Total Maximum Daily Load of Sediment in the Double Pipe Creek Watershed, Frederick and Carroll 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
CBP P5	Chesapeake Bay Program Phase 5
CV	Coefficient of Variation
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
EPSC	Environmental Permit Service Center
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ETM	Enhanced Thematic Mapper
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
IBI	Index of Biotic Integrity
Ind.	Indeterminate
LA	Load Allocation
MACS	Maryland Agriculture water quality cost share program
MBSS	Maryland Biological Stream Survey
MD 8-Digit	Maryland 8-digit Watershed
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
MS4	Municipal Separate Storm Sewer System
N/A	Not Applicable
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service

NRI	Natural Resources Inventory
NS	No Sample
PSU	Primary Sampling Unit
RESAC	Regional Earth Science Applications Center
SSDI	Sediment Stream Disturbance Index
TMDL	Total Maximum Daily Load
Ton/yr	Tons per Year
TSD	Technical Support Document
TSS	Total Suspended Solids
TM	Thematic Mapper
USGS	United Stated Geological Survey
WLA	Waste Load Allocation
WTP	Water Treatment Plant
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for sediment in the Double Pipe Creek watershed (basin number 02140304) (303(d) Assessment Unit ID: MD-02140304). 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 2007b).

The Maryland Department of the Environment (MDE) has identified the waters of Double Pipe Creek on the State's 303(d) List as impaired by sediments (1996), nutrients (1996), bacteria (2002), and impacts to biological communities (2002)(MDE 2007). The designated use of Double Pipe Creek and its tributaries is Use IV-P (Recreational Trout Waters and Public Water Supply) (COMAR 2007a,b).

A data solicitation for sediments was conducted by MDE, and all readily available data from the past five years have been considered. A TMDL for fecal coliform to address the 2002 bacteria listing was submitted to the EPA in 2007. The listings for nutrients and impacts to biological communities will be addressed separately at a future date.

The Double Pipe Creek watershed aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI), indicate that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions (Roth et al. 2005). The objective of the TMDL established herein is to ensure that there will be no sediment impacts affecting aquatic health, thereby establishing a sediment load that supports the Use IV-P designation for the Double Pipe Creek watershed.

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems. To determine whether aquatic health is impacted by elevated sediment loads, a weight-of-evidence stressor identification approach was used. This approach applies a composite stressor indicator, defined as the *sediment stream disturbance index* (SSDI). Similar to the Index of Biotic Integrity (IBI), the SSDI is based on a comparison of specific watershed parameters with those from streams with a healthy aquatic community (i.e., reference watersheds) and is scored separately for the benthic and fish communities. Watershed specific SSDI values indicate whether sediment is one of the stressors affecting the biological community.

In order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL approach was used and resulted in the establishment of a *sediment loading threshold* (Currey et al. 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998). This threshold is then used to determine a watershed specific sediment TMDL.

The computational framework chosen for the Double Pipe Creek watershed TMDL was the Chesapeake Bay Program Phase 5 (CBP P5) watershed model target *edge-of-field* (EOF) land use sediment loading rate calculations combined with a *sediment delivery ratio*. The *edge-of-stream* (EOS) sediment load is calculated per land use as a product of the land use area, land use target loading rate, and loss from the EOF to the main channel. The spatial domain of the CBP P5 watershed model segmentation aggregates to the Maryland 8-digit watersheds, which is consistent with the impairment listing.

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2007b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds integrates the stress effects over the course of time and thus inherently addresses critical conditions. Seasonality is captured in two components. First, it is implicitly included in biological sampling. Second, the Maryland Biological Stream Survey (MBSS) dataset included benthic sampling in the spring and fish sampling in the summer.

All TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources generated within the assessment unit, natural background, tributary, and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2007a,b). It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty. This results in an implicit margin of safety of approximately 8%.

The Double Pipe Creek Total Baseline Sediment Load is 35,224.3 tons per year (ton/yr), which can be further subdivided into a nonpoint source baseline load (Nonpoint Source BL_{DP}) and two types of point source baseline loads: National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{DP}) and regulated process water (Process Water BL_{DP}) (see Table ES-1). The Double Pipe Creek Average Annual TMDL of Sediment/Total Suspended Solids (TSS) is 24,199.1 tons per year. The Load Allocation (LA_{DP}) is 20,461.1 tons per year, the NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{DP}) is 3,377.9 tons per year, and the Process Water Waste Load Allocation (Process Water WLA_{DP}) is 360.0 tons per year (see Table ES-2). This TMDL will ensure that the sediment loads and resulting effects are at a level to support the Use IV-P designation for the Double Pipe Creek watershed, and more specifically, at a level to support aquatic health. Appendix D is provided to explain the effect of this TMDL on downstream watersheds.

Table ES-1: Double Pipe Creek Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{DP}	+	NPDES Stormwater BL_{DP}	+	Process Water BL_{DP}
35,224.3	=	29,674.5	+	5,189.8	+	360.0

Table ES-2: Double Pipe Creek Average Annual TMDL of Sediment/TSS (ton/yr)

TMDL (ton/yr) =	LA_{DP} +	NPDES Stormwater WLA_{DP} +	Process Water WLA_{DP} +	MOS
24,199.1	20,461.1	3,377.9	360.0	Implicit

Table ES-3: Double Pipe Creek Baseline Load, TMDL, and Total Reduction Percentage

Baseline Load (ton/yr)	TMDL (ton/yr)	Total Reduction (%)
35,224.3	24,199.1	31.3

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

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) is expected to take place. MDE intends for the required reduction to be implemented in an iterative process that first addresses those sources with the largest impact to water quality, with consideration given to ease and cost of implementation.

Maryland has several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) and the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act). Several potential funding sources for implementation are available, such as the Buffer Incentive Program (BIP), the State Water Quality Revolving Loan Fund, and the Stormwater Pollution Cost Share Program.

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for sediment in the Double Pipe Creek watershed (basin number 02140304) (303(d) Assessment Unit ID: MD-02140304). 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 2007b). A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

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

The Maryland Department of the Environment (MDE) has identified the waters of Double Pipe Creek on the State's 303(d) List as impaired by sediments (1996), nutrients (1996), bacteria (2002), and impacts to biological communities (2002)(MDE 2007). The designated use of Double Pipe Creek and its tributaries is Use IV-P (Recreational Trout Waters and Public Water Supply) (COMAR 2007a,b).

A data solicitation for sediments was conducted by MDE, and all readily available data from the past five years have been considered. A TMDL for fecal coliform to address the 2002 bacteria listing was submitted to the EPA in 2007. The listings for nutrients and impacts to biological communities will be addressed separately at a future date.

The objective of the TMDL established herein is to ensure that there will be no sediment impacts affecting aquatic health, thereby establishing a sediment load that supports the Use IV-P designation for the Double Pipe Creek watershed. Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems. Therefore, to determine whether aquatic health is impacted by elevated sediment loads, a weight-of-evidence stressor identification approach was used. This approach applies a composite stressor indicator, defined as the *sediment stream disturbance index* (SSDI). Similar to the Index of Biotic Integrity (IBI), the SSDI is based on a comparison of specific watershed parameters with those from streams with a healthy aquatic community (i.e., reference watersheds) and is scored separately for the benthic and fish communities. Watershed specific SSDI values indicate whether sediment is one of the stressors affecting the biological community.

In order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL approach was used and resulted in the establishment of a *sediment loading threshold* (Currey et al. 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998). This threshold is then used to determine a watershed specific sediment TMDL.

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. It covers approximately 966 square miles, with approximately 224 square miles located in Pennsylvania and 742 square miles in Maryland. The basin can be subdivided into three distinct watersheds: the Upper Monocacy River, Lower Monocacy River, and Double Pipe Creek.

The Double Pipe Creek watershed is located within Frederick and Carroll Counties, Maryland. The stream system empties into the Maryland 8-Digit (MD 8-Digit) Upper Monocacy River watershed. Therefore, the loads generated within Double Pipe Creek impact downstream conditions within the mainstem of the MD 8-Digit Upper Monocacy River watershed. The hydrological relationship between the three watershed systems and subsequent effect on sediment loads is further explained in Appendix D. The Double Pipe Creek watershed itself consists of two sub-basins, Big Pipe Creek , which makes up 58% of the total watershed area, and Little Pipe Creek, which makes up the remaining 42% of the total watershed area (McCoy and Summers 1992). The watershed encompasses approximately 193 square miles, and approximately 7% of the total watershed is covered by water (i.e. streams, ponds, etc.). The watershed is mostly rural consisting primarily of cropland and livestock/feeding operations. However, there are four minor urban areas and one major urban area within the basin. The four minor urban areas include Taneytown, Manchester, Union Bridge, and New Windsor. The one major urban area is the city of Westminster. The total population in the Double Pipe Creek is estimated to be 39,191 (MDE 2003a).

Geology/Soils

The Double Pipe Creek watershed lies within the north central Piedmont geologic province of Maryland and is characterized by gently rolling to steep uplands with streams of average to steep gradients, which feed into the lower valleys of the Piedmont. The predominant soils in the watershed are moderately erodible. Ground water within the project area occurs primarily in fractures and bedding-plane partings of rocks. It may also occur in solutional cavities in limestone and marble (McCoy and Summers 1992).

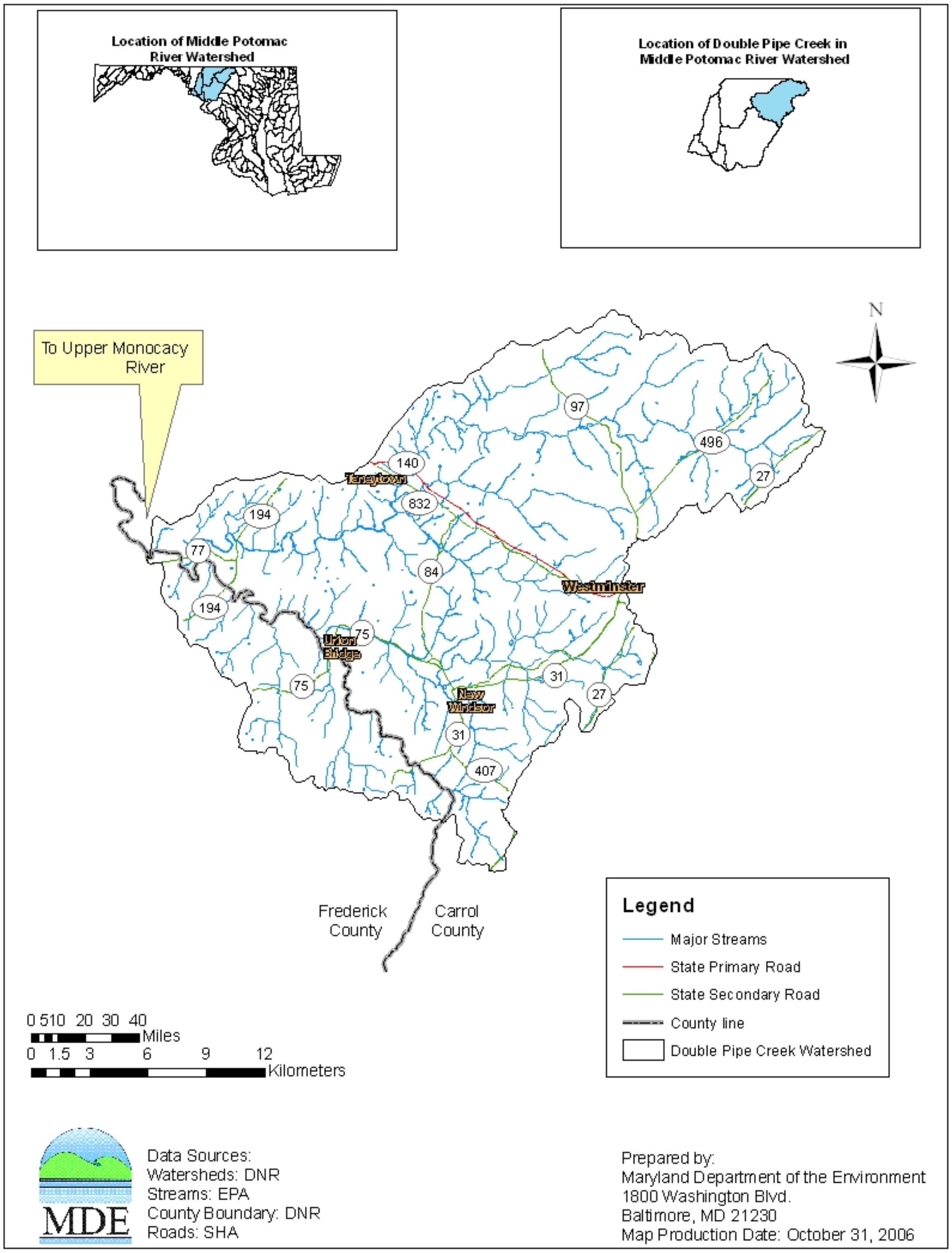

Figure 1: Location Map of Double Pipe Creek in Frederick and Carroll Counties, Maryland

2.1.1. Land Use

Land Use Methodology

The land use framework used to develop this TMDL was originally developed for the Chesapeake Bay Program Phase 5 (CBP P5) watershed model.[1] The CBP P5 land use Geographic Information System (GIS) framework was based on two distinct layers of development. The first GIS layer was developed by the Regional Earth Science Applications Center (RESAC) at the University of Maryland and was based on satellite imagery (Landsat 7-Enhanced Thematic Mapper (ETM) and 5-Thematic Mapper (TM)) (Goetz et al. 2004). This layer did not provide the required level of accuracy that is especially important when developing agricultural land uses. In order to develop accurate agricultural land use calculations, the CBP P5 used county level U.S. Agricultural Census data as a second layer (USDA 1982, 1987, 1992, 1997, 2002).

Given that land cover classifications based on satellite imagery are likely to be least accurate at edges (i.e., boundaries between covers), the RESAC land uses bordering agricultural areas were analyzed separately. If the agricultural census data accounted for more agricultural use than the RESAC's data, appropriate acres were added to agricultural land uses from non-agricultural land uses. Similarly, if census agricultural land estimates were smaller than RESAC's, appropriate acres were added to non-agricultural land uses.

Adjustments were also made to the RESAC land cover to determine developed land uses. RESAC land cover was originally based on the United States Geological Survey (USGS) protocols used to develop the 2000 National Land Cover Database. The only difference between the RESAC and USGS approaches was RESAC's use of town boundaries and road densities to determine urban land covered by trees or grasses. This approach greatly improved the accuracy of the identified urban land uses, but led to the misclassification of some land adjacent to roads and highways as developed land. This was corrected by subsequent analysis. To ensure that the model accurately represented development over the simulation period, post-processing techniques that reflected changes in urban land use have been applied.

The result of this approach is that CBP P5 land use does not exist in a single GIS coverage; instead it is only available in a tabular format. The CBP P5 watershed model is comprised of 25 land uses. Most of these land uses are differentiated only by their nitrogen and phosphorus loading rates. The land uses are divided into 14 classes with distinct sediment erosion rates. Table 1 lists the CBP P5 generalized land uses, detailed land uses, which are classified by their erosion rates, and the acres of each land use in the Double Pipe Creek watershed. Details of the land use development methodology have been summarized in the report entitled "Chesapeake Bay Phase 5 Community Watershed Model: Tracking Nutrient and Sediment Loads on a Regional and Local Scale" (US EPA 2007).

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

Double Pipe Creek Watershed Land Use Distribution

The land use distribution in the Double Pipe Creek watershed consists primarily of crop land (41% of the total watershed area), with forest (28%), urban (19%), and pasture (12%) making up the remainder of the distribution. A land use map is provided in Figure 2 and a summary of the watershed land use areas is presented in Table 1.

Table 1: Land Use Percentage Distribution for the Double Pipe Creek Watershed

General Land Use	Detailed Land Use	Area (Acres)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	29.8	N/A[1]	
	Hay	14,953.4	13.0	
	High Till	11,378.5	9.9	
	Low Till	20,490.9	17.8	
	Nursery	825.0	0.7	41.4
Extractive	Extractive	70.2	0.1	0.1
Forest	Forest	31,598.7	27.5	
	Harvested Forest	319.2	0.3	27.7
Pasture	Natural Grass	260.4	0.2	
	Pasture	13,524.9	11.8	
	Trampled Pasture	70.8	0.1	12.0
Urban	Urban: Barren	230.4	0.2	
	Urban: Imp	2,441.5	2.1	
	Urban: perv	18,867.1	16.4	18.7
	Total	115,060.8	100.0	100.0

Note: [1] Percentage of total land area is minimal.

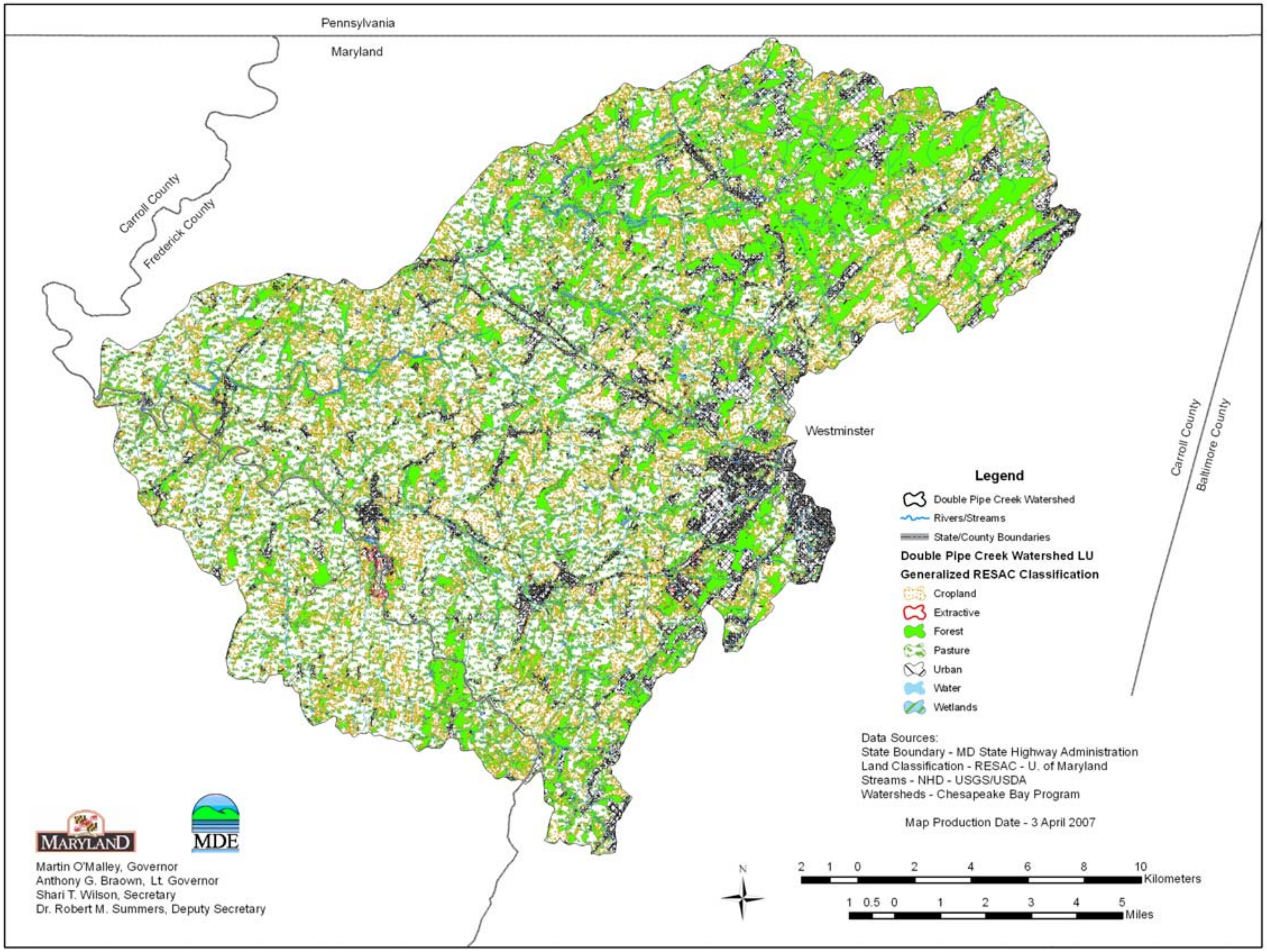


Figure 2: Land Use of the Double Pipe Creek Watershed

2.2 Source Assessment

The Double Pipe Creek Total Baseline Sediment Load can be subdivided into nonpoint and point source loads. This section summarizes the methods used to derive each of these distinct source categories.

2.2.1 Nonpoint Source Assessment

In this document, the nonpoint source loads account for sediment loads from unregulated storm water runoff. This section provides the background and methods for determining the Double Pipe Creek watershed nonpoint source baseline loads (Nonpoint Source BL_{DP}).

General load estimation methodology

Nonpoint source sediment loads are estimated based on the *edge-of-stream (EOS) calibration target loading rates* from the CBP P5 model. This approach is based on the fact that not all of the *edge-of-field* (EOF) sediment load is delivered to the stream or river (some of it is stored on fields down slope, at the foot of hillsides, or in smaller rivers or streams that are not represented in the model). To calculate the actual EOS loads, a *sediment delivery ratio* (the ratio of sediment reaching a basin outlet compared to the total erosion within the basin) is used. Details of the methods used to calculate sediment load have been summarized in the report entitled "Chesapeake Bay Phase 5 Community Watershed Model: Tracking Nutrient and Sediment Loads on a Regional and Local Scale" (US EPA 2007).

Edge-of-Field Target Erosion Rate Methodology

EOF target erosion rates for agricultural land uses and forested land use were based on erosion rates determined by the Natural Resource Inventory (NRI). NRI is a statistical survey of land use and natural resource conditions conducted by the Natural Resources Conservation Service (NRCS) (USDA 2007). Sampling methodology is explained by Nusser and Goebel (1997).

Estimates of average annual erosion rates for pasture and cropland are available on a county basis at five-year intervals, starting in 1982. Erosion rates for forested land uses are not available on a county basis from NRI; however, for the purpose of the CBP Phase 2 watershed model, NRI calculated average annual erosion rates for forested land use on a watershed basis. These rates are still being used as targets in the CBP P5 model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target loads. The erosion rates from this period do not reflect best management practices (BMPs) or other soil conservation policies introduced in the wake of the effort to restore the Chesapeake Bay. To compensate for this, a BMP factor was included in the loading estimates using best available "draft" information from the CBP. However, the effect of these factors was minimal, as most of the anticipated reductions are expected to result from land use changes (e.g. high till to low till). Rates for urban pervious, urban impervious, and barren land were based on a combination of best professional judgment, literature analysis, and regression analysis. Table 2 lists erosion rates specific to the Double Pipe Creek watershed.

Table 2: Summary of EOF Erosion Rate Calculations

Land Use	Data Source	Frederick County (MD) (tons/acre/year)	Carroll County (MD) (tons/acre/year)
Forest	Phase 2 NRI	0.21	0.34
Harvested Forest[1]	Average Phase 2 NRI (x 10)	3	3
Natural Grass	Average NRI Pasture (1982-1987)	1.5	1.5
Pasture	Pasture NRI (1982-1987)	1.48	0.85
Trampled pasture[2]	Pasture NRI (x 9.5)	14.06	8.08
Animal Feeding Operations[2]	Pasture NRI (x 9.5)	14.06	8.08
Hay[2]	Crop NRI (1982-1987) (x 0.32)	2.46	1.05
High Till Without Manure[2]	Crop NRI (1982-1987) (x 1.25)	9.59	4.09
High Till With manure[2]	Crop NRI (1982-1987) (x 1.25)	9.59	4.09
Low till With Manure[2]	Crop NRI (1982-1987) (x 0.75)	5.76	2.45
Pervious Urban	Intercept Regression Analysis	0.74	0.74
Extractive	Best professional judgment	10	10
Barren	Literature survey	12.5	12.5
Impervious	100% Impervious Regression Analysis	5.18	5.18

Notes: [1]Based on an average of NRI values for the Chesapeake Bay Phase 5 segments.
[2]NRI score data adjusted based on land use.

Sediment Delivery Ratio: The base formula for calculating *sediment delivery ratio*s in the CBP P5 model is the same as the formula used by the NRCS (USDA 1983).

$$DF = 0.417762 * A^{-0.134958} - 0.127097 \qquad \text{(Equation 2.1)}$$

where
DF (delivery factor) = the sediment delivery ratio
A = drainage area in square miles

In order to account for the changes in sediment loads due to distance traveled to the stream, the CBP P5 model uses the *sediment delivery ratio*. Land use specific *sediment delivery ratios* were calculated for each river segment using the following procedure:

(1) mean distance of each land use from the river reach was calculated;

(2) *sediment delivery ratio*s for each land use were calculated (drainage area in Equation 2.1 was assumed to be equal to the area of a circle with radius equal to the mean distance between the land use and the river reach).

Edge-of-Stream Loads

Edge-of-stream loads are the loads that actually enter the river reaches (i.e., the mainstem of a watershed). Such loads represent not only the erosion from the land but all of the intervening processes of deposition on hillsides and sediment transport through smaller rivers and streams.

2.2.2 Point Source Assessment

A list of 30 active permitted point sources that contribute to the sediment load in the Double Pipe Creek watershed was compiled using MDE's Environmental Permit Service Center (EPSC) database. The types of permits identified include individual industrial, individual municipal, general mineral mining, general industrial stormwater, and general municipal separate storm sewer systems (MS4s). The permits can be grouped into two categories, process water and stormwater. The stormwater category includes all National Pollutant Discharge Elimination System (NPDES) regulated stormwater discharges. The process water category includes those loads generated by continuous discharge sources whose permits have total suspended solids (TSS) limits. Other permits that do not meet these conditions are considered *de minimis* in terms of the total sediment load.

The sediment loads for the 11process water permits (Process Water BL_{DP}) are calculated based on their TSS limits and corresponding flow information. The 19 NPDES Phase I or Phase II stormwater permits identified throughout the Double Pipe Creek watershed are regulated based on BMPs and do not include TSS limits. In the absence of TSS limits, the NPDES regulated stormwater baseline load (NPDES Stormwater BL_{DP}) is calculated using methods described in Section 2.2.1 and watershed specific urban land use sediment delivery factors. A detailed list of the permits appears in Appendix B.

2.2.3 Summary of Baseline Loads

Table 3 summarizes the Double Pipe Creek Baseline Sediment Load, reported in tons per year (ton/yr) and presented in terms of nonpoint and point source loadings.

Table 3: Double Pipe Creek Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	**Nonpoint Source** BL_{DP}	+	**NPDES Stormwater** BL_{DP}	+	**Process Water** BL_{DP}
35,224.3	=	29,674.5	+	5,189.8	+	360.0

Table 4 presents a breakdown of the Double Pipe Creek Total Baseline Sediment Load, detailing loads per land use. The largest portion of the sediment load is from crop land (71%). The remainder of the sediment load is from urban land (15%), pasture (7%), and forest (6%).

Table 4: Detailed Baseline Sediment Budget Loads Within the Double Pipe Creek Watershed

General Land Use	**Description**	**Load (ton/Yr)**	**Percent**	**Grouped Percent of Total**
Crop	Animal Feeding Operations	49.7	0.1	
	Hay	3,483.5	9.9	
	High Till	9,644.2	27.4	
	Low Till	10,338.4	29.4	
	Nursery	1,369.7	3.9	70.6
Extractive	Extractive	136.2	0.4	0.4
Forest	Forest	2,019.7	5.7	
	Harvested Forest	181.2	0.5	6.2
Pasture	Natural Grass	73.3	0.2	
	Pasture	2,258.0	6.4	
	Trampled Pasture	120.9	0.3	7.0
Urban[1]	Urban: Barren	549.5	1.6	
	Urban: Imp	2,232.5	6.3	
	Urban: perv	2,407.8	6.8	14.7
N/A	Process Water	360.0	1.0	1.0
	Total	35,224.3	100.0	100.0

Note: [1]The urban land use load represents the permitted stormwater load.

2.3 Water Quality Characterization

The Double Pipe Creek watershed was originally listed on Maryland's 1996 303(d) List as impaired by elevated sediments from nonpoint sources, with supporting evidence cited in Maryland's 1996 305(b) report. The 1996 305(b) report did not directly state that elevated sediments were a concern, and it has been determined that the sediment listing was based on best professional judgment (MDE 2004; DNR 1996).

Currently in Maryland, there are no specific numeric criteria for suspended sediments. However, the Maryland 2004 303(d) report states that degraded stream water quality resulting in a sediment impairment is characterized by erosional impacts, depositional impacts, and decreased water clarity (MDE 2004). Therefore, the evaluation of suspended sediment loads will be based on how the sediment related impacts are influencing the designated use of supporting aquatic health, as defined by Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998).

Recently, MDE developed a stressor identification methodology entitled "Using MBSS Data to Identify Stressors for Streams that Fail Biocriteria in Maryland" (Southerland et al. 2007). This document proposes a conceptual model (see Figure 3) that establishes a link between sediment loads and aquatic health. Specifically, it identifies whether current sediment loads have a negative impact on a watershed's aquatic health based on the observed sediment impacts. This linkage between sediment loads, sediment impacts, and aquatic health is used to evaluate a sediment impairment.

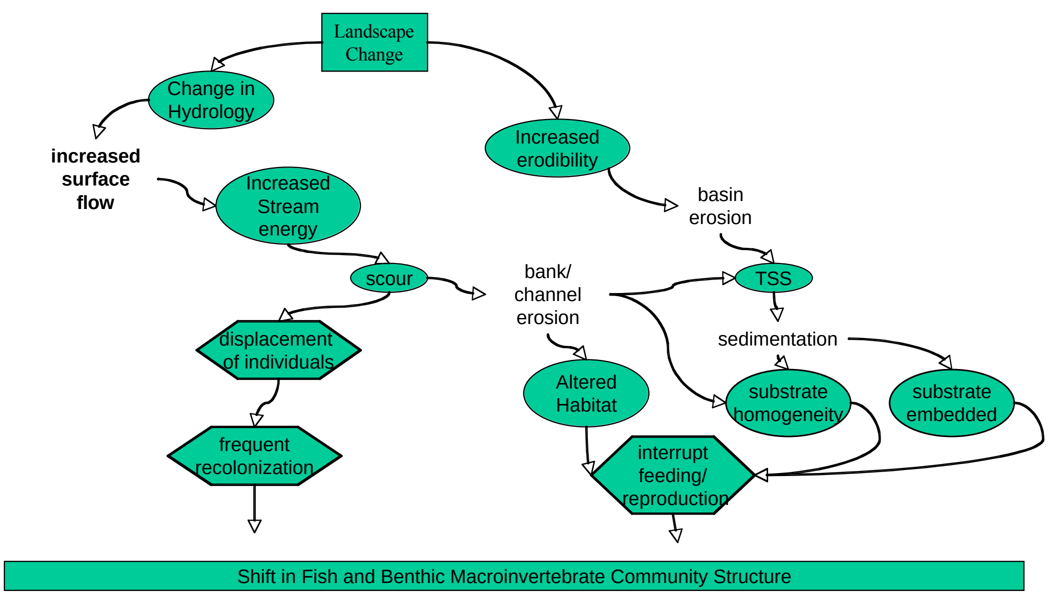


Figure 3: Sediment Stressor Conceptual Model

The sediment stressor conceptual model (adapted from Southerland et al. 2007) illustrates that changes in the landscape result in two possible paths, one triggered by changes in hydrology and the other triggered by increased land erodibility. Both paths ultimately result in changes in TSS and sediment loads, which, if increased, will result in a negative shift in the structure of the biological community.

Furthermore, the stressor conceptual model identifies water column TSS as the most direct measure of sediment loadings. Therefore, TSS was chosen as the most appropriate parameter for the sediment TMDL analysis. While an effective TSS concentration threshold would include both exposure duration and concentration magnitude, due to natural variations in geology, topography, and episodic flows, such a threshold would be extremely difficult to quantify (Rowe et al. 2003). In addition, the collection of sufficient instantaneous TSS concentration and flow data would be difficult due to high cost and limited site access during high flow events. Thus, MDE has not established a specific TSS water column concentration criteria. As a result, the water quality characterization of TSS impacts to aquatic life will be based on the cumulative impacts identified from observed streambed measures. Upon identification of sediment impacts, the TMDL will be estimated as a cumulative loading based on a comparison of the current watershed sediment loads with the acceptable levels derived from reference watersheds.

The streambed measures used to determine the water quality characterization were gathered from the Maryland Biological Stream Survey (MBSS) dataset. The MBSS uses a fixed length (75 m) randomly selected stream segment for collecting site level information within a primary sampling unit (PSU), also defined as a watershed. The randomly selected stream segments, from which field data are collected, are selected using either stratified random sampling with proportional allocation, or simple random sampling (Cochran 1977). This allocation ensures that all sites in a PSU stream network have the same probability of being selected. The random sample design allows for unbiased watershed estimates of mean conditions by averaging results at multiple stations. The average watershed estimates are then used to determine if streams within a watershed have a degraded biology (fish or benthic) and subsequently whether or not sediment is contributing to the observed degradation (Roth et al. 2005).

Double Pipe Creek Watershed Monitoring Stations

A total of 19 water quality monitoring stations were used to characterize the Double Pipe Creek Watershed. There were 17 biological/physical habitat monitoring stations from the MBSS program and 2 biological monitoring stations from the Maryland Core/Trend monitoring network. The stations are presented in Figure 4 and listed in Table 5.

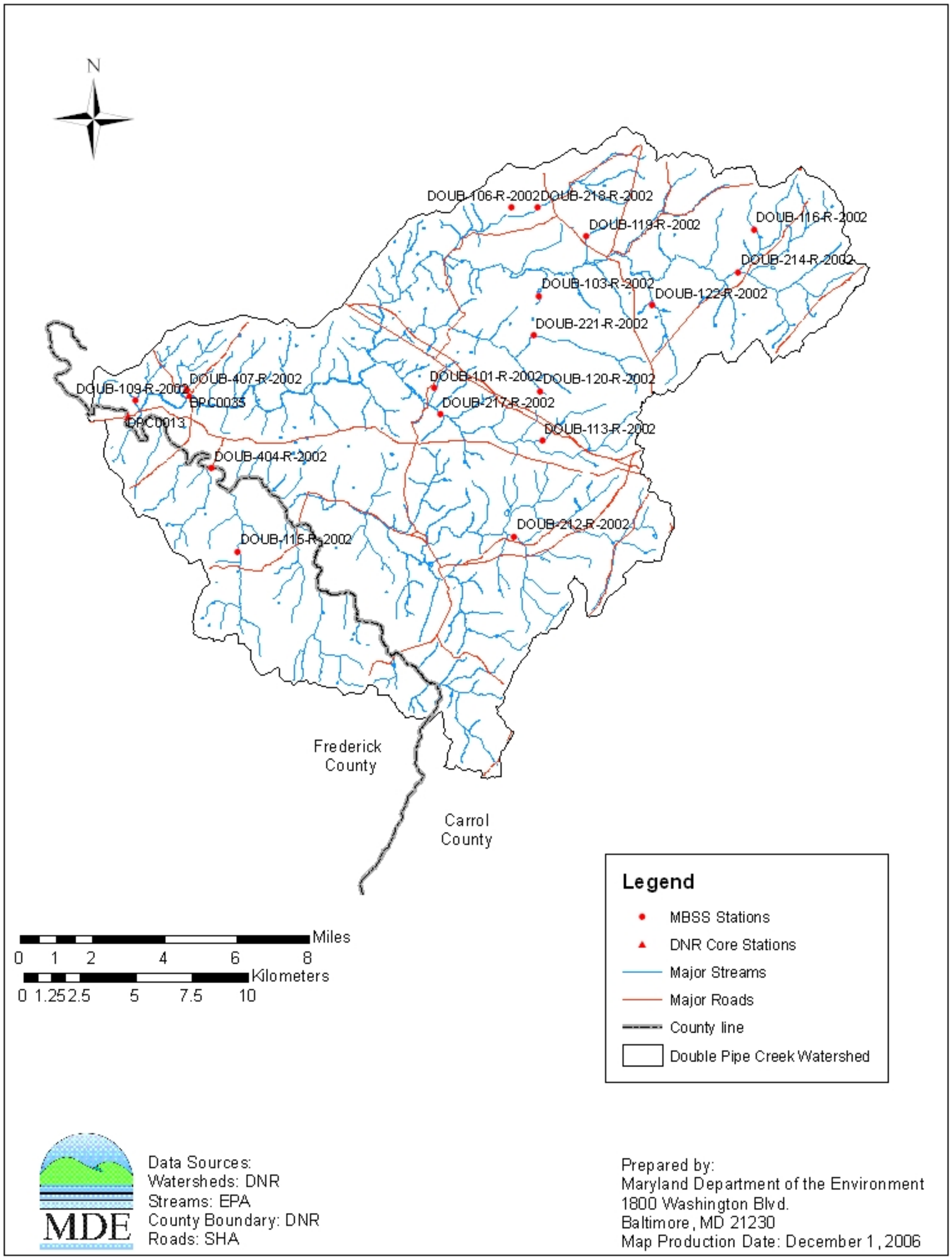


Figure 4: Monitoring Stations in the Double Pipe Creek Watershed

Table 5: Monitoring Stations in the Double Pipe Creek Watershed

Site Number	Sponsor	Site Type	Site Name	Latitude (dec degrees)	Longitude (dec degrees)
DOUB-101-R-2002	MD DNR	MBSS	Meadow Bridge, unnamed tributary 1	39.61518	-77.10986
DOUB-103-R-2002	MD DNR	MBSS	Big Pipe Creek, unnamed tributary 7	39.65203	-77.05572
DOUB-106-R-2002	MD DNR	MBSS	Big Silver Run, unnamed tributary	39.68727	-77.07026
DOUB-109-R-2002	MD DNR	MBSS	Big Pipe Creek, unnamed tributary 6	39.61004	-77.26558
DOUB-113-R-2002	MD DNR	MBSS	Meadow Bridge, unnamed tributary	39.59428	-77.05386
DOUB-115-R-2002	MD DNR	MBSS	Beaver Dam Creek	39.54976	-77.21206
DOUB-116-R-2002	MD DNR	MBSS	Big Pipe Creek, unnamed tributary 5	39.67856	-76.94386
DOUB-119-R-2002	MD DNR	MBSS	Big Pipe Creek, unnamed tributary 8	39.67575	-77.03103
DOUB-120-R-2002	MD DNR	MBSS	Bear Bridge, unnamed tributary	39.61395	-77.05510
DOUB-122-R-2002	MD DNR	MBSS	Bear Bridge	39.64833	-76.99659
DOUB-212-R-2002	MD DNR	MBSS	Turkey Foot Run	39.55579	-77.06834
DOUB-214-R-2002	MD DNR	MBSS	Big Pipe Creek	39.66154	-76.95174
DOUB-217-R-2002	MD DNR	MBSS	Meadow Bridge	39.60457	-77.10705
DOUB-218-R-2002	MD DNR	MBSS	Big Silver Run	39.68722	-77.05655
DOUB-221-R-2002	MD DNR	MBSS	Bear Bridge	39.63630	-77.05855
DOUB-404-R-2002	MD DNR	MBSS	Little Pipe Creek	39.58306	-77.22582
DOUB-407-R-2002	MD DNR	MBSS	Big Pipe Creek	39.61399	-77.23902
BPC0035	MD DNR	Trend	Big Pipe Creek	39.61194	-77.23750
DPC0013	MD DNR	Trend	Double Pipe Creek	39.60361	-77.26944

<u>Double Pipe Creek MBSS Monitoring Stations</u>

The MBSS program monitored 17 locations in the Double Pipe Creek watershed in 2002 (see Figure 4). The MBSS parameters recommended from the stressor identification model for determining a sediment stressor were: percent embeddedness, epifaunal substrate score, instream habitat score, bank stability, and number of benthic tolerant species. These specific parameters were chosen based on their ecological and statistical significance (Southerland et al. 2007) as well as their linkage to increased terrestrial and/or instream erosion. High percent embeddedness indicates that fine particulates are filling the spaces between cobbles, thus covering habitat and limiting food supply. Low epifaunal substrate is an indication of either stream erosion or excess deposition limiting the quality of the streambed to support a benthic community. Decreased instream habitat is an indication of potential erosion removing woody debris and is primarily linked with the Fish Index of Biotic Integrity (FIBI). The bank stability index is a composite score that indicates the lack of channel erosion, based on the presence or absence of riparian vegetation and other stabilizing bank materials. The number of benthic tolerant species is an indicator of frequent stream scouring, which prevents more sensitive species from colonizing the streambed.

Observed values of the above parameters, along with Benthic Index of Biotic Integrity (BIBI) and FIBI scores, are presented in Table 6.

Table 6: Double Pipe Creek MBSS Data

Site	FIBI	BIBI	Epifaunal Substrate	Percent embeddedness	Instream Habitat	Bank Stability	Benthic Tolerant Species
DOUB-101-R-2002	2.00	2.25	5	90	6	11.20	5.27
DOUB-103-R-2002	1.00	1.75	2	100	2	18.53	5.81
DOUB-106-R-2002	NS	1.75	NS	NS	NS	NS	5.83
DOUB-109-R-2002	NS	3.00	NS	NS	NS	NS	5.70
DOUB-113-R-2002	3.67	2.75	13	25	10	13.80	4.80
DOUB-115-R-2002	3.33	2.25	13	25	11	15.53	5.70
DOUB-116-R-2002	4.00	3.75	16	20	15	14.53	4.18
DOUB-119-R-2002	3.67	4.00	12	35	13	14.30	5.00
DOUB-120-R-2002	1.67	2.00	11	25	9	15.90	6.05
DOUB-122-R-2002	3.67	2.75	11	40	12	11.30	4.69
DOUB-212-R-2002	4.00	2.25	12	75	13	10.27	5.61
DOUB-214-R-2002	3.67	2.50	14	45	16	13.60	4.88
DOUB-217-R-2002	3.67	2.75	12	40	13	11.50	5.40
DOUB-218-R-2002	4.00	2.75	11	35	11	7.00	5.24
DOUB-221-R-2002	3.67	3.75	14	35	15	13.00	4.63
DOUB-404-R-2002	3.33	2.25	13	17	15	3.33	5.43
DOUB-407-R-2002	3.67	3.75	8	45	8	18.47	4.44

Note: NS = No Sample

Double Pipe Creek Core Stations

Additional data for Double Pipe Creek was obtained from the Maryland Department of Natural Resources (DNR) Core/Trend program. The program collected benthic macroinvertebrate data between 1976 and 2006. This data was used to calculate four benthic community measures: total number of taxa, Shannon-Weiner diversity index, modified Hilsenhoff biotic index, and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT). DNR has monitoring information for two stations in the mainstem of Double Pipe Creek through the Core/Trend program. The stations are Big Pipe Creek (BPC0035) and Double Pipe Creek (DPC0013). The Big Pipe Creek station has 21 years of data between 1977 and 2006. The Double Pipe Creek station has 15 years of data between 1977 and 2006 (DNR 2007). Overall results for the stations appear in Table 7.

Table 7: Double Pipe Creek DNR Core Data

Site Number	Current Water Quality Status	Trend Since 1970's
BPC0035	Good/Very Good	Degradation
DPC0013	Good	Degradation

2.4 Water Quality Impairment

The Maryland water quality standards surface water use designation for the Double Pipe Creek watershed and its tributaries is Use IV-P (Recreational Trout Waters and Public Water Supply) (COMAR 2007a,b). The water quality impairment of the Double Pipe Creek watershed addressed by this TMDL is caused by an elevated sediment load beyond a level that is supportive of aquatic health, where aquatic health is evaluated based on the benthic and fish IBI scores (BIBI and FIBI $\geq$ 3).

To determine whether aquatic health is impacted by elevated sediment loads, a weight-of-evidence stressor identification approach was used. This approach applies a composite stressor indicator, defined as the *sediment stream disturbance index*. Similar to the Index of Biotic Integrity, the SSDI is based on a comparison of specific watershed parameters with those from streams with a healthy aquatic community (i.e., reference watersheds) and is scored separately for the benthic and fish communities. The benthic SSDI includes benthic tolerant species, embeddedness, bank stability, and epifaunal substrate condition. The fish SSDI includes embeddedness, epifaunal substrate, and instream habitat condition. Watershed specific SSDI values indicate whether sediment is one of the stressors affecting the biological community.

The SSDI is developed by scoring each parameter result (see Section 2.3) and then calculating the average of the scores to form an index value. Each parameter result is scored a value of 1, 3, or 5, depending on whether its original parameter value at a site approximates (5), deviates slightly from (3), or deviates greatly from (1) conditions at reference sites (Karr et al. 1986). This discrete scoring approach was based on Maryland's IBI methodology, so that a direct comparison could be made between the SSDI and the IBI thresholds. Per Maryland's biocriteria, FIBI and BIBI scores less than 3 are indicative of water quality conditions that are not protective of aquatic life (Roth et al. 1998, 2000; Stribling et al. 1998). Similarly, an SSDI score less than 3 provides evidence of a sediment stressor or sediment impact to the aquatic community. An SSDI score significantly greater than 3 indicates that there is no evidence of an adverse sediment impact to the aquatic community.

The threshold values for each selected parameter were established based on how they compared to the values observed at the reference sites (i.e., sites with FIBI & BIBI>3.0). For parameters expected to decrease with degradation, values below the 10^{th} percentile were scored as 1. Values between the 10^{th} and 50^{th} percentiles were scored as 3. Values above the 50^{th} percentile were scored as 5. Scoring was reversed for metrics expected to increase with degradation (i.e., values below the 50^{th} percentile were scored as 5, and values above the 90^{th} percentile were scored as 1). In this method, both the upper and lower thresholds are independently derived from the distribution of reference site values. This approach is based on the assumption that in Maryland, and most other states, even reference sites are expected to have some degree of anthropogenic impact (Southerland et al. 2005). Thresholds used for scoring the SSDI are summarized in Table 8.

Table 8: Sediment Stream Disturbance Index Scoring

Parameter	Score		
	1	3	5
Benthic Tolerant Species Limits	x ≥ 5.3	5.3 > x ≥ 4.2	x <4.2
Bank Stability	x < 12	12 ≤ x < 19	x ≥ 19
Embeddedness Limits	x > 40	40 ≥ x > 25	x ≤ 25
Epifaunal Substrate Limits	x < 10	10 ≤ x < 15	x ≥ 15
Instream Habitat Condition Limits	x < 10	10 ≤ x < 16	x ≥ 16

The Double Pipe Creek watershed average BIBIs, FIBIs, and corresponding SSDIs are listed in Table 9. The BIBIs and FIBIs indicate that the watershed is exhibiting a negative deviation from reference conditions. Both the benthic and fish based SSDIs indicate that sediment is a stressor to the aquatic community. Therefore, it is concluded that a sediment TMDL is required.

Table 9: Double Pipe IBI and SSDI Values

Site	BIBI	BSSDI	FIBI	FSSDI
DOUB-101-R-2002	2.25	1.50	2.00	1.00
DOUB-103-R-2002	1.75	1.50	1.00	1.00
DOUB-106-R-2002	1.75	1.00	NS	NS
DOUB-109-R-2002	3.00	1.00	NS	NS
DOUB-113-R-2002	2.75	3.50	3.67	3.67
DOUB-115-R-2002	2.25	3.00	3.33	3.67
DOUB-116-R-2002	3.75	4.50	4.00	4.33
DOUB-119-R-2002	4.00	3.00	3.67	3.00
DOUB-120-R-2002	2.00	3.00	1.67	3.00
DOUB-122-R-2002	2.75	2.50	3.67	3.00
DOUB-212-R-2002	2.25	1.50	4.00	2.33
DOUB-214-R-2002	2.50	2.50	3.67	3.00
DOUB-217-R-2002	2.75	2.00	3.67	3.00
DOUB-218-R-2002	2.75	2.50	4.00	3.00
DOUB-221-R-2002	3.75	3.00	3.67	3.00
DOUB-404-R-2002	2.25	2.50	3.33	3.67
DOUB-407-R-2002	3.75	2.00	3.67	1.00
Average	**2.72 ± 0.29**	**2.38 ± 0.37**	**3.27 ± 0.39**	**2.78 ± 0.44**

Note: NS = No Sample

3.0 TARGETED WATER QUALITY GOAL

The objective of the sediment TMDL established herein is to reduce sediment loads, and subsequent effects on aquatic health, in the Double Pipe Creek watershed to levels that support the Use IV-P designation (Recreational Trout Waters and Public Water Supply) (COMAR 2007a,b). 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 IBI (Roth et al. 1998, 2000; Stribling et al. 1998).

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

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section describes how the sediment TMDL and the corresponding allocations were developed for Double Pipe Creek. Section 4.2 describes the analysis framework for estimating sediment 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

The stressor identification methodology (see Section 2.3) identifies the most direct measure of sediment pollutant loading as water column TSS concentrations. Elevated TSS loads are linked with negative sediment impacts to stream geomorphology and aquatic health. Since TSS numeric criterion is not available, a reference watershed approach will be used to establish the TMDL.

Watershed Model

The watershed model framework chosen for the Double Pipe Creek TMDL was the CBP P5 long-term average annual watershed model EOS loading rates. The spatial domain of the CBP P5 watershed model segmentation aggregates to the Maryland 8-digit watersheds, which is consistent with the impairment listing. The EOS loading rates were used because actual time variable CBP P5 calibration and scenario runs are currently being developed and are not yet available. These target-loading rates are used to calibrate the land use EOS loads within the CBP P5 model and thus should be consistent with future CBP modeling efforts.

The Double Pipe Creek nonpoint source and NPDES stormwater baseline sediment loads are calculated as the sum of corresponding land use EOS loads within the watershed and represent a long-term average loading rate. Individual land use EOS loads are calculated as a product of the land use area, land use target loading rate, and loss from the EOF to the main channel. The loss from the EOF to the main channel is the *sediment delivery ratio* and is defined as the ratio of the sediment load reaching a basin outlet to the total erosion within the basin. A *sediment delivery ratio* is estimated for each land use type based on the proximity of the land use to the main channel. Thus, as the distance to the main channel increases, more sediment is stored within the channels (i.e., *sediment delivery ratio* decreases). Details of the data sources for the unit loading rates can be found in Section 2.2 of this report.

The Double Pipe Creek watershed was evaluated using two watershed TMDL segments (see Figure 5). TMDL Segment 1 represents the sediment loads transported from Big Pipe Creek in the northern portion of the watershed. TMDL Segment 2 represents the sediment loads transported from Little Pipe Creek in the southern portion of the watershed.

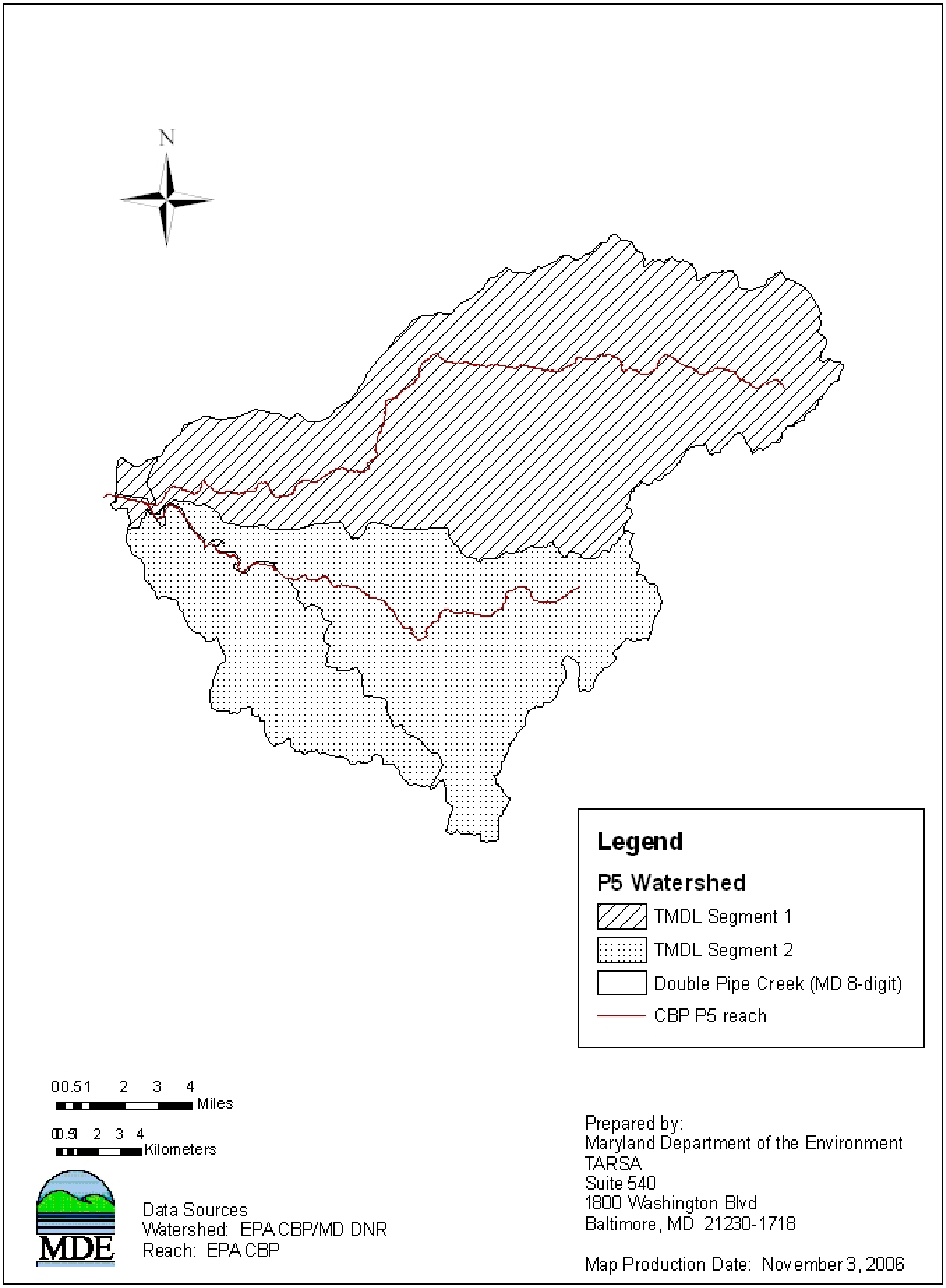


Figure 5: Double Pipe Creek Watershed TMDL Segmentation

Reference Watershed Approach

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems. Therefore, in order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL approach was used and resulted in the establishment of a *sediment loading threshold* for watersheds within the Highland and Piedmont physiographic regions (Currey et al. 2006). In summary, reference watersheds were determined based on the BIBI/FIBI average watershed scores significantly greater than 3.0 (based on a scale of 1 to 5). A threshold of 3.0 was selected because this is the level indicative of satisfactory water quality per Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998). In determining if the average watershed score is significantly greater than 3.0, a 90% confidence interval was calculated for each watershed based on the individual MBSS sampling results.

Comparison of watershed sediment 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 sediment loads were then normalized by a constant background condition, the all forested watershed condition. This new normalized term, defined as the *forest normalized sediment load* (Y_n), represents how many times greater the current watershed sediment load is than the *all forested sediment load*. A similar approach was used by EPA Region 9 for sediment TMDLs in California (e.g., Navarro River or Trinity River TMDLs), where the loading capacity was based on an analysis of the amount of human-caused sediment delivery that can occur in addition to natural sediment delivery, without causing adverse impacts to aquatic life. The *forest normalized sediment load* for this TMDL is calculated as the current watershed sediment load divided by the *all forested sediment load*. The equation for the *forest normalized sediment load* is as follows:

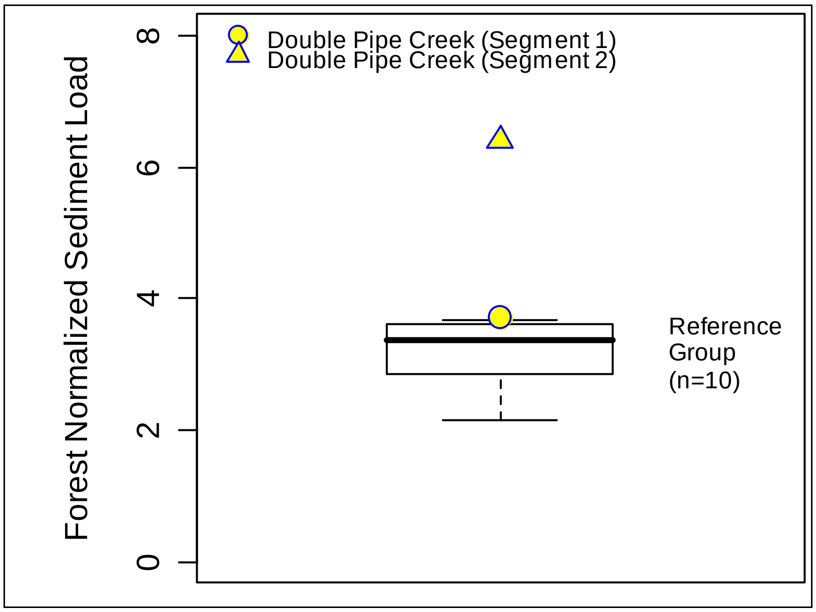
$$Y_n = \frac{y_{ws}}{y_{for}} \qquad \text{(Equation 4.1)}$$

where:

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

An average *sediment loading threshold* of approximately 3.6 was established in Currey et al. (2006) with an 80% confidence interval ranging from 3.3 to 4.1. The lower confidence interval of 3.3 was chosen as an environmentally conservative approach to develop this TMDL (see Appendix A for more details).

A comparison of the Double Pipe Creek watershed *forest normalized sediment loads* to the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) is shown in Figure 6. Both TMDL segments exceed the *sediment loading threshold*, indicating that they are receiving loads that are above the maximum allowable load that the watershed can sustain and still meet water quality standards.



Note: The *forest normalized sediment load* is unitless and represents how many times greater the current watershed sediment load is than the *all forested sediment load.*

Figure 6: Double Pipe Creek Forest Normalized Sediment Load Compared to Reference Watershed Group

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 sediment load reductions. The analyses are grouped according to baseline conditions and future conditions associated with TMDLs.

Baseline Conditions

The baseline conditions are intended to provide a point of reference by which to compare the future scenario that simulates conditions of a TMDL. 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 Double Pipe Creek watershed baseline sediment loads are estimated using the CBP P5 target EOS land use sediment loading rates with the CBP P5 2000 land use. Watershed loading calculations, based on the CBP P5 segmentation scheme, are represented by multiple CBP P5 model segments within each TMDL segment. The TSS loads from these segments are combined to represent the baseline condition. The Maryland point source sediment loads are estimated based on the existing permit information. Details of these loading source estimates can be found in Section 2.2, Section 4.6, and Appendix B of this report.

Future (TMDL) Conditions

This scenario represents the future conditions of maximum allowable sediment loads that will support a healthy biological community. In the TMDL calculation, the allowable load for the impaired watershed is calculated as the product of the *sediment loading threshold* (determined from watersheds with a healthy benthic community) and the Double Pipe Creek *all forested sediment load* (see Section 4.2). The resulting load is considered the maximum allowable load the watershed can receive and still meet water quality standards.

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

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

where
TMDL = allowable load for impaired watershed (ton/yr)
Yn_{ref} = sediment loading threshold = forest normalized reference sediment load (3.3)
$y_{forest\,i}$ = all forested sediment load for segment *i* (ton /yr)
i = CBP P5 model segment
n = number of CBP P5 model segments in watershed

The Double Pipe Creek TMDL is estimated using equation 4.2.

4.4 Critical Condition and Seasonality

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2007b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds integrates the stress effects over the course of time and thus inherently addresses critical conditions. Seasonality is captured in two components. First, it is implicitly included through the use of the biological monitoring data. Second, the MBSS dataset included benthic sampling in the spring and fish sampling in the summer.

4.5 TMDL Loading Caps

This section presents the Double Pipe Creek watershed average annual TMDL of TSS. This load is considered the maximum allowable long-term average annual load the watershed can receive and still meet water quality standards.

The long-term average annual TMDL was calculated for both TMDL Segment 1 and Segment 2 (see Figure 5) independently, based on Equation 4.2 and set at a load 3.3 times the all forested condition. A constant reduction was estimated for the predominant controllable sources (i.e., significant contributors of sediment to the stream system) in each TMDL segment, independent of jurisdiction. If only these predominant (generally the largest) sources are controlled, water quality standards can be achieved in the most effective, efficient, and equitable manner. Predominant sources typically include urban land, high till crops, low till crops, hay, pasture, and harvested forest, but additional sources might need to be controlled in order to ensure that the water quality standards are attained.

The Double Pipe Creek Baseline Load and TMDL are presented in Table 10.

Table 10: Double Pipe Creek Baseline Load and TMDL

	Baseline Load (Ton/Yr)	TMDL (Ton/Yr)	Reduction (%)
TMDL Segment 1	16,823.9	14,871.0	11.6
TMDL Segment 2	18,400.4	9,328.1	49.3
Total	35,224.3	24,199.1	31.3

4.6 Load Allocations Between Point and Nonpoint Sources

The allocations described in this section summarize the TMDL of TSS established to meet the water quality criteria in the Double Pipe Creek watershed. Per EPA regulation, all TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint source loads generated within the assessment unit, as well as natural background, tributary, and adjacent segment loads (CFR 2007a). Consequently, the Double Pipe Creek watershed TMDL allocations are presented in terms of WLAs (i.e., point source loads identified within the watershed) and LAs (i.e., the nonpoint source loads within the watershed). The State reserves the right to revise these allocations provided the revisions are consistent with achieving water quality standards.

As described in Section 4.5, a constant reduction was applied to the predominant controllable sources. In this watershed, crop, pasture, and urban land were identified as the predominant controllable sources. Forest is the only non-controllable source, as it represents the most natural condition in the watershed. No reductions were applied to permitted process water sources because at 1.0% of the total load, such controls would produce no discernable water quality benefit.

Table 11 summarizes the TMDL reductions derived by applying the reduction equally to the predominant controllable sediment sources. Tables 12 and 13 summarize the TMDL scenarios for TMDL Segments 1 and 2 individually. The source categories in Tables 11 – 13 represent aggregates of multiple sources (e.g. crop source is an aggregate of high till, low till, hay, animal feeding operations, and nursery sources). The TMDL results in an overall reduction of 31.3% for the Double Pipe Creek watershed.

Table 11: Double Pipe Creek TMDL Reductions by Source Category

	Baseline Load Source Categories	Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Nonpoint Source	Crop	24,885.4	LA	16,438.1	33.9
	Extractive	136.2		136.2	0.0
	Forest	2,200.8		2,200.8	0.0
	Pasture	2,452.2		1,686.1	31.2
Point Source	Urban	5,189.8	WLA	3,377.9	34.9
	Permitted	360.0		360.0	0.0
	Total	**35,224.3**		**24,199.1**	**31.3**

Table 12: Double Pipe Creek TMDL Segment 1 Reductions by Source Category

	Baseline Load Source Categories	Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Nonpoint Source	Crop	11,838.4	LA	10,286.9	13.1
	Extractive	7.6		7.6	0.0
	Forest	1,564.5		1,564.5	0.0
	Pasture	1,183.1		1,041.4	12.0
Point Source	Urban	2,228.5	WLA	1,968.9	11.7
	Permitted	1.8		1.8	0.0
	Total	**16,823.9**		**14,871.0**	**11.6%**

Table 13: Double Pipe Creek TMDL Segment 2 Reductions by Source Category

	Baseline Load Source Categories	Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Nonpoint Source	Crop	13,047.0	LA	6,151.2	52.9
	Extractive	128.6		128.6	0.0
	Forest	636.3		636.3	0.0
	Pasture	1,269.1		644.7	49.2
Point Source	Urban	2,961.3	WLA	1,409.1	52.4
	Permitted	358.2		358.2	0.0
	Total	**18,400.4**		**9,328.1**	**49.3**

The WLA of the Double Pipe Creek watershed is allocated to two permitted source categories, Process Water WLA and Stormwater WLA. The categories are described below.

Process Water WLA

Process Water permits with specific TSS limits and corresponding flow information are assigned to the WLA. In this case, detailed information is available to accurately estimate the WLA. If specific TSS limits are not explicitly stated in the process water permit, then TSS loads are expected to be *de minimis*. If loads are *de minimis*, then they pose little or no risk to the aquatic environment and are not a significant source.

Process Water permits with specific TSS limits include:

- Individual industrial facilities
- Individual municipal facilities
- General mineral mining facilities

There are 11 process water sources with explicit TSS limits (see Appendix B), which include 1 industrial source, 6 municipal sources, and 4 mineral mines. The total estimated TSS load from all of the process water sources is based on current permit limits and is equal to 360.0 ton/yr. As mentioned above, no reductions were applied to this source because at 1.0% of the total load, such controls would produce no discernable water quality benefit.

Stormwater WLA

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

- Small, medium, and large MS4s – these can be owned by local jurisdictions, municipalities, and state and federal entities e.g., departments of transportation, hospitals, military bases),
- General industrial stormwater permitted facilities, and
- Small and large construction sites.

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 Double Pipe Creek watershed 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 Double Pipe Creek NPDES stormwater WLA is based on reductions applied to the sediment load from the urban land use of the watershed and may include legacy or other sediment sources. Some of these sources may also be subject to controls from other management programs. The Double Pipe Creek NPDES stormwater WLA requires an overall reduction of 34.9% (see Table 11). The NPDES stormwater WLA distribution between Frederick County and Carroll County is presented in Appendix B. It constitutes a proportional allocation of the stormwater load to the entire urban land area of each county and may include any or all of the NPDES stormwater discharges listed above.

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 consistent with achieving water quality standards.

For more information on methods used to calculate the baseline urban sediment load see Section 2.2.2. Additionally, Appendix B provides a detailed summary of all point source allocations.

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 2007b). 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 group *forest normalized sediment loads* indicates that approximately 75% of the reference watersheds have a value of less than 3.6, consistent with the recommended value reported by Currey et al. (2006). Also, 50% of the reference watersheds have a value less than 3.3, consistent with the lower confidence interval value reported in Currey et al. (2006). Based on this analysis the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) was set at the median value of 3.3. This is considered an environmentally conservative estimate, since 50% of the reference watersheds have a load above this value, which when compared to the 75% value, results in an implicit margin of safety of approximately 8%.

4.8 Summary of Total Maximum Daily Loads

The average annual Double Pipe Creek TMDL is summarized in Table 14. The TMDL is the sum of the LA, NPDES Stormwater WLA, Process Water WLA, and MOS. The Maximum Daily Load (MDL) is summarized in Table 15 (See Appendix C for more details).

Table 14: Double Pipe Creek Watershed Average Annual TMDL of Sediment/TSS (ton/yr)

	TMDL (ton/yr) =	LA_{DP} +	NPDES Stormwater WLA_{DP} +	Process Water WLA_{DP} +	MOS
TMDL Segment 1	14,871.0	12,900.3	1,968.9	1.8	Implicit
TMDL Segment 2	9,328.1	7,560.8	1,409.1	358.2	Implicit
Total	24,199.1	20,461.1	3,377.9	360.0	Implicit

Table 15: Double Pipe Watershed Maximum Daily Loads of Sediment/TSS (ton/day)

	MDL (ton/day) =	LA_{DP} +	NPDES Stormwater WLA_{DP} +	Process Water WLA_{DP} +	MOS
TMDL Segment 1	535.3	464.4	70.9	0.02	Implicit
TMDL Segment 2	325.5	272.2	50.7	2.56	Implicit
Total	860.8	736.6	121.6	2.58	Implicit

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the sediment TMDL will be achieved and maintained. 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 (CFR 2007b). Maryland has several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) and the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act).

Potential funding sources for implementation include the Buffer Incentive Program (BIP) and the Maryland Agriculture water quality cost share program (MACS). Other funding available for local governments includes the State Water Quality Revolving Loan Fund and the Stormwater Pollution Cost Share Program. Details of these programs and additional funding sources can be found at http://www.dnr.state.md.us/bay/services/summaries.html.

Potential best management practices for reducing sediment loads and resulting impacts can be grouped into three general categories. The first is directed toward agricultural lands, the second towards urban (developed) land, and the third applies to all land uses.

In agricultural areas comprehensive soil conservation plans can be developed that meet criteria of the USDA-NRCS Field Office Technical Guide (USDA 1983). Soil conservation plans help control erosion by modifying cultural practices or structural practices. Cultural practices may change from year to year and include changes to crop rotations, tillage practices, or use of cover crops. Structural practices are long-term measures that include, but are not limited to, the installation of grass waterways (in areas with concentrated flow), terraces, diversions, sediment basins, or drop structures. The reduction percentage attributed to cultural practices is determined based on changes in land use, while structural practices have a reduction percentage up to 25%. In addition, livestock can be controlled via stream fencing and rotational grazing. Sediment reduction efficiencies of methods applicable to pasture land use range from 40% to 75% (US EPA 2004).

Sediment from urban areas can be reduced by stormwater retrofits, impervious surface reduction, and stream restoration. Stormwater retrofits include modification of existing stormwater structural practices to address water quality. Reductions range from as low as 10% for dry detention to approximately 80% for wet ponds, wetlands, infiltration practices, and filtering practices. Impervious surface reduction results in a change in hydrology that could reduce stream erosion (US EPA 2003).

All non-forested land uses can benefit from improved riparian buffer systems. A riparian buffer reduces the effects of upland sediment sources through trapping and filtering. Riparian buffer efficiencies vary depending on type (grass or forested), land use (urban or agriculture), and physiographic region. The CBP estimates riparian buffer sediment reduction efficiencies in the Double Pipe Creek region to be approximately 50% (US EPA 2006).

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

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APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds

MD 8-digit Name[1]	MD 8-digit	FIBI n	BIBI n	FIBI[4]	BIBI	Forest Normalized[2] Sediment Load
Deer Creek	02120202	28	28	Ind.	Pass	3.63
Broad Creek	02120205	10	10	Ind.	Pass	3.67
Little Gunpowder Falls	02130804	19	20	Ind.	Pass	3.26
Prettyboy Reservoir	02130806	11	11	Pass	Pass	2.87
Liberty Reservoir	02130907	31	31	Pass	Pass	3.28
S Branch Patapsco	02130908	10	10	Pass	Pass	3.57
Rocky Gorge Dam	02131107	10	10	Pass	Pass	3.43
Brighton Dam	02131108	11	11	Ind.	Pass	3.61
Town Creek	02140512	16	20	Ind.	Pass	2.17
Savage River	02141006	13	14	Pass	Pass	2.48
Median[3]						3.3
75th Percentile						3.6

Notes: 1 Potomac River Lower North Branch determined to be an outlier through statistical analysis and best professional judgment; Fifteen Mile Creek watershed was removed because the majority of the watershed is in Pennsylvania.
2 Forest normalized sediment loads based on Maryland watershed area only (consistent with MBSS random monitoring data).
3 Median rounded down (3.36 to 3.3) as conservative estimate.
4 Ind.= Indeterminate.

Table A-2: Benthic SSDI Calculation

Site	Benthic Tolerant Species	Percent embeddedness	Epifaunal Substrate	Bank Stability Index	Benthic SSDI
DOUB-101-R-2002	3	1	1	1	1.50
DOUB-103-R-2002	1	1	1	3	1.50
DOUB-106-R-2002	1	NS	NS	NS	1.00
DOUB-109-R-2002	1	NS	NS	NS	1.00
DOUB-113-R-2002	3	5	3	3	3.50
DOUB-115-R-2002	1	5	3	3	3.00
DOUB-116-R-2002	5	5	5	3	4.50
DOUB-119-R-2002	3	3	3	3	3.00
DOUB-120-R-2002	1	5	3	3	3.00
DOUB-122-R-2002	3	3	3	1	2.50
DOUB-212-R-2002	1	1	3	1	1.50
DOUB-214-R-2002	3	1	3	3	2.50
DOUB-217-R-2002	1	3	3	1	2.00
DOUB-218-R-2002	3	3	3	1	2.50
DOUB-221-R-2002	3	3	3	3	3.00
DOUB-404-R-2002	1	5	3	1	2.50
DOUB-407-R-2002	3	1	1	3	2.00
Average	**2.18**	**3.00**	**2.73**	**2.20**	**2.38 ± 0.37**

Note: NS = No sample

Table A-3: Fish SSDI Calculation

Site	Percent embeddedness	Epifaunal Substrate	Instream Habitat	Fish SSDI
DOUB-101-R-2002	1	1	1	1.00
DOUB-103-R-2002	1	1	1	1.00
DOUB-106-R-2002	NS	NS	NS	NS
DOUB-109-R-2002	NS	NS	NS	NS
DOUB-113-R-2002	5	3	3	3.67
DOUB-115-R-2002	5	3	3	3.67
DOUB-116-R-2002	5	5	3	4.33
DOUB-119-R-2002	3	3	3	3.00
DOUB-120-R-2002	5	3	1	3.00
DOUB-122-R-2002	3	3	3	3.00
DOUB-212-R-2002	1	3	3	2.33
DOUB-214-R-2002	1	3	5	3.00
DOUB-217-R-2002	3	3	3	3.00
DOUB-218-R-2002	3	3	3	3.00
DOUB-221-R-2002	3	3	3	3.00
DOUB-404-R-2002	5	3	3	3.67
DOUB-407-R-2002	1	1	1	1.00
Average	**3.00**	**2.73**	**2.60**	**2.78 ± 0.44**

Note: NS = No sample

APPENDIX B – MDE Permit Information

Table B-1: Permit Summary

Permit #	NPDES	Facility	County	City	Type	TMDL
01DP0573	MD0000779	LEHIGH CEMENT COMPANY – UNION BRIDGE	CARROLL	UNION BRIDGE	WMA1	Process Water WLA
00DP0640	MD0022586	NEW WINDSOR WWTP	CARROLL	NEW WINDSOR	WMA2	Process Water WLA
00DP0774A	MD0022454	UNION BRIDGE WWTP	CARROLL	UNION BRIDGE	WMA2	Process Water WLA
00DP3172	MD0067571	BOWLING BROOK PREPARATORY SCHOOL	CARROLL	KEYMAR	WMA2	Process Water WLA
02DP2912	MD0065927	RUNNYMEDE WWTP	CARROLL	WESTMINSTER	WMA2	Process Water WLA
04DP3044	MD0066745	PLEASANT VALLEY WWTP	CARROLL	PLEASANT VALLEY	WMA2	Process Water WLA
04DP0837	MD0021831	WESTMINSTER WWTP	CARROLL	WESTMINSTER	WMA2M	Process Water WLA
00MM0226	MDG490226	LAFARGE - MEDFORD QUARRY	CARROLL	NEW WINDSOR	WMA5	Process Water WLA
00MM0433	MDG490433	WESTMINSTER CONCRETE PLANT	CARROLL	WESTMINSTER	WMA5	Process Water WLA
00MM2448	MDG492448	LEHIGH CEMENT COMPANY – NEW WINDSOR	CARROLL	NEW WINDSOR	WMA5	Process Water WLA
00MM9852	MDG499852	C. J. MILLER, LLC	CARROLL	WESTMINSTER	WMA5	Process Water WLA
02SW0029	N/A	MARADA INDUSTRIES, INC. - PLANT 1	CARROLL	WESTMINSTER	WMA5SW	Stormwater WLA
02SW0662	N/A	BARK HILL LANDFILL	CARROLL	UNION BRIDGE	WMA5SW	Stormwater WLA
02SW0663	N/A	BACHMAN VALLEY TIRE FACILITY	CARROLL	WESTMINSTER	WMA5SW	Stormwater WLA
02SW0665	N/A	JOHN OWINGS LANDFILL	CARROLL	WESTMINSTER	WMA5SW	Stormwater WLA
02SW0920	N/A	UNIVERSAL FOREST PRODUCTS EASTERN DIVISION	CARROLL	NEW WINDSOR	WMA5SW	Stormwater WLA
02SW1098	N/A	HAHN TRANSPORTATION, INC. – UNION BRIDGE	CARROLL	UNION BRIDGE	WMA5SW	Stormwater WLA
02SW1456	N/A	BABYLON VAULT COMPANY, INC.	CARROLL	NEW WINDSOR	WMA5SW	Stormwater WLA
02SW1821	N/A	IMRM WESTERN CARROLL SITE	CARROLL	KEYMAR	WMA5SW	Stormwater WLA
02SW1861	N/A	CARROLL COUNTY MAINTENANCE FACILITY	CARROLL	WESTMINSTER	WMA5SW	Stormwater WLA
02SW3013	N/A	ALMEGA MANUFACTURING CORP.	CARROLL	WESTMINSTER	WMA5SW	Stormwater WLA
02SW3014	N/A	INTROL COMPANY, INC.	CARROLL	WESTMINSTER	WMA5SW	Stormwater WLA
MS4-CL-001	N/A	CITY OF TANEYTOWN MS4	CARROLL	TANEYTOWN	WMA6G	Stormwater WLA
MS4-CL-002	N/A	CITY OF WESTMINSTER MS4	CARROLL	WESTMINSTER	WMA6G	Stormwater WLA

Permit #	NPDES	Facility	County	City	Type	TMDL
MS4-CL-005	N/A	TOWN OF NEW WINDSOR MS4	CARROLL	NEW WINDSOR	WMA6G	Stormwater WLA
MS4-CL-007	N/A	TOWN OF UNION BRIDGE MS4	CARROLL	UNION BRIDGE	WMA6G	Stormwater WLA
01DP3321	MD0068357	FREDERICK COUNTY MS4	FREDERICK	COUNTY WIDE	WMA6G	Stormwater WLA
05DP3319	MD0068331	CARROLL COUNTY MS4	CARROLL	COUNTY WIDE	WMA6G	Stormwater WLA
05SS5501	MD0055501	STATE HIGHWAY ADMINISTRATION MS4	ALL	ALL	WMA6	Stormwater WLA
		MDE GENERAL PERMIT TO CONSTRUCT	ALL	ALL	N/A	Stormwater WLA

Notes: [1]TMDL column identifies how the permit was considered in the TMDL allocation.
[2]WTP = Water Treatment Plant
[3]WWTP = Wastewater Treatment Plant

Table B-2: Industrial and Municipal Permit Data

Facility name	NPDES #	MDE Permit #	Permit Type	Flow (MGD[1])	Permit Avg Monthly Conc. (mg/l[2])	Permit Daily Max Conc. (mg/l)
LEHIGH CEMENT COMPANY - UNION BRIDGE (Outfall 006, 007)	MD0000779	01DP0573	WMA1	1.63	15	30
LEHIGH CEMENT COMPANY - UNION BRIDGE (Outfall 008)	MD0000779	01DP0573	WMA1	0.48	30	60
NEW WINDSOR WWTP	MD0022586	00DP0640	WMA2	0.094	90	N/A
UNION BRIDGE WWTP	MD0022454	00DP0774A	WMA2	0.2	30	N/A
BOWLING BROOK PREPARATORY SCHOOL	MD0067571	00DP3172	WMA2	0.025	30	N/A
RUNNYMEDE WWTP	MD0065927	02DP2912	WMA2	0.02	30	N/A
PLEASANT VALLEY WWTP	MD0066745	04DP3044	WMA2	0.019	30	N/A
WESTMINSTER WWTP	MD0021831	04DP0837	WMA2M	5.0	30	N/A

Notes: [1] MGD = Millions of gallons per day
[2] mg/l = Milligram per liter

Table B-3: General Mine Permit Data

Facility name	NPDES #	MDE Permit #	Permit Type	Flow (MGD)	Permit Avg Quarterly Conc. (mg/l)	Permit Daily Max Conc. (mg/l)
LAFARGE - MEDFORD QUARRY	MDG490226	00MM0226	WMA5	1.8	15	31
WESTMINSTER CONCRETE PLANT	MDG490433	00MM0433	WMA5	0.0005	30	60
LEHIGH CEMENT COMPANY - NEW WINDSOR	MDG492448	00MM2448	WMA5	0.2	15	31
C. J. MILLER, LLC	MDG499852	00MM9852	WMA5	0.0135	30	60

Table B-4: Stormwater Permits[1]

Permit #	Facility	NPDES group
02SW0029	MARADA INDUSTRIES, INC. - PLANT 1	Phase-I
02SW0662	BARK HILL LANDFILL	Phase-I
02SW0663	BACHMAN VALLEY TIRE FACILITY	Phase-I
02SW0665	JOHN OWINGS LANDFILL	Phase-I
02SW0920	UNIVERSAL FOREST PRODUCTS EASTERN DIVISION	Phase-I
02SW1098	HAHN TRANSPORTATION, INC. – UNION BRIDGE	Phase-I
02SW1456	BABYLON VAULT COMPANY, INC.	Phase-I
02SW1821	IMRM WESTERN CARROLL SITE	Phase-I
02SW1861	CARROLL COUNTY MAINTENANCE FACILITY	Phase-I
02SW3013	ALMEGA MANUFACTURING CORP.	Phase-I
02SW3014	INTROL COMPANY, INC.	Phase-I
MS4-CL-001	CITY OF TANEYTOWN MS4	Phase-II
MS4-CL-002	CITY OF WESTMINSTER MS4	Phase-II
MS4-CL-005	TOWN OF NEW WINDSOR MS4	Phase-II
MS4-CL-007	TOWN OF UNION BRIDGE MS4	Phase-II
01DP3321	FREDERICK COUNTY MS4	Phase-I
05DP3319	CARROLL COUNTY MS4	Phase-I
05SS5501	STATE HIGHWAY ADMINISTRATION MS4	Phase-I
	MDE GENERAL PERMIT TO CONSTRUCT	Phase-I/II

Notes: 1. Although not listed in this table, some individual permits from Tables B-2 and B-3 incorporate stormwater requirements and are accounted for within the NPDES stormwater WLA.

Table B-5: NPDES Stormwater Baseline Loads and Wasteload Allocations per County

County	NPDES Stormwater BL_{DP} (tons/yr)	NPDES Stormwater WLA_{DP} (tons/yr)
Carroll County	4,759.2	3,149.0
Frederick County	430.6	228.9
Total	5,189.8	3,377.9

APPENDIX C – Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define maximum daily loads of TSS consistent with the average annual TMDL, which is protective of water quality standards in the Double Pipe Creek Watershed. The approach builds upon the modeling analysis that was conducted to determine the loadings of TSS 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 maximum daily load values. It is divided into sections discussing:

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

Basis for approach

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

- **Average Annual TMDL:** The basis of the average annual sediment TMDL is that cumulative high sediment loading rates have negative impacts on the biological community. Thus, the average annual sediment load was calculated to be protective of the aquatic life designated use.
- **CBP P5 Watershed Model Sediment Loads:** There are two spatial calibration points for sediment within the CBP P5 watershed model framework. First, EOS loads are calibrated to long term EOS target loads. These target loads are the loads used to determine an average annual TMDL. Furthermore, the target loads were used in the TMDL because, as calibration targets, they are expected to remain relatively unchanged during the final calibration stages of the CBP P5 model, and therefore will be the most consistent with the final CBP P5 watershed model TSS loading estimates. Currently, the CBP P5 model river segments are being calibrated to daily monitoring information for watersheds with a flow greater that 100 cfs, or an approximate area of 100 square miles.

- **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.

The rationale for developing TMDLs expressed as *daily* loads was to accept the existing average annual TMDL, but then develop a method for converting this number to a 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 methods to calculate Double Pipe Creek Maximum Daily Loads.

<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 document on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Double Pipe Creek watershed:

1. **Representative daily load:** In this option, a single daily load (or multiple representative daily loads) is specified that covers all time periods and environmental conditions.
2. **Flow-variable daily load:** This option allows the maximum daily load to vary based upon the observed flow condition.
3. **Temporally-variable daily load:** This option allows the maximum daily load to vary based upon seasons or times of varying source or water body behavior.

<u>Probability Level</u>

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

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often conditions can allowably surpass the combined magnitude and duration components.
2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any loading value has some finite probability of being exceeded.

The draft daily load guidance document states that the probability component of the maximum daily load should be "based on a representative statistical measure" that is dependent upon the specific TMDL and the 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 a maximum daily load that would be exceeded 5% of the time.

Selected Approach

The approach selected for defining a Double Pipe Creek Maximum Daily Load was based upon the specific data that exists for each source category. The approach consists of unique methods for each of the following categories of sources:

- Approach for Nonpoint Sources and Stormwater Point Sources
- Approach for Process Water Point Sources

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

The level of resolution selected for the Double Pipe Creek Maximum Daily Load was a representative daily load, expressed as a single daily load for each loading source. This approach was chosen based upon the specific data that exists for nonpoint sources and stormwater point sources. Currently, the best available data is the CBP P5 model daily time series calibrated to long-term average annual loads (per landuse). The CBP reach simulation results are calibrated to daily monitoring information for watershed segments with a flow typically greater that 100 cfs, but they have not been through appropriate peer review. Therefore, it was concluded that it would not be appropriate to apply the absolute values of the reach simulation model results to the TMDL, and the annual loads were used instead. However, it was assumed that the distribution of the daily values was correct, 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 sediment TMDL, and the coefficient of variation (CV) of the CBP P5 Double Pipe Creek reach simulation daily loads. The probability level (or exceedance frequency) is based upon guidance from EPA (US EPA 1991) where examples suggest that when converting from a long-term average to a daily value, the z-score corresponding to the 99th percentile of the log-normal probability distribution should be used. The average annual sediment TMDL is estimated from the CBP P5 EOS target loads. The calculation of the CV is described below.

The CBP P5 Double Pipe Creek reach simulation consisted of a daily time series beginning in 1985 and extending to the year 2005. The CV was estimated by first converting the daily sediment load values to a log distribution and then verifying that the results approximated the normal distribution (see Figure C-1). Next, the CV 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 5.17 was calculated using the following equation:

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

where:
CV = coefficient of variation
$\beta = \alpha\sqrt{e^{\sigma^2} - 1}$
$\alpha = e^{(\mu + 0.5*\sigma^2)}$
α = mean (arithmetic)
β = standard deviation (arithmetic)
μ = mean of logarithms
σ =standard deviation of logarithms

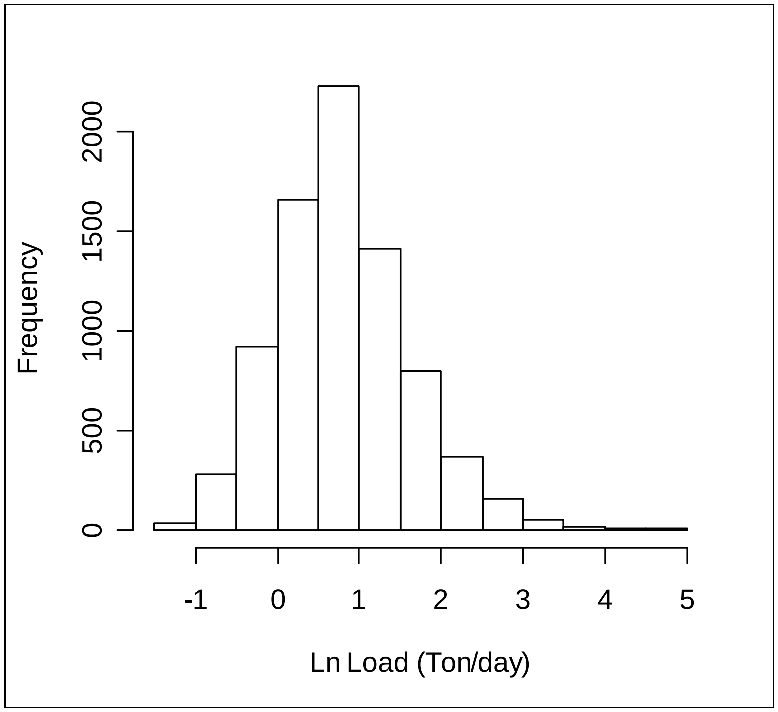


Figure C-1: Histogram of CBP River Segment Daily Simulation Results for the Double Pipe Creek Watershed

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

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

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

Using a z-score associated with the 99^{th} percent probability, a CV of 5.17, and consistent units, the resulting dimensionless conversion factor from long term average annual loads to a maximum daily load is 13.18. The average annual Double Pipe Creek TMDL of sediment/TSS is reported in ton/year, and the conversion from ton/year to a maximum daily load in ton/day is 0.036 (e.g. 13.18/365)

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 sediment limits. As these sources are generally minor contributors to the overall sediment load, the TMDL analysis that defined the average annual TMDL did not propose any reductions for these sources and held each of them constant at their existing technology-based NPDES permit monthly (or daily if monthly was not specified) limit for the entire year.

The approach used to determine 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 Double Pipe Creek TMDL of sediment/TSS is reported in ton/yr, and the conversion from ton/yr to a maximum daily load in ton/day is 0.0085 (e.g. 3.11/365)

Results of approach

This section lists the results of the selected approach to define the Double Pipe Creek Maximum Daily Loads.

- Calculation Approach for Nonpoint Sources and Stormwater Point Sources

LA_{DP} (Ton/day) = Average Annual TMDL LA_{DP} (ton/yr) * .036

NPDES Stormwater WLA_{DP} (Ton/day) = Average Annual TMDL NPDES Stormwater WLA_{DP} (ton/yr) * .036

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

Process Water WLA_{DP} (ton/day) = Permit flow (mgd) * Daily maximum permit limit (mg/l) * 0.0042

  - For permits without a daily maximum limit:

Process Water WLA_{DP} (Ton/day) = Average Annual TMDL Process Water WLA_{DP} Other (ton/yr)* 0.0085

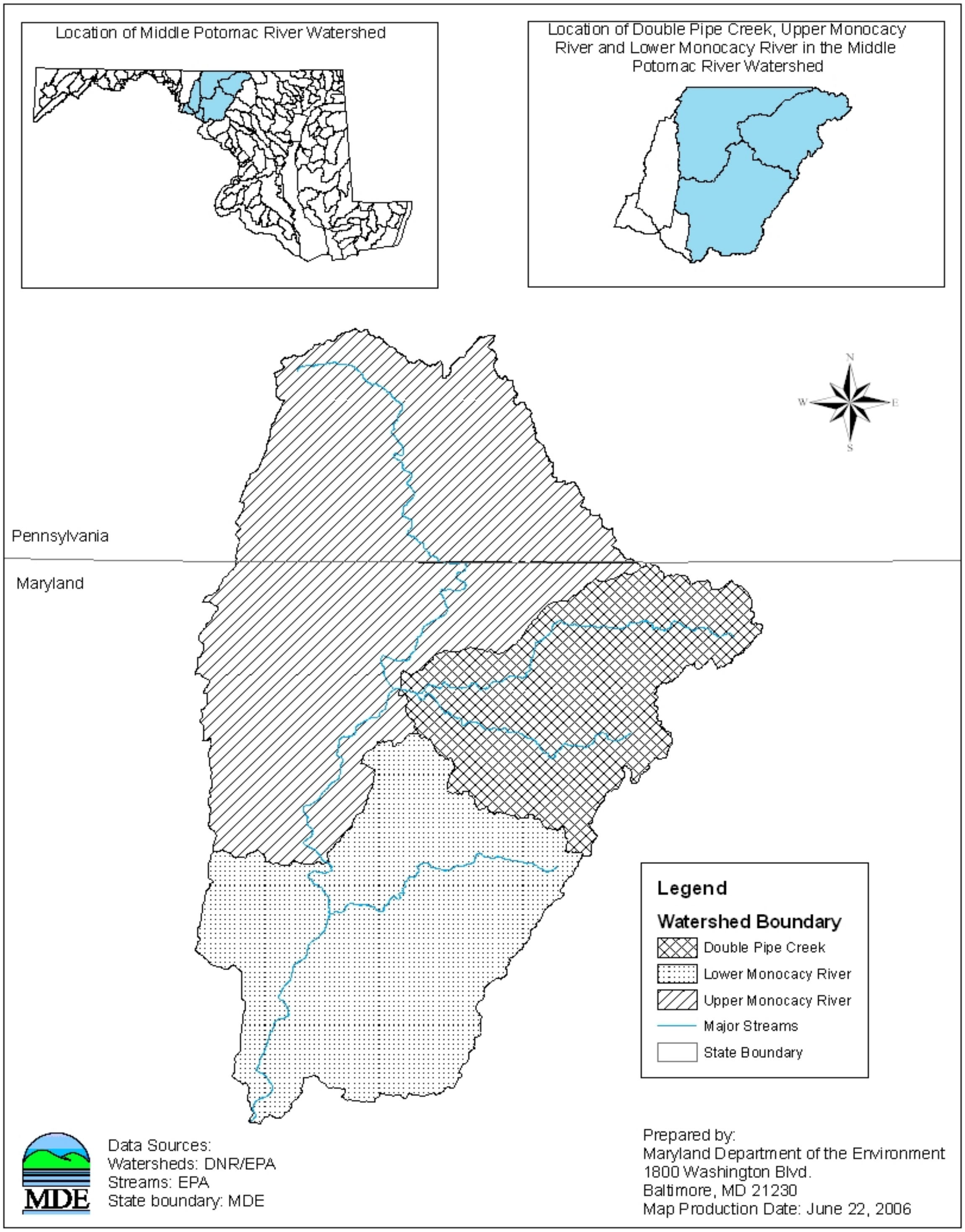
Table C-1: Double Pipe Creek Maximum Daily Loads of Sediment/TSS (ton/day)

MDL (ton/day) =	LA_{DP} +	NPDES Stormwater WLA_{DP} +	Process Water WLA_{DP} +	MOS
860.8	736.6	121.6	2.58	Implicit

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

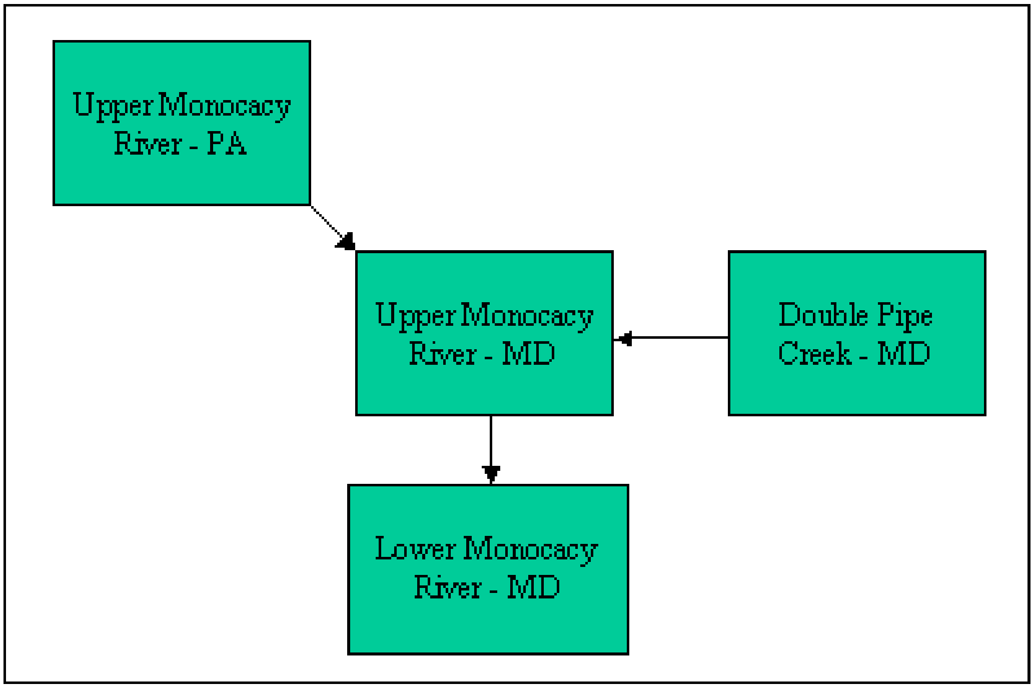
The purpose of this appendix is to explain the hydrologic relationship between the Double Pipe Creek, Upper Monocacy River, and Lower Monocacy River watersheds and how this affects the sediment TMDLs for each of the respective watersheds. As illustrated in Figure D-1, the three watersheds are hydrologically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

The baseline sediment loads for the watersheds are shown in Tables D-1 through D-3. The TMDL calculations are shown in Tables D-4 through D-6. Further information can be found in the individual TMDL documents for each watershed.



Note: A separate sediment TMDL has been developed for Lake Linganore, a subwatershed within Lower Monaocay River watershed (MDE 2003b), and is presented as an upstream load within the Lower Monocacy River TMDL.

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



Note: A separate sediment TMDL has been developed for Lake Linganore, a subwatershed within Lower Monaocay River watershed (MDE 2003b), and is presented as an upstream load within the Lower Monocacy River TMDL.

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

Table D-1: Double Pipe Creek Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{DP}	+	NPDES Stormwater BL_{DP}	+	Process Water BL_{DP}
35,224.3	=	29,674.5	+	5,189.8	+	360.0

Table D-2: MD 8-digit Upper Monocacy River Baseline Sediment Loads (ton/yr)

		Upstream Baseline Load[1]				MD 8-digit Upper Monocacy River Watershed Baseline Load Contribution				
Total Baseline Load (ton/yr)	=	BL_{PA}	+	BL_{DP}[2]	+	Nonpoint Source BL_{UM}	+	NPDES Stormwater BL_{UM}	+	Process Water BL_{UM}
98,725.7	=	20,511.9	+	35,224.3	+	38,679.3	+	4,129.1	+	181.1

Notes:[1] Although the upstream values are reported as single values, they could include point and nonpoint sources.
[2] For Double Pipe Creek point and nonpoint source characterization, please see Section 2.2.3 of this document

Table D-3: Lower Monocacy River Baseline Sediment Loads (ton/yr)

		Upstream Baseline Load[1]			MD 8-digit Lower Monocacy River Watershed Baseline Load Contribution				
Total Baseline Load (ton/yr)	=	BL_{LL}[2]	BL_{UM}[3]	+	Nonpoint Source BL_{LM}	+	NPDES Stormwater BL_{LM}	+	Process Water BL_{LM}
146,420.0	=	11,585.0	98,725.7	+	27,073.4	+	8,312.5	+	723.4

Notes: [1] Although the upstream value is reported as a single value, it includes point and nonpoint sources.
[2] For Lake Linganore watershed point and nonpoint source characterization, please refer to the "Total Maximum Daily Load of Phosphorus and Sediments for Lake Linganore, Frederick County, Maryland" (MDE 2003b).
[3] For Upper Monocacy River watershed point and nonpoint characterization please refer to the "Total Maximum Daily Load of Sediment in the Upper Monocacy River Watershed, Frederick and Carroll Counties, Maryland" (MDE 2008).

Table D-4: Double Pipe Creek Average Annual TMDL (ton/yr)

TMDL (ton/yr) =	LA_{DP} +	NPDES Stormwater WLA_{DP} +	Process Water WLA_{DP} +	MOS
24,199.1	20,461.1	3,377.9	360.0	Implicit

Table D-5: MD 8-digit Upper Monocacy River Average Annual TMDL (ton/yr)

TMDL (ton/yr)	=	LA					+	WLA			+	MOS
		LA_{PA}[1]	+	LA_{DP}[2]	+	LA_{UM}		NPDES Stormwater WLA_{UM}	+	Process Water WLA_{UM}		
66,707.3	=	19,362.2	+	24,199.1	+	20,823.1	+	2,141.8	+	181.1	+	Implicit

Upstream Load Allocation[3, 4] (LA_{PA} + LA_{DP}); MD 8-digit Upper Monocacy River Watershed TMDL Contribution (LA_{UM} through Process Water WLA_{UM})

Notes:
[1] LA_{PA} was determined to be necessary in order to meet Maryland water quality standards within the Upper Monocacy River watershed.
[2] For Double Pipe Creek watershed WLA and LA characterization, see Section 2.2.3 of this document
[3] A delivery factor of 1 was used.
[4] Although for the purpose of this analysis upstream loads are referred to as LAs, they could include point and nonpoint sources.

Table D-6: Lower Monocacy River Average Annual TMDL (ton/yr)

TMDL (ton/yr)	=	LA					+	WLA			+	MOS
		LA_{LL}[1]	+	LA_{UM}[2]	+	LA_{LM}		NPDES Stormwater WLA_{LM}	+	Process Water WLA_{LM}		
90,158.0	=	7,073.0	+	66,707.3	+	12,397.5	+	3,256.8	+	723.4	+	Implicit

Upstream Load Allocation[3,4] (LA_{LL} + LA_{UM}); Lower Monocacy River Watershed TMDL Contribution (LA_{LM} through Process Water WLA_{LM})

Notes:
[1] For the Lake Linganore watershed WLA and LA characterization, please refer to the “Total Maximum Daily Loads of Phosphorus and Sediments for Lake Linganore, Frederick, County, MD” (MDE 2003b).
[2] For Upper Monocacy River watershed point and nonpoint characterization, please refer to the “Total Maximum Daily Load of Sediment in the Upper Monocacy River Watershed, Frederick and Carroll Counties, Maryland” (MDE 2008).
[3] Although for the purpose of this analysis upstream loads are referred to as LAs, they could include point and nonpoint sources.
[4] A delivery factor of 1 was used for all upstream sources.