FINAL

Total Maximum Daily Load of Sediment in the Non-Tidal Patuxent River Lower Watershed, Anne Arundel, Calvert, Charles, Prince George's and Saint Mary's Counties, Maryland

FINAL

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Submitted to:

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List of Abbreviations

AFO	Animal Feeding Operations
BIBI	Benthic Index of Biotic Integrity
BIP	Buffer Incentive Program
BMP	Best Management Practices
BSID	Biological Stressor Identification
CAFOs	Concentrated Animal Feeding Operations
CBLCD	Chesapeake Bay Land-Cover Dataset
CBP	Chesapeake Bay Program
CBP P4.3	Chesapeake Bay Program Model Phase 4.3
CBP P5.3.2	Chesapeake Bay Program Model Phase 5.3.2
CCAP	Coastal Change Analysis Program
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
COMAR	Code of Maryland Regulations
CV	Coefficient of Variation
CWA	Clean Water Act
DI	Diversity Index
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ESD	Environmental Site Design
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HSPF	Hydrological Simulation Program Fortran
IBI	Index of Biotic Integrity
LA	Load Allocation
m	Meter
m^3/yr	Meters cubed per year
MACS	Maryland Agricultural Water Quality Cost-Share Program
MAL	Minimum Allowable IBI Limit
MBSS	Maryland Biological Stream Survey
MDA	Maryland Department of Agriculture
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
MDP	Maryland Department of Planning
MGD	Millions of Gallons per Day
mg/l	Milligrams per liter
MGS	Maryland Geological Survey
MOS	Margin of Safety

MRLC	Multi-Resolution Land Characteristics
MS4	Municipal Separate Storm Sewer System
NLCD	National Land-Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRI	Natural Resources Inventory
PSU	Primary Sampling Unit
SCS	Soil Conservation Service
SDF	Sediment Delivery Factor
SHA	State Highway Administration
TMDL	Total Maximum Daily Load
ton/acre/yr	Tons per acre per year
ton/day	Tons per day
ton/yr	Tons per year
TSD	Technical Support Document
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
WIP	Watershed Implementation Plan
WLA	Waste Load Allocation
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2012b). This document, upon approval by USEPA, establishes a Total Maximum Daily Load (TMDL) for sediment/total suspended solids (TSS) in the non-tidal Maryland 8-Digit Patuxent River Lower watershed (2016 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02131101). In this TMDL report, the terms total suspended solids (TSS) and sediment may be used interchangeably.

The Patuxent River Lower watershed is associated with five assessment units in Maryland's Integrated Report: a non-tidal 8-digit watershed (02131101) and four estuary portions – the Upper Patuxent Tidal Fresh (PAXTF), Lower Patuxent River Mesohaline (PAXMH), Middle Patuxent River Oligohaline (PAXOH), and Lower Chesapeake Bay Mesohaline (CB5MH-MD) segments. This TMDL only addresses sediment loads in the non-tidal 8-digit portion of the watershed. Therefore, upstream loads from the Patuxent River Middle watershed are not included in this TMDL because they discharge directly into the tidal mainstem Patuxent River and do not impact the non-tidal portion of the watershed. Sediment TMDLs for the tidal estuaries were established as part of the Chesapeake Bay TMDLs in 2010. Background information on the tidal portion of the watershed is presented for informational purposes only.

The Maryland Department of the Environment (MDE) identified the waters of the Patuxent River Lower watershed and associated assessment units on the State's 2016 Integrated Report as impaired by multiple pollutants (MDE 2016). Table ES-1 identifies Integrated Report listings associated with this watershed. A data solicitation for TSS was conducted by MDE in March 2016, and all readily available data has been considered.

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Patuxent River Lower watershed's non-tidal tributaries are designated as Use Class I- *water contact recreation and protection of aquatic life.* Tidal tributaries and the Patuxent River Lower mainstem are designated Use Class II - *support of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2016a, b, c).

The non-tidal Patuxent River Lower watershed was originally listed for biological impairment on the 2002 Integrated Report. The listing was based on the biological assessment methodology, which uses aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI). These indices indicated that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions (MDE 2002).

Table ES-1: Patuxent River Lower 2016 Integrated Report Listings

Watershed	Basin Code	Non-tidal/ Tidal	Designated Use Class	Year Listed	Identified Pollutant	Listing Category
Patuxent River Lower	02131101	Non-Tidal	I – Aquatic Life and Wildlife	2014	TSS	5
Lake Lariat			II – Fishing	2002	Mercury in Fish Tissue	4a
Patuxent River Lower	02131101	Tidal	II – Aquatic Life and Wildlife	-	Chlorpyrifos	2
			II – Fishing	-	Mercury in Fish Tissue	2
Middle Patuxent River Oligohaline	PAXOH	Tidal		2008	PCB in Fish Tissue	5
			II – Shellfishing	2012	Fecal Coliform	5
			II – Aquatic Life and Wildlife	2010	Impacts to Estuarine Biological Communities	5
			II – Open-Water Fish and Shellfish subcategory	1996	Total Nitrogen	4a
					Total Phosphorus	
			II – Seasonal Migratory Fish Spawning and Nursery Subcategory	2012	Total Nitrogen	
					Total Phosphorus	
			II – Seasonal Shallow-Water Submerged Aquatic Vegetation Subcategory	2010	TSS	

Table ES-1: Patuxent River Lower 2016 Integrated Report Listings, cont.

Watershed	Basin Code	Non-tidal/ Tidal	Designated Use Class	Year Listed	Identified Pollutant	Listing Category
Lower Patuxent River Mesohaline	PAXMH	Tidal	Fishing	2008	PCBs	5
			II – Seasonal Deep-Water Fish and Shellfish subcategory	1996	Total Nitrogen	4a
				1996	Total Phosphorus	
			II – Open-Water Fish and Shellfish subcategory	1996	Total Nitrogen	
				1996	Total Phosphorus	
			II – Seasonal Migratory Fish Spawning and Nursery Subcategory	2012	Total Nitrogen	
				2012	Total Phosphorus	
			II – Seasonal Shallow-Water Submerged Aquatic Vegetation Subcategory	1996	TSS	
			II – Aquatic Life and Wildlife	2006	Impacts to Estuarine Biological Communities	5
Ramsey Creek				2002	Oil-Spill-PAHs	4b
Swanson Creek						
Indian Creek						
Trent Hall Creek						
Persimmons Creek						
Washington Creek				-		2
Cremona Creek						
Buzzard Island Creek			II – Shellfishing	2012	Fecal Coliform	5
Cuckold Creek				1996		
Battle Creek 2				2010		
Battle Creek 3				2014		
Hog Neck Creek						
Battle Creek				-		2
Washington-Persimmon Creek				1998		4a
Mill Creek						
Trent Hall Creek				1998		
Solomons Island Harbor				1998		
St. Thomas Creek				1998		
Town Creek						
Island Creek				2012		
Indian Creek				2012		
Golden Beach Community			Water Contact Sports	-	Enterococcus	2
Golden Beach Community – Boat Ramp						

Table ES-1: Patuxent River Lower 2016 Integrated Report Listings, cont.

Watershed	Basin Code	Non-tidal/ Tidal	Designated Use Class	Year Listed	Identified Pollutant	Listing Category
Lower Chesapeake Bay Mesohaline	CB5MH	Tidal	Aquatic Life and Wildlife	2006	Impacts to Estuarine Biological Communities	5
			Seasonal Deep-Channel Refuge Use	1996	Total Phosphorus	4a
					Total Nitrogen	
			Seasonal Deep-Water Fish and Shellfish subcategory		Total Nitrogen	
					Total Phosphorus	
			Open-Water Fish and Shellfish subcategory		Total Nitrogen	
					Total Phosphorus	
			Seasonal Shallow-Water Submerged Aquatic Vegetation Subcategory	2008	TSS	
St. Jeromes Creek	CB5MH	Tidal	II – Shellfishing	2010	Fecal Coliform	5
Goose Creek				1998		4a
Harper Pearson Creeks				1998		

Note:

- Category 2 indicates the waterbody is meeting water quality standards for the identified substance
- Category 3 indicates insufficient data to make a listing category determination
- Category 4a indicates a TMDL has been completed and approved by EPA
- Category 4c indicates the cause of the impairment is pollution and not a pollutant
- Category 5 indicates that the waterbody is impaired and a TMDL or water quality analysis (WQA) is needed.

In order to determine what stressor or stressors are impacting aquatic life, MDE’s *Biological Stressor Identification* (BSID) methodology was applied. The BSID analysis for the Patuxent River Lower watershed identified sediment and instream habitat parameters as impairing the watershed. The sediment parameter shows significant association with degraded biological conditions due to marginal to poor epifaunal substrate. Additionally, the instream habitat parameter shows significant association with degraded biological conditions due to marginal to poor and poor instream habitat, marginal to poor and poor pool/glide/eddy quality, and marginal to poor velocity/depth diversity. Further details of this analysis are presented in the 2013 document entitled, *Watershed Report for Biological Impairment of the Non-Tidal Patuxent River Lower Watershed in Anne Arundel, Prince George’s, Calvert, Charles, and Saint Mary’s Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation* (MDE 2013).

As a result of the BSID analysis, the non-tidal MD 8-digit Patuxent River Lower watershed was listed on the 2016 Integrated Report as impaired by TSS and requiring a TMDL. The TMDL will apply only to the non-tidal portion of the watershed. For simplicity, further reference in this document to Patuxent River Lower Watershed will refer only to the non-tidal MD 8-digit watershed.

The objective of this TMDL is to ensure that watershed sediment loads are at a level that supports the Use Class I designations for the Patuxent River Lower watershed. The TMDL will address water clarity problems and associated impacts to aquatic life in the Patuxent River Lower watershed caused by high sediment and TSS concentrations. Separate sediment TMDLs were developed for the Use Class II impairments as part of the Chesapeake Bay TMDLs in 2010.

The CWA requires TMDLs to be protective of all the designated uses applicable to a particular waterbody. The primary focus of this TMDL is the designated use of protection of aquatic life because the Integrated Report listing was based on a biological assessment of the watershed. The biological assessment revealed the current levels of TSS and other pollutants prevent the watershed from achieving its designated use of supporting aquatic life. The required reductions within the TMDL are expected to protect all designated uses of the watershed from sediment impacts, including water contact recreation. Aquatic life is more sensitive to sediment impacts than recreation because of continuous exposure that can affect respiration and propagation. Recreation, on the other hand, is sporadic and sediment is unlikely to pose a human health risk due to dermal contact or minimal ingestion that would occur during recreation.

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of non-tidal stream systems. In order to quantify this impact, a reference watershed TMDL approach was used, which resulted in the establishment of a *sediment loading threshold* (MDE 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland’s biological assessment methodology (Roth *et al*. 1998, 2000; Stribling *et al.* 1998; MDE 2014a). This threshold is then used to determine watershed specific sediment TMDL endpoint. The resulting loads are considered the maximum allowable loads the waterbody can receive without causing any sediment related impacts to aquatic health.

In order to use a reference watershed approach, sediment loads are estimated using a watershed model. For this analysis, the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) watershed model was chosen and specifically, the *edge-of-stream* (EOS) land-use sediment loads were used. The CBP P5.3.2 model was appropriate for this TMDL because the spatial domain of the model segmentation aggregates to the MD 8-digit watershed scale, which is consistent with the impairment listing.

USEPA’s regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2012b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time (i.e., captures the impacts of both high and low flow events). Thus, critical conditions are inherently addressed. Seasonality is captured in several components. First, it is implicitly included in biological sampling as biological communities reflect the impacts of stressors over time, as described above. Second, the Maryland Biological Stream Survey (MBSS) dataset, which serves as the primary dataset for calculating the biological metrics of the watershed (i.e., BIBI and FIBI scores), included benthic sampling in the spring and fish sampling in the summer. Moreover, the sediment loading rates used in the TMDL were determined using the CBP P5.3.2 model, which is a continuous simulation model with a simulation period 1991-2000, based on Hydrological Simulation Program Fortran (HSPF) model, thereby addressing annual changes in hydrology and capturing wet, average, and dry years.

All TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources generated within the assessment unit, accounting for natural background, tributary and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2012a,b). The estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty, and therefore the MOS is implicitly included. Because the sediment loading threshold was conservatively based on the median (50^{th} percentile) sediment loading rates from reference watersheds, Maryland has adopted an implicit MOS for sediment TMDLs.

The Patuxent River Lower watershed total baseline sediment load is 15,007 tons per year (ton/yr). The Patuxent River Lower Watershed Baseline Load Contribution is further subdivided into nonpoint source baseline loads (Nonpoint Source BL_{PRL}) and two types of point source baseline loads: National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{PRL}) and regulated process water (Process Water BL_{PRL}) (see Table ES-2).

Table ES-2: Patuxent River Lower Watershed Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{PRL}	+	NPDES Stormwater BL_{PRL}	+	Wastewater BL_{PRL}
15,007	=	13,650	+	1,355	+	2

The Patuxent River Lower Watershed average annual TMDL of TSS is 9,318 ton/yr (a 38% reduction from the baseline load). The Patuxent River Lower Watershed TMDL Contribution is further subdivided into point and nonpoint source allocations and is comprised of a Load Allocation (LA_{PRL}) of 8,258 ton/yr, an NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{PRL}) of 1,058 tons/yr, and a Wastewater Waste Load Allocation (Wastewater WLA_{PRL}) of 2 ton/yr (see Table ES-3).

Table ES-3: Patuxent River Lower Watershed Average Annual TMDL of Sediment (ton/yr)

TMDL (ton/yr)	=	LA_{PRL}	+	NPDES Stormwater WLA_{PRL}	+	Wastewater WLA_{PRL}	+	MOS
9,318	=	8,258	+	1,058	+	2	+	Implicit

Table ES-4: Patuxent River Lower Watershed Baseline Load, TMDL, and Total Reduction Percentage

Baseline Load (ton/yr)	TMDL (ton/yr)	Total Reduction (%)
15,007	9,318	38

In addition to the TMDL value, a Maximum Daily Load (MDL) is also presented in this document. The calculation of the MDL, which is derived from the TMDL average annual loads, is explained in Appendix B and presented in Table B-1.

While this TMDL establishes a sediment loading target for the watershed, watershed managers and other stakeholders should always remain cognizant that the endpoint of this TMDL, and hence the definition of its successful implementation, is based on in-stream biological health. Load reductions are critical to tracking this effort, since the TMDL target is defined as the point where sediment loads match those seen in reference watersheds, but the watershed cannot be delisted or classified as meeting water quality standards until it is demonstrated that the biological health of the stream system is no longer impaired by sediment. In planning any implementation efforts related to this TMDL, careful consideration should be given both to the sediment load reductions, and to their direct potential impacts on biological communities.

Section 303(d) of the CWA and current USEPA regulations require reasonable assurance that the TMDL can and will be implemented. Once USEPA has approved this TMDL and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. The Patuxent River Lower Sediment TMDL is expected to be implemented as part of a staged process. MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact to water quality, with consideration given to cost of implementation.

Implementation of the Patuxent River Lower Watershed Sediment TMDL is expected to occur in conjunction with implementation efforts to meet sediment target loads consistent with the Chesapeake Bay TMDLs. The Chesapeake Bay TMDLs were established by USEPA and are scheduled for full implementation by 2025 (USEPA 2010a). These TMDLs require reductions of nitrogen, phosphorus, and sediment loads throughout the

Bay watershed to meet water quality standards that protect the designated uses in the Bay and its tidal tributaries.

In addition, MDE published the Final Determinations to Issue Stormwater Permits to Anne Arundel, Charles, and Prince George's Counties in 2014. The permits state, *"By regulation at 40 CFR §122.44, BMPs and programs implemented pursuant to this permit must be consistent with applicable WLAs developed under [US]EPA approved TMDLs."* For TMDLs approved after the permit, implementation plans are due within one year of USEPA approval of the TMDL. Many of the practices which are described in the permittees' stormwater WLA implementation plans may also be used by the permittees as retrofits for meeting their impervious area restoration requirements (20% retrofit per five-year permit cycle) (MDE 2014b, 2014c, and 2014d).

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2012b). This document, upon approval by the USEPA, establishes a Total Maximum Daily Load (TMDL) for sediment in the non-tidal Maryland 8-Digit Patuxent River Lower watershed (2014 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02131101). In this TMDL report, the terms total suspended solids (TSS) and sediment may be used interchangeably.

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, protection of aquatic life, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Patuxent River Lower watershed is associated with five assessment units in Maryland's Integrated Report: a non-tidal 8-digit watershed (02131101) and four estuary portions – Upper Patuxent Tidal Fresh (PAXTF) Lower Patuxent River Mesohaline (PAXMH), Middle Patuxent River Oligohaline (PAXOH), and Lower Chesapeake Bay Mesohaline (CB5MH-MD) segments. This TMDL only addresses the non-tidal portion of the watershed. Sediment TMDLs for the tidal estuaries were established as part of the Chesapeake Bay TMDLs in 2010. Background information on the tidal portions of the watershed is presented for informational purposes only.

The Maryland Department of the Environment (MDE) identified the waters of the Patuxent River Lower watershed and associated assessment units on the State's 2016 Integrated Report as impaired by multiple pollutants (MDE 2016). Table 1 identifies Integrated Report listings associated with this watershed.

A data solicitation for TSS was conducted by MDE in March 2016, and all readily available data have been considered.

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St. Jeromes Creek	CB5MH	Tidal	II – Shellfishing	2010	Fecal Coliform	5
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Harper Pearson Creeks				1998		

Note:
- Category 2 indicates the waterbody is meeting water quality standards for the identified substance
- Category 3 indicates insufficient data to make a listing category determination
- Category 4a indicates a TMDL has been completed and approved by EPA
- Category 4c indicates the cause of the impairment is pollution and not a pollutant
- Category 5 indicates that the waterbody is impaired and a TMDL or water quality analysis (WQA) is needed.

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Patuxent River Lower watershed's nontidal tributaries are designated as Use Class I - *water contact recreation, protection of aquatic life.* Tidal tributaries and the Patuxent River Lower mainstem are designated Use Class II - *support of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2016a, b, c). A map of the Designated Use Classes is provided in Figure 1.

The non-tidal Patuxent River Lower watershed was originally listed for biological impairment on the 2002 Integrated Report. The listing was based on the biological assessment methodology, which uses aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI). These indices indicated that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions (MDE 2002).

In order to determine what stressor or stressors are impacting aquatic life, MDE's *Biological Stressor Identification* (BSID) methodology was applied. The BSID analysis for the Patuxent River Lower watershed identified Sediment and instream habitat parameters as impairing the watershed. The Sediment parameter shows significant association with degraded biological conditions due to marginal to poor epifaunal substrate. The instream habitat parameter shows significant association with degraded biological conditions due to marginal to poor and poor instream habitat and pool/glide/eddy quality and marginal to poor velocity/depth diversity. Further details of this analysis are presented in the 2013 document entitled, *Watershed Report for Biological Impairment of the Non-Tidal Patuxent River Lower Watershed in Anne Arundel, Prince George's, Calvert, Charles, and Saint Mary's Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation* (MDE 2013).

The objective of this TMDL is to ensure that watershed sediment loads are at a level that supports the Use Class I designation for the Patuxent River Lower watershed. The TMDL will address water clarity problems and associated impacts to aquatic life in the non-tidal Patuxent River Lower watershed caused by high sediment and TSS concentrations.

The CWA requires TMDLs to be protective of all the designated uses applicable to a particular waterbody. The primary focus of this TMDL is the designated use of protection of aquatic life because the Integrated Report listing was based on a biological assessment of the watershed. The biological assessment revealed the current levels of TSS and other pollutants prevent the watershed from achieving its designated use of supporting aquatic life. The required reductions within the TMDL are expected to protect all designated uses of the watershed from sediment impacts, including water contact recreation. Aquatic life is more sensitive to sediment impacts than recreation because of continuous exposure that can affect respiration and propagation. Recreation, on the other hand, is sporadic and sediment is unlikely to pose a human health risk due to dermal contact or minimal ingestion that would occur during recreation.

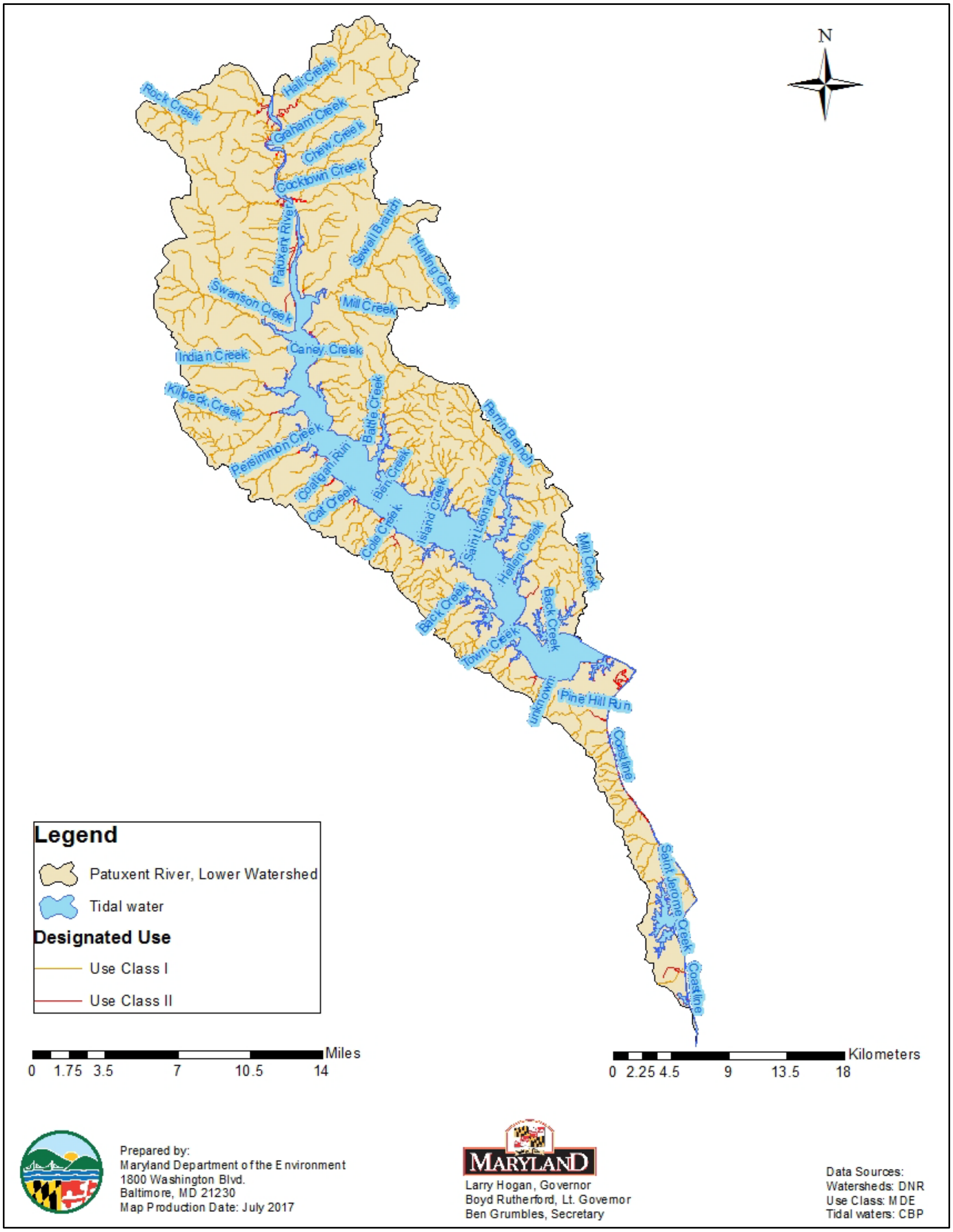

Figure 1: Designated Use Classes of the Patuxent River Lower Watershed

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Patuxent River is the largest river completely located in Maryland, and the basin lies between two large metropolitan areas – Baltimore, Maryland and Washington, D.C. The Patuxent River is comprised of eight separate MD 8-digit watersheds. The Patuxent River Lower watershed is located in Anne Arundel, Calvert, Charles, Prince George's, and St Mary's Counties. The watershed starts at the outlet of the Patuxent River Middle watershed, approximately 5 miles north of the town of Lower Marlboro. It encompasses the Patuxent River mainstem and all tributaries until the confluence with the Chesapeake Bay. A considerable portion of the watershed is tidal, and the navigable portion is crossed by two bridges. One bridge is located on RT 231 in the town of Benedict which is approximately the middle of the watershed. The other bridge is located on RT 4 near the confluence of the Patuxent River and the Chesapeake Bay.

According to the Chesapeake Bay Program's Phase 5.3.2 watershed model, the total drainage area of the Maryland 8-digit watershed is approximately 205,500 acres, not including water/wetlands. Approximately 1,800 acres of the watershed area is covered by water. The total population in the Patuxent River Lower watershed is approximately 80,000 (US Census Bureau 2010).

There are five "high quality," or Tier II, stream segments (BIBI and FIBI aquatic life assessment scores > 4 [scale 1-5]) located within the Patuxent River Lower watershed. Tier II segments require the implementation of Maryland's anti-degradation policy (COMAR 2016d; MDE 2011).

Geology/Soils

The Patuxent River Lower watershed is located solely within the Coastal Plain Province of Maryland. The Coastal Plain province is characterized by unconsolidated sediments, which include sand, gravel, silt, and clay. These unconsolidated sediments overlap the rocks of the Piedmont Plateau along the fall line that separates these two geologic provinces. The sediments of the coastal plain dip toward the east at a very low angle of 3 degrees, and some of the younger formations in the province crop out to the surface with increasing frequency in a southeasterly direction. The majority of the province, however, consists of older formations, which are covered by a thin layer of Quaternary Gravel (MGS 2012). The two predominant soil types in the Patuxent River Lower watershed are the Sassafras and Westphalia soil associations. The Sassafras association makes up the majority of the southeastern portion of the Patuxent River Lower watershed, while the Westphalia association makes up the majority of the lower to northwestern portions of the watershed. The Westphalia soil association is characterized by rolling to steep, moderate to well-drained, severely eroded soils, consisting of either a sandy clay loam or fine sandy loam. The Sassafras soil association is characterized by gently sloping to steep, well-drained, moderately to severely eroded soils, consisting of either sandy clay loam or a silt loam. The remaining watershed area is made up of the Othello soil association, which is found predominantly in the northeastern portion [U.S. Department of Agriculture (USDA) 2006].

The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) classifies soils into 4 hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well drained/excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of soils that are moderately deep to deep and moderately well to well drained soils, with moderately fine/coarse textures; Group C soils have slow infiltration rates with a layer that impedes downward water movement, and they primarily have moderately fine-to-fine textures; Group D soils have very slow infiltration rates consisting of clay soils with a permanently high water table that are often shallow over nearly impervious material. The Patuxent River Lower watershed is comprised primarily of Group B soils (53%) and Group C soils (26%), with small portions of the watershed consisting of Group A soils (15%) and Group D soils (6%) (USDA 2006).

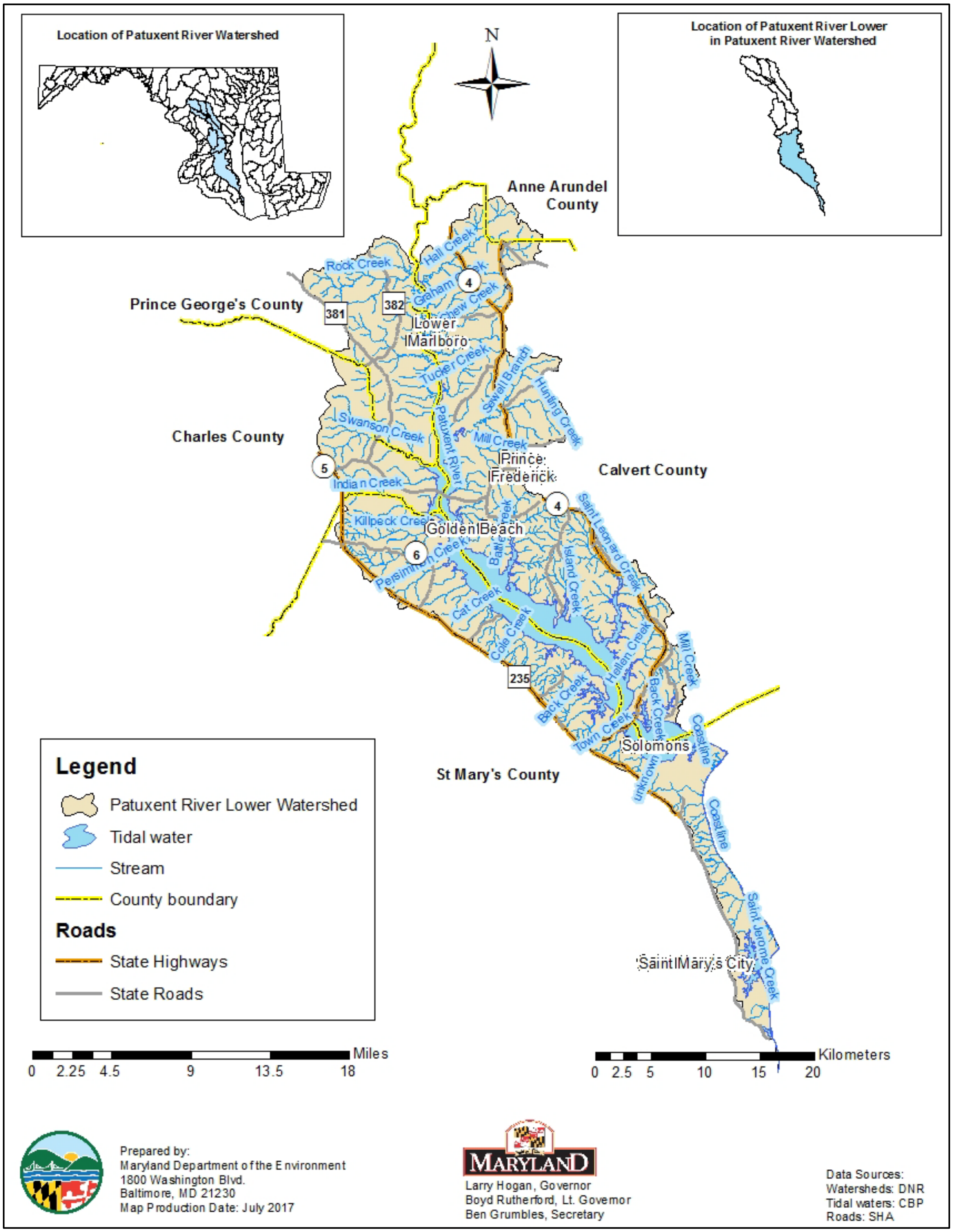

Figure 2: Location Map of the Patuxent River Lower Watershed in Anne Arundel, Calvert, Charles, Prince George's, and Saint Mary's Counties, Maryland

2.1.1 Land-use

Land-use Methodology

The land-use framework used to develop this TMDL was originally developed for the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) Watershed Model. CBP P5.3.2 land-use was based on two distinct stages of development.

The first stage consisted of the development of the Chesapeake Bay Watershed Land-Cover Data (CBLCD) series of Geographic Information System (GIS) datasets. These datasets provide a 30-meter resolution raster representation of land-cover in the Chesapeake Bay watershed, based on sixteen Anderson Level two land-cover classes. The CBLCD basemap, representing 2001 conditions, was primarily derived from the Multi-Resolution Land Characteristics (MRLC) Consortium's National Land-Cover Data (NLCD) and the National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program's (CCAP) Land-Cover Data. By applying Cross Correlation Analysis to Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper satellite imagery, CBLCD datasets for 1984, 1992, and 2006 from the baseline 2001 dataset. The watershed model documentation, *Chesapeake Bay Phase 5.3 Community Watershed Model* (USEPA 2010b), describes the development of the CBLCD series in more detail. USGS and NOAA also developed an impervious cover dataset from Landsat satellite imagery for the CBLCD basemap, which was used to estimate the percent impervious cover associated with CBLCD developed land-cover classifications.

The second stage consisted of using ancillary information for: 1) the creation of a modified 2006 CBLCD raster dataset, and 2) the subsequent development of the CBP P5.3.2 land-use framework in tabular format. Estimates of the urban footprint in the 2006 CBLCD were extensively modified using supplemental datasets. Navteq street data (secondary and primary roads) and institutional delineations were overlaid with the 2006 CBLCD land-cover and used to reclassify underlying pixels. Certain areas adjacent to the secondary road network were also reclassified based on assumptions developed by USGS researchers, in order to capture residential development (*i.e.*, subdivisions not being picked up by the satellite in the CBLCD). In addition to spatially modifying the 2006 CBLCD, the following datasets were used to supplement the developed land cover data in the final CBP P5.3.2 land-use framework: US Census housing unit data, Maryland Department of Planning (MDP) Property View data, and estimates of impervious coefficients for rural residential properties (determined via a sampling of these properties using aerial photography). This additional information was used to estimate the extent of impervious area in roadways and residential lots. Acres of construction and extractive land-uses were determined independently using a method developed by USGS (Claggett, Irani, and Thompson 2012). Finally, in order to develop accurate agricultural land-use acreages, the CBP P5.3.2 land use incorporated county level US Agricultural Census data (USDA 1982, 1987, 1992, 1997, 2002). The watershed model documentation, *Chesapeake Bay Phase 5.3 Community Watershed Model* (USEPA 2010b), describes these modifications in more detail.

The result of these modifications is that CBP P5.3.2 land-use does not exist in a single GIS coverage; instead, it is only available in a tabular format. The CBP P5.3.2 watershed model is comprised of 30 land-uses. The land-uses are divided into 13 classes with distinct sediment erosion rates. Table 2 lists the CBP P5.3.2 generalized land-uses, detailed land-uses, which are classified by their sediment erosion rates, and the acres of each land-use in the Patuxent River Lower watershed. The land-use acreage used to inform this TMDL is based on the CBP P5.3.2 2009 Progress Scenario.

Patuxent River Lower Watershed Land-Use Distribution

The land-use distribution of the Patuxent River Lower watershed consists primarily of forest (65%), urban (20%), and agricultural lands (15%). A detailed summary of the watershed land-use areas is presented in Table 2, and a land-use map is provided in Figure 3.

Table 2: Land-Use Percentage Distribution for the Patuxent River Lower Watershed

General Land Use	Detailed Land-Use	Area (Acres)	Percent (%)	Grouped Percent of Total (%)
Forest	Forest	134,143	64.7	65.3
	Harvested Forest	1,345	0.6	
Pasture	Pasture	5,447	2.6	2.6
Crop	Crop	23,168	11.2	11.2
Nursery	Nursery	128	0.1	0.1
Unregulated urban[1]	Unregulated urban	34,274	16.5	16.5
Regulated Urban[1]	Construction	1,442	0.7	3.4
	Developed	5,149	2.5	
	Extractive	373	0.2	
Water	Water	1,782	0.9	0.9
Total[2]		**207,251**	**100.0**	**100.0**

[1]Unregulated urban land use is not regulated by a Municipal Separate Storm Sewer System (MS4) permit. Regulated urban land use is regulated by an MS4 permit.
[2]Individual values may not add to total load due to rounding.

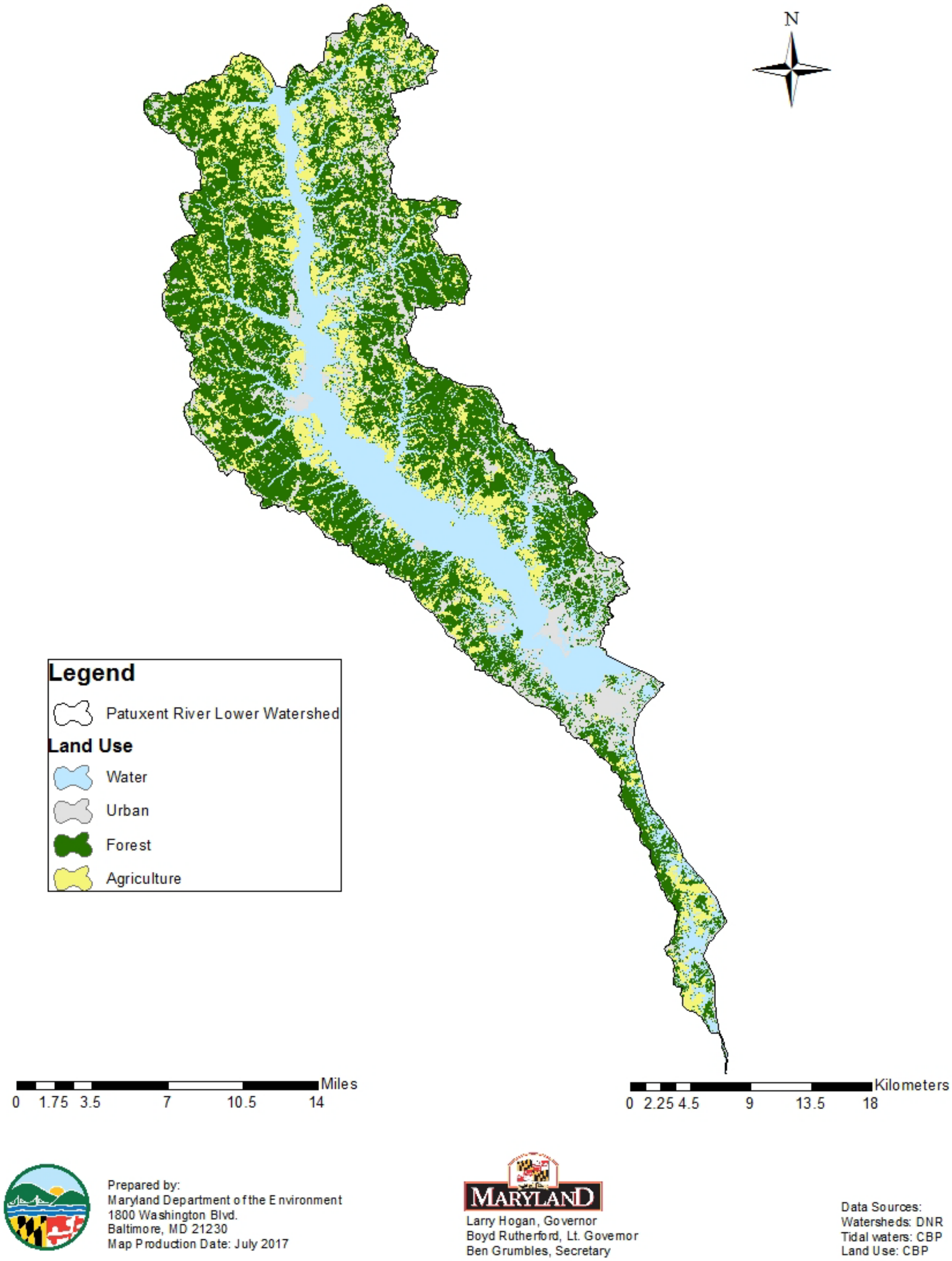

Figure 3: Land-use of the Patuxent River Lower Watershed

2.2 Source Assessment

The Patuxent River Lower watershed baseline load contributions consists of nonpoint sources loads, and point source loads which can be further divided into National Pollutant Discharge Elimination System (NPDES) Stormwater loads, and Wastewater loads. This section summarizes the methods used to derive each of these distinct source categories.

2.2.1 Nonpoint Source Assessment

In this document, the nonpoint source loads account for all sediment loads not covered under a NPDES permit within the Patuxent River Lower watershed. In general, these are rainfall driven land-use based loads from agricultural and forested lands. In this watershed, unregulated urban land use in Calvert and Saint Mary's Counties is also included in the nonpoint source load. Calvert and Saint Mary's Counties are not regulated under an MS4 permit. This section provides the background and methods for determining the nonpoint source baseline loads generated within the Patuxent River Lower watershed (Nonpoint Source BL_{PRL}).

General Load Estimation Methodology

Nonpoint source sediment loads generated within the Patuxent River Lower watershed are estimated based on the *edge-of-stream (EOS)* loads from the CBP P5.3.2 watershed model 2009 Progress Scenario. Within the CBP P5.3.2 watershed model, EOS sediment loads are calculated based on the fact that not all of the *edge-of-field* (EOF) sediment load is delivered to the stream or river (some of it is stored on fields down slope, at the foot of hillsides, or in smaller rivers or streams that are not represented in the model). To calculate the actual EOS loads, a *sediment delivery factor (SDF)* (the ratio of sediment reaching a basin outlet compared to the total erosion within the basin) is used. Details of the methods used to calculate sediment load have been documented in the report entitled *Chesapeake Bay Phase 5 Community Watershed Model* (USEPA 2010b). A summary of the methodology is presented in the following sections.

Edge-of-Field Target Erosion Rate Methodology

Edge-of-field erosion can be defined as erosion or sediment loss from any particular land surface. EOF target erosion rates are the values used in the calibration of the CBP model, based on literature values. EOF target erosion rates for agricultural land-uses and forested land-use were based on erosion rates determined by the Natural Resource Inventory (NRI). NRI is a statistical survey of land-use and natural resource conditions conducted by the Natural Resources Conservation Service (NRCS) (USDA 2006). The sampling methodology is explained by Nusser and Goebel (1997).

Estimates of average annual erosion rates for pasture and cropland are available on a county basis at five-year intervals, starting in 1982. Erosion rates for forested land-uses are not available on a county basis from NRI; however, for the purpose of the Chesapeake Bay Program Phase 4.3 (CBP P4.3) watershed model, NRI calculated average annual erosion rates for forested land-use on a watershed basis. These rates were used as targets in the CBP P5.3.2 model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target rates for pasture and cropland. Rates for urban pervious, urban impervious, extractive, and barren land were based on a combination of best professional judgment, literature analysis, and regression analysis. The EOF erosion rates do not reflect best management practices (BMPs) or other soil conservation policies introduced in the wake of the effort to restore the Chesapeake Bay. To compensate for this, BMPs are applied to the modeled EOS loads in the CBP P5.3.2 2009 Progress Scenario. BMP data, representing BMPs in place in 2009, was collected by the Chesapeake Bay Program (CBP), and TSS reduction efficiencies have been estimated by CBP for specific types of BMPs based on peer reviewed studies, data collected by local jurisdictions, and an analysis of available literature values. For further details regarding EOF erosion rates, please see Section 9.2.1 of the *Chesapeake Bay Phase 5 Community Watershed Model* (USEPA 2010b). Table 3 lists EOF erosion rates specific to Anne Arundel, Calvert, Charles, Prince George's, and Saint Mary's Counties, where the Patuxent River Lower watershed is located.

Table 3: Anne Arundel, Calvert, Charles, St. Mary's and Prince George's Counties Target EOF TSS Loading Rates (ton/acre/yr) by Land-Use

Land-use	Data Source	Anne Arundel County Target EOF TSS Loading rate (ton/acre/yr)	Calvert County Target EOF TSS Loading rate (ton/acre/yr)	Charles County Target EOF TSS Loading rate (ton/acre/yr)	Prince George's County Target EOF TSS Loading rate (ton/acre/yr)	Saint Mary's County Target EOF TSS Loading rate (ton/acre/yr)
Forest	NRI (1987)	0.29	0.30	0.33	0.34	0.33
Harvested Forest	Literature values	3	3	3	3	3
Nursery	Equivalent to conventional till	10.06	22.15	14.41	22.28	7.3
Pasture	NRI average (1982-1987)	0.47	1.15	0.36	2.99	0.28
Animal Feeding Operations	NRI pasture average (1982-1987) multiplied by 9	4.2	10.35	3.24	26.9	2.52
Hay	Adjusted NRI average (1982-1987)	2.58	5.67	3.69	5.7	2.0
Conventional Till	Adjusted NRI average (1982 – 1987)	10.06	22.15	14.41	22.28	7.3
Conservation Till	Adjusted NRI average (1982 – 1987)	6.04	13.29	8.65	13.37	4.7
Pervious Urban	Regression Analysis	0.74	0.74	0.74	0.74	0.74
Extractive	Literature values/best professional judgment	10	10	10	10	10
Barren (Construction)	Literature values	23	23	23	23	23
Impervious Urban	Regression Analysis	5.18	5.18	5.18	5.18	5.18

Edge-of-Stream Sediment Loads

EOS sediment loads are the loads that enter the modeled river reaches. Modeled river reaches are those with discharges of 100 cubic feet per second (cfs) or greater. Exceptions were made for some river reaches that had useful monitoring data but were less than 100 cfs. EOS sediment loads represent not only the erosion from the land but all of the intervening processes of deposition on hillsides and sediment transport through smaller rivers and streams. The influence of the sum of these processes is represented in the estimated SDF.

The formula for the EOS load calculation within the CBP P5.3.2 watershed model is as follows:

$$\sum_{i}^{n} EOS = Acres_i * EOF_i * SDF_i \qquad \text{(Equation 2.1)}$$

where:

n = number of land-use classifications
i = land-use classification
EOS = Edge of stream load, tons per year (ton/yr)
Acres = acreage for land-use i
EOF = Edge-of-field erosion rate for land-use i, ton/acre/yr
SDF = sediment delivery factor for land-use i

2.2.2 Point Source Assessment

A list of active permitted point sources that contribute to the sediment load in the Patuxent River Lower watershed was compiled using best available resources. The types of permits identified were individual municipal permits, individual Municipal Separate Storm Sewer System (MS4) permits, general mining permits, general stormwater permits, and the general permit for stormwater discharges from construction sites. The permits can be grouped into two categories: wastewater and stormwater. The wastewater category includes those loads generated by continuous discharge sources whose permits have TSS limits. Wastewater permits that do not meet these conditions are considered *de minimis* in terms of the total sediment load. The stormwater category includes all NPDES regulated stormwater discharges. The technical memorandum to this document, entitled *Point Sources of Sediment in the Non-Tidal Patuxent River Lower Watershed*, identifies all the wastewater permits and NPDES regulated stormwater discharges that contribute to the sediment load in the Patuxent River Lower watershed.

The baseline sediment loads for the wastewater permits (Wastewater BL_{PRL}) are calculated based on their permitted TSS limits (average monthly or weekly concentration values) and corresponding flow information. The stormwater permits identified throughout the Patuxent River Lower watershed do not include numeric TSS limits. In the absence of TSS limits, the NPDES regulated stormwater baseline load (NPDES Stormwater BL_{PRL}) is calculated using the CBP P5.3.2 Progress Scenario urban land-use EOS loads (as per Equation 2.1) similar to the approach for NPS loads outlined in Section 2.1. The technical memorandum to this document entitled *Point Sources of Sediment in the Non-Tidal Patuxent River Lower Watershed* provides detailed information regarding the calculation of the Patuxent River Lower watershed Wastewater BL_{PRL} and NPDES Stormwater BL_{PRL}.

2.2.3 Urban Land Use in Calvert and St Mary's Counties

As discussed in Section 2.2.2, all urban land covered by a NPDES MS4 permit is considered to be a stormwater point source. Currently, Calvert and Saint Mary's Counties are not covered by NPDES MS4 permits and therefore loads from urban land use in these counties are included in the nonpoint source load. However, in December 2016, the Maryland Department of the Environment reached a tentative determination to issue a NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (General Discharge Permit No. 13-IM-5500, General NPDES No. MDR055500). Portions of Calvert and Saint Mary's Counties will be included in the updated permit, and once the permit is approved, these urban lands will become part of the stormwater point source load. A full analysis of the impact of the approved permit appears in Appendix C.

2.2.4 Summary of Baseline Loads

Table 4 summarizes the Patuxent River Lower Baseline Sediment Load, reported in tons per year (ton/yr) and presented in terms of Nonpoint Source Baseline Loads and NPDES Stormwater and Wastewater Baseline Loads.

Table 4: Patuxent River Lower Watershed Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	**Nonpoint Source BL_{PRL}**	+	**NPDES Stormwater BL_{PRL}**	+	**Wastewater BL_{PRL}**
15,007	=	13,650	+	1,355	+	2

Table 5 presents a breakdown of Patuxent River Lower Watershed Total Baseline Sediment Load, detailing loads per land-use or other source category.

Table 5: Detailed Baseline Sediment Loads Generated Within the Patuxent River Lower Watershed

General Land Use	Detailed Land-Use	Tons	Percent (%)	Grouped Percent of Total (%)
Forest	Forest	1,544	10.3	10.9
	Harvested Forest	85	0.6	
AFOs	Animal Feeding Operations	26	0.2	0.2
Pasture	Pasture	235	1.6	1.6
Crop	Crop	9,380	62.5	62.5
Nursery	Nursery	115	0.8	0.8
Unregulated Urban[1]	Unregulated Urban	2,265	15.1	15.1
Regulated Urban[1]	Construction	990	6.6	9.0
	Developed	256	1.7	
	Extractive	109	0.7	
Point Sources	Industrial Point Sources	1	0.0	0.0
	Municipal Point Sources	1	0.0	
Total[2]		**15,007**	**100.0**	**100.0**

[1]Unregulated urban land use is not regulated by a Municipal Separate Storm Sewer System (MS4) permit. Regulated urban land use is regulated by a MS4 permit.
[2]Individual values may not add to total load due to rounding.

2.3 Water Quality Characterization

The non-tidal Patuxent River Lower watershed was originally listed for impacts to biological communities in the 2002 Integrated Report. To refine the listing for impacts to biological communities, Maryland conducted a stressor identification analysis. Details of this analysis are presented below and in the document entitled, *Watershed Report for Biological Impairment of the Patuxent River Lower Watershed in Anne Arundel, Calvert, Charles, Prince George's, and Saint Mary's Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation* (MDE 2013).

Currently in Maryland, there are no specific numeric criteria for suspended sediments. Therefore, to determine whether aquatic life is impacted by elevated sediment loads, MDE's BSID methodology was applied. The primary goal of the BSID analysis is to identify the most probable cause(s) for observed biological impairments throughout MD's 8-digit watersheds (MDE 2009).

The BSID analysis applies a case-control, risk-based, weight-of-evidence approach to identify potential causes of biological impairment. The risk-based approach estimates the strength of association between various stressors and an impaired biological community. The BSID analysis then identifies individual stressors as probable or unlikely causes of the poor biological conditions within a given watershed, and subsequently reviews ecological plausibility. Finally, the analysis concludes whether or not these individual stressors or groups of stressors are contributing to the impairment (MDE 2009).

The primary dataset for BSID analysis includes MDDNR-MBSS Round 2 and Round 3 data (collected between 2000-2009) because it provides a broad spectrum of paired data variables, which allow for a more comprehensive stressor analysis. MDDNR-MBSS Round 1 can also be used if there is limited Round 2 and 3 data. The MBSS is a robust statewide probability-based sampling survey for assessing the biological conditions of 1st through 4th order, non-tidal streams (Klauda *et al*. 1998; Roth *et al.* 2005). It uses a fixed length (75 meter) randomly selected stream segment for collecting site level information within a primary sampling unit (PSU), also defined as a watershed. The randomly selected stream segments, from which field data are collected, are selected using either stratified random sampling with proportional allocation, or simple random sampling (Cochran 1977). The random sample design allows for unbiased estimates of overall watershed conditions. Thus, the dataset facilitated case-control analyses because: 1) in-stream biological data are paired with chemical, physical, and land-use data variables that could be identified as possible stressors; and 2) it uses a probabilistic statewide monitoring design.

The BSID analysis combines the individual stressors (physical and chemical variables) into three generalized parameter groups in order to assess how the resulting impacts of these stressors can alter the biological community and structure. The three generalized parameter groups include: sediment, habitat, and water chemistry. Identification of a sediment stressor as contributing to the biological impairment is based on the results of the individual stressor associations within the sediment parameter grouping, which reveal the effects of sediment related impacts on stream biota (MDE 2009).

Patuxent River Lower Watershed Monitoring Stations

A total of 37 water quality monitoring stations were used to characterize the Patuxent River Lower watershed for the purpose of this TMDL. The biological assessment was based on the combined results of MBSS Round 1 and Round 2 data, which includes 35 stations. The BSID analysis used stations from MBSS Round 1- 3, which includes 37 stations. All stations are listed in Table 6 and presented in Figure 4.

Table 6: Monitoring Stations in the Patuxent River Lower Watershed

Site Number	Site Type	Location	Latitude (decimal degrees)	Longitude (decimal degrees)
AA-S-008-132-97	MBSS Round 1	Hall Creek, unnamed tributary #1	38.7455	-76.6109
CA-S-014-134-97	MBSS Round 1	Fowlers Mill Branch	38.6952	-76.6149
CA-S-089-201-97	MBSS Round 1	Chew Creek	38.6651	-76.6338
CA-S-123-136-97	MBSS Round 1	Buzzard Island Creek	38.5071	-76.6278
CA-S-187-133-97	MBSS Round 1	Patuxent River unnamed tributary #3	38.5950	-76.6562
CA-S-198-107-97	MBSS Round 1	Cocktown Creek, unnamed tributary #1	38.6339	-76.6223
CA-S-210-230-97	MBSS Round 1	Battle Creek	38.5083	-76.5876
CH-S-091-131-97	MBSS Round 1	Swanson Creek, unnamed tributary #1	38.5537	-76.7739
CH-S-231-202-97	MBSS Round 1	Swanson Creek	38.5744	-76.7424
CH-S-231-209-97	MBSS Round 1	Swanson Creek	38.5967	-76.7461
PG-S-007-108-97	MBSS Round 1	Summerville Creek, unnamed tributary #1	38.6100	-76.7180
PG-S-035-301-97	MBSS Round 1	Swanson Creek	38.5574	-76.7387
PG-S-047-211-97	MBSS Round 1	Rock Creek	38.6913	-76.7396
SM-S-090-238-97	MBSS Round 1	Killpeck Creek	38.4809	-76.7689
SM-S-125-142-97	MBSS Round 1	Cuckold Creek	38.3408	-76.5538
SM-S-166-143-97	MBSS Round 1	Cole Creek, unnamed tributary #1	38.3770	-76.5821
PAXL-101-R-2004	MBSS Round 2	Cypress Swamp Creek, unnamed tributary #1	38.4927	-76.5526
PAXL-106-R-2004	MBSS Round 2	Sewell Branch unnamed tributary #1	38.6142	-76.5897
PAXL-107-R-2004	MBSS Round 2	Cole Creek unnamed tributary #2	38.3828	-76.5956
PAXL-108-R-2004	MBSS Round 2	Stanley Run unnamed tributary #1	38.5606	-76.7109
PAXL-109-R-2004	MBSS Round 2	Horse Landing Creek	38.4260	-76.6778
PAXL-110-R-2004	MBSS Round 2	Patuxent River unnamed tributary #11	38.3914	-76.6334
PAXL-111-R-2004	MBSS Round 2	Island Creek, unnamed tributary #1	38.4449	-76.5383
PAXL-112-R-2004	MBSS Round 2	Patuxent River, unnamed tributary #10	38.6220	-76.6631
PAXL-114-R-2004	MBSS Round 2	Hall Creek, unnamed tributary #1	38.7196	-76.6402
PAXL-115-R-2004	MBSS Round 2	Indian Creek, unnamed tributary #1	38.5192	-76.7571
PAXL-116-R-2004	MBSS Round 2	Chesapeake Bay,	38.2552	-76.4156

Site Number	Site Type	Location	Latitude (decimal degrees)	Longitude (decimal degrees)
		unnamed tributary #1		
PAXL-119-R-2004	MBSS Round 2	Patuxent River, unnamed tributary #15	38.5905	-76.6899
PAXL-120-R-2004	MBSS Round 2	Chew Creek	38.6580	-76.6451
PAXL-124-R-2004	MBSS Round 2	Horse Landing Creek	38.4283	-76.6740
PAXL-125-R-2004	MBSS Round 2	Patuxent River, unnamed tributary #6	38.5942	-76.7062
PAXL-136-R-2004	MBSS Round 2	Fowlers Mill Branch	38.6950	-76.6136
PAXL-205-R-2004	MBSS Round 2	Tom Walls Branch	38.6847	-76.7307
PAXL-294-S-2000	MBSS Round 2	Swanson Creek	38.5639	-76.7601
PAXL-303-R-2004	MBSS Round 2	Hall Creek	38.7076	-76.6541
PAXL-104-R-2008	MBSS Round 3	Persimmon Creek, unnamed tributary	38.2655	-76.4349
PAXL-107-R-2008	MBSS Round 3	Summerville Creek, unnamed tributary	38.6098	-76.6919

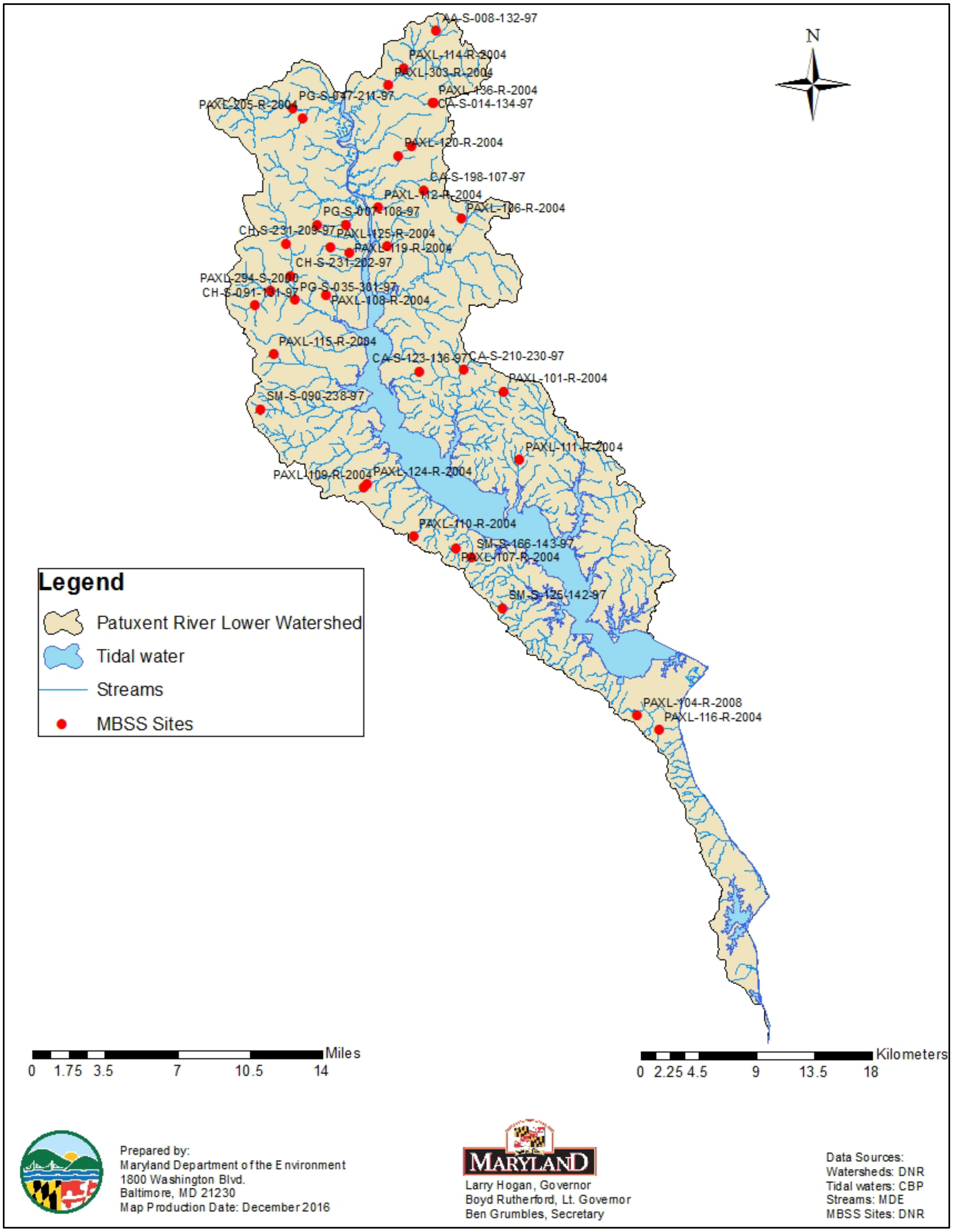

Figure 4: Monitoring Stations in the Patuxent River Lower Watershed

2.4 Water Quality Impairment

The Maryland Surface Water Use Designation in the COMAR for the Patuxent River Lower watershed's non-tidal streams is Use Class I - *water contact recreation, and protection of nontidal warmwater aquatic life.* All of the tidal waters are designated Use Class II - *support of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2016a, b, c). This TMDL only addresses the non-tidal portion of the watershed. Sediment TMDLs for the tidal estuaries were established as part the Chesapeake Bay TMDLs in 2010.

The water quality impairment of the Patuxent River Lower watershed addressed by this TMDL is caused by an elevated sediment load beyond a level that the watershed can sustain; thereby causing sediment related impacts to aquatic life. Assessment of aquatic life is based on BIBI and FIBI scores, as demonstrated via the BSID analysis for the watershed.

The Patuxent River Lower watershed was originally listed on Maryland's 2002 Integrated Report as impaired for impacts to biological communities. The biological assessment was based on the combined MBSS Round 1 (1995-1997) and Round 2 (2000-2004) data, which included 35 stations. 43% of the stream miles in the watershed, were assessed as having BIBI and/or FIBI scores significantly lower than 3.0 (on a scale of 1 to 5) (MDE 2002). See Figure 4 and Table 6 for station locations and information.

The results of the BSID analysis for the Patuxent River Lower watershed are presented in a report entitled *Watershed Report for Biological Impairment of the Non-Tidal Patuxent River Lower Watershed in Anne Arundel, Prince George's, Calvert, Charles, and Saint Mary's Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation*. The report states that the degradation of biological communities in the Patuxent River Lower watershed is strongly associated with marginal to poor epifaunal substrate and velocity/depth diversity, poor and marginal to poor instream habitat, and pool/glide/eddy quality (MDE 2013).

The BSID analysis determined that the biological impairment in the Patuxent River Lower watershed is due to in part to stressors within the sediment parameter grouping. Overall, stressors within the sediment parameter grouping were identified as having a statistically significant association with impaired biological communities at approximately 29% of the sites with BIBI and/or FIBI scores significantly less than 3.0 throughout the watershed (MDE 2013). Therefore, since sediment is identified as a stressor to the biological communities in the Patuxent River Lower watershed, the watershed was listed as impaired by sediment in the 2014 Integrated Report, thus a TMDL is required.

3.0 TARGETED WATER QUALITY GOAL

The objective of the sediment TMDL established herein is to reduce sediment loads, and their detrimental, negative effects on aquatic life in the Patuxent River Lower watershed, to levels that support the Use Class I designation for the watershed. Excessive sediment has been identified by the USEPA as the leading cause of impairment of our nation's waters, and as contributing to the decline of populations of aquatic life in North America (USEPA 2003a). Sediment in streams may reduce visibility, preventing fish from seeing their prey, and may clog gills and filter feeding mechanisms of fish and benthic (bottom-dwelling) organisms. Excessive deposition of sediment on streambeds may bury eggs or larvae of fish and benthic macroinvertebrates, or degrade habitat by clogging the interstitial spaces between sand and gravel particles. Excessive sediment can also create hazards for recreation due to low visibility and the possibility of unseen objects.

The CWA requires TMDLs to be protective of all the designated uses applicable to a particular waterbody. The primary focus of this TMDL is the designated use of protection of aquatic life because the Integrated Report listing was based on a biological assessment of the watershed. The biological assessment revealed the current levels of TSS and other pollutants prevent the watershed from achieving its designated use of supporting aquatic life. The required reductions within the TMDL are expected to protect all designated uses of the watershed from sediment impacts, including water contact recreation. Aquatic life is more sensitive to sediment impacts than recreation because of continuous exposure that can affect respiration and propagation. Recreation, on the other hand, is sporadic and sediment is unlikely to pose a human health risk due to dermal contact or minimal ingestion that would occur during recreation.

Reductions in sediment loads are expected to result from decreased watershed erosion, which will then lead to improved benthic and fish habitat conditions. Specifically, sediment load reductions are expected to result in an increase in the number of benthic sensitive species present, an increase in the available and suitable habitat for a benthic community, a possible decrease in fine sediment (fines), and improved stream habitat diversity, all of which will result in improved water quality.

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section describes how the sediment TMDL and the corresponding allocations were developed for the Patuxent River Lower watershed.

4.2 Analysis Framework

Since there are no specific numeric criteria in Maryland that quantify the impact of sediment on the aquatic life of non-tidal stream systems, a reference watershed approach was used to establish the TMDL. In order to use a reference watershed approach, sediment loads were estimated using a watershed model. For this analysis, the CBP P5.3.2 model was used to calculate the sediment loads used in the reference watershed approach.

Watershed Model

The CBP P5.3.2 watershed model was chosen to estimate the sediment loads for the Patuxent River Lower watershed TMDL and the loads were expressed as EOS sediment loads. The spatial domain of the CBP P5.3.2 watershed model segmentation aggregates to the MD 8-digit watersheds, which is with the scale of the impairment listing. The nonpoint source baseline sediment loads generated within the Patuxent River Lower watershed are based on the EOS loads from the CBP P5.3.2 watershed model 2009 Progress Scenario. CBP P5.3.2 Progress Scenario EOS loads are calculated as the sum of individual land-use EOS loads within the watershed and represent a long-term average loading rate. Individual land-use EOS loads are calculated within the CBP P5.3.2 watershed model as a product of the land-use area, land-use target EOF loading rate, and loss from the EOF to the main channel. BMP data and reduction efficiencies are subsequently applied to produce the final EOS loads. The loss from the EOF to the main channel is the *sediment delivery factor* and is defined as the ratio of the sediment load reaching a basin outlet to the total erosion within the basin. A *sediment delivery factor* is estimated for each land-use type based on the proximity of the land-use to the main channel. Thus, as the distance to the main channel increases, more sediment is stored within the watershed (i.e., *sediment delivery factor* decreases). Details of the data sources for the unit loading rates can be found in Section 2.2 of this report.

Reference Watershed Approach

In order to quantify the impact of sediment on the aquatic life of non-tidal stream systems, a reference watershed TMDL approach was used. Reference watersheds are those watersheds that are identified as supporting aquatic life, based on Maryland's biological assessment methodology. The biological assessment methodology assesses biological impairment at the watershed scale based on the percentage of MBSS monitoring stations, translated into watershed stream miles, that have BIBI and/or FIBI scores lower than the Minimum Allowable IBI Limit (MAL). The MAL represents the threshold under which a watershed is listed as impaired for biology and is calculated based on the average annual allowable IBI value of 3.0 (on a scale of 1 to 5), the coefficient of variation of annual sentinel site results, and an assumed normal distribution. It accounts for annual variability and helps to avoid classification errors (i.e., false positives) when assessing for biological impairments (Roth *et al*. 1998, 2000; Stribling *et al*. 1998; MDE 2014a). For a full description of the selection of reference watersheds, please see *A Methodology for Addressing Sediment Impairments in Maryland's Nontidal Watersheds* (MDE 2006).

Comparison of sediment loads from impaired watersheds to loads from reference watersheds requires that the watersheds be similar in physical and hydrological characteristics. For the establishment of this specific TMDL, watersheds were selected from the nontidal Coastal Plain region since the Patuxent River Lower watershed is within this geologic province (see Section 2.1). See Appendix A for the list of reference watersheds. The same methodology as described in MDE 2006 for the selection of the Highland and Piedmont reference watersheds was used to select the Coastal Plain reference watersheds. Furthermore, all subsequent methodologies used to establish the TMDL end point, based on these reference watersheds, are exactly the same as those described in MDE 2006.

To further reduce the effect of the variability within the Coastal Plain physiographic regions (i.e., soils, slope, etc.), the watershed sediment loads were then normalized by a constant background condition, the all forested watershed condition. This new normalized term, defined as the *forest normalized sediment load* (Y_n), represents how many times greater the current watershed sediment load is than the *all forested sediment load* (y_{for}). The y_{for} is a modeled simulation of what the sediment load would be if the watershed were in its natural all forested state, instead of its current mixed land use. It is calculated using the CBP P5.3.2 model. The *forest normalized sediment load* for this TMDL is calculated as the baseline watershed sediment load divided by the *all forested sediment load*. The equation for the *forest normalized sediment load* is as follows:

$$Y_n = \frac{y_{ws}}{y_{for}} \qquad \text{(Equation 4.1)}$$

where:
Y_n = forest normalized sediment load
y_{ws} = current watershed sediment load (ton/yr)
y_{for} = all forested sediment load (ton/yr)

Seven reference watersheds were identified in the Coastal Plain physiographic region. Reference watershed *forest normalized sediment loads* were calculated using CBP P5.3.2 watershed model 2009 Progress Scenario EOS loads. The median and 75th percentile of the reference watershed *forest normalized sediment loads* were calculated and found to be 3.9 and 4.5, respectively.[1] The median value of 3.9 was used as an environmentally conservative approach for establishing the sediment loading threshold for the TMDL (see Appendix A for more details).

The *forest normalized sediment load* for the Patuxent River Lower watershed, estimated as 6.3, was calculated using CBP P5.3.2 2009 Progress Scenario EOS loads, as follows:

$$Y_n = \frac{y_{ws}}{y_{for}} = \frac{15{,}007\ ton/yr}{2{,}389\ ton/yr} = 6.3 \qquad \text{(Calculation 4.1)}$$

A comparison of the Patuxent River Lower watershed *forest normalized sediment loads* (6.3) to the *sediment loading threshold* demonstrates that the watershed exceeds the *sediment loading threshold*, indicating that it is receiving loads above the maximum allowable load that it can sustain and still meet water quality standards.

4.3 Scenario Descriptions and Results

The following analyses compare baseline conditions in the watershed (under which water quality problems exist) with potential future conditions, which project the water quality response to various simulated sediment load reductions. The analyses are grouped according to baseline conditions and future conditions associated with TMDLs.

Baseline Conditions

The baseline conditions are intended to provide a point of reference by which to compare the future scenario that simulates conditions of a TMDL. Baseline loads are calculated for nonpoint and point source loads. Point source loads can be subdivided into two categories, wastewater and stormwater.

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[1] The 75th percentile value of reference condition streams was recommended by EPA to be used in establishing numerical criteria (MDE 2006). The median was found, for the sediment reference watersheds, to be approximately equivalent to other more complex statistical analyses and was used for ease of calculation (MDE 2009b). Both of these values ensure that the selected threshold will represent the reference group values, with the median being more conservative (lower).

The Patuxent River Lower watershed baseline nonpoint source sediment loads are estimated using the land-use and EOS sediment loading rates from the CBP P5.3.2 2009 Progress Scenario. The 2009 Progress Scenario was chosen because it is used as the baseline year in the Chesapeake Bay TMDL. The 2009 Progress Scenario represents 2009 land-use and BMP implementation simulated using precipitation and other meteorological inputs from the period 1990-2000 to represent variable hydrological conditions, thereby addressing annual changes in hydrology and capturing wet, average and dry years. The period 1991-2000 is the hydrological simulation period for the Chesapeake Bay TMDL.

The wastewater point source sediment loads are estimated based on the existing permit information. The stormwater point source loads are also based on CBP 5.3.2 loading rates, specifically those for urban land use. Details of these loading source estimates can be found in Section 2.2 and the technical memorandum to this document entitled *Point Sources of Sediment in the Patuxent River Lower Watershed*.

TMDL Conditions

The TMDL scenario simulates conditions under which sediment loads have been reduced to levels that support aquatic life. In the TMDL calculation, the allowable load for the impaired watershed is calculated as the product of the *sediment loading threshold* (determined from watersheds with a healthy biological community) and the Patuxent River Lower watershed *all forested sediment load* (see Section 4.2). The resulting load is considered the maximum allowable load the watershed can sustain and support aquatic life.

The TMDL loading and associated reductions are averaged at the watershed scale, however, it is important to recognize that some subwatersheds may require higher reductions than others, depending on the distribution of the land-use.

The formula for estimating the TMDL is as follows:

$$TMDL = \sum_{i=1}^{n} Yn_{ref} \cdot y_{for\ i} \qquad \text{(Equation 4.2)}$$

where:

TMDL = allowable load for impaired watershed (ton/yr)

Yn_{ref} = sediment loading threshold

$y_{for\ i}$ = all forested sediment load for CBP P5.3.2 model segment *i* (ton/yr)

i = CBP P5.3.2 model segment

n = number of CBP P5.3.2 model segments in watershed

4.4 Critical Condition and Seasonality

USEPA’s regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2012b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time and therefore depict an average stream condition (i.e., captures all high and low flow events). Since the TMDL endpoint is based on the median of forest normalized loads from watersheds assessed as having good biological conditions (i.e., passing Maryland’s biological assessment), by the nature of the biological data described above, it must inherently include the critical conditions of the reference watersheds. Therefore, since the TMDL reduces the watershed sediment load to a level compatible with that of the reference watersheds, critical conditions are inherently addressed. Moreover, the sediment loading rates used in the TMDL were determined using the CBP P5.3.2 model, which is a continuous simulation model with a simulation period 1991-2000, based on Hydrological Simulation Program Fortran (HSPF) model, thereby addressing annual changes in hydrology and capturing wet, average, and dry years.

Seasonality is captured in two components. First, it is implicitly included through the use of the biological monitoring data as this data reflects the impacts of stressors over time, as described above. Second, the MBSS dataset included benthic sampling in the spring (March 1 - April 30) and fish sampling in the summer (June 1 - September 30). Benthic sampling in the spring allows for the most accurate assessment of the benthic population, and therefore provides an excellent means of assessing the anthropogenic effects of sediment impacts on the benthic community. Fish sampling is conducted in the summer when low flow conditions significantly limit the physical habitat of the fish community, and it is therefore most reflective of the effects of anthropogenic stressors as well. Moreover, the sediment loading rates used in the TMDL were determined using the CBP P5.3.2 model, which is a continuous simulation model with a simulation period 1991-2000, based on Hydrological Simulation Program Fortran (HSPF) model, thereby addressing annual changes in hydrology and capturing wet, average, and dry years.

4.5 TMDL Loading Caps

This section presents the Patuxent River Lower watershed average annual sediment TMDL. This load is considered the maximum allowable long-term average annual load the watershed can sustain and support aquatic life.

The long-term average annual TMDL was calculated for the Patuxent River Lower watershed based on Equation 4.2 and set at a load 3.9 times the all forested condition of the watershed. In order to attain the TMDL loading cap calculated for the watershed, reductions were applied to the predominant sediment sources (i.e., significant contributors of sediment to the stream system), independent of jurisdiction. Sediment reductions are also required in Patuxent River Lower watershed to meet the sediment allocations assigned under the 2010

Chesapeake Bay TMDL for sediment in the Upper Patuxent River Tidal Fresh, Lower Patuxent River Mesohaline, Middle Patuxent River Oligohaline, and Lower Chesapeake Bay Mesohaline segments. To ensure consistency with the Bay TMDL, and therefore efficiency in the reduction of sediment loads, reductions will be applied to the same sediment sources identified in Maryland's Watershed Implementation Plans (WIPs) for the Bay TMDL, as applicable in the watershed. These include: (1) regulated developed land; (2) conventional till crops, conservation till crops, hay, and pasture; (3) harvested forest; (4) unregulated animal feeding operations and concentrated animal feeding operations (CAFOs); and (5) industrial wastewater sources and municipal wastewater treatment plants. In this TMDL, reductions were also applied to unregulated urban loads. Forest land is not assigned reductions because it is considered the most natural condition in the watershed.

The Patuxent River Lower Watershed Baseline Load and TMDL are presented in Table 7.

Table 7: Patuxent River Lower Watershed Baseline Load and TMDL

Baseline Load (ton/yr)	TMDL (ton/yr)	Total Reduction (%)
15,007	9,318	38

4.6 Load Allocations Between Point and Nonpoint Sources

Per USEPA regulation, all TMDLs need to be presented as a sum of Wasteload Allocations (WLAs) for point sources and Load Allocations (LAs) for nonpoint source loads generated within the assessment unit, accounting for natural background, tributary, and adjacent segment loads (CFR 2012a). The State reserves the right to allocate the TMDL among different sources in any manner that protects aquatic life from sediment related impacts.

Load Allocation

Individual LAs for each nonpoint land-use sector were calculated using the allocation methodology in the MD Phase I WIP, which was designed to be equitable, effective, and consistent with water quality standards (MDE 2010). The allocations were calculated by applying equal reductions to the *reducible* loads of all sectors. The *reducible* load is defined as the difference between the No Action (NA) scenario and the "Everything, Everyone, Everywhere" (E3) scenario. The NA scenario represents current land-uses without any sediment controls applied, while the E3 scenario represents the application of all possible BMPs and control technologies to current land-use. For more detailed information regarding the calculation of the LA, please see *Maryland's Phase I Watershed Implementation Plan for the Chesapeake Bay Total Maximum Daily Load.*

In this watershed, unregulated urban land and crop land were identified as the predominant nonpoint sources of sediment and require reductions. Other land uses that individually contributed less than 1% of the total sediment load were not reduced as they would produce no discernible reductions. Forest is not assigned reductions, as it represents the most natural condition in the watershed. Sediment loads from regulated urban lands under National

Pollutant Discharge Elimination System (NPDES) permits are considered point source loads that must be included in the Waste Load Allocation (WLA) portion of a TMDL (US EPA 2002).

In this document, the LA for the Patuxent River Lower watershed is expressed as one aggregate value for all nonpoint sources, including unregulated urban land use. For more detailed information regarding the Patuxent River Lower watershed TMDL nonpoint source LA, please see the technical memorandum to this document entitled *Nonpoint Sources of Sediment in the Patuxent River Lower Watershed.*

A summary of the baseline and load allocation for nonpoint sources is presented in Table 8. The percent reduction shown in Table 8 does not represent the reduction applied to reducible loads, but the required reduction between the allocation and the baseline load.

Wasteload Allocation

The WLA of the Patuxent River Lower watershed is allocated to two permitted source categories, the Wastewater WLA and the Stormwater WLA. The categories are described below.

Wastewater WLA

Wastewater permits with specific TSS limits and corresponding flow information are assigned a WLA. In this case, detailed information is available to accurately estimate the WLA. If specific TSS limits are not explicitly stated in the wastewater permit, then TSS loads are expected to be *de minimis*. If loads are *de minimis,* they pose little risk to the aquatic environment.

Wastewater permits with specific TSS limits include:

- Individual industrial facilities
- Individual municipal facilities
- Mineral mining facilities with TSS limits

There is one municipal wastewater source with explicit TSS limits in the Patuxent River Lower watershed that contributes to the watershed sediment load. There is also one general mineral mining permit with explicit TSS limits. The total estimated TSS load from the wastewater source is based on current, average permit limits and is equal to 2 ton/yr. For more detailed information on the wastewater permits, please see the technical memorandum entitled *Point Sources of Sediment in the Patuxent River Lower Watershed*.

Stormwater WLA

Per USEPA requirements, “stormwater discharges that are regulated under Phase I or Phase II of the NPDES stormwater program are point sources that must be included in the WLA portion of a TMDL” (USEPA 2002). Phase I and II permits can include the following types of discharges:

- Small, medium, and large municipal separate storm sewer systems (MS4s) – these can be owned by local jurisdictions, municipalities, and state and federal entities (e.g., departments of transportation, hospitals, military bases),
- Industrial facilities permitted for stormwater discharges, and
- Small and large construction sites
- Mineral mining facilities that do not have TSS limits

USEPA currently recommends that WLAs for NPDES regulated stormwater discharges be expressed as different WLAs for different identifiable categories (e.g., separate WLAs for MS4 and industrial stormwater discharges). These categories should be defined as narrowly as available information allows (e.g., for municipalities, separate WLAs for each municipality and for industrial sources, separate WLAs for different types of industrial stormwater sources or dischargers). In general, states are encouraged to disaggregate the WLA to facilitate implementation. USEPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (USEPA 2014).

The Patuxent River Lower NPDES Stormwater WLA is based on reductions applied to the sediment load from the portion of the urban land-use in the watershed associated with NPDES regulated stormwater permits. The NPDES stormwater WLA is calculated in the same manner as the load allocation for unregulated urban land acreage. Some of these sources may also be subject to controls from other management programs. The Patuxent River Lower NPDES Stormwater WLA requires an overall reduction of 22% (see Table 9).

Table 8: Patuxent River Lower Watershed TMDL Reductions by Source Category

	Baseline Load Source Categories		Baseline Load (ton/yr)	TMDL	TMDL (ton/yr)	Reduction (%)
Patuxent River Lower Watershed Contribution	Nonpoint Source		13,650	LA	8,258	40
	Point Source	Urban	1,355	WLA	1,058	22
		Permits	2		2	0
Total			**15,007**		**9,318**	**38**

For more information on the methods used to calculate the NPDES regulated stormwater baseline sediment load, see Section 2.2.2. For a detailed list of all of the NPDES regulated stormwater discharges within the watershed and information regarding the NPDES stormwater WLA distribution amongst these discharges, please see the technical memorandum to this document entitled *Point Sources of Sediment in the Patuxent River Lower Watershed.*

As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES Stormwater WLA provided the revisions protect aquatic life from sediment related impacts.

4.7 Margin of Safety

All TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2012b). The MOS shall also account for any rounding errors generated in the various calculations used in the development of the TMDL. This TMDL was developed using an environmentally conservative approach that implicitly incorporates an MOS. Specifically, as was described in Section 4.2, the reference watershed forest normalized EOS loads were chosen in a conservative manner. Analysis of the reference group *forest normalized sediment loads* indicates that the 75th percentile of the reference watersheds is a value of 4.5 and that the median value is 3.9. Achieving a 75th percentile forest normalized sediment load would assure that the watershed falls within the range of unimpaired watersheds. However, for this analysis, the *sediment loading threshold* was set at the median value of 3.9 (MDE 2006). Use of the median as the threshold creates an environmentally conservative estimate, and results in an implicit MOS.

4.8 Summary of Total Maximum Daily Loads

The average annual non-tidal Patuxent River Lower watershed TMDL is summarized in Table 9. The TMDL is the sum of the LAs, NPDES Stormwater WLA, Wastewater WLA, and MOS. The LAs include nonpoint source loads generated within the Patuxent River Lower watershed and loads from upstream sources. The attainment of water quality standards within the non-tidal Patuxent River Lower watershed can only be achieved by meeting the average annual TMDL of sediment specified for the watershed within this report. The Maximum Daily Load (MDL) is summarized in Table 10 (See Appendix B for more details).

Table 9: Patuxent River Lower Watershed Average Annual TMDL of Sediment (ton/yr)

TMDL (ton/yr)	=	LA_{PRL}	+	NPDES Stormwater WLA_{PRL}	+	Wastewater WLA_{PRL}	+	MOS
9,318	=	8,258	+	1,058	+	2	+	Implicit

Table 10: Patuxent River Lower Watershed Maximum Daily Load of Sediment (ton/day)

MDL (ton/day)	=	LA_{PRL}	+	NPDES Stormwater WLA_{PRL}	+	Wastewater WLA_{PRL}	+	MOS
36	=	32	+	4	+	0.0087	+	Implicit

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the CWA and current USEPA regulations require reasonable assurance that the sediment TMDL can and will be implemented (CFR 2012b). This section provides the basis for reasonable assurance that the sediment TMDL in the Patuxent River Lower watershed will be achieved and maintained.

While this TMDL establishes a sediment loading target for the watershed, watershed managers and other stakeholders should always remain cognizant that the endpoint of this TMDL, and hence the definition of its successful implementation, is based on in-stream biological health. Load reductions are critical to tracking this effort, since the TMDL target is defined as the point where sediment loads match those seen in reference watersheds, but the watershed cannot be delisted or classified as meeting water quality standards until it is demonstrated that the biological health of the stream system is no longer impaired by sediment. In planning any implementation efforts related to this TMDL, careful consideration should be given both to the sediment load reductions, and to the direct potential impacts on biological communities.

2010 Chesapeake Bay TMDLs

Implementation of the TMDL for sediment in the Patuxent River Lower watershed is expected to occur in conjunction with implementation efforts for the 2010 Chesapeake Bay TMDLs for nutrients and sediment in the the Upper Patuxent River Tidal Fresh, Lower Patuxent River Mesohaline, Middle Patuxent River Oligohaline, and Lower Chesapeake Bay Mesohaline . While the objectives of the two efforts differ, with the 2010 Bay TMDLs focused on tidal water quality and this TMDL targeting biological integrity in non-tidal streams, many of the sediment reductions achieved through implementation activities should result in progress toward both goals.

The strategies for implementing the 2010 Bay TMDLs are described in Maryland's Phase I WIP (MDE 2010) and Phase II WIP (MDE 2012). The WIPs are the centerpieces of the State's "reasonable assurance" of implementation for the 2010 Bay TMDLs, and the strategies encompass a host of BMPs, pollution controls and other actions for all source sectors that cumulatively will result in meeting the State's 2025 targets, as verified by the Chesapeake Bay Water Quality Sediment Transport Model. In particular, the implementation of practices to reduce sediment loadings from the agricultural and urban stormwater sectors should result in decreased loads in the Patuxent River Lower watershed's non-tidal streams.

MS4 Permit Implementation Plans

MDE published the Final Determinations to Issue Stormwater Permits to Anne Arundel County in February 2014, Charles County in December 2014, and Prince George's County in January 2014. The permits state, *"By regulation at 40 CFR §122.44, BMPs and programs implemented pursuant to this permit must be consistent with applicable WLAs developed under [US]EPA approved TMDLs."*

Section IV.E. of the permit details requirements for *Restoration Plans and Total Maximum Daily Loads*. Within one year of permit issuance, the permitee is required to submit an implementation plan for each stormwater WLA approved by USEPA prior to the effective date of the permit. For TMDLs approved after the permit, implementation plans are due within one year of USEPA approval of the TMDL. Implementation plans should include the following: a detailed implementation schedule, the final date for meeting applicable WLAs, a detailed cost estimate for all elements of the plan, a system that evaluates and tracks implementation through monitoring or modeling to document progress towards meeting established benchmarks, deadlines, and stormwater WLAs, and a public participation program. An annual TMDL assessment report shall also be submitted to MDE. Many of the practices which are described in the permittees' stormwater WLA implementation plans may also be used by the permittees as retrofits for meeting their impervious area restoration requirements (20% retrofit per five-year permit cycle).

Stormwater retrofits can address both water quality and quantity. Examples of these retrofits include the reduction of impervious surfaces, modification of existing or installation of new stormwater structural practices, increased urban tree canopy, and stream restoration projects. Based on estimates by CBP, stormwater retrofit reductions range from as low as 10% for dry detention, to approximately 80% for wet ponds, wetlands, infiltration practices, and filtering practices (USEPA 2003b).

For more information on the MS4 permits, please see Maryland's NPDES Municipal Separate Storm Sewer System (MS4) Permits.

Nonpoint Source Urban Lands

Generally speaking, urban areas that do not have NPDES permits do not have mandatory restoration requirements and restoration activities are largely voluntary. The State makes several efforts to encourage jurisdictions to conduct voluntary activities by providing technical assistance and funding opportunities to guide and support local actions. For example, Section 319 of the Clean Water Act provides federal grants to assist in nonpoint source (NPS) management. Section 319(b) requires preparation of a state NPS management program plan for approval by the US Environmental Protection Agency. Maryland's most recent plan, *Maryland's 2015-2019 Nonpoint Source Management Plan*, addresses NPS according to pollutant and source. There are several programs listed in the report that address urban NPS, including Maryland Bay-Wise Program, Maryland Green Schools Awards, and the SMART Homeowner Reporting Program. Additionally, MDE is conducting outreach to non-MS4 jurisdictions regarding stormwater management requirements and retrofit BMPs. Funding sources for urban nonpoint source pollutants include: Federal 319(h) grants, Chesapeake and Atlantic Coastal Bays Trust Fund, and the State Revolving Loan Fund. More information on Maryland's NPS management program can be found at: http://mde.maryland.gov/programs/Water/319NonPointSource/Pages/index.aspx.

Further efforts include offering competitive grant opportunities through the Chesapeake Bay Trust (CBT). Each year since 2015, MDE and DNR have entered into an agreement to pass federal funding through to local jurisdictions to enhance their ability to restore local water quality. The CBT administers the grant process with these funds and awards over $1.2M for use by regulated and non-NPDES jurisdictions. More information about this funding can be found on the CBT website here: https://cbtrust.org/wp-content/uploads/WAGP-2YR-Milestone-2017-2018_FINAL.pdf This grant opportunity combined with technical assistance offered to successful candidates is one more example of the State's plan to address the load allocations and to ensure a better level of reasonable assurance that the TMDL endpoints will be achieved.

Implementation of Agricultural Best Management Practices

In agricultural areas comprehensive soil conservation plans can be developed that meet criteria of the USDA-NRCS Field Office Technical Guide (USDA 1983). Soil conservation plans help control erosion by modifying cultural practices or structural practices. The reduction percentage attributed to cultural practices is determined based on changes in land-use, while structural practices have a reduction percentage of up to 25%. In addition, sediment loadings from livestock can be controlled via stream fencing and rotational grazing. Sediment reduction efficiencies of methods applicable to pasture land-use range from 40% to 75% (USEPA 2004). Lastly, riparian buffers can reduce the effect of agricultural sediment sources through trapping and filtering.

Maryland Funding Programs

In response to the WIP and the increased responsibility for local governments to achieve nutrient and sediment reduction goals, Maryland has continued to increase funding in the Chesapeake and Atlantic Coastal Bays Trust Fund. According to the Section 40 Report, even though the annual restoration funds for the four agencies (MDDNR, MDA, MDE, MDP) varies from year to year, the total restoration funds for the first three years of the Chesapeake Bay WIP implementation evaluated time period (FY10 – FY12) was $882,327,165, while the total for the past four years of the period (FY12 – FY15) was $2,383,507,560, an increase of 170 percent. This increase was driven in part by the two primary Bay restoration Special Funds: The Bay Restoration Fund and the Chesapeake and Atlantic Coastal Bays Trust Fund (MDE *et al*., 2016). For more information on Maryland's implementation and funding strategies to achieve nutrient and sediment reductions throughout the State's portion of the Chesapeake Bay watershed, please see Maryland's Phase II Watershed Implementation Plan.

Some other examples of programs that can provide funding for local governments and agricultural sources include the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act), the Buffer Incentive Program (BIP), the State Water Quality Revolving Loan Fund and the Maryland Agricultural Water Quality Cost-Share Program.

In summary, through the use of the aforementioned funding mechanisms and BMPs, there is reasonable assurance that this TMDL can be implemented.

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APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds in the Coastal Plains Physiographic Region

MD 8-Name	MD 8-digit	Percent Stream Mile BIBI/FIBI < 3.0 (%)[1,2]	Forest Normalized Sediment Load[3]
Potomac River - Lower Tidal	02140102	14.3	2.46
Breton Bay	02140104	16.7	3.81
St. Clements Bay	02140105	16.7	4.30
Wicomico River	02140106	20.0	4.80
Gilbert Swamp	02140107	17.6	4.72
Zekiah Swamp	02140108	14.3	3.91
Nanjemoy Creek	02140110	17.6	2.88
Median			**3.9**
75th percentile			**4.5**

Notes: [1] Based on the percentage of MBSS stations with BIBI and/or FIBI scores significantly lower than 3.0 within the watershed (MDE 2014b).
[2] The percent stream miles with BIBI and/or FIBI scores significantly lower than 3.0 threshold to determine if an 8-digit watershed is impaired for impacts to biological communities is based on a comparison to reference conditions (MDE 2008).
[3] Forest normalized sediment loads based on Maryland watershed area only (consistent with MBSS random monitoring data).

APPENDIX B – Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define maximum daily loads (MDLs) of sediment consistent with the average annual TMDL in the Patuxent River Lower watershed, which is considered the maximum allowable load the watershed can sustain and support aquatic life. The approach builds upon the modeling analysis that was conducted to determine the sediment loadings and can be summarized as follows:

- The approach defines MDLs for each of the source categories.
- The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual loading targets are at a level that support aquatic life.
- The approach converts daily time-series loadings into TMDL values in a manner that is consistent with available USEPA guidance on generating daily loads for TMDLs (USEPA 2007).
- The approach considers a daily load level of a resolution based on the specific data that exists for each source category.

Introduction

This appendix documents the development and application of the approach used to define MDL values. It is divided into sections discussing:

- Basis for approach
- Options considered
- Selected approach
- Results of approach

Basis for approach

The overall approach for the development of daily loads was based upon the following factors:

- **Average Annual TMDL:** The basis of the average annual sediment TMDL is that cumulative high sediment loading rates have negative impacts on the biological community. Thus, the average annual sediment load was calculated so as to ensure the support of aquatic life.

- **CBP P5.3.2 Watershed Model Sediment Loads:** As described in Section 2.2, the nonpoint source sediment loads from the Patuxent River Lower watershed are based on EOS loads from the CBP P5.3.2 watershed model. The CBP P5.3.2 model river segments were calibrated to daily monitoring information for watersheds with a flow greater than 100 cubic feet per second (cfs), or an approximate area of 100 square miles.

- **Draft USEPA guidance document entitled *Developing Daily Loads for Load-based TMDLs:*** This guidance document provides options for defining MDLs when using TMDL approaches that generate daily output (USEPA 2007).

The rationale for developing TMDLs expressed as *daily* loads was to accept the existing average annual TMDL, but then develop a method for converting this number to a MDL in a manner consistent with USEPA guidance and available information.

Options considered

The draft USEPA guidance document for developing daily loads does not specify a single approach that must be adhered to, but rather it contains a range of acceptable options (USEPA 2007). The selection of a specific method for translating a time-series of allowable loads into the expression of a TMDL requires decisions regarding both the level of resolution (e.g., single daily load for all conditions vs. loads that vary with environmental conditions) and level of probability associated with the TMDL.

This section describes the range of options that were considered when developing methods to calculate Patuxent River Lower watershed MDLs.

Level of Resolution

The level of resolution pertains to the amount of detail used in specifying the MDL. The draft USEPA guidance document on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Patuxent River Lower watershed:

1. **Representative daily load:** In this option, a single daily load (or multiple representative daily loads) is specified that covers all time periods and environmental conditions.

2. **Variable daily load:** This option allows the MDL to vary as function of a particular characteristic that affects loading or waterbody response, such as flow or season.

Probability Level

All TMDLs have some probability of being exceeded, with the specific probability being either explicitly specified or implicitly assumed. This level of probability directly or indirectly reflects two separate phenomena:

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often

conditions can allowably surpass the combined magnitude and duration components.

2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any loading value has some finite probability of being exceeded.

The draft daily load guidance document states that the probability component of the MDL should be based on a representative statistical measure that is dependent upon the specific TMDL and the best professional judgment of the developers (USEPA 2007).

This statistical measure represents how often the MDL is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The maximum daily load reflects some central tendency:** In this option, the MDL is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.

2. **The maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the MDL based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in a MDL that would be exceeded 5% of the time.

3. **The maximum daily load reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the MDL is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.

Selected Approach

The approach selected for defining a Patuxent River Lower Watershed MDL was based upon the specific data that exists for each source category. The approach consists of unique methods for each of the following categories of sources:

- Approach for Nonpoint Sources and Stormwater Point Sources within the Patuxent River Lower watershed

- Approach for Wastewater Point Sources within the Patuxent River Lower watershed

Approach for Nonpoint Sources and Stormwater Point Sources within the Patuxent River Lower Watershed

The level of resolution selected for the Patuxent River Lower MDL was a representative daily load, expressed as a single daily load for each loading source. This approach was chosen based upon the specific data that exists for nonpoint sources and stormwater point sources within the Patuxent River Lower watershed. Currently, the best available data is the CBP P5.3.2 model daily time series calibrated to long-term average annual loads (per land-use). The CBP reach simulation results are calibrated to daily monitoring information for watershed segments with a flow typically greater than 100 cfs.

The probability level selected for the Patuxent River Lower MDL was a pre-defined exceedance probability. Based on the USEPA guidance, "in the case where a long term daily load dataset is available, in which multiple years of data and a variety of environmental conditions are represented, it is preferable to select a maximum daily load as a percentile of the load distribution. A sufficiently long-term dataset allows for minimizing error associated with the fact that the daily load dataset might not exactly match a normal or lognormal distribution" (USEPA 2007). The exact percentile value to be used should be determined by the TMDL developer, based on site specific characteristics.

This CBP P5.3.2 model output provides a time series of daily TSS loads from the Patuxent River Lower watershed, covering a 20-year period from 1985 to 2005. Because this is a long-term time series, it captures a broad range of meteorological and hydrological conditions and also minimizes the effect of potential statistical variances. As with the calculation of the TMDL value, environmentally conservative principles are also used in the MDL calculation. A 95th percentile flow was selected for the MDL, meaning that there is a 5% probability that daily loads will exceed this value. This percentile was chosen rather the 99th (which is also considered acceptable based on USEPA), in order to avoid the influence of extreme weather events and statistical outliers. Since the model daily time series represents the baseline condition, the reduction percentage applied to each sector of the TMDL, was applied directly to the 95th percentile values to calculate the final MDL value.

$$MDL = 95th\ percentile\ of\ daily\ load\ series\ values * Reduction\ \%\ from\ TMDL \quad \text{(Eq B-1)}$$

where:
MDL = Maximum Daily Load, ton/day
Daily load series values = CBP 5.3.2 output
TMDL = Long term average annual load, ton/yr

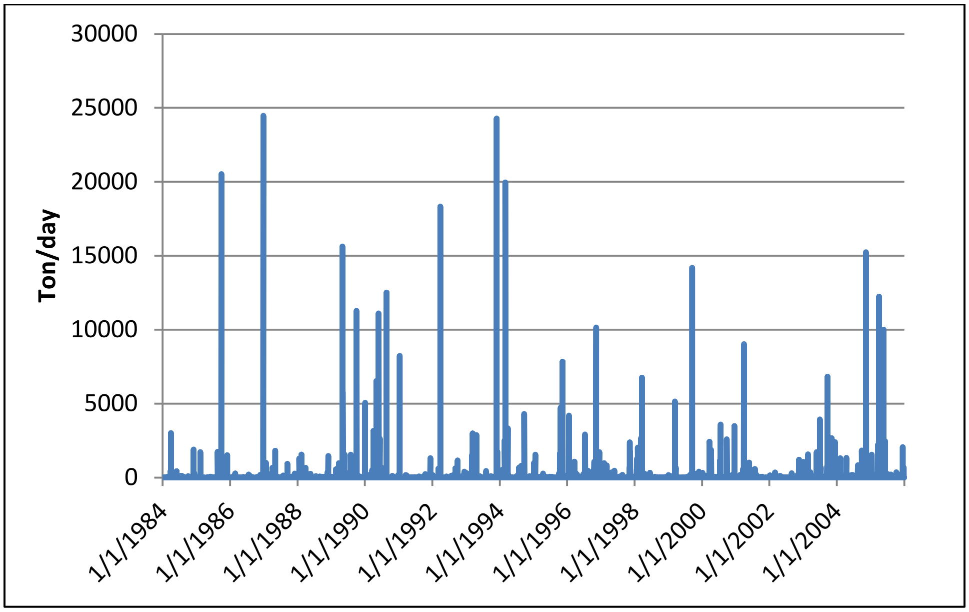

Figure B-1: Daily Time Series of CBP River Segment Daily Simulation Results for the Patuxent River Lower Watershed

Approach for Wastewater Point Sources within the Patuxent River Lower Watershed

The TMDL also considers contributions from other point sources (i.e., sources other than stormwater point sources) in the watershed that have NPDES permits with sediment limits. As these sources are generally minor contributors to the overall sediment load, the TMDL analysis that defined the average annual TMDL did not propose any reductions for these sources and held each of them constant at their existing technology-based NPDES permit monthly (or daily if monthly was not specified) limit for the entire year.

The approach used to determine MDLs for these sources was dependent upon whether a maximum daily limit was specified within the permit. If a maximum daily limit was specified, then the reported average flow was multiplied by the daily maximum limit and a conversion factor of 0.0042 to obtain an MDL in ton/day. If a maximum daily limit was not specified, the MDLs were calculated based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (USEPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Patuxent River Lower TMDL of sediment is reported in ton/yr, and the conversion from ton/yr to a MDL in ton/day is 0.0085 (e.g. 3.11/365).

Results of approach

This section lists the results of the selected approach to define the Patuxent River Lower MDLs. The final results are presented in Table B-1.

- Calculation Approach for Nonpoint Sources and Stormwater Point Sources within the Patuxent River Lower Watershed

The MDL for Nonpoint Sources and Stormwater Point Sources within the Patuxent River Lower Watershed is based upon the 95th percentile value of the CBP P5.3.2 model daily load time series, reduced by the same percentage as the corresponding TMDL value. The 95th percentile load of the daily times series is 57 tons/day and with a TMDL reduction of 38%, it results in a total watershed MDL of 36 tons/day. The total MDL is subdivided in accordance with the same ratios present in the TMDL.

- Calculation Approach for Wastewater Point Sources within the Patuxent River Lower Watershed

  - For permits with a daily maximum limit:

Wastewater WLA_{PRL} (ton/day) = Permit flow (millions of gallons per day (MGD)) * Daily maximum permit limit (milligrams per liter (mg/l)) * 0.0042, where 0.0042 is a combined factor required to convert units to ton/day

  - For permits without a daily maximum limit:

Wastewater WLA_{PRM} (ton/day) = Average Annual TMDL Wastewater WLA_{PRM} Other (ton/yr)* 0.0085, where 0.0085 is the factor required to convert units to ton/day

The aggregate MDL for the point sources in the watershed is negligible.

Table B-1: Patuxent River Lower Watershed Maximum Daily Loads of Sediment (ton/day)

MDL (ton/day)	=	LA_{PRM}	+	NPDES Stormwater WLA_{PRM}	+	Wastewater WLA_{PRM}	+	MOS
36	=	32	+	4	+	0.0087	+	Implicit

APPENDIX C – Extension of Phase II MS4 Requirements to Calvert and St Mary's Counties

In December 2016, the Maryland Department of the Environment reached a tentative determination to issue a National Pollutant Discharge Elimination System (NPDES) General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (General Discharge Permit No. 13-IM-5500, General NPDES No. MDR055500).

Designation criteria for Small MS4s under the second-generation permit are summarized as follows:

Any small municipality with a population greater than 1000 that is located in a Phase I MS4 jurisdiction
Urbanized areas as determined by the latest Decennial Census by the US Census Bureau in accordance with 40 CFR 122.32(a)(1).
Other areas located outside of urbanized areas that are designated by MDE. Based on 40 CFR 123.35 (b)(2), this includes all municipalities with a population of at least 10,000 and a population density of at least 1,000 people per square mile.

Due to recent changes in population, as reported in the latest Decennial Census by the U.S. Census Bureau, portions of Calvert and Saint Mary's Counties that now meet the above population criteria will likely be covered by the NPDES Phase II MS4 permit.
.
At the time of the writing of this TMDL, the final determination for the permit had not been completed, and therefore all urban land in Calvert and Saint Mary's Counties was accounted for as part of the nonpoint source load in the baseline load and as part of the load allocation in the TMDL.

Upon approval of the permit, the following values will become effective.

Table C-1: Patuxent River Lower Watershed Baseline Sediment Loads (ton/yr) Using Draft Permit 13-IM-5500 for Small MS4s

Total Baseline Load	=	Nonpoint Source BL_{PRL}	+	NPDES Stormwater BL_{PRL}	+	Wastewater BL_{PRL}
15,007	=	13,186	+	1,819	+	2

Table C-2: Patuxent River Lower Watershed Average Annual TMDL of Sediment (ton/yr) Using Draft Permit 13-IM-5500 for Small MS4s

TMDL	=	LA_{PRL}	+	NPDES Stormwater WLA_{PRL}	+	Wastewater WLA_{PRL}	+	MOS
9,318	=	8,060	+	1,256	+	2	+	Implicit

Table C-3: Patuxent River Lower Watershed Average Maximum Daily Load of Sediment (ton/yr) Using Draft Permit 13-IM-5500 for Small MS4s

MDL	=	LA_{PRL}	+	NPDES Stormwater WLA_{PRL}	+	Wastewater WLA_{PRL}	+	MOS
36	=	31	+	5	+	0.0087	+	Implicit

Table C-4: Detailed Baseline Sediment Loads Within the Patuxent River Lower Watershed (ton/yr) Using Draft Permit 13-IM-5500 for Small MS4s

General Land Use	Detailed Land-Use	Tons/Yr	Percent (%)	Grouped Percent of Total (%)
Forest	Forest	1,544	10.3	10.9
	Harvested Forest	85	0.6	
AFOs	Animal Feeding Operations	26	0.2	0.2
Pasture	Pasture	235	1.6	1.6
Crop	Crop	9,380	62.5	62.5
Nursery	Nursery	115	0.8	0.8
Unregulated Urban[1]	Unregulated Urban	1,800	12.0	12.0
Regulated Urban[1]	Construction	990	6.6	12.1
	Developed	720	4.8	
	Extractive	109	0.7	
Point Sources	Industrial Point Sources	1	0.0	0.0
	Municipal Point Sources	1	0.0	
Total[2]		**15,007**	**100.0**	**100.0**

[1] Unregulated urban land use is not regulated by a Municipal Separate Storm Sewer System (MS4) permit. Regulated urban land use is regulated by an MS4 permit.
[2] Individual values may not add to total load due to rounding.