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**Total Maximum Daily Load of Phosphorus
in the Rock Creek Watershed,
Montgomery County, Maryland**

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Table of Contents

List of Figures..... i

List of Tables i

List of Abbreviations ii

EXECUTIVE SUMMARY iv

1.0 INTRODUCTION..... 1

2.0 SETTING AND WATER QUALITY DESCRIPTION..... 3

 2.1 General Setting 3

 2.1.1 Land-Use 5

 2.2 Source Assessment 8

 2.2.1 Nonpoint Sources (NPS) Assessment 8

 2.2.2 Point Source (PS) Assessment..... 10

 2.2.3 Overall Phosphorus Budget..... 11

 2.3 Water Quality Characterization 12

 2.3.1 Biological Stressor Identification (BSID) Analysis 16

 2.3.2 Dissolved Oxygen 16

 2.3.3 Nutrients 17

 2.3.4 Nutrient Limitation..... 18

 2.3.5 Rock Creek Mainstem Benthic Macroinvertebrate Monitoring Station... 19

 2.4 Water Quality Impairment..... 19

3.0 TARGETED WATER QUALITY GOAL..... 21

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION..... 22

 4.1 Overview..... 22

 4.2 Analysis Framework..... 22

 4.3 Scenario Descriptions and Results..... 24

 4.4 Critical Conditions and Seasonality..... 26

 4.5 TMDL Loading Caps..... 26

 4.6 Load Allocations Between Point and Nonpoint Sources..... 27

 4.7 Margin of Safety..... 30

 4.8 Summary of Total Maximum Daily Loads..... 30

5.0 ASSURANCE OF IMPLEMENTATION 31

REFERENCES..... 34

APPENDIX A – Watershed Characterization Data A-1

APPENDIX B – Technical Approach Used to Generate Maximum Daily Loads... B-1

FINAL

List of Figures

Figure 1: Location Map of Rock Creek in Montgomery County, Maryland.....	4
Figure 2: Landuse of the Rock Creek Watershed	7
Figure 3: Monitoring Stations in the Rock Creek Watershed.....	15
Figure 4: Rock Creek Dissolved Oxygen Data from 1998 through 2007.....	17
Figure 5: Rock Creek Total Nitrogen Data from 1998 through 2007.....	18
Figure 6: Rock Creek Total Phosphorus Data from 1998 through 2007	18
Figure B-1: Histogram of CBP River Segment Daily Phosphorus Simulation Results for the Rock Creek Watershed.....	B-5

List of Tables

Table ES-1: MD 8-digit Rock Creek Baseline Phosphorus Loads	vii
Table ES-2: Average Annual MD 8-digit Rock Creek TMDL of Phosphorus (lbs/yr)....	vii
Table ES-3: MD 8-Digit Rock Creek Baseline Phosphorus Load, TMDL, and Total Reduction Percentage.....	vii
Table 1: Landuse Percentage Distribution for the Rock Creek Watershed	6
Table 2: Target EOS Loading Rates (lbs/ac/yr) By Landuse and County Land Segment..	9
Table 3: 2009 Process Water Annual Phosphorus Loads for Facilities in Rock Creek Watershed Represented in Phase 5.3 Watershed Model.....	11
Table 4: Rock Creek Watershed Detailed Baseline Total Phosphorus Loads	12
Table 5: MD 8-digit Rock Creek Baseline Phosphorus Loads	12
Table 6: Monitoring Stations in the Rock Creek Watershed	14
Table 7: Rock Creek Mainstem DNR CORE/TREND Data	19
Table 8: Rock Creek Watershed TMDL for Phosphorus.....	27
Table 9: MD 8-digit Rock Creek TMDL Phosphorus TMDL by Source Category	28
Table 10: Average Annual MD 8-digit Rock Creek TMDL of Phosphorus (lbs/yr).....	30
Table 11: MD 8-digit Rock Creek Maximum Daily Load of Phosphorus (lbs/day)	30
Table A-1: Reference Watersheds	A-1
Table B-1: Summary of Maximum Daily Loads of Total Phosphorus for the Rock Creek Watershed	B-7

FINAL

List of Abbreviations

BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practices
BSID	Biological Stressor Identification
CAFO	Concentrated Animal Feeding Operation
CBLCD	Chesapeake Bay Watershed Land Cover Data
CBP P5.3.2	Chesapeake Bay Program Phase 5.3.2
CCAP	Coastal Change Analysis Program
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
COMAR	Code of Maryland Regulations
CNMP	Comprehensive Nutrient Management Plan
CSOs	Combined Sewer Overflows
CV	Coefficient of Variation
CWA	Clean Water Act
DMR	Discharge Monitoring Reports
DNR	Maryland Department of Natural Resources
ENR	Enhanced Nutrient Reduction
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
EPT	<i>Ephemeroptera, Plecoptera, and Trichoptera</i>
DO	Dissolved Oxygen
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
HSPF	Hydrological Simulation Program FORTRAN
IBI	Index of Biotic Integrity
LA	Load Allocation
lbs	Pounds
lbs/ac/yr	Pounds Per Acre Per Year
lbs/day	Pounds Per Day
lbs/yr	Pound Per Year
MAFO	Maryland Animal Feeding Operation
MAL	Minimum Allowable Limit
MBSS	Maryland Biological Stream Survey

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MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
MGD	Millions of Gallons per Day
mg/l	Milligrams per liter
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristics
MS4	Municipal Separate Stormwater System
NLCD	Consortium's National Land Cover Data
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
PCB	Polychlorinated biphenyls
PS	Point Source
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USGS	United States Geological Survey
WIP	Watershed Implementation Plan
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

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EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for total phosphorus (TP) in the Rock Creek watershed (basin number 02140206) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02140206). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's 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 2011a).

The Maryland Department of the Environment (MDE) has identified the waters of the Rock Creek watershed on the State's 2010 Integrated Report as impaired by nutrients (1996) and impacts to biological communities (2002) (MDE 2010a). All impairments are listed for non-tidal streams. Because scientific research supports that phosphorus is generally the limiting nutrient in freshwater aquatic systems, the 1996 nutrients listing was refined in the 2008 Integrated Report to identify phosphorus as the specific impairing substance (MDE 2008). Therefore, the listed impairment of phosphorus will henceforth be referred to in this report and the term "nutrients" should be read as interchangeable with "phosphorus" in this case.

The designated use of the Rock Creek mainstem and its tributaries is Use I (*Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life*), except for 1) the Rock Creek mainstem and its tributaries and the North Branch Rock Creek and its tributaries above Muncaster Mill Road, which are designated as Use III (*Water Contact Recreation, and Protection of Nontidal Cold Water Aquatic Life*), and 2) the Rock Creek mainstem and its tributaries in between Route 28 and Muncaster Mill Road, which are designated as Use IV (*Water Contact Recreation, Protection of Aquatic Life and Recreational Trout Waters*) (COMAR 2012a,b,c,d,e).

A data solicitation for nutrients was conducted by MDE in 2009, and all readily available data from 1998 up to the time of the TMDL development have been considered. A TMDL for bacteria was approved by the EPA in 2007. Water Quality Analyses (WQAs) for eutrophication to address the Needwood Lake and Lake Bernard Frank nutrients/phosphorus listings were approved by the EPA in 2003. A TMDL for sediment was approved by EPA in 2011. In the 2012 Integrated Report, the listing for impacts to biological communities will include the results of a stressor identification analysis.

The Rock Creek watershed aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI), indicate that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions (Roth *et al.* 2005). The Biological Stressor Identification (BSID) analysis for the Rock Creek watershed identified phosphorus, conductivity, and sediment as a potential stressors (MDE 2012a). As much as 27% of the biologically impacted stream miles in the watershed may be degraded due to high total phosphorus. An

FINAL

analysis of observed TN:TP ratios indicates that phosphorus is the limiting nutrient in the Rock Creek watershed. Because nitrogen generally exists in quantities greater than necessary to sustain algal growth, excess nitrogen *per se* is not the cause of the biological impairment in Rock Creek, and the reduction of nitrogen loads would not be an effective means of ensuring that the Rock Creek watershed is free from impacts on aquatic life from eutrophication. Therefore, load allocations for the Rock Creek Nutrient TMDL will apply only to total phosphorus.

The objective of this TMDL is to establish phosphorus loads that will be protective of the Aquatic Life Use designation for the Rock Creek watershed. Currently in Maryland, there are no specific numeric criteria that quantify the impact of nutrients on the aquatic health of non-tidal stream systems; therefore, a reference watershed TMDL approach was used, which resulted in the establishment of a *phosphorus loading threshold*. This threshold is based on a detailed analysis of phosphorus loads from watersheds that are identified as supporting aquatic life (*i.e.*, reference watersheds) based on Maryland's biocriteria (Roth *et al.* 1998, 2000; Stribling *et al.* 1998; MDE 2010a). This threshold is then used to determine a watershed specific phosphorus TMDL. The resulting loads are considered the maximum allowable loads the watershed can receive without causing nutrient related impacts to aquatic health.

The computational framework chosen for the Rock Creek watershed TMDL was the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) Watershed Model. The spatial domain of the CBP P5.3.2 watershed model segmentation aggregates to the Maryland 8-digit watersheds, which is consistent with the impairment listing.

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2011b). 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 all high and low flow events). Thus, critical conditions are inherently addressed. Seasonality is captured in two 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 included benthic sampling in the spring and fish sampling in the summer. Moreover, the loading rates used in the TMDL were determined using the Hydrological Simulation Program Fortran (HSPF) model, which is a continuous simulation model with a simulation period 1991-2000, thereby addressing annual changes in hydrology and capturing wet, average, and dry years.

EPA's regulations also require TMDLs to be presented as a sum of waste load allocations (WLAs) for permitted point sources in the assessment unit and load allocations (LAs) for nonpoint sources generated within the assessment unit. In addition, TMDLs must account for natural background, tributary and adjacent segment loads. Finally, TMDLs must also include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2011a).

FINAL

Because the phosphorus loading threshold was conservatively based on the median phosphorus loading rates from reference watersheds, Maryland has adopted an implicit MOS for nutrient TMDLs.

The MD 8-digit Rock Creek total Baseline Phosphorus Load is 24,441 pounds per year (lbs/yr). The MD 8-digit Rock Creek Watershed Baseline Load Contribution is further subdivided into nonpoint source baseline loads (Nonpoint Source BL) and three types of point source baseline loads: regulated concentrated animal feeding operations (CAFO), National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL), and regulated process water (Process Water BL) (see Table ES-1). There are no CAFOs, however, in the Rock Creek watershed. Phosphorus loads from septic systems are considered insignificant.

The MD 8-digit Rock Creek Average Annual TMDL of Phosphorus (TP) is 16,244 lbs/yr. The MD 8-digit Rock Creek TMDL Contribution is further subdivided into point and nonpoint source allocations and is comprised of a Load Allocation (LA) of 3,720 lbs/yr, an NPDES Stormwater Wasteload Allocation (NPDES Stormwater WLA) of 10,815 lbs/yr, and a Process Water Wasteload Allocation (Process Water WLA) of 1,709 lbs/yr. Because there are no CAFOs in the Rock Creek watershed, the CAFO Wasteload Allocation (CAFO WLA) is equal to zero (see Table ES-2).

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

Overall, this TMDL will establish phosphorus loads that will be protective of the Use I/III/IV designations for the Rock Creek watershed, and more specifically, these loads will be at a level the watershed can sustain without causing any nutrient related impacts to aquatic health. The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Because the BSID watershed analysis identifies other possible stressors (*i.e.*, conductivity, sediment) as impacting the biological conditions, this impairment remains to be fully addressed through the Integrated Report listing process and the TMDL development process, such that all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2009a).

Once the EPA has approved this TMDL and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) are expected to take place. Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load and wasteload allocations can and will be implemented. The Rock Creek phosphorus TMDL is expected to be implemented in a staged process. Reductions of nitrogen and phosphorus loads will be required to meet the Chesapeake Bay TMDL recently established by EPA (US EPA 2010a). These reductions are necessary to meet water quality standards to protect the designated uses of the Chesapeake Bay and its tidal tributaries, independent of any

FINAL

additional nutrient reductions that may be required to meet existing water quality standards designed to protect aquatic life in local non-tidal waterbodies.

MDE expects that the first stage of implementation of the Rock Creek phosphorus TMDL shall be the achievement of the nutrient reductions needed within the Rock Creek watershed in order to meet target loads consistent with the Chesapeake Bay TMDL, which is expected to be fully implemented in Maryland by 2025. Once the Bay TMDL nutrient target loads for the Rock Creek watershed have been met, MDE will revisit the status of nutrient impacts on aquatic life in Rock Creek, based on any additional monitoring data available and any improvements in the scientific understanding of the impacts of nutrients on aquatic life in free-flowing streams.

Table ES-1: MD 8-digit Rock Creek Baseline Phosphorus Loads

MD 8-digit Rock Creek Watershed Baseline Load Contribution										
Total Baseline Load (lbs/yr)	=	Nonpoint Source BL	+	Septic BL	+	CAFO BL	+	NPDES Stormwater BL	+	Process Water BL _c
24,441	=	4,365	+	0	+	0	+	16,261	+	3,815

Table ES-2: Average Annual MD 8-digit Rock Creek TMDL of Phosphorus (lbs/yr)

TMDL (lbs/yr)	=	LA			+	WLA				+	MOS	
		LA	+	Septic		CAFO WLA	+	NPDES Stormwater WLA	+			Process Water WLA
16,244	=	3,720	+	0	+	0	+	10,815	+	1,709	+	Implicit

Table ES-3: MD 8-Digit Rock Creek Baseline Phosphorus Load, TMDL, and Total Reduction Percentage

Baseline Load (lbs/yr)	TMDL (lbs/yr)	Total Reduction (%)
24,441	16,244	34%

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1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for total phosphorus (TP) in the Rock Creek watershed (basin number 02140206) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02140206). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the Section 303(d) List, taking into account seasonal variations, critical conditions, and a protective margin of safety (MOS) to account for uncertainty (CFR 2011a). A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

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 Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Rock Creek mainstem and its tributaries is Use I (*Water Contact Recreation and Protection of Nontidal Warm Water Aquatic Life*), except for 1) the Rock Creek mainstem and its tributaries and the North Branch Rock Creek and its tributaries above Muncaster Mill Road, which are designated as Use III (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life*), and 2) the Rock Creek mainstem and its tributaries in between Route 28 and Muncaster Mill Road, which are designated as Use IV (*Water Contact Recreation, Protection of Aquatic Life and Recreational Trout Waters*) (COMAR 2012a,b,c,d,e).

The Maryland Department of the Environment (MDE) has identified the waters of the Rock Creek watershed on the State's 2010 Integrated Report as impaired by nutrients (1996) and impacts to biological communities (2002) (MDE 2010a). All impairments are listed for non-tidal streams. Because scientific research supports that phosphorus is generally the limiting nutrient in freshwater aquatic systems, the 1996 nutrients listing was refined in the 2008 Integrated Report to identify phosphorus as the specific impairing substance (MDE 2008). Therefore, the listed impairment of phosphorus will henceforth be referred to in this report and the term "nutrients" should be read as interchangeable with "phosphorus" in this case.

A data solicitation for nutrients was conducted by MDE in 2009, and all readily available data from 1998 up to the time of the TMDL development have been considered. A TMDL for bacteria was approved by the EPA in 2007. Water Quality Analyses (WQAs) for eutrophication to address the Needwood Lake and Lake Bernard Frank nutrients/phosphorus listings were approved by the EPA in 2003. A TMDL for sediment

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was approved by EPA in 2011. In the 2012 Integrated Report, the listing for impacts to biological communities will include the results of a stressor identification analysis.

The objective of this TMDL is to establish phosphorus loads that will be protective of the Aquatic Life Use designation for the Rock Creek watershed. A Biological Stressor Identification (BSID) analysis of Rock Creek (MDE 2012a) shows phosphorus is associated with biological impairments in the Rock Creek watershed, confirming the original 1996 listing; therefore, a TMDL will be established for phosphorus.

Currently in Maryland, there are no specific numeric criteria that quantify the impact of nutrients on the aquatic health of non-tidal stream systems; therefore, a reference watershed TMDL approach was used, which resulted in the establishment of a *phosphorus loading threshold*. This threshold is based on a detailed analysis of phosphorus loads from watersheds that are identified as supporting aquatic life (*i.e.*, reference watersheds) based on Maryland's biocriteria (Roth *et al.* 1998, 2000; Stribling *et al.* 1998; MDE 2010a). This threshold is then used to determine a watershed specific phosphorus TMDL. The Chesapeake Bay Program's Phase 5.3.2 Watershed Model (CBP P5.3.2) is used to determine the phosphorus loads in both Rock Creek and the reference watersheds that will be used to set the phosphorus TMDL for Rock Creek.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

Rock Creek is a free-flowing stream that originates near the town of Laytonsville in Montgomery County, Maryland and flows 23 miles in a southeasterly direction until it empties into the tidal Potomac River in Washington, D.C. The watershed is located in the Middle Potomac River sub-basin of the Chesapeake Bay watershed within both Montgomery County, Maryland and Washington, D.C. The entire watershed comprises 52,761 acres, of which 39,273 acres are located within Montgomery County, Maryland (see Figure 1).

The North Branch of Rock Creek originates at Mount Zion, Maryland and discharges into the Rock Creek mainstem in Rockville, Maryland. There are two impoundments located in the watershed: Needwood Lake and Lake Bernard Frank. There are no “high quality”, or Tier II, stream segments (Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (scale 1-5)) located within the watershed requiring the implementation of Maryland’s anti-degradation policy (COMAR 2012f, MDE 2009b). Also, approximately 0.3% of the watershed area is covered by water (*i.e.*, streams, ponds, etc.). The total population in the Rock Creek watershed is approximately 307,000 (US Census Bureau 2000).

Geography/Soils

The Rock Creek watershed lies in both the Piedmont and Coastal Plain geologic provinces of Maryland (upstream portion in Piedmont and downstream portion in Coastal Plain Province). The Piedmont geologic province is characterized by gentle to steep rolling topography, low hills, and ridges. The surficial geology is characterized by crystalline igneous and metamorphic rocks of volcanic origin consisting primarily of schist and gneiss. The Coastal Plain geologic province is characterized by deep sedimentary soil complexes that support broad meandering streams (DNR 2009b, MGS 2009, MDE 2000).

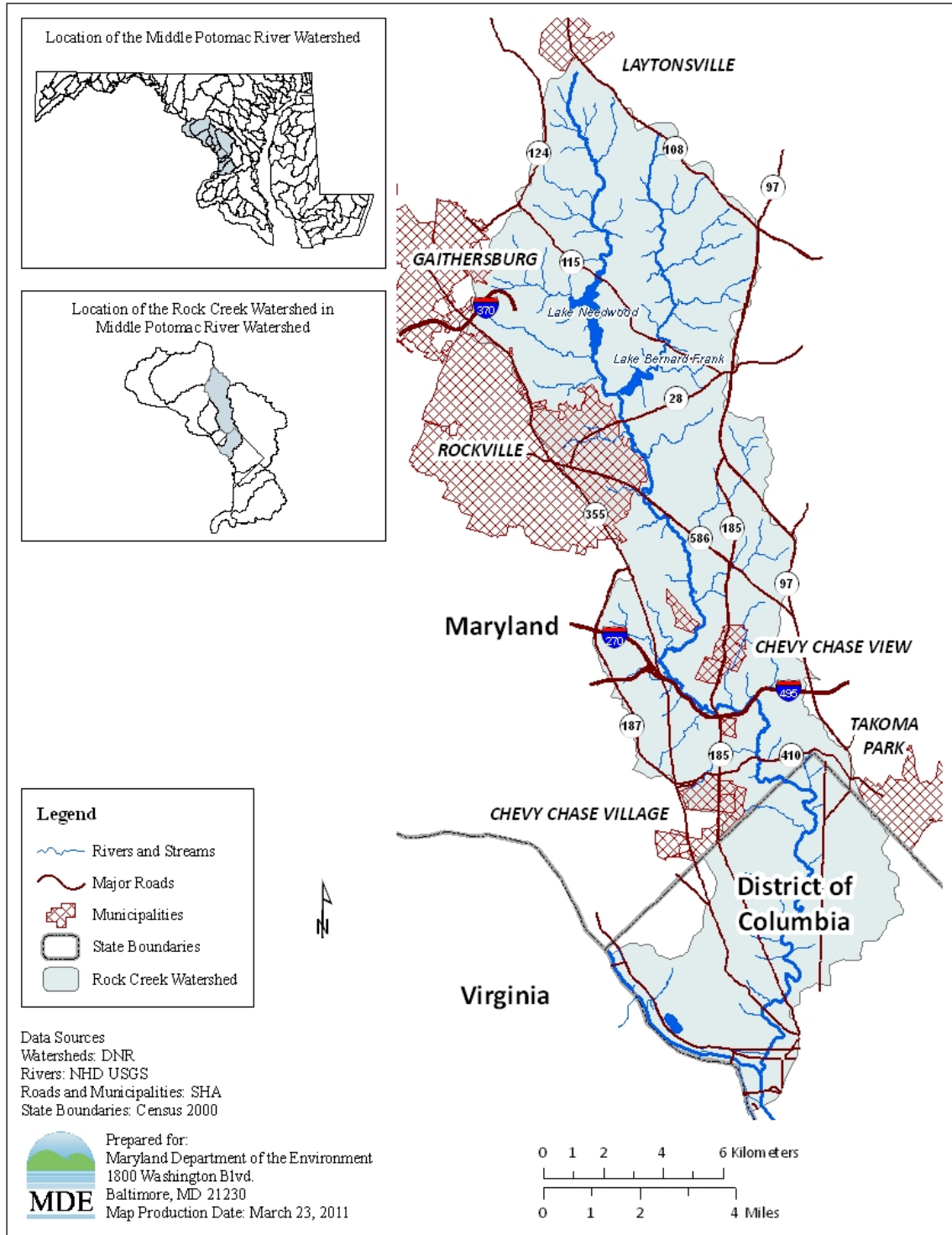


Figure 1: Location Map of Rock Creek in Montgomery County, Maryland

2.1.1 Land-Use

Landuse Methodology

The landuse framework used to develop this TMDL was originally developed for the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) watershed model.¹ The CBP P5.3.2 landuse was based on two distinct stages of development.

The first stage consists 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 2 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, USGS's contractor, MDA Federal, generated CBLCD datasets for 1984, 1992, and 2006 from the 2001 baseline dataset. The "*Chesapeake Bay Phase 5.3 Community Watershed Model*" (US EPA 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 landuse classes.

The second stage consists 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 landuse 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 landuse framework: U.S. 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 (Claggett *et al.* 2012). Finally, in order to develop accurate agricultural landuse acreages, the CBP P5.3.2 incorporated county-level U.S. Agricultural Census data (USDA 1982, 1987, 1992, 1997, 2002, 2007). The "*Chesapeake Bay Phase 5.3 Phase 5.3 Community Watershed Model*" (US EPA 2010b) describes these modifications in more detail.

¹ The EPA Chesapeake Bay Program developed the first watershed model in 1982. There have been many upgrades since the first phase of this model. The latest version, CBP P5.3.2 watershed model was developed to estimate flow, nutrients, and sediment loads to the Bay.

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The result of these modifications is that CBP P5.3.2 landuse 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. Within each general landuse type, most of the subcategories of land uses are differentiated only by their nitrogen and phosphorus loading rates. Table 1 lists the CBP P5.3.2 generalized land uses, detailed land uses, and the acres of each landuse in the Rock Creek watershed. The landuse acreage is based on the CBP P5.3.2 2009 Progress Scenario, which, for the CBP P5.3.2 model, represents current conditions.

Rock Creek Watershed Landuse Distribution

The Rock Creek watershed primary land uses are regulated urban (76.1%), followed by forest (18.3%). There are also small amounts of crop (4.2%) and pasture (1.0%) land uses. A detailed summary of the watershed landuse areas is presented in Table 1, and a landuse map is provided in Figure 2.

Table 1: Landuse Percentage Distribution for the Rock Creek Watershed

General Land-Use	Detailed Land-Use	Area (Acres)	Percent	Grouped Percent of Total
Forest	Forest	7,126	18.1 %	18.3 %
	Harvested Forest	70	0.2 %	
AFOs	Animal Feeding Operations	2	<0.1 %	0.0 %
CAFOs	Concentrated Animal Feeding Operations	0	0.0 %	0.0 %
Pasture	Pasture	387	1.0 %	1.0 %
Crop	Crop	1,661	4.2 %	4.2 %
Nursery	Nursery	28	0.1 %	0.1 %
Regulated Urban	Regulated Construction	191	0.5 %	76.1 %
	Regulated Developed	29,690	75.6 %	
	Regulated Extractive	0	0.0 %	
Water	Water	118	0.3 %	0.3 %
Total		39,273	100.0 %	100.0 %

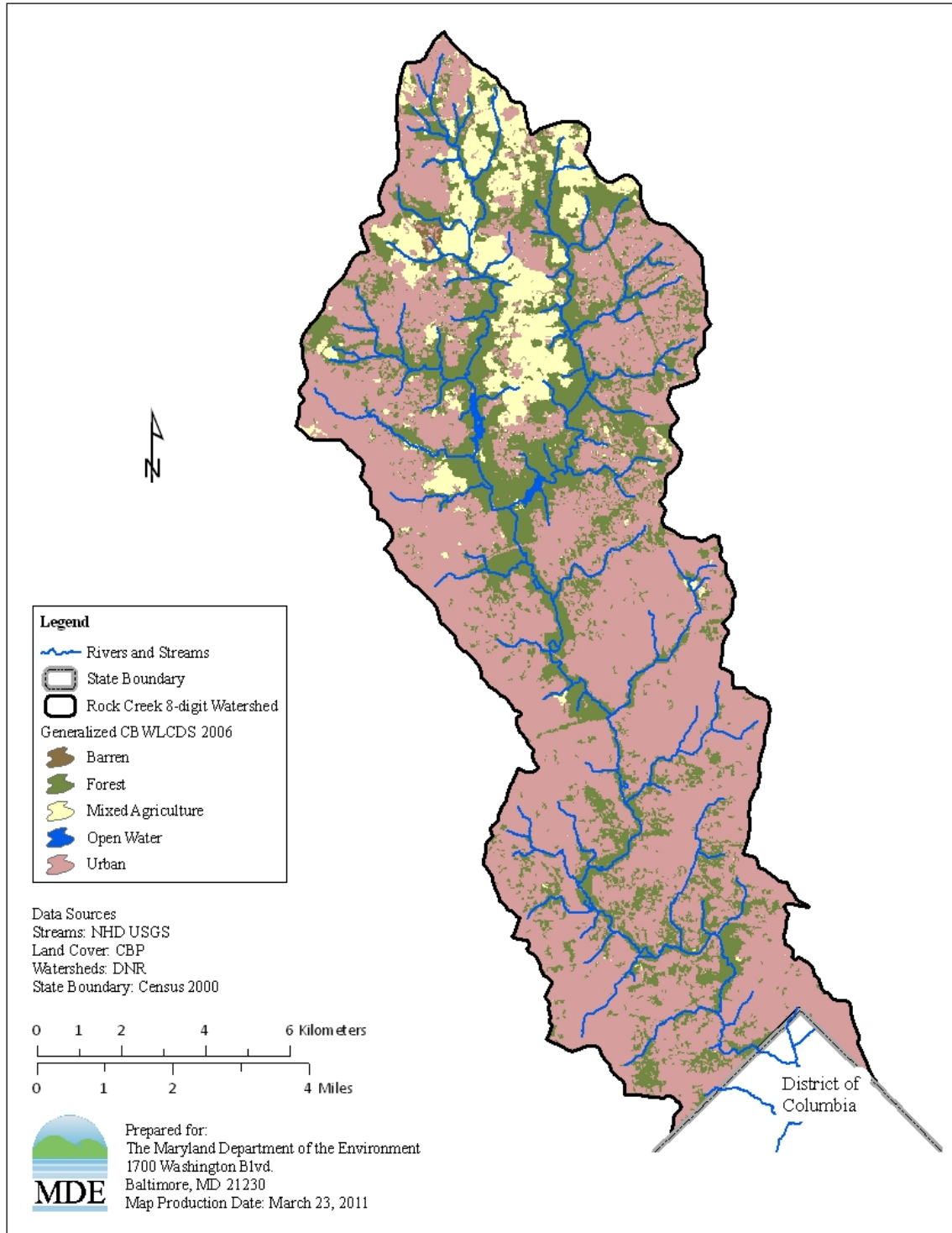


Figure 2: Landuse of the Rock Creek Watershed

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2.2 Source Assessment

2.2.1 Nonpoint Sources (NPS) Assessment

Nonpoint source nutrient loads in the Rock Creek watershed are estimated based on the edge-of-stream (EOS) loading rates from the CBP P5.3.2 Model 2009 Progress Scenario. The 2009 Progress Scenario is a simulation of nutrient loading, to the creek, using as inputs current land use, BMP implementation and estimated loading rates, precipitation and other meteorological data from the period 1991 – 2000. The period 1991-2000 is the baseline hydrological period for the Chesapeake Bay TMDL.

EOS loads in the P5.3.2 model are determined by three factors: (1) the median of landuse specific loading rates found in the scientific literature; (2) the adjustment of the median loading rate based on the excess nutrient inputs applied to agricultural land uses to determine EOS targets by land segment and land-use; and (3) the application of regional factors in the river calibration.

Literature Review

Using Beaulac and Rechow's (1982) literature survey as a starting point, CBP staff conducted a survey of the scientific literature to determine the range of observed nutrient loading rates from land uses. Most of these estimates were made from observations on small, homogeneous watersheds and thus represent edge-of-stream, rather than edge-of-field, nutrient loads. Phosphorus loads for urban land uses are based on the median phosphorus concentration in urban stormwater determined by Pitt *et al.* (2005) in their study of monitoring data collected by jurisdictions for their Municipal Separate Storm Sewer System (MS4) permits. See "*Chesapeake Bay Phase 5.3 Community Watershed Model*" (US EPA 2010b) for further discussion of loading rates found in the scientific literature.

EOS Calibration Targets

Land processes in the P5.3.2 model are simulated by landuse and land segment. Land segments are counties or, in some cases, sections of counties where precipitation is expected to vary because of orographic uplifting.

The median literature loading rate is the starting point for determining calibration targets for EOS loads in the P5.3.2 model. For developed land uses, the target load is the product of average annual simulated runoff in the land segment and the median phosphorus concentration in urban stormwater, 0.27 mg/l, as determined by Pitt *et al.* (2005). For agricultural land uses, median rates were adjusted upwards or downwards depending on how much of the amount of nutrients applied to a landuse in a land segment exceeded the needs of the vegetation on that landuse, compared to the average Chesapeake Bay segment. In other words, land segment calibration targets were distributed around the median literature values in proportion to the excess nutrients applied to the segments.

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CBP calculated the nutrient loading rates for manure, fertilizer, and atmospheric deposition, as well as crop and vegetative uptake, for each landuse and land segment. These calculations were based on the agricultural census, the expert opinion of local and state agronomists, statistics on fertilizer sales, and a mass balance of animal waste based on animal population estimates. See “*Chesapeake Bay Phase 5.3 Phase 5.3 Community Watershed Model*” (US EPA 2010b) for further details on the calculation of loading rates. For land uses with nutrient management, EOS loads are determined by reducing nutrient inputs to their agronomic rates on the corresponding landuse without nutrient management.

Table 2 gives the TP EOS targets for non-nutrient management land uses.

Table 2: Target EOS Loading Rates (lbs/ac/yr) By Landuse and County Land Segment

Land-Use	Montgomery County CBP Land Segment A24031
Forest	0.11
Harvested Forest	0.80
Degraded Riparian Pasture	12.39
Pasture	1.03
Alfalfa	0.70
Hay Without Nutrients	0.40
Hay With Nutrients	0.71
High Till Without Manure	2.77
High Till With Manure	1.94
Low Till With Manure	1.93
Nursery	85.00
Regulated Extractive	3.50
Regulated Construction	7.00
Regulated Impervious Developed	2.05
Regulated Pervious Developed	0.36

Nutrient simulations for specific land uses are calibrated against these targets on a per acre basis over the simulation period 1985-2005. The phosphorus loads from these simulations are multiplied by a time-variable representation of the landuse acreage in each watershed, and the impact of changing levels of BMP implementation are also simulated over the 21-year calibration period. The resulting loads are used as the initial EOS inputs to the river simulation. During the calibration of the river simulation, the EOS loads are adjusted by regional factors, as explained below.

Regional Factors

The use of literature loading rates and their adjustment according to the excess nutrients applied to the land can be expected to provide a good estimate of landuse loading rates relative to each other. To further reduce uncertainty in loading rates, CBP applies a multiplicative regional factor to the simulated land segment loading rate. Regional factors are calculated in the calibration of river segments, where simulated output is

compared to observed monitoring data. Regional factors are calculated on a river segment basis. The regional factor for phosphorus in Rock Creek is 0.75.

2.2.2 Point Source (PS) Assessment

A list of active NPDES permitted point sources that contribute to the phosphorus load in the Rock Creek watershed was compiled using MDE's permits database. The types of permits identified include individual municipal, individual industrial, general industrial stormwater and general municipal separate storm sewer systems (MS4s), general mining, and general Concentrated Animal Feeding Operations (CAFOs).

The types of NPDES permits can be grouped into two categories: (1) process water, (2) stormwater. In turn, process water permits can be divided into permits for municipal wastewater treatment plants (WWTPs) and permits for industrial facilities. Permits for major municipal WWTPs (*i.e.*, WWTPs with design flow equal to or larger than 0.5 MGD are considered major) and major industrial facilities contain flow and TP limits; their current nutrient loads are calculated from discharge monitoring reports (DMR) data. The remaining process water facilities have smaller flows and consequently smaller nutrient loads. There is one minor municipal WWTP and 18 minor industrial facilities permitted to discharge phosphorus in the Rock Creek watershed. Baseline phosphorus loads for minor municipal WWTPs are based on DMR data, while current loads for minor industrial facilities were either based on the results of monitoring required by their permits or on professional judgment.

Loads for all minor municipal and industrial facilities in the watershed are presented as one aggregate load in Table 3. All these facilities with their estimated loads are represented in the Phase 5.3.2 Watershed Model 2009 Progress Scenario. The total estimated 2009 process water TP load is 3,815 lbs/yr.

FINAL

Table 3: 2009 Process Water Annual Phosphorus Loads for Facilities in Rock Creek Watershed Represented in Phase 5.3 Watershed Model

NPDES #	Facility Name	Type		2009 TP Load (lbs/yr)
MD0020931	NIH ANIMAL CENTER	Municipal		
MD0062723	WMATA - MARINELLI ROAD			
MD0069035	WMATA.- RED LINE P.S.			
MD0025496	NATIONAL INSTITUTES OF HEALTH			
MDG918482	WHITE FLINT CROSSING			
MDG915049	SHELL STATION			
MDG766248	GARRETT PARK SWIM POOL ASSOC.			
MDG766476	NORTH CHEVY CHASE SWIMMING POOL ASSOCIATION			
MDG766207	BAR-T RANCH SUMMER CAMP			
MDG766474	BEL PRE RECREATION ASSN.	Industrial	Aggregate	3,815
MDG766898	CONNECTICUT BELAIR CLUB, INC.			
MDG766473	MILL CREEK TOWNE POOL			
MDG766632	MONTGOMERY CENTURY CONDOMINIUM			
MDG766448	FAIRWAYS CONDOS			
MDG499750	CLARK CONSTRUCTION GROUP - TUCKERMAN PLANT			
MD0069825	LAUREL SAND & GRAVEL - SOUTHLAWN READY MIX			
MDG492212	LAFARGE - ROCKVILLE CONCRETE PLANT			
MDG499847	MONTGOMERY CONCRETE OPERATIONS LLC			
MDG492709	ROCKVILLE FUEL FEED COMPANY			

In Maryland’s jurisdictions with Phase I and/or Phase II MS4 permits, all urban stormwater from developed land is regulated under the NPDES MS4 program. These urban stormwater loads are calculated using the developed landuse area in the watershed. The stormwater permits do not include nutrient limits, but are regulated instead based on programmatic approaches. The total regulated stormwater TP baseline load is 16,261 lbs/yr.

Starting in 2009, Maryland began the process of permitting Concentrated Animal Feeding Operations (CAFOs). CAFOs are medium to large animal feeding operations that have some artificial conveyance like a swale or ditch to discharge runoff from feedlots to surface water. Recent EPA regulations require CAFOs to have a NPDES permit. Maryland also designates large animal feeding operations which do not discharge or propose to discharge as “Maryland Animal Feeding Operations“(MAFOs). It is anticipated that on review many MAFOs will require CAFO permits. There are, however, no CAFOs in the Rock Creek watershed.

2.2.3 Overall Phosphorus Budget

Table 4 lists the current overall phosphorus distribution in the Rock Creek watershed. These loads are derived from the P5.3.2 2009 Progress Scenario, which simulates 2009 land uses, BMP implementation, and point source loads over the hydrological period

FINAL

1991-2000. The largest source of phosphorus is regulated developed land (66.5%) followed by point source (*i.e.*, process water) discharges (15.6%). The other phosphorus sources include nurseries (7.6%), crops (6.9%), forest (1.8%), pasture (1.2%), atmospheric deposition (0.3%), and animal feeding operations (AFOs) (0.2%). There are no concentrated animal feeding operations (CAFOs) or combined sewer overflows (CSOs) in the Rock Creek watershed, and phosphorus loads from septic systems are considered insignificant. Table 5 summarizes the Baseline Phosphorus Load, reported in pounds per year (lbs/yr).

Table 4: Rock Creek Watershed Detailed Baseline Total Phosphorus Loads

General Land-Use	Detailed Land-Use	Load (lbs/yr)	Percent (%)	Grouped Percent of Total
Forest	Forest	410	1.7%	1.8%
	Harvested Forest	28	0.1%	
AFOs	Animal Feeding Operations	48	0.2%	0.2%
CAFOs	Concentrated Animal Feeding Operations	0	0.0%	0.0%
Pasture	Pasture	282	1.2%	1.2%
Crop	Crop	1,675	6.9%	6.9%
Nursery	Nursery	1,852	7.6%	7.6%
Regulated Urban	Regulated Construction	615	2.5%	66.5%
	Regulated Developed	15,646	64.0%	
	Regulated Extractive	0	0.0%	
Septic	Septic	0	0.0%	0.0%
CSO	CSO	0	0.0%	0.0%
Point Sources	Industrial Point Sources	1,072	4.4%	15.6%
	Municipal Point Sources	2,742	11.2%	
Atmospheric Deposition	Non-tidal Atmospheric Deposition	70	0.3%	0.3%
Total		24,441	100.0%	100.0%

Note: Individual percentages may not add to 100% due to rounding.

Table 5: MD 8-digit Rock Creek Baseline Phosphorus Loads

MD 8-digit Rock Creek Watershed Baseline Load Contribution										
Total Baseline Load (lbs/yr)	=	Nonpoint Source BL	+	Septic BL	+	CAFO BL	+	NPDES Stormwater BL	+	Process Water BL
24,441	=	4,365	+	0	+	0	+	16,261	+	3,815

2.3 Water Quality Characterization

The Rock Creek watershed was originally listed on Maryland’s 1996 303(d) List as impaired by nutrients. The listing implied that the nutrient impairment was based on the watershed’s contribution to the impairment of the Chesapeake Bay (MDE 2004, DNR 1996).

FINAL

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 support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the waters of Rock Creek is Use I (*Water Contact Recreation and Protection of Nontidal Warm Water Aquatic Life*), except for 1) the Rock Creek mainstem and its tributaries and the North Branch Rock Creek and its tributaries above Muncaster Mill Road, which are designated as Use III (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life*), and 2) the Rock Creek mainstem and its tributaries in between Route 28 and Muncaster Mill Road, which are designated as Use IV (*Water Contact Recreation, Protection of Aquatic Life and Recreational Trout Waters*) (COMAR 2012a,b,c,d,e).

There are no specific numeric criteria for nutrients in Maryland's water quality standards for the protection of aquatic life in free-flowing non-tidal waters. MDE has developed a biological stressor identification (BSID) analysis to identify potential stressors of aquatic life, including nutrients, in 1st through 4th order streams assessed by the Maryland Biological Stream Survey (MBSS). The impact of eutrophication on smaller-order streams in the watershed will be evaluated on the basis of the BSID analysis, which provides necessary and sufficient conditions for determining whether phosphorus is a potential stressor of the biological community in smaller-order streams.

Low levels of dissolved oxygen are sometimes associated with the decay of excess primary production and therefore nutrient over-enrichment. The dissolved oxygen (DO) concentration to protect Use I waters "may not be less than 5 milligrams per liter (mg/l) at any time" and to protect Use III and IV waters "may not be less than 5 mg/l at any time, with a minimum daily average of not less than 6 mg/l" (COMAR 2012g).

A data solicitation for information pertaining to pollutants, including nutrients, in the Rock Creek watershed was conducted by MDE in November 2009. All readily available data from 1998 up to the time of the TMDL development have been considered, including data collected by the Department of Natural Resources (DNR) for the MBSS program during the spring and summer of 2003 and 2004, and for the CORE/TREND Program from January 1998 through June 2007. Data collected by MDE from October 2000 through October 2003 were also used. Figures 4 through 6 provide graphical representation of the collected data for the parameters discussed below.

Rock Creek Watershed Monitoring Stations

A total of 15 water quality monitoring stations were used to characterize the Rock Creek Watershed. There were nine biological/physical habitat monitoring stations from the DNR MBSS program and one biological monitoring station (RCM0111) from the

FINAL

Maryland CORE/TREND monitoring network. MDE also sampled at the CORE/TREND station and at four additional locations. The stations are listed in Table 6 and presented in Figure 3.

Table 6: Monitoring Stations in the Rock Creek Watershed

Station ID	Sponsor	Site Type	Latitude (Decimal-Degrees)	Longitude (Decimal-Degrees)
NCRW-304-N-2004	MD DNR	MBSS	38.980559	-77.043614
ROCK-105-R-2003	MD DNR	MBSS	39.166963	-77.110223
ROCK-106-R-2003	MD DNR	MBSS	39.123633	-77.094682
ROCK-107-R-2003	MD DNR	MBSS	39.035028	-77.114972
ROCK-203-R-2003	MD DNR	MBSS	39.105757	-77.125274
ROCK-204-R-2003	MD DNR	MBSS	39.152869	-77.105103
ROCK-208-R-2003	MD DNR	MBSS	39.125638	-77.101152
ROCK-210-R-2003	MD DNR	MBSS	39.126440	-77.100424
ROCK-211-R-2003	MD DNR	MBSS	39.137552	-77.103225
RCM0111	MD DNR	CORE/TREND	38.992830	-77.062000
RCM0111	MDE	Water Quality	38.992830	-77.062000
RCM0235	MDE	Water Quality	39.102250	-77.124670
RCM0280	MDE	Water Quality	39.137430	-77.129020
MLC0018	MDE	Water Quality	39.131750	-77.147370
ZNB0016	MDE	Water Quality	39.117450	-77.101270

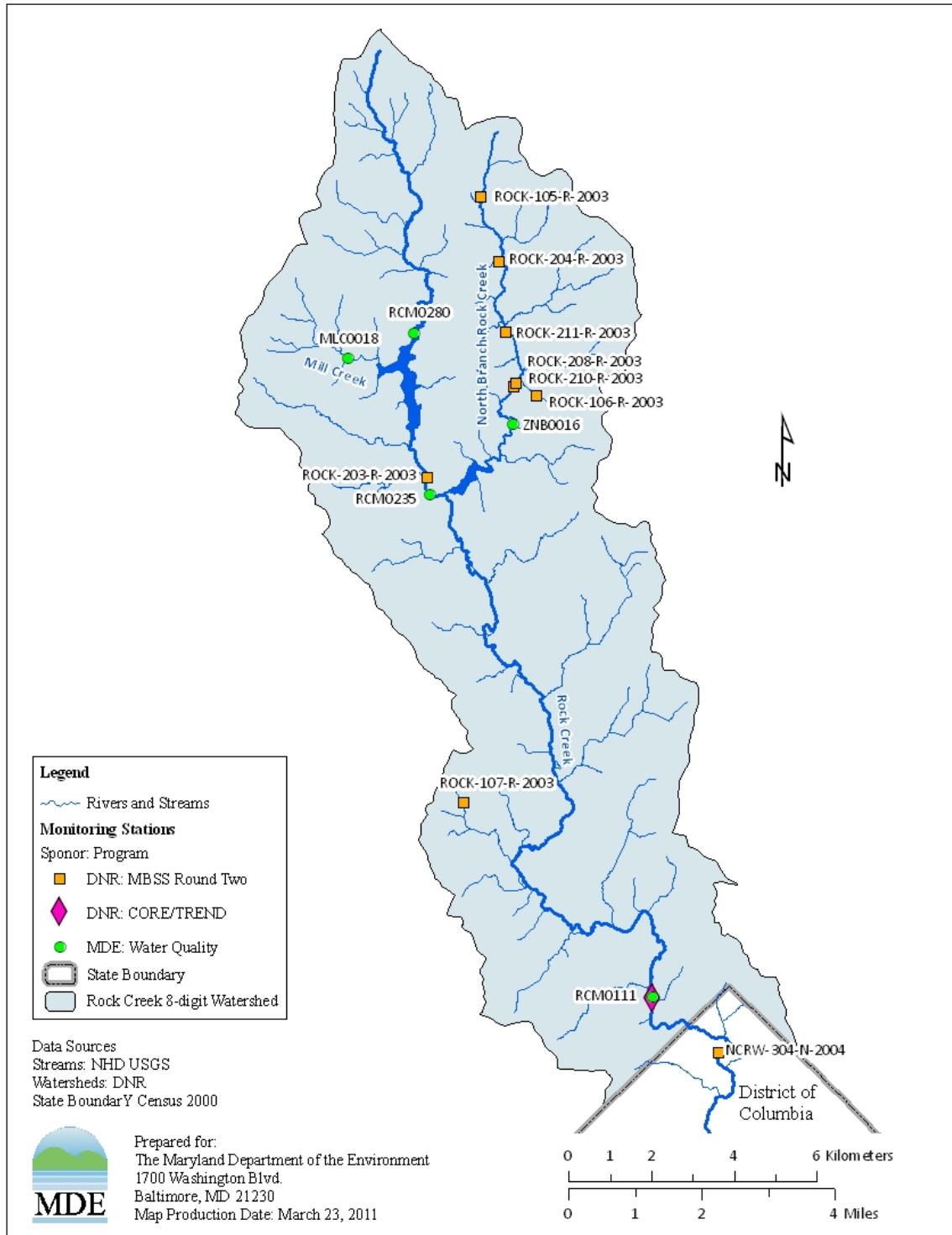


Figure 3: Monitoring Stations in the Rock Creek Watershed

2.3.1 Biological Stressor Identification (BSID) Analysis

MDE has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings in the State's Integrated Report.

The BSID methodology uses data available from the statewide Maryland Department of Natural Resources Maryland Biological Stream Survey (DNR MBSS). The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological stressors to Integrated Report categories.

The BSID analysis for the Rock Creek watershed identified total phosphorus as a potential stressor to aquatic health, in addition to high conductivity and sediment. The total phosphorus results show a significant association with degraded biological conditions. As much as 27% of the biologically impacted stream miles in the Rock Creek watershed are associated with high total phosphorus.

The BSID analysis also examines whether low DO concentrations are associated with degraded biological conditions. The analysis for the Rock Creek watershed concludes that the biologically impacted stream miles in the watershed are not associated with low DO concentrations. The indirect impact of nutrients on nontidal aquatic systems is complex and the science continues to evolve. While DO was not found to be associated with poor biological conditions, there could be confounding effects such as increased primary production resulting in periphyton growth and also diurnal fluctuations. At this time, both the original 1996 listing and the initial BSID analysis point to nutrients in general and phosphorus in particular, as a biological stressor in Rock Creek.

For details on the BSID analysis, please refer to the documents "*Watershed Report for Biological Impairment of the Non-Tidal Rock Creek Basin in Montgomery County, Maryland - Biological Stressor Identification Analysis Results and Interpretation*" (MDE 2012a) and "*Maryland Biological Stressor Identification Process*" (MDE 2009a).

2.3.2 Dissolved Oxygen

DNR CORE/TREND samples were taken in the Rock Creek watershed from January 1998 through June 2007, and MBSS samples were taken in the spring and summers of 2003 and 2004. The monitoring data are presented graphically in Figure 4. MDE samples were taken from October 2000 through October 2003. Samples taken during the growing season (May 1 through October 31) show DO concentrations ranging from 3.30 to 10.5 mg/l. Only one sample (of 112) had a concentration below the DO criterion of 5.0 mg/l. No station with a Use III or IV classification had samples with DO concentrations of less than 6 mg/l. The monitoring data indicate that the water quality standard for DO is being met in Rock Creek watershed.

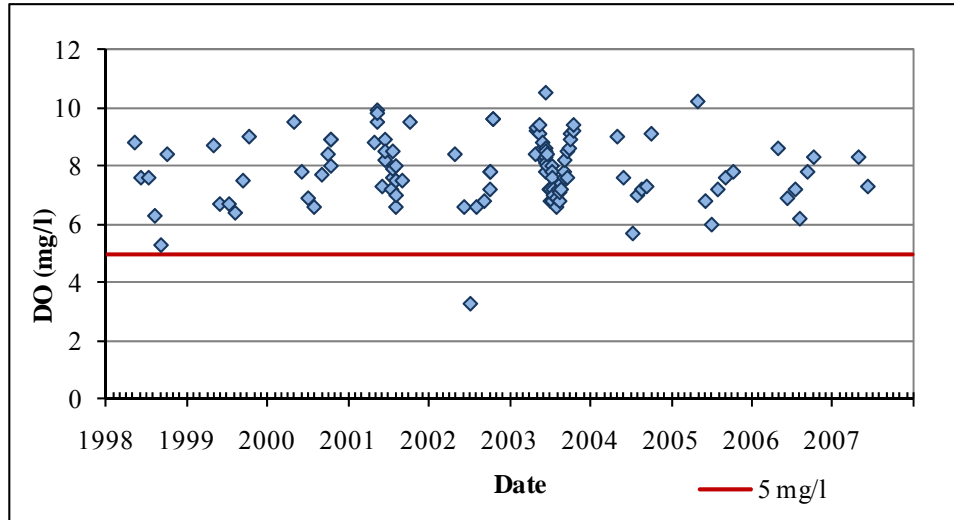


Figure 4: Rock Creek Dissolved Oxygen Data from 1998 through 2007

2.3.3 Nutrients

In the absence of State water quality standards with specific numeric limits for nutrients for the protection of aquatic life in non-tidal free-flowing waters, evaluation of potentially eutrophic conditions is based on the BSID analysis and analysis of dissolved oxygen levels. Consequently, the nutrients data presented in this section are for informational purposes only.

Total nitrogen (TN) and total phosphorus (TP) data for Rock Creek have been collected as part of this study and the results are presented here for informational purposes, graphically in Figures 5 and 6. During the growing season DNR and MDE data have TP concentrations ranging from 0.02 to 0.21 mg/l and TN concentrations ranging from 0.94 to 2.95 mg/l. These data are presented graphically in Figures 5 and 6.

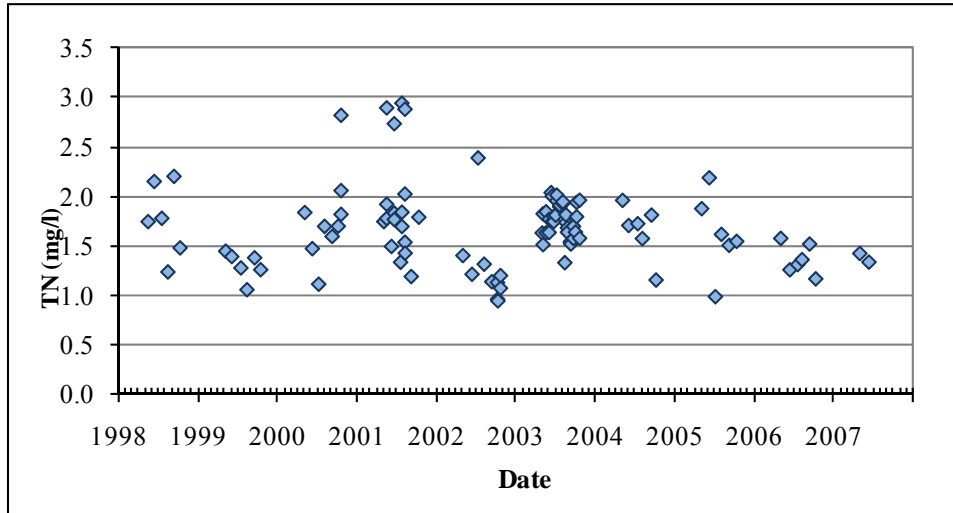


Figure 5: Rock Creek Total Nitrogen Data from 1998 through 2007

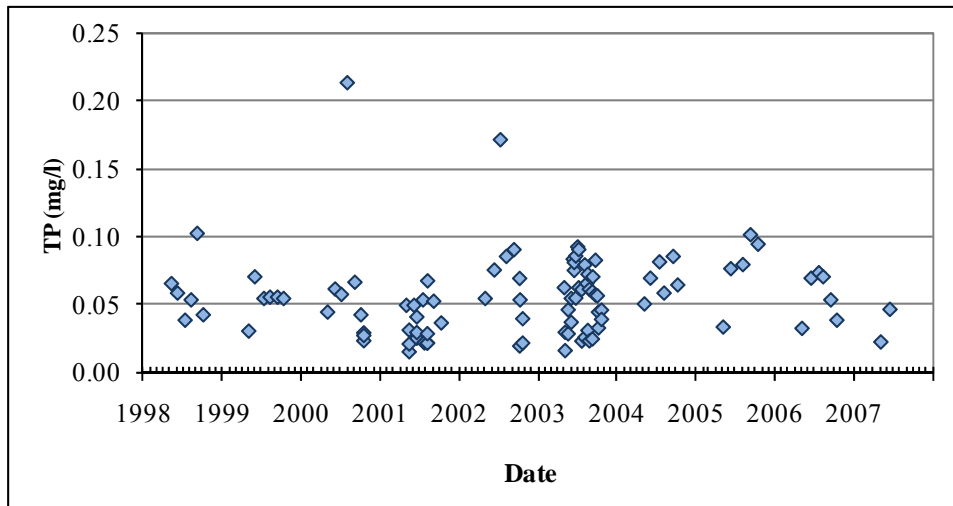


Figure 6: Rock Creek Total Phosphorus Data from 1998 through 2007

2.3.4 Nutrient Limitation

Nitrogen and phosphorus are essential nutrients for algae growth. If one nutrient is available in great abundance relative to the other, then the nutrient that is less available limits the amount of plant matter that can be produced; this is known as the “limiting nutrient.” The amount of the abundant nutrient does not matter because both nutrients are needed for algae growth. In general, a total nitrogen:total phosphorus (TN:TP) ratio in the range of 5:1 to 10:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the TN:TP ratio is greater than 10:1, phosphorus tends to be limiting; if the TN:TP ratio is less than 5:1, nitrogen tends to be limiting (Chiandani *et al.* 1974).

FINAL

The median TN:TP ratio across the MDE and DNR CORE/TREND surveys is 28.6 and the average TN:TP ratio is 40.3. There is only one sample (of 102) where the TN:TP ratio is less than 10 and none is below 5.

The observed data strongly imply that the streams in the Rock Creek watershed are phosphorus limited.

2.3.5 Rock Creek Mainstem Benthic Macroinvertebrate Monitoring Station

Additional data for the Rock Creek watershed was obtained from the Maryland Department of Natural Resources (DNR) CORE/TREND program, which collected benthic macroinvertebrate data between 1976 and 2006. DNR has extensive monitoring information for one station, RCM0111, in the mainstem of Rock Creek through the CORE/TREND program. The station is located at Route 410 (See Table 7 and Figure 3) and has 31 years of benthic macroinvertebrate data (DNR 2007, 2009). These data were used to calculate four benthic community measures: total number of taxa, the Shannon-Wiener diversity index, the modified Hilsenhoff biotic index, and percent *Ephemeroptera*, *Plecoptera*, and *Trichoptera* (EPT). A summary of the results for the station is presented in Table 7.

Table 7: Rock Creek Mainstem DNR CORE/TREND Data

Site Number	Current Water Quality Status	Trend Since 1970's
RMC0111	Fair	Improvement

2.4 Water Quality Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the waters of Rock Creek is Use I (*Water Contact Recreation and Nontidal Warm Water Protection of Aquatic Life*), except for 1) the Rock Creek mainstem and its tributaries and the North Branch Rock Creek and its tributaries above Muncaster Mill Road, which are designated as Use III (*Water Contact Recreation, Nontidal Cold Water Protection of Aquatic Life*), and 2) the Rock Creek mainstem and its tributaries in between Route 28 and Muncaster Mill Road, which are designated as Use IV (*Water Contact Recreation, Protection of Aquatic Life and Recreational Trout Waters*) (COMAR 2012a,b,c,d,e). The nutrient water quality impairment of the Rock Creek watershed addressed by this TMDL is caused by elevated nutrient loads beyond a level that is supportive of aquatic health, where aquatic health is evaluated based on BIBI and FIBI scores (BIBI and FIBI \geq 3). The BSID has identified total phosphorus as associated with 27% of the biologically impaired stream miles in the Rock Creek watershed.

FINAL

The BISD analysis indicates that none of the biologically impacted stream miles are associated with low DO concentrations. The analysis of DO monitoring data in section 2.3.2 supports the conclusion that DO criteria are currently met in the watershed.

Biological results from one DNR CORE/TREND stations (RMC0111) located on the mainstem of Rock Creek indicates that, based on percent EPT, taxa number, biotic index, and diversity index, water quality can be classified as fair (Table 7) (DNR 2007).

The BSID did not indicate that high concentrations of total nitrogen are associated with biological impairment in the Rock Creek watershed. The 1996 nutrients listing was refined in Maryland's 2008 Integrated Report to a listing for phosphorus as the specific impairing nutrient substance. The revised listing was based on the generally accepted view within the scientific community that in fresh water phosphorus is usually the limiting nutrient for algal growth (Allan 1995, Correll 1998). The analysis of observed TN:TP ratios in Section 2.3.4 confirms the assumption that phosphorus is the limiting nutrient in Rock Creek. Because nitrogen generally exists in quantities greater than necessary to sustain algal growth, excess nitrogen *per se* is not the cause of the biological impairment in Rock Creek, and the reduction of nitrogen loads would not be an effective means of ensuring that the Rock Creek watershed is free from impacts on aquatic life from eutrophication. Therefore, load allocations for the Rock Creek Nutrient TMDL will apply only to total phosphorus. Reductions in nitrogen loads will be required in the Rock Creek watershed to meet the nitrogen allocations assigned to the Potomac Tidal Fresh Bay Water Quality Segment by the Chesapeake Bay TMDL, established by the EPA on December 29, 2010.

3.0 TARGETED WATER QUALITY GOAL

The objective of the phosphorus TMDL established herein is to reduce phosphorus loads, and subsequent effects on aquatic health, in the Rock Creek watershed to levels that support the Use I (*Water Contact Recreation and Protection of Nontidal Warm Water Aquatic Life*), Use III (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life*), and Use IV (*Water Contact Recreation, Protection of Aquatic Life and Recreational Trout Waters*) designations (COMAR 2012a,b,c,d,e). Assessment of aquatic health is based on Maryland's biocriteria protocol, which evaluates both the amount and diversity of the benthic and fish community through the use of the Index of Biotic Integrity (IBI) (Roth *et al.* 1998, 2000; Stribling *et al.* 1998). Reduction in phosphorus loads are expected to result in improved benthic and fish communities, by either improving habitat conditions or restoring energy pathways to patterns typical of healthy biological communities in the Piedmont and Highland ecoregions.

There are no specific numeric criteria in Maryland that quantify the impact of nutrients on the aquatic health of non-tidal stream systems. Therefore, a reference watershed TMDL approach was used. Phosphorus loads compatible with water quality standards are determined by comparing current phosphorus loading rates (lbs/ac/yr) in the Rock Creek watershed with the phosphorus loading rates in unimpaired watersheds in the Piedmont and Highland ecoregions of Maryland. The Chesapeake Bay Program's (CBP) Phase 5.3.2 Watershed Model (P5.3.2) was used to determine the phosphorus loads in both Rock Creek and the unimpaired watersheds that will be used to set the phosphorus TMDL for Rock Creek.

Overall, this TMDL will establish phosphorus loads that will be protective of the Use I/III/IV designations for the Rock Creek watershed, and more specifically, these loads will be at a level the watershed can sustain without causing nutrient related impacts to aquatic health. The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Because the BSID watershed analysis identifies other possible stressors (*i.e.*, conductivity, sediment) as impacting the biological conditions, this impairment remains to be fully addressed through the Integrated Report listing process and the TMDL development process, such that all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2009a).

FINAL

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section describes how the phosphorus TMDL allocations were developed for Rock Creek. Section 4.2 describes the analysis framework for estimating phosphorus loading rates and the assimilative capacity of the watershed stream system. Section 4.3 summarizes the scenarios that were used in the analysis and presents results. Section 4.4 discusses critical conditions and seasonality. Section 4.5 explains the calculations of TMDL loading caps. Section 4.6 details the load allocations, and Section 4.7 explains the rationale for the margin of safety. Finally, Section 4.8 summarizes the TMDL.

4.2 Analysis Framework

Because there are no specific numeric criteria that quantify the impact of nutrients on the aquatic health of nontidal stream systems, a reference watershed approach was used to establish the TMDL. Furthermore, as the BSID analysis established a link between biological impairment and nutrient related stressors, the reference watershed approach will utilize biological integrity as the TMDL endpoint.

Watershed Model

An essential element in the reference watershed approach is the use of a computer simulation model to determine the current or baseline loads in the impaired and reference watersheds. These loads are used to calculate the loading rate in the reference watershed and therefore the TMDL load allocations for the impaired watershed. For the Rock Creek phosphorus TMDL, and other nutrient TMDLs for Maryland's non-tidal watersheds, the CBP Phase 5.3.2 Watershed Model will be used to determine phosphorus loads in both the impaired and reference watersheds.

The CBP P5.3.2 model is a Hydrological Simulation Program FORTRAN (HSPF) model of the Maryland, Virginia, and the portions of Pennsylvania, Delaware, New York, and West Virginia in the Chesapeake Bay basin. Its primary purposes are: (1) to determine the sources of nitrogen, phosphorus, and sediment to the Chesapeake Bay, (2) to calculate nutrient and sediment loads to the Chesapeake Bay for use in the CBP model of water quality in the Bay, and (3) to estimate nutrient and sediment load allocations under nutrient and sediment TMDLs for impaired Chesapeake Bay segments. Generally, river reaches that have average annual flows greater than 100 cubic feet per second (cfs) are represented in the model, but MDE has worked with CBP to ensure that all of MD's 8-digit watersheds, the unit of water quality assessment in Maryland, are represented in the model.

Bicknell *et al.* (2001) describe the HSPF model in greater detail. (US EPA 2010b) documents the development of the Phase 5.3 model.

An important aspect of the P5.3.2 model is that it imposes a uniform and consistent methodology for calculating nutrient input loads to land segments. The P5.3.2 model

FINAL

also uses automated calibration procedures to determine land and river parameters as well as the regional factors for EOS loads discussed in Section 2.2.1. This ensures that the land and river segments are simulated in a consistent manner and therefore the allocation of loads under Bay TMDLs is equitable. This aspect of the P5.3.2 model is important for the reference watershed approach, because the uniform and consistent approach to estimation of nutrient loads across watersheds gives greater validity to using load estimates from one watershed to set the TMDL endpoint for another. The P5.3.2 model is used to assign load and wasteload allocations for the Chesapeake Bay TMDLs. The load estimates from the P5.3.2 model will therefore shape water quality management in Maryland for the foreseeable future. The results of the model will impact point source and MS4 permits, as well as nonpoint source management programs for agriculture, silviculture, and stream restoration. Using the P5.3.2 model as the basis for the reference watershed approach enables Maryland to integrate its non-tidal nutrient TMDLs into the management framework for the Chesapeake Bay. It also provides a consistent and equitable way to determine the load contribution from neighboring states.

Reference Watershed Approach

In order to quantify the impact of nutrients on the aquatic health of non-tidal stream systems, a reference watershed TMDL approach was used, which resulted in the establishment of a *phosphorus loading threshold* for watersheds within the Highland and Piedmont physiographic regions. The phosphorus loading threshold was determined by a methodology similar to that used to develop sediment loading thresholds for Maryland's sediment TMDLs (Currey *et al.* 2006, MDE 2009c). Reference watersheds were determined based on Maryland's biocriteria methodology. The biocriteria methodology assesses biological impairment at the 8-digit watershed scale based on the percentage of MBSS monitoring stations, translated into watershed stream miles, which are degraded. Individual monitoring station impairment is determined based on BIBI/FIBI scores lower than the Minimum Allowable IBI Limit (MAL), which is calculated based on the average annual allowable IBI value of 3.0 (on a scale of 1 to 5). Applying the MAL threshold helps avoid classification errors when assessing biological impairment (Roth *et al.* 1998, 2000; Stribling *et al.* 1998; MDE 2010a).

Comparison of watershed phosphorus loads to loads from reference watersheds requires that the watersheds be similar in physical and hydrological characteristics. To satisfy this requirement, Currey *et al.* (2006) selected reference watersheds only from the Highland and Piedmont physiographic regions (See Appendix A for the list of reference watersheds). This region is consistent with the non-coastal region that was identified in the 1998 development of FIBI and subsequently used in the development of BIBI (Roth *et al.* 1998, Stribling *et al.* 1998).

To reduce the effect of the variability within the Highland and Piedmont physiographic regions, the watershed phosphorus loads were then normalized by a constant background condition: the all forested watershed condition. This new normalized term, defined as the *forest normalized phosphorus load* (Y_n), represents how many times greater the current watershed phosphorus load is than the *all forested phosphorus load*. The same methodology has been used to develop sediment TMDLs for non-tidal streams in

FINAL

Maryland (Currey *et al.* 2006, MDE 2009c). The *forest normalized phosphorus load* for this TMDL is calculated as the current watershed phosphorus load (calculated using the CBP P5.3.2 2009 Progress Scenario) divided by the *all forested phosphorus load*.

The equation for the *forest normalized phosphorus load* is as follows:

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

where:

- Y_n = forest normalized phosphorus load
- y_{ws} = current watershed phosphorus load (lbs/yr)
- y_{for} = all forested phosphorus load (lbs/yr).

Based on Equation 4.1, the *forest normalized phosphorus load* for the Rock Creek watershed is 10.81.

Twelve reference watersheds were selected from the Highland/Piedmont region. Reference watershed *forest normalized phosphorus loads* were calculated using CBP P5.3.2 2009 Progress Scenario landuse and phosphorus loads. Table A-1 in Appendix A shows the annual forest normalized phosphorus loads for reference watersheds, averaged over the simulation period 1991-2000 from the CBP P5.3.2 2009 Progress Scenario. The median and 75th percentile of the reference watershed *forest phosphorus loads* were calculated and found to be 7.18 and 8.71 respectively. The median value of 7.18 was established as the *phosphorus loading threshold* as an environmentally conservative approach to develop this TMDL.

Rock Creek's forest normalized load exceeds the *forest normalized reference phosphorus load* (also referred to as the *phosphorus loading threshold*), indicating that Rock Creek is receiving loads above the maximum allowable load the watershed can sustain without causing any phosphorus related impacts to aquatic health.

4.3 Scenario Descriptions and Results

The following analyses allow a comparison of baseline conditions (under which water quality problems exist) with future conditions, which project the water quality response to various simulated nutrient load reductions. The analyses are grouped according to baseline conditions and future conditions associated with the TMDL.

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. The baseline conditions typically reflect an approximation of nonpoint source loads during the monitoring period, as well as estimated point source loads based on discharge data for the same period.

FINAL

The Rock Creek watershed baseline nutrient loads are estimated using the landuse and EOS phosphorus loading rates from the CBP P5.3.2 2009 Progress Scenario. The 2009 Progress Scenario represents current land-use, loading rates, and BMP implementation simulated using precipitation and other meteorological inputs from the period 1991-2000 to represent variable hydrological conditions, thereby addressing annual changes in hydrology and capturing wet, average and dry years. The period 1991-2000 is the baseline hydrological period for the Chesapeake Bay TMDL.

Watershed loading calculations, based on the CBP P5.3.2 segmentation scheme, are represented by multiple CBP P5.3.2 model segments within each MD 8-digit watershed. The nutrient loads from these segments are combined to represent the baseline condition. The Maryland point source nutrient loads are estimated based on the existing discharge monitoring data and existing permit information. Details of these loading source estimates can be found in Section 2.2 and Section 4.6 of this report. The total baseline phosphorus load for the Rock Creek watershed is 24,441 lbs per year.

Future (TMDL) Conditions

This scenario represents the future conditions associated with the maximum allowable phosphorus loads whereby there will be no phosphorus related impacts affecting aquatic health. In the TMDL calculation, the allowable load for the impaired watershed is calculated as the product of the *phosphorus loading threshold* (determined from watersheds with a healthy biological community) and the Rock Creek *all forested phosphorus load* (see Section 4.2). The resulting load is considered the maximum allowable load the watershed can sustain without causing any nutrient related impacts to aquatic health.

The TMDL loading and associated reductions are averaged at the Maryland 8-digit watershed scale, which is consistent with the impairment listing scale. 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:

$$TMDL = Y_{ref} \cdot y_{forest} \quad (\text{Equation 4.2})$$

where:

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

Y_{ref} = phosphorus loading threshold

i.e., forest normalized reference phosphorus load (7.18)

y_{forest} = all forested phosphorus load for watershed (lbs /yr).

The future (TMDL) phosphorus loads from the Rock Creek TMDL are 16,244 lbs per year phosphorus, which represents an overall 34% reduction from baseline loads.

FINAL

4.4 Critical Conditions and Seasonality

EPA's regulations require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters (CFR 2011a). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. EPA's regulations also require that TMDLs take into account seasonal environmental variations.

The premise of the reference watershed approach is that the reference watershed is meeting water quality standards even under critical conditions. Therefore, the phosphorus loading rates derived from the reference watershed protects water quality standards under critical conditions. Moreover, the loading rates used in the TMDL were determined using the HSPF model, which is a continuous simulation model with a simulation period 1991-2000. The ten year simulation period encompasses seasonal variations and a range of hydrological and meteorological conditions.

The biological monitoring data used to determine the reference watersheds also integrates the stress effects over the course of time and thus, inherently addresses critical conditions. Seasonality is captured in two respects. First, it is implicitly included through the use of the biological monitoring data. Second, the MBSS dataset included benthic sampling collected in the spring and fish sampling collected in the summer. Thus, this analysis has captured both spring and summer flow conditions.

4.5 TMDL Loading Caps

This section presents the average annual TMDL of phosphorus for the Rock Creek watershed. These loads are considered the maximum allowable long-term average annual load the watershed can sustain without causing nutrient related impacts to aquatic health.

The long-term average annual TMDL was calculated based on Equation 4.2. In order to attain the TMDL loading cap calculated for the watershed, reductions will be applied to the controllable sources. Significant phosphorus reductions will be required in the Rock Creek watershed to meet the phosphorus allocations assigned to the Potomac Tidal Fresh Bay Water Quality Segment by the Chesapeake Bay TMDL, established by the EPA on December 29, 2010. To ensure consistency with the Bay TMDL, and therefore efficiency in the reduction of phosphorus loads, reductions will be applied to the same controllable sources identified in Maryland's Watershed Implementation Plans (WIPs) for the Bay TMDL. The controllable sources generally include: (1) regulated developed land; (2) high till crops, low till crops, hay, and pasture; (3) harvested forest; (4) unregulated animal feeding operations and CAFOS; and (5) industrial process sources and municipal wastewater treatment plants. Additional sources might need to be controlled in order to ensure that the water quality standards are attained in Chesapeake Bay as well as Rock Creek.

FINAL

An overall reduction of 34% for phosphorus from current estimated loads will be required to meet TMDL allocations and attain Maryland water quality standards. The baseline and TMDL scenarios for Rock Creek watershed are presented in Table 8.

Table 8: Rock Creek Watershed TMDL for Phosphorus

MD 8-digit	Baseline Load (lbs/yr)	TMDL Scenario Load (lbs/yr)	Reduction (%)
	24,441	16,244	34%

4.6 Load Allocations Between Point and Nonpoint Sources

Per EPA regulation, all TMDLs need to be presented as a sum of waste load allocations (WLAs) for permitted point sources in the assessment unit and load allocations (LAs) for nonpoint sources generated within the assessment unit. In addition, TMDLs must account for natural background, tributary and adjacent segment loads if applicable (CFR 2011b). Consequently, the Rock Creek watershed TMDL allocations are presented in terms of WLAs (*i.e.*, point source loads identified within the watershed) and LAs (*i.e.*, the nonpoint source loads within the watershed). The State reserves the right to allocate the TMDL among different sources in any manner that protects aquatic life from nutrient related impacts.

Table 9 summarizes the TMDL scenario results for phosphorus. Equal reductions were applied to the controllable loads from predominant sources. Controllable loads were determined, in accordance with the Chesapeake Bay TMDL (US EPA 2010a), as the difference between the CBP 2010 “No Action” Scenario and the “E3” Scenario, where the No Action Scenario represents current land uses and point sources without nutrients controls, while the E3 Scenario represents application of all possible BMPs and control technologies to current land uses and point sources. This allocation methodology provides credit for existing BMPs in place, which is one the reasons the resulting reduction vary among source sectors.

In this watershed, developed land, municipal process water, and to a lesser extent, crop, nursery, and pasture were identified as the largest controllable sources. Forest is the primary non-controllable source, as it represents the most natural condition in the watershed. Direct atmospheric deposition on water is a minor source that to a large extent originates outside the watershed. Atmospheric deposition will be reduced by existing state and federal programs and thus is not addressed in this TMDL. Urban stormwater nutrient loads are regulated under the NPDES MS4 program and therefore included in the WLA. There are no CAFOs or CSOs in the Rock Creek watershed, and phosphorus loads from septic systems are considered insignificant.

The Rock Creek Phosphorus TMDL requires a 15% reduction in phosphorus loads from nonpoint sources (See Table 9). For more detailed information regarding the Rock Creek Watershed TMDL Contribution nonpoint source allocations, please see the technical memorandum to this document entitled “Significant Phosphorus Nonpoint Sources in the Rock Creek Watershed”.

FINAL

The waste load allocation (WLA) of the Rock Creek watershed is allocated in three categories, Process Water WLA, Stormwater WLA, and CAFO WLA. The categories are described below.

Table 9: MD 8-digit Rock Creek TMDL Phosphorus TMDL by Source Category

Baseline Load Source Categories		Baseline Load (lbs/yr)	TMDL Components	TMDL (lbs/yr)	Reduction (%)
Nonpoint Source	Forest	438	LA	429	2%
	AFOs	48		26	46%
	Pasture	282		219	22%
	Crop	1,675		1,291	23%
	Nursery	1,852		1,685	9%
	Septic	0		0	0%
	Atmospheric Deposition	70		70	0%
Total Nonpoint Source		4,365		3,720	15%
Point Source	CAFOs	0	WLA	0	0%
	Regulated Urban	16,261		10,815	33%
	Process Water	3,815		1,709	55%
	CSO	0		0	0%
Total Point Source		20,076		12,524	38%
Total		24,441		16,244	34%

Process Water WLA

Municipal WWTPs are assigned phosphorus WLAs as follows: (1) if the design flow of a facility is greater than 0.5 MGD and therefore is slated for upgrade to ‘Enhanced Nutrient Reduction’ (ENR), then the facility is given a WLA based on its design flow and the anticipated average annual ENR concentrations of 0.3 mg/l TP; (2) if the design flow of the facility is 0.5 MGD or less and has TP concentration limits, then that facility is assigned a WLA based on its Maryland Tributary Strategy Cap flow and the permit limit; and (3) if the facility does not have permit limits, it is assigned a WLA based on its Maryland Tributary Strategy Cap flow and an assumed maximum average annual concentration of 3 mg/l TP. The Tributary Strategy Cap flow is the design flow of the facility or the projected 2020 flow (projected from 2003 actual discharge flows and Maryland Department of Natural Resources growth rates by county), whichever is less. The only municipal WWTP in the Rock Creek watershed is a minor facility with a design flow of less than 0.5 MGD.

Eighteen industrial facilities discharging process water in the Rock Creek watershed were judged to have the capacity to discharge TP in their process water. All of these facilities are minor. Under the Chesapeake Bay TMDL, industrial facilities capable of discharging phosphorus in their process water were given a WLA based on the results of monitoring required by their permits or professional judgment. In addition, allocations for minor municipal WWTPs (with design flows less than 0.5 MGD) and for minor industrial facilities are presented in the Chesapeake Bay TMDL as a watershed-wide aggregate

FINAL

WLA. A similar approach was adopted for the Rock Creek Phosphorus TMDL, and all minor municipal and minor industrial process water facilities allocations are represented as a watershed-wide WLA.

Based on the Maryland Tributary Strategy Cap flow and permit limits or the allocations under the Chesapeake Bay TMDL, applied to the Rock Creek Phosphorus TMDL; it will result in an overall 55% reduction in phosphorus loads from process water sources (See Table 9). This reduction is a result of statewide policy decisions related to process water. For information regarding allocations to process water, please see the technical memorandum to this document entitled “*Significant Phosphorus Point Sources in the Rock Creek Watershed*”.

Stormwater WLA

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

- MS4s – these can be owned by local jurisdictions, municipalities, and state and federal entities (*i.e.*, departments of transportation, hospitals, military bases, etc.);
- general industrial stormwater permitted facilities; and
- construction sites that are one acre or larger.

EPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (US EPA 2002). Therefore, NPDES regulated stormwater loads within the Rock Creek watershed TMDL will be expressed as a single NPDES stormwater WLA. Upon approval of the TMDL, “NPDES-regulated municipal stormwater and small construction storm water discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits” (US EPA 2002).

The Rock Creek NPDES stormwater WLA is based on reductions applied to the controllable phosphorus loads from the regulated developed landuse in the watershed, with credit provided to existing BMPs in place. The Rock Creek NPDES stormwater WLA requires an overall 33% reduction for phosphorus (See Table 9).

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 are reasonably calculated to protect aquatic life from nutrient related impacts.

For more information regarding the distribution of NPDES stormwater WLAs among jurisdictions, please see the technical memorandum to this document entitled “*Significant Phosphorus Point Sources in the Rock Creek Watershed*”.

FINAL

CAFO WLA

There are no concentrated animal feeding operations (CAFOs) in the Rock Creek watershed, and none of the WLA was allocated to CAFOs.

4.7 Margin of Safety

All TMDLs must include a margin of safety to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2011a). It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty. Analysis of the reference watershed group *forest normalized phosphorus loads* indicates that approximately 75% of the reference watersheds have a value less than 8.71. Also, 50% of the reference watersheds have a value less than 7.18. Based on this analysis the *forest normalized reference phosphorus load* (also referred to as the *phosphorus loading threshold*) was set at the median value of 7.18. This is considered an environmentally conservative estimate, since 50% of the reference watersheds have a load above this value (7.18), which when compared to the 75% value (8.71), results in an implicit MOS of approximately 18%.

4.8 Summary of Total Maximum Daily Loads

The average annual phosphorus TMDL for the Rock Creek watershed is summarized in Table 10, and Maximum Daily Phosphorus Load is summarized in Table 11 (See Appendix C for more details on Maximum Daily Loads).

Table 10: Average Annual MD 8-digit Rock Creek TMDL of Phosphorus (lbs/yr)

TMDL (lbs/yr)	=	LA		+	WLA			+	MOS			
	=	LA	+	Septic	+	CAFO WLA	+	NPDES Stormwater WLA		+	Process Water WLA	
16,244	=	3,720	+	0	+	0	+	10,815	+	1,709	+	Implicit

Table 11: MD 8-digit Rock Creek Maximum Daily Load of Phosphorus (lbs/day)

TMDL (lbs/day)	=	LA		+	WLA			+	MOS			
	=	LA	+	Septic	+	CAFO WLA	+	NPDES Stormwater WLA		+	Process Water WLA	
143	=	33	+	0	+	0	+	95	+	15	+	Implicit

FINAL

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load and wasteload allocations can and will be implemented. This section provides the basis for reasonable assurance that the phosphorus TMDL in the Rock Creek will be achieved and maintained.

The Rock Creek phosphorus TMDL is expected to be implemented as part of a staged process recently developed by Maryland. This staged process is designed to achieve both the nutrient reductions needed within the Rock Creek watershed and to meet target loads consistent with the Chesapeake Bay TMDL, established by EPA in 2010 (US EPA 2010a) and scheduled for full implementation by 2025. The Bay TMDL requires 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. The nutrient reductions for the Bay TMDL are independent of those needed to implement any TMDLs developed to address nutrient-related impairments in Maryland's non-tidal waterbodies, although their reduction goals and strategies do overlap. For example, the implementation planning framework, developed by the Bay watershed jurisdictions in partnership with EPA, provides a staged approach to achieving Bay TMDL nutrient reduction goals that is also applicable to implementation of nutrient TMDLs in local non-tidal watersheds. In short, nutrient reductions required to meet the Chesapeake Bay TMDL will also support the restoration and protection of local water quality.

Maryland's Phase I Watershed Implementation Plan (WIP) for the Chesapeake Bay TMDL, finalized in December 2010, identifies nutrient reduction targets by source sector for the Potomac Tidal Fresh segment-shed, which includes Rock Creek and a number of other Maryland 8-digit watersheds. EPA revised the nutrient and sediment load allocations for the Bay TMDL in August 2011, based on results of the updated Phase 5.3.2 Watershed Model. Maryland has been working with key local partners, including county and municipal staff, soil conservation managers, and a variety of stakeholder organizations and business interests, to help them develop local implementation plans at the county scale. These local plans are being incorporated into the basin-scale implementation plans in the Phase II WIP, which will be finalized in July 2012.

Maryland's Phase II WIP and the State's schedule of two-year milestones provide implementation strategies and a time line for achieving nutrient reductions across the State to meet Chesapeake Bay interim target loads by 2017, equivalent to 60% of the final target goals set for 2025 to fully implement the Chesapeake Bay TMDL in Maryland. A Phase III Plan will be developed in 2017 to address the additional reductions needed from 2018 through 2025 to meet the final targets. Prior to Phase III, the TMDL allocations may again be revised to reflect better data, a greater understanding of the natural systems, and to make use of enhanced analytical tools (such as updated watershed and water quality models). This iterative process provides an adaptive approach for achieving the Chesapeake Bay TMDL goals, as well as a framework and time line for the staged implementation of the Rock Creek non-tidal waters nutrient TMDL.

FINAL

The proposed approach for achieving the Rock Creek reduction targets will be based on deployment of an appropriate selection of the comprehensive implementation strategies described in Maryland's [Phase I WIP](#) (MDE 2010b) and [Phase II WIP](#) (MDE 2012b), the centerpieces of the State's "reasonable assurance" of implementation for the Bay TMDL. The strategies encompass a host of best management practices, pollution controls and other actions for all source sectors that cumulatively will result in meeting the State's 2017 interim nutrient and sediment reduction targets, as verified by the Chesapeake Bay Water Quality Model.

Accounting, tracking and reporting are an important part of the overall WIP strategy, and progress will be closely monitored for the two-year milestones by tracking both implementation and water quality. The setting of 2017 interim targets and a schedule of two-year milestone commitments will allow for an iterative, adaptive management process with ongoing assessments of implementation progress, as well as periodic reevaluation of nutrient impacts on local water quality. This staged approach provides further assurance that the implementation of the Rock Creek phosphorus TMDL will be achieved through increased accountability and verification of water quality improvements over time.

Once the Bay TMDL nutrient target loads for the Rock Creek watershed have been met, MDE will revisit the status of nutrient impacts on aquatic life in Rock Creek, based on any additional monitoring data available and any improvements in the scientific understanding of the impacts of nutrients on aquatic life in free-flowing streams. The results of this reassessment will determine whether additional phosphorus reductions are needed in the watershed, or whether the Rock Creek phosphorus TMDL goals have in fact been met.

Maryland Legislative Actions and Funding Programs to Support TMDL Implementation

Maryland recently enacted significant new legislation that requires Phase I MS4 jurisdictions to establish, by July 1, 2013, an annual stormwater remediation fee and a local watershed protection and restoration fund to support implementation of local stormwater management plans. Maryland has made a commitment to include provisions in Phase I and II MS4 permits, due for issuance in 2012, to implement the State's WIP strategies to reduce nutrient and sediment loads from urban stormwater sources.

Maryland has also enacted significant new legislation to increase the Bay Restoration Fund to provide financing for wastewater treatment plant upgrades and on-site septic system improvements, as well as legislation to guide growth of central sewer and septic systems. These new laws will support local efforts to reduce nutrient loads in both non-tidal watersheds and in downstream tidal waters of the Chesapeake Bay.

In response to the WIP and the increased burden on local governments to achieve nutrient reduction goals, Maryland has continued to increase funding in the Chesapeake and Atlantic Coastal Bays Trust Fund. For Fiscal Year 2013, in addition to \$25 million

FINAL

(pending) for the Trust Fund, \$38 million in general obligation bonds were made available to local communities for implementation of stormwater capital improvements. These funds will not only kick start restoration at the local level, but also create and retain green jobs in Maryland's economy. Funding was also increased to support implementation of natural filters on public lands (\$9 million), and funding for Soil Conservation Districts from 16 to 39 positions (\$2.2 million). In addition, funding for the cover crop program is at \$12 million – a record level.

MD's Water Quality Improvement Act of 1998 (WQIA) requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout MD. This act specifically required such plans for nitrogen be developed and implemented by 2002, and plans for phosphorus be completed by 2005.

Additional potential funding sources for implementation include Maryland's Agricultural Cost Share Program (MACS) which provides grants to farmers to help protect natural resources, and the Environmental Quality and Incentives Program, which focuses on implementing conservation practices and BMPs on land involved with livestock and production.

For the 2012-2013 milestone period, Maryland is working to: restrict fall fertilization of small grain crops on soil testing above a given nitrate level thresholds; require incorporation of organic nutrient sources (with some exceptions); limit fall applications of organic nutrient sources; and, require a cover crop following fall applications of organic nutrient sources. Future changes: nutrient application setbacks of 10-35 feet (depending upon application methods) will be required (2014); best management practices will be required for streams with adjacent livestock (2014); winter application of all organic nutrient sources will be prohibited (2016-2020).

Maryland is also working to adopt a revised Phosphorus Site Index (PSI) and incorporate the new PSI into nutrient management plans in preparation for the 2013 crop season (winter 2012-2013).

To enhance Urban Nutrient Management as a nutrient reduction strategy, the State is working to develop regulations to implement the Fertilizer Use Act. This will: limit nitrogen & phosphorus content in fertilizer content and use on non-agricultural land; require certification and training for non-agricultural applicators; require certain fertilizer product labeling; and require outreach and education programs for homeowner fertilizer use.

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.

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APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds

MD 8-digit Name	MD 8-digit	Percent Stream Mile Degraded (%) ^{1,2}	Forest Normalized Phosphorus Load ^{3,4}
Deer Creek	02120202	11	6.93
Octoraro Creek ⁵	02120203	8	10.14
Broad Creek	02120205	12	5.71
Northeast River ⁵	02130608	14	7.13
Furnace Bay ⁵	02130608	11	7.24
Little Gunpowder Falls ⁵	02130804	15	8.22
Prettyboy Reservoir	02130806	16	11.92
Middle Patuxent River ⁵	02131106	20	8.29
Brighton Dam	02131108	11	9.94
Sideling Creek	02140510	20	2.38
Fifteen Mile Creek ⁵	02140511	4	1.51
Savage River	02141006	7	2.46
Median			7.18
75th Percentile			8.71

- Notes:**
- ¹ Percent stream miles degraded within an 8-digit watershed is based on the percentage of impaired MBSS stations within the watershed (MDE 2008).
 - ² The percent stream miles degraded 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).
 - ⁴ Based on 1991-2000 average annual edge-of-stream loads from CBP Phase 5.3.2 Watershed Model 2009 Progress Scenario and watershed specific forest yields.
 - ⁵ Forest normalized phosphorus load does not include process water point sources discharging to mainstem river.

APPENDIX B – Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define maximum daily loads of phosphorus consistent with the average annual TMDL, which is protective of water quality standards in the Rock Creek watershed. The approach builds upon the modeling analysis that was conducted to determine the loadings of phosphorus and can be summarized as follows.

- The approach defines maximum daily loads for each of the source categories.
- The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual loading targets result in compliance with water quality standards.
- The approach converts daily time-series loadings into TMDL values in a manner that is consistent with available EPA guidance on generating daily loads for TMDLs.
- 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 total maximum daily loads on a daily basis. 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 phosphorus TMDL is that cumulative high nutrient loading rates have negative impacts on the biological community. Thus, the average annual phosphorus loads were calculated to be protective of the aquatic life designated use.
- **CBP P5.3.2 Watershed Model Phosphorus Loads:** As described in Section 2.2.1, the EOS phosphorus loads in the P5.3.2 model are based on (1) median of phosphorus export rates reported in the scientific literature; (2) land segment calibration targets adjusted by nutrient applications in excess of vegetative uptake; and (3) regional factors calculated in the calibration of river segments, where simulated output is compared to observed monitoring data. Riverine processes are calibrated in river segments representing rivers of approximately 100 cfs average annual flow.
- **Draft EPA guidance document entitled “Developing Daily Loads for Load-based TMDLs”:** This guidance document provides options for defining maximum daily loads when using TMDL approaches that generate daily output (EPA, 2007).

FINAL

The rationale for developing TMDLs expressed as *daily* loads was to accept the existing average annual TMDLs, but then develop a method for converting these numbers to a maximum *daily* load – in a manner consistent with EPA guidance and available information.

Options Considered

The draft EPA 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. 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 maximum daily loads for the Rock Creek watershed.

Level of Resolution

The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The draft EPA guidance on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Rock Creek 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. **Flow-variable daily load:** This option allows the maximum daily load to vary based upon the observed flow condition.
3. **Temporally-variable daily load:** This option allows the maximum daily load to vary based upon seasons or times of varying source or water body behavior.

Probability Level

All TMDLs have some probability of being exceeded, with the specific probability being 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 maximum daily load should be “based on a representative statistical measure” that is dependent upon the specific TMDL and best professional judgment of the developers. This statistical measure represents how often the maximum daily load is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

FINAL

1. **The maximum daily load reflects some central tendency:** In this option, the maximum daily load 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 reflects a level of protection implicitly provided by the selection of some “critical” period:** In this option, the maximum daily load 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.
3. **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 maximum daily load based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in maximum daily load that would be exceeded 5% of the time.

Selected Approach

The approach selected for defining a daily maximum load for the Rock Creek watershed 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,
- Approach for Process Water Point Sources,
- Approach for Upstream Loads.

Approach for Nonpoint Sources, CAFOs, and Stormwater Point Sources

The level of resolution selected for defining a daily maximum load for the Rock Creek watershed 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.

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 river reach segments with a flow typically greater than 100 cfs. See US EPA (2010b) for details on the river reach calibration. The calibration of river parameters modifies the EOS input loads to reaches by introducing gains or losses of phosphorus through riverine processes. These gains or losses are associated with the represented reach and therefore the absolute magnitude of the river phosphorus loads are not the appropriate measure of EOS loads at the subwatershed scale where excess nutrients are associated with biological impairments.

It was concluded that it would not be appropriate to apply the absolute values of the reach simulation model results to the TMDL, but to adopt the methodology of the MD sediment TMDLs which is a statistically-based estimate using the annual loads and the distribution of simulated daily loads. In this approach, it is assumed that, since they are based on the same underlying hydrology, the distribution of the daily simulated river reach loads represents the

FINAL

distribution of delivered EOS loads, in order to calculate a normalized statistical parameter to estimate the maximum daily loads.

The maximum daily load was estimated based on three factors: a specified probability level, the average annual phosphorus TMDL, and the coefficient of variation (CV) of the CBP P5.3.2 Rock Creek reach simulation daily loads. The probability level (or exceedance frequency) is based upon guidance from EPA (US EPA 1991) where examples suggest that when converting from a long-term average to a daily value, the z-score corresponding to the 99th percentile of the log-normal probability distribution should be used.

The CBP P5.3.2 Rock Creek reach simulation consisted of a daily time series beginning in 1985 and extending to the year 2005. The CV was estimated by first converting the daily phosphorus load values to a log distribution and then verifying that the results approximated a normal distribution (see Figure C-1). Next, the CV for this distribution was calculated using the arithmetic mean and standard deviation results from the log transformation. The log-transformed values were used to reduce the possible influence of outliers. The resulting CV of 0.624 was calculated using the following equation:

$$CV = \frac{\beta}{\alpha} \quad \text{(Equation B.1)}$$

where:

CV = coefficient of variation

$$\beta = \alpha \sqrt{e^{\sigma^2} - 1}$$

$$\alpha = e^{(\mu + 0.5\sigma^2)}$$

α = mean (arithmetic)

β = standard deviation (arithmetic)

μ = mean of logarithms

σ = standard deviation of logarithms.

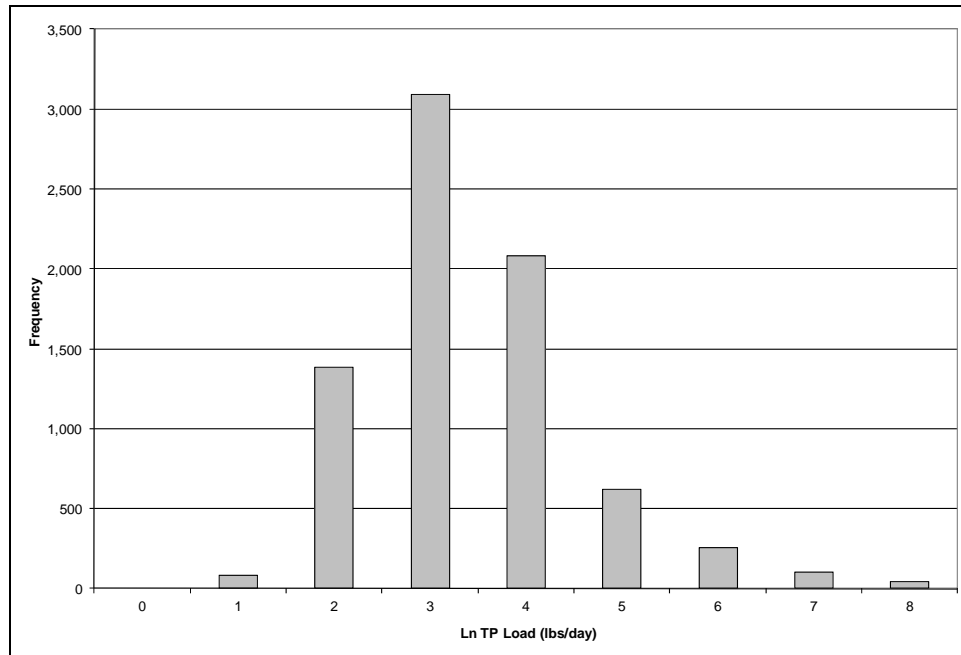


Figure B-1: Histogram of CBP River Segment Daily Phosphorus Simulation Results for the Rock Creek Watershed

The maximum “daily” load for each contributing source is estimated as the long-term average annual load multiplied by a factor that accounts for expected variability of daily loading values. The equation is as follows:

$$MDL = LTA * e^{(z\sigma - 0.5\sigma^2)} \quad \text{(Equation B.2)}$$

where:

MDL = Maximum daily load

LTA = Long-term average (average annual load)

Z = z-score associated with target probability level

$\sigma^2 = \ln(CV^2 + 1)$

CV = Coefficient of variation based on arithmetic mean and standard deviation.

Using a z-score associated with the 99th percent probability, CV of 0.624, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 3.221. The average annual Rock Creek phosphorus TMDL is reported in lbs/year, and the conversion from lbs/year to a maximum daily load in lbs/day is 0.009 (*i.e.*, 3.221/365).

Approach for Process Water Point Sources

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 phosphorus limits. As these sources are generally minor contributors to overall nutrient loads, the TMDL analysis that defined the average annual TMDL did not propose any reductions for these sources and held

FINAL

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 maximum daily loads for these sources was dependent upon whether a maximum daily load was specified within the permit. If a maximum daily limit was specified, then the reported average flow was multiplied by the daily maximum limit to obtain a maximum daily load. If a maximum daily limit was not specified, the maximum daily loads were calculated based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (US EPA 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 Rock Creek phosphorus TMDL are reported in lbs/year, and the conversion from lbs/year to a maximum daily load in lbs/day is 0.0085 (*i.e.*, 3.11/365).

In the case of Rock Creek, all permitted sources with nitrogen or phosphorus concentration limits have no permitted daily maximum concentrations, so the maximum daily load was calculated based on the TSD guidance.

Margin of Safety

As explained in Section 4.7, an implicit margin of safety (MOS) is used in the Rock Creek Phosphorus TMDL.

Results of Approach

This section lists the results of the selected approach to define maximum daily loads for the Rock Creek watershed.

- Calculation Approach for Nonpoint Sources, CAFOs, and Stormwater Point Sources

$$\text{LA (lbs/day)} = \text{Average Annual TMDL LA (lbs/yr)} * 0.009$$

$$\text{Stormwater WLA (lbs/day)} = \text{Average Annual TMDL Stormwater WLA (lbs/yr)} * 0.009.$$

- Calculation Approach for Process Water Point Sources

- For permits with a daily maximum limit:

$$\text{Process Water WLA (lbs/day)} = \text{Permit flow (mgd)} * \text{Daily maximum permit limit (mg/l)} * 0.0042$$

- For permits without a daily maximum limit:

$$\text{Process Water WLA (lbs/day)} = \text{Process Water WLA (lbs/yr)} * 0.0085.$$

FINAL

Table B-1: Summary of Maximum Daily Loads of Total Phosphorus for the Rock Creek Watershed

TMDL (lbs/day)	LA		+	WLA			+	MOS				
	LA	+		Septic	CAFO WLA	+			NPDES Stormwater WLA	+	Process Water WLA	
143	33		0		0		95		15		+	Implicit