Total Maximum Daily Load of Sediment in the Catoctin Creek Watershed, Frederick County, Maryland

FINAL

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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
LA	Load Allocation
MACS	Maryland Agriculture Water Quality Cost Share Program
MBSS	Maryland Biological Stream Survey
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 Stormwater System
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRI	Natural Resources Inventory
NS	No Sample

PS	Point Source
PSU	Primary Sampling Unit
RESAC	Regional Earth Science Applications Center
SSDI	Sediment Stream Disturbance Index
TMDL	Total Maximum Daily Load
TSD	Technical Support Document
TSS	Total Suspended Solids
TM	Thematic Mapper
Ton/yr	Tons per Year
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 Catoctin Creek watershed (basin number 02140305). 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 2007).

The Maryland Department of the Environment (MDE) has identified the waters of the Catoctin Creek watershed on the State's 303(d) List as impaired by sediments (1996), nutrients (1996), bacteria (2004), and impacts to biological communities (2002 and 2006) (MDE 2007). The designated use of Catoctin 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. The listings for nutrients, bacteria, and impacts to biological communities will be addressed separately at a future date.

The Catoctin 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 Catoctin 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 Catoctin 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 regulations require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters (CFR 2007). For this TMDL, 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 respects. First, it is implicitly included through the use of the biological monitoring data. Second, the MBSS dataset included benthic sampling collected in the spring and fish sampling collected in the summer.

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 2007). 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 Catoctin Creek Total Baseline Sediment Load is 28,829.2 tons per year (ton/yr), which can be further subdivided into a nonpoint source baseline load (Nonpoint Source BL_{CT}) and two types of point source baseline loads: National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{CT}) and regulated process water (Process Water BL_{CT}) (see Table ES-1). The Catoctin Creek Average Annual TMDL of Sediment/Total Suspended Solids (TSS) is 14,370.3 ton/yr. The Load Allocation (LA_{CT}) is 12,920.1 ton/yr, the NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{CT}) is 1,392.4 ton/yr, and the Process Water Waste Load Allocation (Process Water WLA_{CT}) is 57.8 ton/yr (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 Catoctin Creek watershed, and more specifically, at a level to support aquatic health.

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

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{CT}	+	NPDES Stormwater BL_{CT}	+	Process Water BL_{CT}
28,829.2	=	26,037.1	+	2,734.4	+	57.8

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

TMDL (ton/yr) =	LA_{CT} +	NPDES Stormwater WLA_{CT} +	Process Water WLA_{CT} +	MOS
14,370.3	12,920.1	1,392.4	57.8	Implicit

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

Baseline Load (ton/yr)	TMDL (ton/yr)	Total Reduction (%)
28,829.2	14,370.3	50.2

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.

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.

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 sediments in the Catoctin Creek watershed (basin number 02140305). 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 2007). 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 the Catoctin Creek watershed on the State's 303(d) List as impaired by sediments (1996), nutrients (1996), bacteria (2004), and impacts to biological communities (2002 and 2006) (MDE 2007). The designated use of Catoctin 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. The listings for nutrients, bacteria, 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 Catoctin 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 Catoctin Creek watershed is located within the Middle Potomac River Sub-basin in Frederick County, Maryland (see Figure 1). It encompasses the southwestern portion of Frederick County and is framed by Catoctin Mountain on the east and South Mountain on the west. The mainstem flows through the Middletown Valley and eventually empties into the Potomac River approximately three miles upstream from Point of Rocks, Maryland. The Catoctin Creek watershed drains an area of 120 square miles, which includes areas of forested mountain slopes, agricultural valleys, and small towns (MDE 2006). Approximately 5% of the total watershed is covered by water (i.e. streams, ponds, etc.).

Geology/Soils

The Catoctin Creek watershed lies within the Blue Ridge Province physiographic region of Maryland. The Blue Ridge Province is on the eastern edge of the Appalachian Mountains. In Frederick County, the province consists of the Middletown Valley and three separate ridges: Catoctin Mountain, South Mountain, and Elk Ridge. It has mountainous soils composed of sandy or stoney loams. Metamorphosed basalt is the predominant rock type in the mountains, although the ridges and crests are formed by erosion resistant quartzite of the Cambrian age (505 to 570 million years old). The Middletown Valley, a rolling upland between the mountain ridges in southwestern Frederick County, is underlain by granodiorite and granitic gneiss of the Precambrian age (greater than 570 million years old). The climate of the Blue Ridge province is similar to that in the Piedmont Province, but somewhat cooler and more moist (DNR 2007b; MGS 2007; MDE 2000).

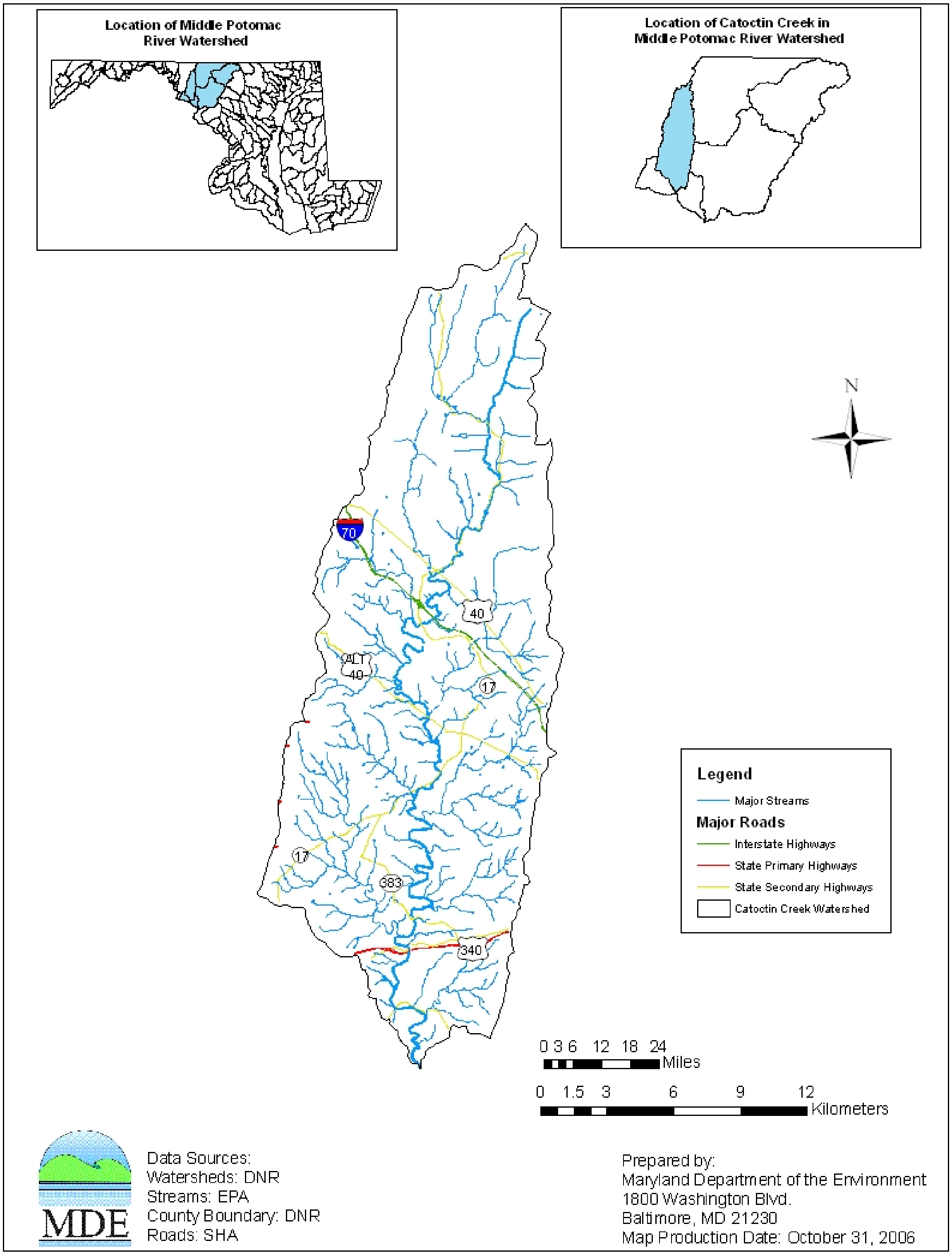

Figure 1: Location Map of Catoctin Creek in Frederick County, Maryland

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 Catoctin 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.

Catoctin Creek Watershed Land Use Distribution

The land use distribution in the Catoctin Creek watershed consists of forest (47.5%), crop (25.9%), urban (16.6%), and pasture (9.9%) land use classifications. 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 Catoctin Creek Watershed

General Land Use	Detailed Land Use	Area (Acres)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	21.8	0.0	
	Hay	7,450.7	10.1	
	High Till	5,765.2	7.8	
	Low Till	5,590.0	7.6	
	Nursery	253.0	0.3	25.9
Extractive	Extractive	2.3	0.0	0.0
Forest	Forest	34,648.3	47.0	
	Harvested Forest	350.0	0.5	47.5
Pasture	Natural Grass	627.0	0.9	
	Pasture	6,662.0	9.0	
	Trampled Pasture	34.9	0.0	9.9
Urban	Urban: Barren	132.5	0.2	
	Urban: Imp	911.4	1.2	
	Urban: perv	11,204.6	15.2	16.6
	Total	73,653.7	100.0	100.0

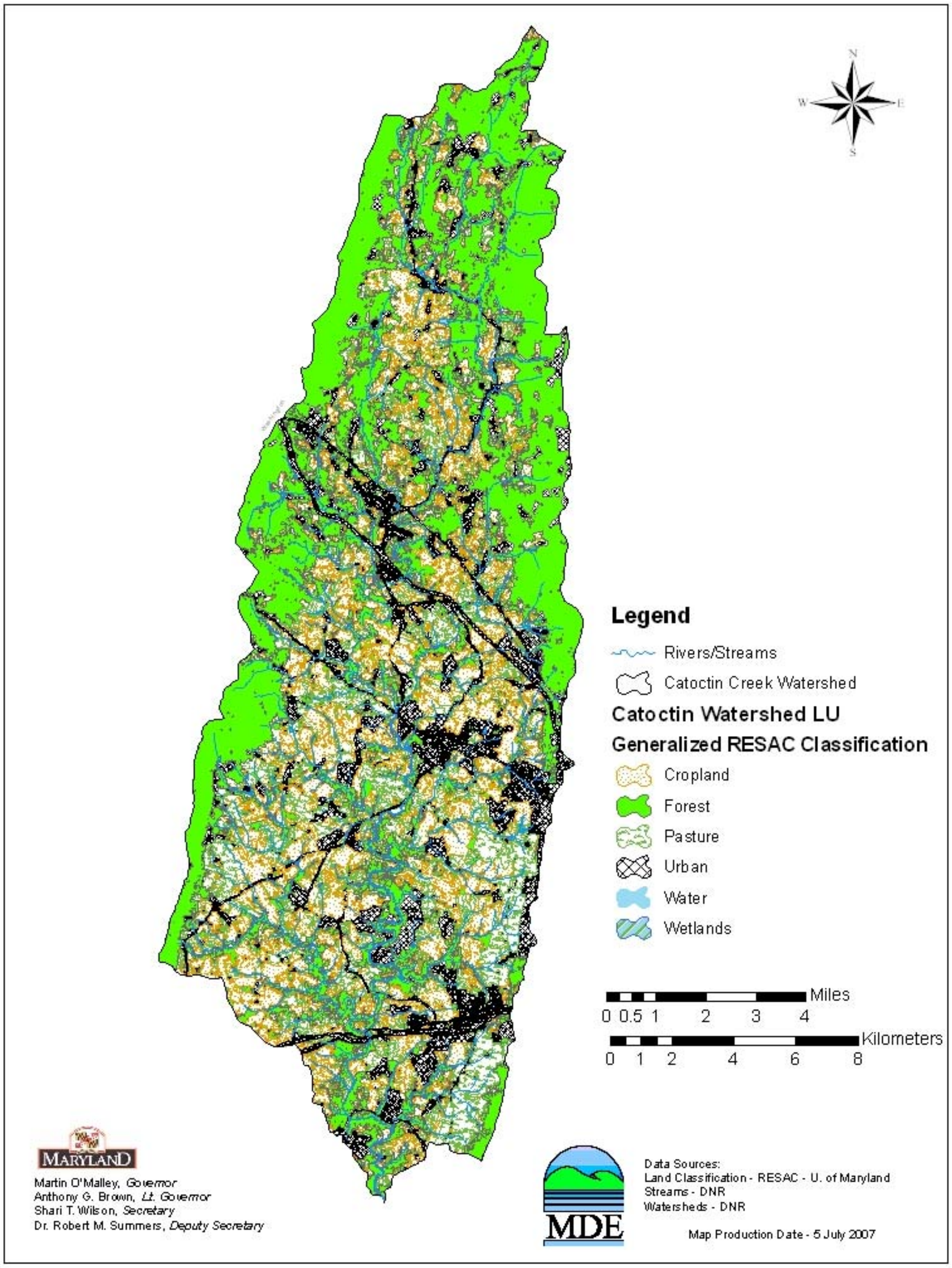


Figure 2: Land Use of the Catoctin Creek Watershed

2.2 Source Assessment

The Catoctin 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 Sources (NPS) 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 Catoctin Creek watershed nonpoint source baseline loads (Nonpoint Source BL_{CT}).

General Load Estimation Methodology

Nonpoint source sediment loads in the Catoctin Creek watershed 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 National 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. 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 Catoctin Creek watershed.

Table 2: Summary of EOF Erosion Rate Calculations

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

Notes: 1. Average based on Chesapeake Bay Basin NRI values.
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; and

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

<u>Edge-of-Stream Loads</u>

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 (PS) Assessment

A list of 13 active permitted point sources that contribute to the sediment load in the Catoctin Creek watershed was compiled using MDE's Environmental Permit Service Center (EPSC) database. The types of permits identified include individual municipal, individual municipal separate storm sewer systems (MS4s), and general 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 8 process water permits (Process Water BL_{CT}) are calculated based on their TSS limits and corresponding flow information. The 5 NPDES Phase I or Phase II stormwater permits identified throughout the Catoctin 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_{CT}) 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 Catoctin Creek Baseline Sediment Load, reported in tons per year (ton/yr) and presented in terms of nonpoint and point source loadings.

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

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{CT}	+	NPDES Stormwater BL_{CT}	+	Process Water BL_{CT}
28,829.2	=	26,037.1	+	2,734.4	+	57.8

Table 4 presents a breakdown of the Catoctin Creek Total Baseline Sediment Load, detailing loads per land use. The largest portion of the sediment load is from crop land (74.4%). The remainder of sediment load is from urban land (9.5%), pasture (8.2%), and forest (7.8%).

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

General Land Use	Description	Load (Ton/Yr)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	63.4	0.2	
	Hay	3587.0	12.4	
	High Till	10640.3	36.9	
	Low Till	6420.4	22.3	
	Nursery	723.6	2.5	74.4
Extractive	Extractive	3.9	0.0	0.0
Forest	Forest	2052.5	7.1	
	Harvested Forest	194.4	0.7	7.8
Pasture	Natural Grass	249.1	0.9	
	Pasture	1993.4	6.9	
	Trampled Pasture	109.1	0.4	8.2
Urban[1]	Urban: Barren	310.2	1.1	
	Urban: Imp	869.9	3.0	
	Urban: perv	1554.3	5.4	9.5
N/A	Process Water	57.8	0.2	0.2
	Total	28,829.2	100.0	100.0

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

2.3 Water Quality Characterization

The Catoctin 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 will be used to evaluate a sediment impairment.

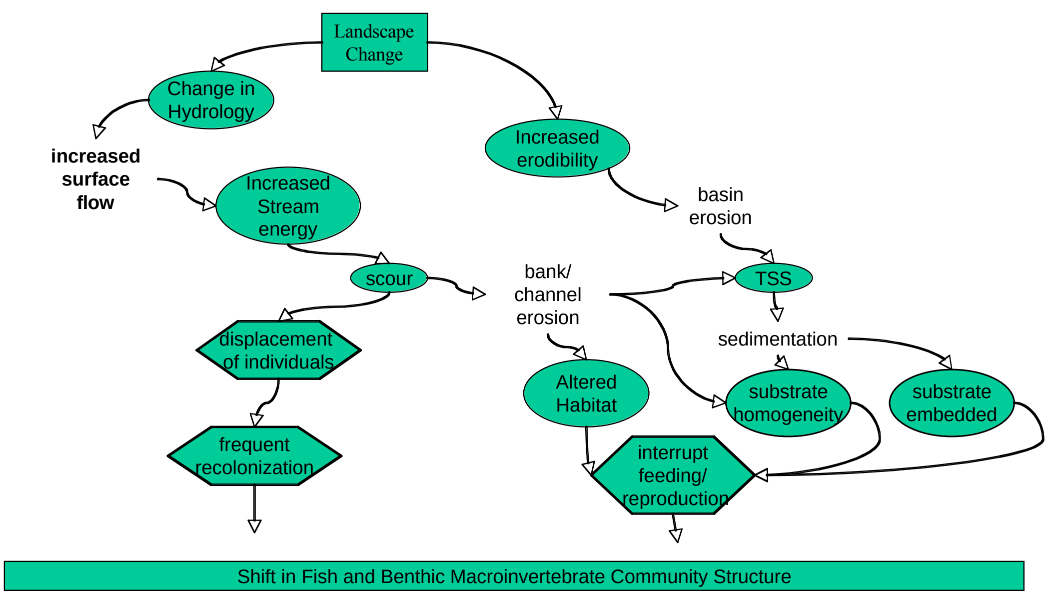


Figure 3: Sediment Stressor Conceptual Model

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. However, in the absence of a water column TSS criterion, a TMDL TSS threshold needed to be established. While an effective 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. As a result, the water quality characterization of TSS will be based on the cumulative impacts identified from streambed measures. 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).

Catoctin Creek Watershed Monitoring Stations

A total of 16 water quality monitoring stations were used to characterize the Catoctin Creek Watershed. There were 14 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.

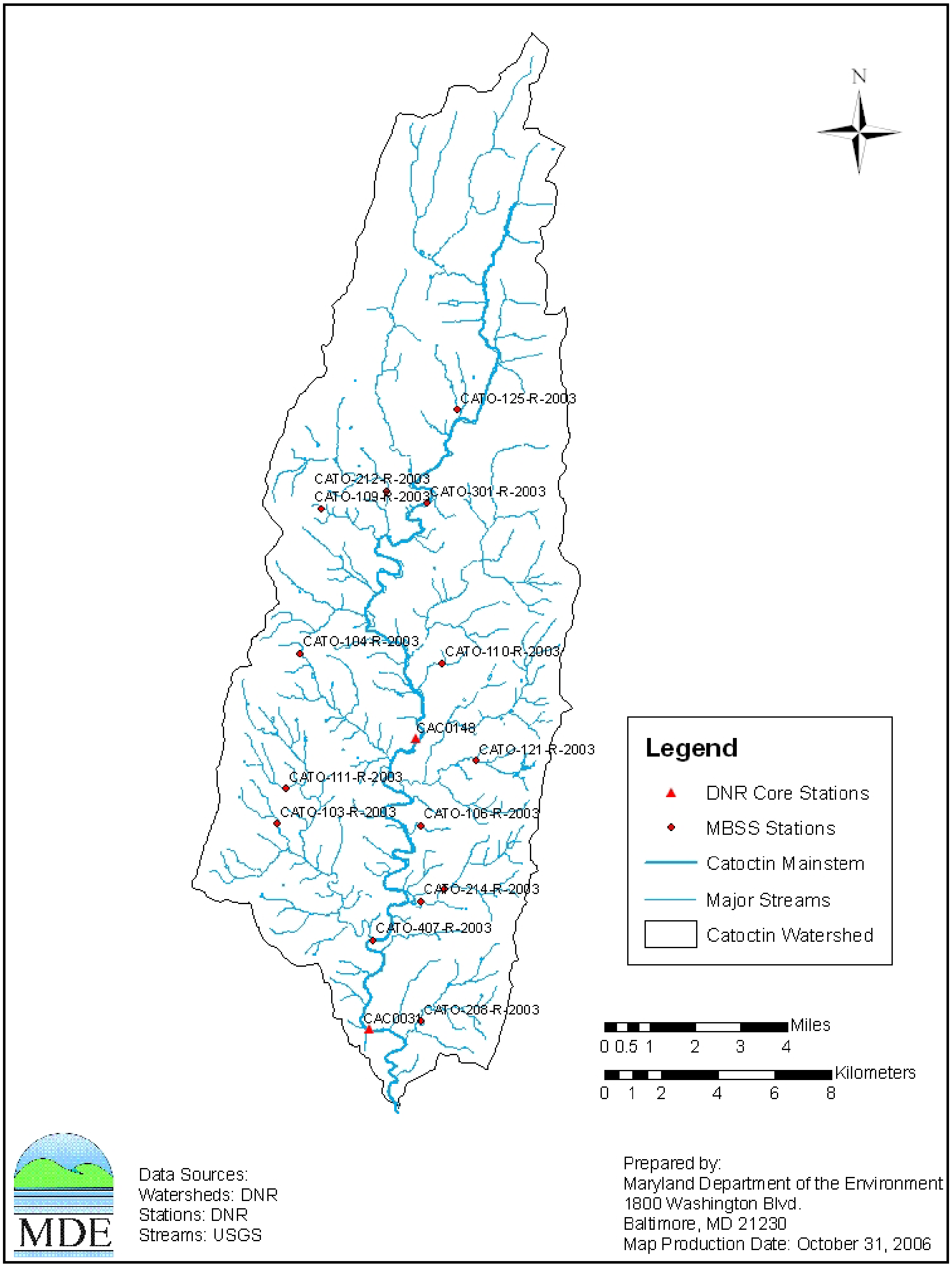


Figure 4: Monitoring Stations in the Catoctin Creek Watershed

Table 5: Monitoring Stations in the Catoctin Creek Watershed

Site Number	Sponsor	Site Type	Site Name	Latitude (dec degrees)	Longitude (dec degrees)
CATO-103-R-2003	MD DNR	MBSS	Manor Run	39.39788	77.61607
CATO-104-R-2003	MD DNR	MBSS	Middle Creek (Catoctin)	39.45225	77.60696
CATO-106-R-2003	MD DNR	MBSS	Catoctin Creek, unnamed tributary 4	39.39752	77.55720
CATO-109-R-2003	MD DNR	MBSS	Catoctin Creek, unnamed tributary 3	39.49824	77.59855
CATO-110-R-2003	MD DNR	MBSS	Catoctin Creek, unnamed tributary 1	39.44912	77.54863
CATO-111-R-2003	MD DNR	MBSS	Broad Run (MP), unnamed tributary 1	39.40908	77.61236
CATO-121-R-2003	MD DNR	MBSS	Deer Springs Bridge, unnamed tributary 1	39.41828	77.53465
CATO-125-R-2003	MD DNR	MBSS	West Bridge (MP), unnamed tributary 1	39.52996	77.54333
CATO-205-R-2003	MD DNR	MBSS	Lewis Mill Bridge	39.37759	77.54694
CATO-208-R-2003	MD DNR	MBSS	Catoctin Creek, unnamed tributary 5	39.33530	77.55667
CATO-212-R-2003	MD DNR	MBSS	Grindstone Run	39.50405	77.57197
CATO-214-R-2003	MD DNR	MBSS	Lewis Mill Bridge	39.37340	77.55682
CATO-301-R-2003	MD DNR	MBSS	Catoctin Creek	39.50024	77.55537
CATO-407-R-2003	MD DNR	MBSS	Catoctin Creek	39.36112	77.57632
CAC0031	MD DNR	Trend	Route 464	39.1959	77.1415
CAC0148	MD DNR	Trend	Route 17	39.2532	77.3333

Catoctin Creek MBSS Monitoring Stations

The MBSS program monitored 14 locations in the Catoctin Creek watershed in 2003 (see Figure 4 and Table 5). 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: Catoctin Creek MBSS Data

Site	FIBI	BIBI	Epifaunal Substrate	Percent Embeddedness	Instream Habitat	Bank Stability	Benthic Tolerant Species
CATO-103-R-2003	2.00	1.75	7	40	9	17.33	6.16
CATO-104-R-2003	1.00	3.50	14	15	6	20.00	4.26
CATO-106-R-2003	1.00	3.75	14	30	9	20.00	4.11
CATO-109-R-2003	1.00	3.00	11	30	4	20.00	4.30
CATO-110-R-2003	1.33	3.00	7	50	9	13.70	5.45
CATO-111-R-2003	3.33	2.50	15	30	16	18.50	4.92
CATO-121-R-2003	NS	2.50	NS	NS	NS	NS	6.20
CATO-125-R-2003	1.00	1.25	13	40	15	20.00	6.67
CATO-205-R-2003	3.33	2.75	14	35	8	10.00	4.46
CATO-208-R-2003	3.67	2.75	13	40	16	20.00	4.79
CATO-212-R-2003	3.67	3.25	15	40	12	9.17	4.62
CATO-214-R-2003	3.67	3.50	12	40	16	20.00	3.63
CATO-301-R-2003	4.00	3.00	6	35	9	16.40	5.05
CATO-407-R-2003	NS	2.50	NS	NS	NS	NS	5.90

Notes: NS = No Sample

Catoctin Creek Core Monitoring Stations

Additional data for the Catoctin Creek watershed was obtained from the Maryland Department of Natural Resources (DNR) Core/Trend Program. The program collected benthic macroinvertebrate data between 1976 and 2006 (DNR 2007a). This data was used to calculate four benthic community measures: total number of taxa, the Shannon-Weiner diversity index, the modified Hilsenhoff biotic index, and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT). DNR has extensive monitoring information for two stations in the mainstem of Catoctin Creek through the Core/Trend Program. The stations are located near Route 464 (CAC0031) and near Route 17 south of Middleton (CAC0148) (see Table 5 and Figure 4). A summary of the results for each of the stations is presented in Table 7.

Table 7: Catoctin Creek Watershed DNR Core Data

Site Number	Current Water Quality Status	Trend Since 1970's
CAC0031	Good/Very Good	No change
CAC0148	Good	Moderate improvement

2.4 Water Quality Impairment

The Maryland water quality standards surface water use designation for the Catoctin Creek mainstem and its tributaries is Use IV-P (Recreational Trout Waters and Public Water Supply) (COMAR 2007a,b). The water quality impairment of the Catoctin 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 BIBI and FIBI scores (BIBI and FIBI ≥ 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, percent embeddedness, epifaunal substrate condition, and bank stability index. 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 the 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. Further details are found in Appendix A.

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 Catoctin 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: Catoctin Creek IBI and SSDI Scores

Site	**Benthic IBI**	**Benthic SSDI**	**Fish IBI**	**Fish SSDI**
CATO-103-R-2003	1.75	2.00	2.00	1.67
CATO-104-R-2003	3.50	4.00	1.00	3.00
CATO-106-R-2003	3.75	4.00	1.00	2.33
CATO-109-R-2003	3.00	3.50	1.00	2.33
CATO-110-R-2003	3.00	1.50	1.33	1.00
CATO-111-R-2003	2.50	3.50	3.33	4.33
CATO-121-R-2003	2.50	1.00	NS	NS
CATO-125-R-2003	1.25	3.00	1.00	3.00
CATO-205-R-2003	2.75	2.50	3.33	2.33
CATO-208-R-2003	2.75	3.50	3.67	3.67
CATO-212-R-2003	3.25	3.00	3.67	3.67
CATO-214-R-2003	3.50	4.00	3.67	3.67
CATO-301-R-2003	3.00	2.50	4.00	1.67
CATO-407-R-2003	2.50	1.00	NS	NS
Average	**2.79 ± 0.30**	**2.79 ± 0.47**	**2.42 ± 0.59**	**2.72 ± 0.46**

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 Catoctin 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 TMDLs and load allocations (LA) were developed for Catoctin 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 Catoctin 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 total watershed sediment load for Catoctin Creek is calculated as the sum of each land use EOS load within the watershed and represents 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 Catoctin Creek watershed was evaluated using two TMDL segments (see Figure 5). TMDL Segment 1 represents the sediment loads generated in the northern portion of the watershed. TMDL Segment 2 represents the sediment loads generated in the southern portion of the watershed. Based on the analysis in Section 2.4, both TMDL segments are impaired and will require a reduction in sediment loads.

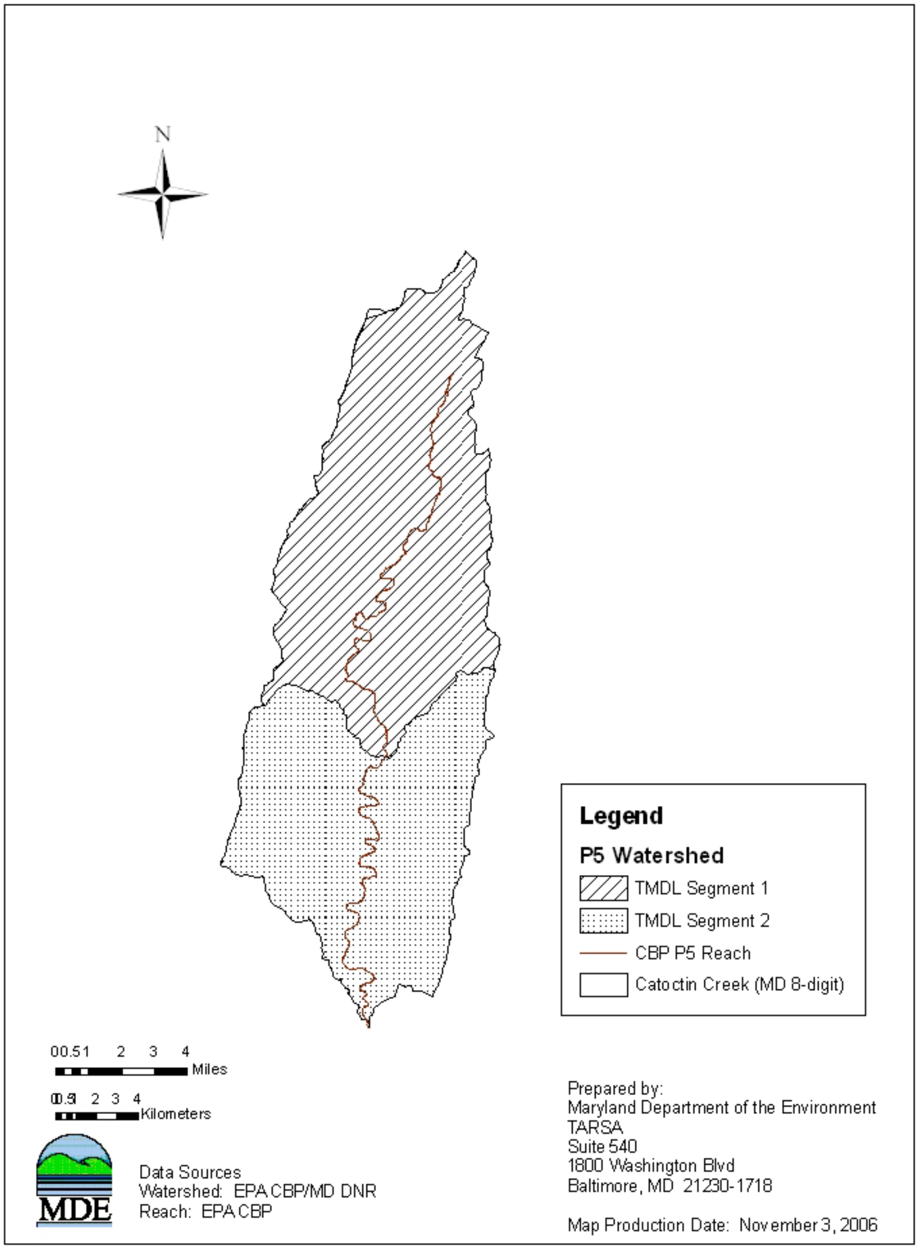


Figure 5: Catoctin Creek Watershed TMDL Segmentation

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).

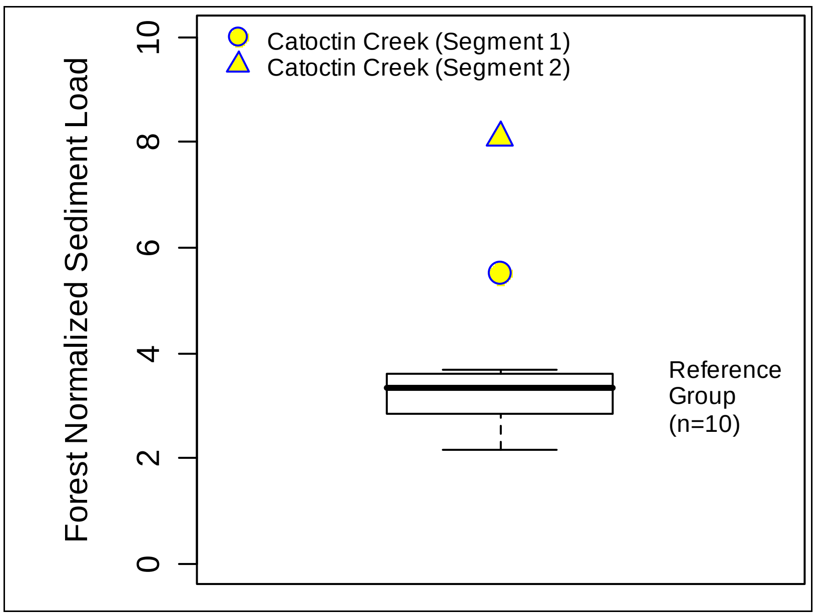
To reduce the effect of the variability within the Highland and Piedmont physiographic regions, the watershed sediment loads were then normalized by a constant background condition, the all forested watershed condition. This new normalized term, defined as the *forest normalized sediment load* (Y_n), 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 (see 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, which also represents the median value of the reference watersheds, was chosen as an environmentally conservative approach to develop this TMDL (see Appendix A for more details).

A comparison of the Catoctin Creek watershed *forest normalized sediment load* to the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) is shown in Figure 6. The *forest normalized sediment load* exceeds the *sediment loading threshold* for both TMDL segments, indicating that Catoctin Creek is 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: Catoctin 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 Catoctin 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. The total baseline sediment load from the Catoctin Creek TMDL Segment 1 is 13,881.6 tons per year and from TMDL Segment 2 is 14,947.6 tons per year.

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 Catoctin Creek *all forested sediment load* (see Section 4.3). 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 future (TMDL) load from the Catoctin Creek TMDL Segment 1 is 8,325.3 tons per year and from TMDL Segment 2 is 6,045.0 tons per year.

4.4 Critical Condition and Seasonality

EPA's regulations require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters (CFR 2007). 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 respects. First, it is implicitly included through the use of the biological monitoring data. Second, the MBSS dataset included benthic sampling collected in the spring and fish sampling collected in the summer. While fish results were not directly applied in the final analysis, Currey et al. (2006) reported that there was minimal difference in the *forest normalized sediment loads* for the reference group watersheds using benthic scores only and the group using both fish and benthic scores. Thus, this analysis has captured both spring and summer flow conditions.

4.5 TMDL Loading Caps

This section presents the average annual TMDL of TSS for the Catoctin Creek watershed. 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 TMDL Segment 1 and TMDL Segment 2 (see Figure 5) independently, based on Equation 4.2. A constant reduction was estimated for the predominant controllable sources (i.e., significant contributors of sediment to the stream system), 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.

An overall reduction of 50.2% from current estimated loads will be required to meet TMDL allocation and attain Maryland water quality standards.

Table 10: Catoctin Creek Watershed TMDL

	Baseline Load (Ton/Yr)	TMDL Scenario Load (Ton/Yr)	Reduction
Segment 1	13,881.6	8,325.3	40.0%
Segment 2	14,947.6	6,045.0	59.6%
Total	28,829.2	14,370.3	50.2%

4.6 Load Allocations Between Point and Nonpoint Sources

The allocations described in this section demonstrate how the TMDL of TSS can be implemented to meet the water quality criteria in the Catoctin Creek watershed. The State reserves the right to revise these allocations provided the revisions are consistent with achieving water quality standards.

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. Additionally, no reductions were applied to permitted process load sources because at 0.2% of the total load, such controls would produce no discernable water quality benefit.

Table 11 summarizes the TMDL scenario results based on applying the reduction equally to the predominant controllable sediment sources. The source categories are based on multiple sources (e.g. high till, low till, hay, animal feeding operations, and nursery are all considered crop sources).

Table 11: Total Watershed WLA and LA

	Source	Baseline Load (Ton/Yr)	TMDL Scenario Load (Ton/Yr)	Reduction
LA	Crop	21,434.7	9,508.6	55.6%
	Extractive	3.9	3.9	0.0%
	Forest	2,246.8	2,246.8	0.0%
	Pasture	2,351.6	1,160.8	50.6%
WLA	Urban	2,734.4	1,392.4	49.1%
	Process Water	57.8	57.8	0.0%
Total		**28,829.2**	**14,370.3**	**50.2%**

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

<u>Process Water WLA</u>

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 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 municipal facilities.

There are 8 process water sources with explicit TSS limits (see Appendix B), which are all municipal sources. The total estimated TSS load from all of the process water sources is 57.8 tons/yr, based on current permit limits.

<u>Stormwater WLA</u>

Pursuant to EPA requirements, “stormwater discharges that are regulated under Phase I or Phase II of the NPDES storm water 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 (i.e., departments of transportation, hospitals, military bases, etc.),
- 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, in the Catoctin Creek watershed, loads from all regulated NPDES stormwater outfalls will be expressed as a single stormwater WLA. The stormwater WLA is calculated based on the sediment load from the urban land use of the watershed. Upon approval of the TMDL "NPDES-regulated municipal storm water 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).

For more information on all point source allocations, see Appendix B.

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 2007). 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 Catoctin Creek TMDL is summarized in Table 12. 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 13 (See Appendix C for more details).

Table 12: Catoctin Creek Watershed Average Annual TMDL of Sediment/TSS (ton/yr)

	TMDL (ton/yr) =	LA_{CT} +	NPDES Stormwater WLA_{CT} +	Process Water WLA_{CT} +	MOS
Segment 1	8,325.3	7,498.3	799.3	27.7	Implicit
Segment 2	6,045.0	5,421.8	593.1	30.1	Implicit
Total	14,370.3	12,920.1	1,392.4	57.8	Implicit

Table 13: Catoctin Creek Watershed Maximum Daily Loads of Sediment/TSS (ton/day)

	MDL (ton/yr) =	LA_{CT} +	NPDES Stormwater WLA_{CT} +	Process Water WLA_{CT} +	MOS
Segment 1	299.0	269.9	28.8	0.2	Implicit
Segment 2	216.8	195.2	21.4	0.3	Implicit
Total	515.7	465.1	50.1	0.5	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 2007). 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 to 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 of 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 Catoctin 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	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	Epifaunal Substrate	Percent embeddedness	Benthic Tolerant Species	Bank Stability Index	Benthic SSDI
CATO-103-R-2003	1	3	1	3	2.00
CATO-104-R-2003	3	5	3	5	4.00
CATO-106-R-2003	3	3	5	5	4.00
CATO-109-R-2003	3	3	3	5	3.50
CATO-110-R-2003	1	1	1	3	1.50
CATO-111-R-2003	5	3	3	3	3.50
CATO-121-R-2003	NS	NS	1	NS	1.00
CATO-125-R-2003	3	3	1	5	3.00
CATO-205-R-2003	3	3	3	1	2.50
CATO-208-R-2003	3	3	3	5	3.50
CATO-212-R-2003	5	3	3	1	3.00
CATO-214-R-2003	3	3	5	5	4.00
CATO-301-R-2003	1	3	3	3	2.50
CATO-407-R-2003	NS	NS	1	NS	1.00
Average	**2.83**	**3.00**	**2.57**	**3.67**	**2.79 ± 0.47**

Notes: NS = No Sample

Table A-3: Fish SSDI Calculation

Site	Percent embeddedness	Instream Habitat	Epifaunal Substrate	Fish SSDI
CATO-103-R-2003	3	1	1	1.67
CATO-104-R-2003	5	1	3	3.00
CATO-106-R-2003	3	1	3	2.33
CATO-109-R-2003	3	1	3	2.33
CATO-110-R-2003	1	1	1	1.00
CATO-111-R-2003	3	5	5	4.33
CATO-121-R-2003	NS	NS	NS	NS
CATO-125-R-2003	3	3	3	3.00
CATO-205-R-2003	3	1	3	2.33
CATO-208-R-2003	3	5	3	3.67
CATO-212-R-2003	3	3	5	3.67
CATO-214-R-2003	3	5	3	3.67
CATO-301-R-2003	3	1	1	1.67
CATO-407-R-2003	NS	NS	NS	NS
Average	**3.00**	**2.33**	**2.83**	**2.72 ± 0.46**

Notes: NS = No Sample

APPENDIX B – MDE Permit Information

Table B-1: Permit Summary

MDE #	NPDES	Name	County	City	Type	TMDL
00DP0650	MD0023680	I-70 REST STOP WWTP	FREDERICK	MYERSVILLE	WMA2	Process Water WLA
00DP1440	MD0055425	OLD SOUTH MOUNTAIN INN	FREDERICK	BOONSBORO	WMA2	Process Water WLA
00DP3160	MD0067521	THE JEFFERSON SCHOOL	FREDERICK	JEFFERSON	WMA2	Process Water WLA
01DP3182	MD0067628	MIDDLETOWN WWTP - EAST	FREDERICK	MIDDLETOWN	WMA2	Process Water WLA
03DP0097A	MD0020737	JEFFERSON WWTP	FREDERICK	JEFFERSON	WMA2	Process Water WLA
03DP0124	MD0020699	MYERSVILLE WWTP	FREDERICK	MYERSVILLE	WMA2	Process Water WLA
03DP0668	MD0022721	FOUNTAINDALE WWTP	FREDERICK	MIDDLETOWN	WMA2	Process Water WLA
99DP0462	MD0024406	MIDDLETOWN WWTP	FREDERICK	MIDDLETOWN	WMA2	Process Water WLA
MS4-FR-005		TOWN OF MIDDLETON MS4	FREDERICK	MIDDLETOWN	WMA6G	Stormwater WLA
MS4-FR-007		TOWN OF MYERSVILLE MS4	FREDERICK	MYERSVILLE	WMA6G	Stormwater WLA
02DP3321	MD0068357	FREDERICK COUNTY MS4	FREDERICK	ALL CITIES	WMA6	Stormwater WLA
05SS5501	MD0055501	STATE HIGHWAY ADMINISTRATION MS4	All PHASE I	STATE-WIDE	WMA6	Stormwater WLA
		MDE GENERAL PERMIT TO CONSTRUCT	ALL	ALL		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: Municipal Permit Data

MDE #	NPDES #	Facility name	Flow (MGD)	Permit Avg Monthly Conc. (mg/l)	Permit Weekly Max Conc. (mg/l)
00DP0650	MD0023680	I-70 REST STOP WWTP	0.028	30	45
00DP1440	MD0055425	OLD SOUTH MOUNTAIN INN	0.03	30	45
00DP3160	MD0067521	THE JEFFERSON SCHOOL	0.01	30	45
01DP3182	MD0067628	MIDDLETOWN WWTP - EAST	0.15	30	45
03DP0097A	MD0020737	JEFFERSON WWTP	0.3	30	45
03DP0124	MD0020699	MYERSVILLE WWTP	0.3	30	45
03DP0668	MD0022721	FOUNTAINDALE WWTP	0.2	30	45
99DP0462	MD0024406	MIDDLETOWN WWTP	0.25	30	45

Notes: 1. MGD = Millions of Gallons per Day
2. mg/l = Milligram per liter

Table B-3: Stormwater Permits[1]

MDE Permit	Facility	NPDES group
MS4-FR-005	TOWN OF MIDDLETON MS4	Phase-II
MS4-FR-007	TOWN OF MYERSVILLE MS4	Phase-II
01DP3321	FREDERICK COUNTY MS4	Phase-I
05SS5501	STATE HIGHWAY ADMINISTRATION MS4	Phase I
	MDE GENERAL PERMIT TO CONSTRUCT	Phase-I/II

Note: [1] Although not listed in this table, some individual permits from Table B-2 incorporate stormwater requirements and are accounted for within the NPDES stormwater WLA as well additional Phase II permitted MS4s, such as military bases, hospitals, etc.

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 Catoctin 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 total maximum daily loads on a daily basis. It is divided into sections discussing:

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

Basis for approach

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

- **Average Annual TMDL:** The basis of the average annual 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 maximum daily loads for the Catoctin Creek watershed.

<u>Level of Resolution</u>

The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The draft EPA guidance on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Catoctin 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 explicitly specified or implicitly assumed. This level of probability directly or indirectly reflects two separate phenomena:

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often conditions can allowably surpass the combined magnitude and duration components.

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

The draft daily load guidance document states that the probability component of the maximum daily load should be "based on a representative statistical measure" that is dependent upon the specific TMDL and best professional judgment of the developers. This statistical measure represents how often the maximum daily load is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The maximum daily load reflects some central tendency:** In this option, the maximum daily load is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.
2. **The maximum daily load reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the maximum daily load is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.
3. **The maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the maximum daily load based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in maximum daily load that would be exceeded 5% of the time.

Selected Approach

The approach selected for defining a daily maximum load for the Catoctin Creek watershed was based upon the specific data that exists for each source category. The approach consists of unique methods for each of the following categories of sources:

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

Approach for Stormwater and Nonpoint Sources

The level of resolution selected for defining a daily maximum load for the Catoctin Creek watershed was a representative daily load, expressed as a single daily load for each loading source. This approach was chosen based upon the specific data that exists for Stormwater and nonpoint sources. Currently, the best available data is the CBP P5 model daily time series calibrated to long-term average annual loads (per land use). The CBP reach simulation results are calibrated to daily monitoring information for watershed segments with a flow typically greater 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 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 Catoctin 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 be used.

The CBP P5 Catoctin 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 5.23 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

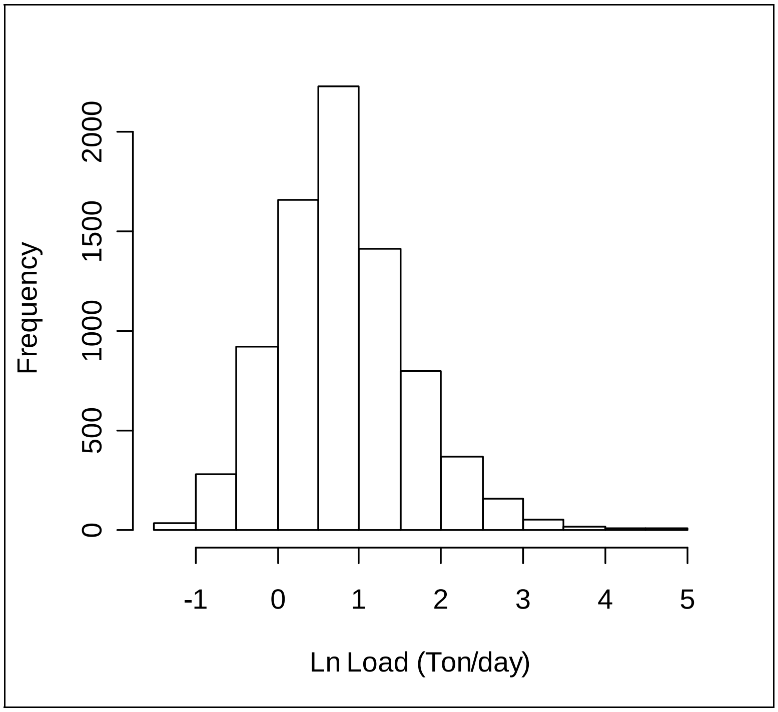

Figure C-1: Histogram of CBP River Segment Daily Simulation Results for the Catoctin Creek Watershed

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

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

where

MDL = Maximum daily load
LTA = Long-term average (average annual load)
Z = z-score associated with target probability level
$\sigma = \ln(CV^2+1)$
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 5.23, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 13.23. The average annual Catoctin Creek sediment TMDL is reported in tons/year, and the conversion from tons/year to a maximum daily load in tons/day is 0.036 (e.g. 13.23/365)

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 99^{th} percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Catoctin Creek sediment TMDL is reported in tons/year, and the conversion from tons/year to a maximum daily load in tons/day is 0.0085 (e.g. 3.11/365)

Results of Approach

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

- Calculation Approach for Nonpoint Sources and Stormwater Point Sources

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

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

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

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

- For permits without a daily maximum limit:

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

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

MDL (ton/day) =	LA_{CT} +	NPDES Stormwater WLA_{CT} +	Process Water WLA_{CT} +	MOS
515.7	465.1	50.1	0.5	Implicit