed context—watersheds are land areas and their network of streams that convey stormwater runoff to a common body of water. Successful stormwater management consists of structural practices (e.g., vegetated roadway swales) and public outreach (e.g., pet waste campaigns and education) at both the public and private levels. Stormwater management must be implemented per the County's State-approved stormwater regulations and ordinances. These guidelines use changes and their stormwater runoff management requirements. The State provides the County with prescribed methods for restoration for addressing various types of impairments through its accounting for SW-WLA guidance (MDE 2021a), which contains recommended BMP practices and their associated pollutant load removal efficiencies. In preparation for this WIP, the County must follow MDE recommendations as prescribed in the guidance. The WIP development process will address changes that are needed to the County's priorities to comply with water quality regulations, to improve the health of the streams in the County, and to create value for neighborhoods in the County's watersheds.

The overall goals of restoration planning are to:

- Protect, restore, and enhance habitat in the watershed.
- Restore watershed functions, including hydrology, water quality, and habitat, using a balanced approach that minimizes negative impacts.
- Support compliance with regional, state, and federal regulatory requirements.
- Increase awareness and stewardship within the watershed, including encouraging policymakers to develop policies that support a healthy watershed.
- Support environmental justice initiatives to help underserved and overburdened communities
- Provide the understanding that these implementation plans will carry over several years and be based on adaptive management.

This document represents the first stage in achieving these goals. This plan focuses on watershed-based planning, not site-level planning. The restoration planning process seeks to:

- Identify the causes and sources of pollution.
- Estimate pollutant load reductions.
- Describe management options and identify critical areas.
- Estimate the technical and financial assistance needed.
- Develop an education component.
- Develop a project schedule.
- Describe interim, measurable milestones.
- Identify indicators to measure progress.
- Develop a monitoring component.

WIP progress is tracked and reported to MDE via annual NPDES reports, which include a geodatabase with updated restoration information and geographic features representing BMP locations. The County prepares a financial assurance plan that provides information on the County's financial capacity to fund projects two years in advance. That plan also includes lists of completed projects and future planned projects. This is discussed in Section 8.

1.1.3 Stakeholders

Overall success of the WIP will depend on the concerted effort of the County and many regional agencies, municipalities, community leaders, and local landowners. Each watershed partner has an important role to play in the restoration process. The proposed management actions will require significant time and resources from all those entities. Technical assistance and other in-kind support from the watershed partners and the public will be important in implementing the plan, especially when addressing obstacles, including permitting challenges, technological limitations, and a lack of available sites where best management practices (BMPs) can be implemented.

The intended audience of the WIP includes a wide range of interest groups including local watershed groups, individual citizens (landowners), developers (new and re-development), DoE restoration program planning staff (e.g., DoE Capital Improvement Project [CIP] Section, Clean Water Partnership), DPW&T CIP planning staff, and nongovernment organizations (e.g., Low Impact Development Center, Chesapeake Bay Trust).

This WIP was developed to aid County decision makers and watershed planners in the watershed restoration process. DoE staff use the WIP for BMP project planning and design. It also serves to inform the public and stakeholders on the restoration strategies that the County is taking for impaired waterbodies. The County routinely engages watershed groups countywide. There are watershed groups already formed that can participate as stakeholders during the development of these plans, which are available online for comments and collaboration. Information on how the public and stakeholders can contribute to the restoration process is provided in Appendix E. For instance, watershed groups can search various County sources for information using the County websites, focusing on issues affecting the watershed (e.g., littering, illegal dumping, illicit discharges, erosion control). They can participate in volunteer clean ups or address community stormwater BMPs needs that also treat water quality.

Developers also are stakeholders in watershed health. They are required to treat stormwater from their properties during construction using erosion and sediment control practices to prevent sediment from entering the MS4 and waterways. Developers are also required to implement post-construction BMPs to offset increased impervious areas and they are responsible for operation and maintenance (O&M) activities to keep the practices functioning properly. This and other WIPs are available to the County Department of Permitting, Inspections, and Enforcement (DPIE) to ensure developers follow BMP recommendations and practices.

When approved, all County restoration plans and WIPs are made available via a County website, along with the materials from public meetings, for anyone who wishes to participate in making improvements to the watershed.[1] The County's annual MS4 reports are also posted on the County website for stakeholders to review.[2]

1.1.4 Previous Studies

Over the years, the County and other agencies have conducted studies and developed plans in the County, including for the Patuxent River watershed. This section details the more recent studies.

In 2010, the Maryland-National Capital Park and Planning Commission (M-NCPPC) developed its Water Resources Functional Master Plan (M-NCPPC 2010). The document amended the County's 2002 General Plan. The update summarized estimated existing and future nutrient loadings and looked at the County's water and sewer services capacity relative to planned growth through 2030.

In 2011, the County developed a countywide Chesapeake Bay WIP in response to the 2010 Chesapeake Bay Nutrient and Sediment TMDL. The Chesapeake Bay WIP was finalized in 2012 and laid out a plan for BMP implementation and other restoration activities through two target years: 2017 and 2025. In addition to urban stormwater runoff, the Chesapeake Bay WIP covered agricultural practices and upgrades to wastewater systems (i.e., municipal wastewater treatment plants and on-site wastewater systems). Although the plan is Countywide, many of its elements apply to PR-L, PR-M, PR-U, and Western Branch watersheds and have been used to develop the restoration plan.

In 2002 and 2003, the Maryland Department of Natural Resources (MD DNR), through funding from the National Oceanic and Atmospheric Administration, produced a series of reports on the Upper Patuxent River watershed. These reports include:

- *Report on Nutrient and Biological Synoptic Surveys in the Upper Patuxent Watershed, Anne Arundel and Prince George's Counties, Maryland, April 2002 as part of the Watershed Restoration Action Strategy* (MD DNR 2002a);
- *Stream Corridor Assessment Survey in Upper Patuxent River* (MD DNR 2003); and
- *Watershed Characterization Reports for Upper Patuxent River* (MD DNR 2002b).

The nutrient synoptic survey and watershed characterization reports for the Upper Patuxent River watershed also included drainage areas in adjacent counties, but the remainder of the reports covered only the County areas. The first report looked at data collected from 2002 and 2003 at multiple stations. Nutrient levels were reported to be low and did not pose significant problems in either watershed, although the Western Branch subwatersheds with dense developments had high conductivity levels possibly from road salt application. The second two reports assessed the conditions of the stream channels by looking at several environmental degradation factors such as inadequate stream buffers, channel alterations, trash dumping, exposed pipes, erosion, in- or near-stream construction sites, and fish migration barriers. Several opportunities for restoration and protection were identified. The last pair of reports were earlier watershed characterization

[1] https://www.pgcdoe.net/pgc_watershedassesments. Accessed December 2023.
[2] https://www.princegeorgescountymd.gov/departments-offices/environment/stormwater-management/clean-water-program/npdes-ms4-permit. Accessed December 2023.

efforts pursued by the Maryland Department of Natural Resources (MD DNR), which covered several similar topics to this report.

The County also pursued flood mitigation and water quality improvement efforts in the Bear Branch watershed mostly within Laurel, Maryland (D&D 2003, 2006). This tributary to the Upper Patuxent River watershed is in the northern portion of the County. Excessive sedimentation, turbidity habitat impairment, and flooding within the Laurel Lakes complex were the focus of the D&D (2003) assessment, and D&D (2006) developed specific management measures including active stream bed and bank erosion measures, retrofitting existing stormwater ponds, and implementing BMPs in upland areas to reduce sediments.

The state of Maryland published its Chesapeake Bay Phase I WIP in December 2010 for major basins, including the Anacostia River. A primary goal was to identify target pollutant load reductions that need to be achieved by various sources and geographic areas within the state. In 2011, the County developed a countywide Chesapeake Bay WIP in response to the 2010 Chesapeake Bay Nutrient and Sediment TMDL (PGC DER 2012). The Chesapeake Bay WIP was finalized in 2012 and laid out a plan for BMP implementation and other restoration activities through two target years: 2017 and 2025. In addition to urban stormwater runoff, the Chesapeake Bay WIP covered agricultural practices and upgrades to wastewater systems (i.e., municipal wastewater treatment plants and on-site wastewater systems). MDE also published a Phase II WIP in October 2012, which contained detailed plans for meeting the TMDL at a local level. The plans identified the target loads for each individual jurisdiction (i.e., counties and the city of Baltimore) within the area. The MDE Phase II WIP included the Prince George's County Phase II WIP.

Versar (2012) developed a WIP on behalf of Montgomery County for the portion of the Upper Patuxent River upstream of the Triadelphia and Rocky Gorge reservoirs. The Rocky Gorge Reservoir exists in Howard, Montgomery, and Prince George's Counties. A watershed treatment model was developed and applied to evaluate different scenarios of BMPs to reduce sediment and phosphorus loads into these reservoirs. Restoration projects with high to low priority levels were also identified to guide the implementation process.

In 2014, the County developed restoration plans to serve as blueprints for improving water quality and meeting pollutant reduction goals called for in approved local TMDLs. One of these plans was for sediment and bacteria in the Upper Patuxent River and phosphorous in the Rocky Gorge Reservoir watersheds (Tetra Tech 2015). That plan describes the pollutants and sources of those pollutants specific to each body of water, the land uses and natural features in the watershed, a method for determining the amount of pollutant reductions that need to be achieved, and targeted pollutant reduction strategies for each watershed. The strategies include both programmatic initiatives (e.g., tree planting, street sweeping) as well as on-the-ground, pollution-reducing BMPs.

This WIP builds on the 2015 restoration plan with new information, such as land use. The 2015 plan used Maryland Department of Planning 2010 land use. This updated plan uses land cover data provided by MDE representing 2015. This new land cover data is the same as used in the recent Chesapeake Bay model and the land cover categories match the updated land-cover loading rates and BMP efficiencies from MDE's 2021 wasteload allocation guidance (MDE

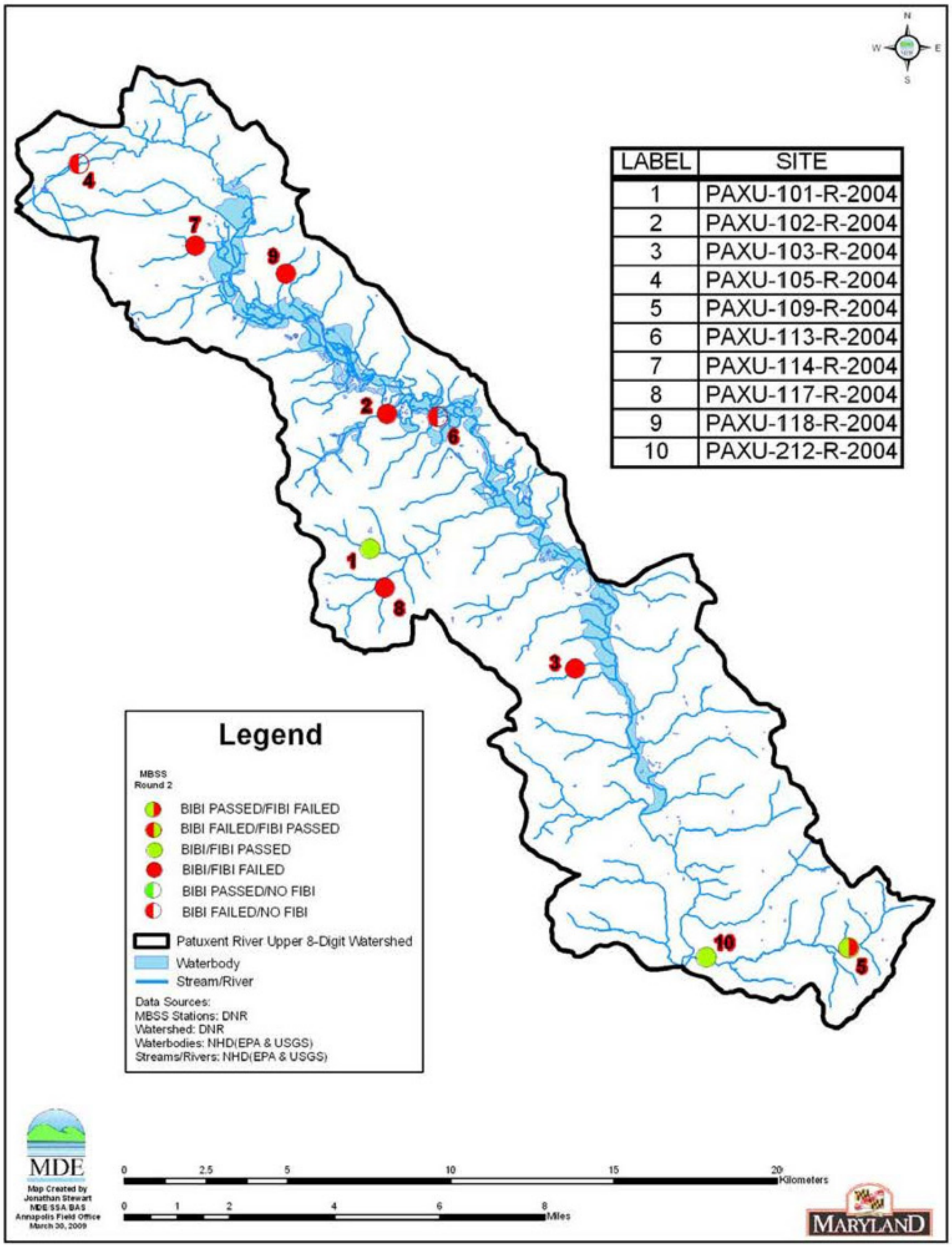
2021a). In early 2022, MDE released its *General Guidance for Local TMDL (Total Maximum Daily Load) Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plans (WIPs)* (MDE 2022a). This document lays out the required elements of a WIP, along with additional data. This plan follows MDE guidance.

In 2024, the County finalized its countywide plans for addressing bacteria and polychlorinated biphenyls (PCBs). Both plans follow recent MDE guidance. The bacteria strategy covers the bacteria TMDLs in Anacostia River, Piscataway Creek, and a portion of the Upper Patuxent River watersheds (Tetra Tech 2024a). The PCB strategy covers the bacteria TMDLs in Anacostia River, Mattawoman Creek, Piscataway Creek, the Patuxent River, and the Potomac River watersheds (Tetra Tech 2024b). Also, in 2024, the County reviewed and analyzed data on chlorides in the County (Tetra Tech 2024c). This analysis was in response to new MDE permit requirements in the County's 2022 MS4 permit. The County has five watersheds (Anacostia, Mattawoman, Piscataway, Upper Potomac Tidal, and Upper Patuxent) on Maryland's list of impaired waters due to chloride, however, not all have established TMDLs. The County Department of Public Works and Transportation (DPW&T) will be developing the overall salt/de-icer management plan for the County to meet the permit requirement by December 2025.

1.2 Patuxent River Water Quality Impairments

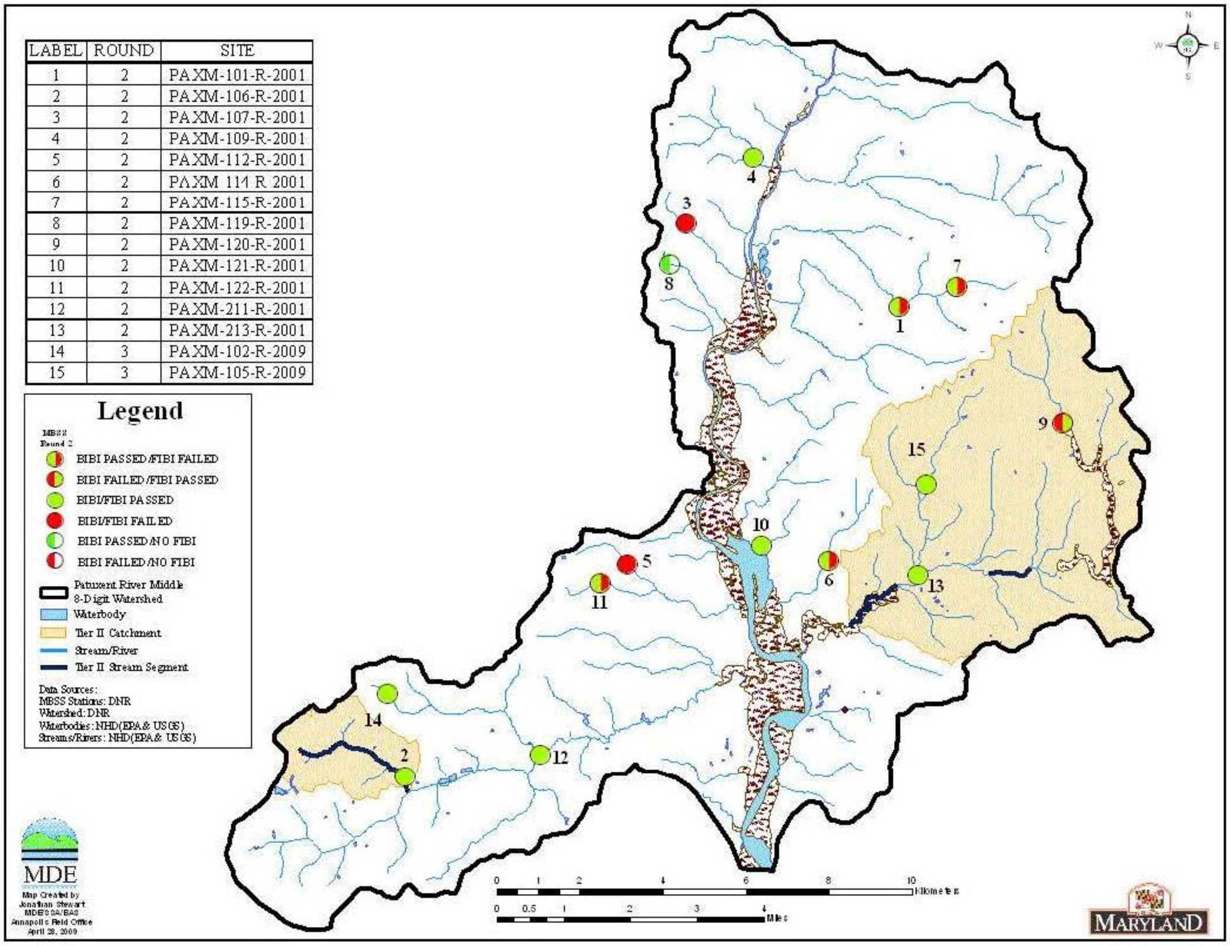
This section summarizes the various water quality problems identified in the Patuxent River watershed. MDE used its Biological Stressor Identification (BSID) data to support its impairment decisions (MDE 2010, 2013a, 2013b). The reports for biological impairment (MDE 2010, 2013a, 2013b) indicated that long-term monitoring data collected in the watershed showed significant negative deviations from reference biological conditions, indicating impacts to biological communities that impair the watershed's ability to support aquatic life and wildlife (support of aquatic life and wildlife must be achieved to meet water quality standards). These 303(d) listings for impairment use a biological assessment methodology, the BSID method, which examines the Benthic Index of Biotic Integrity (BIBI) and the Fish Index of Biotic Integrity (FIBI). In addition to the Index of Biotic Integrity (IBI) data, the TMDL development process also examined physical habitat assessments in the context of epifaunal substrate (surfaces on which aquatic organisms may live), and other in-stream habitat considerations, finding correlated results of these measures with sediment influence in the watershed. The BSID identified that the biological communities were likely degraded due to sediment-related stressors.

MDE (MDE 2010, 2013a, 2013b) estimates that 73 percent of stream miles in the PR-U watershed, 47 percent of stream miles in the PR-M watershed, and 43 percent of stream miles in the PR-L watershed have benthic and/or fish indices of biological impairment in the poor to very poor category. Biological impairment listing data of PR-U were collected during Maryland Biological Stream Survey (MBSS) round 1 (1995–1997) and round 2 (2000–2004) monitoring activities, which include 15 sites. 11 of the 15 stations exhibited benthic and/or fish IBIs significantly lower than 3.0 (i.e., poor to very poor). The results from the principal dataset (round 2 with 10 sites) are presented in Figure 1-2. Data of PR-M were collected from round 1 and round 2, which include 17 sites. Seven of the 17 stations have benthic and/or fish index of biotic integrity scores significantly lower than 3.0. The results from the principal dataset (round 2 and round 3 with 15 sites) are presented in Figure 1-3. Data of PR-L were collected from round 1 and round 2, which include 34 sites. 16 of the 34 stations have benthic and/or fish index of biotic integrity scores significantly lower than 3.0. Data collected in round 3 (2007-2009) were also included in the BSID analysis, as shown in Figure 1-4. The low scoring IBIs can be attributed to the watersheds having undergone full development with no stormwater management controls, predating the first stormwater management (SWM) ordinance in 1985. The hydrologic watershed balance was disrupted and created a domino effect to the biology and fish.



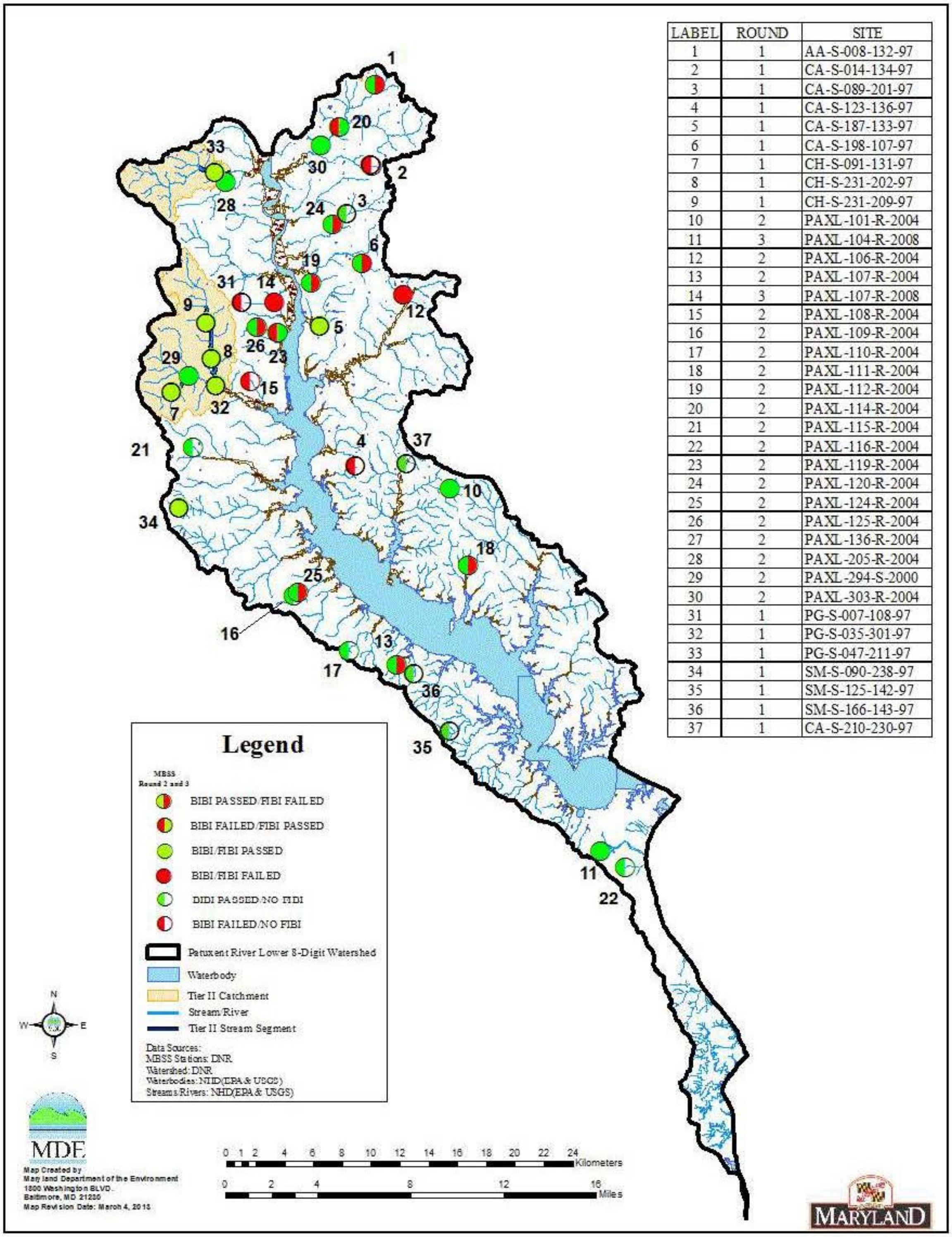
Source: MDE 2010.

Figure 1-2. MBSS results from MDE 2010 for Patuxent River Upper watershed.



Source: MDE 2013.

Figure 1-3. MBSS results from MDE 2013 for Patuxent River Middle watershed.



Source: MDE 2013.

Figure 1-4. MBSS results from MDE 2013 for Patuxent River Lower watershed.

1.2.1 Designated Uses

MDE has classified waterbodies in the state based on the waterbody's existing conditions and the potential uses for the waterbody. Additional information on designated uses is found in the *Code of Maryland Regulations* (COMAR) Sections 26.08.02.02[3] and 26.08.02.02-1.[4]

Figure 1-5 presents the designated uses in the watershed, which are also listed below:

- Use Class I: Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life
- Use Class II: Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting
- Use Class III: Nontidal Cold Water
- Use Class IV: Recreational Trout Waters

The Class I designation includes waters that are suitable for:

a) water contact sports;
b) play and leisure time activities where individuals may come in direct contact with the surface water;
c) fishing;
d) the growth and propagation of fish (other than trout), other aquatic life, and wildlife;
e) agricultural water supply; and
f) industrial water supply.

The Class II designation includes waters in support of Estuarine and Marine Aquatic Life and Shellfish Harvesting. This class designation includes all applicable uses identified for Class I in:

a) All tidally influenced waters of the Chesapeake Bay and tributaries, the Coastal Bays, and the Atlantic Ocean to the 3-nautical-mile boundary;
b) Tidally influenced waters that are or have the potential for:
   (i). Shellfish propagation and storage, or harvest for marketing purposes;
   (ii). Actual or potential areas for the harvesting of oysters, soft-shell clams, hard-shell clams, and brackish water clams.

The Class III designation includes all uses identified for Class I and waters which have the potential for or are suitable for the growth and propagation of self-sustaining trout populations and other coldwater obligate species including, but not limited to the stoneflies, *Tallape*rla, and *Sweltsa*.

The Class IV designation includes all uses identified for Class I in cold or warm waters that have the potential for or are:

- Capable of holding or supporting adult trout for put-and-take fishing;

[3] http://mdrules.elaws.us/comar/26.08.02.02
[4] http://mdrules.elaws.us/comar/26.08.02.02-1

- Managed as a special fishery by periodic stocking and seasonal catching.

Maryland has also designated Tier II high-quality waters, which are waterbodies with existing water quality that is significantly better than water quality standards. Per federal regulations (Title 40 of the *Code of Federal Regulations* Section 131.12 [40 CFR 131.12]), these waters must be maintained at their high-quality level.

The Patuxent River has no stream segment that has been designated as Tier II waters (Figure 1-5).

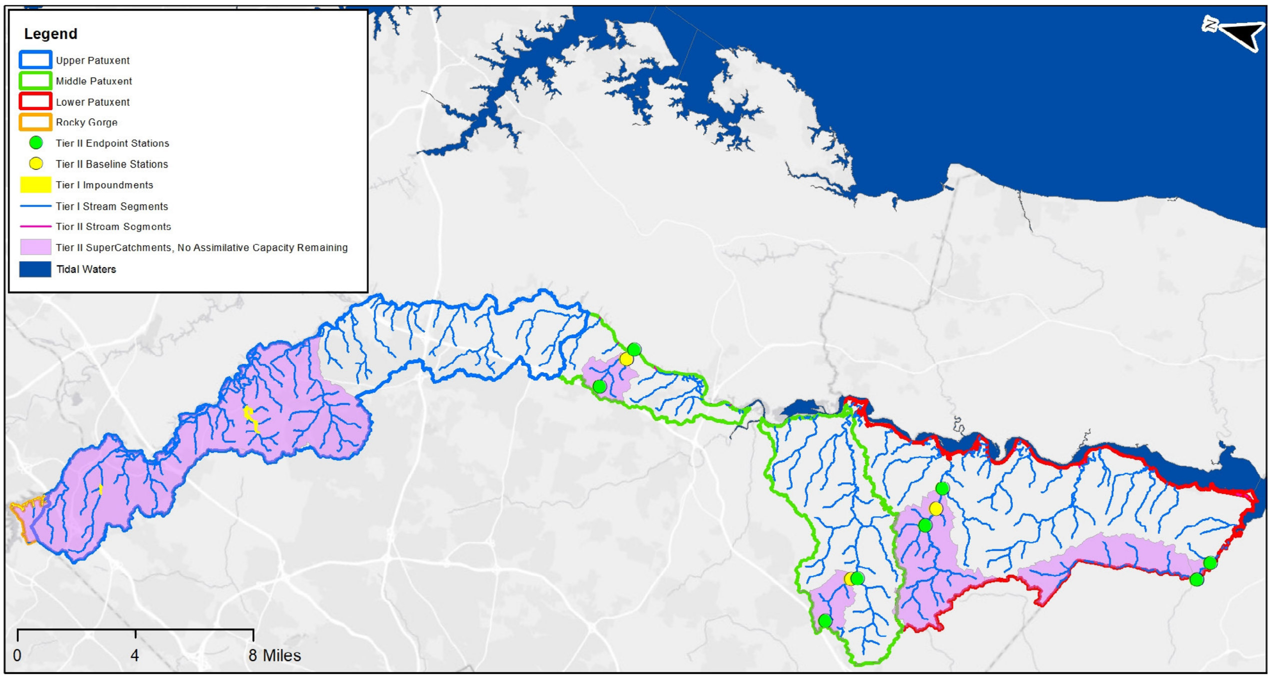


Figure 1-5. Designated uses and Tier II waters in the Patuxent River watershed.

1.2.2 Impairment Listings

Patuxent River and its tributaries are included on the MDE 303(d) list of impaired waters for several pollutants. Table 1-1 lists these pollutants, their listing year, if a TMDL was developed, and the resulting percent reductions. For each TMDL, MDE provided Montgomery, Anne Arundel, and Howard counties with their own percent reductions.

Table 1-1. List of impaired waters in the Patuxent River watershed in Prince George's County.

Pollutant	Waterbody	Year	Finalized TMDL? (Year)	TMDL Percent Reduction for MS4	Included in this WIP?
Nutrients (phosphorus)	Rocky Gorge Reservoir	1996	Yes (2008)	15%	Yes
	Allen Pond (Western Branch)	2024	No. Required (low priority).	n/a	n/a
Nutrients (Biological Oxygen Demand)	Western Branch	1996	2000	n/a [a]	n/a

Pollutant	Waterbody	Year	Finalized TMDL? (Year)	TMDL Percent Reduction for MS4	Included in this WIP?
Sediment, total suspended solids [b]	Patuxent River - Upper	1996	Yes (2011)	11.4%	Yes
	Patuxent River - Middle	2014	Yes (2018)	56%	Yes
	Patuxent River - Lower	2014	Yes (2018)	61%	Yes
	Rocky Gorge Reservoir	2014	No. Required (low priority).	n/a	n/a
Nutrients (nitrogen, phosphorus) and Sediment, as part of Chesapeake Bay TMDL	All	2012	Yes (2010)	Patuxent Upper Tidal Fresh TN: 17.5% TP: 32.1% Patuxent Middle Oligohaline TN: 26.9% TP: 43.6% Patuxent Lower Mesohaline TN: 26.2% TP: 41.9% Western Branch TN: 20.2% TP: 35.3%	No. See PGC DER 2012.
Bacteria: *Escherichia coli* (*E. coli*)	Patuxent River – Upper (non-tidal)	2008	Yes (2011)		No. See Tetra Tech 2024a.
Bacteria: Fecal Coliform	Middle Patuxent River Oligohaline	2012	No. Required (high priority).	n/a	n/a
	Lower Patuxent River Mesohaline	2024	No. Required (high priority).	n/a	n/a
Mercury	Cash Lake (Patuxent River – Upper)	2004	Yes (2011)	n/a [c]	n/a
Polychlorinated biphenyls (PCBs) in fish tissue	Upper Patuxent River Tidal Fresh	2014	Yes (2017)	99.9%	No. See Tetra Tech 2024b.
	Middle Patuxent River Tidal Fresh	2016	Yes (2017)	0%	No. See Tetra Tech 2024b.
	Lower Patuxent River Oligohaline	2008	Yes (2017)	0%	No. See Tetra Tech 2024b.
Perfluorooctane Sulfonate (PFOS) In Fish Tissue	Patuxent River – Upper (nontidal) / Patuxent River – Lower (tidal) / Middle Patuxent River Tidal Fresh	2024	No. Required (high priority).	n/a	n/a
Chloride[b]		2014	No[d]	n/a	n/a

Source: MDE 2024.
Notes:
n/a = not applicable.
[a] The Western Branch TMDL was developed to address low flow water conditions. It only contains a wasteload allocation for wastewater treatment plants and not the County MS4.
[b] Replaces biological integrity biological listing.
[c] Cash Lake is in the federally-owned Patuxent Research Refuge. The WLAs in the TMDL are for a small on-site wastewater treatment facility and industrial stormwater facility. Therefore, the County is not required to reduce loads from its MS4 are part of this TMDL.
[d] High priority to be addressed through pollution control requirements. Low priority for TMDL development.

MDE developed TMDLs and WLAs for the County MS4 to address impairments caused by the exceedance of water quality standards for bacteria, polychlorinated biphenyls (PCBs), total nitrogen (TN), total phosphorus (TP), and sediment. This WIP addresses the nutrient and sediment impairments. Other documents address the bacteria and PCB impairments (Tetra Tech 2024a, Tetra Tech 2024b). In addition, EPA developed an overall TMDL for the Chesapeake Bay watershed for nitrogen, phosphorus, and sediment (USEPA 2010). MDE suggests that the Chesapeake Bay TMDL sediment reductions will be met by achieving nutrient reductions and, therefore, does not provide a percent load reduction needed for sediment. The County has developed a Watershed Implementation Plan (WIP) in response to the Chesapeake Bay TMDL (PGC DER 2012b).

1.2.3 Water Quality Standards

Patuxent River Upper

A sediment TMDL was developed for the PR-U watershed to protect aquatic life. In the PR-U, aquatic life assessment scores, the Maryland BIBI and FIB, are significantly below reference conditions based on Maryland's biocriteria listing methodology. Maryland's BSID methodology was applied to identify the most likely cause of biological impairment. The BSID analysis concluded that biological communities in the PR-U are likely impaired due to flow and sediment related stressors strongly associated with urban land use and its corresponding effects. In Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of nontidal stream systems.

To quantify the impact of sediment on aquatic life, a reference watershed TMDL approach was used. The model used to calculate sediment loading in the PR-U watershed TMDL was the Chesapeake Bay Program Phase 5.2 watershed model. A sediment loading threshold was established by performing a detailed analysis of sediment loads from other Maryland watersheds that were identified as supporting aquatic life based on Maryland's biocriteria (reference watersheds). This threshold was extrapolated to prescribe sediment reductions for the PR-U under the TMDL, assuming that aquatic life in the PR-U would be protected if sedimentation was reduced to levels observed in streams with good biotic integrity.

Patuxent River Middle and Patuxent River Lower

The Maryland water quality standards Surface Water Use Designation Code of Maryland Regulations for the non-tidal portion of the PR-M and PR-L are Use I - Water Contact Recreation, Fishing, And Protection of Aquatic Life and Wildlife [COMAR) 26.08.02.08M]. The tidal PR-M and tidal PR-L mainstems and tidal tributaries are designated Use Class II - support of estuarine and marine aquatic life and shellfish harvesting.

Maryland's BSID analyses determined PR-M and PR-L watersheds were impaired by total suspended solids (TSS). To address these impairments, TMDLs for sediment/TSS were developed for the non-tidal PR-M watershed and non-tidal PR-L watershed. For the purposes of the TMDL, the terms TSS and sediment are used interchangeably. In Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of nontidal stream systems.

To quantify the impact of sediment on aquatic life, a reference watershed TMDL approach was used. A sediment loading threshold was established by performing a detailed analysis of sediment loads from other Maryland watersheds that were identified as supporting aquatic life based on Maryland's biocriteria (reference watersheds). The Chesapeake Bay Program Phase 5.3.2 watershed model was chosen to calculate reference watershed sediment loading thresholds. The median (50th percentile) sediment loading rate from reference watersheds was applied to the non-tidal PR-M and non-tidal PR-L watershed to quantify a reduction in sediment needed to protect aquatic life. This assumes that aquatic life would be protected if sedimentation rates were reduced to levels observed in streams with good biotic integrity.

A sediment TMDL for the tidal portion of PR-M and PR-L was established under the Chesapeake Bay TMDL in 2010. Suspended sediment in the water column reduces the amount of sunlight reaching the leaves of submerged aquatic vegetation (SAV). The Chesapeake Bay TMDL prescribes reductions to sediment necessary to meet water clarity and SAV restoration goals in concert with projected water quality improvement from concurrent nutrient reductions.

Rocky Gorge Reservoir

The Maryland water quality standards Surface Water Use Designation Code of Maryland Regulations for Rocky Gorge Reservoir is Use I-P - Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply [COMAR 26.08.02.08M(1)]. Also under Use I-P guidelines, dissolved oxygen (DO) concentrations may not be less than 5.0 mg/l at any time [COMAR 26.08.02.03-3A(2)].

A phosphorus TMDL was developed for Rocky Gorge Reservoir because of observed algal blooms with higher than acceptable levels of chlorophyll *a*. Elevated levels of chlorophyll *a* are associated with a nuisance level of algae that interferes with desired uses such as fishing and swimming. Excess nutrients in an aquatic system act as a fertilizer that promotes algal growth. When algae die and decompose, bacteria feeding on the dead algae consume DO in the waterbody. The nutrient phosphorus was identified as the substance promoting the growth of algae causing a chlorophyll *a* violation.

To attain conditions consistent with Use I waters, phosphorus reductions in Rocky Gorge Reservoir were prescribed by the TMDL to reduce peak chlorophyll *a* concentrations such that:

- A ninetieth percentile instantaneous chlorophyll *a* concentration not to exceed 30 µg/L in the surface layers.
- A 30-day moving average chlorophyll *a* concentration not to exceed 10 µg/L in the surface layers. Average chlorophyll *a* concentrations above 10 µg/L are associated with a shift to blue-green algae that can create taste, odor, and treatment problems.

- A reduction in algal growth is also expected to help prevent seasonal low DO events in the reservoir, maintaining DO not less than 5.0 mg/L.

1.3 TMDL Pollutants

TMDLs for TP and sediment were developed by MDE to address water quality impairments. Below are brief descriptions of the TMDL pollutants.

Phosphorous

Like nitrogen, excessive loading of phosphorus into surface water bodies can lead to eutrophication by fueling aquatic plant growth. Phosphorus in fresh and marine waters exists in organic and inorganic forms. The most readily available form for plants is soluble inorganic phosphorus ($H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3}), also commonly referred to as soluble reactive phosphorus. Phosphorus is also able to sorb to sediment particles and is carried into water bodies by upland and streambank erosional processes. Maryland does not have numeric criteria for phosphorus.

Total Suspended Solids

TSS are small soil particles, including particles that make up sediment, that are carried in water and capable of being captured by a filter. Stream channel erosion is a major source of TSS and tends to worsen because of land development if runoff is not effectively controlled.

TSS concentrations in streams tends to increase with the amount of impervious surface in a watershed. As the impervious surfaces send runoff more quickly to local streams, the higher velocities and volumes of water in typically incised stream channels tends to increase rates of erosion. Channel erosion moves soil particles into the water from both the stream banks and the stream bed. Much of the resulting suspended sediment that is generated during a stormwater runoff event could settle out in deposits as the water slows between events. But those sediments can be resuspended and transported downstream with increased stream flow velocity.

In addition to the erosive effects, excessive settling of sediment on the stream bed and into the gravel blocks the flow of fresh, oxygenated water into the substrate. This situation leads to the destruction of fish spawning beds, a loss of aquatic habitat, and an increase in the mortality rate of macroinvertebrates from damaged or clogged gills and loss of food sources. Suspended sediment blocks light transmission, which limits the growth and survival of SAV. Sediment and sediment deposits in tidal reaches can also contribute to the demise of aquatic life there.

2 WATERSHED CHARACTERIZATION

The PR-U segment is free flowing and not influenced by tides. It begins just downstream of the Rocky Gorge Reservoir and flows in a southeastern direction to join the PR-M. The PR-U segment spans about 28 miles, with the PR-L and PR-M sections comprising the rest of the Patuxent River's non-tidal and tidal portions, respectively (Figure 2-1). This watershed is within the Patuxent River subwatershed of the Chesapeake Bay watershed and encompasses drainage areas within Howard, Montgomery, Anne Arundel, and Prince George's Counties in Maryland.

Approximately 54,533 acres (96 percent) of the overall 56,446 acres are within Anne Arundel and Prince George's counties, with the remainder in Montgomery and Howard counties. Of the 54,533 acres, most of the drainage area (31,881 acres) is within Prince George's County. The Patuxent River Upper serves as the boundary between the two counties; therefore, the drainage areas are hydrologically distinct and have been characterized by the two counties separately as well as jointly in various studies. The PR-L watershed has a drainage area of about 205,500 acres (ac), or 321 square miles, and the PR-M watershed has a drainage area of about 55,200 ac, or 86 square miles, for a total area of 407 square miles.

In the PR-L and PR-M watersheds, water flows through a dense network of streams, of which 227 miles in the PR-L watershed and 185 miles in the PR-M watershed are large enough to be mapped. The Patuxent River main stem—14 miles in the PR-L watershed and 10 miles in the PR-M watershed—is tidal throughout its reach.

Both the Rocky Gorge Reservoir and the Little Patuxent River empty into the upstream end of the Patuxent River Upper. Water surfaces (stream, ponds, etc.) cover approximately 305 acres in Prince George's County, with the remainder, 32,008 acres, constituting the various land uses ranging from urban to rural.

The PR-U watershed includes the municipalities of Laurel, South Laurel, West Laurel, Mitchellville, Davidsonville, and Bowie. The watershed also contains a large area of federal land (Patuxent Research Refuge) owned and maintained by the U.S. Fish and Wildlife Service. This refuge is the only national wildlife refuge dedicated to wildlife research. The County's portion of the Upper Patuxent River watershed includes the central and south tracts of the refuge.

While the sediment TMDL characterized the entire 54,533 acres, the fecal coliform TMDL explicitly included only 18,362 acres within Bowie, Davidsonville, and Mitchellville and consolidated the upper areas, including watersheds to the Patuxent Reservoirs, as upstream sources. The Patuxent Reservoirs include Triadelphia Reservoir, with a watershed area of approximately 50,000 acres, and the Rocky Gorge Reservoir (basin code: 02-13-11-07), with an additional watershed area of 35,000 acres. The County includes a small portion of the Rocky Gorge Reservoir watershed (about 530 acres, or 0.83 square miles).

All urban drainage areas, except for the federal and state government properties and the city of Bowie that is performing its own restoration plan, are covered by the County's MS4 permit.

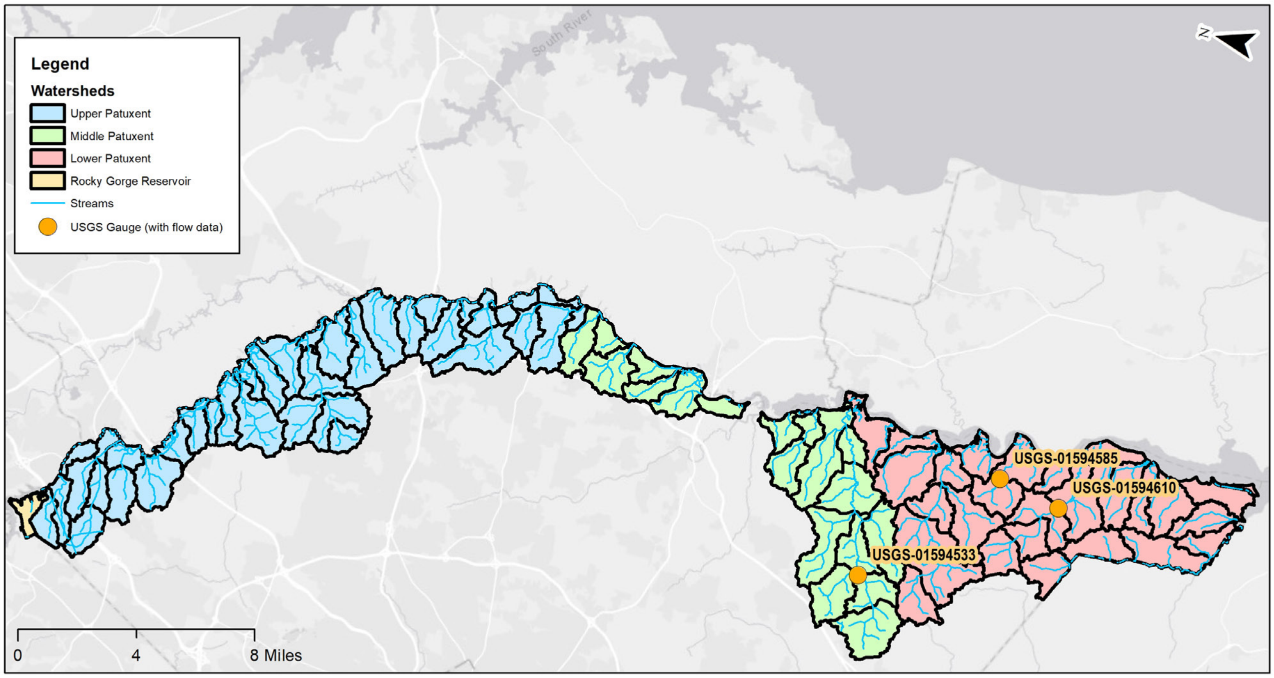


Figure 2-1. Location of the Patuxent River watershed.

2.1 Physical and Natural Features

2.1.1 Hydrology

The Patuxent River Upper watershed is composed of over 12 subwatersheds, including Bear Branch, Thomas Branch, Horsepen Branch, White Marsh Branch, Ropers Branch, Green Branch, Mill Branch, Kings Branch, Davidsonville Branch, Honey Branch, Mount Nebo Branch, and Stocketts Run. Out of these, Bear Branch, Horsepen Branch, White Marsh Branch, Green Branch, Mill Branch, Honey Branch, and Mount Nebo Branch are in the County's portion of the watershed. The 595-acre Rocky Gorge portion is represented as one subwatershed. The mainstem of the PR-L and PR-M watersheds forms the political boundary of Prince George's County. U.S. Geological Survey (USGS) stream gages along the main stem of the PR-L and PR-M reaches are limited, which makes characterizing stream depth and discharge in those areas difficult.

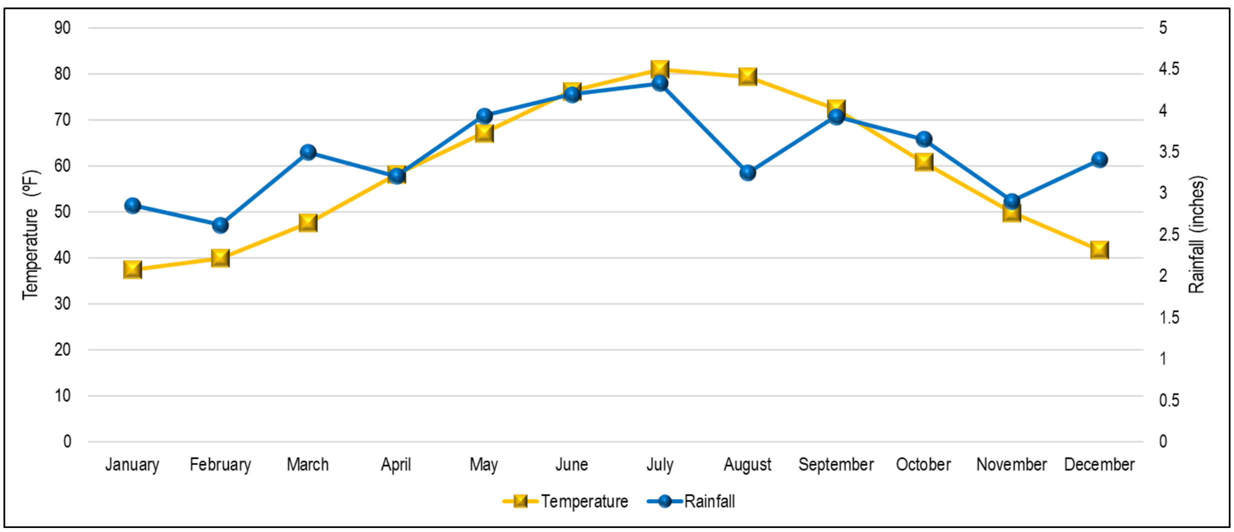
There are three USGS stream gages in the watershed with flow data (see Section 3.1). USGS-01594533 is on the downstream side of Middle Patuxent watershed, and USGS-01594585 and USGS-01594610 are in Lower Patuxent watershed. Flow data provides general historical trends that can help the County understand hydrologic response in the watershed. The station is not collecting data specific to the impairments; however, they are helpful as a big picture of watershed conditions.

The County has broken down the main watershed into small subwatersheds (e.g., 500–1,000 acres) to help address restoration at a smaller scale. The smaller watersheds are not considered watershed management areas. Implementation strategies are presented in later sections for the entire watershed, as individual project opportunities are unknown at the time of WIP development.

There are three USGS stream gages in the watershed with flow data (see Section 3.1). USGS-01594533 is on the downstream side of Middle Patuxent watershed, and USGS-01594585 and USGS-01594610 are in Lower Patuxent watershed. Flow data provides general historical trends that can help the County understand hydrologic response in the watershed. The station is not collecting data specific to the impairments; however, they are helpful as a big picture of watershed conditions.

2.1.2 Climate/Precipitation

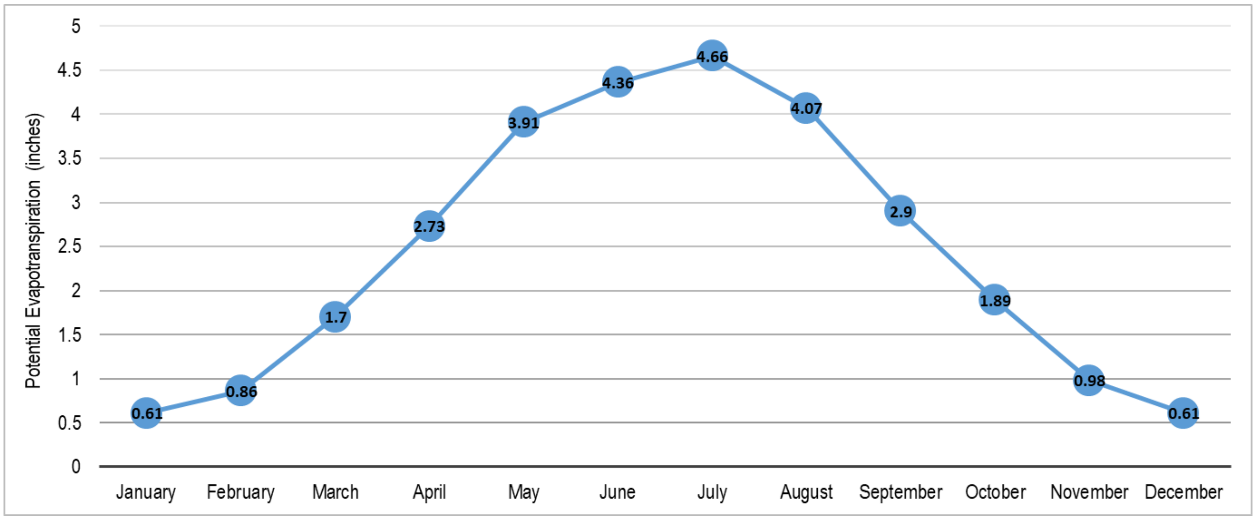
The climate of the Patuxent River watershed is characterized as temperate. The National Weather Service (NWS) Forecast Office reports a 30-year average annual precipitation of 39.74 inches (NWS 2023). On average, winter is the driest season, with 8.48 inches of precipitation, and summer is the wettest season, with 10.44 inches (NWS 2023). Precipitation is highest in late spring to late summer. The average annual temperature is 58.2 degrees Fahrenheit (°F), with the January normal low at 28.6 °F and the July normal high at 88.4 °F (NWS 2022). The normal monthly precipitation and temperature for Upper Marlboro are presented in Figure 2-2. Average monthly temperatures range from approximately 33 °F in January to a peak of almost 80 °F in July.



Sources: NWS 2022, 2023.

Figure 2-2. Average monthly temperature and precipitation.

Evapotranspiration accounts for water that evaporates from the land surface (including water bodies) and is lost through plant transpiration. Evapotranspiration varies throughout the year because of climate but is greatest in the summer. Figure 2-3 presents the potential evapotranspiration, which is described by the National Oceanic and Atmospheric Administration (NOAA) as "the maximum amount of water that would be evapotranspired if enough water were available (from precipitation and soil moisture)" (NOAA n.d.). That amount is affected by solar radiation, air temperature, vapor pressure, and wind speed. Expected rates of evaporation constitute a design consideration for certain BMPs, particularly those that have permanent water (e.g., wet ponds) or rely on moisture-rich soils (e.g., wetlands).



Source: NRCC 2014.

Figure 2-3. Average monthly potential evapotranspiration in inches (1981–2010).

The County is reviewing the potential effects of climate change on watershed implementation.[5] Climate change is the result of rising temperatures due to elevated levels of heat-trapping greenhouse gases such as carbon dioxide in the atmosphere. Rising temperatures are expected to increase and shift energy distribution in the atmosphere, which could lead to increased evaporation, increased humidity, higher average rainfall, and greater occurrences of heavy rainstorms in some regions and droughts in others (USEPA 2016). Though average annual precipitation in Maryland has increased by approximately 5 percent in the past century, precipitation from extremely heavy events has increased in the eastern United States by more than 25 percent since 1958 (USEPA 2016). Average precipitation is expected to increase during winter and spring, which will cause snow to melt earlier and intensify flooding during these seasons. The higher rates of evaporation will also likely result in drier soil during the summer and fall.

The Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) program maintains a website that helps illustrate the impact of climate change on precipitation under future climate conditions (MARISA 2022). The website provides updated intensity-duration-frequency (IDF) curves by county. These curves describe the relationship between rainfall intensity, rainfall duration, and frequency of the interval (e.g., 5-year rainfall). IDF curves are used for forecasting floods and designing stormwater conveyance and treatment practices. Precipitation frequency is the amount of rainfall at a location for a specified duration that has the probability of occurring. For instance, if a location has an 8.5-inch precipitation frequency for a 100-year, 24-hour storm, it means that for a rainfall event that lasts 24 hours, there would be a one in a hundred (1 percent) chance that 8.5 inches would be exceed in a 24-hour period.

Initial precipitation frequency estimates were developed in 1961 by the U.S. Weather Bureau in Technical Paper Number 40 (TP40). These numbers were revised in 2006 by NOAA and are referred to as Atlas 14. Recently, the MARISA team and the Chesapeake Bay Program looked at

[5] Prince George's County has created an overall County *Climate Actin Plan*. For additional information, please see https://www.princegeorgescountymd.gov/departments-offices/environment/sustainability/climate-change.

future predictions for precipitation frequencies. Table 2-1 presents the precipitation frequencies for Beltsville, MD from TP40, Atlas 14, and MARISA.

Table 2-1. Precipitation (inches) frequency 24-hour estimates for Beltsville, MD.

24 Hour Duration	TP 40	Atlas 14	MARISA Atlas 14 Projected 2020–2070	MARISA Atlas 14 Projected 2050–2100
2-Year	3.3	3.2	3.46	3.68
10-Year	5.3	4.92	5.31	5.71
100-Year	7.4	8.49	9.42	10.1

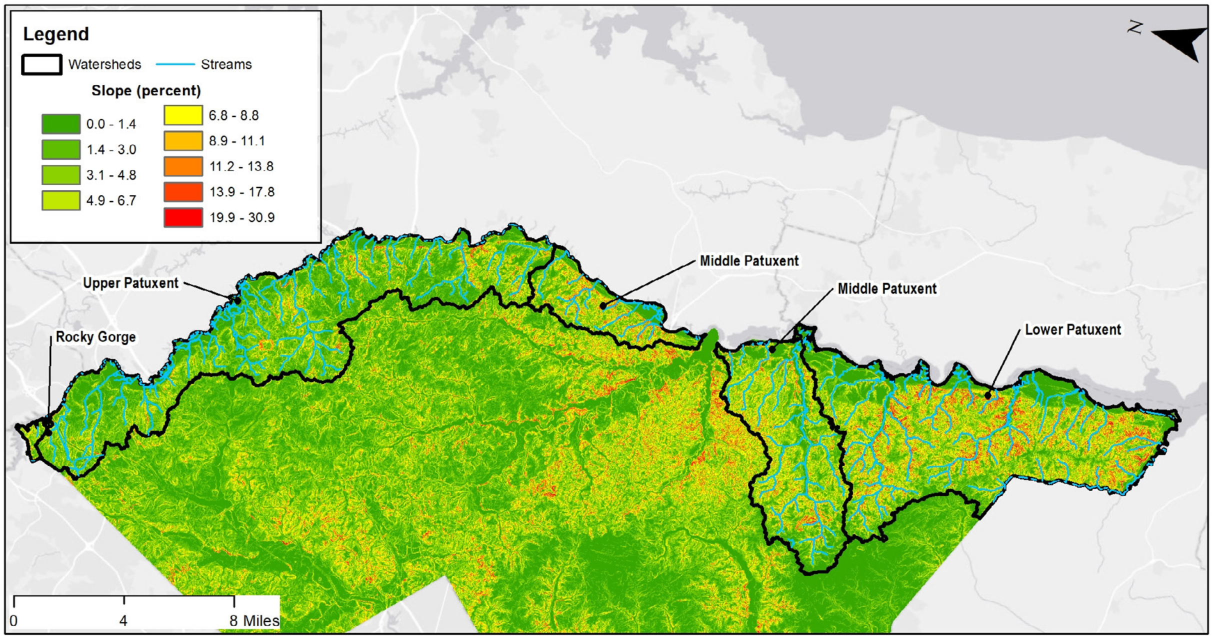
Sources: NOAA 2006, Miro et.al. 2021.

2.1.3 Topography/Elevation

According to the Maryland Geological Survey (MGS), the Fall Line between the Atlantic Coastal Plain and the Piedmont approximates the boundary between Prince George's and Montgomery counties. Most of the County portion of the watershed is in the coastal plain, which is underlain by unconsolidated sediments, including gravel, sand, silt, and clay (MGS 2014). The coastal plain is characterized by gentle slopes, meandering streams, and lower relief.

Figure 2-4 displays land surface slopes across the Patuxent River watershed. This method of mapping identifies the steepest areas of the watershed, which could indicate the variability of speed in overland runoff and suggest places that are more susceptible to higher rates of erosion and increased sediment in the stream. This can help to characterize some of the sediment-influencing capacity of that flow, especially when combined with other relevant information, such as soils data.

The watershed is relatively flat with elevations typically only between sea level and 200 feet. The highest elevations in the watershed are in the northwestern portion near Rocky Gorge Reservoir, reaching more than 400 feet, with the lowest portions are near the municipalities of Bowie and Davidsonville in the lower end of the watershed.



Source: M-NCPPC 2014.

Figure 2-4. Land slopes across the Patuxent River watershed.

2.1.4 Soils

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service has defined four major hydrologic soil groups (HSGs) for categorizing soils by similar infiltration and runoff characteristics (SCS 1974). HSGs are generally categorized into one of four groups: A, B, C, or D. Poorly drained clay soils (group D) have the lowest infiltration rates, resulting in the highest amount of runoff, while well-drained sandy soils (group A) have high infiltration rates with little runoff; group B and group C soils, in between groups A and D, have respectively, moderate levels of infiltration and runoff. Soils in the watershed are frequently also classified as "urban land complex" or "udorthent" soils. These are soils that have been altered by disturbance because of land development activities. Soils affected by urbanization can have a higher density because of compaction during construction activities and might be more poorly drained.

Table 2-2 summarizes soil make-up in the watershed by HSG.

Figure 2-5 presents the USDA HSG data. For some areas, the USDA data were null; therefore, the information was filled in with State Soil Geographic Database (STATSGO) data. Almost all Rocky Gorge watershed and almost half of the Upper Patuxent River watershed are underlain by HSG B soils. HSG A soils are the least represented in these watersheds. A combination of C and D soils are seen in the remaining portions of Upper Patuxent River drainage areas. For PR-L and PR-M watersheds, soils in groups B and C are the predominant soils in the watershed, while soils in group D are the least common.

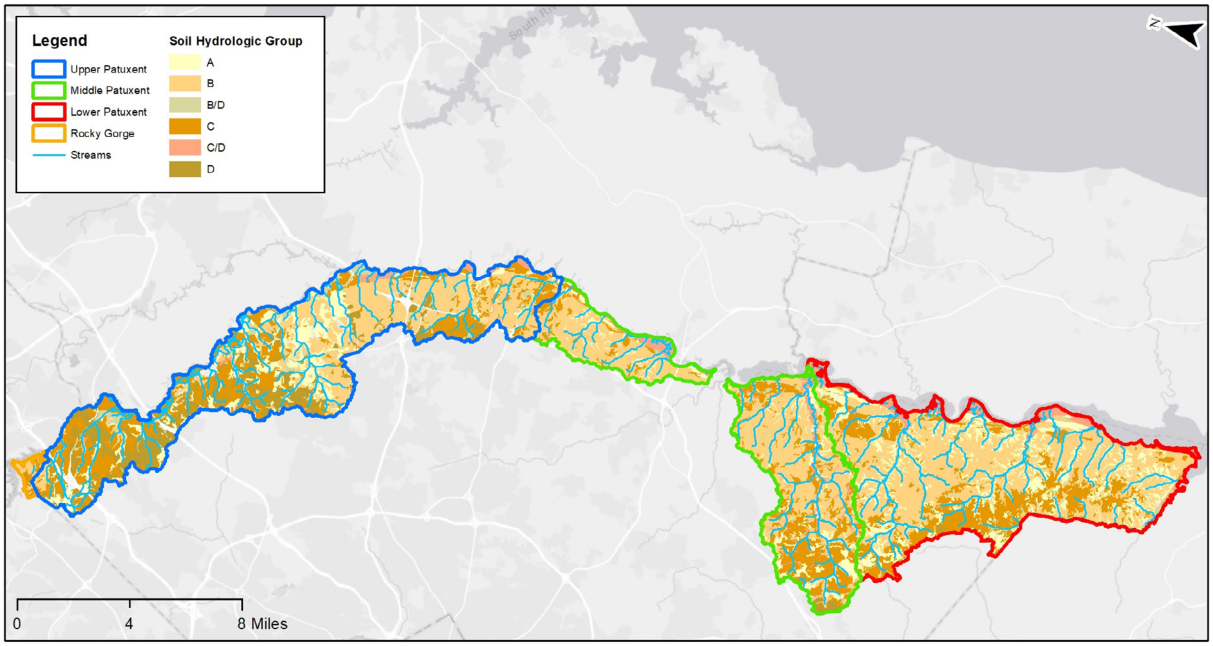
Specifically, the Upper Patuxent watershed is comprised of 47 percent Group B type soils, followed by Group C (27 percent), Group D (18 percent), and Group A soils (8 percent) (USDA 2006). Based on another soil classification used by MDE (2010), the Upper Patuxent has Baile, Chester, and Beltsville series of soils. The Baile series are poorly drained soils, essentially seen in upland depressions and footslopes, with moderately low- to moderately high- saturated hydraulic conductivity. The Chester series are well-drained soils seen in uplands, with moderately high- to high- saturated hydraulic conductivity. Finally, the Beltsville series includes moderately well-drained soils with a saturated hydraulic conductivity in the low- to moderately low- range.

Soils in the watershed are frequently also classified as "urban land complex" or "udorthent" soils. These are soils that have been altered by disturbance because of land development activities. Soils affected by urbanization can have a higher density because of compaction during construction activities and might be more poorly drained.

Table 2-2. Summary of soils in the Patuxent River watershed.

	A	B	B/D	C	C/D	D
Lower Patuxent River						
Acres	5,808	14,447	2,225	6,610	1,388	82
% Total	19.00%	47.30%	7.30%	21.60%	4.50%	0.30%
Middle Patuxent River						
Acres	2,595	11,548	784	5,353	2,551	249
% Total	11.20%	50.00%	3.40%	23.20%	11.10%	1.10%
Upper Patuxent River						
Acres	4,110	9,372	2,528	8,655	906	5,309
% Total	13.30%	30.30%	8.20%	28.00%	2.90%	17.20%
Rocky Gorge Reservoir						
Acres	0	316	0	205	0	11
% Total	0.00%	59.40%	0.00%	38.60%	0.00%	2.00%

Note: Soil types B/D and C/D behave as B or C soils, respectively, during dry weather and soil type D during wet weather.



Source: USDA 2003.

Figure 2-5. Hydrologic soil groups in the Patuxent River watershed.

2.2 Land Use and Land Cover

Land use and land cover are key watershed characteristics that influence the type and amount of pollution entering the County's water bodies. Land use is how the land is being used (e.g., residential neighborhood). Land cover is what is covering the land (e.g., turf, impervious surface).

Over time, land use and land cover changes have caused stream health to be degraded and certain streams to be classified as impaired. Some natural changes have occurred over centuries, others were the result of farming, new development, and construction of roads. The County has many older neighborhoods inside the Beltway, close to the border with Washington DC, which were developed without stormwater quality controls. The areas outside the Beltway, such as the Patuxent River watershed, continue to be developed and are moving from agricultural land and forests to developed land, which is the leading cause of impairments. In 2014, the County Planning Department created *Plan 2035*, which contains the County's future development plans.[6] One of the policy goals of Plan 2035 is to reduce stormwater runoff.

2.2.1 Land Use Distribution

Land use information for the watershed was obtained from the Maryland Department of Planning (MDP) 2010 land use update (MDP 2010). Land uses are made of many different land covers, such as roads, roofs, turf, and tree canopy. The proportion of land covers in each land use control the hydrologic and pollutant loading response of such uses. Table 2-3 summarizes the land use distribution in the Patuxent River Upper and Rocky Gorge Reservoir watersheds. Table 2-4

[6] https://www.mncppcapps.org/planning/publications/BookDetail.cfm?item_id=279&Category_id=1

summarizes the land use distribution in the Patuxent River Middle and Lower watersheds. Figure 2-6 shows the land uses in the watershed.

Most of the land use in the Patuxent River watershed is urban (50 percent), with the majority being medium-density residential areas (23 percent). There are also significant areas of Forest (38 percent) in the watershed. For Patuxent River Middle and Lower watersheds, most of the land use is forest (52 percent), with the majority being deciduous forest (27 percent). 25 percent of the land use is covered by agriculture. The urban area in the watershed is largely low-density residential areas (9 percent). Forest is also the majority land use of the Rocky Gorge Reservoir watershed (51 percent), and there are significant areas of urban (23 percent) and agriculture (18 percent) in this watershed.

Table 2-3. Patuxent River Upper and Rocky Gorge Reservoir watersheds land use.

	Rocky Gorge			Patuxent - Upper		
Land Use	Acres	Percent of Total	Percent of Land Use Grouping	Acres	Percent of Total	Percent of Land Use Grouping
Agriculture	109	18.3%	100%	2,720	8.5%	100%
Agricultural building	0	0.0%	0.0%	9	0.0%	0.3%
Cropland	54	9.1%	49.8%	1,745	5.5%	64.2%
Feeding operations	0	0.0%	0.0%	0	0.0%	0.0%
Large lot subdivision (agriculture)	30	5.1%	28.0%	136	0.4%	5.0%
Orchards/vineyards/horticulture	0	0.0%	0.0%	0	0.0%	0.0%
Pasture	24	4.1%	22.2%	830	2.6%	30.5%
Row and garden crops	0	0.0%	0.0%	0	0.0%	0.0%
Forest	304	51.1%	100%	12,245	38.4%	100%
Brush	15	2.5%	4.9%	258	0.8%	2.1%
Deciduous forest	212	35.6%	69.6%	6,822	21.4%	55.7%
Evergreen forest	22	3.7%	7.3%	578	1.8%	4.7%
Large lot subdivision (forest)	44	7.3%	14.3%	635	2.0%	5.2%
Mixed forest	11	1.9%	3.8%	3,952	12.4%	32.3%
Other	0	0.0%	0.0%	327	1.0%	100%
Bare ground	0	0.0%	0.0%	209	0.7%	63.9%
Extractive	0	0.0%	0.0%	118	0.4%	36.1%
Urban	136	22.9%	100%	16,222	50.9%	100%
Commercial	0	0.0%	0.0%	1,511	4.7%	9.3%
High-density residential	0	0.0%	0.0%	1,648	5.2%	10.2%
Industrial	0	0.0%	0.0%	625	2.0%	3.9%
Institutional	0	0.0%	0.0%	1,007	3.2%	6.2%
Low-density residential	120	20.2%	88.1%	2,879	9.0%	17.7%
Medium-density residential	10	1.6%	7.2%	7,209	22.6%	44.4%
Open urban land	6	1.0%	4.4%	876	2.7%	5.4%
Transportation	0	0.1%	0.3%	467	1.5%	2.9%

Land Use	Rocky Gorge			Patuxent - Upper		
	Acres	Percent of Total	Percent of Land Use Grouping	Acres	Percent of Total	Percent of Land Use Grouping
Water and wetlands	46	7.7%	100%	367	1.2%	100%
Water	46	7.7%	100.0%	277	0.9%	75.5%
Wetlands	0	0.0%	0.0%	90	0.3%	24.5%
Total	**595**	**--**	**--**	**31,881**	**--**	**--**

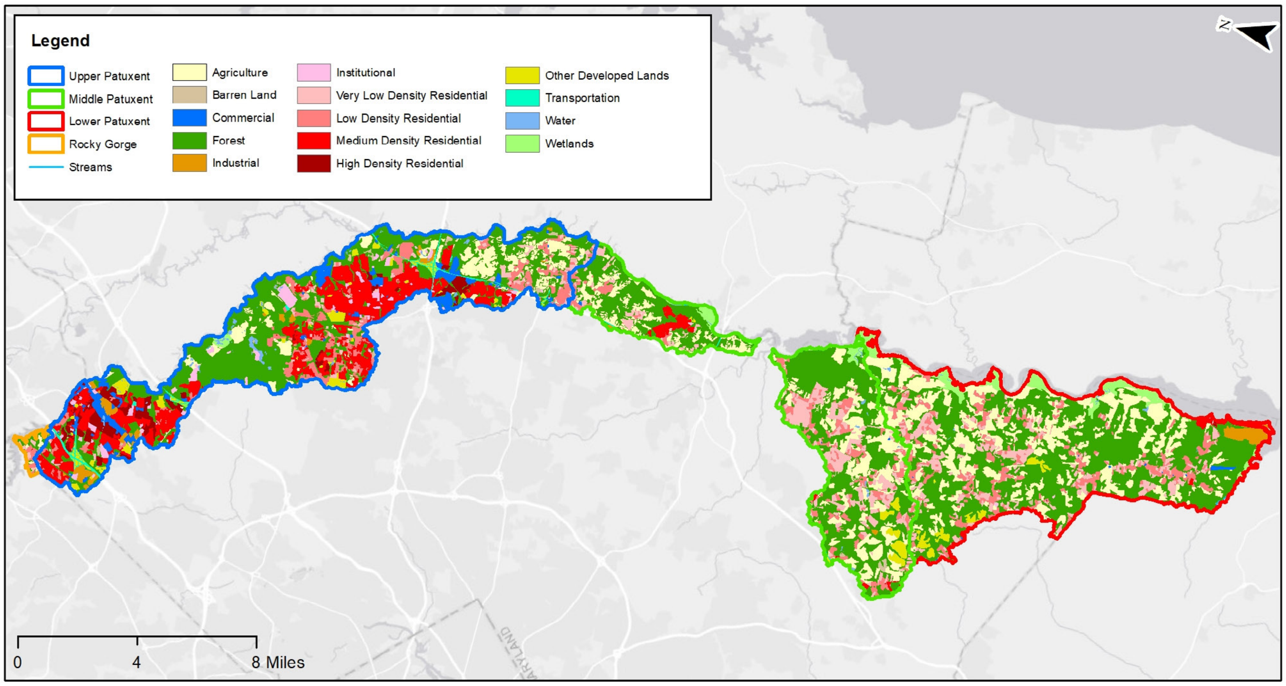
Source: MDP 2010.

Table 2-4. Patuxent River Middle and Patuxent River Lower watersheds land use.

Land Use	Patuxent - Middle			Patuxent - Lower		
	Acres	Percent of Total	Percent of Land Use Grouping	Acres	Percent of Total	Percent of Land Use Grouping
Agriculture	7,412	25.07%	100.00%	6,854	24.90%	100.00%
Agricultural building	167	0.56%	2.25%	130	0.47%	1.90%
Cropland	4,836	16.36%	65.25%	5,355	19.45%	78.13%
Feeding operations	68	0.23%	0.92%	0	0.00%	0.00%
Large lot subdivision (agriculture)	822	2.78%	11.09%	407	1.48%	5.94%
Orchards/vineyards/horticulture	0	0.00%	0.00%	54	0.20%	0.79%
Pasture	1,516	5.13%	20.45%	742	2.70%	10.83%
Row and garden crops	3	0.01%	0.04%	166	0.60%	2.42%
Forest	14,434	48.82%	100.00%	15,491	56.27%	100.00%
Brush	255	0.86%	1.77%	159	0.58%	1.03%
Deciduous forest	9,930	33.59%	68.80%	5,235	19.01%	33.79%
Evergreen forest	196	0.66%	1.36%	218	0.79%	1.41%
Large lot subdivision (forest)	2,020	6.83%	13.99%	1,913	6.95%	12.35%
Mixed forest	2,033	6.88%	14.08%	7,966	28.93%	51.42%
Other	592	2.00%	100.00%	366	1.33%	100.00%
Bare ground	73	0.25%	12.33%	24	0.09%	6.56%
Extractive	519	1.76%	87.67%	342	1.24%	93.44%
Urban	3,313	11.21%	100.00%	3,631	13.19%	100.00%
Commercial	17	0.06%	0.51%	77	0.28%	2.12%
High-density residential	10	0.03%	0.30%	12	0.04%	0.33%
Industrial	71	0.24%	2.14%	555	2.02%	15.29%
Institutional	47	0.16%	1.42%	27	0.10%	0.74%
Low-density residential	2,549	8.62%	76.94%	2,819	10.24%	77.64%
Medium-density residential	525	1.78%	15.85%	141	0.51%	3.88%
Open urban land	38	0.13%	1.15%	0	0.00%	0.00%
Transportation	56	0.19%	1.69%	0	0.00%	0.00%
Water and wetlands	3,814	12.90%	100.00%	1,189	4.32%	100.00%

Land Use	Patuxent - Middle			Patuxent - Lower		
	Acres	Percent of Total	Percent of Land Use Grouping	Acres	Percent of Total	Percent of Land Use Grouping
Water	2,629	8.89%	68.93%	25	0.09%	2.10%
Wetlands	1,185	4.01%	31.07%	1,164	4.23%	97.90%
Total	**29,565**	**--**	**--**	**27,531**	**--**	**--**

Source: MDP 2010.



Source: MDP 2010.

Figure 2-6. Land use in the Patuxent River watershed.

2.2.2 Land Cover Distribution

Land cover differs from land use in that it describes what covers the land instead of how the land is used. Land cover information was obtained from MDE (2021b) and matches the land cover data in the Chesapeake Bay model. Table 2-5 through Table 2-8 summarize the land cover distribution in the PR-L, PR-M, PR-U and Rocky Gorge Reservoir watersheds. Figure 2-7 shows a map of land cover in the watershed.

Overall, most of the land cover in all four watersheds is forest. Significant areas of mixed open/agriculture land cover are also considered outside the MS4 area. Only a very small part of the land cover is urban.

Table 2-5. Patuxent River Lower watershed land cover.

Land Cover Category	Area (acres)	% Total
Water	221.3	0.68%
Wetlands	1,507.7	4.62%
Forest	19,723.7	60.40%
Shrubland	101.8	0.31%
Mixed Open/Agriculture	8,906.6	27.27%
Barren	115.6	0.35%
Structures	142.6	0.44%
Impervious Surfaces	239.1	0.73%
Impervious Roads	132.5	0.41%
Tree Canopy Over Structures	20.7	0.06%
Tree Canopy Over Impervious Surfaces	62.1	0.19%
Tree Canopy Over Impervious Roads	60.0	0.18%
Turf	653.7	2.00%
Tree Canopy Over Turf	768.5	2.35%
Total	**32,655.9**	**100.00%**

Source: MDE 2021b.

Table 2-6. Patuxent River Middle watershed land cover.

Land Cover Category	Area (acres)	% Total
Water	99.9	0.47%
Wetlands	376.6	1.76%
Forest	13,306.3	62.15%
Shrubland	63.7	0.30%
Mixed Open/Agriculture	5,293.5	24.72%
Barren	182.1	0.85%
Structures	140.1	0.65%
Impervious Surfaces	164.2	0.77%
Impervious Roads	140.7	0.66%
Tree Canopy Over Structures	29.0	0.14%
Tree Canopy Over Impervious Surfaces	86.5	0.40%
Tree Canopy Over Impervious Roads	85.4	0.40%
Turf	557.0	2.60%
Tree Canopy Over Turf	886.6	4.14%
Total	**21,411.6**	**100.00%**

Source: MDE 2021b.

Table 2-7. Patuxent River Upper watershed land cover.

Land Cover Category	Area (acres)	% Total
Water	121.3	0.38%
Forest	14,753.9	45.77%

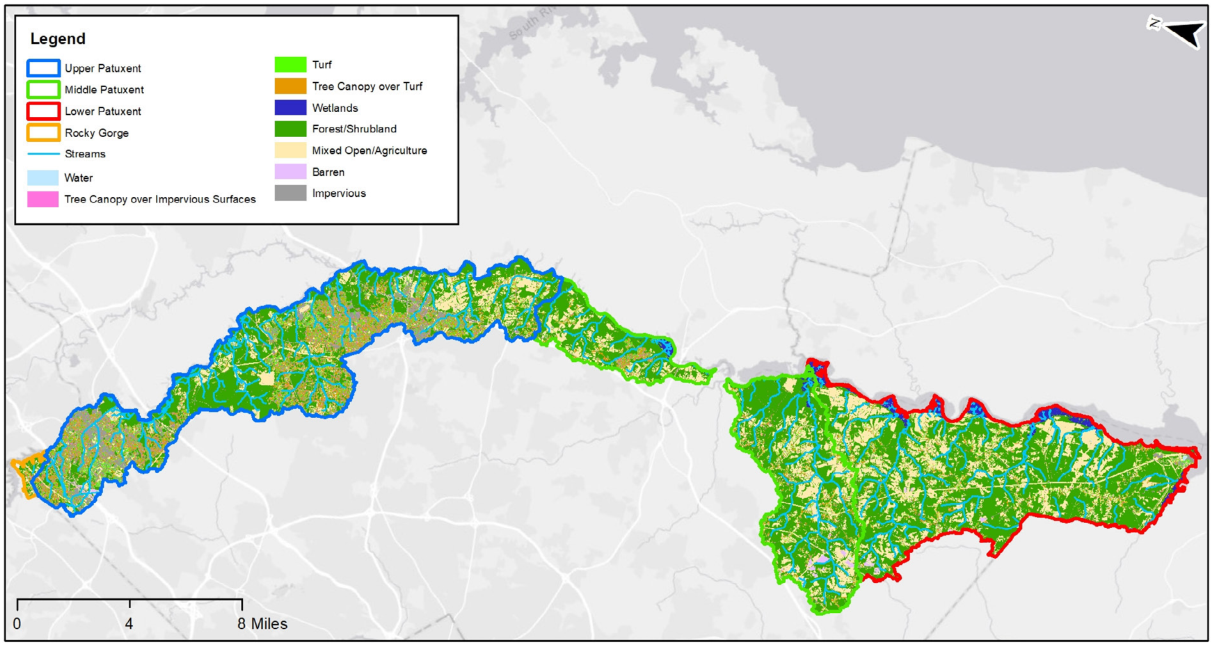
Land Cover Category	Area (acres)	% Total
Shrubland	220.8	0.68%
Mixed Open/Agriculture	4,848.3	15.04%
Barren	114.3	0.35%
Structures	1,518.6	4.71%
Impervious Surfaces	1,873.4	5.81%
Impervious Roads	1,311.6	4.07%
Tree Canopy Over Structures	155.8	0.48%
Tree Canopy Over Impervious Surfaces	481.1	1.49%
Tree Canopy Over Impervious Roads	307.2	0.95%
Turf	2,694.2	8.36%
Tree Canopy Over Turf	3,833.6	11.89%
Total	**32,234.0**	**100.00%**

Source: MDE 2021b.

Table 2-8. Rocky Gorge Reservoir watershed land cover.

Land Cover Category	Area (acres)	% Total
Water	0.2	0.05%
Forest	276.6	55.64%
Shrubland	1.8	0.35%
Mixed Open/Agriculture	100.3	20.18%
Barren	3.6	0.72%
Structures	7.8	1.56%
Impervious Surfaces	10.5	2.11%
Impervious Roads	8.7	1.76%
Tree Canopy Over Structures	1.7	0.35%
Tree Canopy Over Impervious Surfaces	4.6	0.92%
Tree Canopy Over Impervious Roads	2.8	0.56%
Turf	30.1	6.06%
Tree Canopy Over Turf	48.4	9.74%
Total	**497.2**	**100.00%**

Source: MDE 2021b.



Source: MDE 2021b.

Figure 2-7. Land cover in the Patuxent River watershed.

2.2.3 Impervious Area

Impervious area is the land surface covered with a solid material or compacted to the point at which water cannot infiltrate into underlying soils (e.g., parking lots, roads, houses, patios, swimming pools, compacted gravel areas). Consequently, impervious areas resulting from land development affect both the amount and the quality of runoff.

Compared to naturally vegetated areas, impervious areas generally decrease the amount of water infiltrating into groundwater and increase the amount of water flowing to the stream channels in the watershed. This increased surface flow not only carries greater amounts of sediment and other pollutants but also increases the velocity of the streams, which worsens erosion. More erosion increases the amount of sediment carried by the water, which can be detrimental to the appearance of a stream and its ecological health.

Figure 2-8, Figure 2-9, Figure 2-10, and Figure 2-11 show the percent of each type of impervious area (e.g., roads) in the PR-L, PR-M, PR-U, and Rocky Gorge Reservoir watersheds. Roads accounted for 30 percent of impervious area in the PR-L watershed, followed by driveways and buildings each accounting for 26 percent and 22 percent, respectively. Roads accounted for 32 percent of impervious area in the PR-M watershed, followed by driveways and buildings each accounting for 26 percent and 24 percent, respectively, of the watershed. Buildings accounted for 31 percent of impervious area in the PR-U watershed, followed by roads and parking lot each accounting for 30 percent and 23 percent, respectively. Roads accounted for 29 percent of impervious area in the Rocky Gorge Reservoir watershed, followed by buildings and driveways accounting for 27 percent and 22 percent, respectively.

Figure 2-12 shows the impervious land cover, which is available from the Prince George's County GIS Open Data Portal (M-NCPPC 2022). Greater proportions of impervious land cover may be seen in more developed areas on smaller scales, especially in the form of roadways, parking facilities, and buildings.

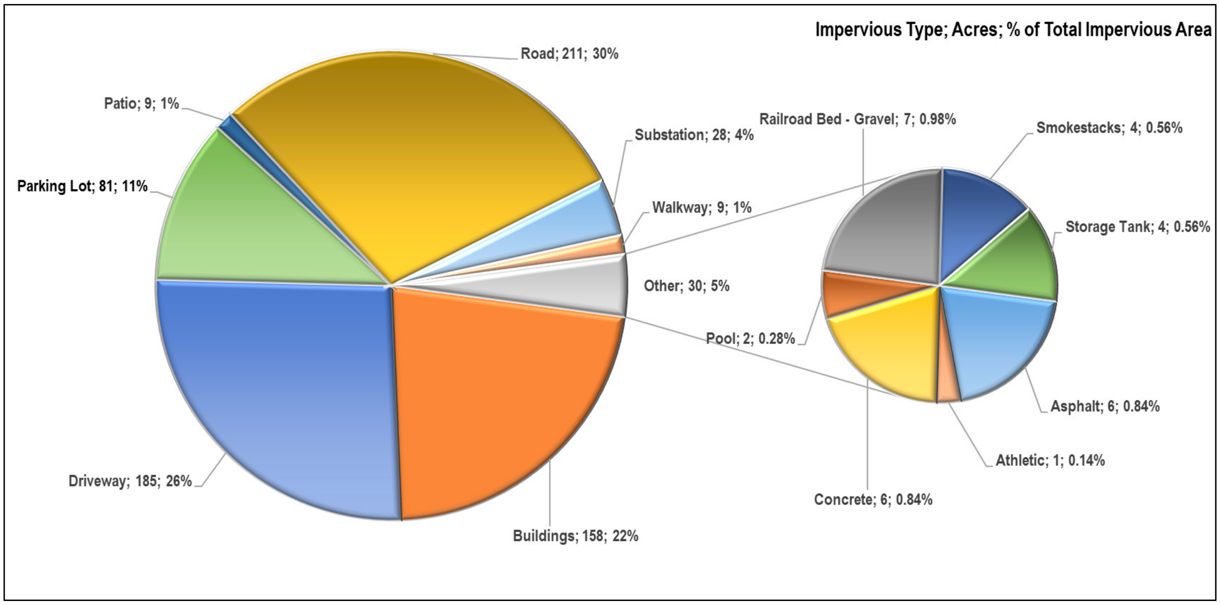


Figure 2-8. Patuxent River Lower watershed percent of impervious area by source.

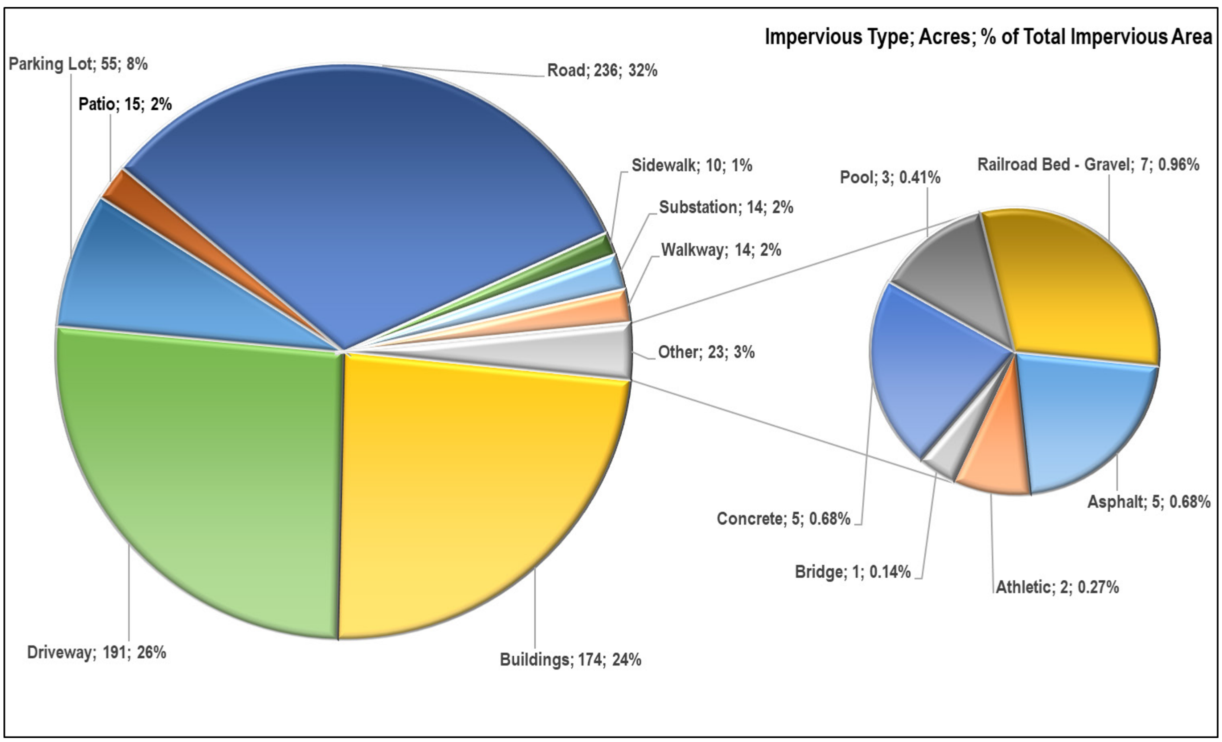


Figure 2-9. Patuxent River Middle watershed percent of impervious area by source.

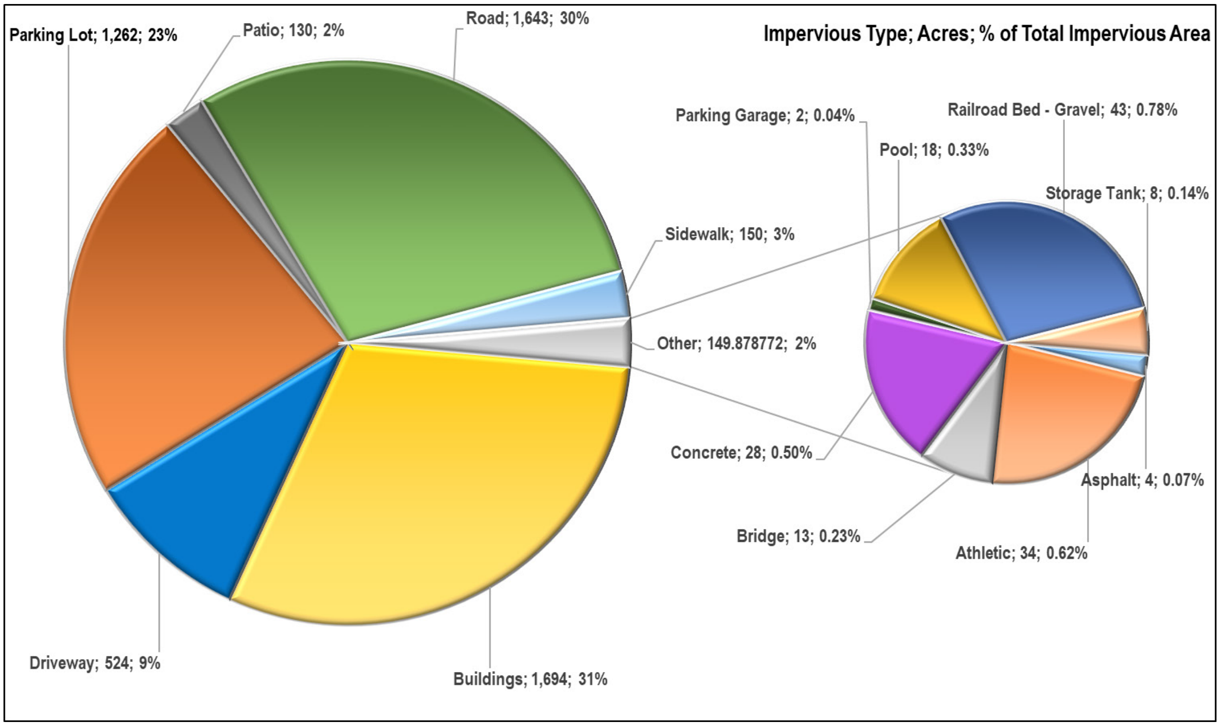


Figure 2-10. Patuxent River Upper watershed percent of impervious area by source.

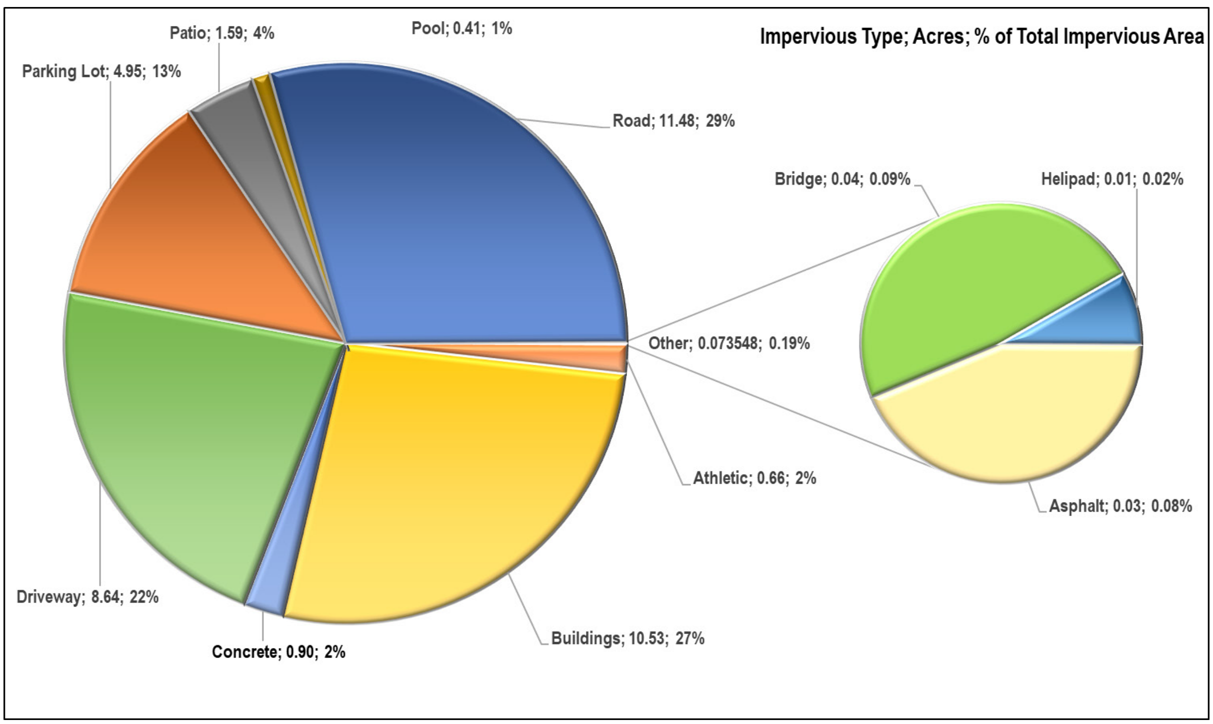
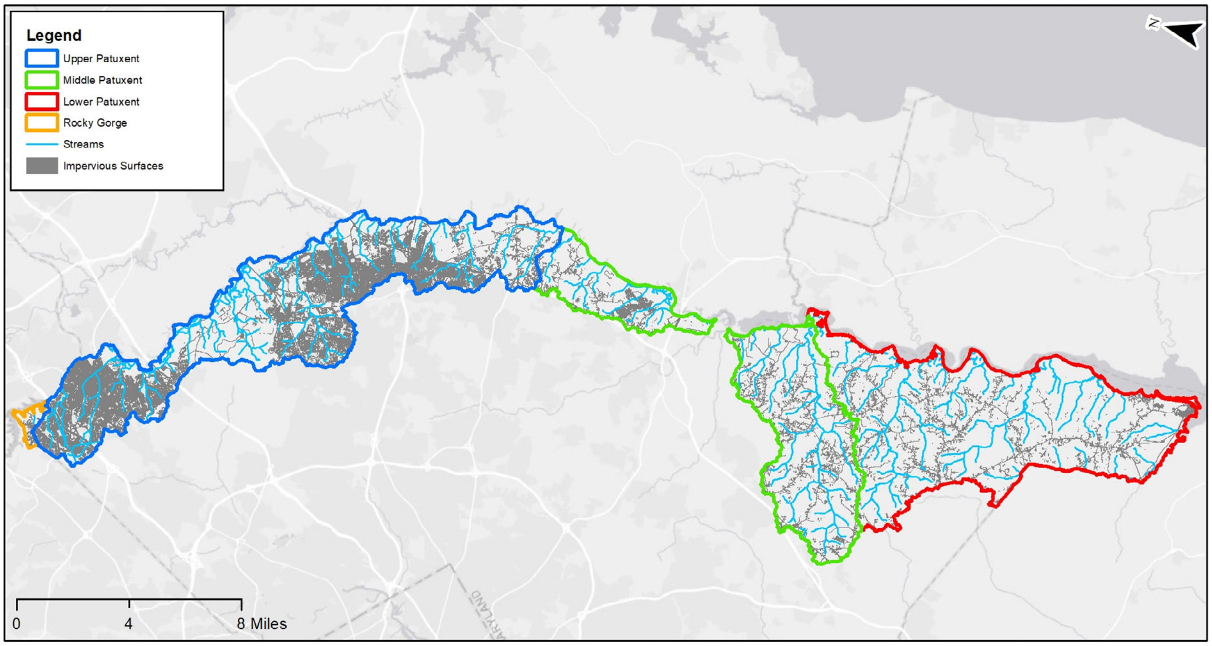


Figure 2-11. Rocky Gorge Reservoir watershed percent of impervious area by source.



Source: M-NCPPC 2022.

Figure 2-12. Impervious cover in the Patuxent River watershed.

2.3 Land Ownership

Overall, all four watersheds are primarily privately owned commercial/industrial/transit and residential land (Figure 2-13, Figure 2-14, Figure 2-15, Figure 2-16, and Figure 2-17). Specifically, the majority (57 percent) of land in the PR-L watershed is owned by commercial/industrial/transit, with 15 percent owned by residential, and 14 percent owned by state. The majority (40 percent) of land in the PR-M watershed is owned by commercial/industrial/transit, with 21 percent owned by state and 21 percent owned by residential. The majority (34 percent) of the land in PR-U watershed is owned by residential, with 14 percent owned by commercial/industrial/transit and 12 percent owned by state. The majority (50 percent) of land in the Rocky Gorge Reservoir watershed is owned by commercial/industrial/transit, with 35 percent owned by residential and 14 percent owned by private. A closer examination of land ownership will come into play during specific restoration planning, as it can sometimes be a simpler solution to implement BMPs on County, or otherwise publicly-owned, lands. While roadways are usually considered public right-of-way, Figure 2-17 was created using parcel information available from the Prince George's County GIS Open Data Portal (M-NCPPC 2022), which does not include roadway information, so roadways show on the map as white lines.

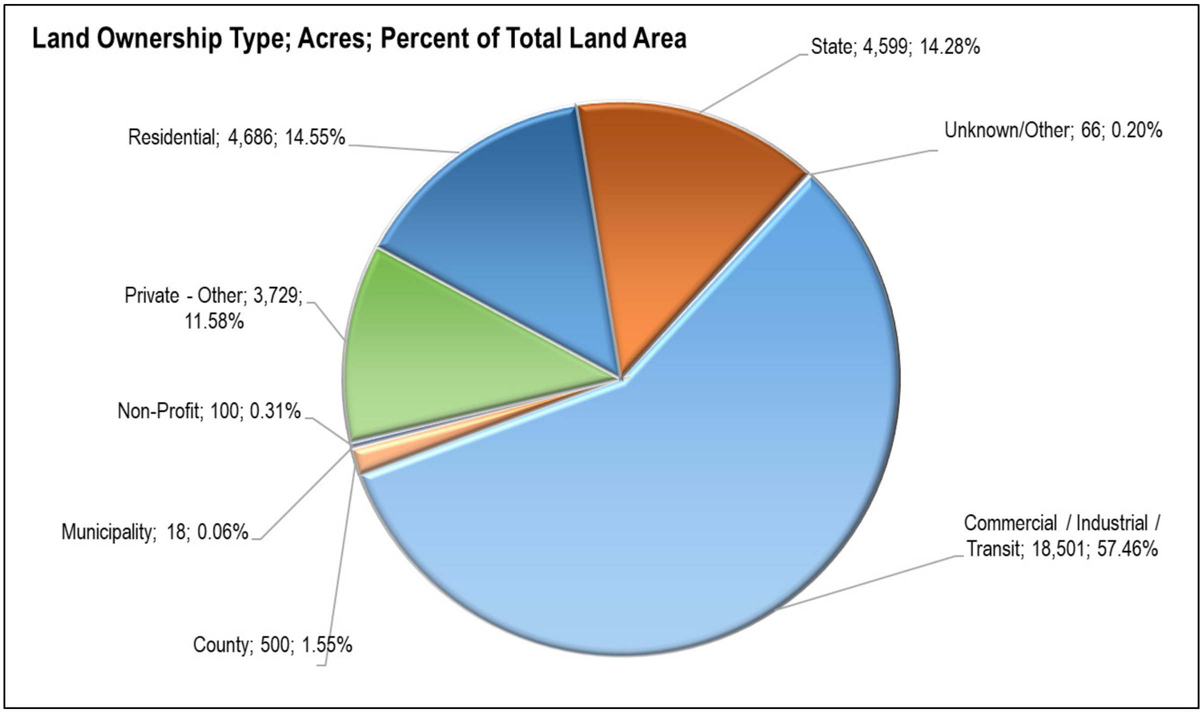


Figure 2-13. Patuxent River Lower watershed land ownership percent by source.

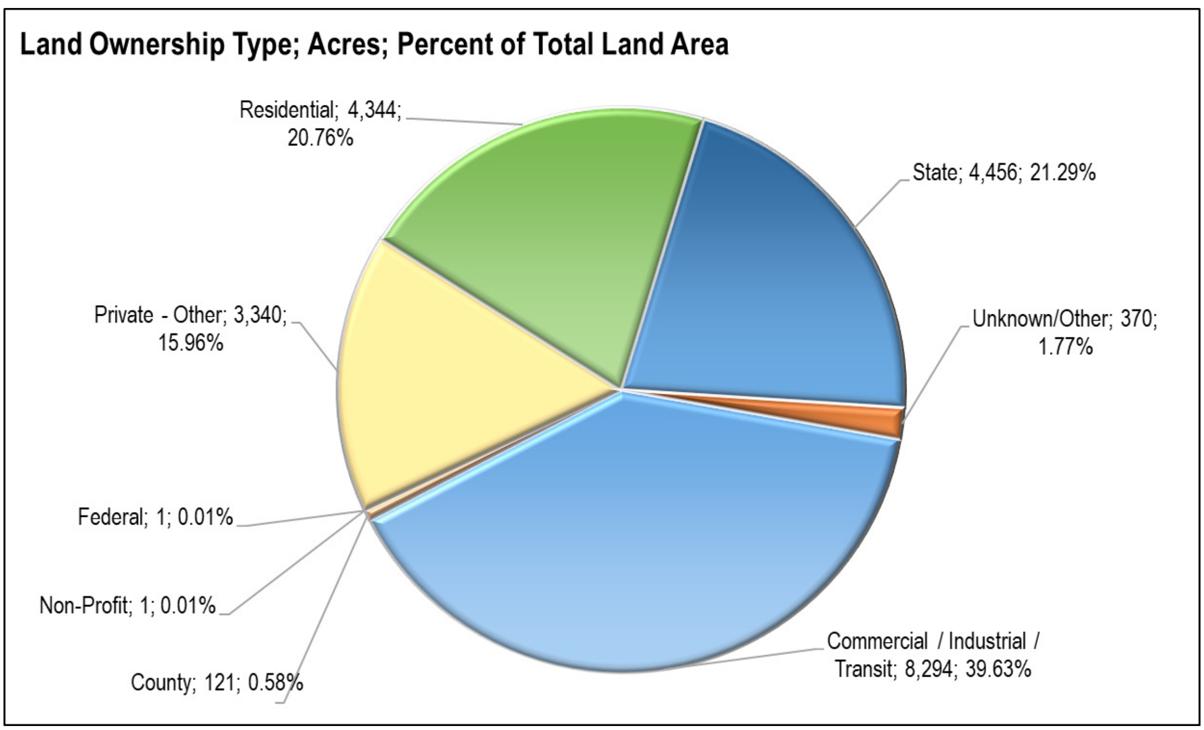


Figure 2-14. Patuxent River Middle watershed land ownership percent by source.

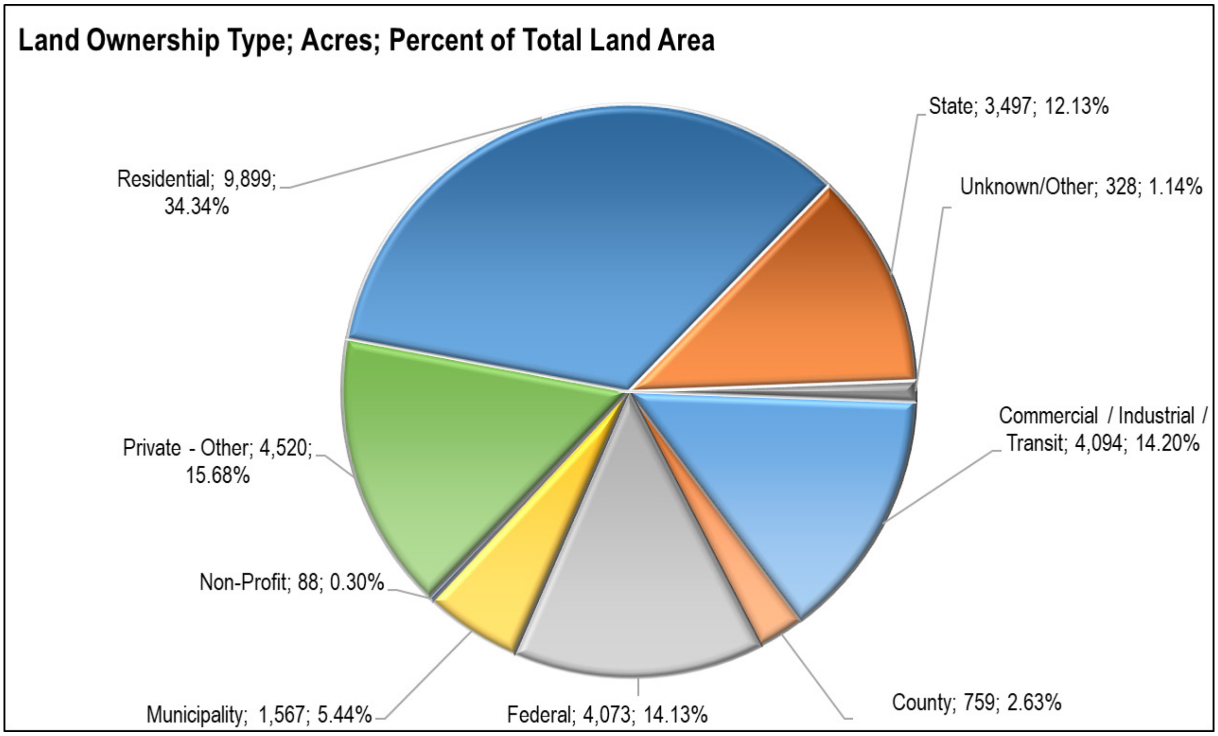


Figure 2-15. Patuxent River Upper watershed land ownership percent by source.

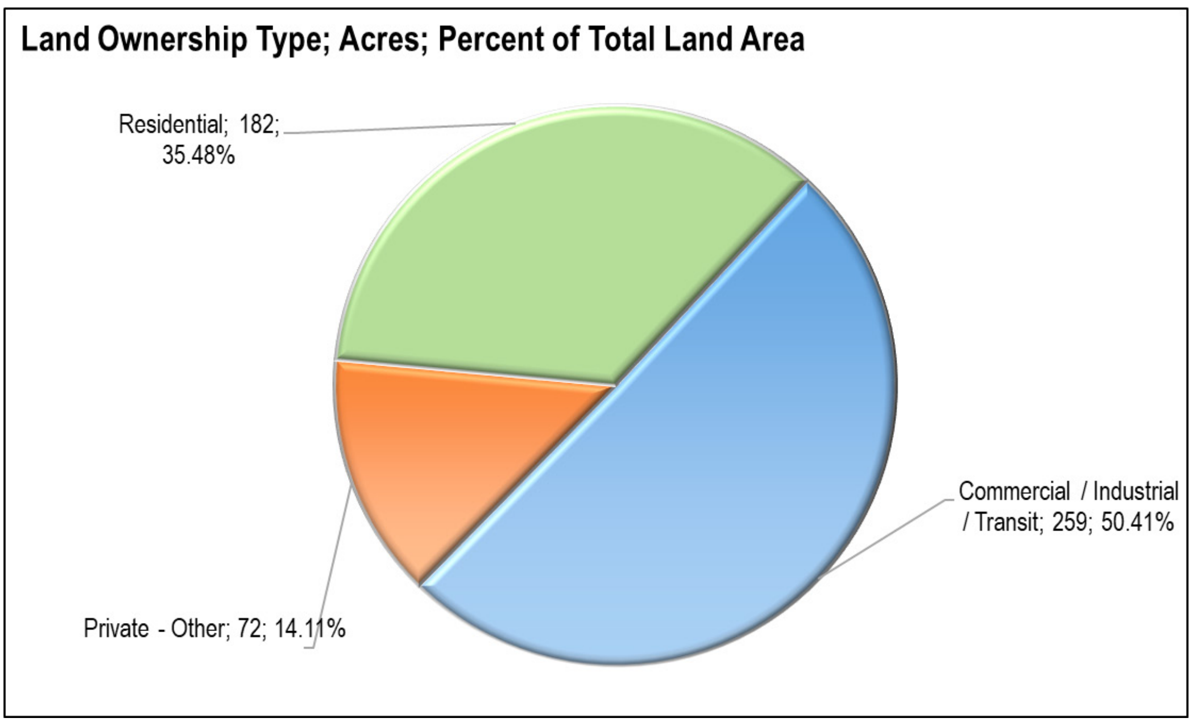
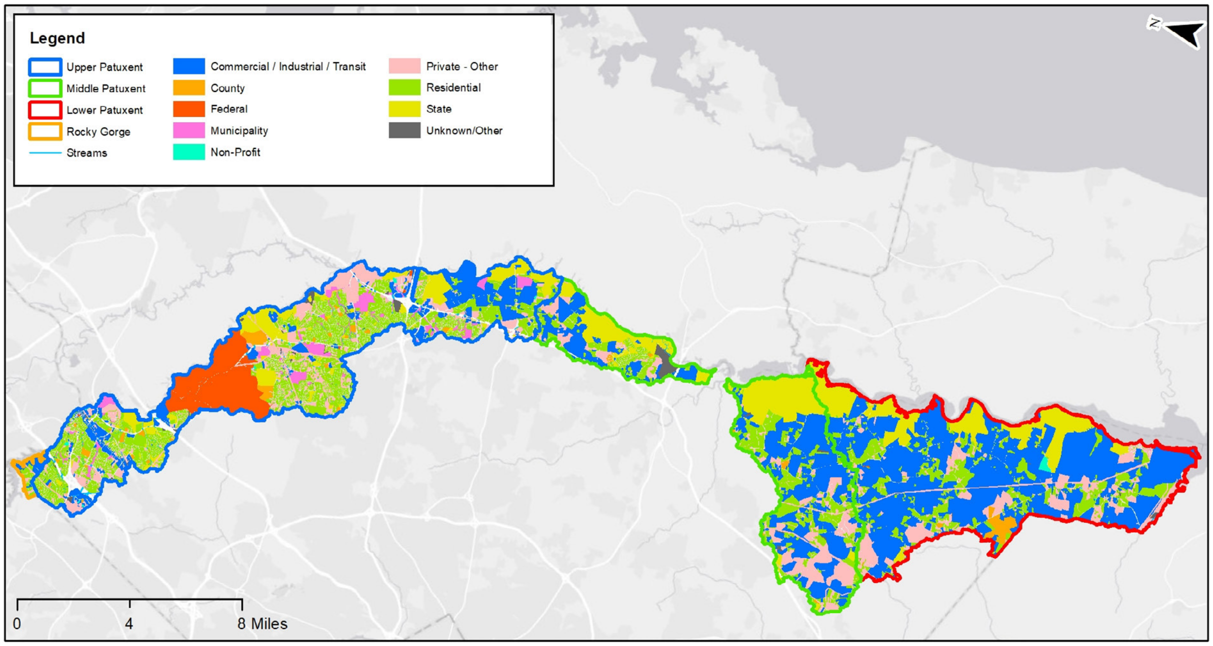


Figure 2-16. Rocky Gorge Reservoir watershed land ownership percent by source.



Source: M-NCPPC 2022.

Figure 2-17. Land ownership in the Patuxent River watershed.

2.4 Population and Growth

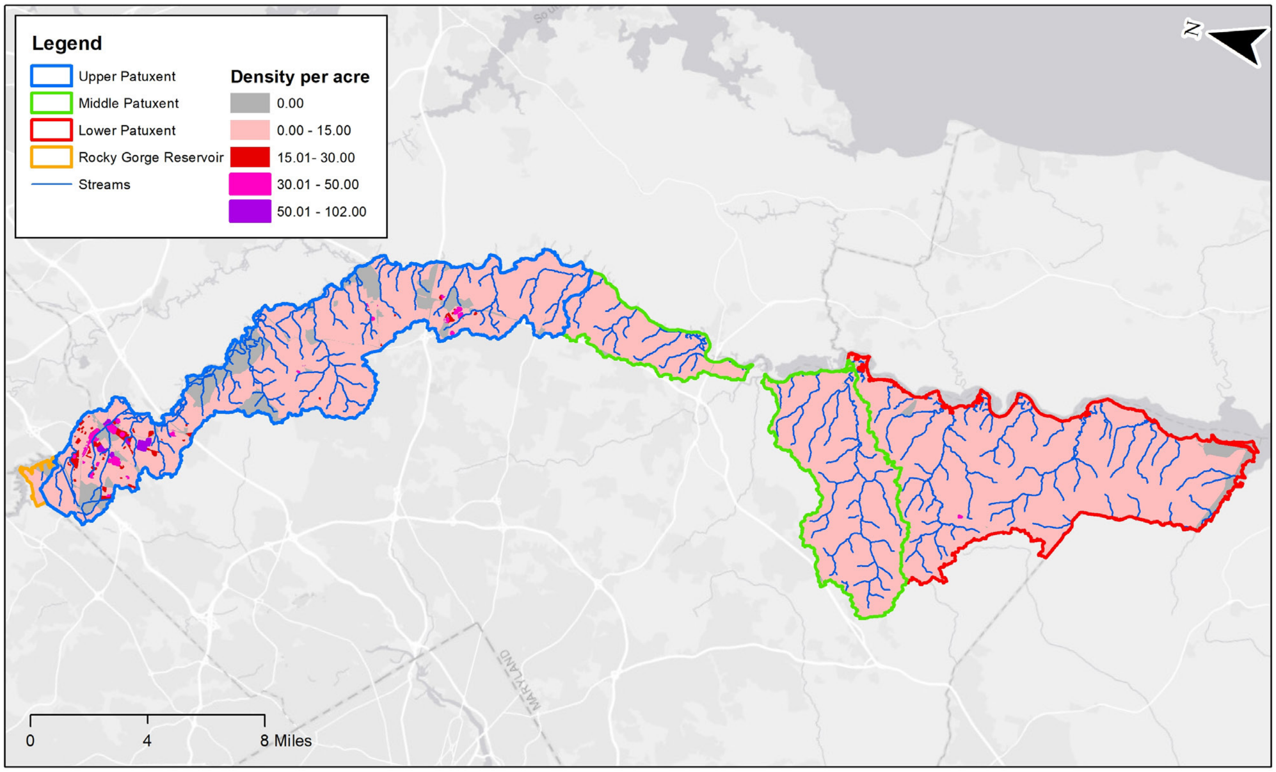
Table 2-9 presents the recent U.S. Census population estimates for Prince George's County. These numbers are not available by watershed level but there is a continuing upward trend in population. Figure 2-18 presents the population density of the watershed, by U.S. census block. There are higher density populations at Road 198 in the Upper Patuxent Watershed.

Table 2-9.Prince George's County population (1980–2020).

1980	1990	2000	2010	2020
665,071	729,268	801,515	863,420	967,201

Source: Wikipedia 2023.

In 2010, the Prince George's County Planning Department developed the County's *Water Resources Functional Master Plan*, which amended the 2002 *General Plan*. (M-NCPPC 2010). The plan contains information on the County's water and sewer service capacity for planned growth through 2030. It included a methodology to calculate nutrient loadings from existing and future conditions. The plan discusses County agency responsibilities regarding stormwater, key issues, and overarching policies and strategies.



Source: U.S. Census 2023.

Figure 2-18. Population density by census block in the Patuxent River watershed.

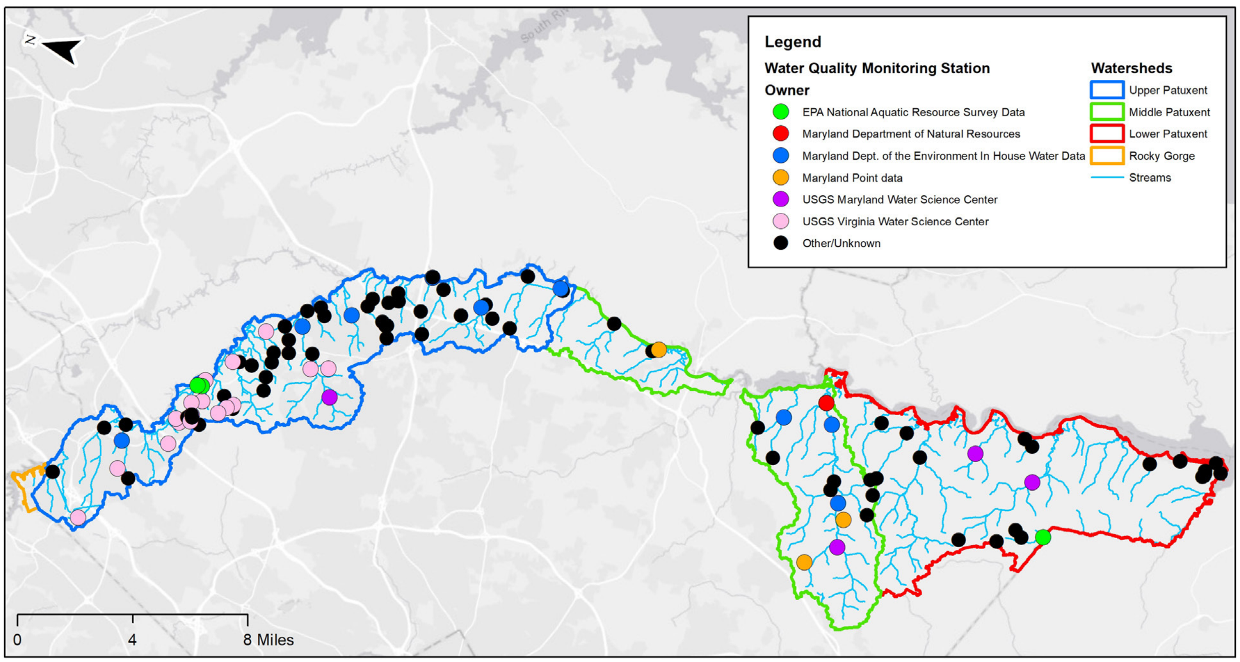
3 Watershed and Water Quality Conditions

3.1 Water Quality Data

Water quality data were analyzed to assess the degree to which water quality might be getting better or worse. Graphs later in this section present a record of TSS and TP concentrations over different periods of record. Figure 3-1 presents the locations of the water quality monitoring stations in the Patuxent River watershed. The County is unaware of any ongoing monitoring programs.

Water quality data were obtained from the following sources:

- EPA's STORET (STOrage and RETrieval) Data Warehouse.
- Federal Water Quality Portal (www.waterqualitydata.us/). (This service, which is sponsored by EPA, USGS, and the National Water Quality Monitoring Council, collects data from more than 400 federal, state, local, and tribal agencies.)



Source: NWQMC 2023.

Figure 3-1. Locations of water quality monitoring stations in the Patuxent River watershed.

3.1.1 Total Suspended Solids

Time series of TSS data from these monitoring stations for the periods in Table 3-1 are shown in Figure 3-2 for the PR-L watershed, Figure 3-3 for the PR-M watershed, and Figure 3-4 for the PR-U watershed. This section only discusses stations with recent water quality data after 2000 and at least 50 data points.

Two monitoring stations with recent data are in the PR-L watershed and they both have comprehensive datasets ranging from 1985 to 2020 (Table 3-1 and Figure 3-2). Monitoring stations TF1.6 and TF1.7 represent the most complete datasets in the watershed, with a respective 898 and 936 records (Table 3-1 and Figure 3-2). TSS concentrations at both TF1.6 and TF1.7 have a slightly positive slope (+0.0006 for TF1.6, +0.0004 for TF1.7). The trend line slopes are small and not significant. The coefficient of determination (R2 value) for both are under 0.02, indicating there is no significant trend of concentration versus time.

Six monitoring stations with recent data are in the PR-M watershed and two of those monitoring stations have comprehensive datasets ranging from 1985 to 2020 (Table 3-1, Figure 3-3). Monitoring stations TF1.3 and TF1.4 represent the most complete datasets in the watershed, with a representative 905 and 907 records (Figure 3-3). TSS concentrations at TF1.4 have a slightly positive slope (+0.00005), and the concentrations at TF1.3 have a slightly negative slope (-0.00009). The trend line slopes are small and not significant. The coefficient of determination (R^2 value) for both are under 0.02, indicating there is no significant trend of concentration versus time.

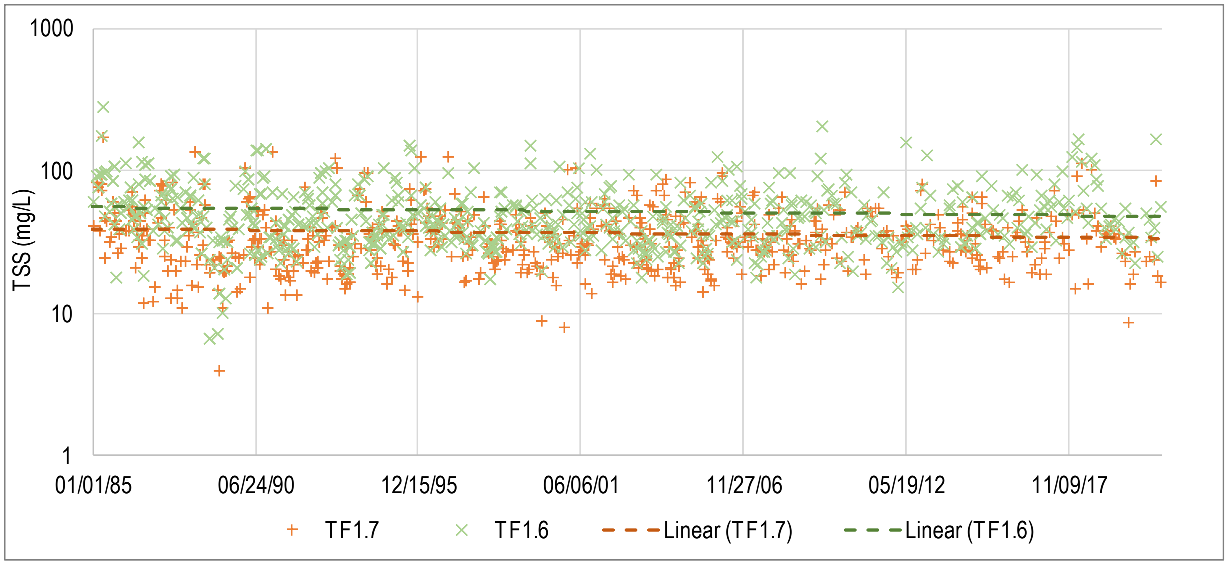
Three monitoring stations with recent data are in the PR-U watershed, and one of those monitoring stations has comprehensive datasets ranging from 1985 to 2020 (Table 3-1). Monitoring station TF1.0 represents the most complete datasets in the watershed with 1288 records (Figure 3-4). TSS concentrations at TF1.0 have a slightly positive slope (+0.0006), and the coefficient determination (R^2 value) is under 0.02, indicating there is no significant trend of concentration versus time.

The other monitoring stations in the Patuxent River watershed have significantly fewer data records (less than 100) for analysis (Table 3-1). The limited sample sizes of those stations and shorter period of record contribute to uncertainty because the extreme values could influence the slopes of the trendlines for those data. Stations with more than 50 data points since 2000 are plotted in Figure 3-4.

Table 3-1. Summary of TSS data in the Patuxent River watershed.

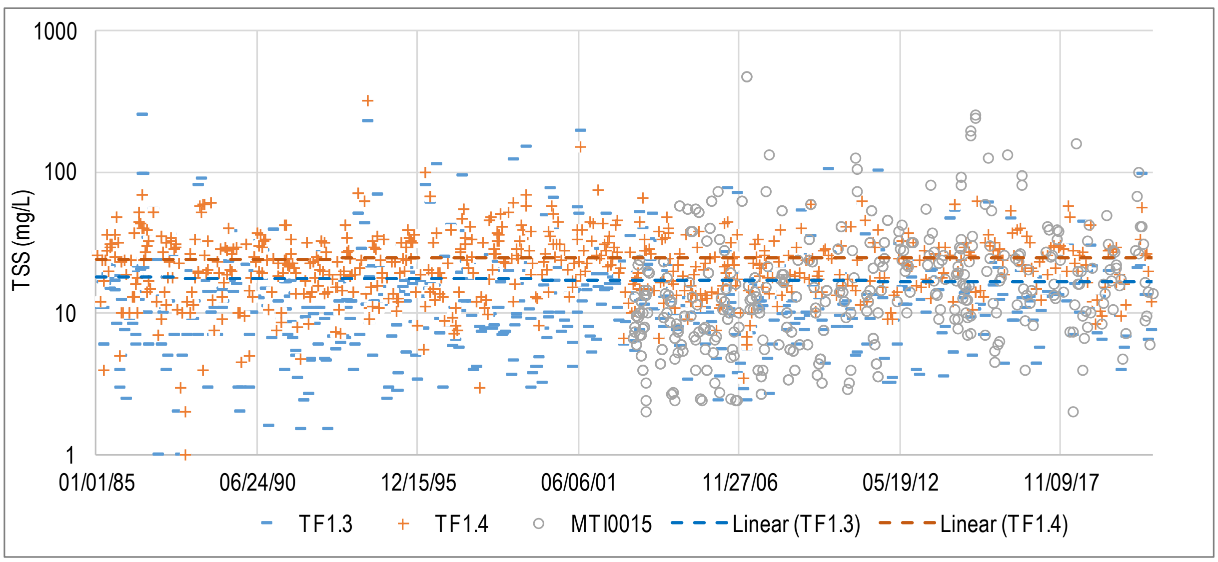
Station ID	Station Name	Owner	Start Date	End Date	Number of Records	Min. Value (mg/L)	Mean Value (mg/L)	Max. Value (mg/L)
TF1.6	TF1.6	MD DNR	01/09/85	12/09/20	898	6.67	52.78	287.33
TF1.7	TF1.7	MD DNR	01/09/85	12/09/20	936	4.00	37.16	174.00
MTI0015	MTI0015	MD DNR	04/22/03	12/22/20	507	2.00	22.08	474.00
TF1.3	TF1.3	MD DNR	01/09/85	12/09/20	905	1.00	17.43	250.00
TF1.4	TF1.4	MD DNR	01/09/85	12/09/20	907	1.00	24.46	322.00
TF1.0	TF1.0	MD DNR	01/09/85	12/09/20	1,288	1.00	20.30	482.25

Note:
mg/L = milligrams per liter.



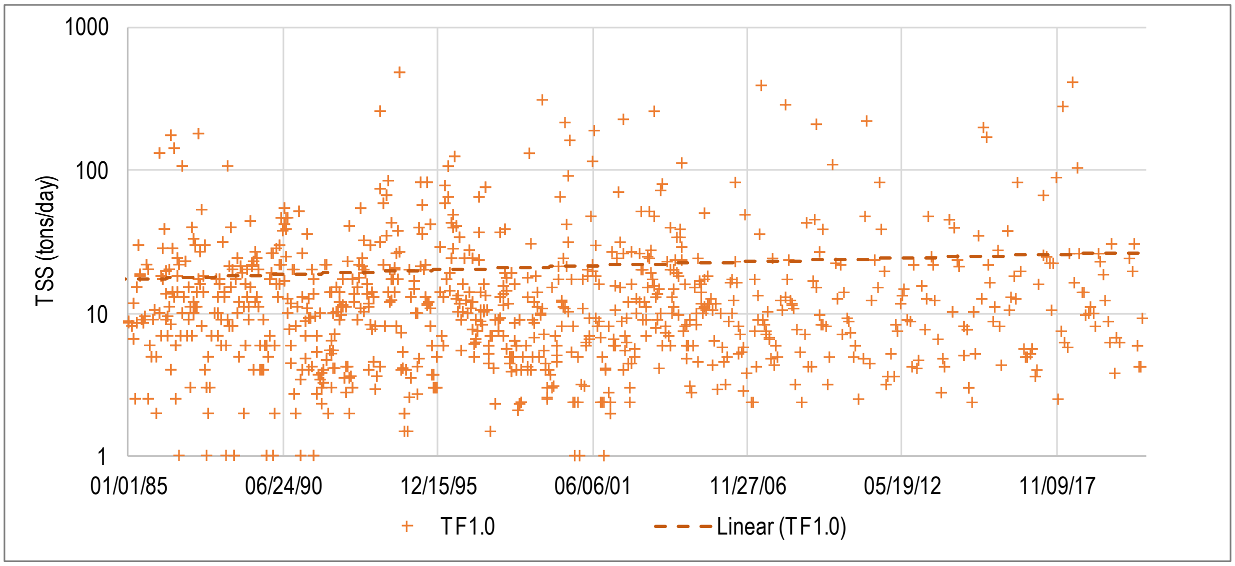
Source: NWQMC 2023.

Figure 3-2. Plot of TSS concentration over time at monitoring stations TF1.6 and TF1.7 in the Patuxent River Lower watershed.



Source: NWQMC 2023.

Figure 3-3. Plot of TSS concentration over time at monitoring stations MTI0015, TF1.3, and TF1.4 in the Patuxent River Middle watershed.



Source: NWQMC 2023.

Figure 3-4. Plot of TSS concentration over time at monitoring station TF1.0 in the Patuxent River Upper watershed.

3.1.2 Total Phosphorous

TP was only measured in two monitoring stations for the Rocky Gorge Reservoir watershed. Time series of TP data from the two monitoring stations for the periods in Table 3-2 are shown in Figure 3-5 and Figure 3-6. Time series of TP data either range from 1986 to 1987, or in 2000.

Monitoring station PXT0831 has six records from March 2000 to September 2000, and monitoring station USGS-1592500 has 24 records from 1986 to 1987 (Figure 3-5 and Figure 3-6). It is hard to determine any trendline due to uncertainty resulting from the limited sample sizes of those stations and shorter periods of record.

Table 3-2. Summary of TP data in the Rocky Gorge Reservoir watershed.

Station ID	Station Name	Owner	Start Date	End Date	Number of Records	Min. Value	Mean Value	Max. Value	Unit
PXT0831	Rocky Gorge Reservoir	MDE	03/20/00	09/18/00	6	0.01	0.01	0.02	mg/L
USGS-1592500	PATUXENT RIV NEAR LAUREL, MD	USGS	01/06/86	12/14/87	24	0.03	0.06	0.27	mg/L as P

Notes:
mg/L = milligrams per liter.

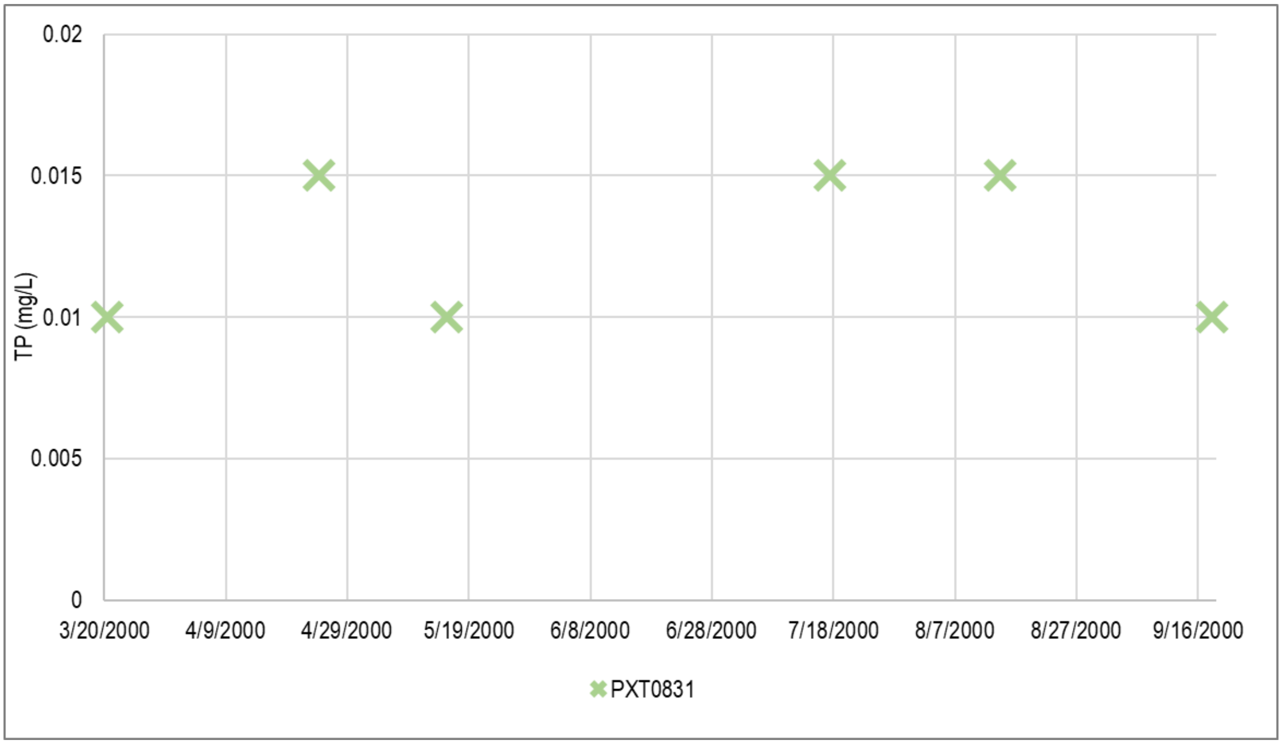


Figure 3-5. Plot of TP concentration over time at monitoring station PXT0831 in the Rocky Gorge Reservoir watershed.

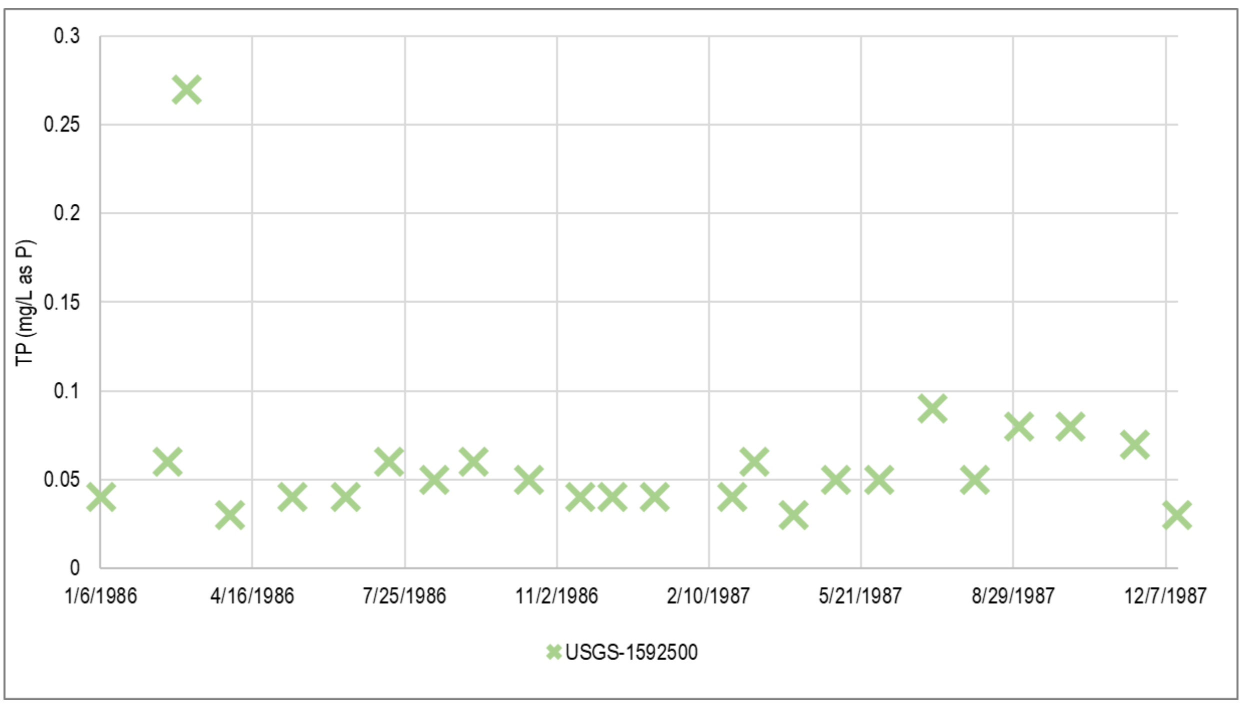


Figure 3-6. Plot of TP concentration over time at monitoring station USGS-1592500 in the Rocky Gorge Reservoir watershed.

3.2 Biological Assessment

Analyses of biological monitoring program data provide insights into the status and trends of ecological conditions in a stream and watershed. Watershed planners can use biological monitoring data to identify problems; document relationships among stressor sources, stressors, and response indicators; and evaluate environmental management activities, including restoration. Especially with a TMDL for sediment specific to first- through fourth-order streams, biological monitoring data is central to targeting potential restoration to the areas of the watershed with the greatest need because biological responses are closely related to upland land use changes. Lack of or insufficient stormwater management controls will cause stream scour, incision, sediments, and other geomorphic changes affecting the benthic macroinvertebrate communities. The County's biological monitoring collects annual stream samples of those communities, and a report is submitted to MDE. Past bioassessment data can be compared to future bioassessment data to determine trends.

3.2.1 Assessment Methodology

DoE began implementing its countywide, watershed-scale biological monitoring and assessment program in 1996. To date, the department has collected 395 stream samples in the Patuxent River watershed through four rounds of data gathering. The primary measure of stream health is the BIBI (Southerland et al. 2007). Because different stream conditions support different types of "benthic"—or bottom-dwelling—organisms, analyzing the benthic organisms collected along a stream reach can provide a good indication of the health of that reach.

Field sampling and data analysis protocols employed by the County for the program are comparable to those used in the MD DNR MBSS. Streams assessed are wadeable and generally first- through third-order according to the Strahler Stream Order system (Strahler 1957). Stream order designation is based on the National Hydrography Dataset map scale of 1:100,000. The numbers of streams sampled in each watershed are proportional to the size of the watershed and are allocated among first- to third-order streams, with a larger number of sites on smaller first-order streams. Samples and data collected at each location include benthic macroinvertebrates, visual-based physical habitat quality, substrate particle size distribution, and field chemistry (DO, conductivity, pH, and water temperature).

For the County's biological monitoring assessment, a 100-meter reach was sampled at each selected site. At a laboratory, technicians identified these biological samples each to a target taxonomic level, usually genus. The numbers of the different kinds of organisms found were used to calculate the BIBI numeric value or score. Based on that score, the biological integrity was rated as Good, Fair, Poor, or Very Poor. Stream reaches rated as Poor or Very Poor are considered degraded. All biological data is supplied to MDE and MD DNR annually for tracking progress and inclusion on MDE's Integrated report.

3.2.2 Biological Assessment Results

This section evaluates the results in three ways: (1) plots of percent degradation by assessment round and major basin, (2) plots of number of sites per basin and round per narrative rating, and (3) a map of monitoring locations and their narrative ratings.

The percent of sites identified as degraded were plotted by sampling round for the PR-L, PR-M and PR-U watersheds. The specific stream reaches (sites) sampled in a basin are different each year. They are randomly selected to be more representative of stream and basinwide conditions. This is why there are differences from one round to the next, reflecting expected environmental variability. The biological data reveal that the PR-L and PR-U watersheds consistently had moderate-to-high levels of degradation through the four assessment rounds (Figure 3-7 and Figure 3-9). The PR-M watershed, on the other hand, had a low-to-moderate level of degradation through the four assessment rounds. The biological assessment narrative ratings by monitoring location for rounds 1–4 in PR-L, PR-M, PR-U, and Rocky Gorge Reservoir watersheds are depicted in Figure 3-10, Figure 3-11, Figure 3-12, and Figure 3-13.

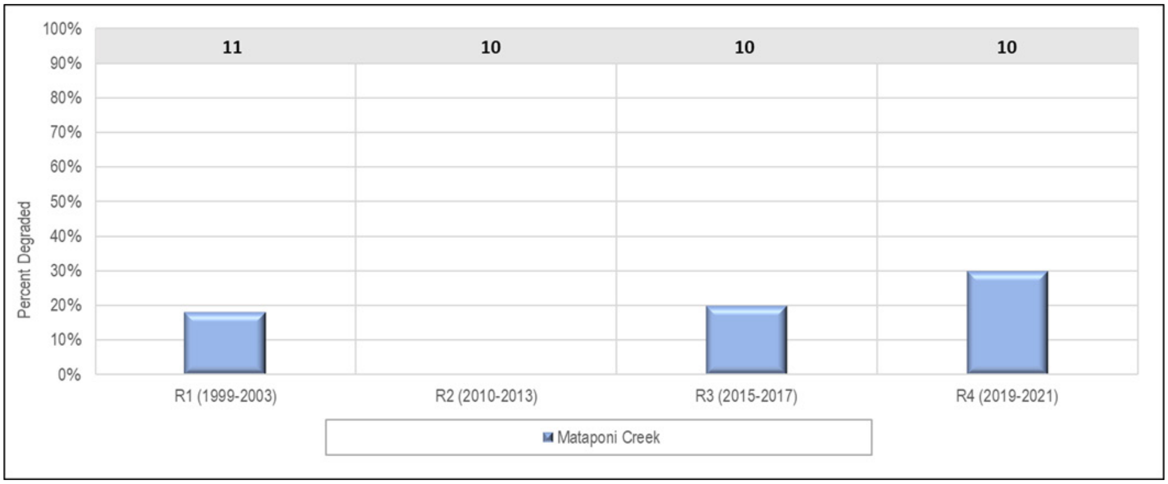
The biological assessment narrative ratings by monitoring location for round 1-4 in PR-L, PR-M, and PR-U watersheds are depicted in Figure 3-10 to Figure 3-13. Most sites were rated as Fair or Good, with only a few being rated as degraded (Poor or Very Poor) in all rounds tested in the PR-L watershed (Figure 3-10). Later sampling rounds showed an improvement of biological assessment results. As for the PR-M watershed (Figure 3-11), most sites were rated as Fair or Good, while the 4th round of the Lower Patuxent River revealed a degradation for one site. And, for Mataponi Creek, there is also a tendency of degradation for few sites.

The PR-U watershed has a more complex mixed result (Figure 3-12). For Bear Branch, Horsepen Branch, and Upper Patuxent, the later sampling rounds revealed a decreased frequency of sites that may be described as degraded. The Crows Branch has an increasing trend for degradation. The number of sites that were rated as Very Poor rate for Lower Patuxent River rose from the first round to the second, but then declined in later rounds. For Walker Branch, on the other hand, the number of sites rated as Fair increased at first and, then, all sites were rated as Poor.

As for the Rocky Gorge Reservoir watershed (Figure 3-13), there are not enough data to analyze. But there is a tendency of water quality improvement since there is no Very Poor rating on later rounds of testing. The geographic distribution of the narrative results of the biological assessments can be seen in Figure 3-14, where the PR-M and PR-L watersheds have more areas rated as Fair to Good while the PR-U watershed has more areas rated as Poor to Very Poor.

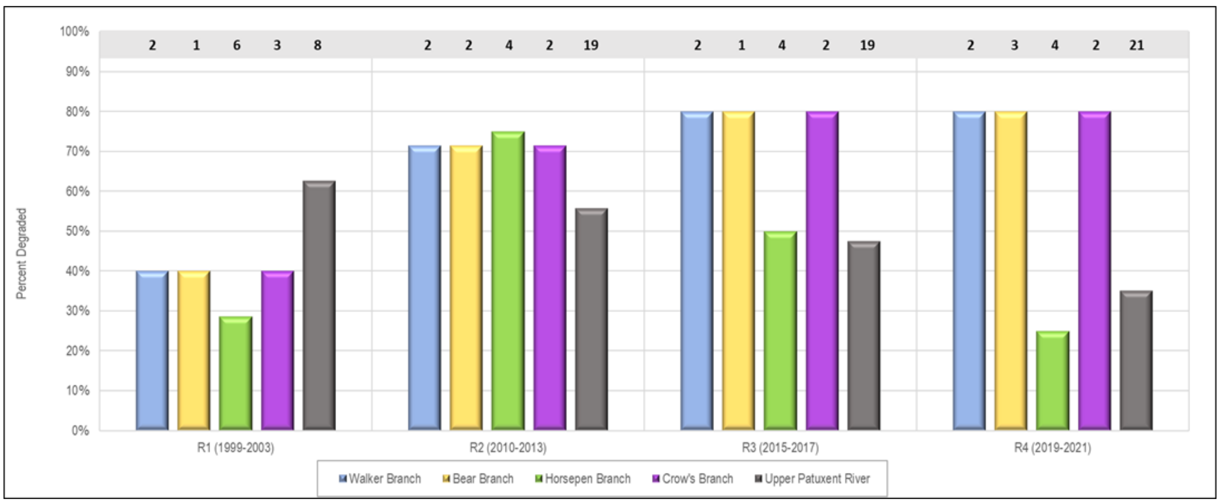
Note: The gray bar across the top shows the number of site locations sampled in each basin for the assessment round.

Figure 3-7. Patuxent River Lower watershed percent degraded by assessment round.



Note: The gray bar across the top shows the number of site locations sampled in each basin for the assessment round.

Figure 3-8. Patuxent River Middle watershed percent degraded by assessment round.



Note: The gray bar across the top shows the number of site locations sampled in each basin for the assessment round.

Figure 3-9. Patuxent River Upper watershed percent degraded by assessment round.

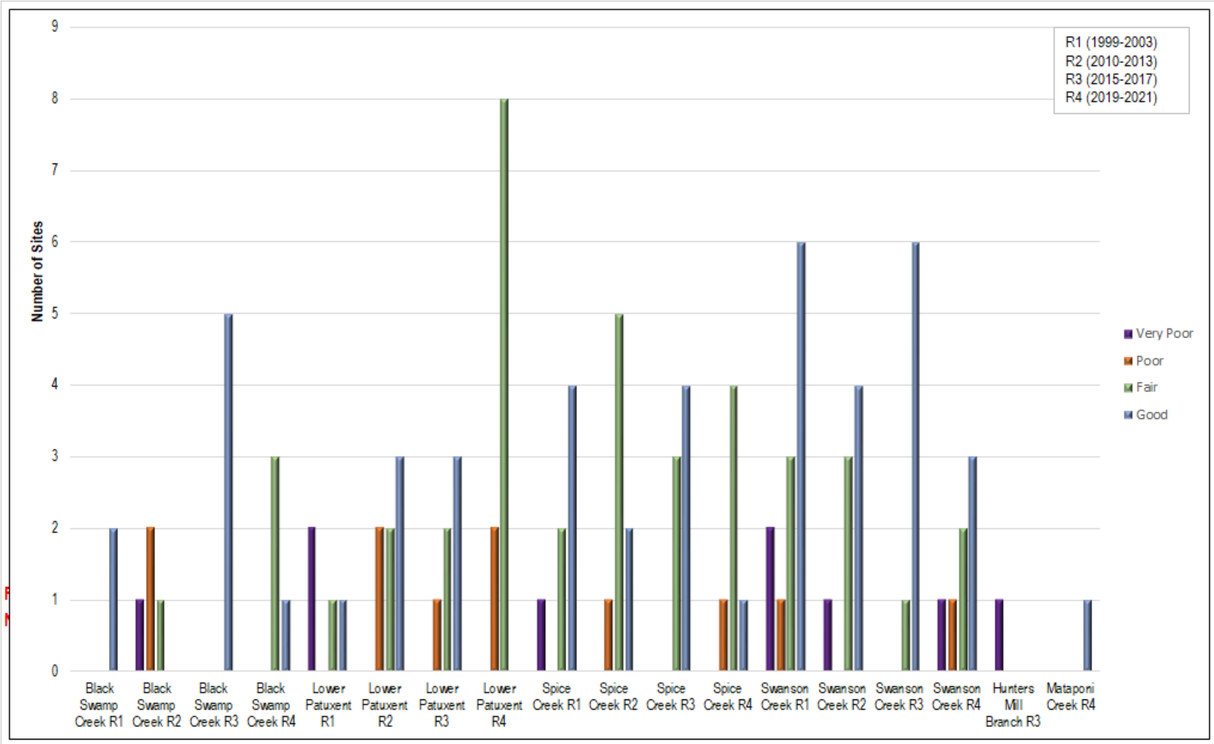


Figure 3-10. Patuxent River Lower watershed IBI narrative results by assessment round.

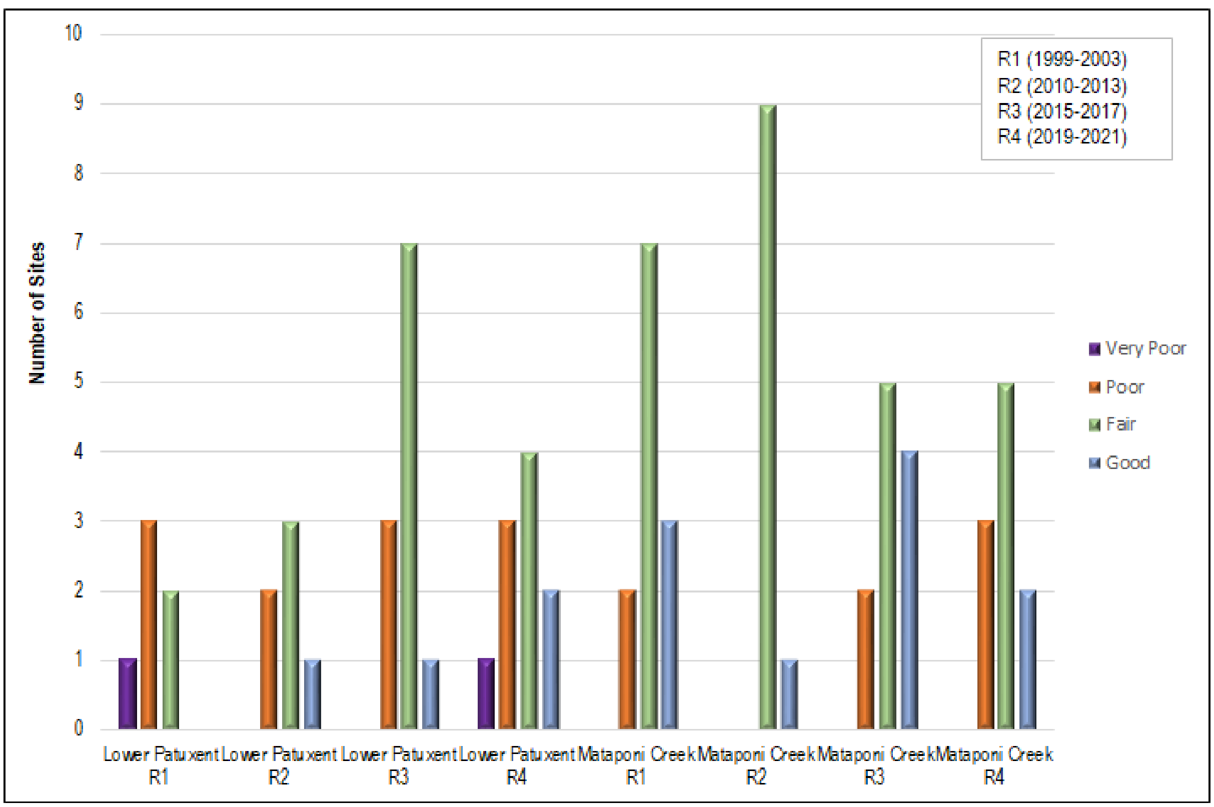


Figure 3-11. Patuxent River Middle watershed IBI narrative results by assessment round.

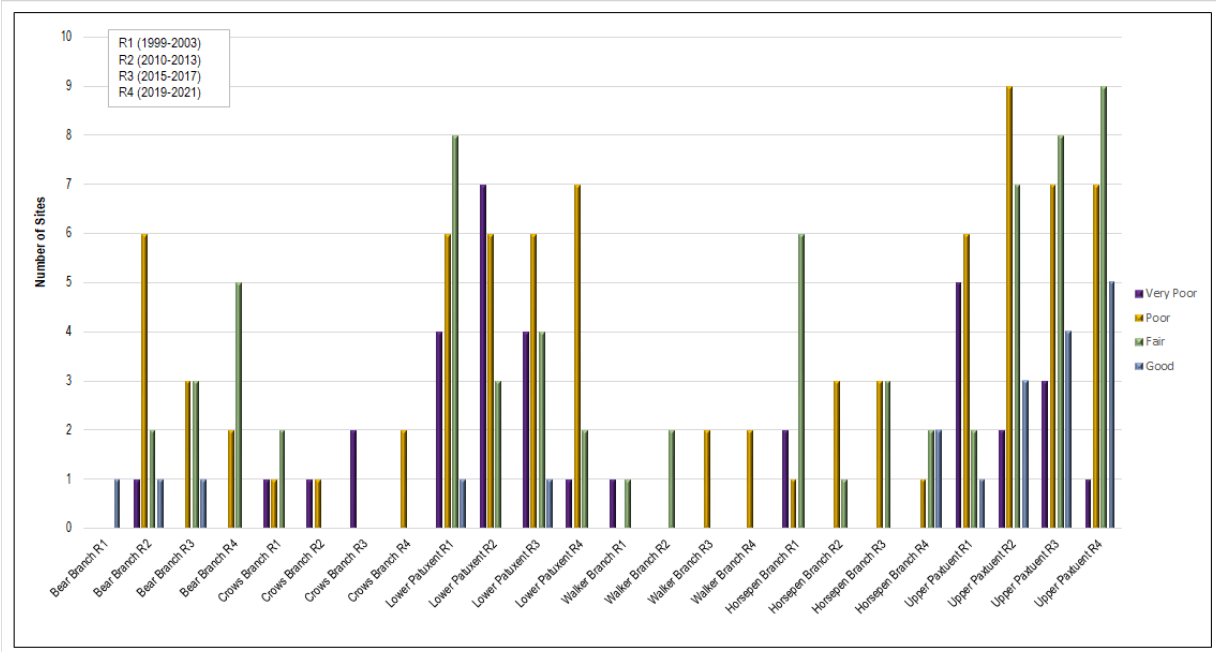


Figure 3-12. Patuxent River Upper watershed IBI narrative results by assessment round.

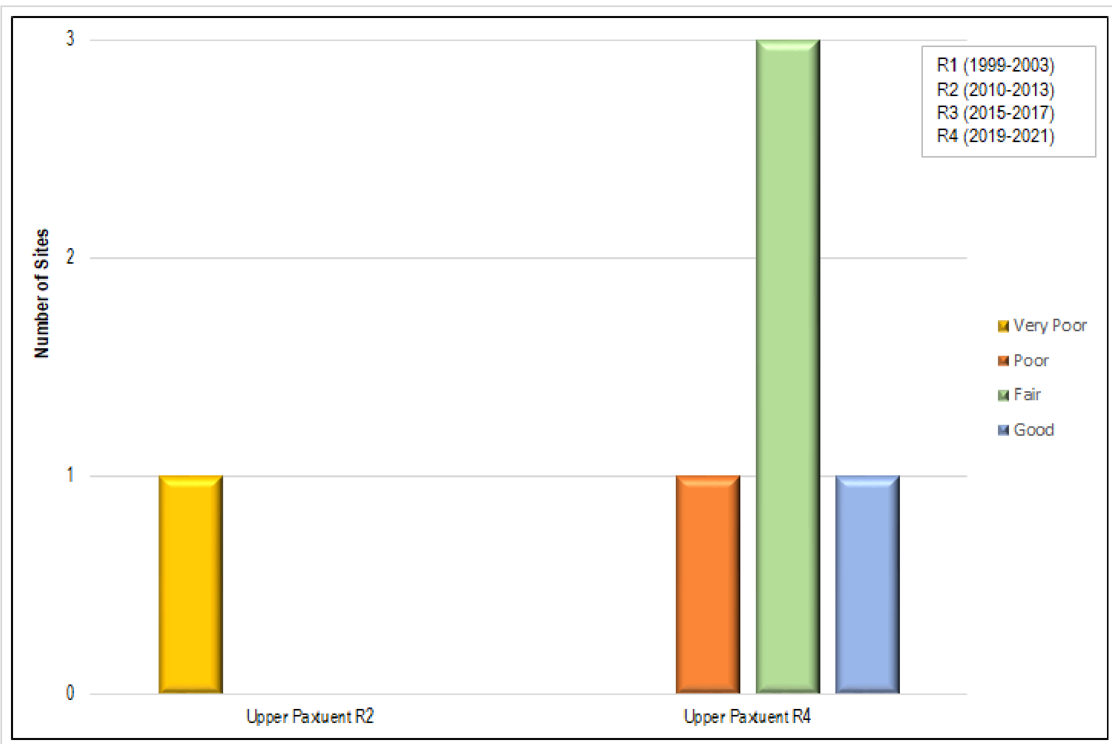


Figure 3-13. Patuxent Rocky Gorge Reservoir watershed IBI narrative results by assessment round.

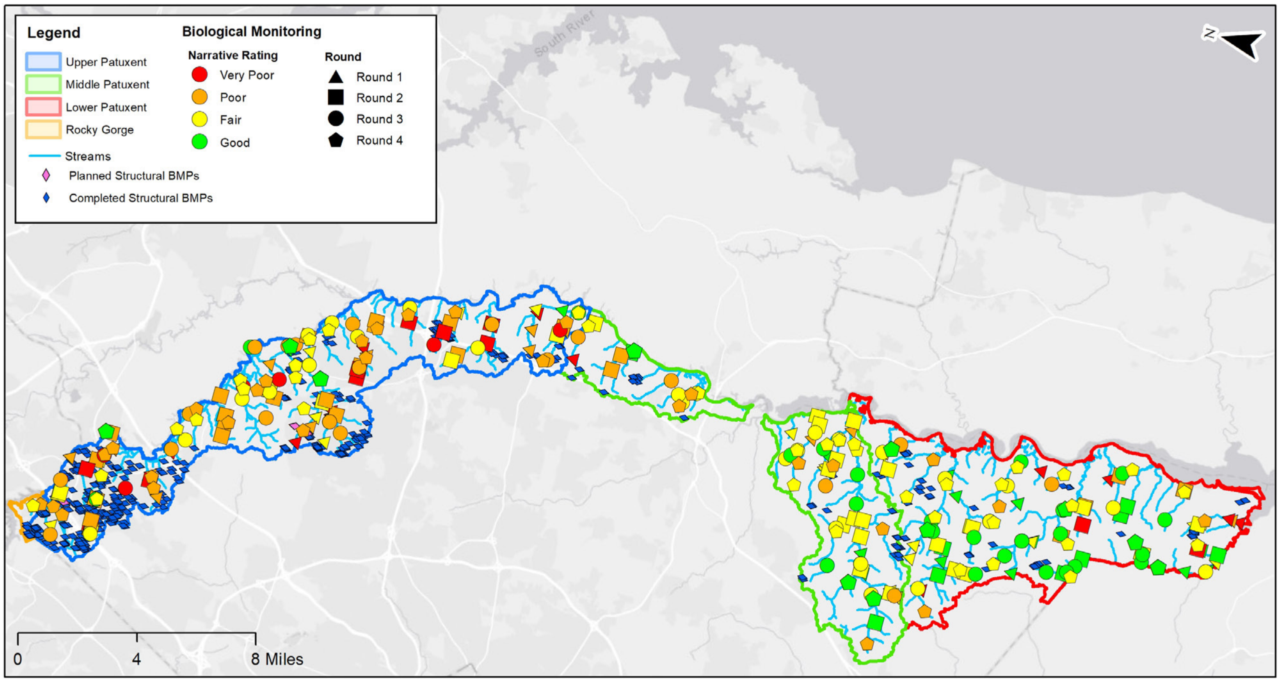


Figure 3-14. Biological assessment narrative ratings by monitoring location.

3.3 Geomorphic Cross Section Assessment

During round 1 and part of round 2 of the countywide biological assessments, DoE assessed fluvial geomorphic conditions (primarily Rosgen Level II classification) to document and characterize channel stability. Rosgen Level II is a quantitative morphological assessment of the stream reach, which provides greater detail from data collected in the field for the implementation into land management/design decisions as part of the analysis for alternatives of proposed repairs. Rosgen Level II will help determine if the stream channel is stable and describes channel aggradation/degradation. These are directly related to the MBSS physical habitat determination as required by DNR. Restoration opportunities can be derived from the collected field data, including assessments of the channel cross-section, longitudinal profile, and plan-form pattern. Often, restoration engineers use geomorphic assessment entrenchment ratios as indicators for excess discharges from upland sources, requiring further evaluation of effective stormwater management controls. If a stream segment needs repair or stabilization due to damage or infringement (soil loss), the geomorphic assessments contain cross-section measurements, entrenchment ratio, width:depth ratio, dominant substrate, slope, stream bed features, sinuosity, and meander, which will aid in restoration design.

Physical habitat is widely understood to be the principal environmental factor controlling stream biological condition, as well as a reflection of the complex interplay among surface water flows, topography/gradient, soils, vegetation, and surrounding land cover characteristics. Thus, when a stream is exposed to altered patterns of flow and the resulting accelerated erosion, the relative stability of stream channel morphology is compromised and is (A) directly related to the quality of the habitat supporting the survival and reproduction of aquatic life, such as benthic macroinvertebrates and fish, and (B) an indicator of sources of unmanaged storm flow that cause the instability, thus supplying information for siting and potentially designing control measures. The County reassessed 80 cross-section sites with historic monumented cross section data randomly selected throughout the County for the 2020 re-surveying effort (Tetra Tech 2022). The historic cross-section locations were co-located with stations monitored over the first several years of countywide biological monitoring. The original, and subsequent, biological stations are chosen at random sampling sites with GRTS (Generalized Random Tessellation Stratified), adopting a sampling approach stratifying by at least the Maryland 8-digit watershed and adopting a 1:24,000 scale map, enhancing the temporal and spatial resolution of the data and its usefulness in data analysis. Of the 78 re-assessed sites, there were 16 sites assessed in this manner in the Patuxent River watershed (Figure 3-15).

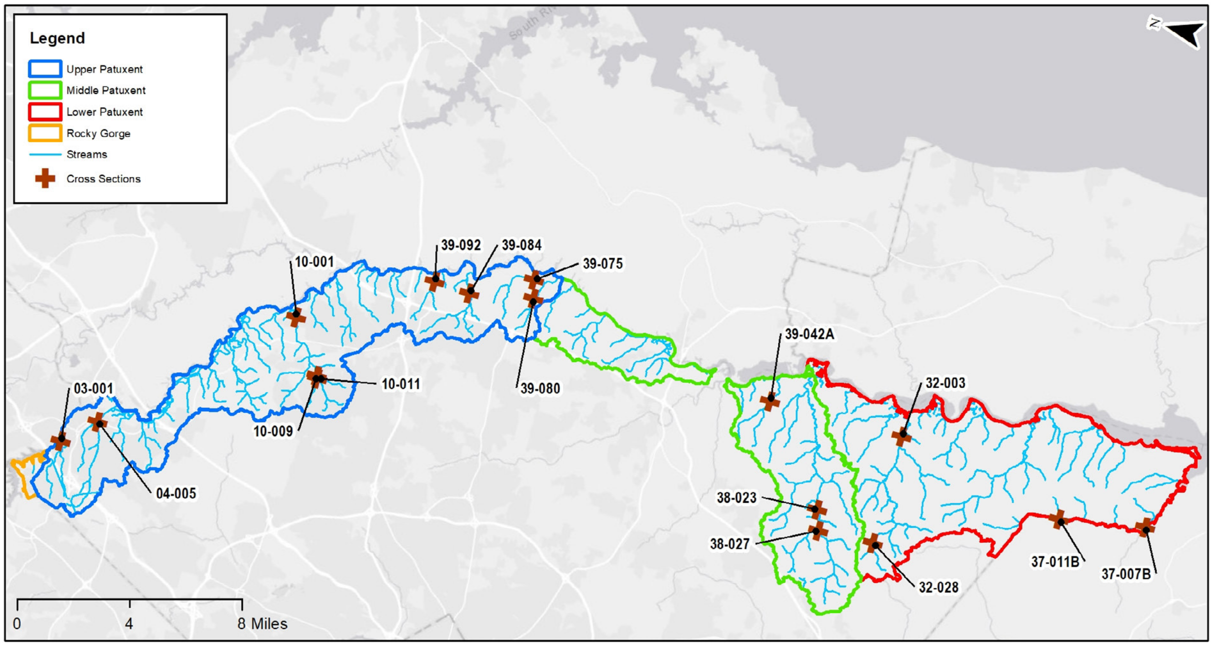


Figure 3-15. Cross-section measurement locations.

3.3.1 Assessment Methodology

Permanent monuments were established as the point of reference for taking channel cross-sectional (XS) measurements, which also allowed several other components of channel form to be measured and documented. Following a time interval ranging from approximately 12–20 years, 78 reaches were visited to re-survey; comparisons of results allowed calculation of changes in XS area (square meters) and the amounts of sediment lost (erosion) or gained (sedimentation). In addition to XS, we also collected modified Wolman 100-particle pebble counts and other data needed for the Rosgen Level II classification of each reach. Data were downloaded, organized, and processed to characterize changes in land use and land cover contributing to conditions potentially affecting rates and magnitudes of erosion. The County calculated changes in XS area over the 15- to 21-year intervals and used a conversion factor developed by a mid-Atlantic expert panel for the two nontidal physiographic provinces in which the County lies: the Coastal Plain Lowland Non-Tidal and the Coastal Plain Dissected Uplands Non-Tidal. The conversion factor was used to calculate annual sediment yield (tons) from changes in XS area due to erosion and deposition. Additional analyses of the results will include site-specific bulk density values, which will provide a more accurate estimate of sediment yield.

Sites were ranked to isolate those with the greatest geomorphic activity, specifically each of the 10 undergoing the most erosion (sediment loss) and deposition (sediment gain).

3.3.2 Geomorphic Assessment Results

Appendix F presents geomorphic assessment results for twelve branches from the 2001 and 2020 assessment years. The data presented is from the field geomorphic field observations and measurements, and the subsequent geomorphic calculations. Sediment yield is calculated using changes in full stream channel cross-sectional area (XSa) and by converting the volume (freight tons) of sediment lost (degradation) or gained (aggradation) into annual changes. Detailed assessment results are shown in Appendix G. The results suggest there is erosion upstream, and the resulting sediment is being deposited in the study reaches.

Comparison of fluvial geomorphic conditions using the Rosgen classification system organizes several pieces of data and information to help interpret relative stream channel stability, including entrenchment, width:depth ratio, sinuosity, slope, and substrate characteristics. The County compared stream classification from the original field geomorphic characterization to those taken in 2020. Elevated channel instability is generally associated with F- and G-type channels, and relative geomorphic stability is generally associated with E-, C-, and B-type channels. Results from current and historical data showed that three reaches were classified as having experienced little to no change in relative stability, with the final station going from an unstable channel to a stable channel. Due to the limited space and the number of cross sections, changes in cross sections at the 16 stations are presented in Appendix G. The plots show how the stream channel cross-sections have changed at 16- to 20-year intervals due to erosion and deposition. While only a few cross sections were relatively stable, most cross sections significantly changed through channel migration and incision.

3.4 Known Stream Erosion Issues

The MD DNR conducted stream corridor assessments (SCAs) of all County watersheds in the 2000s. These assessments included field site visits and stream walks to determine the conditions of the streams. Each site was given an identification number and photographed. Stream bank erosion and head cutting were investigated during the analysis. Stream reaches were rated on the severity of erosion, correctability, and access to the stream. This WIP assumes that if a stream had erosion issues in the 2000s, it is likely to have them still today if no corrective actions have been taken.

Only a few SCAs showed severe in-stream erosion concerns (Figure 3-16). The greatest concentration of stream reaches identified as being of at least moderate concern was in the middle portion of the PR-U watershed, These SCAs identified 52,593 linear feet of stream—rated as severe or very severe—for potential restoration. These will be part of the restoration strategy presented in Section 7 of this WIP.

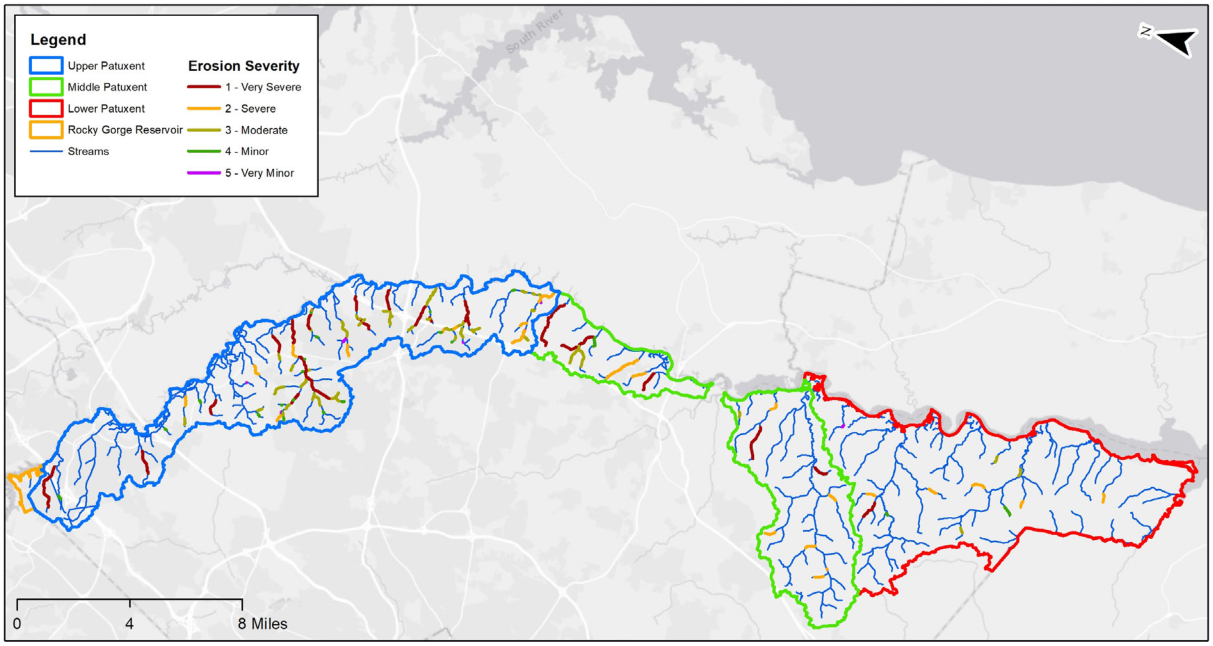


Figure 3-16. Locations of SCA-identified erosion (with severity) in the Patuxent River watershed.

3.5 Other Potential Pollutant Sources

Identifying the sources of pollutants of concern is valuable in developing appropriate strategies to reduce the amount of those pollutants entering the environment. This section provides an assessment of the potential point and nonpoint pollutant sources in the watershed. Point sources discharge effluent through distinct points that are regulated through permits from the NPDES program. Nonpoint sources are not covered by this permitting program. They are diffuse sources that typically cannot be identified as entering a water body through a discrete conveyance at one location. Nonpoint sources can originate from land activities that contribute pollutants to surface water from rainfall runoff. Types of nonpoint source pollution include wildlife, atmospheric deposition, onsite wastewater disposal systems (septic tanks), and agricultural practices.

3.5.1 NPDES-Permitted Point Sources

Under 40 CFR 122.2, a point source is described as a discernible, confined, and discrete conveyance from which pollutants may be discharged to surface waters. The NPDES program, established under CWA Sections 318, 402, and 405, requires permits for the discharge of pollutants from point sources, including urban stormwater systems known as MS4s. The County is an MS4-permitted discharger.

Stormwater discharges are generated by runoff during precipitation events from urban land and impervious areas, such as paved streets, parking lots, and rooftops. These discharges often contain high concentrations of pollutants that can eventually enter nearby water bodies.

Under the NPDES stormwater program, operators of large, medium, and regulated small MS4s must obtain authorization from MDE to discharge pollutants. The Stormwater Phase I Rule requires all medium and large MS4s operators to obtain NPDES permits and develop stormwater management programs (55 Federal Register [FR] 47990, November 16, 1990). Medium and large

MS4s are defined by the size of the population in the MS4 service area, not including the population served by combined sewer systems. A medium MS4 serves a population of between 100,000 and 249,999. A large MS4 serves a population of 250,000 or more. The Stormwater Phase II Rule applies to operators of regulated small MS4s serving a population of less than 100,000 not already covered by Phase I; however, the Phase II Rule is more flexible and allows greater variability of regulated entities than does the Phase I Rule (64 FR 68722, December 8, 1999).

Regulated small MS4s include those lying within the boundaries of urbanized areas, as defined by the U.S. Census Bureau, and those designated by the NPDES permitting authority. The NPDES permitting authority can designate a small MS4 as requiring regulation under any of the following circumstances: the MS4's discharges do or can negatively affect water quality, the population served exceeds 10,000, the population density is at least 1,000 people per square mile, or the contribution of pollutant loadings to a physically interconnected MS4 is evident. The Phase II MS4 in the PR-L and PR-M watersheds serves the mostly rural southeastern portions of the County.

Table 3-3 lists the federal, state, and other entities in the PR-L, PR-M, and PR-U watersheds that possess an MS4 permit. These entities should have their own stormwater or sediment load goals and are not included in Prince George's County restoration calculations. Figure 3-17 shows the locations of other regulatory MS4s in the watershed. Figure 3-17 shows where there are federal and state lands in which the County is not responsible for stormwater. Other MS4 entities cover 9.1 percent of the watershed.

Table 3-3. MS4 permitted federal, state, and other entities in the Patuxent Watershed.

Watershed	Agency	Installation/Facility	Area (acres)
Patuxent River Lower	State of Maryland	Multiple Properties	2,408.0
Patuxent River Lower	U.S. Federal Government; Federal Aviation Administration; General Services Administration	Cluster of federal lands in the vicinity of 13205 Croom Road, Upper Marlboro, MD	4.1
Patuxent River Middle	State of Maryland	Multiple Properties	747.3
Patuxent River Middle	U.S. Federal Government	Small parcel adjacent to Mount Calvert Road ROW 0.4 miles west of Duvall Road, Marlboro, MD	1.5
Patuxent River Upper	U.S. Federal Government	Multiple Properties (including Patuxent Research Refuge)	4,050.0
Patuxent River Upper	State of Maryland	Multiple Properties	503.5
Patuxent River Upper	Washington Suburban Sanitary Commission	Multiple Properties	185.0

Watershed	Agency	Installation/Facility	Area (acres)
Patuxent River Upper	United States Postal Service	Multiple Properties	6.8

Information on other permitted facilities was available from MDE's website and EPA's Integrated Compliance Information System. There are 51 privately owned permitted facilities in the watershed, with many being listed as discharging stormwater. Other facilities are permitted for discharging from construction sites, mining facilities, dewatering activities, refuse sites, and swimming pools. No permitted facilities are in the County's Rocky Gorge portion of the watershed. The County is not responsible for these facilities meeting their WLAs.

Wastewater facilities might include publicly owned treatment works providing wastewater treatment and disinfection for sanitary sewer systems or industrial facilities providing treatment of process waters. In the PR-U watershed, one federal facility (National Wildlife Visitor Center), and two municipal plants operated within Bowie—Parkway Wastewater Treatment Plant, and a sewerage system operated by the Patuxent River 4-H Center—are permitted to discharge treated sanitary wastewater into the watershed. The Washington Suburban Sanitary Commission (WSSC) recently addressed problems that cause sanitary sewer overflows and leaks through their Sewer Repair, Replacement and Rehabilitation Program.

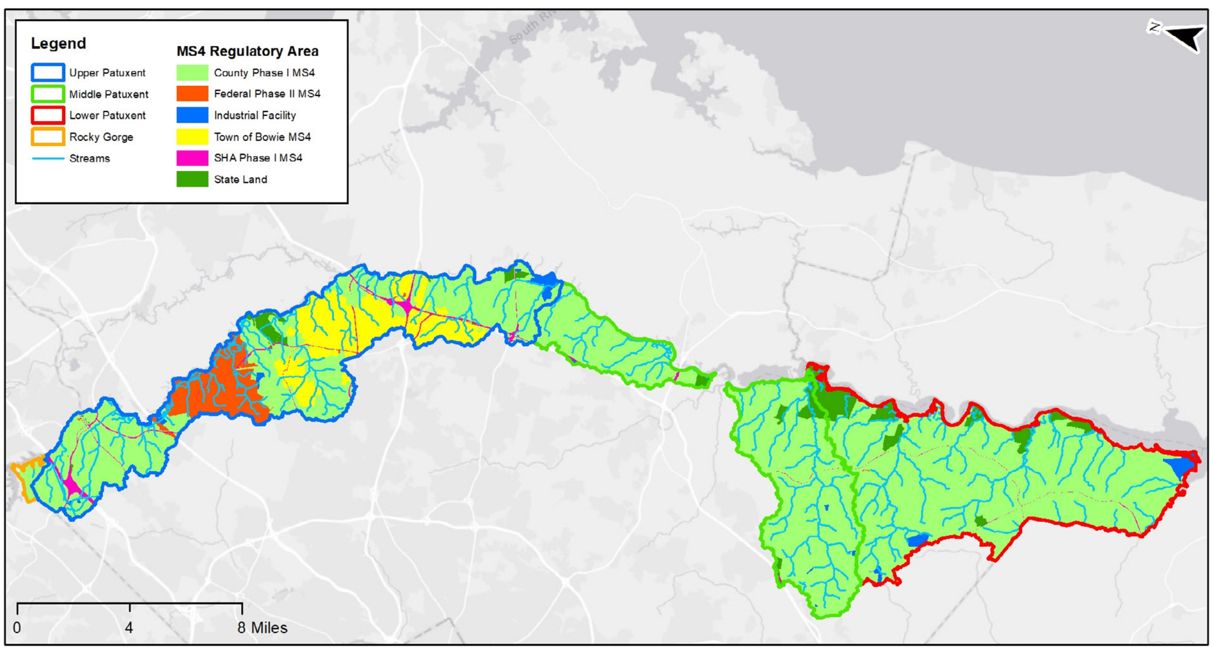


Figure 3-17. MS4-regulated areas in the Patuxent River watershed.

3.5.2 Nonpoint and Other Sources

Potential nonpoint sources vary greatly, including agriculture-related activities, atmospheric deposition, on-site treatment systems, and, wildlife.

Nonpoint sources of pollution from agricultural activities include the runoff of fertilizers and exposed soils from crop fields, and waste from animal operations. The Maryland Department of Agriculture regulates agricultural activities, which are outside of the jurisdiction of DoE. Consequently, the Patuxent River watershed WIP does not include restoration activities for agricultural practices.

Streams and rivers can be vulnerable to wildlife impacts. Wild animals with direct access to streams, such as deer, raccoons, other small mammals, and avian species, can potentially increase erosion. For example, deer populations can clear low vegetation, including regenerative forest growth, which poses potential vulnerabilities to sediment load reduction efforts. Deer and other animals also create paths to the stream's edge, exposing base sediment and potentially causing stream bank erosion at the site of their access to the stream.

4 Current Stormwater Management Activities

When precipitation falls in the County, the resulting runoff flows off roofs, lawns, driveways, and roads into a network of stormwater sewers that discharge directly to area streams. The stormwater flow picks up pollutants such as sediments and transports them into the waterways of the County. High volumes of water flowing to the stream channel during storm events cause erosion of the land and the channel itself. Many areas of the County were developed before stormwater regulations and practices were adopted in the 1970s and early 1980s. Many of these older developments did not have adequate stormwater controls for water quality at the time of their construction; since then, the County has accelerated a restoration program to address stormwater and water quality restoration.

The State adopted a statewide stormwater law and new regulations in 1983, and the County enacted a SWM ordinance in 1985. Since 2000, following new state regulations, developers of new and redevelopment projects in the County are required to provide water quality treatment for this urban runoff using a wide range of stormwater practices. During the initial years of stormwater regulation, those practices were somewhat crude and straightforward, but they have been continuously improved. Today, *environmental site design* (ESD)—the approach to SWM required by MDE—is based on the use of landscape-based practices, such as rain gardens and bioswales, and is considered an ecologically sustainable approach to SWM. The County is currently installing those types of BMPs. This section describes current SWM programs and the BMPs installed in the County.

The County has implemented a wide range of programmatic SWM initiatives over the years to address existing water quality concerns. They are grouped into three categories: stormwater-specific programs, tree planting and landscape revitalization programs, and public education programs. This section describes each grouping (and its respective individual initiatives), including the contributions the programs make to water quality protection and improvement.

4.1 Stormwater Programs

Many of the County's stormwater-related programmatic initiatives target more than one issue area. For example, in addition to promoting the adoption of on-the-ground BMPs, the Alternative Compliance Program promotes stormwater education via environmentally focused sermons at places of worship. Appendix A provides full descriptions of the programs that directly or indirectly support water quality improvement and are administered by various departments within the County government or its partners. These programs include:

- Stormwater-specific programs
  - Stormwater Management Program
  - Clean Water Partnership (CWP)
  - Alternative Compliance Program
  - Rain Check Rebate and Grant Program
  - Stormwater Stewardship Grant Program
  - Countywide Green/Complete Streets Program

- Erosion and sediment control
- Street sweeping
- Storm drain maintenance: inlet, storm drain, and channel cleaning
- Storm drain stenciling
- Illicit Connection and Enforcement Program

- Tree planting and landscape revitalization programs
  - Volunteer Tree Planting
  - Tree ReLeaf Grant Program
  - Neighborhood Design Center
  - Arbor Day Every Day
  - Tree planting demonstrations
- Public education programs
  - Interactive displays and speakers for community meetings
  - Stormwater Audit Program
  - Master Gardeners
  - Flood Awareness Month

4.2 Existing Stormwater BMPs

The County has been installing BMPs since 1985, with the inception of the first SWM ordinance. BMPs were applied to control peak discharges and infiltration where possible. In 2000, the County's new SWM ordinance instituted the requirement for improving water quality from runoff. This later requirement introduced the new ESD concept, by combining BMP strategies to treat runoff at the source.

Since the Chesapeake Bay TMDL was developed in 2010, the County has implemented SWM BMPs to control and reduce the pollutant load. This section describes the type and distribution of BMPs the County has installed in the watershed and evaluates the load reductions from the BMPs.

BMPs are measures used to control and reduce sources of pollution. They can be structural or nonstructural and are used to address both urban and agricultural sources of pollution. Structural practices include the placement of retention ponds, porous pavement, tree planting, stream restoration, and bioretention systems. Nonstructural BMPs include institutional, educational, or pollution prevention activities that, when implemented, work to reduce pollutant loadings. Examples of nonstructural BMPs include implementing strategic disconnection of impervious areas in a municipality, street sweeping, homeowner and landowner education campaigns, and nutrient management. Different BMP types remove pollutants at varying levels of efficiency. Ponds tend to have lower efficiencies but can treat large areas, while bioretention systems and infiltration practices tend to have higher efficiencies but can treat only smaller areas.

The two main reasons for installing BMPs are: (1) new development and (2) watershed restoration. Developer BMPs are installed as new development is constructed to negate the effects of excess runoff and pollution. As part of their construction permit, developers are required to install these BMPs. These do not get credited toward the TMDL load reduction targets. Even with developer BMPs installed, a waterbody might not meet water quality criteria due to development prior to stormwater regulations. In these circumstances, additional water quality treatment is needed. BMPs for watershed restoration are installed to improve the water quality of streams and, if installed after the date of the TMDL, can be credited towards meeting the TMDL.

The Patuxent River watershed has limited BMP coverage. The County actively updates a BMP geodatabase with new information as it becomes available. The BMPs were installed to support restoration activities or as offsets for new development. Table 4-1, Table 4-2, Table 4-3, and Table 4-4 list the number of each type of restoration BMPs per PR-L, PR-M, PR-U, and Rocky Gorge Reservoir watersheds and categorize them as a part of the baseline period (prior to 2015), progress, and planned BMPs. Table 4-5, Table 4-6, Table 4-7, and Table 4-8 show similar information for developer BMPs. For these four tables, the baseline BMPs are considered part of the baseline calculations (prior to 2015), and the other column lists developer BMPs after the baseline period. These developer BMPs do not count towards TMDL restoration progress. Figure 4-1 shows the locations of the developer and restoration BMPs as of August 2022. While ponds make up the majority of BMPs, stream restoration and outfall stabilization treat more watershed area.

Table 4-1. Restoration BMPs in the Patuxent River Lower watershed as of August 2023.

BMP Type	Baseline		Progress		Planned		Total	
	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]
Bioretention	0	0.00	1	0.55	0	0.00	1	0.55
Micro-Bioretention	0	0.00	1	0.23	0	0.00	1	0.23
Planting Trees or Forestation on Previous Urban	1	22.53	0	0.00	0	0.00	1	22.53
Rainwater Harvesting	1	0.01	0	0.00	0	0.00	1	0.01
Shoreline Stabilization	0	0.00	1	704.00	3	5,054.92	4	5,758.92
Stream Restoration	0	0.00	2	29,621.12	1	3,100.00	3	32,721.12
Street Trees	20	0.20	31	0.31	0	0.00	51	0.51
Total	**22**	**22.74**	**36**	**30326.21**	**4**	**8154.92**	**62**	**38503.87**

Source: DoE 2023.
Note:
[a] Stream restoration totals are provided in linear feet.

Table 4-2. Restoration BMPs in the Patuxent River Middle watershed as of August 2023.

BMP Type	Baseline		Progress		Planned		Total	
	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]
Bioretention	0	0.00	1	0.90	0	0	1	0.90
Micro-Bioretention	0	0.00	1	0.33	0	0	1	0.33
Planting Trees or Forestation on Previous Urban	1	11.64	0	0.00	0	0	1	11.64

BMP Type	Baseline		Progress		Planned		Total	
	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]
Rainwater Harvesting	3	0.06	0	0.00	0	0	3	0.06
Street Trees	0	0.00	361	3.61	0	0	361	3.61
Total	**4**	**11.7**	**363**	**4.84**	**0**	**0**	**367**	**16.54**

Source: DoE 2023.
Note:
[a] Stream restoration totals are provided in linear feet.

Table 4-3. Restoration BMPs in the Patuxent River Upper watershed as of August 2023.

BMP Type	Baseline		Progress		Planned		Total	
	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]
Bioretention	3	1.48	4	2.95	0	0.00	7	4.43
Bio-Swale	0	0.00	1	0.32	0	0.00	1	0.32
Grass Swale	0	0.00	1	0.53	0	0.00	1	0.53
Impervious Surface Elimination (to pervious)	0	0.00	5	0.08	0	0.00	5	0.08
Micro-Bioretention	0	0.00	9	2.51	0	0.00	9	2.51
Permeable Pavements	0	0.00	2	0.10	0	0.00	2	0.10
Rain Gardens	2	0.08	3	0.23	0	0.00	5	0.31
Rainwater Harvesting	0	0.00	6	0.11	0	0.00	6	0.11
Retention Pond (Wet Pond)	0	0.00	8	538.21	1	23.72	9	561.94
Sand Filter	0	0.00	1	0.73	0	0.00	1	0.73
Step Pool Storm Conveyance	1	1.32	0	0.00	0	0.00	1	1.32
Stream Restoration	1	254.78	6	12,336.31	3	8,346.00	10	20,937.09
Street Trees	0	0.00	5,231	52.31	0	0.00	5,231	52.31
Submerged Gravel Wetlands	0	0.00	1	1.78	0	0.00	1	1.78
Total	**7**	**257.66**	**5278**	**12936.17**	**4**	**8369.72**	**5289**	**21563.56**

Source: DoE 2023.
Note:
[a] Stream restoration totals are provided in linear feet.

Table 4-4. Restoration BMPs in the Rocky Gorge Reservoir watershed as of August 2023.

BMP Type	Baseline		Progress		Planned		Total	
	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]	#	Acres Treated[a]
Stream Restoration	0	0.00	0	0.00	1	1,282.00	1	1,282.00
Street Trees	0	0.00	86	0.86	0	0.00	86	0.86
Total	**0**	**0**	**86**	**0.86**	**1**	**1282**	**87**	**1282.86**

Source: DoE 2023.
Note:
[a] Stream restoration totals are provided in linear feet.

Table 4-5. Developer BMPs in the Patuxent River Lower watershed as of August 2023.

BMP Type	Developer Baseline		Developer	
	#	Acres Treated	#	Acres Treated
Disconnection of Rooftop Runoff	3	0.18	6	0.00
Dry Swale	0	0.00	1	0.00
Dry Well	10	0.40	16	0.12
Extended Detention Structure, Wet	1	0.74	0	0
Grass Swale	1	0.13	6	0.00
Infiltration Berms	0	0.00	2	0.00
Micro-Bioretention	1	0.45	0	0
Retention Pond (Wet Pond)	1	9.49	0	0
Sheetflow to Conservation Areas	1	0.26	0	0
Total	**18**	**11.65**	**31**	**0.12**

Source: DoE 2023.

Table 4-6. Developer BMPs in the Patuxent River Middle watershed as of August 2023.

BMP Type	Developer Baseline		Developer	
	#	Acres Treated	#	Acres Treated
Bio-Swale	0	0.00	1	0.04
Disconnection of Non-Rooftop Runoff	1	0.79	0	0.00
Dry Well	14	1.26	28	0.57
Grass Swale	0	0.00	1	0.36
Infiltration Berms	0	0.00	4	0.00
Micro-Bioretention	0	0.00	3	0.34
Permeable Pavements	0	0.00	8	0.02
Pocket Pond	0	0.00	2	0.00
Retention Pond (Wet Pond)	2	10.64	0	0.00
Submerged Gravel Wetlands	0	0.00	1	0.00
Wet Swale	0	0.00	9	0.01
Total	**17**	**12.69**	**57**	**1.34**

Source: DoE 2023.

Table 4-7. Developer BMPs in the Patuxent River Upper watershed as of August 2023.

BMP Type	Developer Baseline		Developer	
	#	Acres Treated	#	Acres Treated
Bioretention	30	15.24	6	2.42
Bio-Swale	0	0	12	0.79
Detention Structure (Dry Pond)	3	3.20	1	0.32
Disconnection of Non-Rooftop Runoff	0	0.00	2	0.28

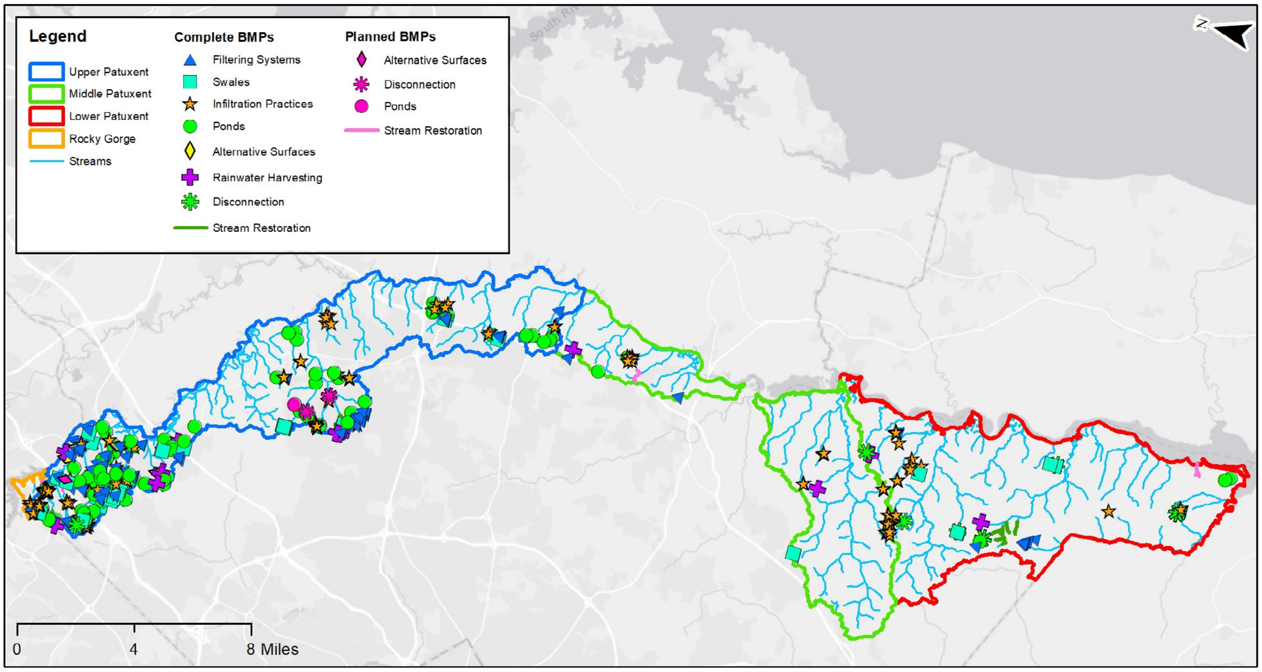
BMP Type	Developer Baseline		Developer	
	#	Acres Treated	#	Acres Treated
Dry Swale	0	0.00	9	0.74
Dry Well	64	2.74	20	0.15
Extended Detention Structure, Dry	4	9.38	1	0.00
Extended Detention Structure, Wet	17	183.41	0	0.00
Flood Management Area	11	25.96	1	2.19
Grass Swale	1	0.48	19	1.38
Green Roof - Extensive	0	0.00	1	0.00
Infiltration Basin	2	2.04	0	0.00
Infiltration Berms	0	0.00	1	0.05
Infiltration Trench	24	23.73	9	3.63
Landscape Infiltration	0	0.00	4	0.00
Micro-Bioretention	1	1.18	45	4.97
Oil Grit Separator	15	22.66	1	0.84
Permeable Pavements	0	0.00	6	0.73
Rain Gardens	0	0.00	1	0.00
Rainwater Harvesting	0	0.00	2	0.00
Retention Pond (Wet Pond)	38	217.34	1	3.26
Sand Filter	1	0.39	3	0.85
Submerged Gravel Wetlands	0	0.00	3	0.12
Underground Filter	5	15.28	0	0.00
Total	**216**	**523.03**	**148**	**22.72**

Source: DoE 2023.

Table 4-8. Developer BMPs in Rocky Gorge Reservoir watershed as of August 2023.

BMP Type	Developer Baseline		Developer	
	#	Acres Treated	#	Acres Treated
Bioretention	0	0.00	16	0.28
Dry Well	2	0.06	3	0.00
Infiltration Berms	0	0.00	2	0.01
Total	**2**	**0.06**	**21**	**0.29**

Source: DoE 2023.



Source: DoE 2023.

Figure 4-1. Developer and restoration BMPs in the Patuxent River watershed.

5 Load Reduction Targets and Current Progress

This section discusses the calculation of load reduction targets for the watershed, reductions that have resulted from current BMPs, and reductions remaining to be met through this WIP. The calculations rely on TMDL, land cover, and existing BMP information. This WIP examines local TP and sediment TMDL reductions for the Patuxent River watershed.

5.1 Load Reduction Terminology

The amount of sediment load still required to be reduced after accounting for load reductions from current practices is called the *load reduction gap*. Figure 5-1 illustrates that concept.

The following load reduction terms are used in text, tables, and plots in the Executive Summary and throughout the remainder of this document:

- **No-action load:** This load is the pollutant load directly from the land surface without the influence of any BMPs.
- **Baseline load:** This load is the pollutant load from the land surface at the time the TMDL was developed. It includes reductions from restoration BMPs installed prior to the TMDL and developer BMPs installed prior to the date of the land use.
- **Target load:** This is the load that is met once load reductions specified in the Chesapeake Bay TMDL are met. This is determined using the baseline load and required percent reduction from the TMDL Data Center (MDE 2019b).
- **Required load reduction:** This is the load that will need to be reduced through restoration BMPs. This load is the difference between the baseline load and the target load.
- **Permit load:** The load at the beginning of the 2014 MS4 permit term (December 2014).
- **Progress load:** The County has already installed BMPs in the watersheds. This is the current load accounting for these BMPs and is the difference between baseline loads and the loads treated by restoration BMPs after the date of the TMDL.
- **Milestone load:** The load is based on all BMPs planned to be installed by the end of fiscal year (FY) 2025 (Milestone 1) and FY 2027 (Milestone 2).
- **Planned load:** The load reduction is based on BMPs identified during the development of this WIP.
- **Load reduction to date:** This is the load reduced by currently installed BMPs or the difference between the baseline and current loads.
- **% of target:** This is the percent of the required load reduction removed by installed BMPs.
- **Progress load reduction gap:** This is the required load reduction remaining (i.e., gap) once the load reduction to date is subtracted from the required load reduction.
- **Load removed from BMPs in planning/design:** This value is the load reduction from the implementation of BMPs for watershed restoration not yet constructed but already being planned and designed.
- **Final load gap:** This is the required load reduction that remains (i.e., gap) once the load reductions from current BMPs and restoration BMPs in design and planning are subtracted. This is the load reduction this plan addresses.

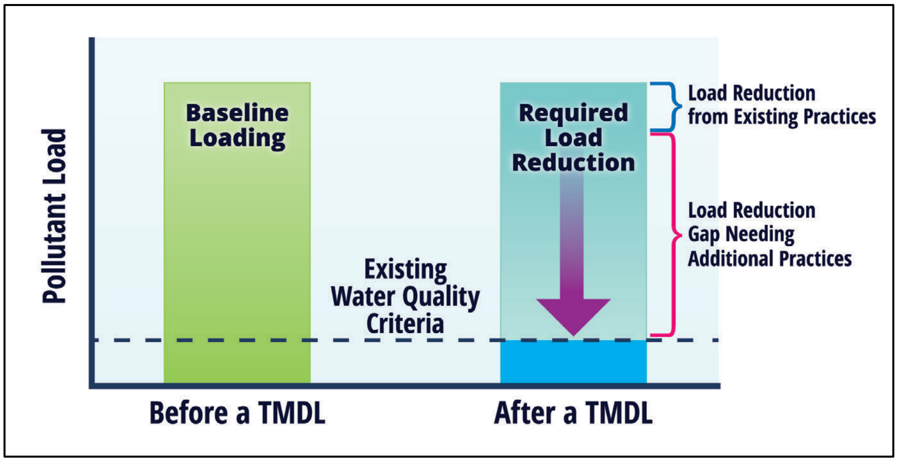


Figure 5-1. Schematic for typical pollution diet (TMDL) showing existing load reduction credits.

5.2 Load Calculation Methodology

Prior to the development of this WIP, the County had consulted and collaborated with MDE on the load calculation approach and methodology. The County used the load calculation methodology from MDE's *TMDL Implementation Progress and Planning (TIPP) Tool* (MDE 2022c). "MDE requires the use of TIPP to ensure consistency among load reduction calculation methods" for "meeting Phase I MS4 permit implementation planning and reporting requirements" for applicable TMDLs (MDE 2022b). The loads calculated in this WIP incorporate recent land use data, land use loading rates, and restoration data for the portions of the Patuxent River watershed in the County's MS4 area. The loadings will not match the loads in the local Patuxent River watershed TMDL because of the different data used in the TMDL.

The County uses a Microsoft Access database in its load calculation process that uses the data and methodology of MDE's April 2022 TIPP Tool (MDE 2022c). Still, the County's process breaks down the loadings into smaller subwatersheds for planning purposes. For example, the County's tool follows the MDE spreadsheet tool in only including impervious area and turf in its baseline load calculations. Like the MDE tool, the County's load calculations did not include loads generated from agriculture, wetlands, forested areas, or mixed open land areas, which are considered outside the County's MS4 area. Similarly, TSS loads from state and federal lands were not used in this WIP. In developing its loads, the County used the land cover-specific loading rates for TSS of the PR-L, PR-M, and PR-U watersheds as well as the TP of the Rocky Gorge Reservoir watershed provided by MDE in its TIPP Tool (MDE 2022c), which is in Microsoft Excel (Table 5-1). The MDE rates were derived from the latest Chesapeake Bay model data, which include loading contributions from stream bed and bank erosion. After developing the Access tool, the County compared the results from the Mattawoman Creek, Piscataway Creek, and Anacostia River watersheds. The largest percent difference for any watershed/analyte pair is 0.12 percent difference. Differences are attributed to slight rounding differences and that the TIPP Tool uses the BMP rating curves for rainfall treated values greater than 2.6, as opposed to using the numeric tables. Based on these results, the County is confident that the Access Tool can replicate the TIPP Tool results.

Table 5-1. TIPP land cover/use loading rates for the Patuxent River watershed.

TIPP Land Cover/Use	MS4 Land	Lower Patuxent TSS (lb/ac/yr)	Middle Patuxent TSS (lb/ac/yr)	Upper Patuxent TSS (lb/ac/yr)	Rocky Gorge TP (lb/ac/yr)
Aggregate impervious	Yes	10,082	10,224	5,579	0.681
Barren	No	3,552	3,552	3,552	1.580
Forest	No	319	308	224	0.040
Impervious Roads	Yes	9,160	9,244	6,785	0.816
Impervious Surfaces	Yes	5,381	5,568	4,091	0.620
Mixed Open/Agriculture	No	1,756	1,821	1,338	0.671
Shrubland	No	319	308	224	0.040
Structures	Yes	5,381	5,568	4,091	0.620
Tree Canopy over Aggregate Impervious	Yes	9,376	9,508	5,188	0.606
Tree Canopy over Impervious Roads	Yes	8,519	8,597	6,310	0.726
Tree Canopy over Impervious Surfaces	Yes	5,005	5,179	3,805	0.551
Tree Canopy over Structures	Yes	5,005	5,179	3,805	0.551
Tree Canopy over Turf	Yes	1,654	1,715	1,261	0.682
Turf	Yes	1,756	1,821	1,338	0.895
Wetlands	No	747	747	747	0.320

Source: MDE 2022c.

Note: lbs/ac/yr = pounds per acre per year.

5.3 BMP Pollutant Load Reduction Calculation

The primary purpose of implementing BMPs is to remove stormwater pollutants (e.g., sediment) near their source and prevent pollutant loads from entering and degrading water bodies. Different types of BMPs remove pollutants with differing degrees of effectiveness or pollutant removal efficiency. Estimating pollutant reductions achieved through implementing BMPs is a two-step process: (1) determine the varying removal efficiencies of the BMPs being considered and (2) calculate the load reduction.

The information available for most BMPs included drainage area (i.e., total land area flowing to a specific BMP [e.g., a bioretention system]). Load reductions for the existing BMPs were calculated using the documented pollutant removal rates (Appendix B) in conjunction with BMP drainage area land cover and the land-cover-specific pollutant loading rate. MDE's *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated* (MDE 2021a) incorporates recent Chesapeake Bay Program recommendations for sediment load reduction removal efficiencies associated with BMP implementation. This information is incorporated into their TIPP Tool (MDE 2022c). By using those removal efficiencies in its reduction calculations, the County is consistent with regional efforts to meet the Chesapeake Bay TMDL. See Appendix B for additional information on BMP effectiveness. That calculation provided the loading attributed to the BMP drainage area, which was then multiplied by the BMP pollutant removal efficiency to determine the amount of load reduction attributed to a specific BMP.

The County implemented restoration BMPs prior to the TMDL. The load reductions from these BMPs are reflected in the baseline loadings. Besides restoration BMPs, developers also install BMPs to offset the increased pollutant loads from new developments. Because those BMPs are installed to offset new loadings and not to remove existing loadings, they are not counted towards watershed restoration. Partial credits can be counted towards restoration from redevelopment BMPs if the BMPs meet specific requirements.

All BMPs (restoration, retrofit, and developer) installed up to and including 2014 (date of land use) were used to calculate the baseline loads along with restoration BMPs installed up to 2019 (date of TMDL). Load reductions from completed restoration BMPs since 2019 are considered as progress load reductions.

Table 5-2, Table 5-3, Table 5-4, and Table 5-5 list load reductions of TSS and TP by BMP type for the baseline period and for those counted towards TMDL progress. They also include load reductions from specific BMPs that are already in the planning, design, or construction phase. These tables include restoration BMPs that were implemented under one of the programs discussed in Appendix A.

Table 5-2. Baseline, progress, and planned TSS load reductions by BMP types of PR-L watershed.

BMP Type	Baseline TSS Reduction (lbs/yr)	Progress TSS Reduction (lbs/yr)	Planned TSS Reduction (lbs/yr)	Total TSS Reduction (lbs/yr)
Bioretention	0	2,861	0	2,861
Micro-Bioretention	0	1,276	0	1,276
Planting Trees or Forestation on Previous Urban	32,373	0	0	32,373
Rainwater Harvesting	39	0	0	39
Shoreline Stabilization	0	4,400	168,538	172,938
Stream Restoration	0	3,673,019	768,800	4,441,819
Street Trees	141	219	0	360
Total	**32,553**	**3,681,775**	**937,338**	**4,651,666**

Source: DoE 2023.
Note: lbs/yr = pounds per year.

Table 5-3. Baseline, progress, and planned TSS load reductions by BMP types of PR-M watershed.

BMP Type	Baseline TSS Reduction (lbs/yr)	Progress TSS Reduction (lbs/yr)	Planned TSS Reduction (lbs/yr)	Total TSS Reduction (lbs/yr)
Bioretention	0	4,868	0	4,868
Micro-Bioretention	0	1,884	0	1,884
Planting Trees or Forestation on Previous Urban	17,613	0	0	17,613
Rainwater Harvesting	254	0	0	254
Street Trees	1,367	2,584	0	3,951
Total	**19,234**	**9,336**	**0**	**28,570**

Source: DoE 2023.
Note: lbs/yr = pounds per year.

Table 5-4. Baseline, progress, and planned TSS load reductions by BMP types of PR-U watershed.

BMP Type	Baseline TSS Reduction (lbs/yr)	Progress TSS Reduction (lbs/yr)	Planned TSS Reduction (lbs/yr)	Total TSS Reduction (lbs/yr)
Bioretention	4,992	10,360	0	15,352
Bio-Swale	0	1,144	0	1,144
Grass Swale	0	1,851	0	1,851
Impervious Surface Elimination (to pervious)	0	228	0	228
Micro-Bioretention	0	10,130	0	10,130
Permeable Pavements	0	546	0	546
Rain Gardens	485	704	0	1,189
Rainwater Harvesting	0	172	0	172
Retention Pond (Wet Pond)	0	2,474,857	134,648	2,609,505
Sand Filter	0	2,447	0	2,447
Step Pool Storm Conveyance	0	0	0	0
Stream Restoration	63,185	1,596,371	973,886	2,633,442
Street Trees	0	20,427	0	20,427
Submerged Gravel Wetlands	0	10,266	0	10,266
Total	**68,662**	**4,129,502**	**1,108,534**	**5,306,698**

Source: DoE 2023.
Note: lbs/yr = pounds per year.

Table 5-5. Baseline, progress, and planned TP load reductions by BMP types of Rocky Gorge Reservoir watershed.

BMP Type	Baseline TP Reduction (lbs/yr)	Progress TP Reduction (lbs/yr)	Planned TP Reduction (lbs/yr)	Total TP Reduction (lbs/yr)
Stream Restoration	0	0	155	155
Street Trees	0	0.06	0	0
Total	**0**	**0.06**	**155**	**155**

Source: DoE 2023.
Note: lbs/yr = pounds per year.

5.4 Baseline, Progress, and Target Load Calculation

Table 5-6 presents County MS4 baseline loads for the Patuxent River Middle watershed. Load reduction targets for PR-L, PR-U, and Rocky Gorge Reservoir watersheds are not presented because they are anticipated to meet reductions based on current and planned BMPs. Those baseline loads do not include loads attributed to the town of Bowie or federal or state land because the County MS4 permit does not cover these areas. The loads in Table 5-6 account for all BMPs installed through 2022. The methodology for calculating the baseline loads followed MDE's TIPP Tool (MDE 2022c). Table 5-6 also presents the percent reduction reported in the TMDL, which was applied to the calculated baseline load to determine the implementation load reduction target. The TMDL percent reduction values were obtained directly from the MDE TMDL Data Center (MDE 2019b). That target, and the amount by which the loads need to be reduced, are also presented. Table 5-6 presents the sediment loads for different scenarios (e.g., progress, milestones).

As shown in Table 5-6, the load reductions from existing restoration activities are insufficient to meet the targeted reductions. The sediment reductions for PR-L and PR-U, along with the total phosphorus reductions for Rocky Gorge Reservoir are expected to be met with BMPs in the planning or design phase. With the BMPs either previously implemented or planned, a reduction gap still exists in the PR-M watershed. Additional practices will need to be planned to close the gap in its pollutant reduction requirements to meet the TMDLs. These are discussed in Section 7.

Table 5-6. Sediment loads targets for the Patuxent River Watershed.

Measure	Units	Patuxent - Lower	Patuxent - Middle	Patuxent - Upper	Rocky Gorge
		TSS	TSS	TSS	TP
No-action load	(lbs/yr)	5,959,794	6,523,563	18,423,147	84
Baseline reductions	(lbs/yr)	69,294	65,249	1,801,880	0
Baseline load	(lbs/yr)	5,890,500	6,458,313	16,621,267	84
Reduction required %	%	61%	56%	11.4%	15%
Target load	(lbs/yr)	2,297,295	2,841,658	14,726,442	71
Required reduction	(lbs/yr)	3,593,205	3,616,655	1,894,824	13
Progress reductions	(lbs/yr)	3,681,774	9,336	4,129,502	0
Progress load	(lbs/yr)	2,208,726	6,448,977	12,491,765	84
Current load reduction gap	(lbs/yr)	0	3,607,320	0	13
Planned reductions	(lbs/yr)	937,338	0	1,108,534	155
Planned load	(lbs/yr)	1,271,388	6,448,977	11,383,231	0
Restoration gap (Remaining load reduction to meet target. See Section 7.2.)	**(lbs/yr)**	**0**	**3,607,320**	**0**	**0**

Notes: lbs/yr = pounds per year; tons/yr = tons per year.
See Section 5.1 for a discussion of the terminology in this table.

6 Load Reduction Strategy

The County has constructed BMPs countywide, including in the Patuxent River watershed. The restoration activities in the Patuxent River watershed will require a sustained level of effort annually to reach the reduction targets outlined in the TMDL. Consequently, the County has developed a strategy with five components to achieve the goals of the plan:

- Use MDE-developed land use loading rates and accepted BMP pollutant load reduction efficiencies to evaluate the ability of existing practices and programmatic initiatives to meet the local TMDL SW-WLAs.
- Quantify future BMPs necessary to meet the SW-WLAs.
- Develop cost estimates associated with implementing the BMPs and initiatives.
- Develop timelines associated with the deployment of BMP practices and initiatives to determine if the timelines required by the TMDL program can be achieved.

- Identify the financial and technical resources required to implement the BMPs and initiatives and develop achievable timelines that can meet TMDL program requirements with the greatest efficiency.

The County's strategy for developing a WIP includes evaluating the capacity of existing BMPs and restoration activities and identifying future activities necessary to meet the SW-WLAs. The methodology emphasizes the use of adaptive management as outlined in Section 8.3 and a simplified project identification and implementation framework to achieve greater cost efficiency while not sacrificing the resiliency of the WIP.

In a simplified framework, once the existing BMPs have been accounted for and the load reduction gap has been calculated, the County will attempt to identify potential future BMPs that could be implemented to close the remaining gap. Generally, the County's implementation of those BMPs would be prioritized by the cost-effectiveness for meeting water quality goals. Seeking out cost-effective opportunities that deliver the greatest pollutant load reduction will ensure that the most beneficial practices that are easiest to accomplish are not overlooked during the implementation process.

The overall load calculation process will follow these general steps:

1) Calculate the *no action* load using the MDE land use and land use loading rates.
2) Determine baseline load, which accounts for existing BMPs.
    a) Calculate the load reductions from developer BMPs implemented prior to the date of the land cover data (2014).
    b) Calculate the load reduction from restoration BMPs implemented prior to the date of the TMDL (2019).
    c) Subtract these amounts from the no action load to obtain the baseline load.
3) Apply the TMDL percent reduction to the baseline load to obtain the target load.
4) Calculate the total reduction required.
5) Calculate the load reductions from restoration BMPs installed since the date of TMDL (2019) to determine the current restoration progress.
6) Determine the remaining load reduction gap.
7) Calculate the load reductions from BMPs that are currently in the planning, design, or construction phase.
8) Determine the remaining load reduction gap.
9) Determine the amount of BMPs needed to fill in the load restoration gap.

6.1 Programmatic Initiatives

The County analyzed current stormwater programs (discussed in Section 4 and Appendix A). The existing programmatic activities are expected to continue and will be supplemented with additional practices, to support the programmatic strategies for this WIP as they are identified and/or developed.

6.2 BMP Identification and Selection

The MDE 2000 *Stormwater Design Manual* provides guidance for designing several types of structural BMPs, including wet ponds, wetlands, filtering practices, infiltration practices, and swales (MDE 2009). MDE also describes nonstructural BMPs that include programmatic, educational, and pollution prevention practices that work to reduce pollutant loadings. Examples of nonstructural BMPs include diverting stormwater from impervious to pervious areas, street sweeping, and public education campaigns (MDE 2009). Additionally, the County will use MDE's *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for National Pollutant Discharge Elimination System Stormwater Permits* in planning future BMPs (MDE 2021a).

The County has implemented and will continue to implement runoff reduction (RR) practices, stormwater treatment (ST) practices, nonstructural stormwater treatment practices, and MDE-approved alternative BMP practices to meet its programmatic goals and responsibilities, including MS4 permit compliance, TMDL WLAs, and flood mitigation. Appendix A has additional information on specific practices.

The County does not own many sites that are suitable for BMP implementation. The County could seek partnerships with other organizations (e.g., nonprofit organizations, businesses) to gain access to private lands and conduct restoration activities on them. For example, a shopping center owner could partner with the County to gain assistance with installing BMPs. (For more information, please see Appendix section *E.2. Public Involvement to Support Implementation Activities*.) This assistance may range from technical assistance to partnering to install a BMP that treats the shopping center parking area and the County right-of-way (ROW). Nonprofit organizations can participate with the County through the raincheck rebate and stewardship grant programs (see Appendix A.1). These programs are in place to help property owners work with the County in restoring their own properties. Examples of projects include tree planting, reforestation, impervious surface removal, and nonstructural BMPs. Without forming partnerships and being granted access to private land, the County will be limited to installing BMPs only on properties to which it has direct access, such as ROWs or County government-owned land. Appendix C has additional information on BMP site selection.

BMP types and locations are not explicitly specified in this WIP, giving the County flexibility to identify specific locations for BMPs and to work with partners on implementing them (e.g., installing BMPs on institutional land). The County also will have the flexibility to select suitable BMPs based on costs, land availability, feasibility, pollutant removal efficiencies, and other factors.

6.3 Implementation Budgeting

This section provides projected estimated budgets for the probable expenditures and staff resources that might be anticipated over the implementation period. Given the iterative and adaptive nature of the WIP and the potential for modified proposed activities, the estimated budget in this plan should be considered preliminary for the year estimated; in later years, it should be revisited as the implementation period moves forward and new data becomes available.

6.3.1 Programmatic Initiatives Estimating

Generally, the costs of programmatic initiatives for nonstructural BMPs (e.g., public education, tree planting, downspout disconnection) are more challenging to determine than costs for structural BMPs (e.g., ponds, stream restoration, RR/ST practices). Some programmatic initiatives are included in current County practices; thus, the County has already accounted for those costs. For instance, the ReLeaf Grant Program is one of the County's active tree planting programs with an existing budget. Costs for programs that result in structural BMP implementation, such as the Clean Water Partnership (CWP), are included in the BMP analysis; the only additional cost to the County is staff time for administering and coordinating the program as part of regular duties. Nonstructural BMPs are funded through DoE's operating budget, whereas structural BMPs are funded through the CIP budget. Appendix D has information on the County's funding sources.

6.3.2 BMP Implementation Estimating

Table 6-1 presents data on BMP unit cost per impervious acre treated, including costs for O&M. These unit costs were developed in *Cost Analysis of Stormwater and Agricultural Practices for Reducing Nitrogen and Phosphorus Runoff in Maryland* (UMCES 2019). The costs in Table 6-1 were converted to January 2020 dollars using the RSMeans historical cost indexes (Gordian 2020). Table 6-1 shows simple annual unit costs and annualized costs with and without land purchase costs. Simple costs were determined using the median implementation cost divided by the BMP lifespan and adding annual O&M costs. The annualized costs assumed a 5 percent annualization rate applied to the median implementation cost. Then, annual O&M costs were added. Simple annual costs without land costs were used in this plan and do not account for inflation over the course of this plan.

Table 6-1. Typical BMP unit costs by stormwater BMP by impervious acre treated.

Stormwater Practices	Type of Practice	Life-span	Median Implement-ation Cost ($/imp acre per year)[a]	Annual O&M ($/imp acre per year)[a]	Simple Annual ($/imp acre per year)[a]		Annualized ($/imp acre per year)[a]	
					No Land Costs	With Land Costs	No Land Costs	With Land Costs
Bioretention	RR	20	$211,110	$24,278	$34,833	$35,018	$41,217	$41,402
Micro-bioretention	RR	20	$311,121	$35,779	$51,334	$51,519	$60,744	$60,867
Rain gardens	RR	20	$147,635	$16,978	$24,360	$24,544	$28,825	$29,010
Bio-swale	RR	20	$59,994	$6,899	$9,899	$10,022	$11,714	$11,837
Grass swale	RR	20	$250,054	$28,756	$41,259	$41,382	$48,821	$48,944
Dry swale	RR	20	$203,772	$23,434	$33,623	$33,746	$39,785	$39,908
Micro-pool extended detention pond	pond	30	$75,894	$8,727	$11,257	$11,340	$13,665	$13,788
Multiple pond system	pond	30	$163,087	$18,755	$24,191	$24,274	$29,364	$29,487
Extended detention structure, wet	pond	30	$28,816	$3,314	$4,274	$4,357	$5,189	$5,312
Retention pond (wet pond)	pond	30	$53,782	$6,185	$7,977	$8,060	$9,683	$9,806
Extended detention - wetland	stormwater	30	$78,413	$9,018	$11,631	$11,714	$14,118	$14,241

Stormwater Practices	Type of Practice	Life-span	Median Implement-ation Cost ($/imp acre per year)[a]	Annual O&M ($/imp acre per year)[a]	Simple Annual ($/imp acre per year)[a]		Annualized ($/imp acre per year)[a]	
					No Land Costs	With Land Costs	No Land Costs	With Land Costs
Wet pond - wetland	stormwater	30	$58,082	$6,679	$8,616	$8,697	$10,458	$10,581
Shallow marsh	stormwater	30	$36,842	$4,237	$5,465	$5,547	$6,633	$6,756
Impervious surface elimination (to pervious)	alternative	20	$911,948	$0	$45,598	$48,672	$73,177	$76,252
Infiltration basin	stormwater	20	$68,653	$9,199	$12,633	$12,940	$14,709	$15,016
Infiltration trench	stormwater	20	$121,571	$16,291	$22,370	$22,677	$26,046	$26,353
Permeable pavements	RR	20	$389,890	$52,246	$71,740	$71,740	$83,531	$83,531
Organic filter (peat filter)	stormwater	20	$219,834	$25,281	$36,272	$36,580	$42,921	$43,229
Submerged gravel wetlands	RR	30	$161,582	$18,582	$23,968	$24,050	$29,093	$29,216
Sand filter	stormwater	20	$18,759	$2,158	$3,096	$3,403	$3,663	$3,970
Underground filter	stormwater	20	$112,979	$12,993	$18,642	$18,950	$22,059	$22,366
Regenerative step pool conveyance	RR	20	$75,236	$6,169	$9,931	$9,931	$12,207	$12,207
Outfall stabilization	alternative	20	$207,941	$17,051	$27,449	$27,449	$33,737	$33,737
Stream restoration	alternative	20	$61,047	$5,005	$8,059	$8,059	$9,905	$9,905
Planting trees or forestation or pervious urban	alternative	20	$35,385	$0	$1,769	$9,860	$2,840	$10,930
Wet pond average	**pond**	**30**	**--**	**--**	**$11,925**	**$12,008**	**$14,475**	**$14,598**
Runoff reduction average	**RR**	**20**	**--**	**--**	**$33,439**	**$33,550**	**$39,549**	**$39,658**

Source: UMCES 2019.
Notes: $/imp acre = dollars per impervious acre, RR = runoff reduction.
[a] Costs inflated to January 2020 dollars.

7 WIP Restoration Activities

The County is in its 5th generation NPDES permit and has been constructing BMPs as part of SWM controls and restoration requirement countywide, including in the Patuxent River watershed. This section describes the County's proposed changes intended to strengthen the implementation process it uses to improve water quality and, thereby, meet the goals and objectives of this WIP. It includes specific planned actions, cost estimates, and a proposed schedule, as well as describes the financial and technical resources available to support and implement the plan. This section also describes how the County will involve the public throughout the plan's implementation, including keeping residents informed and encouraging them to participate directly in the implementation actions. The WIP creates the overall blueprint and timeline for restoration activities in the Patuxent River watershed.

7.1 Programmatic Initiatives

The County's existing programmatic practices (Section 4 and Appendix A) are expected to remain in place. They will be supplemented with additional practices discussed in this section to make up the programmatic strategies for this WIP.

Estimating potential load reductions resulting from programmatic initiatives is challenging because some of the initiatives require public participation and changes in long-standing behaviors. Some of the programmatic initiatives will result in BMPs being installed. The acreage that will be treated through those programs has yet to be estimated. The BMPs that are installed as those programs are implemented will be credited towards the identified load reduction targets and load reduction gap discussed in Section 5.3.

Programmatic activities are generally not measured for load reductions unless they were designed specifically for a surrogate benefit. One of the County's measurable programmatic activities includes inlet cleaning. (See Appendix A for a list of County programs.) Although the cumulative effects of programmatic activities will help reduce loads entering local water bodies in different ways, thus improving their health, their impacts cannot be calculated and are not included as part of this WIP. Those activities do, however, form an important part of this plan. Most of them serve to educate the public on how they can help improve water quality. The improvements in water quality resulting from the activities will be reflected through adaptive management, through which the County will assess cumulative improvements in the water quality and health of water bodies under the WIP.

7.2 Structural BMPs

This section assesses different treatment options, including stream restoration. It also explores outfall stabilization, tree planting, new wet ponds, and RR practices (e.g., grass swales, bioretention systems) that treat stormwater runoff from both pervious and impervious land. The combination of pervious and impervious land is used in calculating the load reduction potential of new wet ponds and RR practices. RR practices are typically smaller and treat smaller areas than wet ponds. (Based on the County's BMP database, RR practices treat an average of 0.5 acres and wet ponds an average of 40 acres). Wet ponds are typically regional facilities that remove sediments and other pollutants by treating runoff from large drainage areas, but they have lower removal efficiencies. Only the impervious area is assessed for costing because the available cost data are provided per impervious acre treated rather than for the total land area treated (Section 6.3.2).

As recommended by MDE's accounting for SW-WLA guidance (MDE 2021a) the County will consider the following practices; however, the County can choose practices based on available resources and priorities. Please refer to Appendix C for additional information on the types of BMPs in this WIP:

- Stream restoration
- Outfall stabilization
- Tree planting (forest planning, tree canopy, riparian buffers)
- Impervious to pervious (turf)
- Wet ponds (treating 3-inch rainfall)
- RR practices (treating 3-inch rainfall)

7.2.1 BMP Determination – Desktop Excel Analysis

The County could use many different combinations of BMPs to meet the load reductions for these TMDLs. However, the cost and lack of available space for implementation would make many of them unfeasible. The results of a cost-effectiveness analysis of various scenarios with different combinations of BMPs will assist the County in selecting a strategy that can work together most effectively to meet the load reduction targets at the lowest cost.

Given the large geographical area in the watershed for potential restoration, including factors such as land use/land cover types, soil classes, and existing developments without SWM controls, Microsoft Excel Solver Add-in was used to determine the most cost-effective scenarios to meet the load reductions for this WIP. Solver processes a set of conditions to meet the County's objective: *the lowest cost*. The main condition was meeting the load reduction target in every scenario. Other conditions set a range of implementation for RR practices, outfall stabilization, stream restoration, tree planting, and new wet ponds. For example, a scenario could limit RR practices to treat runoff to 100 acres of land, while another scenario allows for treatment of up to 250 acres. The amount of stream restoration and outfall stabilization was determined using information on known stream erosion issues from the MD DNR SCA (Section 3.4). Solver then determined the best value in that range for that scenario. In Solver, forest planting accounts for 10 percent of the total tree acres planted, with street trees 40 percent, urban tree canopy 45 percent, and riparian buffers at 5 percent. The total acres for forest planting and riparian buffers need to be greater than 0.5 acres each per their BMP definition.

The overall costs for ten scenarios for the Patuxent River Middle TMDL load reductions ranged from $46.8 million to $124.5 million, with a median of $119.3 million. The scenario closest to the median cost (shown in Table 7-1) was selected for the WIP to provide the County with several options. The scenario that has been selected for presentation with this plan serves as a starting point for the County to make future decisions. The actual combination of BMPs implemented to meet the TMDL can change over time as adaptive management principles are applied to this plan. Table 7-2 presents a comparison of the ten most cost-effective scenarios. The tree planting was used as BMPs practice in all low-cost scenarios. The low-cost scenarios maximized the amount of stream restoration, tree planting, and wet ponds.

Table 7-1. Results of cost optimization to meet TMDL.

Variable (unit)	Value	Constraints
Stream restoration (linear feet)	2,417	0–50% of MD DNR SCA known erosion issues (section 3.4)
Outfall stabilization (outfalls)	0	0–100% of MD DNR SCA outfalls
Tree planting (acres planted)	25.0	0–25 acres
Impervious to turf (acres)	0	0–3 acre
New wet ponds (acres treated)	658	0–1000 acres
RR practices (acres treated)	99.1	0-100 acres
Cost (January 2020 $M)	$118.6	Lowest cost for the constraints listed above.

Note: $M = in millions of dollars.

Table 7-2. Comparisons of top 10 cost optimization scenarios for the PR-M watershed.

Practice (unit)	Top Five Low-Cost Scenarios				
	1 (Lowest)	2	3	4	5
Stream restoration (linear feet)	14,379	14,416	12,142	12,101	2,417
Outfall stabilization (outfalls)	0	0	0	0	0
Tree planting (acres planted)	12.8	10.0	15.0	10.0	25.0
Impervious to Turf (acres)	0.0	0.0	0.0	0.0	0.0
New wet ponds (acres treated)	0	0	69	71	658
RR practices (acres treated)	0	0	66.6	70.7	99.1
Total cost ($M)	$46.8	$46.8	$66.2	$67.3	$118.6
Practice (unit)	**Cost Scenarios 6–10**				
	6	**7**	**8**	**9**	**10**
Stream restoration (linear feet)	0	1,442	0	0	3,698
Outfall stabilization (outfalls)	0	0	0	0	0
Tree planting (acres planted)	10.0	24.9	15.0	10.0	25.0
Impervious to Turf (acres)	0.0	0.0	0.0	0.0	0.0
New wet ponds (acres treated)	942	750	922	923	462
RR practices (acres treated)	0.0	74.1	12.4	15.0	199.1
Total cost ($M)	$119.9	$120.5	$120.9	$121.5	$124.5

Note: $M = in millions of dollars.

7.2.2 Load Reductions

Table 7-3 and Table 7-4 restates the load calculations from earlier in the document (Table 5-6) along with new reductions for the different restoration activities relevant to this plan (BMPs and programmatic initiatives). The most significant reductions will be obtained through wet ponds and stream restoration.

Table 7-3. WIP TSS load reductions for the PR-M watershed.

Measure or Practice	TSS (lbs/yr)	% of Baseline Load
Information from Table 5-6		
Baseline Load	6,458,313	100%
Target Load	2,841,658	44%
Required Reduction	3,616,655	56%
Current Restoration BMP Reductions (through June 30, 2023)	9,336	0%
Progress Load	6,448,977	100%
Current Load Reduction Gap	3,607,320	56%
Planned BMP Reductions	0	0%
Planned Load	6,448,977	100%
Remaining Restoration Gap to meet TMDL	3,607,320	56%
BMPs identified in this WIP to Meet Restoration Gap		
Stream Restoration / Outfall Stabilization	599,311	9%
Tree Planting	80,595	1%
Wet Ponds	2,502,491	39%
RR Practices	424,942	7%
Impervious to Turf	0	0%
Total WIP	3,607,339	56%
Total Restoration Activities		
Current BMPs, Planned BMPs, and WIP BMPs	3,616,674	56%

Notes:
lbs/yr = pounds per year.
See Section 5.1 for a discussion of the terminology in this table.

Table 7-4. Summary of WIP TSS load reductions for the PR-M watershed, as presented in the TIPP Tool.

Load Category	TSS	Units
***Baseline** – Estimated load at time of TMDL*		
Impairment Baseline Load	6,458,313	lbs/yr
Target Reduction %	56.0%	%
Target Load	2,841,658	lbs/yr
Total Reduction Required	3,616,655	lbs/yr
Permit – *Estimated load at beginning of 2014 permit (includes BMP reductions since TMDL development)*		
Total Permit Load	6,451,489	lbs/yr
% of Total Reduction Required	0.2%	%
Progress – *Estimated load as of July 2023 (includes BMP reductions since TMDL development)*		
Total Progress Load	6,448,977	lbs/yr

Load Category	TSS	Units
% of Total Reduction Required	0.3%	%
Implementation (Milestone 1) – *Estimated load with Planned BMPs through 2025 (includes BMP reductions since TMDL development)*		
Total Load after Implementation	6,448,977	lbs/yr
% of Total Reduction Required	0.3%	%
Implementation (Milestone 1 + Milestone 2) – *Estimated load with Planned BMPs through 2027 (includes BMP reductions since TMDL development)*		
Total Load after Implementation	6,448,977	lbs/yr
% of Total Reduction Required	0.3%	%
Implementation (Milestone 1 + Milestone 2 + Planned) – *Estimated load with Planned BMPs through 2027 and BMPs identified in this WIP (includes BMP reductions since TMDL development)*		
Total Load after Implementation	2,841,639	lbs/yr
% of Total Reduction Required	100.0%	%

7.3 Restoration Budget

The planning level costs per restoration activity are shown in Table 7-5, along with the estimated load reductions and cost per pound of sediment reduced for scenario #5. The overall cost for this plan is $118.6 million. These costs include the O&M of each new BMP over the lifespan of the BMP. The total cost does not include the O&M costs for existing BMPs, replacements of BMPs that have exceeded their lifespan, or aging stormwater infrastructure. Appendix D has information on the County's funding sources.

The BMP unit costs from Table 6-1 were used to determine the restoration plan budget. Because this plan does not specify exact RR types, the average of the RR practices was used to determine the budget for the RR practices in Table 7-5. The most cost-effective strategy is planting trees, while ESD practices are the least cost-effective. Stream restoration and outfall stabilization are also relatively cost-effective, followed by creating new wet ponds.

The median cost scenario serves as a starting point for the County to make future decisions. The actual combination of BMPs implemented to meet the TMDL can change over time as adaptive management principles are applied to this plan.

Table 7-5. Total BMP proposed implementation costs and cost efficiency by restoration strategy for the PR-M watershed.

Practice	Budget	TSS			
		TSS (lbs/yr)	$/lb/yr	Impervious Credit	$/Imp Acre
Stream restoration / outfall stabilization	$7,789,854	599,311	$0.65	48.33	$161,175
Tree planting	$884,363	80,595	$0.55	11.78	$75,105
Impervious to Turf	$0	0.00	$0	0.00	$0

Practice	Budget	TSS		Impervious Credit	$/Imp Acre
		TSS (lbs/yr)	$/lb/yr		
Wet pond	$83,525,948	2,502,491	$1.11	233.48	$357,748
ESD practices	$26,444,536	424,942	$2.95	37.46	$705,925
Total Restoration Plan	**$118,644,700**	**3,607,339**	**$1.22**	**331.04**	**$358,395**

Notes:
lbs/yr = pounds per year; $/lb = dollars per pound; $/imp acre = dollars per impervious acre.
Costs inflated to January 2020 dollars.

7.4 Implementation Schedule

This section provides the planning-level implementation schedule for the BMP and programmatic strategy necessary to meet TMDL compliance milestones. There is no mandated end date for the local TMDL WIPs; however, the County understands the public prefers an expedited restoration process and shares that sense of urgency. The County and its watershed partners are committed to finding site opportunities and expediting the planning, design, and construction phases for management activity to the maximum extent practicable. The County identifies specific BMP opportunities over a 6-year planning horizon, which becomes part of the approved annual county budget. These opportunities are included in the County's biannual Financial Assurance Plan (FAP) and summarized in the County's annual MS4 progress report. Planning, design, and construction activities follow a rigorous internal evaluation, including budget, CIP progress tracking, and necessary adjustments to implementation schedules due to unforeseen conditions. The result of this process is adjusted annually. Any BMPs installed by the County to address local TMDLs will help meet Chesapeake Bay load reduction goals.

Implementing the restoration activities in the proposed schedule will depend largely on future available funding and program capacity. The County has additional local nutrient and sediment TMDL WIPs in the Anacostia River, Mattawoman Creek, and Piscataway Creek watersheds and will need to allocate available funding and resources across those priority watersheds. These are competing funding priorities in addition to reducing bacteria and PCBs for several local TMDLs through monitoring, source trackdown, and elimination.

DoE estimates that it can retrofit an average of 2 percent of its untreated impervious area per year (as per anticipated new NPDES permit conditions) over the course of WIP implementation. This estimate is backed up by MDE in its Phase III Chesapeake Bay WIP (MDE 2019a). Using that implementation average as a guide, we can determine the time needed to implement this WIP fully. There are 460 acres of untreated impervious area (for both existing and currently planned restoration BMPs) in the PR-M watershed. Meeting the TMDL will require treating 331 impervious acres based on the restoration scenario (Table 7-1).

The sediment reductions for PR-L and PR-U, along with the total phosphorus reductions for Rocky Gorge Reservoir, are expected to be met with BMPs in the planning or design phase. This WIP is anticipated to be fully implemented by fiscal year (FY) 2060 for the Patuxent River Middle, including treating the identified impervious acres with BMPs and all programmatic activities. This end date considers the 2 percent implementation estimate, other competing priority WIPs, source identification, available BMP technologies, and ease of implementation, in addition to the County's need to pay more towards its restoration debt service during the implementation phase of this WIP. This is the date that implementation will be expected to be completed; however, complete improvements in stream health (e.g., benthic macroinvertebrates) are expected to lag until the aquatic organisms repopulate the streams. In addition, the County already has several BMPs in the planning or design phase for the watershed, including stream restoration, outfall stabilization, street trees, reforestation, forest conservation, and a wet pond conversion.

The projected end date was developed using estimates of the number of acres of impervious area that could be treated each year. During that period, the County will be implementing several other watershed WIPs, creating competing priorities that could limit the pace at which restoration is accomplished in the Patuxent River watershed. Faster implementation would require additional funding, staffing, and industry resources (e.g., bioretention soils, plants) sooner. The County is working with its watershed protection restoration program to increase the County's TMDL reduction rates. The County continues to research and evaluate innovative practices to help increase BMP efficiencies while lowering costs. Additional staff at the local level and close coordination with the state would be needed to review and approve BMP plans and permits in a timely manner to avoid slowed implementation. Between now and FY 2060, implementation uncertainties could emerge that will require adjustments to the plan.

Table 7-6 presents the estimated average annual number of impervious acres treated and the estimated load reductions by year from BMP implementation based on a steady implementation rate. There will be fluctuations in the annual load reductions due to the types of BMPs used and the land uses they treat but the County will aim to meet or exceed the annual goals. In addition, the County reserves the right to focus on specific areas of the County for restoration and not implement in certain watersheds in a given year. Table 7-6 also presents the overall target milestone timeline for this restoration effort. The County will continuously monitor this schedule to assess ways to increase the rate of implementation and to ensure practices are implemented as planned. Progress on this WIP will be monitored annually in the County's MS4 annual report based on its 5-year permit milestones.

Restoration activities on the scale of this plan are difficult to estimate to the exact acres treated per year. WIPs are planning guides for the estimated level of effort that could be needed to meet reduction goals. The number of impervious acres to be treated every year will vary depending on funding, program capacity, and availability of sites. It is always the County's goal to exceed those estimates to speed up the restoration process. The County realizes that some efforts might be more successful than others and reserves the right to prioritize specific watersheds with higher load reduction requirements. For that reason, this WIP offers an adaptive management component to ensure issues are identified and addressed early (Section 8.3). The County expects to reevaluate this plan every five years based on program capacity, funding, priority watersheds, staffing, and industry resources.

Table 7-6.Proposed WIP cumulative number of impervious area (acres) and load reductions based on steady implementation rate.

Fiscal Year	Impervious Acres Treated	Estimated Budget	TSS (lb/year)
2025	9.21	$3,300,292	123

Fiscal Year	Impervious Acres Treated	Estimated Budget	TSS (lb/year)
2026	18.42	$6,600,583	245
2027	27.63	$9,900,875	368
2028	36.83	$13,201,167	491
2029	46.04	$16,501,458	614
2030	55.25	$19,801,750	736
2031	64.46	$23,102,042	859
2032	73.67	$26,402,334	982
2033	82.88	$29,702,625	1,105
2034	92.09	$33,002,917	1,227
2035	101.29	$36,303,209	1,350
2036	110.50	$39,603,500	1,473
2037	119.71	$42,903,792	1,595
2038	128.92	$46,204,084	1,718
2039	138.13	$49,504,375	1,841
2040	147.34	$52,804,667	1,964
2041	156.55	$56,104,959	2,086
2042	165.75	$59,405,251	2,209
2043	174.96	$62,705,542	2,332
2044	184.17	$66,005,834	2,455
2045	193.38	$69,306,126	2,577
2046	202.59	$72,606,417	2,700
2047	211.80	$75,906,709	2,823
2048	221.00	$79,207,001	2,945
2049	230.21	$82,507,292	3,068
2050	239.42	$85,807,584	3,191
2051	248.63	$89,107,876	3,314
2052	257.84	$92,408,167	3,436
2053	267.05	$95,708,459	3,559
2054	276.26	$99,008,751	3,682
2055	285.46	$102,309,043	3,805
2056	294.67	$105,609,334	3,927
2057	303.88	$108,909,626	4,050
2058	313.09	$112,209,918	4,173
2059	322.30	$115,510,209	4,295
2060	331.04	$118,644,700	4,412

8 TRACKING PROGRESS, MONITORING STREAM HEALTH, AND CONDUCTING ADAPTIVE MANAGEMENT

The County is required by its MS4 permit to:

> …[e]valuate and track the implementation of WIPs through monitoring or modeling to document the progress toward meeting established benchmarks, deadlines, and stormwater WLAs.

The County will fulfill this requirement by producing its annual MS4 report, annual countywide implementation plan, and environmental monitoring. The County intends to track its implementation of this WIP and evaluate how well its efforts improve the conditions in the County's surface waters and adjust its restoration activities accordingly. The County will use the data from tracking and monitoring efforts to inform its adaptive management of this WIP.

At the end of each 5-year NPDES permit term, the County will assess the effectiveness of the strategies and their impact on the TMDL goals and recommend adjustments to the plan for MDE review. This could include changing implementation strategies that may not yield results and redirecting funding to strategies that are demonstrated to be more effective.

The overall adaptive management approach for this WIP is provided in Figure 8-1. The approach follows a cyclic process of planning, implementing, monitoring, evaluating, and adjusting. Each of these has its own list of tasks. For example, implementation includes BMP installation, public education and outreach, and BMP O&M.

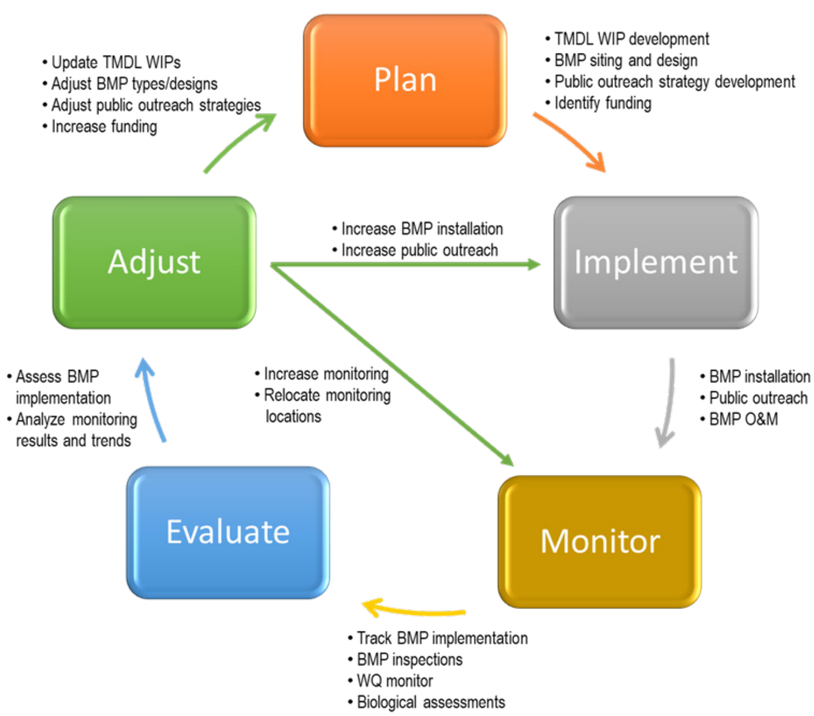


Figure 8-1. Generalized adaptive management approach.

8.1 Progress Tracking

The County's MS4 permit sets implementation goals for the permit term in terms of impervious acres treated over the 5-year permit term. To assess compliance with its permit, the County has a process to track and report impervious acres treated and pollutant load reductions. The County also reports the calculated load reductions using MDE's TIPP tool methodology, as per MDE's *Guidance for Developing Local Nutrient and Sediment TMDL (Total Maximum Daily Load) Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plans (WIPs)* (MDE2022b), while also conducting watershed assessment monitoring. The County's annual MS4 report is the main mechanism for tracking permit activities and reporting them to MDE. While DoE is responsible for its submittal, it is a collaborative effort between the DPW&T and DPIE. The completed annual report and appendices are posted on DoE's stormwater management website.[7]

As specified in the County's permit, the annual report includes information about the County's BMP implementation, illicit discharge detection and elimination (IDDE), trash and litter control measures, public outreach and education initiatives, watershed assessments, and funding. It is the chief vehicle for tracking and reporting BMP implementation and programmatic initiatives.The annual report provides the following information:

- Estimated pollutant load reductions resulting from all completed structural and nonstructural water quality improvement projects and enhanced stormwater management programs. Load reductions will be calculated according to TIPP Tool methodology and data.
- Comparison of achieved load reductions to required load reductions by year to determine the degree to which the County is meeting its restoration goals (annual and total) or needs to adjust its programs to be more effective.

The annual report is accompanied by supplemental data about BMPs (including alternative practices such as stream restoration, septic system upgrades, and tree planting), funding, and water quality. Stormwater BMP data are provided in a georeferenced database. The database provides descriptive details for each BMP, including BMP type, project location, drainage area delineation, equivalent acres of impervious surface treated, maintenance records, year installed, and estimated load reductions. County staff update the database continuously with new and planned projects, which provides an indication if restoration is progressing as planned and allows for adjustments in future BMP implementation.

8.2 Monitoring Stream Health

The purpose of monitoring the conditions in the watershed is to determine the degree to which implementation of the WIP is resulting in the intended improvements. Past monitoring data (water quality, biological, geomorphic) can be compared to future monitoring data to show changes that can affect future restoration activities. This information is useful for project and BMP type selection, as it can provide insight into activities related to land use changes.

DoE recognizes that effective environmental monitoring requires a long-term commitment to routine and consistent sampling, measurement, analysis, and reporting. Although some of the

[7] https://www.princegeorgescountymd.gov/293/NPDES-MS4-Permit. Accessed June 2022.

monitoring requirements for assessing progress toward meeting TMDLs originate with MDE, others reflect the County's interest in providing additional meaningful information to policymakers and the public.

The County will continue evaluating options for its monitoring activities in consultation with MDE. Regardless of which monitoring activities are undertaken by the County, it will remain MDE's responsibility to perform the official monitoring for the state's Integrated Report assessments and impairment. MDE gathers monitoring data for every watershed in the state on a 5-year cycle.

8.2.1 Biological Monitoring

Biological indicators will continue to be used to document and report ecological conditions throughout the County. Other types of monitoring will contribute to understanding whether restoration activities are leading to the elimination, reduction, or otherwise more effective management of pollutants within the County. To ensure that the compiled data sets are accurate, monitoring is performed in accordance with a quality plan with standard operating procedures for sample collection. The County uses biological conditions as indicators of restoration activities. The data will be used to show overall changes in the watershed.

The biological condition of the County's streams is rated using MD DNR's BIBI, which is calculated based on the number of different kinds of organisms (benthic macroinvertebrates) found in samples taken along a stream section or reach. Because the types of organisms found reflect the cumulative influence of a variety of environmental factors, a low BIBI value alone is unlikely to point definitively to a pollutant or other stressor that should be reduced to improve the condition of the stream. Rather, the usefulness of the BIBI in the context of a stream restoration effort is that a sufficiently long record of BIBI values can be expected to reveal the overall effect of a broad restoration program aimed at eliminating, reducing, or otherwise managing known and potentially unknown stressors and their sources.

The County has been implementing biological monitoring since 1999. Sampling at each stream location encompassed benthic macroinvertebrate populations, physical habitat quality, and in situ water quality (pH, conductivity, temperature, and DO). Site locations were selected for each round using a stratified random process, where all wadeable, nontidal streams were stratified by subwatershed and stream order. Stream order designations (generally, first- through fourth-order) were based on the Strahler system of 1:100,000 map scale (Strahler 1957). Distribution of sample locations was more heavily weighted to smaller first- and second-order streams. The County started sampling round 5 in 2023 and it will run until 2025. For each subwatershed, the County will obtain a value for percent biological degradation from round 3, noting the intensity of impairment and any known or most probable sources of pollution or other stressors. It will then compare the percent degradation with the values found in round 5 to determine the direction and magnitude of changes.

The County will focus its efforts on areas of rapid BMP implementation through the CWP. Additional and more detailed analyses of conditions and data in individual subwatersheds can help associate stream biological health with the implementation of BMPs (and programmatic initiatives) so the County can adjust its restoration strategy, if needed.

The approach presented here assumes the continuation of routine, countywide monitoring of biological conditions for wadeable streams in round 5 and beyond, with potentially additional effort being applied to data analyses related to physical habitat characteristics, altered hydrology, and water chemistry. This not only provides insight into those stressors most likely causing biological degradation, but it also aids in identifying sources of stressors where additional restoration efforts would be beneficial.

8.2.2 Geomorphic Monitoring

The County is planning for future characterization and monitoring of fluvial geomorphic activity. This will focus on additional locations, as well as enhancing the calculation accuracy of (A) sediment yield and (B) nutrients (i.e., nitrogen, phosphorus). These enhancements will contribute to the DoE stream restoration crediting. The number and frequency of geomorphic surveys will increase, depending on budget constraints, to have a greater and more even coverage of the County and a frequency that will allow the County to be more immediately responsive to incremental changes in erosion rates as well as catastrophic bank failures. Initial thoughts on increased frequency are that monumented XS might be revisited every 3–5 years and could be done in a rotating basin design. The biomonitoring sites are selected using a stratified random approach but for channel erosion measures, it is likely more meaningful to have time-series data from fixed locations.

8.2.3 Water Quality Monitoring

Water quality monitoring is conducted to assess a set of upstream restoration practices. The 2022 MDE guidance for developing local TMDL nutrient and sediment WIPs includes suggested monitoring. Currently, the County does not have the resources to conduct watershed restoration and water quality monitoring at multiple locations. The County will consider targeted monitoring for TMDL compliance at the previous monitoring location as the County nears its load reduction goals. The County is enrolled in the pooled monitoring for BMP effectiveness as part of its NPDES MS4 permit requirements. Future monitoring will not be conducted at individual BMP sites to assess their effectiveness in reducing pollutant loads. Pollutant removal efficiencies have already been established for the proposed BMP types, so only new and innovative BMPs will need to be individually monitored to assess their load-reduction capabilities.

8.3 Adaptive Management Approach

This WIP was developed using the best information available at the time the plan was developed. As implementation progresses, adaptive management allows for adjustments to restoration activities as new information becomes available from the state or different stakeholders, and opportunities to increase effectiveness and reduce costs emerge. The County will use new information as it becomes available to assess the effectiveness of its restoration program and adjust as needed.

To address the nutrient and sediment load reduction targets, MDE issued Prince George's County a permit that focused on treating untreated impervious surfaces. The County NPDES permit requires restoration to be reported as equivalent impervious acres as the main measurement of progress. The County will evaluate and analyze TMDL plans for necessary updates on a 5-year cycle, coinciding with the NPDES permit cycle. Depending on the impairment type, WIP adjustments could increase or decrease the timeline for milestones based on County regulatory priorities and community needs. WIP revisions will include new documented data, updated science, and modeling tools.

It will be important for the County, MDE, and watershed partners to work together to ensure successful ongoing implementation. Close coordination is especially valuable for adaptive management because of the possibility of unanticipated circumstances arising during WIP implementation. For example, the installed BMPs might remove significantly more or less than the amount of pollution expected. A natural disaster could affect the plan's implementation. If BMPs are being implemented at a slower rate than is called for in the WIP, the adaptive management process will need to include a look at the causes of the lag in implementation and either address those causes or otherwise propose additional activities to compensate for the lag. Additional factors include the following:

- County factors: Budgets, restoration opportunities, and community buy-in on certain types of projects addressing environmental justice concerns.
- MDE factors: Approval of new technologies, models, tools, and science, which are continuously being developed and evolving.

Implementation lags can be caused by a lack of available land, delays in obtaining the necessary permits for constructing BMPs, being denied permission to build a BMP on private land, and lapses in funding. The County has a process to prevent many issues through initial project discussions and planning. Some implementation issues are not preventable (e.g., weather). In these cases, the County will work to develop contingency plans to keep watershed restoration on or ahead of schedule through adaptive management.

In addition, new BMP technologies are being researched that will help lower costs, decrease BMP footprints, and increase removal efficiencies. MDE and the Chesapeake Bay Program will need to approve the technologies and assign them removal efficiencies in a timely manner. In addition to having new BMP technologies approved, the County looks to MDE to continue issuing grant funding for stormwater restoration activities and to help perform water quality monitoring in high-priority County watersheds.

The County will evaluate the progress of this WIP implementation during its next permit cycle following this adaptive management approach. The evaluation will use an updated BMP inventory, new BMP technologies, experience with the new programmatic initiatives, and more recent water quality data. The evaluation could provide the County with the opportunity to remove practices from consideration that are expensive and show no water quality improvement. For this WIP, adaptive management will involve ongoing biological monitoring, evaluating applied strategies, assessing progress, and incorporating any useful new knowledge into further restoration activities.

Several aspects of this WIP support the use of adaptive management:

- Large portions of the County's inner Beltway development predate stormwater management regulation first established in the regulations in 1985 where greater than 85 percent of development already occurred. This makes watershed restoration challenging and costly, where the watershed needs to address upland BMPs to be installed, while also addressing stream erosion through armoring banks, thereby protecting impacted properties from further erosion. Adaptive management will be important to help these challenges so that this plan can undergo adjustments in the future.

- The County has a stormwater management ordinance that requires developers to install BMPs to offset the increased impervious area due to new construction.
- The County will use adaptive management to determine the most appropriate restoration practices at the best locations. This means that the County will look across land uses to determine where restoration projects will be most cost-effective in achieving pollutant load reductions. The County reserves the right to use alternative restoration activities if the opportunity arises and the alternative practices will produce greater load reductions or a similar load reduction at a lower cost.
- Part of the adaptive management strategy is to help reduce long-term costs while increasing load reduction. The County recognizes that future BMP-related research could result in new, more efficient pollution reduction technologies becoming available. These advances could decrease cost, decrease the footprints of the BMPs, or increase load reduction efficiencies. Some of the advances could come from proprietary technologies, which the County will evaluate based on their cost and performance.
- Using biological monitoring results, DoE can adjust implementation priorities and target areas of poor stream health. The biological assessment results will be interpreted at multiple spatial scales as Degraded/Not Degraded (for specific stream sites) and percent degradation (for sets of sites within subwatersheds and the watershed as a whole). The County will use these results as the principal indicator of stressor-reduction effectiveness. A lack of positive response will be taken as evidence that additional or more intensive stormwater management is necessary to achieve ecologically meaningful pollutant reductions.

In the future, climate change will play a role in watershed restoration and BMP implementation. The County is becoming more aware of the potential effects of climate change and its impact on BMPs. The EPA conducted a modeling study investigating the resilience of BMPs with the potential for more extreme precipitation events due to climate change (USEPA 2018). The study's results (*Improving the Resilience of Best Management Practices in a Changing Environment: Urban Stormwater Modeling Studies*) found that BMPs designed for current conditions will most likely fail to treat and reduce runoff from the larger and more intense storm events projected in future conditions. This failure could cause stormwater to overflow BMPs; thus, the BMPs would not treat all the runoff and would not reduce runoff volume reaching the County's water bodies. This could result in downstream channel erosion and flooding impacts. BMPs built with current design standards will require a larger temporary storage volume or reconfigured outlet structures to reduce the likelihood of flooding and channel erosion.

MDE is working to address flooding issues. In June 2021, the Stormwater Management Law was signed. This requires the MDE to perform several actions to help address flooding issues in the state. MDE is to collect and report the most recent precipitation data, investigate flooding events since 2000, and update the state's stormwater quantity management standards for flood control. MDE has started working with municipalities and will adopt new regulations in 2023. MDE is also creating a stormwater management climate change action plan with their *Advancing Stormwater Resiliency in Maryland (A-StoRM)* program. Climate change challenges will be handled through adaptive management and future assessments of WIP implementation.

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Appendix A: Current Stormwater Management Programs

A.1 Stormwater Specific Programs

As required under NPDES regulations, the County must operate an overall stormwater program that addresses six minimum control measures—public education and outreach, public participation/involvement, IDDE, construction site runoff control, post-construction runoff control, and pollution prevention/good housekeeping. To meet that requirement, the County administers various programs and initiatives, many of which have goals to help achieve pollution reductions in response to TMDL requirements. Stormwater-specific program initiatives are designed to reduce flow volumes and pollutant loads reaching surface waters by facilitating the implementation of practices to retain and infiltrate runoff. Stormwater-specific programs include the following:

- ***Stormwater Management Program (Capital Improvement Program [CIP] SWM Program).*** The SWM Program is responsible for performing detailed assessments of impairments to address stormwater management and existing water quality. It also is responsible for preparing design plans for and overseeing the construction of regional stormwater management facilities and water quality control projects. Those activities contribute to annual load reductions through improved planning and assessment and implementation of BMPs that reduce pollutant loading.
- ***Clean Water Partnership* (*CWP*).** The County recently initiated this program, which is a community-based public-private partnership, to assist in addressing the restoration requirements of the Chesapeake Bay WIP program. The CWP program initially focused on ROW runoff management in older communities, which are primarily inside the Capital Beltway. The program is expected to be responsible for providing water quality treatment for impervious land.
- ***Alternative Compliance Program.*** The Alternative Compliance Program, administered by DoE, allows tax-exempt religious and nonprofit organizations to receive reductions in their CWA Fee if they adopt stormwater management practices. The organizations have three options and can use any combination to receive the credits. The options are to (1) provide easements so the County can install BMPs on their property; (2) agree to take part in outreach and education encouraging others to participate in the Rain Check Rebate and Grant Program and create an environmental team for trash pickups, tree planting, recycling, planting rain gardens, and so forth; and (3) agree to use good housekeeping techniques to keep their lots clean and to use lawn management companies certified in the proper use of fertilizers.

- ***Rain Check Rebate and Grant Program.*** The Rain Check Rebate and Grant Program, administered by the DoE, allows property owners to receive rebates for installing County-approved stormwater management practices. It was established in 2012 through County Bill CB-40-2012 and implemented in 2013. The County will reimburse homeowners, businesses, and nonprofit entities (including housing cooperatives and places of worship) for some of the costs of installing practices covered by the program. Installing practices at the individual property level helps reduce the volume of stormwater runoff entering the storm drain system as well as the amount of pollutants in the runoff. In addition, property owners implementing these techniques through the program will reduce their CWA Fee if they maintain the practice for three years. Currently, rebates are capped at $6,000 for residential properties and $20,000 for nonprofit groups and residential, commercial, industrial, and institutional properties and nonprofit groups.

- ***Stormwater Stewardship Grant Program.*** Through the County's Stormwater Stewardship Grant Program, the Chesapeake Bay Trust currently funds requests for the construction of water quality improvement projects. The Trust also funds citizen engagement and behavior change projects implemented by various nonprofit groups, including homeowner associations (HOAs). Nonprofit organizations, municipalities, watershed organizations, education institutions, community associations, faith-based organizations, and civic groups can be awarded $50,000 to $150,000 for water quality projects and $50,000 to $100,000 for tree planting projects. Projects must complete on-the-ground restoration that will improve water quality and watershed health (reduction in loads of nutrients or sediment) or significantly engage members of the public in stormwater issues by promoting awareness and behavioral change.
- ***Countywide Green/Complete Streets Program.*** DPW&T initiated a countywide Green/Complete Streets Program in 2013 as a strategy for addressing mounting MS4 and TMDL treatment requirements. The program identifies opportunities to incorporate stormwater control measures, environmental enhancements, and community amenities into DPW&T's capital improvement projects. The types of projects that can contribute to pollutant load reductions include ESD practices, tree shading, alternative pavements, and landscape covers.
- ***Erosion and Sediment Control.*** MDE has assigned the responsibility for conducting erosion and sediment control enforcement to the County. For new developments, this responsibility is assigned to DPIE. It involves conducting site inspections and providing Responsible Personnel Certification courses, which educate construction site operators to conscientiously manage disturbed land areas commonly found at construction sites. These

control measures prevent excess sediment entering County water bodies from active construction sites.

- ***Street Sweeping.*** The County conducts street sweeping operations on select arterial, collector, and industrial roadways. Residential subdivisions are swept on a request-only basis. Street sweeping can reduce the amount of debris, including sediment, that reaches waterways.
- ***Litter Control.*** The County maintains an aggressive litter control and collection program along County-maintained roadways. The litter service schedule is based on historical collection data; therefore, the most highly littered roadways are serviced as often as 24 times per year.
- ***Storm Drain Maintenance: Inlet, Storm Drain, and Channel Cleaning.*** These are systematic water quality-based storm drain programs that provide routine inspections and cleanouts of targeted infrastructure with high sediment and trash accumulation rates. Municipal inspections of the storm drain system can be used to identify priority areas. DPW&T inspects and cleans major channels on a 3-year cycle. Additionally, the County performs storm drain vacuuming that removes sediments from the storm drain system.
- ***Storm Drain Stenciling.*** The Storm Drain Stenciling Program continues to raise community awareness and alert community members to the connection between storm drains and the Chesapeake Bay. The County uses Chesapeake Bay Trust funding to purchase the paint, tools, and stencils used by the volunteers to stencil the "Don't Dump—Chesapeake Bay Drainage" message. It is difficult to estimate the load reduction from storm drain stenciling; however, it is expected to help reduce pollutant loads to local water bodies.

- ***Illicit Connection and Enforcement Program.*** DoE conducts field screening and outfall sampling to detect and eliminate nonpermitted discharges from the County's MS4.

A.2 Tree Planting and Landscape Revitalization Programs

Significant hydrologic and water quality benefits accrue when localities convert urban land to forest. Tree planting typically occurs piecemeal across the urban landscape, whereas reforestation usually occurs on a much larger scale. In either case, to claim pollutant reduction credits from those plantings, a survival rate of 100 or more trees per acre is necessary, with at least 50 percent of the trees being 2 inches or more in diameter at 4.5 feet above ground level (MDE 2021a).

The pollutant load reduction credit for planting trees is based on the load difference when the land cover is converted from urban to forest. To qualify for the alternative credits for Reforestation on Pervious Urban Land, the County will need to demonstrate compliance with the credits criteria.

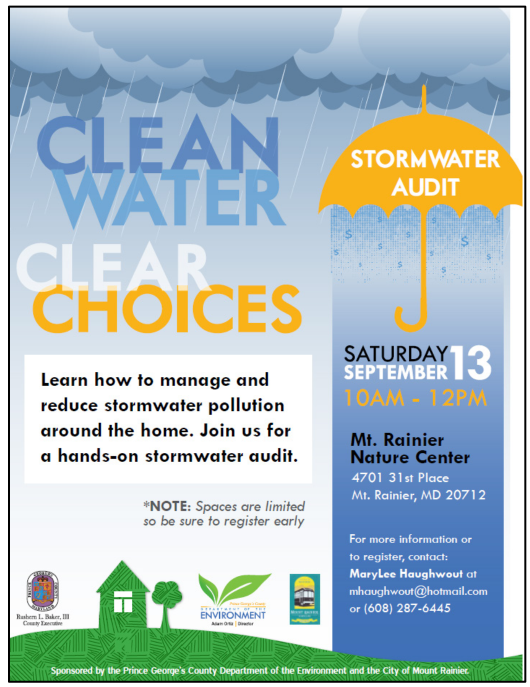
- ***Volunteer Tree Planting.*** DPW&T oversees volunteer tree planting in October of every year. Trees are planted by organizations (e.g., HOAs) in public spaces (e.g., parks and institutional areas). Approximately 2,000–2,500 trees are planted under the program every year.
- ***Tree ReLeaf Grant Program.*** DoE's Tree ReLeaf Grant Program is funded by fees-in-lieu; therefore, it only supports planting projects on public property. The program funds neighborhood, civic, and community/homeowner organizations; schools; libraries; and municipalities for tree and shrub planting projects in public spaces or common areas. The goals of the program include increasing the native tree canopy to improve air and water quality, conserve energy, and reduce stormwater runoff. Organizations can receive up to $5,000 under the program, and municipalities are eligible for grants up to $10,000.
- ***Neighborhood Design Center.*** The Neighborhood Design Center, a local nonprofit in Riverdale, is an important partner in many County initiatives. They furnish pro bono design and planning services to a wide variety of individuals, organizations, and low-to-moderate-income communities. Their goal is to involve the entire community in developing and implementing initiatives and projects designed to revitalize neighborhoods. The Neighborhood Design Center develops plans for parks, gardens, and community plantings, including wetland and rain gardens, reforestation projects, and median and shade tree plantings. Collectively, these efforts have increased the County's green space, reduced stormwater runoff, and improved water quality through the creation of natural systems to cleanse stormwater runoff.
- ***Arbor Day Every Day***. Arbor Day Every Day provides free trees to schools to plant and maintain on school grounds. This program educates students on the everyday importance of native trees, empowers them to enhance their community, and provides funds for planting projects.
- ***Tree Planting Demonstrations.*** The Sustainable Initiatives Division recently began a tree planting demonstration program to increase tree canopy and promote tree care.

A.3 Public Education Programs

DoE seeks every opportunity to promote environmental awareness, green initiatives, and community involvement to protect natural resources and promote clean and healthy communities. The County also integrates water quality outreach as a vital component of watershed restoration projects. At public outreach events, DoE staff provide handouts, answer questions, make presentations, promote programs, and display posters and real-world examples of stormwater pollution prevention materials (e.g., sample rain barrels and samples of permeable pavement). The County also has published a series of brochures to raise stormwater pollution awareness and educate the residential, business, and industrial sectors on their roles in preventing stormwater pollution. Topics include stormwater BMPs such as rain gardens, cisterns, and pavement removal.

Following are details about other County-administered outreach and education efforts that have the potential to reduce stormwater pollution through BMP implementation:

- ***Interactive Displays and Speakers for Community Meetings.*** County staff support multiple outreach events to provide presentations, displays, and handouts; answer questions; and promote environmental stewardship. At these events, County staff provide information on the importance of trees and tree planting, stormwater pollution prevention, lawn care, Bayscaping (replacing turf with plants native to the Chesapeake Bay region), and trash prevention and cleanup.
- ***Stormwater Audit Program.*** DoE conducts stormwater audits on residential properties. During the audits, County staff walk a property with the homeowner and make suggestions on the most appropriate types and potential locations for stormwater BMPs.



- ***Master Gardeners.*** Master Gardeners are volunteer educators who provide horticultural education services to individuals, groups/ institutions, and communities. The program's mission is to educate Maryland residents about safe, effective, and sustainable horticultural practices that build healthy gardens, landscapes, and communities. The program has the potential to aid the overall reduction of fertilizer and pesticide use as well as promote increases in stormwater practices such as installing rain gardens and using rain barrels.
- ***Flood Management.*** During June, DoE works to raise awareness of flood risks and what County residents can do to protect their homes, families, and personal belongings if flooding occurs. DoE incorporates messages encouraging residents to implement flood-prevention stormwater practices (e.g., BMPs), such as using permeable pavers and rain gardens to help prevent costly property damage caused by backyard flooding.

APPENDIX B: BMP REMOVAL EFFICACIES

MDE's *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated* (MDE 2021a) incorporates recent Chesapeake Bay Program recommendations for sediment load reduction removal efficiencies associated with implementing BMPs. This information is incorporated into their TIPP Tool (MDE 2022c). By using those removal efficiencies in its reduction calculations, the County is consistent with regional efforts to meet the Chesapeake Bay TMDL.

Pollutant removal efficiencies were calculated by runoff depth treated and are provided in Table B-1. MDE (2021a) separates BMPs into three broad classes—runoff reduction (RR), stormwater treatment (ST), and alternative BMP practices (ALT). RR practices reduce pollutants through infiltration interception by vegetation and adsorption by soil (e.g., bioswales and permeable pavement). ST practices reduce pollutants through filtration or settling (e.g., sand filters and wet ponds). RR practices have a higher level of pollutant removal than ST practices because of their removal mechanisms. ALT practices are restoration activities such as stream restoration. For RR and ST practices, the removal efficiency increases as more runoff volume is treated. The table also illustrates that RR practices consistently reduce pollutant loads at a higher efficiency than structural practices at all treatment volumes. The RR curves should be used in locations where RR practices are used or other acceptable RR practices predominate. Otherwise, the ST practice curves should be used. If a BMP did not have a reported runoff depth treated, it was assumed to be 0.5 inches.

Table B-1. Pollutant removal rates for runoff reduction and structural practices.

Runoff Depth Treated (inches)	Total Nitrogen		Total Phosphorus		TSS	
	Runoff Reduction (%)	Structural Practices (%)	Runoff Reduction (%)	Structural Practices (%)	Runoff Reduction (%)	Structural Practices (%)
0.00	0%	0%	0%	0%	0%	0%
0.25	32%	19%	38%	29%	40%	37%
0.50	44%	26%	52%	41%	56%	52%
0.75	52%	30%	60%	47%	64%	60%
1.00	57%	33%	66%	52%	70%	66%
1.25	60%	35%	70%	55%	76%	71%
1.50	64%	37%	74%	58%	80%	74%
1.75	66%	39%	77%	61%	83%	77%
2.00	69%	40%	80%	63%	86%	80%
2.25	71%	41%	82%	65%	88%	83%
2.50	72%	42%	85%	66%	90%	85%

Source: MDE 2021a.

Typical RR practices include:

- Bioretention
- Bioswale

- Dry swale
- Dry well
- Enhanced filter
- Grass swale
- Green roof
- Landscape infiltration
- Micro-bioretention
- Permeable pavements
- Rain gardens
- Rainwater harvesting
- Reinforced turf
- Wet swale

Typical ST practices include:

- Extended detention–wetland
- Extended detention structure, wet
- Micro-pool extended detention pond
- Pocket pond
- Pocket wetland
- Retention pond (wet pond)
- Infiltration basin
- Infiltration trench
- Sand filter
- Shallow marsh
- Submerged gravel wetlands
- Underground filter

Table B-2 presents the pollutant reduction efficiency of several ALT practices, including stream restoration (for which the load reduction efficiencies are only for planning purposes). Once the stream restoration projects are installed, the County will use the approved protocols—based on design and field measurements—to determine their actual load reductions.

Table B-2. Pollutant removal efficiencies of selected alternative BMPs.

BMP Type	Units	TSS Removal
Stream restoration (planning only)	lb/ft/yr	248
Outfall stabilization (planning only)	lb/ft/yr	248
Shoreline management (planning only)	lb/ft/yr	328
Impervious surface reduction (imp. to turf)[a]	lb/ac/yr	3,590
Forest planting (turf to forest)[a]	lb/ac/yr	1,409
Street trees (imp. to tree canopy over imp.)[a]	lb/ac/yr	529
Urban tree canopy planting (turf to tree canopy over turf)[a]	lb/ac/yr	101
Riparian forest planting (turf to forest) [a]	lb/ac/yr	2,342

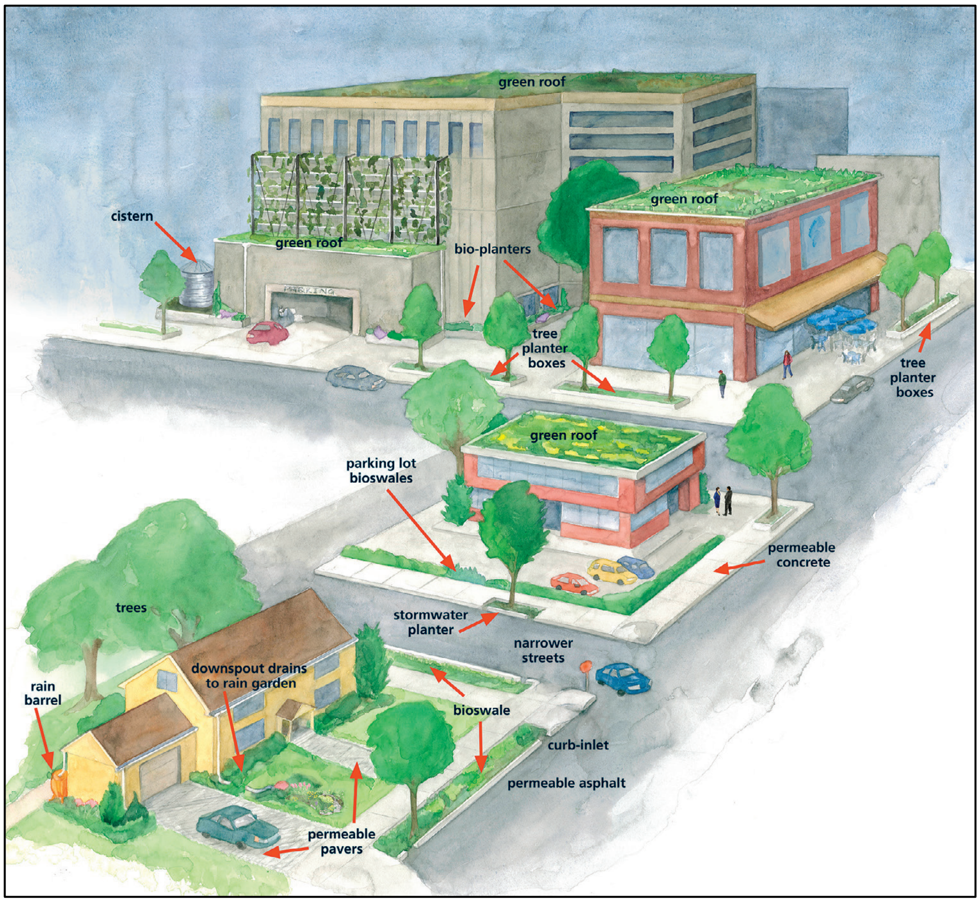
Source: MDE 2021a.
Notes:
lb/ac/yr = pound per acre per year; lb/ft/yr = pound per foot per year.
[a] Varies by major watershed based on land use loading rates.

Appendix C: BMP Identification and Selection

C.1 BMP Identification and Selection

The MDE 2000 *Stormwater Design Manual* provides guidance for designing several types of structural BMPs, which include wet ponds, wetlands, filtering practices, infiltration practices, and swales (MDE 2009). MDE also describes nonstructural BMPs that include programmatic, educational, and pollution prevention practices that work to reduce pollutant loadings. Examples of nonstructural BMPs include diverting stormwater from impervious to pervious areas, street sweeping, and homeowner and landowner education campaigns (MDE 2009). Additionally, the County will use the MDE's *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for National Pollutant Discharge Elimination System Stormwater Permits* (MDE 2021a).

Figure C-1 presents conceptual art of an urban area with a variety of practices. It includes some practices not specifically mentioned in the plan, but that could be incorporated into the County's overall strategy.



Credit: EPA Office of Wetlands, Oceans and Watersheds.

Figure C-1. Conceptual urban area with ESD practices.

C.1.1 Urban Stream Restoration

Urban impacts on streams typically include bank and channel erosion, stream health degradation, and loss of natural habitat. Multiple techniques for restoring a stream can be used to mimic the natural state of the stream, provide stability to the channel bed and banks, and improve stream health and habitat in nontidal areas. Various kinds of in-stream structures can be used to restore the main channel by providing stable flow steering and energy dissipation as well as creating pools where natural habitats can develop. In addition to in-stream structures, the increase in riparian vegetation can help to stabilize stream banks, further reducing in-stream erosion in high-velocity areas. The County recently completed a major stream restoration project (7.7 miles) in the upper reaches of the Tinkers Creek subwatershed. This project removed 2,000 tons of sediment. The County is planning another 2.7 miles of stream restoration and outfall stabilization in the watershed, with an estimated sediment removal of over 1,500 tons.

C.1.2 Outfall Stabilization

Storm drainage systems in the County terminate at outfall structures that usually discharge to surface drainage features such as channels or streams. The outfall structures are often the initial source of stream erosion and degradation because they are the delivery point for the increased runoff from impervious areas. As the stream channel erodes and downcuts, it often undercuts the outfall structure, resulting in outlet failure. Outfall stabilization typically involves repairing localized areas of erosion below a storm drainpipe and addressing structural and functional problems associated with exposed infrastructure. Because the failing outfalls actively contribute to stream erosion and sediment generation, they present many restoration opportunities. Many outfalls have been in place for 50 years, and the County should inspect and prioritize old and failing previously installed outfalls to prevent sediment releases in the watershed. As part of their regular maintenance, the DPW&T storm drain division inspects and evaluates outfalls to determine their condition for potential improvements and repairs.

C.1.3 Structural Practices

The County will consider opportunities to implement BMPs on all types of land uses, wherever there is a need to provide treatment to currently untreated impervious surfaces. Some BMPs are better suited to certain land uses than others, and this section discusses examples of those land uses and their primary corresponding but nonexclusive BMPs. The County will also look for BMPs upstream from the ongoing stream restoration project to help reduce flow and future erosion in the restored stream.

C.1.3.1 Rights-of-Way

The County owns and maintains ROWs, which are public space along streets and roadways. They contribute to the impervious runoff impact and represent a high-priority area for restoration and will be a major focus of the County watershed restoration efforts. If opportunities to implement BMPs in ROW areas present themselves, possible retrofits for different types of ROW are available (Table C-1).

Table C-1. Potential BMP types per urban road ROW grouping.

Potential BMP	Urban Open Section with No Sidewalk	Urban Closed Section with Curb and Gutter but No Sidewalk	Urban Closed Section with Curb, Gutter, and Sidewalk	Suburban Open Section with No Curb, Gutter, or Sidewalk	Suburban Closed Section with Curb, Gutter, and Sidewalk
Permeable pavement or sidewalks	X	X	X	X	X
Curbside filter systems		X	X		X
Curb extension with bioretention or bioswale		X	X		X

Potential BMP	Urban Open Section with No Sidewalk	Urban Closed Section with Curb and Gutter but No Sidewalk	Urban Closed Section with Curb, Gutter, and Sidewalk	Suburban Open Section with No Curb, Gutter, or Sidewalk	Suburban Closed Section with Curb, Gutter, and Sidewalk
Curb cuts to underground storage/infiltration or detention device		X	X		X
Grass swales and bioswales				X	
Green street (bioretention or bioswales) to convert an ROW				X	X
Infiltration trenches with underdrains				X	

C.1.3.2 Institutional Land Use

Existing institutional land uses also offer opportunities for BMP retrofits. The land uses include County and nonprofit organization properties such as schools, libraries, places of worship, parks, government buildings, fire and police stations, and hospitals. The County has implemented the Alternative Compliance Program, administered by DoE, which allows nonprofit organization property owners to reduce their CWA Fee by installing approved stormwater management practices. Most of the properties have substantial areas of impervious cover, including rooftops, driveways, and parking areas, that offer opportunities for cost-effective retrofits. A BMP retrofit matrix can be applied to these sites based on impervious cover type (Table C-2). The retrofit matrix will help in the selection process and identify practical and feasible practices that offer the highest pollutant removal at the lowest cost.

Table C-2. Typical impervious area BMP retrofit matrix for institutional property.

BMP Description	Impervious Cover Elements				
	Roofs	Driveways	Parking	Sidewalks	Other[a]
RR practices					
Permeable pavements		X	X	X	X
Rainwater harvesting	X				
Submerged gravel wetlands			X		
Landscape infiltration	X	X	X		X
Dry wells	X				
Bioretention / rain gardens / swales		X	X		X
Enhanced filters	X	X	X	X	X
ST practices					
Wet ponds/wetlands			X		X
Infiltration practices[b]			X		X
Filtering practices		X	X	X	X
Tree planting and reforestation					
Impervious urban to pervious		X	X		X
Planting trees on impervious urban		X	X		X

BMP Description	Impervious Cover Elements				
	Roofs	Driveways	Parking	Sidewalks	Other[a]
Other					
Disconnection of rooftop runoff	X				
Disconnection of nonrooftop runoff		X	X	X	X
Sheet flow to conservation areas		X	X		

Notes:
[a] Includes miscellaneous other impervious surfaces (e.g., basketball courts, tennis courts, patios).
[b] Considered ST unless designed according to Section VI of MDE 2021a.

C.1.3.3 Commercial/Industrial Land Use

Much like institutional properties, commercial and industrial properties are characterized by large areas of impervious cover, including roofs, driveways, parking lots, and other paved areas. From a technical standpoint, the opportunities for implementing a variety of BMPs in those areas are similar to the opportunities in institutional areas (Table C-2). However, most of the commercial and industrial facilities are privately owned. Consequently, the County has limited influence on the use of BMPs in those areas except along the public roads that serve them. The Rain Check Program currently offers financial incentives for property owners to implement approved stormwater management practices. Property owners can benefit through rebates, grants, or a reduction in a portion of their CWA Fee.

C.1.3.4 Residential Land Use

Residential areas comprise roughly 31 percent of the watershed and have varying amounts of impervious cover, such as roofs, driveways, walkways, and patios. Many of the practices in Table C-2 can be used on residential land. The most common practices for individual homeowners are permeable pavement, rooftop disconnection, rainwater harvesting (e.g., rain barrels), landscape infiltration, rain gardens, and planting trees. For row houses, the most common practices are likely permeable pavement (on sidewalks leading to houses and alleyways), rooftop disconnection, rainwater harvesting (e.g., rain barrels), and rain gardens. Apartment and condominium communities could install any of the practices listed in Table C-2.

It is difficult to implement BMPs on residential properties, however, because they are privately owned. As with commercial and industrial property owners, the Rain Check Program offers financial incentives for residential property owners to implement approved stormwater management practices. Additionally, the County could explore opportunities to provide further education and awareness outreach on residential BMPs to help property owners learn about their benefits.

C.2 Prioritizing BMP Locations

The location of a BMP or other restoration practice significantly impacts how successful the restoration will be. For instance, a lawn care campaign will have little effect in areas with few homeowners to implement the strategy. In identifying the best locations for BMPs, the County will consider sites where the most significant water quality benefits will be realized for available funding, and the BMPs can be installed in a desirable time frame with minimal disruption. Three main considerations for prioritizing BMP locations are land ownership and site access, location in the stream watershed, and locations of known issues and existing treatment.

C.2.1 Land Ownership and Site Access

DoE and CWP are actively installing BMPs countywide. The most suitable locations to install BMP practices are municipally owned land such as town halls, police stations, public schools, libraries, and the ROWs or easements along roads and stormwater outfalls. For example, the County has site access to stormwater outfalls (usually available as flood easements), which allows the County to proceed without the delays that would sometimes result from negotiating with private landowners—this accelerates implementation and reduces the resources spent on interacting with landowners.

In some instances, the County is granted permission from a property owner to install a BMP on their property. For example, the County's Alternative Compliance Program provides incentives to faith-based and other nonprofit organizations to allow the County to install BMPs on their properties. The organizations are granted credit toward their CWA Fee. The aesthetics of a restoration project are often preferred to the condition of the site before the BMP was installed. Attractive examples of watershed restoration efforts can be used in an outreach effort to encourage property owners to grant access to their own properties. A public education campaign highlighting those examples can build public support for implementing BMPs on private properties.

C.2.2 Location in the Watershed

Another factor to consider in BMP placement is how close the location is to the stream headwaters. Improvements to water quality and stream stability in stream headwaters will provide benefits along the entire length of the stream. Restoring downstream reaches first, on the other hand, will later expose the restored reaches to sediment from upstream, increasing the risk that the restored channel will fail because of the fresh sediment deposits. Water quality improvement projects that address excess sediment from stream erosion are most appropriately placed in smaller headwater (first- and second-order) subwatersheds. Adding BMPs to headwaters above stream restoration projects will help protect the stream reaches that have been restored. Restoring conditions in the headwaters makes it easier to detect and attribute the water quality improvements to each restoration project because the complexity of factors that could be affecting water quality tends to decrease with drainage area.

C.2.3 Locations of Known Issues and Existing Treatment

A third key consideration in determining where to place BMPs includes identifying known areas of erosion and poor biological health and locating treatment practices that are in place but still need to be adequately implemented. Figure 3-7 shows the biological narrative ratings for the watershed. The contributing drainage areas to locations that were rated as Poor or Very Poor should be targeted for upland restoration. Table 3-2 presents the results of geomorphic assessments in the watershed. This information can be used in combination with the information from Figure 3-13, which presents the known stream and outfall erosion areas. These locations can be targeted for stream restoration, outfall stabilization, and upland measures to reduce the amount of flow (and sediment) entering the stream.

APPENDIX D: FUNDING

D.1 Budget Funding

Funding refers to sources of revenue used to pay for annual operating expenditures, including maintenance and administrative costs; pay for management activities directly out of current revenues; and repay debt issued to finance capital improvements projects.

D.1.1 Sources of Funding

The County has relied mainly on stormwater bonds, general obligation bonds, federal and state grants, and the State Revolving Fund to pay for the stormwater CIP, including watershed restoration projects. The County's Stormwater Enterprise Fund pays for debt service on the bond sales and agency operating costs.

In 2013, the County enacted a CWA Fee that provides a dedicated revenue source for addressing stormwater runoff and improving water quality for regulatory mandates such as the Chesapeake Bay WIP, TMDL WIPs, and the NPDES MS4 permit (independent of the ad valorem tax and General Fund). The CWA Fee is based on a property's assessed impervious surface coverage and provides a mechanism to equitably allocate the fee based on a property's stormwater contribution. Thus, each property contributes a fair and equitable share toward the overall cost of improving water quality and mitigating the impact of stormwater runoff. The fee collects roughly $14 million of dedicated funding annually. Depending on the rate of restoration activities completed by the CWP and County CIP efforts, the County might reevaluate funding options in the future.

Most stormwater restoration funds are from the CWA Fee, stormwater ad valorem tax, and CIP budget. Federal, state, or other grants are expected to provide a minor but essential contribution to funding. The ad valorem tax is based on property assessment, which will vary annually, and supports the DPIE's development process and DPW&Ts long-term stormwater management maintenance program. The County has successfully obtained various grants in the past and expects that trend to continue. The County will continue to pursue grant opportunities available for restoration projects. In addition to grants, federal and state loans (e.g., State Revolving Fund) might be an option for helping to fund part of the TMDL restoration process. In addition, the County encourages government entities (e.g., municipalities) and private organizations (e.g., watershed groups and nonprofits) to identify and apply for grant opportunities.

The County expects current Stormwater Enterprise Fund sources and funding levels to remain consistent with the County's biannual FAP, expected to reoccur over the life of this WIP. The countywide dollars for restoration average no more than $70 million per year for all stormwater restoration. The available funding will need to compete across multiple local WIPs, including the Chesapeake Bay WIP; however, many of the activities in the WIP can be counted toward local WIPs. As part of its NDPES permit requirements, the County updates and submits its 2-year FAP to MDE for review. The FAP includes planned restoration projects of 5-year periods and the funding commitment for the next two fiscal years. The most recent plan approved by County Resolution is for FY 2023 and FY 2024. The County has created a new FAP for FY 2022 and FY 2023, which will be approved in spring 2025.

D.1.2 Budget for Restoration Activities

The stormwater CIP contains project construction budget projections for the next six years for the entire county. For countywide watershed or water quality restoration projects, the County primarily relies on two CIP projects: the CWP Project and NPDES MS4 Permit Compliance and Restoration. Other stormwater CIP projects include funding appropriation for restoration activities.

Table D-1 provides a list of countywide stormwater CIP projects included in the County's FAP that include aspects of watershed restoration, a portion of which are available for projects in the Anacostia River watershed. The projects generally fund new watershed restoration activities or rehabilitation of existing assets to improve water quality. Specific watershed restoration projects or locations are not listed. However, the County maintains a project list that is used to determine the proposed funding. Once this WIP is completed, the County will start incorporating proposed restoration scenarios subject to funding availability.

The County's stormwater CIP budget has, in the past, appropriated up to $50 million per year for countywide watershed or water quality restoration activities. For current funding capacities, the County typically prioritizes programs and shifts funding between watersheds. By doing so, the County can prioritize and shift year-to-year load reduction goals between watersheds; however, the County aims to achieve the targeted completion dates.

Table D-1. FY 2023 to FY 2028 FAP budget for countywide stormwater management projects.

CIP ID	Project Name	Project Class	Total FY23–FY28 Budget ($000)
5.54.0016	Bear Branch Subwatershed	Rehabilitation	$7,439
5.54.0018	Clean Water Partnership NPDES/MS4	Rehabilitation	$99,961
5.54.0019	MS4/NDPES Compliance & Restoration	Rehabilitation	$115,351
5.54.0006	Participation Program Countywide	New construction	$3,000
5.66.0002	Stormwater Management Countywide Restoration	Rehabilitation	$47,138
5.66.0004	Stormwater Structure Restoration and Construction	New construction	$45,500

Source: Prince George's County 2022.
Note: $000 = Dollars in thousands.

APPENDIX E: PUBLIC OUTREACH AND INVOLVEMENT

The County recognizes that involving the public in planning and implementing restoration is important to the success of its stormwater management efforts. It welcomes any ideas citizens have to improve the restoration process, recognizing that the people who live and work in the watersheds are most familiar with them. They can act as the eyes and ears of the County on a day-to-day basis to identify water quality issues, pollutant spills, or potential BMP opportunities. Residents can stay informed on the County's progress through the annual MS4 report to MDE, which is posted on the County's website and contains information on BMP implementation, public outreach events, and other County programs that can help meet TMDL goals. In addition, the County welcomes public input on restoration activities and potential BMP types or locations.

Besides staying informed, homeowners, nonprofit organizations, and business associations can play a more active role in the restoration process. Residents can take a pledge to clean up after their pets and practice environmentally friendly lawn care. In addition, the public can participate in the Rain Check Rebate and Tree ReLEAF Grant Programs and nonprofits can participate in the Alternative Compliance Program. Private landowners and nonprofit organizations can aid in restoring the watersheds by installing BMPs (e.g., rain barrels, rain gardens, permeable pavement) on their properties to help minimize their impact on the overall pollution loading to the County's water bodies. Installing BMPs on private property reduces the owner's CWA Fee. Although those practices might seem insignificant, the overall load reductions can be significant if enough private landowners get involved. Organizations such as HOAs, neighborhood associations, and business organizations can also help by promoting the programmatic initiatives outlined in this WIP.

DoE has initiated a wide range of initiatives to inform County residents about the impacts their daily activities have on the health of their watershed and local water bodies. During FY 2019, the County hosted more than 500 events to promote environmental awareness, green initiatives, and community involvement in reducing the amount of pollution entering the County's waterways, during which nearly 33,000 members of the public participated (DoE 2019). DoE's outreach and educational programs encourage volunteerism and environmental stewardship among community organizations, businesses, and citizens. Under DoE's Sustainability Division, the Natural Resource Protection & Stewardship Programs Section (Programs Section) is the lead office managing and administering most of the education and outreach initiatives described in this section.

Current outreach programs are discussed in Appendix A. Beyond those targeted efforts, the County will work with watershed partners to ensure the public is informed of implementation progress and that active public involvement is pursued throughout the process.

E.1 Outreach to Support Implementation Activities

The County's outreach efforts continue to specifically target TMDL pollutants and pollutant-generating behaviors. Over the past several years, the Programs Section has sponsored the following activities and projects to target TMDL pollutants and encourage the adoption of pollutant-reducing behaviors:

- ***Inventory of Environmental Outreach Programs in and around Prince George's County***. The Programs Section inventoried existing local programs (e.g., nonprofits and educational institutions) that are working toward shared goals of environmental stewardship or stormwater pollution reduction and already have ongoing or planned outreach efforts in and around the County. This was done to identify potential outside partners and overlapping programs/efforts. The Programs Section researched which programs and materials have been successful and are available to share and cross-market to target audiences.
- ***Audience Research Analysis: A Review of Target Audience Characteristics in Prince George's County for a Stormwater Outreach Strategy.*** The County is made up of a diverse population in terms of age, race, culture, language, education, and income. As a result, the Programs Section analyzed U.S. Census data and secondary research to gain an understanding of the potential target audiences and their specific characteristics as well as possible barriers to environmental messages (e.g., lack of homeownership, native language, age, household economics). This analysis helped determine the best way to reach diverse groups and identify different messaging and methods that would resonate with target audiences.
- ***Priority Watersheds Analysis***. The County has nine major watersheds, each with different water quality concerns. The Programs Section identified location-specific outreach needs based on water quality priorities and areas where the County should target its outreach efforts. Coupled with the Audience Research Analysis, this analysis recommended target locations and audiences for developing topic-specific outreach campaigns (e.g., pet waste and lawn care).
- ***Prince George's County Stormwater Outreach and Engagement Strategies***. The Programs Section developed seven individual campaign strategies: pet waste disposal, increasing the tree canopy, stormwater management and implementation, antilittering, lawn stewardship, household hazardous waste, and residential car care. Each campaign included goals, target audiences, priority locations, key messages, delivery techniques (e.g., events, materials, trainings, social media, developing and promoting programs), metrics, potential partnerships, and priority neighborhoods. The campaigns also included slogans and messages on what citizens should be doing (e.g., using fertilizer only if soil tests dictate a need) and not be doing (e.g., spilling fertilizer on driveways). The Programs Section is using these outreach and engagement strategies to plan and implement programs, events, and other efforts to encourage residents to adopt pollutant-reducing behaviors.
- ***Enhancing and Growing Partnerships***. The County's numerous partnerships with groups such as Master Gardeners, Chesapeake Bay Trust, and the University of Maryland Environmental Finance Center continue to be fostered and supported so that outreach efforts piggybacking on the efforts undertaken by those groups can continue to grow. In addition, new partnerships with groups such as landscapers, nursery suppliers, HOAs, and local boy scout or girl scout groups help broaden stormwater outreach and reach citizens who have not been reached in the past.

Although the results of outreach and involvement efforts are difficult to quantify in terms of pollutant reductions, these activities make a difference by slowly changing the mindsets and behaviors of County residents over time.

E.2 Public Involvement to Support Implementation Activities

Community organizations and citizen groups can participate in restoration activities by getting involved in local nonprofit groups with which the County is currently partnering. This section lists ways County residents and organizations can stay informed and help promote pollutant-reducing behaviors. These activities will also reduce the demand on the County's resources and staff's limited time.

- **Learn about County programs that promote tree plantings, cleanup events, and community awareness**. The Programs Section manages numerous programs in which citizens can get involved and promote pollutant-reducing behaviors. Residents can either organize or participate in volunteer efforts by working with their civic associations or schools or one-on-one with property owners. The public can visit the Community Outreach web page at https://www.princegeorgescountymd.gov/departments-offices/environment/sustainability/community-outreach for more information on the Programs Section programs and how to contact the County. Appendix A for details about the County's tree planting and landscape revitalization programs. Other volunteer programs included:
  - **Volunteer Neighborhood Cleanup Program** provides interested communities with technical assistance and materials such as trash bags, gloves, and roll-off containers (depending on availability). The public can visit the website at https://www.princegeorgescountymd.gov/464/Volunteer-Neighborhood-Cleanup-Program.
  - **Volunteer Storm Drain Stenciling Program** helps spread the word to prevent water pollution by stenciling/inlet marking the storm drains in neighborhoods with "Don't Dump – Chesapeake Bay Drainage." Stenciling serves as a visual reminder to neighbors that anything dumped in the storm drain contaminates the Chesapeake Bay. The Programs Section provides the supplies and helps design a storm drain stenciling/inlet marking project that can be accomplished with any size team or age group at https://www.princegeorgescountymd.gov/465/Volunteer-Storm-Drain-Stenciling-Program.
- **Apply for grants to implement projects through the Chesapeake Bay Trust**, which manages the Rain Check Rebate and Stormwater Stewardship programs as well as the Litter Reduction and Citizen Engagement Mini Grant. See Appendix A for details on the Rain Check Rebate and Stormwater Stewardship programs. The public can find more information about the grants at https://cbtrust.org/grants/.
  - **Litter Reduction and Citizen Engagement Mini Grants** support efforts that engage and educate residents, students, and businesses on ways to make their communities cleaner and greener. Up to $2,500 can be awarded to HOAs and nonprofits to develop and implement projects such as community cleanups, "Adopt-a-Stream" projects to remove litter from a local stream, and storm drain stenciling.
- **Stay informed**. The County provides numerous ways for residents to stay informed about community events, trainings, emergencies, and County news:
  - **Monitor the County's social media accounts** to become aware of trainings and community events that promote environmental education and include opportunities to provide feedback to the County. See the County's accounts at Facebook (PGC

Department of the Environment), Twitter (PGC Environment @PGCsprout), and Instagram (pgcsprout).

  - **Monitor the County's website** to view information about upcoming events, meetings, recent news, and details about the County's programs at https://www.princegeorgescountymd.gov/.
  - **Sign up to receive "Alert Prince George's"** to receive emergency alerts, notifications, and updates to registered devices. Example notifications include traffic conditions, government closures, public safety incidents, and severe weather. More information is available at http://www.princegeorgescountymd.gov/794/Alert-Prince-Georges.

- **View the Clean Water Map,** an interactive tool to help the community stay informed about the health of County waters and know where restoration efforts are taking place. Residents can view BMPs, BMP drainage areas, and locations of activities such as Rain Check Rebates and Stormwater Stewardship Grants at https://princegeorges.maps.arcgis.com/apps/webappviewer/index.html?id=dc168a43d3554905b4e4d6e61799025f.
- **Provide feedback**. The County heard through numerous outreach and engagement events that several citizens and watershed groups want to provide information and feedback about on-the-ground support for BMP implementation projects, programmatic initiatives, and other outreach efforts to support implementation. Ways to provide this feedback include:
  - **Attend a public involvement meeting.** The County holds public outreach and involvement meetings as part of restoration planning efforts and other programs. At these meetings, residents can suggest specific locations for biological or water quality monitoring activities to be carried out based on surrounding land uses/ changes, historical water quality problems, or public desires. The County also welcomes suggestions on potential BMP types or locations so that the County can help communities identify and install the best BMPs for specific areas.
  - **Use County Click 3-1-1.** A call center (available weekdays from 7 a.m. to 7 p.m.) and website application (download CountyClick311Mobile) allow County residents to request services or report problems. This tool could be used to report on visual inspections of installed BMPs and is available at www.countyclick311.com.
- **Help foster partnerships.** Residents and civic and environmental groups can work directly with an organization or commercial business with a significant amount of untreated impervious surface, such as large parking lots or a large building footprint. The groups can help obtain a commitment from the business to participate in the Rain Check Rebate Program or Alternative Compliance Program, or they can install stormwater BMPs on the property. Group members can offer technical assistance and volunteer labor hours to support installation and/or maintenance. The participating civic or environmental group should discuss the selected location and BMP type with the County before working with the property owner. Groups can also work with established organizations such as the Alice Ferguson Foundation (https://fergusonfoundation.org/) to participate in cleanup events or provide volunteer hours.

- **Become educated through partner trainings and events**. Numerous organizations in Prince George's County always need volunteers. They also provide meaningful education programs in which participants learn about the issues through hands-on educational experiences. Those organizations include:
  - **Watershed Stewards Academy** equips and supports community leaders to recognize and address local pollution problems in their nearby streams and rivers. They provide community leaders with the tools and resources they need to bring solutions to those problems, restoring their local waterways and the communities they affect. More information is available at http://extension.umd.edu/programs/environment-natural-resources/program-areas/watershed-protection-and-restoration-program/watershed-stewards-academy/.
  - **Alice Ferguson Foundation** has training and outreach events to unite students, educators, park rangers, communities, regional organizations, and government agencies throughout the Washington, DC, metropolitan area to promote the environmental sustainability of the Potomac River watershed. More information is available at https://fergusonfoundation.org/.
  - **Patuxent River Watershed Society** has numerous educational programs, river restoration programs, and community events. More information is available at https://www.anacostiaws.org/.

APPENDIX F: GEOMORPHIC CROSS SECTION ASSESSMENT

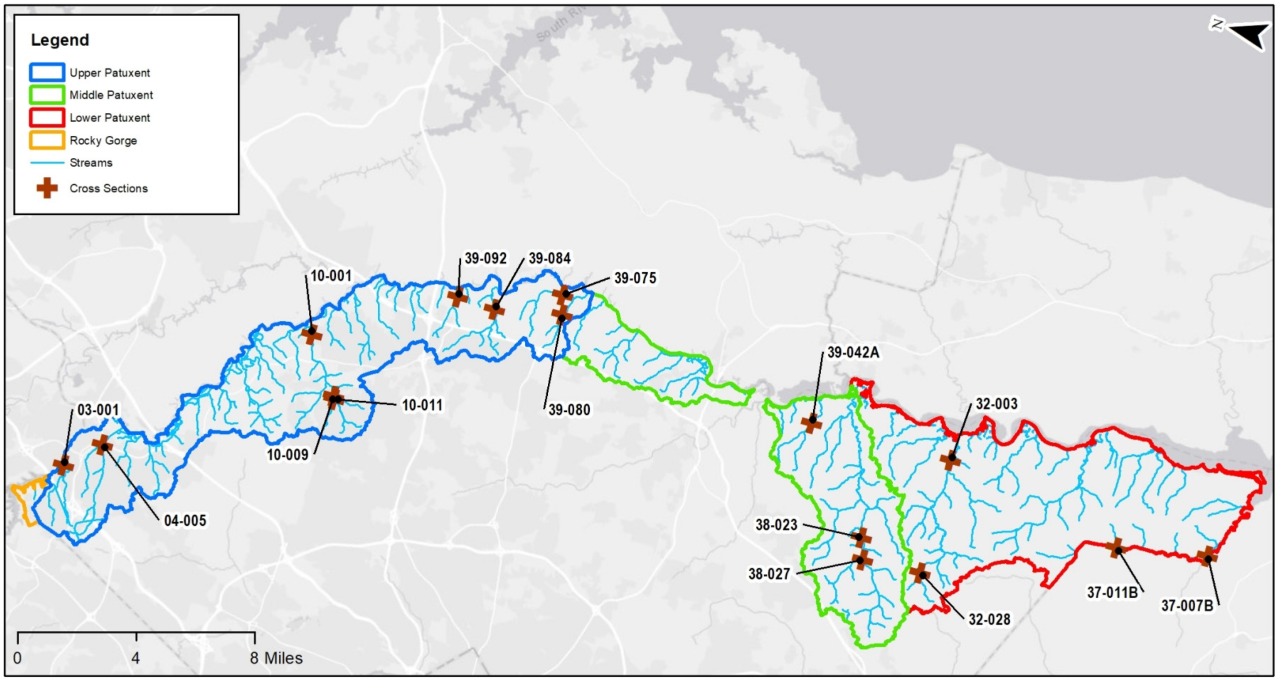


Figure F-1. Locations of Channel Cross-Sections in Patuxent River watershed.

F.1 Geomorphic Assessment Results

Table F-1. Results of geomorphic assessments for site 03-001A on Walker Branch.

Site ID	03-001	
Year	**2000**	**2020**
Entrenchment ratio	1.3	1.2
Width:depth ratio	21	6
Sinuosity	1.51	1.51
Slope	2.6	2.6
Median substrate particle size (D50)	99.5	66.6
Rosgen classification	F3c	G3c
Bankfull XSa (ft^2)	31.7	25.3
Bankfull Xsa difference (ft^2)	-6.4	
Full XSa (ft^2)	105.8	69.2
Full XSa difference (ft^2)	-36.6	
Sed. yield (tons/yr.)	-0.11	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

Table F-2. Results of geomorphic assessments for site 04-005 on Bear Branch.

Site ID	04-005	
Year	**2000**	**2020**
Entrenchment ratio	2.4	1.6
Width:depth ratio	9.8	9.4
Sinuosity	1.02	1.02
Slope	0.5	0.5
Median substrate particle size (D50)	26.7	20.4
Rosgen classification	E4	G4c
Bankfull XSa (ft^2)	61.2	66.2
Bankfull Xsa difference (ft^2)	5	
Full XSa (ft^2)	80.8	128.5
Full XSa difference (ft^2)	47.7	
Sed. yield (tons/yr.)	0.15	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

Table F-3. Results of geomorphic assessments for sites 10-001, 10-009, 10-011 on Horsepen Branch.

Site ID	10-001		10-009		10-011	
Year	**2002**	**2020**	**2002**	**2020**	**2002**	**2020**
Entrenchment ratio	3.3	2.7	2.8	1.1	1.2	1.2
Width:depth ratio	2.2	4.7	2.1	17.5	1.8	6.6
Sinuosity	1.21	1.21	1.22	1.22	1.1	1.1
Slope	0.3	0.3	0.9	0.9	1.7	1.7
Median substrate particle size (D50)	0.211	16	0.16	1	0.068	0.4
Rosgen classification	E5	E4	E5	F5	G5c	G5c
Bankfull XSa (ft^2)	37	103.4	13.7	30.1	7.6	10.3
Bankfull Xsa difference (ft^2)	66.4		16.4		2.7	
Full XSa (ft^2)	42.7	141.3	20.3	139.5	10.4	56.4
Full XSa difference (ft^2)	98.6		119.2		46	
Sed. yield (tons/yr.)	0.34		0.41		0.16	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

Table F-4. Results of geomorphic assessments for site 32-003 on Spice Branch.

Site ID	32-003	
Year	**2001**	**2020**
Entrenchment ratio	7.3	7.1
Width:depth ratio	7.2	6.9
Sinuosity	1.13	1.13
Slope	0.17	0.17

Site ID	32-003	
Year	2001	2020
Median substrate particle size (D50)	0.0625	0.0625
Rosgen classification	E6	E6
Bankfull XSa (ft^2)	26	28.4
Bankfull Xsa difference (ft^2)	2.4	
Full XSa (ft^2)	32.2	30.7
Full XSa difference (ft^2)	-1.5	
Sed. yield (tons/yr.)	0	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

Table F-5. Results of geomorphic assessments for site 32-028 on Rock Creek.

Site ID	32-028	
Year	2001	2020
Entrenchment ratio	2.8	4.3
Width:depth ratio	13	18.2
Sinuosity	1.31	1.31
Slope	0.17	0.17
Median substrate particle size (D50)	0.44	6
Rosgen classification	C5	C4
Bankfull XSa (ft^2)	25	29.3
Bankfull Xsa difference (ft^2)	4.3	
Full XSa (ft^2)	61.5	53.2
Full XSa difference (ft^2)	-6.3	
Sed. yield (tons/yr.)	-0.02	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

Table F-6. Results of geomorphic assessments for sites 37-007B, 37-011B on County Line Creek.

Site ID	37-007B		37-011B	
Year	2001	2020	2001	2020
Entrenchment ratio	3.4	1.1	1.4	1
Width:depth ratio	11.6	17.7	18	18.7
Sinuosity	1.31	1.23	1.23	1.23
Slope	2.09	2.09	1.02	1.02
Median substrate particle size (D50)	0.0625	0.6	0.12	1.3
Rosgen classification	C6b	F5b	F5	F5
Bankfull XSa (ft^2)	18.3	34.6	23.9	28.8

Site ID	37-007B		37-011B	
Year	2001	2020	2001	2020
Bankfull Xsa difference (ft^2)	16.3		4.9	
Full XSa (ft^2)	50.6	191.9	71.5	112.8
Full XSa difference (ft^2)	141.3		41.3	
Sed. yield (tons/yr.)	0.46		0.14	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

Table F-7. Results of geomorphic assessments for sites 38-023, 38-027 on Mataponi Creek.

Site ID	38-023		38-027	
Year	2002	2020	2002	2020
Entrenchment ratio	4	3.3	4.1	5
Width:depth ratio	11.5	15.6	9.1	10.2
Sinuosity	1.35	1.35	1.72	1.72
Slope	0.3	0.3	0.52	0.52
Median substrate particle size (D50)	14.6	11.1	0.123	7.7
Rosgen classification	E4	C4	E5	E4
Bankfull XSa (ft^2)	53.7	58	50	39.6
Bankfull Xsa difference (ft^2)	4.3		-10.4	
Full XSa (ft^2)	76.4	129.5	39.6	75.5
Full XSa difference (ft^2)	53.1		35.9	
Sed. yield (tons/yr.)	0.18		0.12	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

Table F-8. Results of geomorphic assessments for sites 39-042A on Swan Point Creek.

Site ID	39-042A	
Year	2002	2020
Entrenchment ratio	1.1	1.2
Width:depth ratio	3.4	15.4
Sinuosity	1.19	1.19
Slope	0.62	0.62
Median substrate particle size (D50)	0.24	1.4
Rosgen classification	G5c	F5
Bankfull XSa (ft^2)	7.3	12.1
Bankfull Xsa difference (ft^2)	4.8	
Full XSa (ft^2)	26.7	129.6
Full XSa difference (ft^2)	102.9	
Sed. yield (tons/yr.)	0.36	

Note: ft² = square feet; XSa = Stream channel cross-sectional area.

Table F-9. Results of geomorphic assessments for sites 39-075 on Honey Branch.

Site ID	39-075	
Year	2002	2020
Entrenchment ratio	2.2	2.1
Width:depth ratio	10.7	16.8
Sinuosity	1.42	1.42
Slope	0.93	0.93
Median substrate particle size (D50)	0.25	11.6
Rosgen classification	E5	B4c
Bankfull XSa (ft²)	12.7	15
Bankfull Xsa difference (ft²)	2.3	
Full XSa (ft²)	13.9	193.7
Full XSa difference (ft²)	179.8	
Sed. yield (tons/yr.)	0.62	

Note: ft² = square feet; XSa = Stream channel cross-sectional area.

Table F-10. Results of geomorphic assessments for sites 39-080 on Mt. Nebo Branch.

Site ID	39-080	
Year	2002	2020
Entrenchment ratio	1.1	1.1
Width:depth ratio	19.2	25.9
Sinuosity	1.31	1.31
Slope	0.36	0.36
Median substrate particle size (D50)	0.16	0.7
Rosgen classification	F5	F5
Bankfull XSa (ft²)	16.7	34.1
Bankfull Xsa difference (ft²)	17.4	
Full XSa (ft²)	127.9	279.5
Full XSa difference (ft²)	151.6	
Sed. yield (tons/yr.)	0.53	

Note: ft² = square feet; XSa = Stream channel cross-sectional area.

Table F-11. Results of geomorphic assessments for sites 39-084 on Mill Branch.

Site ID	39-084	
Year	2002	2020
Entrenchment ratio	4	1.2
Width:depth ratio	3.1	17.4
Sinuosity	1.26	1.26

Site ID	39-084	
Year	2002	2020
Slope	0.31	0.31
Median substrate particle size (D50)	0.25	1.6
Rosgen classification	E5	F5
Bankfull XSa (ft^2)	40	46
Bankfull Xsa difference (ft^2)	6	
Full XSa (ft^2)	200.9	231.9
Full XSa difference (ft^2)	31	
Sed. yield (tons/yr.)	0.11	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

Table F-12. Results of geomorphic assessments for sites 39-092 on Green Branch.

Site ID	39-092	
Year	2002	2020
Entrenchment ratio	1.1	1.1
Width:depth ratio	4.6	17.8
Sinuosity	1.51	1.51
Slope	0.32	0.32
Median substrate particle size (D50)	0.09	4
Rosgen classification	G5c	F4
Bankfull XSa (ft^2)	20.8	42
Bankfull Xsa difference (ft^2)	21.2	
Full XSa (ft^2)	259.1	226.8
Full XSa difference (ft^2)	-32.3	
Sed. yield (tons/yr.)	-0.11	

Note: ft^2 = square feet; XSa = Stream channel cross-sectional area.

F.2 Change in Cross Sections

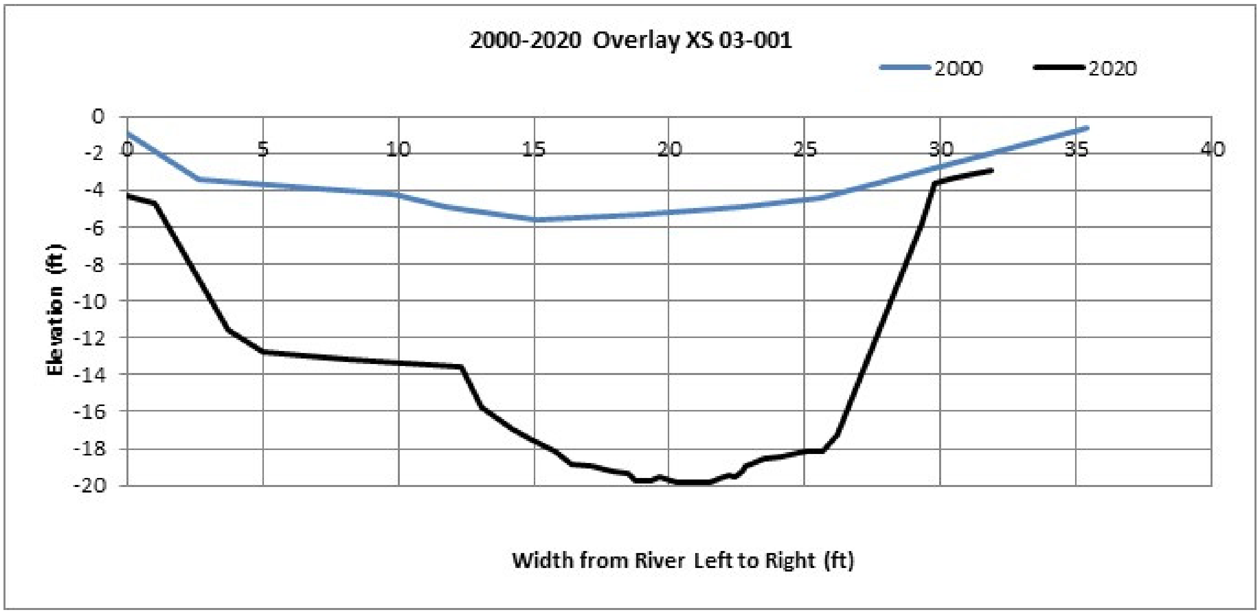


Figure F-2. Change in cross-sections for 03-001 between 2000 and 2020.

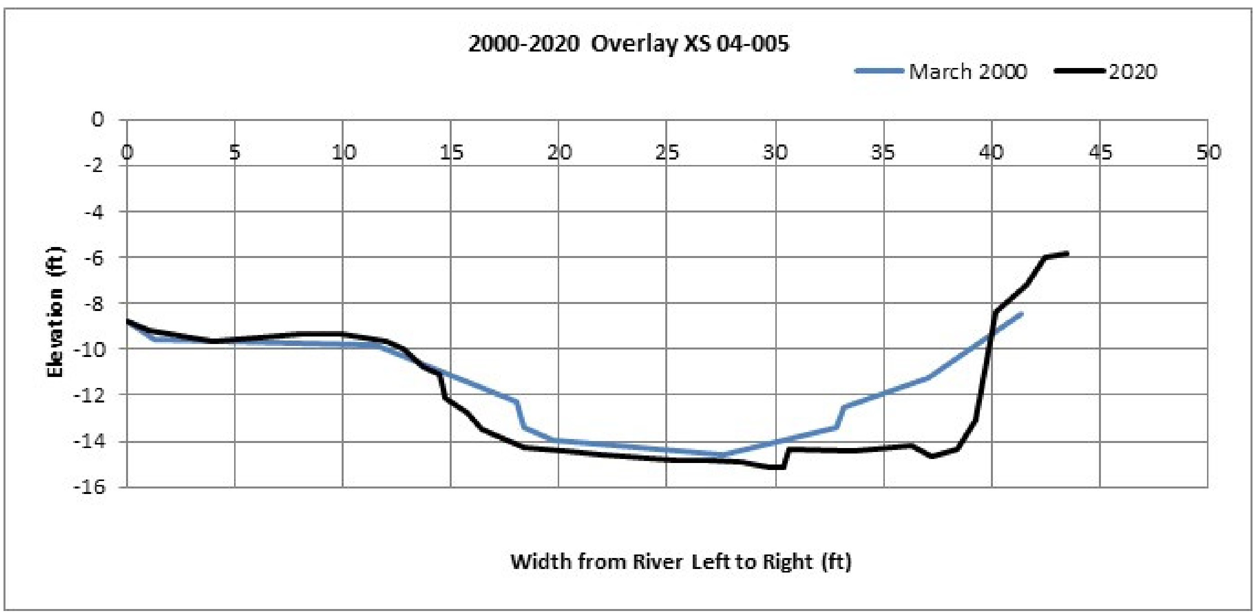


Figure F-3. Change in cross-sections for 04-005 between 2000 and 2020.

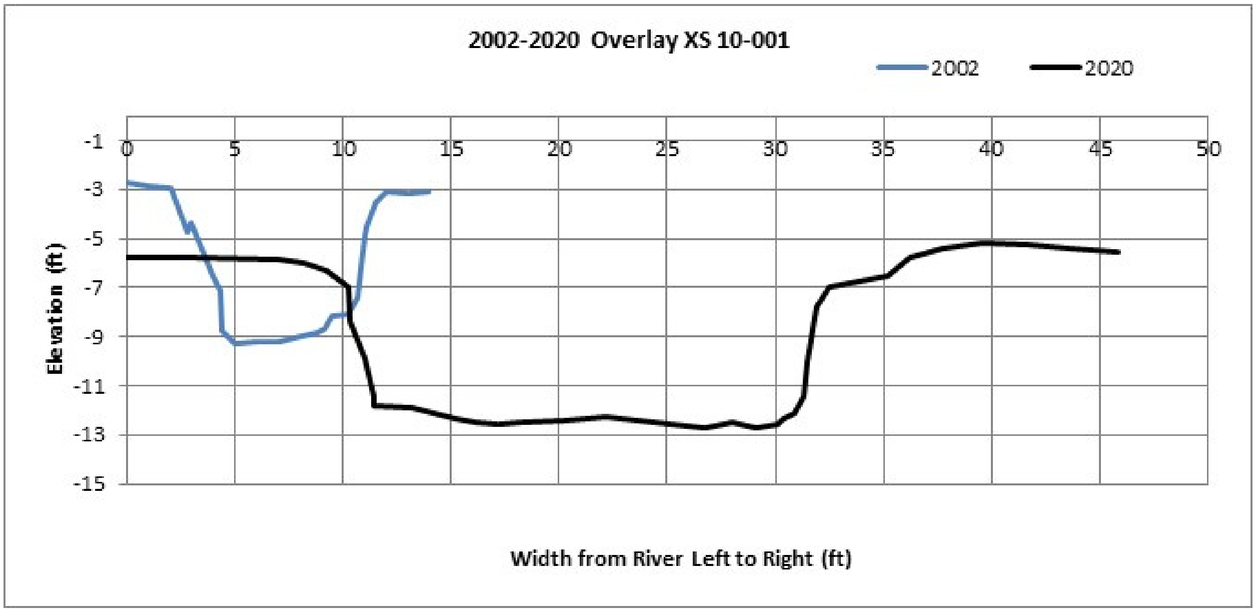


Figure F-4. Change in cross-sections for 10-001 between 2002 and 2020.

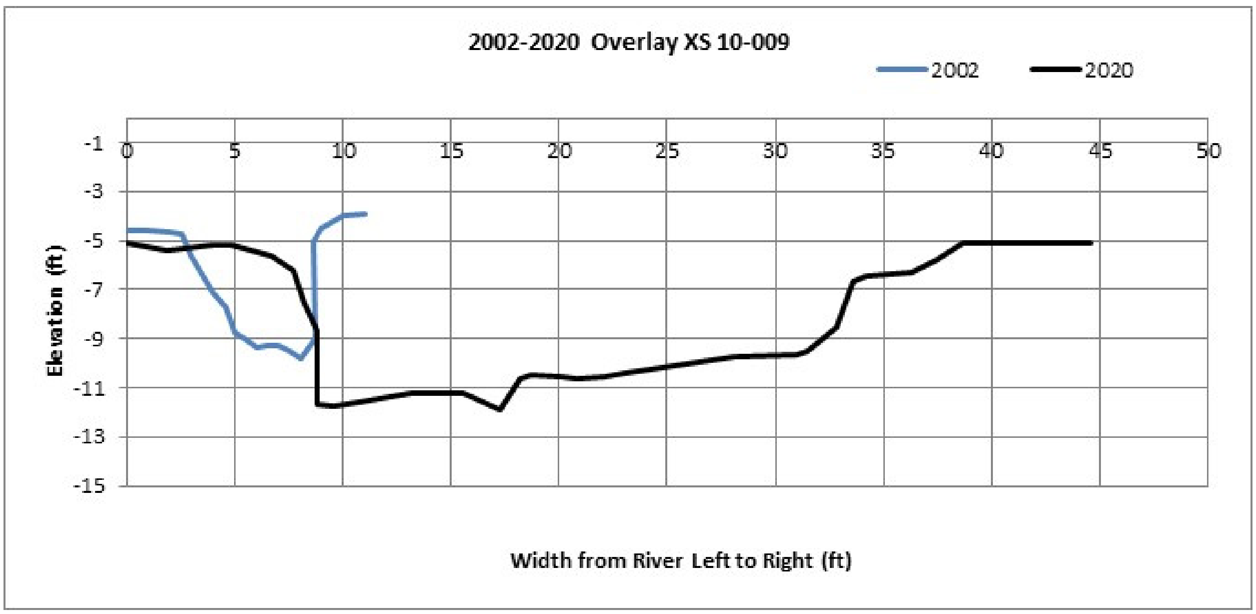


Figure F-5. Change in cross-sections for 10-009 between 2002 and 2020.

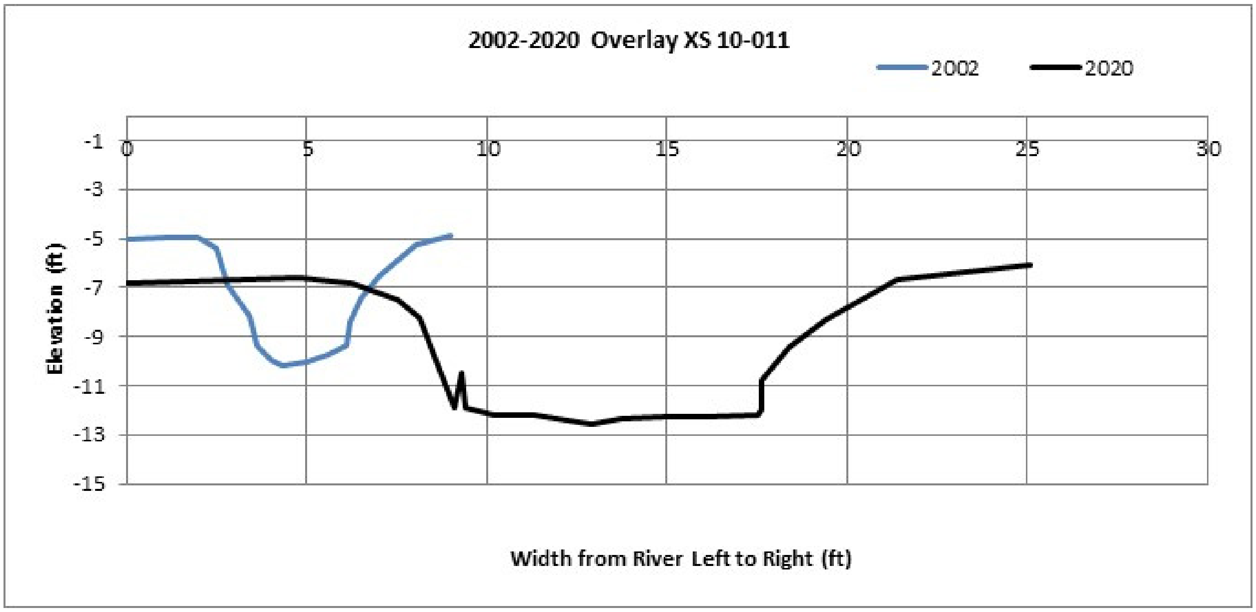


Figure F-6. Change in cross-sections for 10-011 between 2002 and 2020.

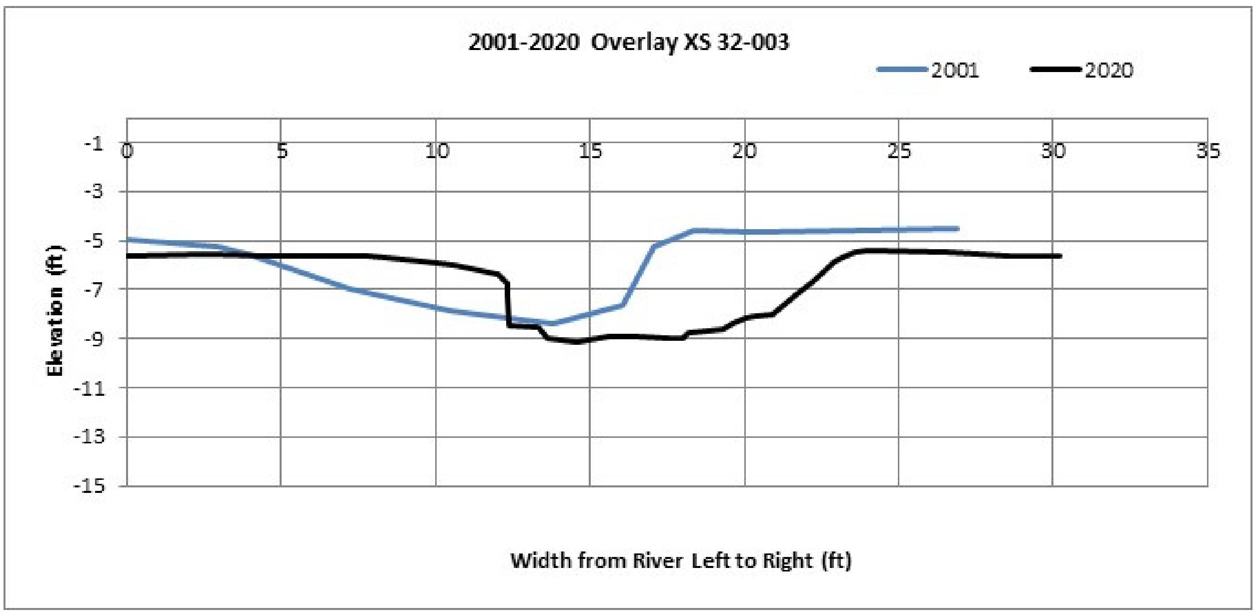


Figure F-7. Change in cross-sections for 32-003 between 2001 and 2020.

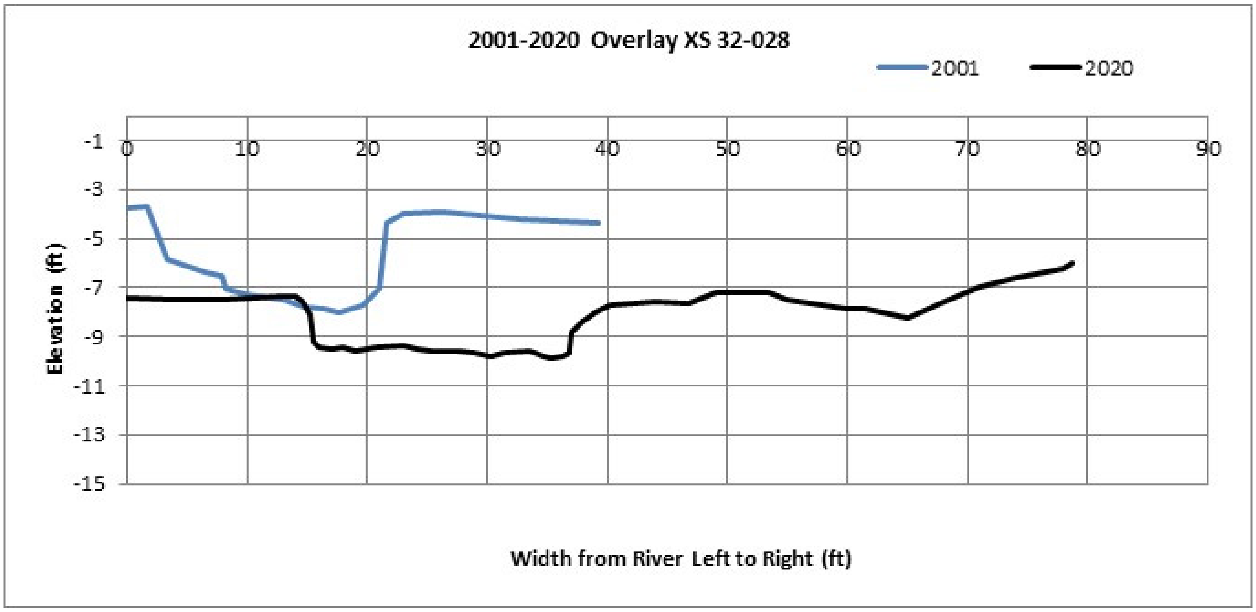


Figure F-8. Change in cross-sections for 32-028 between 2001 and 2020.

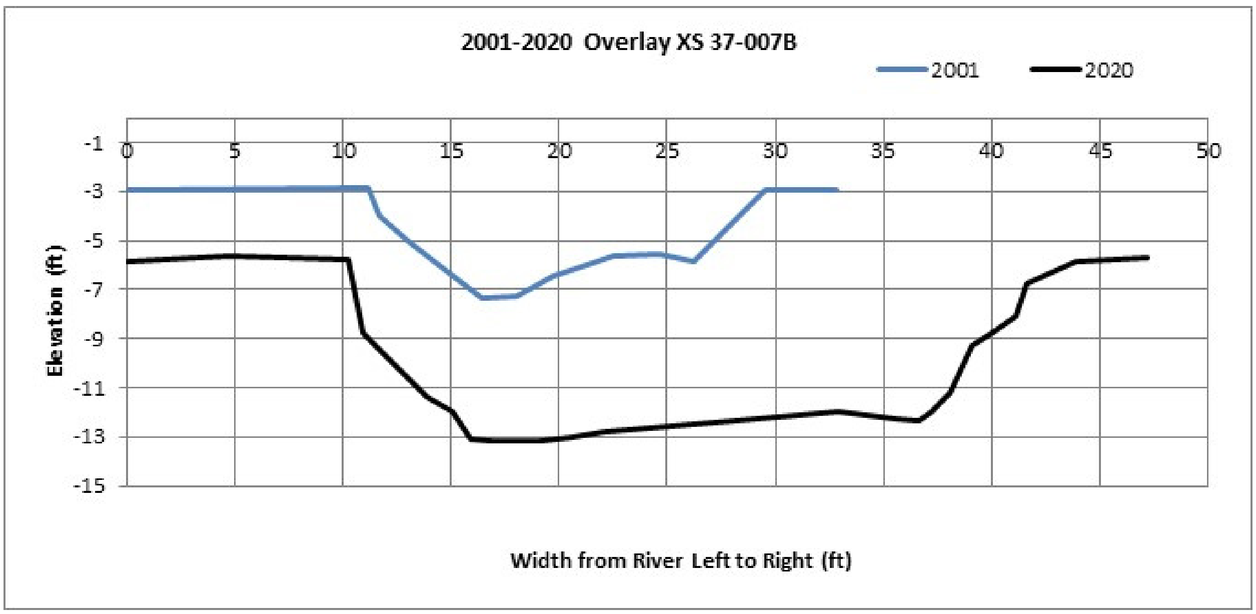


Figure F-9. Change in cross-sections for 37-007B between 2001 and 2020.

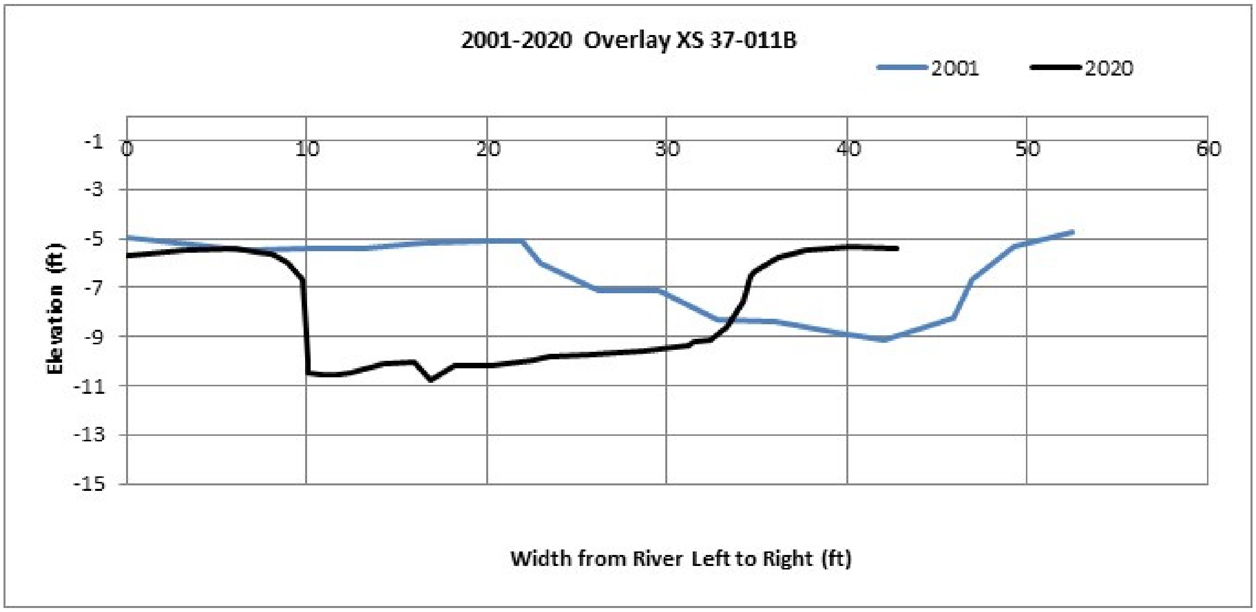


Figure F-10. Change in cross-sections for 37-011B between 2001 and 2020.

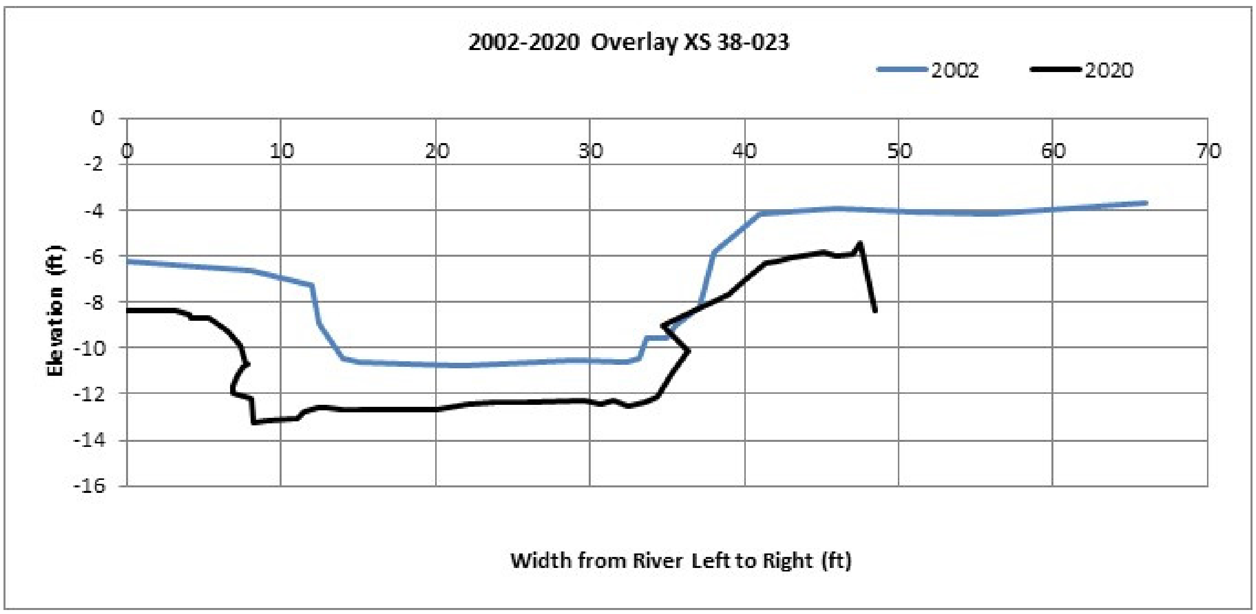


Figure F-11. Change in cross-sections for 38-023 between 2002 and 2020.

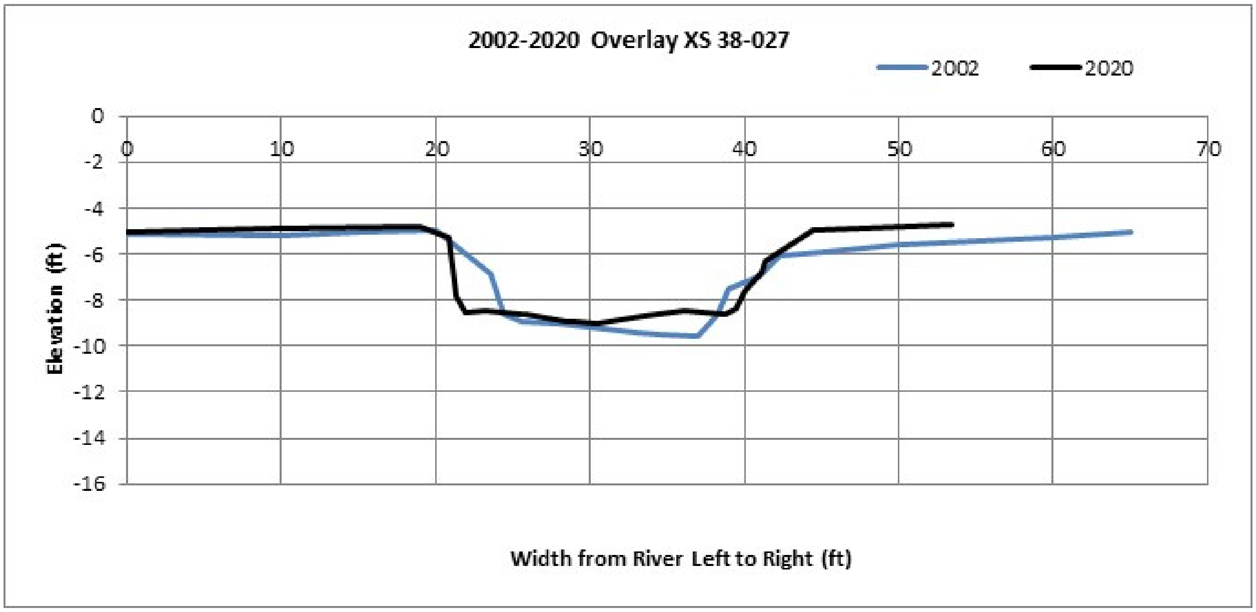


Figure F-12. Change in cross-sections for 38-027 between 2002 and 2020.

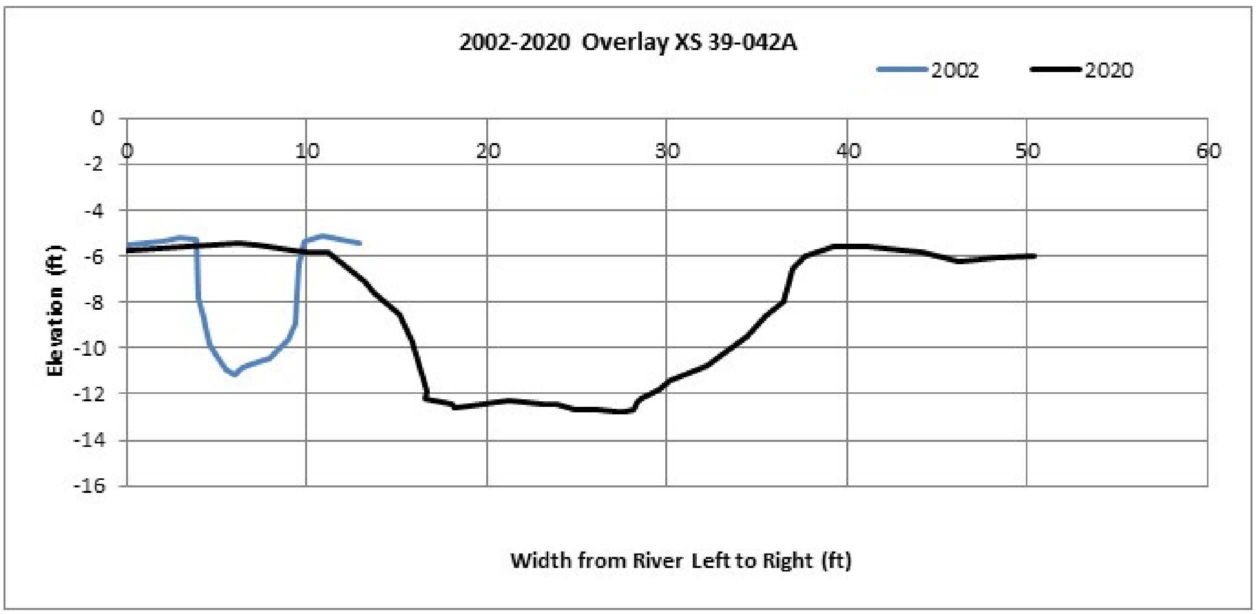


Figure F-13. Change in cross-sections for 39-042A between 2002 and 2020.

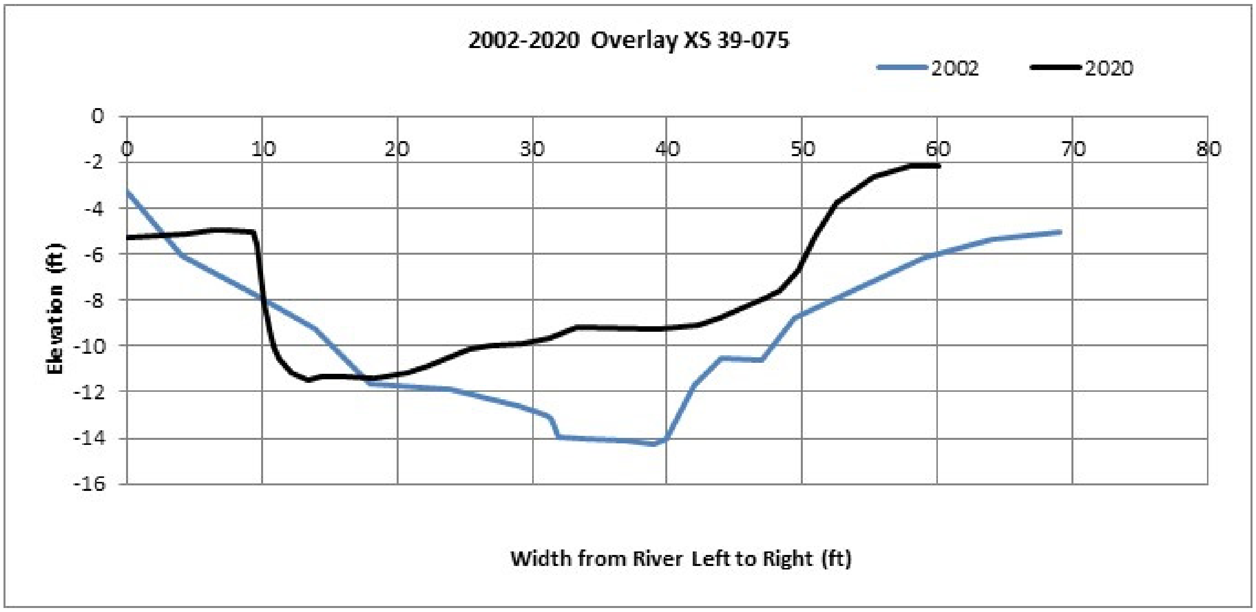


Figure F-14. Change in cross-sections for 39-075 between 2002 and 2020.

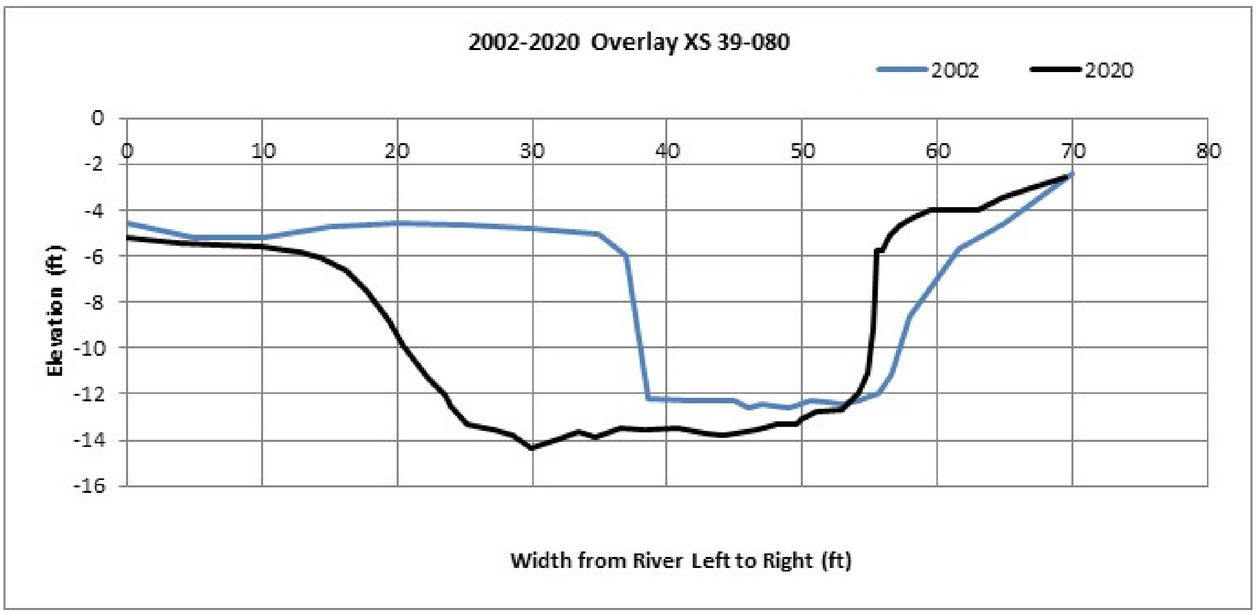


Figure F-15. Change in cross-sections for 39-080 between 2002 and 2020.

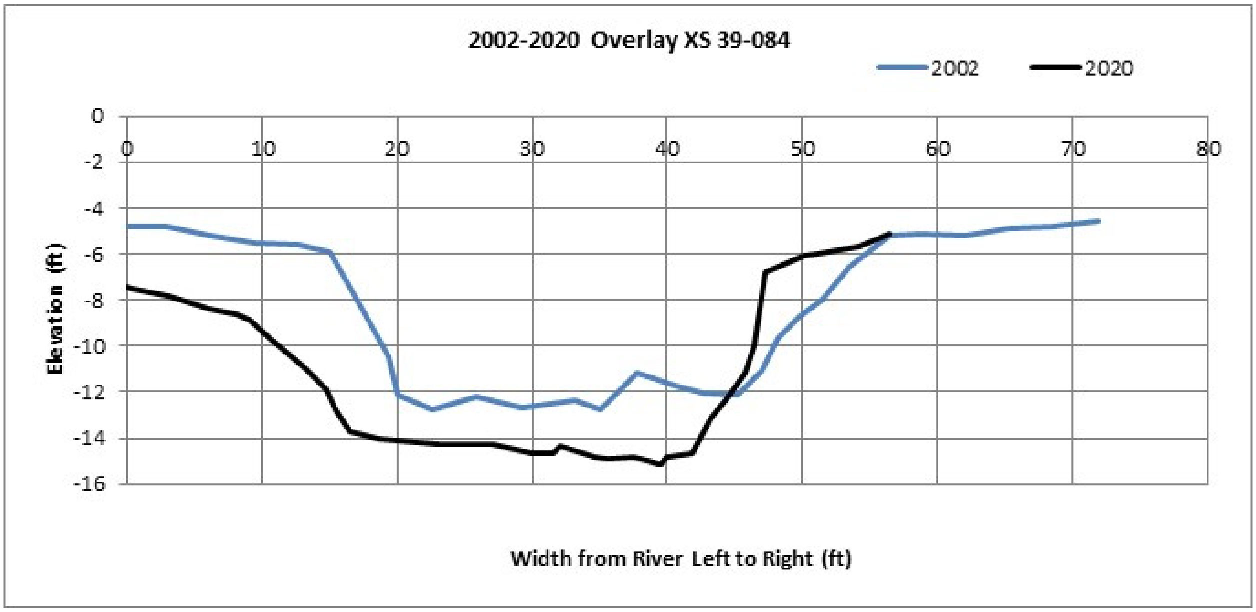


Figure F-16. Change in cross-sections for 39-084 between 2002 and 2020.

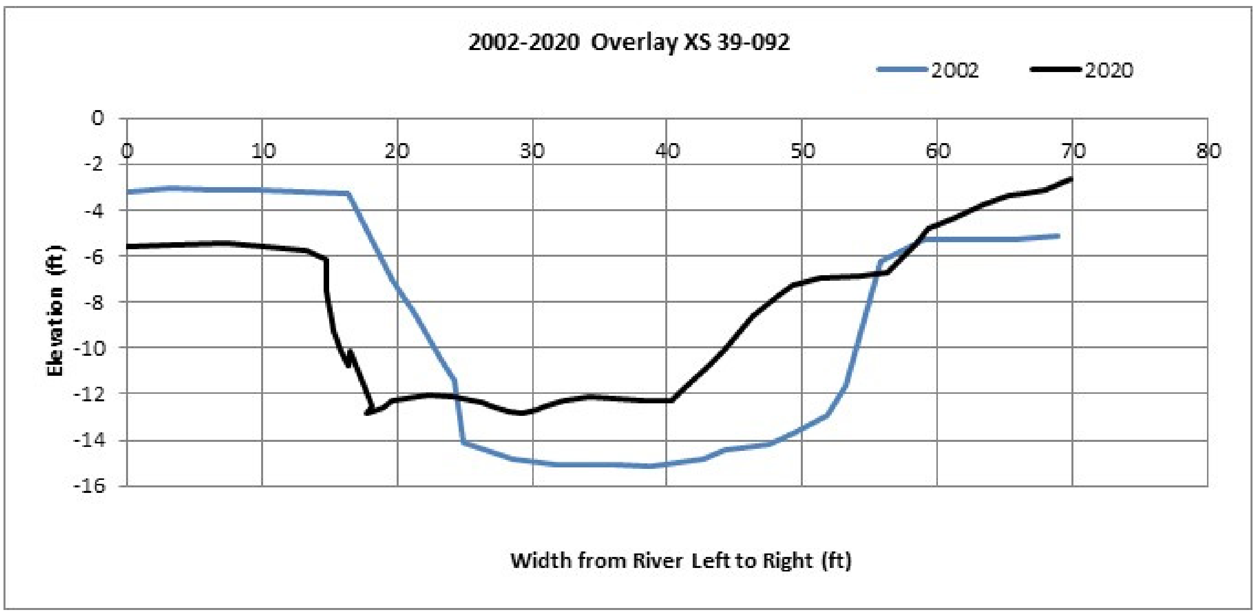


Figure F-17. Change in cross-sections for 39-092 between 2002 and 2020.