FINAL

Total Maximum Daily Load of Phosphorus in the Antietam Creek Watershed, Washington County, Maryland

MARYLAND
FOUNDED 1634
DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore, Maryland 21230-1718

Submitted to:

Watershed Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

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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 5.3.2.2
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
CWAP	Clean Water Action Plan
DNR	Maryland Department of Natural Resources
ENR	Enhanced Nutrient Reduction
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
EPSC	Environmental Permit Service Center
EPT	*Ephemeroptera*, *Plecoptera*, and *Trichoptera*
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
MACS	Maryland Agricultural Cost Share
MAFO	Maryland Animal Feeding Operation
MAL	Minimum Allowable Limit

MBSS	Maryland Biological Stream Survey
MD	Maryland
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
N/A	Not Applicable
NOI	Notice of Intent
NLCD	National Land Cover Data
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
PA	Pennsylvania
PCB	Polychlorinated Biphenyls
PS	Point Source
PSI	Phosphorus Site Index
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USGS	United States Geological Survey
USDI-NPS	United States Dept. of Interior-National Park Service
WIP	Watershed Implementation Plan
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

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 Antietam Creek watershed (basin number 02140502) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02140502). 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 Antietam Creek on the State's 2010 Integrated Report as impaired by nutrients (1996), impacts to biological communities (2002), and polychlorinated biphenyls (PCB) in fish tissue (2008) (MDE 2010a). Because the scientific community supports that phosphorus is generally the limiting nutrient in freshwater aquatic systems, the 1996 nutrients listing was refined in Maryland's 2008 Integrated Report to identify phosphorus as the specific impairing nutrient substance (MDE, 2008).

The designated use of Antietam Creek and its tributaries is Use IV-P (*Water Contact Recreation, Protection of Aquatic Life, Recreational Trout Waters and Public Water Supply*) except for Beaver Creek, Marsh Run, and Little Antietam Creek, which are classified as Use III-P (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life, and Public Water Supply*) (COMAR 2012a,b,c,d,e).

A data solicitation for nutrients was conducted by MDE in November 2009, and all readily available data from 1998 up to the time of the TMDL development have been considered. A TMDL for carbonaceous biochemical oxygen demand (CBOD) and nitrogenous biochemical oxygen demand (NBOD) was approved by the EPA in 2002. A Water Quality Analysis (WQA) of eutrophication for the Greenbrier Lake impoundment was approved by the EPA in 2005. A TMDL for sediment was approved by EPA in 2008, and a TMDL for bacteria was approved by EPA in 2009. The listings for impacts to biological communities and PCB in fish tissue will be addressed separately at a future date.

The Antietam 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 negative deviation from reference conditions (Roth *et al*. 2005). The Biological Stressor Identification (BSID) analysis for the Antietam Creek watershed (MDE 2012a) identified both phosphorus and nitrogen as potential stressors. Both total phosphorus and orthophosphate show a significant association with degraded biological conditions; as much as 20% of the biologically impacted stream miles in the watershed may be degraded due to high total phosphorus and 19% degraded due to high orthophosphate. Similarly, according to the BSID analysis, 31% of the biologically impacted stream miles in the Antietam Creek watershed are associated with high total nitrogen concentrations. An analysis of observed TN:TP ratios shows, however, that phosphorus is the limiting nutrient in Antietam 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 Antietam Creek, and the reduction of nitrogen loads would not be an effective means of ensuring that the Antietam Creek watershed is free from impacts on aquatic life from eutrophication. Therefore, load allocations for the Antietam 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 Antietam 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 and 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 2010). 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 any nutrient related impacts to aquatic health.

The computational framework chosen for the Antietam 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 and load allocations (LAs) for nonpoint sources generated within the assessment unit, accounting for natural background, tributary, and adjacent segment loads. All 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 2011b). 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.

Biological results from both the DNR CORE/TREND and MBSS stations along the mainstem of the MD 8-digit Antietam Creek indicate that mainstem water quality can be classified as good. Consequently, the nutrient impairment is only within the lower order (smaller) streams in the Maryland portion of the watershed, and reductions in phosphorus loads from point and nonpoint sources discharging into lower order streams will be required to address this impairment. Permitted facilities that discharge directly to the Antietam mainstem will be given an informational TMDL based on their allocations under the Chesapeake Bay TMDL.

Similarly, Pennsylvania's portion of the watershed will be divided into two sections: (1) the section of the watershed in Pennsylvania which enters Maryland only through mainstem Antietam Creek, upstream of monitoring station ANT0336, will receive an informational TMDL based on current loading conditions, while (2) the section of Pennsylvania's portion of the watershed which drains into Maryland's lower order streams downstream of ANT0336 will require reductions in phosphorus loads to address the impairment.

The total baseline Phosphorus Load for the MD 8-digit Antietam Creek is 193,364 pounds per year (lbs/yr). This baseline load consists of upstream loads generated outside the assessment unit (*i.e*., MD 8-digit watershed), represented by a Pennsylvania Upstream Baseline Load (BL_{PA}) of 88,815 lbs/yr; and loads generated within the assessment unit, consisting of an MD 8-digit Antietam Creek Watershed Baseline Load Contribution of 104,549 lbs/yr. The MD 8-digit Antietam Creek Watershed Baseline Load Contribution is further subdivided into nonpoint source baseline loads (Nonpoint Source BL_{AC}) and three types of point source baseline loads: regulated concentrated animal feeding operations ($CAFO_{AC}$), National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{AC}), and regulated process water (NPDES Process Water BL_{AC}) (see Table ES-1). Phosphorus loads from septic systems are considered insignificant.

The Average Annual Phosphorus TMDL for the MD 8-digit Antietam Creek is 181,380 lbs/yr. The TMDL consists of allocations attributed to loads generated outside the assessment unit referred to as Upstream Load Allocations, represented by a Pennsylvania Upstream Load Allocation (LA_{PA}) of 79,044 lbs/yr and allocations attributed to loads generated within the assessment unit consisting of an MD 8-digit Antietam Creek Watershed TMDL Contribution of 102,335 lbs/yr. The MD 8-digit Antietam Creek TMDL Contribution is further subdivided into point and nonpoint source allocations and is comprised of a Load Allocation (LA_{AC}), a CAFO Wasteload Allocation (CAFO WLA_{AC}), an NPDES Stormwater Wasteload Allocation (NPDES Stormwater WLA_{AC}), and a Process Water Wasteload Allocation (Process Water WLA_{AC}) (see Table ES-2).

In addition to the average annual 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 III-P/IV-P designations for the Antietam 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.*, high conductivity) 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 Antietam 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 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 Antietam Creek phosphorus TMDL shall be the achievement of the nutrient reductions needed within the Antietam 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 Antietam Creek watershed have been met, MDE will revisit the status of nutrient impacts on aquatic life in Antietam 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 Antietam Creek Baseline Phosphorus Loads (lbs/yr)

Total Baseline Load (lbs/yr)	=	Upstream Baseline Load[1]	+	MD 8-digit Antietam Creek Watershed Baseline Load Contribution								
		BL_{PA}		Nonpoint Source BL_{AC}	+	Septic BL_{AC}	+	CAFO BL_{AC}	+	NPDES Stormwater BL_{AC}	+	Process Water BL_{AC}
193,364	=	88,815	+	70,461	+	0	+	92	+	16,037	+	17,959

[1] Although the Upstream Baseline Load is reported here as a single value, it could include point and nonpoint sources.

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

TMDL (lbs/yr)	+	LA					+	WLA					+	
		LA_{PA}[1,2]	+	LA_{AC}	+	$Septic_{AC}$		CAFO WLA_{AC}	+	NPDES Stormwater WLA_{AC}	+	Process Water WLA_{AC}		MOS
181,380	=	79,044	+	67,598	+	0	+	92	+	12,694	+	21,951	+	Implicit

Upstream Load Allocation[2] (79,044) — MD 8-digit Antietam Creek Watershed TMDL Contribution (67,598 through 21,951)

[1] LA_{PA} includes both (1) the PA load entering Maryland through the mainstem, which is receiving an allocation based on current loads, and (2) the load from those sections of PA which require phosphorus reductions because they drain to MD small order streams.. See sections 2.4 and 4.5.

[2] Although for the purpose of this analysis the upstream load is referred to as an LA, it could include loads from point and nonpoint sources.

Note: Individual load contributions may not add to total load due to rounding.

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

Baseline Load (lbs/yr)	TMDL (lbs/yr)	Total Reduction (%)
193,364	181,380	6%

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 Antietam Creek watershed (basin number 02140502) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02140502). 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 2011b). 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 waters of Antietam Creek and its tributaries is Use IV-P (*Water Contact Recreation, Protection of Aquatic Life, Recreational Trout Waters and Public Water Supply*); except for Beaver Creek, Marsh Run, and Little Antietam Creek, which are classified as Use III-P (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life, and Public Water Supply)* (COMAR 2012a,b,c,d,e).

The Maryland Department of the Environment (MDE) has identified the waters of Antietam Creek on the State's 2010 Integrated Report as impaired by nutrients (1996), impacts to biological communities (2002), and PCB in fish tissue (2008) (MDE 2010a). Because scientific research supports that phosphorus is generally the limiting nutrient in freshwater aquatic systems, the 1996 nutrients listing was refined in Maryland's 2008 Integrated Report to identify phosphorus as the specific impairing nutrient 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 November 2009, and all readily available data from 1998 up to the time of the TMDL development have been considered. A TMDL for carbonaceous biochemical oxygen demand (CBOD) and nitrogenous biochemical oxygen demand (NBOD) was approved by the EPA in 2002. A Water Quality Analysis (WQA) of eutrophication for the Greenbrier Lake impoundment was approved by the EPA in 2005. A TMDL for sediment was approved by EPA in 2008, and a TMDL for bacteria was approved by EPA in 2009. The listings for impacts to biological communities and PCB in fish tissue will be addressed separately at a future date.

The objective of this TMDL is to establish phosphorus loads that will be protective of the Aquatic Life Use designation for the Antietam Creek watershed. A Biological Stressor Identification (BSID) analysis of Antietam Creek (MDE 2012a) shows phosphorus is associated with biological impairments in the Antietam Creek watershed, confirming the original 1998 listing; therefore, a TMDL will be established for phosphorus.

Currently in Maryland, there are no specific numeric criteria that quantify the impact of phosphorus 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 any nutrient related impacts to aquatic health. The Chesapeake Bay Program's (CBP) Phase 5.3.2 Watershed Model (P5.3.2) is used to determine the phosphorus loads in both Antietam Creek and the reference watersheds that will be used to set the phosphorus TMDL for Antietam Creek.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Antietam Creek watershed is located in the Potomac River sub-basin within Washington County, Maryland (see Figure 1). Antietam Creek is a free-flowing stream that originates in Pennsylvania and empties into the Potomac River in Maryland downstream of Shepherdstown, WV; but upstream from Harpers Ferry, WV. It is approximately 54 miles in length, with 37 miles in Maryland and 17 miles in Pennsylvania. The total watershed area covers 186,203 acres, with approximately 118,667 acres in Maryland and 67,536 acres in Pennsylvania.

Geography/Soils

The Antietam Creek watershed lies within the Ridge and Valley Province of Western Maryland, which extends from South Mountain to the southeast to Dan's Mountain to the northwest. More specifically, the Antietam Creek Watershed is located in the Great Valley topographic and geologic zone, a subprovince of the Ridge and Valley. The Great Valley is a wide, flat, and open valley formed on Cambrian and Ordovician limestone, dolomite, and alluvial fan deposits alongside the bordering mountains. The surface geology is characterized by folded and faulted sedimentary rocks, layered limestone and shale, and soils composed of clay, clay loams, and sandy and stony loams (DNR 2007b; MGS 2007; MDE 2000).

The soils in the watershed are primarily in the Hagerstown-Duffield-Ryder Association and are derived from the underlying limestone, impure limestone and calcareous shale limestone respectively. They range from moderately deep to very deep.

The soils of South Mountain are in the Thurmont-Braddock-Trego Association, on the footslopes, and in the Bagtown-Dekalb-Weverton Association on the steeper side slopes and ridge tops. They are all derived from quartzite and phyllite. The Thurmont-Braddock-Trego Association soils are well drained to moderately well drained. They are all very deep and range from moderate to slow permeability. The Bagtown-Dekalb-Weverton Association soils are also well drained to moderately well drained. They range from very deep to moderately deep with permeabilities ranging from slow to rapid. Underlaying the soils in Antietam Creek is a Karst geology shaped by the dissolution of a layer or layers of soluble bedrock, which is limestone (USDA 2003).

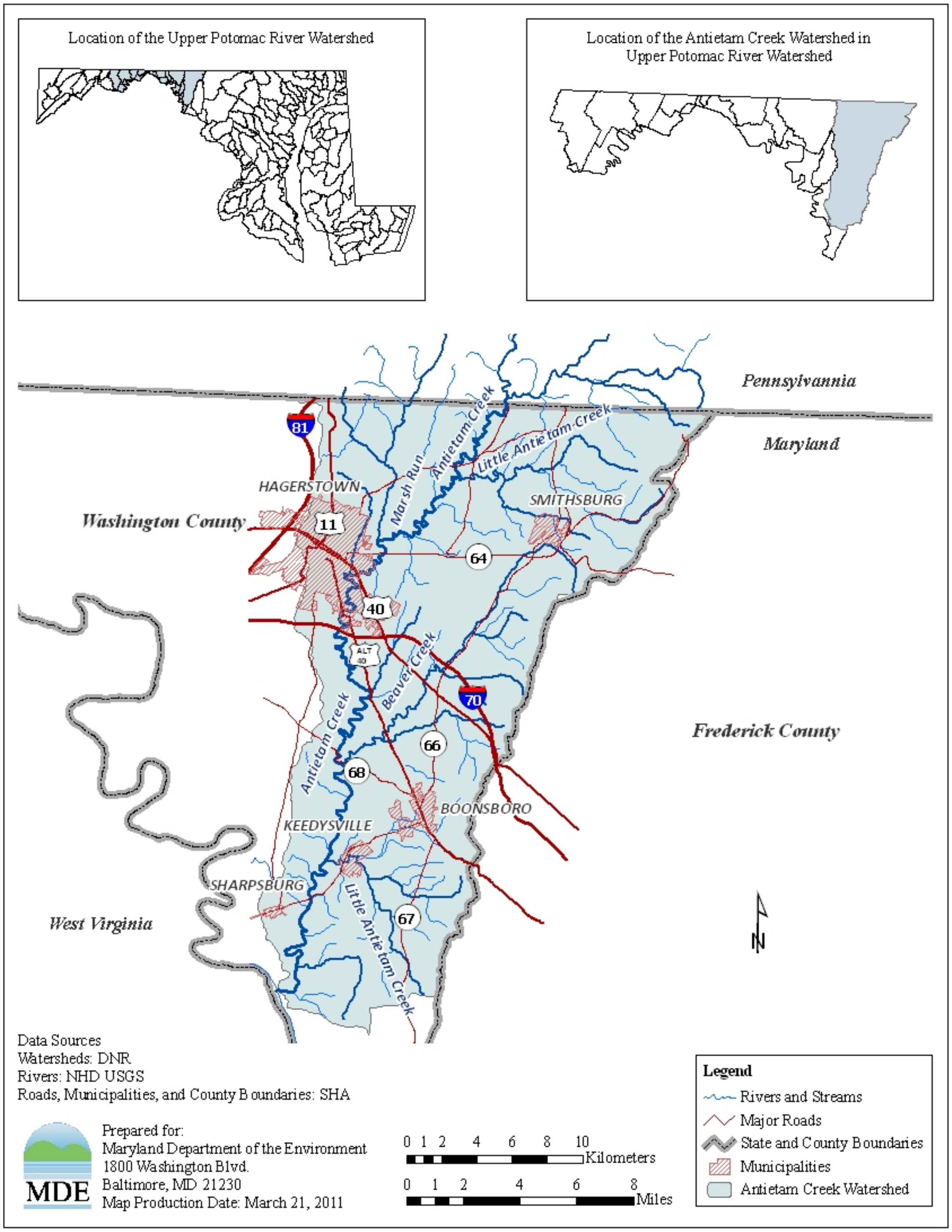

Figure 1: Location Map of Antietam Creek in Washington County, Maryland

2.1.1 Landuse

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). The "*Chesapeake*

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[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 CBP P5.3.2 was developed to estimate flow, nutrients, and sediment loads to the Bay.

Bay Phase 5.3 Community Watershed Model" (US EPA 2010b) describes these modifications in more detail.

The result of these second stage 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 summarizes the acreage of CBP P5.3.2 by sector in the Antietam Creek watershed. The landuse acreage is based on the CBP P5.3.2 2009 Progress Scenario, which, for the P5.3.2 model, represents current conditions.

Antietam Creek Watershed Landuse Distribution

Antietam Creek watershed landuse was evaluated separately for Maryland and Pennsylvania. The landuse distribution in Maryland consists mostly of forest (34.1%) and crop (32.1%), followed by regulated urban (24.3%), and pasture (8.9%). Water (0.6%), animal feeding operations (0.1%), and nurseries (< 0.1) make up the remaining landuse acres. All developed land in Maryland is regulated. In Pennsylvania, the landuse consists mainly of crop (40.6%) and forest (33.7%) land-use, with smaller amounts of non-regulated urban (16.0%), pasture (7.0%), and regulated urban (2.5%), Water, animal feeding operations, and nurseries contribute about 0.1% each to the landuse acres.

A 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 Antietam Creek Watershed

General Land-Use	Detailed Land-Use	Maryland			Pennsylvania		
		Area (Acres)	Percent (%)	Grouped Percent of Total	Area (Acres)	Percent (%)	Grouped Percent of Total
Forest	Forest	40,095	33.8%	34.1%	22,527	33.4%	33.7%
	Harvested Forest	403	0.3%		226	0.3%	
AFOs	Animal Feeding Operations	109	0.1%	0.1%	61	0.1%	0.1%
CAFOs	Concentrated Animal Feeding Operations	0	0.0%	0.0%	13	< 0.1%	< 0.1%
Pasture	Pasture	10,540	8.9%	8.9%	4,696	7.0%	7.0%
Crop	Crop	38,039	32.1%	32.1%	27,416	40.6%	40.6%
Nursery	Nursery	19	< 0.1%	< 0.1%	10	< 0.1%	< 0.1%
Non-Regulated Urban	Non-Regulated Developed	0	0.0%	0.0%	10,792	16.0%	16.0%
Regulated Urban	Construction	36	< 0.1%	24.3%	33	< 0.1%	2.5%
	Developed	28,517	24.0%		1,672	2.5%	
	Extractive	243	0.2%		12	< 0.1%	
Water	Water	667	0.6%	0.6%	78	< 0.1%	0.1%
Total		**118,667**	**100.0%**	**100.0%**	**67,536**	**100.0%**	**100.0%**

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

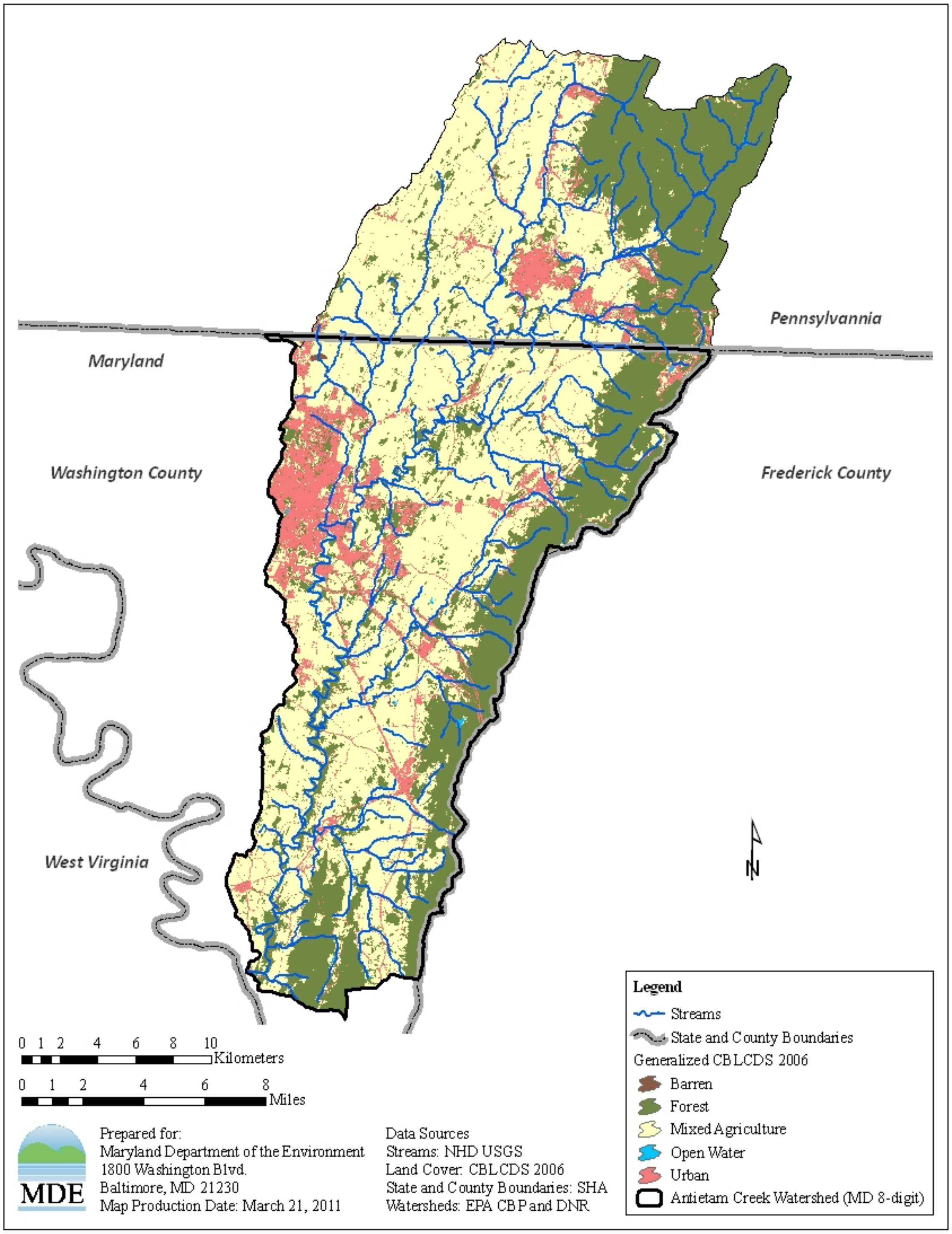

Figure 2: Landuse of the Antietam Creek Watershed

2.2 Source Assessment

2.2.1 Nonpoint Sources (NPS) Assessment

Nonpoint source nutrient loads in the Antietam 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 land-use-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.

<u>Literature Review</u>

Using Beaulac and Reckhow‘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 developed 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.

<u>EOS Calibration Targets</u>

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 uplift.

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.

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	Washington Co., MD CBP Land Segment A24043	Franklin Co., PA CBP Land Segment A42055	Adams Co., PA CBP Land Segment B42001
Forest	0.10	0.10	0.10
Harvested Forest	0.80	0.80	0.80
Degraded Riparian Pasture	12.46	18.65	11.73
Pasture	1.04	1.55	0.98
Alfalfa	0.70	0.70	0.70
Hay Without Nutrients	0.40	0.40	0.40
Hay With Nutrients	0.85	1.49	1.54
High Till Without Manure	2.65	2.74	2.76
High Till With Manure	1.99	2.20	2.27
Low Till With Manure	1.98	2.18	2.25
Nursery	85.00	85.00	85.00
Regulated Extractive	3.50	3.50	3.50
Regulated Construction	7.00	7.00	7.00
Regulated Impervious Developed	1.93	2.11	2.38
Regulated Pervious Developed	0.25	0.45	1.07
Non-regulated Impervious Developed	N/A	2.11	2.38
Non-regulated Pervious Developed	N/A	0.45	1.07

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. For most of the Antietam Creek watershed, the regional factor for phosphorus is 0.731; a small portion of the watershed below Sharpsburg has a regional factor of 1.463.

2.2.2 Point Source (PS) Assessment

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

The types of NPDES permits can be grouped into three categories: (1) process water, (2) stormwater, and (3) CAFOs. 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 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. There are twelve municipal WWTPs permitted to discharge phosphorus in the watershed, four of them are major facilities. The remaining process water facilities in the watershed are minor municipal and industrial facilities, which have smaller flows and consequently smaller nutrient loads. There are twelve industrial facilities capable of discharging phosphorus, none of which are considered major facilities. Baseline phosphorus loads for minor municipal WWTPs are based on DMR data, while current loads for minor industrial facilities were based either from monitoring required by their permits or professional judgment.

Table 3 lists the process-water facilities with active permits within the Antietam Creek watershed and their estimated baseline loads. Loads for major municipal and major industrial facilities are given on an individual basis; however, loads for all minor municipal and industrial facilities in the watershed are presented as “minor process water aggregate” load. All these facilities with their estimated loads are represented in the Phase 5.3.2 Watershed Model 2009 Progress Scenario. The total estimated 2009 MD process-water TP load is 17,959 lbs/yr.

Table 3: 2009 Process Water Annual Phosphorus Loads (lbs/yr) for MD Facilities in Antietam Creek Watershed Represented in Phase 5.3.2 Watershed Model

NPDES #	Facility Name	Type		2009 TP Load (lb/yr)
MD0020231	BOONSBORO WWTP	Municipal	Individual	1,817
MD0021776	HAGERSTOWN WWTP	Municipal	Individual	8,837
MD0023957	MARYLAND CORRECTIONAL INST	Municipal	Individual	599
MD0003221	WINEBRENNER WATER RECLAMATION FACILITY	Municipal	Individual	1,014
MDG766259	BEAVER CREEK GOLF COURSE	Industrial	Aggregate	5,692
MDG498022	C. WILLIAM HETZER, INC.- HOT MIX ASPHALT PLAN	Industrial		
MDG766220	CAMP LOUISE	Industrial		
MDG766301	FOUNTAIN HEAD COUNTRY CLUB	Industrial		
MD0060267	HESCO, INC.	Industrial		
MD0002151	HOLCIM (US) INC.	Industrial		
MDG498020	L.W. WOLFE ENTERPRISES, INC.	Industrial		
MDG491387	LAFARGE BEAVER CREEK CONCRETE PLANT	Industrial		
MDG490588	MARTIN MARIETTA - BOONSBORO QUARRY	Industrial		
MDG766209	MT. LENA RECREATION CLUB	Industrial		
MD0066974	NEWSTECH MD, LP	Industrial		
MDG493125	THOMAS BENNETT HUNTER INC – HAGERSTOWN CONCRETE PLANT	Industrial		
MD0062308	ANTIETAM WWTP	Municipal		
MD0053198	BROOK LANE PSYCHIACTRIC CENTER WWTP	Municipal		
MD0053066	FAHRNEY-KEEDY MEMORIAL HOME	Municipal		
MD0020362	FUNKSTOWN WWTP	Municipal		
MD0023868	GREENBRIER STATE PARK	Municipal		
MD0024627	HIGHLAND VIEW ACADEMY WWTP	Municipal		
MD0022926	HUNTER HILL APARTMENTS WWTP	Municipal		
MD0024317	SMITHSBURG WWTP	Municipal		
Total				**17,959**

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 current estimated MD stormwater TP load is 16,037 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 discharges or proposes to discharge to surface waters of the State. Recent EPA regulations require CAFOs to have a NPDES permit. Maryland also designates large animal feeding operations that 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.

Several operators in the Antietam Creek watershed have filed notices of intent (NOI) to apply for permits under Maryland's CAFO or MAFO regulations. Based on the NOIs filed by the reporting deadline of February, 2009, CBP estimates that the current average annual phosphorus load from CAFOs in the Antietam Creek watershed is 92 lbs/yr.

2.2.3 Overall Phosphorus Budget

Table 4 lists the current overall phosphorus budget for the Antietam Creek watershed in Maryland and Pennsylvania. These loads are derived from the P5.3.2 2009 Progress Scenario, which represents current land-use, loading rates, and BMP implementation simulated using precipitation and other meteorological inputs from the period 1990-2000 to represent variable hydrological conditions. In Maryland, the largest source of phosphorus is crop land (41.6%). The next largest phosphorus sources are point sources (17.2%), regulated urban land (15.3%), pasture (10.5%), animal feeding operations (AFOs and CAFOs) (9.2%), and forest (4.3%). Loads from nurseries (1.5%) and atmospheric deposition (0.4%) make up the remainder. In Pennsylvania, most of the load comes from crops (39.7%) followed by point sources (27.9%), animal feeding operations (AFOs and CAFOs) (10.5%), pasture (9.1%), and non-regulated urban sources (8.1%). Forest contributes 2.5 %, regulated urban land 1.3%, nurseries 0.8% and atmospheric deposition 0.1%. There are no combined sewer overflows (CSOs) in the Antietam Creek watershed, and phosphorus loads from septic systems are considered insignificant. Table 5 summarizes the MD 8-digit Antietam Creek Baseline Phosphorus Load, reported in pounds per year (lbs/yr) and presented in terms of Upstream Baseline Loads and MD 8-digit Antietam Creek Watershed Baseline Load Contribution nonpoint and point source loadings.

Table 4: Antietam Creek Watershed Detailed Baseline Total Phosphorus Loads

General Land-Use	Detailed Land-Use	Maryland Load (lbs/yr)	Maryland Percent (%)	Maryland Grouped Percent of Total	Pennsylvania Load (lbs/yr)	Pennsylvania Percent (%)	Pennsylvania Grouped Percent of Total
Forest	Forest	4,298	4.1%	4.3%	2,099	2.4%	2.5%
	Harvested Forest	167	0.2%		165	0.2%	
AFOs	Animal Feeding Operations	9,469	9.1%	9.1%	7,900	8.9%	8.9%
CAFOs	Concentrated Animal Feeding Operations	92	0.1%	0.1%	1,419	1.6%	1.6%
Pasture	Pasture	10,999	10.5%	10.5%	8,038	9.1%	9.1%
Crop	Crop	43,537	41.6%	41.6%	35,282	39.7%	39.7%
Nursery	Nursery	1,593	1.5%	1.5%	717	0.8%	0.8%
Non-Regulated Urban	Non-Regulated Developed	0	0.0%	0.0%	7168	8.1%	8.1%
Regulated Urban	Construction	125	0.1%	15.3%	189	0.2%	1.3%
	Developed	15,189	14.5%		933	1.1%	
	Extractive	723	0.7%		36	<0.1%	
Septic	Septic	0	0.0%	0.0%	0	0.0%	0.0%
CSO	CSO	0	0.0%	0.0%	0	0.0%	0.0%
Point Sources	Industrial Point Sources	3,676	3.5%	17.2%	0	0.0%	27.9%
	Municipal Point Sources	14,283	13.7%		24,820	27.9%	
Atmospheric Deposition	Non-tidal Atmospheric Deposition	398	0.4%	0.4%	50	0.1%	0.1%
Total		**104,549**	**100.0%**	**100.0%**	**88,815**	**100.0%**	**100.0%**

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

Table 5: MD 8-digit Antietam Creek Baseline Phosphorus Loads (lbs/yr)

<table>
<tr><th rowspan="2">Total Baseline Load (lbs/yr)</th><th rowspan="2">=</th><th>Upstream Baseline Load[1]</th><th rowspan="2">+</th><th colspan="9">MD 8-digit Antietam Creek Watershed Baseline Load Contribution</th></tr>
<tr><th>BL_{PA}</th><th>Nonpoint Source BL_{AC}</th><th>+</th><th>Septic BL_{AC}</th><th>+</th><th>CAFO BL_{AC}</th><th>+</th><th>NPDES Stormwater BL_{AC}</th><th>+</th><th>Process Water BL_{AC}</th></tr>
<tr><td>193,364</td><td>=</td><td>88,815</td><td>+</td><td>70,461</td><td>+</td><td>0</td><td>+</td><td>92</td><td>+</td><td>16,037</td><td>+</td><td>17,959</td></tr>
</table>

[1] Although the Upstream Baseline Load is reported here as a single value, it could include point and nonpoint sources.

2.3 Water Quality Characterization

The Antietam 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).

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 Antietam Creek mainstem and its tributaries is Use IV-P (*Water Contact Recreation, Protection of Aquatic Life, Recreational Trout Waters and Public Water Supply*) except for Beaver Creek, Marsh Run, and Little Antietam Creek, which are classified as Use III-P (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life, and Public Water Supply*) (COMAR 2012a,b,c,d,e).

Currently, 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-P waters "may not be less than 5 milligrams per liter (mg/l) at any time" and to protect Use III-P 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 2012e).

A data solicitation for information pertaining to pollutants, including nutrients, in the Antietam Creek watershed was conducted by MDE in November 2009 and all readily available data from 1998 up to the time of the TMDL development were considered. All available resources, including Department of Natural Resources (DNR), U.S. Geological Survey (USGS), and the Chesapeake Bay Program (CBP), were also investigated to determine if there were other available data in the Antietam Creek watershed. MDE conducted surveys along the Antietam Creek from November 1999 through December 2005. DNR collected data in the watershed from January 1998 through June 2007. Data from Maryland Biological Stream Survey (MBSS) sampling conducted in April, 2000; March, 2001; April through May, 2003; and March, 2004 were also used. Figures 4 through 6 provide graphical representation of the collected data for the parameters discussed below.

Antietam Creek Watershed Monitoring Stations

A total of 61 monitoring stations were used to characterize the Antietam Creek watershed. There were 33 biological/physical habitat monitoring stations from the MBSS program and four biological monitoring stations from the Maryland CORE/TREND monitoring network, three of which also collect water quality data. MDE also monitored water quality at three CORE/TREND Stations and at 24 additional locations. The stations are presented in Figure 3 and listed in Table 6.

Table 6: Monitoring Stations in the Antietam Creek Watershed

Site Number	Sponsor	Site Type	StreamName	Latitude (dec degree)	Longitude (dec degree)
ANT0002	MDE	Water Quality	Antietam Creek	39.4170	-77.7421
ANT0043	MDE	Water Quality	Antietam Creek	39.4490	-77.7287
ANT0058	MDE	Water Quality	Antietam Creek	39.4655	-77.7254
ANT0084	MDE	Water Quality	Antietam Creek	39.4879	-77.7139
ANT0097	MDE	Water Quality	Antietam Creek	39.5047	-77.7138
ANT0112	MDE	Water Quality	Antietam Creek	39.5178	-77.7015
ANT0132	MDE	Water Quality	Antietam Creek	39.5377	-77.7103
ANT0134	MDE	Water Quality	Antietam Creek	39.5405	-77.7118
ANT0151	MDE	Water Quality	Antietam Creek	39.5531	-77.7007
ANT0176	MDE	Water Quality	Antietam Creek	39.5700	-77.6892
ANT0198	MDE	Water Quality	Antietam Creek	39.5882	-77.7069
ANT0209	MDE	Water Quality	Antietam Creek	39.6106	-77.7215
ANT0223	MDE	Water Quality	Antietam Creek	39.6043	-77.7098
ANT0230	MDE	Water Quality	Antietam Creek	39.6103	-77.7119
ANT0241	MDE	Water Quality	Antietam Creek	39.6260	-77.6997
ANT0250	MDE	Water Quality	Antietam Creek	39.6310	-77.7099
ANT0277	MDE	Water Quality	Antietam Creek	39.6496	-77.6883
ANT0314	MDE	Water Quality	Antietam Creek	39.6661	-77.6508
BEC0001	MDE	Water Quality	Beaver Creek	39.5349	-77.7090
LAN0006	MDE	Water Quality	Little Antietam Creek	39.6825	-77.6289
LAS0004	MDE	Water Quality	Little Antietam Creek	39.4864	-77.7013
LBC0052	MDE	Water Quality	Little Beaver Creek UT	39.5366	-77.6196
MRS0000	MDE	Water Quality	Marsh Run	39.6502	-77.6889
ZEG0001	MDE	Water Quality	Little Beaver Creek UT	39.5366	-77.6197
ANT0044	MDE MD DNR	CORE/TREND	Antietam Creek	39.4503	-77.7319
ANT0203	MDE MD DNR	CORE/TREND	Antietam Creek	39.5943	-77.7098
ANT0229	MD DNR	TREND	Antietam Creek	39.6106	-77.7122
ANT0366	MDE MD DNR	CORE/TREND	Antietam Creek	39.7158	-77.6086
ANTI-101-C-2000	MD DNR	MBSS	Edgemont Reservoir UT1	39.6583	-77.5453
ANTI-101-C-2001	MD DNR	MBSS	Edgemont Reservoir UT1	39.6583	-77.5453
ANTI-105-R-2003	MD DNR	MBSS	Little Antietam Creek UT1	39.4263	-77.6776
ANTI-106-R-2003	MD DNR	MBSS	Landis Spring Branch	39.6019	-77.6704
ANTI-107-R-2003	MD DNR	MBSS	Falls Creek	39.7161	-77.4984

Site Number	Sponsor	Site Type	StreamName	Latitude (dec degree)	Longitude (dec degree)
ANTI-111-R-2003	MD DNR	MBSS	Dog Creek UT1	39.4807	-77.6709
ANTI-113-R-2003	MD DNR	MBSS	Little Antietam Creek	39.6625	-77.5258
ANTI-116-R-2003	MD DNR	MBSS	Little Antietam Creek UT1	39.4389	-77.6712
ANTI-130-R-2003	MD DNR	MBSS	Little Beaver Creek	39.5341	-77.6299
ANTI-201-R-2003	MD DNR	MBSS	Antietam Creek UT1	39.4156	-77.7347
ANTI-208-R-2003	MD DNR	MBSS	Sharmans Branch	39.4294	-77.7335
ANTI-215-R-2003	MD DNR	MBSS	Little Antietam Creek	39.6741	-77.5574
ANTI-226-R-2003	MD DNR	MBSS	Antietam Creek UT2	39.4890	-77.6803
ANTI-304-R-2003	MD DNR	MBSS	Marsh Run	39.6632	-77.6852
ANTI-310-R-2003	MD DNR	MBSS	Beaver Creek	39.5428	-77.6956
ANTI-414-R-2003	MD DNR	MBSS	Antietam Creek	39.4796	-77.7201
ANTM-101-N-2004	MD DNR	MBSS	Antietam Creek UT5	39.4758	-77.7381
ANTM-112-N-2004	MD DNR	MBSS	Antietam Creek UT4	39.4614	-77.7308
NCRW-120-N-2004	MD DNR	MBSS	Antietam Creek UT3	39.4538	-77.7349
WA-V-006-222-95	MD DNR	MBSS	Little Antietam Creek	39.4502	-77.6700
WA-V-062-212-95	MD DNR	MBSS	Beaver Creek	39.5754	-77.6541
WA-V-063-201-95	MD DNR	MBSS	Little Antietam Creek UT1 UT1	39.6906	-77.5675
WA-V-075-220-95	MD DNR	MBSS	Beaver Creek	39.5881	-77.6389
WA-V-084-116-95	MD DNR	MBSS	Little Antietam Creek UT1	39.4226	-77.6738
WA-V-118-117-95	MD DNR	MBSS	Black Rock Creek	39.5802	-77.6282
WA-V-120-233-95	MD DNR	MBSS	Sharmans Branch	39.4290	-77.7292
WA-V-131-224-95	MD DNR	MBSS	Marsh Run	39.6863	-77.6804
WA-V-148-305-95	MD DNR	MBSS	Little Antietam Creek	39.6867	-77.5983
WA-V-157-111-95	MD DNR	MBSS	Little Antietam Creek UT1	39.6958	-77.5668
WA-V-161-214-95	MD DNR	MBSS	Little Beaver Creek	39.5533	-77.6317
WA-V-174-236-95	MD DNR	MBSS	Marsh Run	39.7034	-77.6776
WA-V-186-210-95	MD DNR	MBSS	Little Antietam Creek	39.4639	-77.6811
WA-V-192-115-95	MD DNR	MBSS	Hamilton Run	39.6674	-77.7184

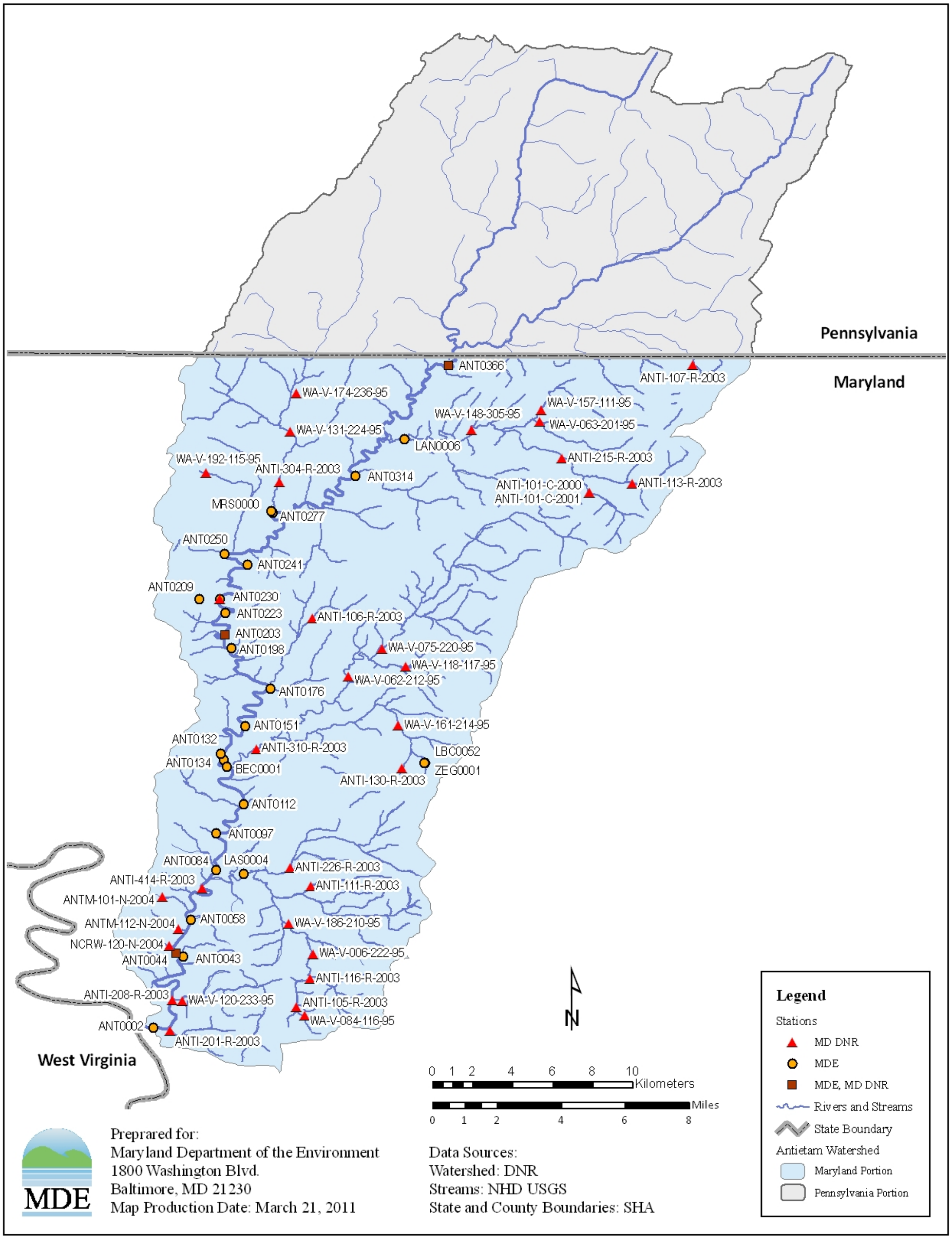

Figure 3: Monitoring Stations in the Antietam Creek Watershed

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 (MDDNR 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 Antietam Creek watershed identified both phosphorus and nitrogen as a potential stressors. Both total phosphorus and orthophosphate show a significant association with degraded biological conditions. As much as 20% of the biologically impacted stream miles in the watershed are associated with high total phosphorus and 19% are associated with high orthophosphate. Similarly, according to the BSID analysis, 31% of the biologically impacted stream miles in the Antietam Creek watershed are associated with high total nitrogen concentrations. Based on the results of the analysis, the BSID report concludes that nitrogen and phosphorus are associated with impairments to aquatic life or biological communities in the Antietam Creek watershed. The indirect impact of nutrient 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 increase primary production resulting in periphyton growth and also diurnal fluctuations. At this time, both the original 1998 listing and the initial BSID analysis point to nutrients in general and phosphorus in particular, as a biological stressor in Antietam Creek.

For details on the BSID analysis, please refer to the document *"Draft Watershed Report for Biological Impairment of the Antietam Creek Watershed in Washington County, Maryland - Biological Stressor Analysis Results and Interpretation"* (MDE 2012a) and *"Maryland Biological Stressor Identification Process"* (MDE 2009a).

2.3.2 Dissolved Oxygen

DNR samples were taken in the Antietam watershed from January 1998 through June 2007. MDE samples were taken from November 1999 through December 2005, and MBSS samples were taken during the Spring and Summer of, 2000, 2001; 2003; and 2004. Samples taken during the growing season (May through October) show DO concentrations ranging from 5.0 to 12.5 mg/l, all above the DO criterion. These data are presented graphically in Figure 4. In March Run, Beaver Creek, or Little Antietam Creek, where the Use III-P DO criteria apply, no concentrations had DO concentrations less than 6 mg/l. The monitoring data indicate that the water quality standard for DO is being met in the Antietam Creek and its tributaries.

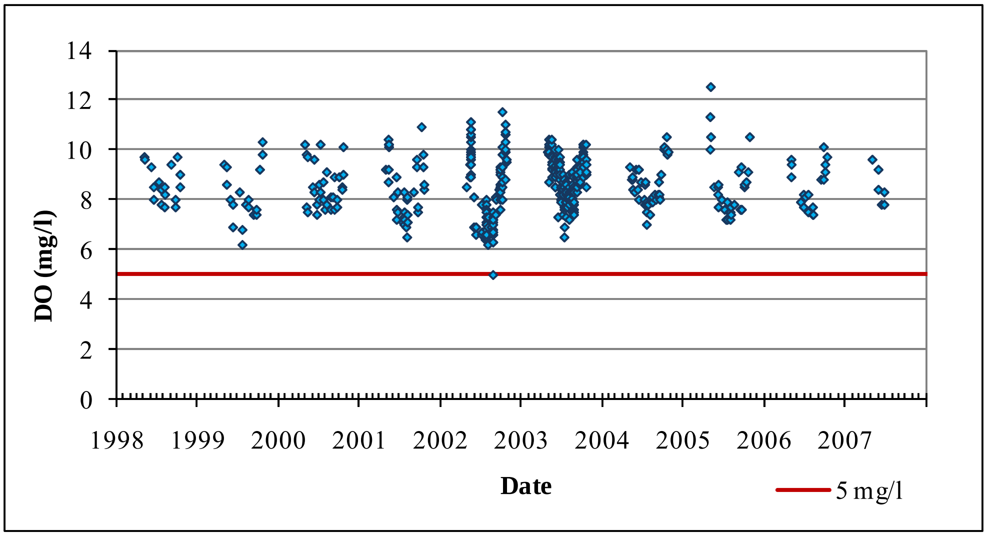

Figure 4: Antietam Dissolved Oxygen Data from 1998 through 2007

2.3.3 Nutrients

In the absence of State water quality standards with specific numeric limits for nutrients, evaluation of potentially eutrophic conditions is based on whether nutrient-related parameters (*i.e*., dissolved oxygen levels and chlorophyll *a* concentrations) are found to impair the designated uses in the Antietam Creek (in this case protection of aquatic life and wildlife, fishing, and swimming). Consequently, the nutrients data presented in this section are for informational purposes only.

Total nitrogen (TN) and total phosphorus (TP) data for the Antietam Creek have been collected as part of this study and the results are presented here for informational purposes. During the growing season DNR, MDE and MBSS, have total nitrogen (TN) concentrations ranging from 0.17 to 10.06 mg/l and total phosphorus (TP) concentrations ranging from 0.01 to 1.11 mg/l. These data are presented graphically in Figures 5 and 6.

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 and Vighi 1974).

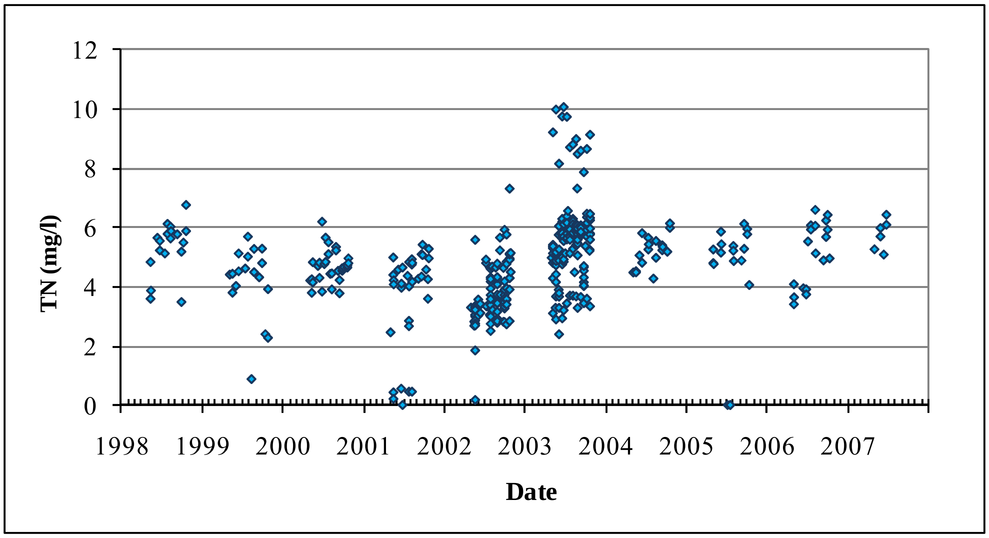

Figure 5: Antietam Total Nitrogen Data from 1998 through 2007

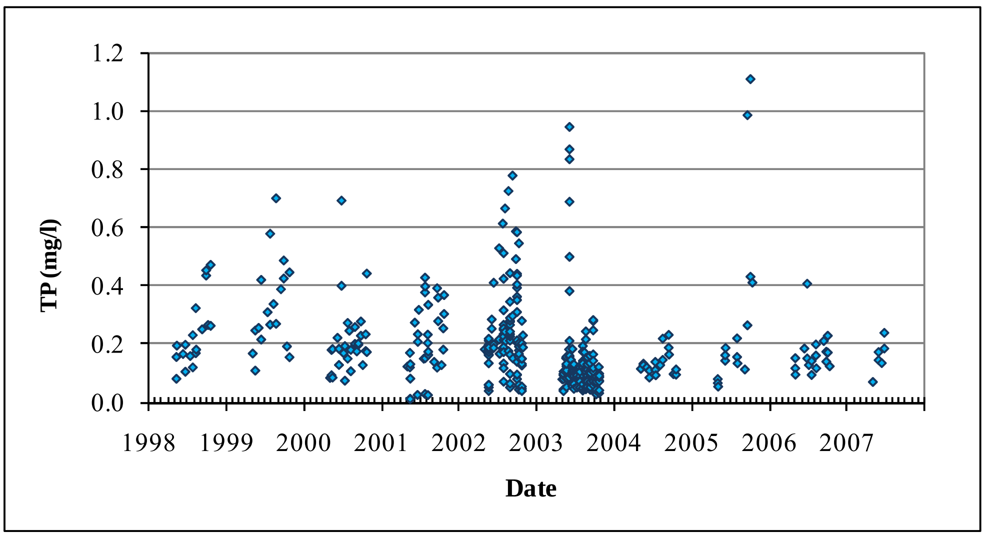

Figure 6: Antietam Total Phosphorus Data from 1998 through 2007

More than 94% of the samples collected in the Antietam Creek watershed since 1998 have TN:TP ratios above 10 and less than 1% had TN:TP ratios below 5. All samples with ratios below 10 come from the mainstem Antietam Creek. The median ratio was 38. The observed data strongly implies that the streams in the Antietam Creek watershed are phosphorus limited.

2.3.5 Antietam Creek Mainstem CORE/TREND Monitoring Stations

Additional biological data for the mainstem Antietam Creek was obtained from the Maryland Department of Natural Resources (DNR) CORE/TREND Program. DNR has extensive monitoring information for four stations in the mainstem of Antietam Creek through the CORE/TREND Program. The program collected benthic macroinvertebrate data at these stations between 1976 and 2006. The stations are located near Burnside Bridge (ANT0044), Poffenberger Road (ANT0203), Funkstown (ANT0229), and Rocky Forge (ANT0366) (see Table 7 and Figure 3). These stations have between 21 and 28 years of benthic macroinvertebrate data (DNR 2007a; DNR 2009). These data were used to calculate four benthic community measures: total number of taxa, the Shannon-Weiner diversity index, the modified Hilsenhoff biotic index, and percent *Ephemeroptera*, *Plecoptera*, and *Trichoptera* (EPT). A summary of the results for each of the stations is presented in Table 7.

Table 7: Antietam Creek DNR Core Data

Site Number	Current Water Quality Status	Trend Since 1970's
ANT0044	Good	Slight improvement
ANT0203	Good	Strong improvement
ANT0229	Good	Moderate improvement
ANT0366	Good	Slight improvement

2.4 Water Quality Impairment

The Maryland water quality standards surface water use designation for the Antietam Creek mainstem and its tributaries is Use IV-P (*Recreational Trout Waters and Public Water Supply*) except for Beaver Creek, Marsh Run, and Little Antietam Creek, which are classified as Use III-P (*Nontidal Cold Water and Public Water Supply*) (COMAR 2012a,b,c). The nutrient water quality impairment of the Antietam 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 and orthophosphate as associated with 20% and 19%, respectively, of the biologically impaired stream miles in the Antietam Creek watershed, and nitrogen as associated with 31% of the impaired stream miles.

The analysis of DO monitoring data in section 2.3.1 confirms that the DO criteria are currently met in the watershed.

Biological results from both the DNR CORE/TREND and MBSS stations along the mainstem of Antietam Creek indicate that mainstem water quality can be classified as good. Statistical analysis of the long-term CORE/TREND data indicates that since 1976, all stations have shown improvement and are ranked as having good water quality based on percent EPT, taxa number, biotic index, and diversity index (DNR 2007a, 2009). In addition, the MBSS mainstem station (ANTI-414-R-2003) has been assigned a BIBI score indicative of acceptable water quality.

Because all biological monitoring results on the Antietam Creek mainstem indicate the mainstem is supporting its aquatic life use, MDE therefore concludes the nutrient impairment is only within the lower order (smaller) streams in the Maryland portion of the watershed. Reductions in phosphorus loads from point and nonpoint sources discharging in to lower order streams will be required to address this impairment.
On the other hand, permitted facilities that discharge directly to the Antietam mainstem will be given an informational TMDL based on their allocations under the Chesapeake Bay TMDL.

Similarly, Pennsylvania's portion of the watershed will be divided into two sections: (1) the section of the watershed in Pennsylvania which enters Maryland only through mainstem Antietam Creek, upstream of ANT0336 (see Figure 3),will receive an informational TMDL based on current loading conditions, while (2) the section of Pennsylvania's portion of the watershed which drains into Maryland's lower order streams downstream of ANT0336 will require reductions in phosphorus loads to address the impairment.

The BSID has also indicated that high concentrations of total nitrogen are associated with biological impairment in the Antietam 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 of 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 2.3.6 confirms the assumption that phosphorus is the limiting nutrient in Antietam 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 Antietam Creek, and the reduction of nitrogen loads would not be an effective means of ensuring that the Antietam Creek watershed is free from impacts on aquatic life from eutrophication. Therefore, load allocations for the Antietam Creek Nutrient TMDL will apply only to total phosphorus. Reductions in nitrogen loads will be required in the Antietam 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 Antietam Creek watershed to levels that support the Use III-P and Use IV-P designations (*Water Contact Recreation, Protection of Aquatic Life, Recreational Trout Waters and Public Water Supply*) (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life, and Public Water Supply*) (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 to those 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 Antietam Creek watershed with the nutrient 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) will be used to determine the nitrogen and phosphorus loads in both Antietam Creek and the unimpaired watersheds that will be used to set the phosphorus TMDL for Antietam Creek.

Overall, this TMDL will establish phosphorus loads that will be protective of the Use III-P/IV-P designations for the Antietam 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*., high conductivity) 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 or stressors 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).

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section describes how the phosphorus TMDL and load allocations (LA) were developed for Antietam 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 will be 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.

Based on the DO data analysis and mainstem benthic macroinvertebrate data shown in Section 2.4, the mainstem of Antietam Creek is unimpaired. Consequently, the section of the watershed in Pennsylvania upstream of ANT0336 (see Figure 3), which enters Maryland only through mainstem Antietam Creek, will receive an informational TMDL based on current loading conditions. The remainder of the Pennsylvania portion of the watershed, as well as the entire Maryland portion of the watershed, will require reductions in phosphorus loads.

In addition, because the mainstem of Antietam Creek has been determined to be supporting its aquatic life designated use and is not impaired by nutrients, permitted process water facilities discharging to the mainstem of Antietam Creek will not be included in the TMDL but will be segregated in their own category. These dischargers include the following major WWTPs discharging over 0.5 MGD: MD Correctional Institute (MD0023957) and Hagerstown WWTP (MD0023868), and three minor facilities. The major facilities will be given individual phosphorus allocations for informational purposes only, based on their allocations under the Chesapeake Bay TMDL. Loads from minor facilities discharging in the mainstem will be included in a “minor process water aggregate” WLA.

<u>Watershed Model</u>

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 Antietam

Creek phosphorus TMDL, and other nutrient TMDLs for Maryland's non-tidal watersheds, the CBP P5.3.2 Watershed Model will be used to determine nitrogen and phosphorus loads in both the impaired and reference watersheds.

The P5.3.2 model is a Hydrological Simulation Program FORTRAN (HSPF) model of 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 water quality 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 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 MD, 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 Watershed 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 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 will be 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, silvaculture, 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 the absence of numeric criteria that quantify the impact of nutrients on the aquatic health of non-tidal stream systems and 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, 2009b). 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 2010).

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

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

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

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 Antietam Creek watershed is 7.37).

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 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.

Antietam Creek's forest normalized load exceeds the *forest normalized reference phosphorus load* (also referred to as the *phosphorus loading threshold*), indicating that the Antietam Creek watershed 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 phosphorus 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 time frame, as well as estimated point source loads based on discharge data for the same period.

The Antietam 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 1990-2000 to represent variable hydrological conditions, thereby addressing annual changes in hydrology and capturing wet, average and dry years. The period 1991-2000 is the 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 phosphorus loads from these segments are combined to represent the baseline condition. The Maryland point source phosphorus loads are estimated based on the 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 from the PA portion of the Antietam Creek watershed is 88,815 lbs per year while the load from the Maryland portion is 94,363 lbs per year, excluding the loads from point sources discharging directly to the mainstem. Mainstem point sources account for 10,187 lbs per year phosphorus under baseline conditions.

Future (TMDL) Conditions

This scenario represents the future conditions of 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 healthy biological communities) and the Antietam 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 MD 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:

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

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)

Based on the analysis in Section 2.4, the mainstem of Antietam Creek is unimpaired. The portion of the watershed in Pennsylvania upstream of ANT033, which enters Maryland only through the mainstem Antietam Creek, will receive an informational TMDL based on current loading conditions. The future conditional (TMDL) loads from the remainder of the Pennsylvania portion of Antietam Creek watershed, as well as the entire Maryland portion of the watershed, will require reductions in phosphorus loads.

4.4 Critical Conditions and Seasonality

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 and therefore depict an average stream condition (*i.e.*, captures all high and low flow events). Because the TMDL endpoint is based on the median of forest normalized loads from watersheds assessed as having good biological conditions (*i.e.*, passing Maryland's biocriteria), by the nature of the biological data described above, it must inherently include the critical conditions of the reference watersheds. Therefore, because the TMDL reduces the watershed sediment load to a level compatible with that of the reference watersheds, critical conditions are inherently addressed. Seasonality is captured in two components. First, it is implicitly included through the use of the biological monitoring data as biological monitoring data reflect the impacts of stressors over time, as described above. Second, the MBSS dataset included benthic sampling in the spring (March 1 - April 30) and fish sampling in the summer (June 1 - September 30). Benthic sampling in the spring allows for the most accurate assessment of the benthic population, and therefore provides an excellent means of assessing the anthropogenic effects of sediment impacts on the benthic community. Fish sampling is conducted in the summer when low flow conditions significantly limit the physical habitat of the fish community, and it is therefore most reflective of the effects of anthropogenic stressors as well.

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 Antietam 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.

As presented above in Section 2.4, the DNR CORE/TREND and MBSS monitoring data show that the Antietam Creek mainstem is supporting its Aquatic Life and Wildlife Use. Based on this information, it was concluded that WWTPs directly discharging into the mainstem of Antietam Creek do not have a negative impact on the aquatic health of the Antietam Creek mainstem, and therefore mainstem point sources will be segregated from the rest of MD TMDL.

Similarly, PA loads entering Maryland from the Antietam Creek mainstem are not having a negative impact on aquatic life in the mainstem, and therefore, load reductions are not required for the section of Pennsylvania's portion of the watershed upstream of ANT0336 (see Figure 3). This section of Pennsylvania's portion of the watershed is assigned an informational TMDL equivalent to its current baseline load. On the other hand, in addition to the phosphorus load reductions required within the MD 8-digit Antietam Creek watershed, reductions are also required for the remaining sections of the watershed in Pennsylvania which flow into Maryland's low order streams. Baseline loads in the Antietam Creek watershed include loads from both sections of Pennsylvania's portion of Antietam Creek watershed. Therefore, the upstream load TMDL allocation will include (1) the informational allocation to Pennsylvania portion of the watershed that drains directly into Antietam Creek as well as (2) the section of Pennsylvania's portion of the watershed which drains into Maryland's lower other streams and requires a load reduction.

Based on Equation 4.2, the long-term average annual TMDL was calculated for the entire MD 8-digit watershed and the section of Pennsylvania's portion of the watershed requiring reductions in phosphorus loads. In order to attain the TMDL loading cap calculated for the watershed, reductions to phosphorus baseline loads will be applied to the controllable sources. It is worth noting that significant phosphorus reductions will be required in the Antietam 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 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 Antietam Creek.

An overall reduction of 6% 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 Antietam Creek watershed are presented in Table 8.

Table 8: Antietam Watershed TMDL for Phosphorus

	Baseline Load (lbs/Yr)	TMDL Scenario Load (lbs/yr)	Reduction (%)
PA[1]	88,815	79,044	11%
MD 8-digit	94,363	91,907	3%
Mainstem[2]	10,187	10,428	0%
Total	**193,364**	**181,380**	**6%**

Notes: [1] Includes all PA loads in the Antietam Creek watershed.
[2] Mainstem comprises WWTPs discharging directly to Antietam Creek. TMDL is for informational purposes only.
Note: Individual baseline loads may not add to total load due to rounding.

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 point sources and load allocations (LAs) for nonpoint source loads generated within the assessment unit, accounting for natural background, tributary, and adjacent segment loads (CFR 2011b). Consequently, the Antietam 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 and loads from upstream watersheds). The State reserves the right to allocate the TMDL among different sources in any manner that is reasonably calculated to protect aquatic life from nutrient related impacts.

Table 9 summarizes the TMDL scenario results for phosphorus. There are no CSOs in the Antietam Creek watershed, and phosphorus loads from septic systems are considered insignificant. Equal reductions were applied to the phosphorus loads from controllable 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; crop, pasture, urban land, CAFOs, and municipal WWTPs were identified as the predominant controllable sources. Forest is the primary non-controllable source, as it represents the most natural condition in 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.

The Antietam Creek Phosphorus TMDL requires a 4% reduction in phosphorus loads from nonpoint sources (See Table 9). For more detailed information regarding the Antietam Creek Watershed TMDL Contribution nonpoint source allocations, please see the technical memorandum to this document entitled "*Significant Phosphorus Nonpoint Sources in the Antietam Creek Watershed*".

The waste load allocation (WLA) of the Antietam 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 Antietam Creek TMDL Phosphorus TMDL by Source Category

	Baseline Load Source Categories		Baseline Load (lbs/yr)	TMDL Components	TMDL (lbs/yr)	Reduction (%)
Antietam Creek Contribution	Nonpoint Source	Forest	4,465	LA	4,465	0%
		AFOs	9,469		7,840	17%
		Pasture	10,999		9,882	10%
		Crop	43,537		43,537	0%
		Nursery	1,593		1,475	7%
		Septic	0		0	0%
		Atmospheric Deposition	398		398	0%
		Sub-total	**70,461**		67,598	4%
	Point Source	CAFOs	92	WLA	92	0%
		Regulated Urban	16,037		12,694	21%
		Process Water	17,959		21,951	0%
		CSO	0		0	0%
		Sub-total	34,088		34,737	0%
	Total MD 8-digit		**104,549**		**102,335**	**2%**
Upstream	**Pennsylvania**		**88,815**	**Upstream LA**	**79,044**	**11%**
Total			**193,364**		**181,380**	**6%**

Note: Individual source categories loads may not add up to total load due to rounding.

Process Water WLA

There are twelve municipal WWTP in the Antietam Creek watershed, four of them discharging into the mainstem. 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.

Twelve industrial facilities discharging process water in the Antietam Creek watershed were judged to have the capacity to discharge TP in their process water. All of these industrial facilities are minor. One of these facilities discharges directly into the mainstem. 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 WLA. A similar approach was adopted for the Antietam Creek TMDL and all minor municipal and minor industrial process water facilities allocations are represented as a watershed-wide WLA

For information regarding individual allocations to major process water facilities and information related to minor process water facilities included in the aggregate WLA, please see the technical memorandum to this document entitled "*Significant Nutrient Point Sources in the Antietam 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). The NPDES stormwater program covers 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 Antietam 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 Antietam 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 Antietam NPDES stormwater WLA requires an overall reduction of 21% 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 Nutrient Point Sources in the Antietam Creek Watershed*".

CAFO WLA

Under the Clean Water Act, concentrated animal feeding operations (CAFOs) require NPDES permits for their discharges or potential discharges (CFR 2010c). In January, 2009, Maryland implemented new regulations governing CAFOs (COMAR 26.08.01, 26.08.03, and 26.08.04), which were approved by the EPA in January, 2010. Under these regulations, CAFOs are required to fulfill the conditions of a general permit. These conditions include instituting a Comprehensive Nutrient Management Plan (CNMP) which meets the Nine Minimum Standards to Protect Water Quality. The general permit also prohibits the discharge of pollutants, including nutrients, from CAFO production areas except as a result of event greater than the 25-year, 24-hour storm. Based on the TMDL methodology approach of applying an equal percent reduction to all controllable loads, the Antietam Creek Phosphorus TMDL does not require a reduction in phosphorus loads from 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 Maryland 8-digit Antietam Creek watershed and Pennsylvania streams draining to the watershed are summarized in Table 10. The Maryland Maximum Daily Phosphorus TMDL is summarized in Table 11 (See Appendix B for more details).

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

TMDL (lbs/yr)	=	**LA**					+	**WLA**					+	
		LA_{PA}[1,2]	**+**	**LA_{AC}**	+	**$Septic_{AC}$**		**CAFO WLA_{AC}**	+	**NPDES Stormwater WLA_{AC}**	+	**Process Water WLA_{AC}**		**MOS**
181,380	=	79,044		67,598	+	0	+	92	+	12,694	+	21,951	+	Implicit

Upstream Load Allocation[2]

MD 8-digit Antietam Creek Watershed TMDL Contribution

[1] LA_{PA} includes both (1) the PA load entering Maryland through the mainstem, which is receiving an allocation based on current loads, and (2) the load from those sections of PA which require phosphorus reductions because they drain to MD small order streams.. See sections 2.4 and 4.5.

[2] Although for the purpose of this analysis the upstream load is referred to as an LA, it could include loads from point and nonpoint sources.

Note: Individual load contributions may not add to total load due to rounding.

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

TMDL (lbs/day)	=	**LA**					+	**WLA**					+	
		LA_{PA}[1,2]	**+**	**LA_{AC}**	+	**$Septic_{AC}$**		**CAFO WLA_{AC}**	+	**NPDES Stormwater WLA_{AC}**	+	**Process Water WLA_{AC}**		**MOS**
2,747	=	1,269	+	1,085	+	0	+	1	+	204	+	187	+	Implicit

Upstream Load Allocation[2]

MD 8-digit Antietam Creek Watershed TMDL Contribution

[1] LA_{PA} includes both (1) the PA load entering Maryland through the mainstem, which is receiving an allocation based on current loads, and (2) the load from those sections of PA which require phosphorus reductions because they drain to MD small order streams. See sections 2.4 and 4.5

[2] Although for the purpose of this analysis the upstream load is referred to as an LA, it could include loads from point and nonpoint sources.

Note: Individual load contributions may not add to total load due to rounding.

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 Antietam Creek will be achieved and maintained.

The Antietam 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 Antietam 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 Antietam 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 Antietam Creek non-tidal waters nutrient TMDL.

The proposed approach for achieving the Antietam 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 Antietam 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 Antietam Creek watershed have been met, MDE will revisit the status of nutrient impacts on aquatic life in Antietam 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 Antietam 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 (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 Hill 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 phosphorus 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 regional average 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 Antietam 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).

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 Antietam 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 Antietam 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:

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 Antietam 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.

<u>Approach for Nonpoint Sources, CAFOs, and Stormwater Point Sources</u>

The level of resolution selected for defining a daily maximum load for the Antietam 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, CAFOs, 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 that 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, because they are based on the same underlying hydrology, the distribution of the daily simulated river reach loads represents the 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 Antietam 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 Antietam 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 B-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 1.196 was calculated using the following equation:

$$CV = \frac{\beta}{\alpha} \qquad \text{(Equation C. 1)}$$

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

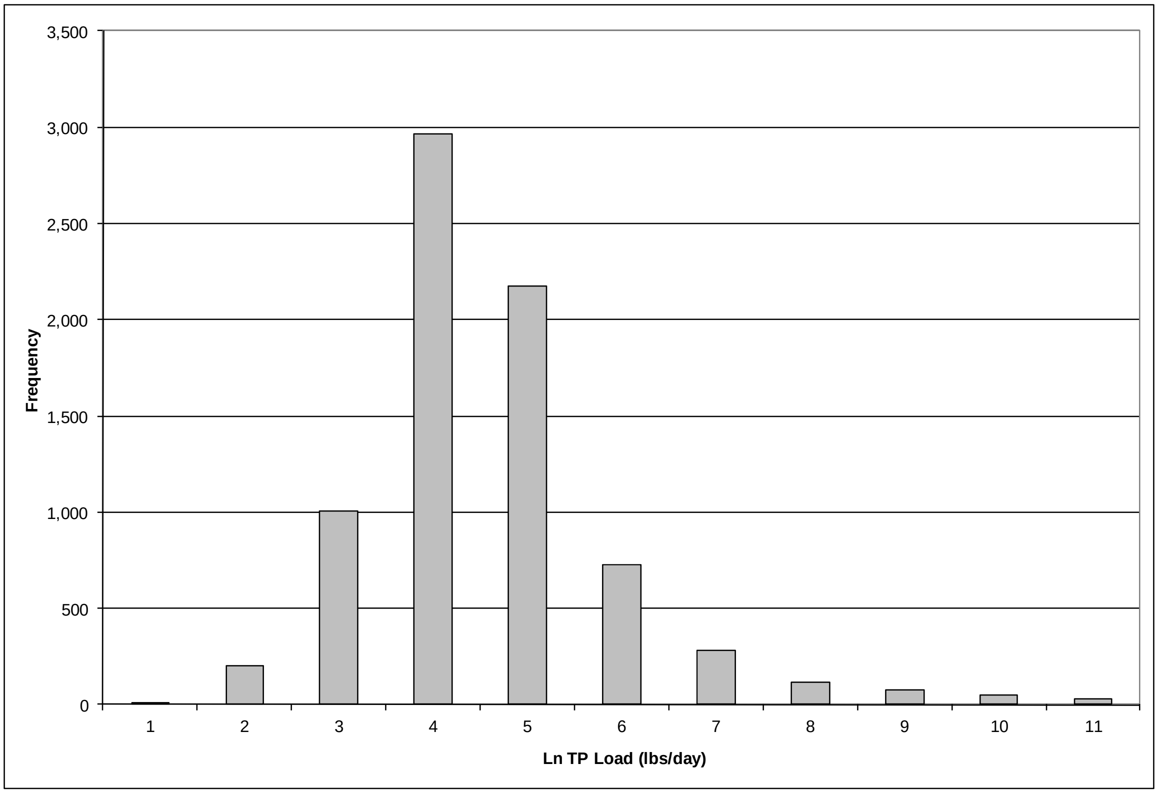

Figure B-1: Histogram of CBP River Segment Daily Phosphorus Simulation Results for the Antietam Creek Watershed

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:

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

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 99^{th} percent probability, CV of 1.224, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 5.861. The average annual Antietam Creek phosphorus TMDL is reported in lbs/year, and the conversion from lbs/year to a maximum daily load in lbs/day is 0.016 (e.g., 5.861/365).

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 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 99^{th} percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Antietam 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 (e.g., 3.11/365).

In the case of Antietam Creek, none of the permitted sources with nitrogen or phosphorus concentration limits have permitted daily maximum concentrations, so the maximum daily load was calculated based on the TSD guidance.

Approach for Upstream Sources

For the purposes of this analysis only one upstream watershed has been identified: the Pennsylvania portion of the Antietam Creek watershed. Pennsylvania maximum daily loads were calculated based on the same approach used for nonpoint sources and NPDES regulated stormwater point sources within the MD 8-digit Antietam Creek watershed.

Margin of Safety

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

Results of Approach

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

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

LA (lbs/day) = Average Annual TMDL LA (lbs/yr) * 0.016

Stormwater WLA (lbs/day) = Average Annual TMDL Stormwater WLA (lbs/yr) * 0.016

- Calculation Approach for Process Water Point Sources

- For permits with a daily maximum limit:

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

- For permits without a daily maximum limit:

Process Water WLA (lbs/day) = Process Water WLA (lbs/yr)* 0.0085

- Calculation Approach for Upstream Sources
  - For Pennsylvania Upstream Sources

LA (lbs/day) = Average Annual TMDL LA (lbs/yr) * 0.016

Table B-1: Summary of Maximum Daily Loads of Total Phosphorus for the Antietam Creek Watershed (lbs/day)

TMDL (lbs/day)	+	**LA** LA_{PA}[1,2]	+	**LA** LA_{AC}	+	**LA** $Septic_{AC}$	+	**WLA** CAFO WLA_{AC}	+	**WLA** NPDES Stormwater WLA_{AC}	+	**WLA** Process Water WLA_{AC}	+	**MOS**
2,747	=	1,269		1,085	+	0	+	1	+	204	+	187	+	Implicit

Upstream Load Allocation[2] (LA_{PA}) — MD 8-digit Antietam Creek Watershed TMDL Contribution (LA_{AC} through Process Water WLA_{AC})

[1] LA_{PA} includes both (1) the PA load entering Maryland through the mainstem, which is receiving an allocation based on current loads, and (2) the load from those sections of PA which require phosphorus reductions because they drain to MD small order streams. See sections 2.4 and 4.5.

[2] Although for the purpose of this analysis the upstream load is referred to as an LA, it could include loads from point and nonpoint sources.