FINAL

Total Maximum Daily Load of Sediment in the Swan Creek Watershed, Harford County, Maryland

FINAL

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DEPARTMENT OF THE ENVIRONMENT
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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AFO	Animal Feeding Operations
BIBI	Benthic Index of Biotic Integrity
BIP	Buffer Incentive Program
BMP	Best Management Practices
BSID	Biological Stressor Identification
CAFOs	Concentrated Animal Feeding Operations
CB1TF	Northern Chesapeake Bay Tidal Fresh
CBLCD	Chesapeake Bay Land-Cover Dataset
CBP	Chesapeake Bay Program
CBP P4.3	Chesapeake Bay Program Model Phase 4.3
CBP P5.32	Chesapeake Bay Program Model Phase 5.3.2
CCAP	Coastal Change Analysis Program
cfs	Cubic Feet per Second
CV	Coefficient of Variation
CWA	Clean Water Act
DI	Diversity Index
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPT	*Ephemeroptera*, *Plecoptera*, and *Trichoptera*
ESD	Environmental Site Design
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HSPF	Hydrological Simulation Program Fortran
IBI	Index of Biotic Integrity
LA	Load Allocation
m	Meter
m^3/yr	Meters cubed per year
MACS	Maryland Agricultural Water Quality Cost-Share Program
MAL	Minimum Allowable IBI Limit
MBSS	Maryland Biological Stream Survey
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
MDP	Maryland Department of Planning
MGD	Millions of Gallons per Day
mg/l	Milligrams per liter
MGS	Maryland Geological Survey
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristics
MS4	Municipal Separate Storm Sewer System

NLCD	National Land-Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRI	Natural Resources Inventory
PSU	Primary Sampling Unit
SCS	Soil Conservation Service
SDF	Sediment Delivery Factor
SHA	State Highway Administration
TMDL	Total Maximum Daily Load
Ton/acre/yr	Tons per acre per year
Ton/yr	Tons per year
TSD	Technical Support Document
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
WIP	Watershed Implementation Plan
WLA	Waste Load Allocation
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the USEPA'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 2012b). This document, upon approval by the U.S. Environmental Protection Agency (USEPA), establishes a Total Maximum Daily Load (TMDL) for sediment/total suspended solids (TSS) in the non-tidal Maryland 8-Digit Swan Creek watershed (2014 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130706). In this TMDL, the terms TSS and sediment may be used interchangeably.

The Maryland Department of the Environment (MDE) identified the waters of the Swan Creek watershed on the State's 2014 Integrated Report as impaired by multiple pollutants (MDE 2014a). The Swan Creek watershed is associated with two assessment units in the Integrated Report: an 8-digit basin covering the non-tidal portions of the watershed and one Chesapeake Bay segment covering the tidal portions. The Chesapeake Bay segment related to Swan Creek is the Chesapeake Bay Tidal Fresh (CB1TF). Table ES-1 identifies the impairment listings associated with this watershed (MDE 2014a). Category 4a indicates a TMDL has been approved and Category 5 indicates that the waterbody is impaired and a TMDL or water quality analysis (WQA) is needed. A data solicitation for TSS/sediment was conducted by MDE in December 2014, and all readily available data have been considered.

Table ES-1: Swan Creek Integrated Report Impairment Listings

Watershed	Basin Code	Tidal/Non-tidal	Designated Use Class	Year Listed	Identified Pollutant	Listing Category
Swan Creek	02130706	Non-tidal	I - Aquatic Life and Wildlife	2014	TSS/Sediments	5
				2014	Phosphorus	5
Northern Chesapeake Bay Tidal Fresh	CB1TF	Tidal	II - Seasonal Migratory Fish Spawning and Nursery Subcategory	2012	TP	4a (2012)
					TN	
			II - Open-Water Fish and Shellfish	1996	TP	4a (2012)
					TN	

As stated above, the Swan Creek watershed is comprised of both tidal and non-tidal waters. The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Swan Creek non-tidal mainstem and its tributaries is Use Class I (Water Contact Recreation and Protection of Aquatic Life). The tidal portion of Swan Creek is

designated Use Class II (Support of Estuarine and Marine Aquatic Life as well as Shellfish Harvesting) (COMAR 2012a,b,c).

The Swan Creek watershed was originally listed on Maryland's 2002 Integrated Report as impaired for impacts to biological communities. The listing was based on the biological assessment methodology, which uses aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI). These indices indicated that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions (MDE 2002a).

In order to determine what stressor or stressors are impacting aquatic life, MDE's *Biological Stressor Identification* (BSID) methodology was applied. The Biological Stressor Identification (BSID) analysis for the Swan Creek watershed identified TSS/sediment/instream habitat, low DO, and high pH as a potential stressors. TSS/sediment shows a significant association with degraded biological conditions; as much as 28% of the biologically impacted stream miles in the watershed may be degraded due to high imbeddedness (percentage of fine sediment surrounding gravel, cobble and boulder particles in the streambed) and the instream habitat stressor group which includes instream habitat structure (poor and marginal to poor), instream habitat structure (poor), riffle/run quality (poor and marginal to poor), riffle/run quality (poor), and velocity/depth diversity (poor) may affect up to 61% of the biologically impacted stream miles in the watershed. Specifically, anthropogenic sources have resulted in altered habitat heterogeneity and possible elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. Details of this analysis are presented in this report and in the document entitled, '*Watershed Report for Biological Impairment of the Swan Creek Watershed in Harford County, Maryland Biological Stressor Identification Analysis Results and Interpretation*'.

As a result of the BSID analysis, this non-tidal MD 8-digit watershed was listed as impaired by TSS and requiring a TMDL. The TMDL will apply only to the non-tidal portion of the watershed. For simplicity, further reference in this document to Swan Creek Watershed will refer only to the non-tidal MD 8-digit watershed.

The objective of this TMDL is to ensure that watershed sediment loads are at a level that supports the Use Class I designation for the Swan Creek watershed. The TMDL will address water clarity problems and associated impacts to aquatic life in Swan Creek caused by high sediment and TSS concentrations.

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of non-tidal stream systems. In order to quantify the impact of sediment on the aquatic life of non-tidal stream systems, a reference watershed TMDL approach was used, which 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; MDE 2008). This threshold is then used to determine a watershed specific sediment TMDL endpoint. The resulting loads are considered the maximum allowable loads the waterbody can receive without causing any sediment related impacts to aquatic health.

In order to use a reference watershed approach, sediment loads must be estimated using a watershed model. For this analysis, the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) watershed model was chosen and specifically, the *edge-of-stream* (EOS) land-use sediment loads were used. The CBP P5.3.2 model was chosen because the spatial domain of the model segmentation aggregates to the MD 8-digit watersheds, which is closely consistent with the impairment listing.

USEPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2012b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time (i.e., captures the impacts of both high and low flow events). Thus, critical conditions are inherently addressed. Seasonality is captured in several components. First, it is implicitly included in biological sampling as biological communities reflect the impacts of stressors over time, as described above. Second, the Maryland Biological Stream Survey (MBSS) dataset, which serves as the primary dataset for calculating the biological metrics of the watershed (i.e., BIBI and FIBI scores), included benthic sampling in the spring and fish sampling in the summer. Moreover, the sediment loading rates used in the TMDL were determined using the CBP P5.3.2 model which is based on Hydrological Simulation Program Fortran (HSPF) model, which is a continuous simulation model with a simulation period 1985-2005, thereby addressing annual changes in hydrology and capturing wet, average, and dry years.

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, accounting for 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 2012a,b). It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty, and therefore the MOS is implicitly included. Because the sediment loading threshold was conservatively based on the median sediment loading rates from reference watersheds, Maryland has adopted an implicit MOS for sediment TMDLs.

The Swan Creek total baseline sediment Load is 770 tons per year (ton/yr). The Swan Creek Watershed baseline load contribution is further subdivided into a nonpoint source baseline load (Nonpoint Source BL_{SC}) and two types of point source baseline loads: National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{SC}) and regulated process water (Process Water BL_{SC}) (see Table ES-2).

Table ES-2: Swan Creek Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{SC}	+	NPDES Stormwater BL_{SC}	+	Process Water BL_{SC}
770	=	361	+	407	+	2

The Swan Creek average annual TMDL of sediment/ TSS is 729 ton/yr (a 5 % reduction from the baseline load). The Swan Creek TMDL contribution is further subdivided into point and nonpoint source allocations and is comprised of a load allocation (LA_{SC}) of 361 ton/yr, an NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{SC}) of 366 ton/yr, and a Process Water Waste Load Allocation (Process Water WLA_{SC}) of 2 ton/yr (see Table ES-2).

Table ES-3: Swan Creek Average Annual TMDL of Sediment/TSS (ton/yr)

TMDL (ton/yr)	=	LA_{SC}	+	NPDES Stormwater WLA_{SC}	+	Process Water WLA_{SC}	+	MOS
729	=	361	+	366	+	2	+	Implicit

Table ES-4: Swan Creek Baseline Load, TMDL, and Total Reduction Percentage

Baseline Load (ton/yr)	**TMDL** (ton/yr)	**Total Reduction** (%)
770	729	5

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 B and presented in Table B-1.

This TMDL will ensure that watershed sediment loads are at a level to support the Use Class I designation for the Swan Creek watershed, and more specifically, at a level to support aquatic life. The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Since the BSID watershed analysis identifies low DO and high pH as possible stressors impacting the biological conditions, additional TMDLs may be needed to address the impacts to biological communities. This impairment to aquatic life will only be fully addressed when all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2014a and 2014b).

Section 303(d) of the CWA and current USEPA regulations require reasonable assurance that the TMDL can and will be implemented. Once the USEPA 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. The Swan Creek Sediment TMDL is expected to be implemented as part of a staged process recently developed by Maryland. This staged process is designed to achieve both the sediment reductions needed within the Swan Creek watershed and to meet sediment target loads consistent with the Chesapeake Bay TMDLs, established by USEPA in 2010 (USEPA 2010a) and scheduled for full implementation by 2025. The Bay TMDLs require reductions of nitrogen, phosphorus, and sediment loads throughout the Bay watershed to meet water quality standards that protect the designated uses in the Bay and its tidal tributaries.

MDE expects that the first stage of implementation of the Swan Creek Sediment TMDL will focus on achieving the sediment reductions required within the watershed as per the Chesapeake Bay TMDL, which is expected to be fully implemented in Maryland by 2025, to meet downstream water quality standards. Once the Bay TMDL target sediment loads for the Swan Creek watershed have been met, MDE will reassess the sediment impacts on aquatic life in the Swan Creek watershed, based on any additional monitoring data available. MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact to water quality, with consideration given to cost of implementation.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the USEPA'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 2012b). This document, upon approval by the U.S. Environmental Protection Agency (USEPA), establishes a Total Maximum Daily Load (TMDL) for sediment in the non-tidal Maryland 8-Digit Swan Creek watershed (2014 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130706).

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 Swan Creek watershed on the State's 2014 Integrated Report of Surface Water Quality (Integrated Report) as impaired by multiple pollutants (MDE 2014a). The Swan Creek watershed is associated with two assessment units in the Integrated Report: an 8-digit basin covering the non-tidal portions of the watershed and one Chesapeake Bay segment covering the tidal portions. The Chesapeake Bay segment related to Swan Creek is the Chesapeake Bay Tidal Fresh (CB1TF). Table 1 identifies the impairment listings associated with this watershed (MDE 2014a). Category 4a indicates a TMDL has been approved and Category 5 indicates that the waterbody is impaired and a TMDL or water quality analysis (WQA) is needed. A data solicitation for TSS/sediment was conducted by MDE in December 2014, and all readily available data have been considered.

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2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Swan Creek watershed is located entirely within Harford County, Maryland. The watershed is located in the Coastal Plain and Piedmont regions, two of three distinct eco-regions identified in the Maryland Department of Natural Resources (MDDNR) Maryland Biological Stream Survey (MBSS) Index of Biological Integrity (IBI) metrics (Southerland *et al.* 2005a). It is located approximately four miles south of the mouth of the Susquehanna River. The lower portion of Swan Creek is a small shallow tidal embayment (MDE 2002b). The watershed is within the Bush River Basin (Maryland 6-digit 021307), which also includes the Bush River, Lower Winter's Run, Atkisson Reservoir, and Bynum Run subwatersheds.

According to the Chesapeake Bay Program's Phase 5.3.2 watershed model, the total drainage area of the Maryland 8-digit watershed is approximately 15,870 acres not including water/wetlands. Approximately 50 acres of the watershed area is covered by water. The total population in the Swan Creek watershed is approximately 12,580 (US Census Bureau 2010).

There are no "high quality," or Tier II, stream segments [Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (scale 1-5)] located within the watershed. Tier II segments would require the implementation of Maryland's anti-degradation policy (COMAR 2012d; MDE 2011).

Geology/Soils

The Swan Creek watershed lies predominately in the Piedmont geologic province of Maryland, with the lower portion of the watershed extending slightly into the Coastal Plain province. The Piedmont geologic province is characterized by gentle to steep rolling topography, low hills, and ridges. The surficial geology is characterized by crystalline igneous and metamorphic rocks of volcanic origin consisting primarily of schist and gneiss. The Coastal Plain geologic province is characterized by deep sedimentary soil complexes that support broad meandering streams (MDDNR 2009;

MGS 2012; MDE 2000). The surface elevations range from approximately 680 feet to sea level at the Chesapeake Bay shoreline.

Soil type for the Swan Creek watershed is characterized by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) into 4 hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well drained/excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of soils that are moderately deep to deep and moderately well to well drained soils, with moderately fine/coarse textures; Group C soils have slow infiltration rates with a layer that impedes downward water movement, and they primarily have moderately fine-to-fine textures; Group D soils have very slow infiltration rates consisting of clay soils with a permanently high water table that are often shallow over nearly impervious material. The actual Swan Creek watershed is comprised primarily of Group B soils (40.2%), Group C soils (38.5%), and Group D soils (20.2%), with a small portion of the watershed consisting of Group A soils (1.1%) (USDA 2006).

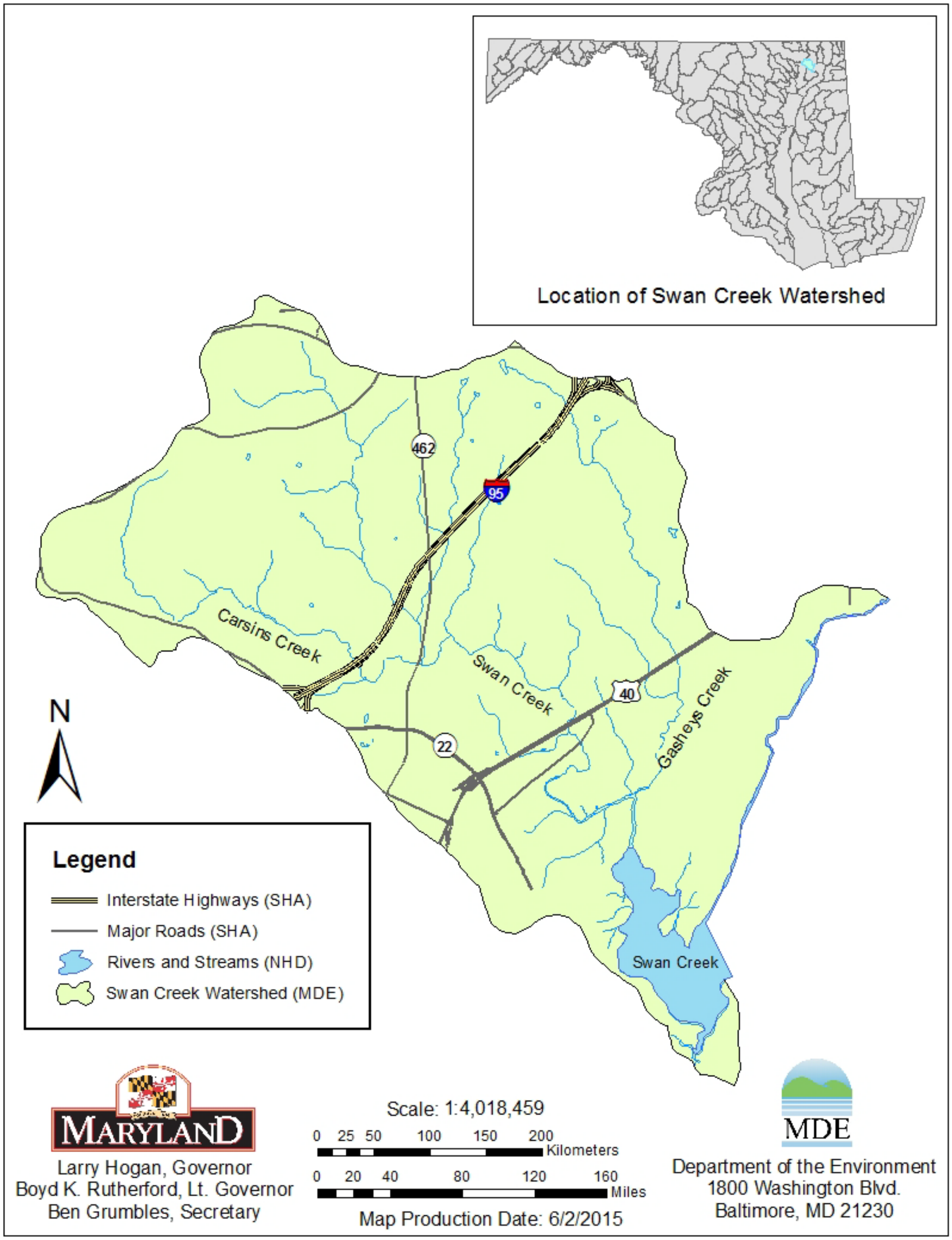


Figure 1: Location Map of the Swan Creek Watershed in Harford County, Maryland

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 5.3.2 (CBP P5.3.2) Watershed Model.[1] CBP P5.3.2 land-use was based on two distinct stages of development.

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

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

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

county level US Agricultural Census data (USDA 1982, 1987, 1992, 1997, 2002). The watershed model documentation, *Chesapeake Bay Phase 5.3 Community Watershed Model* (US USEPA 2010b), describes these modifications in more detail.

The result of these modifications is that CBP P5.3.2 land-use does not exist in a single GIS coverage; instead, it is only available in a tabular format. The CBP P5.3.2 watershed model is comprised of 30 land-uses. Most of these land-uses are differentiated only by their pollutant unit loading rates. The land-uses are divided into 13 classes with distinct sediment erosion rates. Table 1 lists the CBP P5.3.2 generalized land-uses, detailed land-uses, which are classified by their sediment erosion rates, and the acres of each land-use in the Swan Creek watershed. The land-use acreage is based on the CBP P5.3.2 2009 Progress Scenario.

Swan Creek Watershed Land-use Distribution

The land-use distribution of the Swan Creek watershed consists primarily of forest (43.4%) and urban land (39.3%), with smaller amounts of crop (12.8%) and pasture (4.2%). A detailed summary of the watershed land-use areas is presented in Table 2, and a land-use map is provided in Figure 2.

Table 2: Land-use Percentage Distribution for the Swan Creek Watershed

General Land-use	Detailed Land-Use	Area (Acres)	Percent (%)	Grouped Percent of Total
Forest	Forest	6,832	42.9%	43.4%
	Harvested Forest	68	0.4%	
AFOs	Animal Feeding Operations	6	0.0%	0.0%
CAFOs	Concentrated Animal Feeding Operations	0	0.0%	0.0%
Pasture	Pasture	661	4.2%	4.2%
Crop	Crop	2,043	12.8%	12.8%
Nursery	Nursery	8	0.0%	0.0%
Regulated Urban	Construction	160	1.0%	39.3%
	Developed	6,084	38.2%	
	Extractive	6	0.0%	
Water	Water	48	0.3%	0.3%
Total		**15,916**	**100.0%**	**100.0%**

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

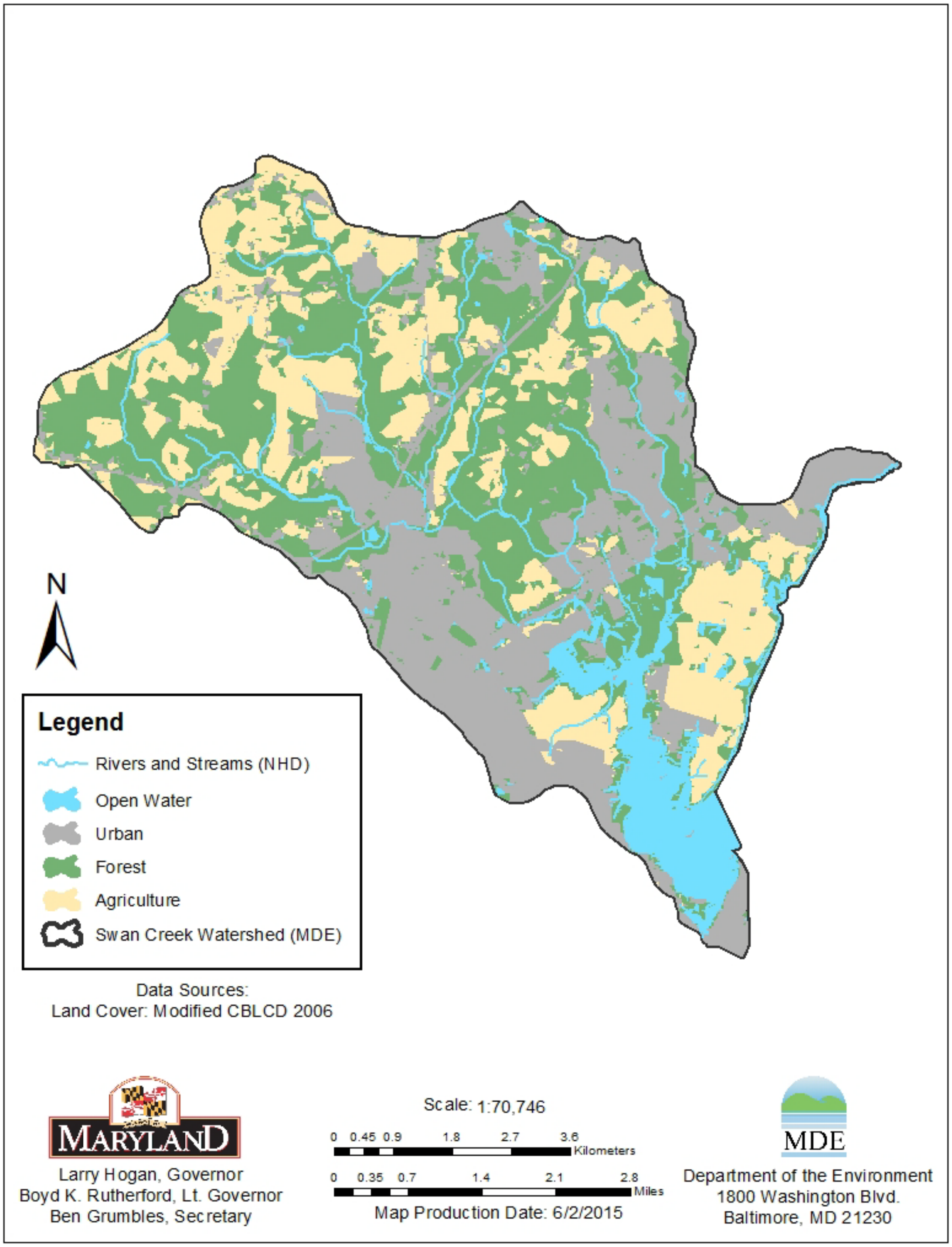


Figure 2: Land-use of the Swan Creek Watershed

2.2 Source Assessment

The Swan Creek watershed total baseline sediment load consists of nonpoint sources loads, National Pollutant Discharge Elimination System (NPDES) Stormwater loads, and Process Water 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 all sediment loads not covered under a NPDES permit within the Swan Creek watershed. In general, these are rainfall driven land-use based loads from agricultural and forest lands. This section provides the background and methods for determining the nonpoint source baseline loads generated within the Swan Creek watershed (Nonpoint Source BL_{SC}).

General Load Estimation Methodology

Nonpoint source sediment loads generated within the Swan Creek watershed are estimated based on the *edge-of-stream (EOS)* loads from the CBP P5.3.2 watershed model 2009 Progress Scenario. Within the CBP P5.3.2 watershed model, EOS sediment loads are calculated 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 factor (SDF)* (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* (USEPA 2010b).

Edge-of-Field Target Erosion Rate Methodology

Edge-of-field erosion can be defined as erosion or sediment loss from any particular land surface. 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 2006). 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 Chesapeake Bay Program Phase 4.3 (CBP P4.3) 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 P5.3.2 model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target rates for pasture and cropland. Rates for urban pervious, urban impervious, extractive, and barren land were based on a combination of best professional judgment, literature analysis, and regression analysis. The EOF erosion rates 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, BMPs are applied to the modeled EOS loads in the CBP P5.3.2 2009 Progress Scenario. BMP data, representing BMPs in place in 2009, was collected by the Chesapeake Bay Program (CBP), and TSS reduction efficiencies have been estimated by CBP for specific types of BMPs based on peer reviewed studies, data collected by local jurisdictions, and an analysis of available literature values. For further details regarding EOF erosion rates, please see Section 9.2.1 of the *Chesapeake Bay Phase 5 Community Watershed Model* (USEPA 2010b). Table 3 lists EOF erosion rates specific to the Swan Creek watershed.

Table 3: Target EOF Loading rates (ton/ac/yr) By Land-use

Land-use	**Data Source**	**Harford County** (ton/acre/yr)
Forest	NRI (1987)	0.34
Harvested Forest	Literature values	3
Nursery	NRI average (1982-1987)	1.5
Pasture	NRI average (1982-1987)	0.38
Trampled Pasture	NRI pasture average (1982-1987) multiplied by 9	3.61
Animal Feeding Operations	NRI pasture average (1982-1987) multiplied by 9	3.61
Hay	Adjusted NRI average (1982-1987)	1.76
High Till	Adjusted NRI average (1982 – 1987)	6.87
Low Till	Adjusted NRI average (1982 – 1987)	4.12
Pervious Urban	Regression Analysis	0.74
Extractive	Literature values/best professional judgment	10
Barren (Construction)	Literature values	12.5
Impervious Urban	Regression Analysis	5.18

Edge-of-Stream Loads

EOS loads are the loads that enter the modeled river reaches. Modeled river reaches are those with discharges of 100 cubic feet per second (cfs) or greater. (Exceptions were made for some river reaches that had useful monitoring data but were less than 100 cfs.) EOS 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. The formula for the EOS load calculation within the CBP P5.3.2 watershed model is as follows:

$$\sum_{i}^{n} EOS = Acres_i * EOF_i * SDF_i \qquad \text{(Equation 2.1)}$$

where:

n = number of land-use classifications
i = land-use classification
EOS = Edge of stream load, tons per year (ton/yr)
Acres = acreage for land-use i
EOF = Edge-of-field erosion rate for land-use i, ton/acre/yr
SDF = sediment delivery factor for land-use i, per Equation 2.2

2.2.2 Point Source Assessment

A list of active permitted point sources that contribute to the sediment load in the Swan Creek watershed was compiled using best available resources. The types of permits identified include individual municipal permits, NPDES stormwater permits, and the general permit for stormwater discharges from construction sites. The permits can be grouped into two categories: process water and stormwater. The process water category includes those loads generated by continuous discharge sources whose permits have TSS limits. Other permits that do not meet these conditions are considered *de minimis* in terms of the total sediment load. The stormwater category includes all NPDES regulated stormwater discharges. The technical memorandum to this document entitled *Significant Sediment Point Sources in the Swan Creek watershed* identifies all the process water permits and NPDES regulated stormwater discharges that contribute to the sediment load in the Swan Creek watershed.

The baseline sediment loads for the process water permits (Process Water BL_{SC}) are calculated based on their permitted TSS limits (average monthly or weekly concentration values) and corresponding flow information. The general permit for stormwater discharges from construction sites identified throughout the Swan 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_{SC}) is calculated using the CBP P5.3.2 Progress Scenario urban land-use EOS loads (as per Equation 2.2) associated with these permits. The technical memorandum to this document entitled

Significant Sediment Point Sources in the Swan Creek watershed provides detailed information regarding the calculation of the Swan Creek watershed Process Water BL_{SC} and NPDES Stormwater BL_{SC}.

2.2.4 Summary of Baseline Loads

Table 4 summarizes the Swan Creek baseline sediment load, reported in ton/yr and presented in terms of Nonpoint Source Load Allocation and NPDES Stormwater and Process Water Wasteload Allocations.

Table 4: Swan Creek Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{SC}	+	NPDES Stormwater BL_{SC}	+	Process Water BL_{SC}
770	=	361	+	407	+	2

Table 5 presents a breakdown of Swan Creek Total Baseline Sediment Load, detailing loads per land-use. The largest portion of the sediment load is regulated urban (42.7%). The remainder of the sediment load is from crop (26.9%), forest (9.4%), and pasture (1.4%).

Table 5: Detailed Baseline Sediment Budget Loads Within the Swan Creek Watershed

General Land-Use	Detailed Land-Use	Tons	Percent (%)	Grouped Percent of Total
Forest	Forest	87	11.3%	11.6%
	Harvested Forest	3	0.4%	
AFOs	Animal Feeding Operations	0	0.0%	0%
CAFOs	Concentrated Animal Feeding Operations	0.4	0.1%	0.1%
Pasture	Pasture	13	1.7%	1.7%
Crop	Crop	256	33.3%	33.3%
Nursery	Nursery	1	0.1%	0.1%
Regulated Urban	Construction	93	12.1%	52.9%
	Developed	311	40.4%	
	Extractive	3	0.4%	
Point Sources	Industrial Point Sources	0	0.0%	0.3%
	Municipal Point Sources	2	0.3%	
Total		**770**	**100.0%**	**100.0%**

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

2.3 Water Quality Characterization

The Swan Creek watershed was originally listed on Maryland's 2002 Integrated Report as impaired for impacts to biological communities. . To refine the listing for impacts to biological communities, Maryland conducted a stressor identification analysis. Details of this analysis are presented below and in the document entitled, '*Watershed Report for Biological Impairment of the Swan Creek Watershed in Harford County, Maryland Biological Stressor Identification Analysis Results and Interpretation*'.

Currently in Maryland, there are no specific numeric criteria for suspended sediments. Therefore, to determine whether aquatic life is impacted by elevated sediment loads, MDE's BSID methodology was applied. The primary goal of the BSID analysis is to identify the most probable cause(s) for observed biological impairments throughout MD's 8-digit watersheds (MDE 2009).

The BSID analysis applies a case-control, risk-based, weight-of-evidence approach to identify potential causes of biological impairment. The risk-based approach estimates the strength of association between various stressors and an impaired biological community. The BSID analysis then identifies individual stressors as probable or unlikely causes of the poor biological conditions within a given watershed, and subsequently reviews ecological plausibility. Finally, the analysis concludes whether or not these individual stressors or groups of stressors are contributing to the impairment (MDE 2009).

The primary dataset for BSID analysis includes MDDNR-MBSS Round 2 and Round 3 data (collected between 2000-2009) because it provides a broad spectrum of paired data variables, which allow for a more comprehensive stressor analysis. MDDNR-MBSS Round 1 can also be used, if needed. The MBSS is a robust statewide probability-based sampling survey for assessing the biological conditions of 1st through 4th order, non-tidal streams (Klauda et al. 1998; Roth et al. 2005). It uses a fixed length (75 meter) 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). The random sample design allows for unbiased estimates of overall watershed conditions. Thus, the dataset facilitated case-control analyses because: 1) in-stream biological data are paired with chemical, physical, and land-use data variables that could be identified as possible stressors; and 2) it uses a probabilistic statewide monitoring design.

The BSID analysis combines the individual stressors (physical and chemical variables) into three generalized parameter groups in order to assess how the resulting impacts of these stressors can alter the biological community and structure. The three generalized parameter groups include: sediment, habitat, and water chemistry. Identification of a sediment stressor as contributing to the biological impairment is based on the results of the individual stressor associations within the sediment parameter grouping, which reveal the effects of sediment related impacts on stream biota (MDE 2009).

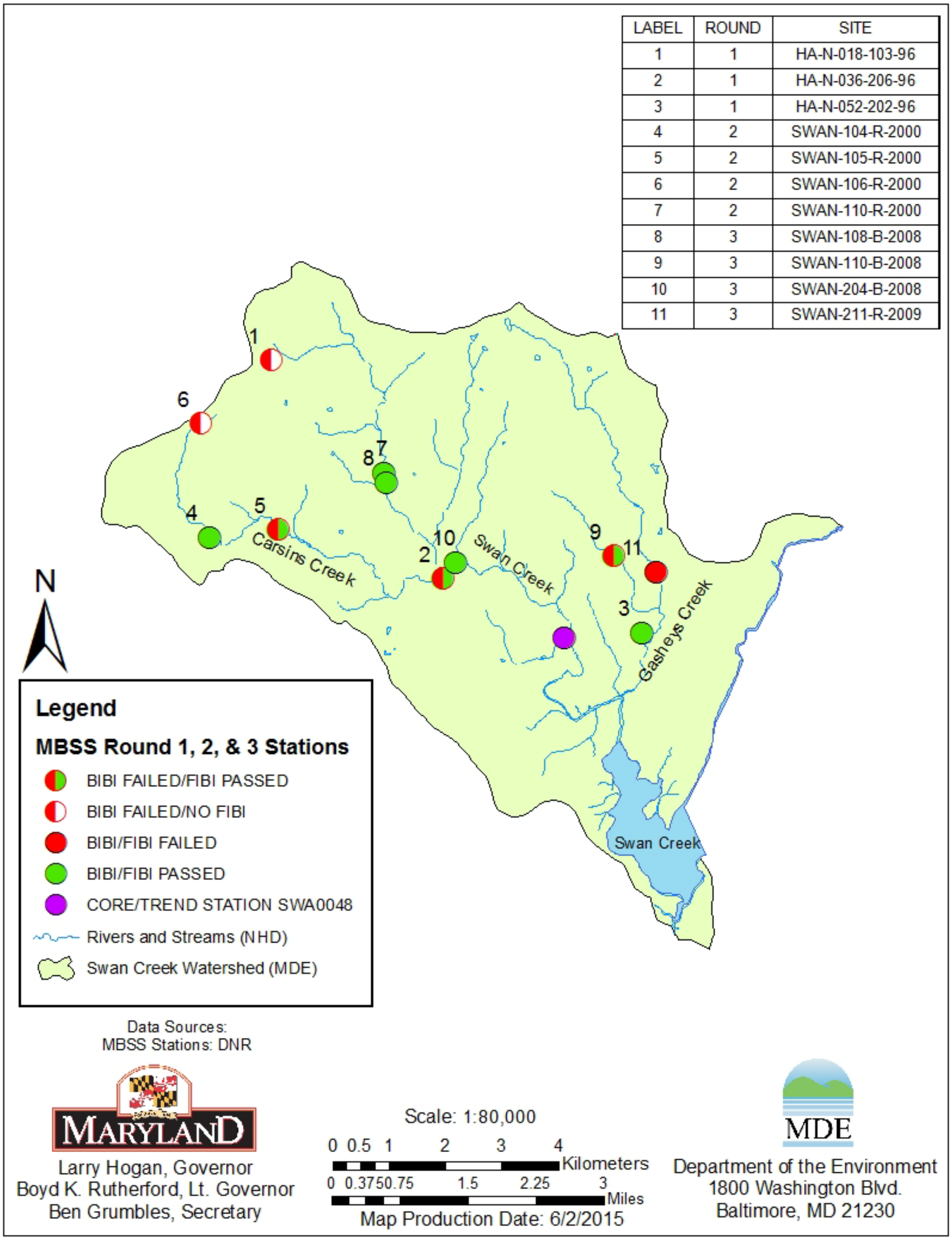
Since it uses MBSS data, the BSID applies only to 1st through 4th order streams in a watershed. In larger order mainstem rivers and streams, MDDNR CORE/TREND program data is used to assess the support of aquatic life. The program collected benthic macroinvertebrate data between 1976 and 2006. These data were used to calculate four benthic community measures: total number of taxa, the Shannon Weiner Diversity Index (DI), the modified Hilsenhoff Biotic Index (HBI), and percent *Ephemeroptera*, *Plecoptera*, and *Trichoptera* (EPT). MDDNR has extensive benthic macroinvertebrate monitoring data for one station on the mainstem of the Swan Creek through the CORE/TREND program. This station has 30 years of benthic macroinvertebrate data (MDDNR 2009).

Swan Creek Watershed Monitoring Stations

A total of 12 water quality monitoring stations were used to characterize the Swan Creek watershed for the purpose of this TMDL. The BSID analysis used the eleven biological/physical habitat monitoring stations from the MBSS Round 1 - 3 data collection. Additionally, one monitoring station from the Maryland CORE/TREND monitoring network was applied within the TMDL analysis. All stations are listed in Table 6 and presented in Figure 3.

Table 6: Monitoring Stations in the Swan Creek Watershed

Site Number	**Sponsor**	**Site Type**	**Location**	**Latitude** (decimal degrees)	**Longitude** (decimal degrees)
SWA0048	DNR	CORE/TREND	Route 40	39.523	76.143
HA-N-018-103-96	DNR	MBSS Round 1	Swan Creek	39.567	76.202
HA-N-036-206-96	DNR	MBSS Round 1	Carsins Run	39.532	76.167
HA-N-05220296	DNR	MBSS Round 1	Gasheys Run	39.523	76.126
SWAN-104-R-2000	DNR	MBSS Round 2	Carsins Run	39.539	76.215
SWAN-105-R-2000	DNR	MBSS Round 2	Carsins Run	39.540	76.201
SWAN-106-R-2000	DNR	MBSS Round 2	Carsins Run	39.557	76.217
SWAN-110-R-2000	DNR	MBSS Round 2	Blenheim Run	39.535	76.132
SWAN-108-B-2008	DNR	MBSS Round 3	Swan Creek	39.549	76.179
SWAN-110-B-2008	DNR	MBSS Round 3	Swan Creek	39.547	76.178
SWAN-204-B-2008	DNR	MBSS Round 3	Swan Creek	39.535	76.164
SWAN-211-R-2008	DNR	MBSS Round 3	Swan Creek	39.533	76.123



LABEL	ROUND	SITE
1	1	HA-N-018-103-96
2	1	HA-N-036-206-96
3	1	HA-N-052-202-96
4	2	SWAN-104-R-2000
5	2	SWAN-105-R-2000
6	2	SWAN-106-R-2000
7	2	SWAN-110-R-2000
8	3	SWAN-108-B-2008
9	3	SWAN-110-B-2008
10	3	SWAN-204-B-2008
11	3	SWAN-211-R-2009

Figure 3: Monitoring Stations in the Swan Creek Watershed

2.4 Water Quality Impairment

The Maryland water quality standards surface water use designation for the Swan Creek mainstem and its tributaries is Use Class I (Water Contact Recreation, Protection of Aquatic Life) (COMAR 2012a,b,c). The water quality impairment of the Swan Creek watershed addressed by this TMDL is caused by an elevated sediment load beyond a level that the watershed can sustain; thereby causing sediment related impacts that cannot support aquatic life. Assessment of aquatic life is based on BIBI and FIBI scores, as demonstrated via the BSID analysis for the watershed.

The Swan Creek watershed was originally listed on Maryland's 2002 Integrated Report as impaired for impacts to biological communities. The biological assessment was based on the combined results of MBSS Round 1 (1995-1997) and Round 2 (2000-2004) data, which includes seven stations. Five of the seven stations, or over 70% of the stream miles in the watershed, are assessed as having BIBI and/or FIBI scores significantly lower than 3.0 (on a scale of 1 to 5) (MDE 2012a). See Figure 3 and Table 6 for station locations and information.

The results of the BSID analysis for the Swan Creek watershed are presented in a report entitled *Watershed Report for Biological Impairment of the Swan Creek Watershed in Harford County, Maryland Biological Stressor Identification Analysis Results and Interpretation*. The report states that the degradation of biological communities in the Swan Creek watershed is strongly associated with anthropogenic impacts, low dissolved oxygen, high pH, high embeddedness, poor instream habitat structure, poor riffle/run quality, and poor velocity/depth diversity (MDE 2014b).

The BSID analysis determined that the biological impairment in the Swan Creek watershed is due in part to sediment-related stressors. Specifically, the analysis confirmed that individual stressors within the sediment parameter and instream habitat grouping were contributing to the biological impairment in the watershed. Overall, stressors within the sediment parameter grouping were identified as having a statistically significant association with impaired biological communities at approximately 28% of the sites with BIBI and/or FIBI scores significantly less than 3.0 throughout the watershed (MDE 2014b). Therefore, since sediment is identified as a stressor to the biological communities in the Swan Creek watershed, the watershed will be listed as impaired by sediment in the Integrated Report, and a TMDL is required.

As discussed in Section 2.3, the BSID applies only to 1st through 4th order streams in a watershed. Therefore, aquatic life in the Swan Creek watershed mainstem is assessed using DNR CORE/TREND program data. As shown in Table 7, the biological monitoring results from one DNR CORE/TREND station data along the Swan Creek watershed mainstem indicate that mainstem water quality can be classified as "GOOD". Statistical analysis of the long term CORE/TREND data indicates that since 1976, the station has shown strong improvement. These results are based on percent EPT, taxa number, biotic index, and diversity index (MDDNR 2009).

Table 7: Swan Creek Watershed CORE/TREND Data

Site Number	Current Water Quality Status	Trend Since 1970's
SWA0048	GOOD	MODERATE IMPROVEMENT

3.0 TARGETED WATER QUALITY GOAL

The objective of the sediment TMDL established herein is to reduce sediment loads, and subsequent effects on aquatic life in the 1st through 4th order streams in the Swan Creek watershed, to levels that support the Use Class I designation for the watershed. Assessment of aquatic life 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; MDE 2008).

Based on the analysis of benthic monitoring results at the CORE/TREND station, it has been determined that the mainstem of the Swan Creek watershed is supportive of aquatic life and is therefore not impaired by sediment. The TMDL will be restricted to the 1st through 4th order tributaries within the watershed and will exclude the Swan Creek mainstem.

Excessive sediment has been identified by the USEPA as the leading cause of impairment of our nation's waters, and as contributing to the decline of populations of aquatic life in North America (USEPA 2003a). Suspended sediment in streams may reduce visibility and prevent fish from seeing their prey, and may clog gills and filter feeding mechanisms of fish and benthic (bottom-dwelling) organisms. Excessive deposition of sediment on streambeds may bury eggs or larvae of fish and benthic macroinvertebrates, or degrade habitat by clogging the interstitial spaces between sand and gravel particles.

Reductions in sediment loads are expected to result from decreased watershed 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.

The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Since the BSID watershed analysis identifies low DO and high pH as possible stressors impacting the biological conditions, additional TMDL or TMDLs may be needed to address the impacts to biological communities. This impairment to aquatic life will only be fully addressed when all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2014a and 2014b).

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 the Swan Creek watershed. 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 MOS. Finally, Section 4.8 summarizes the TMDL.

4.2 Analysis Framework

Since there are no specific numeric criteria in Maryland that quantify the impact of sediment on the aquatic life of non-tidal stream systems, a reference watershed approach will be used to establish the TMDL. In order to use a reference watershed approach, sediment loads must be estimated using a watershed model. For this analysis, the CBP P5.3.2 model was used to calculate the sediment loads used in the reference watershed approach.

Watershed Model

The watershed model chosen to estimate the sediment loads for the Swan Creek watershed TMDL was the CBP P5.3.2 watershed model, and specifically the EOS sediment loads. The spatial domain of the CBP P5.3.2 watershed model segmentation aggregates to the MD 8-digit watersheds, which is closely consistent with the impairment listing. The nonpoint source baseline sediment loads generated within the Swan Creek watershed are based on the EOS loads from the CBP P5.3.2 watershed model 2009 Progress Scenario. CBP P5.3.2 Progress Scenario EOS loads are calculated as the sum of individual land-use EOS loads within the watershed and represent a long-term average loading rate. Individual land-use EOS loads are calculated within the CBP P5.3.2 watershed model as a product of the land-use area, land-use target EOF loading rate, and loss from the EOF to the main channel. BMP data and reduction efficiencies are then subsequently applied to produce the final EOS loads. The loss from the EOF to the main channel is the *sediment delivery factor* and is defined as the ratio of the sediment load reaching a basin outlet to the total erosion within the basin. A *sediment delivery factor* 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 watershed (i.e., *sediment delivery factor* decreases). Details of the data sources for the unit loading rates can be found in Section 2.2 of this report.

Reference Watershed Approach

In order to quantify the impact of sediment on the aquatic life 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). Reference watersheds were determined based on Maryland's biocriteria methodology. The biocriteria methodology assesses biological impairment at the watershed scale based on the percentage of MBSS monitoring stations, translated into watershed stream miles, that have BIBI and/or FIBI scores lower than the Minimum Allowable IBI Limit (MAL). The MAL is calculated based on the average annual allowable IBI value of 3.0 (on a scale of 1 to 5). It accounts for annual variability and helps to avoid classification errors (i.e., false positives) when assessing for biological impairments (Roth et *al*. 1998,2000; Stribling *et al*. 1998; MDE 2008).

Comparison of sediment loads from impaired watersheds 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. 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 further reduce the effect of the variability within the Highland and Piedmont physiographic regions (i.e., soils, slope, etc.), 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 USEPA Region IX 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)

Eleven reference watersheds were selected from the Highland and Piedmont physiographic region. Reference watershed *forest normalized sediment loads* were calculated using CBP P5.3.2 watershed model 2009 Progress Scenario EOS loads. The median and 75^{th} percentile of the reference watershed *forest normalized sediment loads* were calculated and found to be 3.6 and 7.2 respectively. The median value of 3.6 was established as the sediment loading threshold as an environmentally conservative approach to develop this TMDL (see Appendix A for more details).

The *forest normalized sediment load* for the Swan Creek watershed (estimated as 3.8) was calculated using CBP P5.3.2 2009 Progress Scenario EOS loads, to best represent current conditions. A comparison of the Swan Creek watershed *forest normalized sediment loads* to the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) demonstrates that the watershed exceeds the *sediment loading threshold*, indicating that it is receiving loads above the maximum allowable load that it can sustain and still meet water quality standards.

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 and any upstream loads during the monitoring time frame, as well as estimated point source loads based on discharge data for the same period.

The Swan Creek watershed baseline sediment loads are estimated using the land-use and EOS sediment loading rates from the CBP P5.3.2 2009 Progress Scenario. The 2009 Progress Scenario was chosen because it is used as the baseline year in the Chesapeake Bay TMDL. The 2009 Progress Scenario represents 2009 land-use and BMP implementation simulated using precipitation and other meteorological inputs from the period 1985 - 2005 to represent variable hydrological conditions, thereby addressing annual changes in hydrology and capturing wet, average and dry years. The period 1985-2005 is the baseline hydrological period for the Chesapeake Bay TMDL.

Swan Creek watershed loading calculations, based on the CBP P5.3.2 watershed model segmentation scheme, are represented by multiple CBP P5.3.2 watershed model segments. The sediment loads from these segments are combined to represent the baseline condition. The 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 and the technical memorandum to this document entitled *Significant Sediment Point Sources in the Swan Creek Watershed*.

TMDL Conditions

This scenario represents the future conditions of maximum allowable sediment loads that will be at a level to support aquatic life. 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 biological community) and the Swan Creek *all forested sediment load* (see Section 4.2). The resulting load is considered the maximum allowable load the watershed can sustain and support aquatic life.

The TMDL loading and associated reductions are averaged at the watershed scale; however, 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
y_{forest_i} = all forested sediment load for CBP P5.3.2 model segment *i* (ton /yr)
i = CBP P5.3.2 model segment
n = number of CBP P5.3.2 model segments in watershed

The Swan Creek watershed allowable sediment load is estimated using Equation 4.2.

4.4 Critical Condition and Seasonality

USEPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2012b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time and therefore depict an average stream condition (i.e., captures all high and low flow events). Since the TMDL endpoint is based on the median of forest normalized loads from watersheds assessed as having good biological conditions (i.e., passing Maryland's biocriteria), by the nature of the biological data described above, it must inherently include the critical conditions of the reference watersheds. Therefore, since the TMDL reduces the watershed sediment load to a level compatible with that of the reference watersheds, critical conditions are inherently addressed.

Seasonality is captured in several components. First, it is implicitly included through the use of the biological monitoring data as biological monitoring data reflect the impacts of stressors over time, as described above. Second, the MBSS dataset, which serves as the primary dataset for calculating the biological metrics of the watershed (i.e., BIBI and FIBI scores), included benthic sampling in the spring (March 1 - April 30) and fish sampling in the summer (June 1 - September 30). Benthic sampling in the spring allows for the most accurate assessment of the benthic population, and therefore provides an excellent means of assessing the anthropogenic effects of sediment impacts on the benthic community. Fish sampling is conducted in the summer when low flow conditions significantly limit the physical habitat of the fish community, and it is therefore most reflective of the effects of anthropogenic stressors as well. Moreover, the sediment loading rates used in the TMDL were determined using the CBP P5.3.2 model which is based on Hydrological Simulation Program Fortran (HSPF) model, which is a continuous simulation model with a simulation period 1985-2005, thereby addressing annual changes in hydrology and capturing wet, average, and dry years.

4.5 TMDL Loading Caps

This section presents the Swan Creek watershed average annual sediment TMDL. This load is considered the maximum allowable long-term average annual load the watershed can sustain and support aquatic life.

The long-term average annual TMDL was calculated for the Swan Creek watershed based on Equation 4.2 and set at a load 3.6 times the all forested condition. In order to attain the TMDL loading cap calculated for the watershed, constant reductions were applied to the predominant controllable sources (i.e., significant contributors of sediment to the stream system), independent of jurisdiction. It is worth noting that significant sediment reductions will be required in the Swan Creek watershed to meet the sediment allocations assigned to the Chesapeake Bay Tidal Fresh Bay Water Quality Segment by the Chesapeake Bay TMDL, established by the USEPA on December 29, 2010. To ensure consistency with the Bay TMDL, and therefore efficiency in the reduction of sediment loads, reductions will be applied to the same controllable sources identified in Maryland’s Watershed Implementation Plans (WIPs) for the Bay TMDL. The controllable sources include: (1) regulated developed land; (2) high till crops, low till crops, hay, and pasture; (3) harvested forest; (4) unregulated animal feeding operations and CAFOs; and (5) industrial process sources and municipal wastewater treatment plants. Additional sources might need to be controlled in order to ensure that the water quality standards are attained in Chesapeake Bay as well as Swan Creek.

In accordance with the conclusions drawn in Sections 2.4, 3.0, and 4.2, it has been determined that sediments are only impairing aquatic life in the 1st through 4th order tributary streams within the Swan Creek watershed. It has been determined that sediment is not impairing the aquatic life in the watershed’s mainstem.

The Swan Creek Baseline Load and TMDL are presented in Table 8.

Table 8: Swan Creek Baseline Load and TMDL

Baseline Load (ton/yr)	**TMDL** (ton/yr)	**Total Reduction** (%)
770	729	5

4.6 Load Allocations Between Point and Nonpoint Sources

Per USEPA regulation, all TMDLs need to be presented as a sum of Wasteload Allocations (WLAs) for point sources and Load Allocations (LAs) for nonpoint source loads generated within the assessment unit, as accounting for natural background, tributary, and adjacent segment loads (CFR 2012a). The State reserves the right to allocate the TMDL among different sources in any manner that protects aquatic life from sediment related impacts.

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

In this watershed; crop, pasture, nursery, urban land, CAFOs, and municipal WWTPs were identified as the predominant controllable sources. Forest is the primary non-controllable source, as it represents the most natural condition in the watershed. Urban stormwater sediment loads are regulated under the NPDES MS4 program and therefore included in the WLA. No reductions were applied to permitted process load sources, since such controls would produce no discernible water quality benefit when nonpoint sources and regulated stormwater sources comprise greater than 99% of the total watershed sediment load.

Table 9 summarizes the TMDL results derived by applying equal percent reductions to the predominant controllable sediment sources. The TMDL results in an overall reduction of 5%. For more detailed information regarding the Swan Creek watershed TMDL nonpoint source LA, please see the technical memorandum to this document entitled “*Significant Sediment Nonpoint Sources in the Swan Creek Watershed*”.

Table 9: Swan Creek TMDL Reductions by Source Category

	Baseline Load Source Categories		**Baseline Load** (ton/yr)	**TMDL Components**	**TMDL** (ton/yr)	**Reduction** (%)
Swan Creek Watershed Contribution	**Nonpoint Source**		361	**LA**	361	0
	Point Source	Urban Stormwater	407	**WLA**	366	10
		Process Water	2		2	0
Total			**770**		**729**	**5**

The WLA of the Swan Creek watershed is allocated to two permitted source 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 process water permit, then TSS loads are expected to be *de minimis*. If loads are *de minimis* and they pose little or no risk to the aquatic environment and they are not a significant source.

Process Water permits with specific TSS limits include:

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

There is one process water source with explicit TSS limits in the Swan Creek watershed that contributes to the watershed sediment load, which is a municipal discharge. The total estimated TSS load from this source is based on current, average permit limits and is equal to 2 ton/yr. As mentioned above, no reductions were applied to these sources, since such controls would produce no discernable water quality benefit when nonpoint sources and regulated stormwater sources comprise greater than 99% of the total watershed sediment load. Due to its proximity to the tidal portion of the watershed, the Aberdeen Advanced WWTP has not been included in this TMDL. This facility has been addressed in the Chesapeake Bay TMDL. For a detailed list of the process water permits including information on their permit limits and their allocations, please see the technical memorandum to this document entitled "*Significant Sediment Point Sources in the Swan Creek Watershed*.

Stormwater WLA

Per USEPA 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" (USEPA 2002). Phase I and II permits can include the following types of discharges:

- Small, medium, and large municipal separate storm sewer systems (MS4s) – these can be owned by local jurisdictions, municipalities, and state and federal entities (e.g., departments of transportation, hospitals, military bases),
- Industrial facilities permitted for stormwater discharges, and
- Small and large construction sites.

USEPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (USEPA 2002). Therefore, NPDES regulated stormwater loads within the Swan Creek watershed TMDL will be expressed as an aggregate 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" (USEPA 2002).

The Swan Creek NPDES Stormwater WLA is based on reductions applied to the sediment load from the portion of the urban land-use in the watershed associated with the applicable NPDES regulated stormwater permits. The WLA may include legacy or other sediment sources. Some of these sources may also be subject to controls from other management programs. The Swan Creek NPDES Stormwater WLA requires an overall reduction of 10% (see Table 9).

As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES Stormwater WLA provided the revisions protect aquatic life from sediment related impacts.

For more information on the methods used to calculate the NPDES regulated stormwater baseline sediment load, see Section 2.2.2. For a detailed list of all of the NPDES regulated stormwater discharges within the watershed and information regarding the NPDES stormwater WLA distribution amongst these discharges, please see the technical memorandum to this document entitled "*Significant Sediment Point Sources in the Swan Creek Watershed*".

4.7 Margin of Safety

All TMDLs must include a MOS to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2012b). The MOS shall also account for any rounding errors generated in the various calculations used in the development of the TMDL. 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 the 75th percentile of the reference watersheds is a value of 7.2 and that the median value 3.6. 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 3.6 (Currey et al. 2006). Use of the median as the threshold creates an environmentally conservative estimate, and results in an implicit MOS.

4.8 Summary of Total Maximum Daily Loads

The average annual non-tidal Swan Creek watershed TMDL is summarized in Table 10. The TMDL is the sum of the LA, NPDES Stormwater WLA, Process Water WLA, and MOS. The attainment of water quality standards within the non-tidal Swan Creek watershed can only be achieved by meeting the average annual TMDL of sediment/TSS specified for the watershed within this report. The Maximum Daily Load (MDL) is summarized in Table 11 (See Appendix B for more details).

Table 10: Swan Creek Watershed Average Annual TMDL of Sediment/TSS (ton/yr)

TMDL (ton/yr)	=	LA_{SC}	+	NPDES Stormwater WLA_{SC}	+	Process Water WLA_{SC}	+	MOS
729	=	361	+	366	+	2	+	Implicit

Table 11: Swan Creek Maximum Daily Load of Sediment/TSS (ton/day)

MDL (ton/day)	=	LA_{SC}	+	NPDES Stormwater WLA_{SC}	+	Process Water WLA_{SC}	+	MOS
1.97	+	0.97	+	0.98	+	0.02	+	Implicit

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the CWA and current USEPA regulations require reasonable assurance that the sediment TMDL can and will be implemented (CFR 2012b). This section provides the basis for reasonable assurance that the sediment TMDL in the Swan Creek watershed will be achieved and maintained.

Chesapeake Bay TMDL

The Swan Creek Sediment TMDL is expected to be implemented as part of a staged process in conjunction with the Chesapeake Bay TMDL. This staged process is designed to achieve both the sediment reductions needed within the Swan Creek watershed and to meet sediment target loads consistent with the Chesapeake Bay TMDL, established by USEPA in 2010 (USEPA 2010a) and scheduled for full implementation by 2025.

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

Once the Bay TMDL sediment target loads for the Swan Creek Tidal Fresh segment-shed have been met, MDE will revisit the status of sediment impacts on aquatic life in the non-tidal waters of the Swan Creek watershed, based on monitoring data that will be collected in the watershed. The primary dataset that will be used to reevaluate the status of sediment impacts on aquatic life will be MDDNR-MBSS biological monitoring data, which is applied within the BSID analysis for the watershed to determine whether or not sediments are impacting aquatic life. The same parameters used to identify sediment related impacts to aquatic life within the BSID will be reassessed. The results of this reassessment will determine whether additional sediment reductions are needed in the watershed, or whether the sediment TMDL goals for the Swan Creek watershed have in fact been met.

MS4 Permit Implementation Plans

Between December 2013 and December 2014, MDE published Final Determinations to issue stormwater permits for nine Phase I jurisdictions (Montgomery County was issued in 2010). A Tentative Determination to issue a stormwater permit for the State Highway Administration. The permits state, *"By regulation at 40 CFR §122.44, BMPs and programs implemented pursuant to this permit must be consistent with applicable WLAs developed under [US]EPA approved TMDLs."*

Section IV.E. of the permit details requirements for *Restoration Plans and Total Maximum Daily Loads*. Within one year of permit issuance, the County is required to submit an implementation plan for each stormwater WLA approved by USEPA prior to the effective date of the permit. For TMDLs approved after the permit, implementation plans are due within one year of USEPA approval. Implementation plans should include the following: a detailed implementation schedule, the final date for meeting applicable WLAs, a detailed cost estimate for all elements of the plan, a system that evaluates and tracks implementation through monitoring or modeling to document progress towards meeting established benchmarks, deadlines, and stormwater WLAs, and a public participation program. An annual TMDL assessment report with tables shall be submitted to MDE.

Major components of the MS4 implementation plans include a detailed assessment of the pollutant load reductions, installation, and maintenance of BMPs. Sediment from urban areas can be reduced by stormwater retrofits that address both water quality and quantity. Examples of these retrofits include the modification of existing or installation of new stormwater structural practices, a reduction in impervious surfaces, street sweeping, inlet cleaning, increases in the urban tree canopy, and stream restoration. Quantity, including removing impervious surfaces, reducing sheer stress, and limiting bank erosion, address this portion of the urban sediment load. In terms of upland urban sediment loads, stormwater retrofit reductions range from as low as 10% for dry detention to approximately 80% for wet ponds, wetlands, infiltration practices, and filtering practices (USEPA 2003b). BMP specific reduction efficiencies are estimated by CBP, and best professional judgment. MDE estimates that future stormwater retrofits will have approximately a 65% reduction efficiency for TSS.

For more information on the MS4 permits, please see Maryland's NPDES Municipal Separate Storm Sewer System (MS4) Permits.

Implementation of Agricultural Best Management Practices

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. 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% (USEPA 2004). Lastly, riparian buffers can reduce the effect of agricultural sediment sources through trapping and filtering, and reforestation, whether adjacent to part of the watershed stream system or in a watershed's interior, can decrease agricultural sediment sources as well.

Maryland Legislative Actions and Funding Programs

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

$25 million (pending) for the Trust Fund, $38 million in general obligation bonds were made available to local communities for implementation of stormwater capital improvements. Funding was also increased to support implementation of natural filters on public lands ($9 million), funding for Soil Conservation Districts from 16 to 39 positions ($2.2 million), and funding for the cover crop program is at $12 million – a record level. For more information on Maryland's implementation and funding strategies to achieve nutrient and sediment reductions throughout the State's portion of the Chesapeake Bay watershed, please see Maryland's Phase II Watershed Implementation Plan.

Some other examples of programs that can provide funding for local governments and agricultural sources include the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act), Buffer Incentive Program (BIP), State Water Quality Revolving Loan Fund, Bay Restoration Fund, Chesapeake Bay Trust Fund and the Maryland Agricultural Water Quality 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.

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

REFERENCES

Ator, S. J., J. M. Denver, and M. J. Brayton. 2005. Hydrologic and Geochemical Controls on Pesticide and Nutrient Transport to Two Streams on the Delmarva Peninsula. *US Geological Survey National Water Quality Inventory Program Scientific Investigations Report*: 2004-5051.

Baish, A. S., and M. J. Caliri. 2009. *Overall Average Stormwater Effluent Removal Efficiencies for TN, TP, and TSS in Maryland from 1984-2002*. Baltimore, MD: Johns Hopkins University.

Baldwin, A. H., S. E. Weammert, and T. W. Simpson. 2007. *Pollutant Load Reductions from 1985-2002*. College Park, MD: Mid Atlantic Water Program.

Bell, W.H., and P. Favero, 2000. *Moving Water: A Report to the Chesapeake Bay Cabinet by the Public Drainage Taskforce*. Chestertown, MD: Washington College, Center for the Environment and Society.

CFR (Code of Federal Regulations). 2012a. *40 CFR* 130.2(i). http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=43ac087684bf922499af8ffed066cb09;rgn=div5;view=text;node=40%3A21.0.1.1.17;idno=40;cc=ecfr#40:21.0.1.1.17.0.16.3 (Accessed May, 2012).

___________. 2012b. *40 CFR 130.7*. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=43ac087684bf922499af8ffed066cb09;rgn=div5;view=text;node=40%3A21.0.1.1.17;idno=40;cc=ecfr#40:21.0.1.1.17.0.16.8 (Accessed May, 2012).

Claggett, P., F. M. Irani, and R. L. Thompson. 2012. *Estimating the Extent of Impervious Surfaces and Turf Grass across Large Regions*. Annapolis, MD: United States Geological Survey, Chesapeake Bay Program Office.

Claytor, R., and T. R. Schueler. 1997. *Technical Support Document for the State of Maryland Stormwater Design Manual Project*. Baltimore, MD: Maryland Department of the Environment.

Cochran, W. G. 1977. *Sampling Techniques*. New York: John Wiley and Sons.

COMAR (Code of Maryland Regulations). 2012a. *26.08.02.02 B(1 & 3)*; 26.08.02.02-1. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.02.htm (Accessed May, 2012).

___________. 2012b. *26.08.02.08 I*. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.08.htm (Accessed May, 2012).

____________. 2012c. *26.08.02.07 A.* http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.07.htm (Accessed May, 2012).

____________. 2012d. *26.08.02.04.* http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.04.htm (Accessed May, 2012).

Currey, D. L., A. A. Kasko, R. Mandel, and M. J. Brush. 2006. *A Methodology for Addressing Sediment Impairments in Maryland's Non-tidal Watersheds*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/assets/document/Sediment%20TMDL%20Method%20Report_20070728.pdf

DNR (Maryland Department of Natural Resources). 1996. *Maryland Water Quality Inventory, 1993-1995: A report on The Status of Natural Waters in Maryland Required by Section 305(b) of the Federal Water Pollution Control Act and Reported to the US Environmental Protection Agency and Citizens of the State of Maryland*. Annapolis, MD: Department of Natural Resources.

____________. 2009. *Benthic Macroinvertebrate Communities at Maryland's CORE/TREND Monitoring Stations: Water Quality Status and Trends*. Annapolis, MD: Department of Natural Resources, Monitoring and Non-Tidal Assessment Program. Also available at http://www.dnr.state.md.us/streams/pdfs/12-332009-375_benthic.pdf.

____________. 2012. *Physiography of Maryland.* http://www.dnr.state.md.us/forests/healthreport/mdmap.html (Accessed May, 2012).

Gellis, A. C., C. R. Hupp, M. J. Pavich, J. M. Landwehr, W. S. L. Banks, B. E. Hubbard, M. J. Langland, J. C. Ritchie1, and J. M. Reuter. 2009. Sources, transport, and Storage of Sediment in the Chesapeake Bay Watershed: U.S. Geological Survey Scientific Investigations Report: 2008–5186.

Klauda, R., P. Kazyak, S. Stranko, M. Southerland, N. Roth, and J. Chaillou. 1998. The Maryland Biological Stream Survey: A State Agency Program to Assess the Impact of Anthropogenic Stresses on Stream Habitat Quality and Biota. *Environmental Monitoring and Assessment* 51: 299-316.

LESHC (Lower Eastern Shore Heritage Committee). 1994. *Lower Eastern Shore Heritage Plan*. Princess Anne, MD: The Lower Eastern Shore Heritage Committee, Inc.

MDE (Maryland Department of the Environment). 2000. An Overview of Wetlands and Water Resources of Maryland. Baltimore, MD: Maryland Department of the Environment.

___________. 2002a. *2002 List of Impaired Surface Waters [303(d) List] and Integrated Assessment of Water Quality in Maryland Submitted in Accordance with Sections 303(d) and 305(b) of the Clean Water Act*. Baltimore, MD: Maryland Department of the Environment. Also available at: http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Documents/Integrated_Report_Section_PDFs/IR_2002/IR2002_Chap4.pdf

_________. 2002b. Total Maximum Daily Loads of Nitrogen and Phosphorus for Swan Creek Harford County, Maryland. Baltimore, MD: Maryland Department of the Environment. Available at: http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Documents/www.mde.state.md.us/assets/document/tmdl/swan/SwanCr_main_final.pdf

___________. 2009. *Maryland Biological Stressor Identification Process*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://staging.mde.state.md.us/programs/Water/TMDL/Documents/www.mde.state.md.us/assets/document/BSID_Methodology_Final.pdf.

___________. 2010. *Maryland's Phase I Watershed Implementation Plan for the Chesapeake Bay Total Maximum Daily Load*. Baltimore, MD: Maryland Department of the Environment. Also Available at *http://www.mde.maryland.gov/programs/Water/TMDL/TMDLHome/Pages/Final_Bay_WIP_2010.aspx*.

___________. 2011. *Maryland Tier II Dataset.* Baltimore, MD: Maryland Department of the Environment.

___________. 2012. *Maryland's Phase II Watershed Implementation Plan for the Chesapeake Bay Total Maximum Daily Load*. Baltimore, MD: Maryland Department of the Environment. Also available at http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/FINAL_PhaseII_WIPDocument_Main.aspx.

___________. 2014a. *The 2014 Integrated Report of Surface Water Quality in Maryland*. Baltimore, MD: Maryland Department of the Environment. Also Available at: http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/2014IR.aspx

___________. 2014b. *Watershed Report for Biological Impairment of the Non-tidal Swan Creek Watershed in Harford County, Maryland: Biological Stressor Identification Analysis Results and Interpretation*. Baltimore, MD: Maryland Department of the

Environment. Also available at: http://www.mde.state.md.us/programs/Water/TMDL/Documents/BSID_Reports/Swan_Creek_BSID_Final_012714.pdf. (Accessed: June 25, 2015).

MGS (Maryland Geological Survey). 2012. *A Brief Description of the Geology of Maryland*. http://www.mgs.md.gov/esic/brochures/mdgeology.html (Accessed May, 2012).

Nusser, S. M., and J. J. Goebel. 1997. The National Resources Inventory: A Long-Term Multi-Resource Monitoring Program. *Environmental and Ecological Statistics* 4: 181-204.

Roth, N., M. T. Southerland, J. C. Chaillou, R. Klauda, P. F. Kazyak, S. A. Stranko, S. Weisberg, L. Hall Jr., and R. Morgan II. 1998. Maryland Biological Stream Survey: Development of a Fish Index of Biotic Integrity. *Environmental Management and Assessment* 51: 89-106.

Roth, N. E., M. T. Southerland, J. C. Chaillou, P. F. Kazyak, and S. A. Stranko. 2000. *Refinement and Validation of a Fish Index of Biotic Integrity for Maryland Streams*. Columbia, MD: Versar, Inc. with Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division.

Roth, N. E., M. T. Southerland, J. C. Chaillou, G. M. Rogers, and J. H. Volstad. 2001. *Maryland Biological Stream Survey 2000-2004: Volume IV: Ecological Assessment of Watersheds Sampled in 2003.* Columbia, MD: Versar, Inc. with Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division.

Stribling, J. B., B. K. Jessup, J. S. White, D. Boward, and M. Hurd. 1998. *Development of a Benthic Index of Biotic Integrity for Maryland Streams*. Owings Mills, MD: Tetra Tech, Inc. with Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Program.

US Census Bureau. 2010. *2010 Census*. Washington, DC: US Census Bureau.

USDA (United States Department of Agriculture). 1970. *Soil Survey of Wicomico County*. Washington, DC: United States Department of Agriculture, Soil Conservation Service.

____________. 1973. *Soil Survey of Worcester County*. Washington, DC: United States Department of Agriculture, Soil Conservation Service.

____________. 1982. *1982 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

____________. 1983. Sediment Sources, Yields, and Delivery Ratios. In *National Engineering Handbook, Section 3, Sedimentation*. Washington, DC: United States Department of Agriculture, Natural Resources Conservation Service.

____________. 1987. *1987 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

____________. 1992. *1992 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

____________. 1997. *1997 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

____________. 2002. *2002 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

____________. 2006. *State Soil Geographic (STATSGO) Database for Maryland*. Washington, DC: United States Department of Agriculture, Natural Resources Conservation Service. Also available at http://soils.usda.gov/survey/geography/statsgo.

USEPA (U.S. Environmental Protection Agency). 1991. *Technical Support Document (TSD) for Water Quality-based Toxics Control*. Washington, DC: U.S. Environmental Protection Agency. Also available at http://www.epa.gov/npdes/pubs/owm0264.pdf.

___________. 2002. *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs*. Washington, DC: U.S. Environmental Protection Agency.

___________. 2003a. Developing water quality criteria for suspended and bedded sediments (SABS) – Potential Approaches – DRAFT. USEPA Science Advisory Board Consultation, EPA Office of Water, Office of Science and Technology, August 2003.

___________. 2003b. *Stormwater Best Management Practice Categories and Pollutant Removal Efficiencies*. Annapolis, MD: U.S. Environmental Protection Agency with Chesapeake Bay Program.

___________. 2004. *Agricultural BMP Descriptions as Defined for the Chesapeake Bay Program Watershed Model*. Annapolis, MD: U.S. Environmental Protection Agency with Chesapeake Bay Program.

___________. 2007. *Options for the Expression of Daily Loads in TMDLs*. Washington, DC: U.S. Environmental Protection Agency, Office of Wetlands, Oceans & Watersheds. Also available at www.epa.gov/owow/tmdl/draft_daily_loads_tech.pdf.

___________. 2010a. *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus, and Sediment*. Annapolis, MD: U.S. Environmental Protection Agency, Chesapeake Bay Program Office. Also available at http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html.

___________. 2010b. *Chesapeake Bay Phase 5.3 Community Watershed Model*. Annapolis, MD: U.S. Environmental Protection Agency, Chesapeake Bay Program Office. Also available at http://ches.communitymodeling.org/models/CBPhase5/documentation.php#p5modeldoc.

APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds

MD 8-Name	MD 8-digit	Percent Stream Mile BIBI/FIBI < 3.0 (%)[1,2]	Forest Normalized Sediment Load[3]
Big Elk Creek	02130606	12.5	7.8
Brighton Dam	02131108	10.0	3.0
Broad Creek	02120205	10.5	3.4
Deer Creek	02120202	10.2	3.6
Fifteen Mile Creek	02140511	6.7	1.7
Furnace Bay	02130609	10	6.6
Little Gunpowder Falls	02130804	13.3	3.8
Middle Patuxent River	02131106	18.8	2.5
Northeast River	02130608	15.7	9.2
Octoraro Creek	02120203	7.7	8.3
Savage River	02141006	4.9	2.7
Median			**3.6**
75th percentile			**7.2**

Notes:
1 Based on the percentage of MBSS stations with BIBI and/or FIBI scores significantly lower than 3.0 within the watershed (MDE 2012a).
2 The percent stream miles with BIBI and/or FIBI scores significantly lower than 3.0 threshold to determine if an 8-digit watershed is impaired for impacts to biological communities is based on a comparison to reference conditions (MDE 2008).
3 Forest normalized sediment loads based on Maryland watershed area only (consistent with MBSS random monitoring data).

APPENDIX B – Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define MDLs of sediment consistent with the average annual TMDL in the Swan Creek watershed, which is considered the maximum allowable load the watershed can sustain and support aquatic life. The approach builds upon the modeling analysis that was conducted to determine the sediment loadings and can be summarized as follows.

- The approach defines MDLs for each of the source categories.
- The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual loading targets are at a level that support aquatic life.
- The approach converts daily time-series loadings into TMDL values in a manner that is consistent with available USEPA guidance on generating daily loads for TMDLs (USEPA 2007).
- 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 MDL 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 so as to ensure the support of aquatic life.
- **CBP P5.3.2 Watershed Model Sediment Loads:** As described in Section 2.2, the nonpoint source sediment loads from the Swan Creek watershed are based on EOS loads from the CBP P5.3.2 watershed model. The CBP P5.3.2 model river segments were calibrated to daily monitoring information for watersheds with a

flow greater than 100 cubic feet per second (cfs), or an approximate area of 100 square miles.

- **Draft USEPA guidance document entitled "Developing Daily Loads for Load-based TMDLs":** This guidance document provides options for defining MDLs when using TMDL approaches that generate daily output (USEPA 2007).

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 MDL in a manner consistent with USEPA guidance and available information.

Options considered

The draft USEPA 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 (USEPA 2007). 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 Swan Creek watershed MDLs.

Level of Resolution

The level of resolution pertains to the amount of detail used in specifying the MDL. The draft USEPA guidance document on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Swan 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. **Variable daily load:** This option allows the MDL to vary as function of a particular characteristic that affects loading or waterbody response, such as flow or season.

Probability Level

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 MDL should be based on a representative statistical measure that is dependent upon the specific TMDL and the best professional judgment of the developers (USEPA 2007). This statistical measure represents how often the MDL 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 MDL 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 is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the MDL based upon a characterization of the variability of daily loads. For example, selection of the 95^{th} percentile value would result in a MDL that would be exceeded 5% of the time.
3. **The maximum daily load reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the MDL 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.

Selected Approach

The approach selected for defining a Swan Creek MDL 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 within the Swan Creek watershed
- Approach for Process Water Point Sources within the Swan Creek watershed

Approach for Nonpoint Sources and Stormwater Point Sources within the Swan Creek Watershed

The level of resolution selected for the Swan Creek MDL 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 within the Swan Creek watershed. Currently, the best available data is the CBP P5.3.2 model daily time series calibrated to long-term average annual loads (per land-use). The CBP reach simulation results are calibrated to daily monitoring information for watershed segments with a flow typically greater that 100 cfs.

The probability level selected for the Swan Creek MDL was a pre-defined exceedance probability. Based on the USEPA guidance, "in the case where a long term daily load dataset is available, in which multiple years of data and a variety of environmental conditions are represented, it is preferable to select a maximum daily load as a percentile of the load distribution. A sufficiently long-term dataset allows for minimizing error associated with the fact that the daily load dataset might not exactly match a normal or lognormal distribution" (USEPA 2007). The exact percentile value to be used should be determined by the TMDL developer, based on site specific characteristics.

This CBP P5.3.2 model output provides a time series of daily TSS loads from the Swan Creek watershed, covering a 20-year period from 1985 to 2005. This data is shown in Figure B-1. Because this is a long-term time series, it captures a broad range of meteorological and hydrological conditions and also minimizes the effect of potential statistical variances. As with the calculation of the TMDL value, environmentally conservative principles are also used in the MDL calculation. A 95^{th} percentile load was selected for the MDL, meaning that there is a 5% probability that daily loads will exceed this value. This percentile was chosen rather the 99^{th} (which is also considered acceptable based on USEPA), in order to avoid the influence of extreme weather events and statistical outliers. Since the model daily time series represents the current (baseline) condition, the reduction percentage applied to each sector of the TMDL, was applied directly to the 95^{th} percentile values to calculate the final MDL value.

$$MDL = 95th\ percentile\ of\ daily\ load\ series\ values * Reduction\ \%\ from\ TMDL$$
(Eq B-1)

Where:
MDL = Maximum Daily Load, ton/day
Daily load series values = CBP 5.3.2 output
TMDL = Long term average annual load, ton/yr

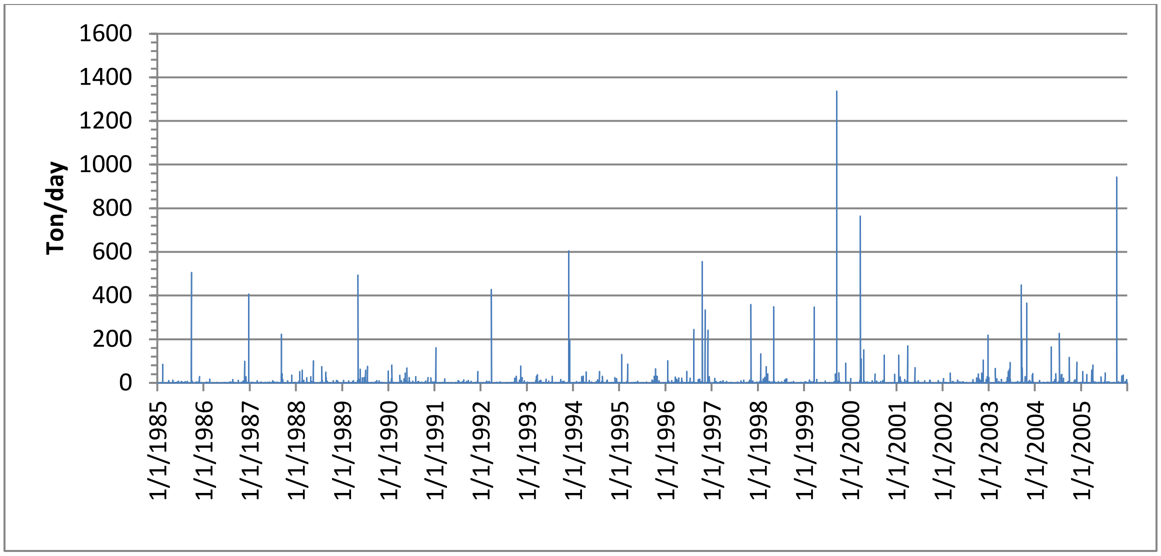


Figure B-1: Daily Time Series of CBP River Segment Daily Simulation Results for the Swan Creek Watershed

<u>Approach for Process Water Point Sources within the Swan Creek Watershed</u>

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 MDLs for these sources was dependent upon whether a maximum daily limit was specified within the permit. If a maximum daily limit was specified, then the reported average flow was multiplied by the daily maximum limit and a conversion factor of 0.0042 to obtain a MDL in ton/day. If a maximum daily limit was not specified, the MDLs were calculated based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (USEPA 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 Swan Creek TMDL of sediment/TSS is reported in ton/yr, and the conversion from ton/yr to a MDL 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 Swan Creek MDLs. The final results are presented in Table B-1.

- Calculation Approach for Nonpoint Sources and Stormwater Point Sources within the Swan Creek Watershed

The MDL for Nonpoint Sources and Stormwater Point Sources within the Swan Creek Watershed is based upon the 95th percentile value of the CBP P5.3.2 model daily load time series, reduced by the same percentage as the corresponding TMDL value. The 95th percentile load is 4.0 lbs/day and with a TMDL reduction of 5%, it results in an nonpoint source MDL of 3.8 tons/day

- Calculation Approach for Process Water Point Sources within the Swan Creek Watershed
    - For permits with a daily maximum limit:

Process Water WLA_{SC} (ton/day) = Permit flow (millions of gallons per day (MGD)) * Daily maximum permit limit (milligrams per liter (mg/l)) * 0.0042, where 0.0042 is a combined factor required to convert units to ton/day

- For permits without a daily maximum limit:

Process Water WLA_{UP} (ton/day) = Average Annual TMDL Process Water WLA_{UP} Other (ton/yr)* 0.0085, where 0.0085 is the factor required to convert units to ton/day

There is one point source facility in the watershed in the watershed and the MDL for this facility equals 0.01 tons/day.

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

MDL (ton/day)	=	LA_{SC}	+	NPDES Stormwater WLA_{SC}	+	Process Water WLA_{SC}	+	MOS
3.8	=	1.9	+	1.9	+	0.01	+	Implicit