FINAL

Total Maximum Daily Load of Phosphorus in the Lower Monocacy River Watershed, Frederick, Carroll, and Montgomery Counties, Maryland

FINAL

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Submitted to:

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List of Abbreviations

BIBI	Benthic Index of Biotic Integrity
BIP	Buffer Incentive Program
BMP	Best Management Practices
BSID	Biological Stressor Identification
CAFO	Concentrated Animal Feeding Operation
CBLCD	Chesapeake Bay Watershed Land Cover Data
CBP P5.3.2	Chesapeake Bay Program Phase 5.3.2
CCAP	Coastal Change Analysis Program
cfs	Cubic Feet Per Second
CFR	Code of Federal Regulations
Chla	Chlorophyll *a*
COMAR	Code of Maryland Regulations
CNMP	Comprehensive Nutrient Management Plan
CSOs	Combined Sewer Overflows
CV	Coefficient of Variation
CWA	Clean Water Act
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*
EQIP	Environmental Quality Incentives Program
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/d	Pounds Per Day
lbs/yr	Pounds 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
NOI	Notice of Intent
NLCD	Consortium's National Land Cover Data
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
PS	Point Source
PSI	Phosphorus Site Index
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Carlson's Trophic State Index
USGS	United States Geological Survey
WIP	Watershed Implementation Plan
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document, upon approval by the US Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for total phosphorus (TP) in the Lower Monocacy River watershed (basin number 02140302) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02140302). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2011a).

The Maryland Department of the Environment (MDE) has identified the waters of the Lower Monocacy River on the State's 303(d) List as impaired by nutrients (1996) and impacts to biological communities (2002, 2004, 2006) (MDE 2010a). All impairments are listed for non-tidal streams. Because scientific research supports that phosphorus is generally the limiting nutrient in freshwater aquatic systems, the 1996 nutrient listing was refined in the 2008 Integrated Report to identify phosphorus as the specific impairing substance (MDE 2008). Therefore, the listed impairment of phosphorus will henceforth be referred to in this report and the term "nutrients" should be read as interchangeable with "phosphorus" in this case.

The Lower Monocacy River, upstream of US Route 40, and its tributary Israel Creek are designated as Use IV-P waterbodies (*Water Contact Recreation, Protection Of Aquatic Life, Recreational Trout Waters and Public Water Supply*); downstream of US Route 40, the Lower Monocacy River is designated as a Use I-P waterbody (*Water Contact Recreation, Protection of Nontidal Warm Water Aquatic Life, and Public Water Supply*). Additional tributaries of the Lower Monocacy River – Ballenger Creek, Bear Branch, Carroll Creek, Furnace Branch, Little Bennett Creek, and Rocky Fountain Run – are designated as Use III-P waterbodies (*Water Contact Recreation, Protection of Nontidal Cold Water Aquatic Life and Public Water Supply*) (COMAR 2012a,b,c,d). The Lake Linganore watershed is designated as Use IV-P.

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 data solicitation have been considered. A TMDL for fecal coliform to address the 2002 bacteria listing was approved by the EPA in 2009. A TMDL for sediment to address the 1996 sediment listing was also approved by the EPA in 2009. A TMDL of sediments and phosphorus for the Lake Linganore impoundment was approved by the EPA in 2003. The listing for impacts to biological communities will be addressed separately at a future date.

The Lower Monocacy River watershed aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI), indicate that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions (Roth *et al.* 2005). The Biological Stressor Identification (BSID) analysis for the Lower Monocacy River watershed identified both phosphorus and nitrogen as a potential stressors.

Orthophosphate shows a significant association with degraded biological conditions. As much as 14% of the biologically impacted stream miles in the watershed are associated with high orthophosphate. Similarly, according to the BSID analysis, 37% of the biologically impacted stream miles in the Lower Monocacy River watershed are associated with high total nitrogen concentrations, and 36% of impacted stream miles are associated with high dissolved nitrogen concentrations. An analysis of observed TN:TP ratios implies, however, that phosphorus is the limiting nutrient in Lower Monocacy River. 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 Lower Monocacy River, and the reduction of nitrogen loads would not be an effective means of ensuring that the Lower Monocacy River watershed is free from impacts on aquatic life from eutrophication. Therefore, load allocations for the Lower Monocacy River 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 Lower Monocacy River watershed. Currently in Maryland, there are no specific numeric criteria that quantify the impact of nutrients on the aquatic health of non-tidal stream systems; therefore, a reference watershed TMDL approach was used, which resulted in the establishment of a *phosphorus loading threshold*. This threshold is based on a detailed analysis of phosphorus loads from watersheds that are identified as supporting aquatic life (*i.e.*, reference watersheds) based on Maryland's biocriteria (Roth *et al.* 1998, 2000; Stribling *et al.* 1998; MDE 2008). This threshold is then used to determine a watershed specific phosphorus TMDL. The resulting loads are considered the maximum allowable loads the watershed can receive without causing nutrient related impacts to aquatic health.

The computational framework chosen for the Lower Monocacy River 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 critical conditions for stream flow, loading, and water quality parameters (CFR 2011a). The premise of the reference watershed approach is that the reference watersheds are meeting water quality standards even under critical conditions. Therefore, the phosphorus loading rate derived from the reference watersheds 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, thereby addressing annual changes in hydrology and capturing wet, average, and dry years. 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.

EPA's regulations also require TMDLs to be presented as a sum of waste load allocations (WLAs) for permitted point sources in the assessment unit and load allocations (LAs) for nonpoint sources generated within the assessment unit. In addition, TMDLs must account for natural background, tributary and adjacent segment loads. Finally, TMDLs must also include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2011a). Because the phosphorus loading threshold was conservatively based on the median phosphorus loading rates from reference watersheds, Maryland has adopted an implicit MOS for nutrient TMDLs.

The MD 8-digit Lower Monocacy River Total Baseline Phosphorus Load is 996,987 pounds per year (lbs/yr). This baseline load consists of upstream loads generated outside the assessment unit (an Upper Monocacy River Upstream Baseline Load (BL_{UM}) of 716,507 lbs/yr) and loads generated within the assessment unit (a Lower Monocacy River Watershed Baseline Load Contribution of 280,480 lbs/yr). The Lower Monocacy River Watershed Baseline Load Contribution is further subdivided into nonpoint source baseline loads (Nonpoint Source BL_{LM}) and three types of point source baseline loads: regulated concentrated animal feeding operations ($CAFO_{CC}$), National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{LM}), and regulated process water (NPDES Process Water BL_{LM}) (see Table ES-1). Phosphorus loads from septic systems are considered insignificant. Appendix C provides a detailed explanation of the upstream loads.

The MD 8-digit Lower Monocacy River Average Annual TMDL of Phosphorus is 843,903 lbs/yr. The TMDL consists of allocations attributed to loads generated outside the assessment unit referred to as Upstream Load Allocations (an Upper Monocacy River Upstream Load Allocation (LA_{UM}) of 606,530 lbs/yr); and loads generated within the assessment unit: a Lower Monocacy River Watershed TMDL Contribution of 237,373 lbs/yr. The Lower Monocacy River Watershed TMDL Contribution is further subdivided into point and nonpoint source allocations and is comprised of a Load Allocation (LA_{LM}), a CAFO Waste Load Allocation (WLA_{LM}), an NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{LM}), and a Process Water Waste Load Allocation (NPDES Process Water WLA_{LM}) (see Table ES-2).

In addition to the Annual Average 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.

The Lake Linganore average annual phosphorus TMDL of 5,288 lb/yr, which was developed by MDE to be protective of water quality standards within the impoundment and approved by EPA in 2003, still applies as the target phosphorus loading capacity within the pond's drainage area, located in the north-eastern portion of the Lower Monocacy River watershed (MDE 2003). The attainment of water quality standards within the MD 8-digit Lower Monocacy River watershed and Lake Linganore impoundment can only be achieved by meeting the average annual TMDL of phosphorus specified for the MD 8-digit watershed within this report as well as the specific TMDL for the Lake Linganore drainage basin established by MDE in 2003. Furthermore, both the baseline phosphorus loading and TMDL for the impoundment are implicitly included within the Lower Monocacy River nonpoint source baseline loads and TMDL load allocation, respectively, due to the spatial resolution of the CBP P5.3.2 Watershed Model segmentation.

Overall, this TMDL will establish phosphorus loads that will be protective of the Use I-P/III-P/IV-P designations for the Lower Monocacy River watershed, and more specifically, these loads will be at a level the watershed can sustain without causing nutrient related impacts to aquatic health. The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Because the BSID watershed analysis identifies other possible stressors (*i.e.*, conductivity, sediment, in-stream habitat, and riparian habitat) 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 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).

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 Lower Monocacy River 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 Lower Monocacy River phosphorus TMDL shall be the achievement of the nutrient reductions needed within the Lower Monocacy River 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 Lower Monocacy River watershed have been met, MDE will revisit the status of nutrient impacts on aquatic life in Lower Monocacy River, 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 Lower Monocacy River Baseline Phosphorus Loads

Total Baseline Load (lbs/yr)	=	Upstream Baseline Load[1]	+	MD 8-digit Lower Monocacy River Watershed Baseline Load Contribution								
		BL_{UMR}[2]		Nonpoint Source BL_{LMR}	+	Septic BL_{LMR}	+	CAFO BL_{LMR}	+	NPDES Stormwater BL_{LMR}	+	Process Water BL_{LMR}
996,987	=	716,507	+	177,630	+	0	+	170	+	68,956	+	33,724

Notes:[1] Although the upstream values are reported as a single value, they include point and nonpoint sources.

[2] For the Upper Monocacy River watershed point and nonpoint source characterization, please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick and Carroll Counties, Maryland" (MDE 2012c).

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

Table ES-2: Average Annual MD 8-digit Lower Monocacy River TMDL of Phosphorus

TMDL (lbs/yr)	+	LA					+	WLA					+	
		LA_{UMR}[1,2]	+	LA_{LMR}	+	$Septic_{LMR}$		CAFO WLA_{LMR}	+	NPDES Stormwater WLA_{LMR}	+	Process Water WLA_{LMR}		MOS
843,903	=	606,530	+	152,804	+	0	+	170	+	52,926	+	31,473	+	Implicit

Upstream Load Allocation[2] (606,530); MD 8-digit Lower Monocacy River Watershed TMDL Contribution (152,804 through 31,473)

Notes: [1] 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.

[2] For Upper Monocacy River watershed WLA and LA characterization please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick, Carroll, and Montgomery Counties, Maryland" (MDE 2012c).

Table ES-3: MD 8-Digit Lower Monocacy River Baseline Phosphorus Load, TMDL, and Total Reduction Percentage

Baseline Load (lbs/yr)	TMDL (lbs/yr)	Total Reduction (%)
996,987	843,903	15%

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 Lower Monocacy River watershed (basin number 02140302) (2008 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02140302). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the Section 303(d) List, taking into account seasonal variations, critical conditions, and a protective margin of safety (MOS) to account for uncertainty (CFR 2011a). A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

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

The Lower Monocacy River, upstream of US Route 40, and its tributary Israel Creek are designated as Use IV-P waterbodies (*Water Contact Recreation and Protection of Aquatic Life, Recreational Trout Waters and Public Water Supply*); downstream of US Route 40, the Lower Monocacy River is designated as a Use I-P waterbody (*Water Contact Recreation, Protection of Nontidal Warm Water Aquatic Life, and Public Water Supply*). Additional tributaries of the Lower Monocacy River – Ballenger Creek, Bear Branch, Carroll Creek, Furnace Branch, Little Bennett Creek, and Rocky Fountain Run – are designated as Use III-P waterbodies (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life, and Public Water Supply*) (COMAR 2012a,b,c,d). The Lake Linganore watershed is designated as Use IV-P.

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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 data solicitation have been considered. A TMDL for fecal coliform to address the 2002 bacteria listing was approved by the EPA in 2009. A TMDL for sediment to address the 1996 sediment listing was also approved by the EPA in 2009. A TMDL of sediments and phosphorus for the Lake Linganore impoundment was approved by the EPA in 2003. The listing for impacts to biological communities 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 Lower Monocacy River watershed. A Biological Stressor Identification (BSID) analysis of Lower Monocacy River (MDE 2009c) shows phosphorus is associated with biological impairments in the Lower Monocacy River 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 Chesapeake Bay Program's (CBP) Phase 5.3.2 Watershed Model (P5.3.2) is used to determine the nutrient loads in both Lower Monocacy River and the reference watersheds that will be used to set the phosphorus TMDL for Lower Monocacy River.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Monocacy River is a free-flowing stream that originates in Pennsylvania and flows 58 miles within Maryland where it finally empties into the Potomac River. The watershed covers approximately 970 square miles (620,496 acres), with approximately 228 square miles (145,679 acres) located in Pennsylvania and 742 square miles (478,817 acres) in Maryland. The basin can be subdivided into three distinct watersheds: the Upper Monocacy River, Lower Monocacy River, and Double Pipe Creek. The Upper Monocacy River drains into the Lower Monocacy River, which flows southward through Frederick and eventually empties into the Middle Potomac River near the town of Dickerson, MD. Double Pipe Creek drains into the Upper Monocacy River.

Upper Monocacy River and Double Pipe Creek are distinct Maryland 8-digit watersheds, and phosphorus TMDLs are in preparation for the Upper Monocacy River and Double Pipe Creek. The phosphorus TMDL for the Upper Monocacy River, which includes the TMDL for Double Pipe Creek, is included as an upstream load in the Lower Monocacy River TMDL. The hydrological relationship between the three Maryland 8-digit watersheds (MD 8-digit) within the Monocacy system and the subsequent effect on phosphorus loads are further explained in Appendix C. Several major tributaries contribute to the Lower Monocacy River, including Bennett Creek, Bush Creek, Israel Creek, Linganore Creek, Ballenger Creek, and Carroll Creek.

The Lower Monocacy River watershed is situated primarily in Frederick County but includes small portions of Carroll and Montgomery Counties as well (see Figure 1). The watershed covers approximately 3,142 square miles (194,790 acres) and is characterized by a moderately steep to flat terrain. There is a significant amount of agriculture within the watershed, which consists mostly of row crops, but also includes dairy production. The watershed contains numerous urban centers including Frederick, the largest city in the watershed, Woodsboro, New Market, and parts of Walkersville and Mount Airy. The total population within the watershed is estimated to be approximately 96,000 (MDE 2007).

Geography/Soils

The Lower Monocacy River watershed lies within the Western Division of the Piedmont geologic province of Central Maryland. The Piedmont Plateau province is characterized by gentle to steep rolling topography, low hills, and ridges (MGS 2009). The outstanding features of the Piedmont's Western Division are the Frederick Valley and the Triassic Upland. The broad, flat Frederick Valley is underlain by limestone as well as dolomite, and has an average elevation of 300 feet. The Triassic Upland borders much of the Frederick Valley. The low to moderate relief of the Triassic Upland is underlain by layered sandstone, siltstone, and red shale. The average elevation of the Upland is approximately 500 feet. A prominent topographic feature of the Piedmont is an erosion resistant monadnock, known as Sugarloaf Mountain, which is composed of highly weather resistant quartz (DNR 2007a; MGS 2009; MDE 2000).

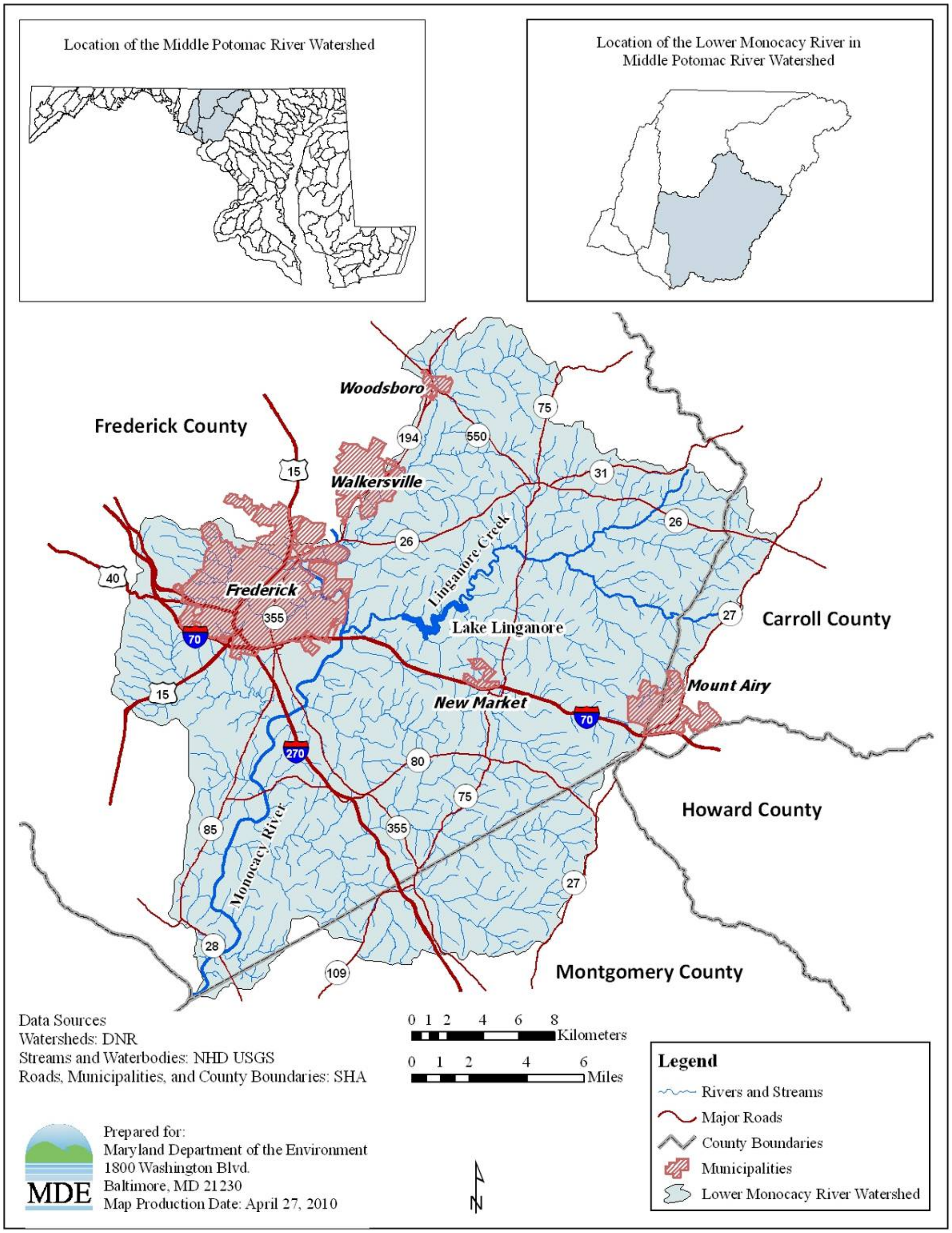

Figure 1: Location Map of the Lower Monocacy River Basin

2.1.1 Land-Use

Landuse Methodology

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

The first stage consists of the development of the Chesapeake Bay Watershed Land Cover Data (CBLCD) series of Geographic Information System (GIS) datasets. These datasets provide a 30-meter resolution raster representation of land cover in the Chesapeake Bay watershed, based on sixteen Anderson Level 2 land cover classes. The CBLCD basemap, representing 2001 conditions, was primarily derived from the Multi-Resolution Land Characteristics (MRLC) Consortium's National Land Cover Data (NLCD) and the National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program's (CCAP) Land Cover Data. By applying Cross Correlation Analysis to Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper satellite imagery, USGS's contractor, MDA Federal, generated CBLCD datasets for 1984, 1992, and 2006 from the 2001 baseline dataset. The "*Chesapeake Bay Phase 5.3 Community Watershed Model" (US EPA 2010b*) describes the development of the CBLCD series in more detail. USGS and NOAA also developed an impervious cover dataset from Landsat satellite imagery for the CBLCD basemap, which was used to estimate the percent impervious cover associated with CBLCD developed landuse classes.

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

[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, nutrient, 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 modifications is that CBP P5.3.2 landuse does not exist in a single GIS coverage; instead it is only available in a tabular format. The CBP P5.3.2 watershed model is comprised of 30 land uses. Within each general landuse type most of the subcategories of land uses are differentiated only by their nitrogen and phosphorus loading rates. Table 1 lists the CBP P5.3.2 generalized land uses, detailed land uses, and the acres of each landuse in the Lower Monocacy River watershed. The landuse acreage is based on the CBP P5.3.2 2009 Progress Scenario, which for the CBP P5.3.2 model, represents current conditions.

Lower Monocacy River Watershed Landuse Distribution

A summary of the watershed landuse area is presented in Table 1 and a landuse map is provided in Figure 2. Table 1 summarizes the landuse for the Lower Monocacy River watershed. The major land uses in the Lower Monocacy River watershed, excluding the Lake Linganore watershed, consist of forest (32.7%), crop (31.6%), developed land (28.0%), and pasture (6.9%).

Table 1: Landuse Percentage Distribution for the Lower Monocacy River Watershed

General Land-Use	Detailed Land-Use	Area (Acres)	Percent (%)	Grouped Percent of Total
Forest	Forest	63,153	32.4%	32.7%
	Harvested Forest	630	0.3%	
AFOs	Animal Feeding Operations	127	0.1%	0.1%
CAFOs	Concentrated Animal Feeding Operations	18	<0.1%	<0.1%
Pasture	Pasture	13,477	6.9%	6.9%
Crop	Crop	61,508	31.6%	31.6%
Nursery	Nursery	204	0.1%	0.1%
Regulated Urban	Regulated Construction	1,544	0.8%	28.0%
	Regulated Developed	52,438	26.9%	
	Regulated Extractive	530	0.3%	
Water	Water	1,160	0.6%	0.6%
Total		**194,790**	**100.0%**	**100.0%**

Note: Individual Land Uses may not add to totals and percentages may not add to 100%; in both cases due to rounding.

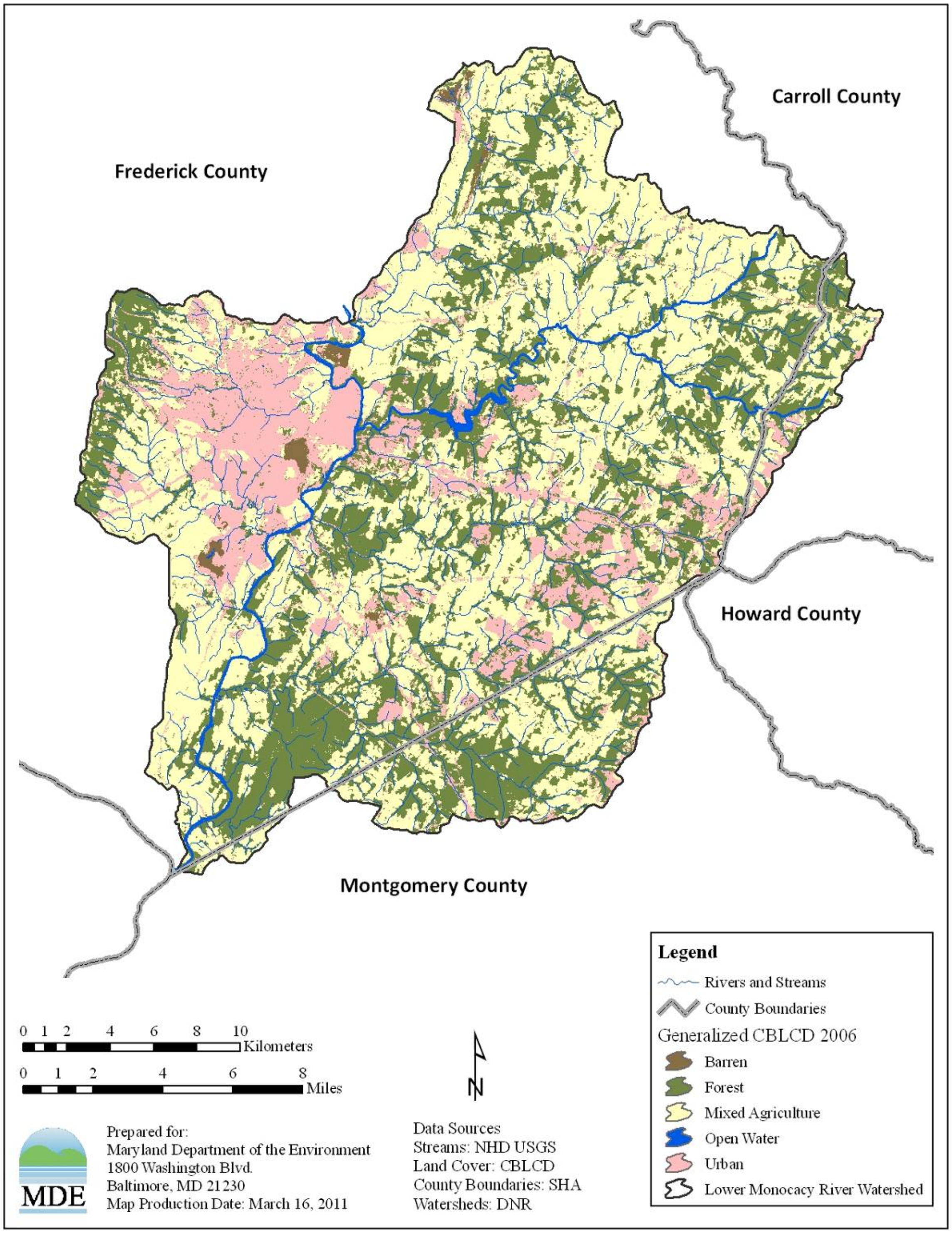

Figure 2: Landuse of the Lower Monocacy River Watershed

2.2 Source Assessment

2.2.1 Nonpoint Sources (NPS) Assessment

Nonpoint source nutrient loads in the Lower Monocacy River 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 river, using as inputs current land use, BMP implementation and estimated loading rates, precipitation and other meteorological data from the period 1991 – 2000. The period 1991-2000 is the baseline hydrological period for the Chesapeake Bay TMDL.

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

<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 urban land uses are based on the median phosphorus concentration in urban stormwater determined by Pitt *et al.* (2005) in their study of monitoring data collected by jurisdictions for their Municipal Separate Storm Sewer System (MS4) permits. See "*Chesapeake Bay Phase 5.3 Community Watershed Model"* US EPA (2010b) for further discussion of loading rates found in the scientific literature.

<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 urban 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 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	Carroll Co. A24013	Frederick Co. A24021	Frederick Co. B24021	Montgomery Co. A24031
Forest	0.11	0.10	0.10	0.11
Harvested Forest	0.80	0.80	0.80	0.80
Degraded Riparian Pasture	13.35	14.77	14.74	12.39
Pasture	1.11	1.23	1.23	1.03
Alfalfa	0.70	0.70	0.70	0.70
Hay Without Nutrients	0.40	0.40	0.40	0.40
Hay With Nutrients	0.72	0.64	0.63	0.71
High Till Without Manure	2.70	2.69	2.68	2.77
High Till With Manure	2.02	2.00	1.99	1.94
Low Till With Manure	2.01	1.99	1.98	1.93
Nursery	85.00	85.00	85.00	85.00
Regulated Extractive	3.50	3.50	3.50	3.50
Regulated Construction	7.00	7.00	7.00	7.00
Regulated Impervious Developed	2.14	2.04	2.15	2.05
Regulated Pervious Developed	0.51	0.48	0.53	0.36

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

Regional Factors

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

Regional factors are calculated on a river segment basis. For all river segments in Lower Monocacy River, the regional factor for phosphorus is 1.463.

2.2.2 Point Source (PS) Assessment

A list of active NPDES permitted point sources that contribute to the phosphorus load in the Lower Monocacy River 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 to or larger than 0.5 MGD are considered major) and major industrial facilities contain flow and TP limits; their current nutrient loads are calculated from discharge monitoring reports (DMR) data. There are seventeen municipal WWTPs permitted to discharge phosphorus in the watershed and three 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 nineteen 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 on monitoring required by their permits or professional judgment.

Table 3 lists the process-water facilities with active permits within the Lower Monocacy River 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 one aggregate load. All these facilities with their estimated loads are represented in the Phase 5.3.2 Watershed Model 2009 Progress Scenario. The total process-water TP load is 33,724 lbs/yr.

In Maryland's jurisdictions with Phase I and/or Phase II MS4 permits, all urban stormwater from developed land in Maryland is regulated under the NPDES MS4 program. These urban stormwater loads are calculated using urban landuse in the watershed. The stormwater permits do not include phosphorus limits, but are regulated instead based on programmatic approaches. The current estimated stormwater TP load is 68,956 lbs/yr.

Table 3: Average Annual Baseline Phosphorus Loads for MD Facilities in Lower Monocacy River Watershed Represented in Phase 5.3.2 Watershed Model

NPDES Permit Number	Facility Name	WLA Type		TP Load (lbs/yr)
MD0020877	FORT DETRICK WWTP	Municipal	Individual	2,085
MD0021610	FREDERICK CITY WWTP	Municipal	Individual	20,225
MD0021822	BALLENGER-MCKINNEY	Municipal	Individual	5,196
MD0020729	NEW MARKET WWTP	Municipal	Aggregate	6,218
MD0022870	SPRINGVIEW MOBILE HOME PARK	Municipal		
MD0023060	CONCORD TRAILER PARK	Municipal		
MD0023710	DAN-DEE MOTEL & COUNTRY INN	Municipal		
MD0056481	KEMPTOWN SCHOOL WWTP	Municipal		
MD0057100	NEW LIFE FOURSQUARE CHURCH AND	Municipal		
MD0058661	WOODSBORO WWTP	Municipal		
MD0059609	MONROVIA WWTP	Municipal		
MD0065269	PLEASANT BRANCH WWTP	Municipal		
MD0065439	MILL BOTTOM WWTP	Municipal		
MD0067237	LEWISTOWN MILLS TREATMENT PLANT	Municipal		
MD0067768	HYATTSTOWN WWTP	Municipal		
MD0067989	LEWISTOWN MILLS WWTP NO.2	Municipal		
MD0060577	LIBERTYTOWN WWTP	Municipal		
MDG499704	ELLIE MAY LLC BUCKEYSTOWN MINE	Industrial		
MD0002038	ESSROC CEMENT CORPORATION	Industrial		
MD0061093	OLD REICHS FORD MUNICIPAL LAND	Industrial		
MD0068853	STUP'S GARAGE / USED CARS, Inc.	Industrial		
MD0070319	JOHN C. GRIMBERG COMPANY, INC.	Industrial		
MD0070700	HORSESHOE POINT LLC	Industrial		
MDG344184	GRIFFITH ENERGY SERVICES, Inc.	Industrial		
MDG490621	LAFARGE - FREDERICK CONCRETE PLANT	Industrial		
MDG490674	FREDERICK ASPHALT CO., L.C. AT ESSROC	Industrial		
MDG490994	LEGORE QUARRY	Industrial		
MDG491429	S.W. BARRICK & SONS, INC. - BARRICK	Industrial		
MDG492695	SUPERIOR PLUS, LLC	Industrial		
MDG498001	AGGREGATE INDUSTRIES - WOODSBORO	Industrial		
MDG498017	CJ MILLER, LLC	Industrial		
MDG499732	JOHN EYLER PIT #2	Industrial		
MDG499818	THOMAS, BENNETT & HUNTER, INC. -	Industrial		
MDG499893	SOUTH STREET PLANT	Industrial		
MDG499899	TAMKO BUILDING PRODUCTS, INC -	Industrial		
MDG766968	VFW COUNTRY CLUB, INC.	Industrial		
Total				**33,724**

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

Starting in 2009, Maryland began the process of permitting Concentrated Animal Feeding Operations (CAFOs). CAFOs are medium to large animal feeding operations that have some artificial conveyance like a swale or ditch to discharge runoff from feedlots to surface water. Recent EPA regulations require CAFOs to have a NPDES permit.

Maryland also designates large animal feeding operations which do not discharge or propose to discharge as, "Maryland Animal Feeding Operations" (MAFOs). It is anticipated that on review many MAFOs will require CAFO permits.

Several operators in the Lower Monocacy River 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 Lower Monocacy River watershed is 170 lbs/yr.

2.2.3 Overall Phosphorus Budget

Table 4 lists the current overall phosphorus budget for the Lower Monocacy River watershed. The largest source of phosphorus in the Lower Monocacy River watershed is crops (38.1%) followed by regulated urban land (24.6%) and process wastewater (12.0%). The next largest phosphorus sources are nurseries (9.5%), pasture (8.7%), forest (3.6%), and AFOs (3.3%).

Table 5 summarizes the MD 8-digit Lower Monocacy Baseline Phosphorus Load, reported in pounds per year (lbs/yr) and presented in terms of Upstream Baseline Loads and MD 8-digit Lower Monocacy River Watershed Baseline Load Contribution nonpoint and point source loadings.

Table 4: Lower Monocacy River Watershed Detailed Baseline Total Phosphorus Loads

General Land-Use	Detailed Land-Use	Load (lbs/yr)	Percent (%)	Grouped Percent of Total
Forest	Forest	9,572	3.4%	3.6%
	Harvested Forest	398	0.1%	
AFOs	Animal Feeding Operations	9,302	3.3%	3.3%
CAFOs	Concentrated Animal Feeding Operations	170	0.1%	0.1%
Pasture	Pasture	24,340	8.7%	8.7%
Crop	Crop	106,779	38.1%	38.1%
Nursery	Nursery	26,535	9.5%	9.5%
Regulated Urban	Regulated Construction	10,093	3.6%	24.6%
	Regulated Developed	55,885	19.9%	
	Regulated Extractive	2,978	1.1%	
Septic	Septic	0	0	0.0%
CSO	CSO	0	0	0.0%
Point Sources	Industrial Point Sources	1,643	0.6%	12.0%
	Municipal Point Sources	32,081	11.4%	
Atmospheric Deposition	Non-tidal Atmospheric Deposition	703	0.3%	0.3%
Total		**280,480**	**100.0%**	**100.0%**

Note: Individual loads may not add to totals and percentages may not add to 100%; in both cases due to rounding.

Table 5: MD 8-digit Lower Monocacy River Baseline Phosphorus Loads

Total Baseline Load (lbs/yr)	=	Upstream Baseline Load[1]	+	MD 8-digit Lower Monocacy River Watershed Baseline Load Contribution								
		BL_{UMR}[2]		Nonpoint Source BL_{LMR}	+	Septic BL_{LMR}	+	CAFO BL_{LMR}	+	NPDES Stormwater BL_{LMR}	+	Process Water BL_{LMR}
996,987	=	716,507	+	177,630	+	0	+	170	+	68,956	+	33,724

Notes:[1] Although the upstream values are reported as a single value, they include point and nonpoint sources.

[2] For the Upper Monocacy River watershed point and nonpoint source characterization, please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick and Carroll Counties, Maryland" (MDE 2012c).

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

2.3 Water Quality Characterization

The Lower Monocacy River watershed was originally listed on Maryland's 1996 303(d) List as impaired by nutrients. The listing implies that the nutrient impairment was based on the watershed's contribution to the impairment of 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 water quality standards surface water use designation for the Lower Monocacy River, upstream of US Route 40, and its tributary Israel Creek is Use IV-P (*Water Contact Recreation and Protection of Aquatic Life, Recreational Trout Waters and Public Water Supply*), while downstream of US Route 40, the Lower Monocacy River is designated as a Use I-P waterbody (*Water Contact Recreation, Protection of Nontidal Warm Water Aquatic Life, and Public Water Supply*). The other tributaries– Ballenger Creek, Bear Branch, Carroll Creek, Furnace Branch, Little Bennett Creek, and Rocky Fountain Run – are designated as Use III-P waterbodies (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life, and Public Water Supply*) (COMAR 2012a,b,c,d).

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 1^{st} through 4^{th} 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 and IV-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 was conducted in November 2009 and all readily available water quality data from 1998 up to the time of the TMDL development were considered. Water quality data from MDE surveys conducted in the Lower Monocacy River watershed from October 2000 through December 2005 were used. DNR data used in the analysis were from January 1998 through June 2007. Data from Maryland Biological Stream Survey (MBSS) sampling conducted in the spring and summer of 2000, 2003, and 2004 were also used. Figures 4 through 6 provide graphical representation of the collected data for the parameters discussed below.

Lower Monocacy River Watershed Monitoring Stations

A total of 71 water quality monitoring stations were used to characterize the Lower Monocacy River watershed. There were 50 biological/physical habitat monitoring stations from the MBSS program and two biological monitoring stations from the

Maryland CORE/TREND monitoring network. MDE sampled at 19 additional locations. The stations are listed in Table 6 and presented in Figure 3.

Table 6: Monitoring Stations in the Lower Monocacy River Watershed

Site Number	Sponsor	Site Type	Stream Name	Latitude (dec degree)	Longitude (dec degree)
BEN0022	MDE	Water Quality	Bennett Creek	39.293930	-77.406950
BNG0005	MDE	Water Quality	Ballenger Creek	39.364783	-77.416483
BSC0013	MDE	Water Quality	Bush Creek	39.360000	-77.368670
BSC0041	MDE	Water Quality	Bush Creek	39.358900	-77.323870
BSC0084	MDE	Water Quality	Bush Creek	39.370450	-77.271717
BSC0105	MDE	Water Quality	Bush Creek	39.375670	-77.231600
BSC0117	MDE	Water Quality	Bush Creek	39.367780	-77.196100
CAR0001	MDE	Water Quality	Carroll Creek	39.427580	-77.382000
ISR0022	MDE	Water Quality	Israel Creek	39.467020	-77.345900
LIN0005	MDE	Water Quality	Linganore Creek	39.409650	-77.360230
LIN0023	MDE	Water Quality	Linganore Creek	39.415470	-77.334470
LIN0072	MDE	Water Quality	Linganore Creek	39.427183	-77.281700
MON0004	MDE	Water Quality	Monocacy River	39.224533	-77.449833
MON0041	MDE	Water Quality	Monocacy River	39.263380	-77.435820
MON0096	MDE	Water Quality	Monocacy River	39.326180	-77.413520
MON0138	MDE	Water Quality	Monocacy River	39.368850	-77.389970
MON0155	MDE	Water Quality	Monocacy River	39.386470	-77.380850
MON0167	MDE	Water Quality	Monocacy River	39.398650	-77.366650
MON0204	MDE	Water Quality	Monocacy River	39.433530	-77.379430
MON0020	DNR/Core	Core/Trend	Monocacy River	39.271710	-77.441574
MON0155	DNR/Core	Core/Trend	Monocacy River	39.386470	-77.380850
LMON-101-T-2000	DNR/MBSS	MBSS	Laurel Branch	39.498476	-77.308539
LMON-104-T-2000	DNR/MBSS	MBSS	Woodville Branch	39.387390	-77.165741
LMON-106-T-2000	DNR/MBSS	MBSS	Laurel Branch	39.503243	-77.306006
LMON-107-R-2003	DNR/MBSS	MBSS	Bens Branch UT1	39.418977	-77.253369
LMON-108-R-2003	DNR/MBSS	MBSS	Weldon Creek	39.474188	-77.114729
LMON-109-R-2003	DNR/MBSS	MBSS	Talbot Branch UT2	39.449031	-77.151776
LMON-112-R-2003	DNR/MBSS	MBSS	Cabbage Run UT1	39.507480	-77.262879
LMON-113-R-2003	DNR/MBSS	MBSS	South Fork Linganore Creek UT1	39.433820	-77.116926
LMON-114-R-2003	DNR/MBSS	MBSS	Bush Creek UT1	39.386085	-77.293059
LMON-118-R-2003	DNR/MBSS	MBSS	Lake Linganore UT1	39.394159	-77.302033
LMON-119-R-2003	DNR/MBSS	MBSS	Little Bennett Creek UT1	39.252063	-77.281193
LMON-119-T-2000	DNR/MBSS	MBSS	Talbot Branch UT1	39.460824	-77.149513
LMON-121-R-2003	DNR/MBSS	MBSS	Monocacy River UT4	39.357500	-77.403097
LMON-122-T-2000	DNR/MBSS	MBSS	Dorcus Branch	39.526314	-77.300166
LMON-123-R-2003	DNR/MBSS	MBSS	Town Branch UT1	39.481724	-77.262001

Site Number	Sponsor	Site Type	Stream Name	Latitude (dec degree)	Longitude (dec degree)
LMON-125-R-2003	DNR/MBSS	MBSS	Church Branch UT1	39.346948	-77.228683
LMON-127-R-2003	DNR/MBSS	MBSS	Long Branch UT1	39.393987	-77.322378
LMON-130-T-2000	DNR/MBSS	MBSS	Bear Branch	39.268834	-77.395654
LMON-131-R-2003	DNR/MBSS	MBSS	Bennett Creek	39.301061	-77.216676
LMON-136-R-2003	DNR/MBSS	MBSS	Rock Creek	39.426804	-77.486130
LMON-136-T-2000	DNR/MBSS	MBSS	Laurel Branch UT1	39.509583	-77.295384
LMON-142-R-2003	DNR/MBSS	MBSS	Linganore Creek UT1	39.421155	-77.335573
LMON-147-T-2000	DNR/MBSS	MBSS	Dollyhyde Creek UT1	39.503881	-77.217865
LMON-202-T-2000	DNR/MBSS	MBSS	Hatchery Run	39.272205	-77.446961
LMON-203-T-2000	DNR/MBSS	MBSS	Israel Creek	39.540669	-77.281557
LMON-209-T-2000	DNR/MBSS	MBSS	Weldon Creek	39.474891	-77.160148
LMON-210-R-2003	DNR/MBSS	MBSS	Furnace Branch	39.241528	-77.435877
LMON-210-T-2000	DNR/MBSS	MBSS	Cabbage Run	39.498643	-77.293160
LMON-215-R-2003	DNR/MBSS	MBSS	Little Bennett Creek	39.262017	-77.266808
LMON-220-R-2003	DNR/MBSS	MBSS	Israel Creek UT1	39.478091	-77.322234
LMON-220-T-2000	DNR/MBSS	MBSS	Rock Creek	39.422225	-77.446884
LMON-227-T-2000	DNR/MBSS	MBSS	Bush Creek	39.376530	-77.233733
LMON-231-T-2000	DNR/MBSS	MBSS	Pike Branch	39.395111	-77.449378
LMON-237-T-2000	DNR/MBSS	MBSS	Carroll Creek	39.430225	-77.439875
LMON-239-T-2000	DNR/MBSS	MBSS	Horsehead Run	39.331455	-77.440958
LMON-240-T-2000	DNR/MBSS	MBSS	Little Bennett Creek	39.269215	-77.259272
LMON-252-T-2000	DNR/MBSS	MBSS	Church Branch	39.357108	-77.263513
LMON-316-T-2000	DNR/MBSS	MBSS	Bush Creek	39.366636	-77.376402
LMON-322-R-2003	DNR/MBSS	MBSS	Little Bennett Creek	39.275915	-77.298987
LMON-328-R-2003	DNR/MBSS	MBSS	North Fork Linganore Creek	39.462742	-77.196041
LMON-337-R-2003	DNR/MBSS	MBSS	Bens Branch	39.416327	-77.286300
LMON-421-T-2000	DNR/MBSS	MBSS	Bennett Creek	39.298182	-77.433930
MONY-101-N-2004	DNR/MBSS	MBSS	Monocacy River UT5	39.366669	-77.387776
MONY-102-N-2004	DNR/MBSS	MBSS	Monocacy River UT4	39.357775	-77.396940
MONY-103-N-2004	DNR/MBSS	MBSS	Monocacy River UT5 UT1	39.363338	-77.389997
MONY-201-N-2004	DNR/MBSS	MBSS	Monocacy River UT5	39.368613	-77.388332
MONY-301-N-2004	DNR/MBSS	MBSS	Bush Creek	39.370003	-77.387225
NCRW-115-N-2004	DNR/MBSS	MBSS	Monocacy River UT4	39.357782	-77.402776
NCRW-217-N-2004	DNR/MBSS	MBSS	Monocacy River UT5	39.367776	-77.388060
NCRW-316-N-2004	DNR/MBSS	MBSS	Bush Creek	39.368889	-77.383610

Note: UT = Unnamed Tributary

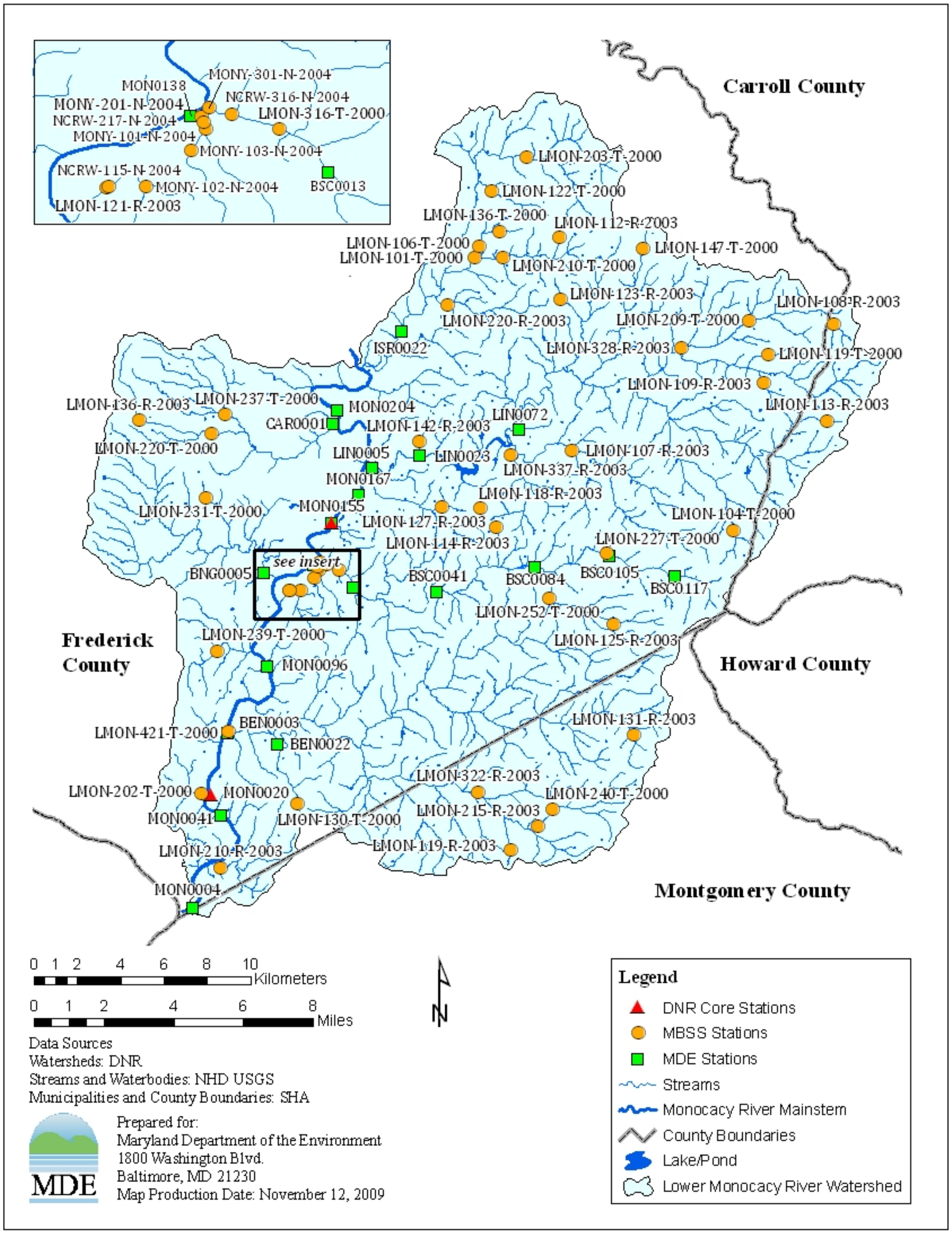

Figure 3: Monitoring Stations in the Lower Monocacy River Watershed

2.3.1 Biological Stressor Identification (BSID) Analysis

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

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

The BSID analysis for the Lower Monocacy River watershed identified high total nitrogen, high total dissolved nitrogen, and high orthophosphate as potential stressors. These water quality constituents show a significant association with degraded biological conditions; as much as 14% of the biologically impacted stream miles in the watershed are associated with high orthophosphate, 37% with high total nitrogen, and 36% with high total dissolved nitrogen concentrations. Based on the results of the analysis, the BSID report concludes that phosphorus and total nitrogen are associated with impairments to aquatic life or biological communities in the Lower Monocacy River watershed.

The BSID analysis also examined whether low dissolved oxygen (DO) concentrations are associated with degraded biological conditions. The BSID analysis for the Lower Monocacy River watershed concludes that the biologically impacted stream miles in the watershed are not associated with low DO concentrations. The indirect impact of nutrients on nontidal aquatic systems is complex and the science continues to evolve. While DO was not found to be associated with poor biological conditions, there could be confounding effects such as increased primary production resulting in periphyton growth and also diurnal fluctuations. At this time, both the original 1998 listing and the initial BSID analysis point to nutrients in general and phosphorus in particular, as a biological stressor in the Lower Monocacy River.

For details on the BSID analysis, please refer to the documents, *"Watershed Report for Biological Impairment of the Lower Monocacy River Watershed, Frederick, Carroll, and Montgomery Counties, Maryland - Biological Stressor Identification Analysis Results and Interpretation"* (MDE 2009c) and *"Maryland Biological Stressor Identification Process"* (MDE 2009a).

2.3.2 Dissolved Oxygen

DNR CORE/TREND samples were taken in the Lower Monocacy River watershed from January 1998 through June 2007. MDE samples were taken from October 2000 through December 2005, and DNR MBSS samples were taken in June through October 2000, June through August 2003, and June and August 2004. Samples taken during the growing season (May 1 through October 31) show DO concentrations ranging from 3.1 to 12.0 mg/l, with only 6 out of 426 (*i.e.*, 1.4 percent) samples below the DO criterion of 5 mg/l. Where Use III-P DO criteria apply, only 2 out of 35 samples (*i.e.*, 5.7 percent) had

DO concentrations of less than 6 mg/l during the growing season. These data are presented graphically in Figure 4.

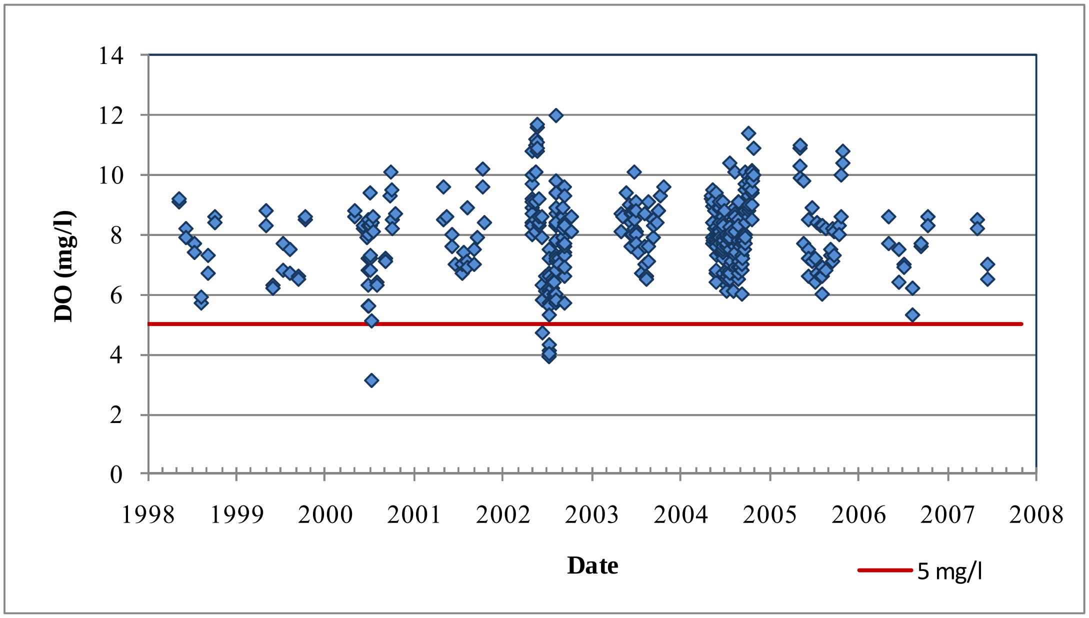

Figure 4: Lower Monocacy Dissolved Oxygen Data from 1998 through 2007

2.3.3 Nutrients

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

Total nitrogen (TN) and total phosphorus (TP) data for the Lower Monocacy River 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 0.72 to 16.74 mg/l and total phosphorus (TP) concentrations ranging from 0.01 to 2.10 mg/l. These data are presented graphically in Figures 5 and 6.

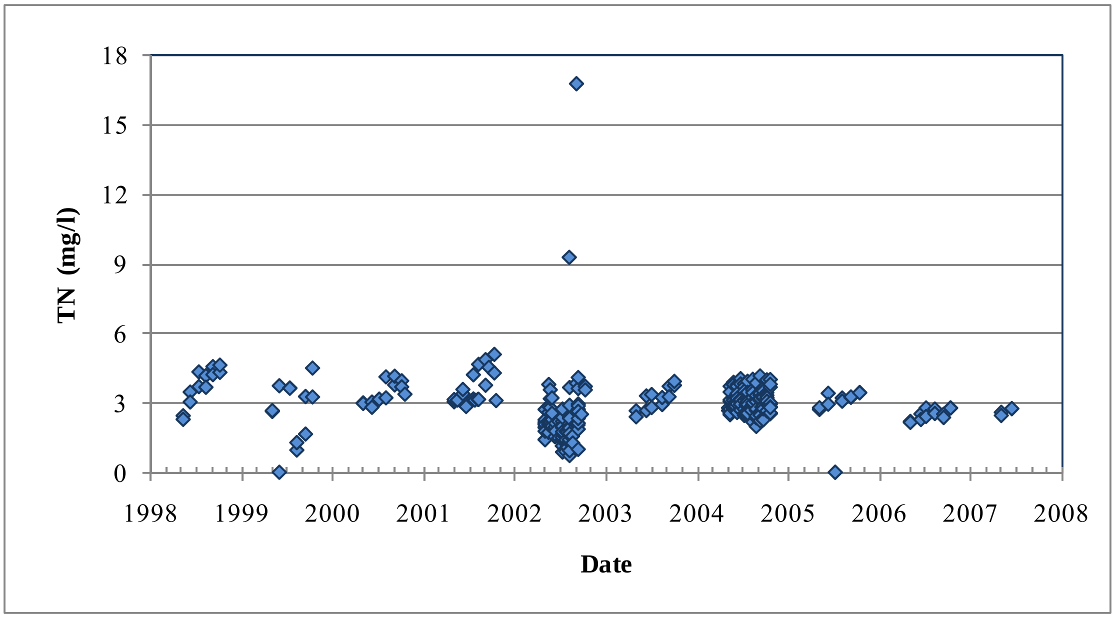

Figure 5: Lower Monocacy Total Nitrogen Data from 1998 through 2007

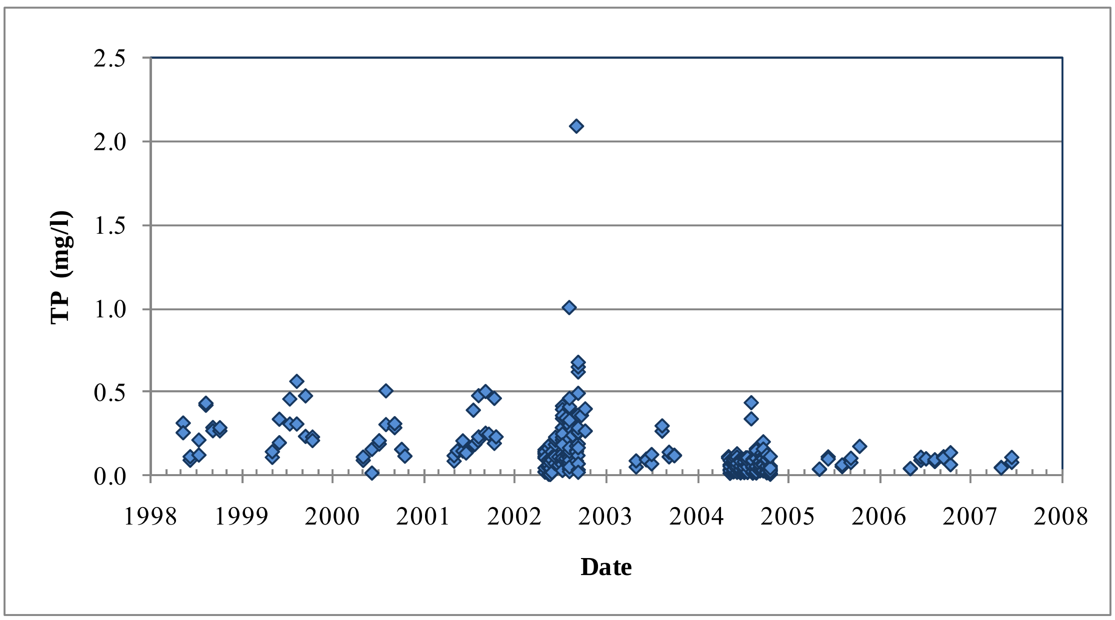

Figure 6: Lower Monocacy Total Phosphorus Data from 1998 through 2007

2.3.4 Nutrient Limitation

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

Out of 629 samples collected between 1998 and 2007, 7.9% had TN:TP ratios less than 10 and 1.4% had TN:TP ratios less than 5. The median TN:TP ratio for the samples was 38 and the average ratio was 69.2. Only one of the 50 samples collected by MBSS had a TN:TP less than 10 and none had a ratio less than 5. The median TN:TP ratio for MBSS samples was 53 and the average ratio was 179. Low TN:TP samples are more prevalent in the growing season: about 15% of the samples collected during the growing season over that time period were less than 10, although most of those samples were collected from the mainstem Monocacy River. Only about 2% of the 141 samples collected during the growing season in the smaller order streams had TN:TP ratios below 10.

The observed data imply that the Lower Monocacy River watershed is phosphorus limited, particularly in smaller order streams and tributaries to the mainstem river.

2.3.5 Lower Monocacy River Benthic Macroinvertebrate Monitoring Stations

Additional data for the Lower Monocacy River watershed was obtained from the Maryland Department of Natural Resources (DNR) CORE/TREND Program. The program collected benthic macroinvertebrate data between 1977 and 2006. DNR has extensive monitoring information for two stations in the mainstem of Lower Monocacy River through the CORE/TREND Program. The stations are located near Route 28 (MONO002) and Reichs Ford Road (MONO0155) (see Table 7 and Figure 3). MONO002 has 29 years of data between 1976 and 2006, and MONO0155 has 27 years of data between 1978 and 2006. These data were used to calculate four benthic community measures: total number of taxa, the Shannon-Wiener diversity index, the modified Hilsenhoff biotic index, and percent *Ephemeroptera*, *Plecoptera*, and *Trichoptera* (EPT). A summary of the results for each of the stations is presented in Table 7.

Table 7: Lower Monocacy River DNR Core Data

Site Number	Current Water Quality Status	Trend Since 1970's
MONO0020	Good	Moderate improvement
MONO0155	Good	Strong improvement

2.4 Water Quality Impairment

The Maryland water quality standards surface water use designation for the Lower Monocacy River, upstream of US Route 40, and its tributary Israel Creek is Use IV-P (*Water Contact Recreation and Protection of Aquatic Life, Recreational Trout Waters and Public Water Supply*), while downstream of US Route 40, the Lower Monocacy

River is designated as a Use I-P waterbody (*Water Contact Recreation, Protection of Nontidal Warm Water Aquatic Life, and Public Water Supply*). The other tributaries–Ballenger Creek, Bear Branch, Carroll Creek, Furnace Branch, Little Bennett Creek, and Rocky Fountain Run –are designated as Use III-P waterbodies (*Water Contact Recreation and Protection of Nontidal Cold Water Aquatic Life, and Public Water Supply*) (COMAR 2012a,b,c,d). The nutrient water quality impairment of the Lower Monocacy River 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 ≥ 3). The BSID has identified orthophosphate as associated with 14% of the biologically impaired stream miles in the Lower Monocacy River watershed, total nitrogen as associated with 37% of the impaired stream miles, and dissolved nitrogen as associated with 36% of the impaired stream miles.

The BSID analysis indicates that none of the biologically impacted stream miles are associated with low DO concentrations. The analysis of DO monitoring data in section 2.3.1 confirms that DO criteria are currently met in the watershed.

Biological results from the two long-term DNR CORE/TREND stations along the mainstem of Lower Monocacy River indicate that mainstem water quality can be classified as good. Statistical analysis of data indicates that since 1977, the stations have shown improvement and are ranked as having good water quality based on percent EPT, taxa number, biotic index, and diversity index (DNR 2007b, 2009).

Because the biological monitoring results for the Lower Monocacy River mainstem indicate that it is supporting its aquatic life use, MDE concludes the nutrient impairment is located within the lower order (smaller) streams. Permitted facilities that discharge directly to the Lower Monocacy mainstem will be given an informational TMDL based on planned upgrades to these facilities.

The BSID has also indicated that high concentrations of total nitrogen and dissolved nitrogen are associated with biological impairment in the Lower Monocacy River watershed. The 1996 nutrients listing was refined in Maryland's 2008 Integrated Report to a listing for phosphorus as the specific impairing nutrient substance. The revised listing was based on the generally accepted view within the scientific community that in fresh water phosphorus is usually the limiting nutrient for algal growth (Allan 1995; Correll 1998). The analysis of observed TN:TP ratios in Section 2.3.6 confirms the assumption that phosphorus is the limiting nutrient in the Lower Monocacy River watershed, particularly in smaller-order streams. 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 the Lower Monocacy River, and the reduction of nitrogen loads would not be an effective means of ensuring that the Lower Monocacy River watershed is free from impacts on aquatic life from eutrophication. Therefore, load allocations for the Lower Monocacy River Nutrient TMDL will apply only to total phosphorus. Reductions in nitrogen loads will be required in the Lower Monocacy River 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 Lower Monocacy River watershed to levels that support the Use I-P (*Water Contact Recreation, Protection of Nontidal Warm Water Aquatic Life, and Public Water Supply*), III-P (*Water Contact Recreation, Protection of Nontidal Cold Water Aquatic Life, and Public Water Supply*) or Use IV-P (*Water Contact Recreation, Protection of Aquatic Life, Recreational Trout Waters and Public Water Supply*) designations (COMAR 2012a,b,c,d). 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.

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. Phosphorus loads compatible with water quality standards are determined by comparing current phosphorus loading rates (lbs/ac/yr) in the Lower Monocacy River 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 phosphorus loads in both Lower Monocacy River and the unimpaired watersheds that will be used to set the phosphorus TMDL for Lower Monocacy River.

Overall, this TMDL will ensure that the phosphorus loads and resulting effects are at a level to support the Use I-P/ III-P/IV-P designations for the Lower Monocacy River watershed, and more specifically, at a level the watershed can sustain without causing any nutrient related impacts to aquatic health. The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Because the BSID watershed analysis identifies other possible stressors (*i.e.*, conductivity, sediment, in-stream habitat, and riparian habitat) 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).

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 Lower Monocacy River. 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 a biological endpoint.

Because the mainstem of Lower Monocacy River 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 Lower Monocacy River will not be included in the TMDL. These dischargers include one minor industrial facility and the following major WWTPs discharging over 0.5 MGD: Ballenger Creek WWTP (MD0021822), Fort Detrick WWTP (MD0020877), and Frederick City WWTP (MD0021610). The major facilities will be given individual phosphorus allocations for informational purposes only, based on their allocations under the Chesapeake Bay TMDL. The load from the minor facility discharging in the mainstem is included in the Minor Process Water aggregate load. Table 1 in a technical memorandum to this document entitled "*Significant Phosphorus Point Sources in the Lower Monocacy River Watershed*" gives the list of facilities discharging directly to the mainstem of the Lower Monocacy River.

<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 Lower Monocacy River phosphorus TMDL, and other nutrient TMDLs for Maryland's non-tidal watersheds, the CBP Phase 5.3 Watershed Model will be used to determine phosphorus loads in both the impaired and reference watersheds.

The CBP P5.3.2 model is a Hydrological Simulation Program FORTRAN (HSPF) model of the portions of Maryland, Virginia, Pennsylvania, the District of Columbia, Delaware, West Virginia, and New York in the Chesapeake Bay basin. Its primary purposes are: (1) to determine the sources of nitrogen, phosphorus, and sediment to the Chesapeake Bay, (2) to calculate nutrient and sediment loads to the Chesapeake Bay for use in the CBP model of water quality in the Bay, and (3) to estimate nutrient and sediment load allocations under nutrient and sediment TMDLs for impaired Chesapeake Bay segments. Generally, river reaches that have average annual flows greater than 100 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 near future. The results of the model will affect point source and MS4 permits, as well as nonpoint source management programs for agriculture, silviculture, and stream restoration. Using the P5.3.2 model as the basis for the reference watershed approach enables Maryland to integrate its non-tidal nutrient TMDLs into the management framework for the Chesapeake Bay. It also provides a consistent and equitable way to determine the load contribution from neighboring states.

Reference Watershed Approach

In order to quantify the impact of nutrients on the aquatic health of non-tidal stream systems, a reference watershed TMDL approach was used, which resulted in the establishment of a *phosphorus loading threshold* for watersheds within the Highland and Piedmont physiographic regions. The phosphorus loading threshold was determined by a methodology similar to that used to develop sediment loading thresholds for Maryland's sediment TMDLs (Currey *et al.* 2006; MDE 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 P5.3.2.2 2009 Progress Scenario) divided by the *all forested phosphorus load*.

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

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

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 Lower Monocacy River watershed is 8.58.

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 Progress 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.

Lower Monocacy River's forest normalized load exceeds the *forest normalized reference phosphorus load* (also referred to as the *phosphorus loading threshold*), indicating that the Lower Monocacy River 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 Lower Monocacy River watershed baseline nutrient loads are estimated using the CBP P5.3.2 landuse and the EOS landuse phosphorus loading rates from the 2009 Progress Scenario. The 2009 Progress Scenario represents current land-use, loading rates, and BMP implementation simulated using precipitation and other meteorological inputs from the period 1991-2000 to represent variable hydrological conditions, thereby addressing annual changes in hydrology and capturing wet, average and dry years. The period 1991-2000 is the baseline hydrological period for the Chesapeake Bay TMDL.

Watershed loading calculations, based on the CBP P5.3.2 segmentation scheme, are represented by multiple CBP P5.3.2 model segments within each MD 8-digit watershed. The nutrient loads from these segments are combined to represent the baseline condition. The point source phosphorus loads are estimated based on the existing discharge monitoring data and permit information. Details of these loading source estimates can be found in Section 2.2 and Section 4.6 of this report. The total baseline phosphorus load for the Lower Monocacy River watershed is 252,974 lbs/yr, excluding the loads from mainstem point sources and upstream loads. Mainstem point sources account for 27,506 lbs/yr phosphorus under baseline conditions. Baseline loads from Upper Monocacy River account for 716,507 lbs/yr under baseline conditions.

Future (TMDL) Conditions

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

The TMDL loading and associated reductions are averaged at the Maryland 8-digit watershed scale, which is consistent with the impairment listing scale. It is important to recognize that some subwatersheds may require higher reductions than others, depending on the distribution of the land-use.

The formula for estimating the TMDL is as follows:

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

where:

TMDL = allowable load for impaired watershed (lbs/yr)
Y_{ref} = phosphorus loading threshold
i.e., forest normalized reference phosphorus load (7.18)
y_{forest} = all forested phosphorus load for watershed (lbs/yr)

The future (TMDL) phosphorus loads for the Lower Monocacy River is 211,791 lbs/yr phosphorus. These numbers exclude mainstem point source phosphorus loads, which under future conditions, will be 25,583 lbs/yr. They also exclude upstream loads from the Upper Monocacy River which will be 606,530 lbs/yr phosphorus under future conditions.

Phosphorus TMDL for Lake Linganore in Lower Monocacy River Watershed

The Lake Linganore average annual phosphorus TMDL of 5,288 lb/yr, which was developed by MDE to be protective of water quality standards within the impoundment and approved by EPA in 2003, still applies as the target phosphorus loading capacity within the pond’s drainage area, located in the north-eastern portion of the Lower Monocacy River watershed (MDE 2003). The attainment of water quality standards within the MD 8-digit Lower Monocacy River watershed and Lake Linganore impoundment can only be achieved by meeting the average annual TMDL of phosphorus specified for the MD 8-digit watershed within this report as well as the specific TMDL for the Lake Linganore drainage basin established by MDE in 2003. Furthermore, both the baseline phosphorus loading and TMDL for the impoundment are implicitly included within the Lower Monocacy River nonpoint source baseline loads and TMDL load allocation, respectively, due to the spatial resolution of the CBP P5.3.2 Watershed Model segmentation.

4.4 Critical Conditions and Seasonality

EPA's regulations require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters (CFR 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. EPA's regulations also require that TMDLs take into account seasonal environmental variations.

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

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

4.5 TMDL Loading Caps

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

The long-term average annual TMDL was calculated for the MD 8-digit watershed, based on Equation 4.2. Significant phosphorus reductions will be required in the Lower Monocacy River 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 Lower Monocacy River.

An overall reduction of 15% 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 Lower Monocacy River watershed are presented in Table 8.

Table 8: Lower Monocacy River Watershed TMDL for Phosphorus

	Baseline Load (lbs/yr)	TMDL Scenario Load (lbs/yr)	Reduction
Upper Monocacy	716,507	606,530	15%
MD 8-digit	252,974	211,791	16%
Mainstem[1]	27,506	25,583	7%
Total	**996,987**	**843,903**	**15%**

Note: [1]Mainstem comprises WWTPs discharging directly to Lower Monocacy River. The Lower Monocacy River TMDL is for informational purposes only, since the reduction shown is required under the Chesapeake Bay TMDL.
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 permitted point sources in the assessment unit and load allocations (LAs) for nonpoint sources generated within the assessment unit. In addition, TMDLs must account for natural background, tributary and adjacent segment loads if applicable (CFR 2011b). Consequently, the Lower Monocacy River 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 combined sewer overflows (CSOs) in the Lower Monocacy River watershed, and phosphorus loads from septic systems are considered insignificant. Equal reductions were applied to 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 nutrient 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; crops, pasture, nurseries, developed land, AFOs, and municipal WWTPs were identified as the largest controllable sources. Forest is the primary non-controllable source, as it represents the most natural condition in the watershed. Direct atmospheric deposition on water is a minor source that to a large extent originates outside the watershed. Atmospheric deposition will be reduced by existing state and federal programs and thus is not addressed in this TMDL. Urban stormwater nutrient loads are regulated under the NPDES MS4 program and therefore included in the WLA.

The Lower Monocacy River Phosphorus TMDL requires a 14% reduction in phosphorus loads from nonpoint sources (*i.e.*, agricultural land uses) (See Table 9). For more detailed information regarding the Lower Monocacy River Watershed TMDL Contribution nonpoint source allocations, please see the technical memorandum to this document entitled: *Significant Phosphorus Nonpoint Sources in the Lower Monocacy River Watershed*.

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

Table 9: MD 8-digit Lower Monocacy River Phosphorus TMDL by Source Category

<table>
<tr><th></th><th colspan="2">Baseline Load Source Categories</th><th>Baseline Load (lbs/yr)</th><th>TMDL Components</th><th>TMDL (lbs/yr)</th><th>Reduction (%)</th></tr>
<tr><td rowspan="13">Lower Monocacy River Contribution</td><td rowspan="7">Nonpoint Source</td><td>Forest</td><td>9,971</td><td rowspan="8">LA</td><td>9,971</td><td>0%</td></tr>
<tr><td>AFOs</td><td>9,302</td><td>6,389</td><td>31%</td></tr>
<tr><td>Pasture</td><td>24,340</td><td>19,651</td><td>19%</td></tr>
<tr><td>Crop</td><td>106,779</td><td>91,360</td><td>14%</td></tr>
<tr><td>Nursery</td><td>26,535</td><td>24,730</td><td>7%</td></tr>
<tr><td>Septic</td><td>0</td><td>0</td><td>0%</td></tr>
<tr><td>Atmospheric Deposition</td><td>703</td><td>703</td><td>0%</td></tr>
<tr><td colspan="2">Total Nonpoint Sources</td><td>177,630</td><td>152,804</td><td>14%</td></tr>
<tr><td rowspan="4">Point Source</td><td>CAFOs</td><td>170</td><td rowspan="6">WLA</td><td>170</td><td>0%</td></tr>
<tr><td>Regulated Urban</td><td>68,956</td><td>52,926</td><td>23%</td></tr>
<tr><td>Process Water</td><td>33,724</td><td>31,473</td><td>7%</td></tr>
<tr><td>CSO</td><td>0</td><td>0</td><td>0%</td></tr>
<tr><td colspan="2">Total Point Sources</td><td>102,850</td><td>84,570</td><td>18%</td></tr>
<tr><td colspan="3">Total 8-digit Watershed</td><td>280,480</td><td>237,373</td><td>15%</td></tr>
<tr><td>Upstream</td><td colspan="2">Upper Monocacy River[1]</td><td>716,507</td><td>Upstream LA</td><td>606,530</td><td>15%</td></tr>
<tr><td colspan="3">Total</td><td>996,987</td><td></td><td>843,903</td><td>15%</td></tr>
</table>

Notes [1] Background relating to the Upper Monocacy River watershed upstream baseline load and TMDL are presented in the Upper Monocacy River watershed TMDL document (MDE 2012c).

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

Process Water WLA

There are seventeen municipal WWTP in the Lower Monocacy watershed, of which three discharge to the mainstem. Municipal WWTPs were 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 discharge flows and Maryland Department of Natural Resources growth rates by county), whichever is less.

Nineteen industrial process water sources in the Lower Monocacy River watershed are judged to have the capacity to discharge TP in their process water. All of these facilities are minor, and one discharges 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. These WLAs were adopted for the Lower Monocacy River Phosphorus TMDL. 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 Lower Monocacy River Phosphorus TMDL, and all minor municipal and minor industrial process water facilities allocations are represented as a watershed-wide WLA.

Based on the Maryland Tributary Strategy Cap flow and permit limits or the allocations under the Chesapeake Bay TMDL, applied to the Lower Monocacy River Phosphorus TMDL; it will result in a overall 7% reduction in phosphorus loads from process water sources (See Table 9). This reduction is a result of statewide policy decisions related to process water. For additional information regarding individual allocations to major process water facilities as well as information related to minor process water facilities included in the minor aggregate WLA, please see the technical memorandum to this document entitled: *Significant Phosphorus Point Sources in the Lower Monocacy River Watershed*.

Stormwater WLA

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

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

EPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (US EPA 2002). Therefore, NPDES regulated stormwater loads within the Lower Monocacy River 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 Lower Monocacy 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 Lower Monocacy River NPDES stormwater WLA requires an overall reduction of 23% 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 a detailed list of all NPDES regulated stormwater discharges within the watershed, and more information regarding the distribution of NPDES stormwater WLAs among jurisdictions, please see the technical memorandum to this document entitled: *Significant Phosphorus Point Sources in* the Lower Monocacy River *Watershed*.

CAFO WLA

Under the Clean Water Act, concentrated animal feeding operations (CAFOs) require NPDES permits for their discharges or potential discharges (CFR 2011c). 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 Lower Monocacy River 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 Lower Monocacy River watershed is 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 Lower Monocacy River TMDL of Phosphorus

TMDL (lbs/yr)	**+**	**LA**					+	**WLA**					+	
		LA_{UMR}[1,2]	**+**	**LA_{LMR}**	+	**$Septic_{LMR}$**		**CAFO WLA_{LMR}**	+	**NPDES Stormwater WLA_{LMR}**	+	**Process Water WLA_{LMR}**		**MOS**
843,903	=	606,530	+	152,804	+	0	+	170	+	52,926	+	31,473	+	Implicit

Upstream Load Allocation[2] (applies to LA_{UMR}); MD 8-digit Lower Monocacy River Watershed TMDL Contribution (applies to LA_{LMR} through Process Water WLA_{LMR})

Notes: [1] 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.

[2] For Upper Monocacy River watershed WLA and LA characterization please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick, Carroll, and Montgomery Counties, Maryland" (MDE 2012c).

Table 11: MD 8-digit Lower Monocacy River Maximum Daily Load of Phosphorus

TMDL (lbs/day)	=	LA					+	WLA					+	
		LA_{UMR}[1,2]	+	LA_{LMR}	+	$Septic_{LMR}$		CAFO WLA_{LMR}	+	NPDES Stormwater WLA_{LMR}	+	Process Water WLA_{LMR}		MOS
5,592	=	3,883	+	1,069	+	0	+	1	+	370	+	268	+	Implicit

Upstream Load Allocation[2] (applies to LA_{UMR}); MD 8-digit Lower Monocacy River Watershed TMDL Contribution (applies to LA_{LMR} through Process Water WLA_{LMR})

Notes: [1] 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.

[2] For Upper Monocacy River watershed WLA and LA characterization please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick, Carroll, and Montgomery Counties, Maryland" (MDE, 2012c).

Note: Individual source categories loads may not add up 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 Lower Monocacy River will be achieved and maintained.

The Lower Monocacy River 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 Lower Monocacy 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 Lower Monocacy River 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 Lower Monocacy River non-tidal waters nutrient TMDL.

The proposed approach for achieving the Lower Monocacy River 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 2012a), 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 Lower Monocacy River 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 Lower Monocacy River watershed have been met, MDE will revisit the status of nutrient impacts on aquatic life in Lower Monocacy River, 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 Lower Monocacy River 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 grown on 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 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 Lower Monocacy River 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 Lower Monocacy River watershed.

<u>Level of Resolution</u>

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 Lower Monocacy River 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.

<u>Probability Level</u>

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 Lower Monocacy River 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, CAFOs, 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 Lower Monocacy River 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 P5.3.2 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, since 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 Lower Monocacy River 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 Lower Monocacy River 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 0.469 was calculated using the following equation:

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

where:

CV = coefficient of variation

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

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

α = mean (arithmetic)

β = standard deviation (arithmetic)

μ = mean of logarithms

σ = standard deviation of logarithms

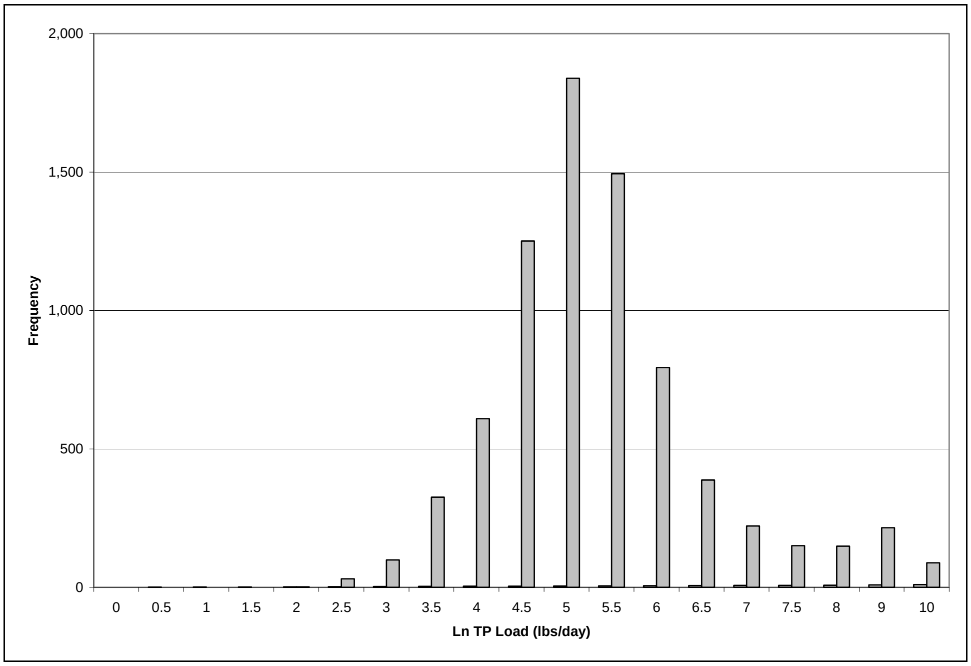

Figure B-1: Histogram of CBP River Segment Daily Phosphorus Simulation Results for the Lower Monocacy River Watershed

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:

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

where:

MDL = Maximum daily load
LTA = Long-term average (average annual load)
Z = z-score associated with target probability level
$\sigma^2 = \ln(CV^2+1)$
CV = Coefficient of variation based on arithmetic mean and standard deviation

Using a z-score associated with the 99th percent probability, CV of 0.469 consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 2.554 average annual Lower Monocacy River phosphorus TMDL is reported in lbs/yr, and the conversion from lbs/yr to a maximum daily load in lbs/d is 0.007 (e.g. 2.554/365).

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 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Lower Monocacy River phosphorus TMDL are reported in lbs/yr, and the conversion from lbs/yr to a maximum daily load in lbs/d is 0.0085 (e.g. 3.11/365).

In the case of Lower Monocacy River, all permitted sources with phosphorus concentration limits have no permitted daily maximum concentrations, so the maximum daily load was calculated based on the TSD guidance.

<u>Approach for Upstream Sources</u>
For the purposes of this analysis one upstream watershed have been identified: the Upper Monocacy River watershed. The Upper Monocacy River Maximum Daily Load is presented in a separate TMDL document and subsequently applied in this analysis (MDE 2012c)

<u>Margin of Safety</u>
As explained in Section 4.7, an implicit margin of safety (MOS) is used in the Lower Monocacy Creek Phosphorus TMDL.

Results of Approach

This section lists the results of the selected approach to define maximum daily loads for the Lower Monocacy River watershed.

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

LA (lbs/d) = Average Annual TMDL LA (lbs/yr) * 0.007

Stormwater WLA (lbs/d) = Average Annual TMDL Stormwater WLA (lbs/yr) * 0.007

- Calculation Approach for Process Water Point Sources
    - For permits with a daily maximum limit:

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

- For permits without a daily maximum limit:

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

- Calculation Approach for Upstream Sources
  - For Upper Monocacy River watershed MDL calculation, please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick and Carroll Counties, Maryland" (MDE 2012c).

Table B-1: Summary of Maximum Daily Loads of Total Phosphorus for the Lower Monocacy Watershed

TMDL[2] (lbs/day)	=	LA					+	WLA					+	
		LA_{UMR}[1,2]	+	**LA_{LMR}**	+	**$Septic_{LMR}$**		**CAFO WLA_{LMR}**	+	**NPDES Stormwater WLA_{LMR}**	+	**Process Water WLA_{LMR}**		**MOS**
5,592	=	3,883	+	1,069	+	0	+	1	+	370	+	268	+	Implicit
		Upstream Load Allocation[2]		MD 8-digit Lower Monocacy River Watershed TMDL Contribution										

Notes: [1] 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.

[2] For Upper Monocacy River watershed WLA and LA characterization please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick, Carroll, and Montgomery Counties, Maryland" (MDE, 2012c).

APPENDIX C – Phosphorus TMDLs for the Double Pipe Creek, MD 8-Digit Upper Monocacy River, and Lower Monocacy River Watersheds

The purpose of this appendix is to explain the hydrologic relationship between the Double Pipe Creek, Upper Monocacy River, and Lower Monocacy River watersheds and how this affects the phosphorus TMDLs for each of the respective watersheds. As illustrated in Figure C-1, the three watersheds are hydrologically connected, beginning with the Double Pipe Creek watershed to the east. The Double Pipe Creek watershed flows into the Upper Monocacy River watershed, near the town of Rocky Ridge. It is also shown in Figure C-1 that the Upper Monocacy River watershed includes land in Pennsylvania and Maryland. The combined flow from the Upper Monocacy River and the Double Pipe Creek flows into the Lower Monocacy River. The hydrologic connectivity of the watersheds is illustrated in Figure C-2.

The baseline phosphorus loads for the watersheds are shown in Tables C-1 through C-3. The TMDL calculations are shown in Tables C-4 through C-6. Further information can be found in the individual TMDL documents for each watershed (MDE 2012b, 2012c).

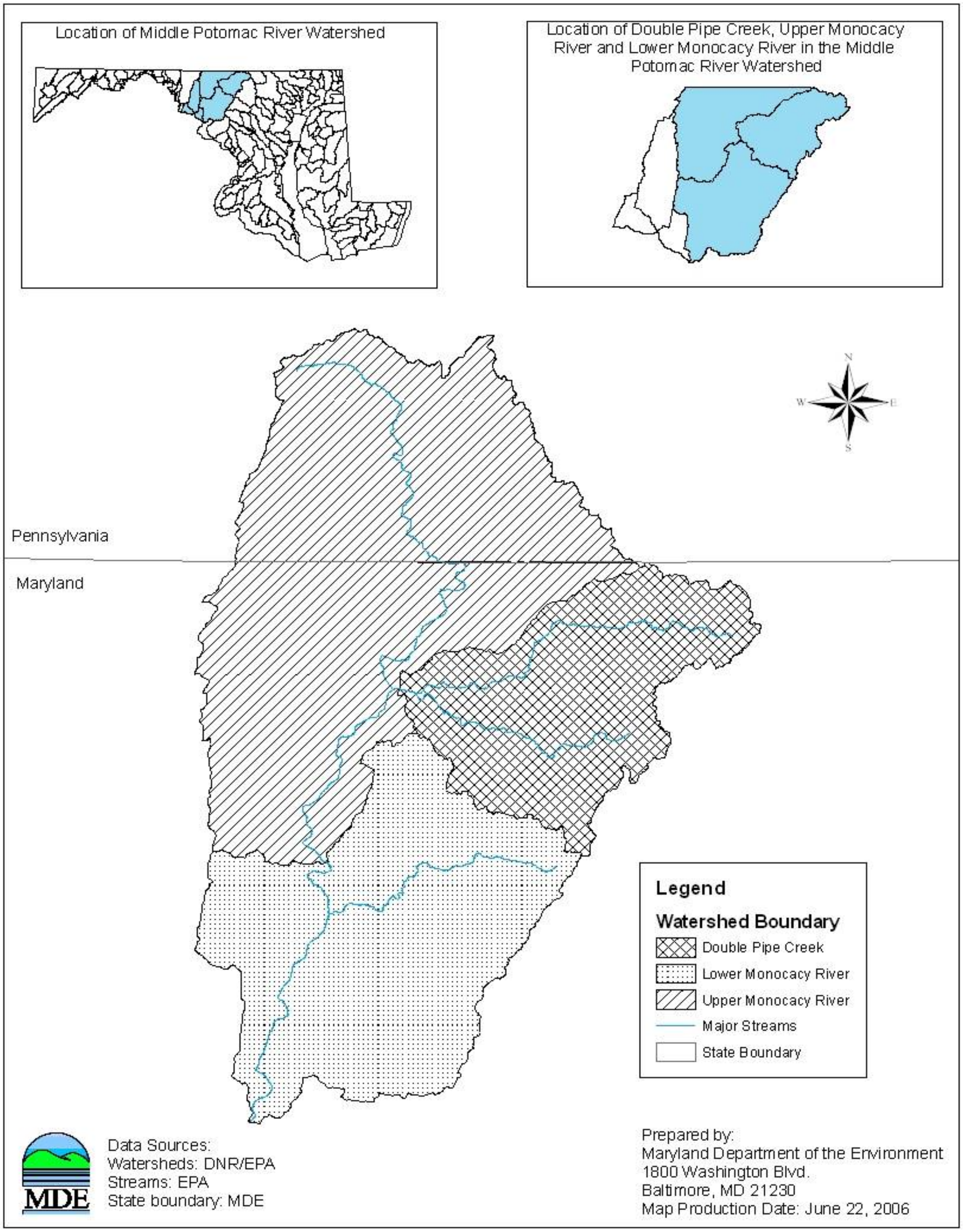

Figure C-1: Location of the Double Pipe Creek, Upper Monocacy River, and Lower Monocacy River Watersheds

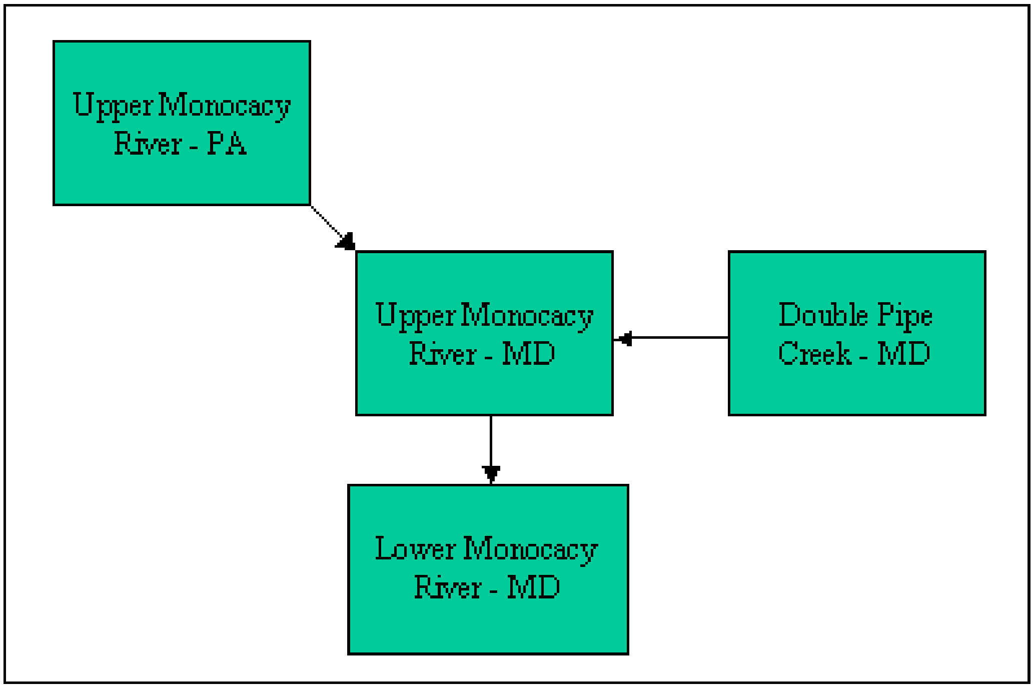

Figure C-2: Flow Schematic of the Double Pipe Creek, Upper Monocacy River, and Lower Monocacy River Watersheds

Table C-1: Double Pipe Creek Baseline Phosphorus Loads

MD 8-digit Double Pipe Creek Watershed Baseline Load Contribution										
Total Baseline Load (lbs/yr)	=	**Nonpoint Source BL**	+	**Septic BL**	+	**CAFO BL**	+	**NPDES Stormwater BL**	+	**Process Water BL**
201,916	=	164,842	+	0	+	1,001	+	25,133	+	10,940

Table C-2: MD 8-digit Upper Monocacy River Baseline Phosphorus Loads

Total Baseline Load (lbs/yr)	=	**Upstream Baseline Load**[1]			+	**MD 8-digit Upper Monocacy River Watershed Baseline Load Contribution**								
		BL_{PA}	+	**BL_{DPC}**		**Nonpoint Source BL_{UMR}**	+	**Septic BL_{UMR}**	+	**CAFO BL_{UMR}**	+	**NPDES Stormwater BL_{UMR}**	+	**Process Water BL_{UMR}**
716,507	=	325,555	+	201,916	+	153,714	+	0	+	379	+	24,513	+	10,430

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

Table C-3: Lower Monocacy River Baseline Phosphorus Loads

Total Baseline Load (lbs/yr)	=	Upstream Baseline Load[1]	+	MD 8-digit Lower Monocacy River Watershed Baseline Load Contribution								
		BL_{UMR}[2]		Nonpoint Source BL_{LMR}	+	Septic BL_{LMR}	+	CAFO BL_{LMR}	+	NPDES Stormwater BL_{LMR}	+	Process Water BL_{LMR}
996,987	=	716,507	+	177,630	+	0	+	170	+	68,956	+	33,724

Notes:[1] Although the upstream values are reported as a single value, they include point and nonpoint sources.

[2] For the Upper Monocacy River watershed point and nonpoint source characterization, please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick and Carroll Counties, Maryland" (MDE 2012c).

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

Table C-4: Double Pipe Creek Average Annual TMDL of Phosphorus

TMDL (lbs/yr)	=	LA			+	WLA					+	MOS
	=	LA	+	Septic	+	CAFO WLA	+	NPDES Stormwater WLA	+	Process Water WLA	+	
128,328	=	112,555	+	0	+	461	+	9,001	+	6,310	+	Implicit

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

Table C-5: Upper Monocacy River Average Annual TMDL of Phosphorus

TMDL (lbs/yr)	=	LA							+	WLA					+	MOS
		LA_{PA}[1,2]	+	LA_{DPC}[3]	+	LA_{UMR}	+	$Septic_{UMR}$		CAFO WLA_{UMR}	+	NPDES Stormwater WLA_{UMR}	+	Process Water WLA_{UMR}		
606,530	=	300,004	+	128,328	+	149,673	+	0	+	379	+	23,741	+	4,406	+	Implicit

Upstream Load Allocation[2]

MD 8-digit Upper Monocacy River Watershed TMDL Contribution

[1] LA_{PA} was determined to be necessary in order to meet Maryland water quality standards within the MD 8-digit Upper Monocacy River watershed. It includes both the PA load entering Maryland through the mainstem and the load from other areas in PA requiring reduction.

[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.

[3] LA_{DPC}: Double Pipe Creek TMDL, it could include loads from point and nonpoint sources

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

Table C-6: Lower Monocacy River Average Annual TMDL of Phosphorus

TMDL (lbs/yr)	+	**LA**					+	**WLA**					+	
		LA_{UMR}[1,2]	+	**LA_{LMR}**	+	**$Septic_{LMR}$**	+	**CAFO WLA_{LMR}**	+	**NPDES Stormwater WLA_{LMR}**	+	**Process Water WLA_{LMR}**	+	**MOS**
843,903	=	606,530	+	152,804	+	0	+	170	+	52,926	+	31,473	+	Implicit

Upstream Load Allocation[2] (606,530); MD 8-digit Lower Monocacy River Watershed TMDL Contribution (152,804 through 31,473)

Notes: [1] 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.

[2] For Upper Monocacy River watershed WLA and LA characterization please refer to the "Total Maximum Daily Load of Phosphorus in the Upper Monocacy River Watershed, Frederick, Carroll, and Montgomery Counties, Maryland" (MDE 2012c).